A comparison of the dune slack invertebrate faunas of Newborough Warren, Morfa Dyffryn and Morfa Harlech in 2015

R.G. Loxton

NRW Evidence Report No. 264

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Contents

1. Crynodeb Gweithredol ……………………………………………………………………..1

2. Executive Summary ………………………………………………………………………..3

3. Introduction ………………………………………………………………….......................5

4. Methods ………………………………………………………………………………………..8
    4.1 Pitfall trapping………………………………………………………………………………8
    4.2 Description of pitfall sites……………………………………………………………...13
    4.3 Principal Components Analysis (PCA) of pitfall samples…………………………15
    4.4 Taxonomic problems……………………………………………………………………..16

5. Results…………………………………………………………………………………………..17
    5.1 Principal Components Analysis (PCA) of pitfall samples…………………………17
    5.2 Observations of *Cicindela maritima*…………………………..……………………...25
    5.3 Observations of *Bledius fergussoni* and *B. subniger*………………………………28
    5.4 Some noteworthy species………………………………………………………………36

6. Discussion ……………………………………………………………..............................38

7. Conclusions……………………………………………………………………………………44

8. Acknowledgements ……………………………………………………………………………45

9. References …………………………………………………………….............................45

10. Appendices
    10.1 Principal Components Analysis (PCA) of pitfall samples (Figures 4 to 31)…….46
    10.2 Bi-plot Ordinations of Pitfall Trapping Data……………………………………..89
    10.3 Images of Morfa Dyffryn, Morfa Harlech and Newborough Warren ……………97
    10.4 Five letter abbreviations of species names …………………………………..103
    10.5 Data Archive Appendix……………………………………………………………..112

List of Figures

Figure 1. Location of Pitfall Sites at Morfa Dyffryn ……………………………..……………10
Figure 2. Location of Pitfall Sites at Morfa Harlech …………………………….................11
Figure 3. Location of Pitfall Sites at Newborough Warren…………………….................12
Figure 32. Distribution of larval burrows of *Cicindela maritima* at Morfa Dyffryn
in the summer of 2015..27
Figure 33. Distribution of *Cicindela maritima* larval burrows across Pioneer Slack 3............28
Figure 34. Distribution of *Bledius fergussoni* on Morfa Dyffryn dunes with Pioneer
Slack habitat recorded by Boyce 2015 30
Figure 35. Distribution of *Bledius subniger* colonies in Cefni Estuary, Newborough.............31
Figure 36. Distribution of *Bledius subniger* colonies in the Braint Estuary, Newborough…...32
Figure 37. Distribution of *Bledius fergussoni* colonies in the Artro Estuary, Morfa Dyffryn....33
Figure 38. Distribution of *Bledius fergussoni* colony at Morfa Harlech 34
Figure 39. Diatoms from gut of *Bledius fergussoni*...35

List of Tables

Table A. Pioneer dune slack invertebrates in the UK as identified by Natural Resources Wales……………………………………………………………………………………..6
Table 1. Distribution of size of samples..13
Table 2. Distribution of numbers of beetles caught...13
Table 3. Numbers of individual species trapped in an excavated slack behind the tide line, Newborough, 12th – 14th 2015 29
Table 4. Pioneer dune slack species recorded at Newborough, Dyffryn and Harlech...........40
Table 5. Pioneer dune slack beetle species as identified by NRW and other beetle species attributed to pioneer slack, post-pioneer slacks and/or other habitats as a result of the current survey……………………………………………………………………43

1. Crynodeb Gweithredol

Yn dilyn gwaith rheoli ar Warchodfa Natur Genedlaethol Cwningar Niwbwrch yn 2013 i greu llaciau twyni a chynefinoedd olyniaethol cynnar arloesol, roedd arolygon infertebratau wedi dangos gwasgariad/gwladychiad cyflym gan saith o 16 o rywogaethau chwilod y mae Cyfoeth Naturiol Cymru yn ystyried bod angen yr amodau hyn arnynt. Rhoddodd cloddiadau ychwanegol ym mis Mawrth 2015 gyfle i ddod o hyd i ba mor gyflym y digwyddodd y gwladychu hwn. O fewn deufis, cofnodwyd tair chwilen llaciau twyni arloesol - *Bembidion pallidipenne*, *Bledius subniger* a *Dyschirius politus* - mewn pydewau maglu a osodwyd yn yr ardal hon, yr oedd pob un eisoes wedi bod yn anodd ei lleoli ar y system dwyni. Oherwydd y tybiwyd bod tarddiad ffawna gwladychu'r slaciau cloddedig yn yr aberoedd i'r gogledd ac i'r de o Gwningar Niwbwrch, ymgymerwyd ag arolygon ar gyfer chwilod *Bledius* yn aberoedd Cefni a Braint gan fapio'r olion a welwyd oherwydd eu gweithgareddau. Ymgymerwyd ag arolygon tebyg ar hyd afon Artro ym Morfa Dyffryn ac yn aberoedd Glaslyn a Dwyryd i'r gogledd o Forfa Harlech. Dangoswyd bod y nythfeydd *Bledius* yn digwydd mewn ardaloedd cyfyngedig ac ymddengys eu bod yn gysylltiedig â thywod newydd a ddyddodwyd oherwydd y gwynt a'r glaw ac â chynnwys organig isel. Gwelwyd digonedd o ddiatomau yng ngholuddion y chwilod *Bledius*.

Mae cynefinoedd slaciau arloesol yn brin ar holl systemau twyni Cymru ar wahân i Forfa Dyffryn lle mae twyni symudol â thywod sy'n symud yn helpu i greu slaciau arloesol wrth i donnau o dywod symud o flaen y gwynt trechol. Roedd yr arolwg hwn o 2015 yn cymharu ffawna infertebratau'r slaciau naturiol hyn â'r slaciau artiffisial ar Gwningar Niwbwrch. Achubwyd ar y cyfle hefyd i ystyried sampl o ddau slac ar Forfa Harlech, slac llawn llystyfiant ar Forfa Dyffryn a dau slac heb eu cloddio ar Gwningar Niwbwrch. Gwnaed yr arolwg ar 20 o safleoedd â phum pydew magl ym mhob un ac roedd y set ddata gyfan yn cynnwys 100,205 o infertebratau unigol wedi'u lledaenu ar draws 505 o rywogaethau. Roedd y tacsonau a ddefnyddiwyd yn yr arolwg hwn yn cynnwys chwilod, pryfed cop, pryfed medi, miltroediaid, nadroedd cantroed, gwrachod y lludw ac ychydig o bryfed orthopteroid. Mae'r astudiaeth hon wedi rhannu diffiniad blaenorol o slaciau arloesol ar Forfa Dyffryn yn slaciau arloesol (llaith, bron yn foel, tywod melyn ar waelod twyn sy'n erydu) a slaciau ôl-arloesol (sy'n mynd yn erbyn y gwynt o slaciau arloesol ac sy'n cynnwys mwy o lystyfiant, gyda thywod moel a chramen ddu). Er bod tueddiadau gyda phydewau maglu a rhai cyfyngiadau ar ddod i gasgliadau o ddadansoddiadau, archwiliwyd data pydewau maglu gan Ddadansoddiad o'r Prif Gydrannau (PCA) ar ôl rhannu'r data'n 13 is-set yn seiliedig ar grwpiau tacsonomig. Aseswyd gorchuddiad tir y llystyfiant yn y tri slac y tynnwyd samplau ohonynt ar Forfa Dyffryn i benderfynu ar y gwahaniaethau rhwng y slaciau arloesol a'r slaciau ôl-arloesol, gyda'r PCA yn eu gwahanu'n ddau glwstwr amlwg. Mae'r dadansoddiad hefyd yn grwpio'r slaciau wedi'u cloddio ar Gwningar Niwbwrch yn agos at slac arloesol Morfa Dyffryn. Mae hyn yn arbennig o amlwg lle mae'r set ddata'n cael ei chyflwyno ar ffurf histogramau nifer y rhywogaethau a ddewiswyd ar draws 20 o safleoedd.

Mae dadansoddiad o'r 16 o rywogaethau chwilod y mae Cyfoeth Naturiol Cymru'n eu hystyried yn gysylltiedig â slaciau arloesol, gan ddefnyddio gwybodaeth o'r astudiaeth hon a ffynonellau eraill (llenyddiaeth gyhoeddedig, cofnodion rhywogaethau yn yr Atlas NBN) yn awgrymu bod sawl un ohonynt yn aml, os nad bob tro'n gysylltiedig â'r cynefin slaciau ôl-arloesol. Mae'r ffawna chwilod slaciau arloesol yn fwy cyfyngedig i bedair rhywogaeth - *Bembidion pallidipenne, Bledius fergussoni, Bledius subniger* a *Dyschirius politus* - y deuir o hyd iddynt hefyd yn y cynefin aberol ar ymyl y morfa heli.

Yn ôl arolwg bach o chwilen deigr y coed, *Cicindela maritima,* gwelwyd ei bod yn bridio mewn niferoedd yn nhywod llaith y slaciau arloesol ym Morfa Dyffryn. Mae rhestr o'r rhywogaethau mwy nodedig sydd i'w gweld yn yr arolwg hwn wedi'i chynnwys.

2. Executive Summary

Following management works on Newborough Warren National Nature Reserve in 2013 to create pioneer dune slacks and other early-successional habitats, invertebrate surveys had demonstrated a rapid dispersal/colonisation by seven of sixteen beetle species which Natural Resources Wales regards as requiring these conditions. Additional excavations in March 2015 provided an opportunity to find how quickly this colonisation occurred. Within two months, three pioneer dune slack beetles – *Bembidion pallidipenne*, *Bledius subniger* and *Dyschirius politus* – were recorded in pitfall traps set in this area, all of which had previously been difficult to locate on the dune system. As it was suspected that the colonising fauna of the excavated slacks had its origin in the estuaries to the north and south of Newborough Warren, surveys for *Bledius* beetles were undertaken in the Cefni and Braint estuaries by mapping the casts thrown up by their activities. Similar surveys were undertaken along the Afon Artro at Morfa Dyffryn and the Glaslyn and Dwyryd estuaries north of Morfa Harlech. It revealed that the *Bledius* colonies occurred in limited areas and seemed to be associated with sand newly deposited by wind or water and of a low organic content. Diatoms were found abundantly in the intestines of the *Bledius* beetles.

Pioneer slack habitat is at a premium on all Welsh dune systems other than Morfa Dyffryn where mobile dunes with drifting sand help to create pioneer slack as waves of sand move in front of the prevailing wind. This 2015 survey compared the invertebrate faunas of these naturally-occurring slacks with the artificially-engineered slacks on Newborough Warren. The opportunity was also taken to sample two slacks on Morfa Harlech, a well-vegetated slack on Morfa Dyffryn and two unexcavated slacks on Newborough Warren. The survey was made at 20 sites with five pitfall traps at each and the total data set consisted of 100,205 individual invertebrates spread across 505 species. The taxa used in this survey consisted of beetles, spiders, harvesters, millipedes, centipedes, woodlice and a few orthopteroid insects. This study has divided a previous definition of pioneer slack on Morfa Dyffryn into pioneer slack (damp, almost bare, yellow sand at the foot of an eroding dune) and post-pioneer slack (upwind of pioneer slacks and more vegetated, with bare sand having a black crust). Whilst there are biases with pitfall trapping and some limitations on drawing conclusions from analyses, pitfall data was examined by Principal Components Analysis (PCA) after splitting the data into 13 sub-sets based on taxonomic groupings. The ground cover of the vegetation was assessed in the three slacks sampled on Morfa Dyffryn to determine the differences between pioneer and post-pioneer slacks, with PCA separating them into two distinct clusters. The analysis also groups the excavated slacks on Newborough Warren close to the Morfa Dyffryn pioneer slack. This is particularly so where the data set is presented in the form of histograms of the numbers of selected species across the 20 sites.

An analysis of the sixteen beetle species regarded by NRW as being associated with pioneer slacks, using information from this study and other sources (published literature, species records in the NBN Atlas) suggests that several are often if not exclusively associated with the post-pioneer slack habitat. The pioneer slack beetle

fauna is more properly restricted to four species - *Bembidion pallidipenne, Bledius fergussoni, Bledius subniger* and *Dyschirius politus* – which are also found in the estuarine habitat at the edge of the salt marsh.

A small survey of the tiger beetle *Cicindela maritima* found it breeding in numbers in the damp sand of the pioneer slacks at Morfa Dyffryn. A list of the more noteworthy species found in this survey is included.

3. Introduction

Welsh sand dunes systems have become increasingly stable since the 1940s, with an almost 90% loss (1600ha) of pioneer habitats including bare sand, sparsely-vegetated ground and pioneer dune slacks to more vegetated conditions such as fixed dune grassland and mature slacks (Howe *et al*., 2012; Pye & Blott, 2012; Pye *et al*., 2014). This is having a significant impact on habitats and species of national and international importance (Howe *et al*., 2012). At Newborough Warren, 51% of the blown sand area comprised bare sand in the 1940s compared with 3% in 2009 (Pye & Blott, 2012), and pioneer dune-slack habitat is all but absent with remaining areas being small, fragmented and of poor quality (Bratton, 2012). At Morfa Dyffryn and Morfa Harlech, the total dune area, as represented by blown sand, has been reduced by 54% from 1678ha to 771ha, with losses of bare sand of 62% and 72% since the 1940s (Howe *et al*., 2012; Pye & Blott, 2012). The only Welsh dune system retaining a high degree of dynamism is Morfa Dyffryn where large-scale sand movements, both at the dune frontage and within the body of the dune, continually create early-successional conditions. Pioneer habitats currently occupy c.40% of the system, including 19% bare sand and in excess of 5,550m^2 of pioneer dune slack (Boyce, 2015). In an attempt to both produce more dynamic conditions and provide pioneer habitats, two mature dune slacks c.800m inland and an artificial pond area were excavated down to bare sand on Newborough Warren in March 2013 by the Countryside Council for Wales. Turf was skimmed off at the windward end of the slacks and the parabolic dune face was also cleared of vegetation. More extensive excavations at the dune frontage were undertaken by Natural Resources Wales in March 2015.

Pioneer dune slacks have been defined by Boyce (2015) as "**areas of damp sand, with an obvious algal crust showing as a dark stain that predominates over the floor of a shallow depression and amounts to at least 50% cover. In certain situations sparse vegetation of creeping willow, fine-leaved grasses, sedges and rushes may be present but together these account for less than 50% of the area of the depression as defined by the algal crust. Patches of habitat are considered significant if they have one axis a minimum of 5 metres length and the other at least 2 metres in length**". Using this definition, Boyce (2015) recorded 18 patches of pioneer dune slack habitat on NRW-owned land on Morfa Dyffryn, totalling an area of 5,784m^2. Boyce (2015) found that the invertebrate fauna of these slacks was relatively impoverished, with just two of the ten specialists associated with this habitat that have been recorded at Morfa Dyffryn previously (the rove beetles *Bledius fergussoni* and *B. fuscipes*) being found in pioneer slacks in 2011 and 2012. However, three further pioneer slack specialist species, the ground beetle *Dyschirius politus*, the water beetle *Dryops striatellus* and the cranefly *Nephrotoma quadristriata* were also recorded but were more clearly associated with later successional slacks and pond margins. In addition to these five pioneer slack species, a number of other invertebrates of higher conservation status was found in the later successional slacks and pond edges, and these clearly support the most diverse and important slack assemblage at Morfa Dyffryn. However, he emphasized that these later successional communities are reliant upon there being sufficient dynamism in the dune system to carry on 'birthing' early-successional pioneer slacks.

Given the paucity of pioneer slack habitat on Newborough Warren, the definition was relaxed for a similar survey on this dune system (Bratton, 2012) to: "**Damp sand larger than 0.5 x 0.5 metres with at least 25% unvegetated and indicator wetland plant species such as *Equisetum variegatum*, *Hydrocotyle vulgaris* and *Salix repens* present. Sand with a thin covering of bryophytes does not qualify.**"

Natural Resources Wales has identified 34 species of invertebrates which are primarily associated with pioneer dune slacks (Howe *et al*., 2012; Mike Howe, pers. comm.), including 16 species of beetles recorded from Newborough Warren (see Table A). Monitoring of the 2013 excavations on Newborough Warren using pitfall traps and visual searches demonstrated that seven of these beetle species had colonised the damp, exposed sand, namely *B. pallidipenne, B. longulus*, *B. subniger, D. politus, D.nitidulus, G. osseticus and H. flexuosus* (Loxton, 2014, 2015). *B. subniger* was common and easily detected by excavation under the loose cast of sand thrown up by its burrowing, and *B. pallidipenne*, *Dyschirius politus* and *D. impunctipennis* were also abundant. With only *D. nitidulus* and *G. osseticus* recorded from the control Slack 1, in 2013, it is possible that these beetles are colonising the excavated slacks from remnant pockets of suitable habitat within the dune system rather than records representing a legacy of existing populations within the slacks (Loxton, 2015).

Table A. Pioneer dune slack invertebrates in the UK as identified by Natural Resources Wales. These are associated with the sandy & muddy margins of dune pools and shallow streams; wet, bare & sparsely-vegetated sand; bare sand & mud in mature slacks and saltmarsh transitions. NR = Nationally Rare; NS = Nationally Scarce. Species that have been recorded on Newborough Warren and Morfa Dyffryn are highlighted (X).

Species	Order	Family	Status	Newborough Warren	Morfa Dyffryn
Dyschirius politus	Coleoptera	Carabidae	Local	X	X
Dyschirius salinus	Coleoptera	Carabidae	Local	X	X
Dyschirius thoracicus	Coleoptera	Carabidae	Local	X	
Asaphidion pallipes	Coleoptera	Carabidae	NS	X	
Bembidion pallidipenne	Coleoptera	Carabidae	NS	X	X
Bembidion clarki	Coleoptera	Carabidae	NS	X	
Bembidion fumigatum	Coleoptera	Carabidae	NS		
Bledius fergussoni	Coleoptera	Staphylinidae	Local	X	X
Bledius fuscipes	Coleoptera	Staphylinidae		X	X
Bledius longulus	Coleoptera	Staphylinidae	Local	X	X
Bledius opacus	Coleoptera	Staphylinidae	Local	X	X
Bledius subniger	Coleoptera	Staphylinidae	Local	X	
Thinobius brevipennis	Coleoptera	Staphylinidae	NR	X	
Gabrius osseticus	Coleoptera	Staphylinidae	NS	X	X

Heterocerus flexuosus	Coleoptera	Heteroceridae	Local	X	
Dryops nitidulus	Coleoptera	Dryopidae	NR	X	X
Dryops striatellus	Coleoptera	Dryopidae	NR	X	X
Monochroa elongella	Lepidoptera	Gelechiidae	NR		
Nephrotoma quadristriata	Diptera	Tipulidae	NR	X	X
Platypalpus excisus	Diptera	Hybotidae	NS		
Hercostomus praetextatus	Diptera	Dolichopodidae	NS		
Tachytrechus insignis	Diptera	Dolichopodidae	Local		X
Syntormon filiger	Diptera	Dolichopodidae	NS	X	
Pherbellia grisescens	Diptera	Sciomyzidae	NS	X	
Pteromicra glabricula	Diptera	Sciomyzidae	NS		
Pteromicra pectorosa	Diptera	Sciomyzidae	NR		
Spilogona scutulata	Diptera	Muscidae	NR		
Neolimnophora maritima	Diptera	Muscidae	NR		
Limnophora scrupulosa	Diptera	Muscidae	NS	X	
Limnophora nigripes	Diptera	Muscidae	NS		
Lispe caesia	Diptera	Muscidae	NS		
Lispe nana	Diptera	Muscidae	NS		
Lispocephala rubricornis	Diptera	Muscidae	NR		
Coenosia atra	Diptera	Muscidae	NS		

The principal aim of the current survey was to compare the fauna of the excavated slacks on Newborough Warren with naturally-occurring pioneer slacks on Morfa Dyffryn. In this report, the data covers all the species taken in the following taxa – Chilopoda, Diplopoda, Isopoda, Orthopteroid insects, Coleoptera, Araneae and Opiliones. The survey also allowed an opportunity to see how quickly excavated areas on Newborough Warren were colonised. The frequent visits necessitated by the pitfall trapping were combined with sampling of other slack habitats at Morfa Dyffryn and Morfa Harlech. In this survey, the pioneer slack habitat of Boyce (2015) has been divided into two slack types: **the pioneer slack habitat at Morfa Dyffryn was taken as the area of almost bare, damp, yellow sand at the foot of an eroding dune face**. As one moves to windward of the pioneer slack, the bare sand gives way, usually abruptly, to a **more vegetated habitat with dominant Sharp Rush *Juncus acutus* and Creeping Willow *Salix repens*, which I have called post-pioneer slack**. Although there is more vegetation in this habitat, there is still a lot of ground without higher plants but here the bare ground is coloured black. I have not been able to find any information concerning the flora of this darkened sand. I have presumed the colour is conferred by a higher organic content. The sand is more accreted than that of the yellow sand of the pioneer slack and probably less eroded by wind and winter flooding. It can be presumed that this darkened sand supports a community of fungi and other micro-organisms. Three pioneer slacks were sampled at Morfa Dyffryn and at each site the post-pioneer slack habitat was also sampled. It was hoped that this would reveal the degree of distinction between these two habitats of the surface invertebrate fauna. However, as the sampling depends on the mobility of the surface invertebrates, there will inevitably be some stray animals trapped outside what may be their preferred habitat. This is a particular hazard where the patches of habitat sampled are rather small in area. In addition, at Morfa Dyffryn pitfall trapping was also carried out at two sites in a large slack that has wet slack habitat with closed vegetation. At all these Morfa Dyffryn sites, eight in all, two $2m^2$ quadrants were laid out and the percentage plant cover of the species present was recorded.

At Morfa Harlech, two sites to seaward of the pine plantation were sampled and two sites at the northern end of the dunes where they run out through Sea Rush *Juncus maritimus* patches to salt marsh. In this latter area there is a low dune behind the tide line and behind this an area of small, low dune ridges with interspersed small areas of damp ground. This is a mosaic of dune and slack habitat but there is no true pioneer slack with bare sand. The vegetation in the slack areas is closely cropped by rabbits and farm stock.

At Newborough Warren, four slacks with two sites each were sampled. Three of these were the Slacks 1, 2 and 3 of Loxton (2015). Slacks 2 & 3 were excavated slacks and Slack 1 a slack that was unexcavated and acted as a control. A fourth slack next to Slack 1, known here as Slack X, was also sampled. This fourth slack had areas of the bare, black sand referred to above - it was thought this might make an interesting comparison with the post-pioneer slack habitat at Morfa Dyffryn.

Other lesser surveys were carried out. A survey of the larval burrows of the tiger beetle *Cicindela maritima* at Morfa Dyffryn was made and mapped on to an aerial photograph. A small study of these burrows was carried out in one of the embryo slacks. As the burrow casts of *Bledius fergussoni* could be easily recognised, the occurrence of this species as an indicator of the pioneer slack habitat was mapped onto an aerial photograph along with the pioneer slacks recorded by Boyce (2015). Colonies of *B. fergussoni* at Morfa Harlech and Morfa Dyffryn were mapped where they could be found on the shoreline and those of *B. subniger* in the Cefni and Braint estuaries at Newborough Warren. Evidence is presented for the rapid colonisation of artificially-produced pioneer slack habitat by *B. subniger* and its associated predators at Newborough in a slack near the coast that was excavated in February and March of 2015. Some preliminary observations were made concerning the diet of *B. fergussoni* and *B. subniger.*

4. Methods

4.1. Pitfall trapping

Pitfall trapping was carried out at each of 20 sampling sites with 5 plastic pots of 1 pint capacity following the methodology of Loxton (2015). Trapping at Morfa Dyffryn (Figure 1) and Morfa Harlech (Figure 2) ran from 22nd April to 23rd July 2015 and from 1st September to 22nd October 2015. At Newborough Warren, the traps (Figure 3) were run from 23rd April to 17th July 2015 and from 2nd September to 23rd October 2015. The sites are labelled D for Morfa Dyffryn, H for Morfa Harlech and N for

Newborough Warren. The numerals 1,2,3,4,5 or X are used to indicate slacks and the letters N,S, E or W to indicate replicates at each slack (north, south, east or west) - these abbreviations are used throughout the rest of the diagrams etc in this report. N (north) at Morfa Dyffryn Slacks 1 to 3 refers to the pioneer slack – damp, bare, yellow sand with little vegetation and S (south) refers to the post-pioneer habitat - often, as can be seen in Figure 1, very close to the pioneer slack habitat. At Morfa Dyffryn, Slack 1 was originally chosen towards the southern end of the reserve but unfortunately setting of the traps was observed by sun bathers. On my next visit, the traps were found to have been pulled up and scattered. As a consequence, Slack 1 was moved to its location as shown in Figure 1. This was a rather dry, pioneer slack with rather small areas of damp sand. It was split into two halves so I split the five traps, three each in D1NW and D1SW and two traps in each of D1NE and D1SE. In the analyses, D1NW and D1NE are combined into one sample D1N, and similarly for the D1S samples. Photographs of the trap sites are shown in Appendix 10.3. At Newborough Warren, N and S are essentially replicates in each of the four slacks sampled, as are E and W, and N and S in the two Morfa Harlech slacks sampled.

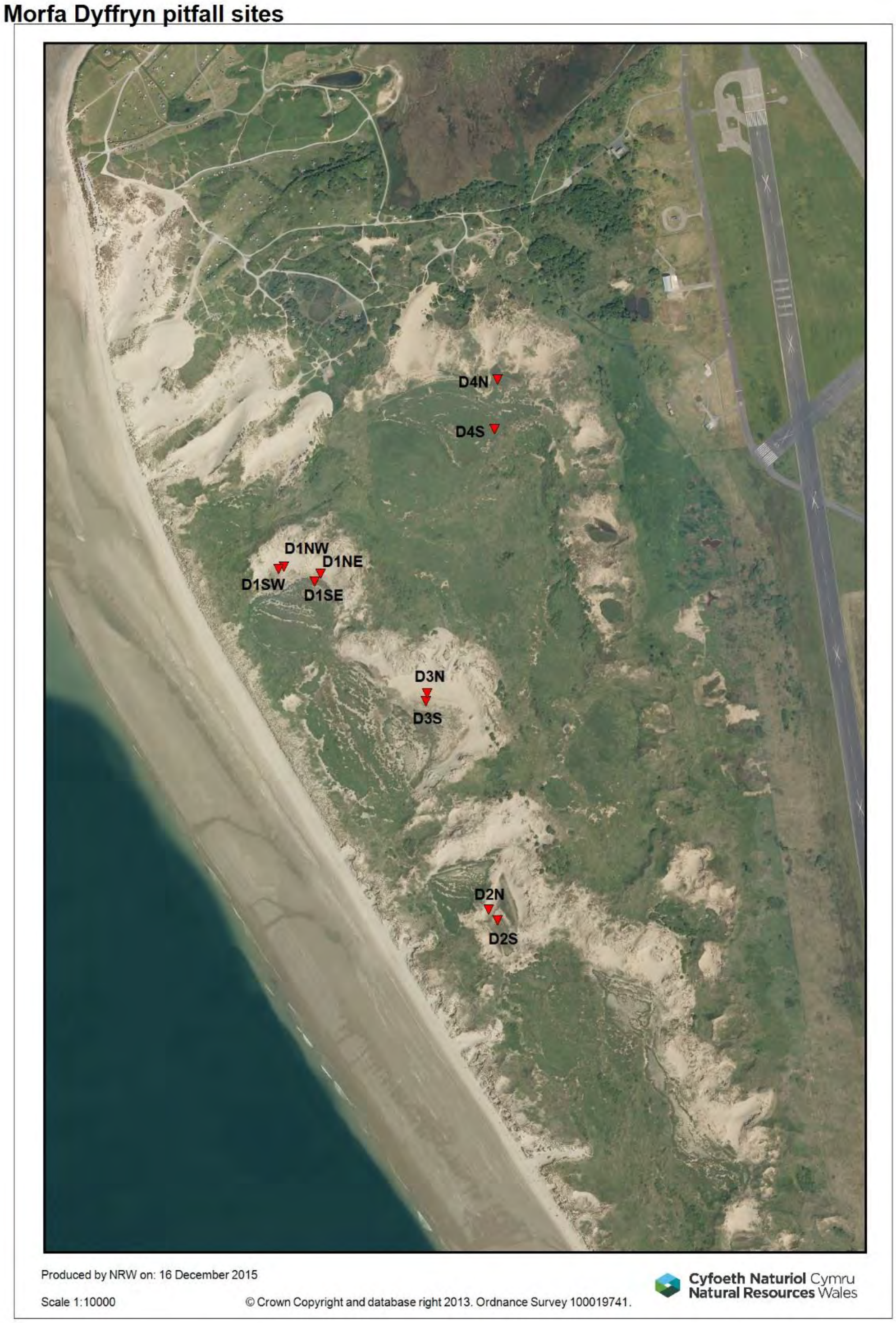

Figure 1: Location of pitfall traps on Morfa Dyffryn.

Figure 2: Location of pitfall traps on Morfa Harlech.

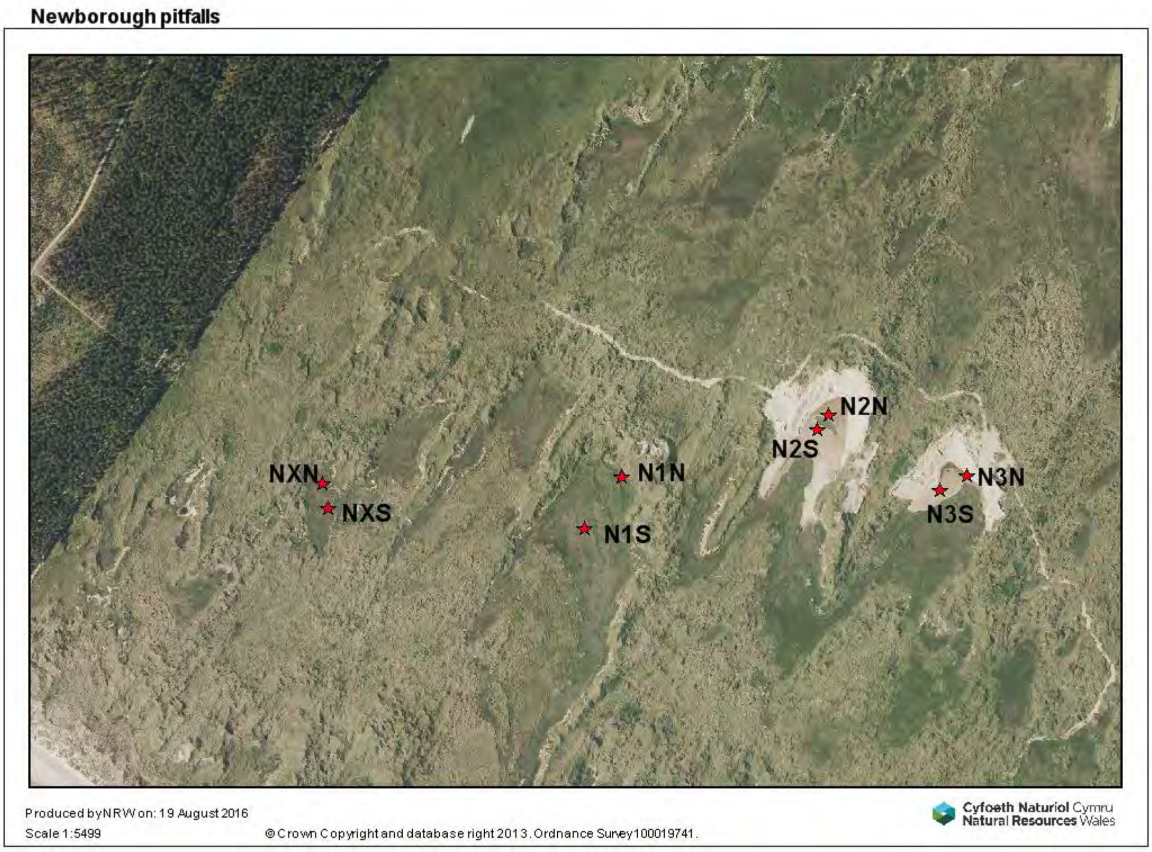

Figure 3: Location of pitfall traps on Newborough Warren.

All invertebrate samples were stored in saturated NaCl solution until they could be sorted and identified. This produced much material and I have not included the Heteroptera (true bugs), Auchenorrhyncha (leafhoppers) or aculeate Hymenoptera (bees, wasps & ants) in this report. This material has been stored and may be presented in a subsequent report. As there was inevitably some disturbance of the traps by grazing stock and flooding with water or sand, the trapping effort at each site was corrected by dividing the total number of animals of each species caught at each site by the number of effective trapping nights and then multiplying by 720 (the maximum number of possible trap nights/site). This correction equalised the trapping effort at each site. There is a great deal of data and it is difficult to appreciate without some form of visual summary. The data was submitted to Principal Component Analysis (PCA) in Program R. The data on which the PCAs are based is presented in Appendix 10.1. These data have been log transformed (due to the skewed nature of the data – see below) before analysis. Casual inspection of the data in Appendix 10.1 will indicate that the data is skewed with many zero values and a few values in excess of 1,000. To make this matter clearer, I have examined the data for the Carabidae (ground beetles), presented in the tables below. This data set consists of 20 habitats and 78 species of beetle – in total 1760 data points. 64.81% of these data points are zero with 4 data points exceeding 1,000 beetles.

Table 1: Distribution of size of samples.

Sample Size	No. of Samples	%
0	1011	64.81
1	143	9.17
2 to 10	187	11.99
11 to 100	137	8.78
101 to 1000	78	5.00
1001 to 2000	3	0.19
2000+	1	0.06
	1560	

Table 2 shows that nine species were represented by only a single capture and a further 21 were represented by 2-10 captures. At the other end of the scale, twelve species are represented by more than a thousand captures.

Table 2: Distribution of numbers of beetles caught.

No. of Beetles caught	No. of Species
1	9
2 to 10	21
11 to 100	20
101 to 1000	16
1001 to 10,000	12
Total Species	78

The effect of these distributions is to make many of the data points, labelled by species on the PCA, cluster at the intersection of the two axes with only a few species influencing the associations of habitats. To present the reader with a presentation that is easier to appreciate, I have split some of the 'natural' data sets to reduce the number of species – for instance the Carabidae have been split into two halves (*Cicindela* – *Pterostichus* and *Amara* – *Syntomus*), into three sets for the Staphylinidae, into two for the rest of the beetles, and into three for the spiders. These are not always satisfactory but the difficulties will be considered in the Results. Three representations of the data are given – ordination labelled by site, ordination labelled by species and an overlay of these two, known as a bi-plot. In the bi-plots, the length of the red arrows pointing to a species is proportional to the strength of the influence of that species on the habitat grouping. The bi-plots can be found in Appendix 10.2. These influential species are those taken in larger numbers at a restricted number of sites. Histograms are also presented of selected species in the form of corrected numbers caught at each trapping site. It should be noted also that a few species that were found in fairly equal numbers across all or most of the sites will also be plotted near the intersection of the axes.

4.2. Description of Pitfall Sites

I do not intend to give a detailed description of the vegetation of the pitfall sites although a quantitative measurement was made for the Morfa Dyffryn sites of the percentage plant cover by the species present in 2m^2 plots. These data were subjected to Principal Components Analysis (PCA) and will be briefly discussed below before presenting the ordinations of the pitfall data. Here a brief description of the sites will be given, referring the reader to photographic images in Appendix 10.3.

Three pioneer slacks on Morfa Dyffryn were selected and designated D1, D2 and D3. At each slack, there were two sites: N & S. N (north) refers to the pioneer slack habitat of the three slacks. Photos 1 to 3 show views of the vegetation, or lack of it, in these three pioneer slacks. All these three Pioneer Slacks sit at the bottom of a steep, eroding dune face (Photos 1, 3 & 4). Slack 1 is drier than the other two slacks with more vegetation at the foot of the dune face. Slack 2 has a rather small area of pioneer slack habitat and Slack 3 has an extensive area of pioneer slack extending to the right from Photo 3 by more than 100m. Slack 3 is also wetter than the other two with more extensive and prolonged winter flooding. Photo 3 shows that there was no open water by 15th April 2015 although the sand was damp into July and August. In contrast in 2016 this slack was still flooded on 27th July. The consequences for the fauna of this variability from season to season will be discussed in the sections concerned with the Dune Tiger Beetle *Cicindela maritima* and the rove beetles *Bledius subniger* and *B. fergussoni.* In the photos, the habitat I have called post-pioneer slack can be seen on the extreme left of Photo 1 as a patch of dark Sharp Rush *Juncus acutus,* on the left of a gentle ridge in Photo 3 and from the edge of the water on the right in Photo 4.

Photos 5 to 7 show the post-pioneer slack habitat of slacks 1 to 3, D1S, D2S and D3S. There is usually a distinct transition between the pioneer slack and post-pioneer habitat, sometimes as in Slack 3 with a small ridge. Typically, there is at Morfa Dyffryn tussocks of *Juncus acutus*, prostrate Creeping Willow *Salix repens* and areas of bare black sand. This habitat does not flood as extensively as the pioneer slack habitat.

At Morfa Harlech, sites 5E and 5W were in a marshy slack to the seaward of a pine plantation. The vegetation was lush with thick *Salix repens*, some *S. cinerea* and is flooded in winter (Photo 10). Site H5E had more *S. repens* and taller vegetation than at H5W (Photo 9). Both sites are grazed by cattle and occasionally by sheep. Sites H6S (Photo 11) and H6N are in damp areas interspersed with low ridges of dune with Marram Grass *Ammophila arenaria*. The sites are closely cropped by rabbits with additional grazing by sheep and cattle.

At Newborough Warren, Slack X was an unexcavated slack with small hummocks of *Salix repens* interspersed with bare black sand (Photo 11). Slack 1 is a large slack with short vegetation at N1S (Photo 12) and slightly taller vegetation at N1N (Photo 13). Both these slacks flood in winter and are grazed by ponies and cattle. Both these slacks were considered as controls to the interventions in Slacks 2 and 3. Slacks 2 & 3 have been described previously (Loxton, 2015). In this survey, the trap sites were placed in the bare, damp sand. The area of excavated slack in Slack 3 is rather small and in August 2015 the surface was eroded (Photos 14 and 15). The surface of the sand was converted from a near flat surface to many small hummocks where sand was held and accumulated by isolated plants (Photo 14). In Photo 15, the marker peg of a botanical quadrant indicates from the darker, lower part of the peg that the surface of the slack was lowered by 3 to 4 inches. Slack 3 has a rather small area of excavated slack and during the autumn pitfall trapping I had to move Site N2S towards the northern site to try and avoid the moving sand but this was only partly effective and most of this trapping period was partly written off at N1S as the traps were flooded with wind-blown sand.

4.3. Principal Components Analysis (PCA) of pitfall samples

Throughout this report, where it is necessary to label diagrams with species names I have used five letter abbreviations using the first two letters of the generic name and the first three of the species name. This rule is sometimes relaxed to prevent confusion – for instance in the case of the genera *Carabus* and *Calathus*. The abbreviations can be found in Appendix 10.4. The corrected data on which the PCAs are based is shown in Appendix 10.1.

In setting out the pitfall sites, I deliberately chose D1N, D2N and D3N as replicate samples from pioneer slack habitat and these pitfall sites on the ordination graphs are labelled with a yellow circular dot. Similarly D1S, D2S and D3S are considered replicate samples of post-pioneer slack habitat – dark green dots. The Newborough Warren excavated slack sites N2N, N2S, N3N and N3S all have red dots and the four Newborough Warren 'Control' Slack sites NXN, NXS, N1N and N1S are shown with black dots. The remaining sites are from the closely-vegetated slack at Morfa Dyffyn (D4N and D4S) and the two slacks at Morfa Harlech (H5E, H5W, H6N and H6S). These six sites are not considered to be replicates but are similar in having closed vegetation and are shown with emerald dots. We might suspect that the Newborough Warren Control slacks would have some affinity with the closely-vegetated slacks of Morfa Dyffryn and Morfa Harlech.

All the ordinations are labelled as above except that for percentage ground cover at Morfa Dyffyn where two replicate quadrants at each site were recorded for the pioneer slack habitat (yellow dots), post-pioneer habitat (green dots) and the two sites in the thickly vegetated Slack 4 (blue dots). As all these sites were at Morfa Dyffryn, the letter D has been left off the labels of the sites in Figure 4a (see Appendix 10.1). Each quadrant is labelled by the slack number (1 to 4), position in slack, N (north) or S (south), and the final number 1 or 2 referring to the replicates at each site. At each site the two quadrants were placed within the line of the pitfall traps.

In Figure 4b (Appendix 10.1), 'Casp' refers to an unidentified *Carex* species and 'Caare' to *Carex arenaria*. One of the problems with this set of data, apart from the author's botanical incompetence, was close nibbling by rabbits of the young plants of grasses, rushes and sedges. I was incapable of identifying these plants to species level and probably 'Casp' is in fact *Carex arenaria*. I have declined to try to identify the 7mosses and these are collectively lumped together as Moss – though I suspect this was mostly *Bryum pseudotriquetrum*.

4.4. Taxonomic problems

Inevitably, the attempt to identify such a wide range of invertebrates presents difficulties in maintaining a high standard of accuracy – and this is besides the labour involved. I have tried to be as scrupulous as possible and have had the advantage of access to the collections at Liverpool and Manchester Museums. In a few cases, I have referred specimens to acquaintances with specialised expertise and these are acknowledged in the relevant section. One of the problems with some of the material was caused by the method of handling the samples. The procedure was to filter the trap contents in the field through a fine plastic tea sieve and empty into a storage pot. The samples were often dirty with blown sand and had to be sieved again at home with gentle agitation of the sieve dipped partly under the surface of water. The material so cleaned was stored and finally examined under a binocular microscope. This procedure inevitably causes some abrasion of fine setae – often useful taxonomic characters. In some cases, particularly in the case of the small and delicate species of Staphylinidae: Aleocharinae, elytra and limbs become detached and in a few cases aedeagi and spermathecae are extruded and lost. If a specimen was too damaged to be identified (fortunately only a few individuals), it was excluded from the data. I had to exclude some five species of Aleocharinae as neither I nor Mike Denton could identify them – these can be a difficult group. This unidentified material has been retained for possible future study. However, these involved only one or two specimens/species so would not greatly affect the PCAs.

Pterostichus nigrita and *P. rhaeticus.* These two closely related species are separated by Luff (2007) by the characters of the right paramere in the male and the eighth sternite in the female. However, Angus *et al.* (2000) defined the two species on the basis of the chromosomes and found the male paramere character to be unreliable in about 20% of males, in an admittedly small sample. It is only possible to separate the males by everting the aedeagus with a fine neurological needle – unavailable to me. The female character is considered reliable and I have examined most of the females from a total sample of 2,102 individuals and found only *P. nigrita.* Although *P. rhaeticus* may be present, I have referred all these to *P. nigrita.*

Tachyporus chrysomelinus and *T. dispar.* These two species are separable by the number of setae on the hind edge of the elytra. As mentioned above, these often wear off and I have probably confused some of the specimens – but both species were definitely present although in low numbers.

Bledius fergussoni and *B. subniger.* These two species are difficult to distinguish but I am fairly confident that I can now tell the difference. I have had the *Bledius subniger* checked by Dr Jarvis Good who specialises in coastal Staphylinidae. It was a surprise to find that apparently all the samples I examined from Newborough Warren were *B. subniger* and those from Morfa Harlech and Morfa Dyffryn were apparently *B. fergussoni.* However, as large numbers of these little beetles were taken in pitfalls in the pioneer and excavated slacks I have not been able to critically examine every specimen. As the two species seem to inhabit similar or identical habitats, I could have entered them into the data sets as a single species entity but have entered them as separate species. There is probably critical work to do on this species pair – not the least to determine if they occupy subtly different habitats.

In our present state of knowledge, the females of some *Gabrius* species (Staphylinae) are, indistinguishable (Lott & Anderson, 2011), and only males of these species have been recorded here. I have also found myself uncertain of a few identifications in the genera *Philonthus* and *Quedius* where I have taken only female specimens. These uncertainties are indicated by ? in the lists of abbreviations – here again this only concerns a few individuals.

5. Results

5.1. Principal Components Analysis (PCA) of pitfall samples

Note that all Figures (Figures 4 to 31) relating to this Section are given in Appendix 10.1.

The data was collected by 100 pitfall traps set at 20 sites and was made up of 100,205 individuals distributed across 505 species.

The three habitats are each distinctly clumped by the PCA with Pioneer Slack and Post-Pioneer Slack respectively greatly influenced by BGY (bare ground yellow) and BGB (bare ground black). These represent an average of 79.3% of the ground surface for the Pioneer Slack and 26.6% for the Sub-Pioneer Slack. The Pioneer Slack quadrants vary in the plants present with, for instance, small amounts of Brookweed *Samolus valerandi* (Saval) in the wettest of the three slacks, Slack 3. Knotted Pearlwort *Sagina nodosa* was present in all the pioneer slack habitats though only in small amounts, 0.1-0.4%, and Creeping Willow *Salix repens* was present, 3-10%. *Sagina nodosa* is a defining species of the NVC SD13 community (*Sagina nodosa-Bryum pseudotriquetrum* dune slack community). This community is further described as "short and often rather open swards dominated by a low and patchy cover of *Salix repens*" (Rodwell *et al*., 2000). Although up to 10% of the plant cover in the Pioneer Slacks was recorded as *Salix repens*, even greater cover was recorded in the Post-Pioneer Slacks, 25-47%. It is possible that the separation I have made between Pioneer and Post-Pioneer Slack habitat is not recognised by the NVC.

The bottom left quadrant of Figure 4b contains *Juncus acutus* (Juacu), *Epipactis palustris* (Eppal) *Salix repens* (Sarep) and *Euphrasia ?nemorosa* (Eunem), all of which are found in both the closed vegetation of Slack 4 and in the Post-Pioneer Slack habitats. One could continue this discussion further but the point of this exercise was to demonstrate that the Pioneer and Post-Pioneer habitats at Morfa Dyffryn were distinct with respect to their plant cover and this difference appears clearly in the photographs. This is as background to considering how they differ with respect to their animal communities.

The rest of this section contains the analyses of a series of sets of data from the pitfall trapping. Each set of data is headed by a summary of the analysis and two presentations of the ordinations (Appendix 10.1). A third presentation of the data was saved from the analysis as a bi-plot where the ordination labelled by trapping site is overlaid by the ordination labelled by species (Appendix 10.2). Here, the length of the red arrows is proportional to the strength of the influence of that species on the grouping of the sites, and this can help to clarify reading of the figures. Another way of understanding the data is to plot some of the data as histograms of the number of each species at each site. A selection of histograms for the most numerous species are presented for the different sets of data (Appendix 10.1).

The ***Carabidae 1*** *Cicindela-Pterostichus* dataset shows the close association of the pioneer slacks at Morfa Dyffryn with the excavated slacks at Newborough Warren (Figure 5a). Inspection of Figures 5a and 5b indicates that this association is apparently caused by the abundance of the ground beetle *Bembidion pallidipenne* (Bepal) in these two habitats (see Figure 6a), with very few at other sites. There were a few *B. pallidipenne* trapped in the post–pioneer habitat at Morfa Dyffryn but these sites are so close to the pioneer slacks that some overspill is to be expected. If one considers the other species in the bottom left quadrant that are apparently influential, *Dyschirius impunctipennis* (Dyimp), *D. politus* (Dypol), *Cicindela maritima* (Cimar) and *Elaphrus riparius* (Elrip), the last two can be excluded from linking these two habitats as *Cicindela maritima* only occurred at Morfa Dyffryn, and principally in the pioneer slack, and *Elaphrus riparius* only on the Newborough Warren excavated slacks. These two species will be causing the strong grouping of the two habitats separately as they are both abundant in the data – total captures were 1376 *C. maritima* and 55 *E. riparius*. *D. impunctipennis* and *D. politus* occur more widely (see Figure 6a), with *D. politus* as common in the post pioneer slack as in the pioneer slacks and occurring also in the northern Morfa Harlech sites, the Newborough Warren control sites and commonly in the Newborough Warren excavated slacks. Similarly, although *D. impunctipennis* is found fairly commonly in the Morfa Dyffryn pioneer slacks and the Newborough Warren excavated slacks, it also turns up in the northern Morfa Harlech slacks. These two *Dyschirius* species cannot be said to define the pioneer slack habitat in this data set.

The top left quadrant of Figure 5a shows the post-pioneer slack sites at Morfa Dyffryn grouping together between the pioneer slacks and the group in the top right quadrant of the vegetated slacks of Morfa Dyffryn (D4N & D4S) and those of Morfa Harlech (H6N &H6S) and the Newborough Warren 'control' slacks (NXN, NXS, N1N & N1S). Here there are three apparently influential species, *Nebria salina, Broscus cephalotes and Bembidion properans.* These species are shown on the histograms in Figures 6b and 6c.

Bembidion properans (Bepro) can be seen to be most numerous in the post-pioneer slack sites (Figure 6b above) and found in all other habitats, but uncommon at the two marsh sites (H5E & H5W) at Morfa Harlech, and the Newborough Warren excavated slacks. *Broscus cephalotes* (Brcep) is an example of the problems of making this sort of survey with pitfall traps. It is a species strongly associated with dry, sandy habitats on the coast and its presence at the pioneer and post-pioneer sites is probably a consequence of it straying down the steep, bare, sand slopes rising from these slacks. It does not appear at the Newborough Warren excavated slacks as this species seems in recent years to have retreated to the coast as the dune system has become more vegetated (Loxton, 2009). *Nebria salina* (Nesal) is a species associated with open habitats in contrast to the closely related *N. brevicollis* (Nebre) which favours more shaded areas. In a mosaic of habitats, as on dunes, these mobile beetles often occur together. Nevertheless, Figure 6c shows that *N. salina* was most abundant in the more open habitats, with *N. brevicollis* favouring the taller, thicker vegetation of Morfa Dyffryn Slack 4 and the Morfa Harlech slacks (Figure 6c).

When considering the top right quadrant, the 'Control' Slacks of Newborough Warren cluster with Morfa Dyffryn Slack 4 and Morfa Harlech Slack 6. The four important species are *Nebria brevicollis* (see Figure 6c), *Dyschirius globosus* (Dyglo), *Notiophilus aquaticus* (Noaqu) and *N. substriatus* (Nosub) – see Figure 6d. *N. brevicollis* and the two *Notiophilus* species are most common in this cluster of sites, with *D. globosus* more widely spread across all the sites – this accounts for its position in Figures 5b & 5c on the border between the right hand quadrants.

But perhaps the most striking aspect of this data set is the distinct position of the two marsh sites at Morfa Harlech (H5E & H5W) in Figure 5a and 5c. There are a group of species that are found predominately at these two sites – *Carabus granulatus* (Cagra) and *C. violaceus* (Cavio) (see Figure 6e), *Poecilus versicolor* (Pover), *Pterostichus nigrita* (Ptnrt), *P. niger* (Ptnig) and *P.vernalis* (Ptver) (see Figure 6f) and finally *Pterostichus diligens* (Ptdil), *P.strenuus* (Ptstr) and *P. gracilis* (Ptgra) (Figure 6g).

The excavated slacks at Newborough Warren have more *Dyschirius globosus* than the pioneer and post-pioneer slack sites at Morfa Dyffryn. The excavated slacks abut onto areas of mature slack where this species is very numerous (NXS, NXN, N1S & N1N).

I have included *Cychrus caraboides* (Cycar) here not because it is influential on the clustering of the marsh sites but it is an example of how the analysis plots a species with a fairly wide distribution but low numbers (see Figure 5b).

The distribution of species across a mosaic of habitats as on sand dunes is complicated – they do not fall into tidy categories defined by the plant cover. Many carabids probably take a variety of prey and are probably influenced more by the physical characteristics and vegetation structure of a habitat rather than its botanical community *per se*. There are further sets of data which will be presented more briefly, with the reader invited to inspect the Figures and perhaps draw his own conclusions.

The dataset ***Carabidae 2*** *Amara-Syntomus* produces a different pattern of association after PCA from that of *Carabidae 1*, although the close association of the pioneer slacks at Morfa Dyffryn and the excavated slacks at Newborough Warren is maintained. The principal difference in *Carabidae 2* from *Carabidae 1* is the separation of the northern sites at Morfa Harlech from the other thickly-vegetated sites at Morfa Dyffryn and Newborough Warren. This is influenced by the presence in numbers of *Calathus cinctus, Amara aenea, A. tibialis, Harpalus anxius* and *Syntomus foveatus* (see Figures 7b, 8a, 8b, 8c and 8d). Many of these species are associated with dry, sandy ground and although Sites H6N and H6S are set in damp ground these are small, damp hollows set among low ridges of dry dune. The separation of the two Morfa Harlech marsh sites is in part explained by a wet ground species, *Agonum thoreyi* (see Figure 8e), and other species shared with the thickly vegetated sites of Morfa Dyffryn and Newborough Warren.

Staphylinidae 1 is a dataset containing many of the small Staphylinidae and many species are represented by small numbers – hence the concentration of species at the intersection of the axes. The only sites that separate clearly from the others in a single group are the Morfa Harlech marsh sites (H5E and H5W). This is at least in part caused by the presence only in these sites of *Tachinus laticollis, T. pallipes, T. proximus* and *T. rufipes,* of which the first three were numerous.

Figure 9c shows the distribution of some of the commoner aleocharines. *Acrotona exigua* is particularly numerous in slacks of all the habitats but is absent in the Morfa Harlech marsh and scarce in the excavated slacks. *Arena tabida* is most common in D1N which is a relatively dry slack and nearest to the coast – *A. tabida* is a species found just above the tide line on sandy coasts. It is probably straying inland here after strong winds.

The dataset of ***Staphylinidae 2*** is made up of fewer species (27) than the previously-discussed sets. The data is dominated by three *Bledius* species *B. fergussoni* (180), B. *fuscipes* (286) and *B. subniger* (602) – the numbers indicate the uncorrected total number of individuals taken in the pitfalls. *Bledius subniger* is clearly the strongest influence in the clustering of the excavated slack sites at Newborough Warren (see Figures 10a and 10b). I had expected that the same would be true for the Morfa Dyffyn pioneer slacks with *B. fergussoni* but fewer were caught and at one site (D1N) only 6 were caught – see Figure 12a. The probable reason for this is that D1N was rather dry and possibly not ideal habitat for *B. fergussoni*. As has been pointed out above, these two *Bledius* species are very similar and seem to occupy identical habitats. There is a possibility of taxonomic confusion here and if they were the same species clearly the analysis would plot the Morfa Dyffyn pioneer slacks and the Newborough Warren excavated slacks close together. *Bledius fuscipes* clearly influences the cluster of Morfa Dyffryn pioneer slacks but only a single individual was caught in the Newborough Warren pioneer slacks. *B. fuscipes* was caught frequently in the post-pioneer habitat and at other habitats so it may live outside the bare sand habitat of the pioneer and excavated slacks. I have found its burrows in the ‘bare black sand’ habitat of the post-pioneer slacks.

Staphylinidae 3 is a dataset containing the larger Staphylinidae and the distribution of species is somewhat irregular between sites so that in Figure 12a only the Morfa Harlech sites separate out clearly. H6N & H6S in the north of the Morfa Harlech dunes have large numbers of all of the species shown in Figure 13a and also the largest numbers of *Ocypus aenocephalus* – see Figure 13b. The Morfa Harlech marsh sites (H5E & H5W) have large numbers of *Staphylinus dimidiaticornis* (Figure 13b) but also in smaller numbers a collection of species found at hardly any other sites – *Philonthus decorus, P. mannerheimi, P. micantoides, Ontholestes murinus, Tasgius morsitans* and *Megalinus glabratus*.

The *Gabrius* species shown in Figure 13c are of interest particularly for the species *G. osseticus.* This species is considered to be particularly associated with pioneer slacks but it can be seen that although present in the pioneer slacks at Morfa Dyffryn and the excavated slacks at Newborough Warren, it was most common in the closed vegetation of Morfa Dyffryn Slack 4. Another species of interest is the rare *G. exiguus* which heretofore was only known in the last 50 years from the slacks of Newborough Warren.

The ***Leaf Beetles and Weevils*** provide a dataset that separates off the Morfa Harlech marsh sites (H5E & H5W) (see Figure 14a). The species influencing this can be seen in Figure 15b. *Phyllotreta exclamationis* feeds on water-cresses *Rorippa* and bitter-cresses *Cardamine*; *Apthona nonstriata* feeds exclusively on Yellow Iris *Iris pseudocorus.* The Newborough Warren ‘Control’ Slacks and Excavated Slacks plot close together with the exception of N3S – this site was affected by strong sand erosion and possibly some of the beetles taken in this site were blown in. *Sitona lepidus* may be a case in point. The three common sand dune weevils and the clover weevil *Hypera nigrirostris* plotted in Figure 15b have a strong influence on Figure 14a. *Philopedon plagiatus* was caught in large numbers in the pioneer and excavated slacks. As this species can be found feeding on marram and other dune grasses in considerable numbers, I suspect that many of these beetles were not ‘resident’ on the damp open sand of the pioneer slacks but are another example of animals tumbling into the slacks down the bare sand of the dune face.

The ***Miscellaneous beetles 1*** dataset contains two families of beetle, the Silphidae and the Scarabaeidae, that distort the analysis. The Silphidae contain the sexton beetles *Nicrophorus* species, here represented only by *N. vespillo.* Although the pitfall traps were designed to exclude small mammals they could not exclude small toads and slugs. Occasionally the traps became fouled by decaying flesh and attracted the sexton beetles. Large numbers can be trapped in a single pitfall – indeed of the total of 49 beetles caught all but two were taken in the Morfa Harlech marsh at H5E, mostly in a single trap. *N. vespillo* is a common and widespread species and there is no reason to think that it would not have been present in several other habitats. Another member of this family, *Silpha tristis,* is not closely associated with carcases, though its biology does not seem to be well known, and was taken only in the taller vegetation of Morfa Dyffryn Slack 4 and Morfa Harlech Slack 5 –

see Figure 17a. *S. tristis* has a strong influence on the association (Figure 16a) of these two slacks.

The dung beetles of the Scarabaeidae present a different problem as Morfa Dyffryn does not have any large herbivores. However the dung beetles *Aphodius depressus, A. erraticus and A. prodromus* were taken at Morfa Dyffryn in single numbers – a testament to their mobility. Dung beetles, particularly *Onthophagus similis,* have a strong influence in grouping all the Newborough Warren sites in the top left quadrant of Figure 16a – see Figure 17b. Why there were so many *O. similis* at N3 (Figure 18b) is unclear – the ponies frequent both the excavated slacks at Newborough Warren and, with cows, leave dung in both slacks. This slack suffered strong wind erosion so the beetles may have been swept into the traps by drifting sand. Also linking these Newborough Warren sites are the small hydrophilid *Georissus crenulatus* and the chafer *Serica brunnea* – neither of these species was found at Morfa Dyffryn or Morfa Harlech. Whether this absence is real or merely due to local seasonal variation in abundance is unknown. However, neither species is apparently recorded by the NBN at these sites. *Aphodius plagiatus* unlike the remainder of its congeners does not feed on dung but on fungi (Loxton, 1966). The adults were seen in the 1960s feeding in the cup fungus *Geopora arenicola* and this species is very common in the pioneer and post-pioneer slacks at Morfa Dyffryn. *A. plagiatus* has become scarce at Newborough Warren (Loxton, 2009) but is abundant at Morfa Dyffryn and in the northern Morfa Harlech sites (Figure 17a). *A. plagiatus* has a strong influence in grouping the sites in the top right quadrant of Figure 16a.

The ***Miscellaneous beetles 2*** dataset contains the four species of *Dryops* and the familiar tenebrionid beetles of sand dunes, *Melanimon tibialis* and *Phylan gibbus.* All these influence the grouping of sites in Figure 18a. *Melanimon tibialis* and *Phylan gibbus* bring together the northern slacks of Morfa Harlech (H6N & H6S) with the well vegetated slack at Morfa Dyffryn (D4N & D4S). *Dryops nitidus* and *D. striatellus* have a strong influence on the bottom half of Figure 19a.

These species are of particular interest as *Dryops nitidulus* and *D. striatellus* are considered characteristic of pioneer slacks. Although *D. nitidulus* is present in both the pioneer slack habitat at Morfa Dyffryn and the excavated slacks at Newborough Warren, it is much commoner in the post-pioneer habitat at Morfa Dyffryn and the 'control' slacks at Newborough Warren. Much the same is true of *D. striatellus,* but with numbers also at D4S and few elsewhere. D4S has shorter vegetation than D4N.

The click beetle *Agrypnus murinus* is widely spread across all sites (Figure 19b) and is another example of how the analysis plots such a species close to the intersection of the axes – see Figure 18b. *Agriotes lineatus* was taken in large numbers at some sites and influences the right hand quadrants of Figure 18a. In contrast, *Agriotes obscurus* was particularly numerous at the two Morfa Harlech marsh sites and largely determines the grouping of these two sites in the top right quadrant of Figure 18a.

In Figure 19c, the pill beetle *Cytilus sericeus* plots diagonally in the bottom left quadrant of Figure 18a but is spread widely across all sites. However, in contrast to *Agrypnus murinus*, there are bigger differences in the numbers between sites, which are of course accounted for in the analysis. Another species of interest is the tenebrionid *Xanthomus pallidus.* In my experience, this species is found on yellow dune but here it was caught only in the pioneer slacks at Morfa Dyffryn. This must be another example of a species tumbling down to the foot of the bare dune face.

The Linyphiidae are small spiders with sheet webs and although taken in pitfalls are probably not best sampled by this method. It would be interesting to compare pitfall trapping with vacuum sampling. ***Linyphiidae*** (Figure 20a) provides a dataset that produces four fairly distinct groups of sites – all the Newborough Warren sites with the Morfa Dyffryn pioneer and post-pioneer slack sites, the two Morfa Dyffryn vegetated slack sites, the two Morfa Harlech marsh sites and the two Morfa Harlech northern sites. The five common species in the genera *Oedothorax* and *Erigone* are some of the most influential in producing this grouping – see Figure 21a. *E. promiscua* was only found at the northern Morfa Harlech sites and *Oedothorax retusus* predominately at the Morfa Harlech marsh sites. Inspection of the histograms will reveal other species influencing the groupings in Figure 20a.

Walckenaeria monoceros is a sand dune species and was numerous at the Morfa Harlech northern slack sites where the slacks are small and interspersed with low dunes. *W. monoceros* also occurred in small numbers in the pioneer slacks of Morfa Dyffryn probably originating from the dune face as also at N1N, which is also close to a dune face. *Mecopisthes peusi* is another dune species and appeared, Figure 21c, again most numerously at the northern Morfa Harlech sites and in smaller numbers at other dry sites. *Milleriana inerrans* was most numerous in the pioneer and post-pioneer slacks of Morfa Dyffryn and the excavated slacks of Newborough Warren. *Bathyphantes gracilis* and *Lepthyphantes tenuis* were most numerous in the taller vegetation of the Morfa Harlech marsh though scattered across the other habitats in smaller numbers (Figure 21d).

The wolf spiders Lycosidae are active, surface runners and are probably well sampled by pitfalls – certainly they are taken in large numbers. The ***Lycosidae*** dataset produces a fairly tight group comprised of the Morfa Dyffryn pioneer and post-pioneer slack habitats – to the left in Figure 22a - and another group composed mainly of the Morfa Harlech sites and the Newborough Warren 'control' slacks – the latter group being rather dispersed. Site D1S is rather displaced towards this latter group and this appears to be because of the large numbers of *Pardosa monticola* and *Xerolycosa miniata* at this site (see Figure 23a). Morfa Dyffryn Slack 1 is rather dry, which may explain this difference.

Two species in Figure 24b have a restricted distribution. *Alopecosa cuneata* was only found at the thickly vegetated slack sites at Morfa Dyffryn (D4N and D4S). *A. cuneata*, though a common species in the south of Britain, is near its northern limit in Wales at Morfa Dyffryn and has only been recorded once (a pre-1980) from

Anglesey (Spider Recording Scheme website). Harvey *et al*. (2002) has a record at the northern end of Morfa Harlech, or possibly across the estuary. *Pardosa nigriceps* is the only wolf spider to be found regularly high in vegetation such as bushes and was found mainly at the sites with taller vegetation.

*Alopecosa barbipe*s was not found at all at either Morfa Dyffryn or Morfa Harlech. *Pirata piraticus* was found principally in the marsh sites at Morfa Harlech, with a single specimen from N2N at Newborough Warren. This species has previously been common in wet slacks at Newborough Warren.

The dataset of the remaining ***Miscellaneous Spiders*** produces a fairly distinct group on the right of Figure 24a, consisting of the Newborough Warren excavated slacks and the Morfa Dyffryn pioneer and post pioneer sites. One site D1S lies outside this grouping towards the bottom right of Figure 24a. The reason for this is the relatively high numbers of the species *Zelotes electus, Xysticus kochi, Scotina gracilipes, Agroeca proxima* and *Ozyptila sanctuaria* – see the relevant histograms. It has already been mentioned that this slack is drier than the other two Pioneer Slacks at Morfa Dyffryn and this analysis and the previous one seems to pick this out. The Morfa Harlech marsh sites (H5N & H5S) plot to the top of Figure 24a – this seems to be in part because of *Pachygnatha clercki,* found only at these sites together with relatively large numbers of *Pachygnatha* degeeri and *Antistea elegans*. The two northern Morfa Harlech sites plot together at the bottom of Figure 24a. The reason they plot here seems to be the wide variety of species found at these sites.

The remaining sites are rather widely scattered with *Pachygnatha degeeri* being influential. However, there is inconsistency of species occurrence between sites. An example is that of D4S which had many *Enoplognatha thoracica* with none at D4N. *E. thoracica* is common elsewhere only at the Newborough Warren 'control' sites. These distributions of species can be seen in the histograms.

The ***Harvester*** dataset is dominated by *Phalangium opilio* but with rather few at the Morfa Harlech sites (Figure 27a). The Morfa Harlech marsh sites plot distinctly away from all the others due to a preponderance *Oligolophus tridens* and *Lacinius ephipiatus* at these.

The taxonomically diffuse ***Miscellaneous Invertebrates*** dataset includes the millipedes, centipedes, woodlice, the groundhoppers and grasshoppers, a cockroach and an earwig. It is dominated by very large numbers of the woodlouse *Armadillidium vulgare.* Figure 29a shows the odd fact that it was not found at any of the Morfa Harlech sites. This probably influences the horizontal distribution of these two slacks (H5 & H6) – to the left – though they are widely separated vertically. H6 has no *Philoscia muscorum*, *Ommatoiulus sabulosus* or *Ophyiulus pilosus (*Figure 29b). H6 has no *Polydesmus angustus* and H5 has neither *Lithobius calcaratus* nor *Forficula auricularia.*

The Newborough Warren ‘control’ slack sites make a cohesive grouping but it is not easy to see why from the relevant histograms, but certainly *Philoscia muscorum* is influential and also in the plotting of D4N and D4S on the right of Figure 29a. A species that may be responsible for vertically separating D4N & D4S is the centipede *Lamyctes emarginatus* - 23 of these centipedes were taken but all at D4S. *L. emarginatus* has also been found at Newborough Warren in the slacks but not in this survey. D4N and D4S differ in their vegetation – see Figure 4a – and they also differ in that D4N had no *Ommatoiulus sabulosus* and few *Tetrix undulata* whereas D4S had few *Forficula auricularia.* Probably none of these widespread species are directly dependent on particular plants and their presence is likely to be influenced more by the structure of the vegetation and the physical characteristics of the habitat.

Another aspect of these animal communities that perhaps merits some consideration is the diversity of species trapped at the different sites. A simple measure is used – the total number of species for the beetles and for the spiders combined with the harvesters (Figures 30 and 31).

The two sites in the Morfa Harlech marsh, H5W & H5E, had distinctly more species than any of the other sites. In the case of the spiders with harvesters, the distinction is not so clear but H5W has more species than any other. This confirms my subjective assessment that the marsh was a biologically-rich site. It contained several notable species such as *Blethisa multipunctata, Pterostichus gracilipes, Anthracus consputus, Chlaenius nigricornis, Leiodes obesa, Stenus europaeus* and *Philonthus mannerheimi* that were only found here apart from a single specimen of *C. nigricornis* from Morfa Dyffryn Slack 4N.

5.2. Observations of *Cicindela maritima*

This large and striking beetle is a familiar creature at both Morfa Harlech and Morfa Dyffryn and in the course of my visits I took the opportunity of making a few observations - the closely related species, *Cicindela hybrida*, has been closely studied on the Lancashire dunes (Judd, 2003). These observations were provoked by finding that the larval burrows (Photos 1 & 2) were abundant in the pioneer slacks that were being sampled with pitfall traps. Although I cannot be said to have walked every foot of Morfa Dyffyn dunes, it soon became apparent that the larval burrows were apparently highly restricted in their occurrence. It is unlikely that the larvae would be found where the vegetation is dense – presumably this would be unsuitable for burrowing. When I considered that I could spot suitable habitat, I walked the length of the Morfa Dyffryn dunes visiting any suitable habitat. This was carried out on five days between 13th and 30th May 2015. As well as the dunes and slacks, I also walked a short length of the eroding dune face on the beach.

The procedure was to estimate the number of burrows at each location and to check occasionally that they were indeed burrows of the tiger beetle larvae. This can be done by sticking a fine grass stem into a burrow and irritating the larva with small movements of the grass stem. The larva will often grip the stem with its mandibles and can be extracted and returned to its burrow. Alternatively, the larva can be dug up with a trowel. After some experience, one becomes practised in recognising the burrows. The only difficulty I found was on the dune above the beach where many burrows of the amphipods of the tide line could confuse the issue. The results of this search are shown in Figure 32.

I did not search for a long distance on the beach dune face – there is a triangle symbol shown towards the north of Figure 32 above the beach where I found a few burrows. I have presumed that the beetle breeds all along this dune face where erosion exposes compacted sand (Photo 16). I did examine the same habitat at Morfa Harlech from the public path across the golf course to the north of the beach on 23rd May 2015 (Photo 17) and found larval burrows all the way along. To the north where the beach dune becomes lower with more sand deposition, I could no longer find the burrows of the beetle. At Morfa Harlech, there seems to be little suitable habitat apart from this frontal dune. I never saw or caught tiger beetles where I was pitfall trapping in the vegetated slacks to the north at Morfa Harlech.

I found some areas towards the south, indicated by rather faint square symbols, where the frontal dune was blown through and there were excavated areas with some damp sand. However, I could find no larval burrows here and thought it might be due to exposure and movement of the sand, and to the prevalence of shingle in these areas. Although I have put an upper limit of 20+ (Figure 32), some of these sites recorded as with 20+ larval burrows probably had hundreds of burrows. The burrows were present in the greatest numbers in the damp pioneer slacks. Apart from the dune above the beach, the remainder of the sites were where a dune face had been eroded by the wind exposing some compressed sand. These sites only held a few burrows. Another habitat that held a few burrows was on the bare, black sand of the post-pioneer slack (Photo 18). In the north-western part of Morfa Dyffyn, there are several large slacks with tall surrounding dunes – these are early pioneer slacks with often no vegetation and have much mobile sand (Photo 19). Photo 20 shows another example of these early pioneer slacks with a small patch of damp sand in the middle distance. This damp sand contained many burrows of the tiger beetle larvae along with the burrow casts of *Bledius fergussoni*. A few nights of pitfall trapping in this slack caught many adult tiger beetles along with *B. fergussoni, Dyschirius politus and Bembidion pallidipenne.*

A few observations were made on the larval burrows in Slack 3 at Morfa Dyffryn. The diameters of the 2nd instar burrows were approximately 2.5 mm and those of the 3rd instar 4mm (Photos 21 & 22). The depth of the burrows of 2nd and 3rd instar larvae were measured by inserting a fine grass stem and measuring the depth to which the stem penetrated. The mean depth of the burrows made by the 2nd instar was 16.05 ± 1.61cm, and for the 3rd instar 17.35 ± 2.01 cm. The variation in these samples was caused by a few burrows in each sample being much shallower. It is likely this is due to the burrow being vacated and then gradually filling with blown sand. The larvae may occasionally move on the surface as a few were caught in pitfalls.

Figure 32: Distribution of larval burrows of *Cicindela maritima* at Morfa Dyffryn in the summer of 2015.

On 13th May 2015, the slack was no longer flooded but the southern part was still damp. It was clear that the burrows were absent from this wet area and disappeared at the edge of the slack to the north as the dune rose from the slack and in the south where the post-pioneer habitat began. Later in the year, larval burrows could be found all over the slack. Three transects were put across the slack in the form of a row of canes and all the burrows within a metre on either side of this line counted within two metre sections. The results are shown in Figure 33 below.

Photo 23 shows the transects in place with the dune face to the left (beyond S1 in Figure 33) and the post-pioneer slack on the right (S13 and beyond in Figure 33). I concluded that the tiger beetles in these slacks needed sand of an intermediate level of water content. Too wet and the burrow will flood with water, too dry and it will collapse. In 2015, there were clearly many tiger beetles breeding in these slacks but the situation was very different in 2016. As late as 27th July 2016, Slack 3 was still flooded (Photo 24); however, there were burrows to be found around the edge of the flooded area. Other slacks at Morfa Dyffryn were also flooded throughout the summer. As the dune rises steeply from the slack, there is not much compensation for the area lost to flooding. It is presumed that the tiger beetle larvae cannot survive long in a flooded burrow. In the case of *C. hybrida*, it has been shown that some of the larvae over-winter and pupate in the spring (Judd, 2003). If this is true for *C. maritima*, then it implies there must be a high mortality of larvae in these slacks in most winters.

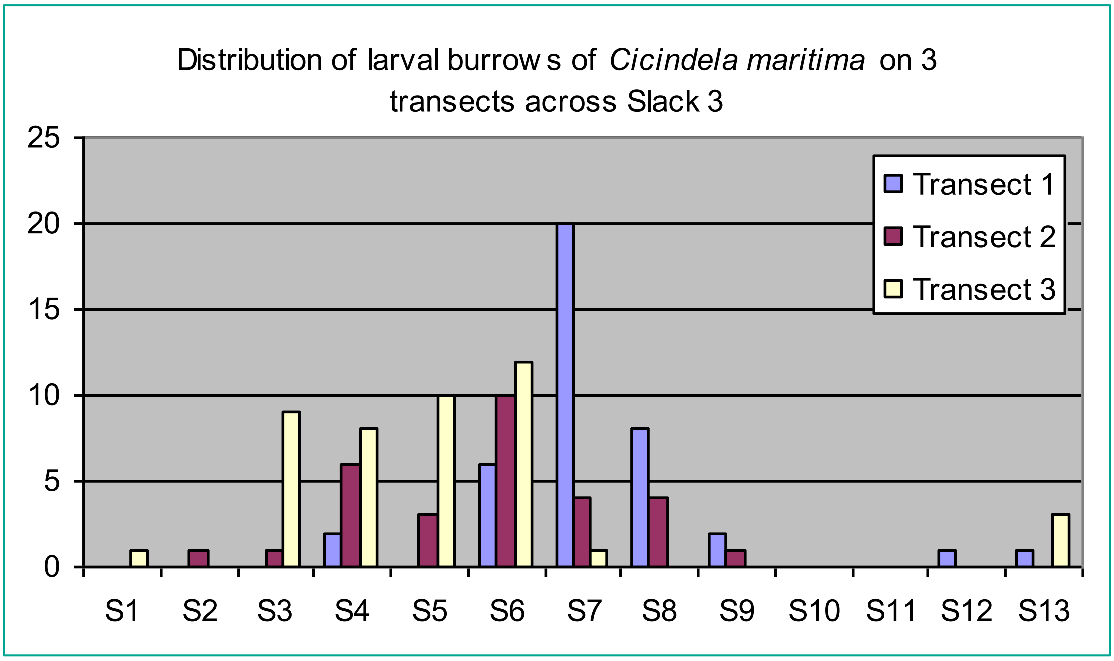

Figure 33: Distribution of *Cicindela maritima* larval burrows every 2m on three transects across Pioneer Slack 3.

5.3 Observations of *Bledius fergussoni* and *B. subniger.*

It has been discussed above that these two species are closely related and it appeared that *B. subniger* was prevalent at Newborough Warren, and *B. fergussoni* at Morfa Dyffryn and Morfa Harlech. However, it requires careful examination to distinguish these two species and many have been recorded and not all critically examined. It is assumed that the two species segregate as outlined above. Whatever the taxonomic position is, the two species seem to have very similar ecologies.

It had previously been noted at Newborough Warren (Loxton 2014, 2015) that *B. subniger* had quickly colonised slacks where the turf had been stripped off in March 2013 to restore a semblance of the pioneer slack habitat. This monitoring also revealed that the small carabids *Dyschirius impunctipennis, D. politus* and *Bembidion pallidipenne* had also colonised the exposed damp sand surface. None of these species was known from monitoring similar slacks since 2007 where the closed vegetation of the slacks and the lack of mobile sand apparently excluded this fauna (Loxton, pers. obs.). In March 2015, breaches were made in the dunes behind the tide line at Newborough Warren with excavations further inland to produce large ‘pioneer’ slacks (Photos 25 & 26). This work provided the opportunity to see if this colonisation was as fast as we expected. 10 small traps were put in for two nights, 12th -14th June 2015. The captures are recorded in Table 3 below.

Table 3: Numbers of individual species trapped in excavated slack behind the tide line, Newborough Warren 12th – 14th June 2015 at SH414630.

Species	Numbers caught
Dyschirius impunctipennis	3
D. politus	1
Bembidion pallidipenne	12
Bledius subniger	7
Aloconota gregaria	1
Ischnosoma splendidum	1
Quedius boops	1
Meligethes aeneus	1
Gastrophysa polygoni	1
Philopedon plagiatum	2
Lasius niger	18
Lepthyphantes tenuis	1
Argenna subnigra	3
Ommatoiulus sabulosus	2
Ophyiulus pilosus	1
Forficula auricularia	1

The burrow casts of *B. subniger* were numerous and excavation with a penknife quickly revealed the *Dyschirius* and *Bembidion*. Clearly, this fauna had rapidly colonised this artificially-produced habitat in a maximum of about two months. It was clear that it was possible to map this fauna by finding the burrow casts of the *Bledius* beetles (Photo 27). At Morfa Dyffryn, the recording was done between 13th and 30th May 2015 whilst mapping tiger beetle larval burrows, and also in the first week of June 2015. As the *Bledius* beetles and their predators are considered to be characteristic of the pioneer slack habitat, it seemed instructive to overlay my results with those of Boyce (2015) (Figure 34). Boyce (2015) carried out his survey in 2010

Figure 34: Distribution of *Bledius fergussoni* on Morfa Dyffryn in 2015 (large white dots), and Pioneer Slacks as recorded and numbered in 2010 and 2011 by Boyce (2015) (small white dots).

and 2011 and he may have been using a broader definition of pioneer slack than I was. Judging by Figure 34, his definition of pioneer slack possibly included what I have called post-pioneer slack. I found the *Bledius* beetles only where the sand was yellow with very little vegetation or none, and at least damp from April to late June in 2015. It has been mentioned elsewhere that Slack 1 was drier than the other slacks monitored with pitfalls and here it was difficult to find *Bledius fergussoni.* The large slacks in the north-west (Photos 19 & 20) were not visited by Boyce (2015) – I understand there were access difficulties.

Figure 35: Distribution of *Bledius subniger* in the Cefni Estuary, Newborough Warren 25th July 2016.

It was suspected that the source of the beetles that colonised the excavated slacks at Newborough Warren would have come from the salt marshes in the Cefni and Braint estuaries. In 2016, I made a series of surveys at Newborough Warren to map the *Bledius* colonies, in the Artro estuary to the north of Morfa Dyffryn, and at Morfa Harlech as the dunes bend eastwards into the estuary of the Glaslyn and Dwyryd rivers. The procedure was to find the casts, check they were those of *Bledius fergussoni* or *B. subniger* and record where they were found with GPS. Starting from the point where the beetles were first found, I walked a zig-zag course determining the outer limits of the colonies. These are recorded as dots on the figures below and enclose the larger colonies. Within these areas, the beetle casts are more or less continuous with very large numbers at some sites as in Photo 27. Single dots represent small colonies.

In the Cefni Estuary, there was a small colony of *Bledius* within the forest, in Figure 35 just to the left of middle at the bottom. This was where a shallow scrape had been made in the forest on the course of a drainage channel (Photo 28). The main colony was as outlined by the red stars. I found no other colonies to the west of this point but did not search further inland. The habitat of the colony is shown in Photo 29. Just to the west of this colony, there has recently been considerable erosion of young dune (Photo 30) that has been recently made from sand blown along Traeth Penrhos and into the estuary.

Figure 36: Distribution of *Bledius subniger* colonies in the Braint Estuary, Newborough Warren 29th July 2015.

Bledius subniger colonies in the Braint estuary are shown in Figure 36. I started the survey from the mouth of the Braint but found no colonies until I came to a tidal gully, two dots on the left of the picture. These were small colonies on the edge of the gully where there was some clean sand (Photo 31). Other colonies were found behind the Abermenai spit in areas of clean yellow sand (Photos 32 & 33).

At first sight in the Artro Estuary at Morfa Dyffryn there seemed to be a large expanse of possible habitat. However, as in the other estuaries much of the exposed sand is dark in colour and with a finer particle size. I have presumed that these properties are conferred by finer particles than the beach sand, admixed with organic material. It makes for a more solid substrate when walking across the estuary than that in which one finds the *Bledius* colonies. I found two colonies here as shown in Figure 37 and Photos 34 & 35. In the north, the colony was in a thin band between the top of the beach and the darker sand to the left in the photograph. In the south, the colony was dispersed between low hummocks of *Elytrigia* and *Spartina* (Photo 35).

Figure 37: Distribution of *Bledius fergussoni* colonies in the Artro Estuary, Morfa Dyffryn 27th July 2016.

Figure 38. Distribution of *Bledius fergussoni* colony at Morfa Harlech 22nd May & 19th July 2016.

B. fergussoni was mapped twice at Morfa Harlech, in May and in July (Figure 38). Both mappings showed a similar distribution, perhaps in July extending further seawards and to the south. In May, in the south of the area there was a strong wind blowing with mobile sand which may have obscured the casts. As the colony begins to disappear in the north east, it was noticeable that the sand was more organic with freshwater debris such as tree leaves and seaweed cast up and spread widely. This transition to darker sand can be seen in Photo 36. Although Figure 38 shows the colony not continuing up the estuary, there are probably small patches on the banks of the streams and saltwater channels crossing the salt-marsh.

It was concluded that habitat for the *Bledius* colonies appeared to be limited in the four estuaries by wave action and immersion seawards and by lack of water landwards. In 2014, it was observed that in the Newborough Warren excavated slacks the *Bledius* colonies followed the retreating winter floodwater as the summer progressed (Loxton, 2015). Another factor seemed to be that the colonies were found on recently-deposited sand, often associated with, or near to, *Elytrigia* on the coast. These are only visual observations, though pH 8.22 – 8.53, and % loss of weight after ignition of 0.25-0.56 was recorded from three excavated slacks at Newborough Warren where there were *Bledius* casts. There is a need to make further observations of this habitat such as moisture content, particle size and organic content if one wanted to more stringently define the habitat of these beetles. I suspect, but it needs testing, that the recently-deposited sand is easier for the beetles to burrow into.

The low organic content raises the question of what the *Bledius* beetles are feeding on. It was suggested to me by Dr Reid of Liverpool Museum that diatoms were a possibility. Dr Reid kindly offered to examine samples from the habitat and from the gut contents of the beetles. There were indeed several species of diatom and in large numbers to be found in the sand samples and the beetles' guts (Figure 39). This work is not completed and it is hoped to publish a short note in the future. Water and light are minimal requirements for the diatoms so possibly the clean sand is a substrate that allows more penetration by light into the upper layers than it would in muddy sand.

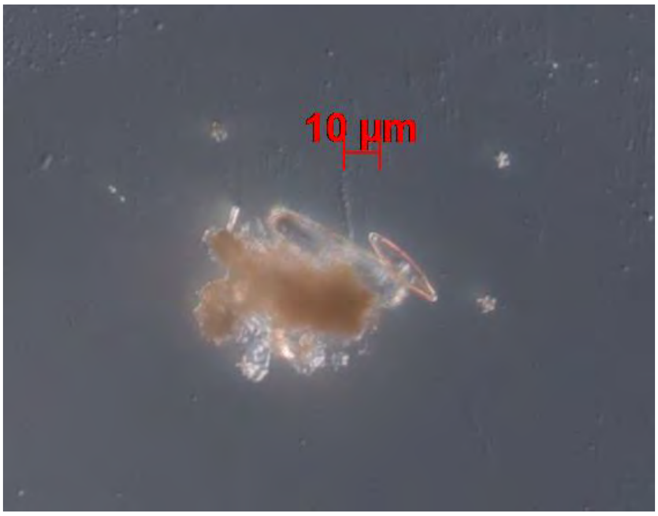

Figure 39: Diatoms from gut of *Bledius fergussoni*. Photographed with Differential Interference Contrast.

It is clear that these faunas of *Bledius* and the carabids are highly adapted to exploit a habitat that is prey to the vagaries of flooding and wind erosion. Presumably winter storms vary in their effect depending on tide and wind on how sand is moved on these flat beaches. The beetles must be able to re-colonize if and when habitat becomes available in the spring. It was suggested in the case of the Newborough Warren excavated slacks that the beetles over-winter as adults away from the winter flooding (Loxton, 2015). It is yet to be established where these beetles over-winter from either the slacks or the estuarine colonies, nor do we know the details of the beetles' life cycles.

5.4. Some noteworthy species

With status reviews of some taxa at present underway, I have remained here with the earlier designations of Na and Nb etc in Recorder 2003. This section records species that were found in this survey and one or two recorded in 2016. For Newborough Warren only new records are listed, as much collecting there has already been put on record.

COLEOPTERA

Carabidae

Blethisa multipunctata (L., 1758). Nb. Three specimens were taken in the Morfa Harlech marsh. 2015, SH566323.
Elaphrus uliginosus Fab., 1792. Nb. Several specimens were taken at the north of Morfa Harlech in a patch of *Juncus maritima.* 2016, SH558349.
Dyschirius impunctipennis Dawson, 1854. Nb. A few were taken at Morfa Dyffryn in the pioneer slacks, SH558250 and at Morfa Harlech in the northern sites SH558348, all in 2015.
Bembidion pallidipenne (Illiger, 1802) Nb. Very numerous in pitfalls in pioneer slacks at Morfa Dyffryn SH558250 and at the edge of the salt marsh at Morfa Harlech SH559353 in 2015.
Pterostichus gracilis (Dejean, 1828) Nb. Common in pitfalls in the marsh at Morfa Harlech, 2015, SH566323.
Amara lucida (Duftschmid, 1812) Nb. In small numbers in pitfalls across a variety of sites at Morfa Dyffryn (e.g. SH555252) and Morfa Harlech SH558348, 2015.
Amara nitida Sturm, 1825. Na. 67 individuals of this species were identified at Newborough Warren from pitfalls set in Slack 1, SH418634, 2015. Identification was checked by Dr Mark Telfer. It is perhaps worth quoting from Dr Telfer's recent status review of Carabidae (Telfer, 2016): "There are verified records from only four hectads in the post-1980 period, and unverified records from three further hectads. There are only six hectads with verified records from the pre-1980 period but 15 more with records that remain unverified. The best interpretation of this evidence, assuming that about half of the unverified records are correctly identified, is that *A. nitida* is undergoing a substantial decline." Finding 67 specimens of this species in a slack that has been sampled previously is a little odd – the probable explanation is that I have overlooked it – it is easy to confuse with some of its close relatives.
Amara praetermissa (Sahlberg, 1827) Nb. A few were trapped at Morfa Dyffryn in Slack 4, SH560256 and at Harlech Slack 6, SH558348, 2015.
Anthracus consputus (Duftschmidt, 1812) Nb. Two were taken in the Morfa Harlech marsh, SH566323, 2015.
Chlaenius nigricornis (F., 1787) Nb. One was taken at Morfa Dyffryn Slack 4, SH560256, and eight at the Morfa Harlech marsh, SH569323, in 2015.

Histeridae

Hypocaccus rugiceps (Duftschmid, 1805). Nb. 24 were taken at Morfa Dyffryn in Slack 1, SH555252, 9 in Slack 2, SH560245, and singletons in the other pioneer and post-pioneer slack sites. Four were taken at the northern Slack 6 at Morfa Harlech, SH558348, 2015.

Leiodidae

Hydnobius punctatus (Sturm, 1807) Nb. A singleton was taken at Morfa Dyffryn Slack 2, SH560244, 2015.

Leiodes obesa (Schmidt, W.L.E., 1841) Local. 12 were taken at the Morfa Harlech marsh sites, SH566323, 2015.

Staphylinidae

Mycetoporus piceolus Rey, 1882. Nb. A singleton at north ern sites at Morfa Harlech, SH558348, 2015.

Lamprinodes saginatus (Gravenhorst, 1806). Na. Two at Morfa Dyffryn, Slack, SH560255, 2015.

Aleochara brevipennis, Gravenhorst, 1806. Nb. 23 in the Morfa Harlech marsh, SH566323 and one at the northern sites at Morfa Harlech, SH558348, 2015.

Badura puncticollis (Benick, 1938). Nb. Two in the Morfa Harlech marsh, SH569323, and two in the northern sites SH558348, 2015. Also recorded from Newborough Warren by Dr Roger Booth in 2015.

Microdota liliputana (Brisout, 1860). Nb, One in Slack 3 at Morfa Dyffryn, SH558250, and one in the Morfa Harlech marsh, SH569323, 2015.

Arena tabida (Kiesenwetter, 1850) pRDB. This species is possibly not as rare as suggested. It can be extremely numerous behind the tide line of sandy shores. This small species seems to get blown inland. Many were taken in 2015 in the pioneer slacks at Morfa Dyffryn, eg 43 at Slack 1, SH555252 – the slack nearest the coast.

Stenus europaeus Puthz, 1966. Nb. Four males were taken in the Morfa Harlech marsh SH569323, 2015. Dr Jonty Denton, the National Recorder, believes this to be a first record for Wales.

Gabrius exiguus (von Nordmann, 1837) RDB1. The only modern records previous to 2015 have been from Newborough Warren. One was taken at Morfa Dyffryn in Slack3, SH558250 and five males from Slack 4, SH560255, 2015. Seven males were also taken in 2015 at Newborough Warren from Slack1, SH418634.

Gabrius keysianus Sharp, 1910. Nb. Several were taken at Morfa Dyffryn, three from Slack 2, SH418634, six from Slack 1, SH555252 and 1 from Slack 4, SH560256. At Morfa Harlech there were eight from the marsh, SH566323, and 12 from the northern slacks, SH558348, in 2015.

Gabrius osseticus (Kolenati, 1846). Nb. There were seven taken in 2015 from the pioneer and post pioneer slacks at Morfa Dyffryn, e.g. SH555252, but 20 from the thickly vegetated Slack 4, SH560256. On this evidence this species does not seem to be characteristic of the pioneer slack habitat.

Philonthus mannerheimi Fauvel, 1869 Nb. Seven were taken in the marsh at Morfa Harlech, SH569323, 2015.

Scarabaeidae

Aphodius plagiatus (L., 1767) Nb. Numerous in the pioneer and post-pioneer slacks at Morfa Dyffyn, with for instance 411 at D3S, SH558250, but also 34 in Slack 4, SH560255. This species was abundant, 1191, at the northern Morfa Harlech sites, SH558348. In recent years this species has become scarce at Newborough Warren, with only two taken in 2015.

Onthophagus nuchicornis (L., 1758). Na. Eight were taken at the northern sites at Morfa Harlech, SH558348, 2015.

Dryopidae

Dryops striatellus (Fairmaire & Brisout, 1859). pRDB3. 21 were taken in the pioneer slacks at Morfa Dyffryn, SH558250, but no less than 998 at the post-pioneer slack sites, SH560244 and 88 in Slack 4. Three were taken in the Morfa Harlech marsh sites SH566323, and three in the northern Morfa Harlech sites SH558348, 2015. This and the following species have been previously thought of as characteristic of pioneer slack habitat but as this habitat is defined here, this cannot be the case.

Dryops nitidulus (Heer, 1841). pRDB3. As with the previous species 29 were taken in the pioneer slack sites, SH560245, at Morfa Dyffryn but 674 in the post-pioneer sites, SH555252, 2015.

Elateridae

Cardiophorus asellus Nb. Two only were taken at Morfa Dyffryn in Slack 4, SH560255, in 2015

Coccinellidae

Scymnus schmidti Fuersch, 1958 Nb. One at the Morfa Harlech marsh sites, SH569323, and another at the northern sites, SH558348, 2015.

Tenebrionidae

Xanthomus pallidus (Curtis, 1830) Nb. 71 were taken at the pioneer slack sites at Morfa Dyffryn, SH558250, with five at the post-pioneer sites, SH558250, 2015. This species should probably not be considered as a resident of the pioneer slack habitat. These large numbers are considered to be the result of tumbling down the steep dune faces above the pioneer slacks.

Chrysomelidae

Cassida hemisphaerica Herbst, 1799 Na. A single specimen from the pioneer slack habitat at Morfa Dyffryn SH560245 – possibly an immigrant rather than a resident – and two from the marsh at Morfa Harlech, SH569323, 2015.

Curculionidae

Orthochaetes setiger (Beck, 1817) Nb. Four from Slack 4 at Morfa Dyffryn, SH560256, 2015.

Kissophagus hederae (Schmitt, 1843) Nb. This species was recorded by Professor Clive Washington in Newborough Forest at SH403634, 24th April 2015.

ARANEAE

Linyphiidae

Mecopisthes peusi Wunderlich, 1972. Nb. Three from the sub-pioneer habitat at Morfa Dyffryn, SH555252, and 29 from the northern sites at Morfa Harlech, SH558348, 2015.

Ceratinopsis romana (O.P.-Cambridge, 1872) Nb. One each from the pioneer slack habitat, SH555252, and the post-pioneer habitat, SH558250, at Morfa Dyffryn, 20015.

6. Discussion

As has been pointed out in the Results section, there are a series of problems with data collected by pitfall trapping such as mobile species being trapped crossing sub-optimal habitat. Two obvious species in this category are *Broscus cephalotes* and *Xanthomus pallidus*. Both are species of yellow dune – a habitat not sampled here –

and yet they appear in significant numbers in the pioneer slack habitat. There are aggregations as in the case of the Sexton Beetle *Nicrophorus vespillo* that was caught in large numbers in a few fouled traps. Another source of aggregation is possibly caused by sex pheromones. I have sometimes caught large numbers of males of the harvester *Phalangium opilio* in a single trap with a few females. Another source of error is the trapping of highly mobile species such as dung beetles away from sources of dung, or the presence of water beetles in traps set away from open water. It is tempting to 'clean up' the data by excluding such instances. I have resisted this impulse on the grounds that though some decisions would seem rational it would be difficult to draw a line on which to exclude. I have therefore included all the data in the PCAs and where appropriate pointed out any anomalies. It should always be born in mind that the numbers caught by pitfall trapping are biased by the activity of individual species, by their behaviour at the rim of the trap (their trapability) and by their size – smaller species are caught proportionally less than larger species.

There are instances where we can be almost certain that a species is absent from an area. A case in point is the two tiger beetles – *C. campestris* was only found at Newborough Warren and *C. maritima* only taken at Morfa Dyffryn (but is also known at Morfa Harlech). *C. maritima* was taken in large numbers in the pioneer slacks at Morfa Dyffryn and as we were interested in seeing if the fauna of the excavated slacks at Newborough Warren was similar to the pioneer slacks, the presence of *C. maritima* in large numbers at Morfa Dyffryn might be considered to bias the comparison of the two faunas. It might be considered that excluding *C. maritima* from the analyses was justified particularly as *C. maritima* is not considered to be a species particularly associated with pioneer slacks. However, of all the habitats sampled in this survey *C. maritima* was overwhelmingly most numerous in the pioneer slacks and therefore it is difficult to find grounds for excluding it. There are other differences in the beetles present such as the strong presence at Newborough Warren of *Elaphrus riparius* and *Agonum marginatum* in the excavated slacks and their absence from the Morfa Dyffryn pioneer slacks. These two species are present at Newborough Warren probably from there having been a small pond in Slack 3. I have again preferred not to tamper with the data and perhaps this is justified as in spite of this possible bias the data seems to be robust enough for the PCA to group the Morfa Dyffryn pioneer slacks sites close to the Newborough Warren excavated slack sites – Figures 5a and 7a for the carabids. The grouping is influenced by the very large numbers of *Bembidion pallidipenne* (Figures 5a & 6a), a species apparently strongly associated with pioneer slack habitat.

In spite of the dataset ***Carabidae 2*** *Amara –Syntomus* not containing any species that are particularly associated with pioneer slacks, the analysis still groups the excavated and pioneer slacks together – mainly on the basis of two open ground species, *Calathus erratus* and *C. mollis* (Figure 7b). There is little point in discussing many of the PCA analyses of other datasets as this has been already done above in the Results section. However, it is worth looking again at those containing beetle species that occur in Table 4.

Table 4: Pioneer dune slack beetle species recorded at Newborough Warren, Morfa Dyffryn and Morfa Harlech in pitfall traps.

Species	Newb 2013	Newb 2014	Newb 2015 Control Slacks	Newb 2015 Excavated Slacks	Dyffryn 2015	Harlech 2015
Dyschirius politus	x	x	x	x	x	x
Dyschirius salinus						
Dyschirius thoracicus						
Asaphidion pallipes						
Bembidion pallidipenne	x	x		x	x	
Bembidion clarki						
Bledius fergussoni					x	x
Bledius fuscipes			x	x	x	x
Bledius longulus			x	x	x	
Bledius opacus			x	x	x	x
Bledius subniger	x	x		x		
Thinobius brevipennis						
Gabrius osseticus	x	x		x	x	
Heterocerus flexuosus		x				
Dryops nitidulus	x	x	x	x	x	
Dryops striatellus			x		x	x

These are species which have been taken to be particularly associated with the pioneer slack habitat. I consider the data collected by pitfall trapping in 2015 (Loxton, 2015) only supports a few species as being associated strongly with the pioneer slack habitat. However it should be remembered that in this report pioneer slack was perhaps defined in a restricted sense that may not conform to other usage. We will discuss first those species in Table 4 that have not been seen recently at any of the three dune systems. *Dyschirius salinus* and *D. thoracicus* are certainly coastal species (Luff, 1998) but he describes *D. salinus* as from 'salt marsh' and *D. thoracicus* as on 'bare sandy shores'. They were last recorded at Newborough Warren in 2003 by Dr Roger Booth at SH43-63. The Grid Reference would put these beetles in the Braint estuary or on the landward dunes where there was no bare damp sand except at the edge of ponds. They could possibly be found in pioneer slacks and they would have been expected at Morfa Dyffryn if pioneer slack was a common habitat for these beetles. *Asaphidion pallipes* in Luff (1998) has more inland records than coastal ones, and in Wales one of the few records is inland. The same can be said of *Bembidion clarki,* which has only been recorded at Newborough Warren by Dr Lott in 1985 with no exact location - Luff (2007) gives its habitat as ‘in shaded wet sites near water, usually inland’. *Thinobius brevipennis* is a very small species which could possibly be overlooked. It was last recorded at Newborough Warren in 1982 by the author from a slack that was certainly past the stage of being thought of as a pioneer slack. *T. brevipennis* has only four records in Britain mapped by the NBN and two of these are inland – Lott (2009) says it is ‘associated with both vegetated and unvegetated wet sand and silt’. On the data outlined above for these species, I can see no good reason to consider them as particularly associated with pioneer slack habitat.

Among the remaining species there seem to be three*, Bembidion pallidipenne, Bledius fergussoni* and *B. subniger*, that occur in this study either exclusively or predominately in the pioneer slack habitat at Morfa Dyffryn or the excavated slacks at Newborough Warren. *B. pallidipenne* was not found exclusively in the pioneer slack habitat at Morfa Dyffryn but appears in small numbers in the post-pioneer slack habitat particularly at D3S (Figure 6a). It is possible that this is a case of ‘straying’ from the preferred habitat. There were very large numbers at D3N – note the logarithmic scale in Figure 6a. The two *Bledius* species were caught exclusively in the pioneer or excavated slack habitat (Figure 11). Three other *Bledius* species are listed in Table 4 and I do not think on the basis of these results that they can be regarded as particularly associated with the pioneer slack habitat. Of the three, *B. fuscipes* was caught most numerously and occurred in numbers in D3N (pioneer slack) but also in the post pioneer sites at Morfa Dyffryn, one of the sites in the northern Morfa Harlech slacks and in both sites at Newborough Warren Slack X (Figure 11). I have found the casts of *B. fuscipes* in the ‘black slack’ habitat but have not come across it in the pioneer slack habitat when digging out *B. fergussoni*. I am inclined to think it is more associated with the post-pioneer than the pioneer slack habitat. *B. longulus* was not found in the Morfa Dyffryn pioneer slack habitat but in small numbers in the post-pioneer habitat, Newborough Warren Slack X and a single individual in the excavated slacks. *B. opacus* was found most commonly in the pioneer slack habitat but also in other habitats (Figure 11). It is difficult to even guess to what extent these distributions are caused by ‘straying’ from the preferred habitat or represent a wider choice of habitat than that exhibited by *B. fergussoni* and *B. subniger* in these data. In my own experience at Newborough Warren when trapping in the yellow dunes behind Traeth Penrhos, I have found large numbers of *B. longulus* and *B. opacus* in hollows in the dunes but these are dry dunes and could not be considered pioneer slacks. *D. politus* is certainly very numerous in these pioneer habitats but it occurred as numerously in the post-pioneer habitat at Morfa Dyffyn and more widely though in fewer numbers in the northern slacks at Morfa Harlech and Slack X at Newborough Warren (Figure 6a).

It is usually assumed that the *Dyschirius* species are predators of *Bledius* species but as far as I know this is based on habitat association rather than direct evidence from immunological or DNA studies of gut contents. When collecting *Bledius* species, it is common to come across the *Dyschirius* species and *B. pallidipenne* in the *Bledius* burrows. It is probably a safe assumption to make in the species-poor habitat of bare sand at the edge of salt marsh but in the dune slacks there may be a greater variety of prey available such as the small aleocharine *Acrotona exigua* (see Figure 9c). This is a small species similar in length to the *Bledius* species but less robustly built and probably a surface dweller rather than a burrower. We have here a community of prey and predators but the precise connections between the species and how they utilise the different habitats would need more detailed studies. This report has found some preliminary evidence that *B. fergussoni* and *B. subniger* feed on diatoms but of course though ingesting diatoms they may getting the bulk of their nutrition from associated other micro-organisms such as bacteria. It would be interesting to know whether the other *Bledius* species are also feeding on diatoms and whether the diatom flora differs between the habitats.

Gabrius osseticus was found in this study in the pioneer slacks, post-pioneer habitat and the Newborough Warren excavated slacks but more numerously in the closed vegetation of Morfa Dyffryn Slack 4, though the numbers are small (Figure 13c). Lott & Anderson (2011) describe the habitat as ‘on damp sandy soils for example in floodplains and sandpits’ and the NBN map records several inland records. Again, there seems little evidence to link this species particularly with pioneer slack habitat. *Heterocerus flexuosus* was not found in this study but my slight acquaintance with this species would incline me to associate it with slack soils with a higher organic content than is found in the pioneer habitat. Finally, we may consider the two *Dryops* species in Table 4. Figure 19a provides no confirmation that these species are particularly associated with pioneer slack habitat. Although *D. nitidulus* did occur in the pioneer slacks at Morfa Dyffryn and the Newborough Warren excavated slacks, it was much more common in the post-pioneer habitat at Morfa Dyffryn and the control slacks at Newborough Warren. The same is true of *D. striatellus* which was very numerous in the post-pioneer sites at Morfa Dyffryn, with some in the closed vegetation of Slack 4 and only four specimens at Newborough Warren in NXN. In pitfall trapping at Newborough Warren in the 1980s, I found this species only at a site similar to NXN – ‘black slack’ habitat between hummocks of *Salix repens.* The NBN gives many records of *D. nitidulus* inland though none in Wales and there are several inland records for *D. striatellus* in Wales. On the evidence of these results and wider data, it seems to me difficult to make out any case for the close association of these two *Dryops* species with pioneer slack habitat. *Dryops* larvae burrow in the soil and the adults can also be found just under or on the soil surface. Examination of the gut contents of *D. ernesti* in the 1980s revealed plant tissue in the gut – I would speculate that these beetles require soil with a higher organic content than that provided by the pioneer slack habitat.

The arguments presented above rely on a restricted definition of pioneer slack and to some extent on possibly insufficient data in the literature and on the NBN database. There is also the possibility of erroneous identification within some of the data. If we united what I have called pioneer slack and post-pioneer slack into a single unity of pioneer slack, as may be more in keeping with Boyce (2015), then some of the exclusions I have proposed from Table 4 might not hold. Many such decisions would still in my view be in conflict with known distributions both within and outside Wales. I am impressed by the sharp contrast between the pioneer and post-pioneer habitats. One of the possible advantages of expanding this survey to include Slack 4 at Morfa Dyffryn, the Morfa Harlech sites and the control slacks at Newborough Warren has been to provide data that demonstrates that only a few species are restricted to the pioneer slack habitat. The pioneer slack with its damper, yellow, eroding sand and little vegetation seems to me to differ from the post-pioneer habitat with its surface accreted, drier ‘black sand’, less sand movement and much more vegetation. The consequence of this view is the reduction of the true pioneer slack fauna to a few, highly mobile species that are also found in great numbers, within defined limits, on beaches in estuaries. These limits appear to be defined by the nature of the sand, its water content and the degree of exposure to wave action. I gained the impression that the *Bledius* colonies in the estuaries were located on recently-deposited sand – deposited either by wind or water. In this view, the pioneer slack habitat is close cousin to the estuarine habitat that was mapped in Section 5.4. In the estuaries and on the dunes, this habitat is likely to be transient, prone to disappear and re-emerge on a short time scale. In this limited sense, the excavated slacks at Newborough Warren seem to be very similar to the naturally occurring pioneer slacks at Morfa Dyffryn but in both cases the beetle fauna limited to this habitat consists of rather few species.

Table 5 summarises the above discussion for pioneer dune slack Coleoptera.

Table 5: Pioneer dune slack beetle species as identified by NRW (in blue) and other beetle species attributed to pioneer slack, post-pioneer slacks and/or other habitats as a result of the current survey.

Species	Pioneer slack	Post-pioneer slack	Other Habitats
Dyschirius politus	x	x	
Dyschirius salinus			Saltmarsh
Dyschirius thoracicus			bare, sandy shore
Asaphidion pallipes			coastal & inland sites
Bembidion pallidipenne	x		
Bembidion clarki			shaded, wet habitats
Bledius fergussoni	x		
Bledius fuscipes		x	mature slacks
Bledius longulus	x	x	yellow dunes
Bledius opacus	x		yellow dunes
Bledius subniger	x		
Thinobius brevipennis		?	vegetated & unvegetated wet sand & silt
Gabrius osseticus	x	x	mature slacks
Heterocerus flexuosus			mature slacks?
Dryops nitidulus	x	x	mature slacks
Dryops striatellus	x	x	mature slacks

Aphodius plagiatus		x	
Gabrius exiguus		x	
Cicindela maritima	x	x	frontal dunes

Though pioneer slack habitat from this survey appears to support few species special to this habitat, this does not mean it is unimportant. Rather I would consider it as a symptom of an active dune system rather than an end in itself. Pioneer slack only occurs when the sand is moving, and the system is not reverting to dune grassland as at Newborough Warren. For a short time, it provides a specialised habitat for a fauna probably more numerous on coastal or estuarine sand. As the dune waves move in the direction of the prevailing wind, the pioneer slack habitat is created at the windward foot of the dune and leaves behind it what I have called post-pioneer slack that is colonised with *Salix repens, Juncus* and *Carex* species, mosses and forbs. This post-pioneer slack is more extensive and with a more diverse fauna and flora. It is here, as outlined above, that several species in Table 4 seem to reside rather than in the pioneer slack habitat and some may be closely associated with this habitat. Besides these, the scarabaeid *Aphodius plagiatus* and the staphylinid *Gabrius exiguus* seem to be only known from this habitat. This survey has shown, within the limitations of the data, that the post-pioneer slack habitat is similar to that of the 'control' slacks at Newborough Warren. However, there do seem to be differences with *A. plagiatus* now rather scarce at Newborough Warren and one can pick out other species indicating that the 'control' slacks at Newborough Warren are more similar to the closely vegetated Slack 4 at Morfa Dyffryn or the northern Slack 6 at Morfa Harlech than to the post-pioneer slack at Morfa Dyffryn. I noticed that in September 2015, a thin layer of sand had blown onto the post-pioneer habitat of Slack 2 at Morfa Dyffryn – this is something that would be almost unknown at Newborough Warren except around the excavated slacks. It seems likely that this is an important factor in maintaining the special character of the post-pioneer habitat. I think it is now recognised that the excavations at Slacks 2, 3 and 4 at Newborough Warren are of only limited value in increasing sand mobility but the recently-made breaches of the dunes behind the beach may be more effective.

7. Conclusions

Colonisation of artificially-engineered pioneer slacks is rapid, with three beetles regarded by NRW as specialists of this habitat - *Bembidion pallidipenne*, *Bledius subniger* and *Dyschirius politus* – recorded within two months of the management intervention on Newborough Warren. The likely sources of these colonisation events, at least for *Bledius subniger*, are sand deposits with a low organic content on the edge of the Braint and Cefni estuaries. The Artro, Dwyryd and Glaslyn estuaries provide a similar function for Morfa Dyffryn and Morfa Harlech.

A division of pioneer slack into **pioneer slack** (damp, almost bare, yellow sand at the foot of an eroding dune) and **post-pioneer slack** (upwind of pioneer slacks and more vegetated, with bare sand having a black crust) is supported by Principal Components Analysis (PCA) which separates them into two distinct clusters.

PCA also groups the excavated slacks on Newborough Warren close to the natural pioneer slacks on Morfa Dyffryn. This is particularly so where the data set is presented in the form of histograms of the numbers of selected species across the 20 sites.

Of the sixteen beetle species regarded by NRW as being associated with pioneer slacks, the fauna is more properly restricted to just four species - *Bembidion pallidipenne, Bledius fergussoni, Bledius subniger* and *Dyschirius politus* – and even these are also found in estuarine habitat at the edge of the salt marsh. Several of the remaining twelve are often if not exclusively associated with the post-pioneer slack habitat.

The tiger beetle *Cicindela maritima* is also associated with pioneer slacks on Morfa Dyffryn, with larval burrows found in large numbers in the damp, bare sand.

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Appendix 10.1. Principal Components Analysis (PCA) of pitfall samples.

Ground Cover – Dyffryn Slacks

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	7.064051	4.237152	3.859301	2.445661	2.008856
Proportion Explained	0.26163	0.15693	0.14294	0.09058	0.0744
Cumulative Proportion	0.26163	0.41856	0.5615	0.65208	0.72648

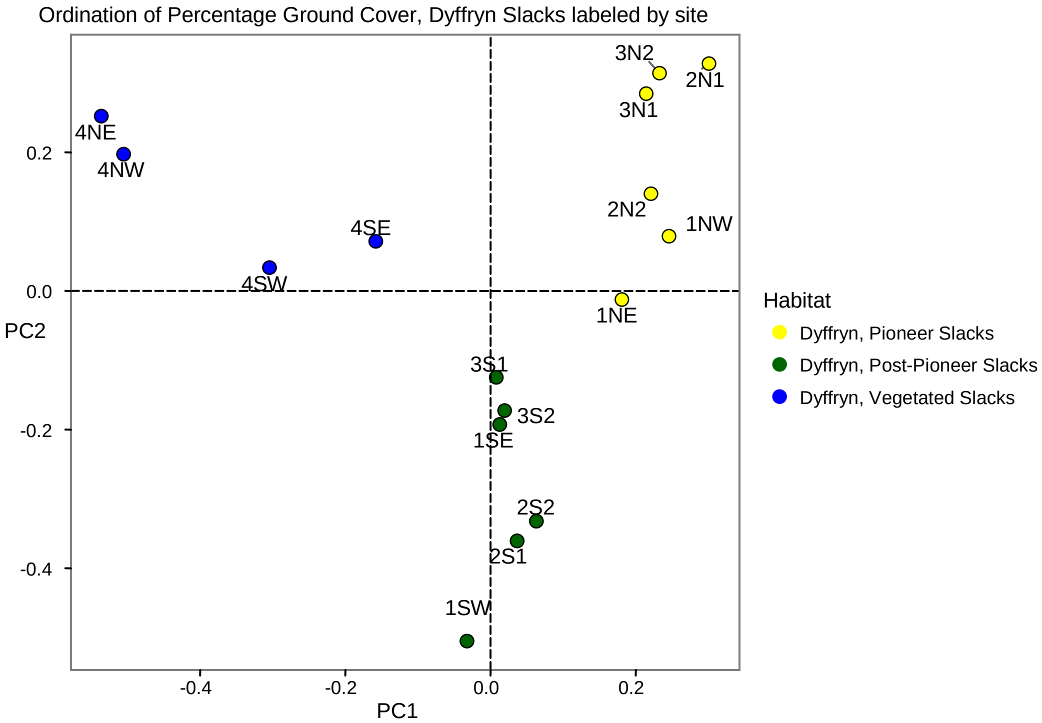


Figure 4a: Ordination of Percentage Ground Cover, Dyffryn Slacks labelled by site.

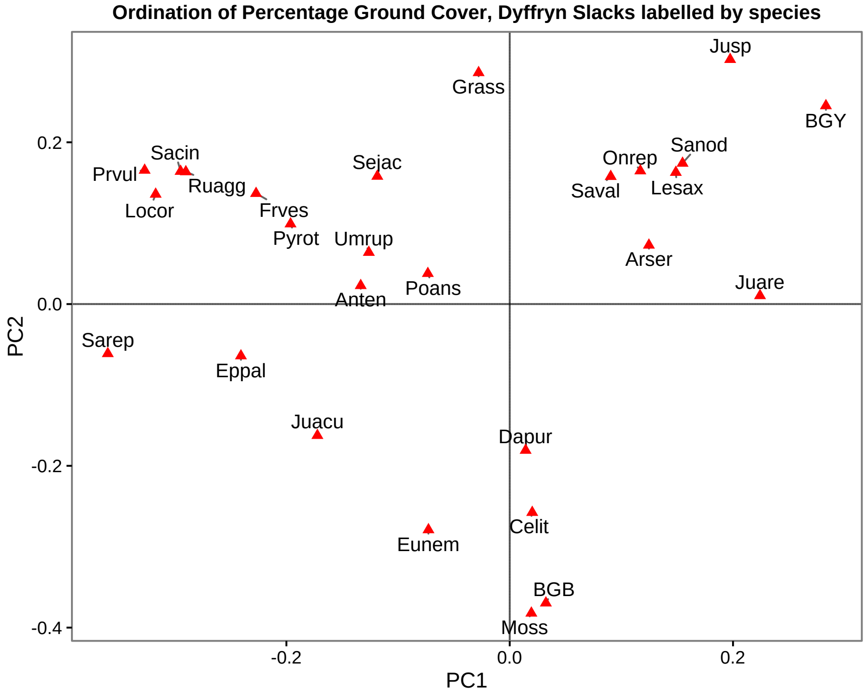


Figure 4b: Ordination of Percentage Ground Cover, Dyffryn Slacks labelled by species.

Carabidae 1: Cicindela-Pterostichus

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	27.59559	13.50506	8.991755	4.982606	3.476905
Proportion explained	0.42313	0.20708	0.137870	0.076400	0.053310
Cumulative Proportion	0.42313	0.63021	0.768090	0.844490	0.897800

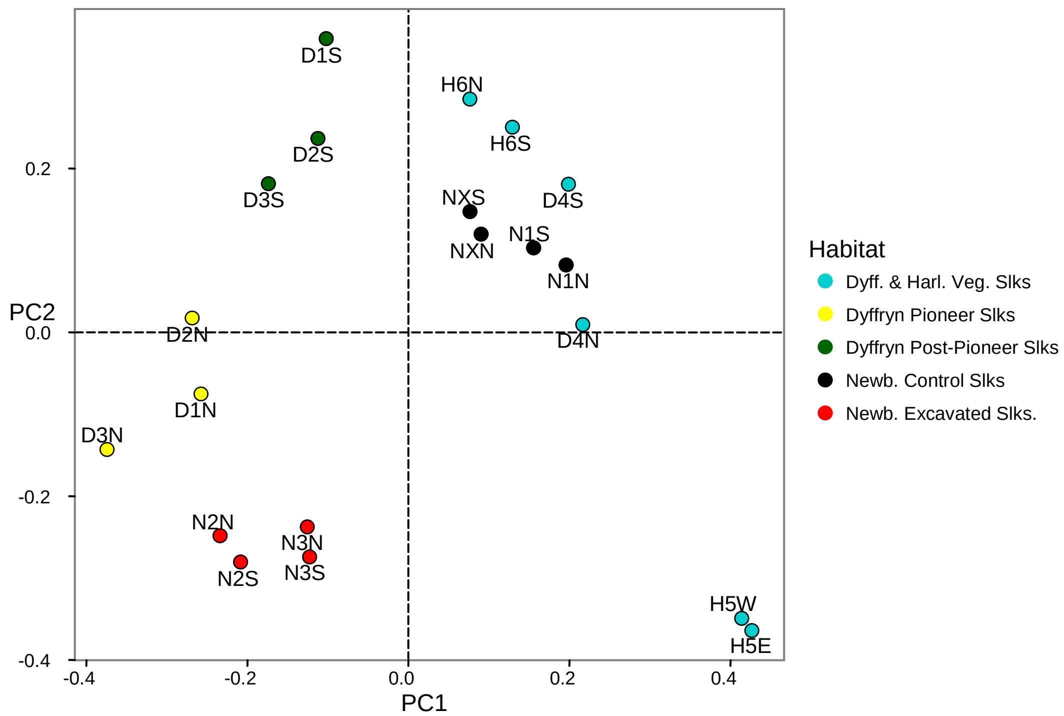


Figure 5a: Ordination of Carabidae 1: *Cicindela* - *Pterostichus* labelled by site.

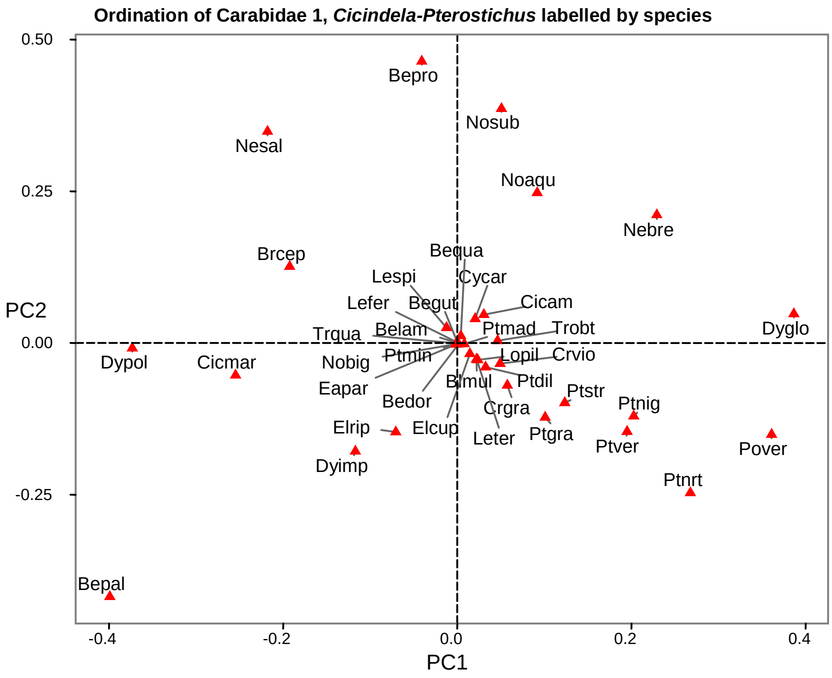


Figure 5b: Ordination of Carabidae 1: *Cicindela - Pterostichus* labelled by species.

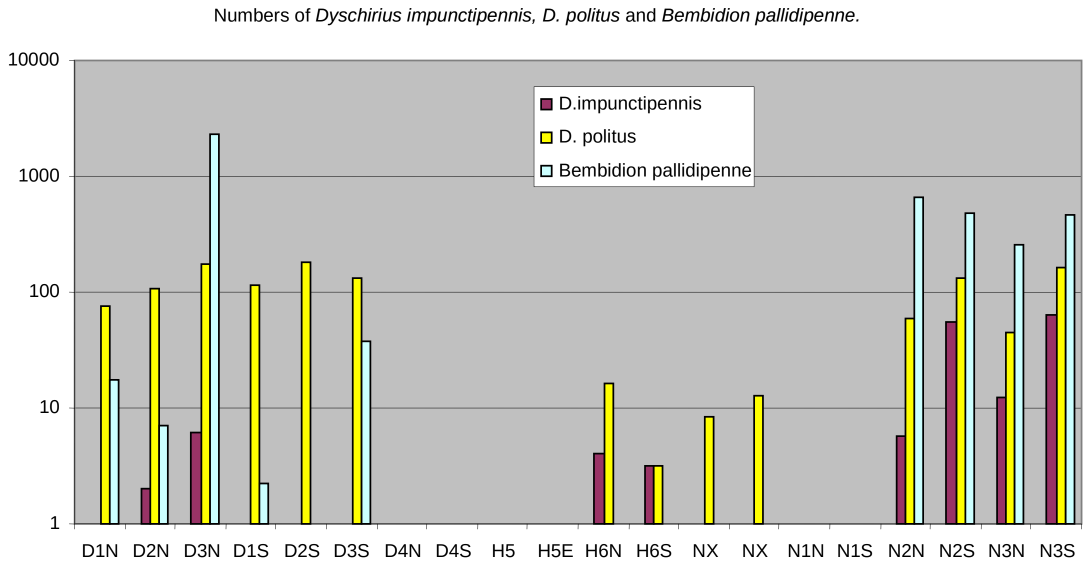


Figure 6a: Numbers *of Dyschirius impunctipennis, D. politus* and *Bembidion pallidipenne,* expressed as logarithms.

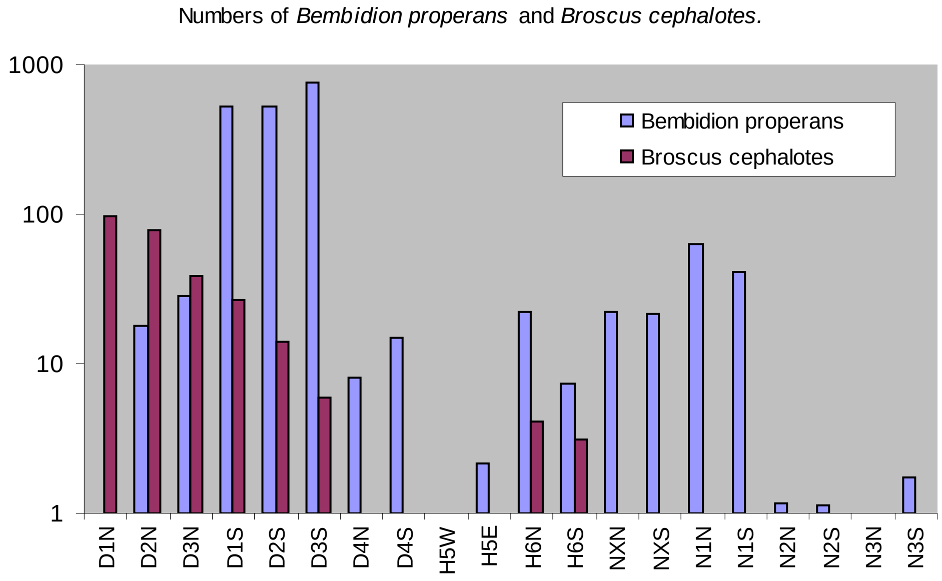


Figure 6b: Numbers of *Bembidion properans* and *Broscus cephalotes* expressed as logarithms.

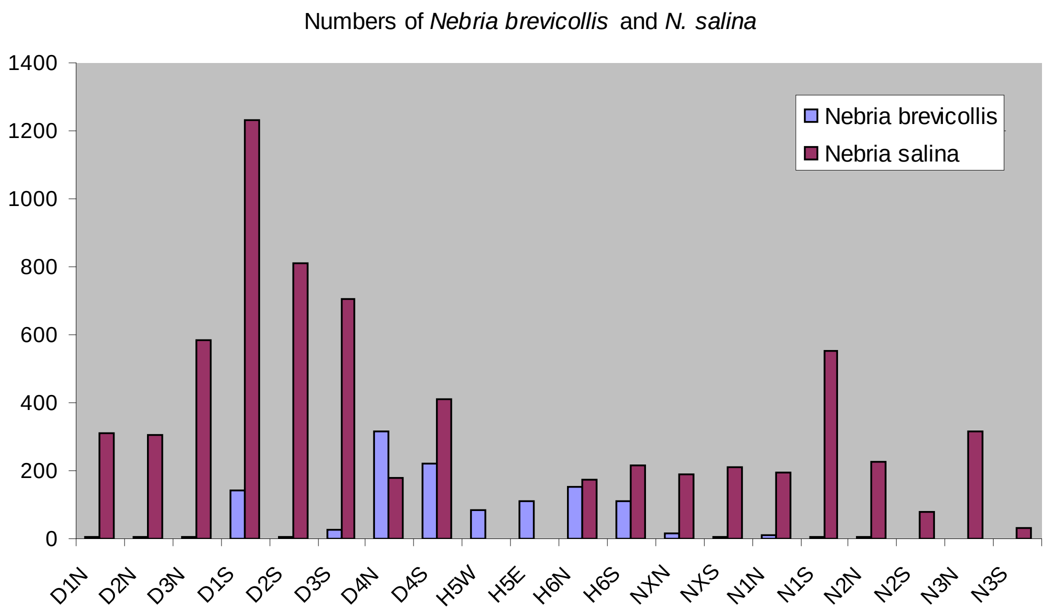


Figure 6c: Numbers of *Nebria brevicollis* and *N. salina*.

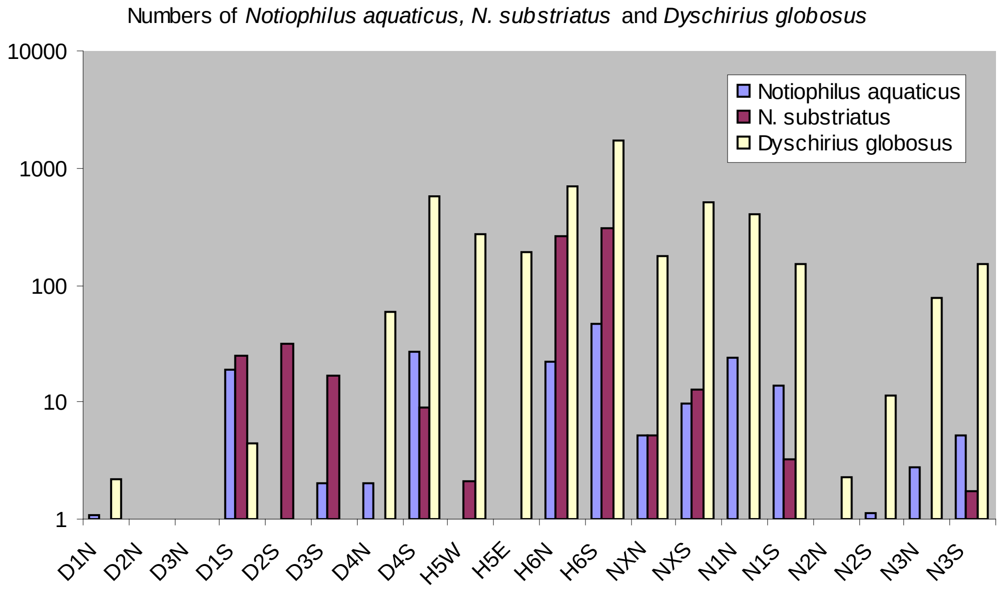


Figure 6d: Numbers of *Notiophilus aquaticus, N. substriatus* and *Dyschirius globosus* expressed as logarithms.

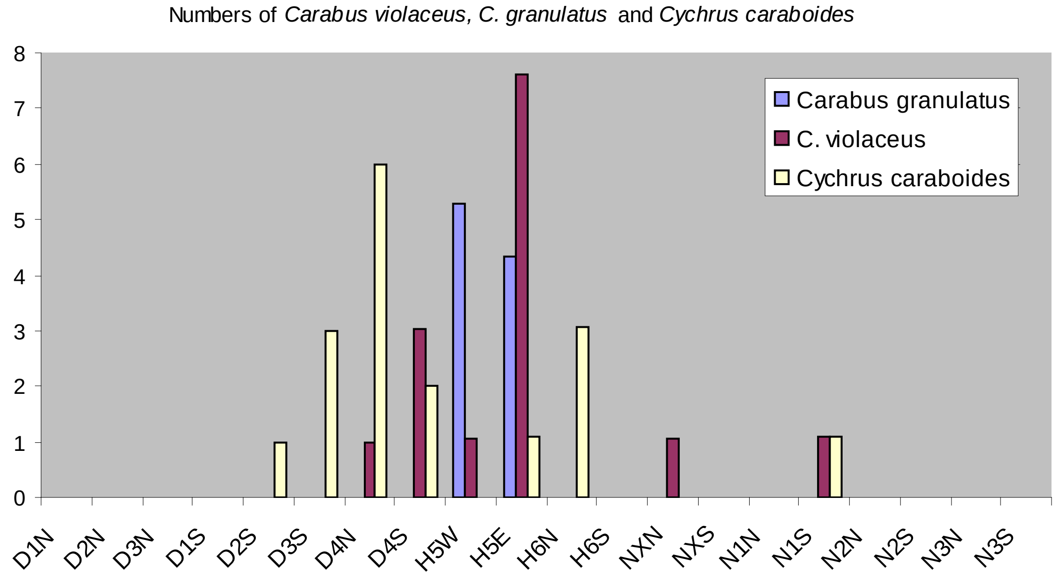


Figure 6e: Numbers *Carabus granulatus, C. violaceus* and *Cychrus caraboides*.

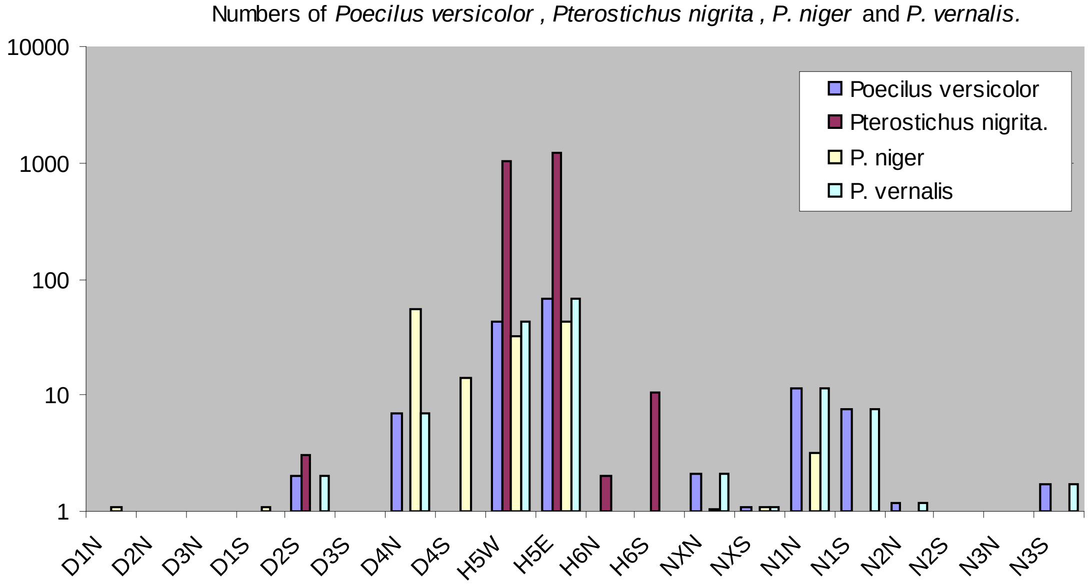


Figure 6f: Numbers of *Poecilus versicolor, Pterostichus nigrita, P. niger* and *P.vernalis* expressed as logarithms.

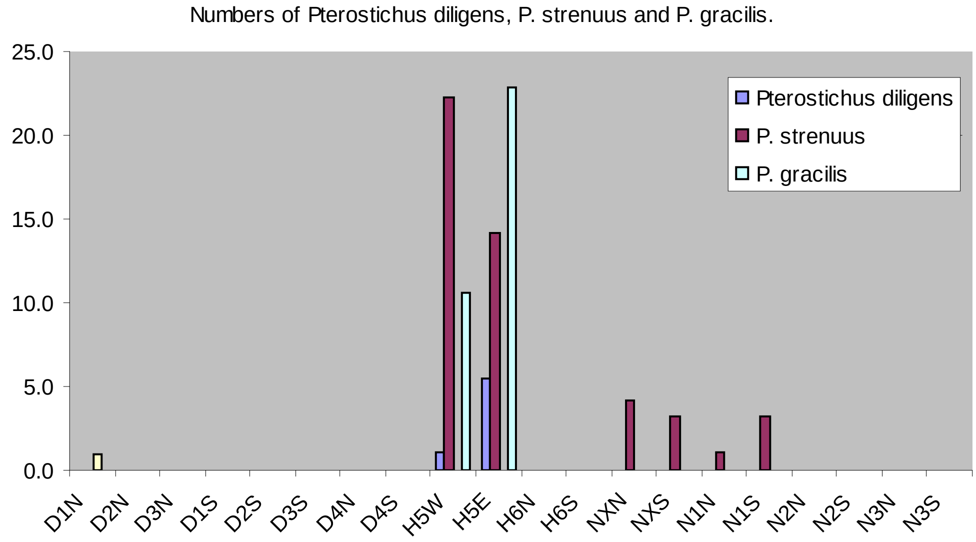


Figure 6g: Numbers of *Pterostichus diligens, P.strenuus* and *P. gracilis*.

Carabidae 2, *Amara - Syntomus*

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	16.24866	11.21174	3.63256	3.056186	2.406743
Proportion Explained 0.070560 0.055560	0.37513	0.25884	0.08386	0.07056	0.05556
Cumulative Proportion	0.37513	0.63398	0.71784	0.7884	0.84396

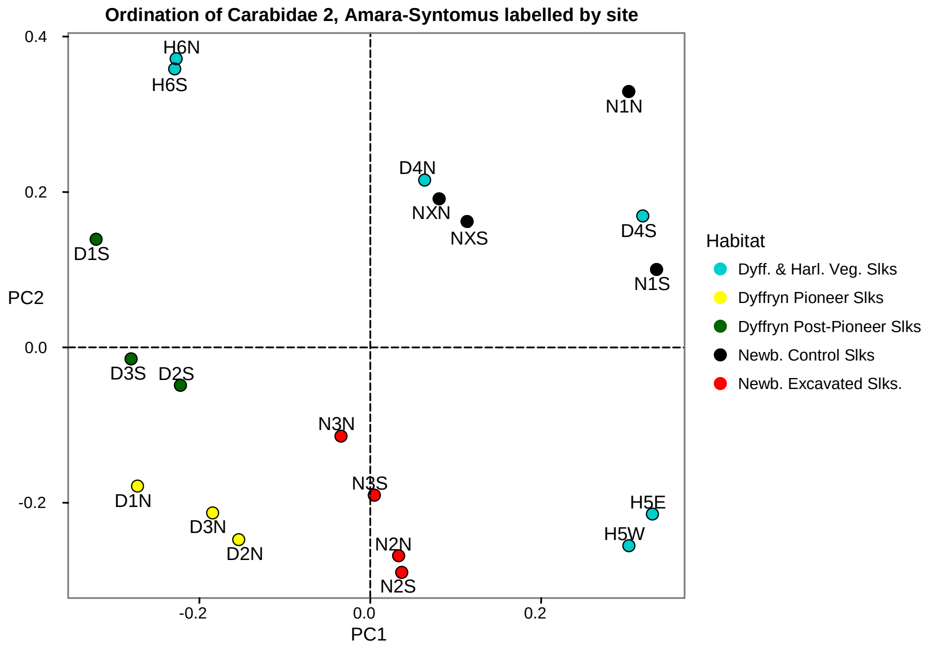


Figure 7a: Ordination of Carabidae 2: *Amara - Syntomus* labelled by site.

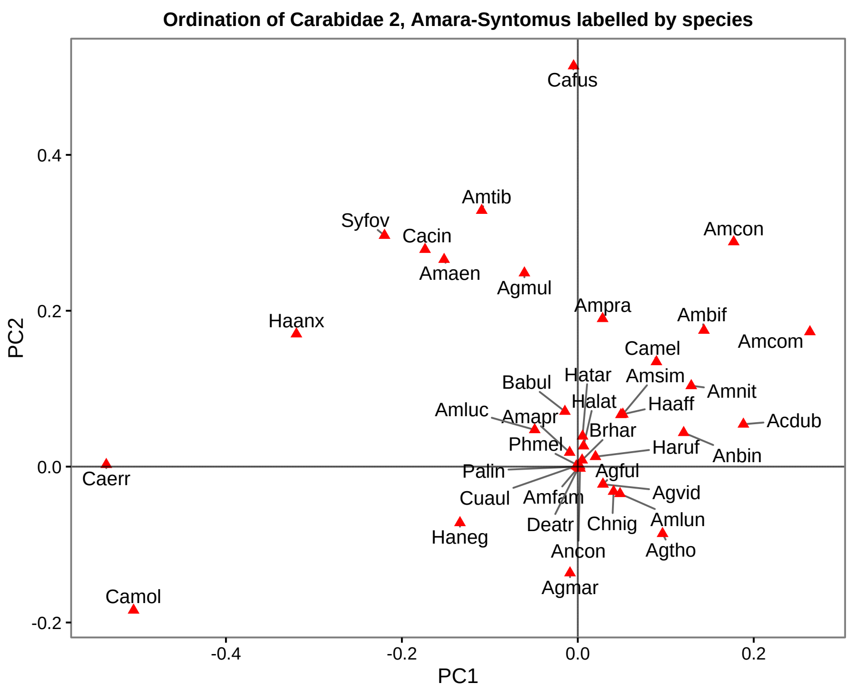


Figure 7b: Ordination of Carabidae 2: *Amara - Syntomus* labelled by species.

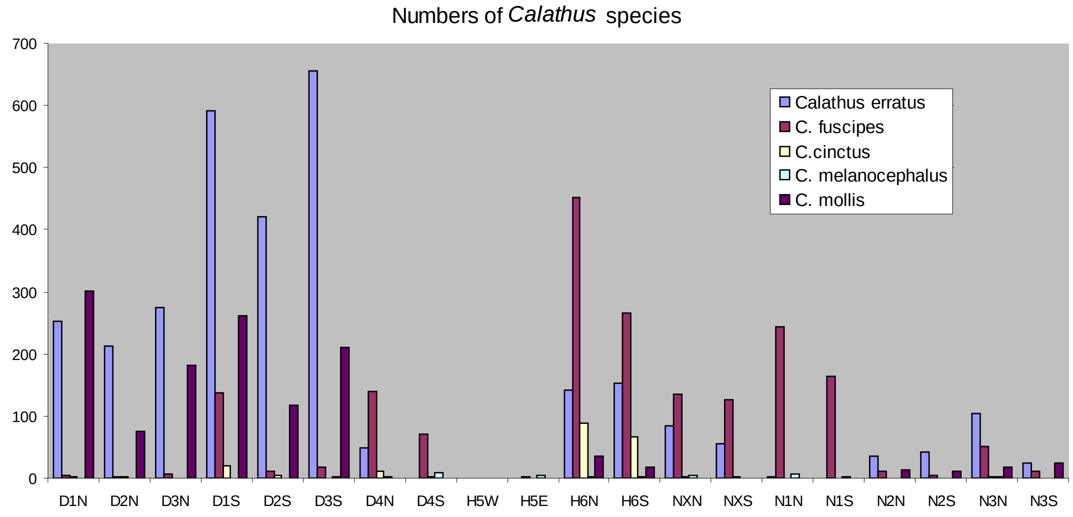


Figure 8a: Numbers of *Calathus* species.

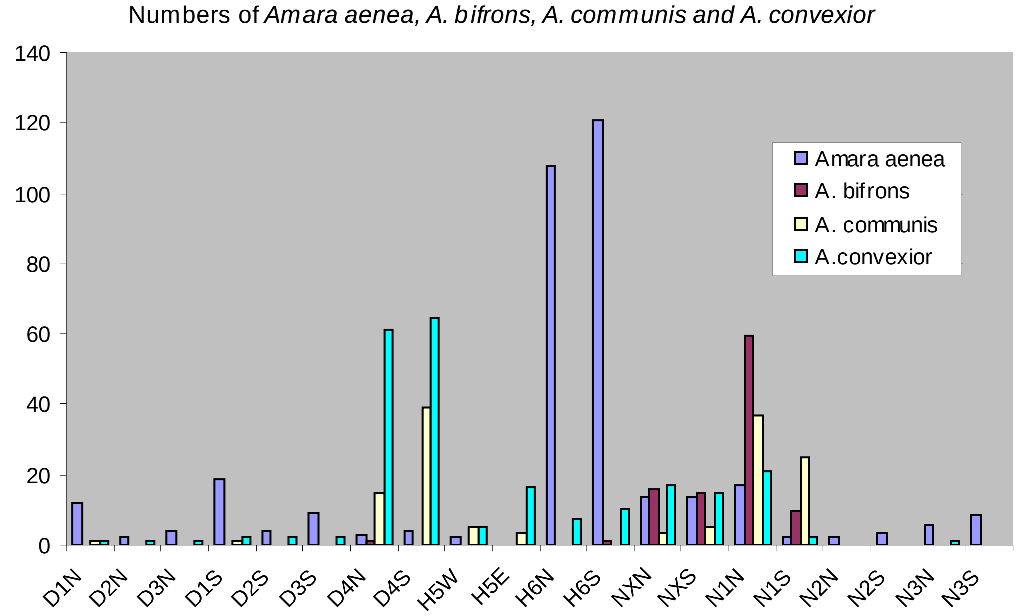


Figure 8b: Numbers of *Amara aenea, A. bifrons, A. communis* and *A. convexior*.

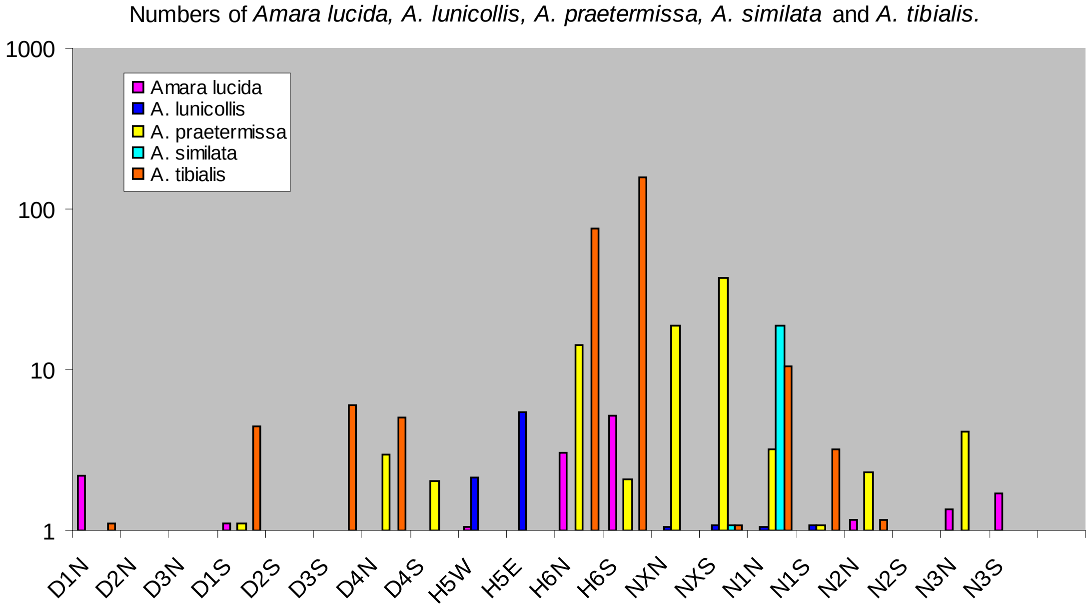


Figure 8c: Numbers of *Amara lucida, A. lunicollis, A. praetermissa, A. similata* and *A. tibialis* expressed as logarithms.

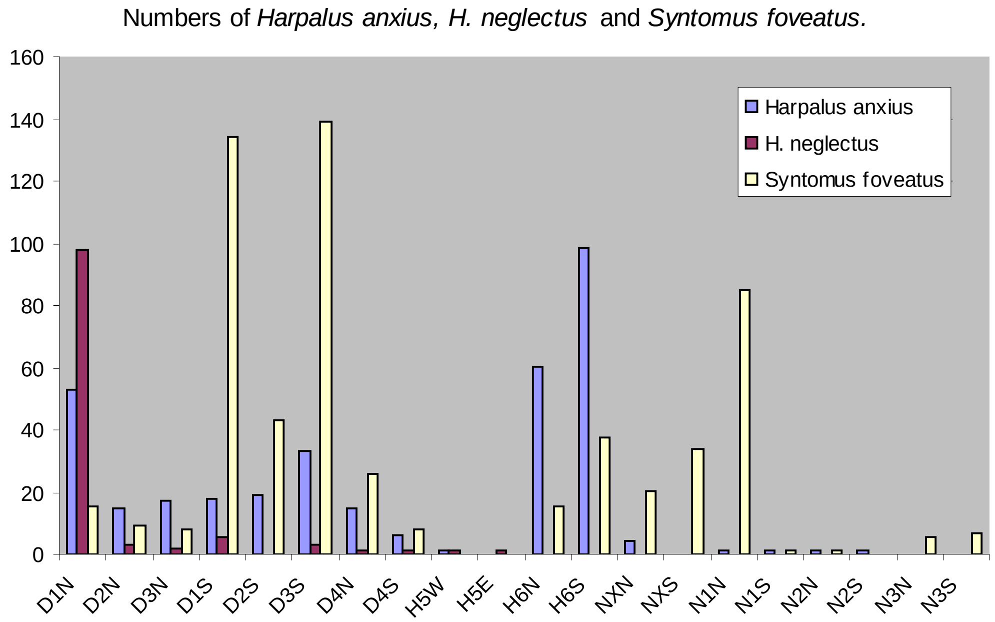


Figure 8d: Numbers of *Harpalus anxius, H. neglectus* and *Syntomus foveatus*.

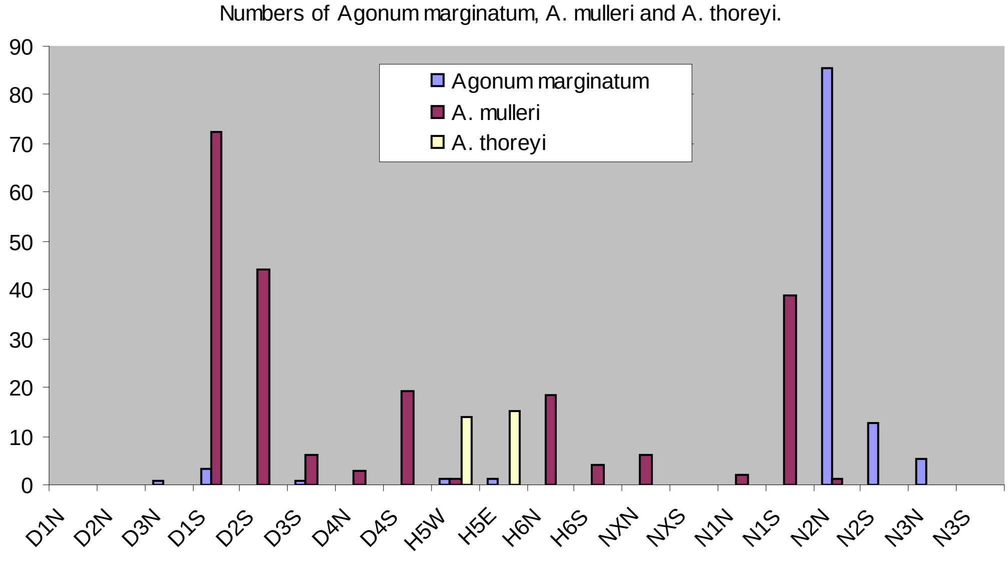


Figure 8e: Numbers of *Agonum marginatum, A. mulleri* and *A. thoreyi.*

Staphylinidae 1 - Omalinae, Psephalinae, Tachyporinae, Aleocharinae

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	5.892315	2.882489	1.840834	1.237974	1.026528
Proportion Explained	0.34947	0.17096	0.10918	0.07342	0.06088
Cumulative Proportion	0.34947	0.52042	0.6296	0.70302	0.76391

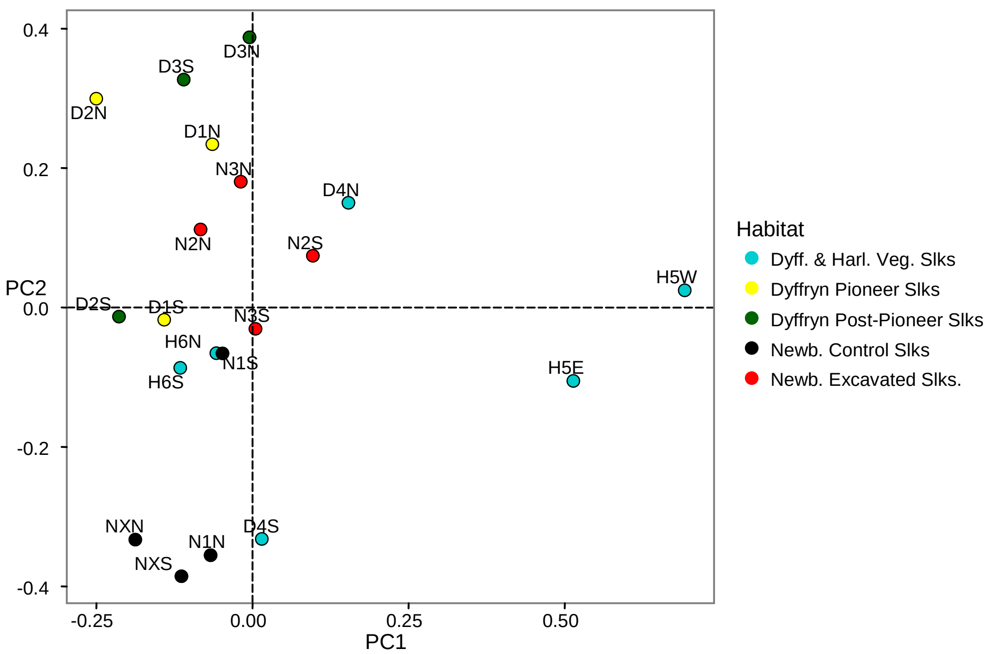


Figure 9a: Ordination Staphylinidae 1 - Omalinae, Psephalinae, Tachyporinae, Aleocharinae labelled by sites.

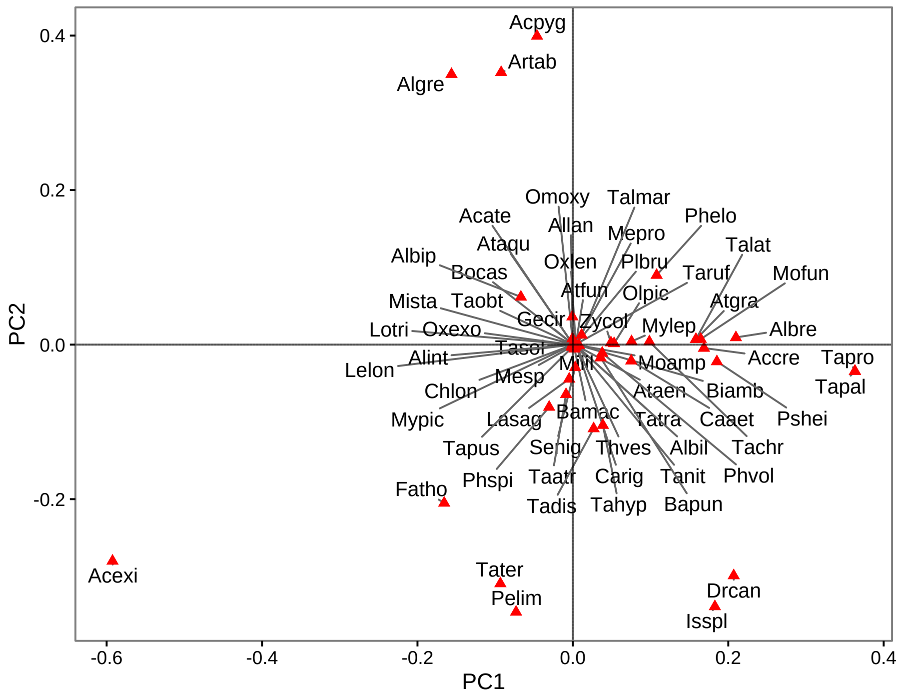


Figure 9b: Ordination Staphylinidae 1 - Omalinae, Psephalinae, Tachyporinae, Aleocharinae labelled by species.

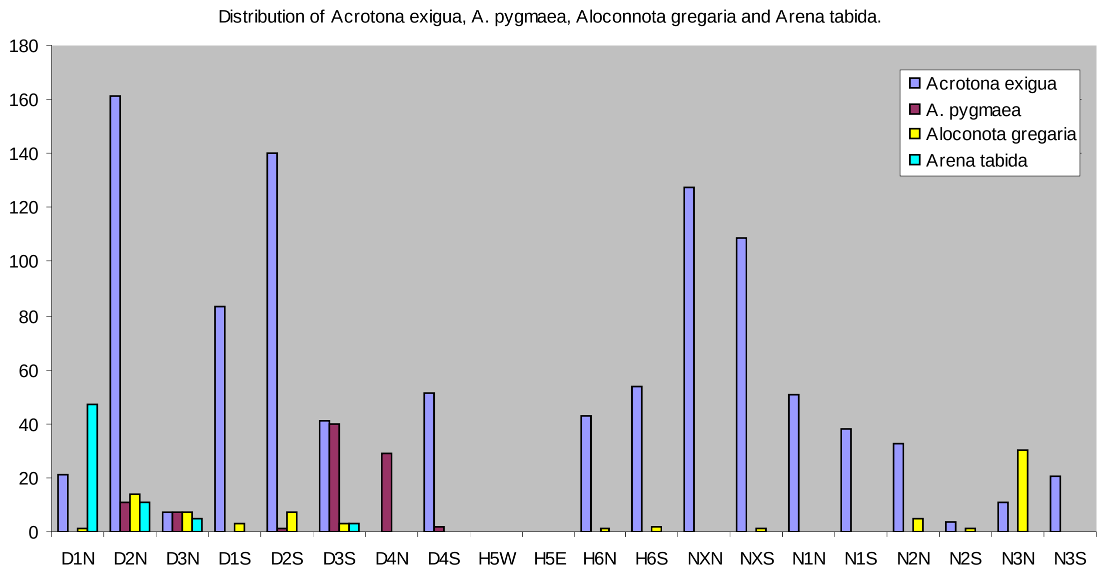


Figure 9c: Distribution of *Acrotona exigua, A. pygmaea, Aloconnota gregaria* and *Arena tabida*.

Staphylinidae 2 - Oxytelinae, Steninae

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	6.068649	3.112481	1.912907	1.573227	1.06308
Proportion Explained	0.37901	0.19438	0.11947	0.09825	0.06639
Cumulative Proportion	0.37901	0.57339	0.69286	0.79111	0.8575

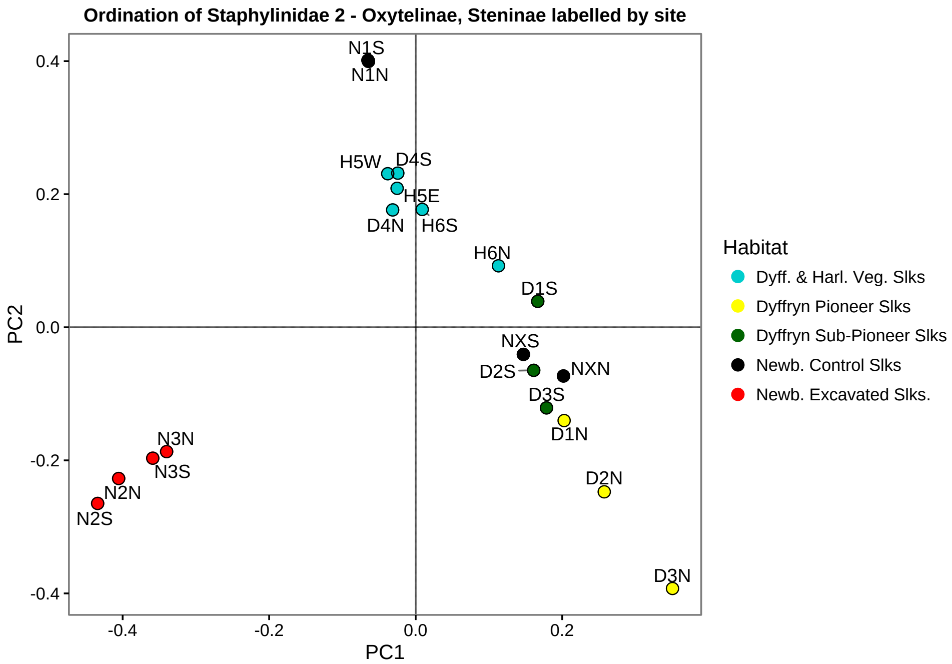


Figure 10a. Ordination of Staphylinidae 2 – Oxytelinae and Steninae labelled by species.

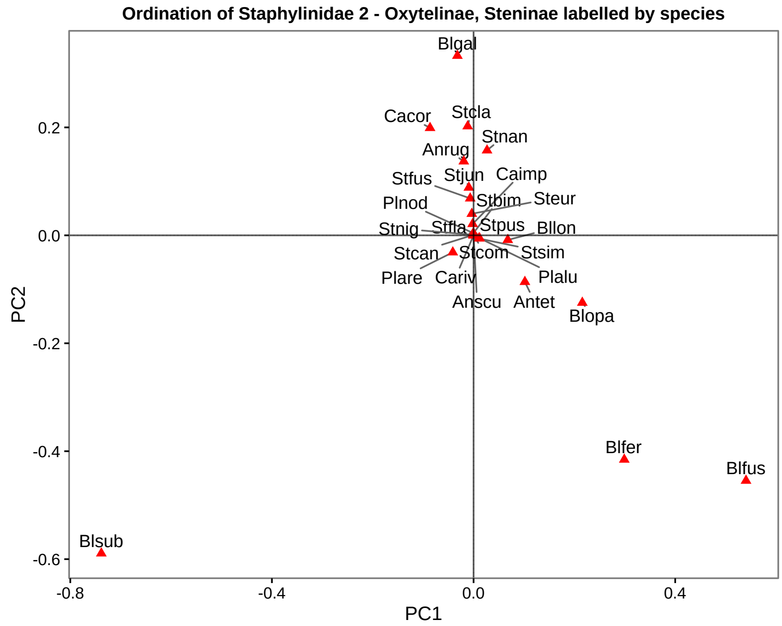


Figure 10b. Ordination of Staphylinidae 2 - Oxytelinae, Steninae labelled by species.

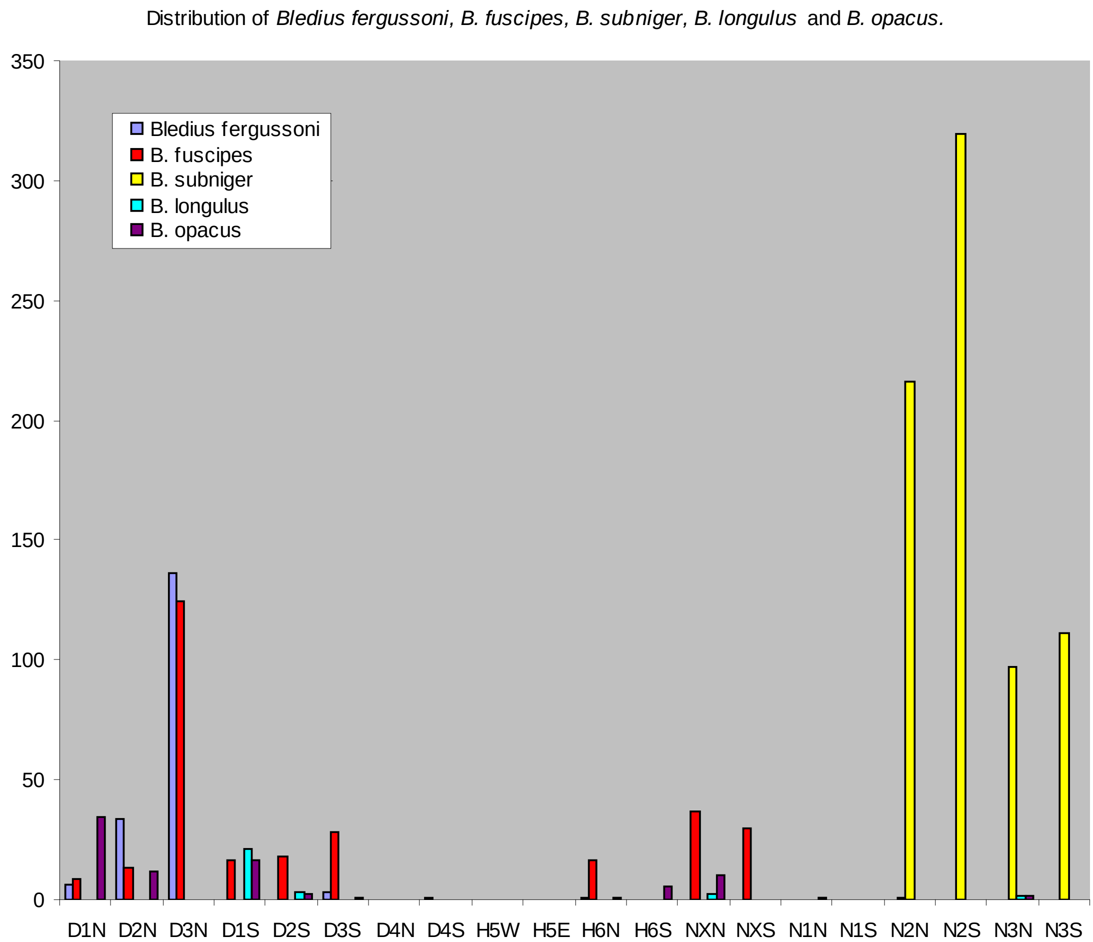


Figure 11: Numbers of *Bledius fergussoni, B. fuscipes, B. subniger, B. longulus* and *B. opacus.*

Staphylinidae 3 - Paederinae, Staphylinae

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	8.305296	5.384423	1.872909	1.569719	1.08662
Proportion Explained	0.38527	0.24977	0.08688	0.07282	0.05041
Cumulative Proportion 0.84515	0.38527	0.63504	0.72192	0.79474	0.79474

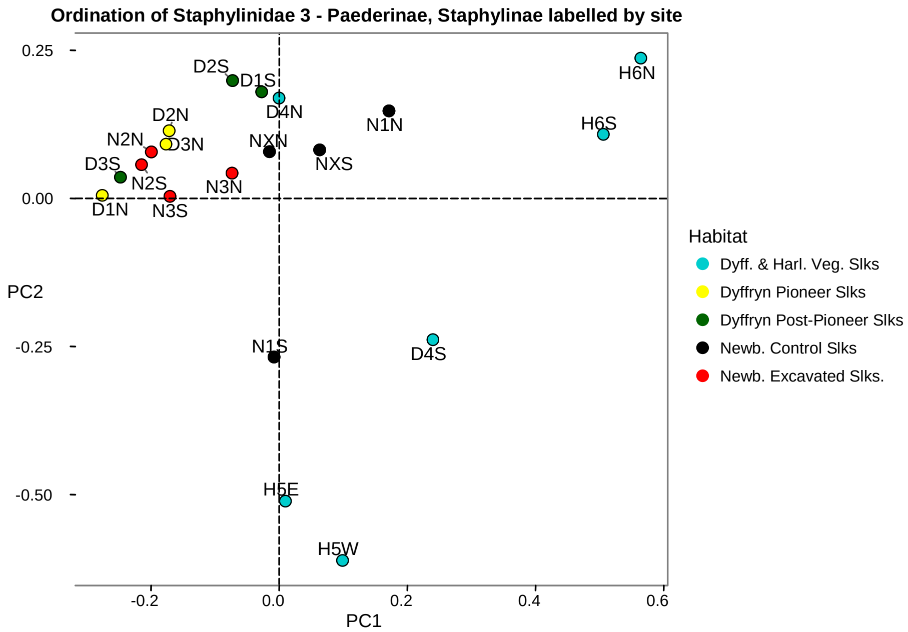


Figure 12a: Ordination of Staphylinidae 3 - Paederinae, Staphylinae labelled by site.

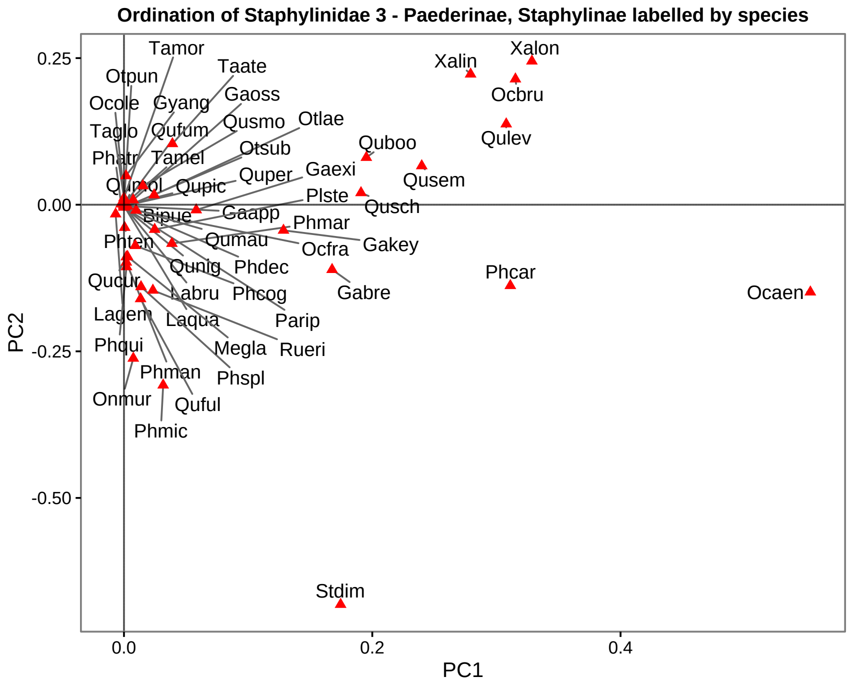


Figure 12b: Ordination of Staphylinidae 3 – Paederinae and Staphylinae labelled by species.

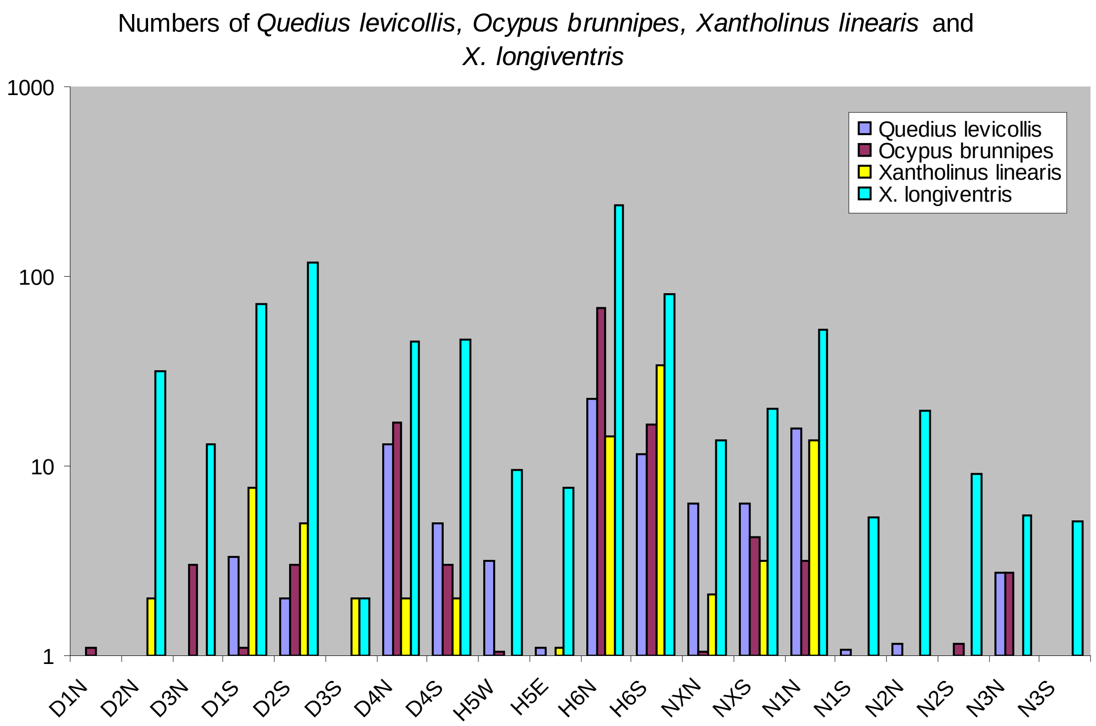


Figure 13a: Numbers of *Quedius levicollis, Ocypus brunnipes, Xantholinus linearis* and *X. longiventris* expressed as logarithms.

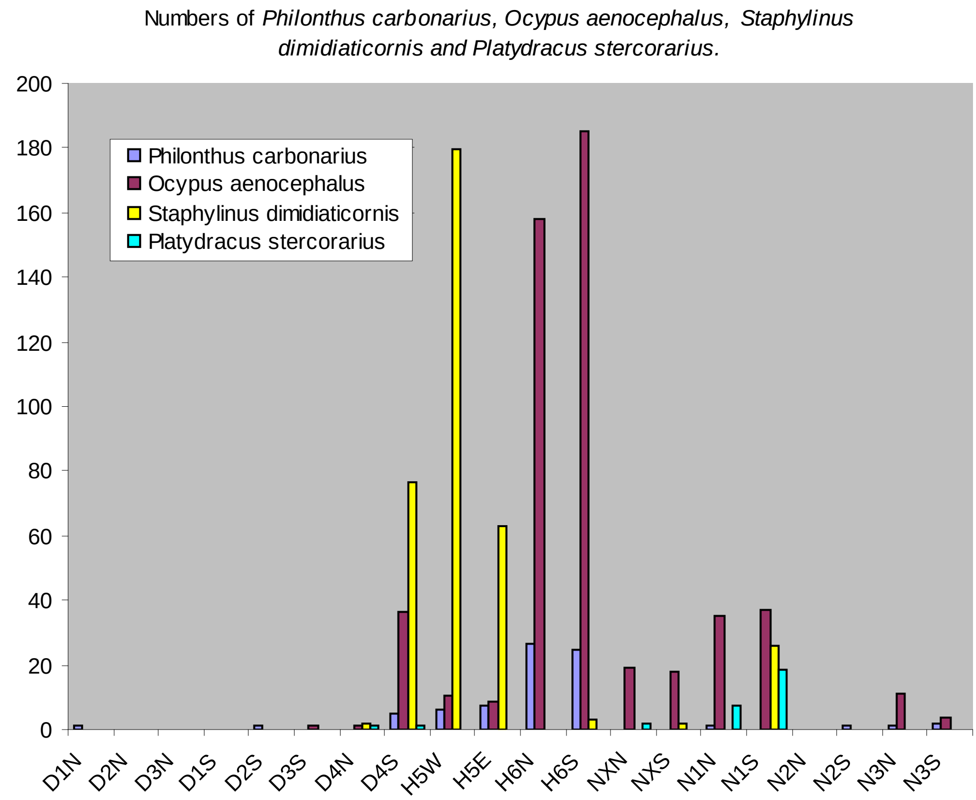


Figure 13b: Numbers of *Philonthus carbonarius, Ocypus aenocephalus* and *Staphylinus dimidiaticornis* and *Platydracus stercorarius*.

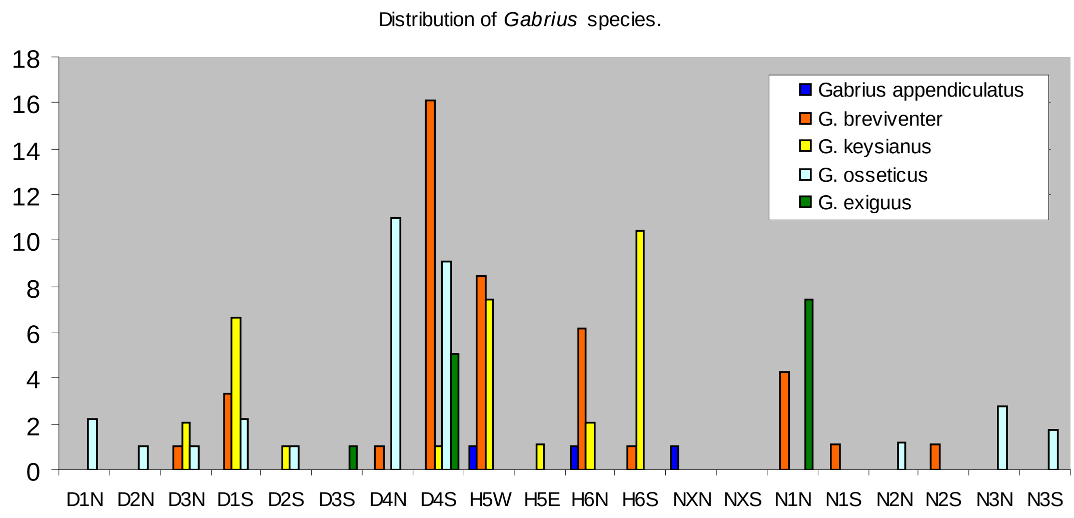


Figure 13c: Distribution of *Gabrius* species.

Leaf Beetles and Weevils

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	7.073858	3.705784	2.260053	1.270749	0.919484
Proportion Explained	0.38874	0.20365	0.1242	0.06983	0.05053
Cumulative Proportion	0.38874	0.5924	0.7166	0.78643	0.83696

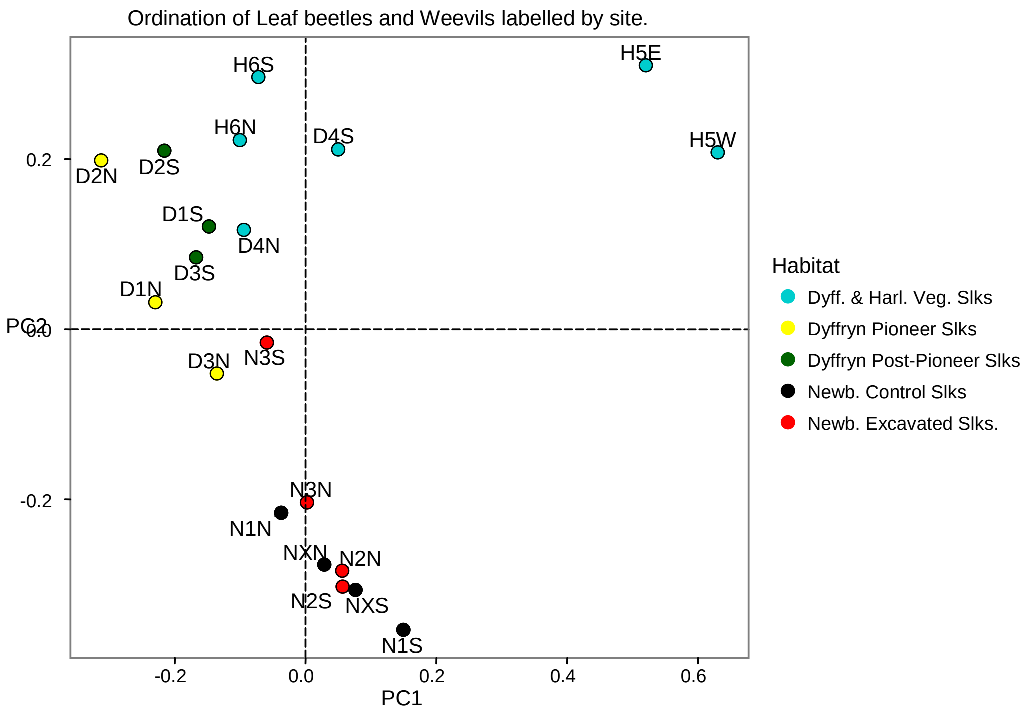


Figure 14a: Ordination of Leaf Beetles and Weevils labelled by site.

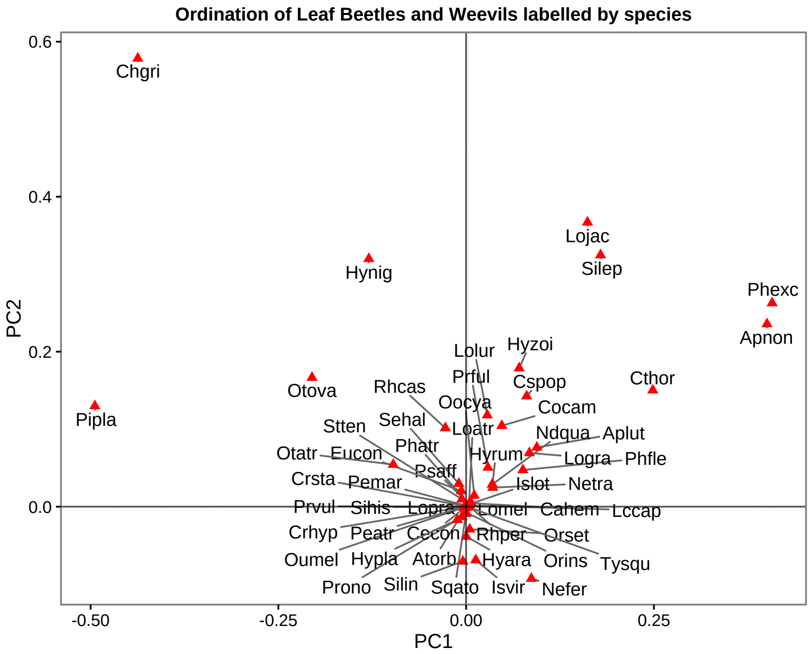


Figure 14b: Ordination of Leaf Beetles and Weevils labelled by species.

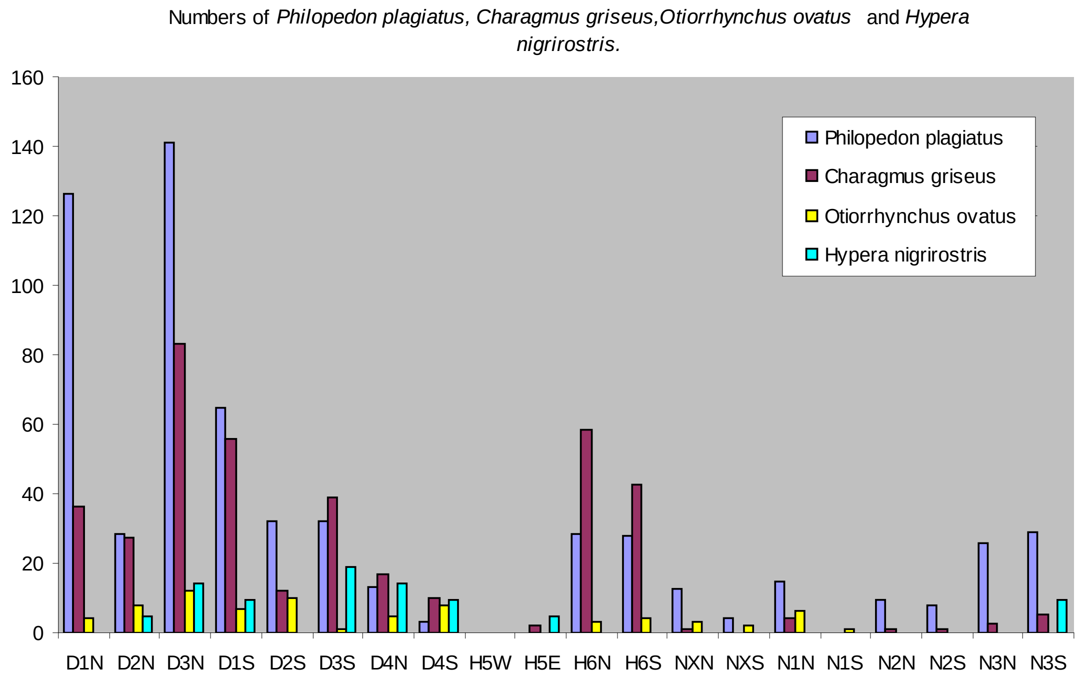


Figure 15a: Numbers of *Philopedon plagiatus, Charagmus griseus, Otiorrhynchus ovatus* and *Hypera nigrirostris.*

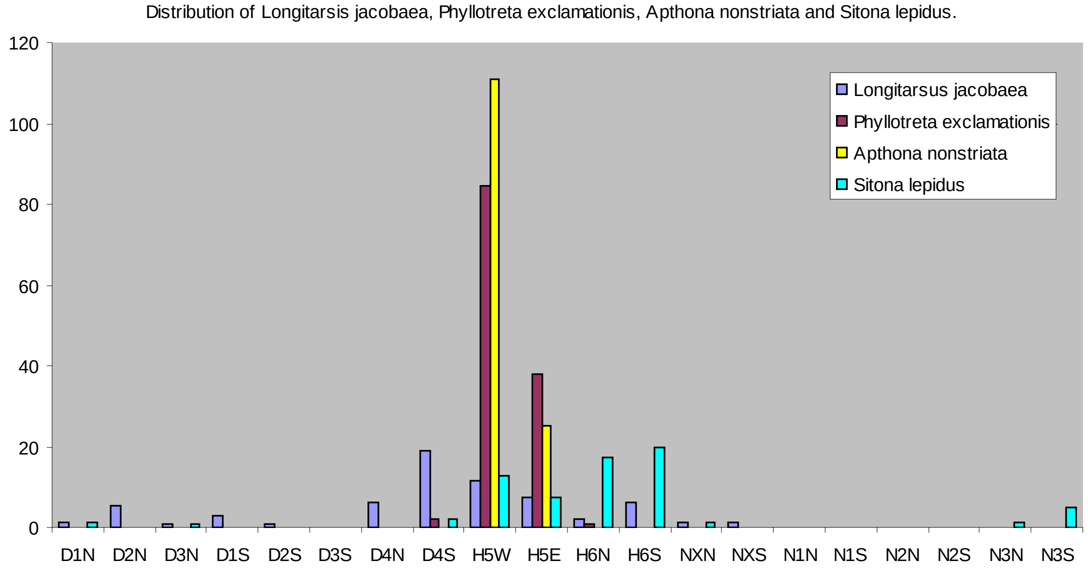


Figure 15b: *Longitarsis jacobaea, Phyllotreta exclamationis, Apthona nonstriata* and *Sitona lepidus.*

Miscellaneous Beetles 1, Dytiscidae – Scarabaeidae.

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	8.911541	6.128837	3.814798	2.664961	1.24187
Proportion Explained	0.33852	0.23282	0.14491	0.10123	0.04717
Cumulative Proportion	0.33852	0.57134	0.71625	0.81749	0.86466

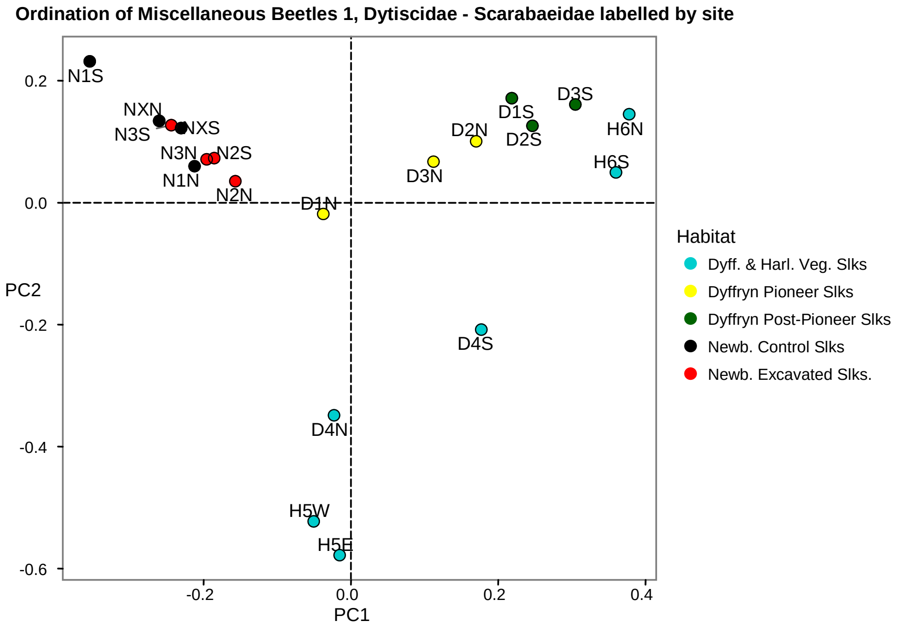


Figure 16a: Ordination of Miscellaneous Beetles 1: Dytiscidae – Scarabaeidae labelled by site.

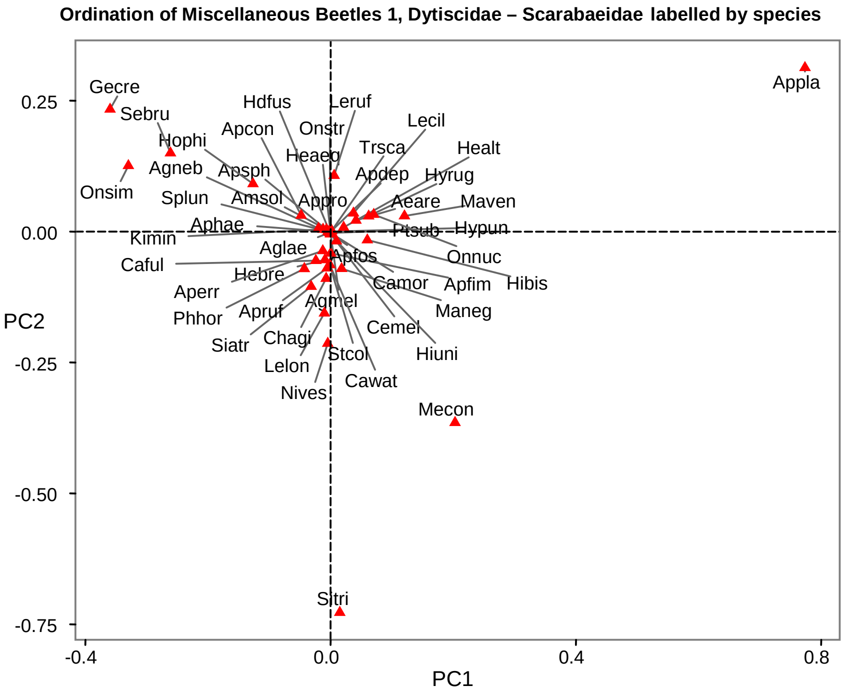


Figure 16b: Ordination of Miscellaneous Beetles 1, Dytiscidae – Scarabaeidae labelled by species.

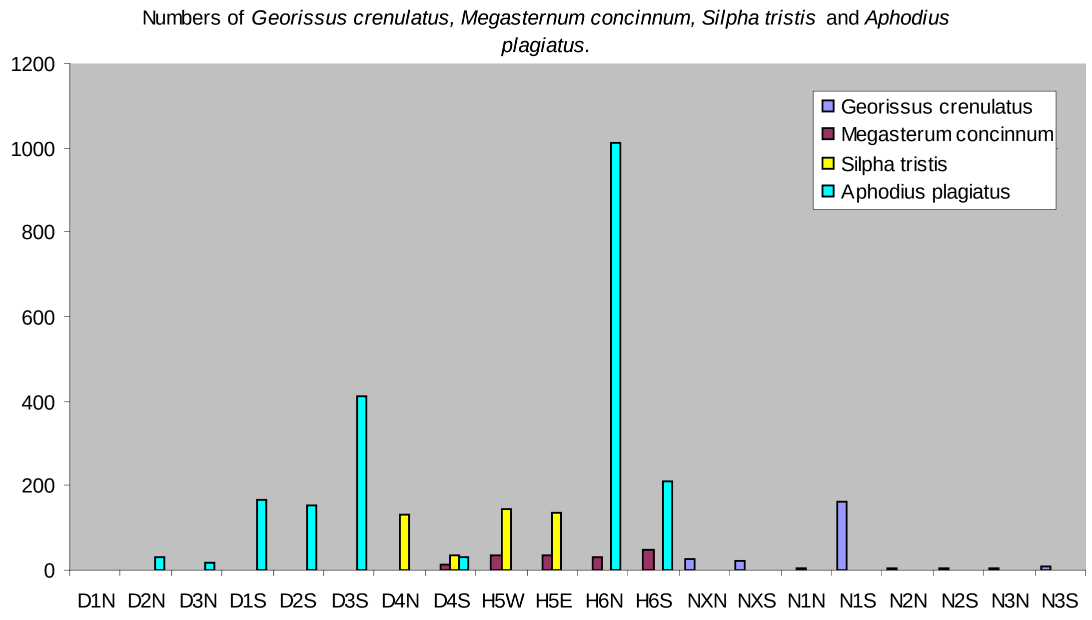


Figure 17a: Distribution of *Georissus crenulatus, Megasternum concinnum, Silpha tristis* and *Aphodius plagiatus.*

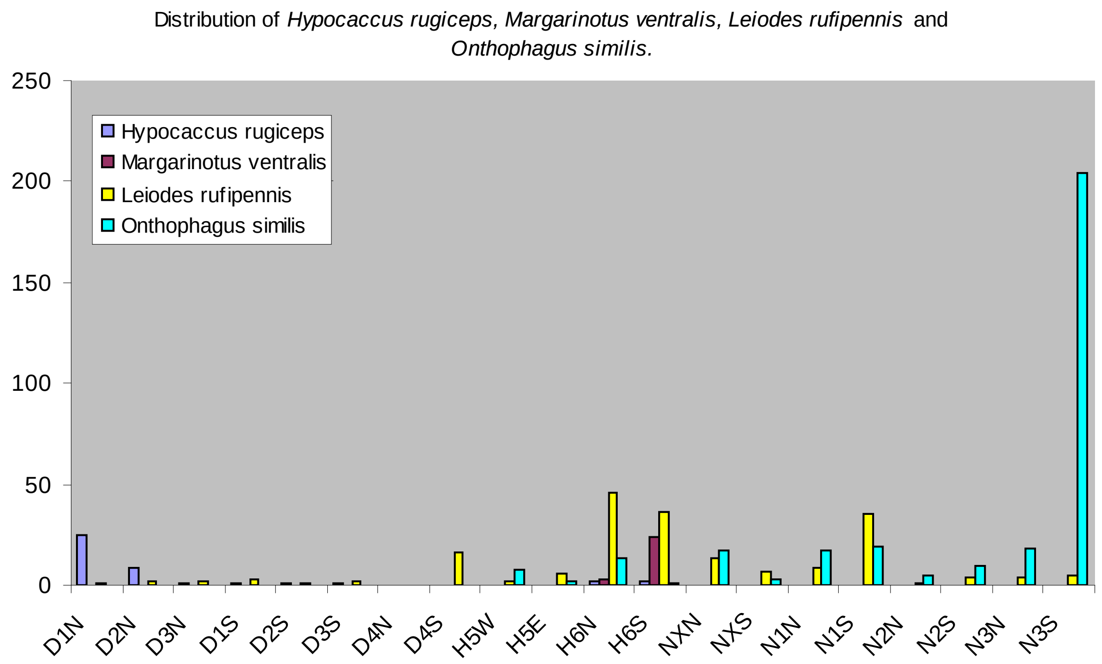


Figure 17b: Distribution of *Hypocaccus rugiceps, margarinotus ventralis, Leiodes rufipennis* and *Onthophagus rufipennis.*

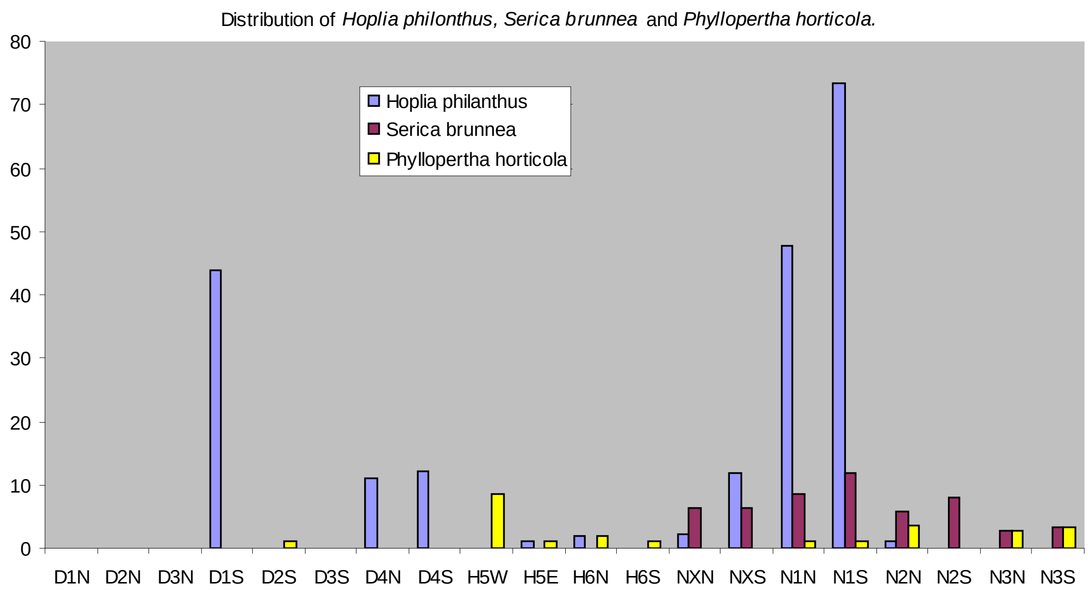


Figure 17c: Distribution of *Hoplia philanthus, Serica brunnea* and *Phyllopertha horticola.*

Miscellaneous beetles 2,

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	12.87558	8.077235	5.126115	3.086041	1.765681
Proportion Explained	0.34501	0.21643	0.13736	0.08269	0.04731
Cumulative Proportion 0.828800	0.34501	0.56144	0.69879	0.78149	0.8288

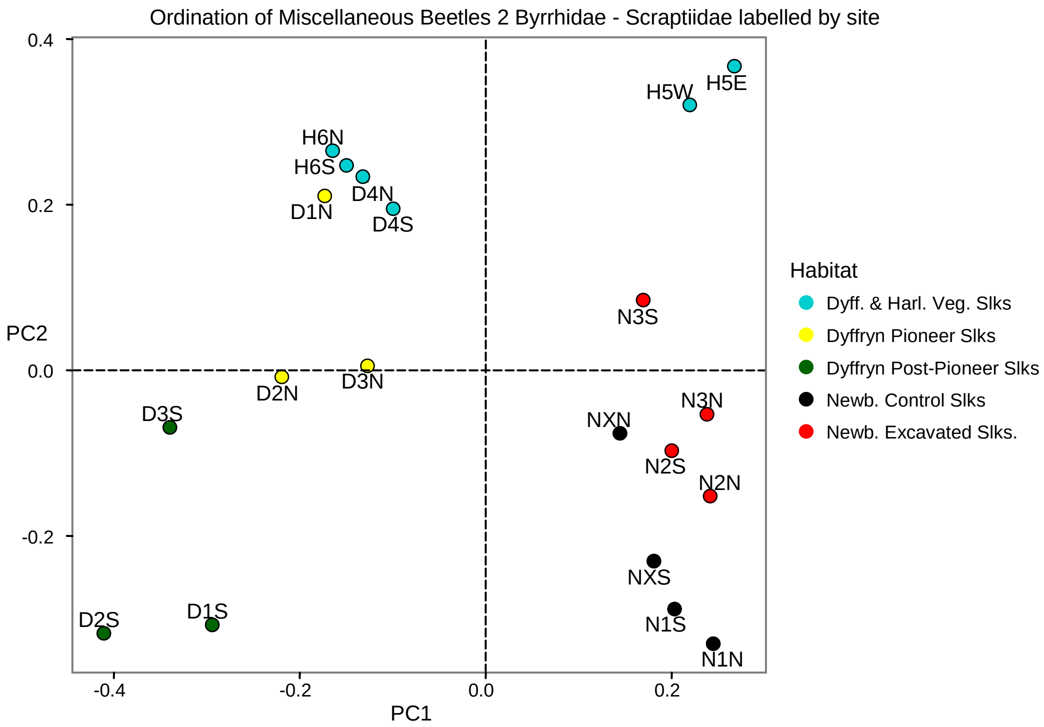


Figure 18a: Ordination of Miscellaneous Beetles 2: Byrrhidae - Scraptiidae labelled by site.

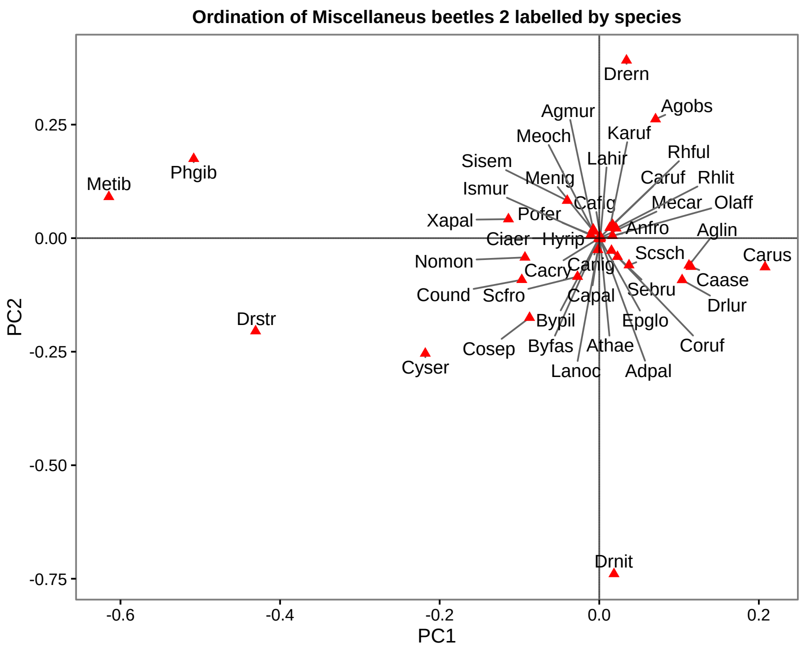


Figure 18b: Ordination of Miscellaneous Beetles 2: Byrrhidae - Scraptiidae labelled by species.

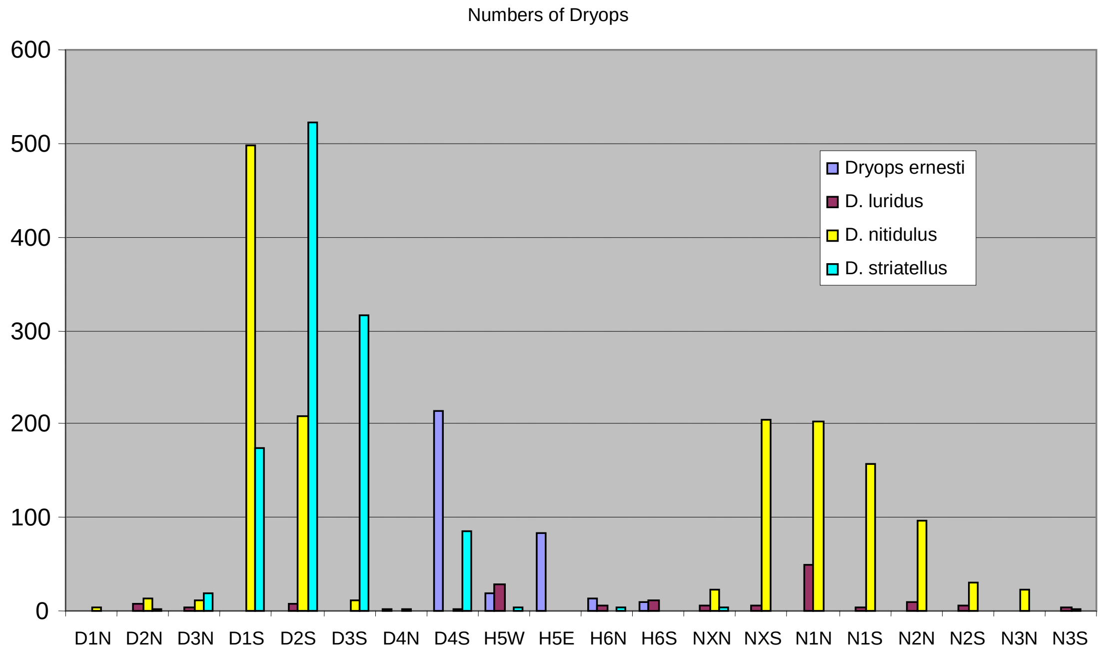


Figure 19a: Numbers of four *Dryops* species.

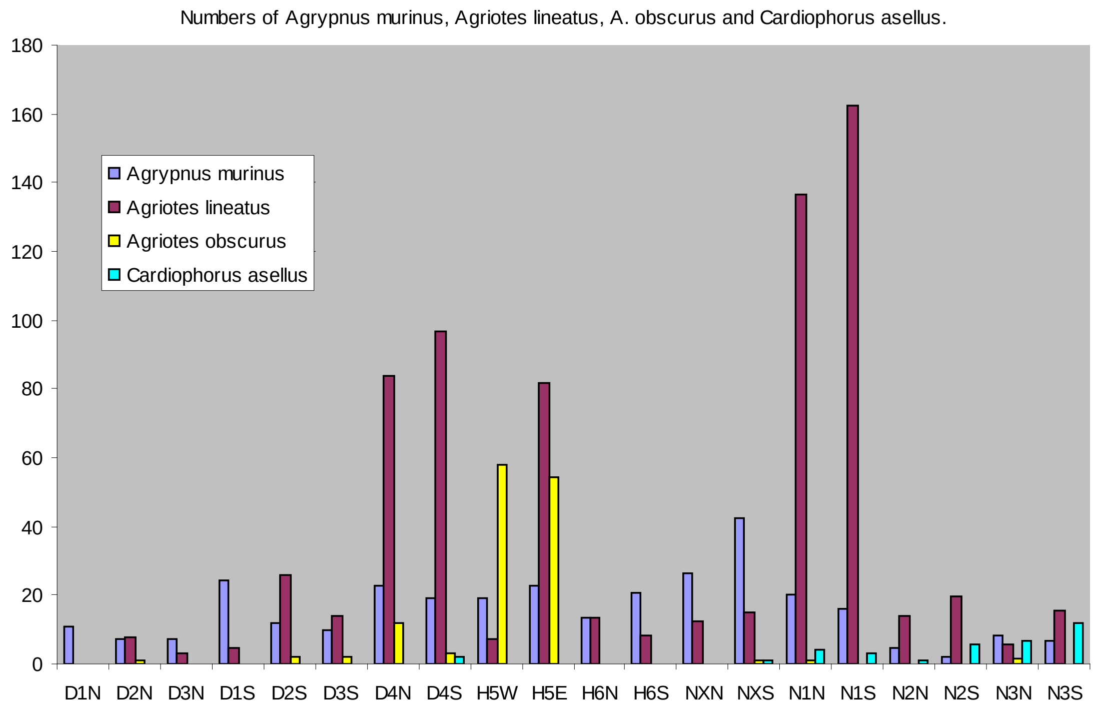


Figure 19b: Numbers of *Agrypnus murinus, Agriotes lineatus, A. obscurus* and *Cardiophorus asellus.*

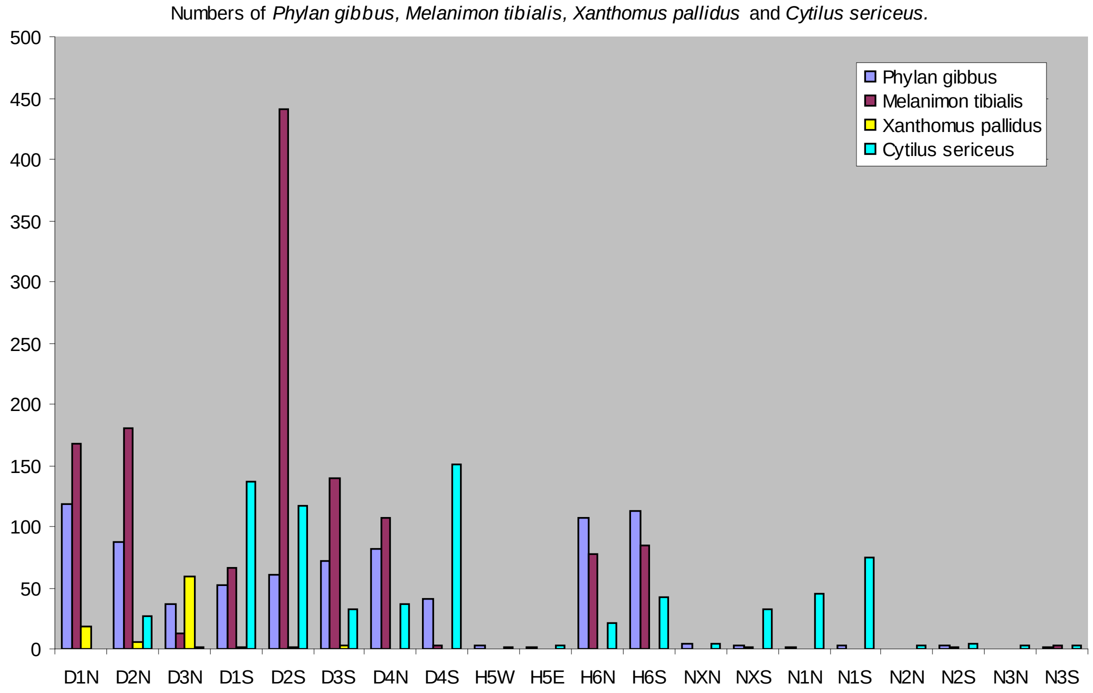


Figure 19c: Numbers of *Phylan gibbus, Melanimon tibialis, Xanthomus pallidus* and *Cytilus sericeus.*

Spiders - Linyphiidae

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	8.045844	4.239045	3.904347	2.901651	0.931841
Proportion Explained.	0.35295	0.18596	0.17127	0.12729	0.04088
Cumulative Proportion	0.35295	0.53891	0.71019	0.83747	0.87835

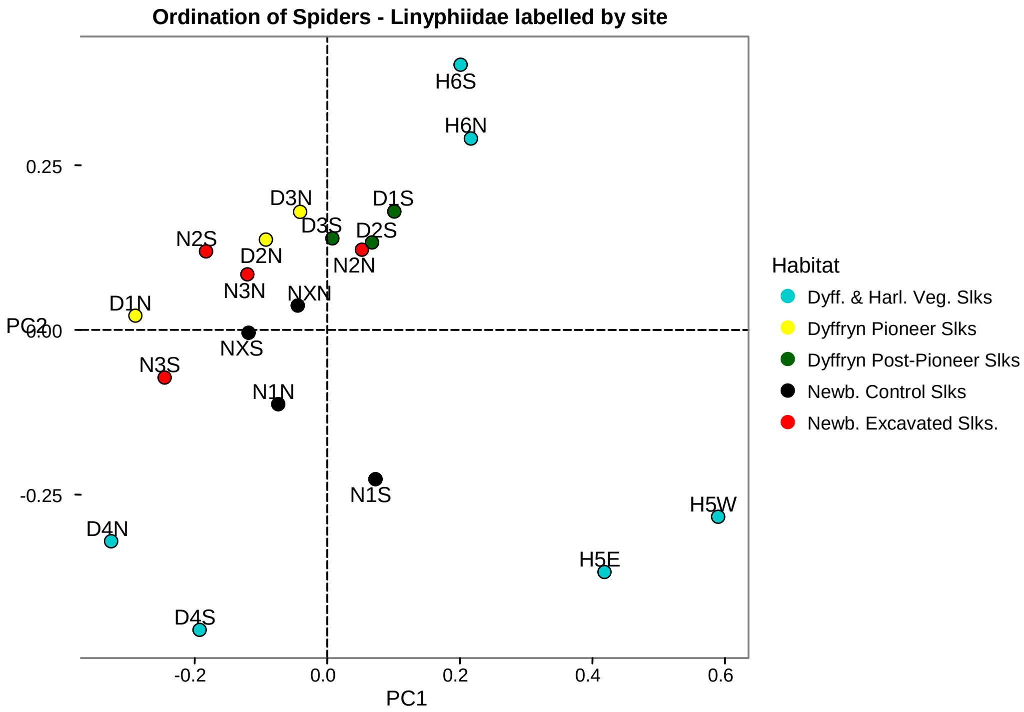


Figure 20a: Ordination of Spiders – Lynyphiidae, labelled by sites.

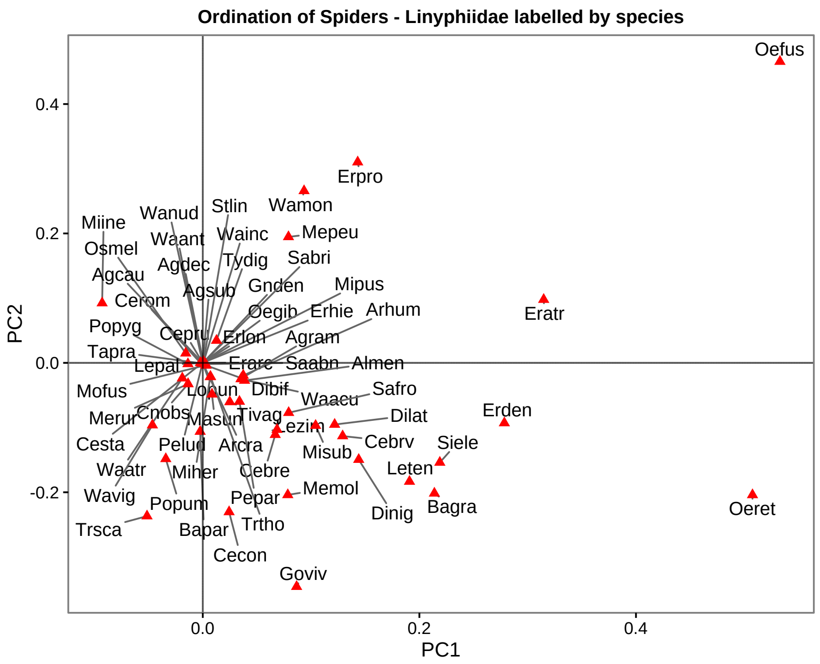


Figure 20b: Ordination of Spiders – Linyphiidae, labelled by species.

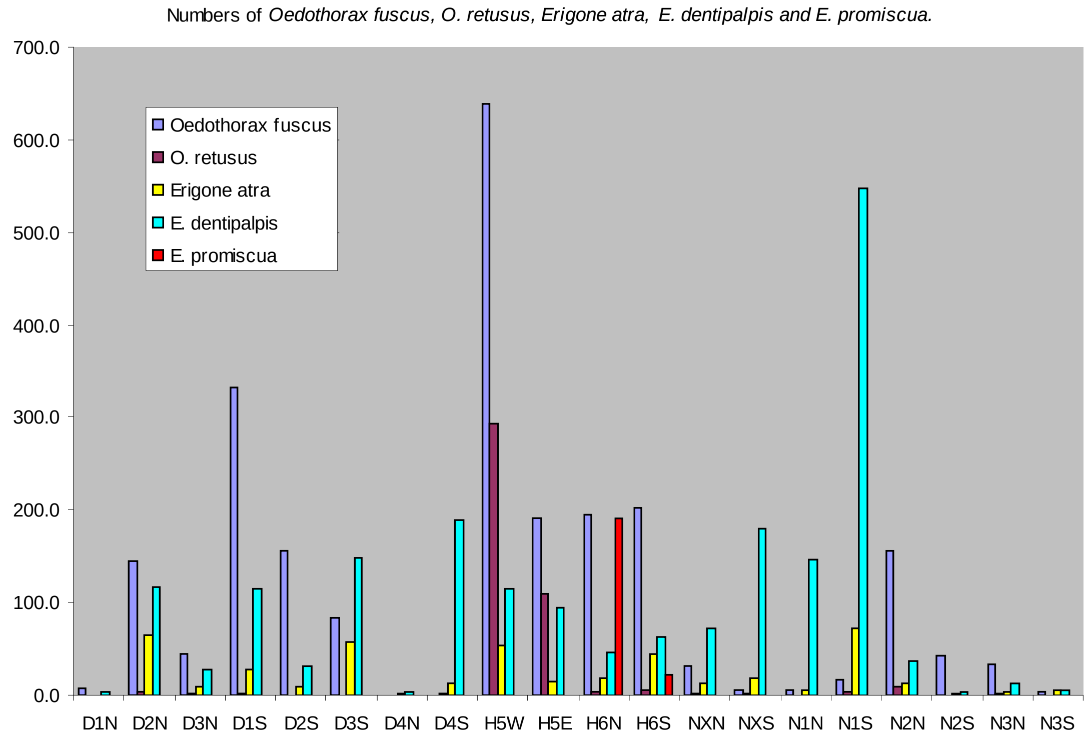


Figure 21a: Numbers of *Oedothorax fuscus, O. retusus, Erigone atra, E. denti*palpis and *E. promiscua*.

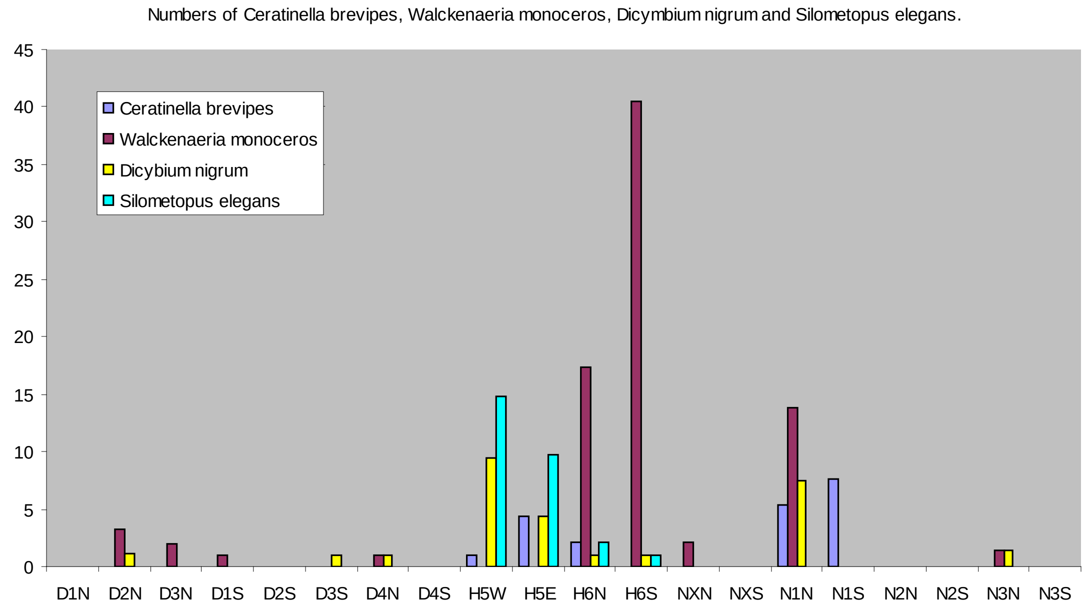


Figure 21b: Numbers of *Ceratinella brevipes, Walckenaeria monoceros, Dicymbium nigrum* and *Silometopus elegans*.

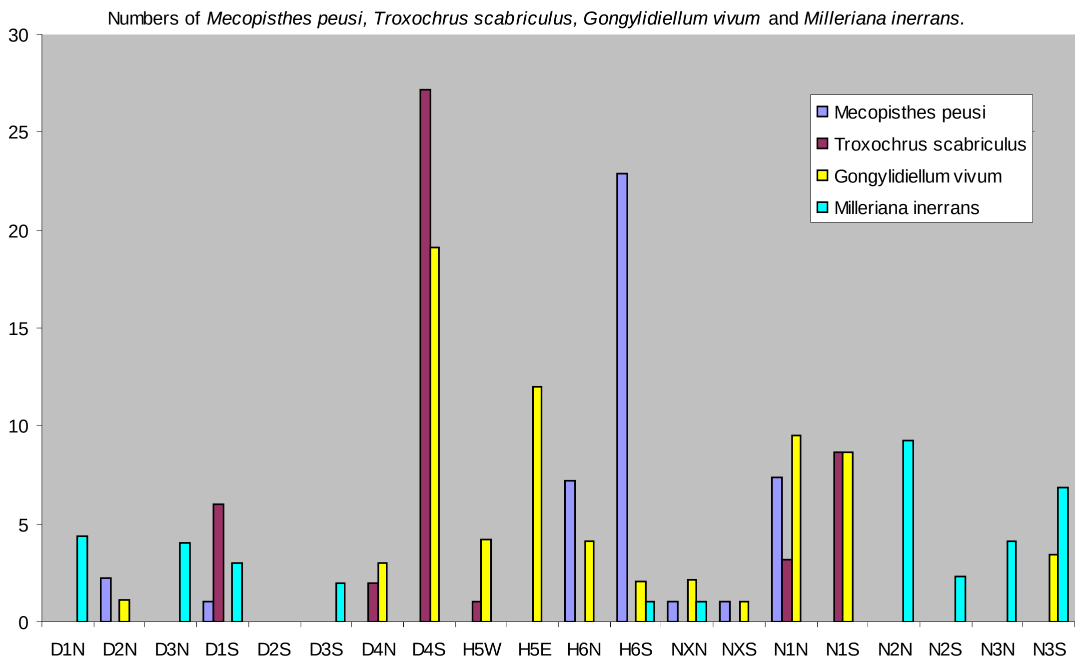


Figure 21c: Numbers of *Mecopisthes peusi, Troxochrus scabriculus, Gongylidiellum vivum* and *Milleriana inerrans.*

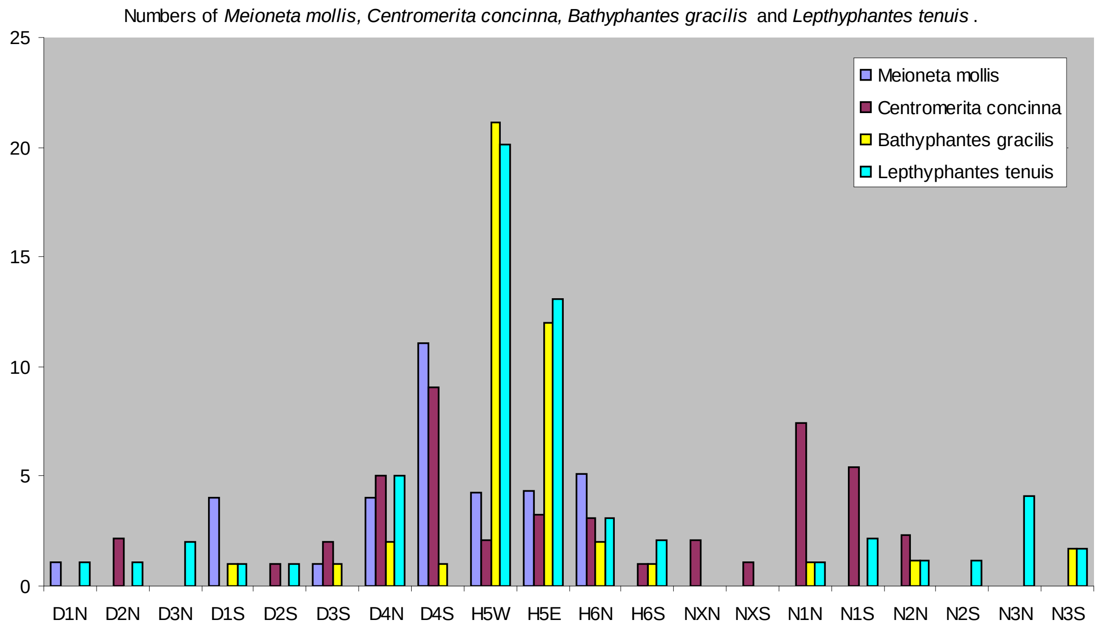


Figure 21d: Numbers of *Meioneta mollis, Centromerita concinna, Bathyphantes gracilis* and *Lepthyphantes tenuis*.

Spiders - Lycosidae

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	18.21655	6.537839	3.188171	2.136435	1.177629
Proportion Explained	0.53216	0.19099	0.09314	0.06241	0.0344
Cumulative Proportion	0.53216	0.72315	0.81629	0.8787	0.9131

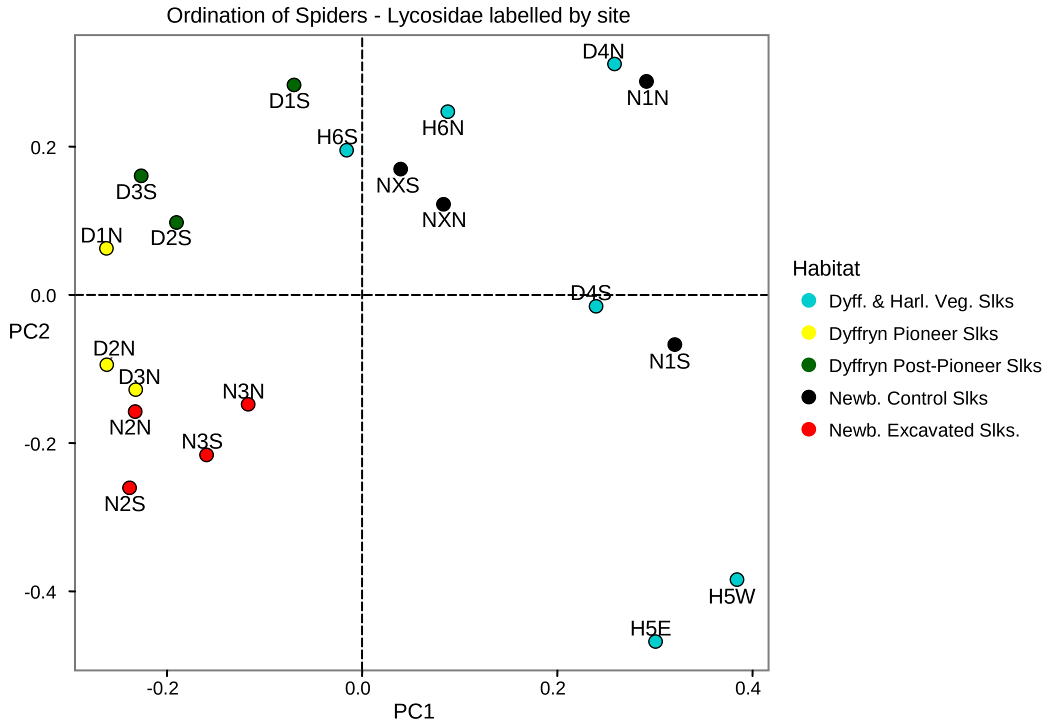


Figure 22a: Ordination of spiders – Lycosidae labelled by site.

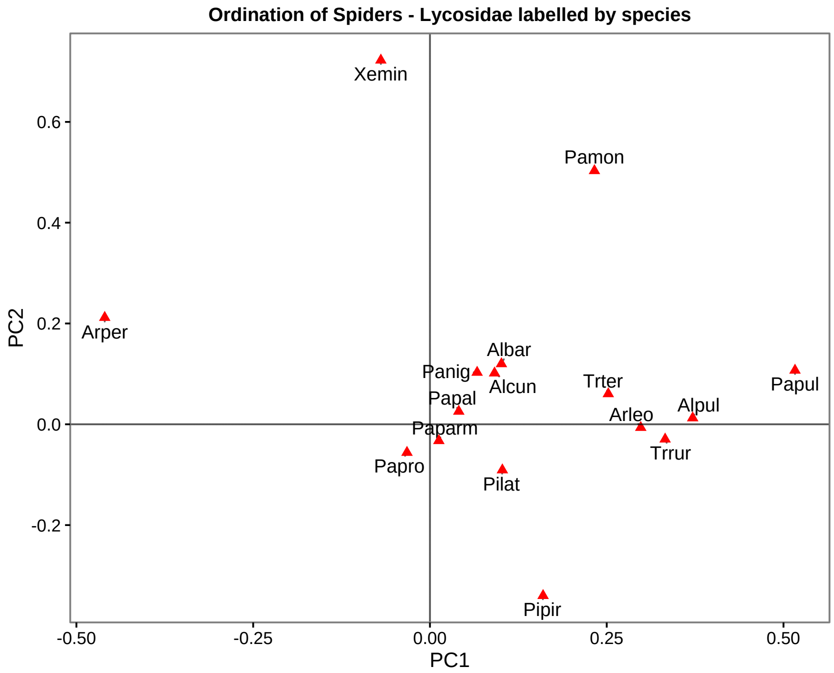


Figure 22b. Ordination of spiders – Lycosidae labelled by species.

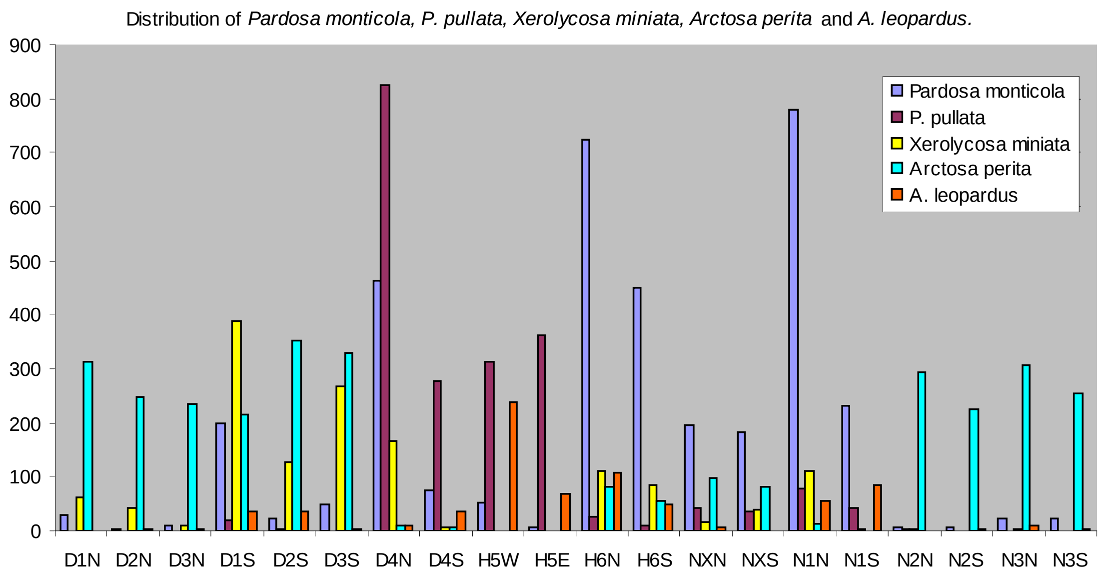


Figure 23a. Numbers of *Pardosa monticola, P. pullata, Xerolycosa miniata, Arctosa perita* and *A. leopardus.*

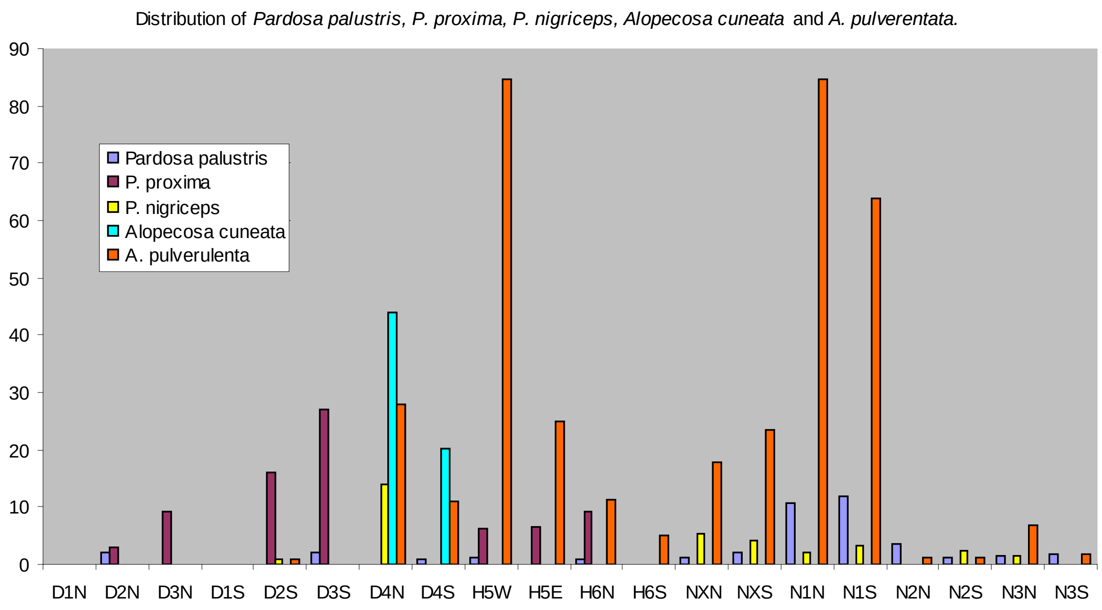


Figure 23b: Numbers of *Pardosa palustris, P. proxima, P. nigriceps, Alopecosa cuneata* and *A. pulverul*enta.

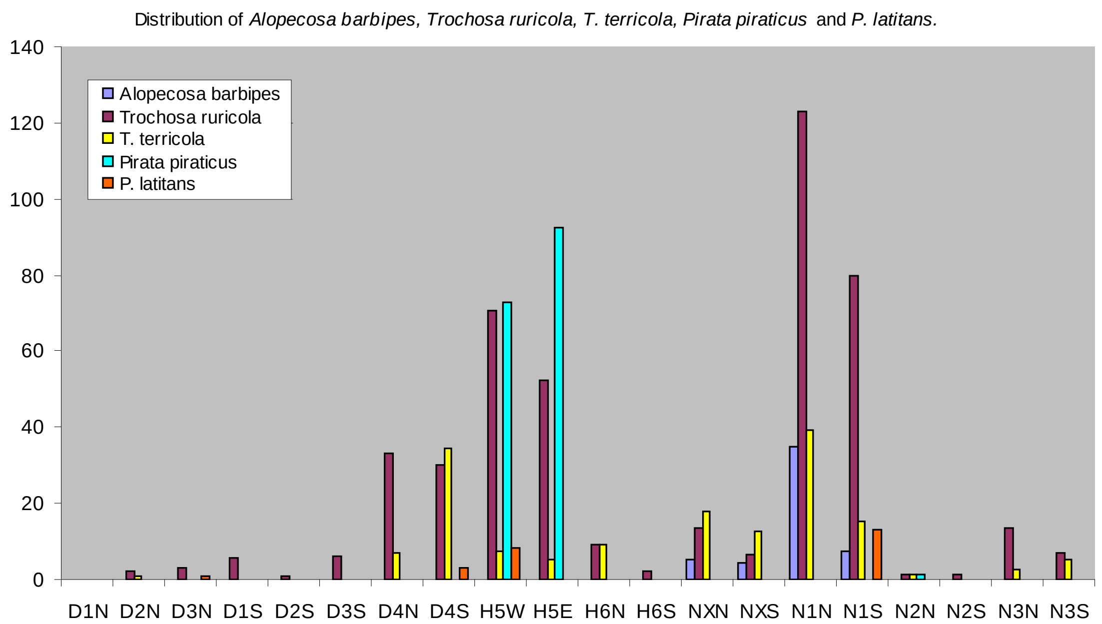


Figure 23c: Numbers of *Alopecosa barbipes, Trochosa ruricola, T. terricola, Pirata piraticus* and *P. latitans.*

Miscellaneous Spiders

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	8.882623	4.091916	3.104999	1.462059	1.257708
Proportion Explained	0.40452	0.18635	0.1414	0.06658	0.05728
Cumulative Proportion	0.40452	0.59087	0.73227	0.79886	0.85614

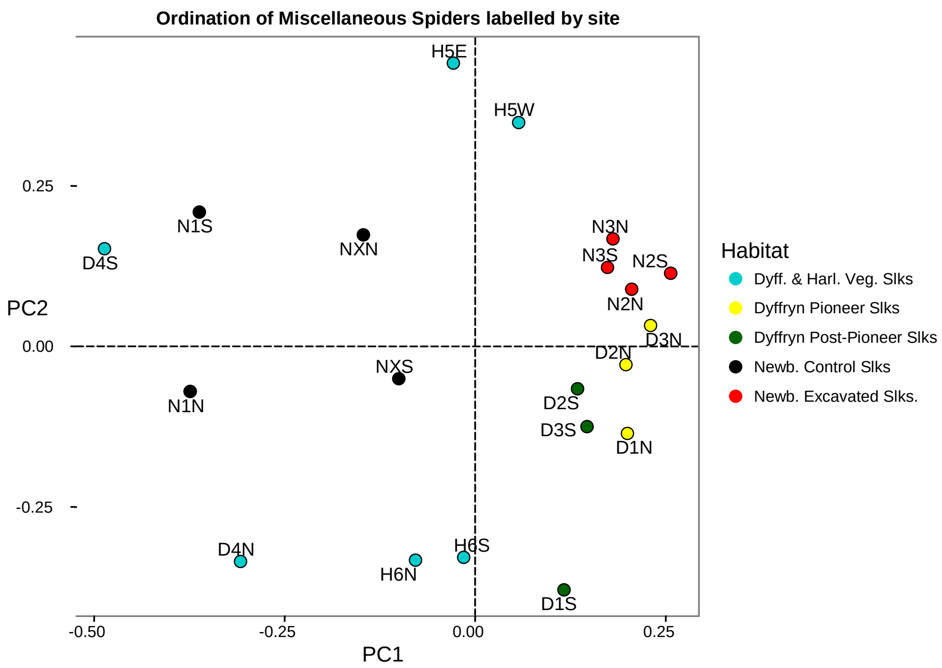


Figure 24a: Ordination of Miscellaneous Spiders labelled by sites.

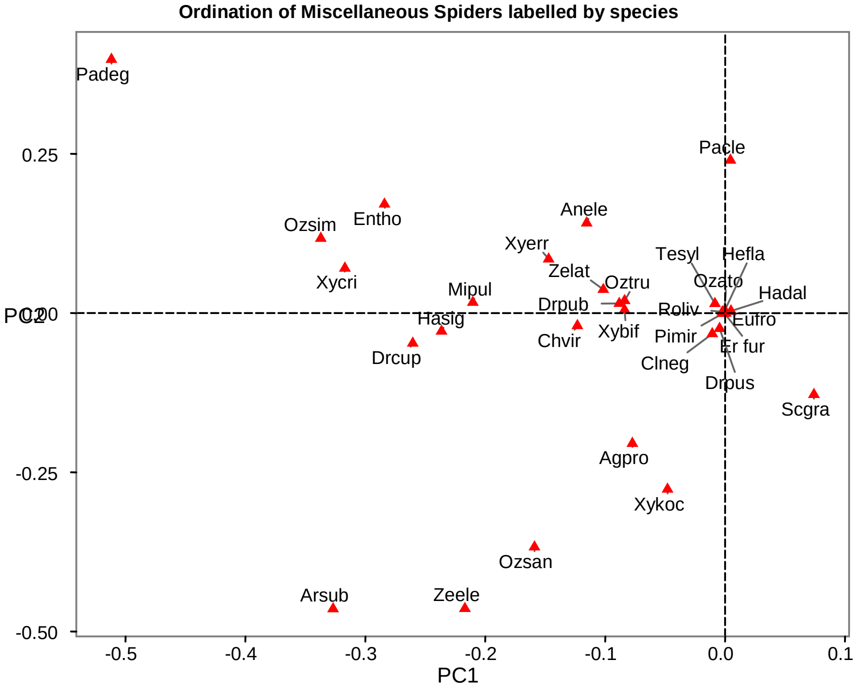


Figure 24b: Ordination of Miscellaneous Spiders labelled by species.

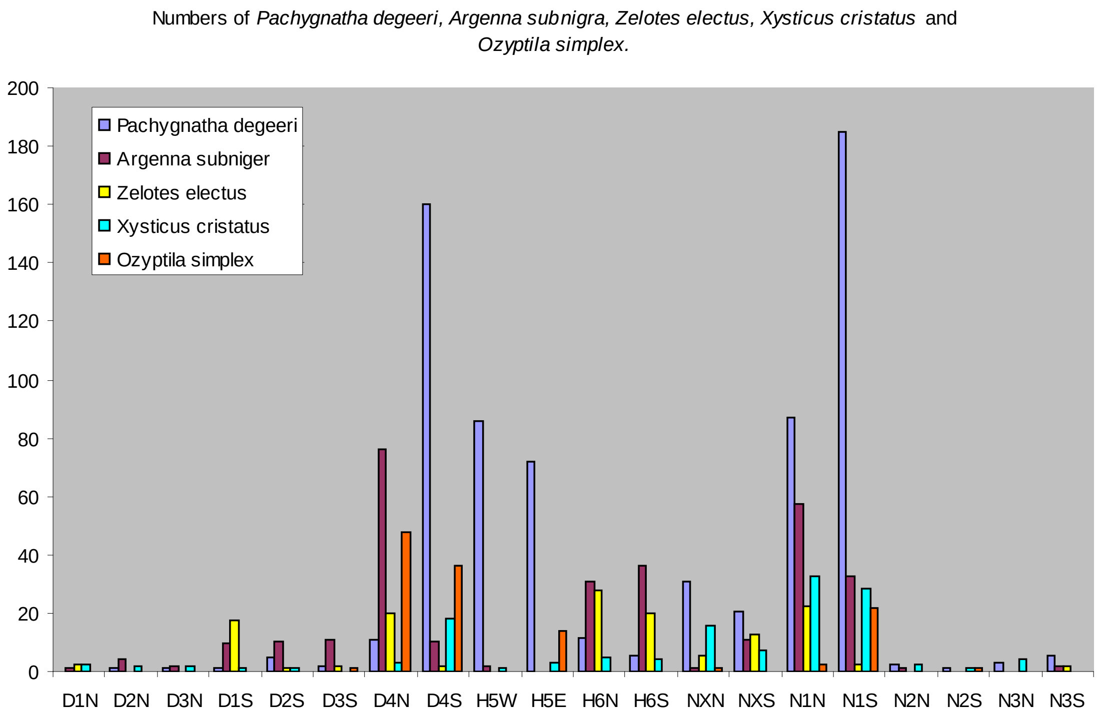


Figure 25a: Numbers of *Pachygnatha degeeri, Argenna subnigra, Zelotes electus, Xysticus cristatus* and *Ozyptila simplex.*

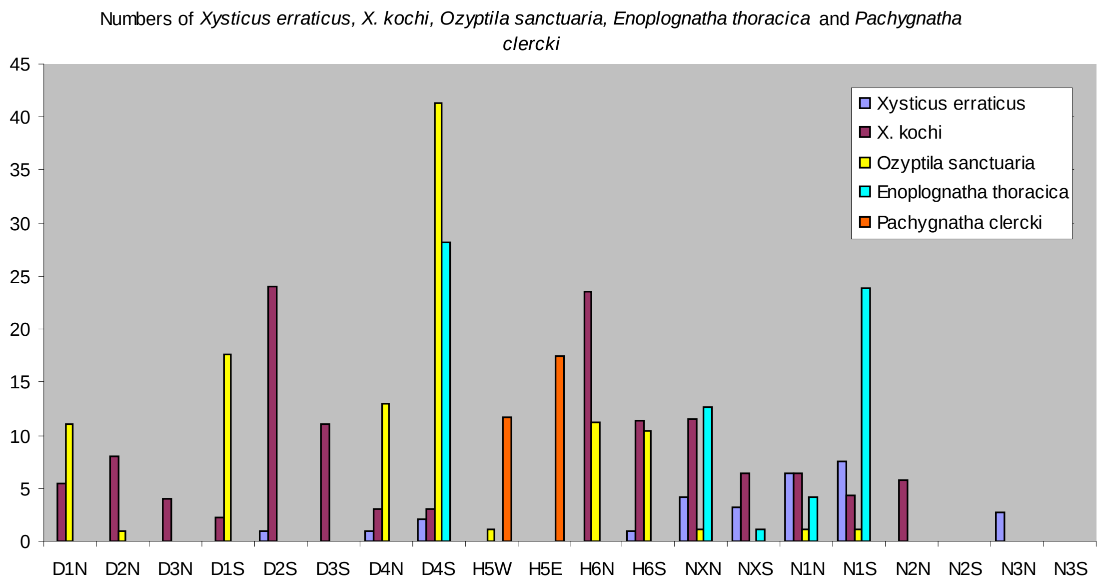


Figure 25b: Numbers of *Xysticus erraticus, X. kochi, Ozyptila sanctuaria, Enoplognatha thoracica* and *Pachygnatha clercki.*

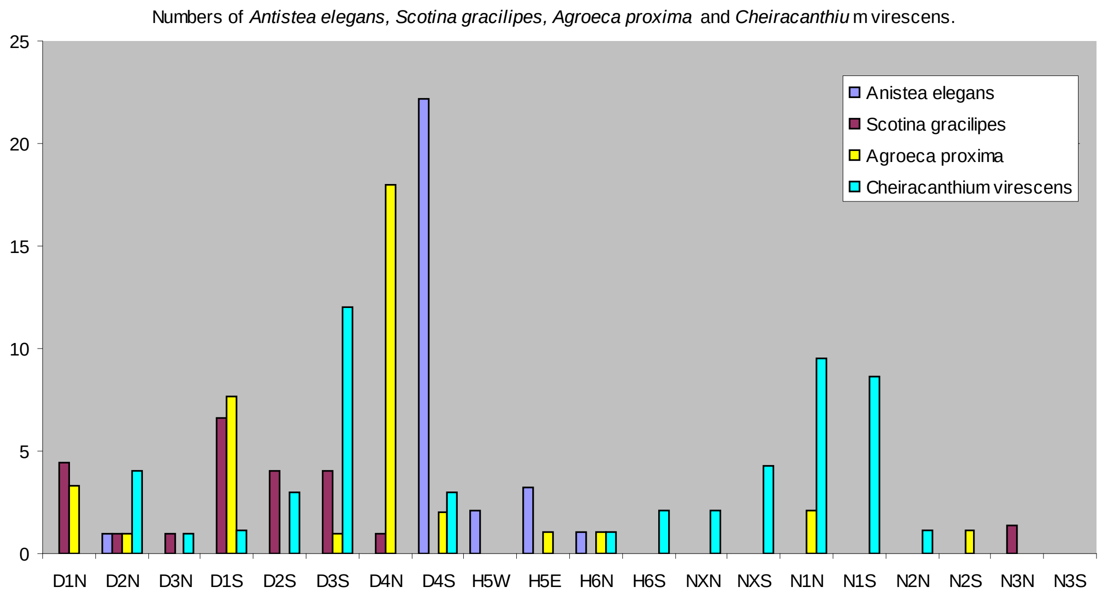


Figure 25c: Numbers of *Antistea elegans, Scotina gracilipes, Agroeca proxima* and *Cheiracanthium virescens.*

Harvesters

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	2.834842	0.735638	0.530922	0.08594	0.021634
Proportion Explained	0.67122	0.17418	0.12571	0.02035	0.00512
Cumulative Proportion	0.67122	0.8454	0.9711	0.99145	0.99657

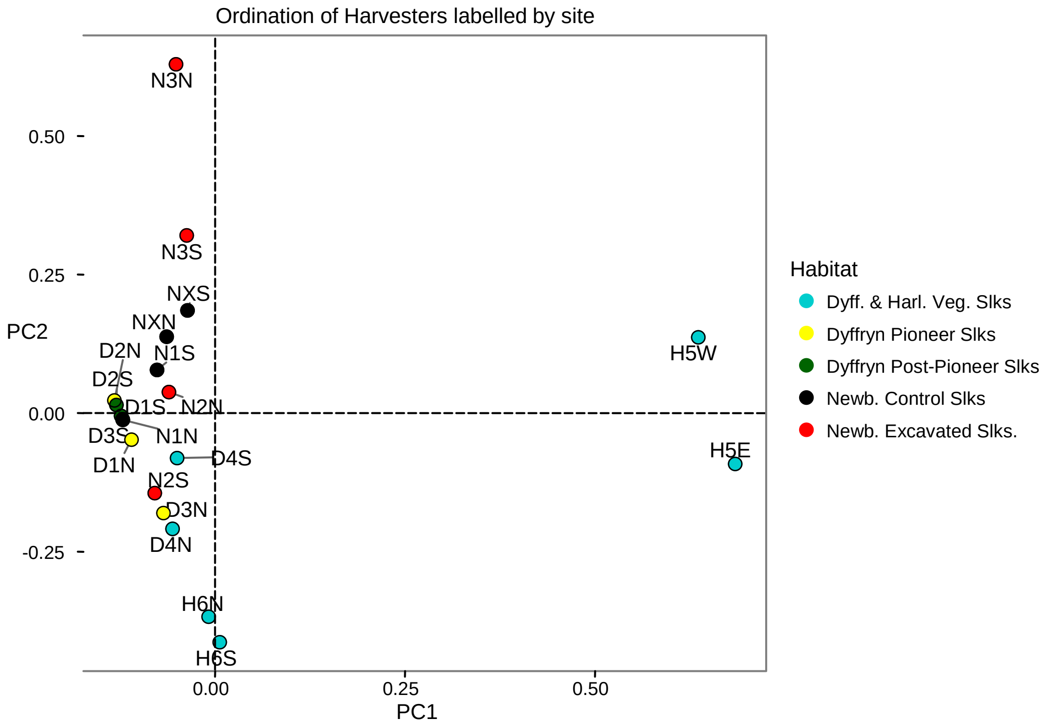


Figure 26a: Ordination of Harvesters labelled by site.

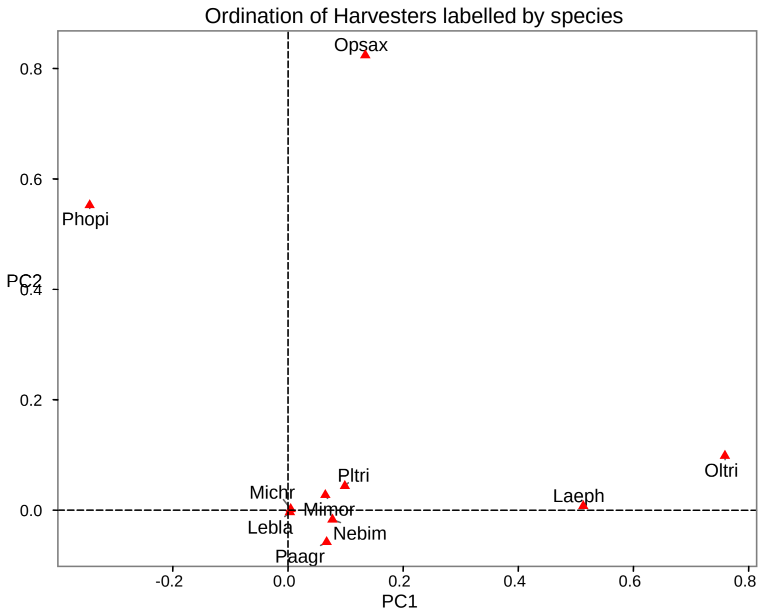


Figure 26b: Ordination of Harvesters labelled by species.

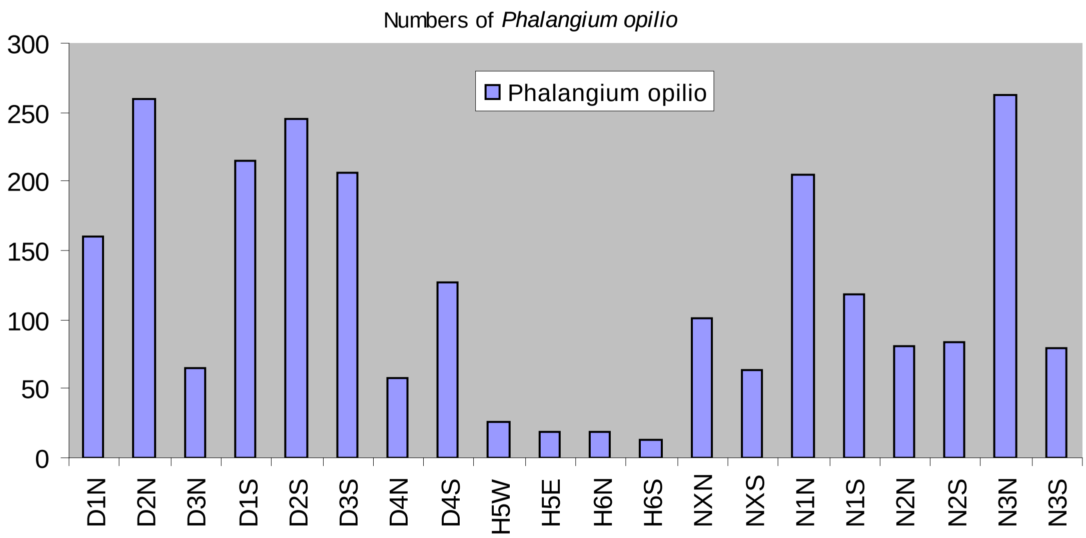


Figure 27a: Numbers of *Phalangium opilio.*

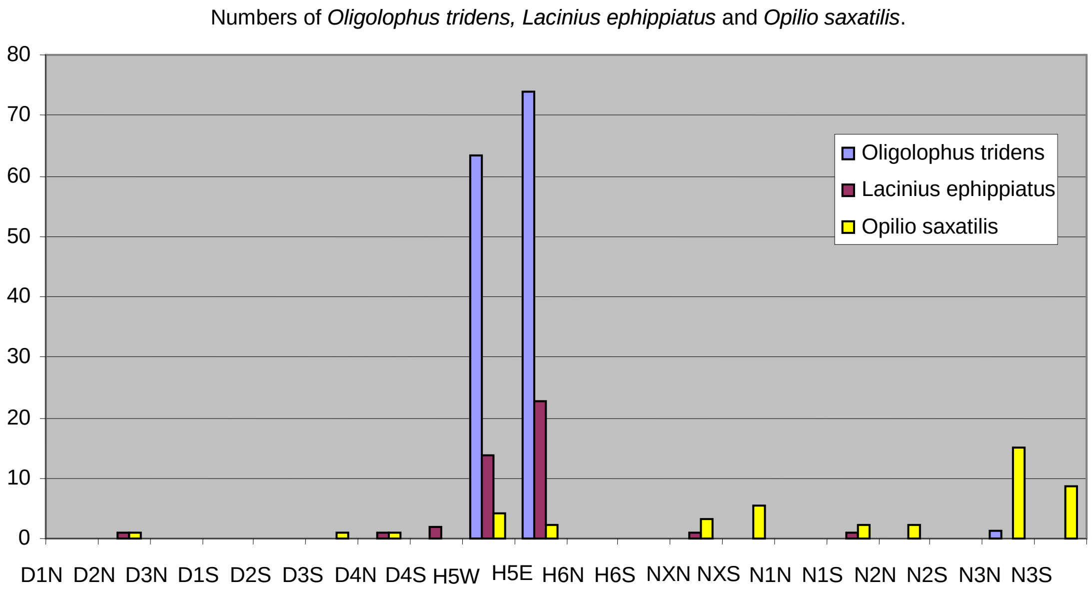


Figure 27b: Numbers of *Oligolophus tridens, Lacinius ephippiatus* and *Opilio saxatilis.*

Miscellaneous Invertebrates

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	10.98201	9.555345	4.755817	3.944194	2.274894
Proportion Explained	0.31569	0.27468	0.13671	0.11338	0.06539
Cumulative Proportion	0.31569	0.59037	0.72708	0.84046	0.90585

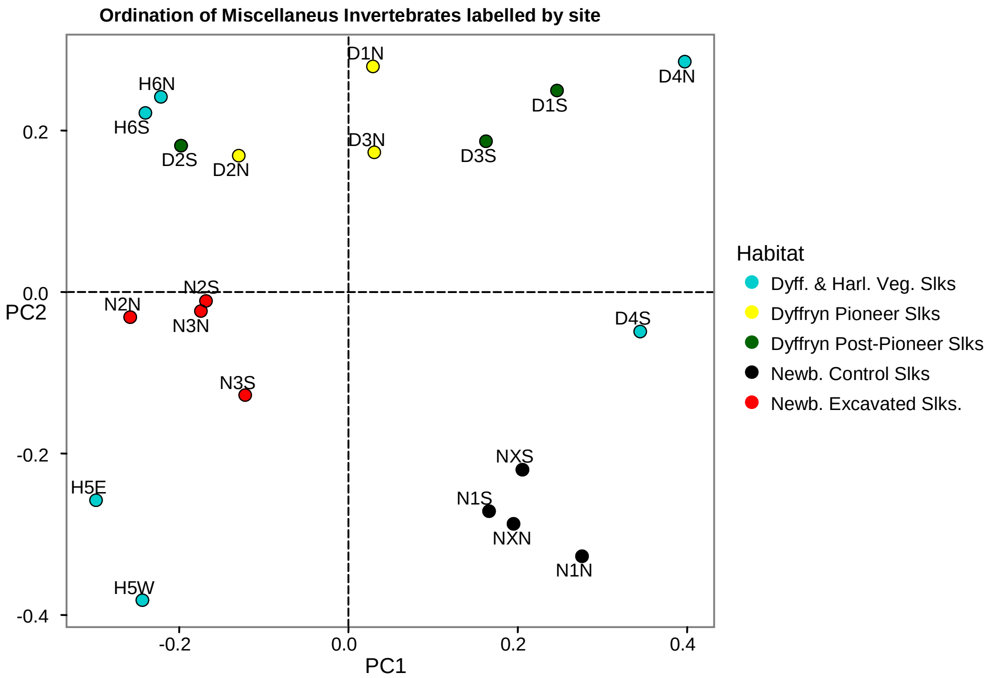


Figure 28a: Ordination of Miscellaneous Invertebrates labelled by site.

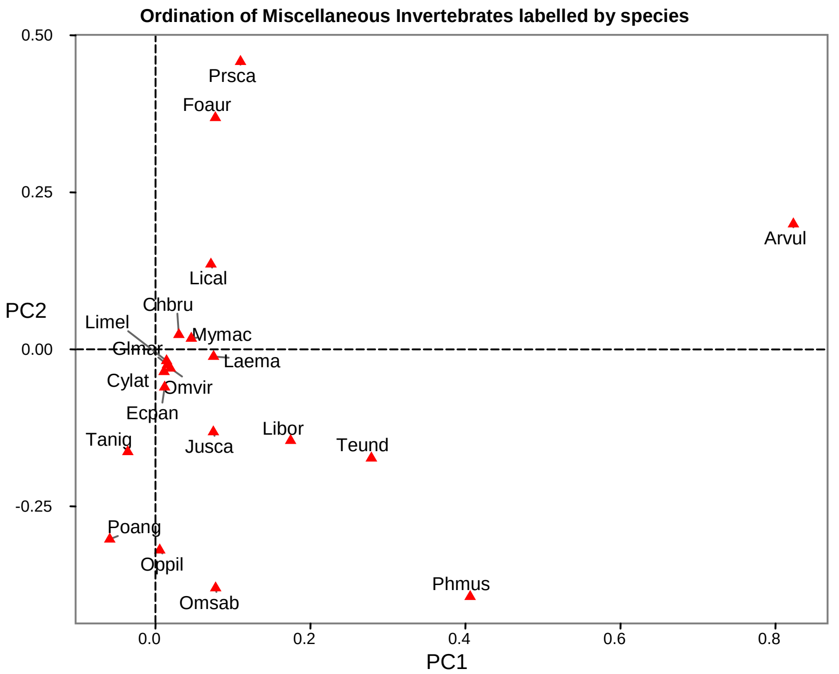


Figure 28b: Ordination of Miscellaneous Invertebrates labelled by species.

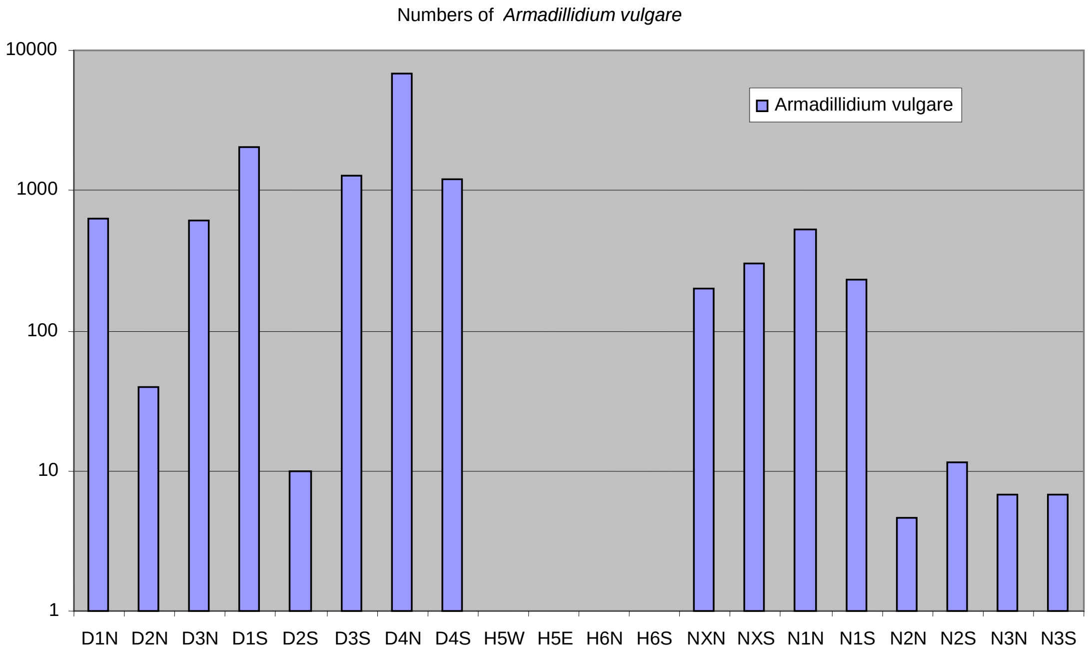


Figure 29a: Numbers of *Armadillidium vulgare* expressed as logarithms.

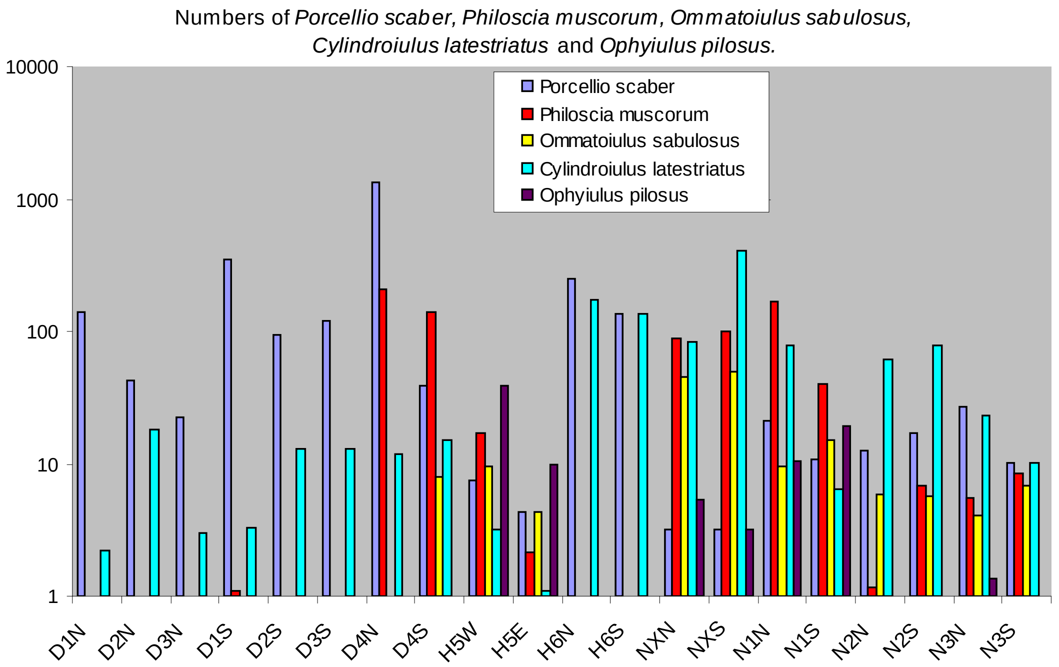


Figure 29b: Numbers of *Porcellio scaber, Philoscia muscorum, Ommatoiulus sabulosus, Cylindroiulus latestriatus* and *Ophyiulus pilosus* expressed as logarithms.

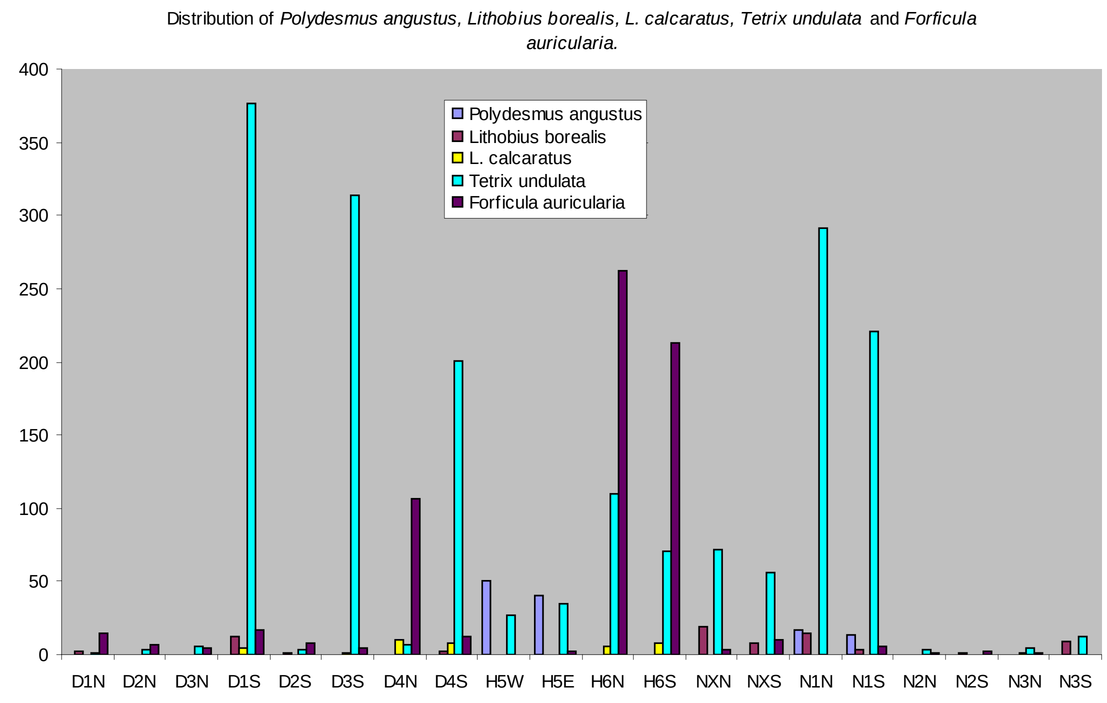


Figure 29c: Distribution of *Polydesmus angustus, Lithobius borealis, L. calcaratus, Tetrix undulata* and *Forficula auricularia.*

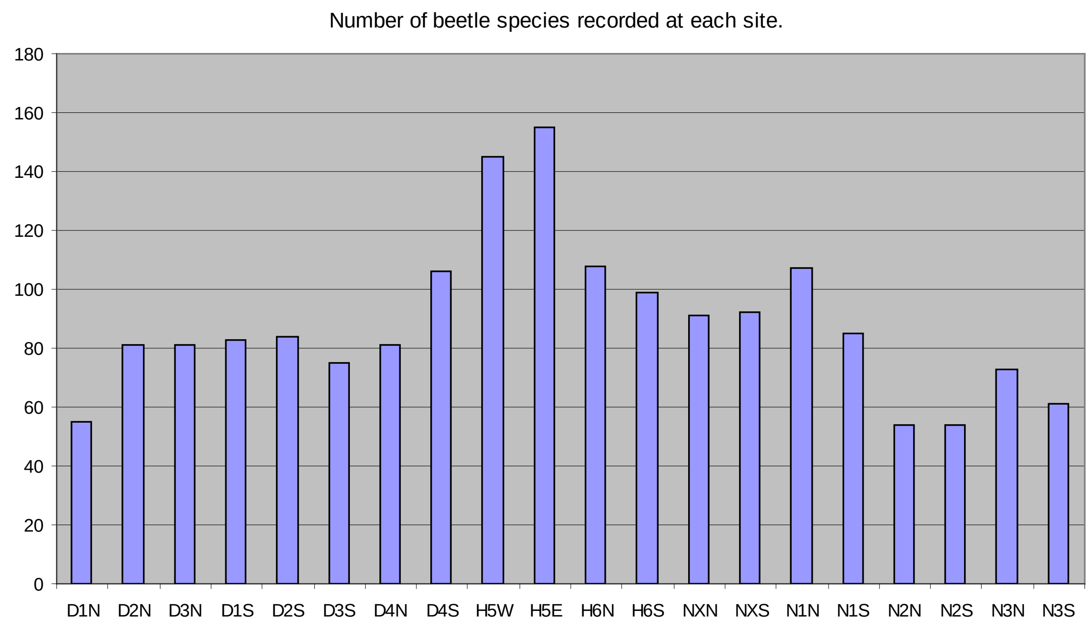


Figure 30: Numbers of beetle species found at each pitfall site.

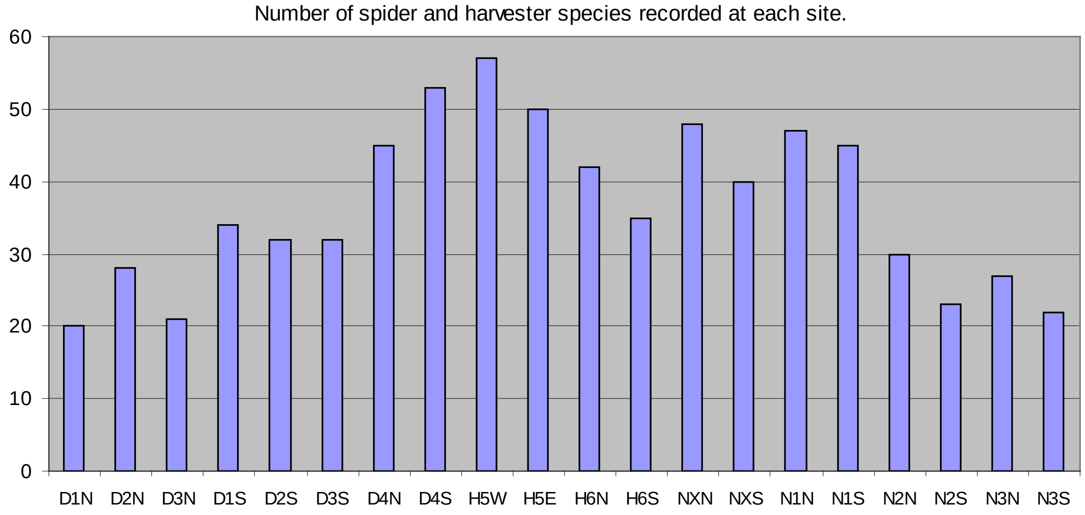
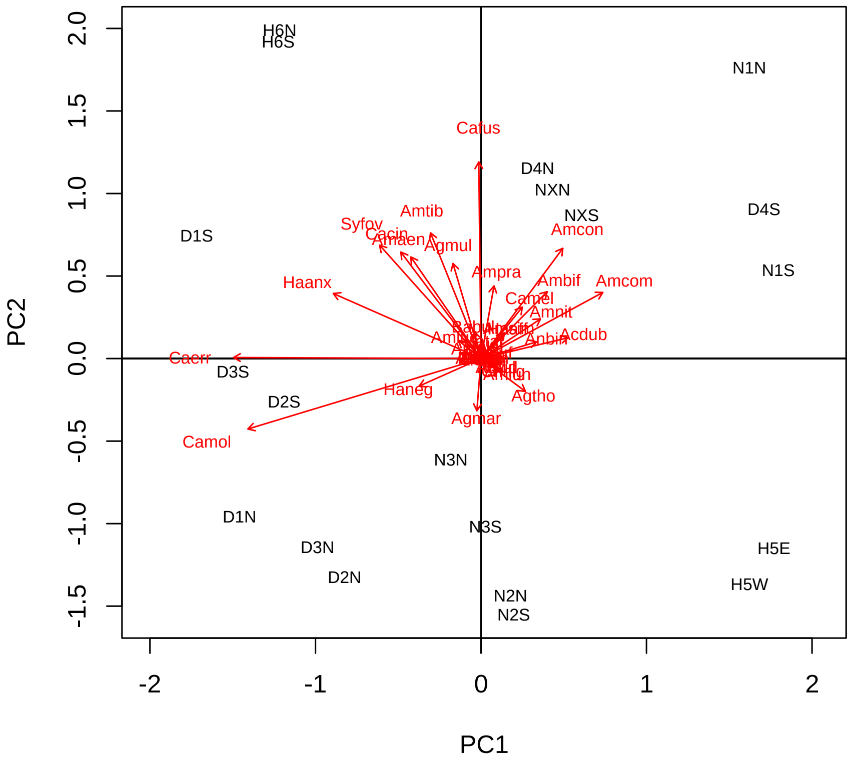


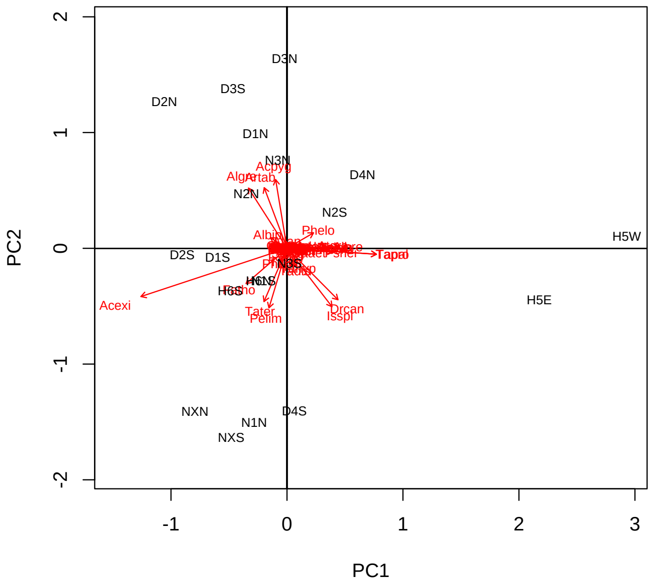
Figure 31: Numbers of spider and harvester species found at each pitfall site.

Appendix 10.2 Bi-plot Ordinations of Pitfall Trapping Data

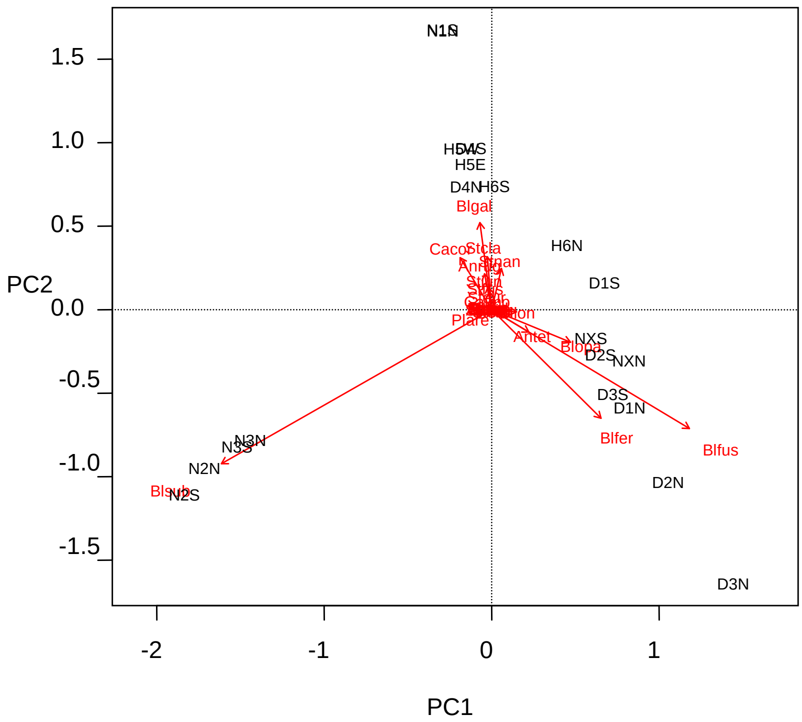
Biplot of Carabidae 2, Amara-Syntomus

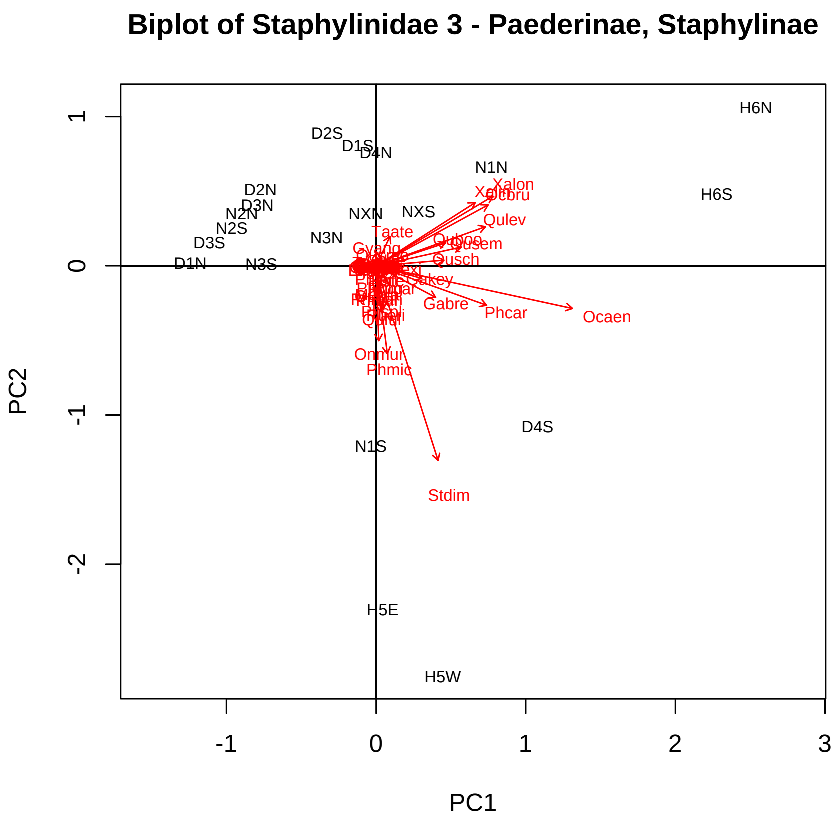


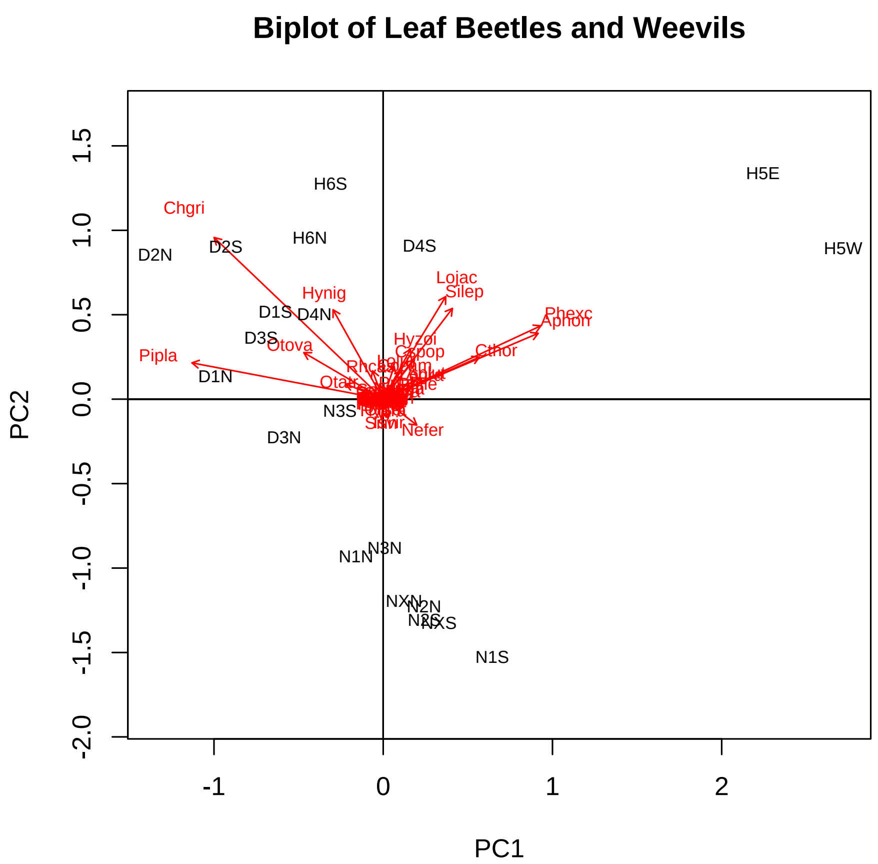
Biplot of Staphylinidae 1.



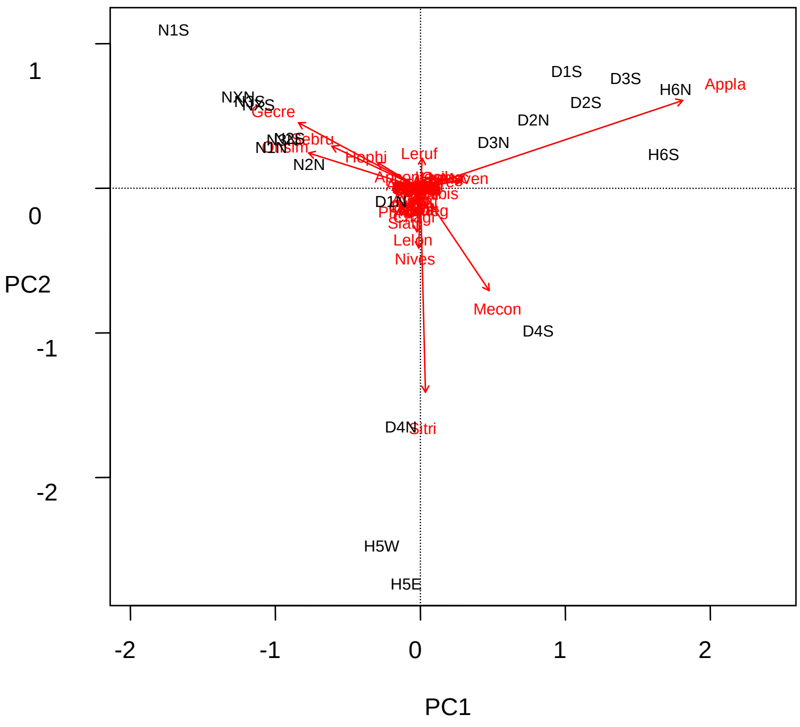
Biplot of Staphylinidae 2 - Oxytelinae, Steninae



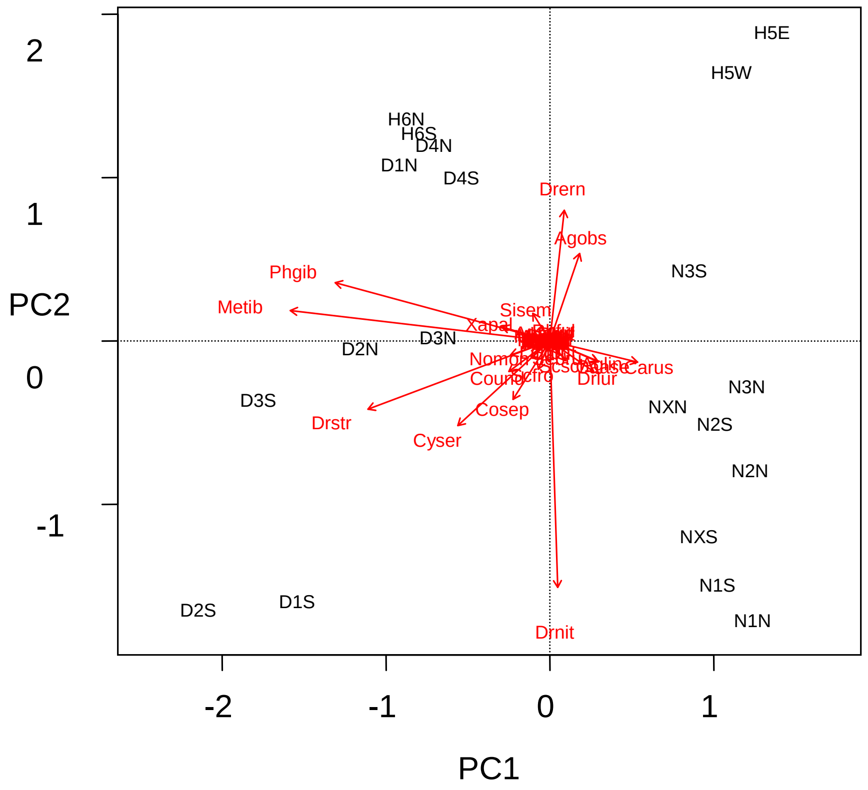

Biplot of Staphylinidae 3 - Paederinae, Staphylinae
PC1
PC2
H6N
H6S
D2S
D1S
D4N
N1N
Xalon
Qubru
Qulev
D2N
D3N
N2N
N2S
D3S
D1N
N3S
NXN
NXS
N3N
Taate
Qusem
Qusch
Ocaen
Phcar
Gabre
Onmur
Phmic
D4S
N1S
Stdim
H5E
H5W
-1
0
1
2
3
-2


Biplot of Leaf Beetles and Weevils
PC1
PC2
H5E
H5W
H6S
Chgri
D2N
D2S
H6N
D4S
Lojac
Silep
Hynig
D1S
D4N
Phexc
Aprion
D3S
Otova
Hyzoi
Pipla
Cthor
D1N
N3S
D3N
Nefer
N1N
N3N
NXN
N2N
N2S
NXS
N1S
-1
0
1
2
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

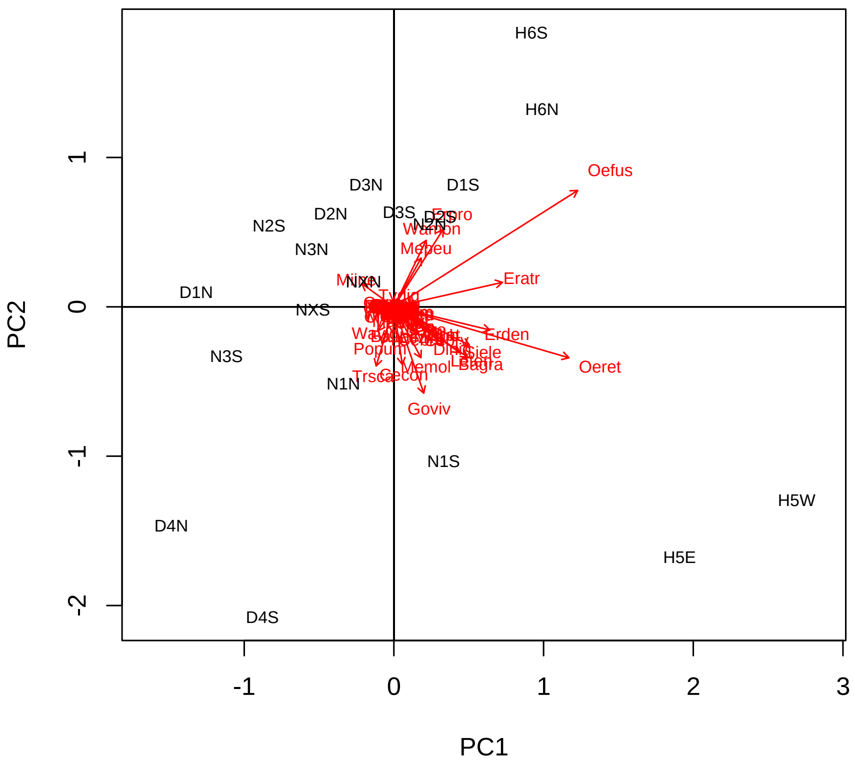
Biplot of Miscellaneous Beetles 1



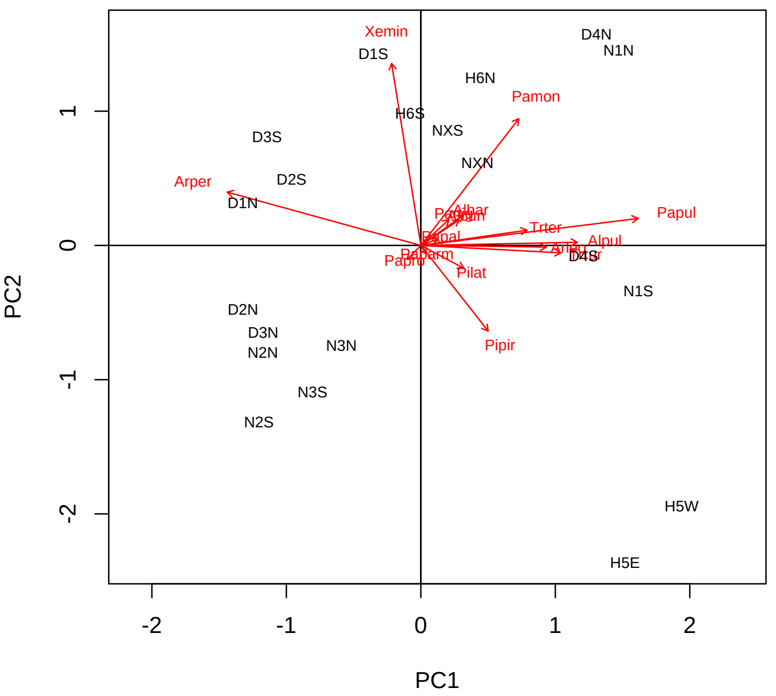
Biplot of Miscellaneous beetles 2



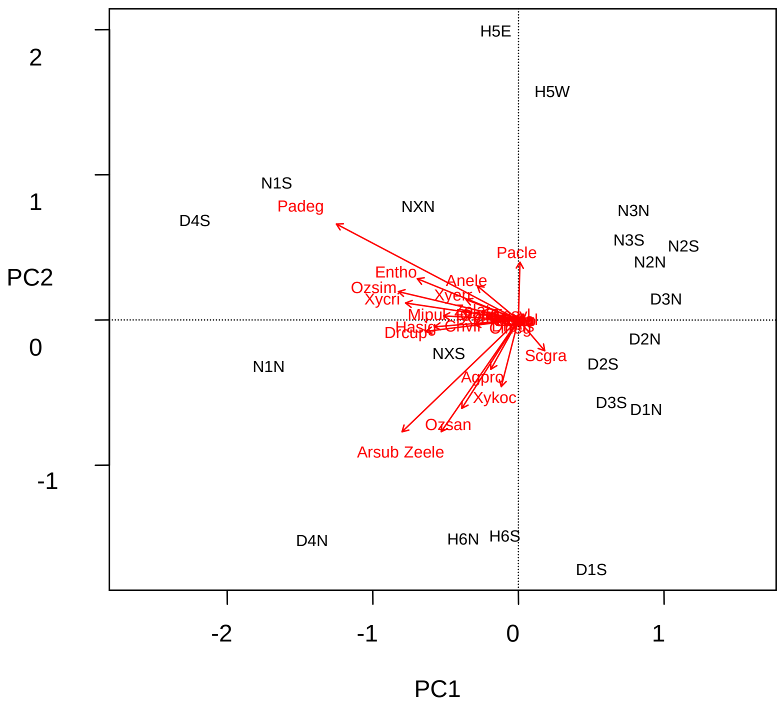
Biplot of Spiders - Linyphiidae



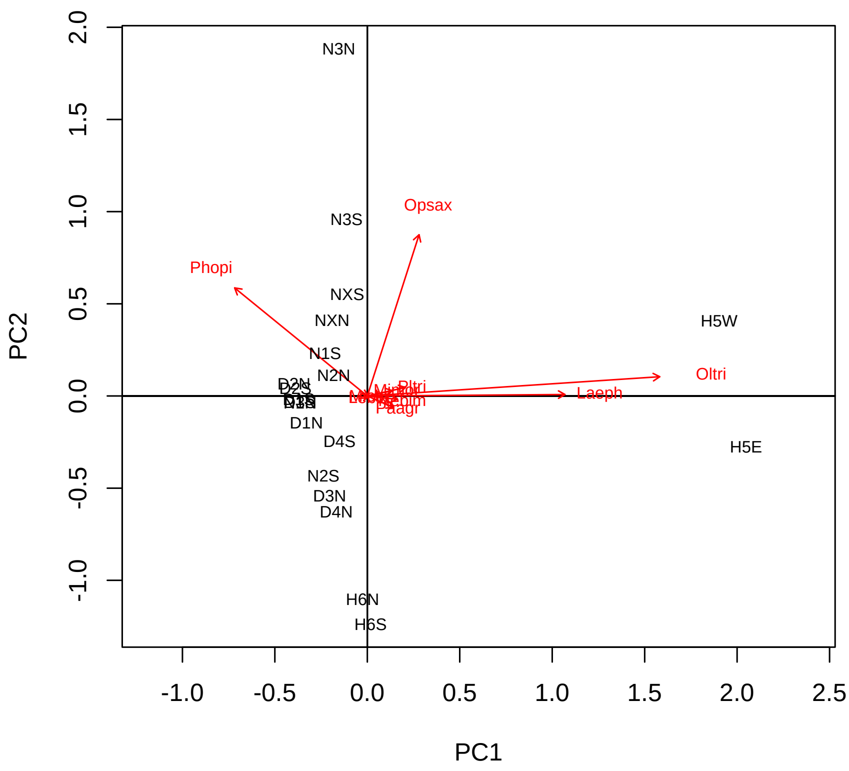
Biplot of Spiders - Lycosidae

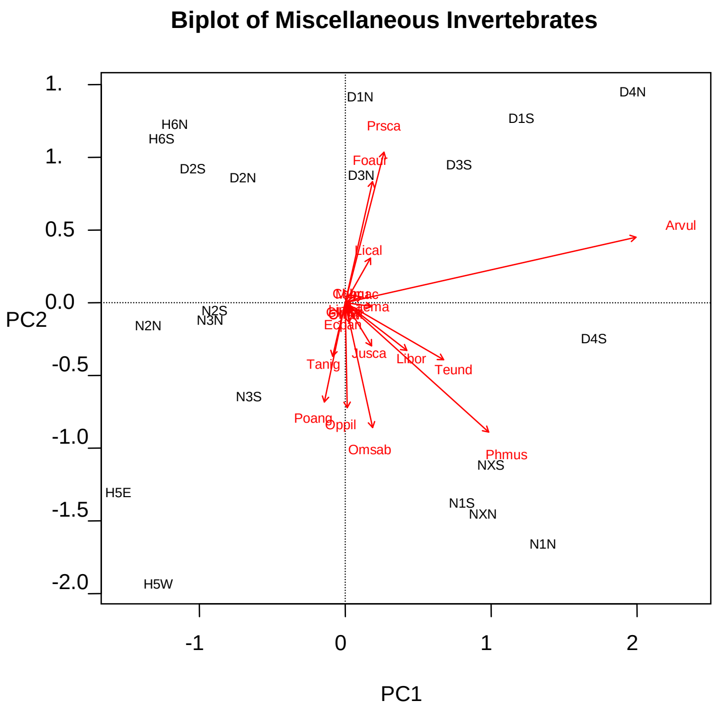


Biplot of Miscellaneous Spiders



Biplot of Harvesters




Biplot of Miscellaneous Invertebrates
PC2
PC1
1.
1.
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-1
0
1
2
D1N
D4N
H6N
H6S
D1S
Prsca
D2S
D2N
Foaur
D3N
D3S
Arvul
Lical
N2S
N3N
N2N
D4S
Ecoan
Tanig
Jusca
Libor
Teund
N3S
Poang
Oppil
Omsab
Phmus
NXS
H5E
N1S
NXN
N1N
H5W

Appendix 10.3 Images of Morfa Dyffryn, Morfa Harlech and Newborough Warren.

Photo 1. Dyffryn, Pioneer Slack habitat of Slack 1N(E), 3rd July 2015.

Photo 2 .Dyffryn, Pioneer Slack habitat of Slack 2N, 3rd July 2015.

Photo 3. Dyffryn, Pioneer Slack habitat of Slack 3N, 15th April 2015.

Photo 4. Dyffryn Slack 3, 27th July 2016.

Photo 5. Dyffryn. Sub-pioneer habitat of Slack 1S, 9th July 2015.

Photo 6. Dyffryn, Sub-pioneer habitat of Slack 2S, 9th July 2015.

Photo 7. Dyffryn, sub-pioneer slack habitat of Slack 3S, 9th July 2015.

Photo 8. Harlech Slack 5W. 19th June 2015.

Photo 9. Harlech. Slack 5 near sites 5E and 5W 6th December 2015.

Photo 10. Harlech Slack 6S, 23rd May 2015.

Photo 11. Newborough. Slack XN, 21st June 2015.

Photo 12. Newborough, Slack 1S, 21st June 2015.


Photo 13. Newborough Slack1N, 21st June 2015.


Photo 14. Newborogh Slack 3 – wind erosion, 9th September 2015.


Photo 15. Newborough, Slack 3 – wind erosion, 9th September 2015.


Photo 16. Morfa Dyffryn 23rd May 2015.


Photo 17. Morfa Harlech 23rd May 2015.


Photo 18. 'Black' sand in sub-pioneer habitat south of Slack 3. Morfa Dyffryn 15th May 2015.

Photo 19. Morfa Dyffryn. Early pioneer Slack in NW. 30th May 2015.

Photo 20. Morfa Dyffryn. 3rd June 2015.

Photo 21. Burrow of 2nd instar larva of *C. maritima* in drier sand at the edge of pioneer Slack 3 at SH558250 - 5p indicates scale. Morfa Dyffryn 15th May 2015.

Photo 22. Burrow of 3rd instar larva in damper sand near the centre of pioneer Slack 3 at SH558250. Morfa Dyffryn. 15th May 2015.

Photo 23. Slack 3 Morfa Dyffryn 13th May 2015. Plant labels as markers of *Cicindela* larval burrows on transects.

Photo 24. Morfa Dyffryn, Slack 3 on 27th July 2016.

Photo 25. Excavated slack, Newborough, behind tide line, 7th June 2015, SH414630, view to north.

Photo 26.Excavated slack, Newborough, behind tide line, 24th April 2016, SH414630, view to south.

Photo 27. Burrow casts of *B. fergussoni* on Harlech beach.

Photo 28. Small scrape in Newborough Forest, 25th July 2016.

Photo 29. Habitat of *Bledius* colony in Cefni estuary, 25th July 2016.

Photo 30. Erosion of dune at SH387659, 25th July 2016.


Photo 31. Small *Bledius* colony at edge of tidal channel, Braint estuary, 29th July 2016.


Photo 32. *Bledius* habitat behind Abermenai spit, 29th July 2016.


Photo 33. *Bledius* habitat behind Abermenai Spit, 29th July 2016.


Photo 34. *Bledius fergussoni* habitat, north shore of Artro Estuary, 27th July. 2016.


Photo 35. *Bledius fergussoni* habitat, south shore of Artro Estuary, 27th July. 2016.


Photo 36. NE extremity of *Bledius* colony at Harlech, SH561355, 21st May 2016.

Appendix 10.4 Five letter abbreviations of species names.

Ground Cover

Anten	Anagallis tenella	*Moss*	‘Moss'
Arser	Arenaria serpylifolia	Onrep	Ononis repens
BGB	Bare Ground/Black	Poans	Potentilla anserina
BGY	Bare Ground/Yellow	Prvul	Prunella vulgaris
Caare	Carex arenaria	Umrup	Umbilicus rupestris
Casp	Carex sp.	Pyrot	Pyrola rotundifolia
Celit	Centaurium littorale	Ruagg	Rubus agg
Dapur	Dactylorhiza purpurella	Sacin	Salix cinerea
Eppal	Epipactis palustris	Sanod	Sagina nodosa
Eunem	Euphrasia sp ?nemorosa	Sarep	Salix repens
Frves	Fragaria vesca	Saval	Samolus valerandi
Grass	Grass'	Sejac	Senecio jacobaea
Juacu	Juncus acutus		
Lesax	Leontodon saxatilis		
Locor	Lotus corniculatus		

Carabidae 1: Cicindela - Pterostichus

Bedor	Bembidion doris	Lespi	Leistus spinibarbis
Begut	Bembidion guttula	Leter	Leistus terminatus
Belam	Bembidion lampros	Lopil	Loricera pilicornis
Bepal	Bembidion pallidipenne	Nebre	Nebria brevicollis
Bepro	Bembidion properans	Nesal	Nebria salina
Bequa	Bembidion quadrimaculatum	Noaqu	Notiophilus aquaticus
Blmul	Blethisa multipunctata	Nobig	Notiophilus biguttatus
Brcep	Broscus cephalotes	Nosub	Notiophilus substriatus
Cicam	Cicindela campestris	Pover	Poecilius versicolor
Cicmar	Cicindela maritima	Ptdil	Pterostichus diligens
Crgra	Carabus granulatus	Ptgra	Pterostichus gracilis
Crvio	Carabus violaceus	Ptmad	Pterostichus madidus
Cycar	Cychrus caraboides	Ptmin	Pterostichus minor
Dyglo	Dyschirius globosus	Ptnig	Pterostichus niger
Dyimp	Dyschirius impunctipennis	Ptnrt	Pterostichus nigrita

Dypol	Dyschirius politus	Ptstr	Pterostichus strennuus
Eapar	Elaphropus parvulus	Ptver	Pterostichus vernalis
Elcup	Elaphrus cupreus	Trobt	Trechus obtusus
Elrip	Elaphrus riparius	Trqua	Trechus quadristriatus
Lefer	Leistus ferrugineus		

Carabidae 2: Calathus - Syntomus

Acdub	Acupalpus dubius	Babul	Badister bullatus
Agful	Agonum fuliginosum	Brhar	Bradycellus harpalinus
Agmar	Agonum marginatum	Cacin	Calathus cinctus
Agmul	Agonum mulleri	Caerr	Calathus erratus
Agtho	Agonum thoreyi	Cafus	Calathus fuscipes
Agvid	Agonum viduum	Camel	Calathus melanocephalus
Amaen	Amara aenea	Camol	Calathus mollis
Amapr	Amara apricaria	Chnig	Chlaenius nigricornis
Ambif	Amara bifrons	Cuaul	Curtonotus aulica
Amcom	Amara communis	Deatr	Demetrias atricapillus
Amcon	Amara convexior	Haaff	Harpalus affinis
Amfam	Amara familiaris	Haanx	Harpalus anxius
Amluc	Amara lucida	Halat	Harpalus latus
Amlun	Amara lunicollis	Haneg	Harpalus neglectus
Amnit	Amara nitida	Haruf	Harpalus rufipes
Ampra	Amara praetermissa	Hatar	Harpalus tardus
Amsim	Amara similata	Palin	Paradromius linearis
Amtib	Amara tibialis	Phmel	Philorhizus melanocephalus
Anbin	Anisodactylus binotatus	Syfov	Syntomus foveatus
Ancon	Anthracus consputus		

Staphylinidae 1: Omaliinae, Proteininae, Tachyporinae, Aleocharinae

Acate	Acrotona aterrima	Moamp	Mocyta amplicollis
Accre	Acidota crenata	Mofun	Mocyta fungi Grp
Acexi	Acrotona exigua	Mylep	Mycetoporus lepidus
Acpyg	Acrotona ?pygmaea	Mypic	Mycetoporus piceolus
Albil	Aleochara bilineata	Olpic	Olophrum piceum
Albip	Aleochara bipustulata	Omoxy	Omalium oxyacanthae
Albre	Aleochara brevipennis	Oxexo	Oxypoda exoleta

Algre	Aloconota gregaria	Oxlen	Oxypoda lentula
Alint	Aleochara intricata	Pelim	Pella limbata
Allan	Aleochara lanuginosa	Phelo	Philhygra elongatula
Artab	Arena tabida	Phspi	Phytosus spinifer
Ataen	Atheta aenicollis	Phvol	Philhygra volans
Ataqu	Atheta aquatica	Plbru	Platarea brunnea
Atfun	Atheta fungicola	Pshei	Pselaphus heisei
Atgra	Atheta graminicola	Senig	Sepedophilus nigripennis
Bamac	Badura macrocera	Zycol	Zyras collaris
Bapun	Badura puncticollis	Taatr	Tachyporus atriceps
Biamb	Bibloplectus ambiguus	Tachr	Tachyporuschrysomelinus
Bocas	Bolitobius castaneus	Tadis	Tachyporus dispar
Caaet	Calodera aethiops	Tahyp	Tachyporus hypnorum
Carig	Callicerus rigidicornis	Talat	Tachinus laticollis
Chlon	Chaetida longicornis	Tamar	Tachinus marginellus
Drcan	Drusilla canaliculata	Tanit	Tachyporus nitidulus
Fatho	Falagrioma thoracica	Taobt	Tachyporus obtusus
Gecir	Geostiba circellaris	Tapal	Tachinus pallipes
Isspl	Ischnosoma splendidum	Tapro	Tachinus proximus
Lasag	Lamprinodes saginatus	Tapus	Tachyporus pusillus
Lelon	Lesteva longoelytra	Taruf	Tachinus rufipes
Lotri	Lordithon trinotatus	Tasol	Tachyporus solutus
Mepro	Megarthrus prosseni	Tater	Tachyporus tersus
Mesp	Meotica sp.	Tatra	Tachyporus transversalis
Milil	Microdota liliputana	Thves	Thinobaena vestita
Mista	Micropeplus staphylinoides		

Staphylinidae 2: Oxytelinae, Steninae

Anscu	A. sculpturatus/?mutator	Plalu	Platystethus alutaceus
Antet	A. tetracarinatus	Plare	Platystethus arenarius
Anrug	Anotylus rugosus	Stfla	S. ?flavipes
Blfus	B. fuscipes	Stpus	S. ?pusillus
Blgal	B. gallicus	Stcan	S. canaliculatus
Bllon	B. longulus	Stcla	S. clavicornis
Blopa	B. opacus	Stcom	S. comma
Blsub	B. subniger	Steur	S. europaeus
Bipue	Bisnius ?puella	Stfus	S. fuscipes
Blfer	Bledius fergussoni	Stjun	S. juno
Cacor	Carpelimus corticinus	Stnig	S. nigritulus
Caimp	Carpelimus impressus	Stsim	S. similis
Cariv	Carpelimus rivularis		

Staphylinidae 2: Paederinae, Staphylinae

Gaexi	G. exiguus	Phqui	P. quisquiliaris
Gakey	G. keysianus	Phspl	P. splendens
Gaoss	G. osseticus	Phten	P. tenuicornis
Gaapp	G. appendiculatus	Plste	Platydracus stercorarius
Gabre	G. breviventer	Qufum	Q. ?fumatus
Gyang	Gyrohypnus angustatus	Qucur	Q. curtipennis
Lagem	L. geminum	Quful	Q. fuliginosus
Laqua	L. quadratum	Qulev	Q. levicollis
Labru	Lathrobium brunipes	Qumau	Q. maurorufus
Megla	Megalinus glabratus	Qumol	Q. molochinus
Ocbru	O. brunnipes	Qunig	Q. nigriceps
Ocole	O. olens	Quper	Q. persimilis
Otpun	O. punctulatus	Qupic	Q. picipes
Otsub	O. subuliformis	Qusch	Q. schatzmayri
Ocfra	Ochthephilum fracticorne	Qusem	Q. semiaeneus
Ocaen	Ocypus aenocephalus	Qusmo	Q. semiobscurus
Onmur	Ontholestes murinus	Quboo	Quedius boops
Otlae	Othius laeviusculus	Rueri	Rugilus erichsoni
Parip	Paederus riparius	Stdim	Staphylinus dimidiaticornis
Phatr	Philonthus atratus	Stbim	Stenus bimaculatus
Phcar	P. carbonarius	Taglo	T. globulifer
Phcog	P. cognatus	Tamel	T. melanarius
Phdec	P. decorus	Tamor	T. morsitans
Phman	P. mannerheimi	Taate	Tasgius ater
Phmar	P. marginatus	Xalon	X. longiventris
Phmic	P. micantoides	Xalin	Xantholinus linearis
Plnod	P. nodifrons		

Chrysomelidae, Apionidae Curculionidae

Aplut	Aphthona lutescens	Nefer	Neocrepidodera ferruginea
Apnon	Apthona nonstriata	Netra	Neocrepidodera transversa
Atorb	Apteropoda orbiculata	Oocya	Orobitis cyanea
Cahem	Cassida hemispherica	Orins	Orthochaetes insignis
Cecon	Ceutohynchus contractus	Orset	Orthochaetes setiger

Chgri	Charagmus griseus	Otatr	Otiorhynchus atroapterus
Chhyp	Chrysolina hyperici	Otova	Otiorhynchus ovatus
Cocam	Coelositona cambricus	Oumel	Oulema melanopus
Crsta	Chrysolina staphylaea	Peatr	Perapion atratulum
Cspop	Chrysomela populi	Pemar	Perapion marchicum
Cthor	Chaetocnema hortensis	Phatr	Phyllotreta atra
Eucon	Euophryum confine	Phexc	Phyllotreta exclamationis
Hyara	Hypera arator	Phfle	Phyllotreta flexuosa
Hynig	Hypera nigrirostris	Pipla	Philopedon plagiatus
Hypla	Hypera plantaginis	Prful	Protapion fulvipes
Hyrum	Hypera rumicis	Prono	Protapion ononidis
Hyzoi	Hypera zoilus	Prvul	Phratora vulgatissima
Islot	Ischopterapion loti	Psaff	Psylliodes affinis
Isvir	Ischnopterapion virens	Rhcas	Rhinoncus castor
Locap	Lochmaea caprea	Rhper	Rhinoncus pericarpius
Loatr	Longitarsus atricillus	Sehal	Sermylassa halensis
Logra	Longitarsus gracilis	Sihis	Sitona hispidulus
Lojac	Longitarsus jacobaea	Silep	Sitona lepidus
Lolur	Longitarsus luridus	Silin	Sitona lineelus
Lomel	Longitarsus melanocephalus	Sqato	Squamapion atomarium
Lopra	Longitarsus pratensis	Stten	Stenopterapion tenue
Ndqua	Nedyus quadrimaculatus	Tysqu	Tychius squamulatus

Miscellaneous Beetles 1: Dytiscidae - Scarabaeidae

Aeare	Aegialia arenaria	Hebre	H. brevipalpis
Aglae	Agathidium laevigatum	Hibis	Hister bissextriatus
Agmel	Agabus melanarius	Hiuni	Hister unicolor
Agneb	Agabus nebulosus	Hypun	Hydnobius punctatus
Amsol	Amphimallon solstitiale	Hyrug	Hypocaccus rugiceps
Apcon	Aphodius contaminatus	Kimin	Kissiter minimus
Apdep	A. depressus	Lecil	Leiodes ciliaris
Aperr	A. erraticus	Lelon	Leiodes longipes
Apfim	A. fimetarius ss.	Leruf	Leiodes rufipennis
Apfos	A. fossor	Maneg	Margarinotus neglectus

Aphae	A. haemorrhoidalis	Maven	M. ventralis
Appla	A. plagiatus	Mecon	Megasternum concinnum sl
Appro	A. prodromus	Nives	Nicrophorus vespillo
Apruf	A. rufipes	Onnuc	Onthophagus nuchicornis
Apsph	A. sphacelatus	Onsim	Onthophagus similis
Caful	Catops fuliginosus	Onstr	Onthophilus striatus
Camor	Catops morio	Phhor	Philopertha horticola
Cawat	Catops watsoni	Ptsub	Ptomophagus subvillosus
Cemel	Cercyon melanocephalus	Sebru	Sericea brunnea
Chagi	Choleva agilis	Siatr	Silpha atrata
Gecre	Georissus crenulatus	Sitri	Silpha tristis
Hdfus	Hydrobius fuscipes	Splun	Sphaeridium lunulatum
Heaeq	Helophorus aequalis	Stcol	Stenichnus collaris
Healt	Helophorus alternans	Trsca	Trox scaber

Miscellaneous Beetles 2: Byrrhidae - Scraptiidae

Adpal	Adrastus pallens	Drstr	Dryops striatellus
Aglin	Agriotes lineatus	Epglo	Ephistemus globulus
Agmur	Agrypnus murinus	Hyrip	Hypnoidus riparius
Agobs	Agriotes obscurus	Ismur	Isomira murina
Anfro	Anaspis frontalis	Karuf	Kateretes rufilabris
Athae	Athous haemorrhoidalis	Lahir	Lagria hirta
Byfas	Byrrhus fasciatus	Lanoc	Lampyris noctiluca
Bypil	Byrrhus pilula	Mecar	Meligethes carinulatus
Caase	Cardiophorus asellus	Menig	Meligethes nigrescens
Cacry	Cantharis cryptica	Meoch	Meligethes ochropus
Cafig	Cantharis figurata	Metib	Melanimon tibialis
Canig	Cantharis nigricans	Nomon	Notoxus monoceros
Capal	Cantharis pallida	Olaff	Olibrus affinis
Caruf	Cantharis rufa	Phgib	Phylan gibbus
Carus	Cantharis rustica	Pofer	Pocadius ferrugineus
Ciaer	Cidnopus aeruginosus	Rhful	Rhagonycha fulva
Coruf	Coccidula rufa	Rhlit	Rhizobius litura
Cosep	Coccinella 7-punctata	Scfro	Scymnus frontalis
Cound	Coccinella 11-punctata	Scsch	Scymnus schmidti

Cyser	Cytilus sericeus	Sebru	Sericus brunneus
Drern	Dryops ernesti	Sisem	Simplocaria semistriata
Drlur	Dryops luridus	Xapal	Xanthomus pallidus
Drnit	Dryops nitidulus		

Spiders: Linyphiidae

Agcau	Agyneta cauta	Memol	Meioneta mollis
Agdec	Agyneta decora	Mepeu	Mecopisthes peusi
Agram	A. ramosa	Merur	M. rurestris
Agsub	A. subtilis	Miher	Micrargus herbigradus
Almen	Allomengea vidua	Miine	Milleriana inerrans
Arcra	Araeoncus crassiceps	Mipus	Minyriolus pusillus
Arhum	A. humilis	Misub	M. subaequalis
Bagra	Bathyphantes gracilis	Mofus	Monocephalus fuscipes
Bapar	B. parvulus	Oefus	O. fuscus
Cebre	Ceratinella brevipes	Oegib	Oedothorax gibbosus
Cebrv	Ceratinella brevis	Oeret	O. retusus
Cecon	Centromerita concinna	Osmel	Ostearius melanopygius
Cepru	Centromerus prudens	Pelud	Peponocranium ludicrum
Cerom	Ceratinopsis romana	Pepar	Pelecopsis parallela
Cesta	Ceratinopsis stativa	Popum	Pocadicnemis pumila
Cnobs	Cnephalocotes obscurus	Popyg	Porrhomma pygmaeum
Dibif	Dismodicus bifrons	Saabn	Saaroista abnormis
Dilat	Diplocephalus latifrons	Sabri	Satilatlas britteni
Dinig	Dicybium nigrum	Safro	Savignia frontata
Erarc	Erigone arctica	Siele	Silometopus elegans
Eratr	E. atra	Tapra	Tapinocyba praecox
Erden	E. dentipalpis	Tivag	Tiso vagans
Erhie	Erigonella hiemalis	Trsca	Troxochrus scabriculus
Erlon	E. longipalpis	Trtho	Trichopterna thorelli
Erpro	E. promiscua	Tydig	Typhochrestus digitatus
Gnden	Gnathonarium dentatum	Waacu	Walckenaeria acuminata
Goviv	Gongylidiellum vivum	Waant	W. antica
Lepal	L. pallidus	Waatr	W. atrotibialis
Leten	Lepthyphantes tenuis	Wainc	W. incisa
Lezim	L. zimmerana	Wamon	W. monoceros
Lopun	Lophomma punctatum	Wanud	W. nudipalpis
Masun	Maso sundervalli	Wavig	W. vigilax

Spiders: Lycosidae

Albar	Alopecosa barbipes
Alcun	Alopecosa cuneata
Alpul	Alopecosa pulverulenta
Arleo	Arctosa leopardus
Arper	Arctosa perita
Pamon	Pardosa monticola
Panig	Pardosa nigriceps
Papal	Pardosa palustris
Paparm	Pardosa armentata

Papro	Pardosa proxima
Papul	Pardosa pullata
Pilat	Pardosa latitans
Pipir	Pirata piraticus
Trrur	Trochosa ruricola
Trter	Trochosa terricola
Xemin	Xerolycosa miniata

Miscellaneous Spiders

Aglab	Agelena labyrinthica	Mipul	Micraria pulicaria
Agpro	Agroeca proxima	Ozato	Ozyptila atomaria
Agstr	Agraecina striata	Ozsan	O. sanctuaria
Anele	Antistea elegans	Ozsim	O. simplex
Arsub	Argenna subnigra	Oztru	O. trux
Chvir	Cheirocanthium virescens	Pacle	Pachygnatha clercki
Clneg	Clubiona neglecta	Padeg	Pachygnatha degeeri
Drcup	Drassodes cupreus	Pimir	Pisaura mirabilis
Drpub	Drassodes pubescens	Roliv	Robertus lividus
Drpus	Drassyllus pusillus	Scgra	Scotina gracilipes
Enova	Enoplognatha ovata	Tesyl	Tegenaria sylvestris
Entho	Enoplognatha thoracica	Xybif	Xysticus bifasciatus
Er fur	Ero furcata	Xycri	X. cristatus
Eufro	Euophrys frontalis	Xyerr	X. erraticus
Hadal	Haplodrassus dalmatensis	Xykoc	X. kochi
Hasig	Haplodrassus signifer	Zeele	Zelotes electus
Hefla	Heliophanus flavipes	Zelat	Zelotes latreillei
Lacor	Larinioides cornutus		

Harvesters

Laeph	Lacinius ephippiatus
Lebla	Leiobunum blackwalli
Michr	Mitosoma chrysomelas
Mimor	Mitopus morio
Nebim	Nemastoma bimaculatum
Oltri	Oligolophus tridens
Opsax	Opilio saxatilis

Paagr	Paroligolophus agrestis
Phopi	Phalangium opilio
Pltri	Platybunus triangularis

Miscellaneous Invertebrates

Arvul	Armadillidium vulgare	Limel	Lithobius melanops
Chbru	Chorthippus brunneus	Mymac	Myrmeliotettrix maculatus
Cylat	Cylindroiulus latestriatus	Omsab	Ommatoiulus sabulosus
Ecpan	Ectobius panzeri	Omvir	Ommocestus viridulus
Foaur	Forficula auricularia	Oppil	Ophyiulus pilosus
Glmar	Glomerus marginata	Phmus	Philoscia muscorum
Jusca	Julus scandinavius	Poang	Polydesmus angustus
Laema	Lamyctes emarginatus	Prsca	Porcellio scaber
Libor	Lithobius borealis	Tanig	Tachypodiulus niger
Lical	Lithobius calcaratus	Teund	Tetrix undulata

Appendix 10.5. Data Archive Appendix

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] Species records, which are held on the NRW Recorder 6 database.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue http://libcat.naturalresources.wales or http://catllyfr.cyfoethnaturiol.cymru by searching 'Dataset Titles'. The metadata is held as record no. 121591.

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