THE IMPORTANCE OF SEA WALLS FOR THE MOSS CARDER BEE *BOMBUS MUSCORUM* IN ESSEX

TIM GARDINER & TED BENTON

2011

Hymettus

Lea-Side, Carron Lane
MIDHURST
West Sussex GU29 9LB
Registered in England No. 5761114
Registered Charity No. 1124636

Author affiliations:

Tim Gardiner
Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD
tim.gardiner@environment-agency.gov.uk

Ted Benton
University of Essex
Wivenhoe Park
Colchester
Essex
CO4 3SQ

Contents

Summary

- The moss carder bee *Bombus muscorum* is a declining UK Biodiversity Action Plan (BAP) bumblebee with a coastal distribution in Essex. It is often found on sea wall flood defences managed by the Environment Agency (EA), although current grass mowing regimes may be unfavourable due to midsummer cutting in July and August.

- This bumblebee is often found on the folding of sea walls, which is the flat grassy area between the landward toe of the raised embankment and the borrowdyke. The folding is believed to be suitable for *B. muscorum* due to the range of forage plants available during the summer in locations where mowing does not remove all vegetation in July or August.

- The aim of this study was to determine the importance of sea walls for *B. muscorum* by examining the occurrence of foldings (e.g. presence or absence) and area of habitat where this bumblebee occurs, and comparing them with unoccupied sea walls.

- The results show that where *B. muscorum* has been recorded, sea walls have a much higher percentage of their length with a folding (as opposed to no folding), and a greater area of habitat (> 1 ha of folding per linear km). This suggests that sea walls are a more favourable habitat for the bumblebee where there is a greater area of folding, which is likely to be important for foraging and nesting.

- The study highlights the value of the sea wall folding for this scarce UK BAP bumblebee on the Essex coast, therefore it is important to undertake sustainable management of flood defences where significant populations occur. It is likely that mowing regimes which consider bee populations (e.g. leaving an area of uncut grassland on the folding every year) may be particularly effective where there is a wider folding (> 20 m wide) and a greater area of foraging and nesting habitat.

1. Background

1.1 Essex sea walls

The Essex coast is one of the longest in England at approximately 480 km, the majority of the terrestrial land being protected from tidal flooding by sea wall flood defences (c. 450 km of sea wall) (Jermyn 1974). Hard surfaced sea walls provide little value for biodiversity, but the majority of walls are earth banks dominated by coarse grasses such as false oat-grass *Arrhenatherum elatius*, cock's-foot *Dactylis glomerata* and sea couch *Elytrigia atherica*. Grasslands on sea walls are predominantly unimproved (they have not been agriculturally improved by ploughing, fertiliser input or herbicide applications), and as such provide an extremely important wildlife resource in the intensively managed Essex countryside (Gardiner 2009). Sea walls also form a continuous network of grassland habitat allowing species to disperse along the banks (Gibson 2000). Historically, in Essex, sea walls were erected to enclose salt marsh and make it suitable for agricultural production. They were built of marsh clay obtained from borrow pits on the landward side, or from the salt marsh on the seaward frontage (Institute of Estuarine & Coastal Studies 1992). Currently, the Environment Agency (EA is the government agency responsible for flood defence maintenance) maintains many sea walls on the Essex coast under its permissive powers.

1.2 Sea walls as bumblebee habitats

Due to the presence of unimproved grassland, sea walls provide sites where rare insect species can flourish on the Essex coast. It would seem that sea walls can form important corridors which bumblebees utilise effectively when there are extensive habitats such as coastal grazing marsh on the landward side of the flood defences. Benton (2000) states that the moss carder bee *Bombus muscorum*, a declining bumblebee included in the UK Biodiversity Action Plan (BAP), can be found on sea walls in Essex, but it is not known whether flood defences support populations of this bee alone when the inland habitats are unfavourable (e.g. arable farmland). Nevertheless, it is clear that sea walls harbour important populations of scarce bumblebees, even if they only utilise unmown areas as foraging habitat. It is estimated that approximately 1 km^2 of forage habitat is needed for each bumblebee nest (Edwards 2001) which may restrict species such as *B. muscorum* to extensive areas of flower-rich grassland. It was believed that workers foraged very close to their nests, indicating that they may require nesting and foraging habitat in close proximity (Walther-Hellwig & Frankl 2000). However, Walther-Hellwig & Frankl's research has been questioned by leading bumblebee authorities such as Mike Edwards who believe there is currently no reliable evidence to suggest that *B. muscorum* forages close to the nest.

This insect may be particularly susceptible to inbreeding depression as a result of geographical isolation with small populations existing in fragmented landscapes particularly vulnerable (Darvill *et al*. 2006). Isolation of populations by more than 10 km of open water can lead to significant genetic variation suggesting that dispersal is particularly limited between islands; however, it may be easier over land (Darvill *et al*. 2006). Decreased genetic variation can reduce the ability of populations of this species to respond to environmental change caused by natural (e.g. drought, as this bumblebee may be more common in damper seasons; Benton 2000) or human factors (e.g. summer mowing).

The Essex Sea Wall Survey (Eco Surveys 1990) underlined the value of the folding for vascular plants likely to be used as forage sources by bumblebees. Key forage species for *B. muscorum* such as narrow-leaved bird's-foot trefoil *Lotus glaber*, spiny restharrow *Ononis spinosa* and sea clover *Trifolium squamosum* (Benton 2000), were predominantly recorded on the folding, with only a few observations of them from the landward/seaward slopes of sea walls. *Bombus muscorum* is likely to need flowering forage plants throughout the spring and summer (March-September; Saunders 2008). Benton (2000) suggests that unmanaged grassland which is not mown every year can form important nesting habitat for bumblebees, particularly scarce species such as *B. muscorum*. This bumblebee is a surface-nesting species, utilising old summer nests of small mammals in tall, but open grassland with mosses (Edwards 2002). Bumblebee nests can be destroyed by mowing in summer, making cutting regimes especially important in determining the occurrence of *B. muscorum*. It has been suggested that microclimate may influence the distribution of *B. muscorum* in the south-east of England, with the insect possibly preferring the cooler, damper sea wall embankments of the north Kent coast in comparison to the drier and warmer south-facing flood defences of the south coast of Essex (Benton 2000; Edwards 2008). However, in recent years, the brown-banded carder bee *Bombus humilis* appears to have replaced *B. muscorum* on the north Kent coast which casts some doubt on this theory (Edwards 2008).

2. Sea wall habitats

2.1 Description of a typical sea wall

A typical sea wall in Essex can be divided into four sections for the purposes of grassland management: folding (the flat grassy area between the landward toe of the raised embankment and the borrowdyke, infrequent vehicular usage; Fig. 1), landward sea wall slope, footpath on the crest (mown regularly and trampled by walkers), and sea wall slope on the seaward side (usually unmown). Salt marsh is often adjacent to the foot of the sea wall on its seaward side. From a flood defence point of view, the folding is the least important part of the sea wall, whereas the crest and landward slope are critically important in a tidal overtopping event. Therefore, there is the significant opportunity to manage the folding in a more bee friendly way than at present. Currently, most sea wall foldings on the Essex coast are mown annually by the EA in late July and August to prevent scrub encroachment and maintain a grass sward, however, this eliminates most bumblebee forage plants and nests as well as causing significant bee mortality during cutting (Benton 2000).

2.2 Aim of the research

In essence, the effectiveness of leaving the folding uncut to aid the conservation of species such as *B. muscorum* relies on its width from the toe of the landward slope to the borrowdyke edge. It is possible that managing the folding on a long cutting rotation could ensure that uncut vegetation is present throughout the year on sea walls to benefit bumblebees such as *B. muscorum*. To determine how important sea walls are throughout Essex for *B. muscorum*, it was decided to measure the width of sea wall foldings using Geographic Information Systems (GIS) software to enable calculation of the area of folding that could come under more bee friendly management. It is the aim of this report to discuss the results of the analysis in relation to the conservation of *B. muscorum*.

Fig. 1: A typical Essex sea wall near Moverons Farm, Brightlingsea, the wide (c. 33 m) folding (vehicle ruts and uncut grassland to the right of photo) is habitat for *Bombus muscorum* at one of its last remaining coastal sites in the county and *Bombus ruderarius* is also present © Tim Gardiner

3. Sea wall foldings

3.1 Calculating folding width and area

Information from the EA's database on the length of sea walls which it maintains within each of the 72 systems on the coastline of Essex (a system is a single stretch of sea wall as determined by the EA) was obtained. Some stretches of sea wall in several systems have no folding at all (e.g. centre of towns), therefore the length of sea wall with no folding was measured and subtracted from the total sea wall length for each system, to give a length of sea wall with folding measurement for each system. Folding width was measured (in m) at several random points along each system using GIS software (ArcView), and then averaged to give a mean folding width for each system. The number of measurements taken in each system depended on the system length – on average there was one every km (up to 10 measurements within each system). All measurements were taken from 1:10000 maps – at a resolution of 1:2501 to give consistent measurements. Mean folding area (in ha) for each system was then calculated by multiplying folding length by mean folding width.

It must be noted that one sea wall system not maintained by the EA, Foulness Island, was included in the analysis due to the significant length of flood defence around it. The Ministry of Defence (MoD) maintains the sea walls around the Island and access is restricted for safety and security reasons. Due to the size of Foulness Island (30 km of sea wall) it was decided to measure folding width at 3 km intervals (10 measurements in total) starting at Havengore Bridge and working clockwise around the Island.

3.2 Statistical analysis of foldings where *Bombus muscorum* occurs

To ascertain whether there was a key relationship between the occurrence of *B. muscorum* and the presence of sea wall foldings and their width/area, simple statistics were utilised. Firstly, the former/current presence of *B. muscorum* within each sea wall system was determined by obtaining records published in Benton (2000) covering the period 1980-1999, and from the Essex Field Club website (from 1998-2010). If a record of the bumblebee was obtained for a system (including sea walls maintained by the MoD) then this was classified as an occupied stretch of sea wall. If no records of the bumblebee were obtained for a system then it was classified as an unoccupied stretch of sea wall.

The distributional data analysed in this report should be reviewed with some caution due to the observer bias that may have occurred. For example, it was not possible to visit all sea walls looking for *B. muscorum*, the recorders tended to survey those sections of flood defence that were easily accessible. Restrictions on access to sites such as Foulness Island hampered survey effort leading to the distribution data reflecting locations surveyed rather than genuine occurrence of the bumblebee. There was also the chance that confusion occurred in the identification of *B. muscorum*, particularly as it was sometimes found with other BAP carder bees such as *B. humilis*. There has been significant expansion in the range of *B. humilis* and the shrill carder bee *Bombus sylvarum* so that their distribution now overlaps with *B. muscorum* in north-east Essex. We do not yet know how this may impact on *B. muscorum*, perhaps there may be an issue with competition for limited forage resources/nesting sites on some sea walls? It could also be the case that the range expansion of both *B. humilis* and *B. sylvarum* has been driven by climatic factors that favour them but not *B. muscorum*. With these considerations in mind, the data presented in this report should only be viewed as provisional pending further investigation.

Once the systems had been divided into occupied and unoccupied, the mean percentage of sea wall length with folding, mean folding width, and mean area of folding in ha per linear km (to standardise for systems with differing lengths of flood defence), were compared for occupied and unoccupied sea wall systems using a Student's t test. All data were square-root transformed to correct for non-normality before analysis using the t test.

4. *Bombus muscorum* occurrence on sea wall foldings

4.1 Distribution of the bumblebee and foldings

In total there were 18 occupied sea wall systems (c. 25% of 72 systems) with records of *B. muscorum* since 1980, compared to 54 (75%) unoccupied sea wall systems with no sightings of the bumblebee. This indicates how scarce this declining species is on the Essex coast. Most of the occupied systems were on the north-east Essex coast (e.g. SO 13-40) with only one system on the Dengie Peninsula (SO 50) and four in the south-east of the county (SO 65-73 and Foulness Island). The 18 occupied systems and the percentage length with folding and width/area of their foldings are detailed in Table 1. There is clear evidence from this study that sea walls occupied by *B. muscorum* had a much higher percentage of their length with a folding (as opposed to no folding), indeed this difference was statistically significant (t test value 2.88: $P<0.01$). Many of the occupied sea walls had a folding present for their entire length (100% at Foulness Island, Moverons Farm and Old Hall Marshes; Table 1). This indicates that the presence of a sea wall folding is probably essential for the occupation of a section of coastline by *B. muscorum*. This may be due to the presence of key forage plants on the folding or the location of suitable nesting sites in tall uncut grassland. Indeed, for occupied systems such as Dengie Marshes, Holland Haven, Moverons Farm, Old Hall Marshes and Paglesham Eastend much of the folding has been left uncut for many years, which should provide adequate nesting habitat and forage provision throughout the summer.

However, despite the study findings, no attempt has been made to assess the suitability of other sections of sea walls (e.g. landward slope, crest and seaward slope) which may offer favourable bumblebee habitats. Forage resources such as meadow vetchling *Lathyrus pratensis*, red clover *Trifolium pratense* and tufted vetch *Vicia cracca* can be important and are not necessarily restricted to the folding. For example, at Little Oakley (SO13; Table 1), an important forage species such as *T. pratense* is recorded mainly on the crest, while *V. cracca* is present predominantly on the landward slope; therefore the entire sea wall can form a favourable habitat for bumblebees not just the folding.

4.2 Influence of folding width and area

A key feature of occupied sea wall systems was that they had a higher folding width (15 m) when compared to unoccupied stretches of flood defence (11 m), although this difference was not statistically significant (t test value 2.03). This suggests that *B. muscorum* may be found on wider foldings, even though this may not be the most important factor determining its occurrence. In some systems, a very wide folding was present (e.g. 33 m at Moverons Farm, 30 m at Holland Haven, 25 m at Little Oakley and 21 m at Brightlingsea Marsh; Table 1). Significant stretches of sea wall on the Blackwater Estuary had wide foldings, and a continuous length of coastline from Salcott (SO 35) in the north to Goldhanger (SO 40) in the south was classed as occupied by *B. muscorum*. In this 45 km stretch of sea wall, a total of 33 ha of folding is present suggesting that flood defences in themselves may form important habitats with a considerable area of unimproved grassland which could potentially be utilised by this bumblebee.

The Blackwater sea walls represent one of the last remaining coastal refuges of this bee in Essex (which has almost disappeared from sea walls in the north-east of the county in recent years), perhaps due to the extensive patches of habitat on the flood defences. Several of the Blackwater sea wall systems had significant areas of coastal grazing marsh on their landward side (e.g. Old Hall Marshes (c. 459 ha) and Tollesbury Wick Marshes (c. 240 ha)), indicating that the folding was part of a much larger mosaic of favourable bumblebee habitat. It has been suggested that *B. muscorum* is associated with wet habitats such as grazing marsh (Edwards 2008), but a recent study in the south-west found no evidence for this (Saunders 2008). At Old Hall Marshes in particular, *B. muscorum* may not be entirely dependent on sea wall habitats for its foraging and nesting requirements. However, in many of the other systems, the main inland land use is arable cropping, not suitable for populations of the bumblebee. In these situations, *B. muscorum* may rely heavily on sea wall habitats for its continued survival in the area. A good example of this comes from the Dengie Marshes where intensive arable cropping has eliminated almost all favourable bee habitats, indicating that the bumblebee will be reliant on the sea wall folding for nesting and foraging.

This research only deals with the presence or absence of *B. muscorum* on sea walls, based on historic records collected since 1980. There are very few reliable estimates of population abundance (if this is even possible to determine) or comparative densities of foraging workers. From standard transect counts (method detailed in Carvell *et al*. 2007), numbers of *B. muscorum* workers observed can vary from 1-7 bees per km walked (Gardiner 2011 in press), indicating very small populations on the Essex coast. Therefore, the bee may be highly vulnerable to localised extinctions on sea wall flood defences, although recolonisation is likely if they abut favourable habitats with existing populations (e.g. grazing marshes). However, the abundance of foraging workers is similar to other scarce species of Essex sea walls such as *B. humilis* (1.8-10.6 bees per km) and *B. sylvarum* (5.3-7.0 bees per km) (Gardiner 2011 in press).

Despite the small and declining populations of *B. muscorum* over the entire county, a total of 207 ha of folding were present in occupied sea wall systems, suggesting that if correctly managed sea walls could form a very important habitat for *B. muscorum*, an added benefit being the interconnected nature of many of the flood defences allowing the bee to disperse along stretches of coastline. However, the possible requirement for large areas of forage habitat (c. 1 km^2; Edwards 2001; Edwards & Williams 2004), suggests that no sea wall (even on the Blackwater Estuary) will be able to completely fulfil the foraging requirements of *B. muscorum*. However, they may form part of a much larger mosaic of habitat when combined with the grazing marshes at Brightlingsea Marsh (combined area of marsh and sea wall folding = 0.5 km^2), Holland Haven (area = 2.2 km^2), Old Hall Marshes (area = 4.7 km^2) and Tollesbury Wick Marshes (area = 2.5 km^2). Interestingly, on Foulness Island managed by the MoD as a firing range, there is 6 km^2 of grazing marsh, rough grassland and sea wall folding combined that may form a flower-rich habitat on a landscape scale. There is 30 km of sea wall around the Island which has a continuous folding, an excellent corridor for dispersal of *B. muscorum* to grasslands across the MoD site. Restrictions on access to the Island mean that the full potential of the interconnected grassland and sea wall folding habitats has not been fully assessed yet.

Generally, the area of folding habitat was greater for occupied sea wall systems (1.3 ha of folding/km) than for unoccupied (0.7 ha of folding/km), this difference being statistically significant (t test value 3.97: $P<0.001$). This suggests that where *B. muscorum* occurred there was a larger area of folding habitat which it could have utilised for foraging and nesting. The results from the analysis indicate the value of sea wall foldings for this scarce bumblebee on the Essex coast, therefore it is important to undertake sustainable management of flood defences where significant populations occur. It is likely that improved mowing regimes which consider bee populations may be particularly effective where there are wider foldings and a greater area of foraging and nesting habitat.

This study suggests that microclimate may also be important in determining the suitability of sea wall habitats for *B. muscorum* in Essex (Benton 2000). At several existing locations for this bumblebee, the folding utilised as foraging habitat is predominantly on the north or west side of the raised embankments (e.g. seaward side is to the south or east), for example, at Holland Haven (west side), Lee-over-Sands (north), Little Oakley (north) and Tollesbury Wick Marshes (west). A folding on the northern side of a raised embankment is protected by the sea wall from the prevailing south-westerly winds (Gardiner 2011 in press), whereas, a folding to the west of a flood wall will be shielded from easterly 'on shore' winds (but exposed to south-westerly's) which can have a significant cooling effect. There are very few instances of this insect occurring on foldings which are on the east side of a raised embankment, these environments receive early morning sunlight raising ground temperatures and creating a very warm and dry microclimate which may be unsuitable for *B. muscorum* (reputedly an insect of damper environments; Benton 2000). Further systematic research is to be undertaken in 2011 into the impact of sea wall embankment orientation and the occurrence of bumblebees as it could have a significant influence. Other studies will focus on the occurrence of bumblebees and plant species in relation to sea wall cutting regimes.

4.3 Folding management to benefit *Bombus muscorum*

If a 3 m wide mown access track (needed to ensure safe passage of vehicles for cutting) is deducted from the mean width of foldings with *B. muscorum* (15 m for Essex), that would still leave on average a 12 m wide strip of unmown grassland next to the borrowdyke. This could be left uncut throughout the summer and winter forming important habitat for nesting bumblebees. It will be important to cut this strip of unmown grassland on the folding on a rotational basis, perhaps once every three years, or where it quickly becomes too tussocky, possibly on a two year rotation, cutting half of the area each summer/autumn. For some sea walls such as Little Oakley and Moverons Farm, which have folding widths of 25 m or more, there is potential for very wide grassland strips to be left uncut when the mown access track is taken into consideration. However, the access track, which receives vehicular disturbance at least once a year during EA mowing (but also from farm machinery on an ad hoc basis in many cases) may form an important habitat in its own right (Gardiner 2011 in press). The disturbance of the soil combined with cutting may allow forage plants for bumblebees to persist, which could otherwise be smothered by coarse grasses on sections of a folding mown on a long rotation.

Important forage species such as *T. pratense*, *T. squamosum* and bird's-foot trefoil *Lotus corniculatus* are often restricted to the disturbed ground of the access track, without this disturbance they would struggle to compete against the coarser, aggressive grasses found on other parts of sea walls (e.g. *A. elatius* and *Elytrigia* spp. on the landward slope). Regular vehicular disturbance on the folding may be important to maintain a diversity of forage resources for bumblebees, trampling by walkers on public footpaths also creates similar conditions on the crest.

Table 1: The characteristics of sea walls occupied (with records) and unoccupied (without records) by *Bombus muscorum* (G = grazing marsh present inland) (means ± standard error) which are maintained by the Environment Agency (EA) under its permissive powers (except Foulness which is managed by the Ministry of Defence (MoD)

EA system code and area	% length with folding	Mean folding width (in m)	Folding area in ha per km
Occupied sea walls			
SO13 Little Oakley	100	25 ± 6	2.5
SO16 Hamford Water	89	14 ± 5	1.2
SO19 Holland Haven (G)	76	30 ± 1	2.2
SO20 Clacton/Jaywick (G)	76	8 ± 2	0.6
SO21 Lee-over-Sands	89	16 ± 3	1.4
SO25 Brightlingsea Marsh (G)	60	21 ± 9	1.3
SO26 Moverons Farm (G)	100	33 ± 9	3.3
SO35 Salcott	100	10 ± 1	1.0
SO36 Old Hall Marshes (G)	100	12 ± 2	1.2
SO37 Tolleshunt D'Arcy	100	4 ± 1	0.4
SO38 Tollesbury	36	6 ± 1	0.2
SO39 Tollesbury Wick Marshes (G)	96	12 ± 1	1.2
SO40 Goldhanger	100	10 ± 1	1.0
SO50 Dengie Marshes	98	11 ± 2	1.1
SO65 Wallasea Island	96	14 ± 2	1.3
SO68 Paglesham Eastend	87	16 ± 4	1.4
SO73 Southend	77	13 ± 1	1.0
Foulness Island – MoD	100	12 ± 1	1.2
Mean for occupied sea walls	**88 ± 4**	**15 ± 2**	**1.3 ± 0.2**
Mean for unoccupied sea walls	**62 ± 5**	**11 ± 1**	**0.7 ± 0.1**

It is probably worth noting that the width of folding varied significantly within sea wall systems, as can be seen along the 30 km stretch of flood defence around Foulness Island, for example (Fig 2). At one location on the northern edge of Foulness Island, folding width is nearly 15 m, whereas, at other locations along the southern and western edges it is less than 10 m. One record of *B. muscorum* from the Island was near Foulness Point in 1998 where folding width was greatest. This indicates that *B. muscorum* may be restricted to parts of Foulness with a wide sea wall folding where a greater area of habitat will be present. Effectively, several kilometres of narrow folding may be quite a barrier to dispersal for this bee. There is a substantial opportunity along the wide sea walls on the eastern side of the Island (Fishermen’s Head to Sharpness Head) to undertake rotational mowing regimes to encourage the dispersal of *B. muscorum* from Foulness Point and extend its range.

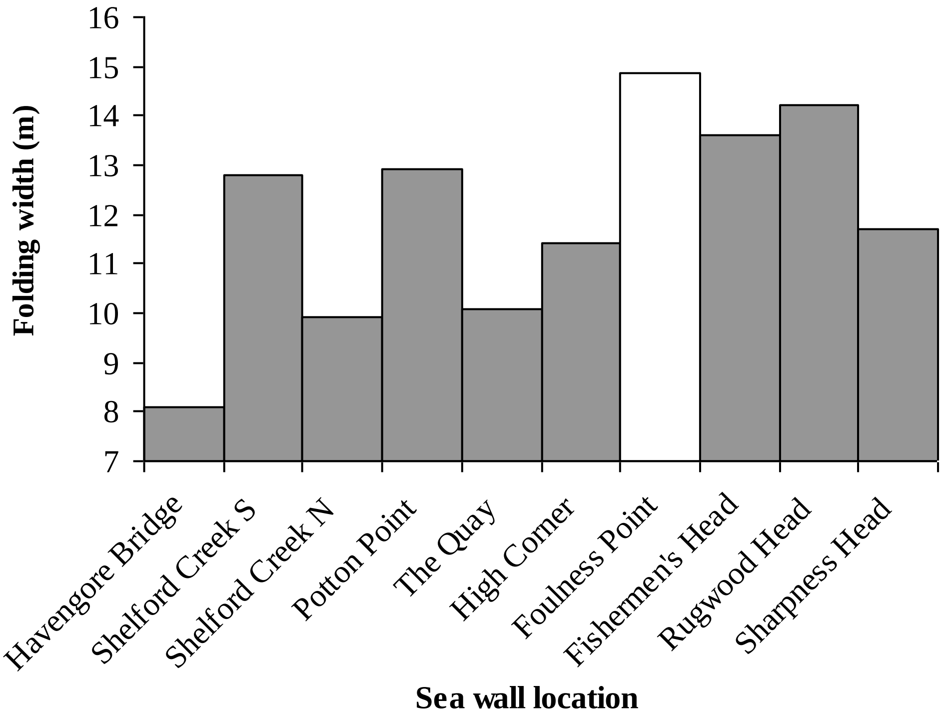

Fig. 2: Folding width at 3 km intervals around Foulness Island, location of *Bombus muscorum* record is highlighted by white bar

At other sites a rotational mowing regime is undertaken by the EA, for example, at Old Hall Marshes in liaison with the Royal Society for the Protection of Birds (RSPB) sections of sea wall are cut every year interspersed with uncut areas. The folding is also rarely mown but may occasionally be grazed. A rotational mowing regime is also undertaken at Tollesbury Wick Marshes in liaison with Essex Wildlife Trust (EWT), and on the Holland Haven and Lee-over-Sands sea walls the folding remains uncut throughout the summer (Fig. 3). There has been a dramatic decline in the population of this bee in the last five years, with colonies remaining at Holland Haven, Lee-over-Sands, Moverons Farm, Old Hall Marshes and Tollesbury Wick Marshes, all sea walls that are managed more sensitively due to their wildlife interest, have a large area of folding habitat (> 1 ha per km), and which, with the exception of Lee-over-Sands, are adjacent to extensive areas of inland grazing marsh. It is possible that the range of *B. muscorum* has contracted to sea walls with a large area of folding adjacent to grazing marsh, because these environments provide high quality foraging and nesting habitat within a landscape mosaic. Where sea walls are not bordered by extensive grazing marsh habitat they may be more reliant on the folding present on the flood defences, making these small populations in a limited area of habitat very susceptible to localised extinctions due to unfavourable mowing regimes (e.g. all sea wall grassland cut in midsummer).

It should also be noted that rotational folding management which considers the foraging and nesting requirements of *B. muscorum* may also benefit other UK BAP bumblebees of sea walls in Essex such as the red-shanked carder bee *Bombus ruderarius* (present at Foulness Island, Holland Haven and Moverons Farm), large garden bumblebee *Bombus ruderatus* at Lee-over-Sands, and *B. humilis* and *B.*

sylvarum at Mersea Island and Old Hall Marshes. Therefore, bee friendly sea wall management may provide significant benefits to a range of scarce and declining bumblebees on the Essex coast.

Fig. 3: Folding left uncut (left) during summer mowing in 2010 at Lee-over-Sands which may form a suitable nesting location and foraging habitat for *Bombus muscorum* in comparison to the shorter vegetation of the 3 m wide mown access track (centre) and landward slope (right), photograph taken June 2011 © Tim Gardiner

5. Acknowledgements

We would like to thank staff at the Environment Agency (whom TG works for) for their assistance with the considerable task of measuring the area of sea wall folding in Essex on ArcView GIS software. Particular mention should be made of the contributions from Stephanie Stedman and Tom Wallace. Thanks are also extended to those who contributed the *B. muscorum* records which have been analysed in this report.

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