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Factors affecting European badger (*Meles meles*) capture numbers in one county in Ireland

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ABSTRACT

Understanding factors affecting the number of badgers captured at and around badger setts (burrows) is of considerable applied importance. These factors could be used to estimate probable badger densities for bovine tuberculosis (bTB) control and also for monitoring badger populations from a conservation perspective. Furthermore, badger management and vaccination programs would benefit by increasing the probability of efficiently capturing the target badger populations. Within this context, it was investigated whether badger capture numbers can be estimated from field signs and previous capture histories. Badger capture records (initial and repeated capture numbers at a sett) from a large-scale removal program (405 km^2, 643 setts) were used. Univariable count models indicated that there were a number of significant potential predictors of badger numbers, during initial capture attempts. Using a multivariable zero-inflated Poisson (ZIP) model of initial captures we found that badger capture numbers were significantly affected by sett type, season, year, and the number of sett entrances in active use. Badger capture numbers were also affected by the total previous catch during repeated capture events and by the number of previous capture attempts. There was a significant negative trend in badger captures across events. Measures of the ability of these models to estimate badger captures suggested that the models might be useful in estimating badger numbers across a population; however the confidence intervals associated with these predictions were large.

1. Introduction

The badger (*Meles meles*) is a known spill-over species for *Mycobacterium bovis*, the causative agent of bovine tuberculosis (bTB). Badgers infected with *M. bovis* have been reported in a number of European countries (Republic of Ireland (ROI), United Kingdom (UK), Spain, Portugal, France, Switzerland and Poland) (Gortázar et al., 2012). However, it is primarily only within the ROI and the UK that badgers have been implicated in the maintenance and epidemiology of bTB within the national herds (Gortázar et al., 2012). Indeed, the disease is endemic within the badger populations in both jurisdictions (Clifton-Hadley et al., 1993; Hammond et al., 2001). Large-scale field experiments have shown significant declines in cattle bTB in areas where badger populations have been reduced to very low levels through culling in both Britain (Clifton-Hadley et al., 1995; Donnelly

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et al., 2006; Jenkins et al., 2010) and Ireland (O'Mairtin et al., 1998; Griffin et al., 2005). However, the magnitude and duration of such benefits have differed considerably between the two countries (Bourne et al., 2008; Jenkins et al., 2010). These disparities have been attributed to fundamental ecological differences between badger populations on both islands (Bourne et al., 2008; Vial et al., 2011; Wilson et al., 2011; Byrne et al., 2012a). For example, the Irish badger population is of lower density than that of southern Britain (Byrne et al., 2012a), where the greatest incidences of cattle bTB occur (Gilbert et al., 2005). Thus, estimating badger numbers accurately at large spatial scales is of fundamental importance in researching the links between badger presence, or abundance, and the risk to herd bTB breakdowns (e.g. Olea-Popelka et al., 2009).

Current policy options are limited with regards to controlling bTB in badger populations (More and Good, 2006). Since 2004, a national-scale strategy has been employed within the ROI whereby badgers are removed from areas where there are chronic bTB problems within herds (O'Keeffe, 2006; Sheridan, 2011). There is evidence to suggest that where removals had taken place, there were significant decreases in badger relative abundance (Byrne et al., 2012b). The extent of these removals is limited to <30% of the agricultural land area of the ROI (O'Keeffe, 2006). The reintroduction of badger culling strategies is at the consultation phase in England, and is being considered at government level in Northern Ireland (Wilson et al., 2011; O'Connor et al., 2012). The development of an effective wildlife vaccine implemented alone or in combination with partial culling, has been proposed as a preferred option to culling alone (Corner et al., 2008a; Lesellier et al., 2011). Currently, there is a large-scale field trial to test the efficacy of an oral lipid-encapsulated Bacille Calmette Guerin (BCG) vaccine on badgers in Co. Kilkenny, ROI (Corner et al., 2008b; Aznar et al., 2011) and another intramuscular BCG vaccine pilot project has begun in Co. Longford, ROI (James O' Keeffe pers. comm.). The success of such vaccine programs relies on targeted delivery of vaccine to a large proportion of the badger population. Currently, in the case of oral or intramuscular injection of BCG, this means successful capture of badgers. If oral baits are developed for the delivery of BCG to badgers (e.g. Kelly et al., 2011), finding field signs that indicate badger numbers will be equally important. Thus, it is imperative to understand the capturing process, and to develop improved strategies to increase the probabilities of successful capture.

In this paper, badger numbers captured as a component of the bTB control strategy within one county in ROI were used to model potential predictors of badger capture. We modelled initial and repeated captures using zero-inflated count models.

2. Materials and methods

Badger capture data from a large-scale wildlife removal program (Sheridan, 2011) operated in Co. Longford between 2004 and 2010 were utilised for this study. Longford was chosen for this study as: (1) a large proportion of this county is under capture (37%; Byrne et al., 2012b); (2) Longford has been part of a national bovine tuberculosis (bTB) strategy including badger removals since 2004 (O'Keeffe, 2006); (3) Longford was not part of an extensive badger removal program prior to this study period; and (4) Longford contains a site for a forthcoming badger intramuscular BCG vaccination pilot programme.

Badger capturing was concentrated at badger setts. Badger setts are a complex system of burrows, dug by the members of a badger social group, with multiple entrances (Byrne et al., 2012a). Setts can be broadly categorised into main and non-main sett types. Main setts are larger than non-main setts. These are breeding setts and are normally in continuous use. Setts were recruited into the study in response to cattle herd bTB breakdowns. Only setts within 2 km of a herd breakdown farm could be recruited into the study (O'Keeffe, 2006). Capture events were instigated following evidence of badger activity at a sett. All setts were revisited at a minimum frequency of once per year. If a sett showed signs of badger activity, irrespective of previous history, an attempt to capture badgers would be made. During initial sett surveys a number of different signs of badger activity were recorded (Table 1). However, during repeat capture attempts only the number of entrances that were deemed to be "in use" (i.e. active) was recorded. In

Table 1
Independent variables used during the modelling process relating to the number of badgers captured per sett during the initial capture event.

Name	Description	Variable type
MAIN	Sett type, main/non-main (1/0)	Binary variable
USED	Number of active holes (mean: 2.21)	Continuous variable
UNUSED	Number of inactive holes (mean: 1.97)	Continuous variable
BEDDING	Presence of bedding material close to sett openings	Binary variable
LATRINES	Presence of latrines near setts	Binary variable
PATHS	Presence of paths near setts	Binary variable
ROOTING	Presence of rooting (foraging amongst soil) near setts	Binary variable
HAIRS	Presence of badger hairs at or near setts (mostly caught in branches or barbed wire, if present)	Binary variable
HEDGE	Habitat (hedgerow or not)	Binary variable
BOG	Setts in raised bog edge or not	Binary variable
YEAR	Calendar year (2005–2010)	Control (dummy variable)
SEASON	Winter/spring (December-March); summer/autumn (April-November)	Control (binary)
TRAPS	Number of restraints laid divided by the number of active openings at a sett (log transformed; (log)mean: 1.39)	Continuous variable
DENSITY	Proxy measure of local sett density – the mean distance (km) to the three nearest neighbour setts (mean: 0.76 km)	Continuous variable