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Investigating the potential impact on native flora and fauna of a non-native macropod, the red-necked wallaby (*Notamacropus rufogriseus*), on the Isle of Man.

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Abstract

Introduced non-native mammals to island ecosystems can cause significant impact on native flora and fauna. Large herbivores present in high density can cause significant changes in woodland vegetation dynamics and composition, altering biodiversity considerably. Since their escape from a zoo in the mid-20th century, the red-necked wallaby (*Notamacropus rufogriseus*) has established multiple dense populations in the north of the Isle of Man, now exceeding 500 individuals. The wallabies are frequently reported to be in poor physical condition, and so investigations into the potential causes of their symptoms are of importance to stakeholders in the animal agriculture industry whose animals share habitat with the wallabies, as well as animal welfare groups. With the majority of wallabies inhabiting the northwest curraghyn, a RAMSAR and ASSI site, there is great concern for the impact they may be having on native species. However, there have not been any quantifiable studies assessing the impact of wallaby presence on vegetation composition on the island. Here we show that the wallabies are causing significant reductions in vegetation height and cover but not in biomass. We found that vegetation cover was significantly reduced in grasses and other non-woody vegetation, but was not significantly reduced in ferns, mosses nor rushes. There were indications from rapid assessments undertaken, that browsing damage is occurring due to bark stripping by the wallabies, whilst they cause minimal impact to woodland via mechanic disturbance and stem consumption. We found that it is unlikely that the reported health issues commonly seen in the wallaby population are caused by parasitic helminth infection, although their parasitic load and feeding behaviour suggest they may increase spread of disease across the region. Our results demonstrate how the wallabies of the Isle of Man are significantly altering the vegetation composition of their habitat and so potentially shifting the species evenness of the region.

Lay summary

Mammals not originally from an island can have a significant impact on native animals and their environment. Large mammals which feed on vegetation can cause significant changes to which plants can thrive in a woodland or grassland, and so change which animals can also be supported in that environment.

Multiple red-necked wallabies escaped a zoo on the Isle of Man in the mid 1900's. The population now exceeds 500 individuals in a relatively small space. Many sightings of the wallabies have reported that they are in poor physical health, and so it is important to animal welfare groups and people involved in animal farming to discover what the cause of their ill health is, to improve their welfare and make sure farm animals are not endangered. Also, as the wallabies are large vegetation eating mammals, that live in high numbers, there is great concern that they may be having a negative effect on animals and plants that are native to the island.

Here, we show that the wallabies have reduced the height of vegetation, as well as reduced the amount of space that some vegetation like grasses, now cover. However, they have not reduced the overall weight of vegetation. Also, we show that the wallabies have not caused other groups of vegetation, like rushes or ferns, to cover less space. We also show that some damage is being caused by the wallabies to trees, by stripping the bark off, as well as some damage to the ground when moving along it. We also showed that it is unlikely that parasites like tapeworms, are causing the health issues in the wallabies. However, the wallabies may be increasing the spread of such parasites between farms.

We have shown that the red-necked wallaby is causing significant changes to vegetation, so may be changing which plants can thrive near them going forward.

Declarations

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed [redacted] ....

Date 31.10.24 ....

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

Signed.. [redacted] ....

Date..... 31.10.24 ....

I hereby give consent for my thesis, if accepted, to be available for electronic sharing

Signed [redacted] ....

Date..... 31.10.24 ....

The University's ethical procedures have been followed and, where appropriate, that ethical approval has been granted.

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Date..... 31.10.24 ....

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Definitions/Abbreviations

eggs per gram- epg.

Curragh- a wooded wetland predominantly made up of willow.

Curraghyn- plural of curragh.

Woodland herbivore impact assessment- WHIA

Introduction

To understand how herbivores effect woodland and grassland ecosystems, the mechanisms which cause these effects and their relationship to each other must be investigated. Globally, herbivory is a key factor in vegetation composition and dynamics, altering plant richness, biomass, abundance, evenness/dominance and diversity (Frank et al., 2017; Jia et al., 2018; Huntly., 1991; Pringle et al., 2023). The presence of such herbivores can therefore incur great economic costs to agriculture, endanger conservation and environmental projects, as well as affect the transmission of diseases between wildlife, animal agriculture and humans (Cooke et al., 2013; Latham et al.,2020; Gormley et al., 2012; Mack et al., 2000; Wiethoelter et al., 2015). So, identifying the impacts of an alien herbivore is of great importance so that negative effects can be minimised.

Identifying the specific impacts of herbivores on woodland and grassland habitats can be difficult, and so understanding the mechanisms by which their impacts can occur is crucial. The mechanisms and strength to which herbivores effect vegetation and so their ecosystem varies greatly, even for individuals of the same species acting under different mechanisms (Pringle et al., 2023; Augustine, 1998). In this study, size category of herbivore and feeding strategies were investigated, as they are significant mechanisms which cause the effects listed and are responsible for the strength of their impact (Huntly., 1991; Trepel et al., 2024; Frank et al., 2017; Foster et al., 2015; Comita et al., 2014).

Size category

The extent to which plant composition and dynamics are altered by herbivory varies at different size categories. (Trepel et al., 2024; Pringle et al., 2023). In numerous large herbivore exclusion studies, reduced competition for food has not enabled smaller herbivores to achieve the same grazing pressures as larger species which were excluded, and so vegetation is found to grow significantly higher and denser (Smit et al., 2001; Daskin and Pringle, 2016). Large herbivores (≥2 kg) play a unique role in ecosystems, placing a greater energetic cost on the biomass of their plant community, due to the greater amount of food required with larger body mass, which can result in significant impacts on vegetation composition in their habitat and suppression of smaller herbivores (Flowerdew and Ellwood, 2001; Olff et al., 2002; Pringle et al., 2023). Bakker et al., (2009) found cattle were responsible for reducing vegetation biomass and height, which negatively affected voles which rely on vegetation height for predator protection. Changes in herbivore species assemblages can then themselves further alter vegetation composition, as the pressures being applied by herbivores shifts to the displacing herbivore. Understanding the effect a large herbivore has on the vegetation composition of its habitat can then help to understand how other herbivores will react, with some herbivores such as rabbits (*Oryctolagus cuniculus*) benefiting from reduced vegetation height (Bakker et al., 2009). This significant difference in herbivore effect on vegetation composition has been seen in exclusion investigations including wallabies, in which their exclusion along with other large macropods resulted in significant growth of vegetation, even with smaller herbivores accessing the exclusion zone (Dexter et al., 2013). Red-necked wallabies are the largest wild herbivore on the isle of Man, on average more than 10 kg heavier than brown hares (*Lepus europaeus*), the next heaviest (Macdonald and Barrett., 1993). This increased energetic cost to the ecosystem since wallaby introduction and proliferation may exceed what can currently be maintained, with a further increase in energetic demand on vegetation by the hares, if they benefit from a reduced vegetation height, similarly to rabbits.

Herbivore size can alter the composition of vegetation without the consideration of their dietary needs, via mechanical disruption, such as trampling when moving through their habitat (Spengler et al., 2021). Megafauna (≥45 kg) are important ecosystem engineers (Coverdale et al., 2016). Besides their higher energetic costs on their home range due to increased nutritional needs relative to smaller herbivores, megafauna also cause considerable changes to plant communities through movement. Vegetation is trampled by megafauna, during their movements through their home range, as well as when resting. This encourages a more open composition in vegetation, as well as increased soil health through their excretions (Trepel et al., 2024; Spengler et al., 2021). The Giant deer (*Megaloceros giganteus*) lived on the Isle of Man 10,000 years ago, with no megafauna known to have existed there since its extinction (Innes et al., 2004). However, the red-necked wallaby is of considerable size, with males being recorded to have reached 26.8kg (King and Forsyth, 2021). It has been suggested that macropods may play an important role in seed dispersal and alteration of vegetation dynamics via trampling (Braden et al., 2021). However, although Ferguson et al., (2010) found trampling to occur due to red-necked wallabies and other macropods, it did not seem to accelerate the process of soil erosion which occurs from human and hard-hooved mammal paths. With little known about the mechanical disruption caused by wallabies, further investigation could prove important in an area of such high density as the Ballaugh curragh of the Isle of Man.

Feeding strategies

The red-necked wallaby is predominantly a grazer, with a dietary preference for grasses, which makes up most of their diet (74%), followed by broad-leaved forbes (16%) (Spent and McArthur, 2002). When grazing, red-necked wallabies extract plant matter in a similar fashion to sheep (*Ovis aries*), trimming the vegetation down, in contrast to other herbivorous mammals which may graze from closer to the surface (Lentle et al., 2003; Sjaastad et al., 2015). Red-necked wallabies can also be described as browsers, stripping bark and consuming stems off trees from pine plantations and eucalypt forests (Statham 1983; Smith et al., 2020a).

The mixed feeding strategy of the wallaby (described above) results in a wider range of potential effects on vegetation communities than that of true grazers or browsers and so the presence of such effects needs to be investigated. Grazing can benefit trees in some cases, by reducing competition from grasses, but this tends to be in low intensity, short grazing periods (Roberts et al., 2010; Ribeiro et al., 2023). Generally, high-intensity grazing reduces biomass and abundance in grass systems, whilst increasing species evenness. During periods of reduced graze material, high density herbivore sites incur at least light browsing, as most herbivores are not true grazers, and so negatively impact trees via bark stripping and tree/branch trampling (Pringle et al., 2023).

The use of a rapid assessment methodology can bolster the validity and confidence in quantitative research findings, as well as provide information on a wider set of parameters with reduced financial and temporal cost to the surveyors, enabling a greater quantity of valuable information to be collected without significant additional funding (Fennessy et al., 2007; Hockings, 2009). The use of the woodland herbivore impact assessment (hereafter WHIA) enables further investigation into the mechanisms by which wallabies may be affecting vegetation, not only further investigating grazing pressures, but also providing an indication of how the wallabies may be impacting trees. Additionally, the use of this method will set a benchmark for management practitioners to compare impacts going forward, at a relatively low temporal/financial cost.

High density browsing can have a similar effect on trees that grazing has on grasses and forbes. Generally, mixed feeders have a greater effect on tree responses than obligate browsers, due to being able to achieve higher densities than browsers (Staver et al., 2021). On Tasmania, the red-necked wallaby has been shown to display browsing on woody species which they have a significant impact on, such as *Eucalyptus delegatensis*, as well as newly planted pines (Statham 1983). Being the primary species responsible for bark stripping in some plant species, the wallaby may contribute to the rotting and death of woody vegetation (Jelonek et al., 2022). With woodland making up a significant proportion of the red-necked wallaby's habitat on the Isle of Man, areas with a high density could be at risk of significant vegetation change.

In the case of wallabies and other macropods, density has played a significant role on changes in vegetation composition in their native ranges. At Booderee National Park, areas managed to remove predators saw a 10-fold increase in macropod numbers, followed by understory plants experiencing statistically significant reductions in their abundance. Additionally, less palatable plants, such as ferns, were taller and in greater abundance in areas grazed by macropods than areas not grazed, due to reduced interspecific competition. These results contrast with the vegetation in areas where wallabies were excluded, in which palatable vegetation, such as flowering shrubs, were not suppressed and grew taller. (Dexter et al., 2013).

The change in vegetation composition that occurs in Australia when macropods are abundant whilst lacking predation may be an indicator of the effect of red-necked wallabies on the Isle of Man. Similar to the Booderee population, the largest population of wallabies on the Isle of Man live in high density and are predator free. The red fox (*Vulpes vulpes*) has not been documented in significant numbers on the island since the mid 90's and is believed to have an upper estimated count of 15 across the island (Reynolds and Short, 2003). Thus, investigations into the potential effect on vegetation composition changes, and their relation to increased wallaby numbers, is of importance, as changes in vegetation ultimately alters the ability of other groups to inhabit an area, such as invertebrates and ground-nesting birds, of which 48 species are at risk on the island (Kooch and Noghre, 2020; Bennett et al., 2014; Manx BirdLife, 2021).

Disease risk

The high density of red-necked wallaby, non-native to the Isle of Man, may pose a health risk to wildlife, agriculture and humans through the introduction of new parasites or proliferation of existing helminths (Chalkowski, Lepczyk and Zohdy 2018). Understanding the parasitology of the Manx wallabies could help reduce parasite spread and increase animal welfare for livestock, pets and the wallabies themselves. Macropods are highly susceptible to being intermediate hosts of tapeworms, specifically those which find dogs and sheep as their definitive host (Barnes, Morton and Coleman, 2007). All infected macropod carcasses investigated in a study by Barnes, Morton and Coleman (2007) were found to have at least one cyst on their lungs, with many having multiple. The wallabies of the Isle of Man share fields with sheep and so there is potential for spread between species, potentially to the detriment of both species. With many reports of wallabies in poor physical condition on the island, investigations into the causes of this animal welfare concern could benefit all who inhabit their ecosystem.

Exclusion fencing is a widely adopted method for preventing impacts from external wildlife on whatever is kept within, whether that is protecting agricultural investments or native flora/fauna (Tolhurst et al., 2008; Anson, 2017). Exclusion fences have become an ever increasingly important research tool, to compare multiple locations with varying treatments allowed and so their impacts can be accessed (Dexter et al., 2013). Many such structures have been constructed across Australia to keep wallabies and other macropods off farmland, as well as to keep invasive species off land (Dexter et al., 2013; Hayward et al., 2015). Although a useful tool, fences can be costly both financially and in terms of manpower to construct and maintain, with designs varying depending on the target species to keep excluded (West et al., 2019; Smith et al., 2020b). Further considerations need to be taken when planning exclusion fences, so that impacts on non-target species are understood, and can be mitigated against, such as corridors for other species to travel and plans for environmental emergencies such as a bushfire (Smith et al., 2020b). Sites utilising exclusion fencing have been used in this study to facilitate comparisons between vegetation compositions at varying wallaby presence levels (explored further in the "Method" section.

Wallabies of the British Isles

The distribution and abundance of wallabies in the United Kingdom and the rest of the British Isles is largely unknown, with limited citizen sightings and media reports making up the majority of sightings. From data available on most recent sightings (2010-2018) in the United Kingdom, the area with the highest frequency of sightings is the Chiltern hills of Southern England, with 11 sightings over a four-year period. As with most wild wallabies on the British Isles, these individuals are believed to have originally escaped private collections (English and Caravaggi, 2020). The distribution of wallaby sightings in Britain is primarily in the South of England, with infrequent sightings across the midlands and North of England, as well as a few sightings in Wales (English and Caravaggi, 2020). However, research has been conducted on three populations, a small population around Loch Lomond (Scotland), the Peak District (now extinct) and the focus of this research, the wallabies on the Isle of Man (Weir et al., 1995; Yalden 2013; Havlin et al., 2018).

Wallabies can be found as north as Loch Lomond, Scotland, where they were released by a private landowner. With reduced availability of grass in winter, the red-necked wallaby diet composition changes considerably, with grasses only contributing 13%. During this period, blueberries and heather make up the majority of their diet, each contributing 35% of plant fragments found in wallaby faeces (Weir et al., 1995).

The vegetative composition of their habitat consists of mixed woodland, primarily of Birch, oak and Scots Pine, with an understory of blueberries, heather and bracken. This composition is similar to that of their native habitat, in that they have the woodland required for shelter. Although patches of grassland are present, a lack of wide spread, open grassland does show a distinct difference from their native habitat, which may suggest the reasoning for their altered diet (Weir et al., 1995).

Now extinct, a population of red-necked wallabies persisted in the Peak District from the 1970's until a gradual decline in the early 21st century, with long term researcher of the population declaring them extinct in a final article in 2013 (Yalden 2013). Similar to the Loch Lomond population, the diet of the Peak District wallabies varies greatly in the winter to the rest of the year, with a far greater importance of heather and blueberries (Yalden and Hosey, 1971). This English population inhabited an area dominated with heather moor, with some grasses, bracken and blueberry. Similar to the Loch Lomond population, there was also some cover for the wallabies, provided by scrubby birch and pine. This composition possesses the required cover needed during the daytime, whilst providing necessary vegetation for feeding, although open grassland is not dominant, as it often is in their native habitat. However, the ample supply of heather, supplemented with blueberries, has taken the place of grassland in their diet. Yalden and Hosey (1971) suggest that heather domination in the diet is not simply due to lack of quality grass, as even during summer months when grass was plentiful, heather remained at least 50% of fragments found in faecal samples, suggesting selection rather than requirement. Research by Havlin et al., 2018 found no heather in any faeces examined, suggesting differentiation in preference. However, this may be important in understanding wallaby distribution, as there is plentiful heather on the island, which could become a key resource for wallabies, especially as it has been shown to be a critical dietary option in the winter months in other populations.

On the Isle of Man, wallaby sightings have been recorded across much of the north of the island, with numbers generally declining the further from the Ballaugh curraghyn they are found. However, the population at the Ballaugh curraghyn is by far the most substantial and appears to be the origin point of their wider spread, after colonising the area in the mid-20th century after escaping the wildlife park (Yalden 2013).

Importance of woodland/curragh ecosystems

The wet woodlands of the Isle of Man may play an important role in carbon sequestration and are an important habitat for high biodiversity that are present, so any shift in vegetation evenness or species number may cause a significant shift in fauna that can thrive (Milner et al., 2024; Isle of Man Government, 2006). Wet woodlands, which the Ballaugh Curragh can be categorised as, often have a wide variety of habitats composing them, which is the case on the Isle of Man. The Ballaugh Curragh is made up of boggy woodland, open and closed, with grassland, peatland and wildflower meadows (Isle of Man Government, 2006). With historic agricultural uses in parts of the woodland, there is a variety of age range in the vegetation present, further benefiting a wider variety of biodiversity. Of the curragh specifically, it has been identified as containing at least 39 breeding bird species, including the red listed corncrake (*Crex crex*) and lapwing (*Vanellus vanellus*) (Manx BirdLife 2021). The bogs, pools and ditches also support a wide range of aquatic fauna, including eels (*Anguilla Anguilla*) and common frogs (*Rana temporaria*). Importantly, the curragh is home to wildflower meadows, containing many marsh orchids, such as the greater butterfly orchid (*Platanthera chlorantha*) and spotted orchid (*Dactylorhiza spp*) (Isle of Man Government, 2006). As there is such an importance placed on this environment for its historical and environmental significance, any shift caused by the dense presence of the wallabies is important to understand so that damage or shifts in species presence and evenness can be mitigated against in management strategies and policies. Additionally, the peatland formed in this wetland can play an important role in carbon sequestration, trapping more carbon than other soils (Milner et al., 2024). Disturbance of this soil by a large mammal such as the red-necked wallaby could hinder this process, and so a greater understanding of the effect this large mammal living in a high density is important to understand the future of the soil health.

Research questions

To investigate the significance of the wallabies on the native biota of the Isle of Man, the following is considered:

Is vegetation height significantly reduced with increased wallaby density?

Is plant biomass and cover significantly impacted at increasing wallaby density?

Are the wallabies a potential accelerant in the spread of disease amongst wildlife, agriculture and humans?

Objectives:

To investigate the effect wallabies are having on plant height, biomass and plant cover, these variables will be measured at sights of varying wallaby density. These variables will be used as indicators of wallaby impact as they are strong indicators of the mechanisms which fuel vegetation change by herbivores (Huntly, 1991; Jia et al., 2018; Pringle et al., 2023; Trepel et al., 2024). Additionally, we implemented the WHIA to further investigate the mechanisms by which wallabies may be affecting vegetation, both woody and non-woody species, to provide a benchmark for management practitioners to compare impacts going forward, at a relatively low temporal/financial cost. To investigate the welfare of the wallabies and their potential impact on disease spread to/from wildlife, livestock and humans, faecal samples were collected for the identification of parasites.

Method

Study site/site selection

Fieldwork was conducted over May 2024 at three sites; Goshen and Close Sartfeild wildlife trust reserves and the central curraghyn (plural of curragh) in the Greeba area, Isle of Man (Figure 1 and Figure 2). Each site consists of grasslands and curraghyn, a wooded wetland predominantly made up of willow (Garrad, 1972). The Ballaugh curraghyn is a RAMSAR and ASSI site, hosting many RSPB red listed species, as well as rare orchid species (Isle of Man Government, 2006).

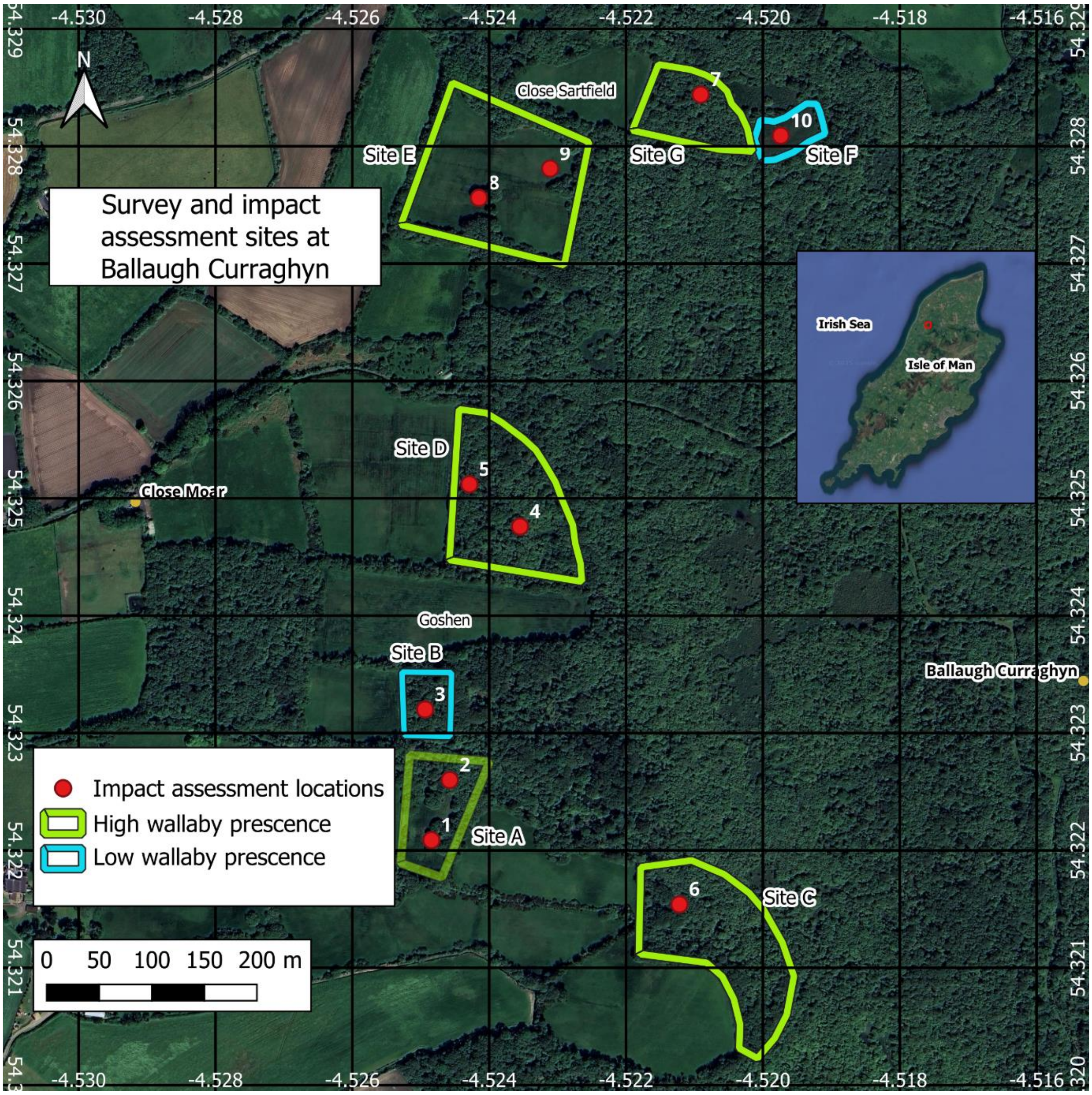

Figure 1. Map of sites surveyed at the Ballaugh Curraghyn May 2024. Both quadrat surveys and impact assessment surveys (referred to as WHIA stops in body of work) were conducted in all of the low and high wallaby presence sites (Seven sites total).

There were a total of ten sites categoriesed by their wallaby density. Due to difficulty finding entry to two other desirable sites, a site was split to create survey sites eight and ten. Wallaby density was calculated from drone survey data provided by BH wildlife consultancy 2023 and 2024 (Harrower, 2023; Harrower, 2024). The ballaugh sites categorised as "low" presence make use of exclusion fencing, which have reduced wallaby presence (Davies, 2024). Site six (low presence) was found to have a wallaby present during the drone survey, as well as a faecal sample found at the site, estimated to be at least six months old. The other "low" presence sight has similarly had a single wallaby recorded to have entered, but no further sightings have been recorded by the trust's camera traps since the individual's departure (Davies, 2024).

Due to the significant costs of constructing and maintaining exclusion fences, more such sites were not created, and the alternative of control sites was considered. The absent sites were selected for their similar vegetation structure to the low and high presence sites; with curragh, grassland and wetland mosaics (Figure 2).

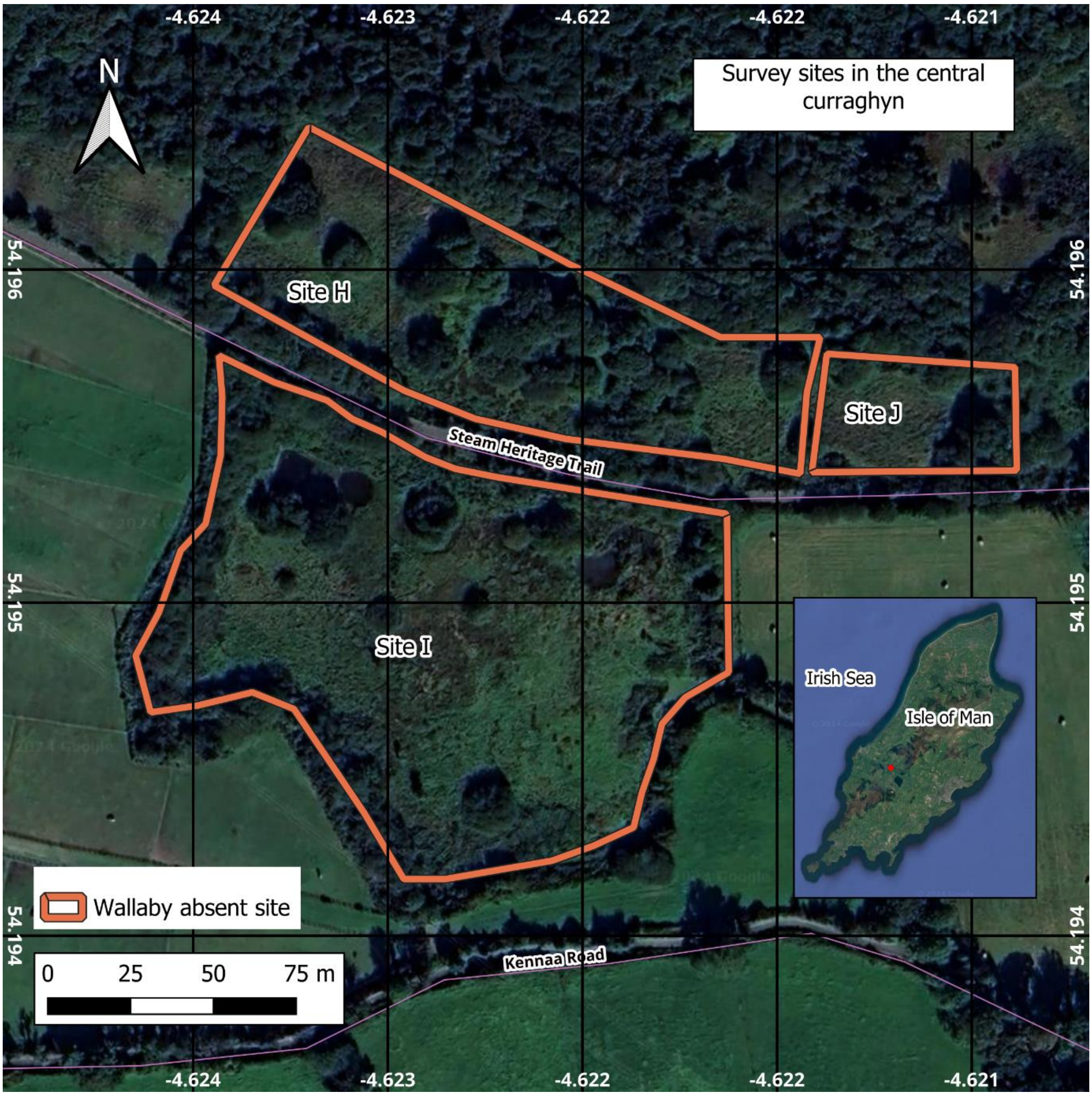

Figure 2. Map of "absent" survey sites in the central curraghyn, Greeba.

Table 1. Survey site locations, habitats, size and wallaby presence.

Site number	Site description (habitat categorisations)	Wallaby presence	Site location (Decimal degrees)	Site size (acres)
1	Curragh and grassland	High	Goshen- 54.32230257699254N, 4.524899458635886W	1.65
2	Curragh	Low	Goshen- 54.323020564098336N, 4.525043206804471W	0.73
3	Curragh	High	Goshen- 54.32119583683093N, 4.52073946101714W	4.01
4	Curragh	High	Goshen- 54.325009351557796N, 4.5236248715561W	4.84
5	Meadow	High	Close Sartfeild- 54.327932264774N, 4.524157851283918W	5.83
6	Wetland	Low	Close Sartfeild- 54.32808354584424N, 4.519839179364269W	0.39
7	Curragh	High	Close Sartfeild- 54.328260557676465N, 4.521194016772514W	5.17
8	Curragh, grassland and wetland	Absent	Greeba- 54.19609870075841N, 4.622927248518483W	1.41
9	Grassland and wetland	Absent	Greeba- 54.195248949742286N, 4.623082631753886W	4.55
10	Curragh and grassland	Absent	Greeba- 54.19577821409101N, 4.620606631058507W	0.74

Woodland herbivore Impact assessment

To assess wallaby browsing impact, as well as provide an initial assessment of their effects which can be used to aid management priorities, methodology has been adapted from Armstrong et al., 2023. Ten sites were selected across two Manx wildlife trust reserves, in the high-density wallaby area, Ballaugh (Figure 1). The stops were selected by meeting set criteria: size, habitat type, herbivore access and survey accessibility. No stops were positioned in fields where sheep graze, so to reduce the herbivore impact to just wallabies and hares. Each stop had at least a 15 m radius and care was taken to increase distance from public paths/fences/gates, as to reduce anthropogenic effects (Ohayon et al., 2023). Most stops were made up of a 25 m radius, as advised in the WHIA. However, some stop areas were not large enough or the terrain was too difficult to traverse, for a 25 m radius to be possible. In such cases, a radius of 15 m was used. The radius selected is meant to cover enough of a stop as to be able to give a strong representation of the area, so the reduction in size for smaller areas is acceptable (Armstrong et al., 2023).

Stops three and ten were located within attempted wallaby exclusion zones surrounded by high presence locations. Stop ten is primarily a boggy open field, so is not suitable for herbivore impact indicators related to browsing or bark stripping. However, it was selected as mechanical disruption and grazing pressure could be investigated, useful indicators both for the purpose of informing practitioners through the WHIA method, but also to inform on data collected through the quadrat portion of this study. Stop three is a fenced curragh area, so is suitable for investigation of all seven indicators.

The WHIA measures vegetation damage by seven factors (Armstrong et al., 2023):

1. Ground disturbance
2. Bark stripping, fraying and stem breakage
3. Browsing of basal shoots
4. Browsing of epicormic/lower shoots
5. Browsing of seedlings/saplings
6. Preferentially browsed or grazed plants
7. Other plants

Each of these indicators were investigated and given an impact score for each site and then an overall impact for the entire area. All vegetation within a stop was assessed. Impact levels from least impact to most are ‘no impact’, ‘low’, medium’, ‘high’ and ‘very high’, with intermediate scores between each level. How each level was assigned is shown in figures 3-6, from the WHIA user guide (Armstrong et al., 2023). Any signs of other herbivores were also recorded at each stop. This along with information regarding herbivore presence in the area can then inform on any data analysis, to reduce misinterpretation of vegetation damage by any particular species.

The ideal time to conduct the survey is at the end of winter, so that the previous year's vegetation growth can be assessed before the next year's growth begins. As surveying was conducted during May, the current year's growth on trees was ignored, with just the previous year's growth assessed for herbivore browsing (Armstrong et al., 2023). However, assessing previous season's growth on grazed vegetation was not possible, so this year's grazing was measured for "preferentially grazed plants" as well as "other plants".

General:	Record examples of indicators in each category as: **exact number up to 9, 10-20, 20-50, 50-100, >100** Browsing on **trees**: **Percentage of a tree's current year's shoot biomass** browsed Grazing /browsing on non-tree plants: **Percentage of the total number of a plant's shoots or leaves** grazed /browsed		
	Definition:	**Record:**	**Not Applicable if:**
Ground disturbance	Ground 'poached' by trampling or rooting. Pathways Wallows Scrapes	Percentage of ground disturbed by large herbivores **(0, <5, 5-15, 15-30, >30 %)** No. of wallows, scrapes No. of pathways (unvegetated, partially vegetated or totally vegetated)	The ground is composed of rock, boulders or scree that cannot show signs of disturbance by large herbivores.
Bark stripping, fraying & stem breakage	***Bark stripping***: bark stripped from susceptible trees or fallen branches. Trees > 2 m tall, smooth barked ***Fraying***: bark removed by deer using antlers Trees 50-200 cm tall, < 5 cm dbh ***Stem breakage***: live stems broken by being pushed over by cattle or red deer Trees < 5 cm dbh	No. & % of susceptible trees bark stripped and frayed **(0, <5, 5-20, 20-50, >50 %)** No. & % of susceptible trees broken **(0, <5, 5-10, 10-20, >20 %)**	No trees present are susceptible to bark stripping fraying or stem breakage. All damage occurred prior to the time period of interest.
Basal shoots	Shoots growing from the base of intact or felled (by humans or beavers) tree trunks.	No. of trees of each species in each browsing category **(0, <25, 25-75, 75-90, >90 %)**	No trees present with basal shoots. It is unclear whether basal shoots have been browsed or have died and broken off. All shoots are inaccessible, or are too large in diameter, to be browsed.
Epicormic and lower shoots	Shoots growing from tree trunks, lower branches or fallen trees.	No. of trees of each species in each browsing category **(0, <25, 25-75, 75-90, >90 %)** Current year's shoots hard to find? Shoots browsed into woody growth?	No trees present with epicormic or lower shoots. All shoots are inaccessible to large herbivores.
Seedlings and saplings	Trees 5 – 200 cm tall Exclude unbrowsed shoots < 2 cm in length Exclude 'new' seedlings if assessing previous 12-month impact in summer.	No. of trees of each species in each browsing category **(0, <25, 25-75, 75-90, >90 %)** Shoots browsed into woody growth?	Seedlings and saplings are absent or are inaccessible to large herbivores.
Preferentially browsed or grazed plants	Plants listed as "***very palatable***" in Table 2.	No. of plants of each species in each grazing /browsing category **(0, <25, 25-75, 75-90, >90 just tips, >90 more than just tips %)**	Preferentially browsed or grazed plants, or parts of plants, are absent or are inaccessible to large herbivores.
Other plants	Plants listed as "***moderately***" or "***slightly***" palatable in Table 3. Also plant species not listed in Table 3 but that have been grazed.	No. of plants of each species in each grazing /browsing category **(0, <25, 25-75, 75-90, >90 %)**	'Other' plants, or parts of plants, are absent or are inaccessible to large herbivores.
Signs of herbivores	e.g. wool, hair, pellet groups, hoof prints, species-specific bite marks		
Notes	e.g. dominant plant species /vegetation type, browsing on seedlings < 5 cm tall, presence of indicators in inaccessible places. past impacts		

Figure 3. Field recording 'aide memoire' from Armstrong et al., 2023.

Indicator	Not Applicable	Very High	High	Medium	Low	No impact
Ground disturbance Disturbance by large herbivores = poached ground, pathways, scrapes or wallows created within the time period of interest.	The ground is composed of bare rock, boulders or scree. N.B. plant litter is very quickly mineralised in moist, very rich woodlands and soil may be bare in spring. The lack of vegetation in these cases is not due to animal disturbance	>30% of ground showing signs of disturbance by large herbivores. And /or ***Deer and /or livestock***: pathways frequent wide, heavily used, and wholly unvegetated and /or, on wet, open ground, there may be kicked out clods of turf and *Sphagnum* as well as well-defined deer wallows. ***Livestock***: there may also be substantial areas of bare ground caused by poaching especially if the ground is wet. There may be heavier disturbance around feeding areas and pig shelters.	15-30% of ground showing signs of disturbance by large herbivores. And /or ***Deer and /or livestock***: pathways frequent and partially, or mostly, unvegetated. ***Livestock***: disturbance may be more widely distributed with some poached and /or unvegetated ground especially if the ground is wet. There may be heavier disturbance around feeding areas and pig shelters.	5-15% of ground showing signs of disturbance by large herbivores. And /or ***Deer and /or livestock***: pathways frequent but largely vegetated or pathways rare but unvegetated. ***Livestock***: There may be heavier disturbance around feeding areas and pig shelters.	<5% of ground showing signs of disturbance by large herbivores. And /or ***Deer and /or livestock***: pathways rare and almost completely vegetated.	No areas of ground showing signs of disturbance by large herbivores. And /or No recognisable pathways.
Bark stripping, fraying & stem breakage Bark stripping = removal of bark from older trees using teeth (all herbivore species except roe deer). Fraying = bark removal from saplings by deer rubbing their antlers on stems. ²dbh = diameter at breast height (1.3 m above ground).	There are no trees susceptible to bark stripping or stem breakage or if all damage occurred prior to the time period of interest.	>50% of susceptible live stems, and recently fallen branches, showing recent bark stripping and /or fraying that may be severe. And /or >20% of live stems of saplings <5 cm dbh² snapped.	20-50% of susceptible live stems, and recently fallen branches, showing recent bark stripping and /or fraying. And /or 10-20% of live stems of saplings <5cm dbh² snapped.	5-20% of susceptible live stems, and recently fallen branches, showing signs of bark stripping and /or fraying. And /or 5-10% live stems of saplings <5 cm dbh² snapped.	<5% of susceptible live stems, and recently fallen branches, showing signs of bark stripping and /or fraying. And /or < 5% of live stems of saplings <5 cm dbh² snapped.	No recent bark stripping or fraying or stems snapped by large herbivores.

Figure 4. Current impact of herbivores on indicators “Ground disturbance”, “Bark stripping, fraying and stem breakage” from Armstrong et al., 2023.

Indicator	Not Applicable	Very High	High	Medium	Low	No impact
Basal shoots Includes all accessible shoots sprouting from tree bases.	There are no trees with basal shoots or it is unclear whether shoots have been browsed or have died, and broken off, for other reasons e.g. frost, drought or lack of light (this may be an issue especially for birch). Shoots are inaccessible or are too large a diameter to be browsed.	***Palatable*** species >90% browsed. ***Unpalatable*** species 75-90% or >90% browsed. If shoots are browsed at >90%, all of the current year's growth may have been removed, possibly along with some of the previous year's growth.	***Palatable*** species generally 75-90% browsed; a few may be >90% browsed. ***Unpalatable*** species 25-75% browsed; a few may be 75-90% browsed.	***Palatable*** species generally 25-75% browsed; a few may be 75-90% browsed. ***Unpalatable*** species generally <25% browsed; a few may be 25-75% browsed.	***Palatable*** species generally <25% browsed; a few may be 25-75% browsed. ***Unpalatable*** species generally unbrowsed; a few may be <25% browsed.	***Palatable*** species unbrowsed. ***Unpalatable*** species unbrowsed.
Epicormic & lower shoots Includes all shoots growing from tree trunks (epicormic), lower branches or fallen trees that are within reach of herbivores. ³ If only unpalatable species are present, and browsing rates are 25-75% or 75-90%, record the impact as High – Very High.	There are no trees with epicormic or lower shoots or, if there are, they are not accessible to large herbivores.	***Palatable*** species >90% browsed. ***Unpalatable*** species³ 25-75%, 75-90% or >90% browsed. If shoots are browsed at >90%, all of the current year's growth may have been removed, possibly along with some of the previous year's growth.	***Palatable*** species 75-90% browsed. ***Unpalatable*** species² 25-75% or 75-90% browsed.	***Palatable*** species 25-75% browsed. ***Unpalatable*** species unbrowsed or <25% browsed.	***Palatable*** species <25% browsed. ***Unpalatable*** species unbrowsed.	**Palatable** and **unpalatable** species unbrowsed.
Seedlings & saplings Trees 5 - 200 cm tall. Seedlings less than 5 cm tall are not included because these are often hidden by vegetation so are unreliable indicators. A note can be made of observations of browsing on seedlings < 5 cm tall. See Table 4 for palatability classes of trees.	Seedlings and saplings are absent or seedlings & saplings are inaccessible to large herbivores	***Palatable*** species, if present, >90% browsed. ***Unpalatable, class 4 or 5***: 75-90% or >90% browsed. ***Unpalatable, class 6***: 25-75%, 75-90% or >90% browsed. If shoots are browsed at >90%, all of the current year's growth may have been removed, possibly along with some of the previous year's growth.	***Palatable*** species, if present, 75-90% browsed. ***Unpalatable, class 4 or 5***: 25-75% browsed. ***Unpalatable, class 6***: <25% browsed.	***Palatable*** species generally 25-75% browsed; a few may be 75-90% browsed. ***Unpalatable, class 4 or 5***: <25% browsed. ***Unpalatable, class 6***: unbrowsed.	***Palatable*** species generally <25% browsed; a few may be 25-75% browsed. ***Unpalatable***: all species unbrowsed.	All species unbrowsed.

Figure 5. Current impact of herbivores on indicators “Basal shoots”, “Epicormic and lower shoots” and “Seedlings and saplings” from Armstrong et al., 2023.

Indicator	Not Applicable	Very High	High	Medium	Low	No impact
Preferentially browsed or grazed plants Vegetation other than trees; that are listed as "very palatable" in Table 3.	No accessible preferentially browsed /grazed plants, or parts of plants, can be found.	>90% browsed /grazed. More than just the tips of shoots or leaves have been browsed /grazed.	Either 75-90% browsed /grazed or >90% browsed /grazed but the latter with only the tips of shoots or leaves removed.	Generally 25-75% browsed /grazed. Some of the most palatable species may be >75% browsed /grazed while others are unbrowsed /ungrazed e.g. bramble browsed but blaeberry unbrowsed.	Generally <25% browsed /grazed but there may be some shoots or individual species that are 25-75% browsed /grazed or are unbrowsed /ungrazed.	No browsing /grazing on shoots /leaves.
Other plants Vegetation, other than trees, that are listed as "moderately" or "slightly" palatable in Table 3. Assume plant species not listed in Table 3 are in the "slightly palatable" category if they have been grazed.	No accessible 'other' plants, or parts of plants, can be found.	***Moderately palatable*** species 75-90% or >90% browsed /grazed. ***Slightly palatable*** species 25-75%, 75-90% or >90% browsed /grazed. If grazing limited to autumn /winter, slightly palatable species may be <25% browsed /grazed.	***Moderately palatable*** species 25-75% browsed /grazed. ***Slightly palatable*** species <25% browsed /grazed. If grazing is limited to autumn /winter, slightly palatable species may be unbrowsed /ungrazed.	***Moderately palatable*** species <25% browsed /grazed. ***Slightly palatable*** species unbrowsed /ungrazed.	***Moderately and slightly palatable*** species unbrowsed /ungrazed.	***Moderately and slightly palatable*** species unbrowsed /ungrazed.

Figure 6. Current impact of herbivores on indicators "Preferentially browsed or grazed plants", and "Other plants" from Armstrong et al., 2023.

Quadrat surveys

Each site was surveyed with the use of two 100 m transects. The placement of the transects was selected to reduce border and anthropogenic effects as much as feasable, as well as to enable as many transects to be conducted under the desired distance as possible. Where sites were not large enough for 100 m transects (sites two and six), 50 m transects were implemented.

At 10 m intervals in a transect, a 0.5 m x 0.5 m quadrat was placed, in which indicators were measured. In total, 200 quadrats were placed and data collected. In each quadrat, sward height, vegetation cover, bareground and faeces count were recorded. Vegetation was grouped into broad categories to meet time constraints of survey period. Sward height was measured by taking the mean of four height measurements across the quadrat, using the direct method of sward height recording as it provides the most consistent and accurate results, as well as being the most capable of detecting height variation in short grass (Stewart et al., 2001). At the second transect of each site, plant weight was also recorded. Three 10 cm x 10 cm cuttings were weighed and height measured (resulting in seven heights recorded for the quadrats' height) at the first, fifth and ninth quadrats, totalling nine cuttings per transect (Ninty cuttings collected between all sites).These cuttings were then bagged to be dried for a dry weight to be calculated and so biomass calculated. Samples were dried in an oven at 70°C until a consistent weight was achieved (Flombaum and Sala, 2007). Percentage plant cover was measured at broad vegetation groups of Grass, rush, other non-woody vegetation (such as orchids), moss, fern and woody vegetation (such as seedlings/Ivy). Percentage plant cover included the vertical element of plant overlap so does not relate to percentage bare ground.

Biomass was calculated for quadrats that did not have cuttings by using the FIREMON equation B=H*C*BD, where B=biomass, H= average height, C=average vegetation cover, BD= bulk density. Once biomasses were calculated for quadrats in a site which had cuttings taken, an average bulk density could be calculated for a site, which can then be used in the FIREMON equation to calculate biomass for all other qudrats in the site (Butler, 2007).

Faeces collection and examination

Ten wallaby faecal samples were collected between both Close Sartfield and Goshen. Samples were selected that appeared fresh upon visual inspection. Samples were refrigerated until examined in the lab. Faeces was not collected as it was dropped by wallabies as this would have taken too much of the survey period time. The number of eggs per gram were estimated using the McMaster technique, whist presence of larvae was investigated using the Baermann technique and a simple flotation technique.

Statistical analysis

Linear mixed effect models assume that data is normally distributed and that the relationship between explanatory data and response data is linear (Grilli and Rampichini, 2015; Schielzeth et al., 2020). In visual exploration of the data via histograms, the data was found to be non-normally distributed and so transformation of the data was required for statistical testing (Lee, 2020). Boxcoxon graphs were used to identify the appropriate transformations for the response variables (Table 2). Q-Q plots were then created to check the transformed data was normally distributed (Marden, 2004). Additionally, the relationship between the response and explanatory data cannot be assumed to be linear, as there is bias based on site location and grid/quadrat placement within a site (Paciorek, 2010). As these factors cannot be explained by a linear model, random effect variables “Site_Label” and “Transect_ID” were implemented, with wallaby presence and site type being the fixed effects. AIC values were calculated for each model generated to determine whether wallaby presence, habitat type or a combination of these explanatory/fixed effect variables best describes the change in the response variables, as well as whether data transformation better fit the assumptions of the models. This then enabled the first two research questions to be answered. Models were generated by using the “lmer” function in R version 4.4.1.

Table 2. Transformation of response data for statistical analysis.

Response variable	Transformation
Average height (cm)	Power of 0.2
Biomass (% cover)	Power of 0.4
Vegetation (% cover)	Natural log
Bare ground (% cover)	Natural log
Grass (% cover)	Power of 0.6
Rush (% cover)	Power of -0.5
Other non-woody vegetation (% cover)	Power of 0.3
Woody (% cover)	Natural log
Fern (% cover)	Natural log
Moss (% cover)	Natural log

Results

Quadrat results

Height

Both a low and high wallaby presence led to a decrease in the average height of vegetation (coefficient estimates =-0.251 +/-0.049, -0.560 +/-0.039 respectfully). Thus, we can conclude that there is a significant negative effect of wallaby presence on average vegetation height ($p<0.05$) (table 3). Median vegetation hight was more than 10 cm less when there was a low wallaby presence compared to no wallabies, with a greater than 20 cm reduction in height in high wallaby presence sites (Figure 7). Median vegetation height at a high wallaby presence was lower than any recorded vegetation height when wallabies were not present. The additive model including wallaby presence without site type best explains the variation in the average height of vegetation (selected by using the Akaike information criterion AIC, minimum AIC difference of 12).

Table 3. Results from additive linear mixed effect models of vegetation height under differing wallaby presence levels.

Parameter	Estimate	S.E.	t-value	p-value
Intercept	2.006	0.031	64.93	p<0.001
Presence_levelHigh	-0.560	0.039	-14.32	p<0.001
Presence_levelLow	-0.251	0.049	-5.14	0.001

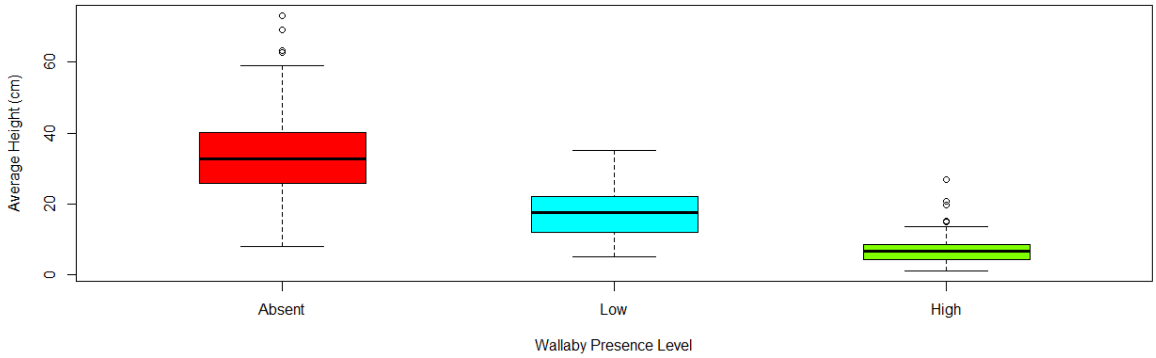

Figure 7. Average vegetation height (cm) at varying wallaby presence levels, sample size=200.

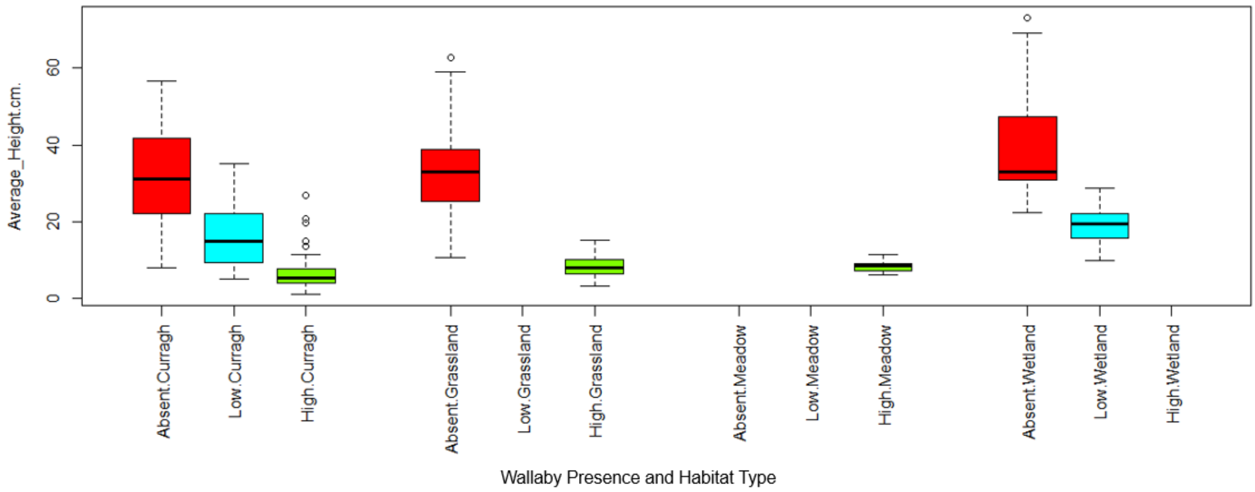

Figure 8. Average vegetation height (cm) in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as “Absent”, “Low” or “High”. Habitat type categorised as “Curragh”, “Grassland”, “Meadow” or “Wetland”.

Biomass

There was a significant difference in biomass across the site types (table 4). As wallaby presence did not explain the variation in biomass, we cannot conclude that wallaby presence does not significantly reduce plant biomass. The additive model including site type but not wallaby presence best explains the variation in the average height of vegetation (selected by using the AIC, minimum AIC difference of 19).

Table 4. Results from additive linear mixed effect models of vegetation biomass under differing habitat types.

Parameter	**Estimate**	**S.E.**	**t-value**	**p-value**
Intercept	0.417	0.037	11.345	p<0.001
Site_TypeGrassland	0.218	0.034	6.342	p<0.001
Site_TypeMeadow	0.230	0.105	2.189	0.063
Site_TypeWetland	0.346	0.049	7.065	p<0.001

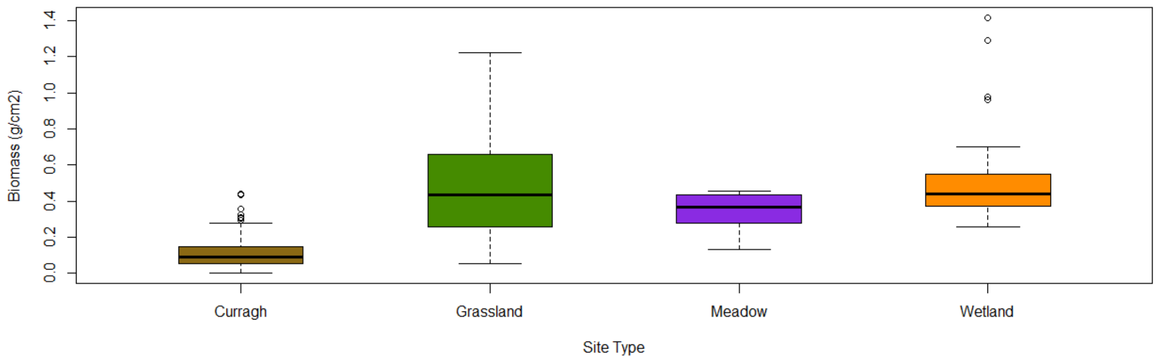

Figure 9. Biomass of vegetation (g/cm2) at different site types, sample size=200. Site type categorised as “Curragh”, “Grassland”, “Meadow” or “Wetland”.

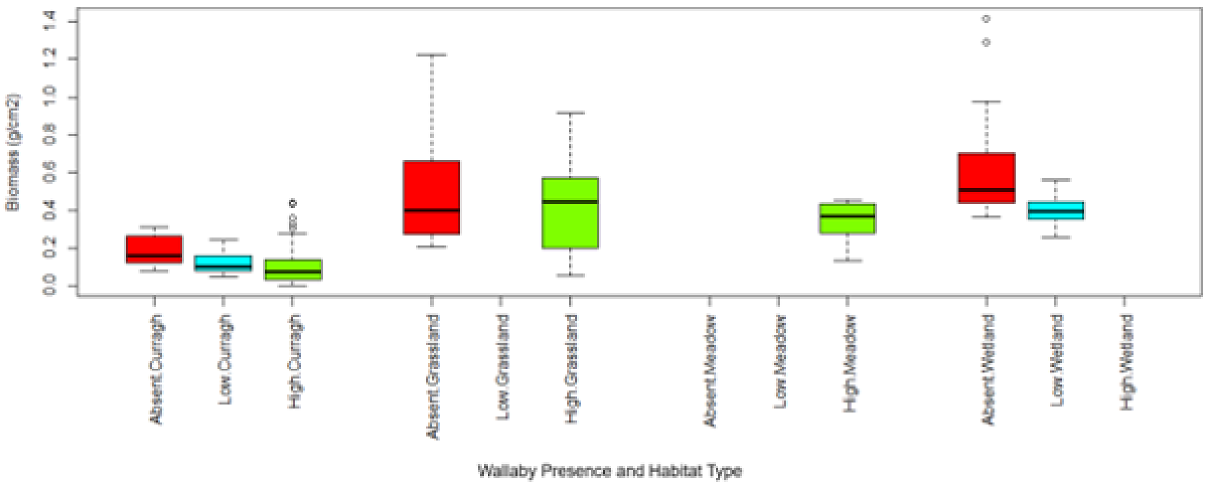

Figure 10. Biomass of vegetation (g/cm2) in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as “Absent”, “Low” or “High”. Habitat type categorised as “Curragh”, “Grassland”, “Meadow” or “Wetland”.

Bare ground

There was a significant difference in bare ground across the site types (Table 5). As wallaby presence did not explain the variation in percentage bare ground, we cannot conclude that wallaby presence does not significantly increase percentage bare ground. The additive model including site type but not wallaby presence best explains the variation in the average height of vegetation (selected by using the AIC, minimum AIC difference of 1112). Median percentage bare ground was recorded at more than 20% in curragh, whereas bare ground was barely represented in the other habitat types (medians <5%) (Figure 11).

Table 5. Results from additive linear mixed effect models of percentage bare ground under varying habitat types.

Parameter	**Estimate**	**S.E.**	**t-value**	**p-value**
Intercept	3.149	0.177	17.790	p<0.001
Site_TypeGrassland	-2.415	0.260	-9.311	p<0.001
Site_TypeMeadow	-2.876	0.457	-6.301	p<0.001
Site_TypeWetland	-2.240	0.317	-7.062	p<0.001

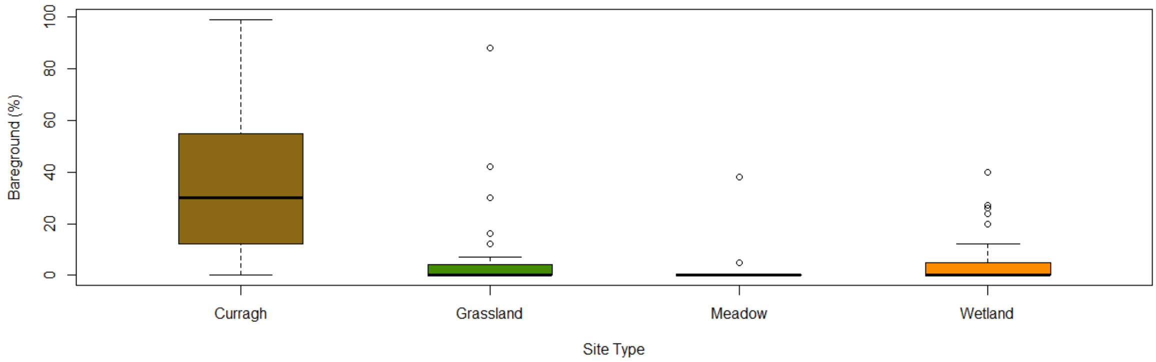

Figure 11. Percentage of bare ground at different site types, sample size=200. Site type categorised as “Curragh”, “Grassland”, “Meadow” or “Wetland”.

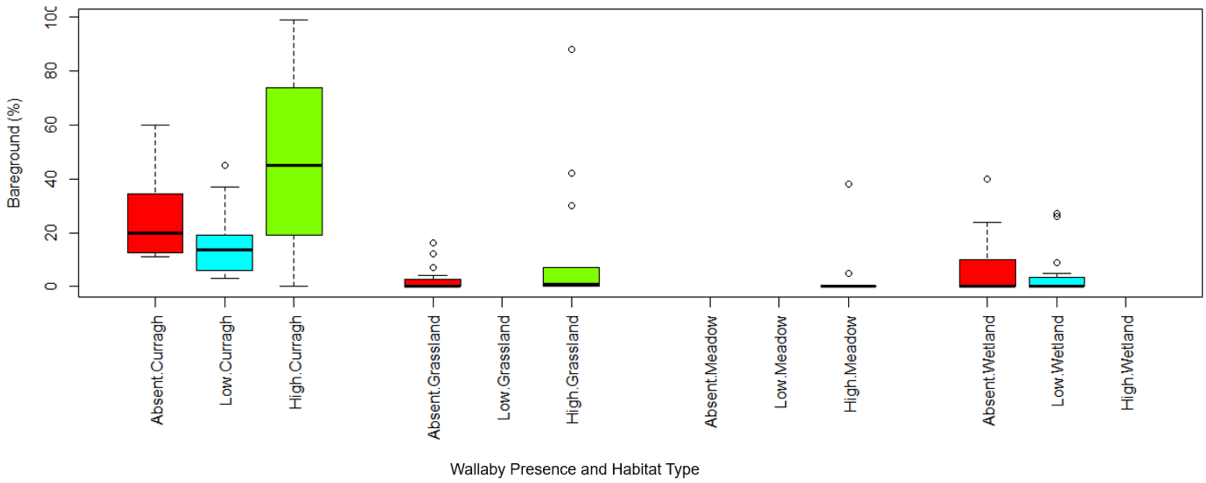

Figure 12. Percentage of bare ground in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as “Absent”, “Low” or “High”. Habitat type categorised as “Curragh”, “Grassland”, “Meadow” or “Wetland”.

Plant cover

A high wallaby presence led to a decrease in percentage vegetation cover (coefficient estimates =-0.667+/-0.235). Thus, we can conclude that there is a significant negative effect of high wallaby presence on percentage vegetation cover ($p<0.05$) (table 6). There was not a significant change in percentage vegetation cover at low wallaby presence however (coefficient estimates =0.026+/-0.263). Thus, it cannot be concluded that there is a significant negative effect on vegetation cover at a low wallaby presence ($p>0.05$) (table 6). The additive model including both wallaby presence and site type best explains the variation in the average height of vegetation (selected by using the AIC, however difference from lowest AIC only ranged from two-five so not a large variation in model usefulness).

The effects of wallaby presence varied when broad categories of vegetation cover were tested. For explaining variation in percentage cover of grass, rush, woody vegetation and moss the interactive model including both wallaby presence and site type were best (selected by using the AIC, however difference in AIC for rush and moss were <10). For explaining variation in percentage cover of fern, an additive model including wallaby presence but not site type best explains the variation in the percentage cover of vegetation (selected by using the AIC, however difference in AIC were <10). For explaining variation in percentage cover of other non-woody vegetation, an additive model including both wallaby presence and site type best explains the variation in the average height of vegetation (selected by using the AIC, however difference in AIC were <10). Median plant cover decreased by more than 25% when wallaby presence was high compared to absent in curraghyn, with the range in plant cover more than doubling at high presence. Variation in median and range was less extreme in other habitats (Figure 13).

A low wallaby presence resulted in a decrease in percentage cover of grass, other non-woody and woody vegetation (coefficient estimates = 9.277 +/-1.799, -0.711 +/-0.260, -2.496 +/-0.544 respectfully). A high wallaby presence resulted in a decrease in percentage cover of other non-woody and woody vegetation (coefficient estimates = -1.374 +/-0.232, -1.927 +/-0.392 respectfully). Thus, we can conclude that there is a significant negative effect of increased wallaby presence on percentage vegetation cover in select vegetation groups ($p<0.05$) (table 7; table 9; table 10). Highest other non-woody cover recorded was more than double in wallaby absent areas compared to high wallaby presence when comparing the same habitat was possible (Figure 16). However, rushes, ferns nor mosses experienced a significant change in their percentage cover due to wallaby presence, with variation in their cover being explained by site type (table 8, table 11 and table 12).

Table 6. Results from additive linear mixed effect models of percentage vegetation cover under differing wallaby presence levels and varying habitat types.

Parameter	Estimate	S.E.	t-value	p-value
Intercept	4.375	0.205	21.383	p<0.001
Presence_levelHigh	-0.667	0.235	-2.832	0.025
Presence_levelLow	0.026	0.263	0.099	0.925
Site_TypeGrassland	0.452	0.165	2.743	0.008
Site_TypeMeadow	1.067	0.310	3.439	0.015
Site_TypeWetland	0.391	0.217	1.799	0.084

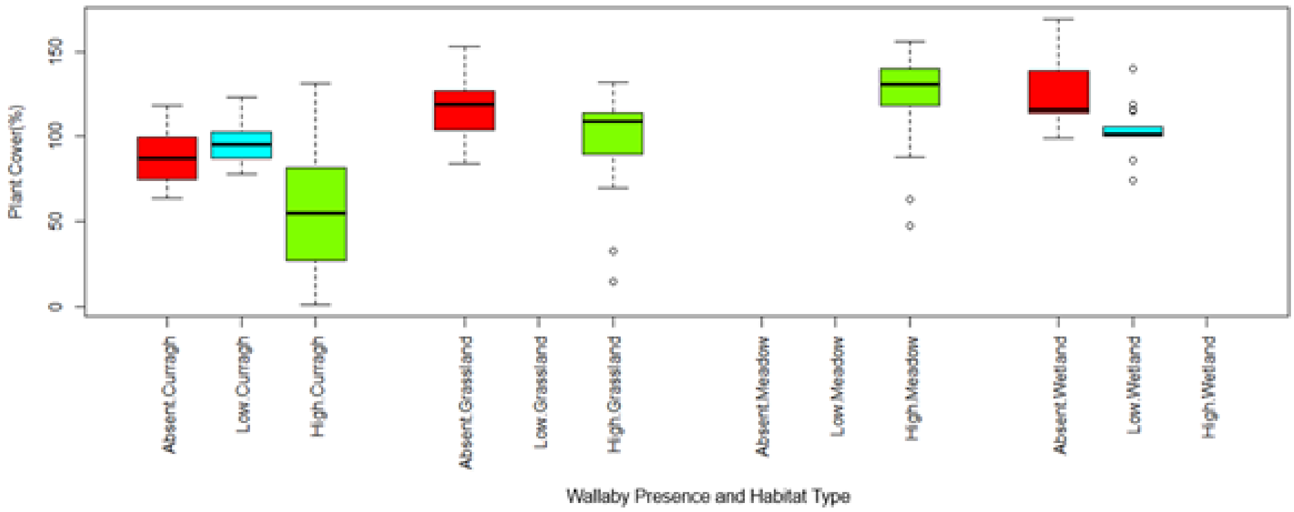

Figure 13. Variation in percentage plant cover in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as "Absent", "Low" or "High". Habitat type categorised as "Curragh", "Grassland", "Meadow" or "Wetland".

Table 7. Results from interactive linear mixed effect models of percentage grass cover under differing wallaby presence levels and varying habitat types.

Parameter	Estimate	S.E.	t-value	p-value
Intercept	3.688	1.247	2.957	0.009
Presence_levelHigh	0.678	1.420	0.477	0.642
Presence_levelLow	9.277	1.799	5.158	0.001
Site_TypeGrassland	7.471	1.252	5.965	p<0.001
Site_TypeMeadow	5.171	1.463	3.534	0.023
Site_TypeWetland	5.501	1.525	3.607	p<0.001
Presence_levelHigh:Site_TypeGrassland	-1.309	1.778	-0.736	0.464
Presence_levelLow:Site_TypeWetland	-3.968	2.384	-1.664	0.133

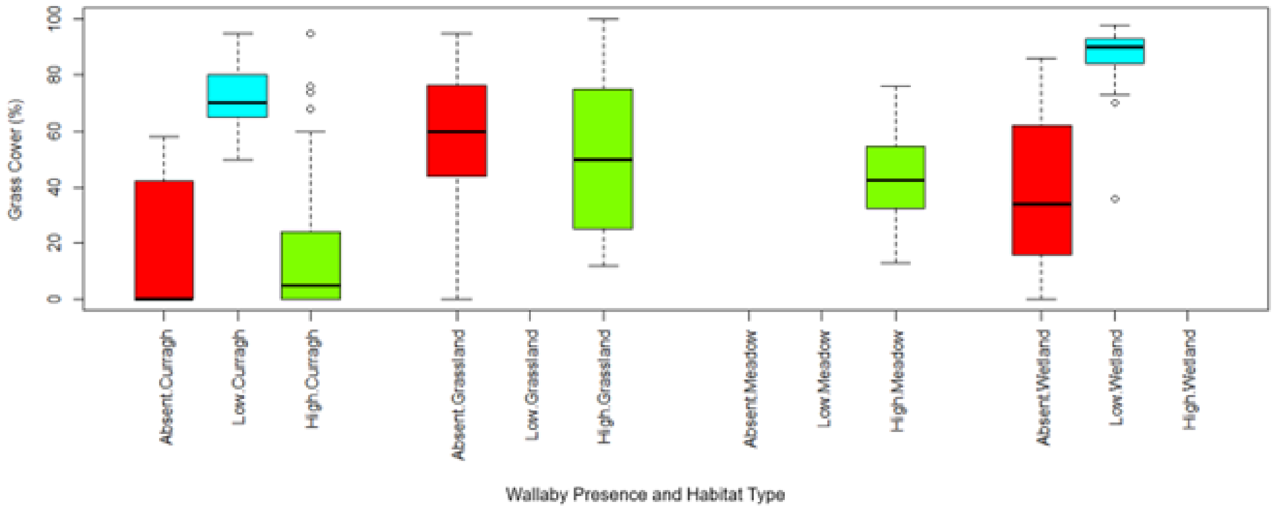

Figure 14. Percentage grass cover in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as “Absent”, “Low” or “High”. Habitat type categorised as “Curragh”, “Grassland”, “Meadow” or “Wetland”.

Table 8. Results from interactive linear mixed effect models of percentage rush cover under differing wallaby presence levels and varying habitat types.

Parameter	Estimate	S.E.	t-value	p-value
Intercept	0.926	0.118	7.864	p<0.001
Presence_levelHigh	-0.258	0.135	-1.907	0.081
Presence_levelLow	-0.046	0.173	-0.264	0.799
Site_TypeGrassland	-0.075	0.115	-0.648	0.518
Site_TypeMeadow	-0.317	0.143	-2.215	0.085
Site_TypeWetland	-0.553	0.141	-3.909	p<0.001
Presence_levelHigh:Site_TypeGrassland	-0.242	0.165	-1.472	0.145
Presence_levelLow:Site_TypeWetland	0.553	0.228	2.421	0.040

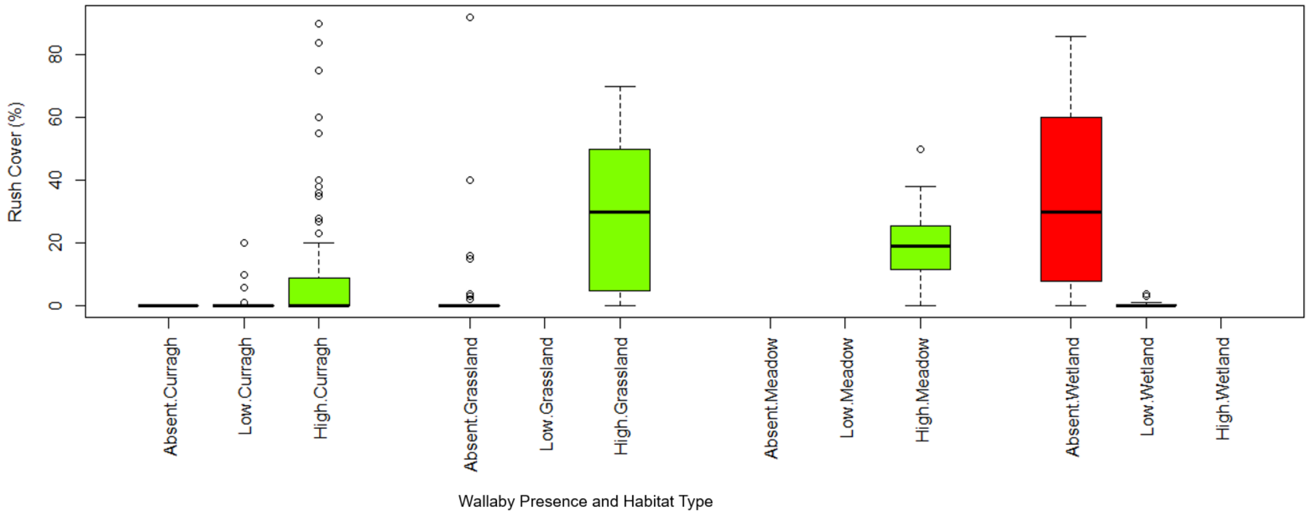

Figure 15. Percentage rush cover in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as “Absent”, “Low” or “High”. Habitat type categorised as “Curragh”, “Grassland”, “Meadow” or “Wetland”.

Table 9. Results from additive linear mixed effect models of percentage other non-woody cover under differing wallaby presence levels and varying habitat types.

Parameter	Estimate	S.E.	t-value	p-value
Intercept	3.032	0.200	15.138	p<0.001
Presence_levelHigh	-1.374	0.232	-5.910	p<0.001
Presence_levelLow	-0.711	0.260	-2.731	0.032
Site_TypeGrassland	0.217	0.156	1.391	0.168
Site_TypeMeadow	1.600	0.309	5.180	0.002
Site_TypeWetland	0.027	0.208	0.128	0.899

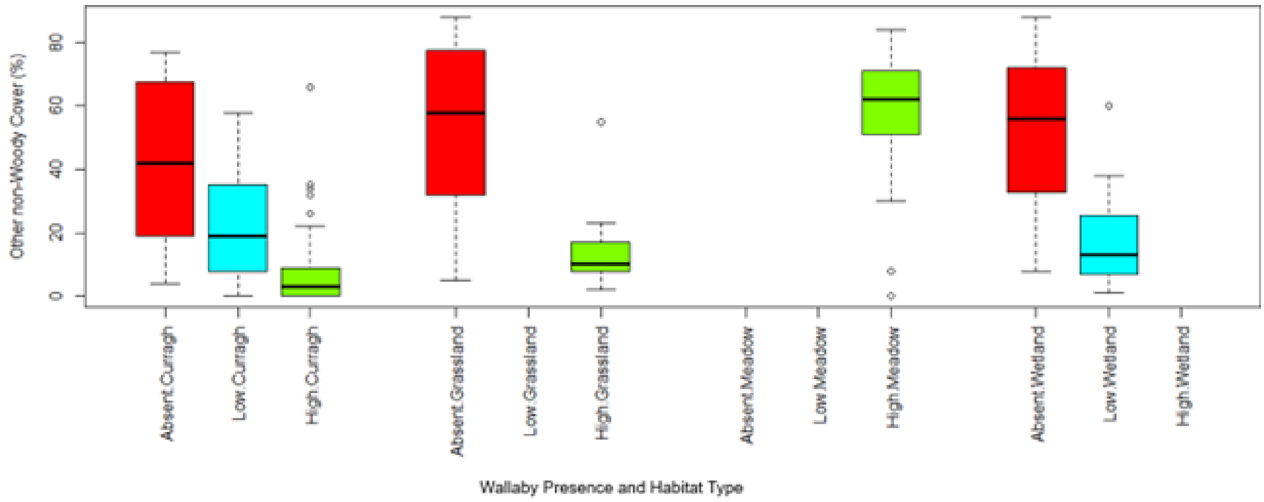

Figure 16. Percentage other non-woody cover in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as "Absent", "Low" or "High". Habitat type categorised as "Curragh", "Grassland", "Meadow" or "Wetland".

Table 10. Results from interactive linear mixed effect models of percentage woody cover under differing wallaby presence levels and varying habitat types.

Parameter	Estimate	S.E.	t-value	p-value
Intercept	2.496	0.322	7.743	p<0.001
Presence_levelHigh	-1.927	0.392	-4.915	0.001
Presence_levelLow	-2.496	0.544	-4.590	0.003
Site_TypeGrassland	-2.417	0.245	-9.885	p<0.001
Site_TypeMeadow	-0.569	0.492	-1.157	0.301
Site_TypeWetland	-2.274	0.312	-7.296	p<0.001
Presence_levelHigh:Site_TypeGrassland	1.596	0.361	4.428	p<0.001
Presence_levelLow:Site_TypeWetland	2.274	0.694	3.280	0.0132

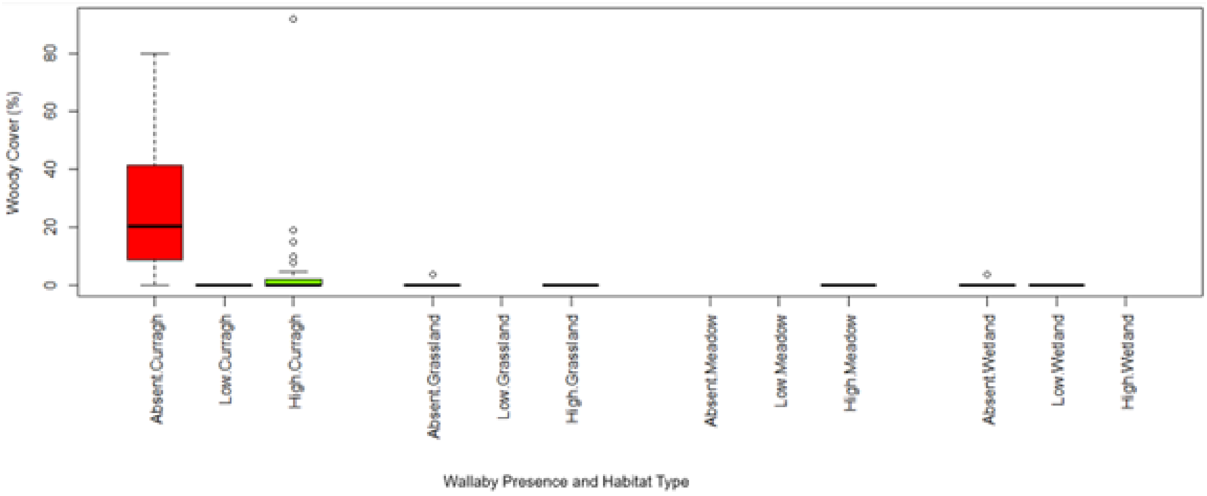

Figure 17. Percentage woody cover in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as “Absent”, “Low” or “High”. Habitat type categorised as “Curragh”, “Grassland”, “Meadow” or “Wetland”.

Table 11. Results from additive linear mixed effect models of percentage fern cover under varying wallaby presence levels.

Parameter	**Estimate**	**S.E.**	**t-value**	**p-value**
Intercept	0.096	0.072	1.346	0.220
Presence_levelHigh	-0.020	0.091	-0.217	0.835
Presence_levelLow	-0.056	0.113	-0.496	0.635

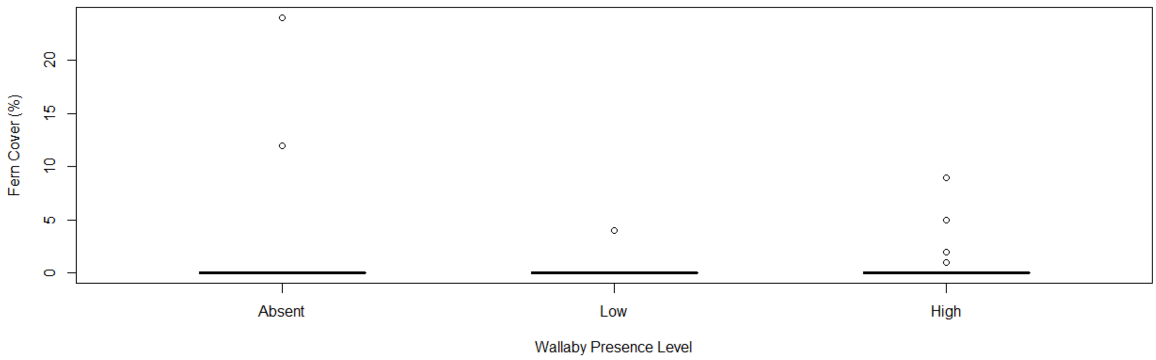

Figure 18. Percentage fern cover at varying wallaby presence levels, sample size=200.

Table 12. Results from interactive linear mixed effect models of percentage moss cover under differing wallaby presence levels and varying habitat types.

Parameter	Estimate	S.E.	t-value	p-value
Intercept	<-0.001	0.438	0.000	1.000
Presence_levelHigh	1.565	0.508	3.079	0.001
Presence_levelLow	0.097	0.662	0.147	0.887
Site_TypeGrassland	<0.001	0.412	0.000	1.000
Site_TypeMeadow	-0.774	0.559	-1.385	0.228
Site_TypeWetland	<-0.001	0.510	0.000	1.000
Presence_levelHigh:Site_TypeGrassland	-1.284	0.592	-2.168	0.033
Presence_levelLow:Site_TypeWetland	-0.097	0.868	-0.112	0.913

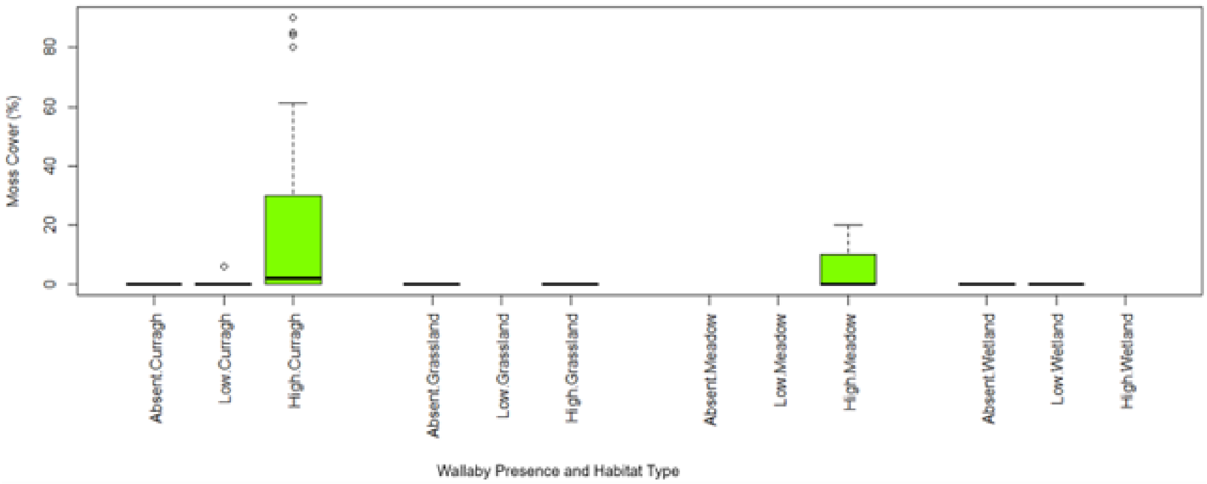

Figure 19. Percentage moss cover in multiple environments, under varying wallaby presence levels. Missing boxplots show herbivore and habitat combinations which were not included in the experimental design (see methods for more detail), sample size=200. Wallaby presence categorised as "Absent", "Low" or "High". Habitat type categorised as "Curragh", "Grassland", "Meadow" or "Wetland".

WHIA results

Ground disturbance

Ground disturbance was recorded at a low impact and no impact at four sites each, whilst two of the curragh sites did not have enough ground vegetation due to lack of light to be applicable. The only indicator of ground disturbance present was trampling, with no rooting or stem breaking found (Figure 20 and Table 13).

Table 13. Table summarising the impact level measured at each stop for each impact indicator, across ten sites (NI= No impact, NI-L= No impact to Low impact, L= Low impact, L-M= Low to medium impact, M= medium impact, M-H= Medium to high impact, H= High impact, H-VH= High to very high impact, VH= Very high impact).

Indicator	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7	Stop 8	Stop 9	Stop 10
Ground Disturbance	NI	L	NI	L	N/A	N/A	L	L	NI	NI
Bark stripping and stem breakage	M	L	NI	L	L	M	H	M	VH	N/A
Basal shoots	NI	L	NI	L	NI	N/A	N/A	N/A	N/A	N/A
Epicormic and lower shoots	L	L	L	L	L	L	M	L	L	N/A
Seedlings and saplings	L	L	NI	NI	NI	NI	L	NI	N/A	N/A
Preferentially browsed or grazed plants	NI-L	NI-L	NI	L	NI-L	NI-L	L	NI-L	NI	N/A
Other Plants	VH	H	NI	M	M	M	M	H	M	NI

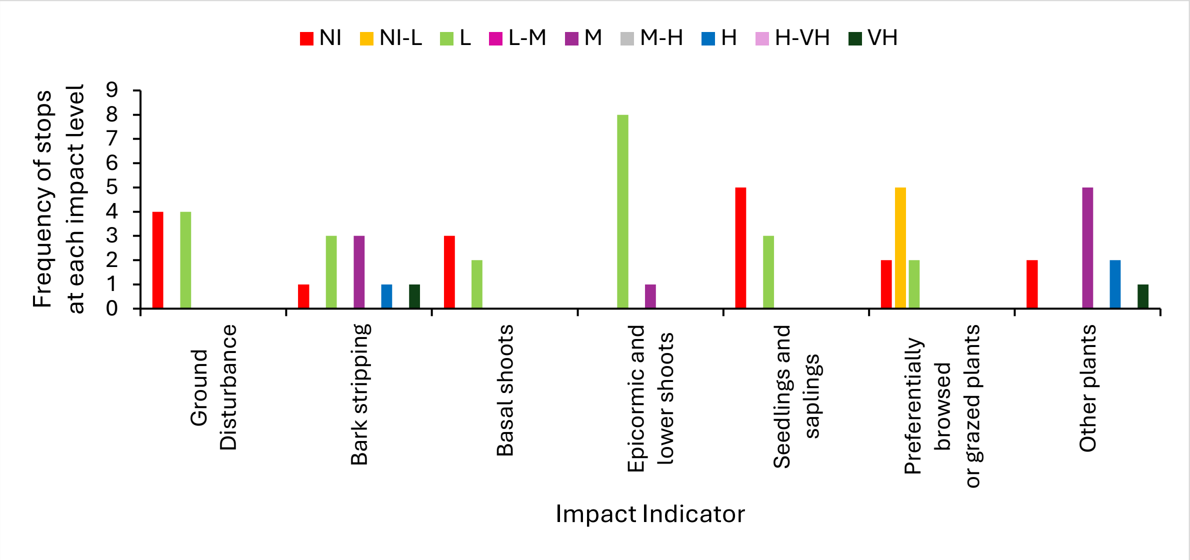

Figure 20. Graph showing the frequency at which each impact indicator was recorded at different impact levels, across ten sites (NI= No impact, NI-L= No impact to Low impact, L= Low impact, L-M= Low to medium impact, M= medium impact, M-H= Medium to high impact, H= High impact, H-VH= High to very high impact, VH= Very high impact).

Bark stripping and stem breakage

Eight of the ten stops had signs of bark stripping by wallabies, ranging from “low” to “very high”, with an overall impact of “medium”. All impact recorded was from bark stripping, with no signs of stem/branch breakage detected (Figure 20 and Table 13).

Basal shoots

Half of the sites did not have tress with basal shoots, and only two stops had any basal browsing at “low” impact. Both stops had few recordable examples of browsing, with only palatable species browsed (Figure 20 and Table 13).

Epicormic and lower shoots

All stops that contain trees (stops 1-9) exhibited signs of epicormic and/or lower shoot browsing. All were of “low” impact, except stop seven which was categorised as “medium” Most indications of browsing were of palatable trees such as grey willow and sycamore, however there were multiple cases of birch being browsed at low levels (<25%) (Figure 20 and Table 13, with further details in “Appendices”).

Seedlings and saplings

No impact-low impact was the overall impact level on seedlings and saplings, with only three stops indicating any level of browsing, all of which were graded at “low” impact (Figure 20 and Table 13).

Preferentially browsed or grazed plants

No impact-low impact was the overall impact on preferentially browsed or grazed plants. Seven of the ten stops showed signs of grazing, but only two had an impact of “low”, with the remaining five categorised as “no impact-low” due to very few recordable instances (Figure 20 and Table 13).

Other plants

Excluding sites with restricted wallaby access, grazing impact was categorised as “medium-high” with all stops indicating a minimum of a “medium” rating and stop 1 showing “very high” impact (Figure 20 and Table 13).

Faecal investigation

Sample "Goshen 1" was not prepared correctly and so faecal analysis could not be performed. All other samples, nine in total, were used in the Baermann technique, McMaster slide technique and simple floatation technique.

Seven of the nine samples had enough eggs for a density to be calculated using the McMaster technique (Figure 21). All had an eggs per gram (epg) density of between 50 and 400, except Close Sartfield 1, which was calculated at 1150 epg. An average epg of 244 was calculated from all nine samples (Figure 21).

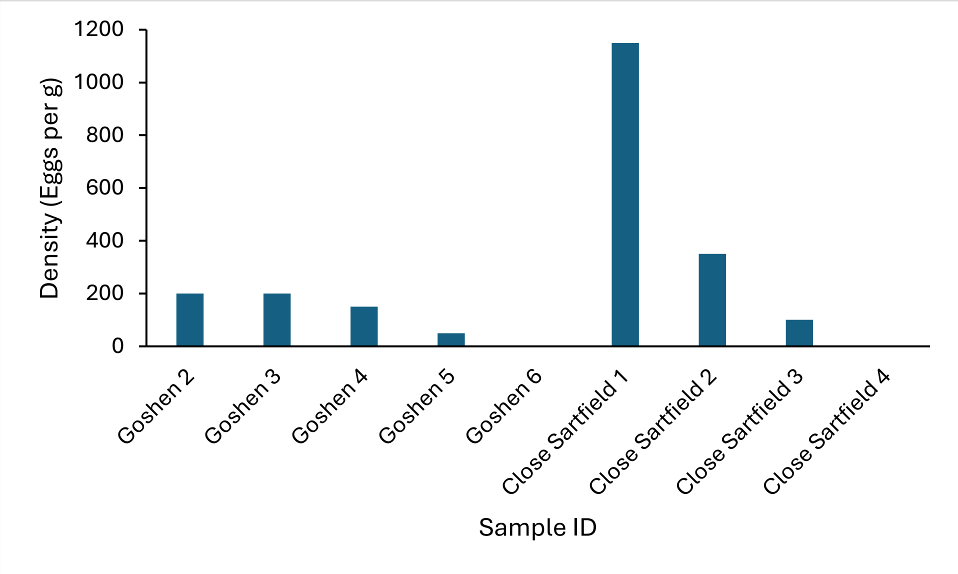

Figure 21. Density of eggs found in wallaby faecal samples via the McMaster technique (Goshen 1 sample was incorrectly prepared and so data was not obtained).

Parasites were found in all nine samples tested. Cestoda, Nematoda and Trematoda eggs were all found, with cestoda eggs being found in eight of the nine samples tested. Nematoda larvae were found in 78% of samples, including all samples collected at Goshen (Figure 22). At least eight parasite species are present in the Ballaugh wallabies, with all three broad groups being found in most samples (Table 14 and table 15).

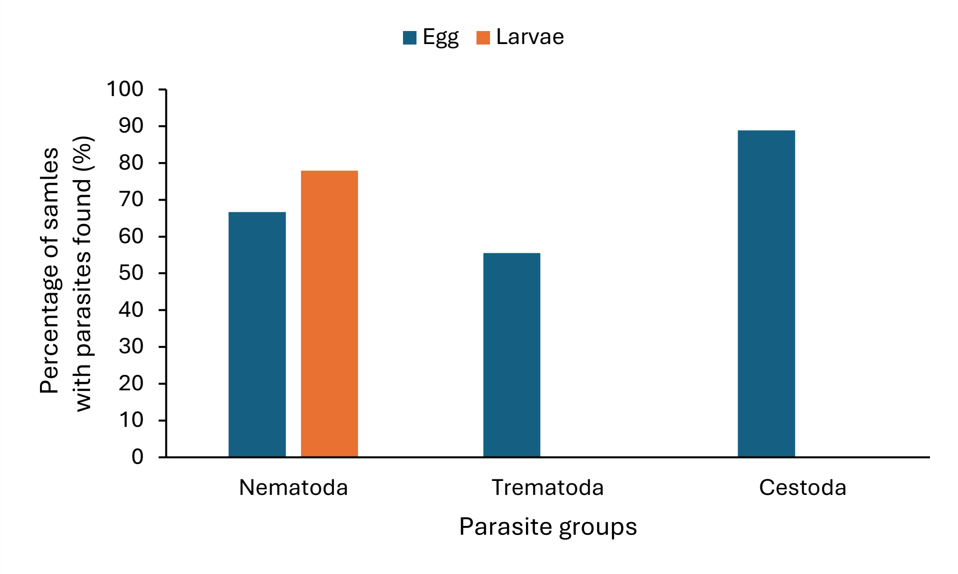

Figure 22. Percentage of faecal samples identified as carrying helminths.

Table 14. Life stages of helminths found in wallaby faecal samples, across two sites (Nine samples in total).

Sample ID	Helminth life stages present
Goshen 2	Nematoda eggs and larvae. Trematoda eggs. Cestoda eggs.
Goshen 3	Nematoda eggs and larvae. Trematoda eggs. Cestoda eggs.
Goshen 4	Nematoda eggs and larvae. Cestoda eggs.
Goshen 5	Nematoda larvae. Cestoda eggs.
Goshen 6	Nematoda larvae
Close Sartfield 1	Nematoda eggs. Trematoda eggs. Cestoda eggs.
Close Sartfield 2	Nematoda eggs. Trematoda eggs. Cestoda eggs.
Close Sartfield 3	Nematoda larvae. Trematoda eggs. Cestoda eggs.
Close Sartfield 4	Nematoda eggs and larvae. Cestoda eggs.

Table 15. sub-divisions of helminths found in the Ballaugh wallabies, categorised to minimum species present based on number of specimens able to be identified to species level (Nine samples in total).

Parasite group	Sub-divisions found	Minimum species present
Cestoda	Diphyllobothium, Taenia, Vampirolepis nana	3
Nematoda	Ancylostoma duodenale, Ascaris lumbricoides, Enterobius vermicularis, Trichostrongylus	4
Trematoda	Flukeworms unknown	1

Discussion

A high density of wallabies in the Ballaugh curraghyn has caused a significant reduction in vegetation height and percentage plant cover, endangering biodiversity of both flora and fauna. Both the abundance and species diversity of birds and invertebrates are found to decrease in woodland ecosystems of high herbivory increase, such as that occurring in the north of the Island (González et al., 2017; Vandegehuchte et al., 2017). With 29% of surveyed birds on the island being listed as at the greatest conservation concern, further pressures on these vulnerable species may need to be considered in management strategies if the strain related to the wallabies increases or is maintained long-term (Manx BirdLife 2021).

Native rodents on the Isle may be negatively affected by a loss of vegetation cover, consequently further reducing prey availability for carnivorous mammals and birds native to the island, such as stoats (*Mustela erminea*) and hen harriers (*Circus cyaneus*). Many small mammals rely on complex vegetation composition and cover in the understory of woodland habitat for shelter (Smit et al., 2001). The reduced vegetation cover shown in this research may indicate increased vulnerability of rodents to predation and fatality through insufficient protection from extreme weather. Not only potentially detrimental to the rodent species, but could have a bottom-up effect, reducing prey availability to species such as stouts and birds of prey (Fuller., 2001).

Biomass and evenness shift

The continued presence of wallabies in high density will likely continue to shift the evenness of both plant and animal species present, but not necessarily reduce their overall abundance. As previously discussed, reduction in plant height and cover in woodland can cause the decline in species diversity and abundance in many animal groups, such as birds and invertebrates. However, biomass was not found to have significantly reduced due to the presence of wallabies. This, as well as the findings that plant groups such as rushes and ferns were not significantly reduced in cover suggests that the extent of the negative effects occurring may not be as intense as other situations of high herbivory. Instead, the higher energetic cost of the wallabies than other smaller herbivores in the area, is likely causing a shift in species evenness towards less palatable vegetation, which may also shift the dominance of faunal species inhabiting the curragh (Pringle et al., 2023; Jia et al., 2018; Rees et al., 2017). Understanding this shift in species dominance will be important going forward, so that management strategies can be achieved.

Wallabies for land management

The wallabies of the Isle of Man may be able to be utilised for land management, if access to areas can be reduced or restricted. In many land management strategies, where the opening of land and creation/maintenance of grassland-woodland mosaics are preferential or desired, large herbivores are introduced to suppress vegetation regeneration and create space for species desired by land managers to increase in abundance and prominence (Ribeiro et al., 2023). It is important to note, however, that this use of large herbivores has its beneficial effects most when used for short periods of time. Ribeiro et al., (2023) found that in many studies, allowing herbivores to graze long-term resulted in an overall negative outcome, as biodiversity decreases along with habitat degradation increasing. Some areas of the Ballagh wallabies' current range are already fenced to stop their entrance, in both Goshen and Close Sartfield. Similar fields and less boggy woodland could also be fenced in a similar way, to target the wallaby grazing/browsing. However, the majority of their range is very boggy curragh, which would be far more difficult to access and then implement fencing, meaning their utility in the current range is limited (Vercauteren et al., 2006). This potential use may however become important if new populations establish themselves in other parts of the island.

Wallaby grazing pressures may be of benefit to orchids and other rare flowering species. No control site was found to compare the effect of wallabies at the orchid meadow of Close Sartfield, so it is difficult to draw conclusions based on the transect surveys at the site. However, the results of the WHIA from the location, showed no evidence for wallaby grazing on orchids. Similar results were found by Havlin et al., (2018), who found no traces of orchids in wallaby faeces investigated. These most recent findings further strengthen the evidence that wallabies may be having a negligible effect on orchids. Additionally, the reduced cover of other vegetation in the community such as grasses and other non-woody vegetation, may enable the orchids to become more dominant, potentially increasing their abundance. The reduced plant cover may also increase light reaching the curragh floor, allowing more flowering plants to grow, increasing the proportion of relatively unpalatable species.

There is very limited ground disturbance being caused by the Ballaugh wallabies. Wallabies and macropods collectively are generally perceived to have little impact on vegetation through mechanical disruption, even in areas where they are reported having a significant impact on vegetation in other ways (Bennett 1999; Latham et al., 2020). In the Ballaugh curraghyn, the most ground disturbance recorded only achieved a rating of "Low", suggesting that similar to other regions they inhabit, their impact on vegetation via mechanical disruption is highly limited, if not negligible (Bennett 1999; Latham et al., 2020).

Effect on trees

Indicators suggest the Ballaugh wallabies are having less of an impact on established woodland than other red-necked wallaby populations globally. Populations in their native range of Tasmania as well as alien populations in New Zealand have been shown to cause significant damage via browsing, bark stripping and seedling/sapling suppression (Smith et al., 2020a; Statham,1983; Latham et al., 2020). The impact of the Manx population is less clear, however. The results from the impact assessment suggest the wallabies are having no impact to a low impact on these areas of tree health, with the exception of bark stripping. However, the low damage to seedlings and saplings recorded is not only in contrast to research of other populations, but also in contrast to previous sightings by the wildlife trust. The trust found that the wallabies had completely browsed a newly planted crop of willow saplings, requiring them to plant different tree species that could become established (Davies, 2024). So, although the browsing damage by wallabies measured in this study suggest a reduced effect than found in literature, there are indicators of potential impacts to monitor. The significant bark stripping measured replicates findings of multiple other studies into other red-necked wallaby populations, suggesting that similar damage to the woodland structure they inhabit via disease and reduced resistance to extreme weather may increase

(Jelonek, T. et al., 2022). Collectively, the impacts of the wallabies on their woodland habitat found in the WHIA suggest a shift in non-woody species to less palatable vegetation, also found in the quadrat surveys. This shift in species presence without reduced biomass will not necessarily see a reduction in faunal abundance, but a shift in the dominance of species found (Jia et al., 2018).

Parasite investigations

The Ballaugh wallabies contain a similar volume of parasite eggs as British livestock, suggesting the presence of the wallabies may contribute to the spread of parasites to others in their ecosystem. Most samples collected contained an eggs per gram lower than 400, with a mean of 244 (Figure 21). This average, along with a range of 0-1150, holds similarities to livestock helminths across the UK. A study of nematoda infections in sheep across mainland Britain found the range far exceeded the Isle of Man range, reaching 2000 (epg). The mean epg for both ewes and lambs were very similar to that found in the Ballaugh wallabies (Burgess et al., 2012). Additionally, horses (*Equus caballus*) in the UK have a much larger max epg, but a lower mean epg than the Ballaugh wallabies (Relf et al., 2013). This suggests there may be increased connectivity between farmlands which surround and are a part of the Ballaugh curraghs, as the wallabies occupy and move through land the livestock cannot. Additionally, drone surveys conducted by Harrower (2023), suggest that the wallabies move out into farmland during the night to feed before retracting to the curraghyn to rest during the day. This could be a potential pathway for the spread of helminths between livestock and wallabies, as well as between farms (Gortázar., 2007). However, research on the spread of helminths via movement of small ruminants such as sheep found that increased spread of parasites in various life stages, does not necessarily increase rate of infection (Vasileiou et al., 2015). So, this increased connectivity on the island may not result in higher infection rates.

Unlike other wallaby populations of the British Isles, multiple species of tapeworms were identified (Table 15; Weir., 1995). Since their introduction to Australia, tapeworms have been reported in wallaby populations primarily on the East coast. Research by Barnes, Morton and Coleman (2007), found that all individuals infected had lung cysts, with some experiencing sufficient cyst volume to suggest respiratory distress.

Additionally, the potential for spread with sheep in agriculture and humans, means monitoring of these infections and a better understanding of the spread may not only benefit wallabies, but animals in agriculture and the humans that share their habitat.

Pathological significance of helminths cannot be concluded from these faecal investigations, only indications of wallaby-parasitic pathways with their wider community. As found in research of egg densities in brush-tailed rock wallabies (*Petrogale penicillata*) species, there is not a clear relationship between epg and pathological stress on those infected (Barnes et al., 2010).

It is unlikely that the prominent health issues occurring in the Ballaugh wallabies is caused by helminths. Although multiple studies have found signs of respiratory issues and gastrointestinal lesions caused by helminths in marsupials (Spratt and Beveridge., 2018; Barnes et al., 2007), most helminths have been found to be non-pathological in macropods (Spratt and Beveridge., 2018), although it is expected that their parasite biodiversity is widely underestimated (Beveridge and Spratt., 2015). All three broad groups of parasitic helminths were found in the faecal samples, with a minimum of eight species identified (Table 14 and Table 15). Of the species identified, symptoms are usually mild if not present, or do not match symptoms observed in the population (Davies, 2024; Spratt and Beveridge., 2018; Wunschmann, A., 2024). So, although parasites cannot be discounted as the culprit of this health issue, an emphasis should be placed on investigating other potential causes.

To better understand the cause of health issues observed in many individuals of these wallabies, more autopsies of wallabies found deceased would be very beneficial. The recent autopsy of two individuals found meningoencephalitis in one of the individuals. As meningoencephalitis can result in neurological defects, hearing loss and sight issues, all symptoms observed in wallabies on the Isle Of man in poor condition, the cause of these symptoms is of great welfare importance. The effect of these conditions on the individual and whether it was the cause of the individuals' emaciated state is unknown. In a German zoo, all three red-necked wallabies examined by autopsy had meningoencephalitis, seemingly a product of rustrela virus (Voss et al., 2022). Whether this virus is prevalent on the Isle of Man, or whether conditions common in wallabies are the cause of the population's health issues, is of great importance to understanding the welfare issues of these wallabies.

Limitations/further research

This baseline research has significant findings in relation to the significance of wallabies on vegetation composition on the Isle of Man, as well as indicators as to their effect on disease spread and their current health issues. However, much further research is needed to fully understand what the presence of this introduced species means for native flora and fauna. Monitoring of species within the home range of the wallabies will help better forecast their further impact. Additionally, further surveys of vegetation height, biomass and cover similar to that conducted in this study would benefit from investigating plant communities at a functional level, to gain deeper insights into the effect of herbivory, whether through direct plant competition, apparent competition/associational susceptibility or associational resistance (Huntly., 1991; Barbosa et al., 2009). Repeating the WHIA assessment in future years would be advisable, so that direct comparisons can be made on the effect of current herbivores in the curraghyn to their effect at this time. To better understand the connectivity of disease between wallabies and animal agriculture, it would be beneficial for investigations into the parasitology of nearby farms. This would not only benefit farms involved but may help stem the flow of helminths between these systems. As mentioned previously, further investigations, into the cause of meningoencephalitis found in deceased wallabies would be of great benefit to uncover the cause of welfare issues prevalent in the wallaby population.

Conclusion

The wallabies of the Isle of Man are significantly changing the vegetation composition of their ecosystem, and these effects are likely to continue to become more prevalent as their number increase/stabilise. Vegetation composition is likely to spread to less palatable species such as ferns and woody species, reducing grassland and herbaceous spaces, whilst also opening up the understory in curraghyn. These changes will undoubtably change which animal species can thrive in this altered landscape.

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Appendices

Contributor Role	Persons involved (Kai Wayne Davies- KWD, Tricia Sayle-TS, Luca Borger-LB, Aisling Devine-AD, Gethin Thomas- GT, Helen.M.Armstrong-HMA.
Conceptualisation	KWD, TS, LB, AD, GT
Data Curation	KWD
Formal Analysis	KWD, LB, AD
Funding Acquisition	N/A
Investigation	KWD, TS
Methodology	KWD, TS, LB, AD, GT, HMA

Project Administration	KWD
Resources	KWD, TS, LB, AD, GT
Software	KWD, LB, AD
Supervision	KWD, LB, AD
Validation	N/A
Visualisation	KWD, LB, AD
Writing- original draft preparation	KWD
Writing- Review and editing	KWD, LB, AD

WHIA field sheets:

19

Site: Lodan - Field	Stop no.: 1	Grid ref: 54.32209, -4.5215	Date: 8th May 2024	Surveyor: Kai Dawes

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	Disturbed 0% No impact
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	M	Bark stripping yes <20% ; Fraying no 0% ; Stem breakage no 0%
Basal shoots 0, <25, 25-75, 75-90, >90 %	NI	Grey willow 0 III, <25 ; 25-75, 75-90, >90%
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	L	Grey willow (P) 0 IIII II, <25 IIII, 25-75 I, 75-90, >90% ; Sycamore (P) <25 I ; NA IIII IIII IIII I
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	L	Sycamore (P) 0 IIII, <25, 25-75 II, 75-90, >90%
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	NI-L	Ivy <25 I (1), 0 IIII (5) ; Angelica 0 >100 (100), <25 I (1) ; Meadowsweet 0 >100 (100) ; Male fern 0 III (3), <25 I (1)
Other plants 0, <25, 25-75, 75-90, >90 %	VH	Sweet vernal grass 75-90% >100 (100) ; Tormentil 8 ; Smooth meadow grass 0 ← check ; Soft rush >100 <25% (100), >100 75-90% (100)
Herbivore species /signs		rabbit seen
Notes		Frog seen multiple. Lots of willow with dead branches at browse height.

Tally table (right margin):

Basal shoots	0	P: III
	<25	0
Epicormic	0	P: 7, UP: 0
	<25	P: 6, UP: 0
	25-75	P: 1, UP: 0
Seedlings	0	P: 5
	<25	0
	25-75	2
Preferentially browsed (Total)	0	21
	<25	3
Other plants (Total)	0	200
	<25	100
	75-90	200

No. willow 𝍸 𝍸 𝍸 |||

54.3226, -4.52458

Site: Goldan Curragh + field	Stop no.: 2	Grid ref:	Date: 10th May 2024	Surveyor: Kei Dennis

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	L	No 𝍸 Grey willow; 1 B/ <5%
Basal shoots 0, <25, 25-75, 75-90, >90 %	L	Sycamore (P) <25 1; 0 1 — 0: 1; <25: 1
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	L	Grey willow (P) 0 𝍸 ‖ (7); <25 |||| (4); 25-75 N/A; 75-90; >90; Sycamore (P) 0 |||| (4) — 0: ‖; <25: 4
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	L	Grey willow (P) 0 𝍸 𝍸 𝍸 (17); <25 1 (1); Sycamore (P) <25 ||| (3); 0 1 (1) — 0: 1; <25: 3
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	NI-L	Angelica IVY 0 >100 (100) (100); 0 >100; 0 𝍸 𝍸 (10); <25 |||| (4); Some sort of grass 25-75 >100 (100); unknown grass <25 >100 (100); male fern 0 100 >100; 25 < 1 (1); buckler fern 0 |||| (4) — 0: 214; <25: 5
Other plants 0, <25, 25-75, 75-90, >90 %	H	cock's-foot grass 25-75 1 (1); Soft rush 25-75 >100 (100); 75-90 20-50 (35) — 0: 100; <25: 100; 25-75: 201; 75-90: 35
Herbivore species /signs		two wallabies seen. One lying down / grazing
Notes		misid'd seedling at first, so corrected.

54.3232, -4.52494

Site: Goshen - exclusion (wing)	Stop no.: 3	Grid ref:	Date: 11/05/24	Surveyor: Kai Dawes

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	N/A	NO Impact
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	NI	NO impact
Basal shoots 0, <25, 25-75, 75-90, >90 %	NI	Birch (UP) 0 (18) <25; Willow (P) 0 (2); Ash (P) 0 (1)
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	L	Birch (P) 0 (15) <25 (1); Grey willow (P) 0 (14) <25 (1); Sycamore (P) 0 (9) <25 (1); Ash (P) 0 (1); Elder (P) 0 (1)
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	NI	Sycamore (P) 0 (17) <25
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	NI	Ivy 0 >100 (100) <25% 0; Lady or male fern 0% 50-75 (87.5); Angelica 0 >100 (100); Honeysuckle 0 (10); Meadowsweet 0 >100 (100)
Other plants 0, <25, 25-75, 75-90, >90 %	NI	Soft rush 0
Herbivore species /signs		
Notes	At least 2 grass species, not in flower so unsure species. Ivy dominating 1/3 floor cover + strong prop trees	

Sweet vernal grass?

54.32476, -4.52355

Site: Goshen-TOC Curragh	Stop no.: 4	Grid ref:	Date: 13/06/24	Surveyor: Kat Davis

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	L	Grey willow (P) NO <5% (5); Ash (P) 1 5-20% (1)
Basal shoots 0, <25, 25-75, 75-90, >90 %	L	Sycamore (P) 0 1 (1) <25 1 (1); 4 (P) (P) (P)
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	L	Grey willow (P) 0 (13) <25 (4); birch 0 (4) <25 1 (1); Ash 0 (3); Sycamore 0 (2); Hawthorn 0 (4)
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	NI	Sycamore (P) 0 11 (2); ~~Sycamore 0 >100 (100)~~
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	L	Angelica 0 >100 (100) <25; Ivy (P) 0 <25 (100); Honeysuckle 0 (4) <25 (1); male/lady fern 0 (25) <25
Other plants 0, <25, 25-75, 75-90, >90 %	M	grass 0% >100 (100) <25% >100 (100); soft rush 0 >100 (100) <25 20-50 (35)
Herbivore species /signs		wallaby scats, 4 individuals seen
Notes		

	P	
0	1	
<25	1	

	P	NPW
0	22	4
<25	4	1

	total
0	136
<25	101
0	200
<25	135

19

54.32512, -4.52429

Site: Curragh – North Goshen	Stop no.: 5	Grid ref:	Date: 13/05/24	Surveyor: [illegible]

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	L	Grey willow (P) 111 (3)
Basal shoots 0, <25, 25-75, 75-90, >90 %	NI	Sycamore (P) 011 (2)
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	L	Grey willow (P) 0 ǂǂǂǂ 1 (6) <25 1 (1); Ash (P) 01111 (4); tally: P — 0: 10, <25: 1
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	NI	Sycamore (P) 0 ǂǂǂǂ (5)
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	NI-L	Ivy (100) 0 >100 (100) <25 1 (1); Angelica 0 >100 (100); Honeysuckle <25 11 (2) 01111 (4); Lady/male fern 01111 (4)
Other plants 0, <25, 25-75, 75-90, >90 %	M	Grass >100 (100) very short, not grazed; Soft rush 0 ǂǂǂǂ 111 (8) 25-75 1 (1) <25 1 (1); tally: 0: 108, <25: 1, 25-75: 1
Herbivore species /signs		
Notes		Lots of Ivy covering trees + ground

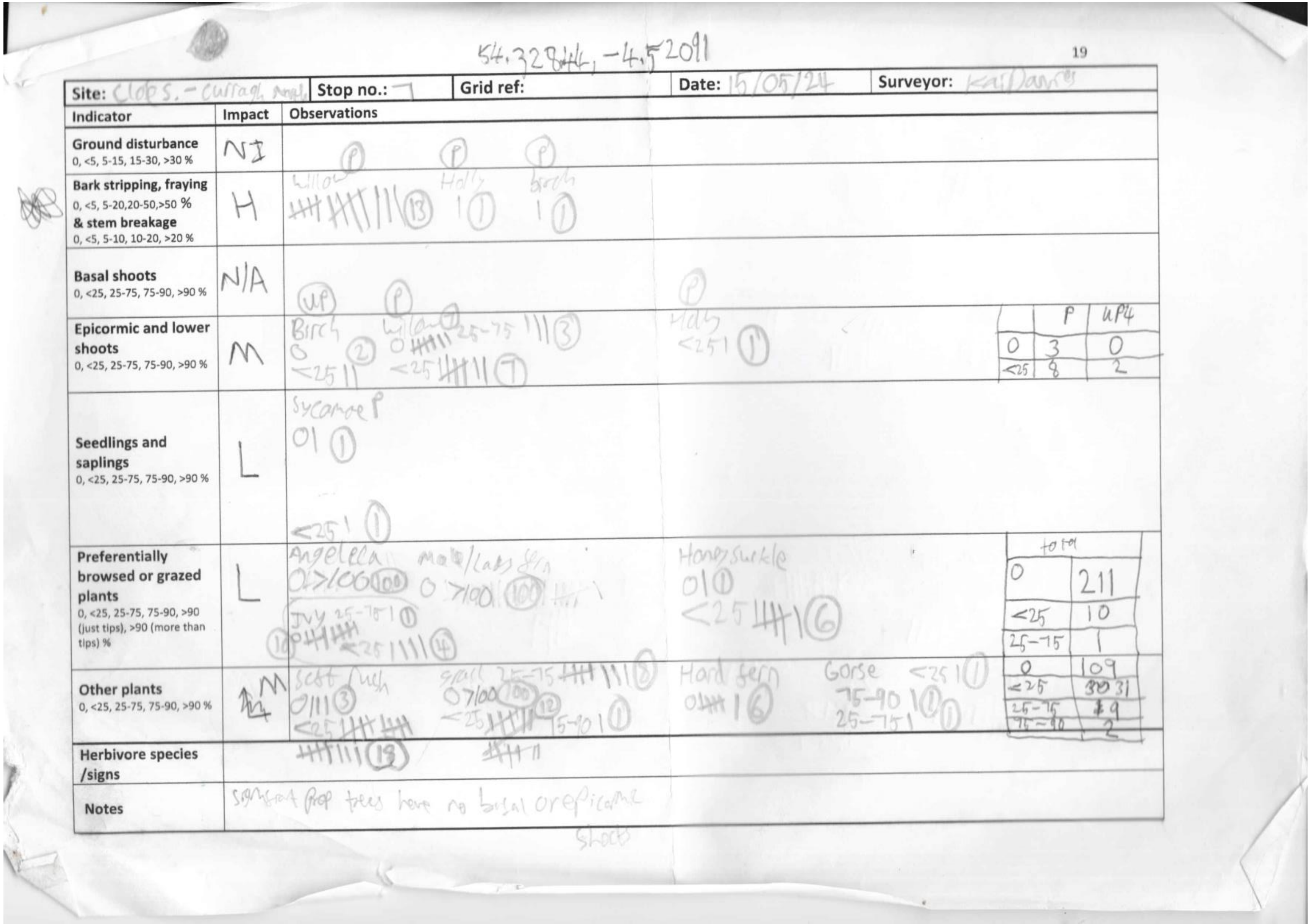
54.32154, -4.52122

Site: Loshon - far east cu	Stop no.: 6	Grid ref:	Date: 13th/05/24	Surveyor:

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	M	willow (P) 6 20-50%; sycamore (P) 1 <5%
Basal shoots 0, <25, 25-75, 75-90, >90 %	NI N/A	
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	L	sycamore (P) 0 7, <25 7; birch (UP) 0 4, <25 1; willow (P) 0 8
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	NI	sycamore (P) 0 1
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	L NI-L	Angelica 0; male fern 0 >100 (100); Ivy 0 >100 (100), <25 3; honeysuckle 0 2, <25 1
Other plants 0, <25, 25-75, 75-90, >90 %	M	small grass 0 3; soft rush 0 >100 (100), <25 50-100 (75)
Herbivore species /signs		
Notes		

	P	UP
0	15	4
<25	7	1

	Total
0	202
<25	4
0	103
<25	75



54.328, -4.52091

19

Site: Clops. - Curragh	Stop no.: 7	Grid ref:	Date: 15/05/24	Surveyor: Kai Danes

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	H	Willow (13) Holly (1) birch (1)
Basal shoots 0, <25, 25-75, 75-90, >90 %	N/A	
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	M	Birch 0 (2) <25 (1); Willow 0 (7) 25-75 (3); Holly <25 (1)
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	L	Sycamore 0 (1) <25 (1)
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	L	Angelica 0 >100 (100); Male/Lady fern 0 >100 (100); Ivy 25-75 (1) 0 (10) <25 (4); Honeysuckle 0 (1) <25 (6)
Other plants 0, <25, 25-75, 75-90, >90 %	M	Soft rush 0 (3) <25 (13); Grass 0 >100 (100) 25-75 (8) <25 (12) 75-90 (1); Hard fern 0 (6); Gorse <25 (1) 75-90 (1) 25-75 (1)
Herbivore species /signs		
Notes	Some tree have no basal or epicormic shoots	

54.32756, -4.52415

Site: Close Sartfield – Meadow	Stop no.: 8	Grid ref:	Date: 16/05/24	Surveyor:
Indicator	**Impact**	**Observations**		
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	(P)		
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	M	willow III (3) 5-20%		
Basal shoots 0, <25, 25-75, 75-90, >90 %	N/A			
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	L	P willow 25-75 II (2) 0 ~~IIII~~ III (8) <25 ~~IIII~~ I (6) UP birch 0III (3)		
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	NI	sycamore P 0 I (1)		
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	NI–L	P Angelica 0>100 (100) <25 I (1) P Ivy 0 I (1)		
Other plants 0, <25, 25-75, 75-90, >90 %	H	Salt rush 0>100 (100) <25 sweet-vernal grass 0 I (1) <25 >100 (100) Pimpernel 0 <25 field woodrush 0>100 (100) <25 III (3) Meadow foxtail 0 III (4)		
Herbivore species /signs	rabbit seen, wallaby seen, wallaby feces			
Notes	common spotted orchid For more grass not grazed than 100%			

	P	UP4
0	8	3
<25	6	0
25-75	2	0

	total
0	201
<25	103

54.32781, -4.52311

19

Site: [illegible]	Stop no.: 9	Grid ref:	Date: 16/05/24	Surveyor: [illegible]

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	VH	willow (6) ~~||||~~ | >50%
Basal shoots 0, <25, 25-75, 75-90, >90 %	N/A	
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	L	willow 0 ~~||||~~ ||| (8) <25 ~~||||~~ | (6)
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	N/A	
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	N/A I	Angelica 0 :50–78 (60)
Other plants 0, <25, 25-75, 75-90, >90 %	[illegible]	common sedge 0 ||(2) <25 25-75 | (1); salt rush 0 >100 (100) <25 25–50 (37.5); [illegible] rush 0 ||| (3); grass 0 >100 (100) <25 ||| (3); [illegible] grass 0 | (1)
Herbivore species /signs	hare seen, lots of wallaby faeces	
Notes	most grass + rush not grazed	

54.32809, -4.51974

19

Site: Close sartesield - Ocdun	Stop no.: 10	Grid ref:	Date: 16/05/24	Surveyor: Becu Daw

Indicator	Impact	Observations
Ground disturbance 0, <5, 5-15, 15-30, >30 %	NI	
Bark stripping, fraying 0, <5, 5-20,20-50,>50 % **& stem breakage** 0, <5, 5-10, 10-20, >20 %	N/A	
Basal shoots 0, <25, 25-75, 75-90, >90 %	N/A	
Epicormic and lower shoots 0, <25, 25-75, 75-90, >90 %	N/A	
Seedlings and saplings 0, <25, 25-75, 75-90, >90 %	N/A	
Preferentially browsed or grazed plants 0, <25, 25-75, 75-90, >90 (just tips), >90 (more than tips) %	N/A	If any ↓
Other plants 0, <25, 25-75, 75-90, >90 %	NI	Bog myrtle <25 0 >100 (100); grass <25 less than 25 read; grass; rush; royal fern 0 𝍸 (5)
Herbivore species /signs		one deer species, at least 6 months ago
Notes		multiple canna drops

Expenditure

Category	Item	Description	Cost*
Consumables	Faecal helminth kit	McMaster, flotation and Baermann analysis of faecal samples	<£50
Consumables	Gloves, sample pots and collection bags	Equipment for faecal and vegetation collection	<£50
Travel	Ferry	England to Isle of Man and return, to conduct field work	£463.72
Conference	Conference fee	ISEC 2024 registration	£300
Relevant training course	Training course fee	Field studies council woodland plant ID course	£80
Total			<£943.72

*Including VAT

Signature (Supervisor)

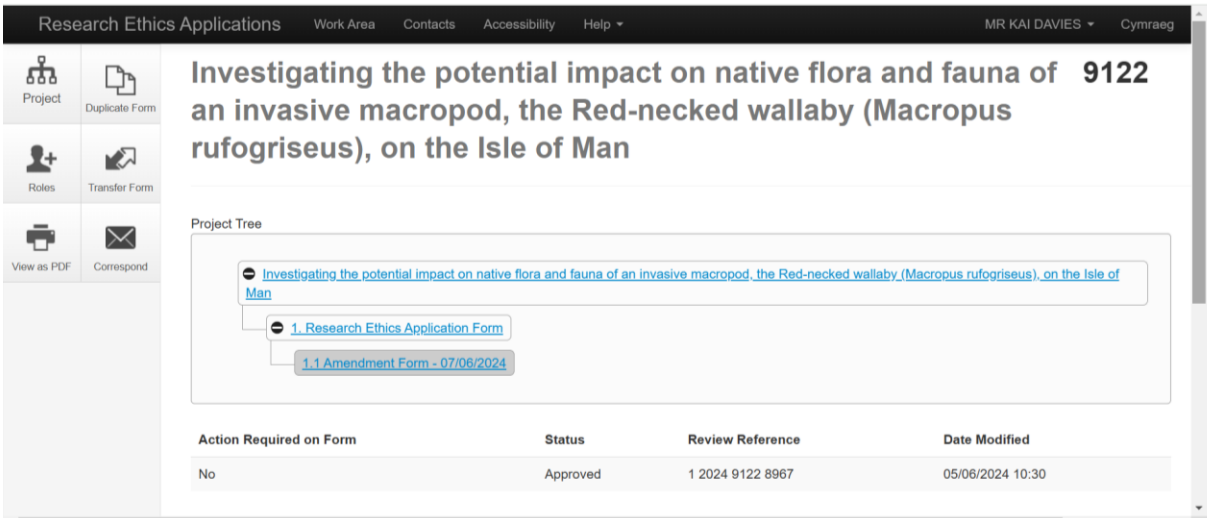
[redacted]

....

Signature (Candidate)

[redacted]............

Ethics approval


Research Ethics Applications | Work Area | Contacts | Accessibility | Help | MR KAI DAVIES | Cymraeg

Project | Duplicate Form | Roles | Transfer Form | View as PDF | Correspond

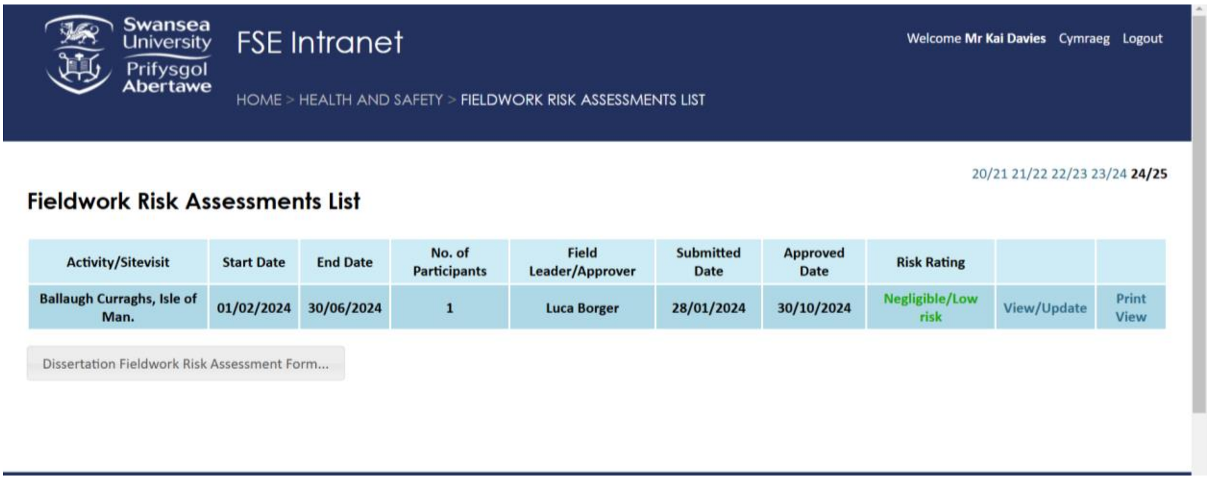
Investigating the potential impact on native flora and fauna of an invasive macropod, the Red-necked wallaby (Macropus rufogriseus), on the Isle of Man **9122**

Project Tree

- Investigating the potential impact on native flora and fauna of an invasive macropod, the Red-necked wallaby (Macropus rufogriseus), on the Isle of Man
  - 1. Research Ethics Application Form
    - 1.1 Amendment Form - 07/06/2024

Action Required on Form	Status	Review Reference	Date Modified
No	Approved	1 2024 9122 8967	05/06/2024 10:30

Field risk assessment


Swansea University Prifysgol Abertawe | FSE Intranet | Welcome Mr Kai Davies | Cymraeg | Logout

HOME > HEALTH AND SAFETY > FIELDWORK RISK ASSESSMENTS LIST

20/21 21/22 22/23 23/24 **24/25**

Fieldwork Risk Assessments List

Activity/Sitevisit	Start Date	End Date	No. of Participants	Field Leader/Approver	Submitted Date	Approved Date	Risk Rating		
Ballaugh Curraghs, Isle of Man.	01/02/2024	30/06/2024	1	Luca Borger	28/01/2024	30/10/2024	Negligible/Low risk	View/Update	Print View

Dissertation Fieldwork Risk Assessment Form...

Lab health and safety

<table>
<tr><td>Name: Kai Davies</td><td>Student number: [redacted]</td></tr>
<tr><td colspan="2">Supervisor(s): Luca Borger and Aisling Devine</td></tr>
<tr><td>Type of project:
A. ☒ laboratory based (no fieldwork).
B. Field and laboratory based.
C. ☐ Field only (no lab space - lab, aquarium, or greenhouse - required).
D. ☐ Desk based</td><td>Space required:
☒Student project lab
☐Student aquarium
☐Greenhouse</td></tr>
<tr><td colspan="2">Completed the FSE Safety & Sustainability course (only needed if you need access to lab space)
Yes ☒</td></tr>
</table>

Not applicable ☐
Project title: Investigating the potential impact on native flora and fauna of an invasive macropod, the Red-necked wallaby (Macropus rufogriseus), on the Isle of Man
Summary of project: In the Isle of Man, wallabies are already known to be present in relatively high densities of at least 1.4 per hectares in the Ballaugh Curragh. Their impact on vegetation in this area will be investigated. The health of the wallabies will also be investigated via faecal examination for parasites.
Sample type(s)/number of samples: 5 cmX5 cm vegetation cuttings, 90 samples to be dried. 10 frozen wallaby faeces samples, each in a 100 ml tube. 10 refrigerated wallaby faeces samples, each in a 100 ml tube.
Type of waste generated: Biological material, plastics.

Equipment list

Below is a list of items we currently stock, please tick any pieces of equipment you will need for your project.

***Requires specialist training from the Technical Team.**

Air stones	☐	Incubator*	☐
Autoclave*	☐	Laminar flow*	☐
Balance	☒	Light microscope	☒
Bunsen burner	☐	PCR*	☐
Centrifuge*	☒	Pipettes	☒
Clamp stands	☒	Shakers	☐
Dissecting microscope	☐	Spectrophotometer*	☐
Fume hood*	☐	Stirrers	☒
Gel electrophoresis*	☐	Water bath	☐
Hot plates	☐	Water pumps/filtering equipment	☐

General Risk Assessment for Teaching and Research Activities

Swansea University; FSE: Biosciences

Name: Kai Davies	**Signature: KAI DAVIES**	**Date: 27/07/2024**
Supervisor: Luca Borger	**Signature: Luca Borger**	**Date: 29/07/2024**
Dissertation project title: Investigating the potential impact on native flora and fauna of an invasive macropod, the Red-necked wallaby (Macropus rufogriseus), on the Isle of Man	**Space required:** ☒**Student project lab** ☐Student aquarium ☐Greenhouse	
Student number: [redacted]	**Start date (cannot predate signature dates: 7/06/24**	
Ethics approval number: 9122	**End date (or 'ongoing'): ongoing**	

Is your project: (tick the appropriate choice A-D)

A. ☒ Laboratory-based only (i.e. you **never** work in the field)
B. ☐ Field AND laboratory-based
C. ☐ Field-only based (i.e. you do not have an allocated laboratory space and **never** work in a laboratory)
D. ☐ Desk based (i.e. no field or laboratory base. i.e. you are only allocated office space [if you are a PhD or research member of staff])

For **category A** complete this Risk Assessment template and associated laboratory protocols, and a Training Record form.

For **category B** complete this Risk Assessment template and associated laboratory protocols, a Training Record form, AND either complete the FSE on-line Field Risk Assessment (**for UG, MSc**) or the relevant University-template form (i.e. Red Form- Off Campus Activities & Risk Assessment Form) (**for MRes, PhD, all staff, visitors**)

For **category C** complete this Risk Assessment template (but not the protocol sheets) and the relevant on-line FSE field risk assessment or University-template forms (see B above for details) and complete a Training Record

For **category D** complete the Training Record template **and** this front page.

<u>*N.B. All</u> staff, visitors and students must have risk assessments for their studies in the University. No work can commence until these have been completed. They must be always available for inspection. Some of these may be paper-based but others can be stored electronically.

art 1: General Risk Assessment

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	S	L	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
Ingestion of faecal matter through contact with skin	Researcher or anyone using work space after researcher.	Ingest harmful parasites or pathogens from samples	Disposable plastic gloves are worn whilst handling samples. Hands washed routinely Waste disposed of by freezing for 24 hours before disposal	2	2	4=moderate	Work stations will be disinfected after use.	2	1	2=low	
Iodine solution	Researcher	Spillage of iodine solution onto skin/eyes	Appropriate PPE, such as lab coat, gloves, goggles and skin covered on legs and feet via long clothing and closed footwear is always	2	1	2=low	N/A				

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	S	L	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
			worn in lab. PPE is also regularly cleaned.								
Stools and other people in the lab	Anyone in the lab	Tripping or colliding with stools or other workers	Any stools are to be tucked under the work bench when not in use to prevent tripping on them. Earphones are not to be worn to ensure awareness of surroundings are not impeded.	1	1	1=low	N/A				
Glass equipment	Anyone in the lab	Stepping on or touching broken glass	Glass equipment should be checked for damage before use. Any breakage of glass should be reported and cleared carefully, to ensure non has been missed	2	1	2=low	N/A				
Contaminants	Researcher and anyone in contact with researcher	Inhalation/ingestion of contaminants	Ensure all water, gas and electric supplies are turned off before leaving lab. Ensure hands are washed after removing lab coat and gloves.	2	1	2=low	N/A				
Sharps/slide	Anyone	Cuts could occur if	Careful use of	2	2	4=moderat	N/A				

What are the hazards?	Who might be harmed?	How could they be harmed?	What are you already doing?	S	L	Risk (SxL)	Do you need to do anything else to manage this risk?	S	L	Risk (SxL)	Additional Action Required
s	near work area	microscope slides break, exposing sharp edges. Injury or disease transmission.	sharps, have a nearby first aid box, sharps should be disposed of in a designated sharps bin			e					
Disinfectant	Anyone near work area	Irritation	PPE always worn whilst disinfectant is in use	1	1	1=low	N/A				
Parasites	Researcher	Parasite infection can cause gastrointestinal illness	Go to doctor if any symptoms occur whilst conducting research	3	1	3=low	N/A				
Electrical, burn and fire.	Researcher and anyone in the lab	Putting explosive material in the oven, burns from exposure to high temperatures of oven and burns from fire if machine not maintained appropriately. Electric shocks and electrical fires can be caused if water is spilled on electrical components of oven.	No liquids are to be consumed or handled near the machine. Door is only opened a long as required to place and replace samples. Door is secured shut when on or off. Any exposed wires are to be reported and the oven not used.	4	1	4=moderate	N/A				

Risk Matrix

		Consequences				
		1 **Insignificant** No injuries/ minimal financial loss	**2** **Minor** First aid treatment/ medium financial loss	**3** **Moderate** Medical treatment/high financial loss	**4** **Major** Hospitalised/ large financial loss	**5** **Catastrophic** Death/ Massive Finanical Loss
Likelihood	**5** **Almost Certain** Often occurs/ once a week	5 Moderate	10 High	15 High	20 Catastrophic	25 Catastrophic
	4 **Likely** Could easily happen/ once a week	4 Moderate	8 Moderate	12 High	16 Catastrophic	20 Catastrophic
	3 **Possible** Could happen/ happen once a year	3 Low	6 Moderate	9 Moderate	12 High	15 High
	2 **Unlikely** Hasn't' yet happened but could happen	2 Low	4 Moderate	6 Moderate	8 High	10 High
	1 **Rare** Concievable but 1/100 year event	1 Low	2 Low	3 Low	4 Moderate	5 Moderate

Summary of laboratory and/or field protocols used.

Protocol sheets to be appended and updated as necessary.

#	Title	1st Assessment Date	Frequency of re-assessment
1	McMaster egg count	N/A	
2	Baermann technique	N/A	
3	Quantitative test tube flotation	N/A	
4	Faecal smear	N/A	
5	Faecal sedimentation	N/A	
6	Vegetation drying	N/A	
7			
8			
9			
10			

Reassessment - the first reassessment must be undertaken as soon as possible after the first time the protocol has been undertaken in order to identify any unforeseen hazards. After this first reassessment, the protocol should be reassessed every 6-12m. The protocol must be reassessed immediately if new knowledge on the chemical hazards becomes available.

Protocol Risk Assessment Form (Laboratory-only)

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol # **1**	**Title:** **McMaster egg count**
Associated Protocols ***#........N/A..................***	**Location and local rules** *In addition to Good Laboratory Practice, identify any local rules that apply (specific risks and control measures for work in this environment).* **Not applicable beyond general good lab practice, or beyond anything already described in risk assessment (pages 6-7).**

Description of the protocol: 4g of faeces is to be weighed and placed in container, with 56ml of chosen fluid. The contents are then stirred with a spatula. A tea strainer is used to filter into a second container. The sample in the second container is then stirred with a Pasteur pipette. A sub-sample is withdrawn using the pipette whilst the filtrate is still being stirred. Fill first compartment of McMaster counting chamber with sub-sample. Stir filtrate again, and fill second chamber with another sub-sample. After leaving counting chambers to stand for five minutes, chambers are investigated using a compound microscope. Eggs are to be counted and identified in each engraved area.

Additional risks and control measures specific to this protocol:

In addition to the local rules, identify the risks associated with use of equipment (e.g. autoclaves, centrifuges), other mechanical and electrical hazards AND control measures.
**Note chemical hazards are summarised below and any biological hazards should be identified in a separate Biological Risk Assessment form.*

Appropriate PPE to be worn so as not to spread harmful pathogens in samples. Samples to be frozen before disposal.

Who or what may be harmed?	**Vulnerable groups present:**
☒ Staff/ PG student carrying out the activity ☐ Contractors ☐ Visitors ☐ Cleaners ☐ Maintenance staff ☐ UG student carrying out activity ☒ Other staff/ students in the vicinity	☐ U18/ U16 ☐ New or expectant mother ☐ Other: ☒ **Environment** (via release to air/water/ground, or incorrect disposal)

PROTOCOL RISK MANAGEMENT

Secondary Containment (of protocol): e.g. open bench/fume hood/special **N/A**	
Measures taken to eliminate or substitute/reduce: e.g. using less hazardous, less volume of chemicals N/A	
Personal Protective Equipment and all specific control measures Include a full description e.g. latex/nitrile/heavy gloves; safety glasses, screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state) Lab coat and latex gloves to be worn at all times. Long clothing and enclosed footwear to reduce amount of exposed skin.	
Emergency procedures (include first aid, fire, spillage, communication methods) N.B. full emergency plans for each chemical are detailed in individual Chemical data Sheets First aid kit always in lab. Spillages and communication for assistance will be conducted as suggested in University training/policy.	
Is exposure monitoring required? No	**Is health surveillance required?** No
Justification and controls for any work outside normal hours (N.B. UG project students cannot work outside normal hours in a laboratory) N/A	
Supervision/training for worker (highlight) **N.B. All relevant training forms (e.g. for specific laboratories) should be completed** None required Already trained **Training required** Supervised always	
Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures. *Name & signature of worker ....KAI DAVIES..* *Name & counter-signature of supervisor..........Luca Borger...* *Date.....06/06/24..................*	

Protocol Risk Assessment Form (Laboratory-only)

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol # **2**	**Title:** **Baermann technique**
Associated Protocols ***#........N/A..................***	**Location and local rules** *In addition to Good Laboratory Practice, identify any local rules that apply (specific risks and control measures for work in this environment).* **Not applicable beyond general good lab practice, or beyond anything already described in risk assessment (pages 6-7).**

Description of the protocol: 5-10g of faeces is placed on cheesecloth, then lift all four corners of cloth around faeces. A rubber band is then used to close the pouch, and a stick placed under the band to enable pouch to be suspended. The pouch is then to be placed in a funnel. The funnel should have a clamped tube attached at the stem, and be held vertical by a stand. The funnel is then filled with water, so that cheesecloth is submerged and to be left standing for 24 hours. A few millimeters of fluid will then be extracted and left for 30 minutes. Pipette from this sample onto a microscope slide and add iodine, so that nematodes can be seen using a compound microscope.	
Additional risks and control measures specific to this protocol: *In addition to the local rules, identify the risks associated with use of equipment (e.g. autoclaves, centrifuges), other mechanical and electrical hazards AND control measures. *Note chemical hazards are summarised below and any biological hazards should be identified in a separate Biological Risk Assessment form.* Appropriate PPE to be worn so as not to spread harmful pathogens in samples. Samples to be frozen before disposal.	
Who or what may be harmed? ☒ Staff/ PG student carrying out the activity ☐ Contractors ☐ Visitors ☐ Cleaners ☐ Maintenance staff ☐ UG student carrying out activity ☒ Other staff/ students in the vicinity	**Vulnerable groups present:** ☐ U18/ U16 ☐ New or expectant mother ☐ Other: ☒ **Environment** (via release to air/water/ground, or incorrect disposal)

PROTOCOL RISK MANAGEMENT

Secondary Containment (of protocol): e.g. open bench/fume hood/special

N/A

Measures taken to eliminate or substitute/reduce: e.g. using less hazardous, less volume of chemicals

N/A

Personal Protective Equipment and all specific control measures Include a full description e.g. latex/nitrile/heavy gloves; safety glasses, screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state)
Lab coat and latex gloves to be worn at all times. Long clothing and enclosed footwear to reduce amount of exposed skin.

Emergency procedures (include first aid, fire, spillage, communication methods) N.B. full emergency plans for each chemical are detailed in individual Chemical data Sheets

First aid kit always in lab. Spillages and communication for assistance will be conducted as suggested in University training/policy.

Is exposure monitoring required? No	**Is exposure monitoring required?** No

Justification and controls for any work outside normal hours (N.B. UG project students cannot work outside normal hours in a laboratory)

N/A

Supervision/training for worker (highlight) **N.B. All relevant training forms (e.g. for specific laboratories) should be completed**

None required Already trained **Training required** Supervised always

Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures.

Name & signature of worker ....KAI DAVIES..

Name & counter-signature of supervisor.. *Date.....06/06/24..................*

Date of first reassessment Frequency of reassessments

Protocol Risk Assessment Form (Laboratory-only)

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol # **3**	**Title:** **Quantitative test tube flotation**
Associated Protocols ***#........N/A..................***	**Location and local rules** *In addition to Good Laboratory Practice, identify any local rules that apply (specific risks and control measures for work in this environment).* **Not applicable beyond general good lab practice, or beyond anything already described in risk assessment (pages 6-7).**

Description of the protocol: 3g of faeces in tea strainer is placed into mortar with 42ml of water and grinded until broken down. Then, remove tea strainer and any matter remaining inside it. Stir mortar contents before pouring into four centrifuge tubes. Samples are then in centrifuge at 1500 r.p.m foe two minutes. Will then add 0.5ml of saturated NaCl to tubes. Each tube will be inverted six times carefully, with thumb on end. Tubes will then be placed in test tube rack and NaCl added to form positive meniscus. A number 2 22x22mm, coverslip is then added. After two hours, coverslips can then be removed and placed on a microscope slide so that eggs can be counted using a microscope.	
Additional risks and control measures specific to this protocol: *In addition to the local rules, identify the risks associated with use of equipment (e.g. autoclaves, centrifuges), other mechanical and electrical hazards AND control measures. *Note chemical hazards are summarised below and any biological hazards should be identified in a separate Biological Risk Assessment form.* Appropriate PPE to be worn so as not to spread harmful pathogens in samples. Samples to be frozen before disposal.	
Who or what may be harmed? ☒ Staff/ PG student carrying out the activity ☐ Contractors ☐ Visitors ☐ Cleaners ☐ Maintenance staff ☐ UG student carrying out activity ☒ Other staff/ students in the vicinity	**Vulnerable groups present:** ☐ U18/ U16 ☐ New or expectant mother ☐ Other: ☒ **Environment** (via release to air/water/ground, or incorrect disposal)

PROTOCOL RISK MANAGEMENT

Secondary Containment (of protocol): e.g. open bench/fume hood/special **N/A**	
Measures taken to eliminate or substitute/reduce: e.g. using less hazardous, less volume of chemicals N/A	
Personal Protective Equipment and all specific control measures Include a full description e.g. latex/nitrile/heavy gloves; safety glasses, screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state) Lab coat and latex gloves to be worn at all times. Long clothing and enclosed footwear to reduce amount of exposed skin.	
Emergency procedures (include first aid, fire, spillage, communication methods) N.B. full emergency plans for each chemical are detailed in individual Chemical data Sheets First aid kit always in lab. Spillages and communication for assistance will be conducted as suggested in University training/policy.	
Is exposure monitoring required? No	**Is exposure monitoring required?** No
Justification and controls for any work outside normal hours (N.B. UG project students cannot work outside normal hours in a laboratory) N/A	
Supervision/training for worker (highlight) **N.B. All relevant training forms (e.g. for specific laboratories) should be completed** None required Already trained **Training required** Supervised always	
Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures. *Name & signature of worker ....KAI DAVIES..* *Name & counter-signature of supervisor...* *Date.....06/06/24..................*	

Protocol Risk Assessment Form (Laboratory-only)

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol # **4**	**Title:** **Faecal smear**
Associated Protocols ***#........N/A..................***	**Location and local rules** *In addition to Good Laboratory Practice, identify any local rules that apply (specific risks and control measures for work in this environment).* **Not applicable beyond general good lab practice, or beyond anything already described in risk assessment (pages 6-7).**

Description of the protocol: Smear faeces onto microscope slide and add a few drops of water. Add coverslip and then investigate sample with microscope.

Additional risks and control measures specific to this protocol:

In addition to the local rules, identify the risks associated with use of equipment (e.g. autoclaves, centrifuges), other mechanical and electrical hazards AND control measures.
**Note chemical hazards are summarised below and any biological hazards should be identified in a separate Biological Risk Assessment form.*

Not applicable beyond general good lab practice, or beyond anything already described in risk assessment (pages 6-7).

Who or what may be harmed? ☒ Staff/ PG student carrying out the activity ☐ Contractors ☐ Visitors ☐ Cleaners ☐ Maintenance staff ☐ UG student carrying out activity ☒ Other staff/ students in the vicinity	**Vulnerable groups present:** ☐ U18/ U16 ☐ New or expectant mother ☐ Other: ☒ **Environment** (via release to air/water/ground, or incorrect disposal)

PROTOCOL RISK MANAGEMENT

Secondary Containment (of protocol): e.g. open bench/fume hood/special **N/A**	
Measures taken to eliminate or substitute/reduce: e.g. using less hazardous, less volume of chemicals N/A	
Personal Protective Equipment and all specific control measures Include a full description e.g. latex/nitrile/heavy gloves; safety glasses, screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state) Lab coat and latex gloves to be worn at all times. Long clothing and enclosed footwear to reduce amount of exposed skin.	
Emergency procedures (include first aid, fire, spillage, communication methods) N.B. full emergency plans for each chemical are detailed in individual Chemical data Sheets First aid kit always in lab. Spillages and communication for assistance will be conducted as suggested in University training/policy.	
Is exposure monitoring required? No	**Is exposure monitoring required?** No
Justification and controls for any work outside normal hours (N.B. UG project students cannot work outside normal hours in a laboratory) N/A	
Supervision/training for worker (highlight) **N.B. All relevant training forms (e.g. for specific laboratories) should be completed** None required Already trained **Training required** Supervised always	
Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures. *Name & signature of worker ....KAI DAVIES..* *Name & counter-signature of supervisor...* *Date.....06/06/24..................*	

Protocol Risk Assessment Form (Laboratory-only)

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol # **5**	**Title:** **Faecal sedimentation**
Associated Protocols ***#........N/A..................***	**Location and local rules** *In addition to Good Laboratory Practice, identify any local rules that apply (specific risks and control measures for work in this environment).* **Not applicable beyond general good lab practice, or beyond anything already described in risk assessment (pages 6-7).**

Description of the protocol: Place 3g of faeces into a container with 50ml of water and stir, before filtering into a second container using a tea strainer. Pour the solution not a test tube and leave to sediment for five minutes, after which the sediment can be resubmerged in 5ml of water and sediment for five additional minutes. The sediment is then stained with methylene blue. The sediment can then be removed in small quantities for examination under microscope.

Additional risks and control measures specific to this protocol:

In addition to the local rules, identify the risks associated with use of equipment (e.g. autoclaves, centrifuges), other mechanical and electrical hazards AND control measures.
**Note chemical hazards are summarised below and any biological hazards should be identified in a separate Biological Risk Assessment form.*

Who or what may be harmed? ☒ Staff/ PG student carrying out the activity ☐ Contractors ☐ Visitors ☐ Cleaners ☐ Maintenance staff ☐ UG student carrying out activity ☒ Other staff/ students in the vicinity	**Vulnerable groups present:** ☐ U18/ U16 ☐ New or expectant mother ☐ Other: ☒ **Environment** (via release to air/water/ground, or incorrect disposal)

PROTOCOL RISK MANAGEMENT

Secondary Containment (of protocol): e.g. open bench/fume hood/special **N/A**	
Measures taken to eliminate or substitute/reduce: e.g. using less hazardous, less volume of chemicals N/A	
Personal Protective Equipment and all specific control measures Include a full description e.g. latex/nitrile/heavy gloves; safety glasses, screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state) Lab coat and latex gloves to be worn at all times. Long clothing and enclosed footwear to reduce amount of exposed skin.	
Emergency procedures (include first aid, fire, spillage, communication methods) N.B. full emergency plans for each chemical are detailed in individual Chemical data Sheets First aid kit always in lab. Spillages and communication for assistance will be conducted as suggested in University training/policy.	
Is exposure monitoring required? No	**Is exposure monitoring required?** No
Justification and controls for any work outside normal hours (N.B. UG project students cannot work outside normal hours in a laboratory) N/A	
Supervision/training for worker (highlight) **N.B. All relevant training forms (e.g. for specific laboratories) should be completed** None required Already trained **Training required** Supervised always	
Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures. *Name & signature of worker ....KAI DAVIES..* *Name & counter-signature of supervisor..* *Date.....06/06/24..................*	
Date of first reassessment Frequency of reassessments	

Protocol Risk Assessment Form (Laboratory-only)

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol # **6**	**Title:** **Vegetation drying**
Associated Protocols ***#........N/A..................***	**Location and local rules** *In addition to Good Laboratory Practice, identify any local rules that apply (specific risks and control measures for work in this environment).* **Not applicable beyond general good lab practice, or beyond anything already described in risk assessment (pages 6-7).**

Description of the protocol: Oven turned on and set to 70°C and left to heat up. Foil container weighed on a balance. Vegetation sample is then placed in the foil container and weighed. The sample is then placed in the oven and left to dry until the weight is consistent.

Additional risks and control measures specific to this protocol:

In addition to the local rules, identify the risks associated with use of equipment (e.g. autoclaves, centrifuges), other mechanical and electrical hazards AND control measures.

**Note chemical hazards are summarised below and any biological hazards should be identified in a separate Biological Risk Assessment form.*

Who or what may be harmed? ☒ Staff/ PG student carrying out the activity ☐ Contractors ☐ Visitors ☐ Cleaners ☐ Maintenance staff ☐ UG student carrying out activity ☒ Other staff/ students in the vicinity	**Vulnerable groups present:** ☐ U18/ U16 ☐ New or expectant mother ☐ Other: ☒ **Environment** (via release to air/water/ground, or incorrect disposal)

PROTOCOL RISK MANAGEMENT

Secondary Containment (of protocol): e.g. open bench/fume hood/special **N/A**	
Measures taken to eliminate or substitute/reduce: e.g. using less hazardous, less volume of chemicals N/A	
Personal Protective Equipment and all specific control measures Include a full description e.g. latex/nitrile/heavy gloves; safety glasses, screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state) Lab coat and latex gloves to be worn at all times. Long clothing and enclosed footwear to reduce amount of exposed skin.	
Emergency procedures (include first aid, fire, spillage, communication methods) N.B. full emergency plans for each chemical are detailed in individual Chemical data Sheets First aid kit always in lab. Spillages and communication for assistance will be conducted as suggested in University training/policy.	
Is exposure monitoring required? No	**Is exposure monitoring required?** No
Justification and controls for any work outside normal hours (N.B. UG project students cannot work outside normal hours in a laboratory) N/A	
Supervision/training for worker (highlight) **N.B. All relevant training forms (e.g. for specific laboratories) should be completed** None required Already trained **Training required** Supervised always	
Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures. *Name & signature of worker ....KAI DAVIES...*	

Name & counter-signature of supervisor...	*Date.....06/06/24..................*
Date of first reassessment	Frequency of reassessments