The Ecology of the Marsh Pea, *Lathyrus palustris*

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I. Abstract

The Marsh Pea, *Lathyrus palustris*, is a climbing perennial herb found in fens, marshes and reed beds (Rose, 2006) and is nationally scarce in the UK due to habitat loss. A study into the ecology of the Marsh Pea was undertaken in summer 2014 at Ffrwd Farm Mire nature reserve, Pembrey, in order to map the distribution of the species at the site and understand how environmental changes have affected its distribution and abundance, and also look at the botanical associations of the species in order to gain information on how to better conserve it. Percent (%) cover of species, R:FR ratio of light and height of tallest plant (cm) were recorded for each quadrat (n = 100 total). A soil sample was also taken for each quadrat and analysed in a laboratory. Soil moisture, pH and conductivity were recorded. The results show that *L. palustris* has a frequency of 54% at the study site and mean percent (%) cover of 5.56%. A multivariate analysis showed that *L. palustris* was classified with species highly associated with wet areas, and only occurred in a tall herb fen area in the study site. An NVC analysis confirmed that *L. palustris* was found to be in an NVC S24/S25 (*Phragmites australis-Peucedanum palustre/Phragmites australis-Eupatorium cannabinum*) community. A Principal Components Analysis (PCA) showed moisture and conductivity were important factors in the distribution of *L. palustris*. A Chi-squared association established that *L. palustris* was strongly associated with Common Reed, *Phragmites australis* and Skullcap, *Scutellaria galericulata.* The results from this study can be used in the selection of favourable habitats for possible reintroduction of *L. palustris* and can also provide information on successful management techniques. By conserving *L. palustris* other species of conservation concern, such as Tubular Waterdropwort, *Oenanthe fistulosa*, and the Marsh Fritilliary butterfly, *Euphydryas aurinia* that also occupy similar habitats can also be conserved.

II. Acknowledgements

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III. Introduction

Conservation of species and habitats

In an increasingly changing environment, conservation of habitats and species is becoming progressively more important. Not only do native species provide ecosystem services such as food, materials and fuel, the habitats in which they are found also provide ecosystem services such as water purification, recreation, education and primary production (Millennium Ecosystem Assessment, 2005). However, species also have an intrinsic value and an inherent right to be conserved (Sandler, 2012). In recent years, conservation has become increasingly important as biodiversity has declined due to human activity (Loreau et al., 2001). Biodiversity has decreased to a point where there are considered to be only 25 'hotspots' left on Earth (Myers et al., 2000). Thus the semi-natural habitats that remain should be of conservation concern due to the diversity they support. In Britain there are 1149 UK BAP species and 40 UK BAP habitats (JNCC, 2007).

Wetlands and fens

Wetlands are essential for biodiversity, and are one of the most productive habitat types, storing more carbon than rainforests despite only covering 6% of the earth (Cherry, 2011; WWT, 2014). Wetland is the term used for any habitat type that is either seasonally or permanently inundated with water. These habitats are usually dynamic and often highly variable in the environmental conditions that affect them, for example wetlands can be saline, brackish or freshwater and also inland or coastal. Wetlands include fens, marshes, swamps, estuaries, rivers and lakes (Wetlands International, 2014). These habitat types support a variety of flora and fauna. More than 100,000 species of animal rely on freshwater ecosystems (WWT, 2014). In the UK there are 170 wetland habitats covering 1,278,923 hectares (ha) designated as Ramsar sites for conservation (RSIS, 2014).

Introduction to fens

Lowland wetlands are a priority for conservation in the UK, being one of the most threatened habitats in Britain. This habitat type consists of bogs and fens (JNCC, 2014). Lowland fens are UK BAP habitats (JNCC, 2014), occurring mainly in Wales, England and Northern Ireland. There are 25,785 ha of lowland fen in the UK, with 6,200 ha in Wales (JNCC, 2014). These habitat types are often species rich and have high biodiversity due to consisting of mixtures of monocotyledonous swamp emergent species and also a variety of perennial dicotyledons (Rodwell, 1995). Fens grow on peat or mineral soils subject to variable degrees of waterlogging (JNCC, 2014). Unlike raised bogs, although fens occur on a peat base the rate of decomposition is high, leading to shallow peat depth and lack of peat dome (JNCC, 2014). There are primarily two types of fen habitats; topogenous mires (Rodwell, 1995) are associated with vertical water movement and include habitats such as floodplain and basin fens, whereas soligenous fens are associated with lateral water movement and include habitats such as springs, flushes and valley mires (JNCC, 2014). As such, fens are fed by groundwater and surface run-off rather than precipitation, which consequently gives rise to high nutrient levels leading to the growth of lush vegetation (JNCC, 2014). Fens can also be classified by their fertility. Poor fens are fed by acid water derived from bedrock such as sandstone and granite and are characteristically species-poor, occurring in the uplands. Common species of poor fens are *Sphagnum spp.* (for example *Sphagnum squarrosum*), Bottle Sedge, *Carex rostrata* and Marsh Cinquefoil, *Potentilla palustris*. Rich fens are alkaline and mineral-enriched, largely confined to the lowlands with rich flora and fauna, often dominated by sedges and forbs such as Lesser Spearwort, *Ranunculus flammula,* Marsh bedstraw, *Galium palustre*, and Ragged Robin, *Lychnis flos-cuculi*. Rich fens are also known to support tall herb communities such as reed bed and species such as Hemp Agrimony, *Eupatorium cannibinum* and Meadowsweet, *Filipendula ulmaria* (JNCC, 2014; Scottish National Heritage, 2014).

Fen species

Fens are a component of the hydroseral succession from water to dry land (Williams, 1993), and are dynamic ecosystems that form mosaics with various other habitat types such as reed bed, meadow, wet woodland, marshy grassland and heathland (JNCC, 2014) thus they support a diversity of plant species, all of which are adapted to have elevated tolerances to soil moisture. Fens are also known to support a diversity of invertebrate fauna (JNCC, 2014). Such habitats are often rich in Lepidoptera, Odonata, Diptera, Mollusca and Arachnids. Some bird species are also reliant on fens. Due to the decline in wetlands these habitats also act as reservoirs for highly specialised, rare and vulnerable species. For example, fens are important habitats for species such as the Cetti's warbler, *Cettia cetti*, Desmoulin's whorl snail*, Vertigo moulinsiana,* the fen raft spider, *Dolomedes plantarius* and reed leopard moth, *Phragmataecia castaneae*. The Marsh Pea, *Lathyrus palustris,* is also an important fen species (Figure 1).

Marshy Grasslands

Marshy grassland is another wetland habitat worth discussing. This habitat is also known as purple moor-grass pasture or Rhos pasture in Wales (Grasslands Trust, 2012). Marshy grassland is characterised by having a higher peat content than most other grasslands, which is reflected in the flora of the habitat; a combination of rushes (*Juncus spp.*) and purple moor-grass, *Molinia caerulea,* dominates. This habitat is important for a variety of fauna, for example all UK amphibians can be found in this habitat type (Arkive, 2014). It is also important for the conservation of the Marsh Fritillary butterfly due to the presence of Devil's-bit scabious, *Succisa pratensis* (Grasslands Trust, 2012).

Soil characteristics of wetlands

Soil is the primary source of plant nutrients (Whitehead, 2000). The nature of the soil parent material influences concentrations of nutrients present. Environmental factors such as pH, conductivity and moisture are key factors in the composition of plant communities. In a fen habitat, the soil is composed of organic matter derived from preceding vegetation (Whitehead, 2000) and is subject to anaerobic conditions caused by inundation of water due to high rainfall and poor drainage (Faulkner and Richardson, 1989). High soil moisture plays a role in soil redox reactions and rate of decomposition by microbial activity (JNCC, 2004). Soils with high organic matter are classified as histosols, although soils of England and Wales are generally classed as inceptisols, being relatively new with undefined horizons (NRCS, 1999; Dominati et al., 2010). Soils with high concentrations of organic matter are usually more acidic than soils with high mineral content (Faulkner and Richardson, 1989), thus lowland fens are unique in that the soil is composed of peat and also high in nutrients due to being fed by groundwater. Soil pH is an important factor indicative of the richness of a given habitat. Many plants can be classified as either calcicoles (growing on calcareous soils) or calcifuges (growing on acidic soils). Calcareous soils are usually associated with relatively higher species richness and diversity (Poschlod et al, 1998; JNCC, 2014) thus base-rich fens (pH >5.5) (JNCC, 2004) are known for their diversity of flora and fauna. Soil pH also affects mineral availability, consequently affecting the local flora by increasing or decreasing competition between species. Conductivity is a measurement of the concentration of ions present in the soil, which provides an indication of a soil's nutrient availability. A higher conductivity value suggests a high concentration of ions present. Also, a pH of >6.5 generally conveys a high availability of nutrients such as Iron and Phosphorus (JNCC, 2004).

<u>Marsh Pea, *Lathyrus palustris*</u>

Lathyrus palustris is a perennial legume found in reed beds, fens and calcareous peats (Rose, 2006) and is nationally scarce in Britain (Cheffings & Farrel, 2006), after populations were reduced in the 19th and 20th century by drainage and agricultural development (Suffolk wildlife trust, 2014). *Lathyrus palustris* is a hemicryptophyte, far-creeping herb and thrives in the interface of reed bed, fen and marshy grassland (Fitter and Peat, 1994; Wildlife Trust, 2014). It is associated with NVC codes S24/S24a (Rodwell, 1994). Today the species is still threatened by habitat loss due to lack of management and increasing urbanisation (Preston et al., 2002) (Figure 2). Globally *L. palustris* has a circumpolar boreo-temperate element (Preston et al., 2002) and is listed as a species of least concern, having a wide distribution range (Kavak, 2014); however information on this species is scarce. *L. palustris* was thought to be extinct in Wales until it was discovered in 1971 at Ffrwd Farm Mire, Pembrey (Williams, 1993). Its discovery contributed to the site becoming a designated SSSI in 1973. Due to *L. palustris* being associated with fen areas a study into its ecology could provide insight into important factors linked to the maintenance of such wetland sites and the conservation of biodiversity in these habitats.

Figure 1. Photograph of *Lathyrus palustris* at the study site, July 2014.

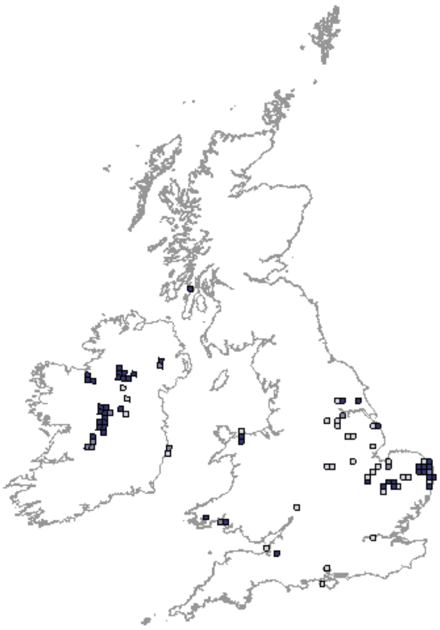


Figure 2. Distribution of *L. palustris* in Great Britain (NBN Gateway, 2011)

In July 2014 an investigation into the ecology of *L. palustris* was undertaken at Ffrwd Farm Mire aiming to map the distribution of *L. palustris* at Ffrwd Farm Mire Nature Reserve and compare the distribution of *L. palustris* to that of 21 years previously. It also aimed to determine how soil factors such as moisture, pH and conductivity affect the abundance of *L. palustris*, and determine the botanical associations of *L. palustris*. Possible conservation strategies for the species and its habitat will be highlighted along with other species of importance on the study site. Lastly, this study aimed to contribute to the current literature surrounding the subject.

IV. Method

Ffrwd Farm Mire

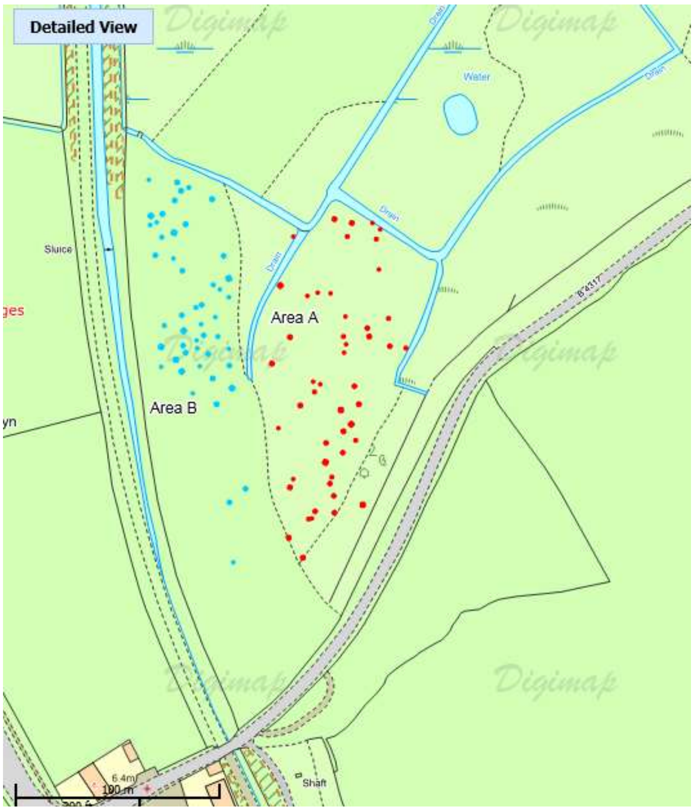
The study was conducted in July 2014 at Ffrwd Farm Mire Nature Reserve, Pembrey. Ffrwd Farm Mire is currently owned by The Wildlife Trust and the Llanelli Naturalists Society and is part of the Gwernedd Pembre SSSI. It is 19ha in size and lies 4m above sea level (Wildlife Trust, 2006). A population of *L. palustris* is found in a 1.3ha portion of the reserve (Grid Ref SN418021) (Figure 3). Literature surrounding the ecology of *L. palustris* is limited, however a study into the ecology of *L. palustris* at the Ffrwd Farm Mire nature reserve was undertaken in 1993 which first mapped the distribution of the Marsh Pea on the site and also gave an insight into the botanical associations of the species (Williams, 1993). The site was regularly grazed by cattle and ditches were subject to clearing in previous years. The site was also selected for a water vole reintroduction project.

Figure 3. Map (Created on an OS Map using DIGIMAP, 2014) and satellite image showing study site at Ffrwd Farm Mire Nature Reserve, Pembrey (Google Maps, 2014).

Sampling

A pilot visit was conducted on 30/06/14 in order to assess the area and aid in establishing the experimental design as well as determining risks associated with the site. The site was divided into two sections due to there being two distinct homogenous stands of vegetation; Section A consisted of a species-rich fen and was dominated by Common reed, *Phragmites australis,* whereas Section B was relatively drier, however still marshy grassland and was dominated by graminoid species and acid grassland indicator species such as Tormentil, *Potentilla erecta* (Hill et al., 2004; Rose, 2006).

For each section, 50 samples were obtained (n = 100 total) using 0.5 m x 0.5 m = 0.25 m^2 quadrats (Figure 4). Samples were obtained randomly to prevent bias. A GPS device (Garmin Etrex, Kansas USA) was used to record the position of each quadrat in order to avoid pseudoreplication. GPS Coordinates were also used in the event quadrat positions needed to be located at a later date, for example in order to record moisture samples. For each quadrat, plant species were identified to species level (Rose, 2006; Streeter, 2009). The percentage (%) abundance of plant species present was recorded along with height of tallest plant (cm) and R:FR (Zeta) values. R:FR values were recorded using a Skye light sensor (Skye Instruments, Powys, Wales). A soil sample was also taken for each quadrat using a soil corer (2 cm diameter, 10 cm depth). Soil samples were put into sample bags labelled with quadrat number and date and frozen for laboratory analysis.



Key

= Area A (Fen) samples

= Area B (Marshy Grassland) samples

Figure 4 - Map showing distribution of quadrats at the study site (Digimap, 2014).

Soil analysis

In the laboratory each sample of frozen soil was put into aluminium foil trays and weighed using Mettler PC 400 weighing scales. After the first weighing, samples were left to air dry for at least 2 weeks. Once dried, samples were reweighed. The percentage (%) moisture of each sample was then calculated using Equation 1.

$$Soil\ moisture\ (\%) = \left(\frac{initial\ weight - final\ weight}{initial\ weight}\right) * 100$$

Equation 1 – used to calculate % soil moisture

Moisture values were obtained *ex-situ* due to Area A being too wet to provide an accurate reading using a moisture sensor. Once dried, 5g of each sample was weighed in a beaker and mixed with 50 ml distilled water to form a consistent paste. This was used to test the pH and conductivity (µS/cm) of each soil sample. The pH was tested using a Hanna Waterproof Tester (Hanna Instruments, Bedfordshire) and conductivity was tested using a Cole Parmer Data Meter (CON 410 Series) (Cole Parmer Instruments, Singapore).

Plant species richness of each site was determined. Non-Parametric data was analysed using a Mann Whitney U test carried out on SPSS to calculate statistical differences. Mean (±SE) Shannon diversity (H') was calculated for each site (Equation 2), using the program Species Diversity and Richness (Pisces Conservation Ltd). A National Vegetation Classification (NVC) analysis was carried out using TABLEFIT (Hill, 1996) to define the plant communities present.

$$H' = -\sum_{i=1}^{R} Pi \ln Pi$$

Equation 2 – used to calculate Shannon diversity

Multivariate analysis of vegetation data was undertaken Community Analysis Package (CAP 4.0) Pisces Conservation Ltd, using Two Way Indicator Species Analysis (TWINSPAN) and Detrended Correspondence Analysis (DECORANA) for both samples and species. This type of analysis is used to simplify the matrix data in the context of site aspects and species (Wheater et al., 2011). Furthermore chi-squared association analysis was performed to determine significant associations between species. Principal Components Analysis (PCA) was undertaken using ECOM II (Pisces Conservation Ltd) to determine the environmental factors affecting distribution of species. Spearman's Rank correlation was implemented to determine relationships between plant species richness or diversity and abiotic variables such as pH and conductivity.

V. Results

A total of 60 species were recorded at the study site (Table 1). Species richness and Shannon Diversity was similar for each area. The strongest botanical associations of *Lathyrus palustris* were Common Reed, *Phragmites australis* and Skullcap, *Scutellaria galericulata*. The mean Ellenberg F value for each site was higher in Area A than in Area B. Soil % moisture and conductivity were also significantly different between areas A and B, and it was found that these factors were the most influential in the distribution of *Lathyrus palustris.* At the study site, *Lathyrus palustris* was found to have a frequency of 54% in Area A (Figure 5), and a mean % cover of 5.56%.

Plant Species Richness and diversity at Ffrwd Farm Mire

The species richness for each site was determined (Table 1). The total species richness for Area A (Fen) = 44, whereas species richness for Area B (Marshy grassland) = 41. The mean species richness per quadrat for Area A was 9.26 ±SE 0.089. The mean species richness for Area B was 9.52 ±SE 0.074. There was no significant difference in the species richness between sites ($U = 1148.5$, $P = >0.05$). The mean (± SE) Shannon Diversity (H') was also calculated. H' for Area A (Fen) = 2.649, SE = 0.065. H' for Area B (Marshy grassland) = 2.796, SE = 0.066.

Table 1. Comparison of species presence and richness across study site

Species List		**Presence (X = present; 0 = absent)**	
Scientific Name	**Common Name**	**Area A Fen**	**Area B Marshy Grassland**
Achillea ptarmica	Sneezewort	X	0
Agrostis canina	Velvet Bent	X	X
Anthoxanthum odoratum	Sweet Vernal Grass	X	X
Arrhenatherum elatius	False oat-grass	X	0
Berula erecta	Lesser water parsnip	X	0
Caltha palustris	Marsh Marigold	X	X
Carex ovalis	Oval sedge	X	0

Carex nigra	Common Sedge	0	X
Carex rostrata	Bottle Sedge	X	0
Carum verticillatum	Whorled Caraway	0	X
Chamerion angustifolium	Rosebay Willowherb	0	X
Cirsium dissectum	Meadow Thistle	X	X
Cynosurus cristatus	Crested Dog's Tail	0	X
Dactylorhiza praetermissa	Southern Marsh Orchid	X	X
Epilobium hirsutum	Greater Willowherb	X	X
Epilobium parviflorum	Hoary Willowherb	X	0
Equisetum arvense	Field Horsetail	X	X
Equisetum palustre	Marsh Horsetail	X	X
Eupatorium cannabinum	Hemp Agrimony	X	0
Festuca arundinacea	Tall Fescue	X	0
Filipendula ulmaria	Meadowsweet	X	0
Galium palustre	Marsh Bedstraw	X	X
Holcus lanatus	Yorkshire Fog	X	X
Hydrocotyle vulgaris	Marsh Pennywort	X	X
Hypericum tetrapterum	Square-stalked St John's Wort	X	0
Hypochaeris radicata	Common Cat's Ear	0	X
Iris pseudacorus	Yellow Iris	X	0
Juncus acutiflorus	Sharp-flowered Rush	X	X
Juncus conglomeratus	Compact Rush	X	X
Juncus effusus	Soft Rush	X	X
Lathyrus palustris	Marsh Pea	X	0
Leontodon hispidus	Rough Hawkbit	0	X
Lotus pedunculatus	Greater Bird's-foot Trefoil	X	X
Lychnis flos-cuculi	Ragged Robin	X	X
Lythrum salicaria	Purple Loosestrife	X	X
Mentha aquatica	Water Mint	X	0
Menyanthes trifoliata	Bogbean	X	0
Molinia caerulea	Purple Moor Grass	X	X
Myosotis laxa	Tufted Forget-Me-Not	X	0
Nardus stricta	Mat-grass	0	X
Oeanthe crocata	Hemlock Waterdropwort	X	0
Oeanthe fistulosa	Tubular Waterdropwort	X	0
Phragmites australis	Common Reed	X	X
Plantago lanceolota	Ribwort Plantain	X	X
Potentilla erecta	Tormentil	X	X
Ranunculus acris	Meadow Buttercup	X	X
Ranunculus flammula	Lesser Spearwort	X	0
Ranunculus repens	Creeping Buttercup	X	X
Rumex acetosa	Common Sorrel	0	X
Rumex crispus	Curled dock	X	X
Rumex obtusifolius	Broad leaved dock	0	X
Scutellaria galericulata	Skullcap	X	0

Senecio aquaticus	Marsh Ragwort	X	X
Stellaria graminea	Lesser Stitchwort	0	X
Succisa pratensis	Devil's-bit Scabious	0	X
Taraxacum agg.	Dandelion	0	X
Trifolium pratense	Red Clover	0	X
Trifolium repens	White Clover	0	X
Vicia sativa	Common Vetch	0	X
Vicia cracca	Tufted Vetch	0	X

Botanical communities present; National Vegetation Classification

An NVC analysis was undertaken to determine the plant communities present. Area A was classified as NVC S25a, *Phragmites-Eupatorium* fen, with a subcommunity of *Phragmites australis*. Goodness of fit = 42% (poor). Constant species are *Phragmites australis, Eupatorium cannabinum* and *Galium palustre* (Rodwell, 1995). Area B was classified as NVC M23a, *Juncus effusus/acutiflora - Galium palustre* rush-pasture with a sub community of *Juncus effusus* meadow. Goodness of fit = 49% (poor). Constant species are *Juncus effusus, Juncus acutiflora, Galium palustre* and *Holcus lanatus*.

Ellenberg Values

A species list for the whole study site was compiled and Ellenberg F (Moisture), R (Reaction) and N (Nitrogen) values obtained (Appendix 1), (Hill et al., 2004). The mean Ellenberg F Value for each area was calculated. The mean Ellenberg F Value for Area A (Fen): F = 7.3 ±STDEV = 1.31. The mean Ellenberg F Value for Area B (Marshy grassland) = 6.76 ±STDEV = 1.57.

Distribution of *L. palustris* at Ffrwd Farm Mire

The distribution and frequency of *L. palustris* was also compared to that of 1993. Results in this section are limited due to insufficient distribution data for this site from previous years. However it was found that during this study, *L. palustris* was present in 27 out of 50 quadrats (54%) for Area A (where the population was found) (Figures 5 and 6) compared to being present in 20 out of 36 (53%) quadrats in a study undergone in 1993 (Williams, 1993). The mean percent (%) cover of *L. palustris* in this study was 5.56%. In the previous study by Williams, 1993 it was 3.13%.

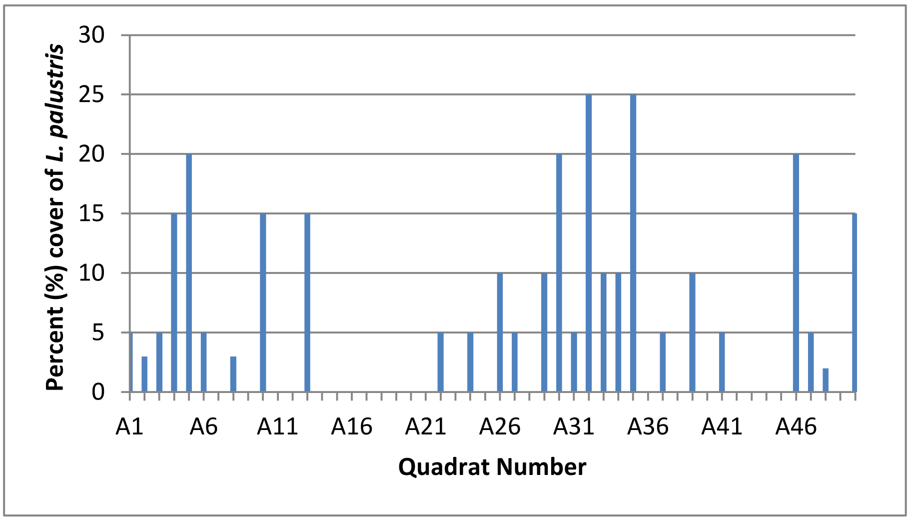
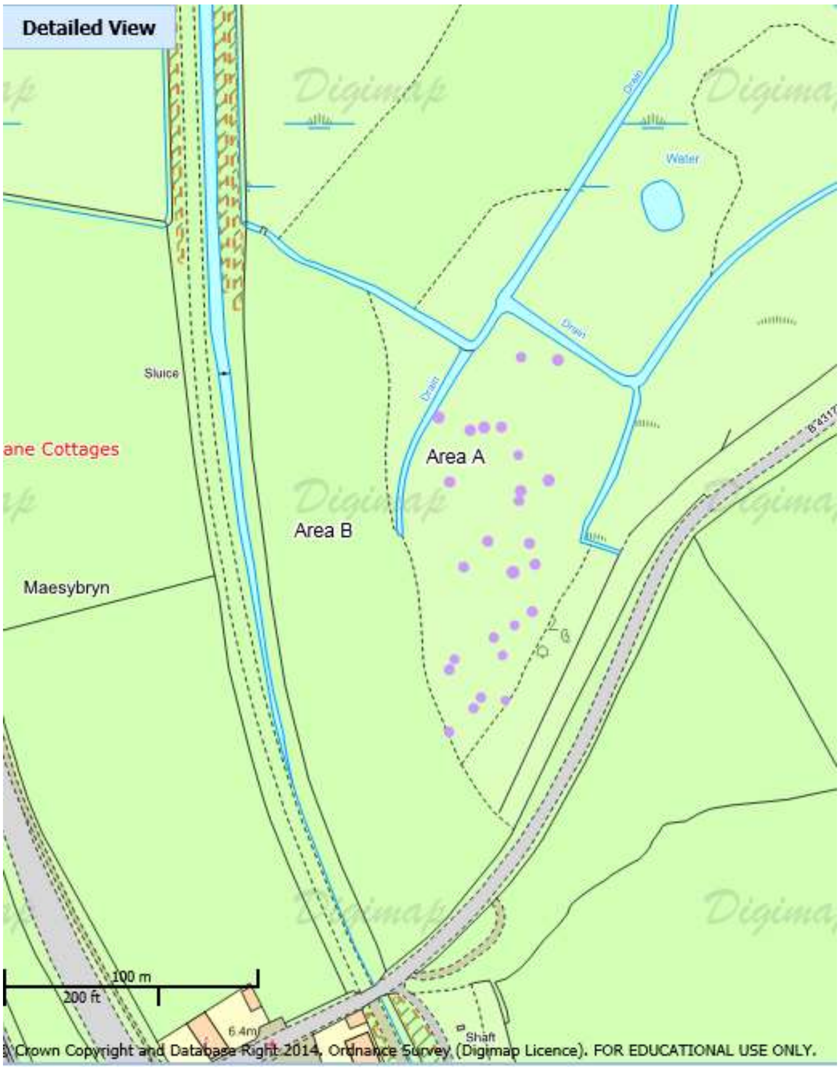


Figure 5 – Percentage (%) cover of *L. palustris* in each quadrat in Area A (Fen) 2014

A map showing the distribution of quadrats with *L. palustris* present was also created (Figure 6) and shows that *L. palustris* is widespread throughout but confined to Area A.



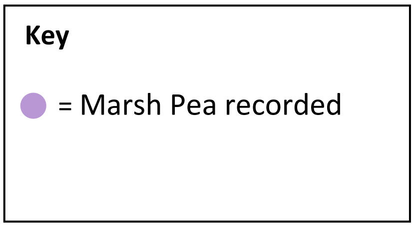


Figure 6 – Map showing the distribution of samples with Marsh Pea, *L. palustris* present (Digimap, 2014).

Environmental factors – Soil analysis

Percent (%) moisture, conductivity and pH were calculated for each soil sample. Table 2 shows the mean values for each site. A Mann Whitney U test found there was a significant difference in soil moisture between the two sites (U = 80, p = <0.01). There was also a significant difference in conductivity for each site (U = 190, p =<0.01).

Table 2. Mean soil % moisture, pH and conductivity for each site

	Area A			**Area B**		
	% Moisture	**pH**	**Conductivity (µS/cm)**	**% Moisture**	**pH**	**Conductivity (µS/cm)**
Mean	75.12	6.08	256.37	34.38	6.08	94.78
±SE	0.144	0.042	0.144	0.385	0.02	1.583

Species distributions and environmental factors at Ffrwd Farm Mire

A multivariate analysis was carried out to determine the distributions of samples and species with relation to an environmental gradient. The multivariate analysis was comprised of a DECORANA Ordination (Figures 7 and 8) and a TWINSPAN Classification (Figures 9 and 10).

Figure 7 shows that samples have been ordered into two groups. Samples from Area A are found on the left hand side (red) and samples from Area B are found on the right hand side (blue), indicating that samples were taken from two distinct stands of vegetation along an environmental gradient.

Species have also been ordered into two separate groups (Figure 8). For example, on the right hand side there are species such as Ribwort Plantain, *Plantago lanceolota*, Dandelion, *Taraxacum agg.,* and graminoid species such as Yorkshire Fog, *Holcus lanatus.* On the left hand side there are species such as Ragged Robin, *Lychnis flos-cuculi,* Water Mint, *Mentha aquatic*a, and Common Reed, *Phragmites australis.* Marsh Pea, *Lathyrus palustris* is also found on the left side.

Figure 9 shows samples have been classified on the presence or absence of indicator species. It can be seen that *Phragmites australis* is the species used to separate between the two sample groups. The samples from Area A (fen) are further classified according to the presence of species such as *Epilobium hirsutum, Lotus pedunculatus, Galium palustre* and *Hydrocotyle vulgaris*. Samples from Area B (Marshy Grassland) have been classified based on the presence of species such as Yorkshire Fog, *Holcus lanatus,* Tormentil, *Potentilla erecta,* and Mat-Grass, *Nardus stricta*. Area B samples are towards the top and Area A samples are at the bottom.

Figure 10 demonstrates that species have been classified into groups also. Graminoid species such as Velvet Bent, *Agrostis canina* and Mat-grass, *Nardus stricta* have been grouped towards the top with other species such as Whorled Carraway, *Carum verticillatum,* Devil's-Bit Scabious, *Succisa pratensis*, and Sneezewort, *Achillea ptarmica.* The bottom half of the dendrogram shows species such as Marsh Marigold, *Caltha palustris,* Yellow Iris, *Iris pseudacorus,* Meadowsweet, *Filipendula ulmaria*, Water Mint, *Mentha aquatica* and Marsh Pea, *Lathyrus palustris* have been classified together. It can be seen that Ellenberg moisture values increase down the dendrogram.

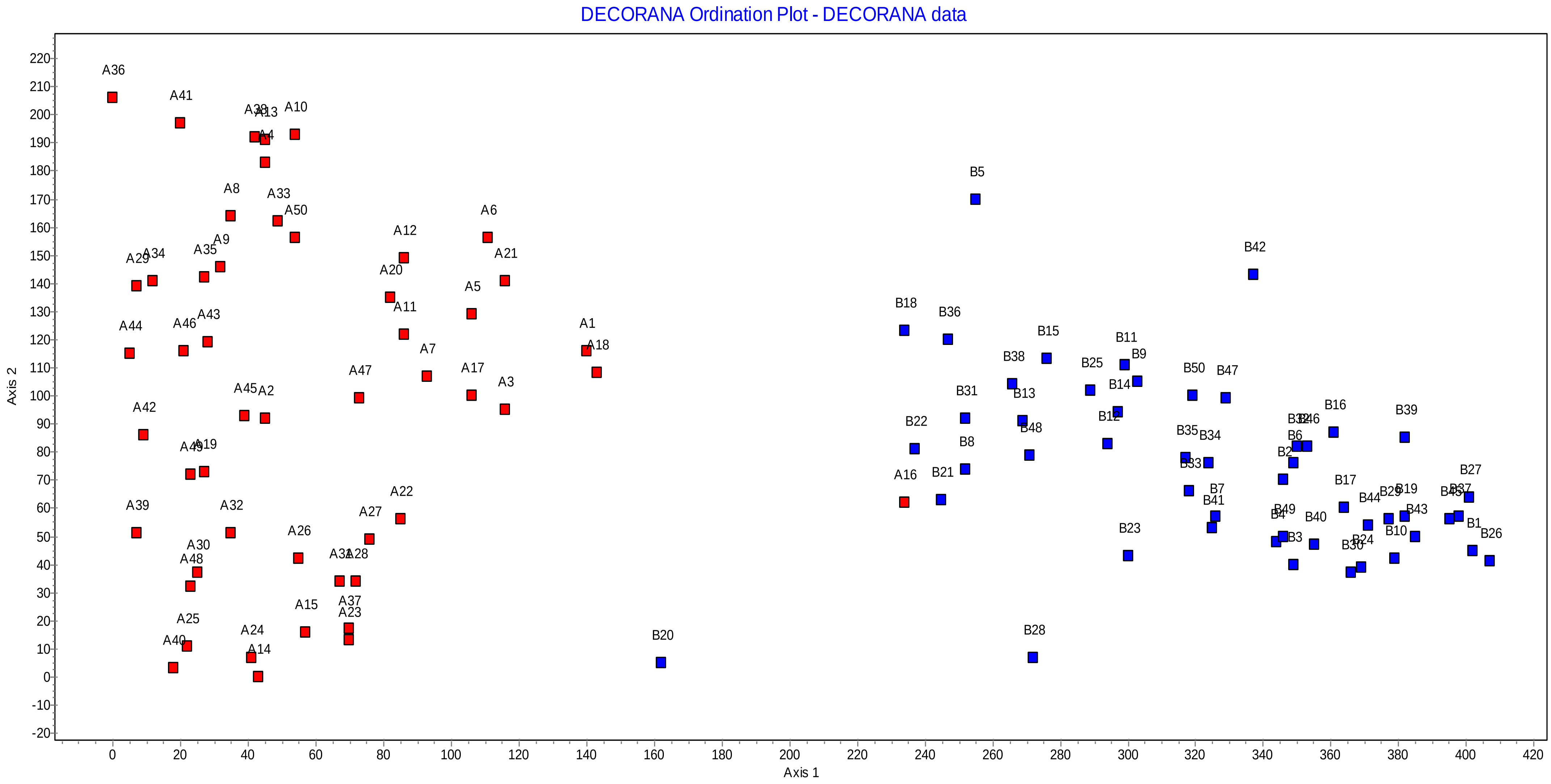


Figure 7 – DECORANA ordination plot for samples (A = fen; B = marshy grassland)

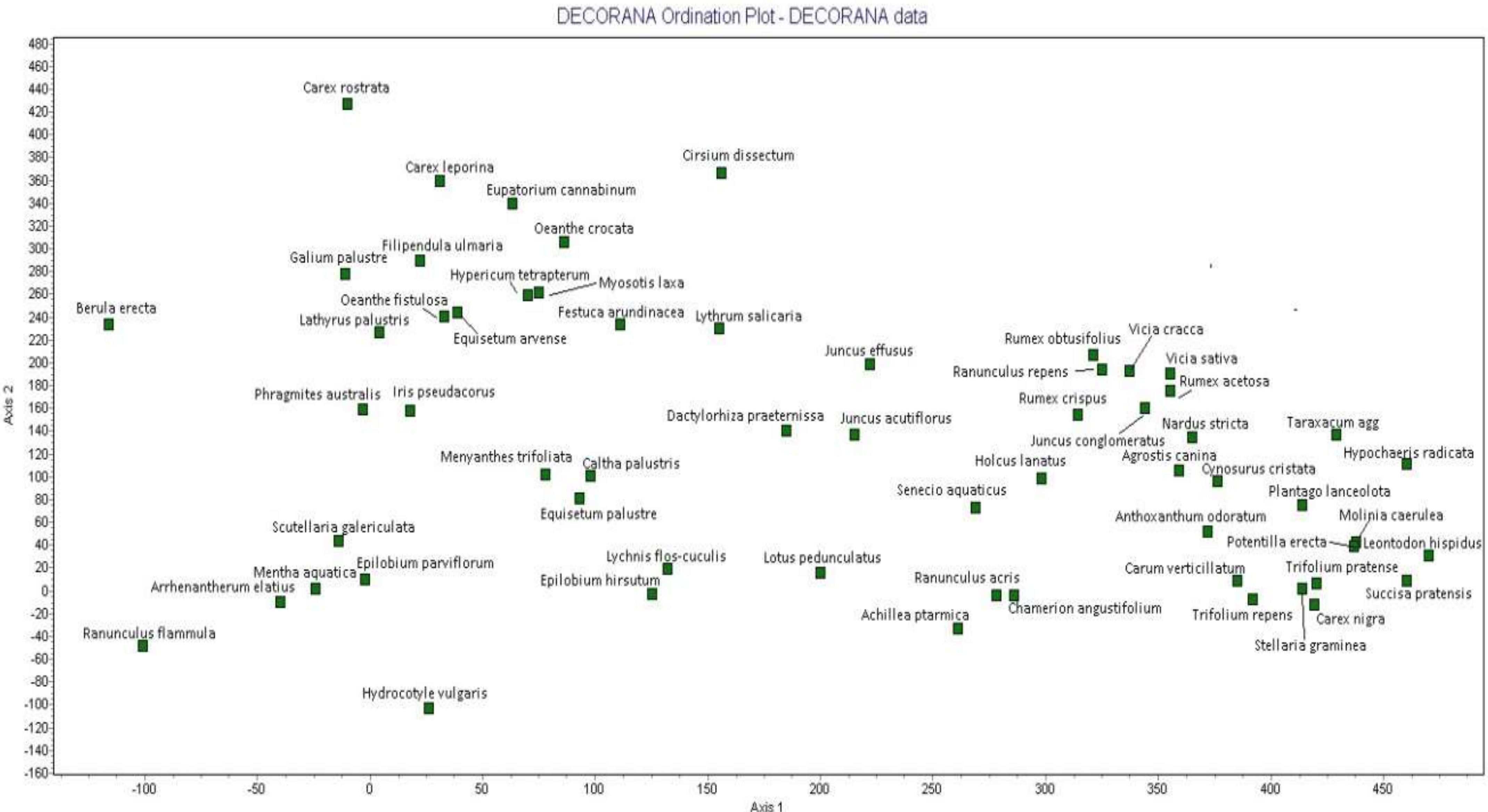


Figure 8 – DECORANA ordination plot for species (for corresponding Ellenberg F, R and N values see Appendix 1).

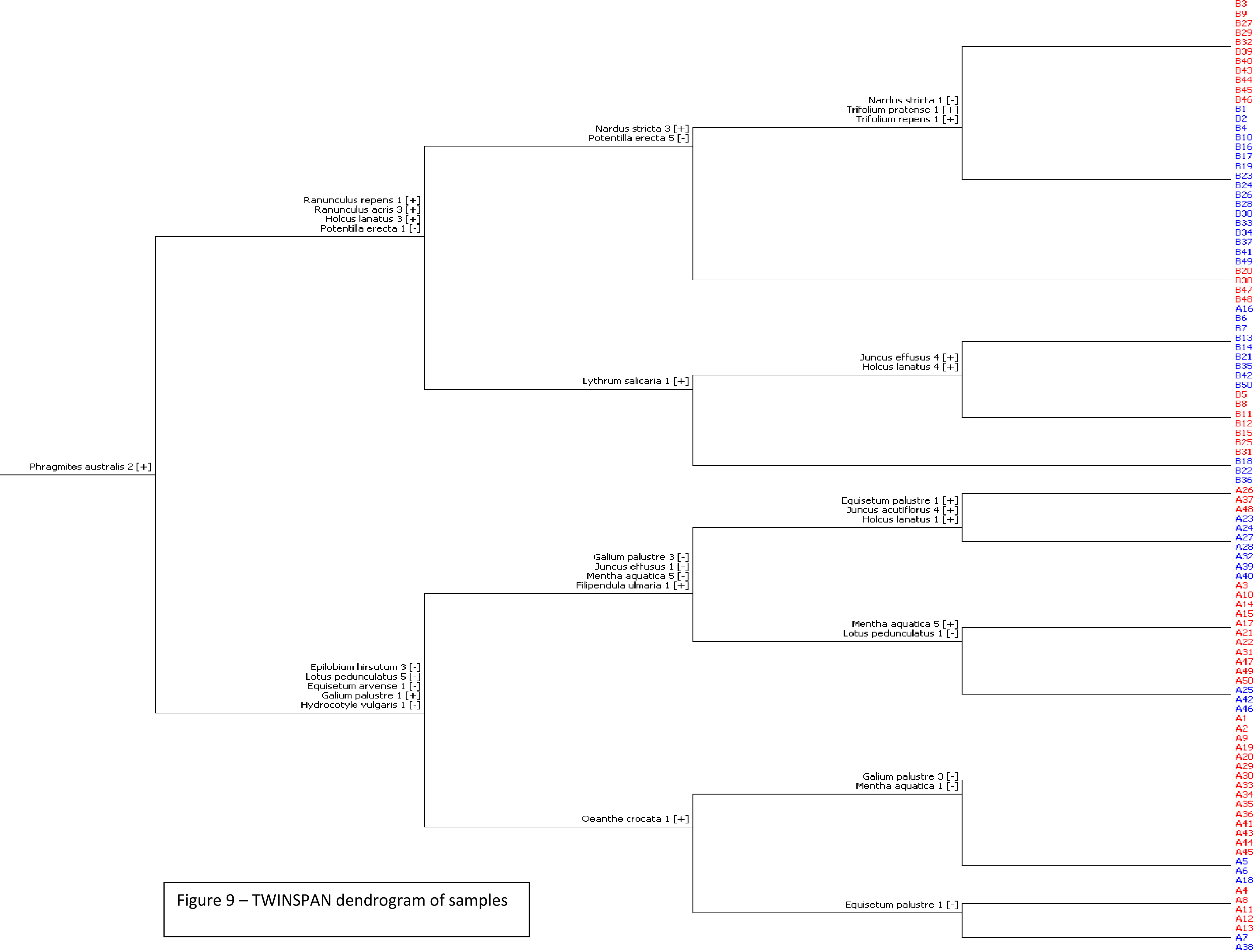


Figure 9 – TWINSPAN dendrogram of samples

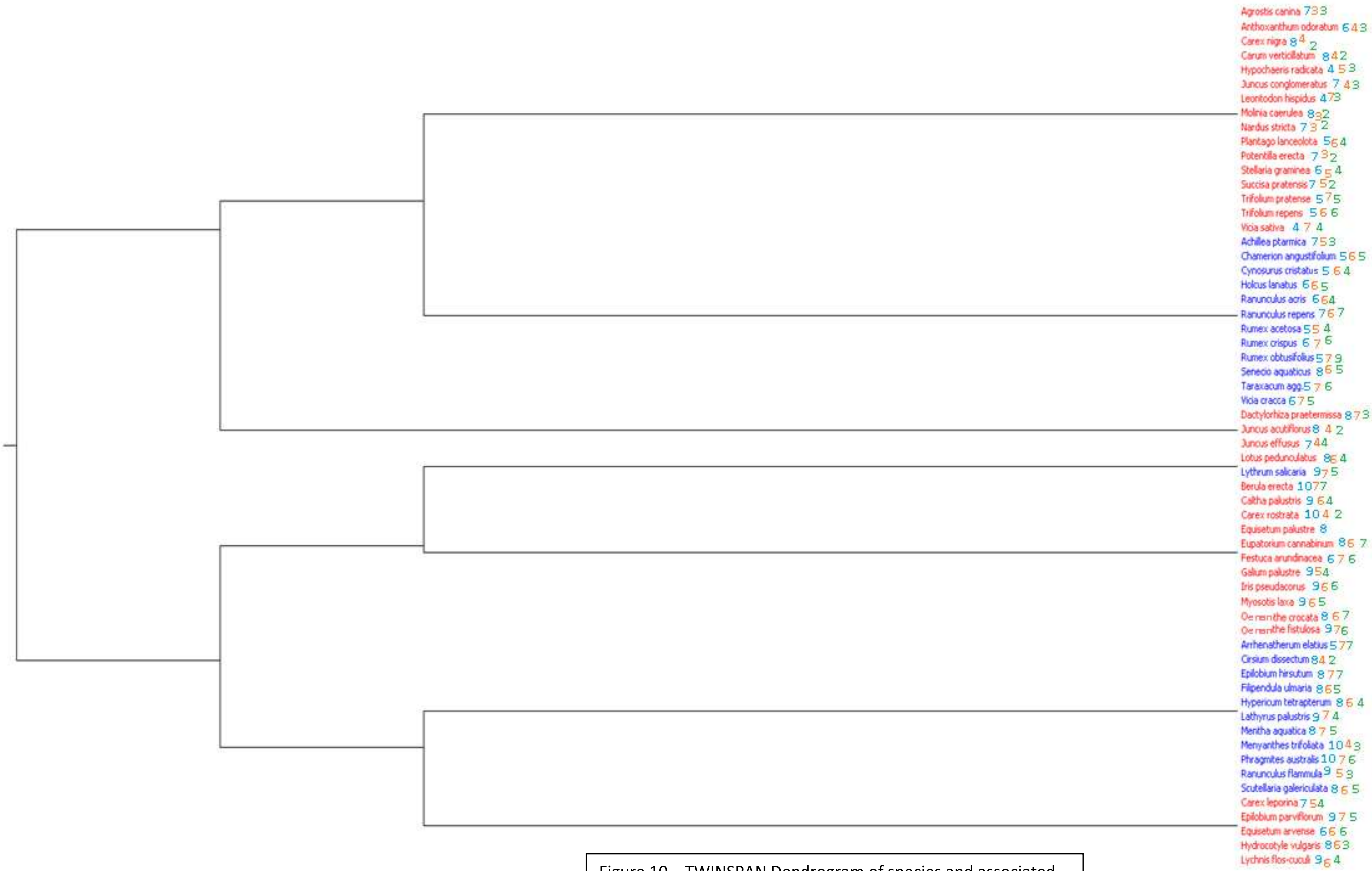


Figure 10 – TWINSPAN Dendrogram of species and associated Ellenberg F (moisture), R (reaction) and N (nitrogen) values

Botanical (Chi-squared) associations of *L. palustris*

A Chi-squared association analysis was also carried out in order to determine the botanical associations of *L. palustris*. Significant results are presented in table 3.

Table 3 – Chi-squared associations of *L. palustris*

Species	**Chi-squared Association Value**
Cirsium dissectum	7.46
Equisetum arvense	4.74
Equisetum palustre	9.83
Filipendula ulmaria	13.38
Galium palustre	14.5
Hydrocotyle vulgaris	10.08
Mentha aquatica	18.39
Myosotis laxa	7.46
Phragmites australis	29.22
Scutellaria galericulata	19.69
Cynosurus cristata	-7.07
Holcus lanatus	-12.13
Lotus pedunculatus	-5.29
Plantago lanceolota	-17.86
Potentilla erecta	-15.45
Ranunculus repens	-12.54
Succisa pratensis	-4.53
Trifolium pratense	-7.07
Trifolium repens	-8.75

Blue = positive association; red = negative association

It was found that *L. palustris* was strongly associated with Common Reed, *Phragmites australis* (χ^2 = 29.2237, P = <0.05) and Skullcap, *Scutellaria galericulata* (χ^2 = 19.69, P = <0.05). Other positive associations of *L. palustris* were Meadow Thistle*, Cirsium, dissectum*, Field Horsetail, *Equisetum arvense*, Marsh Horsetail, *Equisetum palustre,* Meadowsweet, *Filipendula ulmaria*, Marsh Bedstraw, *Galium palustre,* Marsh Pennywort, *Hydrocotyle* *vulgaris,* Water Mint, *Mentha aquatic* and Tufted Forget-Me-Not, *Myosotis laxa*. L. *palustris* was most negatively associated with Ribwort Plantain, *Plantago lanceolota* (χ^2 = -17.86) and Tormentil, *Potentilla erecta* (χ^2 = -15.45).

<u>Environmental factors affecting the distribution of *L. palustris;* Principal Components Analysis (PCA)</u>

A PCA was also undertaken (Figure 11) to determine the most influential environmental factors in both sites. It is demonstrated that samples from Area A are clustered on the right whereas samples from Area B are clustered on the left. Moisture and conductivity are the most important environmental factors (having the longest arrows). It is indicated that pH also has an effect on some samples.

A Spearman's Rank correlation was carried out to determine the relationship between species richness and abiotic variables. Although moisture was an important factor, and significantly different between Area A and B (U = 80, p = <0.01) for Area A (fen) there was no statistically significant relationship between moisture and species richness (r_s = 0.043, p = >0.05, df = 48). For Area B (marshy grassland) there was also no statistically significant relationship between moisture and species richness (r_s = 0.152, p = >0.05, df = 48). There was also no significant relationship between conductivity and species richness for Area A (r_s = -0.032, P = >0.05). However, in Area B there was a significant relationship between Conductivity and species richness (r_s = 0.324, P = <0.05).

Height of tallest plant (cm) was also recorded for each quadrat. It was found that the mean height of tallest plant for Area A = 93.98cm ±SE 0.368. The mean height of tallest plant for Area B = 59.64cm ±0.268. The height of tallest vegetation was significantly higher in Area A than Area B (U = 290.5, P = <0.01). However, no significant correlation between height of tallest plant and species richness was found (r_s = 0.44 , P = >0.05).

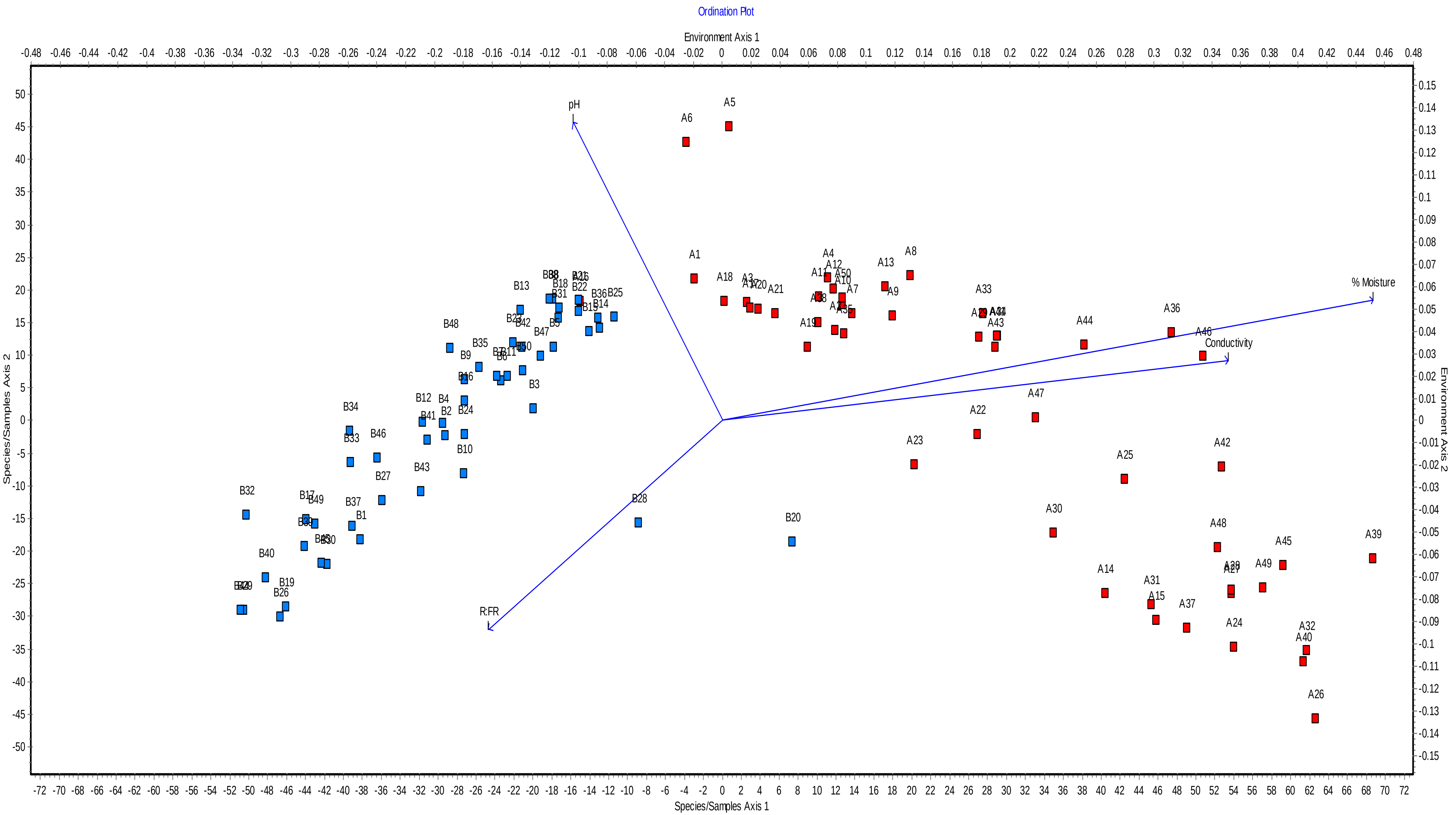


Figure 11 - Principal Components Analysis for samples (A = Fen samples; B = Marshy grassland samples).

VI. Discussion

Species Richness and Diversity at Ffrwd Farm Mire

From the results above, it can be seen that species richness was similar in each site, although the species compositions were contrasting (Table 1). Although *Lathyrus palustris* is the subject of this study, other notable species included Devil's-bit Scabious, *Succisa pratensis,* which is an important food plant for the Marsh Fritillary Butterfly, *Euphydryas aurinia*, (Grasslands Trust, 2012) and Tubular Waterdropwort, *Oenanthe fistulosa* which is classed as vulnerable in the UK (Cheffings and Farrel, 2006). The whole study site had a high Shannon diversity, due to consisting of a mosaic of habitats and ecotones (JNCC, 2014). It is known that marshes and fens are dynamic ecosystems associated with high biodiversity and can act as 'strongholds' for a variety of species in the UK (Mossman et al., 2012; JNCC, 2014). Fens have characteristically high species richness, with hundreds of species associated with these habitats. As fens are such diverse environments, species richness is often variable (Rodwell, 1995).

Plant communities present and species distributions

An NVC analysis was carried out and Area A was classified as an NVC S25a Community (*Phragmites australis-Eupatorium cannabinum* community) sub-community *Phragmites australis*. The goodness of fit was 42% (poor). This habitat type is noted for its variable vegetation and prominence of tall dicotyledons such as Hemp Agrimony, *Eupatorium cannabinum,* Purple Loosestrife, *Lythrum salicaria,* Meadowsweet, *Filipendula ulmaria,* Great Willowherb, *Epilobium hirsutum* and Yellow Iris, *Iris pseudacorus* (Rodwell, 1995), all of which were found at Ffrwd Farm Mire (Table 1). These habitats are often stratified and complex (Hájek et al., 2006) and species such as Water Mint, *Mentha aquatica,* Marsh Bedstraw, *Galium palustre* and Marsh Marigold, *Caltha palustris* are frequent (Rodwell, 1995). This habitat type has a widespread distribution throughout the English and Welsh lowlands and is characterised as the richest type of fen vegetation outside Broadland (Rodwell, 1995). It is known that *Phragmites australis* forms dominant stands; it is classified as a competitor (Grime et al., 2007) thus this analysis is appropriate. However despite Area A being classified as NVC S25a, *Lathyrus* palustris is not present in the floristic tables produced by Rodwell, 1995 for this community type. Another possible classification of Area

A would be NVC S24, *Phragmites australis-Peucedanum palustre* tall-herb fen, where the constant species include Hemp Agrimony, *Eupatorium cannabinum,* Meadowsweet, *Filipendula ulmaria,* Marsh Bedstraw, *Galium palustre,* Purple Loosestrife, *Lythrum salicaria,* Water Mint, *Mentha aquatica* and Common Reed, *Phragmites australis.* Rare species include Marsh Pea, *Lathyrus palustris*, and Milk Parsley, *Peucedanum palustre* (Rodwell, 1995). The NVC S24 habitat type has been previously stated as the NVC community most associated with *L. palustris* (Fitter et al., 1994). However, the distribution of NVC S25 communities is similar to the distribution of *L. palustris* (Figures 2 and 12). It is suggested that *L. palustris* might be classed as a rare species in this habitat type also, as it is known to be a species generally occurring in fens, marshes and swamps (Mountford, 2014).

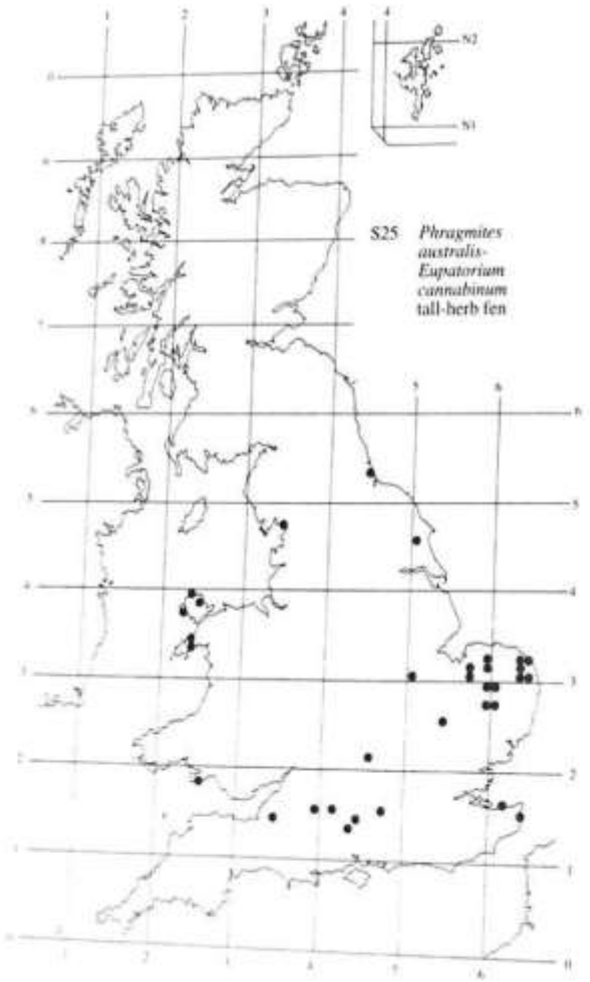


Figure 12 - Distribution of NVC S25 *Phragmites australis-Eupatorium cannabinum* tall-herb fens (Rodwell, 1995).

Area B was classified as NVC M23a *Juncus effusus/acutiflora - Galium palustre* rush-pasture, sub-community *Juncus acutiflorus* meadow. There was a goodness of fit score of 49% (poor). Constant species in this habitat type are Marsh Bedstraw, *Galium palustre*, Yorkshire Fog, *Holcus lanatus,* Soft Rush, *Juncus effusus,* Sharp rush, *Juncus acutiflorus,* and Greater Bird's-Foot Trefoil, *Lotus pedunculatus.* This habitat type is associated with moist agricultural grasslands and is common in Wales (Rodwell, 1995, Figure 13). Species such as Purple Moor Grass, *Molinia caerulea,* Tormentil*, Potentilla erecta*, an indicator of acidic soil (Streeter, 2009), Sneezewort, *Achillea ptarmica*, an indicator of wet ground (Rose, 2006), Whorled Carraway, *Carum verticillatum* and Common Stitchwort, *Stellaria graminea* are present either frequently or occasionally (Rodwell, 1995), all of which were recorded in Area B (Table 1).

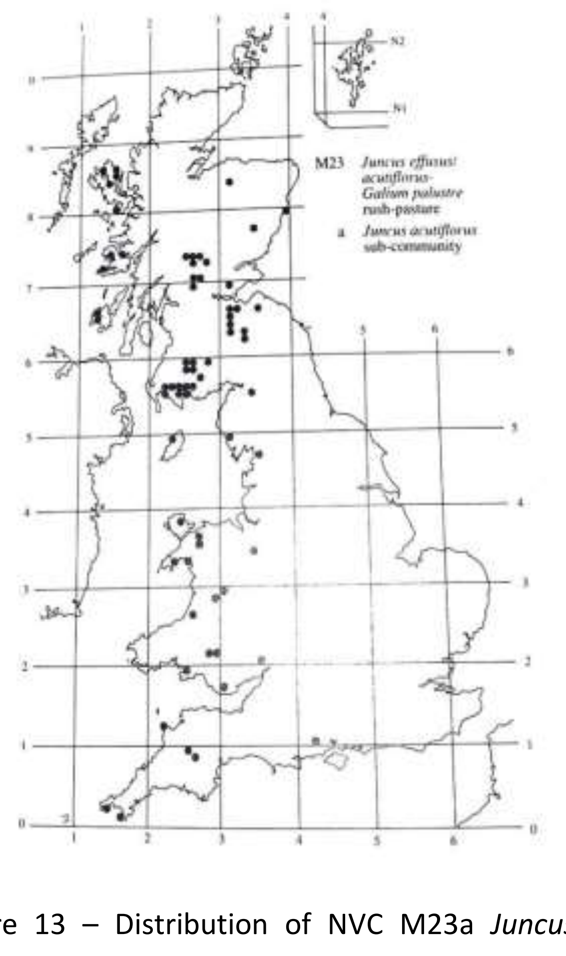


Figure 13 – Distribution of NVC M23a *Juncus effusus/acutiflorus-Galium palustre* Rush pasture, *Juncus acutiflorus* sub-community (Rodwell, 1995)

The poor goodness of fit scores for the analysis of both sites could be attributed to the small area that was sampled. Also, the variability of floristic compositions (Arkive, 2014; JNCC,

2014) associated with wetland habitats could also be a factor. It has been noted that NVC S24 and S25 are similar in vegetation composition. Furthermore, wetland habitat types are known to be highly variable and difficult to classify (Rodwell, 1995).

Environmental factors affecting the distribution of species

A Multivariate Analysis was carried out (Figures 7-10). It can be seen that both samples and species were separated according to the area they were recorded (Figure 6). This indicates there were two distinct homogenous stands of vegetation, and the two stands differed in their floristic communities. It is known that species compositions change along environmental gradients (Dyakov, 2010), and it is hypothesised that the flora of Ffrwd Farm Mire changes along a gradient of moisture. Area A (NVC S25/S24) consists of species with relatively higher affinities to soil moisture than those of Area B (NVC M23a). Figure 7 shows that species such as Water Mint, *Mentha aquatica,* Common Reed, *Phragmites australis*, Bogbean, *Menyanthes trifoliata* and Marsh Pea, *Lathyrus palustris* are grouped together based on their higher tolerances to moisture. The association of such species with high soil moisture is well established in current literature (Rodwell, 1995; Rose, 2006; Stace; 2010). A separate group including species such as Dandelion, *Taraxacum agg.,* Ribwort Plantain, *Plantago lanceolota,* Devil's-Bit Scabious, *Succisa pratensis* and Crested Dog's-Tail, *Cynosurus cristata* have been ordered together due to their relatively lower tolerances to moisture. There was a significant difference in soil moisture and conductivity between the two sites (Table 2). Also the mean Ellenberg F value for Area A = 7.8 and Area B = 6.76.

A TWINSPAN classification was carried out on both samples and species (Figures 9 and 10). Figure 9 shows samples were classified based on the presence or absence of indicator species. It can be seen that the presence of Common Reed, *Phragmites australis,* was used to classify samples between Area A and Area B. This is expected, as *P. australis* is known to be associated with wet areas and has an Ellenberg F value of 10 (Hill et al., 2004) thus would only be found in Area A where there was significantly higher soil moisture than Area B. It can be seen from Figure 9 that there are two distinct groups (Area A and Area B) which are separated by the species of two distinct communities. For example, species such as Tormentil, *Potentilla erecta,* Clover, *Trifolium spp.,* Mat-Grass, *Nardus stricta,* Soft Rush, *Juncus effusus,* and Yorkshire Fog, *Holcus lanatus* were key species in the classification of

Area B. Species such as Water Mint, *Mentha aquatica,* Marsh Bedstraw, *Galium palustre*, Meadowsweet, *Filipendula ulmaria* and Hemlock Waterdropwort, *Oenanthe crocata* were significant species in the classification of Area A. Figure 10 also shows species have been classified into distinct groups based on their tolerances to moisture. It can be seen that species with high affinities to moisture (and high Ellenberg F values) have been grouped towards the bottom of the dendrogram. Marsh Pea, *Lathyrus palustris* is classified with such species as Water Mint, *Mentha aquatica,* Common Reed, *Phragmites australis* and Square-stalked St John's Wort, *Hypericum tetrapterum*. It can be seen in Figure 10 that these species all have Ellenberg F values of 8 or higher (Hill et al., 2004; Appendix 1).

A Principal Components Analysis (PCA) was undergone to determine which factors affected the distribution of *L. palustris* at Ffrwd Farm Mire. Figure 11 shows moisture and conductivity were key environmental factors in species distribution in Area A. A Mann Whitney U test found that there was a significant difference in soil moisture and conductivity between the two sites, however a Spearman's Rank Correlation showed that there was no significant correlation between these factors and species richness. This could be due to the small sample size used (df = 49). It could also be due to adverse weather conditions encountered during the sampling period, which would possibly contribute to unreliable soil moisture values. Conductivity values might have also been affected by adverse weather conditions. Mineral eluviation is known to occur in areas of highly decayed organic matter (Prescott, 1950). It is established in the literature that *L. palustris* frequents wet areas (Fitter and Peat, 1994; Mountford et al., 2014). It has an Ellenberg F value of 9 (Hill et al., 2004) and so it is hypothesised that there is a positive correlation between soil moisture and the distribution of *L. palustris* despite the negative results found. pH was shown to have a greater effect on species in Area B, which contained species such as Tormentil, *Potentilla erecta*, an acid grassland indicator (Rose, 2006).

A range of abiotic factors have been suggested as possible factors in the distribution of species at Ffrwd Farm Mire. Although there is a general pattern of species composition depending on soil moisture and conductivity, pH and R:FR ratio were also contributing factors. Although there was no significant relationship between pH and species richness, it is known that species have varying tolerances to soil pH (Crawley, 1997). The mean pH for each area was 6.08 (Table 2). It was previously stated that soils of pH >5.5 are classed as base-rich (JNCC, 2004), which supports surrounding literature that *L. palustris* favours base-rich fens (Rose, 2006; Mountford et al., 2014). It is hypothesised that species such as Tormentil, *Potentilla erecta* that inhabit acidic areas (Rose, 2006) were present at the site due to spatial fluctuations in soil acidity, and were found in regions of lower pH.

The ratio of red to far-red light was also a factor recorded in this study. It was postulated this might be a contributing factor due to dominant stands of Common Reed, *Phragmites australis* present at the site possibly outcompeting smaller species for light, which has been detailed in the past (Preston et al., 2002). However it was found to be the factor with least influence over the distribution of species. Biotic factors were also considered. Height of tallest plant (cm) was recorded. It was found that although height of tallest vegetation was significantly higher in Area A where *Phragmites australis* dominated, there was no significant correlation between this and species richness. This could be due to the presence of grazing cattle at the study site, implemented to control stands of *P. australis* (Wildlife Trust, 2014). It has been found that species richness decreases when *P. australis* is allowed to dominate in certain communities due to being invasive in nature (Rose, 2006). It has been proposed that grazing of reed beds by cattle increases species richness (Ausden et al., 2005). Stands of *P. australis* become sparser when subject to grazing (Jutila, 2000), which could provide physical and competitive space for other species to occupy. Hence the grazing of reed beds at Ffrwd Farm Mire is suggested to be a successful method of management in the conservation of *L. palustris* and other species of conservation concern.

A recent water vole reintroduction at the site could also have an effect on the population of *L. palustris*. Although water voles predominantly eat grasses, sedges and rushes (Arkive, 2014), there are 227 wetland plant species in their diet (Woodroffe, 2000; The Mammal Society, 2014). They could play a role in managing reed bed, which could see *L. palustris* increase; however it is also possible that *L. palustris* could become subject to herbivory. It is predicted that in an area dominated by reeds *L. palustris* will not suffer, however more research is needed to determine the long term effects.

Distribution of *L. palustris* at Ffrwd Farm Mire

The distribution of *L. palustris* was mapped and it was found to be widespread throughout, but confined to Area A (NVC S25/S24 Tall-herb fen) (Figure 6). The fact that *L. palustris* is confined to Area A is hypothesised to be due to its affinity for moisture (Figures 10 and 11). It was found that soil moisture was significantly higher in Area A (Table 2) and was one of the main factors in the distribution of *L. palustris* (Figure 11). It was also found that the frequency of *L. palustris* at Ffrwd Farm Mire was 56%, and the mean percent (%) cover of *L. palustris* was 5.56%. Comparison to results in 1993 is limited due to differences in survey methodology and sample size; however the frequency and mean percent cover calculated in this study were higher than that of Williams, 1993. This higher frequency and mean percent cover could be due to the grazing regime introduced at Ffrwd Farm Mire. As mentioned previously, grazing is known to increase species richness (Ausden et al., 2005) and as a species associated with *P. australis,* (Rose, 2006) *Lathyrus palustris* may increase in response to light grazing of reeds which could increase light and nutrient availability. Additionally, it is hypothesised that the site has increased in soil moisture since 1993 (Wildlife Trust, 2014). Soil moisture was found to be one of the primary factors in the distribution of species (Figure 11) and so an increase in moisture could be a factor in the increase of *L. palustris* in frequency.

Botanical Associations of *L. palustris*

A Chi-squared association was carried out in order to determine the botanical associations of *L. palustris*. It was found that *L. palustris* had the strongest association with Common Reed, *Phragmites australis* and Skullcap, *Scutellaria galericulata*. *L. palustris* is a climbing perennial herb with tendrils (Streeter, 2009) and thrives in an interface of reed bed, fen and marshy grassland vegetation (Fitter and Peat, 1994) and so it was expected to have a high association with *P. australis*. It was found that significant botanical associations of *L. palustris* all have Ellenberg F values of >8 (Figure 10, Hill et al., 2004). Information on the botanical associations of *L. palustris* could provide insight into creating habitats with floristic communities favourable to its growth and survival.

VII. Conclusions

In conclusion, it has been found that the frequency of *L. palustris* at Ffrwd Farm Mire has increased since 1993 (Figures 5 and 6). The distribution of *L. palustris* at the nature reserve is widespread throughout, but restricted to an NVC S24/S25 tall herb fen. A Principal Components Analysis found that soil moisture and conductivity were important environmental factors in the distribution of *L. palustris*, and a Chi-squared association established that Common Reed, *Phragmites australis*, and Skullcap, *Scutellaria galericulata* were strong botanical associations of the Marsh Pea. Possible improvements for this study would be to increase the sample size in order to gain more representative results. Another area of the nature reserve is known to hold a small population of *L. palustris*, and also similar habitats are found throughout the reserve, thus an additional improvement would have been to also sample and classify other areas if time had allowed. Furthermore, the study could be improved by recording all bryophytes along with vascular plants. Connectivity between fen habitats is an important factor that has been overlooked in this study. At Ffrwd Farm Mire connectivity is relatively high; wetlands are distributed throughout the reserve and throughout the Llanelli/Pembrey area. It is postulated that plants respond to decreased fragment size by establishing smaller populations (Kiviniemi, 2008). In future looking at this factor could improve understanding of pollination, seed dispersal and population growth and herbivory response of the species.

Wider implications and conservation of species

From the results gathered, some information on how to better conserve the species has been assembled. Grazing by cattle on the site could have played a role in the increased frequency of *L. palustris*. Ausden et al., 2005 proposed that grazing by cows increases species richness, and it has been hypothesised that grazing of *Phragmites australis,* the strongest botanical association of *L. palustris* could improve its abundance by creating open spaces for increased access to light and water, reducing competition (Crawley, 1997; Jutila, 2000). A recent reintroduction of water voles, *Arvicola amphibius* may have an effect on the distribution of *L. palustris.* They may play a role in controlling stands of *Phragmites australis* as they feed mainly on grasses, sedges and reeds (Wildwood Trust, 2006), however they are known to feed on 227 wetland plant species (Woodroffe, 2000) and may feed on *L.*

palustris. It is also postulated that an increase in soil moisture since 1993 could have led to an increase in *L. palustris*, as the species is highly associated with areas of high moisture (Fitter and Peat, 1994; Mountford et al., 2014). Therefore site management to maintain wetter conditions could prove advantageous. Also it is possible that studying the ecology of other species of conservation concern found on the study site such as Tubular Waterdropwort, *Oenanthe fistulosa* could provide further insight into the requirements of such species.

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IX. Appendices

1. Species list and Ellenberg Values
2. Soil data

Appendix 1. Species list and Ellenberg Values

Table 3. List of species recorded at Ffrwd Farm Mire and Ellenberg F values

Species	**Ellenberg F Value**	**Ellenberg R Value**	**Ellenberg N Value**
Achillea ptarmica	7	5	3
Agrostis canina	7	3	3
Anthoxanthum odoratum	6	4	3
Arrhenatherum elatius	5	7	7
Berula erecta	10	7	7
Caltha palustris	9	6	4
Carex nigra	8	5	2
Carex ovalis	7	4	4
Carex rostrata	10	4	2
Carum verticillatum	8	4	2
Chamerion angustifolium	5	6	5
Cirsium dissectum	8	4	2
Cynosurus cristatus	5	6	4
Dactylorhiza praetermissa	8	7	3
Epilobium hirsutum	8	7	7
Epilobium parviflorum	9	7	5
Equisetum arvense	6	6	6
Equisetum palustre	8	6	3
Eupatorium cannabinum	8	6	7
Festuca arundinacea	6	7	6
Filipendula ulmaria	8	6	5
Galium palustre	9	5	4
Holcus lanatus	6	6	5
Hydrocotyle vulgaris	8	6	3
Hypericum tetrapterum	8	6	4
Hypochaeris radicata	4	5	3
Iris pseudacorus	9	6	6
Juncus acutiflorus	8	4	2
Juncus conglomeratus	7	4	3
Juncus effusus	7	4	4
Lathyrus palustris	9	7	4
Leontodon hispidus	4	7	3
Lotus pedunculatus	8	6	4
Lychnis flos-cuculi	9	6	4
Lythrum salicaria	9	7	5
Mentha aquatica	8	7	5
Menyanthes trifoliata	10	4	3
Molinia caerulea	8	3	2

Myosotis laxa	9	6	5
Nardus stricta	7	3	2
Oenathe crocata	8	6	7
Oenathe fistulosa	9	7	6
Phragmites australis	10	7	6
Plantago lanceolota	5	6	4
Potentilla erecta	7	3	2
Ranunculus acris	6	6	4
Ranunculus flammula	9	5	3
Ranunculus repens	7	6	7
Rumex acetosa	5	5	4
Rumex crispus	6	7	6
Rumex obtusifolius	5	7	9
Scutellaria galericulata	8	6	5
Senecio aquaticus	8	6	5
Stellaria graminea	6	5	4
Succisa pratensis	7	5	2
Taraxacum agg.	5	7	6
Trifolium pratense	5	7	5
Trifolium repens	5	6	6
Vicia cracca	6	7	5
Vicia sativa	4	7	4

Appendix 2. Raw soil data

Area A (FEN)						
Quadrat No.	**Weight 1 (g)**	**Weight 2 (g)**	**w1-w2**	**% Moisture**	**pH**	**Conductivity**
1	71.64	13.6	58.04	81.01619207	7.3	147.01
2	40.92	7.07	33.85	82.72238514	7.4	150.07
3	46.93	9.99	36.94	78.71297677	7.6	123.8
4	122.87	18.5	104.37	84.94343615	6.8	348
5	43.43	10.73	32.7	75.29357587	6.8	321
6	56.83	11.51	45.32	79.7466127	7.5	285
7	81.57	14.09	67.48	82.72649258	7.2	327
8	61.16	12.35	48.81	79.80706344	7.5	381
9	74.55	13.02	61.53	82.53521127	7.6	269
10	61.49	16.2	45.29	73.65425272	5.9	270
11	70.36	13.04	57.32	81.46674247	6.7	435
12	221.63	34.25	187.38	84.54631593	6.8	320
13	132	25.43	106.57	80.73484848	6.5	252
14	192.49	32.08	160.41	83.33419918	6.1	266
15	125.04	20.99	104.05	83.21337172	6.8	233
16	27.02	17.8	9.22	34.12287195	5.8	56.2
17	34.38	12.02	22.36	65.03781268	5.9	270
18	123.43	28.11	95.32	77.22595803	6.1	196.8
19	115.87	18.6	97.27	83.9475274	6.3	259
20	47.45	11.11	36.34	76.58587987	6	235
21	42.7	16.09	26.61	62.31850117	6	199.9
22	52.98	17.47	35.51	67.02529256	5.8	135.6
23	45.85	13.42	32.43	70.7306434	6.3	215
24	157.42	29.34	128.08	81.36196163	5.9	275
25	49.27	13.87	35.4	71.84899533	5.8	251
26	61.91	19.56	42.35	68.40575028	5.9	168.4
27	49.39	15.64	33.75	68.33367078	6.1	323
28	44.7	13.64	31.06	69.48545861	6	234
29	51.65	13.47	38.18	73.92061955	6	261
30	48.9	12.98	35.92	73.45603272	6.4	385
31	52.37	15.43	36.94	70.53656674	5.8	305
32	57.19	15.22	41.97	73.38695576	5.7	237
33	78.48	18.72	59.76	76.14678899	5.6	172.8
34	169.05	29.32	139.73	82.65601893	5.5	179
35	108.16	38.8	69.36	64.12721893	5.3	145.9
36	74	14.46	59.54	80.45945946	5.6	254
37	67.456	13.52	53.936	79.9573055	5.5	280
38	110.61	19.83	90.78	82.07214538	5.7	267
39	101.46	18.79	82.67	81.48038636	5.6	271
40	112.66	36.85	75.81	67.29096396	4.1	332
41	98.3	34.71	63.59	64.68972533	4.8	346

42	127.95	30.6	97.35	76.08440797	5.4	122.3
43	101.73	38.74	62.99	61.91880468	5.4	194.1
44	103.3	33.9	69.4	67.18296225	5.2	295
45	90.304	26.4	63.904	70.7654146	5.3	263
46	74.402	14.58	59.822	80.40375259	5.7	296
47	107.48	19.85	87.63	81.53144771	5.6	267
48	135.04	26.48	108.56	80.39099526	6	327
49	88.463	18.67	69.793	78.8951313	5.7	304
50	97.328	21.91	75.418	77.48849252	6.1	368

Area B (GRASSLAND)						
Quadrat No.	**Weight 1 (g)**	**Weight 2 (g)**	**w1-w2**	**% Moisture**	**pH**	**Conductivity**
1	38.98	29.63	9.35	23.98665983	5.1	612
2	43.1	30.79	12.31	28.56148492	5.5	471
3	40.14	32.56	7.58	18.88390633	5.4	31.3
4	30.74	20.93	9.81	31.91281718	5.9	55.6
5	58.76	32.27	26.49	45.08168822	5.5	71.1
6	34.69	27.87	6.82	19.65984434	5.2	91.8
7	25.83	10.97	14.86	57.53000387	6.5	179.4
8	34.34	14.97	19.37	56.40652301	6.4	246
9	30.62	21.54	9.08	29.65382103	6.1	230
10	38.13	24.35	13.78	36.13952269	5.5	102.1
11	42.63	28.73	13.9	32.60614591	5.8	124.4
12	33.44	25.18	8.26	24.70095694	6	87
13	41.9	33.48	8.42	20.09546539	6	103.3
14	51.79	39.23	12.56	24.25178606	6.4	85
15	41.63	32.23	9.4	22.57987029	6.5	52.5
16	47.56	36.03	11.53	24.2430614	6.2	74.2
17	35.2	26.45	8.75	24.85795455	5.9	60
18	36.18	19.54	16.64	45.99226092	6.1	114.5
19	27.59	17.37	10.22	37.04240667	6	99.6
20	18.88	9.43	9.45	50.0529661	6.1	108.7
21	131.72	31.59	100.13	76.01730944	6.2	186.6
22	143.59	40.55	103.04	71.75987186	6.5	169.4
23	206.71	73.51	133.2	64.43810169	6.8	122.6
24	156.17	114.62	41.55	26.60562208	6.4	120
25	107.63	69.5	38.13	35.42692558	6.4	36.9
26	150.83	109.37	41.46	27.48790029	6.1	22.4
27	136.97	103.9	33.07	24.14397313	5.9	22
28	157.44	47.88	109.56	69.58841463	6.1	110.3
29	89.11	64.42	24.69	27.70732802	5.8	44.1
30	176.35	139.64	36.71	20.81655798	5.9	17.98
31	79.11	59.53	19.58	24.75034762	6.4	24.9
32	56.24	41.31	14.93	26.54694168	6.2	37.9

33	54.37	35.43	18.94	34.83538716	6.2	55.1
34	75.08	50.34	24.74	32.95151838	6.1	35.2
35	135.15	65.13	70.02	51.809101	6.7	60.5
36	65.54	17.77	47.77	72.8867867	6.4	184.5
37	79.67	60	19.67	24.68934354	6.1	27.6
38	114.37	76.88	37.49	32.77957506	6.3	30.1
39	107.84	84.05	23.79	22.06045994	6.3	20.2
40	59.17	47.59	11.58	19.57072841	6	22.8
41	106.02	83.99	22.03	20.77909828	6.3	21.7
42	116.64	87.48	29.16	25	6.4	37.5
43	132.16	87.91	44.25	33.48214286	5.9	36.2
44	137.92	107.47	30.45	22.07801624	5.8	68.4
45	125.21	60.79	64.42	51.44956473	6.1	53.4
46	137.08	98.02	39.06	28.49430989	6	54
47	130.3	83.86	46.44	35.64082886	6.2	38
48	136.17	103.11	33.06	24.27847544	6.3	29.3
49	144.68	107.62	37.06	25.61515068	6.1	24.7
50	151.72	134.8	16.92	11.15212233	6.1	25.3