The response of bumblebee forage plants to 'cut and rut' restoration management of sea wall grassland on the Dengie Peninsula, Essex, England

Tim Gardiner[1]* & Kimberley Fargeaud[2]

[1]Environment Agency, Fisheries, Biodiversity & Geomorphology (FBG), Iceni House, Cobham Road, Ipswich, Suffolk, IP3 9JD, UK
[2]École Pratique des Hautes Études, Les Patios Saint-Jacques, 4-14 Rue Ferrus, 75014 Paris, France

SUMMARY

Sea wall flood defences provide important grassland habitats for bumblebees in the UK but the abandonment of cutting could be deleterious for declining species, such as the shrill carder bee *Bombus sylvarum,* due to the development of floristically-poor swards and scrub encroachment. This paper reports the results from a study of bumblebees (*Bombus* spp.) and forage plants in rotational summer cut plots with winter soil disturbance (cut and rut) implemented in grassland unmanaged for over 10 years on a sea wall. For the cut and rut plots, bumblebee forage-plant species richness significantly increased, but not on the control, suggesting that the cut and rut management was leading to the improvement of the tussocky sward for pollinators with the increased frequency of leguminous species (e.g. *Lotus tenuis* and *Trifolium pratense*) favoured by long-tongued bumblebees (e.g. *B. humilis, B. muscorum*). Queens of *B. sylvarum* were seen foraging on the cut and rut plots four years after restoration management was initiated. An increase in the floristic diversity of the cut and rut treatment was evident after four years, suggesting that there is the potential for a significant corridor of favourable bumblebee habitat to be created in the long-term on the Essex coast.

BACKGROUND

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 being in Essex (450 km) (Gardiner & Benton 2011). Management of grassland on sea walls is essential to allow their inspection and 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). UK Biodiversity Action Plan (UK BAP) 'priority' species, such as the large carder bee *Bombus muscorum*, were once considered fairly widespread. However, in England, they are now regarded as primarily coastal species restricted to coastal grazing marsh (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. With approximately 1 km^2 of forage habitat estimated as possibly being needed to support each bumblebee nest (Edwards & Williams 2004), this species may be restricted to extensive areas of flower-rich grassland in the heart of coastal grazing marsh where it forages on *Trifolium* spp. and other legumes while complementing these resources with *Cirsium* spp., *Rubus fruticosus* agg. and *Lotus* spp. on sea walls (Falk 2015). Other UK BAP 'priority' bumblebees found on sea walls include 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 management of a sward that maintains optimal coverage of flowering plants (Benton 2000). 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 cause significant bee mortality (Benton 2000, Gardiner & Fargeaud 2018). Abandonment of mowing can also have serious consequences for the diversity of flowers on which bees depend.

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 EA'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 *Elytrigia* spp. with a poor floristic diversity (Gardiner *et al*. 2015), which can further deteriorate with the abandonment of cutting and encroachment of scrub.

This paper reports the results from a study of bumblebees (*Bombus* spp.) and forage plants in plots rotationally mown and rutted to increase the floristic diversity of long-term, unmanaged grassland on a sea wall flood defence on the Dengie Peninsula, Essex, UK.

*corresponding author:
tim.gardiner@environment-agency.gov.uk

ISSN 1758-2067

ACTION

An unmown 2 km long section of sea wall flood defence folding (see Figure 1 for layout) at Marsh House on the Dengie Peninsula, Essex coast (Ordnance Survey start and end grid references: plot 1: 51° 42' 7.092" N, 0° 56' 24.8712" E and plot 16: 51° 41' 9.8232" N, 0° 56' 15.324" E) was selected by the Environment Agency (EA) for a rotational mowing and rutting regime with the aim of conserving the population of the late nesting *B. humilis* and *B. sylvarum* that had been recorded on the sea wall (Benton 2000, Benton & Dobson 2007). Much of the grassland (50%) had not been cut for many years (10+) and was species poor (with an abundance of coarse grasses, such as cock's-foot *Dactylis glomerata* and couch grasses *Elytrigia* spp.), and of limited value for bumblebees and forage plant species.

Within the uncut grassland, eight plots cut in 2015 and 2017 were alternated with eight plots cut in 2014 and 2016 (Figure 1). All plots were 100 m long and 3 m wide and contiguous with each other, running parallel to the control plots (Figure 1). The aim of the alternating two-year cutting regime (known as cut and rut) was to develop the previously unmown, tussocky sward to allow wildflowers to re-establish.

Treatment details		Sea wall folding		Sea wall bank
Years cut & rut		Cut & rut plot no.	Control plot no.	↑
2014 & 2016		1	1	
2015 & 2017		2	2	
2014 & 2016	B	3	3	
2015 & 2017	o	4	4	
2014 & 2016	r	5	5	
2015 & 2017	r	6	6	
2014 & 2016	o	7	7	
2015 & 2017	w	8	8	1.6
				km
2014 & 2016	d	9	9	
2015 & 2017	y	10	10	
2014 & 2016	k	11	11	
2015 & 2017	e	12	12	
2014 & 2016		13	13	
2015 & 2017		14	14	
2014 & 2016		15	15	
2015 & 2017		16	16	↓

Figure 1. Layout of the Marsh House sea wall cut and rut (years managed shown) and control plots (each plot 100 m long north to south x 3 m wide contains one bee and forage transect)

Cutting of the folding was undertaken with a front-loaded flail mower 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 at 10 cm from the ground to protect reptile populations and allow some habitat to remain after mowing (Gardiner *et al*. 2015). To further encourage the germination of forage plant species on the folding, soil disturbance was undertaken on an annual basis overwinter starting in 2014. This involved creating bare earth on the eight strips cut in the previous summer through wheel rutting in wet conditions using a 4x4 vehicle (Figure 2).

Figure 2. Cut and rut plot in May 2015 after winter rutting by a 4 x 4 vehicle

To provide a control for the rotational cut and rut sea wall folding, a 2 km long section of sea wall folding parallel to it (approximately 5 m distant towards the landward slope of sea wall bank) was cut annually using an Aebi flail as per the standard EA cutting regime on much of the Essex coast (from mid-July, after peak bird nesting season has finished, to early September), with no arisings collected and the flail set at 10 cm from the ground. There was no deliberate soil disturbance in the 16 control plots on this annually cut grassland adjacent to the cut and rut plots.

Bumblebee monitoring: In the rotational cut and rut and control plots of the sea wall folding, 16 100 m long transects were established, one per plot (a total of 16 transects for each treatment; see Figure 1 for layout).

The methodology for surveying bumblebees followed that for butterflies; surveys were undertaken between 10:00 and 17:00 h, when weather conditions conformed to the criteria for the UK Butterfly Monitoring Scheme (Pollard & Yates 1993). Bumblebees (*Bombus* spp.) were monitored once in June 2015 and once in June 2018. The monitoring was deemed appropriate to record the main period of bumblebee activity (of workers and drones) as determined from past surveys on Essex sea walls. Queens were counted in May 2018 on the cut and rut plots only. 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 as these are difficult to locate in the field.

During surveys, foraging bumblebees were counted along 3 m wide transects, with the recorder walking along the centre of each transect (Carvell *et al*. 2007). The plant species on which each bumblebee was first seen foraging was noted in addition to all flowering forage plant species (whether used or not) within the transect boundaries of each plot (100 x 3 m).

ISSN 1758-2067

There can be considerable difficulty in distinguishing between *B. muscorum* and *B. humilis* and between *B. terrestris* and *B. lucorum* in the field (Falk 2015). As all four species have been previously recorded at the site (Benton 2000, Benton & Dobson 2007), identification of any of these species could not be confidently determined in the field. Therefore, they were combined into two groups for this study (*B. lucorum/terrestris* and *B. humilis/muscorum*).

Data analysis: Mean forage plant species richness, after square root transformation to correct for non-normality, was analysed using a two-way ANOVA test with year and treatment as factors and interaction tested for (Heath 1995). It was not possible to analyse the bumblebee data due to low recorded numbers and experimental design (lack of proper replication).

CONSEQUENCES

Forage richness: There was significantly higher forage species richness on the control compared to the cut and rut treatment ($F = 20.96$, $p < 0.001$). Forage species richness was also higher in 2018 than 2015 ($F = 6.63$, $p = 0.013$). An interaction was noted between factors ($F = 4.1$, $p = 0.047$); notably a significant increase ($p < 0.01$) in forage species richness on the cut and rut treatment but not the control (Figure 3).

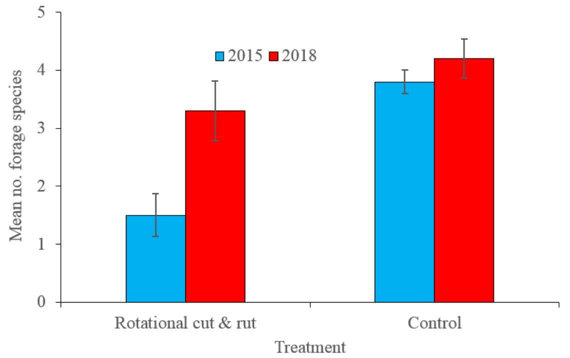

Figure 3. Mean forage plant species richness on the rotational cut and rut and control treatments (standard error bars shown)

Workers: Workers of eight species or species groups were recorded on the control folding, compared to just three species on the cut and rut plots. The most frequent species on both the control and cut and rut plots were *B. lucorum/terrestris* and *B. lapidarius* (Figure 4) with 135 out of 166 workers (81%) for these species combined. Of the priority bee species, *B. humilis/muscorum* were the most frequently sighted (20 workers), with small numbers of *B. sylvarum* (3) and one solitary *B. ruderatus* observed on the control folding. The only priority species to have workers sighted on the cut and rut plots were *B. humilis/muscorum* (Figure 4). The survey of queens in 2018, revealed priority species using the cut and rut plots (*B. humilis/muscorum* and *B. sylvarum*).

Queens: Seven *B. humilis/muscorum* queens and a solitary *B. sylvarum* queen were observed on the cut and rut plots, foraging on *V. sativa* in May 2018.

Forage usage by bees: Workers on the control folding (142 bees) foraged mainly on *Trifolium pratense* and *Trifolium repens*, the two most frequently occurring

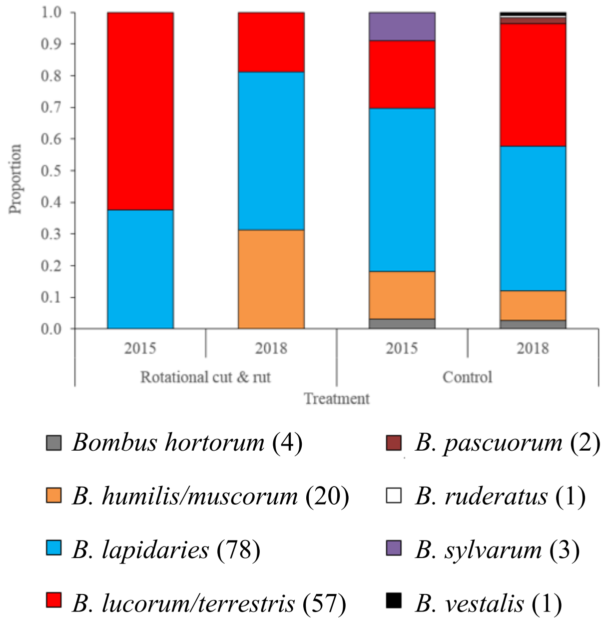

Figure 4. The proportion of workers recorded to each *Bombus* species on the control and cut and rut plots in 2015 and 2018 (number of workers in parentheses)

forage plants (Table 1). The smaller number of workers on the cut and rut plots (24 bees) frequently visited *Vicia sativa* and *Lotus tenuis*; these were the two most commonly occurring forage species (Table 1). The forage species most visited by the long-tongued *B. humilis/muscorum* and *B. sylvarum* was *T. pratense* (56% and 100% of observations respectively), while the single *B. ruderatus* was also recorded on this plant. In contrast, *T. repens* was the most frequently visited forage plant by the abundant short-tongued bumblebee *B. lapidarius* (53% of observations). On the cut and rut plots, there were increases in the occurrence of forage plants such as *L. tenuis*, *Medicago lupulina*, *Ononis spinosa* and *T. pratense* by 2018, in terms of number of occupied transects, compared to only one species (*M. lupulina*) becoming more frequently occurring on the control plot (Table 1).

Table 1. The total number of transects (n = 32) for all forage plants used by bumblebee workers in the cut and rut and control treatments (2015 and 2018 data combined; increase, decrease or no change (=) between the two survey years is indicated). Number of foraging workers shown for each plant species.

Plant species	Cut & rut		No. bees	Control		No. bees
Hieracium spp.	0	=	0	2	=	1
Lotus tenuis	10	+6	5	9	-1	1
Medicago lupulina	7	+5	1	16	+4	0
Ononis spinosa	3	+3	3	0	=	0
Trifolium pratense	2	+2	0	31	-1	87
Trifolium repens	0	=	0	31	-1	52
Vicia sativa	24	=	15	25	-1	1

ISSN 1758-2067

DISCUSSION

In response to the experimental cut and rut management, leguminous plant species have begun to develop on the folding (Figure 5) with evidence of usage by foraging queens and workers. After years of management, some key forage species such as *L. tenuis* had similar frequency on the cut and rut plots to the control folding. But for other important species such as *T. pratense*, establishment on the cut and rut plots was slower. It appears that the cut and rut plots may provide a complementary foraging habitat to the regularly mown folding, which had a much higher abundance of bees and frequency of forage plants. The abundance of leguminous species under a mowing regime represents the desired long-term goal of the rotational cut and rut plots (Figure 6). *Bombus muscorum* has a poor dispersal ability, 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 between the two treatments, provides an excellent matrix of habitats.

Figure 5. *Vicia sativa* established on the rotational cut and rut treatment

Figure 6. Clover-rich (*Trifolium* spp.) sward on the control treatment

The diversity in sward structure due to rotational cutting may provide habitat for queens of bee species such as *B. humilis/muscorum* and *B. sylvarum* that form nests low down in grass and moss (Falk 2015). Early flowering leguminous species such as *V. sativa* were used by the queens of long-tongued species, such as *B. humilis/muscorum,* on the cut and rut plots.

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). After four years, a rotational cut and rut treatment led to an increase in forage plant species richness, along with the frequency of key species such as *L. tenuis* and *T. pratense*. Queens of scarce species such as *B. sylvarum* also used the forage on offer early in the season (May), perhaps because of its proximity to their preferred nesting habitat of tussocky grass.

Early indications of an increase in the floristic diversity of the cut and rut treatment were evident after four years. Given that the cut and rut management is undertaken along 16 km of the Dengie Peninsula, there is the potential for a significant corridor of favourable habitat to be created over time. Other pollinators found on the cut and rut treatment such as the small heath *Coenonympha pamphilus,* grayling *Hipparchia semele* and wall butterflies *Lasiommata megera* (a UK BAP priority species), may benefit from the establishment of bare earth in tussocky swards by vehicular rutting. The treatment could also be introduced to other important bumblebee habitats on flood defences in the Norfolk Broads or on North Kent or Suffolk sea walls, many of which have wide areas of unmanaged folding and several priority pollinator species.

ACKNOWLEDGEMENTS

The authors would like to thank the Environment Agency's Blackwater Operations Delivery Team for undertaking the management of the sea walls.

REFERENCES

Benton T. (2000) *The Bumblebees of Essex*. Lopinga Books, Wimbish.

Benton T. & Dobson J. (2007) Bumblebee report for 2006-7. *Essex Naturalist (New Series)*, **24**, 66-69.

Carvell C., Meek W.R., Pywell R.F., Goulson D. & Nowakowski M. (2007) Comparing the efficacy of agri-environment schemes to enhance bumble bee abundance and diversity on arable field margins. *Journal of Applied Ecology*, **44**, 29-40.

Dicks L.V., Showler D.A. & Sutherland W.J. (2010) *Bee Conservation: Evidence for the effects of interventions*. Pelagic Publishing, Exeter.

Diekötter T., Walther-Hellwig K., Conradi M., Suter M. & Frankl R. (2006) Effects of Landscape Elements on the Distribution of the Rare Bumblebee Species *Bombus muscorum* in an Agricultural Landscape. *Biodiversity & Conservation*, **15**, 57-68.

Edwards M. & Williams P. (2004) Where have all the bumblebees gone, and could they ever return? *British Wildlife*, **15**, 305-312.

Falk S. (2015) *Field Guide to the Bees of Great Britain and Ireland*. British Wildlife Publishing, Oxford.

Gardiner T. & Benton T. (2011) *The Importance of Sea Walls for the Moss Carder Bee Bombus Muscorum in Essex*. Hymettus, Midhurst.

ISSN 1758-2067

Gardiner T. & Fargeaud K. (2018) The effect of late cutting on bumblebees (*Bombus* spp.) in sea wall grassland. *Aspects of Applied Biology*, **139**, 43-50.

Gardiner T., Pilcher R. & Wade M. (2015) *Sea Wall Biodiversity Handbook*. RPS, Cambridge.

Heath D. (1995) *An Introduction To Experimental Design and Statistics for Biology*. CRC Press, London

Pollard E. & Yates T. (1993) *Monitoring Butterflies for Ecology and Conservation*. Chapman & Hall, London.

Walther-Hellwig K. & Frankl R. (2000) Foraging habitats and foraging distances of bumblebees, *Bombus* spp. (Hym., Apidae), in an agricultural landscape. *Journal of Applied Entomology*, **124**, 299-306.

ISSN 1758-2067