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Original Investigation

Use of hedgerows as a key element of badger (*Meles meles*) behaviour in Ireland

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ABSTRACT

Human modification of landscapes is one of the greatest threats facing biodiversity worldwide and conversion of native habitat to agricultural land is widely perceived as contributing significantly to biodiversity declines. However, some species have proven to be adaptable to human-induced habitat change. Here, we show that over the course of the relatively short period of co-existence between badgers (*Meles meles*) and humans in Ireland, badgers have adapted to using the man-made field boundaries that have replaced native woodland. Our study population, which was located in an intensively managed agricultural landscape, predominantly located their setts and latrines in or alongside hedgerows. In addition, for the first time, we show that badgers selectively foraged along field boundaries, with this behaviour perhaps linked to a greater diversity of dietary items in hedgerows and the potential cover from perceived threats offered by dense undergrowth. This preferential use of man-made landscape features has implications for how we assess habitat use in this species and perhaps also for modelling studies of bovine tuberculosis transmission in agricultural landscapes.

Introduction

Much is made of the negative impact humans have in terms of modifying natural habitats, which tends to have dire consequences for wildlife (e.g. Sanderson et al., 2002; Leu et al., 2008; Newbold et al., 2014). However, over time, some species can adapt to these human impacts and a certain degree of co-existence can develop (e.g. Mavatur and Singh, 2010; Carter et al., 2012). In protected areas, where human impacts can be managed, the potential for human-wildlife conflict can be minimised, whereas in agricultural landscapes the human-wildlife interface is broad and the degree to which adaptations to human impacts can evolve is an important facet of conservation biology research for fauna in such landscapes (Carlson, 1985; Wright et al., 2012). Here, we examine how European badgers (*Meles meles*) have adapted their behaviour to modification of the Irish landscape by humans, with a particular focus on their preference for foraging along hedgerows (which are man-made constructions) and for locating setts and latrines in them.

Although the timing of human arrival on Irish shores following extensive Midlandian (80,000–13,000 years BP) glacial coverage cannot be determined exactly, evidence suggests that humans were established on the island by the mid-Mesolithic (~7500 years BP, Woodman, 1986). The earliest evidence for a field-based agricultural system in Ireland comes from the Céide Fields in western Ireland that date to about 5700 years BP (Caulfield et al., 1998). Extensive modification of the Irish landscape for agricultural purposes (both arable and pastoral) only began in the late 12th century and intensified in the 17th and 18th centuries, culminating in the early 20th century when less than 2% of the country is estimated to have been covered by forest (Smith et al., 2011; O'Hanlon, 2012). Despite considerable evolutions in agricultural practices in Ireland, pre-Christian field layouts persist in many areas of Ireland suggesting that the field boundaries in Ireland, and the hedgerows that define them, are very stable through time.

Genetic and archaeological evidence seems to indicate that badgers only colonised Ireland following the arrival of humans and, in fact, were probably introduced by early human colonists (Frantz et al., 2014). Thus, badgers on the island of Ireland have evolved in concert with humans, adapting to increasingly pervasive anthropogenic impacts. Badgers in Ireland are generalist foragers, varying their diets across seasons and with earthworms forming an important though not predominant element of the diet (Cleary et al., 2009, 2011). Earthworm abundance tends to be higher on pasture fields compared to other land use types such as arable or forest (Cuendet, 1996), so farming practices may have a direct impact on badgers in terms of foraging behaviour. We have previously shown that

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badgers in Ireland largely avoid arable fields and actively select pasture fields when foraging (Elliott et al., 2015). Furthermore, hedgerows provide a broader diversity of potential foods compared to open fields (e.g. Thomas and Marshall, 1999; Facey et al., 2014) and we have also shown that badgers actively forage in hedgerows (Elliott et al., 2015). We hypothesised that our study badgers would selectively forage along field margins. We anticipated that such a pattern would occur because field boundaries would provide a greater diversity of potential dietary items than field centres (e.g. Thomas and Marshall, 1999; Facey et al., 2014), hedgerows would offer a degree of security and shelter to hide from threats such as humans and dogs (e.g. Hilty and Merenlender, 2004) and may act both as convenient landscape markers and impediments to free movement and, under some circumstances, the shade provided by trees and dense shrubs would generate an amenable microclimate that would favour earthworms (Hauser, 1993).

Badger setts are important resources within a badger group's territory (Macdonald et al., 2004), evidenced by their long-term persistence and use in the landscape and the considerable energetic investment spent by badgers in maintaining them (Stewart et al., 2001). Likewise, at least in medium to high density populations, badgers invest significant time in replenishing their network of latrines – preferred points for scent-marking, urination and faecal deposition that have a function in territorial defence and advertisement of reproductive status (Buesching and Macdonald, 2001) – which can have a significant impact on their nightly behavioural patterns (Loureiro et al., 2009). Hedgerows have already been reported as being important habitats for the location of badger setts in Ireland (Smal, 1995) and the UK (Hazel and French, 2000), and for latrine sites (Brown, 1993; Macdonald et al., 2004; Delahay et al., 2007; Balestrieri et al., 2011). We were interested in determining if such patterns of hedgerow use in terms of sett and latrine locations also occurred in our study population which, if combined with our investigation of selective foraging along field boundaries, would reinforce the importance of these man-made habitat features in the ecology of Irish badgers.

Material and methods

Study area

Our study area was located approximately 32 km north-east of the city of Dublin in eastern Ireland (53°30′ N, 6°35′ W) and covered approximately 11.36 km^2. The landscape is typical of rural areas in eastern Ireland with managed pasture predominating area coverage (74% overall – beef ~27%, dairy ~13%, sheep ~5%, horses ~4%, mixed ~25%), interspersed with tracts of arable land (18% – wheat, oats and barley), particularly low woodland coverage (0.45%), and houses, farmyards and gardens (2%) concentrated along road margins. Since practically all field boundaries, roads, tracks and river banks in the study area featured a hedgerow, we did not classify these features separately in our analyses. The only exception was the area surrounding the Teagasc Agricultural Research Centre (TARC, Fig. 1A and B), where many of the original hedgerows had been removed and replaced with sheep wire or single-strand electric fencing to delimit fields (and we discuss this exception further in the discussion of our results). Hedgerows constituted 3% of the study area (i.e. greatly exceeding woodland coverage) and comprised mostly hawthorn (*Crataegus monogyna*), interspersed with trees such as ash (*Fraxinus excelsior*) and beech (*Fagus sylvatica*), with hedgerows in Meath having a mean width of 2.2 m [proportions of hedgerows in different width classes: <1 m = 0.02; 1–2 m = 0.39; 2–3 m = 0.49; >3 m = 0.1] and a density of 7.26 km/km^2, with most exceeding 2.5 m in height (Smith et al., 2011).

A cull carried out by the Irish Department of Agriculture (December 1998 to January 1999) as part of their bovine tuberculosis control regime after our fieldwork had ceased indicated a minimum badger density in the study area of approximately 2 badgers/km^2, suggesting a population size of approximately 22–25 badgers in the study area, although it should be noted that estimates from a single trapping event can considerably underestimate badger numbers (Byrne et al., 2012; Noonan et al., 2015). A comprehensive survey of a non-culled population in similar habitat in Northern Ireland also estimated a mean badger density of 2.04 badgers/km^2 (95% CI 0.68–3.41) (Reid et al., 2012) based on a mean social group size of 4.27 badgers/main sett (95% CI 3.65–4.89).

Radiotelemetry and sett and latrine surveys

The study area was first surveyed for badger setts in late 1994 and then in conjunction with bi-annual latrine bait-marking surveys. Latrine/sett surveys were carried out over a four-week period on seven separate occasions during the study period (Spring and Autumn in 1995, 1996 and 1997 and the Spring of 1998). Surveys involved walking the study area in daylight searching for both latrines and setts, and the area covered progressively increased with each survey (see Supplementary Material). We categorised setts as either main, annex, subsidiary or outlier following Thornton (1988). Bait-marking followed the protocol of Kruuk (1978), except our bait consisted of a chocolate/peanut base in which coloured plastic pellets (Athlone Extrusions Ltd.) were mixed – we acknowledge that nowadays chocolate is not considered a suitable bait for wildlife. Latrines presenting more than one colour pellet were considered boundary latrines, latrines with a unique colour pellet were considered hinterland, and latrines with no bait were termed 'unbaited' (Kilshaw et al., 2009). Radiotracking was carried out between February 1996 and May 1998. Badgers were captured in cage traps and anaesthetised by intra-muscular injection of 20 mg/kg ketamine hydrochloride (nowadays, a lower dose in conjunction with other agents is recommended, e.g. McLaren et al., 2005) under licence from the Office of Public Works, in association with the Department of Agriculture, Forestry & Food and according to the ethical standards of University College Dublin. Captured badgers were aged according to toothwear (da Silva and Macdonald, 1989) as adult (>2 years) and subadult (<2 years). Ten badgers (five males and five females) were radiotracked for various timeframes in the study period (see Supplementary Material and Elliott et al., 2015) using Yagi antennae and observed using hand-held night-vision monoculars. Tracking was typically carried out between 22:00 and 04:00 during which locations (fixes) and behaviour were recorded every 10 min, but tracking effort varied from night to night depending on how quickly a badger was located, if telemetry signals were lost or if a session had to end prematurely. Since radiotracked badgers were under continuous observation, we could characterise foraging behaviour as being typified by active searching in a meandering pathway, accompanied by audible lip-smacking noises. Our use of night-vision and the open nature of the landscape meant that both location (and behaviour) could be determined accurately so we did not generate error polygons around fixes. We only used fixes attributed to foraging activity in our analyses, so our results only pertain to that behaviour. Although this dataset is over 15 years old, since habitat structure and farming practices have changed little over the intervening years both within the study area and regionally (O'Brien, pers. obs.), we assert that our findings are still relevant today.

Analysis

Foraging fixes, setts and latrines were overlaid on a habitat raster in ArcMap 10.2.1 (ESRI, 2014). We selected fields where badgers