The effects of late cutting on threatened bumblebees *Bombus* spp. in sea wall grassland at Goldhanger Creek, Essex, England

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SUMMARY

Sea wall flood defences provide important grassland habitats for bumblebees in the UK but cutting in July and August could be deleterious for declining species, such as the shrill carder-bee *Bombus sylvarum*. The effect on the abundance of bee species of changing the timing of cutting to an annual late cut (after 15 September) on a sea wall at Goldhanger Creek on the Essex coast was compared with a control sward which was cut annually in July or August from 2013-18. On the late cut sea wall there was a significant increase in the overall abundance of threatened bee species, probably because the later mowing avoided the destruction of nests constructed close to the ground. The increase in bee numbers did not correspond with a change in overall forage plant species richness or red clover *Trifolium pratense* abundance. Late-nesting bumblebees are likely to be favoured by delaying the timing of cutting to later in the season.

INTRODUCTION

Sea walls (vegetated earth embankments) are vital engineered structures for the defence of low-lying areas along estuaries and the coast of the UK, such as much of the Essex seaboard, the North Kent Marshes and the Gwent Levels (Gardiner *et al*. 2015). As strong continuous linear features in the landscape, there are over 2000 km of sea walls in England and Wales, with the greatest length in Essex (450 km) (Gardiner & Benton 2011). Management of the grassland on sea walls is essential to allow their engineering inspection and also to provide an erosion-resistant sward of short grass during overtopping which is most likely to occur during winter storm surges (Gardiner *et al*. 2015). Mowing also restricts the development of scrub which can promote burrowing animals leading to damage to defence integrity (Gardiner & Fargeaud 2018).

Sea wall flood defences support some of the richest modern bumblebee assemblages, with 14 social species capable of regularly exploiting this habitat (Gardiner *et al*. 2015). Once considered fairly widespread, UK Biodiversity Action Plan (UK BAP) priority species such as the moss carder-bee *Bombus muscorum* are now primarily coastal species in the English parts of their range, where they are largely restricted to coastal grazing marsh and sea walls (Gardiner & Benton 2011).

Queens of *B. muscorum* usually emerge between March and May to search for a nest site. The nest is built at ground level and covered by moss, dry grass or leaf litter collected by the bees. Approximately one square kilometre of forage habitat has been estimated as possibly being needed to support each bumblebee nest (Edwards & Williams 2004). Therefore this species may be restricted to extensive areas of flower-rich grassland in the heart of coastal grazing marsh where it forages on clovers *Trifolium* spp. and other legumes, complemented with thistles *Cirsium* spp., bramble *Rubus fruticosus* agg. and bird's-foot trefoils *Lotus* spp. on sea walls (S. Falk pers. comm.). Other UK BAP priority bumblebees found on sea walls include the brown-banded carder-bee *Bombus humilis* and ruderal bumblebee *Bombus ruderatus* (Gardiner *et al*. 2015).

As a colony can persist until August or September, there needs to be a continuous succession of flowers from spring through to autumn to ensure a continual food supply (Gardiner & Fargeaud 2018). Bumblebees therefore benefit from sward management that maintains optimal levels of flowering plants (Benton 2000) and the provision of pollen and nectar resources in the landscape is of crucial importance in their conservation (Pywell *et al*. 2006). However, annual mowing of sea walls in late July and August to prevent scrub encroachment and maintain a grass sward could potentially eliminate most bumblebee forage plants and nests as well as causing significant bee mortality (Benton 2000, Gardiner & Fargeaud 2018). Delaying the timing of cutting can increase bee abundance and diversity (Knop *et al*. 2006), although reducing the number of cuts may be less beneficial for common bumblebee species (Potts *et al*. 2009).

This paper reports the results from a six-year study investigating the effect of changing the timing of mowing on the abundance of UK BAP priority bumblebees on a sea wall flood defence on the Essex coast at Goldhanger Creek, southeast England. The results are discussed in relation to other factors such as forage plant species richness and abundance.

ACTION

A 3.6 km section of sea wall flood defence at Goldhanger Creek on the Essex coast (Ordnance Survey grid references TL906084 to TL891070) was selected by the Environment Agency for a change in management, from an annual cut in July or August to a later cut from 15 September onwards, with the aim of conserving the populations of the late-nesting *B. humilis* and *B. muscorum*, which have been recorded from this sea wall (Benton 2000, Benton & Dobson 2007). The cutting of the crest, landward slope and a 3-4 m wide band of grassland on the access track (see Figure 1 for cross section of sea wall) was undertaken with a front-loaded flail mower

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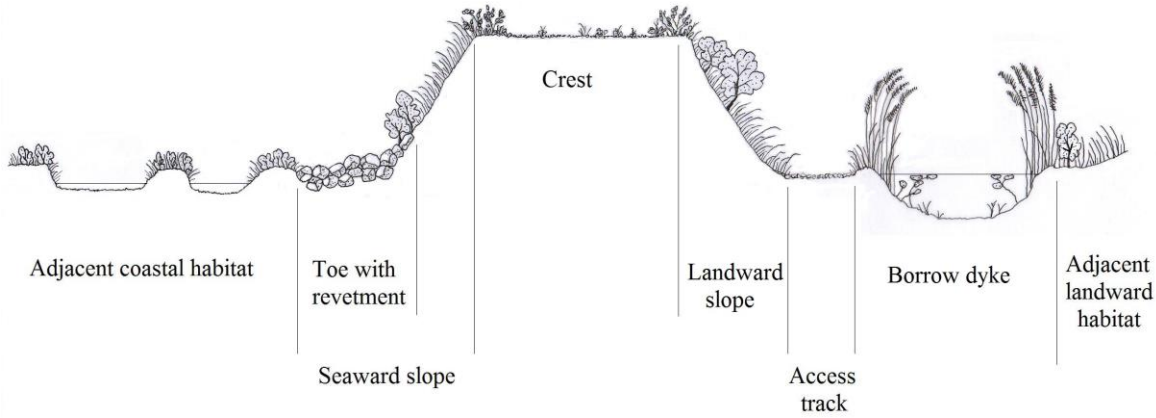

Figure 1. Cross section of the Goldhanger Creek sea wall showing crest, landward slope and folding access track cut. Bee transects were located on the landward slope and access track.

mounted on an Aebi tractor (Aebi TT206 Terratrac), which is used for mowing on steep slopes. No arisings were collected during the operations and the flail cutting height was set 10 cm from the ground to protect reptile populations and allow some habitat to remain after mowing (Gardiner *et al.* 2015). The late cutting was introduced in 2012.

To provide a control for the late cut sea wall, a 0.6 km long section of sea wall (Ordnance Survey grid references TL906084 to TL911080) was cut using an Aebi flail following the standard Environment Agency cutting regime on much of the Essex coast (from mid-July to late August, after the peak bird nesting season has finished), with no arisings collected and the flail set 10 cm from the ground.

Bumblebee monitoring: In the late cut and control sections of sea wall grassland, three 100 m long transects were established on the access track and the landward slope (a total of six transects each for the late cut and control sea walls). The transects were separated by 50 m from each other. The methodology for surveying bumblebees followed that of Carvell *et al*. (2007). Surveys were undertaken between 10:00 and 17:00 h, when weather conditions conformed to the following criteria for the UK Butterfly Monitoring Scheme: 1) transects were not walked when the temperature is below 13 °C; 2) between 13-17 °C, a transect could be walked providing there is at least 60% sun; 3) above 17 °C, a transect could be walked in any conditions, providing it is not raining; 4) when wind speeds are above 5 on the Beaufort scale, transects were not walked (Pollard & Yates 1993).

Bumblebees (priority species only) were monitored on the transects once a month from June-September in the six years (2013-2018) after the late cut had been introduced (a total of 24 surveys). The monitoring was deemed adequate to record the main period of bumblebee activity of workers and drones (queens were not recorded in this survey). The standardised counting technique for foraging bees visiting flowers established by Carvell *et al.* (2007) was used to monitor the attractiveness of the sea wall grassland and potential for forage provision. No attempt was made to search for bumblebee nests, which are difficult to locate in the field.

During surveys, foraging bumblebees were counted along 6 m wide strips along each 100 m transect, with the recorder walking down the centre line of each transect (Carvell *et al*. 2007). The plant species on which each priority bumblebee was first seen foraging was noted. There can be considerable difficulty in distinguishing between *B. muscorum* and *B. humilis* in the field (Falk 2015)., and both species have been recorded from the sea wall (Benton 2000; Benton & Dobson 2007). Therefore, these species cannot be confidently distinguished in the field (T. Benton pers. comm.) and the species were counted together. The different castes of each species were not separated (Carvell *et al*. 2007), as the main aim of this study was to determine the overall abundance of priority bumblebees and forage plants on the sea walls in relation to mowing management.

Forage plant monitoring*:* To determine the abundance of foraging resources on the sea walls throughout the season and between years, an estimate of the number of flowers present on the transects was made on each survey using the methodology of Carvell *et al.* (2007). All plant species were identified in the field (using Stace 1997) and the following scores were used to record their abundance: 1: 1-25 flowers, 2: 26-200 flowers, 3: 201-1000 flowers, 4: 1001-5000 flowers, 5: more than 5000 flowers. One flower 'unit' was counted as a single flower, or for multi-flowered stems, as an umbel (e.g. hog's fennel *Peucedanum officinale*), head (e.g. red clover *Trifolium pratense*), spike (e.g. agrimony *Agrimonia eupatoria*), or capitulum (e.g. knapweed *Centaurea nigra*).

Data analysis: The number of bumblebees (overall abundance) of all priority species were lumped together (due to difficulties in identification between *B. humilis* and *B. muscorum* and low numbers of some bee species i.e. *B. ruderatus* and *B. sylvarum*) and summed for each transect in each year. Due to the differing aspect of the late cut (west facing) and control (east facing) transects, it was not possible to directly compare abundance between them. However, the change through time in mean total bee abundance, mean forage plant species richness and mean flower units for *T. pratense*, after square root transformation to correct for non-normality, were analysed for the monitoring period using linear regression (Heath 1995).

CONSEQUENCES

The most abundant priority species in the survey were *B. humilis/muscorum* (260 bees: 96.6% of observations), with only small numbers of *B. sylvarum* (8 bees: 3% of observations) and *B. ruderatus* (1 bee: 0.4% of observations). A total of 250 priority bumblebees were recorded on the late

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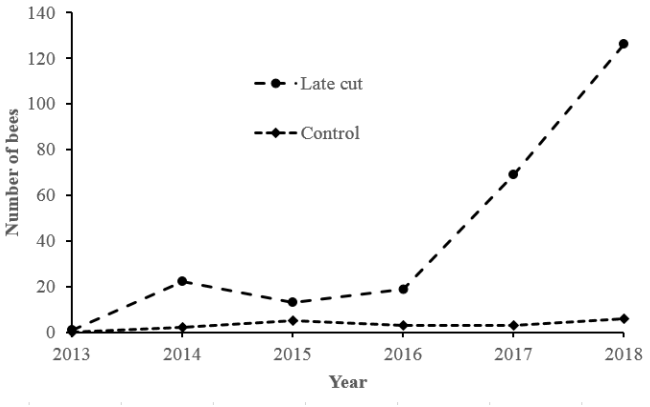

Figure 2. Abundance of priority bees for the late cut and control sea walls over the six-year monitoring period

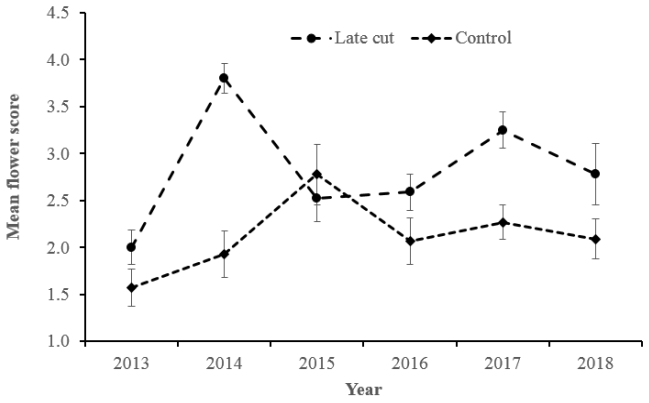

Figure 3. Mean flower units (± s.e.) for red clover *Trifolium pratense* on the late cut and control sea walls over the six-year monitoring period

cut sea wall, compared to only 19 on the control transects. There was a significant increase in priority bee numbers for the late cut (linear regression: y = 1.79x - 361; r^2 = 0.85; p = 0.0094) but not for the control cut (y = 0.363x - 730; r^2 0.61; p = 0.066) sea walls, indicating a significant increase in abundance over the six-year period at the site where cutting was delayed only (Figure 2).

There was a clear preference by *B. humilis/muscorum* for foraging on *T. pratense* (163 bees: 63% of observations), with *C. nigra* (45 bees: 17% of observations) the other species frequently used in addition to spear thistle *Cirsium vulgare* and narrow-leaved bird's-foot trefoil *Lotus tenuis* (15 bees each: 6% of observations each). In total, 13 plant species were used for foraging by *B. humilis/muscorum*. The other priority species, *B. sylvarum*, was found foraging on three species (*T. pratense*: 4 bees, *C. nigra*: 3 bees, hawkweeds *Hieracium* spp.: 1 bee). The only *B. ruderatus* was seen on *T. pratense*.

Over the survey period, the abundance of *T. pratense* did not increase significantly on either the late cut (y = 0.0249x - 48.4, r^2 0.06, p = 0.63) or control (y = 0.0323x - 63.6, r^2 = 0.19, p = 0.39) sea walls (Figure 3). *Trifolium pratense* was seen flowering throughout the entire monitoring period, often with a first flush of flowers in June and July, before a later flowering in August and September. The species richness of forage plants also did not increase significantly across years on either the late cut (y = 0.00914x – 16.0, r^2 = 0.01, p = 0.85) or control (y = -0.0980x + 200, r^2 = 0.37, p = 0.20) sea walls.

DISCUSSION

Forage availability on sea walls is governed largely by weather patterns within the year, soil disturbance, timing of cut and whether the cuttings are collected. Currently, the Environment Agency's flail mowers do not collect the cuttings which are left to rot 'in situ.' This leads to sea wall grassland dominated by coarse grasses such as couch *Elytrigia* spp. with a poor floristic diversity (Gardiner *et al*. 2015). The cuttings may also smother the nests of late nesting species such as *B. humilis* and *B. sylvarum* if cutting occurs during July and August.

It appears that late cutting was favourable for priority bee species (Figure 1). However, the increase in bee numbers did not correspond with a change in overall forage plant species richness. The abundance of *T. pratense*, a key foraging resource for *B. humilis/muscorum* and *B. sylvarum*, did not increase significantly through time on either the late cut or control sea walls (Figure 3). The absence of an increase in *T. pratense* availability does suggest that other factors may be important in colony persistence. For example, a delay in cutting until after 15 September may have prevented the destruction of carder-bee nests at ground level covered in moss and dry grass.

Earlier cutting in July and August could completely eradicate nests on the slope and access track, although small numbers of priority bees were present on the control transects (Figure 1). Cutting height was raised to 10 cm above the soil surface on Essex sea walls to reduce reptile mortality (Gardiner *et al*. 2015); this may also benefit carder-bees which nest close to the ground. The study also showed the importance of *T. pratense* for priority long-tongued bees such as *B. humilis/muscorum*. This preference for clovers with a long corolla has been noted by Diekötter *et al.* (2006).

Bombus muscorum has a poor dispersal ability, and workers tend to forage within 100 m of the nest and no further than 500 m (Walther-Hellwig & Frankl 2000). The contiguous nature of the sea wall corridor, with an abundance of suitable forage resources, provides an excellent matrix of habitats. An uncut strip of grassland was also left along the borrow dyke edge of both the late cut and control sea walls which provided excellent nesting habitat and additional foraging (e.g. *Cirsium* spp.) later in the season.

Rare and endangered bumblebee species are likely to continue to decline unless suitable flower-rich foraging habitats, including sea walls, are sympathetically managed (Dicks *et al.* 2010) so it is pleasing to have evidence that late cutting is beneficial. Over 118 km of sea wall grassland in Essex is now managed by the Environment Agency with pollinator conservation in mind; this represents 26% of the 450 km of sea wall flood defences in Essex.

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