Analysis of the pollinator communities at Buckland Abbey and recommendations for their improved survivability and species richness

Executive summary

Due to a combination of anthropomorphic effects pollinators have been declining globally. It has never been more important for management or nature reserves to accommodate for these pollinators and to carry out management intervention to bolster and develop pollinator numbers and species diversity. With this in mind, a network analysis was carried out to summarise plant pollinator relations and make inferences of specific restoration techniques to create a more robust pollinator community. The asymmetric pattern found in this study was across habitat types and concurs with other literature on the subject. The nested structure of the pollinator webs was highest in the woodland habitat, but relatively low overall and suggests the pollinator communities are vulnerable to stochastic events. The main restoration method suggested, is the planting of bridging and framework species. This proliferation of floral richness will increase the long-term temporal stability of pollinator populations and communities.

Introduction

A global decline in pollinators has heightened the interest in the significance of pollinators (Pauw, 2007). Threats to plant-pollinator communities are mainly anthropogenic and include: habitat loss, habitat fragmentation and isolation, overuse of pesticides and herbicides, grazing and introduction of non-native species (Potts *et al*., 2000). Insect pollination is an essential role in the maintenance of plant communities and contributes to the reproduction of >70% of flowering plant species (Kaiser-Bunbury, Memmott and Müller, 2009; Menz *et al*., 2011; Vila *et al*., 2009).

Buckland Abbey (204 hectares) is a reserve managed by the National Trust and is made up of large areas of semi-improved natural grassland, enclosed by well-managed hedgerows and also extensive 'ancient' original woodland priority habitat. Following discussions with the estate managers at Buckland Abbey in Devon it was decided that a high conservation interest would be to undertake a study of pollinator communities (Pearson, 2016).

Plant-pollinator interactions are perceived as networks with robust architectural properties (Vila *et al*., 2009). Network analysis of flowering plants and flower-visiting animals have recently been widely been used to: summarise plant-pollinator relationships, detect changes in ecological gradients, outline the consequences of disturbance, show the restoration of degraded ecosystems and analyse the impact of introduced species (Basilio *et al*., 2006; Potts *et al*., 2000). Recent insight into the structure of pollination webs emphasise the significance of generalist pollinators (Pauw, 2007). Pollination webs are asymmetrically specialised so that plant links to generalist pollinators tend to be specialists (Vila *et al*., 2009). Therefore, a loss of generalists has the potential to precipitate the cascade of linked declines among the multiple plant species they pollinate (Pauw, 2007). Plant-pollinator mutualisms are one of the several functional relationships that must be reinstated to ensure the long-term success of habitat restoration projects (Memmott and Müller, 2009).

Methods

Due to the time constraints of this study there has been a limited sampling effort which may affect the community network properties. Therefore, a robust, comprehensive and well-designed sampling procedure has been devised which can be easily repeated by the management of the study reserve. Buckland Abbey consists of three broad habitat types; mixed woodland, grassland and hedgerows (Pearson, 2016). Surveys were conducted at three separate points in each of the habitat types (figure 1). Data collection was carried out on the 18th June 2019 and focused on recording all interactions between entomophilous plant species and insects which came into contact with the sexual parts of plants (hereafter, called pollinators). Each point was surveyed for 30 minutes, via a semi-circular sampling unit of 5m (figure 2). The pollinators were collected and identified in the field, then released after the site was completed to avoid repeated catches. Due to the financial constraints it was not possible to identify certain individuals to a species level without laboratory equipment. These individuals were assigned a number, and any of the same species found at another site were assigned the corresponding number. Observations were conducted on sunny days, without strong wind (>7mph). In total 9 different sites were observed totalling 4 hours 30 minutes.

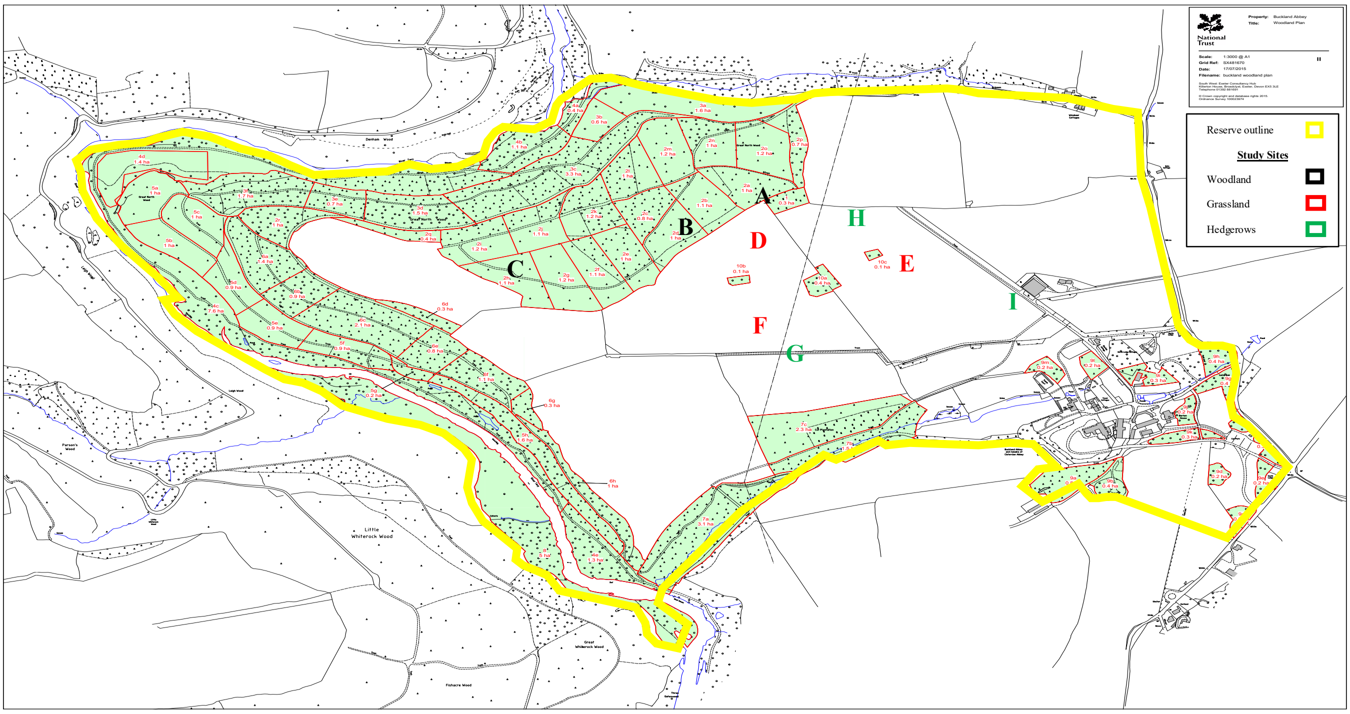

Figure 1 Map of Buckland Abbey with study locations

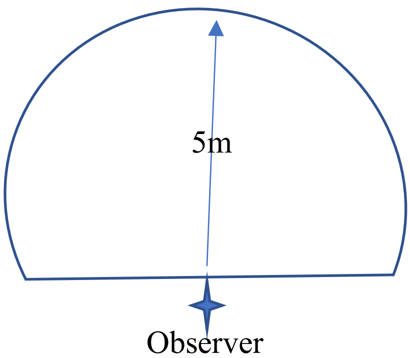

Figure 2 sample site layout

A matrix (community web), which is a graphical representation of a set of entities, or vertices, linked by edges that represent the connections or interactions between these two vertices (Fang and Huang, 2013). The size of the interaction between the pollinator and the plant is proportional to the frequency of interaction at the plots. These webs were illustrated as bipartite visitation graphs which were drawn in programmes written in R studio package Bipartite[2] (Dormann *et al*., 2009; R Development Core Team, 2005). In the case of this study four separate community webs were created, which represent the three habitat types found in Buckland Abbey and one for the reserve as a whole. Each of the webs consisted of the total number of visits observed for each plant-pollinator interaction.

Network structure was assessed by studying nestedness. This is a measure of structure of an ecological system or a network expressing the tendency for specialised species to interact with a subset of the interaction partners of more generalised species or, more precisely, the degree of symmetry in the distribution of unexpected absences and presences on each side of the boundary line defining perfected nestedness (Almeida-Neto *et al*., 2008; Chacoff *et al*., 2012). Nested values of 0 indicate non-nestedness, while 100 indicates perfect nesting. Two measures of specialisation were used: connectance and specialisation index. Connectance is the realised proportion of possible links (Dunne, Williams and Martinez, 2002). The specialisation index describes the level of specialisation, or selectiveness, of each particular species in the given habitat, ranging from 0 (low sensitive) to 1 (high selectiveness). Unlike connectiveness, this index is not affected by the matrix size and sampling intensity (Chacoff *et al*., 2012). The cluster coefficient for this matrix is the average cluster coefficients of its members. The cluster coefficient for each species, in turn, is simply the number of realised links divided by the number of possible links. Niche overlap is the mean similarity in interaction pattern between species of that level, calculated by Horn's index. Values near 0 indicate no common use of niches, 1 indicates perfect niche overlap. The mean linkages for pollinators and plant species were also determined i.e. mean number of interactions per species, and the linkage of the most connected animal. The plant and pollinator linkages are equivalent to the measures of generality and vulnerability in pollination webs (Chacoff *et al*., 2012). The Shannon diversity index was used as a mathematical measurement to define community composition and commonness of species in a community.

Results

Overall eight flowering plants and 28 species of pollinator were recorded across the three different habitat types. All species recorded were endemic to Britain. A community web was created for the three different habitats and the reserve as a whole. The webs showed low levels of nestedness with woodland being the highest (table 5). Asymmetry is generally high with the highest being the web for the reserve as a whole (table 6). At the species level the different habitats showed different levels of specialisation. Generally, the higher the nestedness, the higher the level of specialisation the species of that habitat tended to have (table 1, 2, 3).

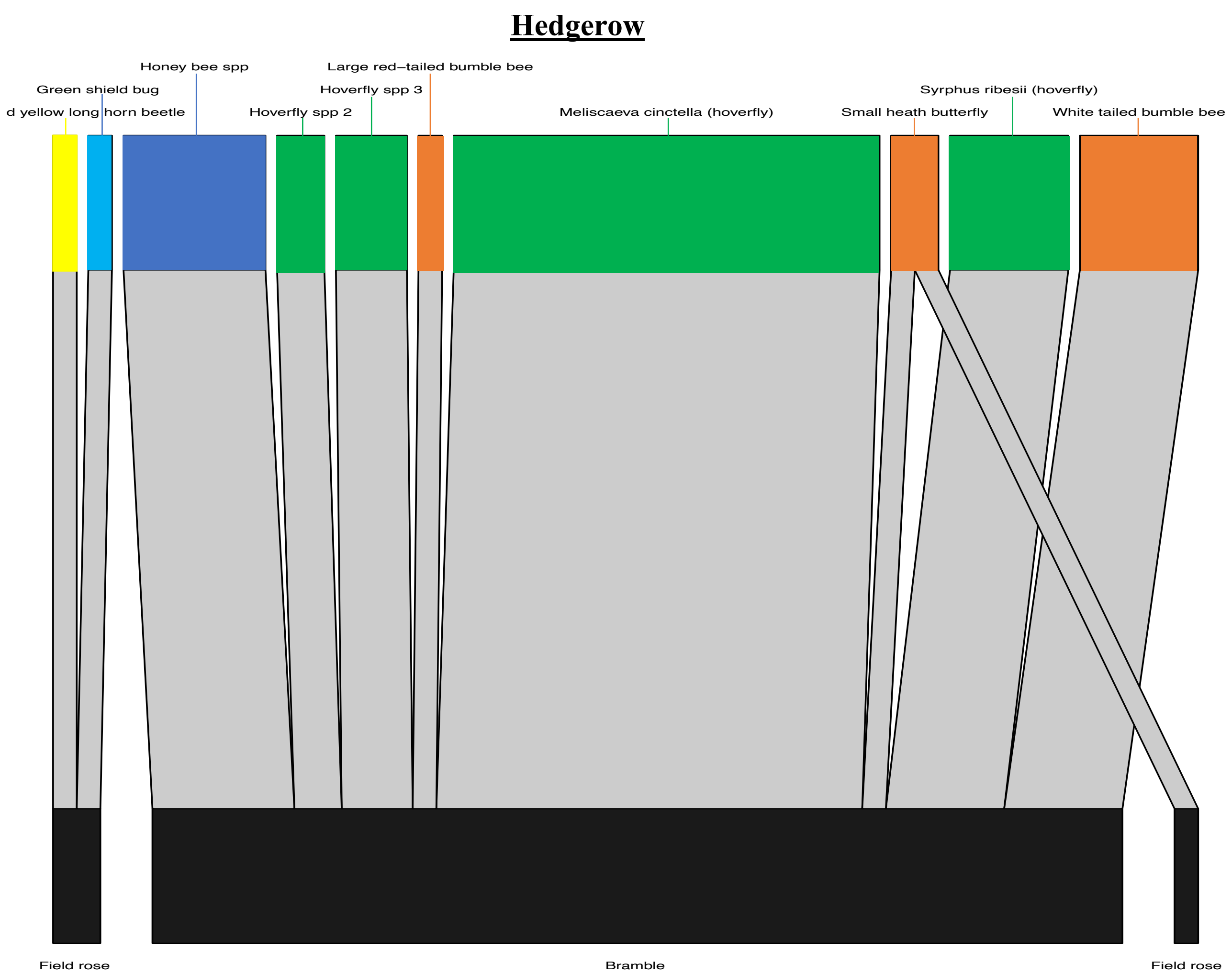

Figure 1 Community matrix of Hedgerow habitat

Table 1 Statistics of the hedgerow community matrix

Hedgerows	Connectance	0.36	
	Asymmetry	0.5	
	Nestedness	36.77	
	Weighted nestedness	Na	
	Cluster coefficient	0.333	
	Shannon diversity	1.885	
	Group level	**Higher Level**	**Lower Level**
	Mean number of links	1.04	7.57
	Cluster coefficient	0.35	0.76
	Niche overlap	0.59	0.01

Table 2 Species level statistics of the hedgerow community matrix

Species level		
		Specialisation index
Hedgerows	Black and yellow long horn beetle	0.5
	Green shield bug	0.5
	Honey bee spp	0.14
	Hoverfly 2	0.05
	Hoverfly 3	0.07
	Large red-tailed bumble bee	0.02
	Meliscaeva cinctella (hoverfly	0.43
	Small heath butterfly	0.51
	Syrphus ribesii (hoverfly)	0.12
	White tailed bumble bee	0.12

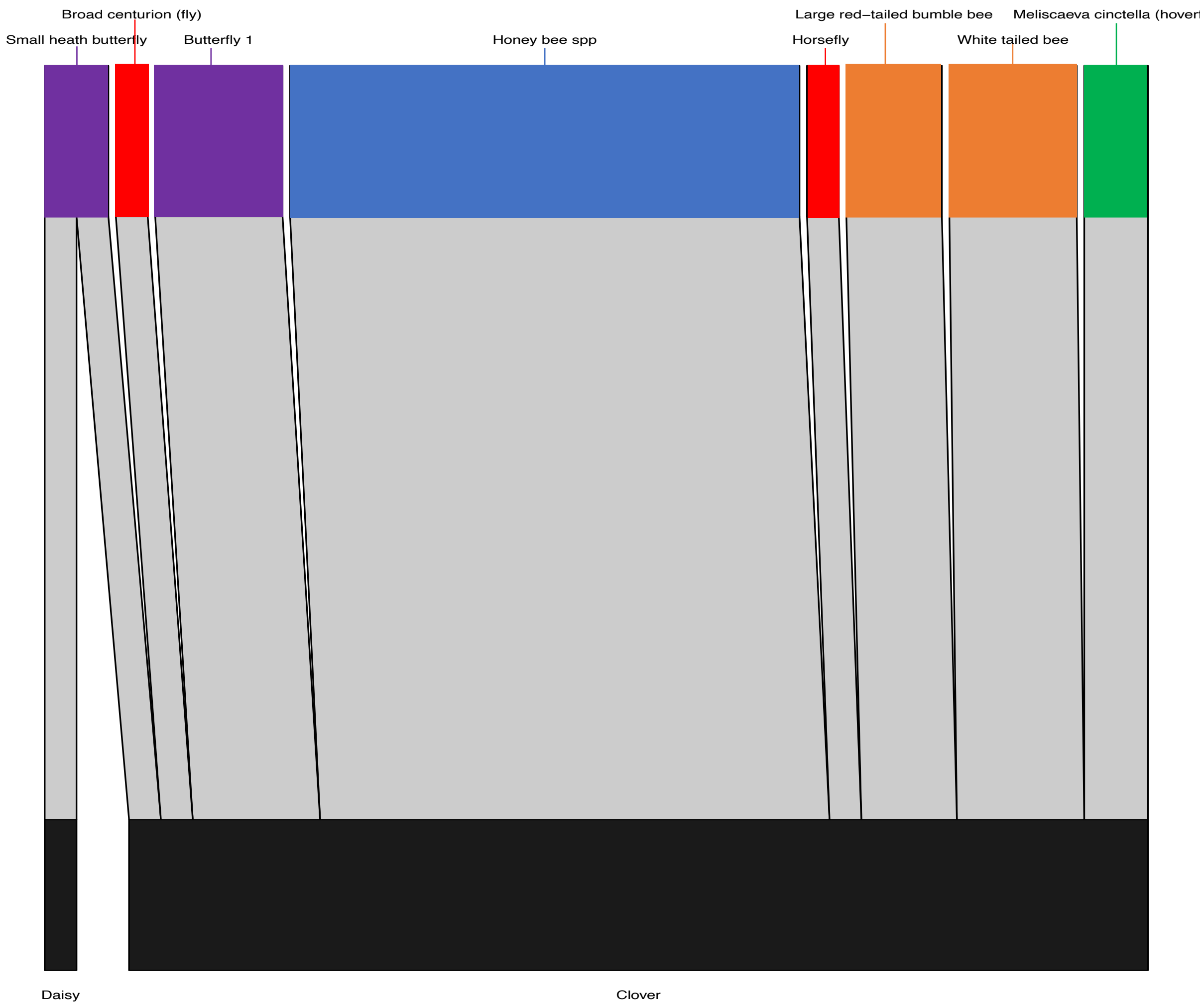

Figure 2 Community matrix of grassland habitat

Table 1 Statistics of the grassland community matrix

Grasslands	Connectance	0.56	
	Asymmetry	0.6	
	Nestedness	10.12	
	Weighted nestedness	0.76	
	Cluster coefficient	0.5	
	Shannon diversity	1.674	
	Group level	**Higher Level**	**Lower Level**
	Mean number of links	1.06	7.78
	Cluster coefficient	0.53	0.97
	Niche overlap	0.91	0.05

Table 2 Species level statistics of the grassland community matrix

		Specialisation index
Grasslands	Broad centurion (fly)	1
	Butterfly 1	1
	Honeybee spp	1
	Horsefly	1
	Large red-tailed bumble bee	1
	Meliscaeva cinctella (hoverfly)	1
	Small heath butterfly	1
	White tailed bee	1

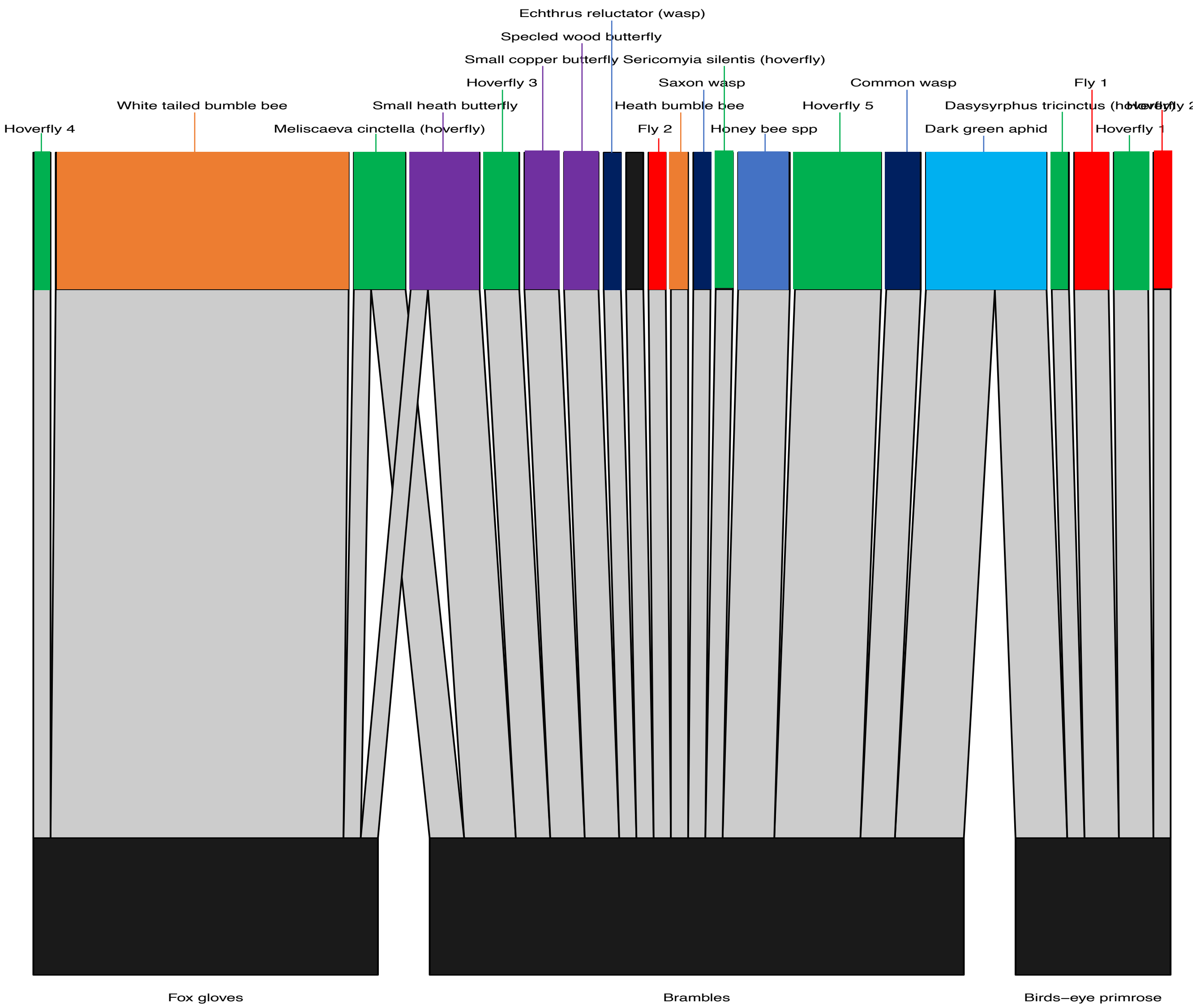

Figure 3 Community matric of woodland habitat

Table 5 Statistics of the woodland community matrix

Woodland	Connectance	0.3	
	Asymmetry	0.75	
	Nestedness	43.374	
	Weighted nestedness	0.43	
	Cluster coefficient	0.333	
	Shannon diversity	2.7385	
	Group level	**Higher Level**	**Lower Level**
	Mean number of links	1.23	9.83
	Cluster coefficient	0.41	0.46
	Niche overlap	0.52	0.09

Table 6 Species level statistics of the woodland community matrix

Species Level			
		Specialisation index	Nested rank
Woodland	Common wasp	0.06	0.3
	Dark green aphid	0.21	0
	Dasysyrphus tricinctus (hoverfly	0.11	0.6
	Echthrus reluctator (wasp	0.03	0.65
	Eupeodes corollae (hoverfly	0.03	0.7
	Fly 1	0.22	0.35
	Fly 2	0.03	0.75
	Heath bumble bee	0.03	0.8
	Honey bee spp	0.1	0.25
	Hoverfly 1	0.22	0.4
	Hoverfly 2	0.11	0.85
	Hoverfly 3	0.06	0.45
	Hoverfly 4	0.05	0.9
	Hoverfly 5	0.16	0.2
	Meliscaeva cinctella (hoverfly	0.06	0.1
	Saxon wasp	0.03	0.95
	Sericomyia silentis (hoverfly	0.03	1
	Small copper butterfly	0.06	0.5
	Small heath butterfly	0.09	0.05
	Specticled wood butterfly	0.06	0.55
	White tailed bumble bee	0.85	0.15

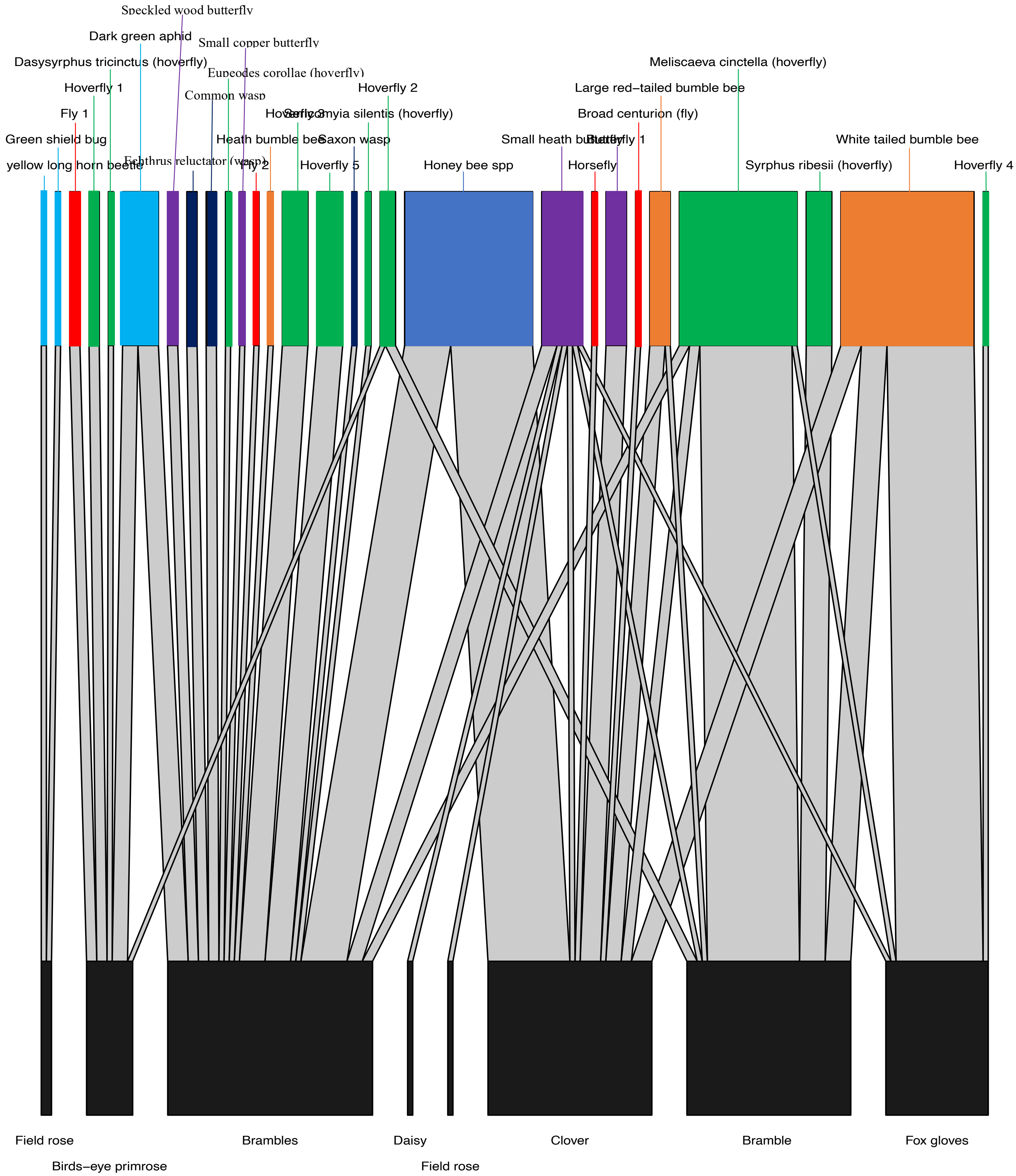

Figure 4 Community matrix of Buckland Abbey

Table 7 Statistics of the community matrix of Buckland Abbey

Reserve whole	Connectance	0.19	
	Asymmetry	0.56	
	Nestedness	18.71	
	Weighted nestedness	0.46	
	Cluster coefficient	0.13	
	Shannon diversity	3.21	
	Group level	**Higher Level**	**Lower Level**
	Mean number of links	2.45	8.61
	Cluster coefficient	0.31	0.31
	Niche overlap	0.27	0.11

Table 8 Species level statistics of the community matrix of Buckland Abbey

		Specialisation index	**Nested rank**
Reserve whole	Black and yellow long horn beetle	0.05	0.59
	Broad centurion (fly)	0.031	0.62
	Butterfly 1	0.13	0.37
	Common wasp	0.05	0.41
	Dark green aphid	0.2	0.15
	Dasysyrphus tricinctus (hoverfly)	0.11	0.67
	Echthrus reluctator (wasp)	0.03	0.7
	Eupeodes corollae (hoverfly)	0.03	0.74
	Fly 1	0.22	0.44
	Fly 2	0.03	0.78
	Green shield bug	0.5	0.81
	Heath bumble bee	0.03	0.85
	Honey bee spp	0.4	0.11
	Horsefly	0.03	0.88
	Hoverfly 1	0.22	0.48
	Hoverfly 2	0.08	0.22
	Hoverfly 3	0.13	0.26
	Hoverfly 4	0.05	0.93
	Hoverfly 5	0.13	0.3
	Large red-tailed bumble bee	0.08	0.19
	Meliscaeva cinctella (hoverfly)	0.45	0.04
	Saxon wasp	0.03	0.96
	Sericomyia silentis (hoverfly)	0.03	1
	Small copper butterfly	0.05	0.52
	Small heath butterfly	0.29	0
	Specled wood butterfly	0.05	0.56
	Syrphus ribesii (hoverfly)	0.16	0.33
	White tailed bumble bee	0.6	0.07

Table 9 Community matrix legend

(green)	**Hoverfly spp.**
(orange)	**Bumble bee spp.**
(purple)	**Butterfly spp.**
(red)	**Fly spp.**
(blue)	**Honey bee spp.**
(navy)	**Wasp spp.**
(light blue)	**Beetles spp.**

Discussion

This study has been an important first step in understanding the plant-pollinator communities on the Buckland Abbey reserve. It has provided information for the study of plant-pollinator mutualistic interactions by contributing highly detailed, quantitative data of the community networks.

Petanidou *et al*., (2008); Aizen, Morales and Morales (2008) has found that plant-pollinator mutualisms are highly asymmetric, such that if the plant species depends strongly on an animal species, the animal typically depends weakly on the plant, and vice versa. This asymmetric pattern was also found at Buckland Abbey, with asymmetry being as high as 0.75 in woodland habitat (table 5). The resulting mutualistic webs tend to have a nested structure, exhibiting some degree of modularity, which is a robust property of this type of network, whereby specialists interact preferentially with generalists, rather than with other specialists (Aizen, Morales and Morales, 2008; Chacoff *et al*., 2012). This nested structure has claimed to be very stable to environment and biotic stochasticity with low sensitivity to sampling effort (Vila *et al*., 2019). However, this nested structure was not prominent in the results of this report. Nestedness was highest in woodland habitat but relatively low in hedgerows and grasslands. This may be due to the limited species diversity in the latter two habitats. This hypothesis is supported by the Shannon diversity index which shows woodland to be far more species diverse (table 5).

At the species level the majority of the species found in the reserve, with the exception of green shield bug, honey bee spp. and *Meliscaeva cinctella*, have a very low specialisation index (table 8). This suggests that there is a low level of specialisation, or selectiveness, of each particular species. This limited reciprocal dependence or mutualism strength may increase web stability, buffering plant and animal species against extinction of any of their partners (Aizen, Morales and Morales, 2008).

Generalist pollinators have higher network connections and plant-niche overlap to create more redundant and robust networks. Thus, when networks experience species declines, the increased niche overlap and connectance created by generalist pollinators buffer them against further species loss (Cusser and Goodell, 2013). The data suggests that Buckland Abbey as a whole has a relatively small niche overlap (0.27, table 7), however, on a habitat basis the niche overlap is much higher (0.91-0.52, table 1, 3 and 5). This shows the different habitat types have relatively different pollinator communities and restoration of these habitats should be carried out with these species in mind, thereby strengthening the existing communities. Only once this is carried out should attempts be made to expand the community. However, due to the time constraints of this report, little is known about the pollinators of Buckland Abbey at different temporal scales. This can be resolved with repeated studies at different times of the year which will outline the resources available to the pollinators and measures which can be taken to boost their survivability throughout the year.

Baseline data of the pollinator communities is lacking (Bascompte and Jordano, 2007; Memmott, 1999), which makes it difficult to estimate the optimum species diversity for the different habitats at Buckland Abbey. However, judging by the nestedness, number of linkages, cluster coefficient and Shannon diversity index there is great potential to restore the individual ecosystems at the site, with the aim of increasing the pollinator species diversity and creating a more robust community.

Recommendations

By restoring habitat, conservation biologists and restoration ecologists seek to promote the reassembly of diverse ecological communities while also enhancing the ecological communities they provide (M'Gonigle *et al*., 2015). The most widely used restoration technique to promote pollinators within a landscape is the planting of flowering native shrubs and forbes (Devoto *et al*., 2012). Pollinator richness generally increases with floral richness and distance to high quality habitat (Cusser and Goodell, 2013). M'Gonigle *et al*. (2015) has shown that this can increase the long-term temporal stability of pollinator populations and communities. Most pollinators are entirely reliant upon nectar and pollen to forage (Morandin and Kremen, 2013). Therefore, it is not too simplistic to say high species diversity of flowering plant will boost pollinator numbers and diversity (Saunders, 2012). However, summer management has great potential to damage habitat features utilised by pollinators by either grazing or cutting the flowers (Saunders, 2012). Certain species of plants are more beneficial for pollinators, for instance, red clover (*Trifolium pratense*) has high protein content in their pollen which is crucial for larval or brood development of many bumble bees (M'Gonigle *et al*., 2015). Bridging plants (plants that provide resources over resource limited times) will provide a source of nectar and pollen during otherwise resource limited times (Menz *et al*., 2011), such as knapweeds and Devil's bit scabious, which flower later in the season (Saunders, 2012). This planting of native flowering species could be carried out across the reserve. However, to minimise any conflict with the farming community, the priority should be to restore the mixed woodland and hedgerows, which can be carried out relatively inexpensively. M'Gonigle *et al*. (2015) has found that restorations of hedgerows increase the rate of persistence of bee and fly pollinator colonisation along with enhancing the abundance of neighbouring fields, which in turn leads to the assemblages of a more species rich pollinator community.

Pollinators tend to need suitable abundant quality habitat close to nesting sites. Therefore, suitable nesting sites can be a limiting factor (Dixon, 2009). Measures can be put in place such as:

- Stacking cut logs on south facing sheltered areas with holes ranging from 3mm to 10mm, ideally with clay between the logs.
- Stacks of thermal blocks with a slate on top to protect from the weather. Holes should be drilled from 3mm to 15mm on the south facing side in sheltered areas.
- Drilled holes in the southern face of standing dead wood

These measures will increase the number and diversity of pollinator species. At present these measures would be effective in the mixed woodland of Buckland Abbey. These nesting sites will not only strengthen pollinator community robustness and nestedness but also provide an educational element for the visitors of this National Trust property.

Some areas of grassy bracken, which is prominent in the woodland fragments would benefit from more frequent summer cutting in order to promote flower rich habitats. Dense strands of bracken inhibit seed germination and offer very few opportunities for other plant species (Potts *et al*., 2000).

The management of Buckland Abbey intends to sow a perennial butterfly and bee mix in the allotment field (figure 7). Therefore, priority should be to restore hedgerows to create corridors made up of bridging species and framework species (species that provide a major source of nectar or pollen) (Devoto *et al*., 2012) to connect this field to the woodland fragment, or, to connect existing woodland habitats, (Figure 7) which was shown to be the most pollinator diverse habitat. Restoration of the mixed woodland habitat should take place from the north eastern edge (closest to the allotment field) and when time and funds permits, spreading west and south into the remaining fragment.

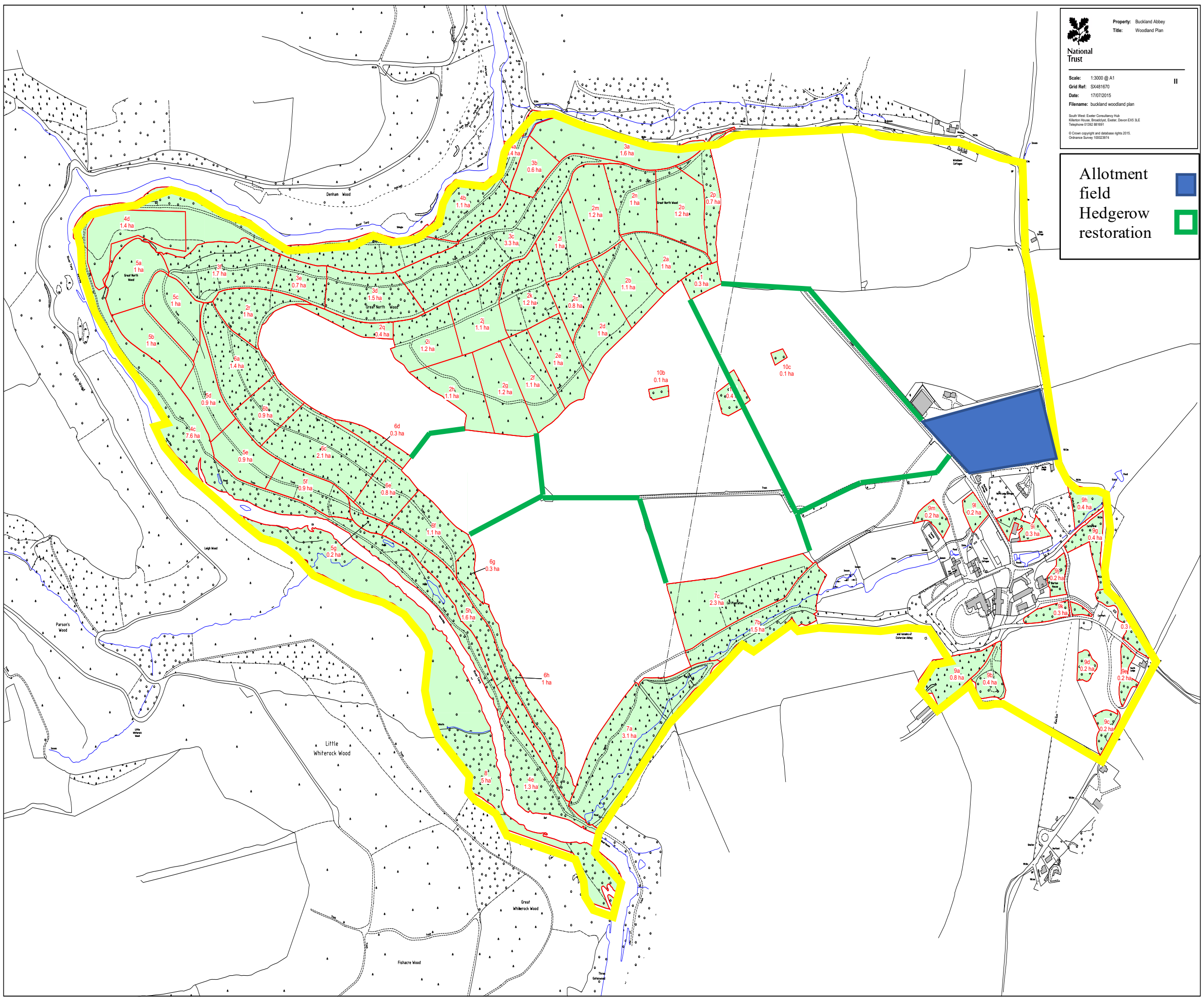

Figure 5 Map of Buckland Abbey with planned restoration sites

Restoration has been seen to positively change pollinator numbers, behaviour, performance and network structure in communities. 6 to 14 months after restoration, the number of pollinator species was on average 21.6% higher (Kaiser-Bunbury et al., 2017). Therefore, these restorative measures will reinforce network structure through increased connections and niche overlap, thereby reducing the risk of further extirpation and species loss through stochastic events (Cusser and Goodell, 2013).

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Risk Assessment

University of the West of England BRISTOL

GENERAL RISK ASSESSMENT FORM

Ref:

Describe the activity being assessed:	Assessed by:	Endorsed by:
E.g. Community analysis survey of broad leafed ancient woodland and open grassland in Buckland Abbey. The survey will ID pollinator species along with the particular flower that the pollinator was found on. Only to be carried out during daylight and when weather conditions are suitable.	*Alexander Woolcock*	*<leave blank>*
Who might be harmed: *Alexander Woolcock* How many exposed to risk:	Date of Assessment: June 2019	Review date(s): June 2020

Hazards Identified *(state the potential harm)*	Existing Control Measures	S	L	Risk Level	Additional Control Measures	S	L	Risk Level	By whom and by when	
Lone Working Risk of attack. Not being able to summon help if needed.	The researcher will either have mobile coverage over the survey area or be in contact with relavent employees at the reserve with a two-way radio If working alone, ensure that a buddy system is in place. The manager or the ecologist of the reserve will be aware that I am carrying out research and where in the reserve I intend to be.	5	1	5						
Weather –cold, rain, wind leading to hypothermia. Heat and sun leading to hyperthermia.	Avoid working in poor weather conditions by planning work in conjunction with weather forecast. If on arrival the weather is bad, try to make alternative arrangements.	5	1	5						
	Appropriate outdoor clothing, such as walking boots, warm clothing, waterproof trousers and coat, woollen hat and gloves. Hat, sunblock and sunglasses, plus a supply of water and food. Ensure that you can find shade at some point during your work. Water is permanently available at the reserve offices.									
Working in remote areas. Trips, falls, resulting in injury, and possible immobilisation. Harm caused by other people or animals eg attack leading to injury	Appropriate footwear. Work with somebody else, and carry a mobile phone. If working alone, ensure that a buddy system is in place. Inform the reserve manager that you are on site and follow any health and safety advice they provide.	5	1	5						
Lyme's disease from bites by ticks. Symptoms include Headache Extreme Fatigue EM Rash, Other Rashes (Only found in 50% of Patients) A typical bull's eye rash, spreading outwards not necessarily in the area of the bite.	Ticks can carry Lyme's disease. Working for long spells outside it is possible to pick up ticks. Wear long trousers and longsleeved shirts and a hat where possible, particularly when working in long grass.	5	1	5	Check for ticks on your body after you have been out in the field. If you develop any of the symptoms in the left hand column, or if you have been bitten by a tick, seek medical advice as timely treatment is highly advisable.	3	1	3		
Other bites & allergies. Some plants and animals may cause adverse reactions, particularly on the skin, when in contact with or biting a person. This may lead to anything from rashes to anaphylactic shock.	Avoid being bitten by animals or coming into extensive contact with plants. Keep well covered up, using gloves if handling plants or animals, and using common sense around ants nests, wasps nests etc. Known allergy suffers should have anti-histamines or epi-pens with them at all times.	5	1	5						

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Deleted: *Survey will plant species ID and coverage within 50x50m (tree) and 4x4m (ground flora) quadrats*
Deleted: .
Deleted: *<enter your name and if anyone is coming with you>...*
Deleted: ¶
Deleted: 2
Deleted: Additional person to accompany surveyor wherever possible on the survey. Check mobile coverage across the wood. ¶
Deleted: Inform the reserve manager that you are on site and follow any health and safety advice they provide.
Deleted:

Travel to site	Ensure that you have full directions and, if driving, have identified a safe car parking area near the site which provides safe access.	5	1	5						
Sediments can contain pathogens and parasites, particularly where dogs have fouled the area. This may lead to illness.	Try to keep away from areas that are dog fouled. Take extra water and alcohol gel for hand washing. If handling sediments, wear gloves.	5	1	5						
Equipment Risk of injury through lack of training / competencies	Only use equipment which you are trained to use. The assignment does not require the use of large, heavy, sharp or dangerous equipment.	3	1	3						
Dangerous landscape features Risk of encountering landforms e.g. cliffs / quarries / mine shafts.	Understand the location of potentially hazardous landscape features such as cliffs, quarries or mine shafts in the survey area. Avoid planning surveys in the vicinity of these areas. Ensure you know whereabouts in the reserve you are at all times. Take a map.	5	1	5						
Injury from livestock found on the reserve	Ensure you stick to public rights of way and abide by the signage that the reserve puts up.	4	1	4						
Harm caused by members of the public	Ensure someone (friends, family, colleagues) is informed of where I am going and when I will be returning. Carry a cell phone, two-way radio, extra cash and emergency numbers at all times.	4	1	4						

Deleted: ¶
If working by the sea, this carries the risk of tidal waters coming in quickly and the risk of drowning.¶
¶
¶
On saltmarshes the mud can be very wet, especially on incoming tides, and carries the risk of getting stuck in it.¶
¶
... [1]

RISK MATRIX: (To generate the risk level).

Very likely 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Possible 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Extremely unlikely 1	1	2	3	4	5
Likelihood (L) ↑ Severity (S) →	Minor injury – No first aid treatment required 1	Minor injury – Requires First Aid Treatment 2	Injury - requires GP treatment or Hospital attendance 3	Major Injury 4	Fatality 5

ACTION LEVEL: (To identify what action needs to be taken).

POINTS:	RISK LEVEL:	ACTION:
1 – 2	NEGLIGIBLE	No further action is necessary.
3 – 5	TOLERABLE	Where possible, reduce the risk further
6 - 12	MODERATE	Additional control measures are required
15 – 16	HIGH	Immediate action is necessary
20 - 25	INTOLERABLE	Stop the activity/ do not start the activity