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Farm husbandry and the risks of disease transmission between wild and domestic mammals: a brief review focusing on bovine tuberculosis in badgers and cattle

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Abstract

Where wildlife act as a reservoir of disease for domestic mammals, measures solely based on management of either in isolation are unlikely to resolve the problem. Many such diseases can have serious economic implications for farmers and the economy and their management can present considerable challenges. Traditionally, wildlife populations have been culled in attempts to reduce the risks of disease transmission to livestock (e.g. bovine tuberculosis in European badgers and brushtail possums). However, this may be both undesirable and potentially counter-productive in some circumstances. Consequently, in recent years increasing attention has focused on changing livestock husbandry and farm management practices so as to reduce risks of disease transmission from wildlife to livestock. Here we present a brief review of husbandry and farm management practices that may influence disease transmission risks from wild to domestic mammals, with particular attention to bovine tuberculosis in the UK. We conclude that the manipulation of farming practices could potentially make a significant contribution to disease risk management. However, there are currently scant empirical data on risk reduction methods and further information will undoubtedly be required to inform husbandry best-practice.

Keywords: *biosecurity, wildlife, zoonoses.*

Introduction

Diseases of livestock may have serious implications for the welfare of both animals and farmers, for the national economy and farmers' incomes (Caldow, 2004; University of Reading, 2004). Wild mammals have been implicated in the transmission of some of the most familiar diseases of livestock in Europe (Frőhlich *et al.*, 2002; Artois, 2003), including classical swine fever, foot and mouth disease, rabies, anthrax, brucellosis and bovine tuberculosis (bTB). In many cases several species of wildlife can be involved in transmission of the same diseases to livestock. Of 980 pathogens of domestic mammals reviewed by Cleaveland *et al.* (2001) 77·3% can infect multiple hosts. For example, Capel-Edwards (1971) reviewed the susceptibility of small mammals to foot and mouth disease and listed studies on 33 different species worldwide. During a recent survey for bTB in wild mammals in south-west England, infection was detected in 12 different species (Delahay *et al.*, 2006).

While the pathology of many diseases has been relatively well documented, applied investigations into the behavioural and ecological aspects of disease epidemiology are more limited. Where wildlife is involved in transmitting disease to livestock this may pose a considerable management problem. An understanding of the way that livestock and wildlife interact with their environment and each other is required in order to formulate strategies to reduce opportunities for disease transmission.

It is likely that modern agricultural practices sometimes exacerbate the problem of wildlife and livestock coming into contact (Phillips *et al.*, 2000 and 2003). In contrast to 19th century farming practices, modern livestock husbandry is characterized by larger herd and field sizes, longer periods of housing, increased use of supplementary foods (and hence increased requirement for food storage), novel foods, a variety of feeding methods (including increased mechanization) and changes to grazing regimes (Shrubb, 2003). Over the last century cattle farming has increased in the south-west of England so that this region now has the highest abundance of cattle in the UK and has large areas covered by improved grassland for grazing or forage production (Department for Environment Food and Rural Affairs (DEFRA), 2006a). This environment incidentally also provides ideal foraging habitat for European badgers (*Meles meles*) (da Silva *et al.*, 1993). Increasing areas of improved grassland may have contributed to the apparent increase in badger abundance in recent decades (Wilson *et al.*, 1997).

This brief review aims to summarize current knowledge regarding the effects of farming practices on disease transmission risks from wild to domestic mammals (while acknowledging that transmission may occur in both directions). It focuses on bTB in cattle since most work has been undertaken in this area.

Disease transmission from wild to domestic mammals

Identification of the specific routes of transmission from wildlife to domestic animals, whether direct or indirect, can be extremely difficult to achieve. Direct contact constitutes physical contact or sufficiently close proximity between two animals for transmission of air-borne agents to occur. Direct contact is thought to be the primary route of transmission of *Mycobacterium bovis* (the causative agent of bTB) from brush-tail possums (*Trichosurus vulpecula*) to cattle in New Zealand (Paterson and Morris, 1995) and of *Mannheimia haemolytica* (formerly *Pasteurella haemolytica*; the causative agent of pasteurellosis) from domestic sheep to wild bighorn sheep (*Ovis canadensis*) in North America (Foyet, 1989). Indirect contact involves exposure to contaminated material from infected hosts in the environment. In the case of *M. bovis* infection in British cattle this might include contact with badger faeces, urine, sputum or wound exudates (Delahay *et al.*, 2005) on grazing land (Hutchings and Harris, 1999), or within farmyards and buildings (Garnett *et al.*, 2002; Roper *et al.*, 2003).

Most studies on the transmission of *M. bovis* from badgers to cattle have focused on contamination of grazing land (Benham, 1985; Benham and Broom, 1989; Hutchings and Harris, 1997 and 1999; Phillips *et al.*, 2000 and 2003). However, there is an increasing body of evidence to suggest that wildlife visits to farmyards and buildings may pose a comparable disease transmission risk (Garnett *et al.*, 2002; Daniels *et al.*, 2003; Roper *et al.*, 2003; Central Science Laboratory (CSL), 2006). Badgers, red foxes (*Vulpes vulpes*), brown rats (*Rattus norvegicus*), mice (*Mus* spp.), rabbits (*Oryctolagus cuniculus*), polecat/ferrets (*Mustela putorius*) and hedgehogs (*Erinaceus europeus*) have all been observed in farmyards in south-west England (CSL, 2006), all of which are known to carry diseases transmissible to cattle (see Table 1).

Control of infections of wildlife and livestock may also be important from a public health perspective, as many such pathogens are zoonotic and some can cause serious disease in humans. Hinton (2000) reviewed 14 pathogens that are known to contaminate cattle food and which present a health hazard to humans. Of these, 12 may be transmitted from wildlife. A survey of parasites of wild brown rats on 11 farms in England and Wales identified 10 non-zoonotic and 13 zoonotic parasitic species (Webster and Macdonald, 1995). Daniels *et al.* (2003) calculated that the volume of rodent faeces found in stored farm foods, the volume of contaminated food consumed by cattle and sheep and the prevalence of paratuberculosis, *Salmonella* and cryptosporidiosis in rodents, were sufficient to explain the prevalence of each disease in cattle and sheep throughout eastern Scotland. Clearly, where wild mammals can gain access and contaminate stored foods, this is likely to enhance risks of disease transmission to livestock and ultimately to humans.

Risk factors

Independent studies on a range of diseases have consistently identified the importance of cattle-based factors, such as herd size and movements of cattle between farms, as of paramount importance in explaining risks of infection within cattle herds. Examples include foot and mouth disease in cattle (Paterson *et al.*, 2003), para-tuberculosis in cattle (Collins *et al.*, 1994), bTB in cattle from 1988–1996 (White and Benhin, 2004), bTB in cattle prior to 2001 (Johnston *et al.*, 2005) and bTB in cattle from 2002 to 2003 (Gilbert *et al.*, 2005). Cattle movement history was consistently more influential than environmental, topographic and other anthropogenic variables when attempting to explain the occurrence of new bTB herd breakdowns in Great Britain from 2002 to 2003 (Gilbert *et al.*, 2005). Nevertheless, other studies have identified livestock husbandry and farm management practices as significant risk factors for bTB in cattle (Griffin *et al.*, 1992, 1993 and 1996; Martin *et al.*, 1997; Ó Máirtín *et al.*, 1998; Denny and Wilesmith, 1999; Christiansen and Clifton-Hadley, 2000). Several of these risk factors are consistent with enhanced opportunities for contact with wildlife. For example, the identification of cattle access to woodland as a risk factor (Christiansen and Clifton-Hadley, 2000) could be related to the presence of badger setts.

It is important to note that disease transmission can also occur from domestic animals to wildlife and, for species of conservation value, this may present a significant management problem (Woodroffe, 1999). Alteration of livestock and farm management practices may present relatively simple options to manage such risks. For example, methods of sheep herd management such as guarding of sheep and housing in enclosures were negatively associated with exposure to sheep-born pasteurellosis and brucellosis by

Table 1 *Examples of pathogens and diseases of domestic mammals identified in UK wild mammal carcasses submitted by the public to the State Veterinary Service (Veterinary Laboratories Agency, 1999, 2000, 2001, 2002, 2003 and 2004)*

Wild mammal species	Pathogen/disease
Brown rat	Cowpox, *Salmonella*, paraTB, cryptosporidiosis
Red fox	Mange, *Leptospira*, *Toxocara*, *Streptococcus*, paraTB
Badger	*Salmonella*, *Campylobacter*, *Staphylococcus*, parvovirus, bTB
Mouse	Cowpox, *Salmonella*
Polecat	bTB
Rabbit	*Salmonella*, *E. coli*, paraTB, cryptosporidiosis
Hedgehog	*Salmonella*, lungworm, ringworm, cryptosporidiosis

chamois (*Rupicapra rupicapra*) and Alpine ibex (*Capra ibex*) in the French Alps, while provision of salt licks at pasture was positively associated (Richomme *et al.*, 2006). Maintaining sheep within enclosures or guarding them and providing mineral licks only within enclosures may reduce disease transmission risks to these species.

Disease management strategies

A traditional approach to managing disease transmission risks posed by wildlife has been to reduce their abundance by lethal control. In some cases, such as rabies in foxes in Europe (Aubert, 1995) and bTB in brushtail possums in New Zealand (Caley *et al.*, 1999), culling of infected wildlife has met with some success. However, this may not always be the most desirable or effective strategy. For example, in northern USA, pasture contaminated by white tailed deer (*Odocoileus virginianus*) and Rocky mountain elk (*Cervus elaphus nelsoni*) appears to have been involved in epidemics of chronic wasting disease (a transmissible spongiform encephalopathy) amongst livestock (Miller *et al.*, 1998). However, widespread culling of cervids was considered unlikely to reduce disease transmission risks owing to their social and migratory behaviour (Williams *et al.*, 2005). Furthermore, selective culling of suspected cases in endemic areas of Colorado and Wyoming was unsuccessful in reducing disease prevalence in wild cervid populations (Williams *et al.*, 2005). Instead, quarantine or culling of infected livestock herds, improvements to farm biosecurity and the banning of wild cervid translocations and artificial feeding in problem areas form the main strategies in the USA for combating this disease in both wild deer and livestock (Williams *et al.*, 2005).

Even in cases where wildlife population reduction should reasonably be expected to be effective, the method of population reduction employed may have an impact upon its success. For example, Q fever is a zoonotic disease caused by infection with the bacterium *Coxiella burnetii*. It is transmitted to humans via aerosol from livestock, and brown rats are thought to be a significant wildlife reservoir (Webster *et al.*, 1995). Rat control should theoretically reduce risks of transmission and domestic cats have traditionally been used to control rats. However, cats appear to play an important rôle in the epidemiology of Q fever, probably contracting infection whilst living in close proximity to rats and predating them (Webster *et al.*, 1995). Hence, lethal control of rats using trapping or poisoning for example, or population reduction through habitat manipulation may be more effective at reducing the risks of Q fever transmission to livestock and humans.

Recent studies in southern England have provided evidence of the potentially counter-productive effects of some wildlife disease control measures. A large-scale, replicated field experiment showed that the incidence of bTB in cattle either remained similar or increased when badgers were culled locally in response to a herd bTB breakdown (Donnelly *et al.*, 2003). Furthermore, when badger culling was proactive and extensive although the incidence of bTB in cattle decreased within the treatment areas, it increased at its edges (Donnelly *et al.*, 2005). The precise mechanism behind these results has yet to be determined but there is increasing evidence to suggest that culling-induced perturbation of the social structure of badger populations causes enhanced movement (Cheeseman *et al.*, 1993; Roper and Lüps, 1993; Tuyttens *et al.*, 2000; Woodroffe *et al.*, 2006) and increased transmission of infection.

An alternative approach to culling is the vaccination of either livestock (Aubert, 1995; Suazo *et al.*, 2003) or wildlife (Brochier *et al.*, 1991; Delahay *et al.*, 2003). However, vaccination of livestock may confound interpretation of diagnostic tests designed to identify infection, and may not confer complete protection whilst remaining exposed to the potential source of infection in wildlife (O'Reilly and Daborn, 1995). Challenges to the successful vaccination of wildlife include development of an effective vaccine, and of a strategy that will deliver an adequate dose to a sufficient number of animals (Delahay *et al.*, 2003). In the UK, whilst researchers continue to explore the potential for vaccination to play a rôle in the control of bTB in badgers and cattle (Independent Scientific Group on Bovine Tuberculosis, 2003), increasing attention has focused, in recent years, on identifying ways that farming practices may influence the risks of disease transmission (Griffin *et al.*, 1992, 1993 and 1996; Martin *et al.*, 1997; Ó Máirtín *et al.*, 1998; Denny and Wilesmith, 1999; Christiansen and Clifton-Hadley, 2000; Phillips *et al.*, 2000 and 2003). A national-scale study (TB99) is currently underway to identify practices that may be associated with increased risks of cattle herd bTB breakdowns. The hypothesis underpinning such studies is that identification of important risk factors will be essential to the formulation of preventive management strategies.

Phillips *et al.* (2000 and 2003) undertook an extensive review of the literature relating to cattle husbandry and its potential influence on bTB in cattle. The authors identified many practices that have the potential to influence the degree of contact between cattle and badgers, and hence transmission of bTB, and their review concentrated on direct and indirect contact at pasture. Badgers generally avoid cattle on pasture (Benham, 1985; Benham and Broom, 1989) but the common practice of set-stocking, where grazing herds have constant access to all the pasture, promotes dispersal among cattle and familiarity between them and badgers, hence reducing avoidance (Benham, 1985; Benham and Broom, 1989). On the other hand, rotational or strip-grazing promotes cattle herd cohesion presenting badgers with a greater opportunity to avoid cattle and therefore potentially reducing transmission risks (Hutchings and Harris, 1997; Phillips *et al.*, 2000 and 2003; Gallagher *et al.*, 2003). Owing to the inquisitive nature of cattle, they may also come into direct contact with dead or moribund badgers (Dolan, 1993; Flanagan, 1993). It has been suggested that to reduce the associated disease transmission risks, farmers should regularly walk their property in order to find and dispose of wildlife carcasses (Ministry of Agriculture, Fisheries and Food (MAFF), 1999). This may present an easy and effective solution to the risks posed to cattle by direct contact with badgers. However, since alteration of grazing regimes relies upon behavioural responses in both cattle and badgers, which are likely to be highly variable this method cannot be considered as a truly preventive measure (Figure 1).

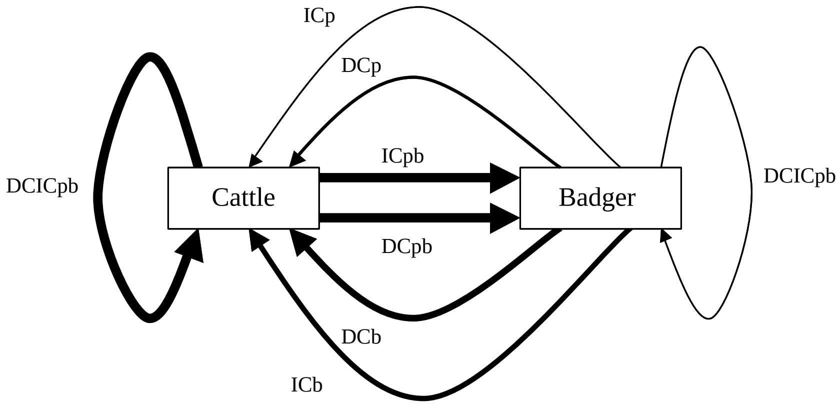

Figure 1 Potential routes of bovine tuberculosis (bTB) transmission between badgers and cattle. Arrow thickness represents the likely increase in the amenability of these routes to management. IC = indirect contact, DC = direct contact, p = at pasture, b = in farm buildings. Arrows represent the direction of transmission.

At medium to high densities, if undisturbed, badgers tend to live in stable social groups with relatively discrete territories (Cheeseman and Mallinson, 1979). Territories are marked with urine and faeces in latrines, often along linear features and particularly where their paths cross linear landscape features, such as at gaps in hedges and walls (Kruuk, 1989). Since badger urine and faeces may potentially contain *M. bovis* (Clifton-Hadley *et al.*, 1993) latrines on pasture may pose an infection risk to cattle (Muirhead *et al.*, 1974). Although most cattle generally avoid grazing over badger latrines they are habitually selected by some individuals (Hutchings and Harris, 1997). Furthermore, under set-stocking high grazing pressure on the grass sward may encourage cattle to eat vegetation around badger latrines (Hutchings and Harris, 1997), which may be particularly lush due to nutrient leaching (Haynes and Williams, 1993). Cattle contact with badger latrines may be managed by reducing grazing pressure, by for example, switching from set-stocking to strip or paddock grazing (Phillips *et al.*, 2000 and 2003). Alternatively, cattle can be excluded from badger latrines, using electric fencing for example (Phillips *et al.*, 2000 and 2003). Cattle should also be prevented from gaining access to badger setts, where latrines, discarded bedding and contaminated soil may be potential sources of infection (Phillips *et al.*, 2000 and 2003). Where changes to grazing regimes are not practical, reduction in stocking densities may provide similar benefits (Phillips *et al.*, 2000 and 2003). High stocking densities promote rapid cattle dispersion across pasture (Phillips, 2002), increase grazing pressure and so raise the likelihood of contact with potentially infectious badger excretions (Hutchings and Harris, 1997; Phillips *et al.*, 2000 and 2003; Gallagher *et al.*, 2003).

Food and water provided for cattle at pasture, whether in troughs, on the ground or from natural water bodies may potentially be contaminated by infected badgers. Previous guidance to farmers has therefore included keeping food off the ground, raising troughs to over 80 cm and providing only mains water (MAFF, 1999). Although the latter remains sound advice, Garnett *et al.* (2003) demonstrated experimentally that badgers could climb into troughs over 80 cm tall and above heights at which cattle could comfortably eat from them (Phillips, 2002). Provision of supplementary food at pasture cannot therefore be recommended as a safe practice, since it may promote close direct and indirect contact between badgers and cattle (Garnett *et al.*, 2003). The development of novel trough designs may be required to prevent badgers from gaining access to them. Again, methods to effectively exclude badgers from gaining access to vulnerable facilities are likely to present simple, effective solutions. However, since some cattle habitually graze over badger latrines (Hutchings and Harris, 1997) and the locations of badger urine and some latrines at pasture is unpredictable (Brown, 1993), management of these high-risk areas are likely to represent the least tractable options (Figure 1).

An area not dealt with in any great detail by Phillips *et al.* (2000 and 2003) was the potential disease transmission risk posed to cattle by badgers visiting farm buildings. Cheeseman and Mallinson (1981) suggested that badgers with bTB may behave differently to healthy badgers and may be more likely to visit farm buildings. Further work identified a high frequency of badger visits to farm buildings to forage (Garnett *et al.*, 2002). Badger visits peaked during particularly dry periods, which may be related to a decrease in the availability of their preferred prey of earthworms (Garnett *et al.*, 2002; Roper *et al.*, 2003). Following adequate rainfall, earthworms are abundant at pasture but are largely absent from the soil surface during dry periods (Kruuk and Parish, 1985). Hence during periods of dry weather badgers may be forced to seek alternative food sources and consequently forage in farm buildings.

Tuberculous badgers have been observed to range more widely and forage further from their main setts than healthy animals (Cheeseman and Mallinson, 1981; Garnett *et al.*, 2005). During their visits to farmyards badgers have been observed in all types of farm buildings and facilities, including cattle housing, troughs, food stores, silage clamps and slurry pits (Brown, 1993; Garnett *et al.*, 2002). On several occasions Garnett *et al.* (2002) observed badger faeces and urine being deposited on stored food that was destined for consumption by cattle. In addition, badgers have been observed to regularly forage or gather bedding in cattle housing within 2 m of cattle (Garnett *et al.*, 2002). Although the potential opportunities for *M. bovis* transmission between badgers and cattle in farm buildings are clear, the studies by Garnett *et al.* (2002 and 2005) were only conducted on two farms. However, a recent extensive survey provided evidence that badger visits to farm buildings might be a common and widespread phenomenon in bTB hotspots throughout south-west England (CSL, 2006). Extrapolation of the results suggested that the risk posed to cattle by badger visits to farm buildings may be of a similar magnitude as that from contact at pasture (as estimated by Hutchings and Harris (1999)). The study suggested that the generally low standards of biosecurity practised widely among the 36 farms surveyed allowed badgers freely to gain access to key resources such as animal food in storage and in cattle troughs (CSL, 2006). Certain foods, such as cattle cake (a pelleted mix of cereals, minerals, fats and molasses) seem particularly attractive to badgers and their storage on farms may encourage visits (CSL, 2006). However, changing the types of livestock foods stored on farms does not present a practical option for controlling badger visits but exclusion may be possible. An electric fence that had been designed to exclude badgers from fields of growing maize (Poole *et al.*, 2002) could successfully exclude badgers from food stores, cattle houses and troughs (CSL, 2006). It is likely that other barrier methods, such as bottom-sheeting of gates and walls, may prove equally successful and could therefore contribute significantly to reducing the risks associated with badger visits to farms (Figure 1). However, estimates of the costs and practicalities of installing such features in working farmyards and the benefits that can accrue from their installation have yet to be determined. It is likely that prevention of direct contact within farmyard facilities would be easier than indirect contact due to fewer facilities requiring protection (cattle houses and troughs) (Figure 1), although both should be addressed to effectively manage risks within farmyards.

The degree to which any of the suggested methods might contribute to reducing the likelihood of a cattle herd bTB breakdown cannot yet be quantified since the relative contribution of badgers and other cattle remains unclear. However, it is likely that the continuation of the test and slaughter policy for cattle reacting to the diagnostic test and the introduction of pre-movement testing will reduce opportunities for onward transmission from cattle (DEFRA, 2006b) (Figure 1).

Turning science into practice

In a survey of 151 British farmers who had recently experienced a cattle-herd bTB breakdown (Bennett and Cooke, 2005), 8% had fenced off badger latrines, 20% had fenced badger setts, 14% had attempted to exclude badgers from their buildings, 16% had badger-proofed their silage clamps and 34% had raised their troughs to over 80 cm. A further 23%, 28%, 39%, 31% and 30%, respectively stated that they would invest in such measures if grant-aid was made available to assist them. However, approximately 50% of farmers surveyed stated that they would never invest in such measures or that it was impractical to do so (Bennett and Cooke, 2005). The reasons for this reluctance to invest in preventive husbandry methods are not clear. One reason that many farmers may appear reluctant to implement recommended best-practice to exclude wildlife from gaining access to vulnerable farm facilities may be because few perceive this to be a problem (CSL, 2006). In addition, inappropriate previous advice (such as the recommended height of troughs given by MAFF (1999)) may have reduced farmer confidence in such guidance. Provision of advice underpinned by robust evidence gathered from working farm environments may go some way towards increasing farmer confidence. Such evidence would need to include demonstration of the efficacy and cost-effectiveness of wildlife exclusion methods within farmyards.

Conclusion

Wild mammals are known to carry a range of diseases that are transmissible to livestock via either direct or indirect contact. Such contacts are likely to be far more common in modern agricultural systems than is generally perceived. Modern grazing regimes, stocking densities, the storage and handling of foods that are palatable to wild mammals and poor biosecurity practices within the farmyard all promote contact between wildlife and livestock. Changes to farming practices and enhanced biosecurity measures within farmyards are required to manage the risks associated with such contacts. However, limited knowledge of the risks involved and lack of information on the balance of costs and benefits associated with adherence to best-practice mean that farmers are not currently sufficiently equipped to make rational decisions regarding investment of limited resources in farm husbandry and biosecurity improvements. However, current evidence suggests that significant associations exist between farm husbandry methods and disease risks, and that alterations to management practices could therefore contribute significantly to programmes of livestock disease control.

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