The behaviour of badgers (Meles meles) in response to a period of pre-baiting and trapping undertaken for disease management research

Submitted by Amy Louise Griffiths
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I certify that all material in this dissertation which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

(Signature) ………………………………………………………………………………

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Section 1 – Literature Review. Managing wildlife diseases

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Introduction

Importance of wildlife diseases

Wildlife diseases can have a huge impact on human and livestock health and on the survival of endangered populations (Daszak *et al*., 2000; Cleaveland *et al*., 2001; Dobson & Foufopoulos, 2001). The threat of wildlife diseases is increasing due to an array of anthropogenic and ecological factors, which is aiding disease transmission between wild, human and domestic populations. These factors are resulting in a surge of emerging diseases, such as HIV/AIDS and avian influenza, that are causing serious health, welfare and economic implications around the globe. In South East Asia from late-2003 to mid-2005, the economic cost of the Highly Pathogenic Avian Influenza (HPAI) virus has been estimated at more than US$10 billion and 140 million birds had died or been culled. (European Commission, 2010). The aim of disease management is to prevent, control or eradicate disease accomplished through a variety of strategies that can either target the parasitic or infectious agent or can involve some degree of environmental manipulation. Using examples, this review will critically evaluate management options currently available for disease management in free-ranging wild populations.

In its simplest form, disease can be regarded as an “impairment of normal functions” such as growth, fecundity, metabolic requirements or behaviour and can result in morbidity or mortality (Delahay *et al*., 2009). Infectious disease is increasingly recognised as an important factor influencing the dynamics of wildlife populations (Woodroffe *et al*., 2004).

Definition of disease

Disease can be classified as infectious or non-infectious. Infectious disease is caused by a pathogen, which can cause harm while residing either internally or externally on the host’s surface. In comparison, non-infectious diseases are caused by other factors that include genetic disorders and nutrient deficiencies and are less of a feature in wildlife management. Infectious diseases can be categorised further into two distinct groups; macroparasites and microparasites. Macroparasites generally consist of helminths and arthropods, which do not tend to reproduce within their definitive hosts, instead producing eggs and larvae which pass into the environment or vectors (Delahay *et al*., 2009). The infection is often chronic and sub lethal, which the host animal will not develop immunity against and is often subject to re-infection. Virus, bacteria, fungi or protozoan pathogens make up the known types of microparasite. For example, controlling bovine tuberculosis (bTB), caused by the bacterium *Mycobacterium bovis*, resulted in the slaughter of 25,557 cattle in England 2009/2010 and cost £63 million (DEFRA, 2011*a*). Unlike macroparasites, they replicate rapidly within the host. The diseases tend to be short lived and can be severe, however, the host animal can quickly develop immunity and re-infection is uncommon (Anderson & May, 1979; Wobeser, 2006). Exceptions to these two disease classifications are prions which are transmissible spongiform encephalopathies (TSEs) and infectious cancers (Delahay *et al* 2009)

Transmission routes

Transmission can occur vertically (parent to offspring), pseudovertically (to neonates after birth,) and horizontally which is subdivided into direct or indirect transmission. Direct transmission occurs during intimate social contact between infectious and susceptible animals, with an increased risk of transmission during mating, grooming and aggressive behaviour. The main methods of direct transmission are: skin-to-skin contact (e.g. mange); short range aerosols/droplets (e.g. rabies); secretions and excretions (e.g. bTB); genital discharge (e.g. brucellosis); venereal transmission (e.g. chlamydiosis) and contact with carcasses (e.g. brucellosis). Indirect transmission occurs via a contaminated environment and requires the involvement of more than one species for the completion of a parasitic lifecycle (Wobeser, 2006).

Disease transmission can vary within or between groups and within groups and can be affected by social structure, sex, social status and age. For example, Tasmanian devil (*Sarcophilus harrisii*) adults are far more likely to become infected by Devil Facial Tumour Disease (DFTD) than juveniles, which could be due to the adult’s lifestyle, frequently engaging in aggressive and sexual encounters (Lachish, 2007). Group size, composition, territoriality and levels of inter group movement may affect transmission between groups (Cross *et al*., 2009).

Emerging infectious diseases

Every disease is influenced by a range of environmental factors and can be classed as either abiotic (climate) or biotic (intra- and inter-specific interactions with other animals, such as human activity) (Wobeser, 2006).

Emerging (or re-emerging) infectious diseases can be broadly defined as ‘infectious diseases whose geographical range, host range or prevalence have been increasing in recent years' (Dobson & Foufopoulos, 2001). Wildlife is frequently implicated as a factor in sudden outbreaks of emerging disease, particularly when they affect both human and livestock populations. Increasing demands for habitat and other resources caused by an increasing population has resulted in problems at the human-wildlife-domestic animal interface (Cleaveland *et al*., 2001). A variety of anthropogenic factors and natural influences have put humans and wildlife into closer contact and also indirectly put populations under stress, making them more susceptible to disease outbreaks (Deem *et al*., 2001).

According to Dobson and Foufopoulos (2001) in the two years between 1998 -2000 31 different pathogens were associated with outbreaks of new and emerging disease. A number of zoonoses, e.g. West Nile Virus (WNV), have had serious implications for human health. Diseases are not only transmitted from wildlife to humans and domestic animals, but can be transmitted from domestic animals and human populations to wild animals. The appearance of Canine Distemper (CDV) in lions (*Leo panthera*) is thought to be a direct result of the rapid expansion of domestic dog populations (Cleaveland, 2003).

Habitat destruction leads to an increase in contacts with humans and domestic species while fragmentation makes animals more susceptible as small populations have lower genetic viability and ultimately leaves them vulnerable to extinction threats. Recent increases in international travel and global animal trading facilitates the transmission of pathogens and their vectors around the globe (Daszak *et al*., 2000; Cunningham, 2005; Williams *et al*., 2002; Bengis *et al*., 2004). Climate change can also expand the distribution of some disease vectors, e.g. global warming has been suggested as a reason for the northward expansion of bluetongue virus due to the northward expansion of its major vector *Culicoides imicola* (Böhm *et al*., 2007).

New species introduced to a new location can act as a reservoir host for disease. An example of a disease exacerbated by the introduction of a new species is bTB in cattle in New Zealand, as the introduced brushtail possum (*Trichosurus Vulpecula*) acts as a reservoir host (Cowan *et al*., 2008).

Why manage disease?

Disease management in wild animals is primarily undertaken to benefit humans, normally if the disease poses a risk to human or domestic animal health and/or may result in economic loses due to a negative effect on agricultural activity and trade (Wobeser, 2006). For example, in Europe, rabies was once a significant threat to human populations but is now a low risk due to effective management through control or eradication in domestic species and foxes (Gortázar *et al.* 2007).

Management undertaken for the benefit of wild animals is rare, mainly implemented when disease poses a threat for species of high conservation value (Wobeser, 2006), such as the Ethiopian Wolf (*Canis simensis*) that was vaccinated against rabies (Haydon *et al*. 2006).

How is disease managed?

Management will vary depending on a variety of different factors such as the species involved and transmission routes (Bengis *et al*., 2002). It is vital to have a clear understanding of disease ecology and any limiting factors such as cost and public opinion.

It is normally accepted that there are three basic strategies to be considered when managing wildlife: prevention, control and eradication although sometimes a fourth option, do nothing, may be suggested (Wobeser, 2002 & 2006; Delahay *et al*., 2009). Management can be directed at reducing the reproductive rate of the disease agent, reducing host or infected host density or manipulating the environment (Wobeser, 2003). Other useful management tools include surveillance, modelling and education. Diseases are often difficult to detect in wild animals, their presence may only become evident due to mass mortality or obvious external abnormalities.

Targeting the infectious or parasitic agent

Vaccines work by directly affecting host immune systems, which in turn influence the likelihood of infection (Delahay, *pers comms*, 2010). Blancou *et al*., (2009) suggested various goals that vaccination may achieve, which include elimination of disease, a reduction in the prevalence of a disease to an acceptable level, or the prevention of extinction of a valued population or species. The actual proportion of a population that must be immunised to produce effective disease control depends on many factors including ease of disease transmission and population density (Wobeser, 2006).

There are two principal routes of vaccine administration – injection or via oral ingestion. Dart guns have been effectively used to vaccinate bison (*Bison bison*) against brucellosis in Yellowstone National Park (Wobeser, 2002; Olsen *et al*., 2005). It may be more practical to capture and administer vaccine directly by injection. Trap-Vaccinate-Release (TVR) was used in Canada to vaccinate urban racoons (*Procyon lotor*), skunks

(*Mephitis mephitis*) and foxes (*Vulpes vulpes*) against rabies (Rosatte *et al*., 1992). It is believed that TVR is mostly impractical for free-ranging populations due to the effort and resources required, however, it has the advantage of being species- and dose-specific (Delahay *et al*., 2003).

Oral vaccination is achieved by the ingestion of bait that consists of two main components, the bait matrix (attractive food) and the vaccine. Uptake can be determined visually by rate of bait disappearance (methods must be in place to reduce non-target bait uptake) or through the use of biomarkers e.g. Rhodamine, which is impregnated in baits and subsequent carcass retrieval or sampling of the population can detect its presence in hair and whiskers. Bait uptake may be affected by factors such as food resources, weather conditions and the fear of novel objects (Blancou *et al*., 2009)

Due to ease of implementation, oral delivery is the most likely route of vaccine deployment (Cross *et al*., 2007) although there are safety concerns to consider. Undertaking safety trials in areas of high biodiversity is problematic, which could lead to untested non target species being adversely affected. Bingham *et al*. (1995) found that a rabies vaccine strain that was protective for jackals (*Canis mesomelas* and *C. adustus*) induced clinical rabies in baboons (*Papio ursinus*).

Only rabies, classical swine fever (CSF) and bTB have been targeted by vaccines that were either developed or adapted specifically for use in mammal populations (Blancou *et al*., 2009). The oral immunisation of red foxes against rabies in Europe has resulted in near complete elimination of the disease from west and central Europe (Wobeser, 2002). Research began in Switzerland in 1978 using baits concealed in chicken heads (Steck *et al*., 1982) and now millions of baits are deployed aerially across parts of Europe at selected times of the year (Artois *et al*., 2001).

Unfortunately, vaccination of some endangered species has proven to be unsuccessful with some catastrophic results. In the Serengeti, the vaccination of African wild dogs (*Lycaon pictus*) against rabies was blamed for causing their local extinction. Free-ranging African wild dogs received inactivated rabies vaccines but subsequently died with rabies being reported as cause of death in most cases because only a single dose was administered when actually multiple doses were required (Woodroffe 1999; Woodroffe *et al*., 2004).

Disease may also be managed through the use of a variety of drugs (antibiotics, anthelmintics, antifungal and antiviral agents) that work by inactivating or killing the agent in the host and limit the damage caused by an established infection (Wobeser, 2006). This strategy should only be used in small, accessible populations and on a short-term basis as drug resistance may occur. Sarcoptic mange has been successfully treated with the administration of an injectable form of Ivermectin in Spanish ibex (*Capra pyrenaica*) (León-Vizcaníо *et al*., 2001). However, the effect of these drugs may be variable, as research by Murray *et al.* (1996) showed that the use of Ivermectin in snowshoe hares (*Lepus americanu*), produced extremely variable levels of parasite load reduction.

Targeting the host

Traditionally, wildlife disease management was attempted by population reduction of both infected and susceptible animals through lethal control (Ward *et al*., 2006). The objective of population reduction can be to eliminate disease from a specific area or maintain numbers below a certain threshold (Carter *et al*., 2009) although the degree of population reduction required to prevent disease transmission is unknown for most diseases (Wobeser, 2002). Culling is a highly contentious issue and often invokes a strong reaction (Carter *et al*., 2009).

Culling has been used in a variety of species including badgers (*Meles meles*), wild boar (*Sus scrofa*) and cervids in response to bTB, CSF and Chronic Wasting Disease (CWD) respectively (Artois *et al*., 2001; Williams, *et al*., 2002). Culling normally removes individuals without any regard for infection status, however population control can also be achieved through selective culling (test and slaughter) This requires capture and testing of individuals to identify those individuals infected (Carter *et al*., 2009). This strategy is not particularly suitable for use in wild animals due to a lack of suitable diagnostic tools and testing wild animals is logistically challenging. Therefore, it is best suited for diseases in which infected animals can be easily identified (Wobeser, 2006). Attempts have been made in Canada to obtain a population of bison free from brucellosis and bTB. The Hook Lane Wood Bison Recovery Project (HLWBRP) involved trapping a herd of animals where disease prevalence was high in both diseases. The uninfected animals are removed, treated with antibiotics, reared in pairs and tested repeatedly. The resulting offspring become the foundation of a new herd free from disease (Nishi *et al.,* 2001).

Hunting, trapping, gassing and poisoning are the four methods that are most commonly used to cull wildlife populations and the method selected is usually dependant on the target species and disease distribution. Biological control may also be taken into consideration and aims to reduce population density via the introduction of a natural predator/pathogen (Carter *et al*., 2009).

There are behavioural, social structure and ecological consequences associated with culling. It can invoke neophobia, compensatory reproduction and increased dispersal by surviving individuals, which may offset attempts to reduce population size (Caughley & Sinclair, 1994). Increased immigration into the culled area may not only disrupt social structure but the associated increased movement can increase the risk of disease transmission. Animals may be more immunologically compromised due to the stresses of dispersal and in poor condition making them more susceptible to disease. An example of this is the perturbation effect that was observed in badgers following culling to reduce the incidence of bTB. For example, badger culling to reduce the incidence of bTB in cattle was found to perturb the social structure of badger populations resulting in enhanced movement and higher incidences of bTB in badgers (Woodroffe *et al*., 2006; Woodroffe *et al*., 2006a). This ‘perturbation effect’ may help to explain the detrimental effects of badger culling on the incidence of bTB in cattle (Bourne *et al*., 2007).

Fertility control is now being proposed as another approach to manage disease (Barlow, 1996). Changes in reproductive behaviour may slow the rate of transmission by reducing contact during mating when disease transmission could be high. Supported by various computer models (Swinton *et al*., 1997; Barlow, 1994), fertility control has the potential to replace or enhance culling (Bomford, 1990), and could work independently, or in conjunction, with either culling or vaccination. Fertility control is more strongly supported by the general public who perceive it to be more humane than culling. A thorough understanding of the normal behaviour and reproductive biology of an animal must be obtained before selecting an appropriate choice of contraceptive and delivery (Muller *et al*., 1997) and any possible direct or indirect behavioural effects must be properly considered (Kirkpatrick & Turner, 1985).

There are a number of possible tools available within fertility control that include chemical and hormone agents, surgical sterilisation, intra-uterine devices and immunocontraceptives (Carter *et al*., 2009). The development of immunocontraceptives e.g. Gonadotrophin Releasing Hormone (GNRH) and zona pellucida (ZP) proteins look the most promising for use in wildlife (Carter *et al*., 2009) and both are known to be effective in many mammals (Fagerstone *et al*., 2006). Currently, the main delivery method is by injection, but oral vaccination would be a more practical and cost effective means of delivery. An alternative approach being developed for brushtail possums in Australia is the engineering of a biological dissemination agent – a virally vectored immunocontraceptive (VVIC), which requires the production of a recombinant virus containing an immunogen that renders an infected animal infertile (Duckworth *et al*., 2008). Additionally, the use of GonaCon (a contraceptive vaccine) administered at the same time as rabies vaccine in domestic dogs can reduce both fecundity and dog abundance (Bender *et al*., 2009) simultaneously. Tuttyens and Macdonald (1998) put forward a theory, supported by modelling by Swinton *et al.* (1997), that sterilisation could work as method to reduce bTB in badgers.

There are a number of advantages that have been put forward in support of fertility control. It can reduce the risk associated with vertical transmission as well as the risk of transmission during reproductive behaviours (Tuttyens & Macdonald, 1998). The physical condition of the females will be improved with the removal of the burden of reproduction and lactation, so may reduce susceptibility to disease infection (Carter *et al*., 2009). A study involving brushtail possums (Ramsey, 2007) has shown no differences in social structure or behaviour as a result of artificially reduced fertility.

The main disadvantage to this strategy is that infertile animals will be present in the population until they die, therefore population reduction will be slow (Carter et al., 2009) and therefore infection could potentially continue to spread. The use of GnRH in male white-tailed deer (*Odocoileus virginantus*) has produced disadvantageous alterations in antler development (Killian *et al*., 2005) and Porcine Zona Pellucida (PZP) can also cause detrimental effects, especially in species such as deer that have a multiple cycling strategy as it may lead to an extended breeding season. This could result in loss of condition for the bucks and hence an increased susceptibility to infection (Muller *et al*., 1997; Carter *et al*., 2009).

It may be possible to disperse animals away from an area if disease is occurring at a localised site. However, this technique is suited for non-infectious disease as movement of any infected animals could increase the probability of infecting a new area. During an outbreak of avian cholera, ducks were dispelled from a particularly high-risk area through the use of exploding propane noise-makers (Wobeser, 2003). Dispersal is not often used as the results can be unsuccessful due to the animals desire to return to the original area (Wobeser 2002 & 2007; Carter *et al*., 2009).

Manipulating the environment

An alternative management strategy is to manipulate the environment, often achieved through simple changes. The aim of this method is to reduce the exposure to the causative agent through influencing the abundance, distribution and behaviour of either the wildlife populations or the pathogens (Wobeser, 2006).

Collection and safe disposal of carcasses can be an efficient method of reducing the likelihood of transmission through scavengers and carrion eaters,. Potential exposure to deer carcasses infected with CWD was researched by Jennelle *et al.* (2009) who found that 14 species of scavenging birds and 14 species of scavenging animals (including domestic animals) investigated the carcasses illustrating that carcasses can provide opportunities for high risk interactions with many species.

Extensive work has been undertaken to try to deter badgers gaining access to both feed and livestock animals. A recent project (DEFRA, 2010) has shown that simply shutting solid, well fitting doors can be 100% effective at preventing badger entry to cattle housing and feed stores. Mackenzie *et al*. (2003) discovered that fencing off fruit trees that are favoured by fruit bats (genus *Pteropus*) can protect horses and pigs at the same location from diseases such as Hendra and Nipah virus.

Landowners can apply a wide range of measures to protect livestock from disease transmission although changing human behaviours itself can be a challenge as many landowners will not actively seek changes in farm practices. These can include using visual and auditory deterrents to reduce contact rates between domestic and wild animals, adequate fencing and altering farm management practices (Ward *et al*., 2006; Ward *et al*., 2009). Fences and buffer zones are expensive to erect and maintain but can be an effective way of preventing contact between livestock and wildlife. Habitat modification can be used to destroy or interfere with disease agents and thus prevent infection. Fire was used in Kruger National Park, South Africa, to destroy the bacteria that causes anthrax with the additional benefit of carcass retrieval when the vegetation was destroyed (Pienaar, 1967). Habitat modification can discourage animals using a specific area and is even more effective when an alternative habitat is made available. To reduce the occurrence of avian cholera in nesting common eiders (*Somateria mollissima*) in Canada, the standing water that the birds waded through that harboured the disease was reduced and the vegetation cleared. (Wobeser, 2003).

Other useful management tools and strategies

Translocations and disease

Annually, millions of animals are transported both locally and globally for conservation programmes, sporting and agricultural purposes, (Woodford, 1993; Leighton, 2002). Such movements have important disease risks for wildlife, agriculture and public health (Leighton, 2002). Therefore, focusing on regulating and monitoring the translocation of animals could minimise the risk of disease transmission (Mathews *et al*., 2006). Two types of risk have been identified with animal translocations: the introduction of an exotic disease may adversely affect animal populations at the release site, or the endemic diseases present in the indigenous animals at the release site may have adverse effects on the translocated animals (Wobeser, 2002). In both instances, the animals will be vulnerable to the potential new disease risk due to a lack of acquired immunity or prior exposure.

There are many examples of disease transmission that have occurred via translocations e.g. Rinderpest in imported cattle to Africa severely affected wild ungulates (Plowright, 1982); and African Horse Sickness (AHS), an insect-borne disease introduced into Spain from zebras imported from Namibia (Meltzer, 2003). Disease can also occur during the translocation process through a combination of stress, unhygienic conditions and the risk of contact with infected humans (Breed *et al*., 2009).

Global wildlife trade poses huge disease risks and can range in scale from local barter to major international routes. It involves millions of live animals and billions of kilos of wild animal meat traded through markets each year and estimates suggest that more than one billion direct and indirect contacts among wildlife, humans and domestic animals result from this trade annually, (Karesh *et al*., 2005). Origins of both human pathogens (e.g. SARS) and pathogens to domestic animals and wildlife e.g. H5N1 have all been traced back to such trade. Regulation, reduction or possibly elimination of the trade in live animals and their products should be considered (Karesh *et al.*, 2005).

Monitoring and surveillance

Animal surveillance is aimed at monitoring endemic, epidemic, and new emerging diseases and should aim to identify changes in the infection/health status of animal and human populations (Pfeieffer & Hugh-Jones, 2002). Detecting new and emerging diseases gives the opportunity to quickly implement counter measures (Mörner *et al*., 2002) consequently lessening the potential impact of the disease. Monitoring increases our understanding of disease ecology and its spread, and when it is carried out over a large geographical area it can help identify potential hotspots of disease (Böhm, 2007). After an extended period of monitoring has been completed, baseline data (such as biological samples, carcass collection, road kills and abattoir inspection of game meat (Mörner *et al*., 2002; Bengis, 2002; Wobeser, 2006) can be used to show past disease trends and can provide information as to which diseases occur in particular populations or species (Mörner *et al*., 2002) and where and when future outbreaks may occur.

The use of animal sentinels is a cost effective way of utilising animals of a different species other than the one of direct concern and is most useful when the species of concern is rare or endangered (Wobeser, 2006). Sentinels act as an early warning system to detect and identify the presence of disease in an area. Sentinels must be capable of developing a detectable response to a particular pathogen i.e. clinical signs or mortality and the type of response an animal mounts will affect the ease at which it is detected (Halliday *et al*., 2007) e.g. mortality of American crows (*Corvus brachyrhynchos*) in the surveillance of WNV (McLean *et al*., 2001).

Education

Education is an important component of many successful disease management programmes. It is vital that the public supports management strategies, understands and are shown how changing general working practices can affect disease (Wobeser, 2002). It is possible that public education can be used to reduce the effect of some diseases without having to control or reduce its prevalence in wild species, as people can employ simple measures to reduce their own or livestock transmission risk. Attempts to limit Ethiopian wolf (*Canis simensis*) contact with domestic dogs involved community education encouraging people to tie up dogs and to keep them at home (Woodroffe *et al*., 2004).

Modelling, GIS and contingency planning

Mathematical modelling can provide a powerful tool for increasing understanding and for generating predictions of the likely efficiency of control strategies (Delahay *et al*., 2009).

GIS is a mapping tool that allows researchers to plot disease prevalence data, which can subsequently be linked to maps of environmental, biological and epidemiological factors such as climatic conditions, population density and disease prevalence in host species (Böhm *et al*., 2007). GIS can be used to predict the effects of wildlife disease and help researchers make key decisions, for example, where to place baits in vaccine campaigns (Pfeiffer and Hugh-Jones 2002).

Contingency plans play an important role and are based on risk assessments of a particular pathogen. Their goal is to reduce the risk of an exotic disease outbreak. They ensure that a state of preparedness exists in the event of a disease introduction and have a clear overall objective which will determine the scale and the characteristics of the response. The most likely risks are identified along with a set of instructions describing the best available methods for its rapid and cost-effective control (Jackson *et al*., 2009). The Rabies Disease Control Strategy (DEFRA, 2004) outlines control strategies should an outbreak materialise in the UK.

Disease and endangered species

Daszak and Cunningham (2000) suggest that diseases can be a significant threat to endangered and small populations. Disease can increase the probability of extinction by killing hosts more rapidly than they can reproduce and by suppressing population growth rates making them more vulnerable to extinction (Wobeser, 2006). Small populations are more susceptible to infection due to low genetic diversity and can be further compromised due to loss of herd immunity by a previously endemic disease becoming extinct, as the population is too small to maintain the pathogen. If the population comes back into contact with this previously endemic pathogen, there can be serious consequences as the population is now immunologically naïve (Cunningham, 1996).

According to Smith *et al*. (2006) in the last 500 years, only 3.7% (ICUN 2004) of the known extinctions have been in some part attributed to disease. There has only been one example of a true extinction of a species solely due to disease and that is of the Polynesian tree snail (*Partula turgida*) (Cunnigham & Daszak, 1998). However, disease is a factor implicated in the decline of a number of species e.g. an array of amphibian species are affected by chytridimicyosis, caused by the fungal pathogen *Batrachochytrium dendrobatidis*, which is listed as the most significant threat to their survival (Daszak *et al*., 2000; Rachowicz *et al*., 2006).

Pederson *et al.* reported in 2007 that disease is a threatening process in 54 species of mammal that face extinction. 88% of these species were from just two orders, carnivora and artiodactyla and families within these two orders contain those species that are most familiar to livestock and domestic animals. This close taxonomic relationship facilitates the sharing of pathogens and the high density global distribution of domestic species will enhance the opportunity for disease transmission. (Pederson *et al*., 2007; Breed *et al*., 2009). Domestic species often act as reservoirs and dogs are a particular problem as they can sustain multiple pathogens and often roam around freely coming into contact with a number of other species (Cleveland *et al*., 2001). Canids have a particularly increased susceptibility to disease as they are extremely closely related to domestic dogs; many pathogens will be carried by their prey and close contact between group members (e.g. grooming) and scent communication will enhance opportunities for disease transmission (Woodroffe *et al*., 2004).

A number of strategies can be implemented to manage disease in endangered/threatened populations and include anti-parasitic drugs, antibiotics and vaccination of the domestic (most often reservoir) host. The latter approach was taken in the Serengeti when domestic dogs were vaccinated against rabies to prevent the spread to the Ethiopian Wolf (Woodroffe, 1999). These methods are not often cost effective for use on wildlife, but when the species in question is of very high conservation value, they may become so. Culling is not normally an option but can occur on rare exceptions in the absence of any other treatment. This approach has been implemented with some success with the selective removal of diseased Tasmanian devils in an attempt to reduce transmission of DFTD to unaffected individuals (Lachish *et al*., 2007; MaCallum & Jones, 2006). Extending the area of available habitat or linking populations through habitat corridors could increase functional size and may also reduce contact with domestic reservoirs (Wobeser, 2007). An insurance population could be set up in captivity as a last resort (Breed *et al*., 2009).

Economic considerations for disease management

Disease outbreaks can produce devastating effects on human livelihoods and livestock industries (Bennett *et al*., 2009) causing hundreds of billions of dollars of economic damage globally (Karesh *et al*., 2005) through loss of both trade and livestock and the cost of management. Disease management can be a considerable undertaking that may require a large investment over a long period of time. It cost $840 million to eliminate brucellosis and tuberculosis from livestock in Australia during a 10 year programme (Neumann, 1997).

Management must be seen to be cost effective and is often financially constrained e.g. mass immunisation with oral vaccines may be limited to a few serious diseases due to the costs of development, testing and delivery (Wobeser, 2002) e.g. the cost of the development of an oral BCG vaccine for badgers has been proposed at over £4 million between 2009-2012 (DEFRA, 2011*b*). Cost-benefit analysis is a requirement for any management strategy in order to ascertain whether a proposed plan is worthwhile by analysing potential advantages and disadvantages. (Bennett *et al*., 2009). Aubert (1999) and Wilkinson *et al*. (2009) have both provided cost-benefit analysis for two major disease programmes, rabies and bTB.

Conclusion

The more that is known about a disease and the species that it affects the greater the chance of finding a suitable disease management strategy. As demonstrated by this review, there are a vast array of possible strategies that can be undertaken. No method is perfect and there are advantages and disadvantages associated with each. In many circumstances, no single technique may be suitable, different techniques could be required at different stages or even several methods could be used in combination (Wobeser, 2006). Tools such as monitoring (to asses effectiveness) and modelling are essential components that should be considered when selecting a suitable management strategy. Control interventions must continue for as long as there is a need and are not limited by financial constraints as this will most likely result in failure (Bennett *et al*., 2009).

Wobeser (2006) states that there is a clear and urgent need for innovative disease control policies to be implemented to try to curb the risk of disease. As the human population continues to grow, facilitating interactions between wild and domesticated animals and humans, the risk of disease will increase.

It is important to consider potential consequences of disease management prior to implementation as detrimental impacts on ecosystems are difficult to amend, e.g the culling of badgers during the RBCT was associated with increased fox densities (Trewby et al., 2008) which may have serious consequences for prey species such as ground nesting birds (Reynolds & Tapper, 1995*a*).

A success story in disease management is the declaration of global freedom from rinderpest to be declared in 2011 (FAO,2010). This eradication has been achieved through a combination of surveillance, testing, removal and the vaccination of more than 300 million cattle. (GREP, 2010). Once declared, this would be the first animal disease ever to be eliminated, and only the second time in history, after smallpox in humans, that a disease has been eradicated worldwide (FAO, 2010) and illustrates that a successful disease management strategy can be a reality.

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Section 2 – Research project. The behaviour of badgers (*Meles meles*) in response to a period of pre-baiting and trapping undertaken for disease management research.

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The behaviour of badgers (Meles meles) in response to a period of pre-baiting and trapping undertaken for disease management research.

Badgers (*Meles meles*) have long been implicated in the transmission of bovine tuberculosis (bTB) and as a result, a considerable amount of time, effort and money have been invested in TB research programmes and control policies. The majority of these operations require badgers to be restrained in cage traps. Three distinct 'populations' (each containing four independent social groups) that had different levels of prior feeding experience (habituated, semi-habituated and naïve) were selected in the south west of England. The 12 setts were filmed using remote infra-red CCTV cameras over the duration of their pre-baiting period and the subsequent behaviour exhibited by the badgers was observed. In addition, the behaviour of badgers once captured was analysed according to the number of times an individual had been caught previously. The results from this research suggests that the pre-baiting period affects badgers' behaviour towards traps and its bait source and that they will respond differently within this period due to differences in habituation to prior feeding. As the pre-baiting period continued, the semi-habituated and naïve badgers became more accustomed to the presence of the trap, which was shown by differences in bait and trap interaction times (an increase in bait interaction and a decrease in trap interaction) and a decrease in time from when a badger was first observed to when a badger would first enter a trap. Artificial feeding did not appear to affect group relations as aggressive encounters were limited. From an animal welfare point of view this research has highlighted that badgers only spend, on average, 37% (range 3 - 71%) of their restraint period trying to actively escape from the trap. Overall, the number of times that a badger had been previously caught had a significant effect on the active escape behaviour exhibited. Badgers that had been caught on more than three occasions would spend less time trying to actively escape than badgers less experienced to entrapment. It is important to note that trapping efficiency is not a direct result of animal behaviour only. When carrying out any form of trapping regime, a range of factors must be considered in order to maximise trapping effort, such as the availability of natural food resource and the presence of non target species.

Key words: animal welfare, badger, behaviour, *Meles meles,* pre-baiting, trapping

Introduction

In its simplest definition, wildlife management is the management of wildlife populations and it normally has four different aims (i) make the population increase; (ii) make the population decrease; (iii) harvest the population for a continuing yield and (iv) do nothing but monitor it (Caughley & Sinclair, 1994). Management programmes are implemented for a variety of reasons which include the control of pest and invasive species, conservation and disease management (Caughley & Sinclair, 1994). Wildlife that acts as a reservoir host for disease is often a major focus of management initiatives and often involves various methods of control, for example, the control of rabies often involves both vaccination and culling options, as demonstrated by focal culling with a ring of vaccination which has proved successful in tackling the disease in racoons (*Procyon lotor)* in Canada (Rosatte et al. 2001).

Managing wildlife populations frequently involves a solution that requires the trapping of animals in some form. Trapping is an essential tool and can be carried out for a variety of different reasons which include the removal of individuals pest control (e.g. European rabbit, *Oryctolagus cuniculus*, Kolb, 1993), to resolve human-wildlife conflict (e.g. Rhesus monkeys, *Macaca mulatta*, Iman et al. 2002), for conservation purposes (e.g. Ethiopian wolves, *Canis simensis*, Knobel et al. 2008) and disease control (e.g. Tasmanian devil, *Sarcophilus harrisii*, Lachish et al. 2010), and these are often interlinked (Shütz et al. 2006, Iossa et al. 2007). Trapping is also becoming widely used for scientific purposes as it can contribute to important research on evolution, ecology, animal behaviour, physiology parasitology, genetics and other disciplines (Powell & Proulx, 2003). For example, research activities, such as mark-recapture trapping programmes (Powell & Proulx, 2003), can provide information on population structure and the movements of individuals (Powell & Prolx, 2003).

As tens of millions of mammals each year are trapped legally worldwide, it is vital that trapping methods meet accepted standards of animal welfare (Iossa et al. 2007).To establish a comprehensive measure of welfare, a number of factors e.g. physical trauma, physiology and behavioural responses must be taken into account (Iossa et al. 2007).Trapping can not only cause injury (see CSL, 2001,Woodroffe et al. 2005, Murphy et al. 2009) and stress (Shütz et al. 2006) but it can also have significant effects on social structure and population dynamics (Carter et al. 2007), foraging behaviour (Patterson et al. 2003) and on survival and mortality rates (Seddon et al. 1999).The effects on others, such as conspecifics, dependants and non-targets must also be considered (Lane & McDonald,2010) together with more general welfare concerns which should include the time of year, extreme weather conditions and non-targets (Lane & McDonald, 2010).

The type of trap used and how the individual animal perceives the situation will affect the overall response of the captured animal (Kreeger et al. 1990a, White et al. 1991, Powell & Proulx, 2003, Shütz et al. 2006). Not only can entrapment cause physical trauma, such as limb, tissue or tooth damage (White et al. 1991, Woodroffe et al. 2005) but it can also cause both behavioural and physiological responses (White et al. 1991, Shütz et al. 2006). There is evidence to suggest that stress may reduce the effectiveness of the immune system, thus increasing the risk of infection or disease (Raberg et al. 1998). For example, capture-related stress has been implicated in reducing cellular immune responses in ferrets (Cross et al. 1999) and has been linked to disease in farm animals (e.g. Koolhaas et al. 1999).

Trapping efficiency, which is the rate at which a trap catches the intended species' (Pawlina & Proulx, 1999), is usually expressed as the number of captures/100 trap nights (Pawlina & Proulx, 1999). It can be affected by a number of factors which should be considered when planning any trapping regime. These factors can be classified into three distinct categories: trapping methods; environmental variables; and biological variables (Pawlina & Prolux, 1999). The type of trap that is used (Woodman et al. 1996) and pre-baiting period (Edalgo & Anderson, 2007) are both examples of factors affected by trapping methods. Environmental factors include seasonality, which affects food availability, and hence an animal's willingness to enter a trap (Tuyttens et al. 1999) and weather conditions which can affect both trap performance (Wiener & Smith, 1972) and animal activity levels (Gentry et al. 1966). Biological variables include population density and distribution (Gehrt & Freitzel, 1996) and an individual's variation in response to the trap (Chitty & Shorten, 1946).

Bovine tuberculosis (bTB) is a serious disease in cattle (Krebs, 1997, ISG, 2007), and it is the UK's biggest endemic animal health issue, costing the British taxpayer around £90 million in 2010/11 with a further £6.9 million on research. (www.defra.gov.uk/animal-diseases/a-z/bovine-tb). Over the next decade, this cost to the taxpayer is expected to exceed over £1bn (www.defra.gov.uk/animal-diseases/a-z/bovine-tb). Around 25,000 cattle were slaughtered for bTB control in 2010 in England and in this period, there were 3,622 new bTB incidents, which is an increase of 7.5% from 2009 (www.defra.gov.uk/animal-diseases/a-z/bovine-tb). Eurasian badgers (*Meles meles*) are a significant reservoir of the causative agent of bTB, *Mycobacterium bovis,* and as a result have been intensively studied in relation to their role in the transmission of the disease (Krebs, 1997). They are widely distributed throughout the western Palaearctic, from Ireland, across Europe and Asia, to Japan. Across their geographical range, badger territory sizes can range from 0.14 km^2 to 14 km^2 (Palphramand et al. 2007). They generally live in mixed-sex social groups ranging in size from 2-30 individuals (Rogers et al. 1997). In the UK, badger density can vary from one to more than 25 individuals per km^2 (Wilson et al. 1997).

The management of badgers to reduce the incidence of bTB in cattle originally began in 1973, when affected farmers were allowed to shoot free ranging badgers on their land (Roper, 2010). This was replaced by gassing in 1975 and continued until 1982 when it was replaced (on welfare grounds) with cage-trapping and shooting (Woodroffe et al. 2005). Since then, there have been a number of badger management control policies and scientific studies that have involved the extensive trapping of badgers. For example, the Randomised Badger Culling Trial (RBCT:1998-2005) was an extensive field trial to evaluate the technical effectiveness of badger culling in reducing the incidence of bTB (Bourne et al. 2000*b*; Woodroffe et al. 2005). In total, 10,979 badgers were culled over an estimated 160,893 trap nights (ISG, 2007). Also, the Woodchester Park (WP) project is a long term ecological and epidemiological study of bTB infection in a wild badger population. WP has one of the highest density of badgers known at 25.3 adults per km^2 (Neal & Cheeseman,1991, Rogers et al. 1997;). Trapping is routinely carried out four times per annum (Rogers et al. 1997). and a suite of clinical samples are taken to determine bTB infection status. To date, there have been over 14,000 capture entries and over 3,000 individual badgers have been caught.

The requirement to capture badgers is ongoing as research into the development of different approaches for the vaccination of badgers continues (Wilson et al. 2011). A vaccine for use in wildlife was licensed in July 2010 after a four-year field trial demonstrated that vaccination of free-living badgers with Bacille Calmette Guerin (BCG) reduced the incidence of positive serological test results by 73.8% (Chambers et al. 2010). In 2010, two Defra-funded projects were initiated to further progress the development and use of a vaccine for badger disease management; the Oral Bait Deployment Study (OBDS) and the Badger Vaccine Deployment Project (BVDP). The OBDS aimed to investigate bait disappearance and uptake by naive badger populations in order to determine the optimal strategy for deploying oral vaccine baits to wild badgers. Naive badger populations were chosen from three different areas in the south-west of England and badgers were fed a highly attractive bait (consisting of 100ml peanuts and syrup) containing biomarkers for 12 consecutive days. Badgers were trapped approximately two weeks after the end of feeding to collect blood samples for determining bait uptake. An additional trapping session was carried out two weeks later to maximise the numbers of animals caught. In total, 269 badgers were captured and sampled. The BVDP was devised with the aim of demonstrating that the injectable BCG can be deployed as a tool for disease management. It also aimed to facilitate the wider deployment of BadgerBCG through training and reduce the risk of bTB transmission between badgers and cattle (www.defra.gov.uk/fera/bvdp). From July 2010, any badgers captured as part of this project were vaccinated parenterally with 1ml of BCG in the field. In total, 541 badgers were trapped and vaccinated from an area of over 90km^2 north-west of Stroud.

Objectives of the research

Although live trapping of badgers has been carried out since the late 1970's, little is known about the impact this has on the behaviour and welfare of badgers during a trapping session and impact of this behaviour on trapping outcomes. This study aimed to compare and contrast three independent badger populations that had had been subjected to various levels of prior feeding experience (1). WP population – habituated to feeding; (2). OBDS population – semi-habituated to feeding as had been fed for 12 days prior to deployment of traps; (3). BVDP population – naïve to feeding. Observations were made from the first night a trap was deployed, throughout the pre-baiting period and for two nights of consecutive trapping (including re-trapping data for the OBDS population).

The aims of this study were to determine if the level of habituation to feeding would influence badger behaviour towards the traps during the pre-baiting period and if this behaviour changed over time. In addition, would the number of times a badger had previously been caught affect its subsequent behaviour in the trap once captured? Specifically, this project aimed to investigate;

1. Whether prior feeding experience or the day of pre-baiting would influence the time at which a badger was initially observed?
2. Was there a difference in the reaction of badgers towards the traps depending on feeding experience and the day of pre-baiting?
3. Did the time a badger was first observed on screen versus the time a badger first entered the trap differ depending on feeding experience and did it become earlier over the pre-baiting period?
4. Did the average time that badgers spent interacting in some way with either the trap and/or bait vary depending on feeding experience and over the pre-bait period?
5. Were habituated badgers more likely to scent mark/fight over a familiar valuable resource (bait)?

6. Did the number of times a badger had been caught previously affect the behaviour it exhibited whilst in the trap?

7. Did capture have an effect on the number of badger visits that were observed in the secondary pre-baiting period for the semi-habituated population?

As very little work has previously been done on this subject, it is hoped that this study may contribute to a better understanding of badger trapping behaviour and highlight any welfare issues associated with capturing badgers in different populations. This project is not investigating trapping methods, but information gathered on how badgers behave around traps may be used to improve trapping methods and consequently improve the overall efficiency of both research programmes and bTB control operations (Tuttyens et al. 1999). The welfare of badger trapping methods can also be examined through behavioural observation.

Materials and method

Study design (i)

Four social groups in each of three badger populations that had been subjected to varying degrees of feeding and trapping interference were selected for this investigation. The classifications of populations refers to prior feeding experience only and does not refer to prior trapping experience as only badgers at Woodchester Park would have been previously trapped.

Setts were selected on the basis of sett activity levels, landowner consent and the avoidance of possible interference of the traps or camera equipment by members of the public. One camera installation were set up on each of two traps at each sett to increase the chance of observing badgers on screen and to allow for any loss of data from equipment malfunction.

It is known that the trappability of badgers varies significantly between seasons (Tuyttens et al. 1999) but the effect of season could unfortunately not be included in this investigation as filming of the different populations was pre-determined by a set fieldwork schedule and as a result the populations could not be filmed within the same season.

Study area

Habituated population - Woodchester Park (WP

Lying in the Cotswold escarpment, Gloucestershire, South West England, WP covers 11km^2 and consists of mixed woodland, grassland and arable (Delahay et al. 2006, Rogers et al. 1997). The WP population has been subjected to over 30 years of trapping and an annual bait marking exercise (Rogers et al. 1997, Delahay et al. 2000) and so in relation to this investigation, were classed as “Habituated” to prior feeding. The four setts, which were the main breeding setts for four separate social groups (Figure 1), were named Hab1-4. Hab1 and Hab3 were filmed in late spring and Hab2 and Hab4 were filmed in the early autumn.

Semi-habituated population - Oral Bait Deployment Study (OBDS)

Four setts were chosen from three areas around Cirencester, Bath and Langford according to sett activity and fieldwork schedules. Setts were located approximately 2km apart to ensure that they were separate social groups and the four setts were named Semi1-

4 (Figure 1). These setts were fed for 12 consecutive days prior to trap deployment as part of the OBDS bait feeding trial and the badgers were classed as being “Semi-habituated” to feeding, but had not been trapped previously. Due to project protocol, semi-habituated setts were re-trapped two weeks after the initial trap-up, and badgers were fur-clipped (Stewart & Macdonald, 1997) on first capture. This allowed filming to be continued during a 2ndperiod of pre-baiting and known individuals to be observed. All setts were filmed during the summer months.

Naïve population - Badger Vaccine Deployment Project (BVDP)

The BVDP area covered 90 km^2 north-west of Stroud, Gloucestershire, and contained mainly pasture, arable and woodland habitat. The four setts chosen for filming were Naive 1-4 Badgers that were part of BVDP had no previous feeding experience and were therefore classed as “Naïve” (Figure 1). All setts were filmed during the summer months.

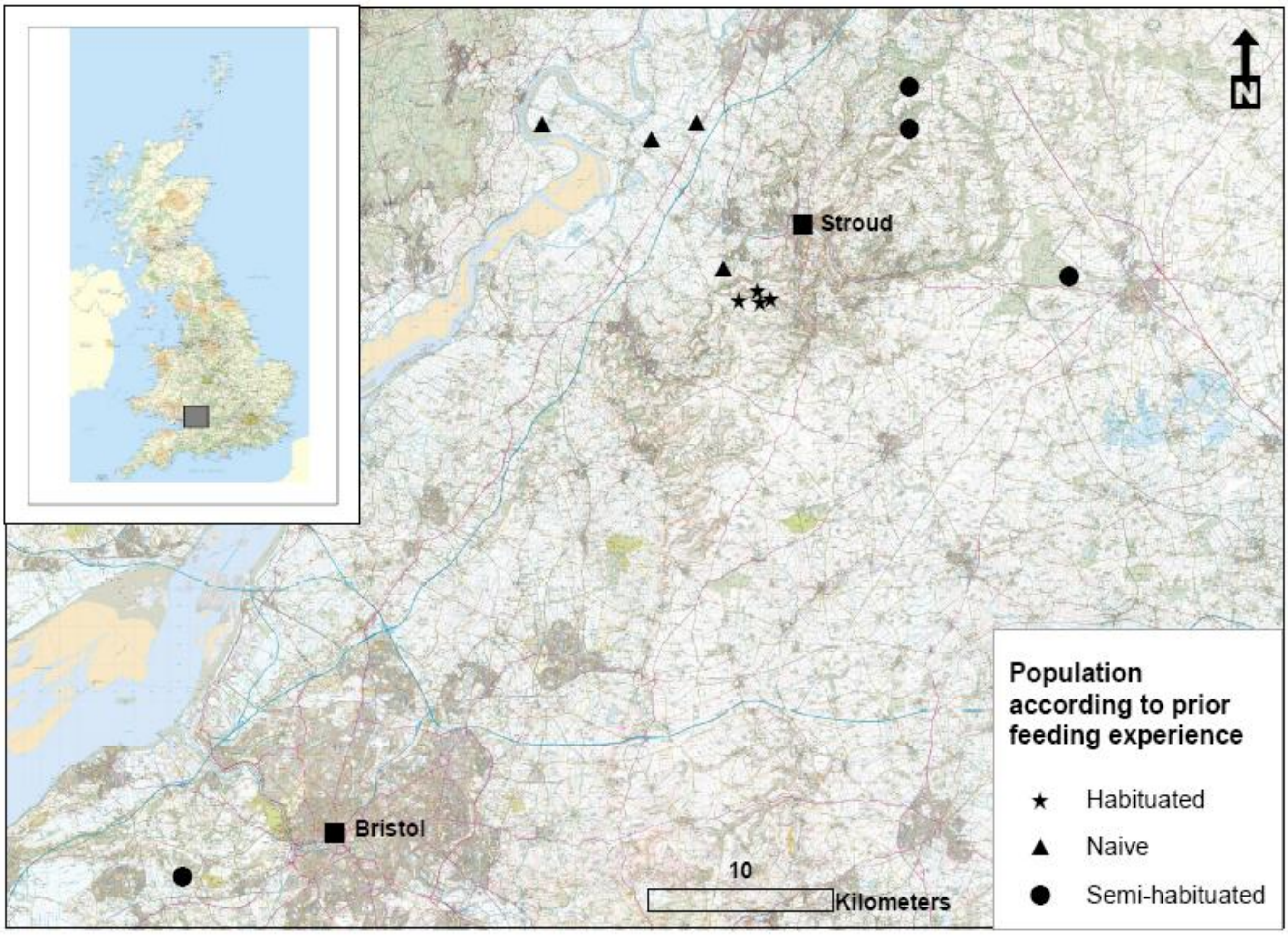


Figure 1. Map showing locations of each of the 12 setts that were filmed.

Study design (ii)

Remote video surveillance

Data was collected using infrared remote video surveillance systems (Stewart et al. 1997). The video equipment consisted of a watertight plastic case in which was fitted a single-channel DVR (Driveproof or MiniD 400 player, supplied by cctvaccess.com, Gloucester, UK) and a 12V dry fit lead acid battery (Numax SLC26-12). A video camera with an internal infrared LED array was connected to the case via a coaxial cable and mounted on a tripod or tree. In order for the memory cards and batteries to be changed, setts were visited daily in the afternoon to minimise disturbance to badgers. The cameras were focussed on an individual trap and were set to record continuously throughout the night from 18:00 to 07:00 (13hrs). Cameras were placed in areas so as not to compromise the ‘normal’ behaviour of badgers. At each sett, one camera was placed next to a trap that had been positioned next to an active hole and the other camera was placed close to an active run. Filming commenced from the day the traps were dug in, wired open and pre-baited with peanuts. The only exception to this was for the habituated population, as the traps remain in situ but wired closed throughout the year. Data collection commenced on the 4th May 2010 and the final night of filming was the 6th October 2010.

Pre-baiting and trapping protocol

For all projects, badgers were captured using cage traps constructed from 2x2” (semi-habituated and naive populations) or 1x2” (habituated population) galvanised steel mesh (CSL, 2001). Traps were dug into the ground with a layer of soil covering the bottom to make them more secure. The doors were locked open with wire to enable badgers to freely enter. Traps were pre-baited with a handful of peanuts to encourage badgers into traps before they were set (Cheeseman & Mallinson, 1979). The length of pre-baiting activity varied between studies due to project protocol and ranged from 5 to 13 days. Bait was placed under a stone or a slab to deter non-target species from consuming the bait.

Following the pre-baiting period, traps were set for two nights. Traps were set in the late afternoon and were checked at first light (Cheeseman et al. 1987, Rogers et al. 1997). The habituated and semi-habituated badgers were transferred into holding cages and taken to a nearby sampling facility and the naive badgers were either vaccinated, marked and released or released immediately if they had already been vaccinated.

Behaviour analyses

Observations of behaviour in relation to traps during the pre-baiting period

Badger behaviour was categorised by the animals' reactions to the trap (Tables 1 & 2). Behaviour was recorded in terms of the numbers of badgers that were observed exhibiting the behaviour and the duration (in seconds) that the behaviour was carried out. This resulted in a cumulative total per night per sett as individual badgers could not generally be identified. As population density was unknown in both the semi-habituated and naive populations, average times of each behaviour per population per night were calculated and this was used in the analyses to take into account any differences in population density.

Table 1. Categorisation of badger behaviour when first observed on camera.

Behaviour	*Description*
No reaction	Badger observed in background only; no interest shown towards the trap
Aware	Badger may stare or sniff in the direction of the trap or approach but no physical interaction is observed
Interest but no entry	Shows interest towards outside of trap with physical interaction e.g. sniff or paw. Does not enter the trap
Entry	Enters the trap and physically interacts with either the trap or bait

Table 2. Description of behaviour types exhibited by badgers during the pre-baiting period.

Type of behaviour	*Description*
Trap interaction	Sniff or paw at entrance, door, side, back and roof of the trap, both internally and externally
Bait interaction	Eat, paw or sniff bait.

Behaviour of trapped badgers

Cage trapped badgers were observed from the moment the trap door went down. The behaviours observed were classified into three categories; active escape, active non-escape and inactive (Table 3). The duration of the behaviour exhibited was recorded in seconds over the entire duration that the badger was captured in the trap until its release. For analyses of the effect of prior trapping experience, badgers were classified according to the number of times the badger had been trapped previously (first, second and more than three). Habituated badgers may have been caught numerous times, whereas semi habituated and naive badgers would have only been trapped recently and only once or twice before.

Table 3. Description of behaviour types exhibited by badgers when captured in traps on trapping nights.

Type of behaviour	*Description*
Active escape (AE)	Bite cage mesh and/ or dig/paw at trap side, ground or roof
Active (ANE)	Feed on bait, forage for scattered bait, groom and interactions with other badgers
Inactive (IN)	Sit, lie or stand still

Secondary pre-baiting period for the semi-habituated populations

As the semi-habituated populations were subjected to an additional pre-baiting period, individual badgers could be identified from their unique fur-clips that they were given when sampled in the laboratory. The first individual to visit the trap, the number of visits per badger and the total number of different badgers observed were recorded.

Statistical analysis

To take into account differences in pre-baiting periods between the different populations, statistical analyses were run using a restricted data set that only included the first six days of the pre-baiting period.

Initial analysis of behaviour in relation to the traps

To investigate the proportion of badgers that exhibited a particular behaviour towards the trap when first noted on screen, a Generalised Linear Model (GLM) with a normal distribution and identity link function was fitted with feeding experience (habituated, semi-habituated and naïve) as a fixed effect and pre-bait day as a continuous fixed effect. Separate models, with the above model structure were run for each observation type (no reaction, aware of the traps, interest but no entry and trap entry). Non-significant terms were removed using stepwise procedures.

Time of first observation

A General Linear Mixed Model (GLMM) was run to investigate (1) whether feeding experience would influence the time a badger was first observed on screen and (2) if the time of the primary observation varied over the pre-baiting period. First observation times were adjusted to time before /after sunset to take into account changes in seasonality. A reference point of 0 seconds was set at the earliest observation point. Feeding experience was fitted as a fixed effect; pre-baiting day fitted as a continuous fixed effect and sett and camera were fitted as random effects. The fixed explanatory variables were entered as an interaction term.

Time of first observation on screen versus first time a badger enters the trap

The time taken from when the first badger was observed to when the first badger entered the trap was investigated using a GLM (with a normal distribution and an identity link function). The response variable, time taken to enter trap, was not normally distributed and therefore log transformed to meet model assumptions. Feeding experience was entered as a fixed effect and pre-bait day entered as a continuous fixed effect.

Interactions with the trap and bait

To investigate potential differences between the populations with different levels of feeding experience, the amount of time spent interacting with the traps and bait and the average time (seconds) per day that each behaviour was observed was analysed using a GLM with a normal distribution and an identity link function. Feeding experience and pre-bait day (a continuous variable) and their interaction fitted as fixed effects. Non-significant terms were removed using stepwise procedures. A separate model was fitted for each behaviour type.

Aggressive encounters

To determine the probability that level of feeding experience may effect the numbers aggressive encounters observed, a Chi square (χ^2) analysis was used The number of aggressive encounters were also pooled to investigate the relationship between aggression and the duration of pre-baiting and a GLM, with a Poisson distribution and logarithm link function was fitted to the number of aggressive encounters. Feeding experience was fitted as a fixed effect and pre-bait day as a continuous fixed effect, with stepwise removal of non-significant terms.

Patterns of olfactory communication

To investigate patterns of olfactory communication, a GLM with a Poisson distribution and logarithm link function was fitted with the average number of visits per day as the response variate with feeding experience fitted as a fixed effect and pre-bait day fitted as a continuous fixed effect. The explanatory variables were also entered as interaction terms.

Behaviour in traps

Although there was only a small sample size (N=13) it was possible to look at relationships between the number of previous captures and the percentage of time (over three periods) that a certain behaviour (active escape, active non-escape and inactive) was observed for. A Spearmans rank correlation was run for each behaviour type and each time period.

Effect of trapping on number of badger visits

A paired t-test was run to determine if the effect of the first round of trapping had affected the number of observations at each of the semi-habituated setts. The numbers of observations in the first and second pre-baiting periods were compared.

All statistical analyses were carried out using Genstat statistical software, 14th edition (Lawes Agricultural Trust, Rothamstead, UK)

Results

In total, 324 nights of filming were analysed, totalling 4225 hours of footage (Appendix 1, Table 1). This included 184 nights of pre-baiting, 42 nights of trapping and 98 nights from the second trap round at semi-habituated setts (82 pre-baiting and 16 capture events), which enabled individual badgers to be identified. In total, only 26 nights of surveillance (7 %) were lost either due to equipment malfunction or operator error.

1912 (individual) sightings of badgers were recorded throughout the duration of the study (Table 4). Overall, 88% of badgers were classed as adults, 7% as cubs and 5% as unsure (Figure 2). Cubs were recorded at only two setts, one each in the habituated and naive population.

Table 4. Numbers of observations during the different stages of filming.

	Period of pre-baiting				
Feeding experience	*Pre-baiting*	*Trapping*	*2nd pre-baiting*	*Re-trapping*	***Totals***
Habituated	709	73	-	-	**782**
Semi-habituated	374	9	367	12	**762**
Naive	350	18	-	-	**368**
Totals	**1433**	**100**	**367**	**12**	**1912**

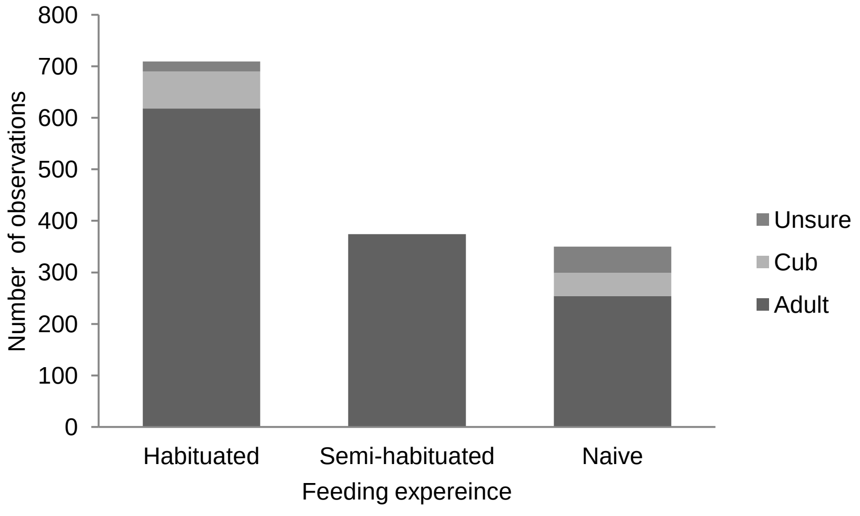


Figure 2. Breakdown of the different age classes of badgers observed for each level of prior feeding experience.

Pre-baiting data

1433 individual sightings of badgers were observed during the pre-baiting period (Table 4). Badgers were observed on 137 out of a possible 185 pre-baiting nights; this equated to 100% (40/40) at the habituated setts, 77% (40/52) at the semi-habituated setts and 61% (57/93) at the naive setts (Appendix 2, Table 1). All badgers regardless of feeding experience were observed on screen within the first two days of pre-baiting.

Observation Times

The majority of first observations for all populations occurred within the first hour after sunset (Figure 3) regardless of feeding experience. On average, the earliest observation times for each population (after sunset) were; habituated – 1 hour 2 minutes; semi-habituated – 1 hour 28 minutes; naïve – 2 hours 27 minutes). On 19 occasions, badgers were observed before sunset, of which all bar one were belonging to those badgers that were semi-habituated and naïve to feeding. The earliest observation was 3 hours 11 minutes before sunrise and the latest was 8 hours 47 minutes after sunset (or 49 minutes after sunrise). Both of these observations were recorded for badgers that had had no prior feeding experience. In contrast, the pattern of first visits for the habituated badgers was more concentrated within a two hour window around sunset. Only 13 badgers out of the total 1433 that were observed were recorded after sunrise.

A GLMM showed a significant interaction between population and pre-baiting day on initial observation times (F = 4.49, d.f. = 2, 8.98, p = 0.014, Table 5). The predicted effects demonstrate that over the duration of the pre-baiting period, the habituated and semi-habituated badgers were observed earlier, whilst in comparison, the naïve badgers first observation became later.

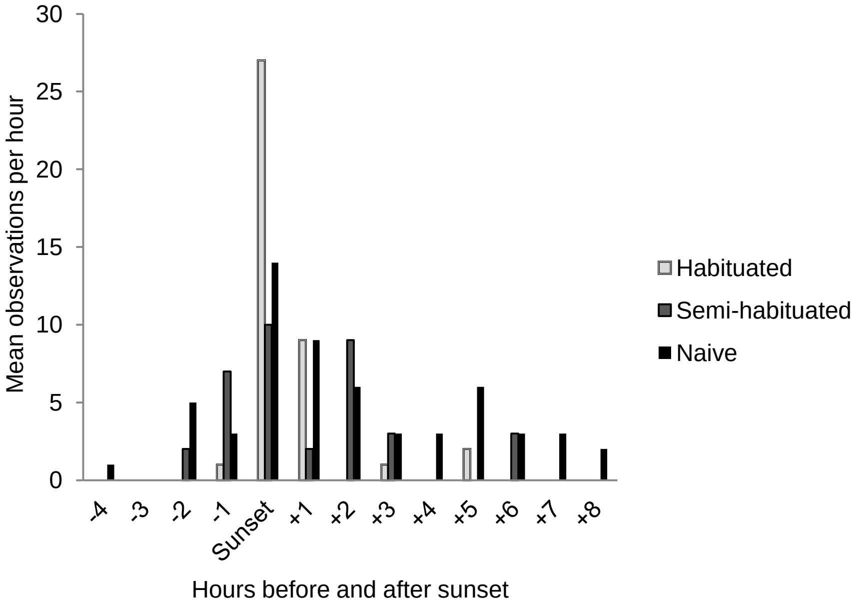


Figure 3. Mean observations per hour in relation to number of hours before or after sunset. The reference point of sunset was chosen to allow for seasonal variation. Badgers classified according to prior feeding experience.

Table 5. GLMM showing the effects of feeding experience and pre-bait day on the time of the first badger observation of each night. There was a significant interaction between model terms

Fixed term	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
Experience	5.98	2	2.99	18.0	0.076
Day_of_prebaiting	2.02	1	2.02	87.4	0.158
Experience.Day_of_prebaiting	8.98	2	4.49	87.9	**0.014**

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Population.Day_of_prebaiting					
	8.98	2	4.49	87.9	**0.014**

Table of effects for Population

Population	Habit	Naïve	Semi
	0.00	108.97	62.88

Table of effects for Day_of_prebaiting

-26.40 Standard error: 11.293

Table of effects for Experience.Day_of_prebaiting

Experience	Habit	Naïve	Semi
	0.00	48.96	7.73

Initial observations

Each badger observation was classified as either ‘no reaction’ (27% of total observed), ‘aware but had no interest in the trap’ (8%), ‘interest but did not enter’ (20%) and entry (45%) (Figure 4). The habituated badgers had the highest proportion (49%) of individuals that were noted as showing ‘no reaction’. Of all observations of badgers that actually entered the traps from the total observed was 39% (561/1433), with great variation within each of the different populations according to feeding experience. When badgers were recorded as entering the trap, either partially or fully, on 85% (N=658) of occasions the badger entered fully and would therefore be able to set a trap off if it had been set. The highest proportion of badgers fully entering traps occurred in the population that were naïve to feeding (89%) (Appendix 2, Table 1).

Feeding experience and the day of pre-baiting had no significant effect on either the percentage of the total observations when no reaction to the traps was observed (GLM $F_{3,98} = 2.18$, $p = 0.095$) or on the percentage of badgers that were interested in the trap but did not enter (GLM $F_{3,98} = 1.96$, $p = 0.125$). The percentage of the total observations in which badgers were aware of the traps was not affected by the day of pre-baiting but significantly affected by feeding experience (GLM $F_{3,98} = 3.35$, $p = 0.022$, Table 5*a*). The naïve badgers exhibited the greatest awareness of the traps.

In relation to the percentage of the total observations that resulted in a badger entering the trap, a significant interaction was noted ($F_{5,96} = 3.45$, $p = 0.006$, Table 5*b*) between feeding experience and day of pre-baiting. Naive animals exhibited a stronger effect of pre-baiting on the tendency to enter traps as the number of naïve badgers that entered the traps increased over the duration of the pre-baiting period.

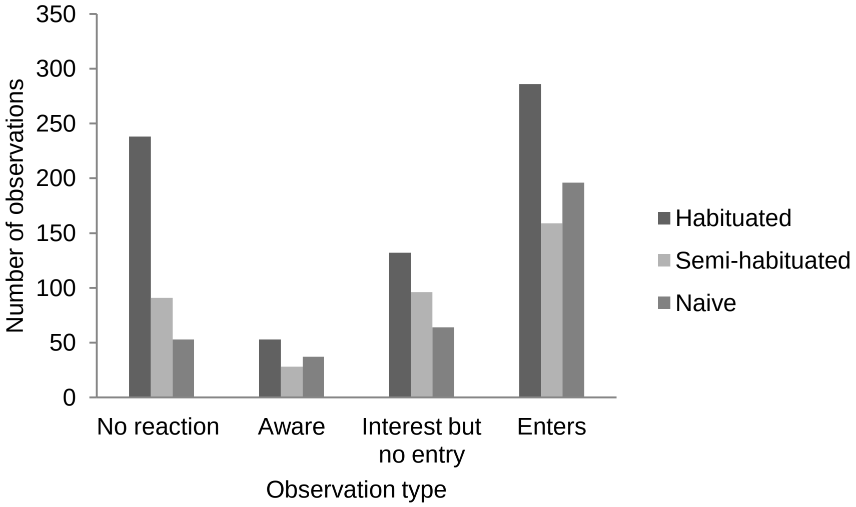


Figure 4. Behaviour observed by badgers towards the trap, classified according to prior feeding experience.

Table 5*a*. GLM showing the effects of feeding experience and day of pre-baiting on the percentage of 'aware' observations.

Parameter	**estimate**	**s.e.**	**t(98)**	**t pr.**
Constant	13.39	5.92	2.26	0.026
Experience Naïve	16.77	5.75	2.92	0.**004**
Experience Semi	8.58	5.26	1.63	0.106
Day_of_prebaiting	-1.90	1.38	-1.38	0.171

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
Experience	8.664	2	4.33	0.016
Day_of_prebaiting	1.899	1	1.90	0.171

Table 5*b.* GLM showing the effects of feeding experience and day of pre-baiting on the percentage of observations of badgers that entered traps

Parameter	**estimate**	**s.e.**	**t(96)**	**t pr.**
Constant	66.82	9.97	6.70	<.001
Experience Naïve	-49.8	15.9	-3.13	0.**002**
Experience Semi	-43.4	15.2	-2.86	0.**005**
Day_of_prebaiting	-4.93	2.65	-1.86	0.066
Day_of_prebaiting.Experience Naïve	11.96	4.05	2.96	**0.004**
Day_of_prebaiting.Experience Semi	7.47	3.88	1.93	0.057

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
Experience.Day_of_prebaiting	9.193	2	4.60	0.01

Trap entry

There was variation between and within the different badger populations depending on prior feeding experience as to when badgers started to enter traps. The habituated badgers took the least amount of time to enter traps, whilst naïve badgers generally took the longest time (Appendix 2, Table 1).

The time badgers spent inside the unset traps varied considerably depending on prior feeding experience. Visits by the habituated badgers lasted, on average, for 98 seconds(SD ± 83 seconds), whilst in comparison, the semi-habituated badgers spent 146 seconds (SD ± 82 seconds) in the trap and the naïve badgers spent 237 seconds (SD ± 152 seconds).

From when a badger was first observed on screen to when a badger actually entered the trap varied according to prior feeding experience and tended to decrease over the pre-bait period. There was a highly significant effect of both experience and day of pre-baiting on this time period (GLM $F_{3,79}$ = 18.89, p = <.001, Table 6)The semi-habituated and naïve badgers both took longer to enter the traps compared to the habituated individuals and this difference was slightly more pronounced in the semi-habituated badgers.

Table 6. GLM showing the log difference in time between when a badger was first observed on screen and when a badger first entered the trap

Parameter	**estimate**	**s.e.**	**t(79)**	**t pr.**
Constant	-2.422	0.272	-8.92	<.001
Experience Naïve	0.849	0.283	3.00	0.**004**
Experience Semi	1.542	0.251	6.14	**<.001**
Day_of_prebaiting	-0.3367	0.0664	-5.07	**<.001**

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
Experience	38.37	2	19.18	<0.001
Day_of_prebaiting	25.74	1	25.74	<0.001

Interactions with trap and baits

The total time that each individual badger spend investigating either the trap (sniffing or pawing behaviour) or the bait (sniffing, pawing or eating) was calculated and recorded in Table 7

Traps were investigated on 56% of the total observations, totalling 5651 seconds of interaction time (range 1-27 s, mean = 6 s, N = 803). Badgers that were semi-habituated and naïve to feeding spent significantly longer investigating the traps than the habituated badgers (GLM $F_{3,78}$ = 9.80, p = <.001, Table 8). Pre-baiting day had a highly significant effect on investigation time; and as pre-baiting continued, trap interaction time decreased.

Although fewer badgers (27%) were observed interacting with the bait than the trap itself , the length of this interaction time was much greater, with a total duration 92,421 s (range 0-1203 s, mean = 206 s, N = 381) compared to only 5651 trap interest. The interaction between feeding experience and day of pre-baiting significantly affected the duration of time investigating bait (GLM $F_{5,75}$ = 4.24, p = 0.002, Table 9) As the pre-baiting period continued, the length of time that the semi-habituated badgers spent interacting with the bait increased quite dramatically.

Table 7. A summary of the numbers of observations, numbers of interactions and length of interaction with trap and bait. Average times were calculated to take into account the difference in badger densities between populations.

Prior feeding experience	*Total Obs.*	*Trap (no)*	*Trap time (s)*	*Average trap time (s)*	*Bait (no.)*	*Bait time (s)*	*Average bait time (s)*
Habit	709	348	1979	6	119	24,025	202
Semi	374	241	2007	8	111	28,554	257
Naive	350	214	1665	8	151	39,842	264
Totals	**1433**	**803**	**5651**	**7**	**381**	**92, 421**	**243**

Table 8. A GLM showing the effects of feeding experience and day of pre-baiting on the average time that badgers spend interacting with traps.

Parameter	**estimate**	**s.e.**	**t(78)**	**t pr.**
Constant	7.741	0.898	8.62	<.001
Experience Naïve	3.821	0.930	4.11	<.**001**
Experience Semi	3.067	0.832	3.69	<.**001**
Day_of_prebaiting	-0.732	0.220	-3.32	**0.001**

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
Experience	22.49	2	11.24	<0.001
Day_of_prebaiting	11.04	1	11.04	0.001

Table 9. A GLM showing the effects of feeding experience and day of pre-baiting on the average time that badgers spend interacting with the bait

Parameter	**estimate**	**s.e.**	**t(75)**	**t pr.**
Constant	375.4	75.1	5.00	<.001
Experience Naïve	21.	144.	0.14	0.887
Experience Semi	-246.	124.	-1.99	0.**050**
Day_of_prebaiting	-55.3	20.4	-2.72	0.**008**
Day_of_prebaiting.Experience.Naïve	32.1	35.4	0.91	0.368
Day_of_prebaiting.Experience.semi	108.5	31.6	3.44	<.**001**

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
Experience.Day_of_prebaiting	11.98	2	5.99	**0.004**

Patterns of olfactory communication in relation to feeding experience and duration of pre-baiting

As illustrated by Figure 5, 193 incidents of olfactory communication (scent marking and urinating) were observed during the pre-baiting period. Most olfactory communication was carried out by habituated badgers (55%; 102/193) and the least by semi-habituated badgers (17%; 41/193). Scent marking accounted for the majority of the total olfactory behaviour recorded (92%; 178/193). The most frequently marked place was close to the trap, in particular, the trap entrance; 47% (91/193) of all olfactory communication was observed in this location. Olfactory communication was not recorded every day and but occurred on 83% of pre-baiting days in the habituated populations, 33% in the semi-habituated population and on 26% in the naive population.

The level of olfactory communication was significantly affected by feeding experience but the day of pre-baiting had no effect (GLM $F_{3,133} = 3.03$, $p = 0.032$, Table 10), the habituated badgers were more likely to carry out some form of olfactory communication compared to the others.

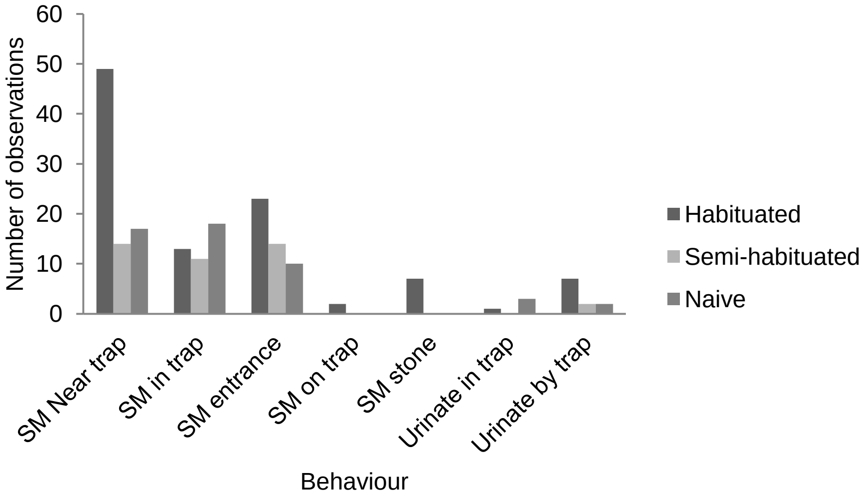


Figure 5. The number and type of olfactory communications depending on feeding experience. SM = scent marking.

Table 10. GLM showing the effects of levels of previous experience to feeding and pre-baiting day on the number of olfactory communications.

Parameter	**estimate**	**s.e.**	**t(133)**	**t pr.**
Constant	0.0532	0.0578	0.92	0.359
Experience semi-habituated	0.0009	0.0491	0.02	0.985
Experience habituated	0.1308	0.0513	2.55	**0.012**
Pre-bait day	0.00923	0.00736	1.25	0.212

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
Experience	8.982	2	4.49	**0.013**
Pre-bait day	1.574	1	1.57	0.212

The effect of pre-baiting on the number of aggressive encounters

Only three percent (38/1433) of observations were classified as aggressive encounters (Table 11), the majority of which (63%) were carried out by the habituated badgers. Only four aggressive encounters were carried out by naïve badgers, representing only 1% of their total observations (350) and ten aggressive encounters were observed by semi habituated individuals, which represented 3% of total observations (374). Although the habituated badgers were involved in more aggressive encounters, this only equated to 3% of their total observations. A Chi square test showed that there was no significant difference in the number of aggressive encounters observed regardless of feeding experience ($\chi^2 = 2.44$, df = 2; p = 0.296).

The number of aggressive encounters were pooled to investigate the relationship between aggression and duration of pre-baiting (Fig 6) A GLM ($F_{3,14} = 5.8$, p = <.001, Table 12) showed that there was a significant relationship between feeding experience but the day of pre-baiting had no effect. Semi-habituated and naïve badgers were both significantly less likely to carry out some sort of aggressive encounter, the effect being more pronounced among the naïve badgers.

Table 11. Number of aggressive encounters observed compared to total observations for each population.

Feeding experience	*Number of aggressive encounters*	*Total number of observations*
Habituated	24	709
Semi-habituated	10	374
Naive	4	350
Totals	**38**	**1433**

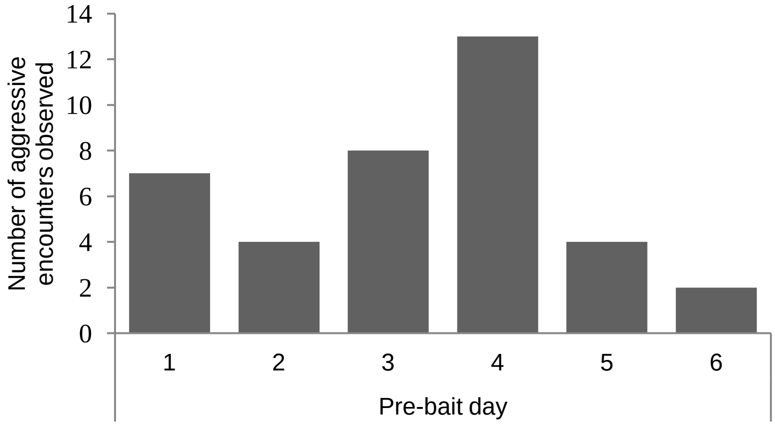


Figure 6. Pooled data of the number of aggressive encounters observed over the duration of the pre-baiting period.

Table 12 GLM showing the effects of feeding experience on the number of aggressive encounters and day of pre-baiting**.**

Parameter	**estimate**	**s.e.**	**t(*)**	**t pr**.
Constant	1.692	0.371	4.56	<.001
Experience Semi-	-0.875	0.376	-2.33	**0.020**
Experience Naive	-1.792	0.540	-3.32	<**.001**
Pre-bait	-0.0907	0.0956	-0.95	0.343

Wald tests for dropping terms

Term	Wald statistic	d.f.	chi. pr.
Experience	13.856	2	**<0.001**
Pre-bait	0.899	1	0.343

Trapping data

During the trapping period 112 badgers were observed over 58 filming nights, across all three study populations. 16 badgers were observed entering traps, sometimes pawing the string and bait and eating bait, before leaving without the traps being sprung. Thirteen badgers were caught in traps on which a camera was focussed, six, four and three from the habituated, semi-habituated and naive populations, respectively (Appendix 3, Table 1). Two traps were sprung by non target species (a mouse and a squirrel).

Seven of the thirteen individuals were trapped within the 1st hour after sunset and two individuals were caught before sunset. The earliest badger trapped was 1 hour 26 minutes before sunset and the latest badger to be trapped was1 hour 13 minutes before sunrise. The average time of capture was 2 hours and 13 minutes after sunset (SD. ± 2 hours 18 minutes)

On average, trapped badgers spent 8 hours 25 minutes in traps (SD ± 2 hours 49). The shortest time spent in a trap was 1 hour 47 minutes and the longest time was 12 hours 25 minutes (Appendix 3, Table 1).

Individuals were classified according to the number of times they had been previously trapped. Of the 13 badgers caught, four had never been caught previously, four had been caught twice and five had been caught on more than three occasions, ranging from five to 10 recaptures (Appendix 3, Table 1). Due to the small sample size (N=13), the relationship between sex and the behaviour of the badgers once captured was not investigated.

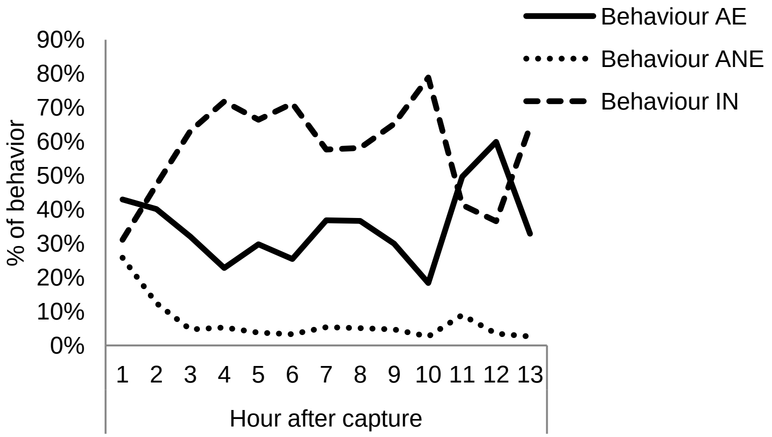
On average (Table 13), badgers spent the majority of their time inactive in the trap (55%, range 16-92%) and the least amount of time active but not escaping (8.3%, range 0.3-18%). Badgers that had been caught on more than three occasions spent on average 69% of their time inactive in the trap and only 22% of their time trying to escape. In contrast, badgers that were experiencing either their first or second capture spent on average 47% and 45% respectively actively trying to escape. Overall, active escape behaviour accounted for only 37% of the total restraint period (range 3-73%). During the first 10 minutes after restraint, badgers spent, on average, 52% of their time trying to escape. However, this percentage varied considerably depending on the number of time they had been previously caught. If it was an individuals first experience of entrapment, they would spend, on average, 79% of their time trying to actively escape which is considerably greater than those badgers that had been caught on more than 3 occasions (30%). A breakdown of behaviour for each badger can be found in Appendix 3, table 1.

Table 13. Mean time in trap and mean percentages of behaviour type depending on the number of times previously caught ******AE* = *Active escape;* ***ANE*** = *Active non-escape (i.e. eating bait/self grooming);* ***IN*** = *Inactive*

Trapping status	*Average time in trap*	*Mean AE (%)*	*Mean ANE (%)*	*Mean IN (%)*	*Mean AE (%) in first 10 mins*
1st capt	08:26:30	46.8	6.8	46.4	78.7
2nd capture	08:21:57	45.4	7.9	46.7	52.1
3rd + capture	08:46:20	21.5	9.7	68.8	30.2
Overall	**08:25:56**	**36.6**	**8.3**	**55.1**	**51.8**

A Spearman's rank correlation revealed that for all observations there was a significant negative association between the number of times previously caught and the proportion of time spent exhibiting active escape behaviour (N=13; p = 0.017). However, there was no significant association between number of times previously caught and time spent exhibiting active non-escape behaviour (p = 0.317) or inactive behaviour (p = 0.165).

Examination of the raw data indicated that some behaviour types were more frequently observed over certain time periods and that there may be relationship between numbers of previous captures and behaviour types exhibited (Figures 7b-d). For example, it appeared that animals caught for more than 10 hours spent more time exhibiting active escape behaviour in the last three hours of capture (Figure 7a). Investigating patterns over different time periods with a Spearman's rank correlation, indicated that there was a particular association between the number of times previously caught and the behaviour exhibited in the last three hours (Active escape: N=13, p = 0.025; Inactive escape: N = 13, p = 0.032), with badgers being caught more than three times exhibiting less active escape behaviour and more inactive behaviour in the last hour of capture. In the last three hours, there was no association between number of times previously caught and the proportion of time spent exhibiting active non-escape behaviour (p = 0.476). Surprisingly, there was no association between trapping status and behaviour type exhibited in the first three hours of capture (Active escape: p = 0.258; Non-active escape: p = 0.111; Inactive: p = 0.399), as may be expected from examining the data (Figures 7b-d).



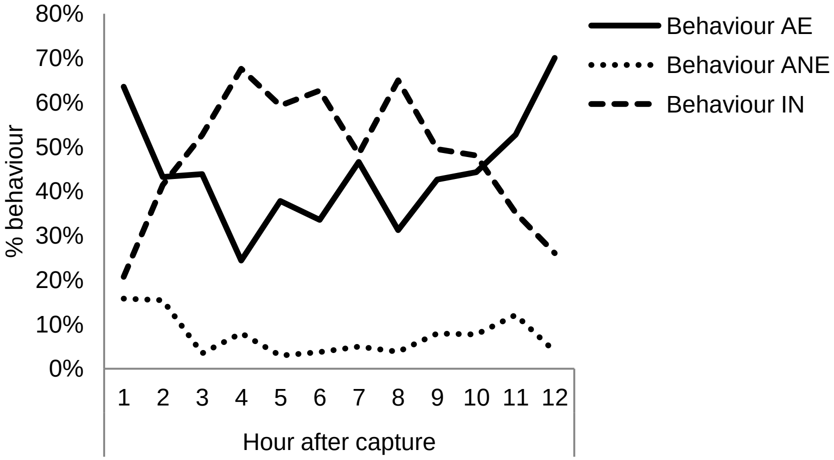
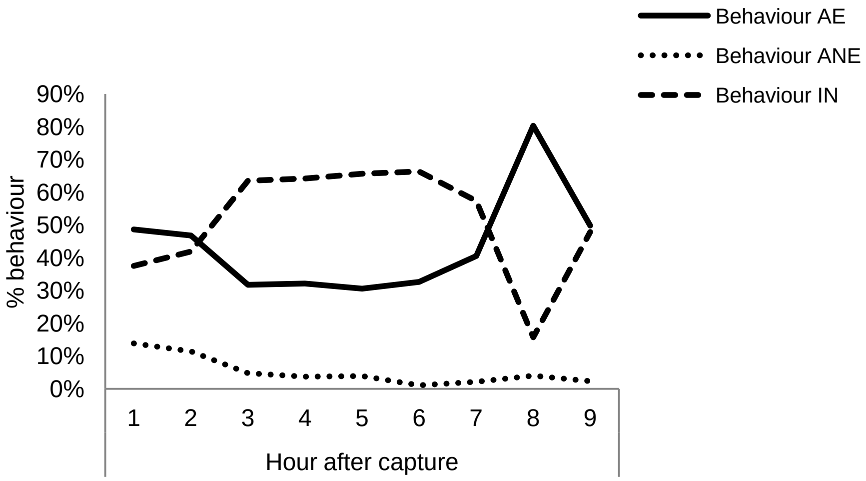


Figure 7a. Average percent of each behaviour type per hour (all captures) (N = 13). AE = Active Escape; ANE = Active Non-Escape; IN = Inactive

Figure 7b. Average percent of behaviour type per hour (1st capture) (N = 4)



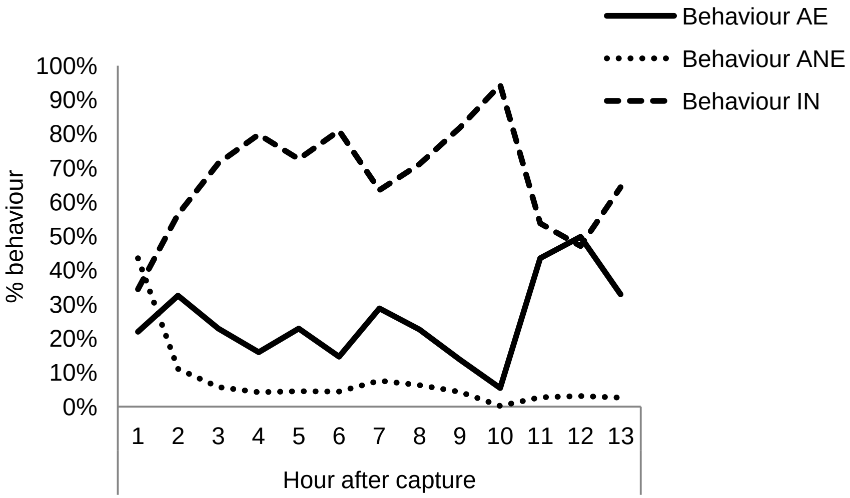


Figure 7c. Average percent of behaviour type per hour (2nd capture) (N = 4)

Figure 7d. Average percent of behaviour type per hour (3+ capture) (N = 5

The effect of being captured on the number of observations during a subsequent pre-baiting period

In the semi-habituated population, 15 badgers were caught at the four setts under observation, of which 14 were fur clipped (Appendix 4, Table 1). An additional unmarked badger was observed at Semi3 but was never captured. 367 observations of badgers were made during the 82 days of secondary pre-baiting filming, compared to 374 observations in the first pre-baiting period. Of these, 186 (51%) were of badgers entering the trap (of which 172 were fur clipped), compared to 159 (43%) badgers observed entering traps during the first pre-baiting period. Of the 14 badgers fur-clipped, all but two (C9 and L33) were observed during the second pre-baiting period and all but two (L29 and L33) were re-caught during the re-trap. Six badgers were observed on the first night after the first round of trapping. C36 was the only badger to be observed every day and L28 was the only badger that entered the trap every time it was recorded on camera. No badgers were observed at Semi1 during the second period of filming.

When the first and second pre-baiting periods were compared, an average of 7.2 and 5.6 observations on screen per night were recorded respectively (Table 14). The average number of visits per night decreased at all setts during the second pre-baiting period. At three of the setts, there was a decrease in the total number of badger observations but an increase at the fourth but the relationship was not significant (t = 0.06, d.f. = 3, p = 0.953).

Table 14. The average number of observations over the first and second pre-baiting periods.

	1st pre-bait period			*2nd pre-bait period*		
Sett	*Observations per night*	*No. of days*	*Average observations per night*	*Observations per night*	*No. of days*	*Average observations per night*
Semi1	5	12	0.4	0	0	0
Semi2	55	14	4	13	20	0.7
Semi3	147	12	12	224	23	9.7
Semi4	167	14	12	130	23	5.7
Totals	**374**	**52**	**7.2**	**367**	**66**	**5.6**

Discussion

The aim of this investigation was to (1) gain a better understanding as to how pre-baiting may enhance trapping efficiency and (2) to understand the impacts that trapping may have on animal welfare from a behavioural point of view. As with pre-baiting, there is currently little information on the behavioural effects of trapping on badgers.

Evidence from this study suggests that pre-baiting markedly affects badger behaviour in relation to bait and traps and prior feeding experience has a significant effect on these behavioural responses. The duration of pre-baiting is particularly important for the behaviour of the semi-habituated and naive badgers whereas the habituated badgers tended to respond independently of pre-baiting duration. Information collected from this study concluded that trapped badgers do not spend the duration of their time in traps trying to escape and spent the majority of the time inactive with periods of grooming and feeding interspersed. The overall level of active escape behaviour exhibited was significantly affected by previous trapping experience, as on average, the amount of time spent trying to escape decreased according to the number of times previously caught. Although the experience of becoming habituated affected behaviour, the effect of capture did not appear to affect the behaviour of badgers after entrapment as they continued to enter the traps during the second pre-bait period and were subsequently caught again a week later.

Pre-baiting is an essential component of most trapping protocols and tries to eliminate ‘new object reaction’ (see Chitty & Shorten, 1946) as it encourages otherwise neophobic animals into the trap and allows them to take bait freely. Although pre-baiting is commonly used to capture animals, e.g. canids (Tietjen & Matschke, 1982) and primates (Bicca-Marques & Garber, 2004), there are very few publications that have evaluated its effect on capture rates (Edalgo & Anderson, 2007). This habituation of animals to the bait and the trap will allow animals to enter the traps more readily when set (Chitty & Kempson, 1949, Edalgo & Anderson, 2007) and hence improve trapping efficiency. However, it is important to note that seasonality and weather conditions may affect bait uptake and hence trapping efficiency by influencing the availability of key alternative food resources (Tuyttens et al. 1999). Animals habituated to feeding are more likely to enter traps during the pre-baiting period than those with no previous experience as they have been conditioned to the scent of the bait and have learnt that the traps contain a valuable resource. This can be illustrated by the work of Mellgren & Roper (1986) who reported that badgers were able to remember the locations of discrete food patches.

Trapping is an essential part of many wildlife management programmes and is used for the capture of a wide ranging number of species and for a variety of reasons. Vaccination and culling programmes are often expensive and time consuming, frequently requiring many years of repeated trapping to see the desired effects (e.g. to ensure that a certain proportion of the population are captured in order for the programme to be successful). Modelling suggests that 50% of badgers need to be vaccinated as part of the BVDP (FERA, 2010), which is being carried out over a five-year period. Therefore, knowledge of how an animal may behave around traps and the subsequent effect that this may have on the trapping efficiency of such vaccination and culling programmes is extremely important as potential problems can be mitigated against. Due to the high economic costs, lengthy trial periods and possible negative reactions to some management programmes, it is essential that these programmes are carried out in the most efficient manner possible, as they are likely to gain public support if proven to be successful. It is also imperative that trapping practices adhere to the highest welfare standards to ensure that the effect of capture on individuals (both target and non-target species) is minimised.

Due to the nature of this project, there were a number of limitations that may have had a significant effect on the number and behaviour of the badgers observed across the different populations. The two most important factors would be (1) the number of badgers at each sett and (2) the effects of seasonality. The habituated setts were in a high density area (Vicente et al. 2007) and although densities at the semi-habituated and naive areas were unknown, they were believed to have been of relatively high density (R. Delahay, *pers. comm.*). This difference may have had an effect on the numbers of badgers observed i.e. more badgers were observed in habituated areas. Seasonality also would have had a profound effect across all three populations, as this would have affected food availability (Tuyttens et al. 1999) and hence, badgers willingness to enter traps. In the summer months, less natural food is available to badgers in comparison to autumn, where food is more plentiful. Therefore, during autumn months, badgers may be less inclined to enter traps. Project timetables affected when filming could be carried out and this resulted in the filming period extending over three seasons (late spring, summer and early autumn).

Behavioural responses during pre-baiting

There was a marked variation in the numbers of badgers observed on screen during the pre-baiting period but this could be a direct result of differences in population density rather than a neophobic reaction to the bait and traps (see Barnett, 1958). Initial observations were normally noted within the first hour after sunset which is when badgers will normally first emerge from the sett (Neal & Cheeseman, 1996). Initial observations became earlier for both the semi-habituated and habituated badgers over the duration of pre-baiting possibly as (1) they remembered the location of the food source (Mellgren & Roper, 1986) and (2) wanted to prevent bait consumption by other badgers. The later visits, as observed within the naive badgers, is more difficult to explain, and could be a result of a smaller population density. Badges could therefore less inclined to go into the traps for food unlike their counterparts from higher density populations where completion for food may be a factor.

Differences in the initial reactions to the traps might largely be attributed to neophobia. This was most apparent with the naive badgers as they had no prior experience to either traps or the bait and would therefore be more wary and hence take longer to enter traps. Naive badgers were significantly more aware of the traps than semi-habituated and habituated badgers and often did not enter the trap. Over the duration of the pre-baiting period, more semi-habituated and naive badgers were observed entering the traps as they became familiar with the presence of the trap and became conditioned to it being a source of food.

Habituated badgers would spend considerably less time in the traps because they had prior experience of pre-baiting and trapping. They could easily move the bait stone, and would eat the bait quickly and move on. In contrast, the semi-habituated and naive badgers struggled with the stone and appeared wary of the trap. The semi-habituated badgers spent slightly less time in the traps than naive badgers presumably as they had had previous experience of moving the bait stone as part of the OBDS. As the semi-habituated and naive badgers became more accustomed to the trap and recognised it as a source of food, the length of time from when a badger was first observed on screen to when it actually entered the trap decreased.

The effect of pre-baiting and prior feeding experience was most evident in the behavioural responses shown towards both the traps and the bait. Over time, the amount of time spent interacting with the trap decreased while the time spent interacting with the bait increased for both the semi-habituated and naive badgers. In the first few days of pre-baiting, naive and semi-habituated badgers were observed being more inquisitive and apprehensive and hence took time to investigate the traps but as they became more familiar with the presence of the trap, this investigatory time declined. The habituated badgers did not seem to display any neophobic behaviour as pre-baiting day was seen to have little effect on trap or bait interaction times. The semi-habituated badgers picked up very rapidly on pre-baiting compared to the naive badgers as there was a marked increase in bait interaction after the first couple of days, possibly as a result of knowledge gained from the prior feeding of peanuts as part of the 12-day feeding trial as part of OBDS. Although the semi-habituated badgers had had no prior experience of traps, their pre-conditioning to the scent of peanuts may have helped to encourage them inside the trap. In contrast the naive population had a much more gradual approach as they had had no experience of prior feeding or traps.

Chemical communication within a species may affect trapping efficiency as traps could be contaminated by an odour from a conspecific (Pawlina & Prolux, 1999). The area close to the traps and trap entrance were most frequently observed to be scent marked by the badgers. Badgers are known to object mark at frequently visited sites (Gorman & Trowbridge, 1989) e.g. latrines, the sett, territory boundaries and at foraging places (Buesching & Macdonald, 2004, Roper, 2010); however, little is known about the significance of these marks (Buesching & Macdonald, 2004). Roper (2010) noted that scent marking could indicate personal ownership as badgers were observed marking sett entrances that they prefer to use. A third of all scent marks are over marked within 24 hours (Buesching & Macdonald, 2004) either by the same or a different individual and serves either to renew the scent if it has lost its potency (Roper et al. 1993) or may be an attempt by one dominant individual to obliterate the scent marks left by another (Roper et al. 1993). This may explain why some areas were observed being repeatedly marked. Scent marking behaviour was more prominent among the habituated badgers but this could simply be a direct response of a higher density of individuals.

Welfare in traps

Directed aggression among badgers as defined by Hewitt et al (2009), only occurred on a small number of occasions with no difference regardless of prior feeding experience but a there was a slight peak in aggressive encounters between three and four although this result was not significant. This is a similar finding to Macdonald et al. (2002), who recorded few signs of aggression between badgers in the presence of a deliberately provided food. In contrast, Neal & Cheeseman (1996) reported that aggressive encounters are more likely to occur in regions of high density, i.e. the habituated population, with badgers more likely to fight over a familiar valuable resource (bait). Although aggression is more likely to be associated with territoriality and mating behaviour, badgers will also defend food resources against neighbours (Neal, 1986) and it is feasible that this could be the case between group members, especially if food resources are limited (Neal, 1986). Kruuk (1989) reported that frequent subtle aggressive interactions were observed in badgers in order to gain priority access to food sources. Aggressive encounters are more pronounced in the first five months of the year (Neal, 1986), which may help to explain the low levels of aggressive encounters observed, as the majority of filming was carried out after this period.

The length of time that badgers spent captive in the traps was consistent with work carried out by the Central Science Laboratory (CSL) in 2001 (see CSL, 2001). The majority of badgers entered traps in the first half of the night, which meant that they were detained for relatively long periods. It is therefore desirable that traps are checked and badgers dealt with as early as possible. Even though the animals may appear quiescent when traps are checked at first light, camera footage revealed that some badgers became more active in escape attempts as daylight approached and this activity ceased just before traps were checked.

The number of times that badgers had been trapped had a significant effect on the behaviour exhibited. Previous research (e.g. Shütz et al. 2006, White et al. 1991) has shown that trapping can be a stressful experience for the animals involved, but from an animal welfare point of view, this investigation has shown that badgers do not spend the duration of their capture trying to escape and do spend time inactive or carrying out ‘normal’ behaviour such as feeding and grooming. It is important to note that trapping behaviour is only one subjective way of investigating stress of capture, and that the physiological responses to capture stress are unknown in this investigation.

A number of factors can determine the coping style (defined by Koolhaas et al. 1999) and hence behaviour of each individual once captured, e.g. previous capture experience, age, sex, genetics, seasonal variations, type of trap, entrapment duration, time of day and species-specific factors such as diurnal rhythms, general activity levels and sociality (Koolhass et al. 1999, Shütz et al. 2006). This study demonstrated that badgers did not spend the entire restraint period trying to actively escape as on average only 37% of the total capture period was spent exhibiting this behaviour (average range: 47% on first capture - 22% if 3+ captures). In contrast, 55% of the behaviour observed was inactive (average range: 46% on first capture - 69% if 3+ captures) and a further 8% (average range: 7% on first capture - 10% if 3+ captures) of the capture period was spent either grooming or eating, although it is unclear if this active non-escape behaviour was an example of displacement activity (stress response e.g. Zeigler, 1964; Maestripieri et al. 1992) due to capture. Overall, the active escape behaviour was similar to White et al. (1991), who found that foxes were physically active for only 36 % of the restraint period. Pacing was noted as the main behaviour observed in foxes compared to the digging (which creates the trenches often found around traps after capture), pawing and biting at the cage mesh observed in badgers. However, the behaviour badgers exhibited in the first 10 minutes after capture was inconsistent with the work of both Shütz et al. (2006) and White et al. (1991).Shütz et al. (2006) reported that badgers spent 89% of this period trying to escape and White et al. (1991) reported 91% escape behaviour in foxes. In this current study, badgers only spent on average 52% of this period trying to escape with a marked difference depending on previous capture experience (average 78% first capture and only 30% if 3+ captures). Although the badgers in the current study appeared to display less stress behaviour in comparison to what has been reported previously in badgers and foxes, any restriction of normal behaviour is bound to have an effect on physiological stress levels (Shütz et al. 2006). This was demonstrated by White et al. (1999), who showed that cortisol levels in trapped foxes were significantly higher compared to un-trapped foxes.

Trapping did not appear to have an adverse on badger susceptibility to capture as the majority of fur-clipped badgers were observed within the first two nights after capture and all but two individuals were caught again. Although this was only a small sample size, this continuous pre-baiting period illustrated that it is possible to re-trap in successive periods and that badgers are not deterred from re-entering traps following entrapment. The capture data from this current study, historical records from the WP study and data collected by Tuyttens et al. (1999) suggests that the majority of badgers are not affected by capture and hence recapture rates are relatively high (Tuyttens et al. 1999). Records show that some badgers at WP are caught at all of the four trapping events that occur each year, and one particular badger was captured 27 times over an 11 year period. However, in comparison, some badgers may only ever be captured once or not at all and will remain unidentified in the population. The behavioural after effects of capture are unknown in this project but Shütz et al. (2006) noted higher levels of activity in badgers once they were released following the restraint period which may suggest that badgers are affected by their capture.

Further work

To gain a more detailed understanding of what factors are most likely to affect the trappability of badgers and the behavioural stress responses exhibited; cameras could be placed on all traps at one or more setts during all pre-baiting and trap nights that occur throughout the year. Where possible, all badgers belonging to that particular sett should be fur clipped to enable individuals to be identified. Saturating all traps with cameras would give a more complete picture of how all badgers within a particular sett behave in the presence of traps and to artificial feeding and could further aid in refining pre-baiting and trapping procedures. Through the identification of individuals, it may be possible to determine (1) the number of visits per night by each individual, (2) if the TB status of an individual (e.g. non-infected, infectious but not excreting, excretor and super-excretor) makes it more likely to enter the trap, (3) if certain individuals monopolise the bait and (4) what proportion of the population would be deemed trap shy by noting unmarked individuals. The number and type of trap-related injuries could also be recorded, which may help refine the trap design for welfare purposes. In addition, the physiological stress response could be measured using a variety of techniques e.g. measurement of cortisol levels (Morton et al. 1995) via faecal analysis (Shütz et al. 2006) or blood (White et al. 1991); leukocyte coping capacity (Mclaren et al. 2003) or neutrophil activation (Montes et al. 2004).

Trials could be undertaken to determine the most efficient length of pre-bait period or possible alternative feeding protocols e.g. do not bait traps every day. Currently the length of the pre-baiting period could be considered to be too long (and requires much effort which therefore affects cost). Establishing the optimum method of pre-baiting could help to make overall trapping regimes much more cost and time effective.

Conclusions

There will be a large number of factors that could help to explain the differences in behaviour exhibited by individual badgers e.g. seasonality, availability of natural food resources and levels of previous ‘disturbance’ that badgers may have been subjected to in the past. These factors would not only affect behaviour at a population level, but also at a social group level and on an individual basis. Some badgers are simply more trappable than others (“trap-happy” vs “trap-shy”; Tuyttens et al. 1999). Results from this study show that the protocol for pre-baiting length and trapping regime used by the Food and Environment Research Agency (FERA) is sufficient, but further research could determine a more efficient pre-baiting procedure. The pre-baiting period serves its desired purpose and can help encourage neophobic badgers into the traps.

The results from this study have also shown that (1) badgers do not spend the duration of their restraint period trying to escape and (2) the effect of capture did not appear to affect the behaviour of badgers after entrapment as they continued to enter the traps during the second pre-bait period and were subsequently caught again a week later.

It is hoped that the findings from this study can contribute to a greater understanding of how the efficiency of trapping regimes can be affected by the behaviour of the species involved during the pre-bait period and how the actual capture event can affect the behaviour of an individual and its subsequent behaviour to future trapping events. An adequate pre-baiting period should be used to encourage the target species regardless of prior experience into the traps, although special considerations should be taken into account for naive, therefore possibly neophobic individuals. It is important to remember that the greater the efficiency of the trapping regime, the more successful a wildlife management programme is likely to be.

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Appendix 1 – Summary all filming data

Table 1. Number of nights filming that occurred at each sett and the percentage of footage that was lost.

Feeding experience	*Sett*	*Date 1st night filming*	*No. days pre-baiting*	*No. trap nights*	*2nd pre-bait period*	*No. re-trap nights*	*Actual footage/ possible footage*
Habituated	Hab1	4th May 2010	11	4	-	-	15/16
Habituated	Hab2	18th May 2010	10	4	-	-	14/14
Habituated	Hab3	29th Oct 2010	10	4	-	-	14/14
Habituated	Hab4	28th Oct 2010	9	4	-	-	13/16
Semi-habituated	Semi 1	31st May 2010	12	2	14	4	32/44
Semi-habituated	Semi 2	8th June 2010	14	4	22	4	44/46
Semi-habituated	Semi 3	26th July 2010	12	4	23	4	43/44
Semi-habituated	Semi 4	27th July 2010	14	1	23	4	42/46
Naive	Naive 1	22nd June 2010	23	3	-	-	27/28
Naive	Naive 2	14th July 2010	25	4	-	-	29/30
Naive	Naive 3	5th Aug 2010	21	4	-	-	25/25
Naive	Naïve 4	5th Aug 2010	23	4	-	-	27/28
		Totals	**184**	**42**	**82**	**16**	**324/351**

Appendix 2 – Pre-baiting data

Table 1. Summary of the number of badgers observed, numbers entering traps and pre-baiting day of memorable events.

Feeding experience	*Sett*	*No. of badgers obs.*	*No. of badgers entering trap (partially or fully*	*No. badgers **fully in**/no. badgers entering traps*	*Overall % fully in/total no. of badgers obs.*	*First day seen*	*First Interest No Entry (INE) (day)*	*First enter trap (day)*	*First enter trap fully (day)*
Habituated	Hab1	414	137	118/137 (86%)	29	1	1	1	1
Habituated	Hab2	79	53	50/53 (94%)	63	1	1	1	1
Habituated	Hab3	135	50	50/69 (72%)	37	1	1	1	1
Habituated	Hab4	81	27	20/27 (74%)	23	1	1	1	1
	Total	**709**	**267**	**238/286 (83%)**	**34**				
Semi-habituated	Semi1	5	0	0/0 (0%)	0	3	3	0	0
Semi-habituated	Semi2	55	10	2/10 (10%)	4	2	3	4	7
Semi-habituated	Semi3	147	71	65/71 (91%)	44	1	1	1	1
Semi-habituated	Semi4	167	78	65/78 (83%)	39	1	1	1	1
	Total	**374**	**159**	**132/159 (83%)**	**35**				
Naive	Naive1	198	110	105/110 (95%)	53	1	1	1	1
Naive	Naive2	20	0	0/0 (0%)	0	2	10	0	0
Naive	Naive3	105	77	63/77 (82%)	60	1	1	1	1
Naive	Naive4	27	9	6/9 (67%)	22	1	10	10	10
	Total	**350**	**196**	**174/196 (89%)**	**50**				
	TOTALS	**1433**	**622**	**544/641 (85%)**	**38**				

Appendix 3 – Trapping data

Table 1. The time spent in traps and time spent exhibiting different behaviours. Trapping status refers to the number of times an individual had been caught i.e. 5th means that this was the fifth time an individual had been trapped. Includes data from the secondary period of filming from the semi-habituated population. N = 13.

Date	*Sett*	*Feeding experience*	*Sex*	*Age*	*Time entered trap*	*Time in trap +/- sunset*	*Total time in trap*	*Total time AE**	*% AE**	*% AE first 10 mins*	*Total time ANE**	*% ANE**	*Total time IN**	*% IN**	*Trapping status*
10/5/2010	Hab1	Habituated	M	Ad	21:45:40	+00:57:40	09:28:15	02:59:51	31.6	94.8	00:57:06	10.0	05:31:18	58.3	7th
10/5/2010	Hab1	Habituated	Ma	Ad	21:26:23	+00:38:23	09:44:44	01:32:22	15.8	9.2	00:50:18	8.6	07:22:04	75.6	5th
11/5/2010	Hab1	Habituated	F	Ad	00:00:32	+03:11:32	07:57:34	00:43:08	9.0	2.2	00:27:34	5.8	06:46:52	85.2	5th
23/5/2010	Hab2	Habituated	M	Ad	21:36:27	+00:29:27	09:01:31	01:42:18	18.9	0	01:38:17	18.1	05:40:56	63.0	10th
4/10/2010	Hab3	Habituated	M	Ad	18:36:56	-00:03:04	12:25:04	04:00:09	32.2	45	00:44:33	6.0	07:40:22	61.8	5th
4/10/2010	Hab4	Habituated	M	Cb	19:12:53	+00:32:53	11:57:49	03:25:33	28.6	24.8	00:47:55	6.7	07:44:21	64.7	1st
15/6/2010	Semi2	Semi-hab.	M	Ad	00:17:41	+02:47:51	05:26:17	03:59:31	73.4	90.8	00:00:55	0.3	01:25:51	26.3	1st
15/6/2010	Semi2	Semi-hab.	F	Ad	22:09:26	+00:39:26	07:39:12	03:23:18	44.3	99.2	00:38:56	8.5	03:36:58	47.2	1st
15/8/2010	Semi3	Semi-hab.	F	Ad	21:08:48	+00:35:48	08:36:00	03:22:00	39.1	28.3	00:40:47	7.9	04:33:13	52.9	2nd
16/8/2010	Semi3	Semi-hab.	F	Ad	21:27:58	+00:57:58	08:41:37	06:09:22	70.8	94	00:18:08	3.5	02:14:07	25.7	2nd
04/7/2010	Naive1	Naive	N/A	Ad	20:04:14	-01:25:46	10:36:36	04:20:14	40.9	100	01:16:03	11.9	05:00:19	47.2	1st
05/7/2010	Naive1	Naive	N/A	Ad	23:47:50	+02:18:50	06:14:36	00:10:05	2.7	6.3	00:18:36	5.0	05:45:55	92.3	2nd
16/8/2010	Naive3	Naive	N/A	Cb	04:42:15	+08:11:15	01:47:55	01:14:24	68.9	80	00:16:33	15.3	00:16:58	15.7	2nd

Appendix 4 – Pre-baiting data from secondary filming

Table 1. Summary of both fur-clipped and unmarked badgers at study setts and subsequent observations during secondary filming.

Sett	*Tattoo*	*Sex*	*Age*	*Weight (Kg)*	*Body Condition*	*Seen again?*	*Day first seen*	*% of days seen again*	*No. of visits on screen*	*No. visits in trap (%)*	*No. of olfactory communication*	*Re-trapped?*
Semi1	C9	M	Ad.	9.7	Good	N	n/a	0	0	n/a	n/a	Y
Semi2	L28	M	Ad.	10.8	Good	Y	3	36	10	10 (100)	7	Y
Semi2	L29	F	Ad.	6.2	Poor	Y	6	5	3	0 (0)	0	N
Semi2	L33	F	Ad.	8.3	Good	N	n/a	0	0	n/a	n/a	N
Semi3	UN	-	-	-	-	Y	2	52	39	2 (5)	1	N
Semi3	C21	F	Ad.	9.1	Good	Y	1	96	56	22 (39)	1	Y
Semi3	C22*	F	Ad.	10.5	Good	Y	1	91	53	32 (60)	1	Y
Semi3	C23*	F	Ad.	8.5	Fair	Y	1	74	30	14 (47)	3	Y
Semi3	C24	F	Ad.	8.2	Fair	Y	1	70	23	14 (61)	5	Y
Semi3	C25	F	Ad.	11.3	Good	Y	2	30	9	1 (11)	1	Y
Semi3	C27	M	Ad.	9.9	Good	Y	3	39	14	6 (43)	0	Y
Semi4	UN	-	-	-	-	Y	5	57	22	12 (55)	1	Y
Semi4	C35	F	Ad.	9.0	Good	Y	2	78	25	15 (60)	6	Y
Semi4	C36	F	Ad.	10.7	Good	Y	1	100	41	24 (59)	10	Y
Semi4	C53	M	Ad.	8.5	Fair	Y	1	65	19	16 (84)	2	Y
Semi4	C54	F	Ad.	7.7	Fair	Y	2	78	23	18 (78)	7	Y

**filmed when captured in trap*

Section 3 – Certificate of training

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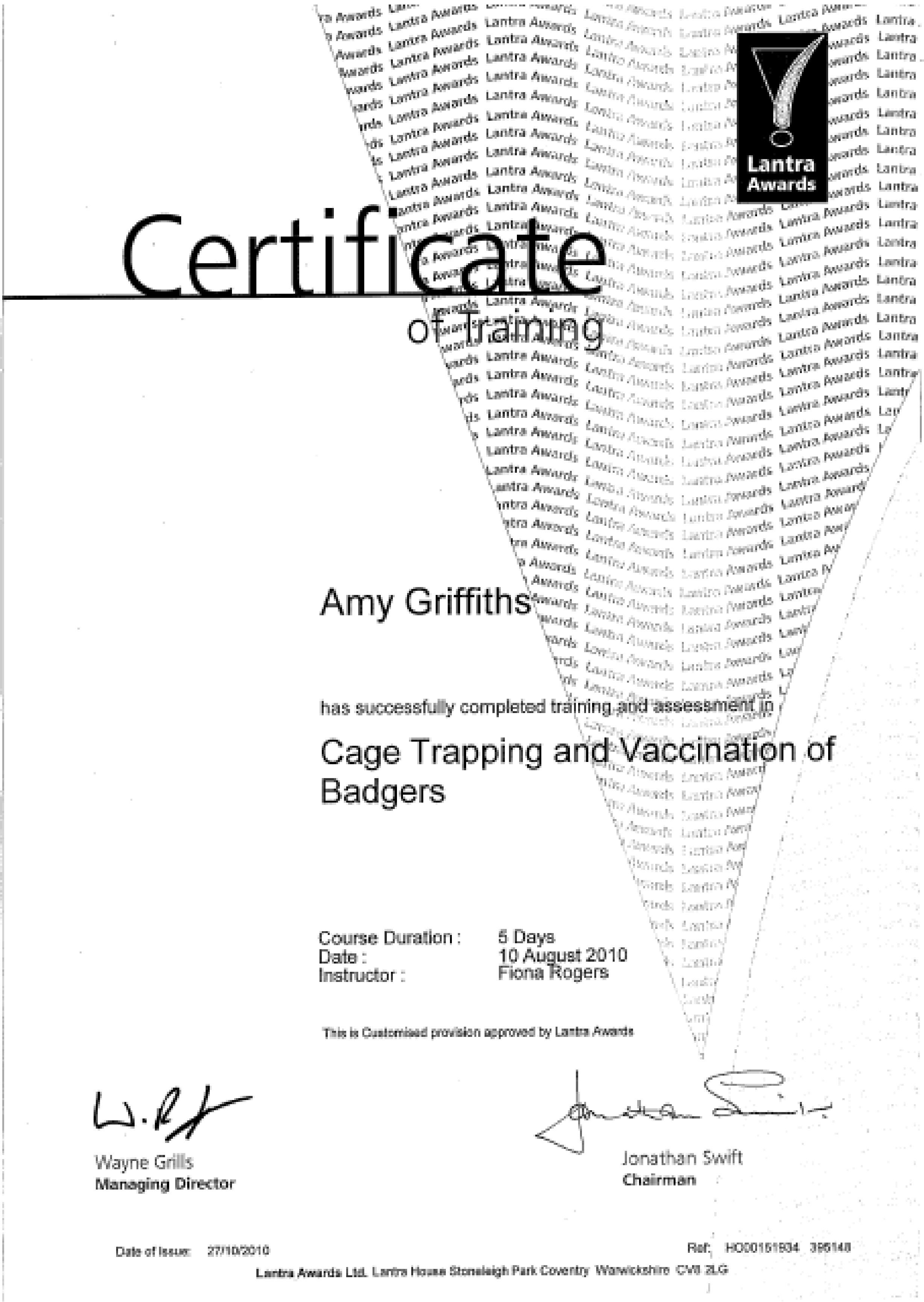

Lantra Awards

Certificate

of Training

Amy Griffiths

has successfully completed training and assessment in

Cage Trapping and Vaccination of Badgers

Course Duration : 5 Days
Date : 10 August 2010
Instructor : Fiona Rogers

This is Customised provision approved by Lantra Awards

Wayne Grills
Managing Director

Jonathan Swift
Chairman

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