Agriculture, Ecosystems and Environment 178 (2013) 31–38

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Great tits *Parus major* and blue tits *Cyanistes caeruleus* as indicators of agri-environmental habitat quality

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ARTICLE INFO

Article history:
Received 28 January 2013
Received in revised form 12 June 2013
Accepted 18 June 2013
Available online 24 July 2013

Keywords:
Landscape structure
Foraging
Indicator species

ABSTRACT

This study examined relationships between habitat and breeding success for two common bird species, the great tit *Parus major* and blue tit *Cyanistes caeruleus*. The aim was to determine the potential of these species to act as indicators of food resource availability for birds in managed semi-natural habitats on farmland and thus as a measure of the effectiveness of specific management practices under agri-environment schemes (AES). Breeding success was recorded for four years (2007–2010) using 90 nestboxes on arable farmland in central England. Habitat parameters were derived from high spatial resolution airborne Light Detection and Ranging (LiDAR) and hyperspectral data.

Relationships of breeding variables with a range of habitat variables, many of which were influenced by AES management, were evident for both species, despite strong interannual variation in breeding parameters. Relationships were strongest for models using habitat variables within a 100 m radius of the nest, compared to values of 50 and 200 m. Both species showed significant, positive relationships with the area and proximity of tree canopy and, for great tits especially, with hedgerow height and volume.

Therefore, tits may act as indicators of the quality of local habitat, particularly within-hedge trees and hedgerows, managed under agri-environmental provision, and provide insight into the spatial arrangement of AES options at the field scale.

1. Introduction

Over the past century, intensification of agricultural practices, including increased mechanisation, simplification of crop rotation and reduction of non-crop features have led to declines in farmland biodiversity, with population declines even in species which have historically thrived on agricultural land (Donald et al., 2001; Stoate et al., 2001; Henle et al., 2008). Agri-environment schemes (AES) have been cited as the only realistic tools for reversing these decreases (Donald and Evans, 2006). AES vary in their precise aims but all involve offering financial incentives to farmers for undertaking measures designed to benefit the environment or biodiversity (Kleijn and Sutherland, 2003). The Environmental Stewardship scheme, introduced in 2005, is the current AES in the UK, and has a wide range of biological and socioeconomic goals including conserving biodiversity and protecting natural resources (Natural England, 2009).

Despite two decades of study across Europe and the USA, a clear consensus has yet to emerge on the present effectiveness and future potential of AES, with widely varying results depending on the spatial scale and target criteria studied (Kleijn and Sutherland, 2003; Davey et al., 2010; Batáry et al., 2011). It is therefore important to establish clear links between specific management practices and biodiversity gains in order to monitor and target AES, if they are to meet their objectives in a cost-effective manner (Kleijn and Sutherland, 2003; Vickery et al., 2004).

Great tits *Parus major* and blue tits *Cyanistes caeruleus* are small (around 18 and 10 g respectively), insectivorous passerines that breed sympatrically across much of Europe and provision their young with invertebrates, particularly caterpillars (Perrins, 1991). Although associated primarily with deciduous woodland, both species also occur widely in a range of alternative habitats, including parkland, urban gardens and agricultural land (Hinsley et al., 2008). Both species are tolerant of human disturbance and readily use nestboxes, which allows detailed recording of breeding parameters and avoids some of the risk and difficulties associated with monitoring open nests (James Reynolds and Schoech, 2012). In the UK both species nest in April-June and are overwhelmingly single-brooded, which simplifies the monitoring of annual reproductive output. The adults typically feed their young several hundred times a day (Cowie and Hinsley, 1987) and are therefore constrained by time and energetic costs to forage within a limited radius around

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0167-8809/$ – see front matter
http://dx.doi.org/10.1016/j.agee.2013.06.015

the nest site (Tremblay et al., 2005). This allows realistic assumptions of likely foraging distances around the nest site to be made (Hinsley et al., 2002).

Although it is well known that great and blue tits experience reduced breeding success in habitats other than large deciduous woodlands (Riddington and Gosler, 1995; Hinsley et al., 2008; Marciniak et al., 2007), there has been relatively little research to identify which habitat features influence breeding success at the level of the individual nest, especially within arable landscapes. In contrast to many farmland birds, the increasing populations of great and blue tits (Baillie et al., 2012) do not make them species of conservation concern in Britain. However, if clear relationships between breeding success and specific farmland habitat variables can be identified, tits may prove useful as indicators of local habitat quality and resource availability for other species which are declining or of conservation concern, and thus of the potential for AES management to benefit such species. Several farmland birds of conservation concern, such as the yellowhammer *Emberiza citrinella*, reed bunting *Emberiza schoeniclus* and tree sparrow *Passer montanus*, share a similar insectivorous nestling diet (Wilson et al., 1996) and forage in a range of vegetation including hedges and shrubs which may be used by tits (Hinsley and Bellamy, 2000). There are also species of other taxa which are targets for conservation under Environmental Stewardship, such as bats (Natural England, 2008; Merckx et al., 2009), which share the tits' insectivorous diet and arboreal habits. The dependence of tits on caterpillars also makes their breeding success a potential indicator for abundance of Lepidoptera (Perrins, 1991; Naef-Daenzer and Keller, 1999).

In this study we use a replicated experiment to evaluate the breeding success of great and blue tits as indicators of local habitat quality as provided by specific Environmental Stewardship options. Nestbox monitoring and high-resolution data from remote sensing were used to identify relationships between breeding performance and habitat variables. This could inform the monitoring, assessment and development of targeted management strategies for the productivity of invertebrates and their insectivorous predators, including those of conservation concern, where diet and habitat overlaps with that of the tits.

2. Methods

The study was conducted on the Hillesden Estate, 1000 ha of farmland in Buckinghamshire, central England (51.95 N, 01.00 W). The Estate is characterised by arable fields cropped under a rotation of autumn-sown oilseed rape *Brassica napus*, wheat *Triticum aestivum*, and field beans *Vicia faba*, bordered by short (<2 m), shrub hedgerows dominated by hawthorn *Crataegus* spp., with scattered, mature trees (mostly English oak *Quercus robur* with some ash *Fraxinus excelsior* and willows *Salix* spp.).

Between 2005 and 2011, the Estate was managed under a large-scale replicated experimental design intended to investigate the effects of Environmental Stewardship on farmland biodiversity, including birds (Hinsley et al., 2010), small mammals, pollinators (Carvell et al., 2012) and invertebrates (Woodcock et al., 2010). Three levels of Environmental Stewardship management were established on plots of between 60 and 90 ha, each replicated five times in a randomised block design (see Hinsley et al., 2010 for further details). The three levels were: Entry Level Stewardship (ELS), Entry Level Stewardship Extra (ELSX) and the control, cross compliance (CC) – the latter representing the minimal obligatory conservation effort required under the European Union Common Agricultural Policy (DEFRA, 2013). Cross compliance field margins were uncultivated areas 2–3 m in width from the centre of a hedgerow, or 1 m from the top of a ditch, with hedges cut annually after harvest. Environmental Stewardship management involved the establishment of a range of non-crop habitats via seed mixes sown as field margins or patches and a biennial hedgerow cutting regime. On ELS treatments, approximately 1% of cultivated land was taken out of production and put into 6 m wide tussocky grass margins and a single patch of winter bird food mix. On ELSX treatments, approximately 5% of land was removed from production, distributed between 6 or 8 m wide margins (including tussocky grass, pollen and nectar mix, and natural regeneration) and several patches of pollen and nectar mix, wildflower mix winter and bird food mix.

In February 2007, 90 nestboxes were placed in hedgerows throughout the estate. Boxes were mounted 1.5–2.5 m above the ground, the majority (86%) on hedgerow trees (68% of which were English oaks) with the remainder attached to bushes or artificial structures (e.g. fenceposts, pylons) within the hedgerow. In addition to five individual boxes, each treatment contained one 'terrace' design consisting of three adjoined boxes, each with its own entrance hole. The latter type was intended for use by tree sparrows but was frequently utilised by either (occasionally both) tit species. There was thus a total of 120 artificial nest sites, all with interior dimensions 160 × 125 × 110 mm and an entrance hole of 32 mm diameter, suitable for use by either tit species. Tits were common breeders on the Estate prior to the provision of boxes, nesting in natural cavities (authors' unpublished data). Thus the comparatively low density of boxes (mean 2 per km of Hedgerow across the Estate) was unlikely to have significantly affected the natural tit population density.

2.1. Measuring breeding performance

Measurements of tit breeding performance were gathered for four years (2007–2010) from April to June. Boxes were visited at least weekly from early April to determine lay date of the first egg and, subsequently, clutch size and hatch date. Dates are presented from here on as 'April dates', where 1 = April 1st and 91 = June 30th. The number of live and dead nestlings was counted 11 d after hatching, and live nestlings were fitted with a uniquely numbered British Trust for Ornithology (BTO) alloy leg-ring, weighed (to 0.1 g) and returned to the nest. The number of nestlings successfully fledged was estimated approximately 20 d after hatching by searching vacated nests for nestlings which had died after 11 d. Two primary indicators of breeding success were chosen to reflect likely food supply: mean nestling mass excluding runts (i.e. nestlings too small to ring at 11 d, <6 and <12 g for blue and great tits, respectively) and total live nestling biomass (including runts) at 11 d after hatching. Runts were rare and were excluded from mean nestling mass to prevent them reducing its usefulness as a measure of overall nestling quality by skewing it downwards. Nestling mass is a good indicator of nestling condition (Tinbergen and Boerlijst, 1990) so these two measures were expected to reflect food abundance in the surrounding habitat coupled with the adults' provisioning abilities, in terms of food supplied to each nestling (mean nestling mass) and total food supply to the nest (total biomass) (Hinsley et al., 2002). Several additional measures were also calculated for each nest: lay date of the first egg, clutch size, number of nestlings alive at 11 d, and nest output (number fledged as a proportion of clutch size).

2.2. Collecting and extracting habitat data

Habitat data were obtained from two airborne remote sensed sources, Light Detection and Ranging (LiDAR) and hyperspectral imaging. These remote sensed data were acquired by the Natural Environment Research Council Airborne Research and Survey Facility on 28th August 2007, under conditions of full leaf canopy, from a mean flight altitude of 1190 m. The two sensors used were an