Ideal habitat for the marsh fritillary *Euphydryas aurinia* (Rottemburg, 1775) in Sheskinmore Nature Reserve, County Donegal

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Rationale

The marsh fritillary, *Euphydryas aurinia*, is a listed species (van Swaay et al., 2014), and is on the 2009 IUCN Red List as 'Vulnerable' (Newland et al., 2015). It is one of Europe's most rapidly declining butterflies (Thomas and Lewington, 2010), considered 'regionally endangered' across much of Europe (Pielech et al., 2017). It is listed in Annex II of the European Community Habitats and Species Directive (92/43/EEC) and has suffered severe declines across Europe since the 20th century (Asher et al., 2001; van Swaay and Warren, 1999). The marsh fritillary is one of Ireland's few legally protected butterflies under the EU Habitats and Species Directive (IWT, no date). The current status of marsh fritillaries in Ireland is unclear, but some studies estimate a greater than 30 percent reduction in populations since 1995 (Regan et al., 2010). Insufficient data and inappropriate conservation strategies, which fail to comprehend the within-patch, micro-scale habitat quality (Thomas and Morris, 1994), and the inter-patch spatial structure of metapopulations (Hanski, 1999) have been unsuccessful in slowing down the species decline.

Sheskinmore Nature Reserve is a designated Special Area of Conservation (SAC) and a Special Protection Area (SPA) (NPWS, 2015), 300 hectares of which is owned and managed by the National Parks and Wildlife Service (NPWS) (Glenveagh National Park, 2022). One of the qualifying interests for the SAC (West of Ardara/Maas Road) is the marsh fritillary and one of the conservation objectives of the area is "to maintain the favourable conservation condition of marsh fritillary" in terms of distribution, breeding, and good quality habitat area (NPWS, 2015). The area is rich in butterfly diversity, and Devil's-bit scabious grows widely across the dune-machair environment at Sheskinmore, providing a breeding place for marsh fritillary, but larvae webs are recorded only in discrete locations each year (*pers. comms.* Magee, 2022).

Certain habitat preferences of the declining marsh fritillary are well understood, such as the abundance of their foodplant, Devil's-bit scabious, a vegetation height of at least 4cm, and variation in vegetation structure. It is also widely cited that marsh fritillaries exist as metapopulations and therefore require a network of habitat patches. However, knowledge of the habitat associations, habitat use, and general behaviour of marsh fritillaries at different life stages is limited. In Sheskinmore, there is very little understanding of how the adult marsh fritillaries use the dune habitats, nor why only some specific areas of Devil's-bit scabious are occupied by larvae.

This study has the following aims:

- To investigate habitat associations for marsh fritillaries.

- To assess the habitat condition, vegetation structure, and habitat composition in different areas of Sheskinmore used by marsh fritillaries.

- To assess the temporal changes in habitat condition in areas used by marsh fritillaries including changes in vegetation height and density of Devil's-bit scabious using primary and secondary data.

- To map sightings of adult marsh fritillaries, combined with analysis of historic larval web records (from NPWS).

- To consider and offer recommendations for the conservation management of habitats for marsh fritillaries in and beyond Sheskinmore.

Methodology

Three areas within Sheskinmore were studied: Magheramore, Mullyvea, and Carrickalahagh (*Figure 1)*, based on previous larval web studies and field observations. Habitat condition and vegetation surveys were conducted by systematically sampling each area using a 1m² quadrat. Counts of adult marsh fritillaries were taken along a transect walk over 21 days in late May to mid-June, 2022, to coincide with their flight period. An average daily count per study area was calculated, which was used with flight areas in hectares to provide an absolute population estimate (A), as adapted from Porter and Ellis (2011):

$$Absolute\ population\ estimate\ (A) = average\ adult\ marsh\ fritillaries\ counted\ per\ day\ x\ flight\ area\ (ha)$$

This method assumes an even distribution of adult butterflies across the search area, whereas, in reality, they are often concentrated in certain areas. Therefore, although dated, a formula taken from Warren (1994) was used to estimate relative adult numbers $(y = 6.039)$ from absolute adult numbers $(x = 0.198)$ to predict approximate population sizes at peak flight periods, according to data from mark-recapture techniques:

$$Population\ index\ (P) = A\ \times (x + y)$$

Historic larval web surveys, field observations, communications with local naturists, and farm management plans were also analysed to ascertain the factors influencing the ideal habitat for marsh fritillary in Sheskinmore. Habitat classifications were derived from the vegetation survey data using TWINSPAN analysis. An ANOVA was performed to determine significant differences in the abundance of Devil's-bit scabious between the study areas, and a PCA was used to summarise the level of similarity across the samples.

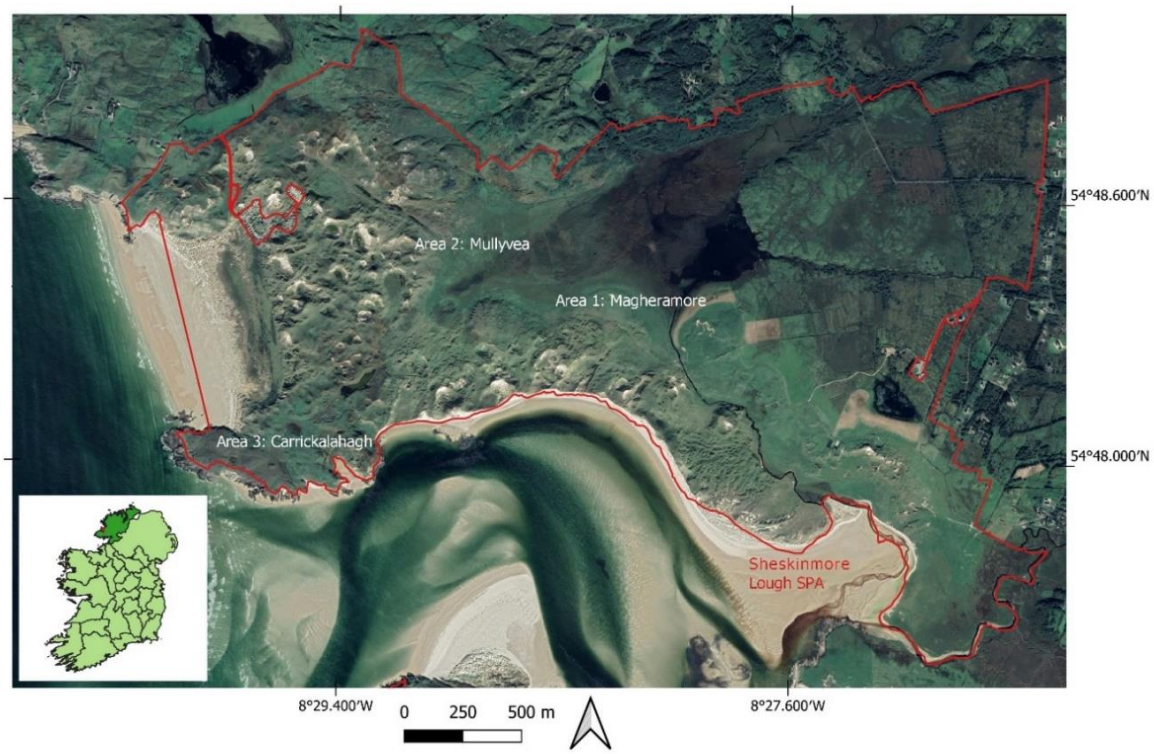

Figure 1. Locations of the three study areas in Sheskinmore Nature Reserve

Summary of findings

Adult marsh fritillaries were spotted throughout the range of the transect walk, with the highest concentration on Carrickalahagh headland to the south of Tramore beach and in Mullyvea, behind the dune system to the east of the beach (*Figure 2*). Few adult marsh fritillaries were spotted in the Magheramore area. Marsh fritillaries were spotted exhibiting a range of behaviours *(Figure 3*). Many other butterfly species were spotted either resting or in flight along the transect walk (*Figure 4*), the most common being Small heath (*Coenonympha pamphilus*). Small heath, Small blue (*Cupido minimus*), and Green hairstreak (*Callophrys rubi*) are considered 'companion species' which are often seen flying together (Aldwell and Smyth, 2013). The full list of sightings can be found in *Appendix 1*.

Although adult marsh fritillaries were sighted in all three study areas (*Figure 5)*, the population index (*Figure 6)* suggests that each study area is supporting a different size marsh fritillary population, with Carrickalahagh having the highest predicted population followed by Mullyvea and Magheramore.

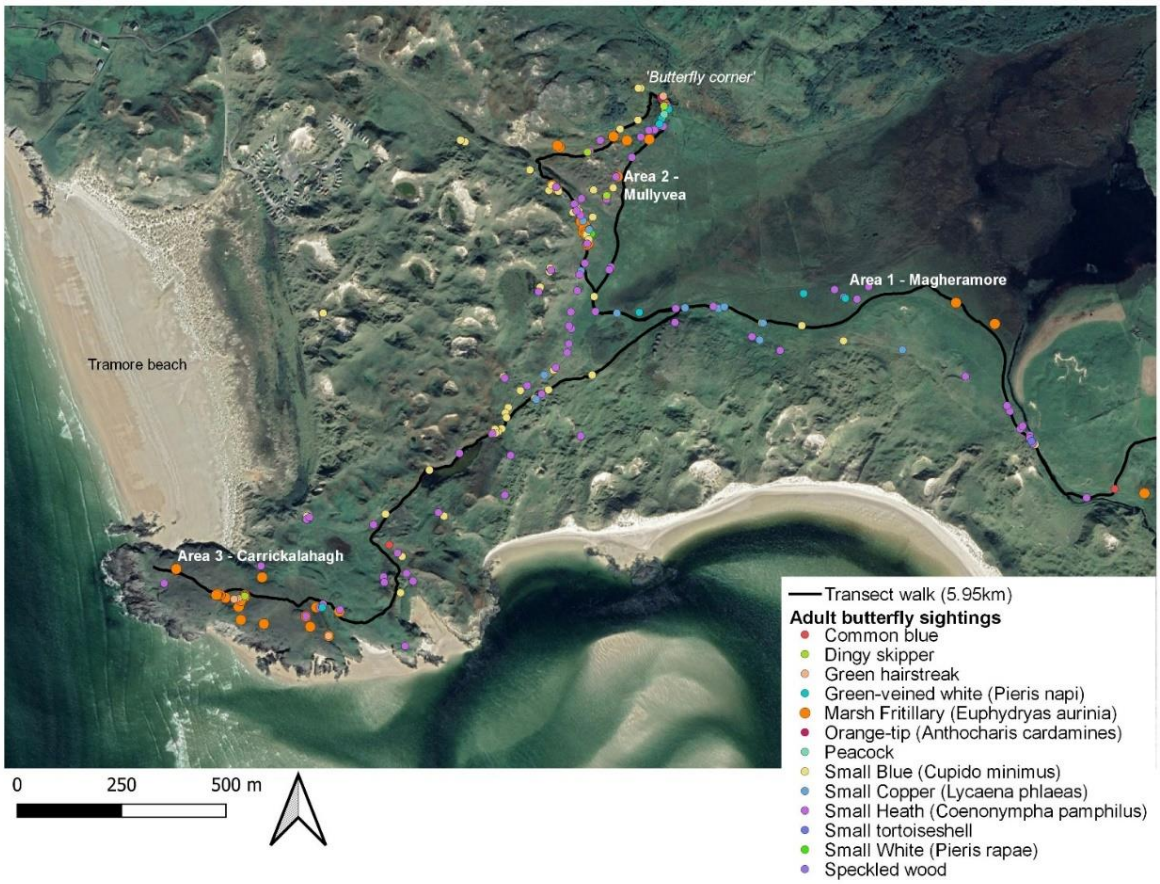

Figure 2. Adult butterfly sightings along the transect walk

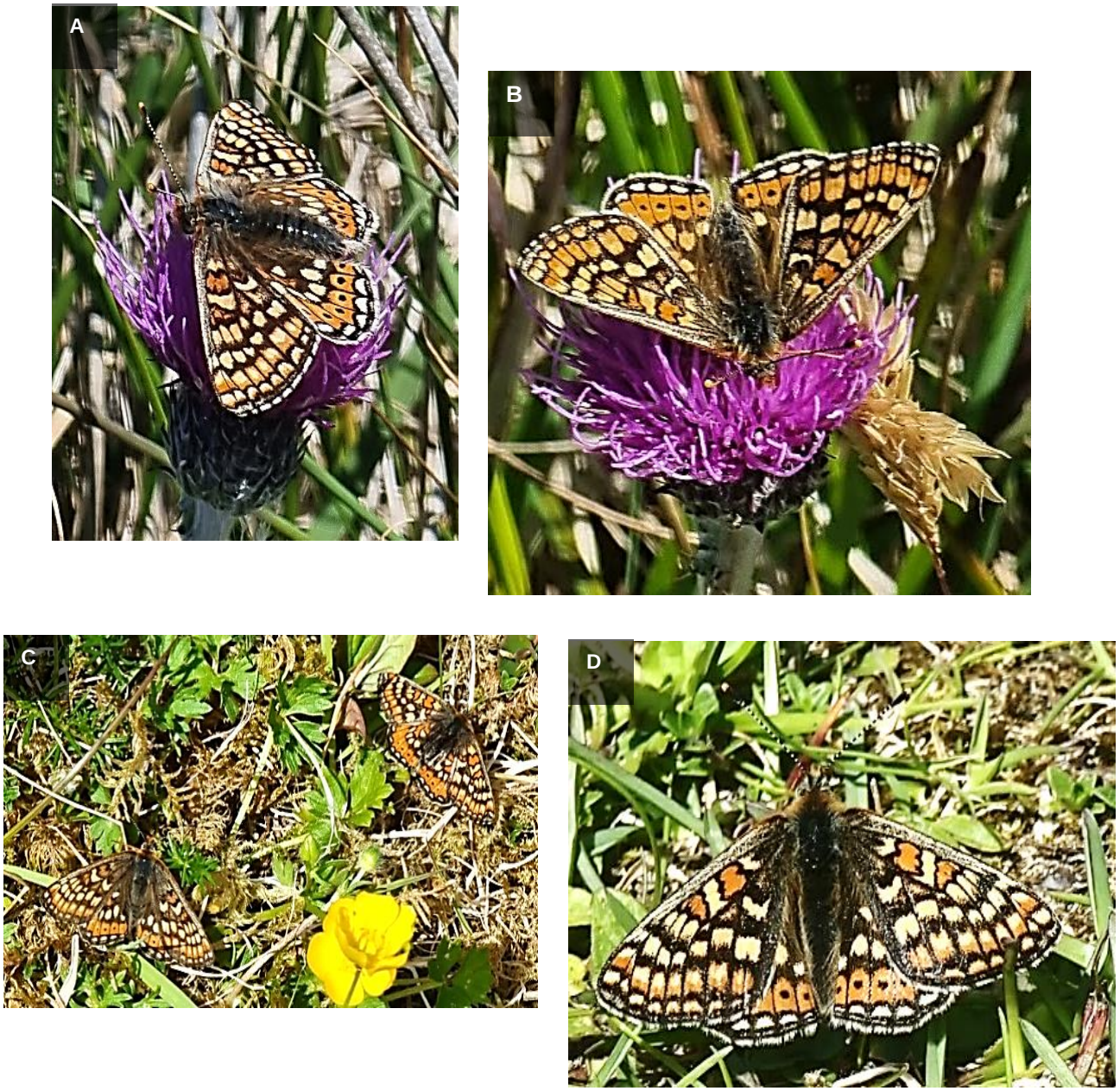

Figure 3. A marsh fritillary adult resting on a marsh thistle flower (A) and (B), a pair of marsh fritillary adults basking on the ground (C), and a marsh fritillary adult basking on the ground (D)

Figure 4. A Green-veined white (A), a Peacock butterfly on a nettle (B), a Small tortoiseshell basking on the ground (C), a pair of Small blues mating (D), a Small blue with open wings (E), a Green hairstreak on a Marsh thistle (F), a pair of Dingy skippers mating (G), a Small copper on a Meadow buttercup (H)

Figure 5. Adult marsh fritillaries sighted in each study area

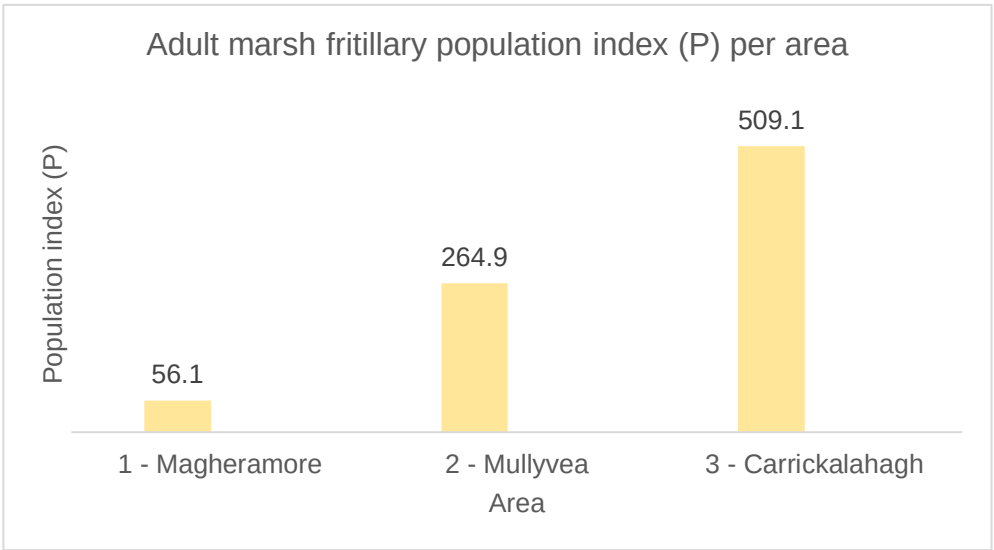

Figure 6. Adult marsh fritillary population index (P) per study area.

Magheramore and Mullyvea (subsite 1) had the same mode vegetation height, whereas vegetation in Mullyvea (subsite 2) was taller and on Carrickalahagh is shorter (*Table 2)*. All four areas had a greater than 40% frequency of Devil's-bit scabious, although in Carrickalahagh most of this was low density (1-2 plants per m²), and most of the higher density Devil's-bit scabious was in low swards (*Figure 7)*. Both subsites in Mullyvea had a high frequency of category C and C+ Devil's-bit scabious (10-20 and 20+ plants per m² respectively). Magheramore and Mullyvea (subsite 1) had the highest frequency of category B/C/C+ Devil's-bit scabious in 12-25cm swards. Mullyvea (subsite 2) had the highest density of Devil's-bit scabious in >25cm swards. All sites had a high proportion of structure vegetation. All sites, except Carrickalahagh, had low invading scrub. Mullyvea (subsite 2) had the highest proportion of low invading scrub, which consisted of bracken, juniper and burnet rose, and the highest proportion of tall scrub cover (>0.5m) and was deemed as a suitable but under grazed habitat. Carrickalahagh had the lowest frequency of stock grazing signs yet was deemed as a suitable but overgrazed habitat. Generally, areas with denser Devil's-bit scabious tended to coincide with areas that had the most adult marsh fritillary sightings (*Figure 8)*.

Table 1. Mode vegetation height of the survey sites

Measure	Magheramore	Mullyvea (subsite 1)	Mullyvea (subsite 2)	Carrickalahagh
Mode vegetation height	12-25cm	12-25cm	>50cm	<12cm

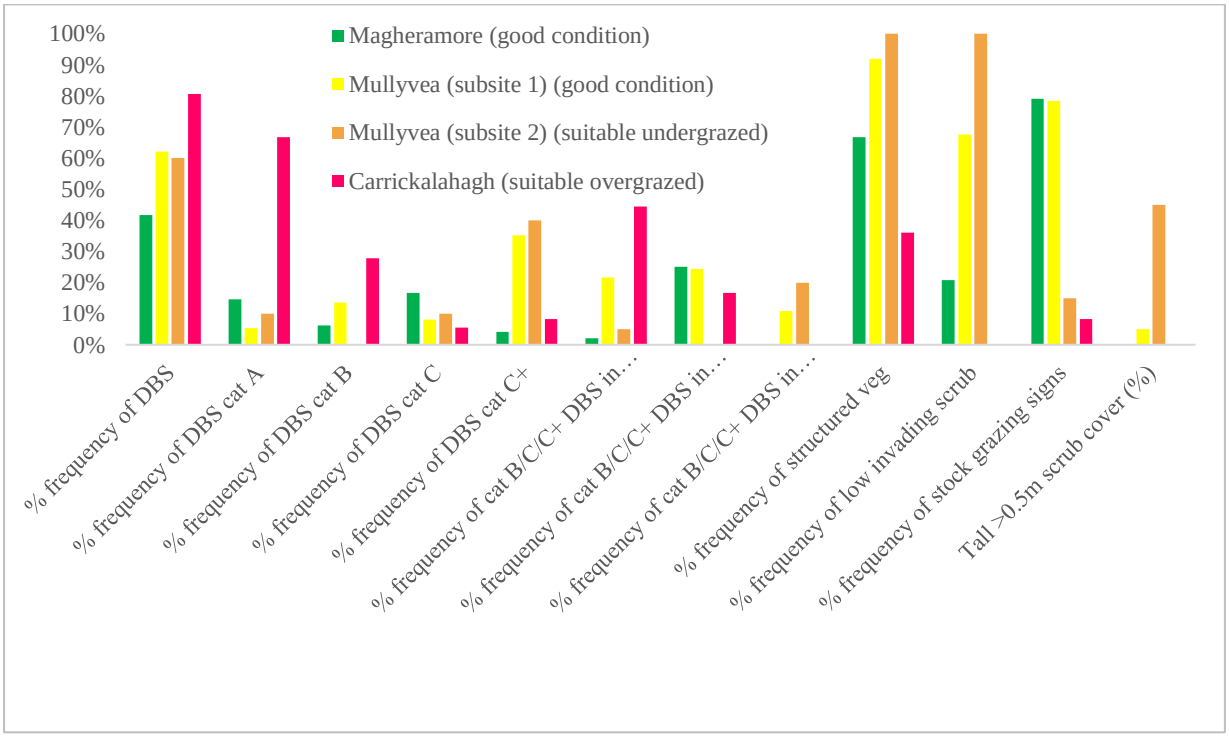

Figure 7. Habitat condition survey results

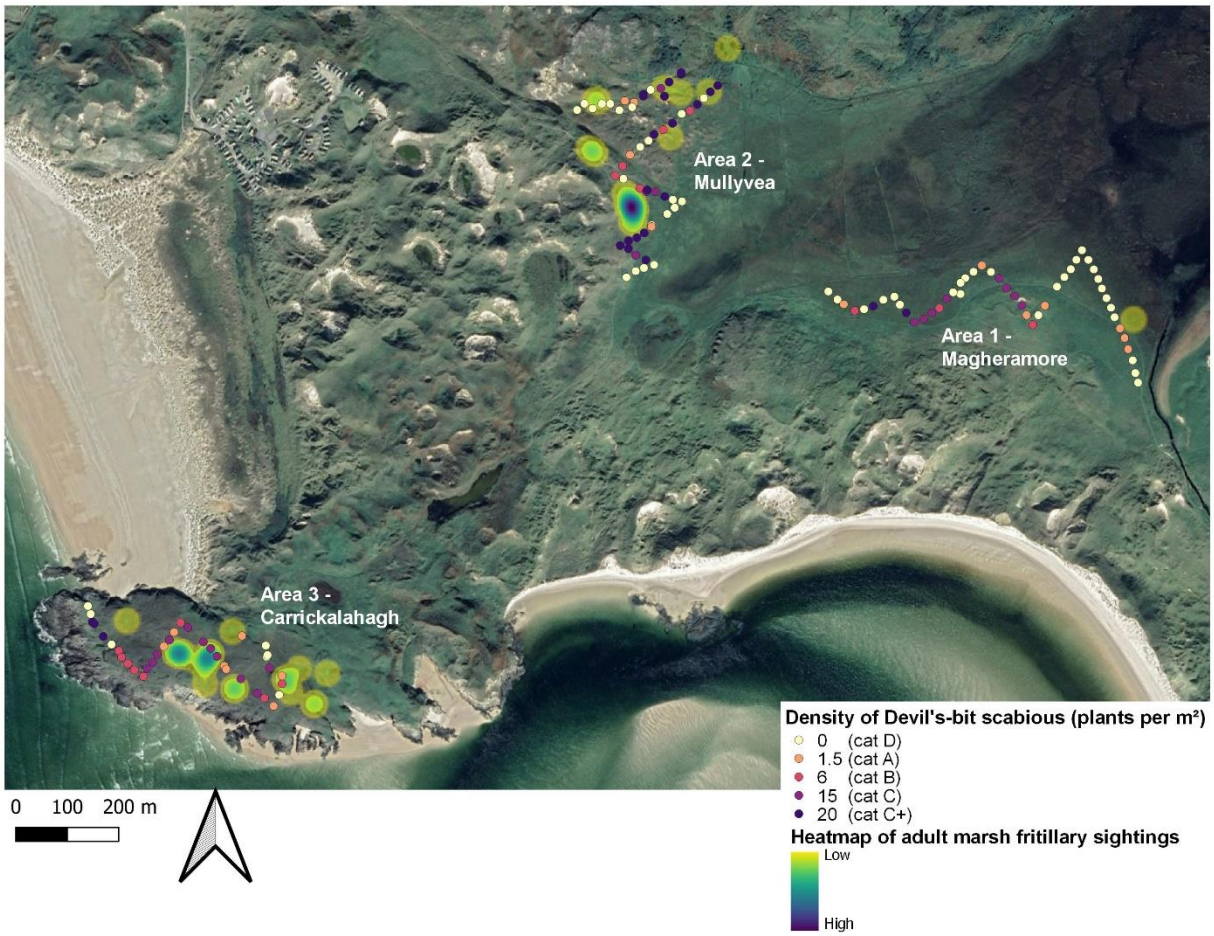

Figure 8. Density of Devil's-bit scabious collected from habitat condition survey with heatmap of adult marsh fritillary sightings

All four sites had Devil's-bit scabious density at both extremes, meaning there were sample sites within each area with no plants and other sample sites with 20+ plants per m² (*Figure 9)*, although, the two sample sites in area 1 with 20+ plants per m² can be considered outliers. Magheramore had the lowest mean and median Devil's-bit scabious density, and Mullyvea (subsite 2) had the highest. Group means were determined with a 95% confidence interval. The differences between the mean Devil's-bit scabious densities were statistically significant with a significance level of <0.01 (*Table 2).* The vegetation differed between the three study areas (*Figures 10, 11, and 12).*

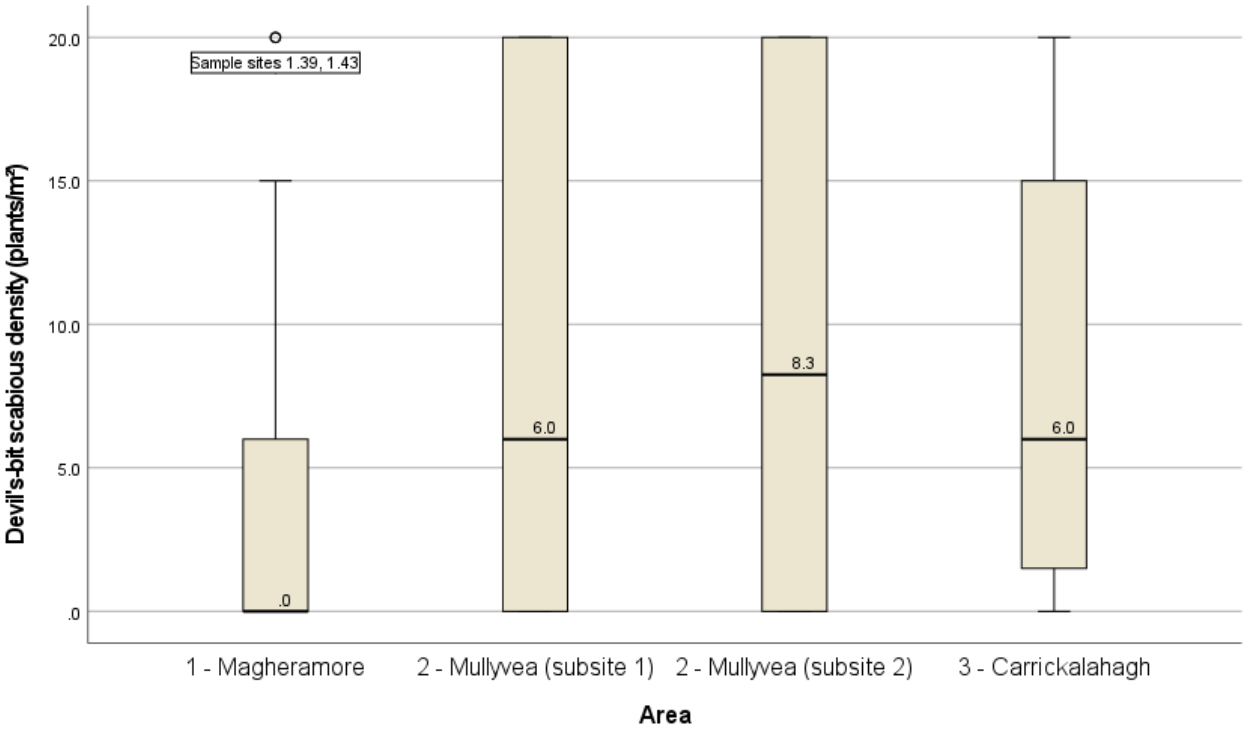

Figure 9. Boxplot of Devil's-bit scabious density (plants per m²) quartiles, outliers, and minimum and maximum values for each study area.

Table 2. ANOVA results for Devil's-bit scabious density between the four study areas

ANOVA

Devil's-bit scabious density

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	788.13	3	262.71	4.24	.007
Within Groups	8493.56	137	62.00		
Total	9281.68	140			

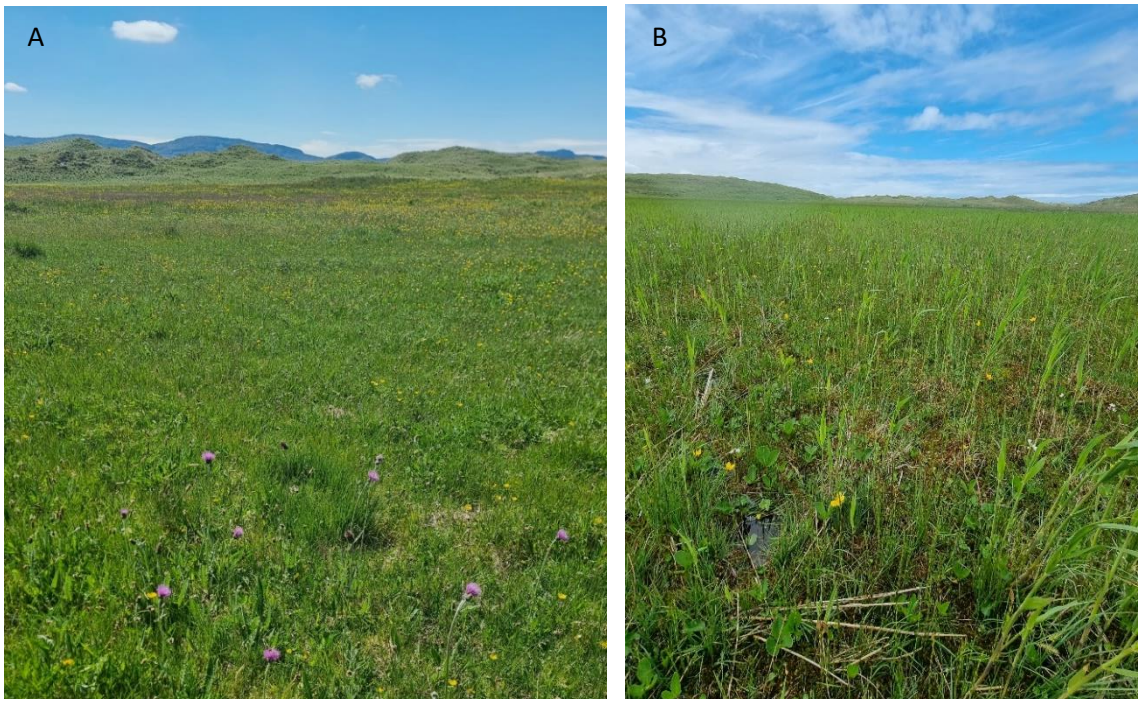

Figure 10. Vegetation in Magheramore. Meadow vegetation consisting of grasses, sedges, meadow buttercup and marsh thistles (A), and wetter areas consisting of horsetails and flowering marsh plants (B)

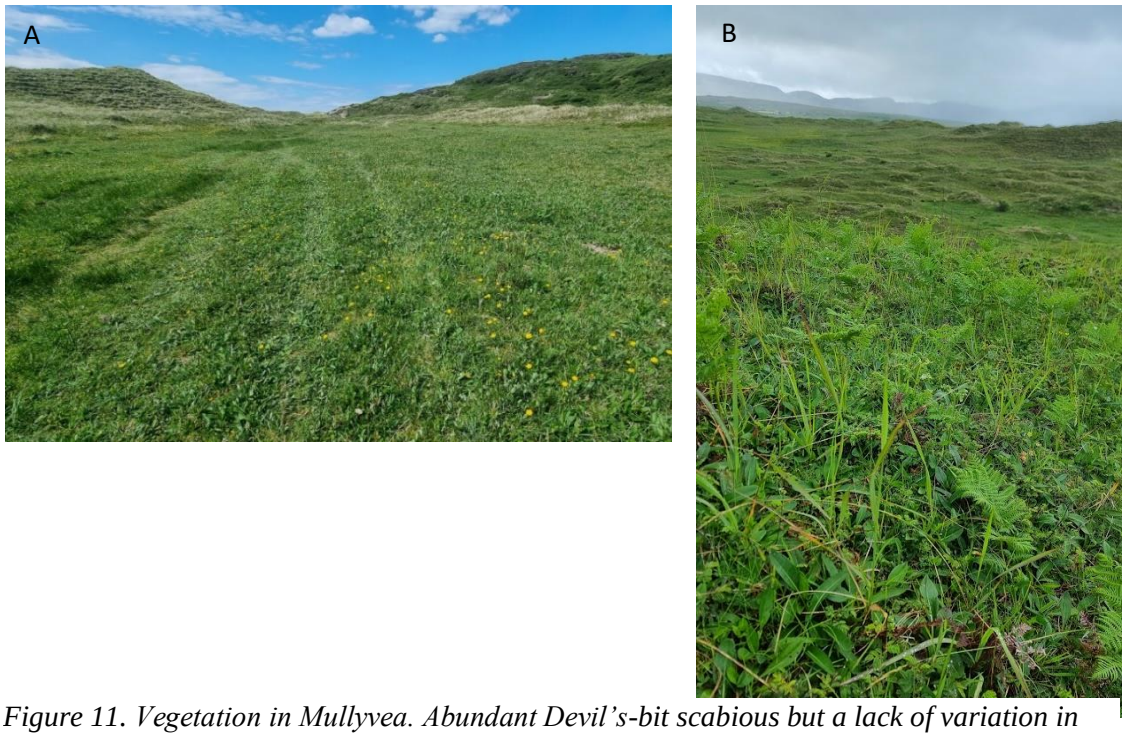

Figure 11. Vegetation in Mullyvea. Abundant Devil's-bit scabious but a lack of variation in vegetation structure or tussocky ground at subsite 1 (A). Larger Devil's-bit scabious plants amongst bracken, and other taller vegetation at subsite 2 (B).

Figure 12. Vegetation in Carrickalahagh. Devil's-bit scabious amongst short vegetation on the headland consisting mainly of heather (A), more dense, larger Devil's-bit scabious plants on a north-east facing slope amongst taller, more tussocky vegetation (B).

There were clear differences between the three study areas. *Figure 13* shows three groupings, into which sample sites can be approximately fitted from study areas 1, 2, and 3. The TWINSPAN analysis of the vegetation survey data produced eight distinct habitats: bracken, perennial meadow, dry meadow, wet perennial grassland, marshland, perennial grassland, heathland, and herbaceous flowering grassland, which were determined by certain indicator species (*Figures 14 and 15)*. The vegetation data collected in Area 1 (Magheramore) suggests the habitats consist of wet perennial grassland, dry meadow, and marshland. The habitats in Area 2 (Mullyvea) were classified as perennial meadow, bracken, wet perennial grassland, perennial grassland, and dry meadow. Area 3 (Carrickalahagh) was defined primarily by heathland, herbaceous flowering grassland, wet perennial grassland, perennial grassland, and perennial meadow.

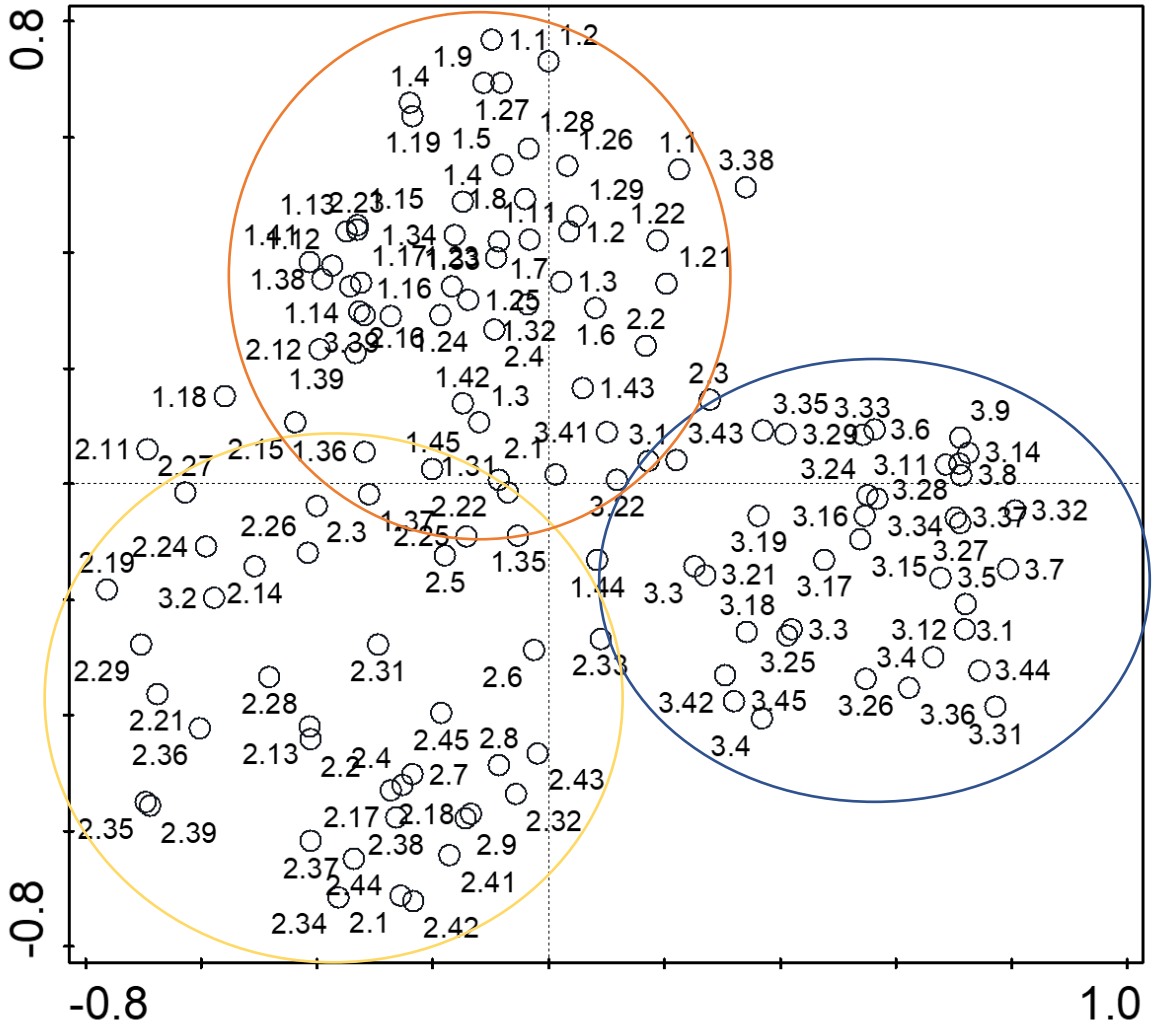

Figure 13. Principal Component Analysis of vegetation survey sample sites. The graph shows three groupings, approximately including sample sites from areas 1, 2 and 3. Explained variation: axis 1: 16.5%, axis 2: 13.3%.

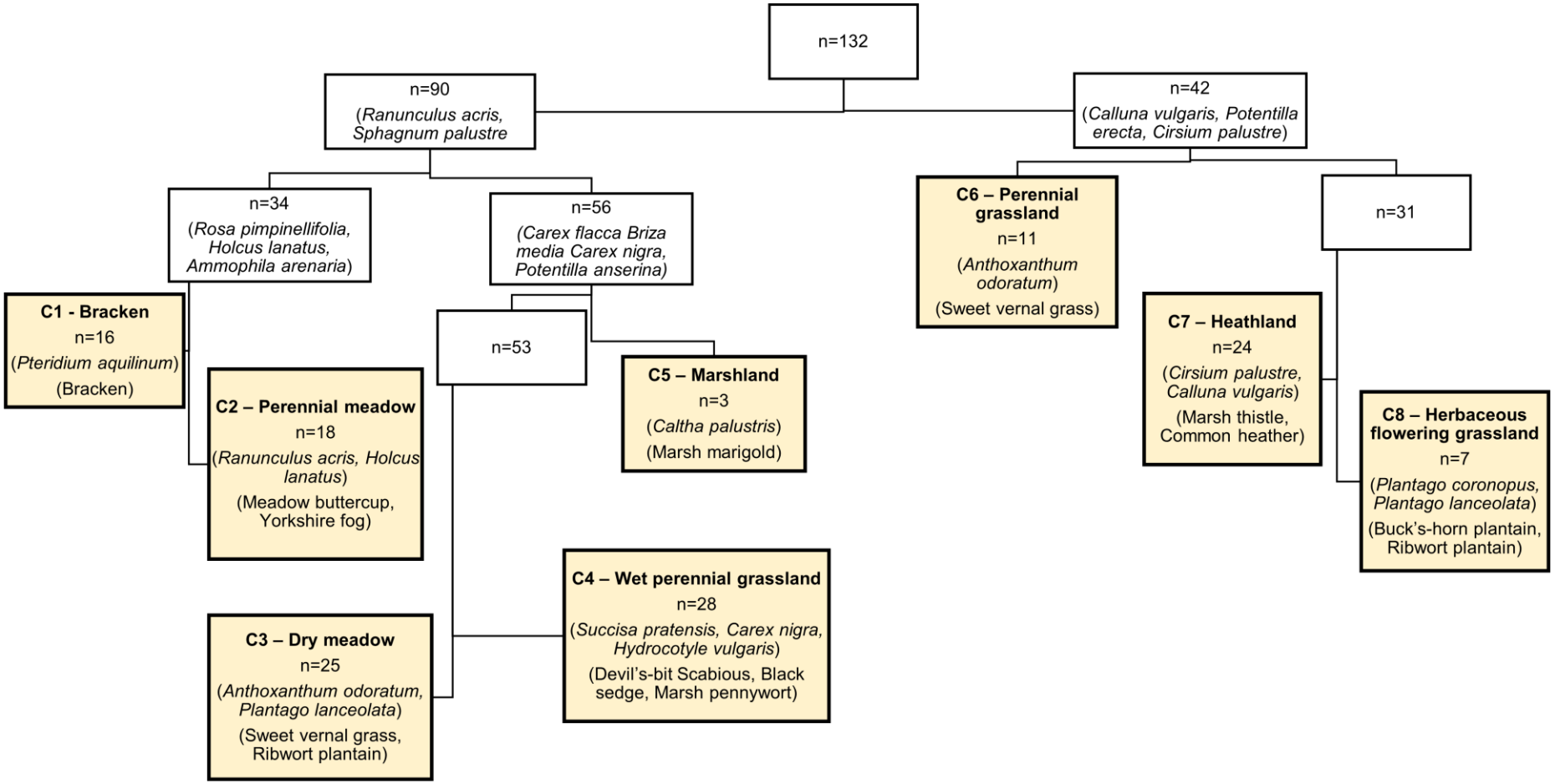

Figure 14. Dendrogram of habitat categories determined by results of TWINSPAN analysis on vegetation surveys. Indicator species are given in brackets under each cluster. All eigenvalues were between 0.275 and 0.330, a measure of the proportion of the total variation in the data

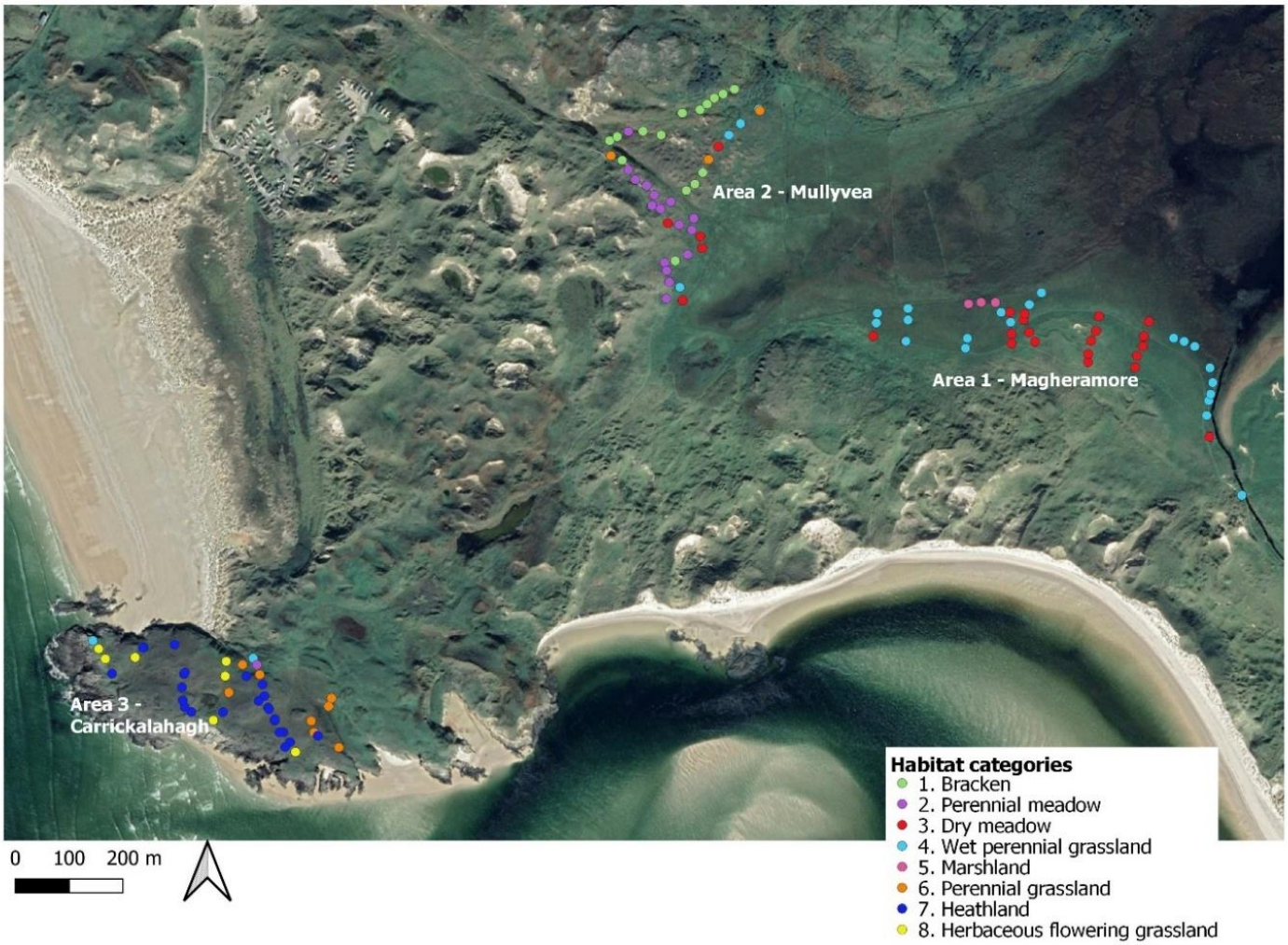

Figure 15. Habitat types determined from vegetation surveys in three study areas, categorised using TWINSPAN software

Conclusion and recommendations

The most suitable habitats were found to be Magheramore and Mullyvea (subsite 1), whereas Mullyvea (subsite 2) and Carrickalahagh were found to be 'suitable under grazed' and 'suitable over grazed', respectively. However, Mullyvea and Carrickalahagh had the highest density of Devil's-bit scabious per m². Distinct vegetation compositions and habitats were found between the study areas, with dry meadow and wet perennial grassland in Magheramore, perennial meadow and bracken in Mullyvea, and heathland and marshland in Carrickalahagh. All three study areas were found to support populations of marsh fritillaries, although most adults were spotted in Carrickalahagh, which has also consistently supported larval webs.

Conservation measures within the management plans of Magheramore and potentially Carrickalahagh should be reconsidered to create more optimal habitats for marsh fritillaries. Conservation management should take a landscape-scale approach across Sheskinmore, and

beyond, to ensure a network of habitats are in good condition to support metapopulations of marsh fritillaries.

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Appendix 1 – Number of butterfly species sighted (May – June 2022)

Species	**Number of adults sighted**
Marsh fritillary (*Euphydryas aurinia*)	63
Small white (*Pieris rapae*)	1
Small blue (*Cupido minimus*)	88
Common blue (*Polyommatus icarus)*	5
Small Copper (*Lycaena phlaeas*)	16
Small Heath (*Coenonympha pamphilus*)	93
Green-veined white (*Pieris napi*)	7
Orange-tip (*Anthocharis cardamines*)	1
Peacock (*Aglais io*)	1
Dingy skipper (*Erynnis tages*)	7
Green hairstreak *(C. rubi)*	10
Speckled wood (*Pararge aegeria)*	2
Small tortoiseshell (*Aglais urticae)*	2