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Conservation of breeding grassland birds requires local management strategies when hay maturation and nutritional quality differ among regions

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ABSTRACT

Early hay harvest can negatively affect grassland bird reproduction. Agriculturists may delay harvest in support of grassland bird conservation if hay quality is not jeopardized. We examined changes in hay quality over time at three latitudes in Ontario, and for the central region, we related results to bobolink (*Dolichonyx oryzivorus*) breeding phenology. We collected hay samples at all latitudes from 1 June through 16 July and quantified changes in percent crude protein (CP), acid detergent fibre (ADF), calcium (Ca) and phosphorus (P). At the same time, we also monitored breeding behaviour of all grassland birds but sufficient data for analyses and comparative purposes were collected only for bobolinks in central Ontario. Most Ontario hayfields sampled were low in energy and digestibility throughout the growing season (mean ADF values > 35%). Ca levels were more than adequate for most livestock but P supplementation may be required depending on the production goals of the farmer. Crude protein levels were higher in forage samples collected from northern study plots and fell below 10% one week later than in central and southern Ontario. In central Ontario, CP levels were highest in the first week of June (12–15%). In the last two weeks of June through to mid-July, mean CP levels dropped from 11% to 9.5%, roughly 0.5% per week. Fledgling bobolinks were first observed on 14 and 16 June; they were counted in larger numbers after 20 June and reached a peak 1–14 July. A delayed hay harvest (mid-July) in this region would support bobolink reproduction without compromising forage quality for a variety of livestock enterprises. Timing of hay harvest to benefit grassland birds in regions to the north and south may differ depending on local geologic and climatic conditions and breeding bird behaviour. Based on our results, farmers that opt to manage their hayfields in support of grassland birds can delay the timing of hay harvest with trade-offs not as severe as once thought. The delayed hay harvest strategy may have wider applications to agro-ecosystems globally; its feasibility would only require knowledge of local breeding bird activity and forage quality over time.

1. Introduction

Grasslands are among the most productive communities in the world (White et al., 2000) and many bird species rely on them for several, and sometimes all, stages of their life cycle (breeding, migration, and wintering). Although native grasslands have largely disappeared (Dengler et al., 2014; Habel et al., 2013; Overbeck et al., 2007; Pieper, 2005) many grassland bird species have adopted agro-ecosystems as surrogate habitat, especially pastures and hayfields (Azpiroz and Blake, 2009; Buckingham et al., 2015; Hurley and Franks, 1976; Vickery et al., 1999).

Historically, the switch to agro-ecosystems proved beneficial to breeding grassland birds; however, these habitats are now proving to be more challenging for many birds due to the advancement of modern machinery and other changes in agricultural practices (Chamberlain et al., 2000; Donald et al., 2006; Fuller et al., 1995; Murphy, 2003; Rodenhouse et al., 1995). Mowing of hayfields during the nesting period is one agrarian change implicated in the decline of grassland bird populations worldwide (Luscier and Thompson, 2009; Nocera and Koslowsky, 2011; Perlut et al., 2006; Vickery et al., 2001). In North America and Europe, hay harvest dates have advanced 2–3 weeks within the last 50 years (Broyer, 2009; Müller et al., 2005; Troy et al., 2005) and now coincide with

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late incubation and/or nestling stages of many grassland and farmland bird species (Broyer et al., 2016; Herkert, 1997; Martin and Gavin, 1995; Warner and Etter, 1989). Progressively earlier and more frequent hay cut dates are likely due to a combination of rising global temperatures (Trenberth et al., 2007), increased use of early-maturing, cool-season grass species, and production of high-moisture, silage bales over dry hay (Giuliano and Daves, 2002; Vickery and Dunwiddie, 1997).

Although it is possible a range of different factors might be driving declines in grassland bird populations worldwide, recruitment is inarguably reduced when breeding habitat is harvested during the nesting period. The most straight-forward management strategy for reducing the adverse effects of hay harvest on breeding grassland birds would be to delay harvest activities until after the breeding season (Bollinger et al., 1990; Broyer et al., 2016; Dale et al., 1997; Grüebler et al., 2012; Müller et al., 2005; Nocera et al., 2005; Perkins et al., 2013). Delayed hay harvests have also proven beneficial for non-avian wildlife, such as bees (Buri et al., 2014), butterflies (Bruppacher et al., 2016), and orthopterans (Buri et al., 2013). However, delay in harvest presents a concern for many farmers because the nutritive value and digestibility of hay declines over time (Buxton and Marten, 1989; Troy et al., 2005). Hay is the primary source of nutrition for most livestock during the winter or non-grazing season and modern farm management practices try to maximize quantity and quality (Frawley and Best, 1991). The stage of maturity of grass at harvest is central to the quality of forage. Early in the growing season, forage plants in the late-bud to first-flower stage contain high concentrations of starches, sugars, proteins, and minerals. As the growing season progresses, the dry matter in these mature plants has a lower proportion of digestible nutrients and a higher proportion of plant fibre (Ball et al., 2001).

For global conservation of grassland bird populations to be effective, efforts must reconcile the interests of both agriculturists and conservationists. Some farming operations (e.g., dairy) will have little flexibility to alter current hay management practices (Troy et al., 2005); however, hayfields associated with less intensive agricultural operations are well-suited for grassland bird conservation. The challenge thus remains to identify a forage management strategy for these farmlands that would both improve breeding success for grassland birds while ensuring the farmer's economic and production needs are met. Some strategies have met with success, such as a program in Vermont, USA where farmers harvested their first hay crop very early in the season (late May-early June) and then did not harvest again for 65 days (Perlut et al., 2011). The early harvest allowed bobolinks (*Dolichonyx oryzivorus*) an opportunity to re-nest if their nest was destroyed, followed by a time window large enough to complete a breeding cycle. The combination of a lower volume but very nutrient-rich first cut and greater quantity but decreased quality second cut offset each other and the farmers incurred little loss. Unfortunately, when the Vermont strategy was tested in Ontario, it posed insurmountable logistical problems (annual spring muds) and failed to attract breeding bobolinks (Diemer and Nocera, 2016). As such, it is clear that forage management strategies may need to be tailored to regional environments and situations.

The hay harvest plan most likely to benefit birds that nest in agricultural grasslands worldwide is a single cut made after most young birds have fledged (Broyer et al., 2016; Green et al., 1997; Grüebler et al., 2012; Müller et al., 2005). The relationship between the phenology of breeding grassland birds and forage nutrient quality under a delayed hay harvest strategy was first assessed in a coastal agro-ecosystem (Nocera et al., 2005). In Nova Scotia, Canada, a delay of hay harvest by one week to late June or early July resulted in only a small reduction in hay nutritional quality for beef cattle; however, the delay gave 20% of young bobolinks an opportunity to fledge successfully compared to 0% in early cut fields. To determine whether the single, delayed hay harvest strategy might have wider-ranging applications, our first objective was to assess the generality of patterns observed in Atlantic Canada. To do this, we examined the relationship between forage quality and phenology of breeding grassland birds in central Ontario, approximately 1000 km inland from the Nova Scotia study area. Although sites were situated at similar latitudes, mean temperatures during the growing season were, on average, lower in the coastal region (Government of Canada (GC, 2016). The sites also differed geologically. The Annapolis Valley of Nova Scotia is eroded into shale and friable sandstone with much of the area layered by deep, loamy, glacial till, alluvium, and fluvioglacial outwash (Hickox, 1962; Holmstrom and Thompson, 1989). As such, in agricultural areas of Nova Scotia, lime and fertilizers are often required to raise pH and phosphorus levels. However, dominant soils in central Ontario are luvisolic underlain by loamy tills derived from underlying sedimentary, carbonate bedrock. These soils are typically well-supplied with base cations such as calcium and magnesium, and have loamy or clay-dominated soil textures (Gillespie et al., 1962; Gillespie and Acton, 1981).

Our second objective was to determine whether temporal patterns of forage quality and nutrients varied within the large province of Ontario (1,076,395 km^2). To do this, we collected hay samples from two additional latitudes, 425 km to the north and 165 km to the south, of our central Ontario sites. In all aspects of our study, our over-arching goal was to explore the feasibility of a delayed hay harvest schedule as a conservation strategy for birds that breed in agricultural hayfields by considering impacts to feed and production goals of farmers.

2. Methods

2.1. Study sites

We centered our study on 13 agricultural sites (dominated by hayfields) in central Ontario, Canada (44°22′N, 77°59′W) during 2010 to 2012. In 2010 and 2011, we also monitored five sites in southern Ontario (42°50′N, 80°18′W) and four sites in northern Ontario (47°54′N, 79°58′W). Field sites in central and northern Ontario differed ecologically and geologically. Central Ontario plots were situated in the mixedwoods plains ecozone where deep, fine-textured luvisols covered primarily sedimentary, carbonate (limestone) bedrock. Study plots in the north were in the boreal shield ecozone; in this area, shallow, coarse-textured podzols covered metamorphic, non-carbonate bedrock (Baker, 1985; Baldwin et al., 2000). There were also climatic differences between regions with mean daily temperatures in the north, on average, 2 °C lower over the growing season (Government of Canada (GC, 2016). Mean daily temperatures were, on average, 1 °C higher in the south during the growing season but underlying bedrock and soils were similar in central and southern Ontario (Baldwin et al., 2000; Government of Canada (GC, 2016). Supplement #1 provides locations of our study sites.

All fields were comprised of cool-season grasses commonly used as hay to provision beef-cattle operations: perennial ryegrass (*Lolium perenne*), timothy (*Phleum pratense*), brome (*Bromus* sp.), tall fescue (*Festuca arundinacea*), orchard grass (*Dactylis glomerata*), and Kentucky bluegrass (*Poa pratensis*). The predominant forbs and legumes were alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), white clover (*Trifolium repens*), trefoil (*Lotus corniculatus*), and common vetch (*Vicia sativa*). Other pasture forbs and weeds such as common milkweed (*Asclepias syriaca*), broomsedge (*Andropogon virginicus*), oxeye daisy (*Leucanthemum vulgare*), asters (*Symphyotrichum* sp.) and goldenrod (*Solidago* sp.) were sometimes present although they are not necessarily desired in