

# Locating where archaeological sites occur in intertidal sequences

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1           **Locating where archaeological sites occur in intertidal**  
2           **sequences: the use of archaeoentomological data as a proxy**  
3           **for tidal regime**

4 .  
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9

10 **ABSTRACT:**

11 Intertidal archaeological deposits occur worldwide, particularly in the temperate latitudes. These  
12 deposits can contain archaeological sites that were constructed at the time these were  
13 terrestrial landscapes, but subsequently were inundated as a result of rising sea levels. Part of  
14 this process can include the development of salt marshes. There is a need, therefore, to  
15 identify where archaeological sites lie within the cline of past tidal regimes. This paper presents  
16 the results of a survey of UK archaeoentomological data recovered from intertidal deposits  
17 which was undertaken in order to identify patterns in archaeoentomological data that might  
18 indicate a deposit's position within a saltmarsh. Such an approach has potential to establish  
19 'indicator groups' for saltmarsh zones, thereby facilitating archaeological interpretation of  
20 intertidal deposits. A statistical ordination of the archaeoentomological dataset has been  
21 undertaken to explore the security and strength of proposed archaeoentomological indicator  
22 groups for various ecological zones within saltmarsh/ intertidal environments and the results are  
23 presented here. These indicator groups also are crossed-checked against the known modern  
24 ecology of the various beetles included within each grouping, to determine if they make good  
25 'ecological sense'. is the dataset discussed here is specific to Northern Europe, but the  
26 approach is applicable worldwide.  
27  
28

29 **KEYWORDS:** Saltmarsh: Estuary: Intertidal Archaeology: Archaeoentomology: Coleoptera:  
30 Tidal Zone  
31

32 **1. INTRODUCTION**

33 In the last 30 years coastal and intertidal archaeology has received increased interest (e.g. Bell  
34 2012; Firth 2011; Ford 2011). Intertidal archaeology was initially developed in the UK and

1 Northern Europe (e.g. Bell *et al.* 2000; Bell 2013; O'Sullivan 2001; Rasmussen 2007; Wilkinson  
2 and Murphy 1995), but there is increasing interest in maritime, and by extension coastal  
3 archaeology, worldwide, ranging from North America, Japan and Australia (e.g. Bell 2012;  
4 Catsambis *et al.* 2011; Croes 2005; Ford 2011; Matsui 1992). Intertidal and coastal deposits  
5 often preserve 'drowned forests', freshwater marshes and other terrestrial environments and  
6 several of these have been sampled for archaeoentomological remains. Examples include  
7 Bronze Age Goldcliff and Redwick, Gwent (Bell *et al.* 2000; Bell 2013) Minehead Bay, Somerset  
8 (Jones *et al.* 2005), Holme-next-the-Sea, Norfolk (Brennand and Taylor 2003), The Stumble,  
9 Essex (Wilkinson and Murphy 1995), and a variety of sites around the Humberhead Levels (van  
10 der Noort 2004). To describe the majority of these sites as 'coastal' archaeology is something  
11 of a misnomer, since they are in fact the remains of woods, fens and marshes that developed  
12 some distance from what would have then the contemporary coast and now happen to be  
13 exposed (often through erosion processes) on our modernforeshores. These deposits  
14 sometimes represent the remains of landscapes and ecologies of the wide continental plain,  
15 including areas such as 'Doggerland', that existed before being submerged through dramatic  
16 sea level rise, between ca. 9,500 – 6500 BC, following the last glaciation and resulting  
17 oscillations in sea levels (e.g. Coles 1998, 1999; Gaffney *et al.* 2010).

18 Some archaeological sites from these locations are, in a more literal sense, truly coastal. They  
19 are located or were constructed at what would have been the contemporary coast. Often these  
20 sites were specifically located in the intertidal zone between the land and the sea. These  
21 intertidal landscapes consisted of a complex mosaic of coastal woods, marshes, estuary creeks  
22 and saltmarshes. In some locations, as sea levels rose, saltmarshes would develop on the  
23 surface of pre-existing wood, fresh water or acidic 'peats' (Cott *et al.* 2012). Clear examples of  
24 such truly intertidal sites are the Bronze and Iron Age buildings and trackways at Goldcliff and  
25 Redwick, Gwent (Bell *et al.* 2000; Bell 2013), the Bronze Age trackway at Cold Harbour Pill,  
26 Gwent (Bell 2013), the Saxon mill race at Springhead, Kent (Barnett *et al.* 2012), the cattle  
27 footprint-filled channels at Walpole, Somerset (Shotter 2012) and the Bronze Age structure at  
28 Caldicot, Gwent (Naylor and Casledine 1997).

29 It is this type of truly coastal landscape, its archaeology and the insects associated with it that  
30 will be discussed in this paper. In the main, these archaeological sites are not embedded in  
31 freshwater 'peats' or part of 'wood peats', but are derived from material deposited directly into  
32 grey or blue estuarine clays. Often these deposits are situated directly at the boundary between  
33 marine clays and any underlying 'peats', or other terrestrial sediments, and represent the point  
34 in time when these intertidal sites were being inundated through rising sea levels. Such coastal  
35 environments are ecologically diverse and provided a wealth of food, resources and habitats to  
36 exploit.

37 If the role and function of these archaeological sites is to be understood, then it is clear that the  
38 location of archaeological sites within the coastal regime, and how this may have changed  
39 during the occupation of a site, needs to be resolved more precisely. For example, the Bronze

1 Age and Iron Age buildings at Goldcliff and Redwick are associated with cattle grazing (Bell *et*  
2 *al.* 2000; Bell 2013) but what landscapes were being grazed? and where precisely were these  
3 sites located within the saltmarsh? What was the nature of the saltmarsh crossed by the  
4 trackway at Cold Harbour Pill? and how often was this landscape flooded by sea water? Were  
5 these archaeological features in use before sea level rise and/or transgression, during or after?

6 Traditionally, these issues have been addressed through the analysis of foraminifera (e.g.  
7 Edwards and Horton 2000; Gehrels 1994; Gehrels *et al.* 2001, Haslett *et al.* 2001; Horton and  
8 Edwards 2005, Kemp *et al.* 2013), ostracods (e.g. Boomer and Eisenhauer 2002; Frenzel and  
9 Boomer 2005), diatoms (Cameron and Dobinson 2000; Devoy 1979; Zong and Horton 1999)  
10 and, to a lesser extent, through plant macrofossils and pollen (e.g. Caseldine 2000; Caseldine  
11 *et al.* 2013; Shennan 1982). In terms of both ostracods and Foraminifera, these environmental  
12 proxies mainly have been used to reconstruct, with notable precision, relative sea level change  
13 on a large scale but rarely provide specific details for the local or immediate environment to  
14 assist landscape reconstruction at the fine-grained level of the immediate surroundings of the  
15 sampling site that is specifically required in order to help solve the archaeological questions  
16 posed above. Insect analysis, like plant macrofossils, can give a very detailed and local  
17 reconstruction, often of the nature of the surrounding landscape within 1000 m of the  
18 archaeological site itself (Smith *et al.* 2010; Hill 2016). Foraminifera and ostracods are strong  
19 indicators for the relative salinity of coastal waters, and the the general nature of tidal regimes,  
20 but do *not* allow direct reconstruction of the terrestrial environment, a detailed reconstruction of  
21 ground conditions or the nature of prevailing terrestrial vegetation. Insects, especially beetles,  
22 have been found to be sensitive indicators for salinity (Nayyar and Smith 2013b; Smith *et al.*  
23 1997, 2000; Smith 2011, 2013b) and, in particular, useful proxies for reconstructing the nature  
24 of terrestrial landscapes and vegetation cover (e.g. Elias 1994, 2010; Smith 2012). Moreover,  
25 insects also can provide direct evidence for the nature of how humans have used landscapes in  
26 the past (e.g. Ellias 1994, 2000; Robinson 1981, 1983; Smith 2012); the use and the nature of  
27 habitation (i.e. archaeological buildings and features – e.g. Hall and Kenward 1990; Kenward  
28 and Hall 1995; Smith 2012); and the formation of archaeological deposits, including the  
29 disposal of settlement waste (e.g. Carrott and Kenward 2001; Hall and Kenward 2003; Kenward  
30 and Hall 1997; Smith 2012). The insect remains from samples associated directly with the  
31 Bronze and Iron Age buildings at Redwick (Smith 2012) and Goldcliff (Smith *et al.* 1997; 2000)  
32 clearly established that the same level of interpretation was possible at estuarine archaeological  
33 sites as at terrestrial, rural or urban locations.

34 There is now sufficient archaeoentomological data from intertidal sites available to support an  
35 exploration of data patterns in order to establish *indicator groups* (*sensu* Kenward and Hall  
36 1997) for zones within saltmarsh. This paper presents the results of a survey of existing British  
37 archaeoentomological data from intertidal sites and their statistical analysis. Those indicator  
38 groups identified through statistical analysis are reviewed in terms of known ecological data.  
39 Finally, saltmarsh zone data from indicator groups are considered in terms of the archaeological

1 contexts for a number of British intertidal archaeological sites. It is hoped that the methods,  
2 techniques and conclusions reached here can be used as model elsewhere in the world for the  
3 identification of tidal regimes at coastal archaeological sites. However, this approach is specific  
4 to the British Isles and its insect fauna and cannot be applied directly elsewhere in the world;  
5 instead, this approach will have to be locally adapted for insect taxa and salt marsh habitats  
6 occurring there.

7

## 8 **2. THE SALTMARSH ENVIRONMENT**

9 Saltmarshes are a relatively common worldwide coastal landform (e.g. Allen and Pye 1992;  
10 Chapman 1974; Scott *et al.* 2014) which normally consist of three to four distinct zones:  
11 pioneer marsh (mudflat) at its most seaward level, low saltmarsh, high saltmarsh further inland  
12 and a transitional zone toward the landward extreme of the marsh as it grades into fully  
13 terrestrial environments (Adnitt *et al.* 2007; Burd 1989; Dijkema 1984; JNCC 2004). Figure 1  
14 outlines the major physical and vegetation zones found in saltmarshes in Northern Europe. The  
15 'zonation' present is very strong in its nature leading to one of the most diverse but structured  
16 ecological gradients that can occur in a relatively small area (Adnitt *et al.* 2007). This is  
17 especially true for saltmarsh vegetation (outlined in Figure 1) which, despite some degree of  
18 geographic variation, occurs widely in Northern Europe and is clearly understood (e.g. Adam  
19 1981; Adnitt *et al.* 2007; Burd 1989; Hemphill and Whittle 2002; Stark *et al.* 2002). This  
20 geological and plant succession is normally thought to be a response to relative elevation  
21 above sea level and to daily, monthly and yearly tidal influence and range. The pioneer marsh  
22 (normally referred to as 'mudflats' – the term which is also used in this paper) tends to occur  
23 from Mean High Water Neap tide to a higher point in the tidal range and are often flooded for 1-  
24 5 hours, twice daily, for majority of the year. Beyond this pioneer marsh is the low marsh,  
25 which often occurs between the final limit of mud flats up to around 50 cm above the Mean High  
26 Water tide line. This area is usually inundated daily. Beyond the low marsh is upper marsh,  
27 which tends to occur from around 50cm above the Mean High Water tide up to the Extreme  
28 High Water tide line, though this can be region dependant. The lower margins of this zone may  
29 be flooded daily when monthly tides are high. The higher margins of the upper marsh are only  
30 flooded once or twice a year. Beyond the upper marsh, at the most landward extreme of the  
31 saltmarsh environment, is an area (sometimes called 'drift line', 'transitional' or 'slack') which,  
32 normally, lies above the highest astronomical tide and is constantly supplied by fresh ground  
33 water. This area often is dominated by reed bed and a variety of freshwater carr woodlands.  
34 Ulrich and colleagues (2002) suggest that the divide between the low saltmarsh community  
35 dominated by *Puccinellia maritima* (Huds.) (common salt marsh grass) and *Atriplex*  
36 *portulacoides* L. (sea purslane) and the high saltmarsh community, dominated by *Limonium*  
37 spp. (sea lavenders), *Festuca rubra* ssp. *litoralis* (G. Mey.) Auquier (coastal variety of red  
38 fescue) and *Juncus maritimus* Lam. (sea rush), seems to commonly occur about 50 cm above  
39 Mean High Tide.

1 The process by which the vegetation succession is determined and maintained has been  
2 studied quite intensely in Northern Europe. This is mainly due to growing concerns over the loss  
3 of saltmarshes to coastal development and erosion and research into their response to climate  
4 change (Adnitt *et al.* 2007; JNCC 2004). A series of survey and experimental projects has  
5 clearly established that the primary factor in the vegetation succession is the relative altitude  
6 above sea level, which has obvious implications for inundation and relative salinity (e.g.  
7 Bockleman *et al.* 2002; Pennings and Bentness 2001; Pennings *et al.* 2005) Research by Adnitt  
8 and colleagues (2007) suggests that this may determine 80% – 90% of the variation in plant  
9 species present. Clearly, the variation of plant communities within saltmarsh is affected by  
10 many factors including competition between plant species (Adnitt 2007; Costa *et al.* 2003;  
11 Pennings *et al.* 2005); wave form and aspect (Pennings and Bentness 2001); relative levels of  
12 saturation, anoxia, salinity and available oxygen (Davy *et al.* 2011; Moffett *et al.* 2010; Pennings  
13 *et al.* 2005) and sediment supply and budget (Pennings and Bentness 2001) or, indeed, a  
14 combination of many of these factors locally (Pennings and Calloway 1992; Silvestri *et al.*  
15 2005).

16 A key objective for this paper is to establish if it is possible to use insects, particularly beetles  
17 from archaeological deposits, to identify the presence of the same, or similar, zonation within  
18 saltmarshes and to relate this directly to the archaeological record.

19

### 20 **3. PREVIOUS MODERN STUDIES OF INSECTS FROM SALTMARSHES**

21 A number of studies have been carried out on the insect faunas from modern saltmarshes  
22 which suggest that 'zonation' in insect faunas is present, but currently is not clearly defined.  
23 Dijkema (1984) has examined a large range of insect species and how their distribution  
24 changed within the saltmarsh environment. He found that around 100 insect species were  
25 associated with the pioneer phase, around 500 with the middle saltmarsh and at least 1300 with  
26 upper saltmarsh. He suggested at least 75% – 80% of the insect species found in mudflats and  
27 low marsh were halobionts (associated exclusively with saline conditions), 25% – 50% of  
28 insects were halobionts in high saltmarsh communities and only 5% – 10 % of insects were  
29 halobionts in the transitional zone at the landward edge of the saltmarsh. Dijkema's survey  
30 established that plant feeders (phytophages), detritivores and carnivores also increase in  
31 number as one moves inland. Several studies have shown similar patterns in terms of the  
32 distribution of a number of insect species and the proportions of halobionts for the Carabidae  
33 'ground beetles' (e.g. Desender and Maelfait 1999; Forster 2000; Petillion *et al.* 2008; Ulrich *et*  
34 *al.* 2002) and it is likely that the same pattern presumably also is true for other beetle families.  
35 In terms of ground beetles in the UK there is clear evidence that the fauna associated with  
36 saltmarshes is restricted. Luff and Eyre (2000) suggest that 28 ground beetles appear to be  
37 associated with saltmarshes, with eight beetle species being true halobionts. For Staphylinidae  
38 or 'rove beetles', Hammond (2000) suggests that in the UK 54 species are predominantly

1 coastal, with 17 specific to saltmarshes. Foster (2000) suggests that only 7% of the British  
2 water beetle fauna is coastal, with 38 species directly associated with brackish water and only  
3 six known to be true halobionts.

4 Saltmarsh insects seem to have a variety of strategies for surviving in a saline environment  
5 (e.g. Forster 2000; Luff and Eyre 2000). Several, such as the *Bledius* and *Heterocerus* species  
6 from the mudflats, are cryptic (live in burrows). These beetles live in air-filled burrows, more or  
7 less fulltime, by sealing the narrow entrance or relying on surface tension to keep out the rising  
8 tide. Others alter the times at which they leave their burrows to avoid the rising tide. For  
9 example, the ground beetle *Dicheirotichus gustavi* Crotch is usually nocturnal, and is only  
10 active and emerges from its burrow in the evening; however, when the tide coincides with  
11 daylight hours it will remain in its burrow for several days. Several species, including many of  
12 the ground beetles and the rove beetles, will actively 'migrate' with the tides moving to drier  
13 ground either on foot or by flying when the saltmarsh they inhabit is inundated (Foster 2000;  
14 Hammond 2000; Luff and Eyre 2000; Ulrich *et al.* 2002). True halobionts not only tolerate saline  
15 water but also can cope with extreme variability in salinity. How they do this is not fully  
16 understood but some (e.g. Foster 2000; Luff and Eyre 2000) suggest that they have the ability  
17 to osmoregulate (or actively regulate the relative salinity in their body). This may also explain  
18 the rectal pads seen on many saltmarsh beetle species. W. Foster (2000) also observed that  
19 *Bledius* beetle species living on saltmarsh also seem to choose to eat algae that are low in salt  
20 at times of high environmental salinity. Certainly, the saltmarsh environment can lead to some  
21 fairly extreme adaptations. For example, *Bledius* females 'curate' their larvae and young and  
22 keep them in the burrow until almost adults (Foster 2000).

23 Many of these studies of saltmarsh insects aim to establish the extent of the fauna, its  
24 conservation status or its national distribution; there are very few studies that specifically  
25 investigate how insects respond to the ecological zonation seen in saltmarshes, as described  
26 above. Ulrich and colleagues (2002) study of saltmarshes from the North Sea and the Baltic  
27 found that two distinct high and low saltmarsh 'zones' could be identified based on ground  
28 beetle communities with the divide occurring at between 60 – 80 cm above MHT for the North  
29 Sea sites. The low marsh was characterised by *Pogonus chalceus* (Marsh.) and *D. gustavi* (with  
30 *P. chalceus* slightly lower in elevation) and high marsh by the presence of *Bembidion minimum*  
31 (F.), *B. normannum* Dej. and *Dyschirius salinus* Schaum. This is potentially an important  
32 distinction for the survey of archaeoentomological faunas reviewed in this article. Similarly,  
33 though it does not distinguish between the saltmarsh zones, the paper by Desender and  
34 Maelfait (1999) describing the coastal shoreline distributions of beetle faunas along the Estuary  
35 of the river Scheldt does draw some very clear distinctions between the faunas of saltmarsh,  
36 sun-exposed areas of sands and freshwater marshes that are relevant here.

37 There are a number of issues that actually prevent direct comparison between the results of  
38 these modern entomological surveys and archaeoentomological assemblages:

- 1) The insects in the modern surveys are collected by hand or from pitfall traps; whereas, the insects from the archaeological sites are collected as fragments from archaeological sediment during excavation.
- 2) The insects from the modern survey are a 'living fauna'; whereas, those from archaeological sites are most likely 'death assemblages'. Death assemblages can be expected to be very different in their nature from living insect communities, especially in terms of how they form and the area of landscape they represent (e.g. Kenward 1975, 1978; Smith 2012; Smith *et al.* 2010).
- 3) Modern surveys usually collect beetles during a very limited period of time or one particular season. The archaeoentomological faunas are collected over an unknown but probably much longer period of time. It is reasonable to assume that archaeoentomological assemblages contain the remains of insects that have gathered over many seasons and years and are unlikely to represent one season or calendar year.
- 4) Many of the modern surveys of saltmarshes concentrate on specific Coleoptera families from the beetle fauna present (normally the Carabidae 'ground beetles'; The Hydrophilidae 'water scavenger beetles' and the Staphylinidae 'rove beetles'). The archaeological faunas are whole faunas that include a mixture of the full range of the beetles present
- 5) The modern insect faunas are usually identified to species level. This level of identification is not always possible with archaeological insects, which are recovered in fragments (usually head, thorax and elytra are sorted from flots) and often lack diagnostic features such as antenna, hairs, legs which frequently feature as criteria to distinguish morphologically similar taxa to species level in entomological keys.
- 6) The modern surveys often only include a list of the species encountered and do not indicate their relative numerical abundance (to be fair this is standard in most modern entomological surveys, which normally do not indicate relative abundance of taxa).
- 7) Finally, with modern assemblages, the beetles sampled are directly collected from an observed habitat using methods where collection biases are understood and can be addressed. However, with archaeoentomological assemblages the past environment is not known, and can only be understood through proxy indicators such as plant macrofossils, pollen or even the beetles themselves. Moreover, it is highly likely that archaeoentomological assemblages will be biased by factors such as preservation, taphonomy (how deposits form and are subsequently modified) and human activity.

#### 4. METHODOLOGY AND ANALYSIS

In order to establish if similar saltmarsh zonation indicators may be detected in archaeological insect faunas, and if this could be used to interpret archaeological site location within a coastal landscape, the following approaches were used:

##### 4.1 Sampling



1 Bulk samples were recovered from either estuarine clays or from underlying freshwater peats  
2 from a wide range of archaeological features from 15 archaeological sites. The location, dating,  
3 site type, nature of sampled material, details of publication and the number of samples analysed  
4 from the individual sites are outlined in Table 1. The site locations are illustrated in Figure 2.

5

## 6 **4.2 Basic identification**

7 The bulk samples were prepared using the standard method of paraffin floatation outlined in  
8 Kenward *et al.* (1980). Waterlogged insect remains were sorted and identified under a low-  
9 power binocular microscope at magnifications between x15 – x45. Where achievable, the insect  
10 remains were identified to species level by direct comparison to specimens in the Gorham and  
11 Girling insect collections, housed in the Department of Classics, Ancient History and  
12 Archaeology at The University of Birmingham. The nomenclature used in this paper for the  
13 beetles is based on Lucht (1987) and is based on Stace (2010) for the plants.

14

## 15 **4.3 Data Analysis**

16 In order to establish whether the insects recovered from archaeological material can reliably  
17 indicate saltmarsh zone the site was located in, a number of analyses were undertaken:

### 18 **1) Identifying if there are differences in species composition between** 19 **archaeological sites**

20 The species lists from the individual archaeological sites were consulted and  
21 the presence and the relative numbers of individual species were noted. The  
22 aim of this analysis was to identify species which are significant in these  
23 faunas and which might therefore be considered as archaeological ‘indicator  
24 species’ (*sensu* Kenward and Hall 1997) for salt marsh landscapes. Obviously  
25 given the many taphonomic and depositional issues that affect insect  
26 faunas in the past (i.e. Kenward 1975; 1978; Smith 2012) it would be a  
27 mistake to attempt to use these proportions directly to interpret the  
28 archaeological record. This is about establishing general trends here, not  
29 directly comparing specific data.

30

### 31 **2) Assigning the archaeological data to ecological groupings**

32 Insect faunas from archaeological sites are now routinely assigned to  
33 ‘ecological groupings’ following the methodology outlined in Kenward (1978)  
34 and Robinson (1981, 1983). The ecological groups used here are based on a  
35 set devised specifically for use in the archaeological record. They are  
36 intentionally broad (often much broader than modern ecological groupings for  
37 insects) since they are designed to be used for comparison of death  
38 assemblages that may not have formed in the same ecologies or in the same  
39 taphonomic circumstances:

40

- 41 1. freshwater aquatic (‘a’ group)
- 42 2. fast-flowing waters (‘ff’ group)
- 43 3. acidic waters (‘aw’ group)
- 44 4. species associated with muddy watersides and waterside vegetation  
45 often reed bed (‘ws’ group)
- 46 5. saline waters (‘sw’ group)
- 47 6. coastal terrestrial (‘c’ group)

- 1 7. moorland ('m' group)
- 2 8. dung fauna ('df' group)
- 3 9. 'house' and settlement fauna ('h' group)
- 4

5 The membership of these groups is outlined in Kenward (1978), Kenward and Hall  
6 (1995), Smith and Howard (2004) and Smith and colleagues (Smith *et al.* 1997, 2000).

7  
8 The proportions for groups 'a', 'sw', 'aw', 'ff' and 'ws' have been calculated as a  
9 percentage of the total minimum number of individuals (MNI) recovered for each  
10 sample. The proportions for groups 'c', 'm', 'df' and 'h' have been calculated as part of  
11 the terrestrial fauna recovered (this is calculated by removing the aquatic species ('a'  
12 '+sw') from the MNI for the whole assemblage). In many archaeological samples, the  
13 terrestrial fauna can be 'swamped' by the aquatic fauna and the relative proportion of  
14 terrestrial beetles therefore can be adversely, and misleadingly, affected by variations  
15 in the aquatic fauna., As a result, the exclusion of aquatic species from the calculation  
16 for terrestrial species is necessary.

### 17 18 **3) Use of statistical ordination to identify data patterns**

19 In order to test the security of the two analyses suggested above, a statistical  
20 ordination was carried out on the entire dataset for the sites. A detrended  
21 correspondence analysis (hereafter DCA) using the CANOCO 4.5 programme (ter  
22 Braak and Šmilauer 2002) was carried out on a total of 59 insect faunas to determine  
23 if the faunas and the archaeological samples recovered were statistically distinct or  
24 clustered. The full data set consisted of 9131 individuals representing 451 taxa. An  
25 initial run of the DCA across the total fauna of all samples indicated that standard  
26 reciprocal averaging gave an undue importance to both rare individuals and individual  
27 taxa from samples where the total counts were low. This is a common problem  
28 encountered with reciprocal averaging (Gauch 1982). The dataset also tended to  
29 divide on aspects of the data regarded as unimportant for the present investigation  
30 (for example the presence or absence of synanthropic, woodland and/ or dung  
31 beetles).

32 As a result, it was decided to restrict the data used in the CANOCO DCA analysis in  
33 two ways:

34 1) Removing faunas in which less than 20 individuals were  
35 recovered and removing taxa which accounted for less than 10% of  
36 the total fauna (in essence this meant the removal of faunas that  
37 would normally not be considered archaeologically interpretable –  
38 Kenward 1978; Smith 2012).

39  
40 2) Restricting the analysis to species that were included in relevant  
41 ecological groups, in this case the 'a', 'sw', 'c', 'ws' and 'm' ecological  
42 groupings.

1

2 These manipulations of the data reduced the dataset analysed to 4482 individuals representing  
3 94 taxa from 44 assemblages, from 15 archaeological sites at 6 locations. The option to down  
4 weight species occurring infrequently was selected for the DCA.

5 This is of course a fairly heavy set of data manipulations for an ordination, and is the kind of  
6 'tidying up' that is specifically not recommended by ter Braak and Šmilauer (2002). However,  
7 given the complexity and taphonomic problems for datasets produced by most  
8 archaeoentomological and other environmental archaeology analyses, to some extent this  
9 approach is defensible and is common practice (previous examples of similar decisions to  
10 restrict archaeoentomological datasets are outlined in Smith 2012, 2013a). For the purposes of  
11 this exercise, the DCA ordination is intended to independently confirm and support the indicator  
12 groups and patterns identified subjectively, or by the use of less complex statistics, rather than  
13 be the sole or determining form of analysis.

14

## 15 **5. RESULTS**

16 Table 2 presents the range of species that are seen to be particularly indicative of saline waters,  
17 estuarine conditions, freshwater and waterside environments from the sites examined. The  
18 shading in the table represents the number of individuals encountered at a particular site.

19 Table 3 and Figures 3, 4 and 5 present the relative proportions of the ecological groups for  
20 each site.

21 Figure 6 presents the results of the CANOCO DCA ordination using the reduced dataset  
22 described above and represents the first and second axes of ordination. Figure 6a presents the  
23 DCA ordination for the species and Figure 6b for the samples from the archaeological sites. An  
24 annotated interpretation of the groups of insects and samples that resulted from this ordination  
25 is presented in Figures 6a–b.

26

## 27 **6. DISCUSSION**

28 The three analyses that have been undertaken all indicate that the insect remains from the  
29 archaeological sites have distinct habitat groups present. The differences in faunas, and which  
30 species seem to be significant, are summarised in detail in Table 4 (species in bold are thought  
31 to be particularly indicative). The relative proportions of the ecological groups present also are  
32 provided. Finally, an indication of where that particular site may have been located within the  
33 saltmarsh landscape is suggested.

34 These groupings appear to make both ecological and archaeological sense and the logic for  
35 this can be explained as follows:

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## **6.1 Differences in taxa and the proportions of ecological groups of aquatic Coleoptera between the sites**

Table 3 clearly illustrates that the individual sites fall into a number of distinct groups. These differences appear to relate to the occurrence and relative numbers of beetle species from saline, aquatic and waterside environments. Similar patterns are seen in the proportions of the ecological groups recovered (see Figures 3, 4 and 5).

The sites at Springhead and Caldicot are distinct from the other archaeological sites as a result of the presence of a range of water beetles, mainly elmids 'riffle beetles', which are usually associated with fast-flowing, well-oxygenated fresh waters, often flowing over sand and gravel substrates (ecological group 'ff'). These taxa only account for 1% of the fauna at Springhead, but account for 27.5% at Caldicot; however, they are completely absent at the other sites examined. In the archaeological record, elmids have been found to be mainly associated with large river channels in the British lowlands during the Early and Mid-Holocene. Their distribution appears to contract with increased river channel alluviation from the Late Bronze Age/ Early Iron Age onwards (Osborne 1988; Smith 2000; Smith and Howard 2004). The other water beetles from these two sites are a fairly mixed blend of species ranging from freshwater and watersides to coastal and saltmarsh environments. Both Springhead and Caldicot were probably located on fast-flowing creeks or tidal inlets, where freshwater channels entered the saltmarsh zone on their way to the sea. On the Gwent Levels, these features are known as 'pills' which is an Anglicisation of the Welsh word '*pwl*', meaning inlet, harbour or pool, but in this area specifically refers to freshwater channels. This 'pill' term at Caldicot may be particularly significant in terms of the Saxon Mill at Springhead, since the Springhead faunas and archaeology suggest that both fresh river water and estuary tides may have been important in the operation of this mill (Barnett *et. al.* 2011).

Two of the trackways at Goldcliff (Trackways 4 and 6) contained no taxa that are associated with saltmarsh environments. These sites are dominated by a wide range of taxa that are associated with slow-flowing or stagnant freshwater (ecological group 'a' which account for 45.5% and 58.4% of the fauna respectively). The faunas also are dominated by a number of species, such as the reed beetle *Plateumaris braccata*, associated with *Phragmites* reed beds and other stands of emergent waterside vegetation (typically ecological group 'ws' which accounts for 29.3% and 18.9% respectively). This ecological group is present in much higher numbers at Goldcliff trackways 4 and 6 than in the other faunas. It is probable, therefore, that deposits from these two sites were located in the freshwater slack at the back of the saltmarsh, where there is a more limited saline influence.

The samples from Cold Harbour Pill and the two buildings at Redwick produced moderate numbers of taxa that are associated with coastal environments. This component of the

1 terrestrial fauna mainly consists of a range of *Bembidion* species and the saltmarsh specialist  
2 *Pogonus chalceus*. The saline tolerant water beetles included limited numbers of *Ochthebius*  
3 *dilatatus* and *O. viridis*. Taken together both the coastal species and salt water species  
4 (ecological groups 'c' and 'sw') usually account for under 15% of the beetle fauna recovered.  
5 Notably, none of the species associated with saline mud flats were recovered at these sites.  
6 Similar proportions (< 15%) of species associated with freshwater and watersides also were  
7 recovered from the samples from Cold Harbour Pill and Redwick (see Table 3 and Figure 4).  
8 Indicators for reed bed are much less common than they were in the material from Trackways 4  
9 and 6 at Goldcliff. Given that saline indicators are present, particularly *Pogonus chalceus*, and  
10 that mud flat species are essentially absent, it seems reasonable to suggest that these sites  
11 were originally located on high or low saltmarsh.

12 Goldcliff buildings 1, 6 and 8 and trackways 1130, 1330, 1311, 1108 and the palaeochannel at  
13 Walpole form a distinct group from the other archaeological sites. Taxa from saline water and  
14 coastal environments account for at least 15% of the fauna recovered from these sites, with the  
15 proportions of saline taxa often exceeding 20% of the overall assemblage (see Table 3 and  
16 figure 3). This suggests that saltwater/ coast conditions were a dominant aspect of the local  
17 landscape. The exception to this is Building 1 at Goldcliff where only 1.8% of the fauna falls into  
18 these ecological groups. This is easy to explain as the deposit was from the internal surface of  
19 the building's floor and its archaeoentomological fauna was dominated instead by members of  
20 'house fauna' (Smith *et al.* 1997, 2000).

21 Perhaps more significant are the specific taxa recovered at these sites. The faunas contain  
22 several individuals which are all normally associated with saline mud and mud flats in the  
23 pioneer zone of saltmarshes (Clarke 1973; Lott 2009; Tottenham 1954); such as, *Bledius*  
24 *spectabilis*, *B. occidentalis*, *Heterocerus fossor*, *H. flexuosus*, *H. ?obsoletus* and *H. maritimus*.  
25 The two species of Hydrophilidae recovered (*Cercyon litoralis* and *Cercyon depressus*) normally  
26 are associated with decaying seaweed (Hansen 1987) and are recovered only at these sites. In  
27 addition, the faunas also contain a wide range of species know to inhabit pioneer mudflats at  
28 low tide, as well as high and low saltmarsh; such as, *Dyschirius aeneus*, *D. salinus*, *Pogonus*  
29 *chalceus*, *Dicheirotrichus gustavi* and a range of *Bembidion* species. Saline water beetles such  
30 as *Ochthebius dilatatus*, *O. marinus* and *O. viridis* are common at these sites as well.

31 Interestingly, despite the presence of taxa clearly signalling saline conditions at Goldcliff, there  
32 are still relatively large amounts of freshwater and waterside species (ecological groups 'a' and  
33 'ws') recovered. This result requires some explanation. Certainly, several of the species of  
34 'freshwater' beetles can, and often do, occur on saltmarshes, suggesting a degree of tolerance  
35 to salinity (e.g. Foster 2000). Several of the waterside plants indicated by the beetles  
36 recovered, such as *Phragmites* water reed and sea club rush (*Bolboschoenus maritimus* L.), will  
37 occur on either low or high saltmarsh, as well as freshwater areas. Their presence also may  
38 result from two well-known archaeological problems.

1 Kenward (1975, 1978) has clearly demonstrated that the formation of death assemblages of  
2 insects in the archaeological record is complex and can routinely incorporate significant  
3 proportions of species that are allochthonous (taxa that originated at a distance from location in  
4 which it is deposited) to the deposit in which they are found. Annoyingly, Kenward's study  
5 established that this often can include beetles from freshwater turning up in deposits far away  
6 from such an environment. Equally, many of the samples from these sites were taken from  
7 directly above or even at, the transition between the underlying marsh/ wood/ acidic peats and  
8 the overlying estuarine clays. It is, therefore, likely that there may have been some mixing of  
9 these deposits either during formation or in sampling.

10 Unfortunately, the distinction identified by Desender and Maelfait (1999) to divide between low  
11 and high saltmarsh using ground beetles (i.e. low saltmarsh characterised by the presence of  
12 *Pogonus chalceus* and *Dicheirotichus gustavi*; high saltmarsh characterised by the presence of  
13 *Bembidion minimum*, *B. normannum* and *Dyschirius salinus*) was not observable in these  
14 archaeological assemblages. These species either occur in low numbers or, when more  
15 numerous, occur across most of the archaeological faunas regardless of whether the deposits  
16 appear to have formed on mudflats, low or high saltmarsh (based on other aspects of the  
17 faunas recovered). The modern ecology and collection records for these taxa in Britain also  
18 suggest that there is an overlap in habitat for these highly mobile ground beetles (e.g. Luff  
19 2007).

20 Archaeologically the presence of all of these taxa occurring together is not surprising. It is  
21 thought that archaeological insects tend to come from a 1000 m area around the sampling site  
22 (e.g. Hill 2016; Smith *et al.* 2010). Although a relative small total area, this potentially could  
23 include all of these tidal regimes within a saltmarsh. Many of these species are very mobile and  
24 will move up and down the tidal sequence on a seasonal timescale, if not daily. This would  
25 inevitably lead to beetles occurring in death assemblages potentially representing quite a wide  
26 area of habitats. The archaeological factors that complicate the formation of insect death  
27 assemblages discussed above would also be a factor here and, of course, both live and dead  
28 beetles can be carried by the tide or freshwater floods into deposits which they do not really  
29 represent.

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## 31 **6.2 Differences in taxa and proportions of ecological groups of terrestrial Coleoptera** 32 **between sites**

33 There are some interesting distinctions between the sites in terms of the terrestrial insect  
34 faunas recovered (Table 3 and Figure 5). Although this may relate to these sites' location within  
35 the saltmarsh, it also is likely that this could relate to other factors; such as, surrounding  
36 landscape or human behaviour.

37 Many of the sites at Goldcliff and Redwick contain small numbers of species that are associated  
38 with moorland (ecological group 'm'). This group accounts for 2.8% of the terrestrial fauna at

1 Goldcliff building 6 to 19.3% at Redwick building 2. The moorland group includes the ground  
2 beetle *Bradycellus ruficollis*, which typically is found on sandy ground amongst heather in  
3 heathland and moorland (Lindroth 1974; Luff 2007); the weevil *Micrelus ericae*, which feeds  
4 only on heathers (*Erica* spp. and *Calluna vulgaris* L.); and *Plateumaris discolor* which is  
5 associated with cotton grass (*Eriophorum angustifolium* Honck.). The small predaceous diving  
6 beetle *Hydroporus melanarius* is normally associated with dark acidic pools in peat bogs (Foster  
7 *et al.* 2014). The presence of these species at the Gwent Levels sites is not surprising. Here,  
8 lowland raised peat bog appears to be one of the landscapes that is commonly inundated due  
9 to rising sea levels in the Middle Iron Age (Bell *et al.* 2000; Bell 2013). The sites examined on  
10 the Gwent Levels (Goldcliff, Redwick, Caldicot, Cold Harbour Pill) all show evidence that the  
11 underlying peat was being eroded during inundation with elements of this material, including  
12 insect remains, becoming incorporated into the overlying estuarine clays. In addition, these  
13 sites also contain moderate amounts of a range of species that are associated with cattle and  
14 other grazing animals (ecological group 'df' in Table 3 and Figure 5); such as, the *Aphodius*  
15 dung beetles, but also can include individuals of the 'dor beetle' *Geotrupes* and the  
16 *Onthophagus* beetles. The presence of such dung beetles can be related to the substantial  
17 archaeological evidence recovered at these sites for seasonal cattle grazing during the Late  
18 Bronze Age and the Early Iron Age (Bell 2013; Bell *et al.* 2000).

19 Perhaps even more striking is the presence of substantial proportions of insects that are  
20 normally associated with human settlement and housing (ecological group 'h') at some of these  
21 saltmarsh sites. This can account for between 5% – 10% of the fauna recovered but does reach  
22 20% of the terrestrial fauna in Building 1 at Goldcliff. This 'house fauna' includes several  
23 species that are seen as particularly strong synanthropes; such as, the 'woodworm' *Anobium*  
24 *punctatum*, the 'hairy fungus beetle' *Typhaea stercorea* and the 'spider beetle' *Ptinus fur*. Smith  
25 and colleagues (Smith 2013b; Smith *et al.* 2000) have suggested that these synanthropes most  
26 likely were brought to site in stored hay and quickly developed into breeding populations in  
27 fodder and other materials stored in the buildings during their use.

28

### 29 **6.3 The Detrended Correspondence Analysis (DCA) Ordination**

30 The results of the CANOCO Detrended Correspondence Analysis (DCA) ordination are shown  
31 in Figures 6a and 6b. It is clear that there is a strong separation seen in both the species and  
32 the sample ordinations. For the species ordination (Figure 6a) there are a clear number of  
33 distinct groupings:

- 34 1) The taxa that constitute the saline waters ('sw') and coastal terrestrial ('c')  
35 groupings fall into a discreet cluster in the lower middle of the plot (labelled 1).  
36 This grouping includes a range of very strong terrestrial halophile species; such  
37 as, *Pogonus chalceus*, *Bembidion minimum*, *B. varium*, *Dyschirius salinus*,  
38 *Bledius occidentalis*, *Heterocerus fenestratus*, *H. maritimus*, *H. ?obsoletus*; and

1 the salt water tolerant hydraenid beetles *marinus*, *O. viridis* and the hydrophilid  
2 *Cercyon depressus*. A small number of saline tolerant species do not fall into this  
3 group but, instead, cluster with a range of fresh water indicators towards the  
4 upper middle of the diagram. However, these are species; such as, *Bembidion*  
5 *assimile*, *B. semipunctatum*, *B. fumigatum*, and *Ochthebius dilatatus*, which are  
6 closely associated with salt marshes, but can occur in a range of freshwater  
7 habitats (Foster *et al.* 2014; Lindroth 1974; Luff 2007).

8 2) The species associated with fast-flowing water, mainly consisting of a range of  
9 elmids, primarily occur together in the upper right hand corner of the plot and  
10 some of these taxa plot out on top of each other (labelled 2).

11 3) There is also a group of species that cluster towards the middle right hand side of  
12 the diagram, which may indicate a general preference for 'reed beds' (labelled 3).  
13 This includes species such as *Agonum thoreyi*, *Odacantha melanura*, *Silis*  
14 *ruficollis* and *Plateumaris braccata* which are very characteristic of this  
15 environment. Notably the 'duckweed' weevil *Tanysphyrus lemnae* and the  
16 'whirligig' beetles *Gyrinus* spp. which have long been thought to be associated  
17 with open areas of water in reed beds in the archaeological record, also plot out  
18 in this area of the diagram (e.g. Girling 1979; Smith and Howard 2004).

19 4) Towards the top left hand side of the diagram is a much wider group of taxa that  
20 are associated with fresh water environments (labelled 4).

21 5) There is a linear spread of species towards the middle and upper left hand side of  
22 the diagram that consist of a range of species that are indicators for acid bogs  
23 and heathlands. There are all members of the moorland ('m') and acidic waters  
24 ('aw') ecological grouping such as *Bradycellus ruficollis*, *Hydroporus striola*, *H.*  
25 *melanarius*, *Acidota crenata*, *Haltica ericeti* and *Micrelus ericae*.

26 6) There are also two notable 'outliers' towards the bottom of the left-hand side of  
27 the diagram. These are the staphylinids *Trogophloeus pusillus* and *T. fuliginosus*.  
28 These were initially included in the ordination since they are species that are  
29 commonly associated with wet mud and decaying vegetation by watersides  
30 (Tottenham 1954; Lott 2009). However, both species are also commonly found in  
31 the archaeological record in deposits that come from wet yards, house floors and  
32 passageways where they are often closely associated with a range of  
33 synanthropic 'house' fauna (Kenward and Hall 1995; Carrott and Kenward 2001;  
34 Smith 2012) and it may be that these two species should have been excluded  
35 from this analysis along with the other members of the synanthropic fauna.

36 This analysis, at least, has suggested that it may be possible to refine the broad, and perhaps  
37 crude, ecological groupings 'saline waters', 'coastal terrestrial' and 'waterside' into further  
38 'functional' sub-groups (see Hill 2016 for one such suggested scheme). However, given the



1 very complex nature of death assemblages, which differ in both time, space and taphonomy,  
2 the extent to which this may be warranted in the long term needs to be considered.

3 The species ordination has therefore separated the taxa into a sequence of environments  
4 running broadly right to left across the diagram with species indicative of fast-flowing water at  
5 the right, through freshwater and reed bed species, to saltmarsh and peat bog and heath at the  
6 left. Given that in these environments local conditions can be quite 'mixed' and we are dealing  
7 with the vagaries of the archaeological record (for example at Iron Age Goldcliff the saltmarsh  
8 deposits becoming mixed with the underlying peat as the result of cattle 'trampling' (Bell *et al.*  
9 2000)), the strength of this ordination is striking and encouraging.

10 In terms of the DCA ordination by samples (Figure 6b), these results generally support the  
11 distinctions between the sites discussed above. The samples from Cold Harbour Pill and  
12 Redwick, the two sites thought to represent high and low saltmarshes, cluster together in the  
13 top left hand corner of the plot. Sites which, based on the ecology of the insect species present,  
14 appear to be from pioneer mudflats are clustered together in the lower left hand area of the plot.  
15 This cluster includes the three buildings from Goldcliff, trackways 1130, 1330, 1311, 1108 at  
16 Goldcliff and the site at Walpole. Though perhaps less clearly clustered the samples from the  
17 potential tidal channel sites at Springhead and Caldicot do seem to cluster together in the  
18 middle right of the diagram. Just below this is a cluster of samples from the two trackways at  
19 Goldcliff (Trackway 4 and 6) which were thought to be from freshwater slack.

20

## 21 **7. Conclusion**

22 This paper set out to establish whether it is possible to use the insect remains from intertidal  
23 archaeological sites to determine where they may have been located within the past tidal  
24 regime of ancient saltmarshes. The ecological data from the individual species, the summary  
25 statistics based on their ecological grouping and the ordination suggest that this is feasible.  
26 Though a distinction between low and high saltmarsh proved difficult, this is likely to be due to  
27 the limited number of archaeological sites examined (N = 6) and the affect of tidal movement on  
28 insects (both dead and alive/ during site formation and since). Nevertheless, the insect faunas  
29 reliably separated freshwater slack from saltmarsh, from mudflat, from tidal creek. Although this  
30 survey was speculative (i.e. were there any patterns to the data), these different faunas  
31 theoretical could be developed (with further data from other archaeological sites in Britain and  
32 elsewhere) as 'indicator groups' for these separate environments in the archaeological record  
33 (*sensu* Hall and Kenward 1997). One way to validate the conclusions drawn here would be to  
34 carry out a series of modern calibration studies in a range of saltmarsh biomes. Ideally this  
35 would use insect 'death assemblages' taken directly from sediment samples to see if the results  
36 presented here are replicable when collected from modern environments (for methodology see  
37 Smith *et al.* 2010).

1 The conclusions presented here are quite timely. Due to modern climate change and coastal  
2 erosion due to sea level rise, many more of these important foreshore archaeological sites  
3 worldwide are likely to be exposed over the next few decades (i.e. Bell 2012, 2013; Bell *et al.*  
4 2000;). Though many of these intertidal sites will be from terrestrial peats, some will be from  
5 sites that were originally located within estuarine and saltmarsh landscapes. Understanding  
6 their location and use is of paramount research and archaeological importance. Insect remains,  
7 as one of the strongest environmental archaeological proxy indicators, clearly have a vital role  
8 to play here, not just in northern Europe, but internationally.

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30

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Table 1. Site details, dates and publication.

SITE NAME	LOCATION	DESCRIPTION	DATE	PUBLICATION	NUMBER OF SAMPLES AT EACH SITE
Springhead	Northfleet, Essex, England	Saxon mill race and shoot	Late 7th or Early 6th century	Smith 2011	7
Goldcliff (Buildings 1, 6 and 8)	Gwent Levels, Newport, Gwent, Wales	Building 1: a range of floor deposits from rectangular timber structure. Building 6 and 8: materials from palaeochannels filled with cattle foot prints around timber structures	Building 6: dendrochronology indicates wood cut in 273 BC. Buildings 1 and 8: radiocarbon dated between 400–100 cal BC.	Smith <i>et al.</i> 1997, 2000	22
Goldcliff, Trackway 1130	Gwent Levels, Newport, Gwent, Wales	Corduroy and brushwood trackway	391–116 cal. BC	Smith <i>et al.</i> 1997, 2000	3
Goldcliff, Trackway 1330	Gwent Levels, Newport, Gwent, Wales	Brushwood trackway	165–129 cal. BC	Smith <i>et al.</i> 1997, 2000	1
Goldcliff, Trackway 1311	Gwent Levels, Newport, Gwent, Wales	Brushwood trackway	366–41 cal. BC	Smith <i>et al.</i> 1997, 2000	1
Goldcliff, Trackway 1108	Gwent Levels, Newport, Gwent, Wales	Brushwood trackway	Dendrochronological date of 336–318 BC	Smith <i>et al.</i> 1997, 2000	4
Redwick Building 4	Gwent Levels, Newport, Gwent, Wales	From edge of channel alongside rectangular building structure	Sample appear to be slightly younger than structure which is dated to 1601–1261 cal. BC and 1376–929 cal. BC	Smith 2013b	3
Redwick Building 2	Gwent Levels, Newport, Gwent, Wales	Occupation deposits around rectangular timber structure. Pit thought occupation layers of site	1379–940 cal. BC 1389–1129 cal. BC	Tetlow 2013	4
Cold Harbour Pill	Gwent Levels, Newport, Gwent, Wales	Section through timber alignment at site 9	Trackway undated but presumed similar to dates of the buildings	Nayyar and Smith 2013	4
Walpole Landfill site	Walpole, nr. Pawlet, Bridgewater, Somerset, England	Estuarine clays from palaeochannels filled with cattle foot prints	Neolithic	Shotter 2012	3
Caldicott	Nr Caldicot Castle, Gwent, Wales	Palaeochannel deposits associated with timber and worked wood	Series of radiocarbon dates place activity in the 2nd millennium BC	Osborne 1997	1



Table 2. The coastal, saline, aquatic and waterside Coleoptera recovered from the archaeological sites examined. The shading and the key below the table outlines their relative occurrence at each site.

	Springhead	Goldcliff Building 1	Goldcliff Building 6	Goldcliff Building 8	Goldcliff Trackway 4	Goldcliff Trackway 6	Goldcliff Trackway 1130	Goldcliff Trackway 1330	Goldcliff Trackway 1311	Goldcliff Trackway 1108	Redwick Building 4	Redwick Building 2	Cold Harbour PIII	Walpole Channels	Caldicot
<b>Freshwater Aquatics</b>															
<i>Hygrotus inaequalis</i> (F.)															
<i>Hydroporus scalesianus</i> Steph															
<i>H. tessellatus</i> Drap.				Diagonal											
<i>Graptodytes cf. granularis</i> (L.)													Checkerboard		
<i>Gyrinus</i> spp.					Diagonal	Diagonal	Diagonal	Diagonal							Checkerboard
<i>Ochthebius bicolor</i> Gem.															
<i>Ochthebius minimus</i> (F.)				Checkerboard	Checkerboard	Checkerboard	Checkerboard	Checkerboard		Diagonal			Black		Checkerboard
<i>Coelostoma orbiculare</i> (F.)		Diagonal			Checkerboard	Diagonal									Checkerboard
<i>Cymbiodyta marginella</i> (F.)															
<i>Chaetarthria seminulum</i> (Hbst.)												Checkerboard			
Helodidae Gen. & spp. Indet.		Diagonal			Checkerboard	Diagonal				Diagonal		Checkerboard			
<b>Saltmarsh and Coastal Species</b>															
<i>Dyschirius aeneus</i> (Dej.)															
<i>Dyschirius salinus</i> Schaum															
<i>Bembidion varium</i> (Ol.)		Diagonal								Diagonal		Diagonal			Diagonal
<i>B. fumigatum</i> (Duft.)													Black		
<i>B. assimile</i> Gyll.										Checkerboard					
<i>Bembidion minimum</i> (F.)			Diagonal							Diagonal		Diagonal			
<i>Bembidion iricolor</i> Bedel															
<i>Pogonus chalceus</i> (Marsh.)				Diagonal											Diagonal
<i>Dicheirotichus gustavi</i> Crotch.															
<i>Sterolophus skrimshiranius</i> Steph.															
<i>Agonum viduum</i> (Panz.)															
<i>Cercyon littoralis</i> (Gyll.)															
<i>C. depressus</i> Steph.		Checkerboard	Diagonal												
<i>Omalius laeviusculum</i> Gyll.															
<i>Bledius spectabilis</i> Kr.															
<i>B. occidentalis</i> Bondr.															
<i>Heterocerus flexuosus</i> Steph.															
<i>Heterocerus fossor</i> Kiesw.															
<i>Heterocerus fossor</i> Kiesw. or <i>H. flexuosus</i> Steph.				Diagonal											
<i>H. ?obsoletus</i> Curt.															
<i>H. maritimus</i> Guer spp.															Checkerboard
<b>Saline water</b>															
<i>Ochthebius dilatatus</i> Steph.															
<i>Ochthebius marinus</i> (Payk.)		Checkerboard	Black				Checkerboard	Checkerboard					Black	Checkerboard	Diagonal
<i>O. viridis</i> Peyrhhf.				Diagonal			Diagonal								
<b>Moorland</b>															
<i>Bradycellus ruficollis</i> (Steph.)			Checkerboard	Diagonal									Checkerboard		
<i>Hydroporus melanarius</i> Strum.								Diagonal					Diagonal		
<i>Plateumaris discolor</i> (Panz.)															
<i>Haltica c.f. ericeti</i> allard															
<i>Micrelus ericae</i> (Gyll.)			Diagonal									Checkerboard	Checkerboard		
<b>Fast flowing freshwater</b>															
<i>Stictotarsus duodecimpustulatus</i> (F.)															
<i>Potamonectes depressus</i> (F.)															
<i>Orectochilus villosus</i> (Müll.)															Diagonal
<i>Elmis aenea</i> (Müll.)															

	Springhead	Goldcliff Building 1	Goldcliff Building 6	Goldcliff Building 8	Goldcliff Trackway 4	Goldcliff Trackway 6	Goldcliff Trackway 1130	Goldcliff Trackway 1330	Goldcliff Trackway 1311	Goldcliff Trackway 1108	Redwick Building 4	Redwick Building 2	Cold Harbour PIII	Walpole Channels	Caldicot
<i>Oulimnius</i> spp.															
<i>Riolus</i> spp.															
<i>Limnius volckmari</i> (Panz.)															
<i>Normandia nitens</i> (P. Müller)															

	Waterside / freshwater marsh														
<i>B. semipunctatum</i> (Donv.)															
<i>A. thoreyi</i> Dej.															
<i>Odacantha melanura</i> (L.)															
<i>Dromius linearis</i> (Ol.)															
<i>Cercyon tristis</i> (Ill.)															
<i>Cercyon convexiusculus</i> Steph.															
<i>L. heeri</i> (Fauv.)															
<i>Lesteva longelytrata</i> (Goeze)															
<i>Platystethus cornutus</i> (Grav.)															
<i>Paederus</i> spp.															
<i>Silis ruficollis</i> (F.)															
<i>Heterocerus marginatus</i> (F.)															
<i>H. fenestratus</i> (Thunb.)															
<i>Plateumaris braccata</i> (Scop.)															
<i>Plateumaris sericea</i> (L.)															
<i>Bagous</i> spp.															
<i>Notaris</i> spp.															
<i>Thyrogenes</i> spp.															
<i>Limnobaris pilistriata</i> (Steph.)															
<i>Corylophus cassidoides</i> (Marsh.)															
<i>Dromius longiceps</i> Dej.															

Key to shading:

<5  
 five - ten  
 eleven - 20  
 >20



Table 3. The relative proportions of the various ecological groups for the coleopteran recovered from the saltmarsh archaeological sites

<b>SITES</b> ECOLOGICAL GROUPING	<b>Springhead</b>	<b>Goldcliff Building 1</b>	<b>Goldcliff Building 6</b>	<b>Goldcliff Building 8</b>	<b>Goldcliff Trackway 4</b>	<b>Goldcliff Trackway 6</b>	<b>Goldcliff Trackway 1130</b>	<b>Goldcliff Trackway 1330</b>	<b>Goldcliff Trackway 1311</b>	<b>Goldcliff Trackway 1108</b>	<b>Redwick Building 2</b>	<b>Redwick Building 4</b>	<b>Cold Harbour Pill</b>	<b>Walpole</b>	<b>Caldicot</b>
<b>saline water</b>	0.9%	1.3%	10.3%	15.2%	0.0%	0.0%	3.1%	16.0%	6.5%	9.9%	0.5%	0.0%	5.7%	23.1%	1.0%
<b>coastal species</b>	1.9%	0.5%	7.7%	10.0%	0.0%	0.0%	7.0%	17.7%	22.2%	9.1%	5.5%	9.2%	11.9%	30.3%	4.8%
<b>freshwater</b>	20.4%	6.1%	17.8%	26.7%	45.4%	58.4%	54.4%	40.7%	37.0%	26.4%	15.9%	9.1%	5.2%	3.8%	27.5%
<b>acid water</b>	0.0%	0.0%	0.2%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
<b>fast-flowing</b>	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	24.2%
<b>waterside species</b>	13.3%	7.4%	3.9%	3.3%	29.3%	18.9%	13.3%	4.9%	6.5%	6.6%	6.4%	7.3%	7.5%	9.4%	6.7%
<b>dung fauna</b>	6.2%	1.0%	9.2%	3.2%	8.8%	1.5%	4.7%	3.2%	3.7%	2.4%	4.6%	7.1%	6.3%	0.0%	7.2%
<b>moorland</b>	0.0%	0.0%	2.8%	6.8%	0.0%	0.0%	0.0%	1.6%	3.7%	0.0%	19.3%	10.9%	3.3%	0.0%	0.0%
<b>house fauna</b>	8.8%	20.7%	11.3%	7.8%	1.7%	3.1%	2.3%	6.5%	0.0%	10.6%	3.3%	0.0%	0.5%	0.0%	0.3%

Table 4. Summary of the main differences between the faunas investigated and an interpretation of where the sites may lie in the saltmarsh environment

Springhead and Caldicot	Particularly Indicative taxa	% and (range) of saltmarsh and coastal	% other ecological grouping	Tidal River or stream channel
Wide range of species from watersides and reed bed	<i>Odacantha melanura</i> , <i>Dromius linearis</i> , range of Dytiscidae, <i>Gyrinus</i> spp., <b>Hydrophilidae</b> , <b>Ochthebius minimus</b> , <b>O. bicolon</b> , <i>Platystethus cornutus</i> , <b>Paederus</b> spp., <b>Helodidae</b> , freshwater <b>Heteroceris</b> spp., <i>Plateumaris braccata</i> , <i>P. sericea</i> , <i>Bagous</i> spp., <i>Thyrogenes</i> spp., <b>Notaris</b> spp.		Aquatic: Springhead 20.4% Caldicot 27.5% Waterside: Springhead 13.3% Caldicot 6.2%	
Limited coastal and salt water faunas (saline tolerant rather than strongly halophilic, water beetles associated with temporary saline pools).	<b>Bembidion varium</b> , <i>B. iricolor</i> , <b>B. fumigatum</b> , <i>B. assimile</i> , <b>Pogonus chalceus</b> , <b>Ochthebius dilatatus</b> , <b>O. marinus</b>	Coastal: Springhead 1.9% (0.0-5.0) Caldicot 4.8% Saline: Springhead 0.9% (0.0-2.9) Caldicot 1.0%		
Moderate to large number of individuals associated with fast flowing water	<i>Stictotarsus duodecimpustulatus</i> , <b>Potamonectes depressus</b> , <b>Orectochilus villosus</b> , <b>Elmis aenea</b> , <b>Oulimnius</b> spp. <i>Limnius volckmari</i> , <i>Normandia nitens</i>		Fast flowing: Springhead: 1.0% Caldicot 24.2%	
Limited dung and house faunas	<i>Geotrupes</i> and <i>Aphodius</i> species. <i>Lyctus linearis</i> , <i>Atomaria</i> spp., <i>Lathridius minutus</i> , <i>Ptinus fur</i>		Dung fauna: Springhead 6.2% Caldicot 7.2% House fauna: springhead 8.6%	
<b>Goldcliff Trackways 4, 6</b>				<b>Freshwater marsh in slack at back of saltmarsh</b>
Dominated by freshwater and waterside species mainly associated with <i>Phragmites</i> reed bed	<b>Bembidion semipunctatum</b> , <i>Agonum thoreyi</i> , <i>Odacantha melanura</i> , <i>Dromius longiceps</i> , <i>Hygrotus inaequalis</i> , <i>H. scalesianus</i> , <b>Ochthebius bicolon</b> , <b>O. minimus</b> , <b>Hydrophilidae</b> , <b>Paederus</b> spp., <b>Cyphon</b> spp. <i>Plateumaris braccata</i> , <i>Notaris</i> spp.		Aquatic: Trackway 4 45.0% Trackway 5 58.4% Waterside: Trackway 4 29.0% Trackway 6 18.9%	
No saltmarsh species, Limited dung fauna, limited house fauna	<i>Aphodius</i> species.		Dung fauna: Trackway 4 8.8% Trackway 6 1.5%	
<b>Cold Harbour Pill and Redwick Building 4 and 2</b>				<b>Upper Saltmarsh</b>
Moderate numbers of a wide range of freshwater and waterside species (less evidence for thick stands of reeds)	<i>Odacantha melanura</i> , <b>Graptodytes granularis</b> , <i>Gyrinus</i> spp., <b>Ochthebius minimus</b> , <b>Coelostoma orbiculare</b> , Aquatic <i>Ceryon</i> , <i>Chaetarthria seminulum</i> , <i>Lesteva heeri</i> , <i>Platystethus cornutus</i> , <b>Helodidae</b> , <b>Corylophus cassidoides</b> , <i>Plateumaris braccata</i>		Aquatic: Redwick 2 15.9% Redwick 4 9.1% Cold H P 5.2% Waterside: Redwick 2 6.4% Redwick 4 7.3% Cold HP 7.5%	
Moderate numbers of coastal species; a few species associated with salt water (but no species associated with open saline mud)	<b>Bembidion varium</b> , <b>B. fumigatum</b> , <i>B. assimile</i> , <b>B. minimum</b> , <i>Pogonus chalceus</i> , <b>Ochthebius dilatatus</b> , <b>O. viridis</b> .	Saline: Redwick 2 0.5% (0.0-1.9%) Redwick 4 0.0% Cold HP 5.7% (0.0-8.6%) Coastal: Redwick 2 5.5% (3.7-10.6%) Redwick 4 9.2% (5.2-18.5%) Cold HP 11.9% (0.0-22.8%)		
Moderate moorland bog Limited dung fauna Small house fauna	<b>Bradycellus ruficollis</b> , <i>Hydroporus melanarius</i> , <b>Micrelus ericae</b> <i>Geotrupes</i> spp. <i>Aphodius</i> spp. <i>Atomaria</i> spp.		Moorland: Redwick 2 19.3% Redwick 4 10.9% Cold HP 3.3% Dung: Redwick 2 4.6% Redwick 4 7.1% Cold H P 6.3% House: Redwick 2 3.3% Redwick 4 0.0% Cold HP 0.5%	
<b>Goldcliff Buildings 1, 6, 8, Trackways 1130, 1330, 1311, 1108 and Walpole</b>				<b>Low saltmarsh and mud flats</b>
Dominated by a wide range of coastal species, saline waters and species associated with open saline mud	<i>Dyschirius aeneus</i> , <i>D. salinus</i> , <b>Bembidion varium</b> , <i>B. fumigatum</i> <i>B. assimile</i> , <b>B. minimum</b> , <b>Pogonus chalceus</b> , <b>Dicheirotrichus gustavi</b> , <b>Ochthebius dilatatus</b> , <b>O. marinus</b> , <b>O. viridis</b> , <i>Ceryon litoralis</i> , <b>C. depressus</b> , <i>Bledius spectabilis</i> , <i>B. occidentalis</i> , <b>Heteroceris fossor</b> , <b>H. flexuosus</b> , <i>H. maritimus</i> .	Saline: Goldcliff B1 1.3% (0.0-6.1%) Goldcliff B6 10.3% (1.4-14.9%) Goldcliff B8 15.2% (0.0-26.9%) Trackway 1130 3.1% (2.7-7.5%) Trackways 1330 1.6% Trackways 1311 6.5%		

		Trackways 1108 9.9% (1.7-13.6%) Walpole 23.1% (6.6-34.4%) Coastal:Goldcliff B1 0.5% (0.0-7.1%) Goldcliff B6 7.7% (0.0-12.0%) Goldcliff B8 10.0% (0.0-16.3%) Trackway 1130 7.0% (3.1-7.5%) Trackways 1330 17.7% Trackways 1311 22.2% Trackways 1108 9.1% (7.1-12.7%) Walpole 30.3% (29.4-50%)		
Moderate proportions of a diverse range of freshwater fauna	<i>Odacantha melanura</i> , <i>Dromius longiceps</i> , <i>Hygrotus inaequalis</i> , <b>H. tessellatus</b> , <i>H. scalesianus</i> , <b>Ochthebius minimus</b> , <b>O. bicolon</b> , various <b>Hydrophilidae</b> , <i>Platystethus cornutus</i> , <b>Paederus spp.</b> , <i>Silis ruficornis</i> , <b>Helodidae</b> , <i>Heterocerus fenestratus</i> , <b>Plateumaris braccata</b> , <b>P. sericea</b> , <i>Bagous</i> spp., <i>Notaris</i> spp., <i>Thyrogenes</i> spp., <i>Limnobaris pilistriata</i> , <b>Corylophus cassidoides</b> .		Aquatic: Goldcliff B1 6.1% Goldcliff B6 17.8% Goldcliff B8 26.7% Trackway 1130 54.4% Trackways 1330 40.7% Trackways 1311 37.0% Trackways 1108 26.4% Walpole 3.8% Waterside:Goldcliff B1 7.4% Goldcliff B6 3.9% Goldcliff B8 3.3% Trackway 1130 13.3% Trackways 1330 4.9% Trackways 1311 6.5% Trackways 1108 6.6% Walpole 9.4%	
Moderate proportions of a limited range of Moorland species  Moderate proportions of a wide range of dung beetles  Large number of individuals of a range of house fauna particularly in the buildings at Goldcliff	<b>Bradycellus ruficollis</b> , <b>Hydroporus melanarius</b> , <i>Plateumaris discolor</i> , <b>Micrelus ericae</b>  <i>Geotrupes</i> spp., <i>Onthophagus</i> spp., <i>Aphodius erraticus</i> , <i>A. contaminatus</i> , <b>A. sphaelatus</b> , <b>A. prodromus</b> , <i>A. fimetarius</i> , <i>A. ater</i> , <i>A. plagiatus</i> , <b>A. granarius</b> .  <b>Anobium punctatum</b> , <i>Typhaea stercorea</i> , <i>Cryptophagus</i> spp., <i>Lathridius minutus</i> (group), <i>Atomaria</i> , <i>Ptinus fur</i> .		Moorland: Goldcliff B1 0.0% Goldcliff B6 2.8% Goldcliff B8 6.8% Trackway 1130 0.0% Trackways 1330 1.6% Trackways 1311 3.7% Trackways 1108 0.0% Walpole 0.0% Dung: Goldcliff B1 1.0% Goldcliff B6 9.2% Goldcliff B8 3.2% Trackway 1130 4.7% Trackways 1330 3.2% Trackways 1311 3.7% Trackways 1108 2.4% Walpole 0.0% Dung: Goldcliff B1 20.7% Goldcliff B6 11.3% Goldcliff B8 7.8% Trackway 1130 2.3% Trackways 1330 6.5% Trackways 1311 0.0% Trackways 1108 10.6% Walpole 0.0%	

Figure 1. Typical zonation in saltmarshes

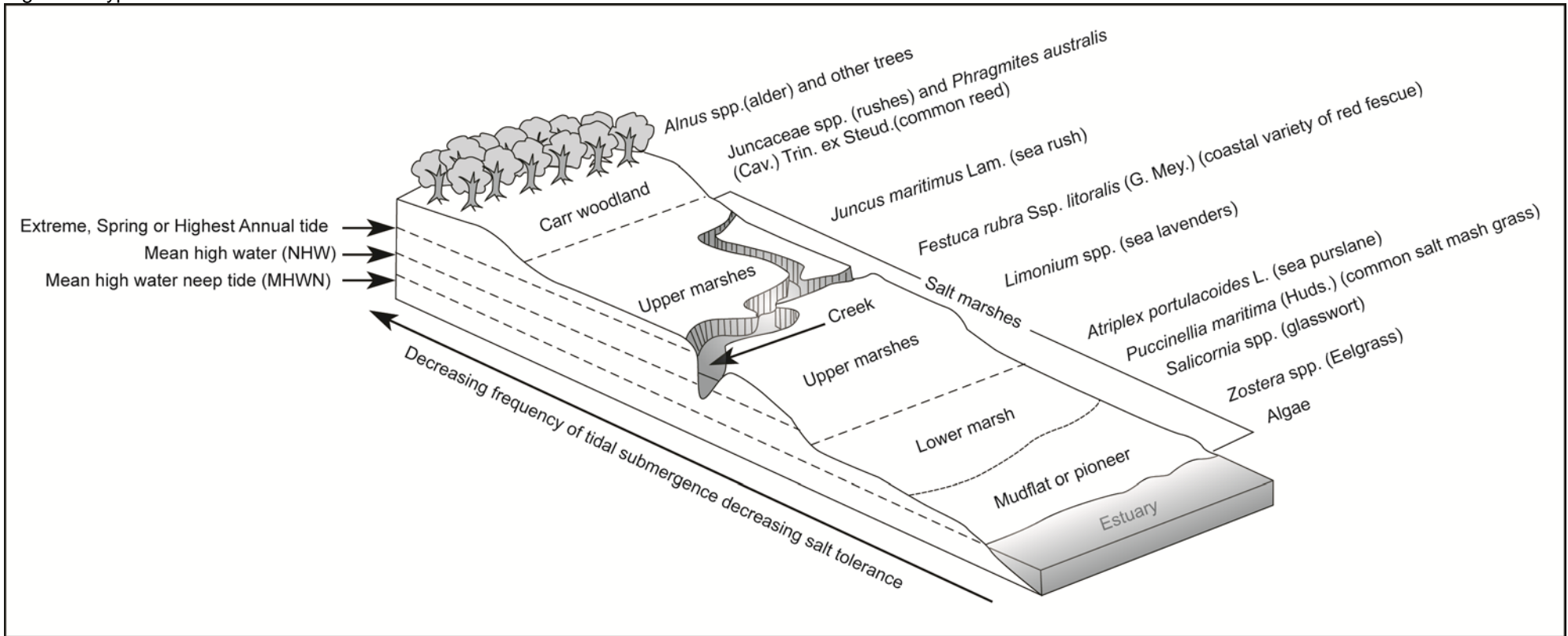


Figure 2. Location of the sites discussed

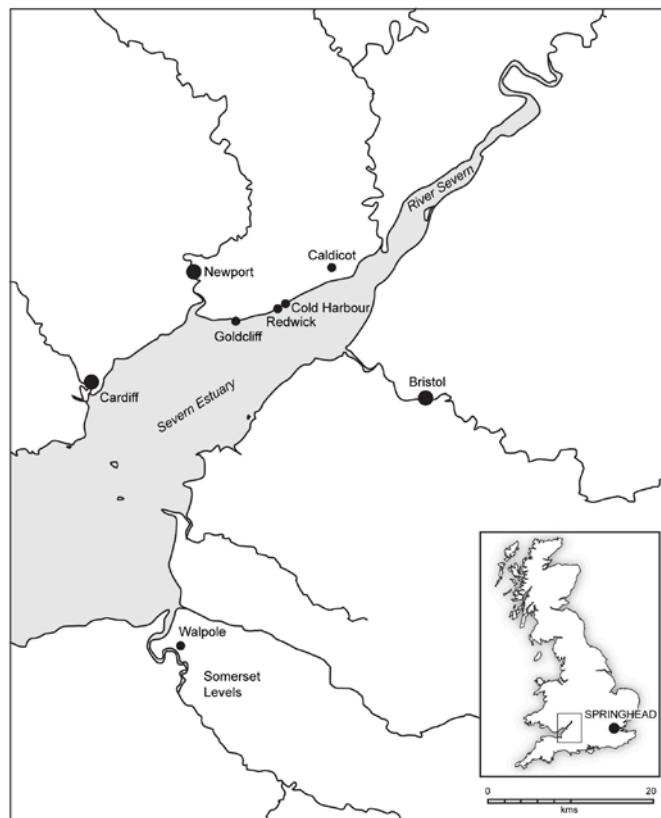


Figure 3. The relative proportions of the saltmarsh and coastal ecological groupings

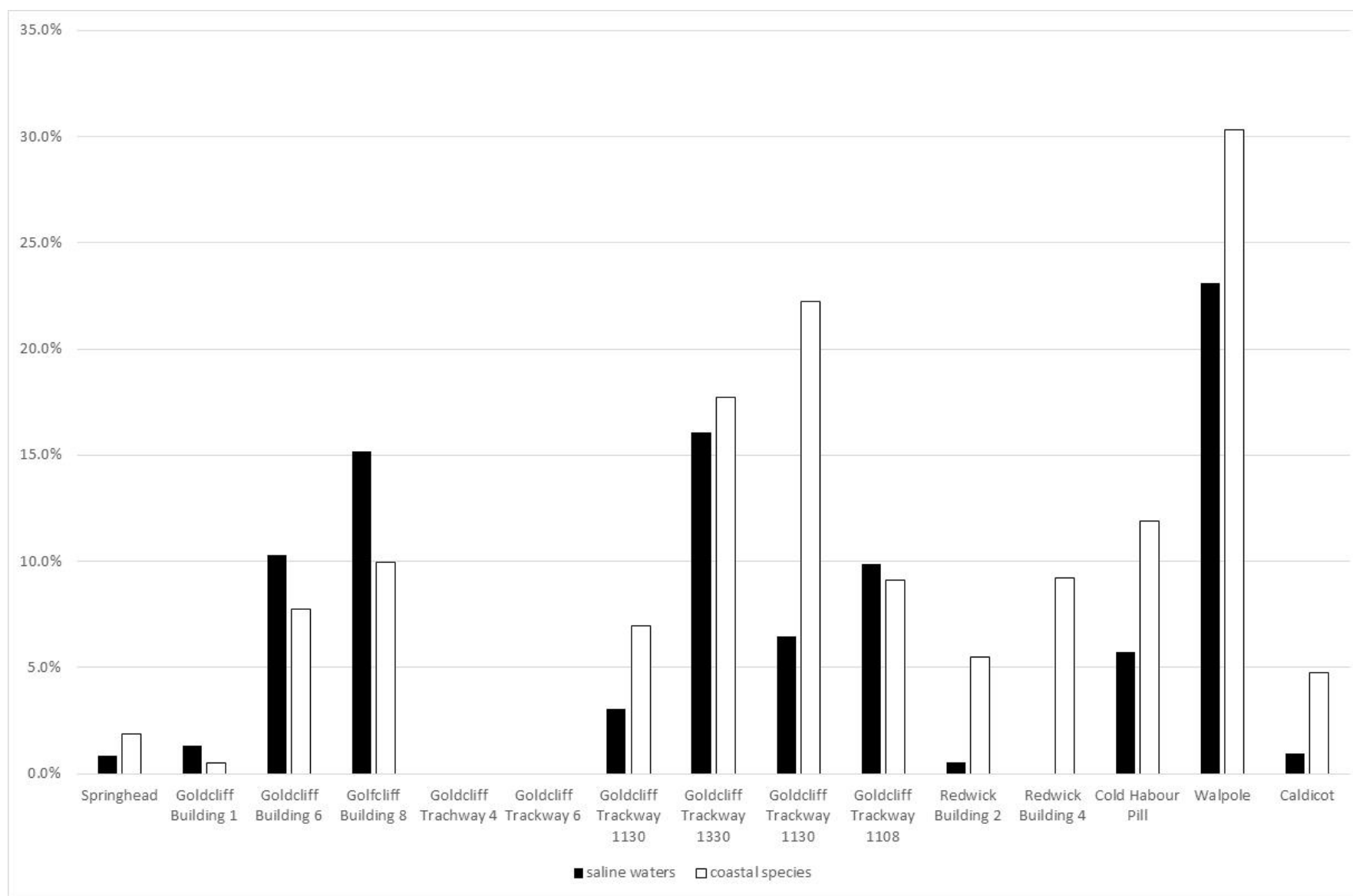




Figure 4. The relative proportions of the non-saline water ecological groupings

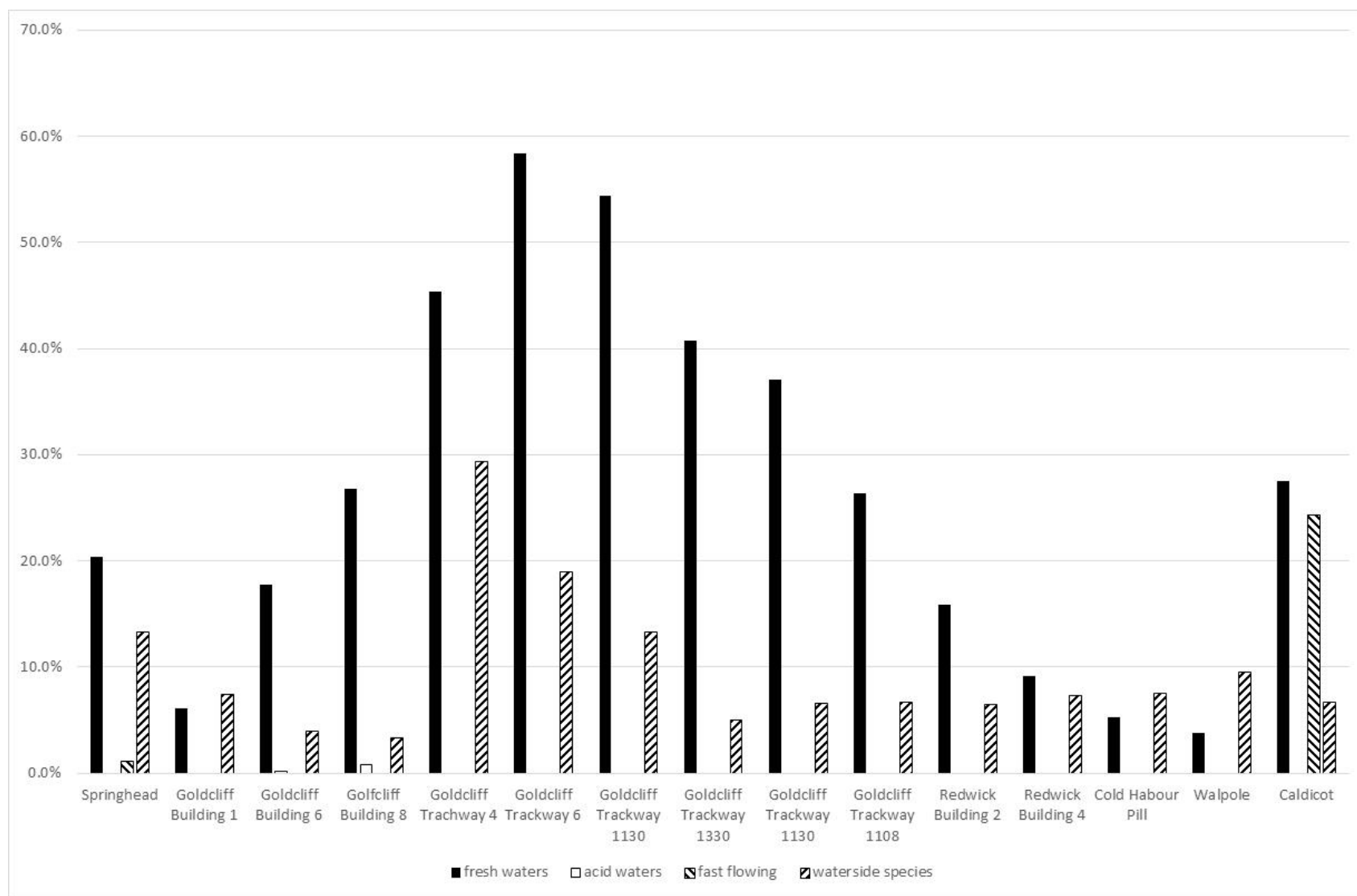


Figure 5. The relative proportions of the terrestrial ecological groups

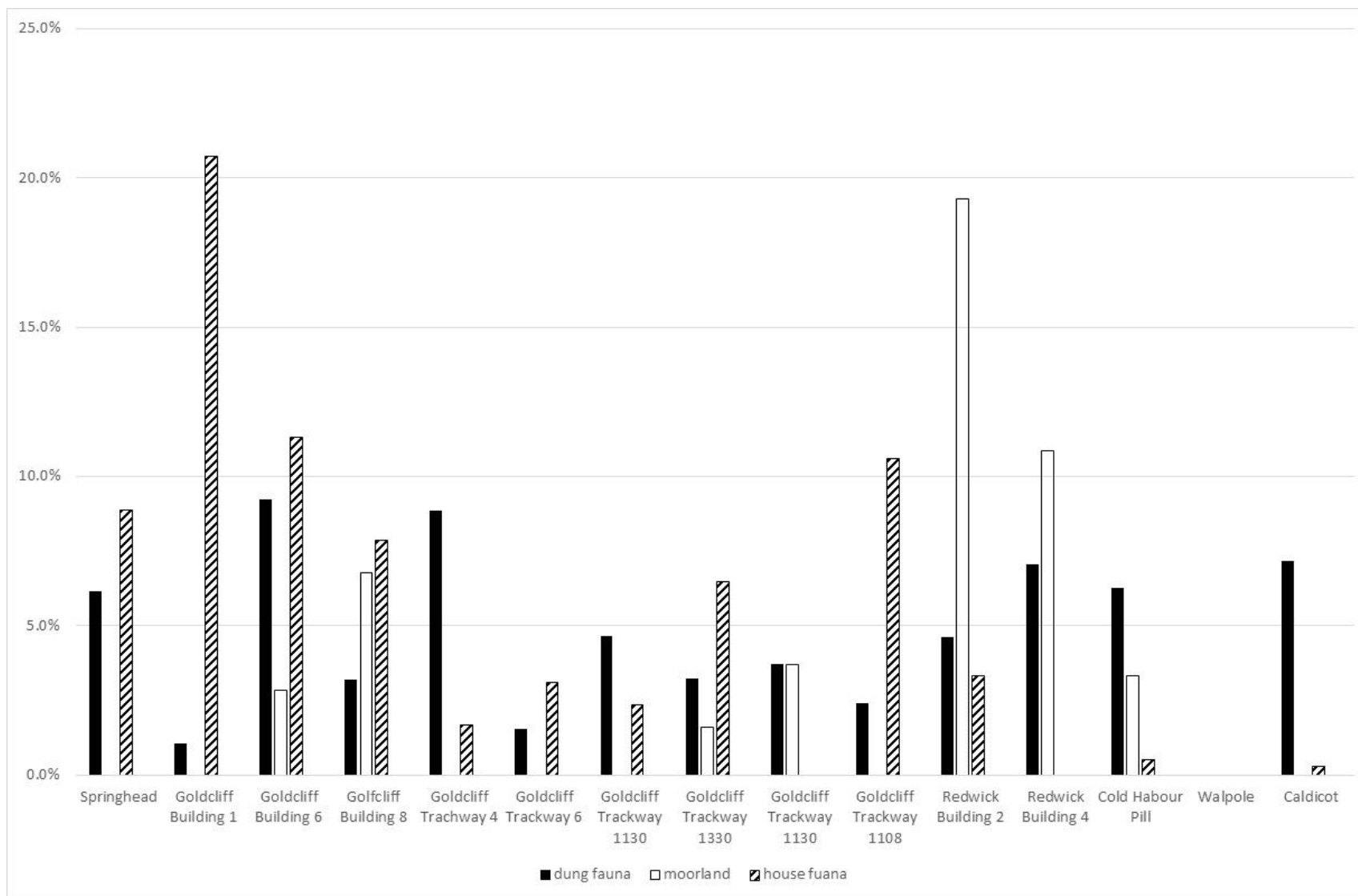
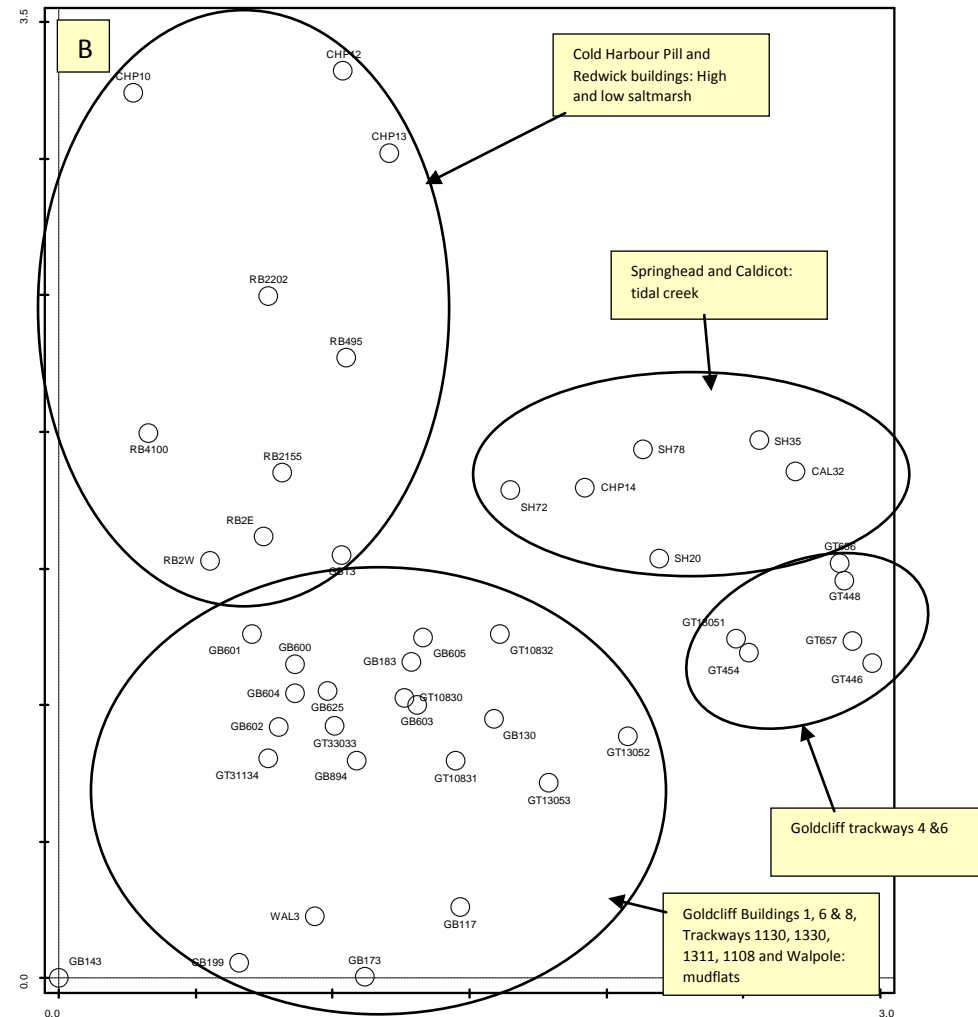
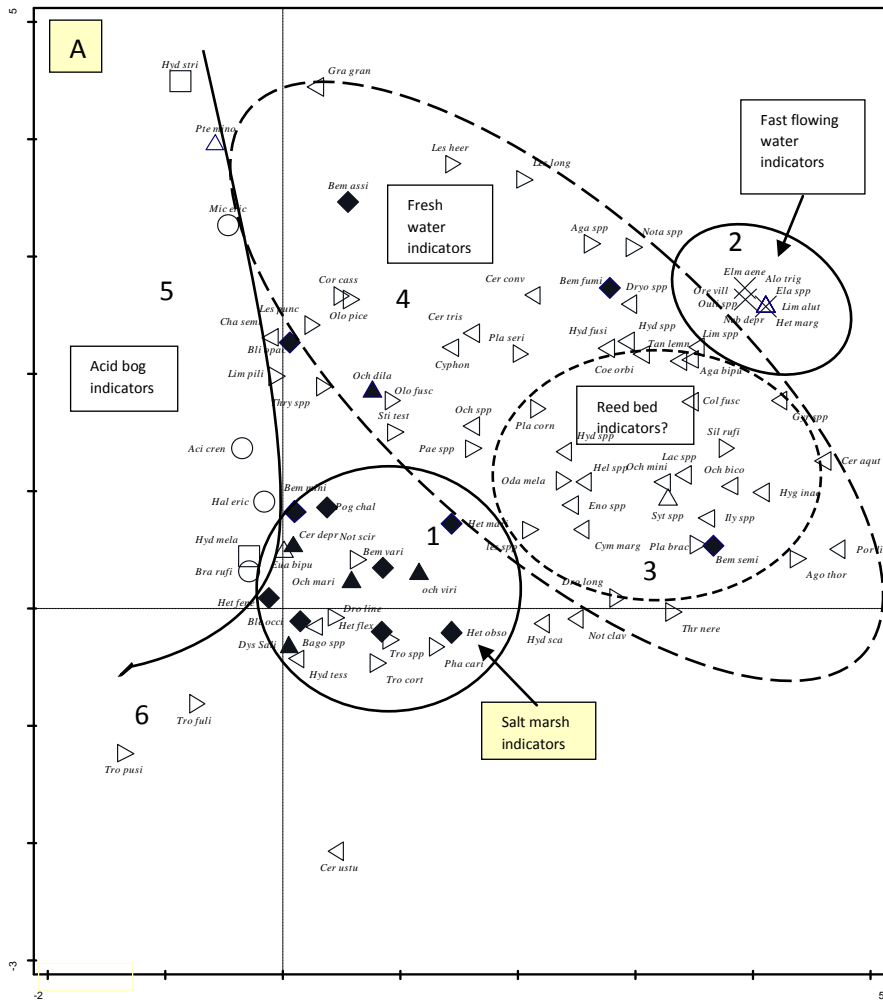


Figure 6: The CANOCO DCA ordinations. Figure 6a is the ordination by species. Figure 6b is the ordination by sample.



- ◁ = 1. Freshwater aquatics ('a' group)
- X = 2. Fast flowing waters ('aff' group)
- ◻ = 3. Acidic waters ('aw' group)
- ▷ = 4. Watersides and reed bed ('ws' group)
- ▲ = 5. Saline waters ('sw' group)
- ◆ = 6. Coastal terrestrial ('c' group)
- = 7. species from moorland ('m' group)

