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Manipulating grass silage management to boost reproductive output of a ground-nesting farmland bird

David L. Buckingham *, Peter Giovannini, Will J. Peach

RSPB Centre for Conservation Science, Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire SG19 2DL, UK

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ABSTRACT

Grass fodder crops are attractive nesting habitats for a suite of declining farmland bird species that nest in taller grass swards. Multiple, early silage harvests cause substantial losses of nests and flightless fledglings, making this widespread crop an influential population sink in temperate farmland. We measured the effects of two simple conservation interventions (raised cutting heights and delayed mowing) designed to increase the reproductive output of a multi-brooded passerine (skylark *Alauda arvensis*). Annual reproductive output of independent juveniles (fecundity) was quantified using a stochastic re-nesting model that allowed us to investigate the impacts of a wide range of potential management interventions (varying cutting heights, dates and machinery) at minimal cost.

Under typical silage management mean skylark fecundity was only 13–17% of the level required for metapopulation stability (the replacement rate). 12–54% of nests and 28–44% of fledglings survived a typical silage harvest with most losses caused by abandonment of nests covered by cut grass, crushing by wheels or predation soon after mowing. Delaying mowing increased fecundity, but only up to a maximum of 44% of the replacement rate. Raising cutting heights had a negligible impact on fecundity. Asynchrony between nesting attempts (due to predation, starvation and protracted delays between nesting attempts) resulted in few attempts taking place when they could benefit from the interventions. In the absence of mowing, fecundity was only 47% of the replacement rate, due to low reproductive output per nesting attempt, while simulations showed that increasing output per nest would have the largest impact on fecundity. Conservation effort should focus on providing alternative high fecundity breeding and foraging habitats at the landscape scale, to counteract silage fields' action as a sink for skylark populations in livestock-farming areas. These conclusions are likely to apply to other multi-brooded ground-nesting species.

1. Introduction

The intensification of grass forage production has been identified as an important driver of farmland bird declines in Britain (Vickery et al., 2001), NW Europe (Broyer, 2009; Müller et al., 2005; Stein-Bachinger and Fuchs, 2012) and North America (Herkert, 1997). The switch from hay to silage production has allowed grass harvests to take place earlier and more frequently in any one year. These timing changes reduce the opportunities for ground-nesting birds to complete their nesting attempts without being exposed to harvesting operations. The most vulnerable species are widespread, declining farmland birds that preferentially nest in taller grass swards, including skylark (*Alauda arvensis*), corn bunting (*Emberiza calandra*) and whinchat (*Saxicola rubetra*) in Europe; bobolink (*Dolichonyx oryzivorus*) and multiple grassland-nesting American sparrow species (e.g. sandwich sparrow *Passerculus sandwichensis* and field sparrow *Spizella pusilla*) in North America. In pastoral landscapes, the tallest grass swards typically occur in grass forage crops, rather than in grazed pastures. Birds attracted to nest in grass forage crops experience high rates of nest losses during harvesting (Green et al., 1997; Müller et al., 2005). Furthermore, chicks of many of these species leave the nest (referred to as fledging throughout this paper) before they can fly, so the fledglings remain vulnerable to harvesting machinery for an extended period. It is likely that mown grasslands act as ecological traps for many tall sward nesting bird species.

Few studies have experimentally manipulated silage-harvesting techniques with the aim of enhancing annual breeding productivity (fecundity) of tall sward nesting birds. Delaying cutting till late in the breeding season or afterwards has proved effective for species that start nesting relatively late and make few nesting attempts in each year. Such measures would be costly to

* Corresponding author. Tel.: +44 1767 693561; fax: +44 1767 692365.
E-mail address: david.buckingham@rspb.org.uk (D.L. Buckingham).

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implement on high-yielding agricultural grasslands and have mainly been applied in areas subject to agricultural constraints such as short growing seasons at northerly latitudes (corncrake (*Crex crex*): Green et al., 1997; corn bunting: Perkins et al., 2013), semi-natural grasslands at higher altitudes (whinchat: Müller et al., 2005) or late hay cuts on natural grasslands (bobolink and American sparrows: Nocera et al., 2005). Conservation measures for multi-brooded species breeding in intensively managed, high-yielding silage fields have received less attention, despite the prevalence of such management practices in Europe and North America and the likelihood of adverse impacts on breeding birds (Smit et al., 2008; Giuliano and Daves, 2002).

Quantifying the effect of mowing practice on the annual fecundity of multi-brooded species on mown grasslands is challenging and most studies have made assumptions to simplify calculations. Important sources of error include assumptions regarding the effect of mowing on the timing of subsequent nesting attempts and ignoring low post-fledging survival. Two commonly used analytical simplifications are that the timing of nesting attempts is not affected by mowing (e.g. Perkins et al., 2013) or that birds will re-nest soon after mowing, so that they can take advantage of any interval between cuts that is sufficiently long to rear a brood (e.g. Wilson et al., 1997; Stein-Bachinger and Fuchs, 2012). If mowing does not affect nest initiation, the exposure of nests to mowing on different dates can be calculated simply from the observed timing of nest attempts. This simplification may be reasonable for late season cuts and species that make few subsequent nest attempts (e.g. Perkins et al., 2013), but it is problematic when a higher proportion of nesting attempts follow early cuts, as in intensive silage systems. The survival of flightless fledglings is rarely incorporated into fecundity estimates, despite high mortality occurring at this stage (Fisher and Davis, 2011) in addition to protracted periods of vulnerability to mowing operations before the fledglings can fly.

This study used skylark as a model species to measure the effects of silage management on fecundity of multi-brooded birds (defined here as the number of free-flying, independent fledglings per pair per year). The skylark is a common breeding bird in farmland throughout Europe, breeding on a wide variety of grassland and arable crops. Intensively managed, productive grasslands harvested for silage are widespread throughout its range, particularly in NW Europe (Smit et al., 2008). A third of the British population breeds in intensive grassland, with the highest densities in silage fields (Browne et al., 2000). In lowland Britain, skylarks start nesting early and make multiple nesting attempts. The nesting season coincides with the main harvesting period for silage (April–August) during which two or three silage cuts are taken. For British skylarks, the best estimate of the minimum fecundity required for metapopulation stability (the replacement rate) is 1.79 independent juveniles pair^{-1} year^{-1}. The true figure in farmland may be higher as this estimate is derived from measurements in semi-natural dune grasslands, where adult annual survival was 0.66 in 1995–98 (Wolfenden and Peach, 2001) and first year survival from independence to first breeding was 0.38 in 1958–64 (Delius, 1965).

The aims of this study were to quantify skylark fecundity in silage fields and to establish how it was affected by crop management. We also tested whether two simple management interventions (raised cutting heights or delayed mowing dates) could increase the fecundity of individual skylark pairs to levels likely to permit population growth in metapopulations within silage fields or at larger scales in grass-dominated farmland. We tested three mechanistic hypotheses: first that delaying mowing would allow more nesting attempts to successfully reach completion, before damaging silage harvesting operations took place. Second, we predicted that raised cutting heights would allow skylarks to re-nest more quickly and reach completion before the next silage cut, as the re-growing sward would reach a minimum threshold sward height for nest initiation more quickly (Kragten et al., 2008). Third, we predicted that raised cutting heights would result in fewer nests and fledglings being struck by mower blades and destroyed.

Skylark fecundity was estimated using a stochastic 're-nesting model' (Beintema and Müskens, 1987). The model provided a simulated distribution of the fecundity of a single skylark pair suitable for use in population modelling (though undertaking that population modelling was beyond the scope of this study). The model is the first to incorporate measurements of nest initiation timing and post-fledging survival prior to independence, avoiding the need for unrealistic assumptions and making this the first study to estimate genuine season-long fecundity of a ground-nesting bird in mown agricultural grasslands (Streby et al., 2014). The model allowed a wide range of different management interventions to be evaluated without the need for prohibitively expensive field trials. Particular attention was given to measures that minimised the economic costs to farmers. Therefore, changing the timing of the economically most important first silage cut (highest yields and quality) was dismissed as an option because moving the cutting date away from the optimum would result in costly losses of silage yield or quality (Hopkins, 2001). In contrast, a high first cut followed by a low second cut can increase overall silage yields (Binnie et al., 1980) in addition to potentially increasing skylark fecundity. Agricultural yields were fully quantified on the study fields but are not reported here.

2. Materials and methods

2.1. Study sites and management of silage fields

Skylark breeding performance was measured between 2006 and 2008 on 47 silage fields spread across 18 dairy farms in Dorset, SW England. All of the study fields, including experimentally manipulated fields and controls, were high-yielding, agriculturally improved, fertilised swards, dominated by ryegrasses (*Lolium*) and ranging from short-term leys to permanent grassland. Each field was occupied by nesting skylarks (mean territory density 0.28 ha^{-1}, 95% CL 0.09–0.56) and was subjected to two or three silage cuts each year. Hay was harvested opportunistically on the same fields (instead of silage) when weather conditions permitted.

The machinery combinations used to harvest silage varied between farms. All farms used rotary disc mowers with one to three cutting bars per tractor (each 3 m wide). Standard mowers deposited the cut grass into rows (swaths). Swather mowers (used on two farms) incorporated conveyor-belts to deflect the cut grass sideways onto previously cut swaths, avoiding the need to use windrowing rakes. Rakes (tedders) were occasionally used to spread cut grass and expedite drying (usually to make drier, baled silage or hay). Windrowing rakes were frequently used to gather multiple swaths of cut grass into compact rows (windrows) for easy collection. Grass intended for fermentation in silage clamps was picked up using self-propelled forage harvesters, otherwise cut grass was baled. Tractors followed forage harvesters and balers with trailers, to remove the cut grass or bales. Grass collection and removal resulted in a high proportion of the field being trafficked by machinery, particularly when baling. In most cases, the entire process took two days to complete: mowing and spreading (if required) on day 1; windrowing and collection on day 2.

Cutting heights were manipulated to measure their effect on skylark nesting phenology and reproductive performance. Cutting heights were raised in split-field experiments (half cut high, half cut low, aiming for a 8 cm difference; 19 fields in 20 field-years,