Vegetation Ecology and Conservation of Potential Turlough Systems in the East Burren Complex SAC, Co. Clare

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ABSTRACT

Turloughs, the ephemeral lakes of Ireland, are unique landforms found in karstic limestone environments that form a dynamic habitat. By flooding seasonally, turloughs support a distinct flora that is capable of withstanding a highly variable environment. The Geological Survey of Ireland recognized 304 turloughs in 2006, and a further one has been designated in Wales. Turloughs are priority habitats under the EU Habitats Directive (2013) and thus turloughs designated as qualifying interests require monitoring. In this study, a group of small depressions in the limestone pavements of the East Burren SAC, Co. Clare were assessed to determine if the features function as turloughs and necessitate ongoing monitoring.

The southern Mullaghmore site is made up of seven features to the south of Mullaghmore, and scattered across the limestone grasslands and pavements between Lough Cuil Reasc and Travann Lough. The features were mapped and surveyed for vegetation community composition through quadrats representing a minimum 2% of the area of the feature. Vegetation communities were then assembled through non-metric scaling (NMS) ordination and indicator species analysis (ISA) to represent the vegetation of each individual feature and allow for identification of an inundation gradient where present. These communities and species of indicator or conservation interest were then related to previous turlough studies.

Feature #1 was shown to contain permanent standing water, fully aquatic species, an inundation gradient, and vegetation communities closely resembling those of designated turloughs. The presence and abundance of *Schoenus nigricans*, *Cladium mariscus*, and *Molinia caerulea*, as well as a sizeable wetland faunal community and *Potentilla fruticosa*, suggest that this feature is a small, relatively dry and flash-flood-prone, oligotrophic turlough, deserving of designation as a turlough and subsequent monitoring. The feature has substantial sources of pressure, from overgrazing and nutrient loading.

While other features were not shown to represent the same degree of conservation value, features #2 and 7 were shown to have characteristics similar to that of upper zones of turloughs, with *Potentilla fruticosa*, *Potentilla anserina*, and *Schoenus nigricans* present, and a tendency to flash-flood often. Feature #8 represented a highly diverse wet limestone grassland community, with *Potentilla anserina* and a small amount of permanent water present.

Features #3, 4, and 6 were shown to contain limestone grassland communities and not to hold significant conservation value as turloughs, though the features did contain relatively high levels of diversity.

The southern Mullaghmore site holds high levels of diversity in these small landforms, with several unique features showing turlough-like function, with distinctly diverse vegetation communities. Feature #1 in particular was shown to resemble a turlough and should be further studied and monitored for changes to its conservation status, in relation to its pressures.

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a. Turloughs

i. Characteristics

Turloughs, described by Joyce in 1869 as “lake[s] that [dry] in summer,” are seasonally flooded temporary lakes found in karstic limestone areas. These systems are generally considered ecotones due to their role as an intersection of terrestrial and aquatic ecosystems, and the temporally shifting status of these zones (Reynolds 1996; Visser *et al*. 2006). In this way, turloughs support a unique flora consisting of opportunistic aquatic and terrestrial species, as well as wetland or terrestrial specialists capable of withstanding the stresses of a habitat in a constant state of flux. Turloughs are found generally in Ireland, with 304 listed by the Geological Survey of Ireland Karst Database in 2006, though a single turlough has been designated within a Special Area of Conservation (SAC) in southern Wales, at the Pant-y-Llyn turlough (Joint Nature Conservation Committee 2017). It has further been debated whether the temporary wetlands of Slovenia, Croatia, Estonia, and Germany constitute a turlough habitat (Sheehy Skeffington & Scott 2008; EU Habitats Committee 2013). Sheehy Skeffington & Scott proposed that the broadly defined poljes of Slovenia be considered turloughs ecologically and in terms of land usage, if not geographically. This broader definition that does not limit turloughs to Ireland and Britain has been utilized by the EU Habitats Committee when defining turloughs as priority Annex I habitat 3180 within a given SAC.

In the past, turloughs were classified under a number of differing systems, based on a range of variables including altitude, extent of fluctuations in water levels, speed of fluctuation, presence of remnant puddles in the summer, or presence of peat (Visser *et al*. 2006). Visser *et al*. proposed to do away with these discrete typologies and instead use a “continuum approach” of dry to wet, as a representation of the most ecologically meaningful factors in describing a turlough system. This study concluded that many of the same variables expressed in previous discrete typologies could be explained in more general and practical terms through the dry-wet continuum. This approach was later reaffirmed by Sharkey’s 2012 study assessing the factors contributing to vegetation community composition, concluding that hydroperiod and water total phosphorus (TP) were most significant in driving vegetation community composition. Turloughs would now be classified along a gradient scale of these two primary factors (Visser *et al*. 2006; Sharkey 2012; Sharkey *et al*. 2015). These factors combine to form the primary drivers of the patterns of vegetation and ecological function within the habitat (Sharkey 2012; Sharkey *et al*. 2015). As such, turloughs with varying water nutrient status, hydroperiod, and subsequent vegetation communities require equally varying grazing regimes suited to the unique combination of variables that constitute a given turlough.

Groundwater stored in karstic limestone flows into turloughs as groundwater levels rise in the winter or during periods of rain, through springs and estavelles, generally at the deepest

point of the turlough or along the intersections of the turlough with exposed limestone pavement (EU Habitats Committee 2013; Naughton *et al*. 2015). Most turloughs flood in the fall and winter and dry out during the summer, through which time many mesotrophic turloughs serve as prime grazing pastures (Ryder *et al*. 2005; EU Habitats Committee 2013; Kimberley 2015). Some turloughs, however, continue to flood through the summer due to daily tidal ranges, such as the Garryland and Caherglassan turloughs of Co. Galway, or during periods of rain. Turloughs' degrees of inundation vary widely both temporally and spatially (Sharkey 2012; Naughton *et al*. 2015). Maximum depth of turloughs range from the deep Blackrock turlough at 16m depth at maximum flooding to the shallower Lisduff and Skealoghan turloughs at 2-3m. Similarly, Turloughmore recorded a hydroperiod of 135 days, where Croaghill recorded 348 days (Naughton *et al*. 2015). These varied depths and hydroperiods form significant drivers of vegetation community composition patterns within the turloughs. As the length of hydroperiod shifts moving vertically along the ecotone of the turlough, so too does the vegetation composition. Through an understanding of these vegetation communities, expected hydroperiod can be hypothesized through the comparison of indicator species abundance (Sharkey *et al*. 2015).

Similarly, indicator species can be used to hypothesize the classification of mean TP levels in a turlough (Naughton *et al*. 2015), identified from ultra-oligotrophic (≤4.0 µg 1^{-1} mean TP) to hypertrophic (≥100 µg 1^{-1} mean TP) (Organization of Economic Cooperation and Development 1982). Water TP was identified by Sharkey in 2012 to be a major driver of vegetation communities, with many turlough species being specialists to a given range of turlough nutrient status. As the vegetation communities and associated invertebrate assemblages are sensitive to changes in the nutrient status of the system, with knock-on effects to grazing quality, it is critical that these levels be identified and monitored for changes to status or nutrient loading from outside sources (Smith *et al*. 1999; Solimini *et al*. 2006).

ii. Legal Protections

Turloughs are protected as priority Annex I habitats of concern under the EU Habitats Directive (EU Habitats Committee 2013) as habitat code 3180 and EUNIS Habitat Classification C1.67. The EU Habitats Directive mandates that member states maintain and monitor priority Annex I habitats, and report on their conservation status. While turloughs are generally considered to be a unique Irish habitat, Natura 2000 sites in Slovenia, the UK, Croatia, Estonia, and Germany have been protected as code 3180 habitats, due to the broad definition under the Habitats Directive that can often include poljes. Under the Habitats Directive definitions, turloughs are "temporary lakes principally filled by subterranean waters and particular to karstic limestone areas in Ireland" and defining a turlough under the Habitats Directive is strongly related to the vegetation composition, due to the difficulty of precisely defining what constitutes a turlough by hydrological or geographic means.

Specifically listed vegetation involves Lolio-Potentillion communities and *Caricion davallianae* (Nomenclature follows Parnell & Curtis 2012), as well as the mosses *Cinclidotus fontinaloides* and *Fontinalis antipyretica* (EU Habitats Committee 2013). As such, for a given site to be designated a turlough, the geographic features of the site must constitute a karstic limestone site that floods seasonally by groundwater sources and has vegetation communities in common with established turloughs. These vegetation communities of turloughs have been documented and characterized in a number of studies, including O'Connell *et al*. (1984), Goodwillie (1992, 2003), Regan *et al*. (2007), Sharkey (2012), and Hanley (2014).

iii. Turlough Flora

Turloughs host a diverse range of plant species, supporting species that are fully aquatic, fully terrestrial, and those in between. These plant species are best described as community assemblages, indicative of their microhabitat within the turlough system and concurrent species. O'Connell in 1984 described turlough vegetation communities through frequency, and Goodwillie (2003) described the most strongly characteristic factors of given species and communities. Regan *et al*. (2007), Sharkey (2012) and Hanley (2014) assembled these vegetation communities utilizing a range of turloughs and assigning communities on the basis of indicator value. This indicator value was calculated on the basis of frequency and consistency of representation within a community, and uniqueness to the community in relation to other communities. The vegetation communities that these species represent are fairly consistent in both their form and function within the turlough system. In this way, these species can be used to provide an indication of habitat characteristics, and this methodology laid the framework for this study.

These previous studies provided a valuable comparison for vegetation composition of established turloughs against this study's features. These recognized turlough vegetation communities were utilized to relate the study features and their subsequent vegetation communities to established turloughs, in terms of vegetation community, hydroperiod, nutrient status, and degree of grazing.

b. Southern Mullaghmore Site

The study site in the southern Mullaghmore area is made up of seven small turlough-like features spread across an area of roughly 1.5 x 1.5 km in the southeastern end of the Burren National Park, within the East Burren Complex SAC (NPWS 2015). The largest of these features is located to the northeastern end of the site and is roughly 5000 m^2 in area (feature #1). Two other features are roughly 250 m^2 in area (features #2 and 3) and the remaining are each under 150 m^2, including a single divot of roughly 40 m^2 (feature #8). The deepest feature (the westernmost, adjacent to Lough Cuil Reasc, feature #7) is roughly 4-5m at its deepest point from the ground level of the surrounding pavement, though the principally flooded area is roughly 2m in depth. Feature #1, the largest in area, is 2-3m below ground level and can

flood to the level of the surrounding pavement, while the principally flooding area is roughly 2m in depth. While turloughs are not strictly defined by their size, the most well-defined and studied have been larger than 10 hectares in maximally flooded area (Goodwillie 1992; Sharkey 2012). There is no publicly available documentation of designated turloughs of comparable size to the turlough-like features in the southern Mullaghmore area (EU Habitats Committee 2013), apart from the 0.5 hectare 'Tree covered turlough' described by Regan *et al*. in 2007 within the East Burren Complex SAC. The turlough-like features are immediately to the east of the heavily inundated and grazed Lough Cuil Reasc, with feature #7 the nearest at 80m east of the northern basin of Lough Cuil Reasc, separated by limestone pavement and a patch of woodland. The easternmost feature, feature #1, is located immediately southwest of Travann Lough, separated by 250m of limestone pavement.

The soil of all features is Basic Shallow Well Drained Material (BminSW) - Renzinas/Lithosols (EPA 2006) and the subsoil is Karstified Limestone Bedrock (KaRck) (EPA 2006). The pastures uphill to the north from features #3-8 along the slopes of Mullaghmore have soil of Basic Deep Well Drained Mineral (BminDW) and subsoil of Limestone Till Carboniferous (TLs) (EPA 2006). Lough Cuil Reasc, proximal to feature #7, has soil of fen peat. These descriptions from the EPA (2006) were confirmed during the study period. Drew (1990) describes the area as sharing a common catchment zone and hydrology to Lough Cuil Reasc, with drainage from the higher altitude points of Mullaghmore to the north. Lough Cuil Reasc was graded by the Geological Survey of Ireland in 2011 as having "extreme" groundwater vulnerability to pollution or nutrient enrichment, due to the rapid diffusion of pollutants through the groundwater of the karstic environment and proximity to agricultural activity providing a significant source of potential pollutants. Movement of water along the surface in the area is minimal, and the majority of water drains directly into the groundwater to flow through the karstic limestone of the area (Drew 1990; NPWS 2015).

The climate of the Burren is best described as marine-temperate, with relatively steady temperatures year-round and high levels of precipitation, particularly in winter months (Met Éireann 2017). Mean annual precipitation from the nearest Met Éireann precipitation station, at Carron, ~10 km to the northwest of the site, from 2007-2016, is 1749 mm/year. The precipitation is highest between November and January (202.2 - 211.7 mm/month) and dries out between March and June (84.4 - 115.49 mm/month). This is a 12.1% rise in annual rainfall over the 1975-1990 Carron Met Éireann station mean of 1560 mm/year. This is demonstrative of the predicted rising levels of precipitation in the Burren, which are predicted to have impacts

on the hydrology of the area and its groundwater systems in the future (Gleeson *et al*. 2013; Penck *et al*. 2015).

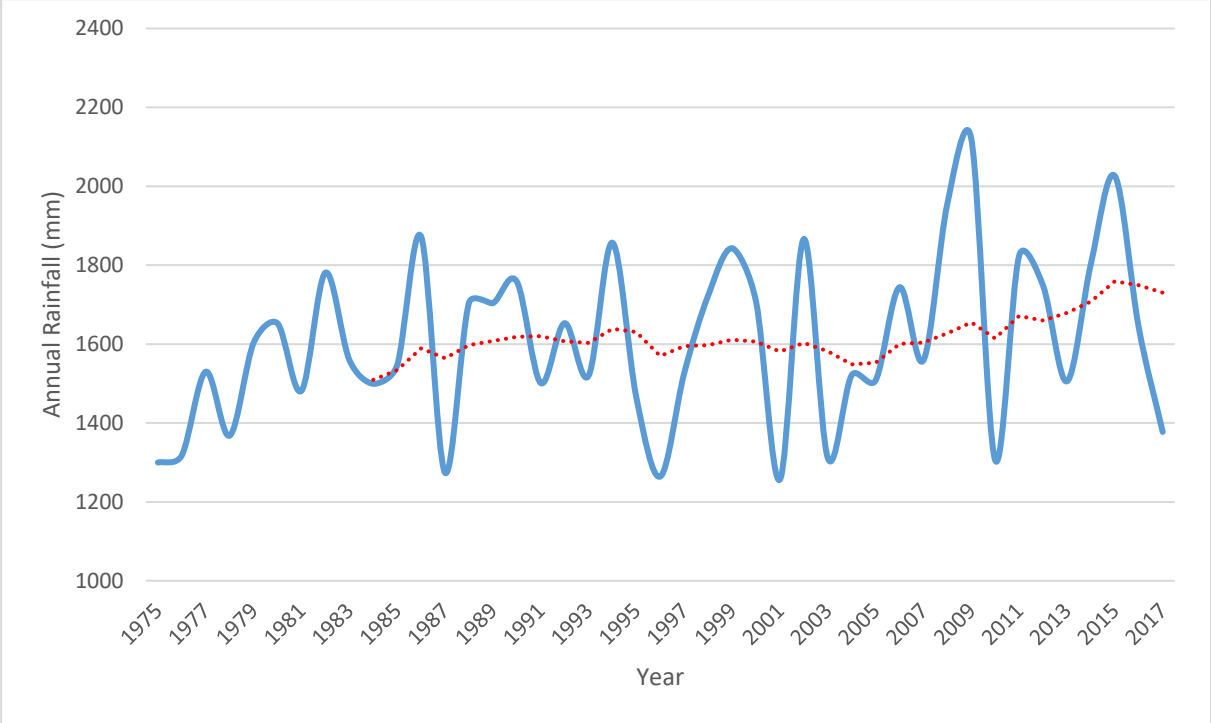

Figure 1. Carron Met Éireann station recorded rainfall (mm) by year, with 10-year moving average

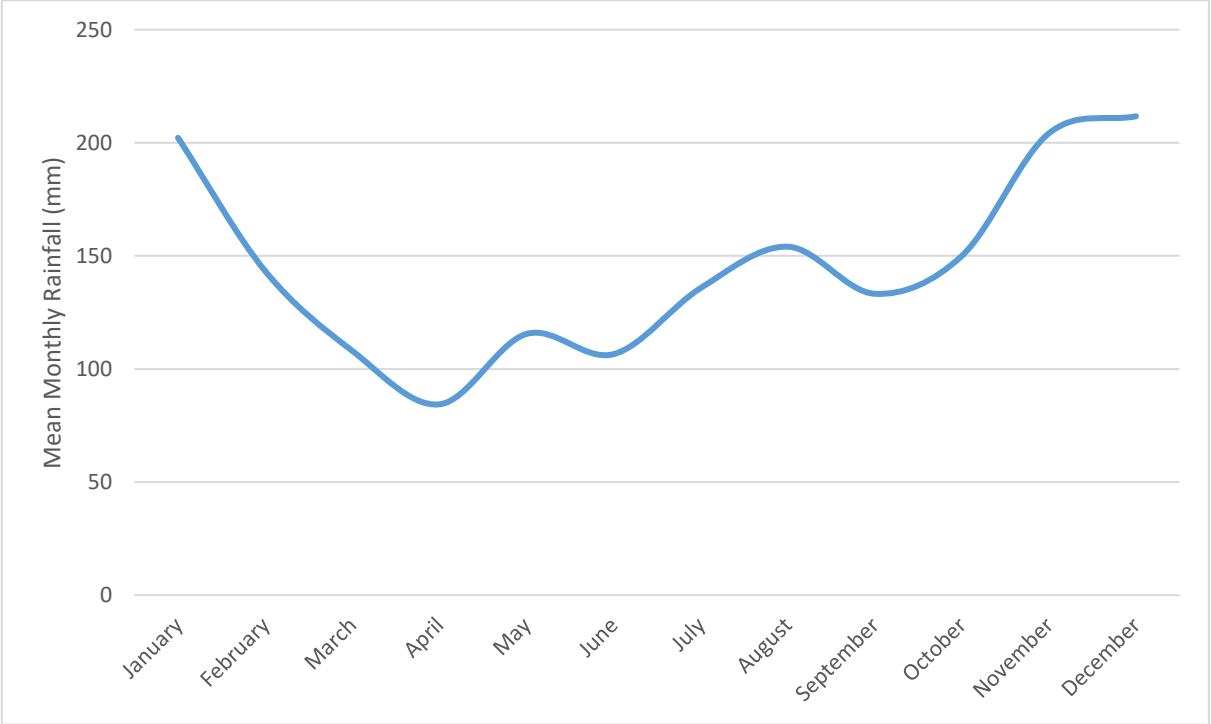

Figure 2. Carron Met Éireann station mean recorded rainfall (mm) by month, 2007-2016

Temperatures are relatively consistent throughout the year, with mean daily air temperature fluctuating between 5.9°C in January and 15.9°C in July, with a mean annual air

temperature of 10.5°C (Met Éireann 2017) at the nearest Met Éireann temperature station, the Shannon Airport, ~40 km to the south of the site. This represents a 0.5°C rise in air temperature from the 1946-1960 Shannon Airport station mean of 5.0°C in January, 15.4°C in July, and 10.0°C annual.

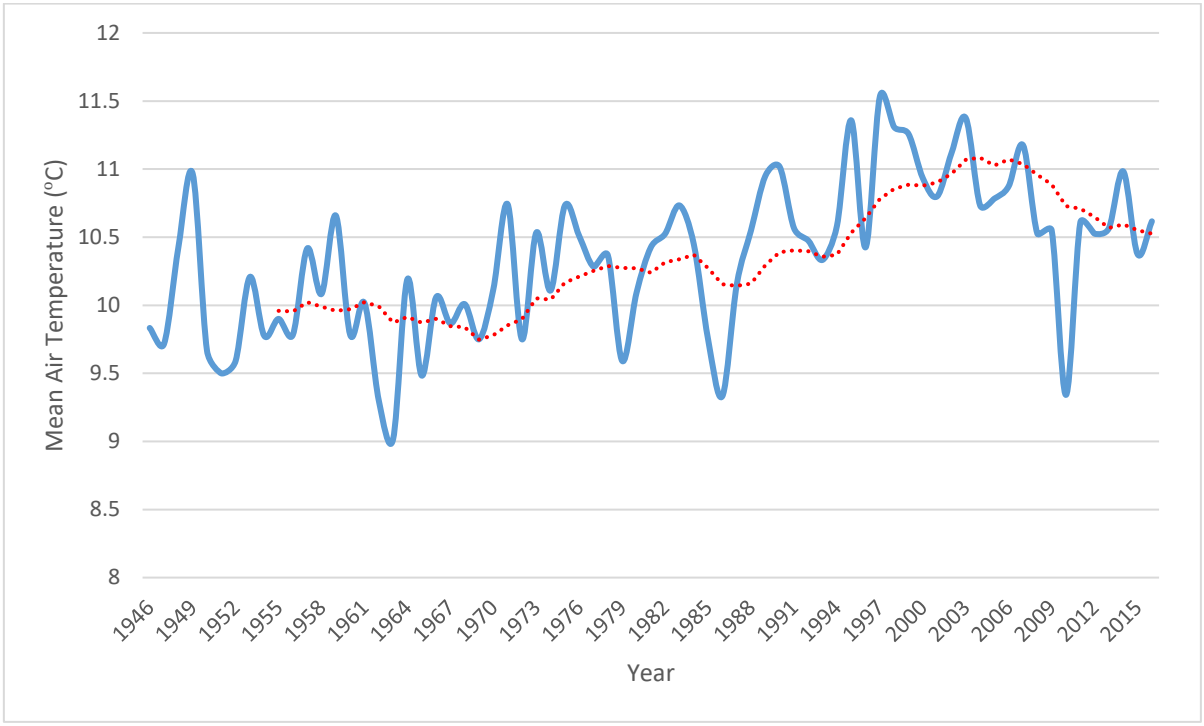

Figure 3. Shannon Airport Met Éireann station mean air temperature (°C) by year, with 10-year moving average

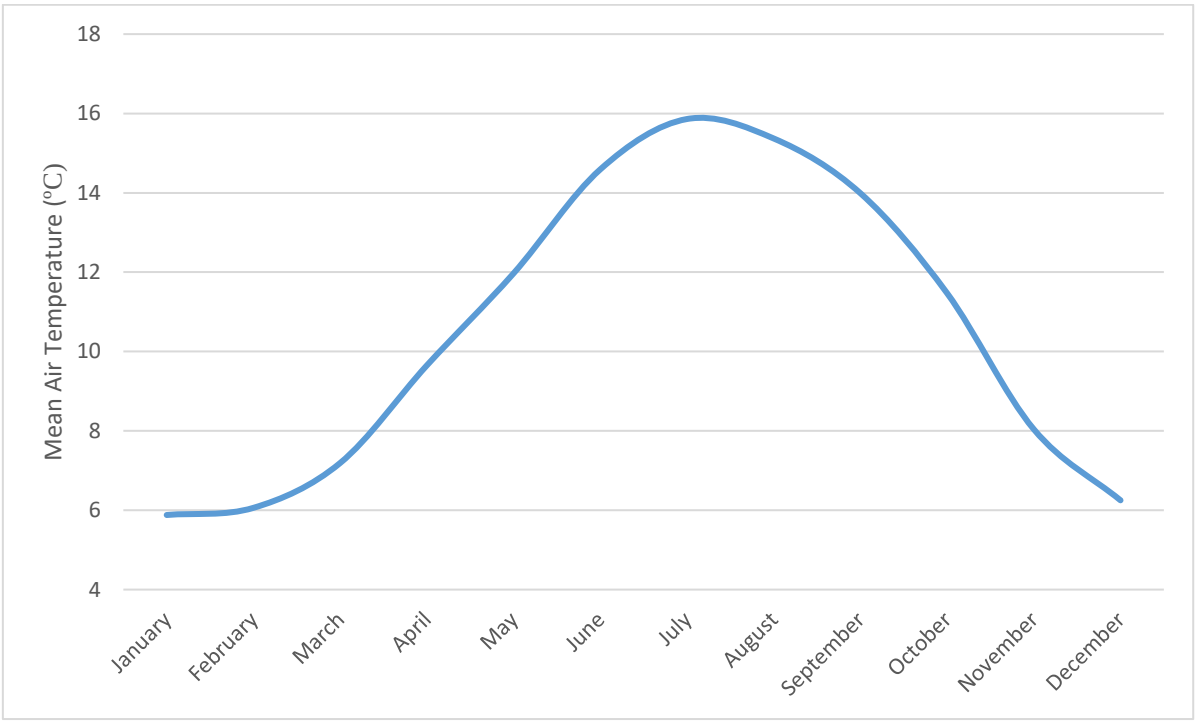

Figure 4. Shannon Airport Met Éireann station mean air temperature (°C) by month, 2007-2016

The East Burren Complex SAC that the site rests within is 188 km^2 composed of a mosaic of habitats, including fourteen sites of qualifying interest as Annex I habitats under the EU Habitats Directive (NPWS 2016). 61% of the SAC is classified as habitat N22 or Inland Rocks, the classification group that turloughs and the associated limestone pavements are classified under (NPWS 2015). The turloughs of the site are associated to calcareous hardwater lakes, fen, bogs, and calcareous marsh habitats (NPWS 2015). The site has been assessed as being under high levels of threat of species composition change (threat code K02.01), problematic native species (I02), groundwater pollution from households (H01.08), contaminated sites (H02.01), and agricultural activity (H02.06).

The southern Mullaghmore area is primarily composed of limestone pavement with sparse vegetation in higher altitude points and varying degrees of calcareous grassland and scrub-covered pavement at the lower levels of the catchment (NPWS 2015). Improved pastures are found to the immediate south of the National Park and along the southern slope of Mullaghmore, with the Mullaghmore pasture uphill from study features #3-8. A path from the private pastures immediately south of the site leads to the pastures on the slopes of Mullaghmore. Along this path are signs of dunging and trampling of the vegetation. The path runs immediately adjacent to feature #8, along the green road dividing the area. This green road is a path constructed by workers during the Great Famine, of piled cracked limestone removed from the immediately adjacent limestone pavements. The green road is elevated an average 1-2m above the ground level adjacent to it. All the study features are located within 65m of a path or road. The green road running parallel to features #6-8 is not heavily trafficked by foot and is not open to vehicles. The two easternmost features, features #1 and 2, are both located within 30m of a public roadway.

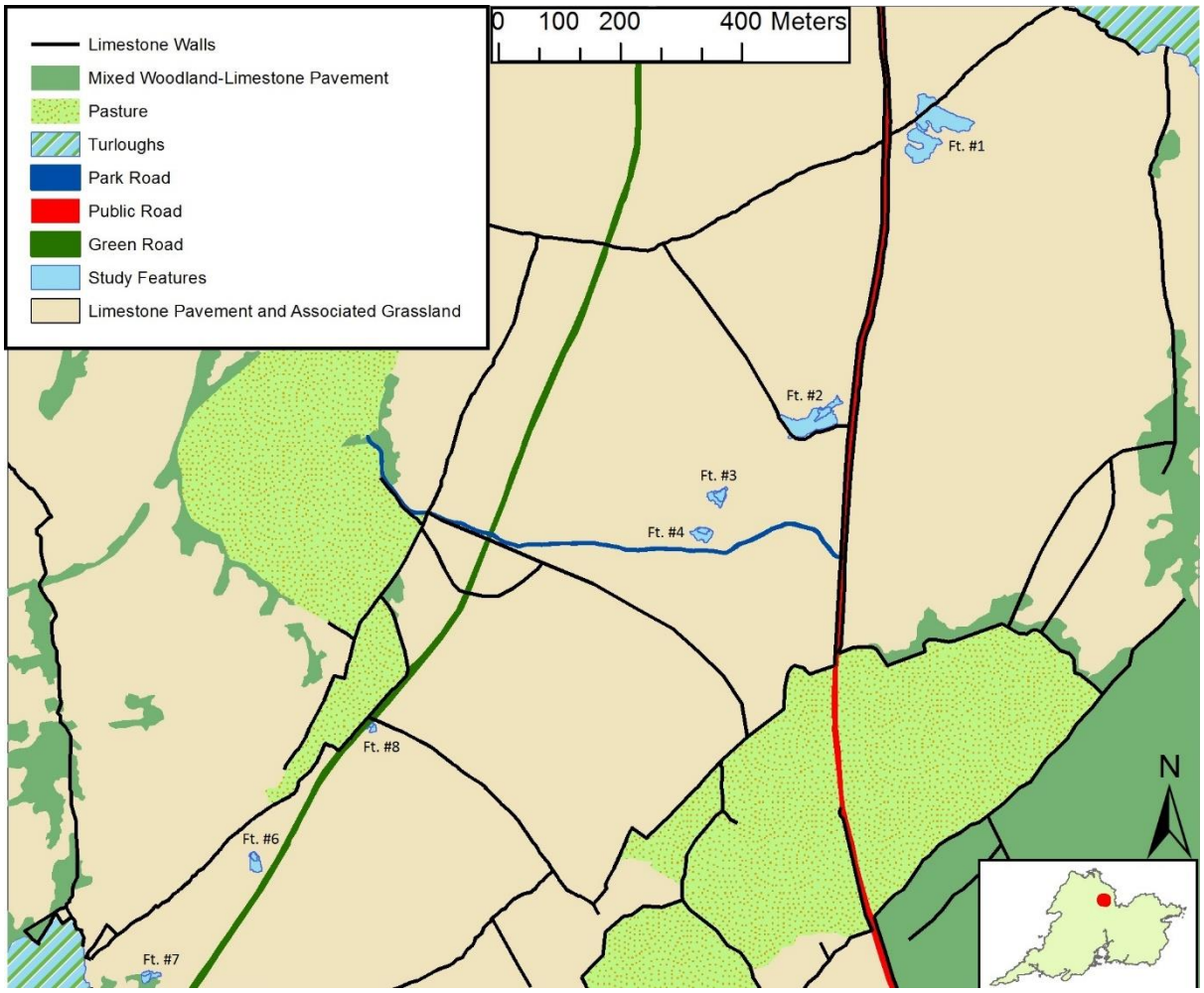

Figure 5. Significant landforms of the Southern Mullaghmore study site, inset from Co. Clare

c. Threats and Pressures to the Southern Mullaghmore Site

Turloughs face widespread threats and concerns, many revolving around their ephemeral and cyclical nature. As they are in a constant state of flux, a proper balance of a number of variables must be achieved for the system to continue functioning, including groundwater levels, nutrient status, and grazing (Kimberley 2015). Further, due to the dependency of turloughs on a karstic limestone environment (EU Habitats Directive habitat code 8240), turloughs are dependent on geologic and hydrologic systems that are themselves under pressure (Wilson & Fernández 2013).

The hydrology of the Burren and its turloughs is under significant pressure of changes to water availability, impacted by changes to the local climate (Gleeson *et al*. 2013; Penck *et al*. 2015; Met Éireann 2017). As discussed above (section 1.b and figures #1 and 3), the climate of the Burren has shifted over the last 70 years (Met Éireann 2017). Mean annual precipitation has increased by 12.1% for 2007-2016 in relation to the average of 1975-1990. This shift has been disproportionate between the seasons, causing wetter winters and drier summers. Precipitation is predicted to remain higher than this standard, with predictions for

Ireland to see a 4.4-7.6% increase in mean annual precipitation by 2100 in relation to the 1990 baseline (Gleeson *et al*. 2013). The seasonal differences are further expected to intensify, with winter precipitation expected to increase by up to 14% and summer to reduce by up to 20%. Evaporation would also be expected to increase, as Ireland is projected to warm by 2.7-5.4°C in mean daily air temperature by 2100 from the 1990 standard, and has already risen by 0.5°C for 2007-2016 from the 1946-1960 average in the Shannon Airport Met Éireann station recordings (Met Éireann 2017). These two interacting shifts would be predicted to contribute to a higher groundwater level and thus flooding level of turloughs in the winter, followed by a faster and more complete drying out in the summer. This will pressure the vegetation communities of turloughs to support primarily species more tolerant of these dramatic shifts in water availability.

Turloughs are sensitive to pollution and water nutrient level changes in their groundwater sources (Naughton *et al*. 2015). The southern Mullaghmore site is particularly susceptible to the nutrient loading of its groundwater and is placed at risk of eutrophication due to its proximity to agricultural activities, paths, and a road. The site is downhill from the north along Mullaghmore from improved pastures grazed by livestock. This is perpetuated by the movement of livestock from the southern pastures along the paths leading along the dividing green road and to the slopes of Mullaghmore. The nutrients from these agricultural activities are likely washed into the groundwater of the karstic limestone environment during rainfall and carried throughout the system (Drew 1990). Runoff from the public road along the eastern end of the site may provide another source of pollution. These combined pressures provide a significant source of pressure on the groundwater systems and can have impacts on the water quality of the entire catchment (Smith *et al*. 1999; McCormack *et al*. 2014).

While many turloughs are at risk of modification through improper landuse or changes in grazing patterns (Marty 2004; Beltman *et al*. 2014; Kimberley 2015; Waldren *et al*. 2015), this appears to be only a minor risk for the southern Mullaghmore site. As the turlough-like features are protected within the Burren National Park and are much too small to provide sufficient pasture for livestock, there is little risk of overgrazing the majority of the study features. However, a portion of feature #1 is accessible to grazing cattle. Further, the green road and livestock paths running adjacent to these features will still contribute risks of the secondary effects of a grazing population. This will include nutrient loading from dunging, trampling of the vegetation, and possibly a low degree of herbivory as the livestock move through the area. Further, the livestock may have a degree of impact on the structure of the limestone pavements surrounding and within the features.

Direct risks from recreational or other human usage of the park land are minimal. While part of the Burren National Park, the site is relatively isolated from the more trafficked areas of the park and is unmarked for trails or park entrances in the section that many of the features

occupy (NPWS 2017), thus expecting few recreational visitors. A locked gate further segregates these features from the more trafficked areas, and the provision of paths discourages visitors from walking on limestone pavements or the study features. The primary source of human disruption would come from park management and the nearby landowners moving their livestock between pastures. This could cause a low degree of disruption through trampling or removal of the limestone and concurrent vegetation, as well as careless disposal of waste.

2. Aims and Research Questions

This study aimed to describe the ecology of the small turlough-like features in the southern Mullaghmore catchment area. This was achieved by assessing the vegetation community composition of these features in terms of species richness and relative abundance, as well as addressing the conservation and indicator values of these communities. These findings were assessed in a manner consistent with previous turlough studies and were presented in terms of the management implications and issues of the features. Features were assessed both individually and as collective units, where appropriately clustered. The main research questions are as follows.

a. What are the vegetation community compositions and ecology of the southern Mullaghmore site features?

The composition of these vegetation communities was assessed in relation to previously described turlough systems, in the aims of relating these communities to the defining features of established turlough classifications and gradients. These indicator values can be used to provide recommendations for the classification and conservation management of these features. Furthermore, the community composition of the individual features was assessed to determine to what extent each individual feature resembled a turlough vegetation community.

b. What conservation values do these features represent?

This question was addressed in direct relation to the Irish Red List (Wyse Jackson *et al*. 2016) and Red Data Book (Curtis & McGough 1988), as well as the IUCN Red List (2017) and the EU Habitats Directive (EU Habitats Committee 2013). All species and habitat features concurrent with a degree of conservation value or threat were surveyed and documented with the intention of providing a greater understanding of areas of concern within the habitat. This documentation will provide evidence and recommendations for the protection of the site, where found to be appropriate. This further aimed to provide recommendations for the possible designation of these features, if appropriate, under the EU Habitats Directive classification 3180, utilizing the Assessing the Conservation Status of Turloughs (ACST) reporting methodology (Waldren *et al*. 2015).

c. What management recommendations can/should be provided for these features?

Management recommendations were provided on the basis of need for, degree of, and style of management. With a greater understanding of the vegetation ecology of each feature established, management of the broader landscape or solely individual features can be designed to suit the needs of the system and set in place protections and management regimes conducive to establishing and/or protecting a well-functioning ecosystem and community.

3. Methodology

a. Field Survey

The field surveying component of the study took place in two primary fieldwork stages with a stage of preparatory work in advance.

i. Preliminary Site Identification and Preparation

Using aerial and satellite photographs, the southern Mullaghmore site was examined for potential turlough-like features. All features were located within the Burren National Park under cooperation of the National Parks & Wildlife Services. Potential features were recorded in the form of "Feature #X" to be used consistently throughout the study. The approximate area of the features was assessed using ArcGIS, as well as relation to landmarks, for field utilization and identification.

Species lists were assembled from a variety of sources (Parnell & Curtis 2012; Sharkey 2012; EU Habitats Committee 2013; Hanley 2014; NPWS 2015; Sharkey *et al*. 2015; NPWS 2016; BSBI 2017) to establish potential species present within the area and the local turloughs and turlough-like features. These species were then cross-referenced with the IUCN (2017) and Irish Red Lists (Wyse Jackson *et al*. 2016), Irish Red Data Book (Curtis & McGough 1988), ACST reporting (Sharkey 2012; Waldren *et al*. 2015), and EU Habitats Directive indicator species (EU Habitats Committee 2013) to establish a list of species of conservation or indicator value.

The southern Mullaghmore site was visited prior to the full survey in mid-May 2017. This initial visit was a single day exercise to confirm records from aerial and satellite photographs and provide perspective to the individual features, as well as allowing for the identification of site access routes, boundaries, and potential difficulties or hazards. In this visit, all identified features underwent a short preliminary survey to establish the relevancy of the feature to the research questions, accuracy of records from satellite photographs, and initial impressions of vegetation community composition. At this point, feature #5 was eliminated from the study. This was due to the feature not appearing to have a vegetation community resembling a possible turlough system and being heavily modified by the construction of a path through the basin. The entire southern Mullaghmore area was then surveyed for any relevant

features not initially included in the study. At this point, feature #8 was added to the study, due to its standing water and vegetation community.

ii. Initial GPS Habitat Mapping

Vegetation survey and habitat mapping was undertaken throughout June 2017. Features were mapped using the handheld Trimble GeoExplorer 2008 Series GPS device, establishing outlined polygons of the features, including both the extent of the depressions and the principally flooding area. The principally flooding area outlines were defined as the high water mark of the feature, often marked by degradation of the limestone, debris left after a flooding period, when present, or the presence of the moss *Cinclidotus fontinaloides*, when present (Sheehy Skeffington *et al*. 2006). When possible, this was further adjusted or reaffirmed during flooding periods. GPS data were recorded using the Irish Transverse Mercator coordinate system. Feature outlines were mapped as polygon and polyline shapefiles by walking the outlines of the feature slowly, logging one position per second, with the GPS device at constant height. When present, estavelles and exposed limestone pavement within study features were recorded as well. Feature #1 was divided into two basins, separated by a 5m strip of limestone pavement, labeled as Features '#1A' and '#1B'. No latitudinal grykes directly connected these two basins through surface movement of water.

iii. Community Composition Survey

To assess the community composition of the features, 1 x 1 m quadrats were stratified throughout the principally flooding area of the feature. The total area of the quadrats placed was equal to 2% of the feature at a minimum. In features of an area less than 450 m^2, a minimum of 9 quadrats were assessed. These 9 quadrats were selected to be representative of a minimum of 2 quadrats at each of the lower, upper, and middle zones of the feature. Each quadrat was recorded in the form of "qX.yy" corresponding to the feature identifier and the quadrat number within the feature. In the period from June 13th to June 27th, a total of 161 quadrats were recorded. Quadrats were recorded as point features on the diagonal centerpoint, logged for 25 positions at a consistent height.

Within the quadrats, all vascular plant species were recorded and identified (Jermy *et al*. 2007; Cope & Gray 2009; Parnell & Curtis 2012; Blamey *et al*. 2013). In consistency with previous studies, mosses were recorded solely as "mosses" and algae or algal paper as "algae" for purposes of community composition analysis (Hanley 2014). Individuals that could not be identified to the species level were recorded as *Genus* sp. This included *Callitriche* sp., *Galium* sp., and *Veronica* sp. Percent cover brackets of 5% steps were used to assess the level of abundance for a given species within the quadrat (Kent 2012). Each quadrat was recorded for average sward height from the ground and relative position within the feature, recorded as "Upper," "Lower," and "Middle" zones in relation to probable flooding zones. Areas of the quadrats uncovered by vegetation were recorded as "bare ground." The northern end of

feature #1's basin B was excluded from vegetation survey due to overgrazing and trampling from cattle. Vegetation had been thoroughly removed or damaged and could not viably be identified.

The frequency of a given species is denoted as described by Rodwell (2006), presented as in Table 1, and presented alphabetically in a table for constant and near constant species. Species are further recorded for average percent cover of quadrats within the given feature. Species in lower frequency classes are recorded below the table in alphabetical order and denoted for frequency class. Species noted as frequency class "0" include species observed solely in the upper depression of the study features.

Table 1. Conversion of frequency to description and denotation

Frequency as Percent of Quadrats Present	Description	Symbol
81-100%	Constant	V
61-80%	Near Constant	IV
41-60%	Common	III
21-40%	Occasional	II
1-20%	Scarce	I
0%	Present in feature, absent from quadrats	0

b. Quantitative Analysis

i. Community Composition

Communities of each feature were assessed on the basis of species percent cover and relative abundance, with consistent methodology to Sharkey (2012) and Hanley (2014). The program PCORD 5 (MjM Software, Oregon) was used for the clustering of vegetation communities. Species recorded in only a single quadrat were excluded from the analyses (McCune & Grace 2002). Quadrats with two or fewer species present, or greater than 67% bare ground, were similarly excluded. Non-metric multidimensional scaling (NMS) using the Sørenson (Bray-Curtis) distance measure and the "slow and thorough approach" defined the similarity values of communities as a factor of distance and explore patterns in the data in terms of axes. These datasets were tested through 250 randomized Monte Carlo test runs. Indicator species analysis (ISA) using the Dufrêne and Legendre (1997) methods of cluster analysis determined the appropriate degree of clustering of quadrats. These quadrats were then assigned based on this clustering process to form representative communities. These analyses allowed for the accurate description of the makeup and distribution of communities within and between the turlough-like features. The vegetation communities of each individual feature were described in terms of solely relative frequency, while the clustered vegetation

communities between the features were described in terms of relative frequency and relative abundance.

ii. Hypothesized Hydroperiod and Nutrient Status

Due to the dry state of the majority of the features throughout the summer months, it was impossible to obtain water samples for these features. Standing water was present only in three features during flash-flooding events and in low permanent volume within two of these. Instead, hypothesized nutrient status and hydroperiod were assessed using the documented indicator species provided by Sharkey *et al*. (2015). The index weights of species for each given feature were compared with the established species abundance values in relation to hydroperiod and level of water phosphorus to provide a hypothesis for expected hydroperiod and nutrient status, for potential comparison with future hydrology studies of the features. Those features that were determined not to contain turlough vegetation communities during community composition analysis (section 2.b.i) were excluded from this assessment. At this point, features #3, 4, 6, and 8 were excluded.

c. Mapping

All mapping used the Irish Transverse Mercator projection. Maps were assembled using Esri ArcGIS 10.4.1. Base maps provided by Esri ArcGIS online maps were overlaid with GPS data collected from the Trimble GeoExplorer device during fieldwork.

d. Conservation Assessment

The conservation assessments of the southern Mullaghmore features utilized the protocol of previous ACST studies (Sharkey 2012; Hanley 2014; Waldren *et al*. 2015) in complying with the Habitats Directive reporting of conservation status of priority habitats (EU Habitats Committee 2013). As these features are not designated as protected 3180 habitats, these assessments are solely for informative usage and to provide recommendations for future conservation efforts in a manner consistent with comparable studies. These assessments can be found in Appendices 1-3. An assessment was reported for each feature independently. Those features that were determined not to contain turlough vegetation communities were excluded from assessment. At this point, features #3, 4, 6, and 8 were excluded.

The assessments described the structure and function of the habitats using prescribed indicators and ecological thresholds consistent with the Habitats Directive (EU Habitats Committee 2013) and ACST studies (Sharkey 2012; Hanley 2014; Waldren *et al*. 2015). Due to the summertime lack of water present in the features, hydrological functions were not possible to assess beyond hypotheses based on indicator species, and will necessitate future study if hydrological factors of the features are to be assessed. Factors that were assessed are as in Table 2. Factors that could not be assessed within the framework of the ACST assessment are excluded from Table 2 and were recorded as “ni” (indicator not available) in reporting.

Table 2. Factors assessed and reported using ACST methodology

1. Prescreening	2. Water Quality	3. Terrestrial biological responses	4. Aquatic biological responses	5. Other
Presence of mineral soil	ni	% cover of *Agrostis stolonifera-Glyceria fluitans* community	% cover/presence of algal paper	Physical damage to turlough
Presence of flooded pavement community		% cover of *Rumex crispus, R. congolomeratus, R. acetosa* (individually or as a community)	Presence/absence of fully aquatic vascular plants	
Presence of limestone pavement within 200m of site		% cover of *Lolium* sp. grassland cover		
Presence of *Potentilla fruticosa*		% cover of grass/forb dominated community		
Presence of *Frangula alnus*		% cover of *Filipendula ulmaria-Potentilla erecta-Viola* sp. community		
Presence of *Schoenus nigricans*		% cover of *Poa annua-Plantago major* community		
		% cover of *Polygonum amphibium*		
		% cover of *Eleocharis acicularis*		
		% cover of limestone grassland, flooded pavement, or woodland communities		
		% cover of *Eleocharis palustris-Ranunculus flammula* community		
		% cover of *Molinia caerulea-Carex panicea* community		
		Average sward height		

4. Results

a. Dataset

In total, 161 quadrats were recorded with 73 species. Nine quadrats were removed from the dataset for analyses to reduce noise from quadrats with two or fewer species present, or greater than 67% bare ground. Seven species were removed from the dataset for analyses to reduce noise from species present in only one quadrat. The final dataset for analyses contained 152 quadrats and 66 species. Removed quadrats and species were included in the documentation of vegetation community composition for individual features and excluded solely from the dataset for cluster analysis. A total species list can be found in Appendix 4.

b. Cluster Analysis and Ordination

NMS ordination was run on the "slow and thorough" approach using the Sørenson (Bray-Curtis) distance measure. Ordination, as shown in Table 3, demonstrated that the real data had a statistically significant lower stress value than the randomized data.

Table 3. NMS ordination statistics comparing real data to Monte Carlo randomized data

NMS Ordination	Real Data	Monte Carlo randomized test
Runs	250	250
Minimum Stress	16.729	22.863
Mean Stress	17.427	29.582
Maximum Stress	19.552	52.842
p-Value	0.0040	0.0040

This was then tested up to 6 axes to represent sources of variance in the data, as shown in Figure 6. Ordination recommended a 3-dimensional solution. The 3-dimensional solution's final ordination had a stress value of 17.3 and an instability value of 0.004 after 500 iterations, and represents 74.6% of variance in the dataset. Axes and axes combinations are represented in Table 4.

Figure 6. Scree plot of stress value of real data compared to Monte Carlo randomized data, by number of dimensions

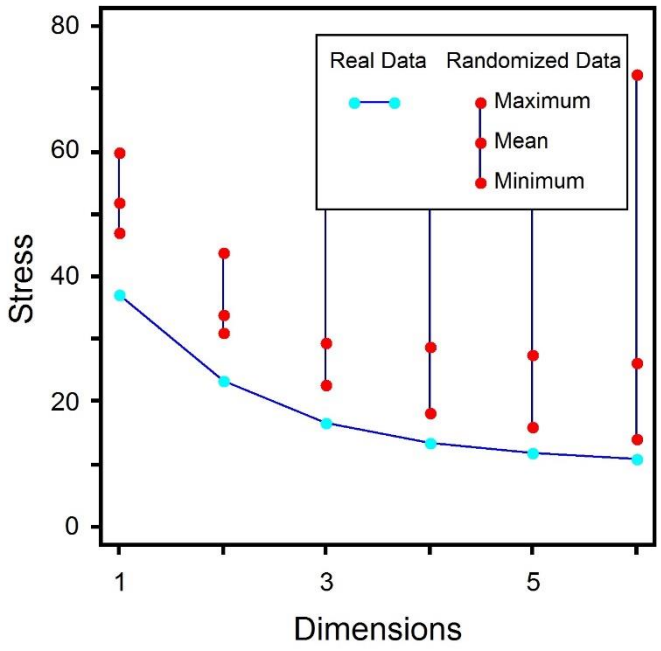

Table 4. NMS ordination variance axes and proportion of representation of variance

Representation of Variance	Proportion of Variance (r^2)
Axis 1	0.183
Axis 2	0.299
Axis 3	0.264
Axes 1 and 2	0.482
Axes 1 and 3	0.447
Axes 2 and 3	0.563
3-dimensional solution	0.746

Species data were grouped using the Dufrêne and Legendre (1997) method of indicator species analysis, as represented in Figure 7. Optimal clustering was shown to occur with 5 groups. At this stage, mean p-value of species-group indication was equal to 0.1049 and there were 45 significant indicator species (p-value<0.05). While a 4-group solution produced sufficiently significant results (mean p-value=0.1126, 46 indicator species), the 5-group solution is more fully descriptive of the community composition of the study features and presents a lower mean p-value.

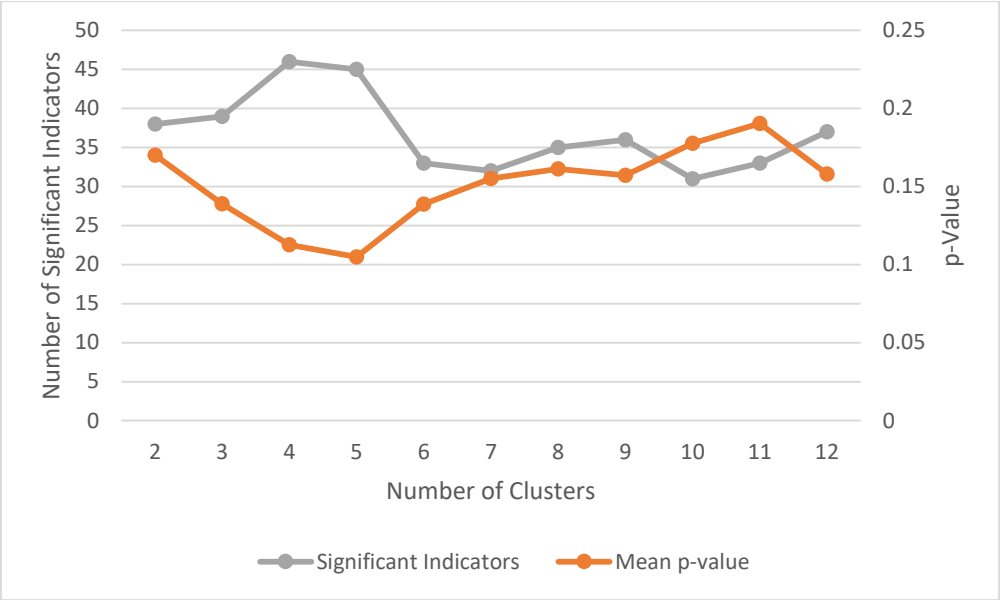

Figure 7. Number of significant indicator species and mean species indicator value by number of clusters

These five clusters are presented within paired axes in Figures 8-10. These relations are further discussed in section 4.c in terms of the relative location and function of these vegetation community clusters.

Axis 1 was the least descriptive axis in terms of proportion of variance represented. It did, however, provide a degree of a gradient with group 5 at one end and group 2 at the opposite. This can be considered a soft gradient of dry-wet within and between the features.

Axis 2 segregated groups 2 and 3 from 1, 4, and 5. This can be described as segregating the lower zone quadrats from the upper zones.

Axis 3 most significantly separated group 5 from groups 1-4 and provided little differentiation within groups 1-4. This can be described as segregating the turlough-like communities from the limestone grassland community.

The combined axes 2 and 3, as shown in Figure 10, represent best the gradient formed by these clusters in terms of position within the features' basins, from the upper, drier zones to the lower, wetter zones.

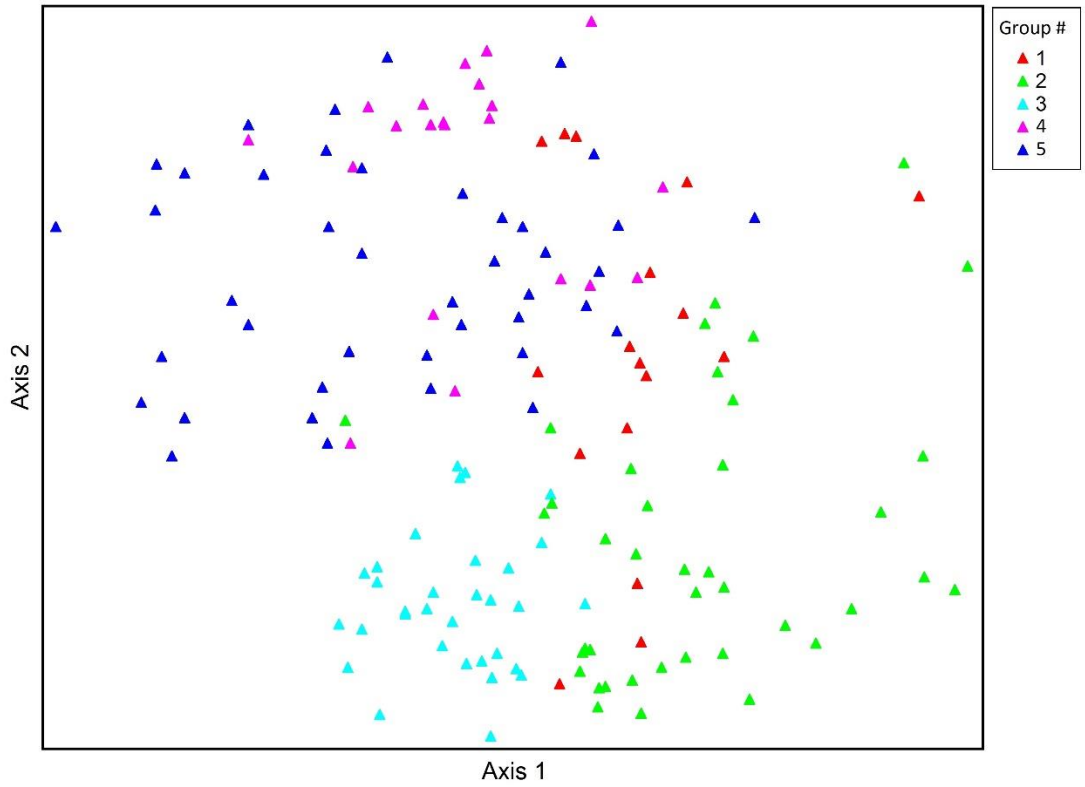

Figure 8. Representation of axes 1 and 2, with quadrats clustered in 5 groups

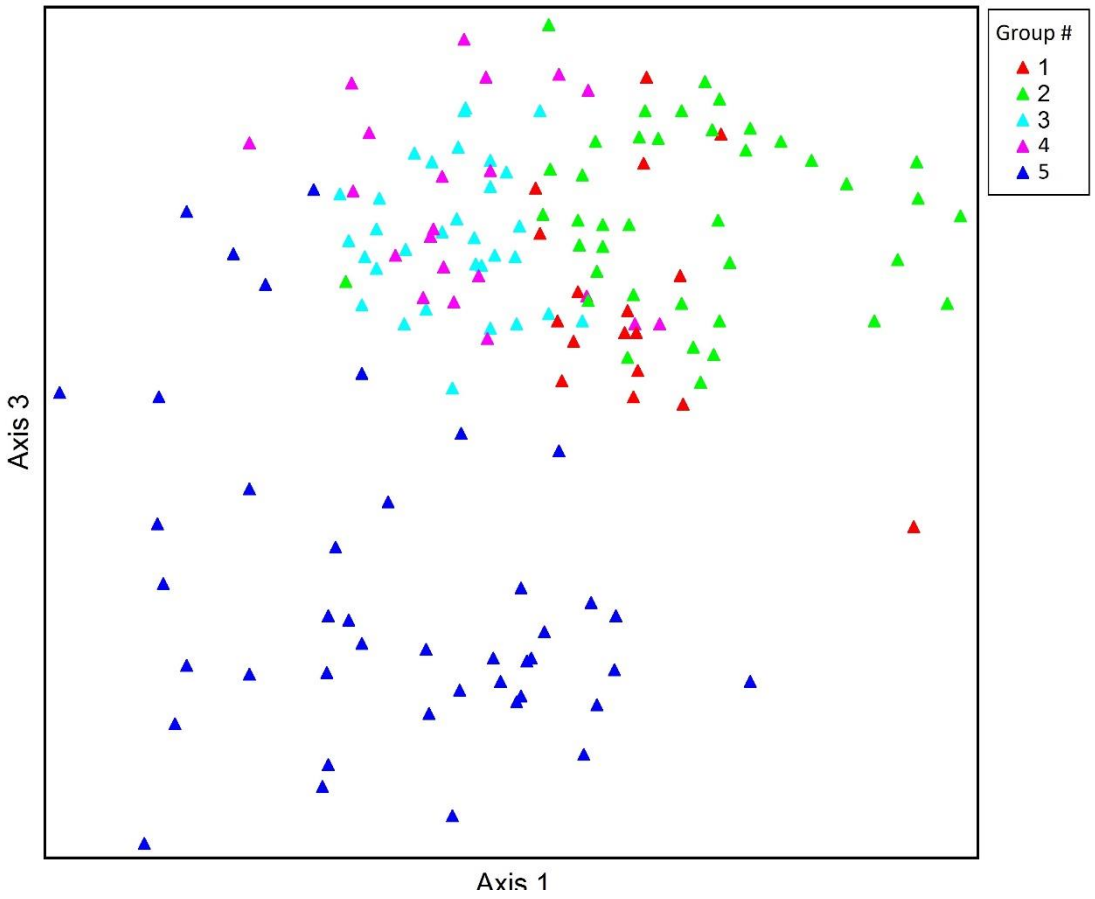

Figure 9. Representation of axes 1 and 3, with quadrats clustered in 5 groups

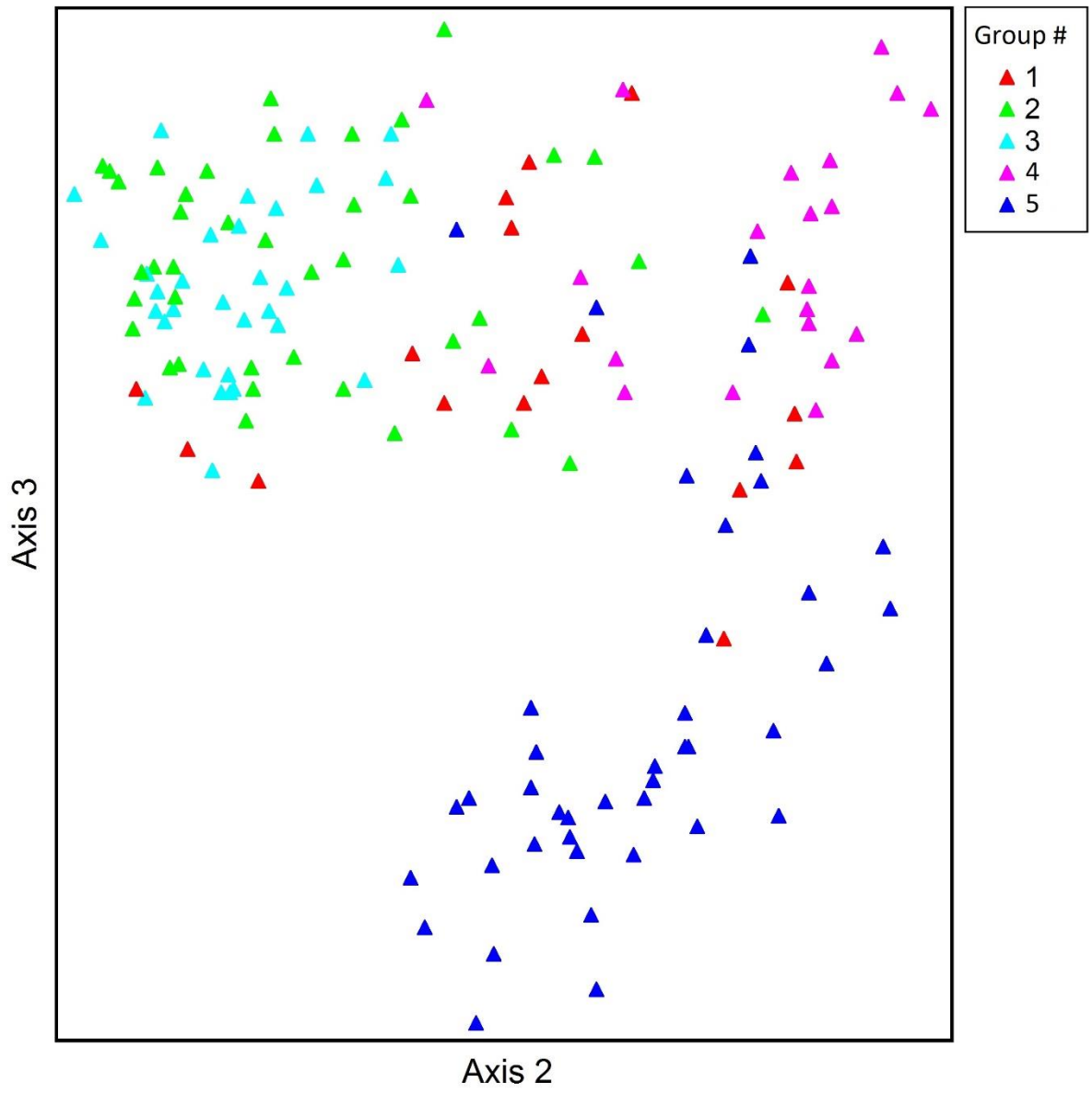

Figure 10. Representation of axes 2 and 3, with quadrats clustered in 5 groups

The vegetation communities were then assembled into a cluster dendrogram in Figure 11 to represent the degree of similarity between quadrats and clusters, and relations within these clusters. Dendrograms for each given vegetation community are presented alongside the given community in section 4.c.

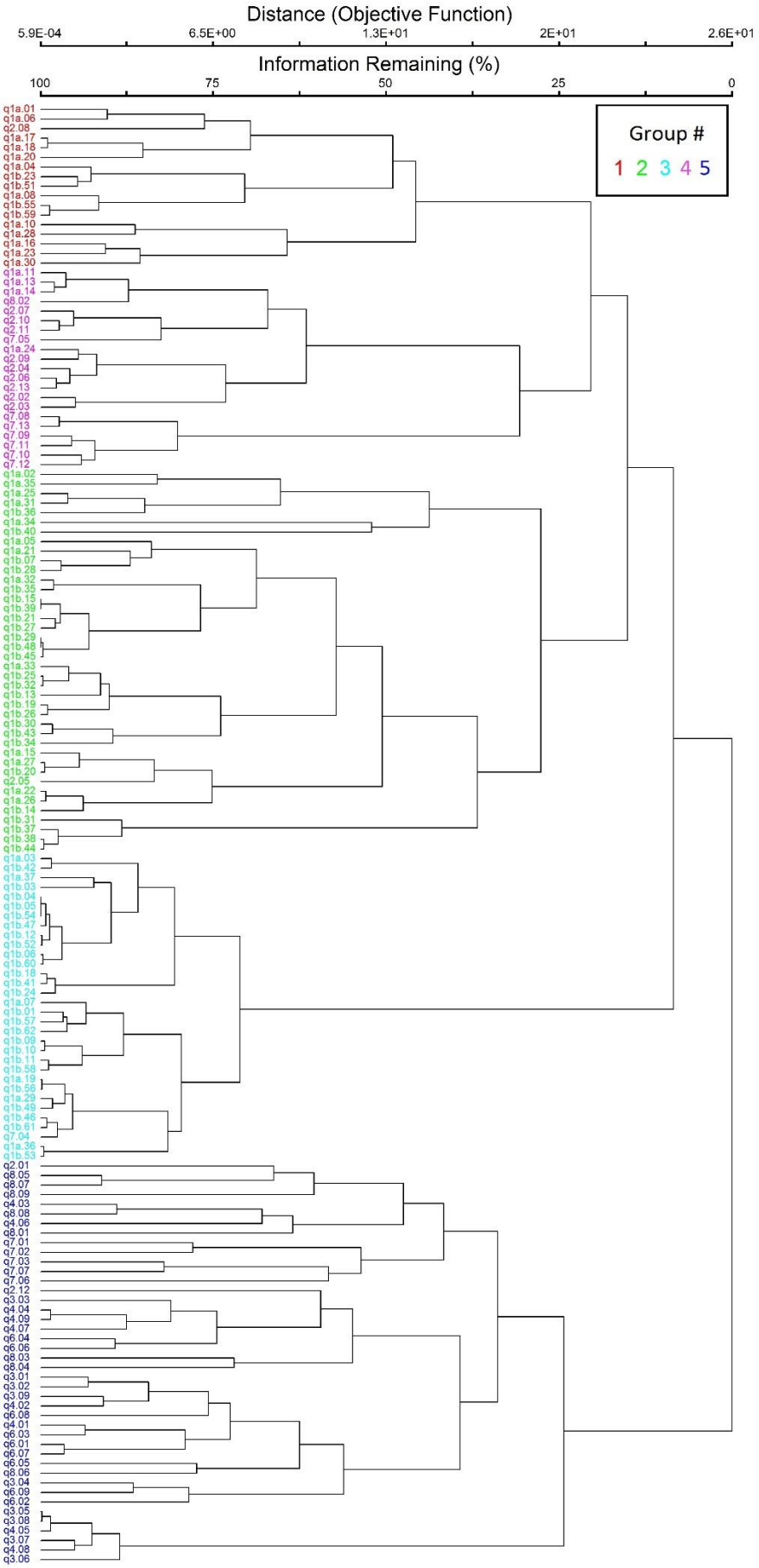

Figure 11. Cluster dendrogram of vegetation communities in 5 groups

c. Vegetation Communities

The vegetation communities are related as in the cluster dendrograms in Figure 11. Species designated as being strong indicators have an indicator value greater than or equal to 20. Vegetation community key characteristics are summarized in Table 5.

Table 5. Key characteristics of vegetation communities

Group #	# of quadrats	Species Richness	# of indicator species	Mean species richness per quadrat	Average sward height (cm)	Percent cover of bare ground	Found in
1	17	31	5	8.76	21.2	27.4%	Middle-upper zones of wet features
2	40	31	3	6.38	31.5	16.2%	Lower zone of wet features
3	32	29	3	7.41	27.2	4.7%	Lower-middle zones of wet features
4	21	42	6	10.48	24.5	9.8%	Lower zones of slightly wet features, and upper zones of wet features
5	42	55	15	12.88	27.1	4.3%	Dry features, and upper zones of slightly wet features

Group 1 was characterized by *Lotus corniculatus*, *Centaurea nigra*, and moss, and will be referred to as the *Lotus-Centaurea* community. This community was found primarily in basin A of feature #1, as well as basin B and a single quadrat of feature #2.

Group 2 was characterized by *Schoenus nigricans*, as well as containing the exclusive group for *Cladium mariscus* and high frequency of *Baldellia ranunculoides*, and will be referred to as the *Schoenus* community. This community was found primarily in both basins of feature #1, as well as a single quadrat of feature #2.

Group 3 was characterized by *Molinia caerulea*, *Potentilla erecta*, and *Cirsium dissectum*, and will be referred to as the *Molinia* community. This community was found primarily in both basins of feature #1, as well as a single quadrat of feature #7.

Group 4 was characterized most strongly by *Carex flacca, Plantago lanceolata*, and *Potentilla anserina*, and will be referred to as the *Carex flacca* community. This community was found primarily in features #2 and 7, as well as basin A of feature #1 and a single quadrat of feature #8. Within these features, the community was most often found in the lower zones of the flooding gradient of slightly wet features #2, 7, and 8, or the upper zones of the wet feature #1.

Group 5 was characterized by a diverse range of indicator species, with *Pteridium aquilinum, Geranium sanguineum*, and *Anthoxanthum odoratum* representing the group most strongly. This group will be referred to as the *Pteridium-Geranium-Anthoxanthum* community. This community was found primarily in features #3, 4, 6, and 8, as well as features #2 and 7. This community was fully absent solely from feature #1. This community was found equally dispersed throughout drier features, as well as the upper zones of the flooding gradient of slightly wet features #2 and 7.

i. Group 1: *Lotus-Centaurea*

This vegetation community was represented in 17 quadrats and 31 species across two features, with two strong indicator species and moss as a strong indicator. This community had a mean species richness of 8.76 species per quadrat. Average percent cover of bare ground was 27.4% (+/- 19.3%). Average sward height was 21.2 cm (+/- 8.2 cm). This was the lowest average sward height and highest percent cover of bare ground of the vegetation communities.

This community most closely resembles that of Sharkey's (2012) group 5, 'Limestone Grassland,' with high frequency of *Lotus corniculatus* and *Carex flacca*, and moderate frequencies of *Centaurea nigra* and *Succisa pratensis.* Sharkey's frequent species included a number of species found in low frequency in this community, including *Plantago lanceolata, Potentilla erecta, Carex panicea*, and *Trifolium repens,* while Sharkey's frequent *Festuca rubra* was absent in this community. Sharkey's group was found on the furthest upper zones of turloughs, in shallow, marginally damp soil. This is largely consistent with the findings of this study, though this community was most often identified in rocky patches.

Cluster analysis, as shown in Figure 11, found this community to be most closely related to the *Carex flacca* community. This community is most notably different from the *Carex flacca* community in having a higher frequency of *Lotus corniculatus* and percent cover of bare ground. This community was found in rockier habitats than the *Carex flacca* community, in similar upper zones of the basin. No distinctive clades or outliers were identified in this community, as shown in Figure 12.

Figure 12. Cluster dendrogram of group 1: Lotus-Centaurea *community*

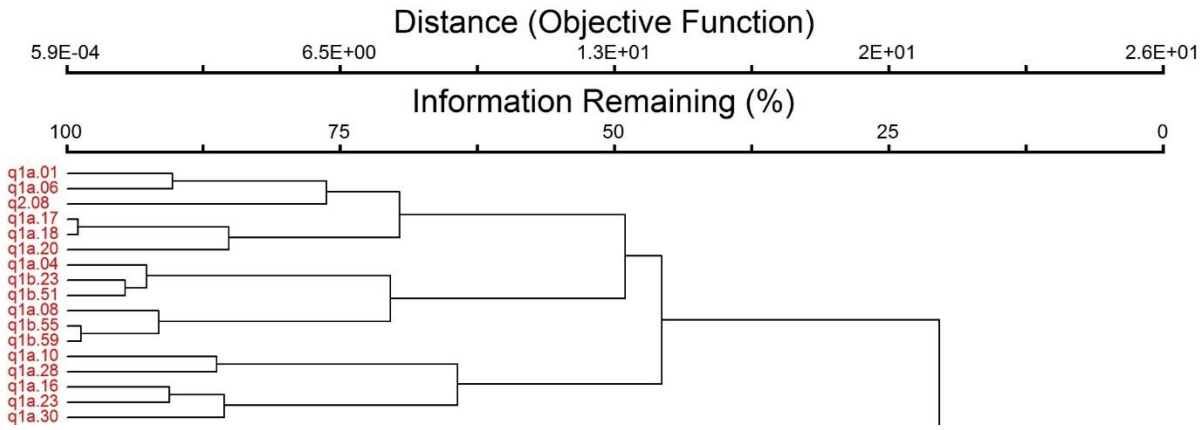

Table 6. Indicator and constant/near-constant species for Lotus-Centaurea *community, with indicator value and frequency*

Indicator	Indicator Value	Frequency
Lotus corniculatus	64	IV
Moss	34	V
Centaurea nigra	25	III
Carex flacca	18	IV
Schoenus nigricans	12	IV

Anthoxanthum odoratum I
Anthyllis vulneraria I
Briza media I
Calluna vulgaris I
Carex nigra I
Carex panicea I
Carex pulicaris I
Cirsium dissectum II
Dactylorhiza fuchsii I
Galium boreale III
Galium verum I
Geranium sanguineum I
Lathyrus pratensis I
Leontodon autumnalis I
Mentha aquatica I
Molinia caerulea III
Parnassia palustris II
Plantago lanceolata II
Plantago maritima III
Potentilla erecta II
Ranunculus flammula I
Ranunculus repens III
Sedum acre I
Succisa pratensis III
Thymus polytrichus I
Trifolium repens I
Triglochin palustris I

ii. Group 2: *Schoenus*

This vegetation community was represented in 40 quadrats and 31 species across two features, with three strong indicator species. This community had a mean species richness of 6.38 species per quadrat. This is the lowest level of diversity of the vegetation communities. Average percent cover of bare ground was 16.2% (+/- 16.8%). Average sward height was 31.5 cm (+/- 10.9 cm). This was the highest average sward height of the vegetation communities.

This community assemblage most closely resembles Sharkey's (2012) group 21, '*Schoenus nigricans* fen,' with high frequency of *Schoenus nigricans* and *Molinia caerulea*. Sharkey's group identified higher frequencies of *Succisa pratensis* and *Potentilla erecta* than this study. Sharkey's group lacked this study's strong indicator species *Baldellia ranunculoides* and *Cladium mariscus*. Sharkey's group was found in the upper zones of the turlough basins,

on damp, but not consistently wet soil. The presence of aquatic *Baldellia ranunculoides* (Kozlowski & Matthies 2009) and primarily aquatic *Cladium mariscus* (Conway 1942) suggests the *Schoenus* community proposed in this study occupies a wetter zone of the turlough basin than does Sharkey's group. The presence of these more aquatic species suggests this community is a middle-lower zone community within the turlough. This is the 'wettest' community identified in this study.

This community further resembles a subsection of the 4b community "Reedswamp and tall sedge communities- Cladietum marisci" described by O'Connell *et al*. in 1984. This community was described as being dominated by tall stands of *Cladium mariscus*, *Schoenus nigricans*, and *Molinia caerulea*, consistent in both species composition and relation of sward height to proximal communities with this proposed community.

Cluster analysis, as shown in Figure 11, found this community to be most closely, though very distantly, related to the *Lotus-Centaurea* and *Carex flacca* communities. This community can also be considered a more aquatic relation to the *Molinia* community, with which it shares the high frequency of *Schoenus nigricans* and *Molinia caerulea*. It is primarily differentiated by its higher frequency of *Baldellia ranunculoides*, lower frequency of *Cirsium dissectum* and *Potentilla erecta*, and presence of *Cladium mariscus*. No distinctive clades or outliers were identified in this community, as shown in Figure 13.

Figure 13. Cluster dendrogram of group 2: Schoenus *community*

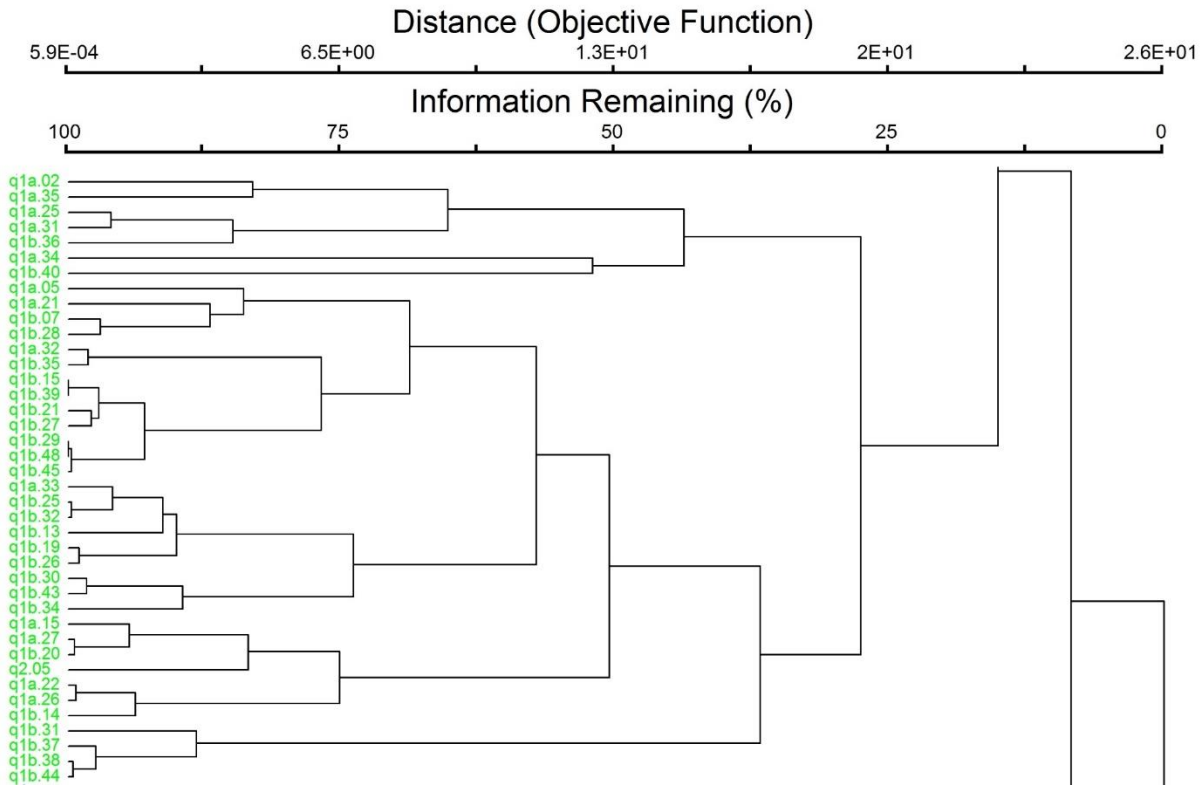

Table 7. Indicator and constant/near-constant species for Schoenus *community, with indicator value and frequency*

Indicator	Indicator Value	Frequency
Schoenus nigricans	61	V
Baldellia ranunculoides	32	II
Cladium mariscus	23	II
Molinia caerulea	14	IV

Algae II
Anthoxanthum odoratum I
Calluna vulgaris I
Carex flacca III
Carex nigra I
Centaurea nigra I
Cirsium dissectum I
Filipendula ulmaria I
Galium boreale II
Galium verum I
Hieracium pilosella I
Leontodon autumnalis I
Lotus corniculatus I
Mentha aquatica I
Moss II
Parnassia palustris I
Plantago lanceolata I
Plantago maritima II
Potentilla erecta II
Pteridium aquilinum I
Ranunculus flammula I
Ranunculus repens II
Rosa pimpinellifolia I
Rubus saxatilis I
Sedum acre II
Seslaria caerulea I
Succisa pratensis II
Trifolium repens I
Triglochin palustris I

iii. Group 3: *Molinia*

This vegetation community was represented in 32 quadrats and 29 species across two features, with three strong indicator species. This community had a mean species richness of 7.41 species per quadrat. Average percent cover of bare ground was 4.7% (+/- 6.7%). Average sward height was 27.2 cm (+/- 8.7 cm).

Similarly to the *Schoenus* community, this community is most closely related to Sharkey's (2012) group 21, '*Schoenus nigricans* fen,' sharing all frequent species from Sharkey's group. Sharkey's group was found in the upper zones of the turlough basins, on damp, but not consistently wet soil. This community diverges in having a high frequency of *Cirsium dissectum*, which is found in relatively low frequency in Sharkey's group. As *Cirsium dissectum* is found in primarily the upper zones of turlough basins (De Vere 2007; Sharkey 2012), this community can be expected to be found in similar habitats to Sharkey's group, or in drier zones than the *Schoenus* community proposed in this study.

This community further resembled group 1 as described by Regan *et al*. (2007), with *Schoenus nigricans*, *Molinia caerulea*, and *Cirsium dissectum* as strong indicators. Regan *et al*. identified this group as having the highest identified soil moisture percentage and lowest water TP of the described communities.

Cluster analysis, as shown in Figure 11, was not closely related to any other communities, and found this community to be the most closely related community within the group, as shown in Figure 14. This community can be considered a less aquatic relation to the *Schoenus* community, with which it shares the high frequency of *Schoenus nigricans* and

Molinia caerulea. It is primarily differentiated by its lower frequency of *Baldellia ranunculoides*, higher frequency of *Cirsium dissectum* and *Potentilla erecta*, and lack of *Cladium mariscus*.

Figure 14. Cluster dendrogram of group 3: Molinia *community*

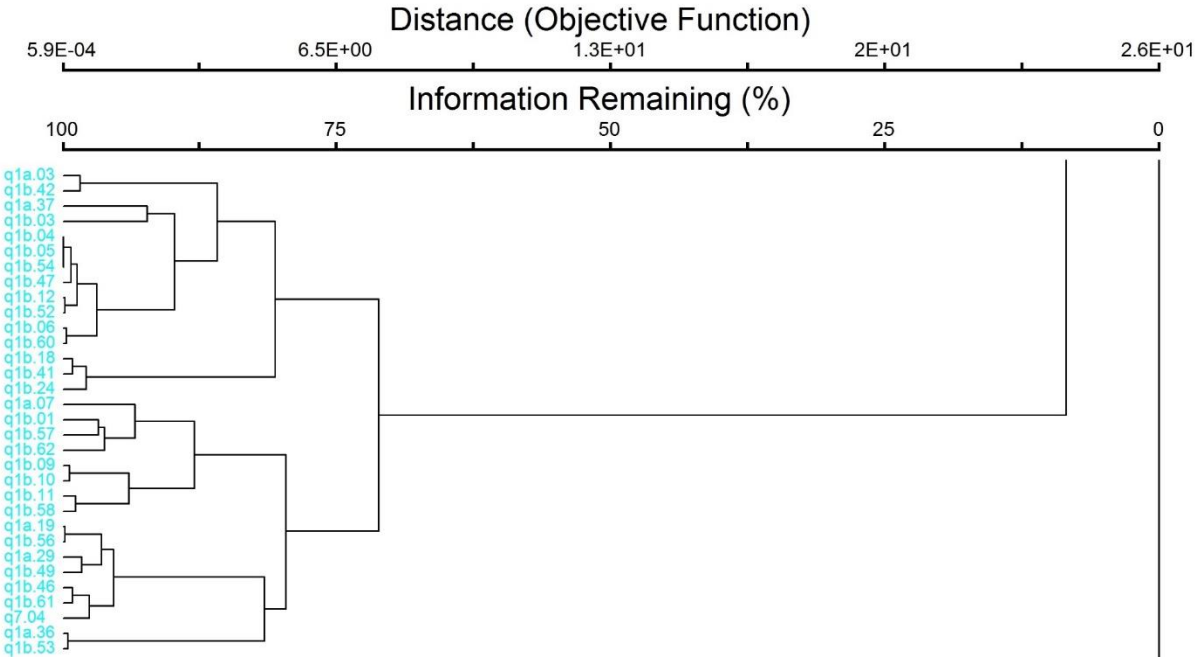

Table 8. Indicator and constant/near-constant species for Molinia *community, with indicator value and frequency*

Indicator	Indicator Value	Frequency
Molinia caerulea	62	V
Potentilla erecta	29	IV
Cirsium dissectum	24	IV
Succisa pratensis	13	IV
Schoenus nigricans	9	IV

Algae I
Anthyllis vulneraria I
Baldellia ranunculoides I
Calluna vulgaris I
Carex flacca III
Carex hostiana I
Carex nigra I
Centaurea nigra I
Dactylorhiza fuchsii I
Filipendula ulmaria I
Galium boreale II
Galium verum I
Hieracium pilosella I
Lotus corniculatus II
Mentha aquatica I
Moss II
Parnassia palustris II
Plantago lanceolata II
Plantago maritima II
Potentilla anserina I
Ranunculus flammula I
Ranunculus repens II
Rubus saxatilis I
Sedum acre I
Trifolium repens I
Triglochin palustris I

iv. Group 4: *Carex flacca*

This vegetation community was represented in 21 quadrats and 42 species across four features, with six strong indicator species. This community had a mean species richness of 10.48 species per quadrat. Average percent cover of bare ground was 9.8% (+/- 14.3%). Average sward height was 24.5 cm (+/- 7.2 cm).

Similarly to the *Lotus-Centaurea* community, this community is most closely related to Sharkey's (2012) group 5, 'Limestone Grassland,' with high frequency of *Carex flacca, Plantago lanceolata, Ranunculus repens*, and *Potentilla erecta*. Sharkey's frequent species *Carex panicea, Lotus corniculatus,* and *Succisa pratensis* were found in lower frequencies in this community, while *Trifolium repens* was absent. Sharkey's group was found on the furthest upper zones of turloughs, in shallow, marginally damp soil. This is consistent with the findings of this study.

This community had similarities to the community described by O'Connell *et al*. in 1984, community 6.b.viii "Fen communities associated with turloughs and related habitats: Ranunculo-Potentilletum ancerinae Braun-Blanque et Tüxen 1952 em.: Ranunculo-Potentilletum ancerinae typicum." These communities share high frequencies of the species *Potentilla anserina*, *Plantago lanceolata*, *Galium* spp., and *Ranunculus repens*. This study's proposed community, however, lacks the presence of *Agrostis stolonifera*, *Trifolium repens*, and *Leontodon autumnalis*, as well as supporting a lower frequency of *Filipendula ulmaria*. The O'Connell *et al*. community was described as being the "main pasturage zone in the upper reaches of turloughs."

Cluster analysis, as shown in Figure 11, found this community to be most closely related to the *Lotus-Centaurea* community. This community is most notably different from the *Lotus-Centaurea* community in having a lower frequency of *Lotus* and percent cover of bare ground. This community was found in fewer rocky habitats than the *Lotus-Centaurea* community, in similar upper zones of the basin.

This community had a distinct branch exclusive to feature #7, identifiable as having a markedly higher frequency and percent cover of *Potentilla anserina,* and shown in Figure 15. This branch was found exclusively at the lowest zone, and included a dense population of *Potentilla anserina* approaching 100% cover in an area of roughly $10m^2$.

Figure 15. Cluster dendrogram of group 4: Carex flacca *community*

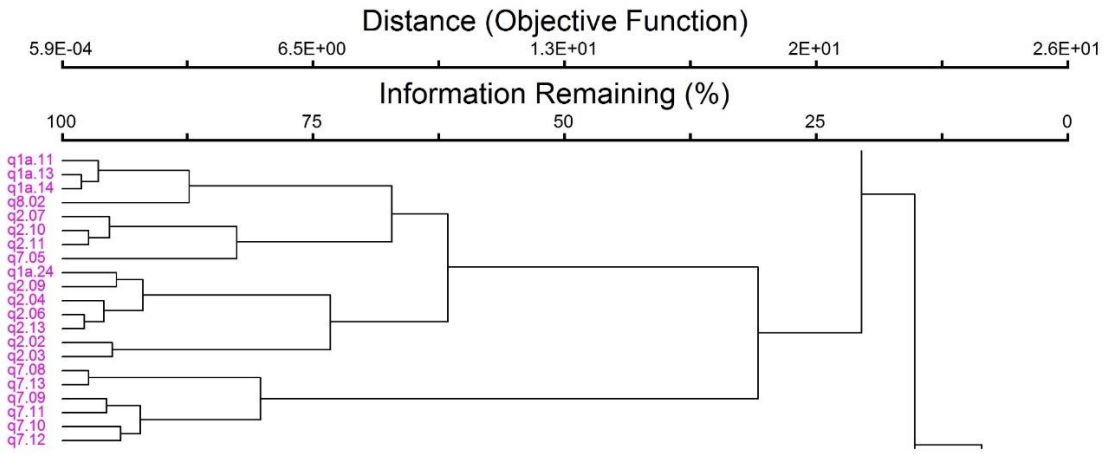

Table 9. Indicator and constant/near-constant species for Carex flacca *community, with indicator value and frequency*

Indicator	Indicator Value	Frequency
Carex flacca	57	V
Potentilla anserina	42	III
Plantago lanceolata	34	IV
Mentha aquatica	30	III
Ranunculus repens	21	IV
Galium boreale	20	III
Potentilla erecta	12	IV

Anthoxanthum odoratum I
Baldellia ranunculoides I
Bellis perennis I
Briza media I
Calluna vulgaris I
Carex hostiana I
Carex nigra I
Carex panicea I
Carex pulicaris I
Centaurea nigra I
Cirsium dissectum III
Dactylorhiza fuchsii I
Filipendula ulmaria II
Galium verum I
Geranium sanguineum I
Hieracium pilosella I
Holcus lanatus I
Hypericium pulchrum I
Lathyrus pratensis I
Leontodon autumnalis I
Lotus corniculatus II
Molinia caerulea II
Moss II
Ophioglossum vulgatum I
Plantago maritima III
Polygala serpyllifolia I
Pteridium aquilinum I
Ranunculus bulbosus I
Ranunculus flammula II
Rosa pimpinellifolia I
Rubus saxatilis II
Schoenus nigricans I
Sedum acre I
Seslaria caerulea I
Succisa pratensis II
Thymus polytrichus I

v. Group 5: *Pteridium-Geranium-Anthoxanthum*

This vegetation community was represented in 42 quadrats and 55 species across 6 features, with 14 strong indicator species and moss as a strong indicator. This community had a mean species richness of 12.88 species per quadrat. This is the highest level of diversity of the vegetation communities. Average percent cover of bare ground was 4.3% (+/- 9.1%). This

was the lowest percent cover of bare ground of the vegetation communities. Average sward height was 27.1 cm (+/- 11.1 cm).

Cluster analysis, as shown in Figure 11, found this community to be significantly separate from the other four vegetation communities identified in this study. This was found to be a very loosely related group, as shown in Figure 16 and could be described as “Other.”

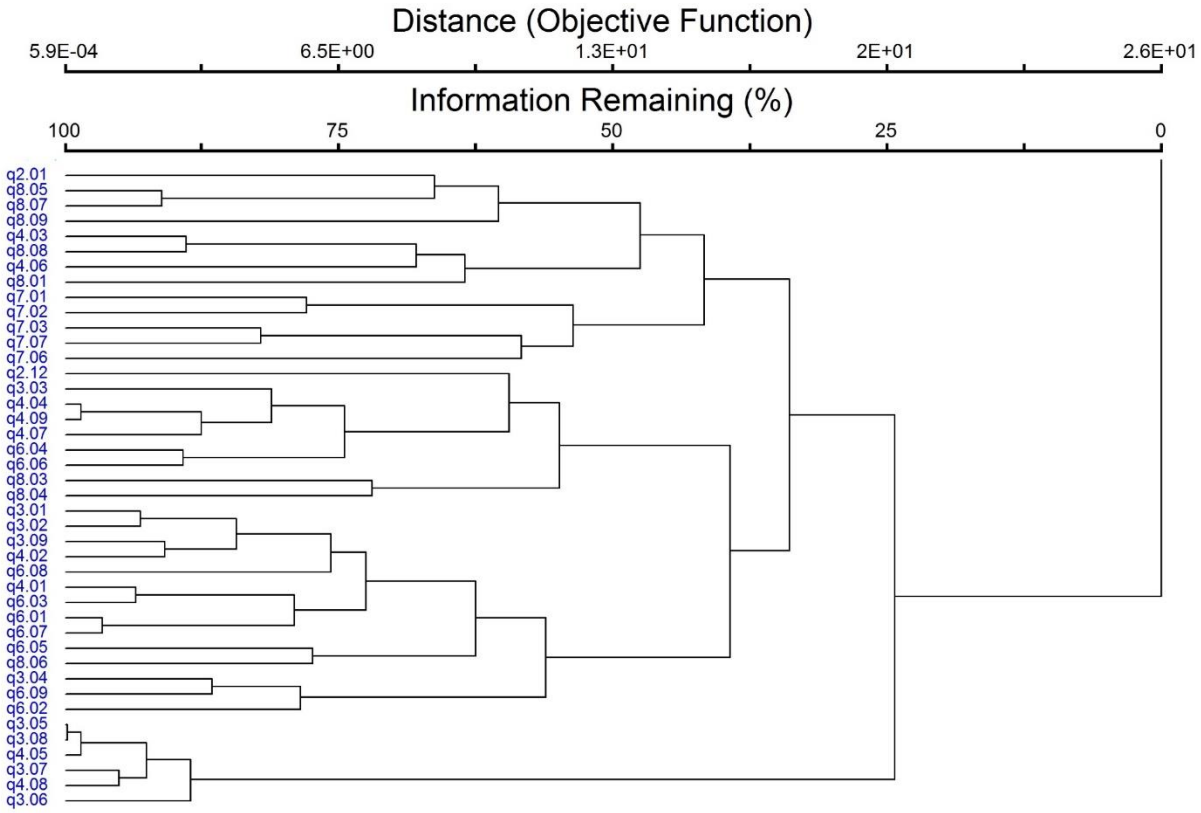

Figure 16. Cluster dendrogram of group 5: Pteridium-Geranium-Anthoxanthum *community*

This community does not closely resemble any community assemblage described within the turloughs of Sharkey’s 2012 or Hanley’s 2014 studies. The dominant species, *Pteridium aquilinum, Geranium sanguineum*, and *Anthoxanthum odoratum*, were infrequently identified within any of the designated turloughs of these studies. *Pteridium aquilinum* was fully absent from both studies and is not tolerant of flooded or wet conditions (Marrs & Watt 2006). Its presence is indicative of dry conditions and would be unlikely to be found within the flooding zone of a turlough. *Geranium sanguineum* is similarly unlikely to be found within a turlough and is considered a heathland species (Feeser & O’Connell 2009). Quadrats represented by this community assemblage can be definitively stated to not be found in the flooding zone of a turlough.

Table 10. Indicator and constant/near-constant species for Pteridium-Geranium-Anthoxanthum *community*

Indicators	Indicator Value	Frequency
Pteridium aquilinum	72	IV
Geranium sanguineum	59	IV
Anthoxanthum odoratum	58	III
Holcus lanatus	44	III
Seslaria caerulea	43	III
Rosa pimpinellifolia	40	III
Succisa pratensis	29	IV
Calluna vulgaris	27	II
Briza media	25	II
Achillea millefolia	24	II
Ranunculus bulbosus	24	II
Moss	22	IV
Plantago lanceolata	21	III
Prunus spinosa	21	II
Leontodon autumnalis	20	II
Potentilla erecta	14	IV
Carex flacca	4	IV

Anthyllis vulneraria I
Bellis perennis I
Carex hostiana I
Carex nigra I
Carex panicea I
Centaurea nigra I
Cirsium dissectum III
Conopodium majus I
Cynosurus cristatus I
Dactylis glomerata I
Dactylorhiza fuchsii II
Filipendula ulmaria I
Galium boreale I
Galium palustre I
Galium verum II
Gymnadenia conopsea I
Hetera helix I
Hieracium pilosella II
Hypericium pulchrum I
Lathyrus pratensis I
Listera ovata I
Lolium perenne I
Lotus corniculatus I
Mentha aquatica I
Molinia caerulea I
Ophioglossum vulneraria I
Plantago maritima I
Polygala serpyllifolia I
Potentilla anserina I
Ranunculus flammula I
Ranunculus repens I
Rhinanthus minor I
Rubus saxatilis I
Sagina nodosa I
Teucrium scorodonia I
Thymus polytrichus I
Trifolium campestre I
Trifolium palustre I
Trifolium repens I

d. Community Composition of Features

A summary of key characteristics of each given feature is provided in Table 11. Table 12 summarizes the percent of quadrats in each given feature that are represented by each given vegetation community. Maps for individual features are presented with prominent landforms in the immediate proximity of the given feature marked. All maps are inset from the total study site (Figure 5).

Table 11. Key characteristics by feature

Feature #	Species Richness	Area of principal flooding (m^2)	Mean species richness per quadrat	Average sward height (cm)	Percent cover of bare ground
1	67	4955	6.64	27.1	14.7%
2	44	283	12.31	26.9	10.8%
3	51	244	10.89	30.6	4.4%
4	48	143	14.67	27.8	7.8%
6	47	114	12.67	22.8	6.9%
7	53	161	11.62	29.2	0.6%
8	58	39	13.11	26.7	0%

Table 12. Percent of quadrats in a given feature represented by vegetation community

Feature #	*Lotus-Centaurea* community	*Schoenus* community	*Molinia* community	*Carex flacca* community	*Pteridium-Geranium-Sanguineum* community
1	17.8%	43.3%	34.4%	4.4%	
2	7.7%	7.7%		69.2%	15.4%
3					100%
4					100%
6					100%
7			7.7%	53.8%	38.5%
8				11.1%	88.9%

i. Feature #1

The principally flooding area of basin A of this feature was 1855 m^2 and 1-2 meters in depth. The principally flooding area of basin B was 3100 m^2 and roughly 2 meters in depth. The feature was flooded for six days during the survey period. Initial flooding took place immediately following significant rainfall and did not recede before the end of the survey period. The feature was observed as flooded twice more after the survey period, in late July and late August. Permanent standing water was present solely in four estavelles, each less than 5 m^2 in area. The majority of the feature had well-drained soil, with only the immediate proximity of the estavelles (<10 m^2 for each estavelle) holding standing water at all times, and the lower zones holding water within the soil. The feature is bounded to the west by limestone grassland leading to a limestone wall and the public road, and exposed limestone pavement on all other sides. A limestone wall dissects basin B, which has fallen in places, has substantial gaps in

the stone, and is lower than the water level when the feature is maximally flooded. This is shown in Figure 17. The northern portion of basin B was overgrazed and trampled by a grazing population of 30 head of cattle. The feature is 25 meters and downhill from the public road, on which farmers had been observed washing agricultural equipment, and garbage was found within the depression. *Coenagrion* sp., *Pyrrhosoma nymphula*, a diverse assemblage of invertebrates, and a sizeable population of *Rana temporaria*, consisting of at least 30 individuals, primarily juveniles, were observed within the feature.

Figure 17. Photo of feature #1's basin B and its intersecting limestone wall

This feature was represented in 37 quadrats and 38 species in basin A quadrats, and 62 quadrats and 28 species in basin B quadrats, for a total of 99 quadrats and 67 species. Vegetation communities found within the feature were identified as primarily *Lotus-Centaurea, Schoenus*, and *Molinia*, as well as *Carex flacca.* Basin A supported all these communities, while basin B did not contain the *Carex flacca* community and represented proportionally less of the *Lotus-Centaurea* community. Mean species richness was 8.35 species per quadrat for basin A and 5.61 for basin B, or 6.64 for the total feature. This is the lowest value of the study features. Average sward height was 27.1 cm (+/- 10.5 cm). Percent cover of bare ground was 14.7% (+/- 17.1%). This was the highest percent cover of bare ground of the study features.

Table 13. Constant/near constant species in feature #1 and percent cover

Frequency Class IV	Percent Cover
Molinia caerulea	32.4%
Schoenus nigricans	18.6%

Algae I
Agrostis stolonifera 0
Anthoxanthum odoratum I
Anthyllis vulneraria I
Baldellia ranunculoides I
Briza media I
Callitriche sp. 0
Calluna vulgaris I
Carex flacca III
Carex hostiana I
Carex nigra I
Carex panicea I
Carex viridula agg. 0
Centaurea nigra I
Cirsium dissectum II
Cladium mariscus I
Dactylorhiza fuchsii I
Dactylorhiza incarnata 0
Eriophorum angustifolium 0
Filipendula vulgaris 0
Frangula alnus 0
Galium boreale II
Galium verum I
Geranium sanguineum I
Hieracium pilosella I
Juncus acutiflorus 0
Juncus effusus 0
Juniperus communis 0
Koelaria macrantha 0
Lathyrus pratensis I
Leontodon autumnalis I
Leontodon hispidus 0
Linum catharticum 0
Lotus corniculatus II
Mentha aquatica I
Minuartia verna 0
Moss III
Parnassia palustris I
Plantago lanceolata I
Plantago maritima II
Platanthera bifolia 0
Potamogeton polygonifolius 0
Potentilla anserina 0
Potentilla erecta III
Potentilla fruticosa 0
Prunella vulgaris 0
Prunus spinosa 0
Ranunculus flammula I
Ranunculus repens II
Rosa pimpinellifolia 0
Rubus saxatilis I
Salix aurita 0
Salix cinerea 0
Salix repens 0
Sedum acre II
Seslaria caerulea I
Succisa pratensis III
Taraxacum officinale 0
Thymus polytrichus I
Trifolium pratense 0
Trifolium repens I
Triglochin palustris I
Veronica sp. 0
Vibernum opulus 0
Vicia cracca 0
Vicia hirsuta 0
Viola canina 0

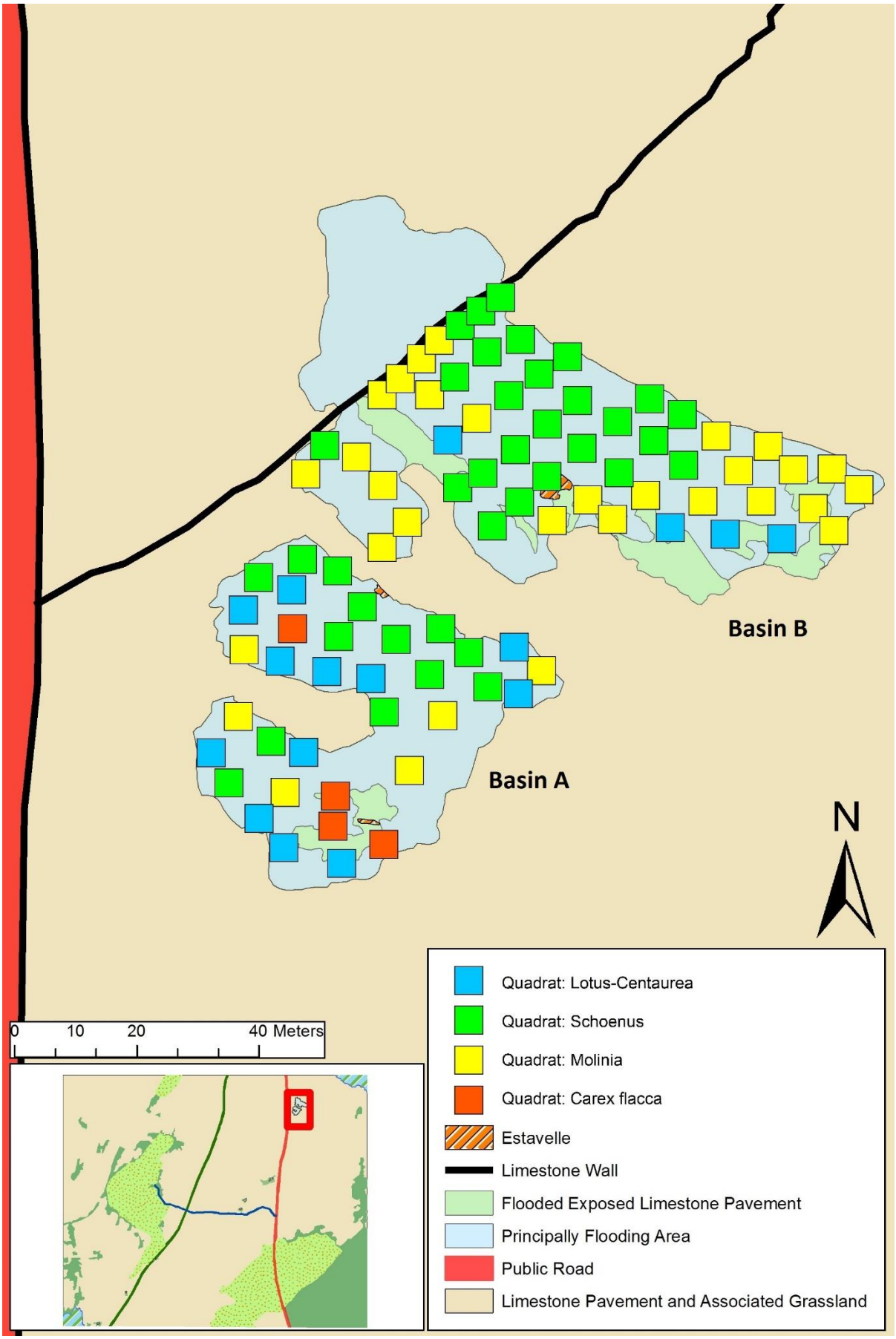

Figure 18. Map of feature #1 with vegetation communities and proximal landforms

ii. Feature #2

The principally flooding area of this feature was 283 m^2 and 1-2 meters in depth. The feature was flooded a total of two days during the survey period, following significant rainfall. No permanent standing water was present in the feature. The majority of the feature had well-drained soil, with only the lowest zones of the principally flooding area (<10 m^2) holding significant amounts of water. The feature is steep-sided and the principally flooding area forms a small proportion of the total depression. The wall at the westernmost end of the depression segregates the end of the depression from the main body and does not intersect the principally flooding area. *Rana temporaria*, *Coenagrion* sp., and a diverse assemblage of invertebrates were observed within the feature.

This feature was represented in 13 quadrats and 44 species. Vegetation communities found within this feature were identified as primarily *Carex flacca*, while *Lotus-Centaurea, Schoenus*, and *Pteridium-Geranium-Anthoxanthum* communities were also present. Mean species richness was 12.31 species per quadrat. Average sward height was 26.9 cm (+/- 6.4 cm). Percent cover of bare ground was 10.8% (+/- 12.1%).

Table 14. Constant/near constant species in feature #2 and percent cover

Frequency Class V	Percent Cover	Frequency Class IV	Percent Cover
Carex flacca	47.1%	*Cirsium dissectum*	4.0%
Plantago lanceolata	11.4%	*Potentilla erecta*	1.9%
Plantago maritima	6.0%	*Ranunculus repens*	1.5%

Anemone nemorosa 0
Anthoxanthum odoratum II
Briza media II
Calluna vulgaris I
Carex hostiana 0
Carex nigra 0
Carex panicea 0
Carex pulicaris II
Centaurea nigra II
Dactylorhiza fuchsii I
Filipendula ulmaria II
Filipendula vulgaris 0
Galium boreale III
Galium verum III
Geranium sanguineum II
Gymnadenia conopsea 0
Holcus lanatus I
Ilex aquifolium 0
Lathyrus pratensis I
Leontodon autumnalis II
Leontodon hispidus 0
Listera ovata 0
Lotus corniculatus I
Mentha aquatica III
Molinia caerulea II
Moss III
Potentilla anserina I
Potentilla fruticosa 0
Pteridium aquilinum II
Ranunculus bulbosus I
Ranunculus flammula II
Rosa pimpinellifolia III
Rubus saxatilis II
Schoenus nigricans I
Sedum acre I
Seslaria caerulea II
Succisa pratensis I
Thymus polytrichus I
Viola canina 0

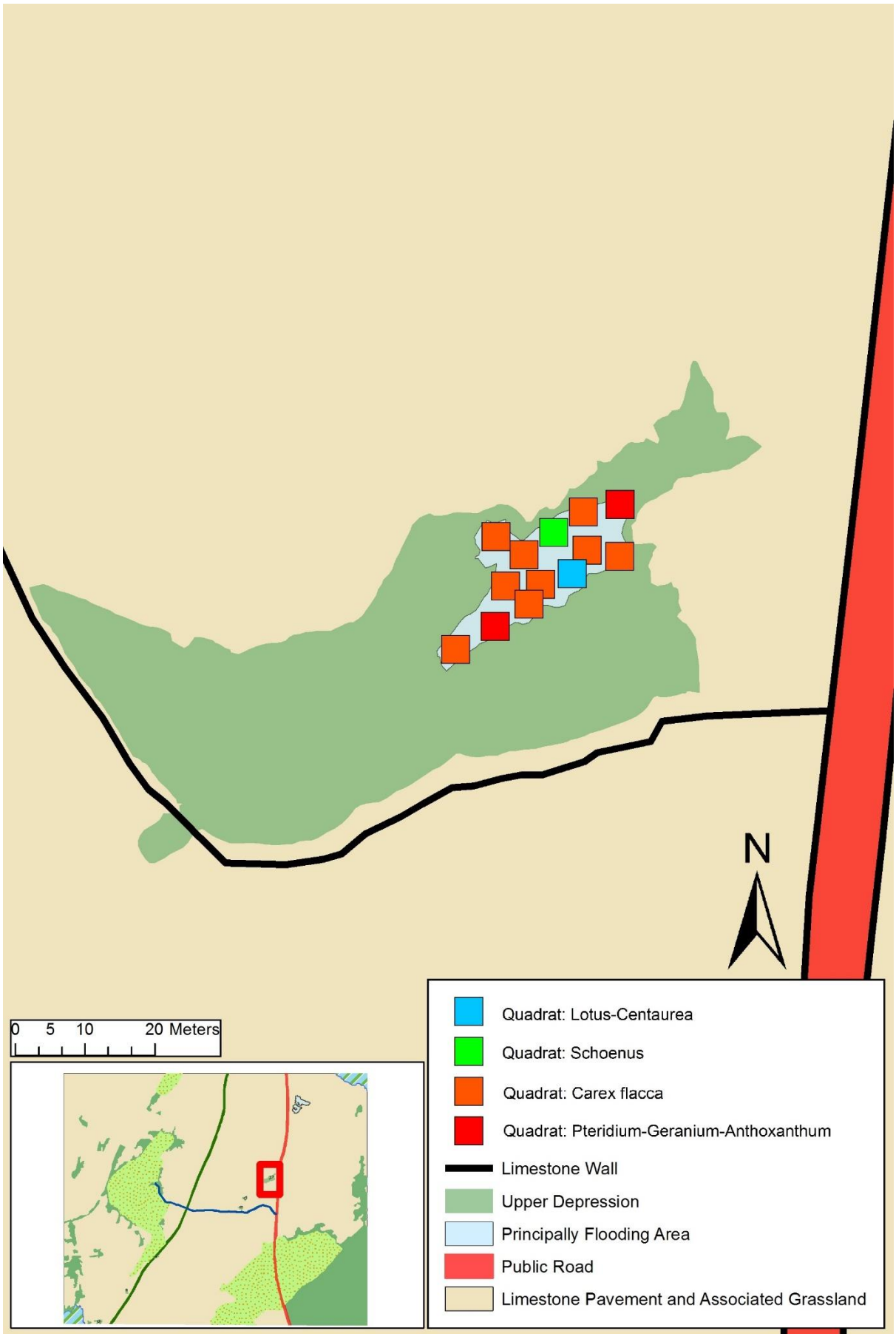

Figure 19. Map of feature #2 with vegetation communities and proximal landforms

iii. Feature #3

The principally flooding area of this feature was 244 m^2 and roughly 1 meter in depth. The feature was flooded for less than a single day during the survey period, drying out before noon on the day following significant rainfall. No permanent standing water was present in the feature and soil was well-drained. The feature is a shallow pan with exposed limestone pavements immediately surrounding it on all sides. *Coenagrion* sp. and a small community of other invertebrates were observed within the feature.

This feature was represented in 9 quadrats and 51 species. The exclusive vegetation community identified within this feature was the *Pteridium-Geranium-Anthoxanthum* community. Mean species richness was 10.89 species per quadrat. Average sward height was 30.6 cm (+/- 12.8 cm). This was the highest average sward height of the study feature. Percent cover of bare ground was 4.4% (+/- 7.5%).

Table 15. Constant/near constant species in feature #3 and percent cover

Frequency Class V	Percent Cover	Frequency Class IV	Percent Cover
Anthoxanthum odoratum	45.0%	*Succisa pratensis*	4.7%
Geranium sanguineum	3.9%		
Potentilla erecta	5.0%		
Pteridium aquilinum	19.4%		

Achillea millefolium II
Agrostis stolonifera 0
Antennaria dioica 0
Briza media I
Calluna vulgaris III
Carex flacca 0
Carex hostiana 0
Carex nigra 0
Carex panicea 0
Carex pulicaris 0
Centaurea nigra 0
Cirsium dissectum II
Conopodium majus I
Crataegus monogyna 0
Dactylorhiza fuchsii II
Dactylorhiza incarnata I
Euonymus europaeus 0
Festuca rubra 0
Filipendula ulmaria 0
Filipendula vulgaris 0
Galium boreale 0
Galium palustre I
Galium verum III
Hetera helix I
Hieracium pilosella I
Holcus lanatus III
Lathyrus pratensis II
Listera ovata 0
Lotus corniculatus I
Moss III
Molinia caerulea 0
Plantago lanceolata II
Plantago maritima 0
Polygala serpyllifolia II
Prunus spinosa II
Ranunculus acris 0
Ranunculus bulbosus III
Ranunculus flammula I
Rhamnus catharticum 0
Rosa pimpinellifolia II
Rubus fruticosus 0
Rubus saxatilis I
Sagina nodosa I
Seslaria caerulea III
Thymus polytrichus 0
Trifolium pratense 0
Vibernum opulus 0
Vicia cracca 0

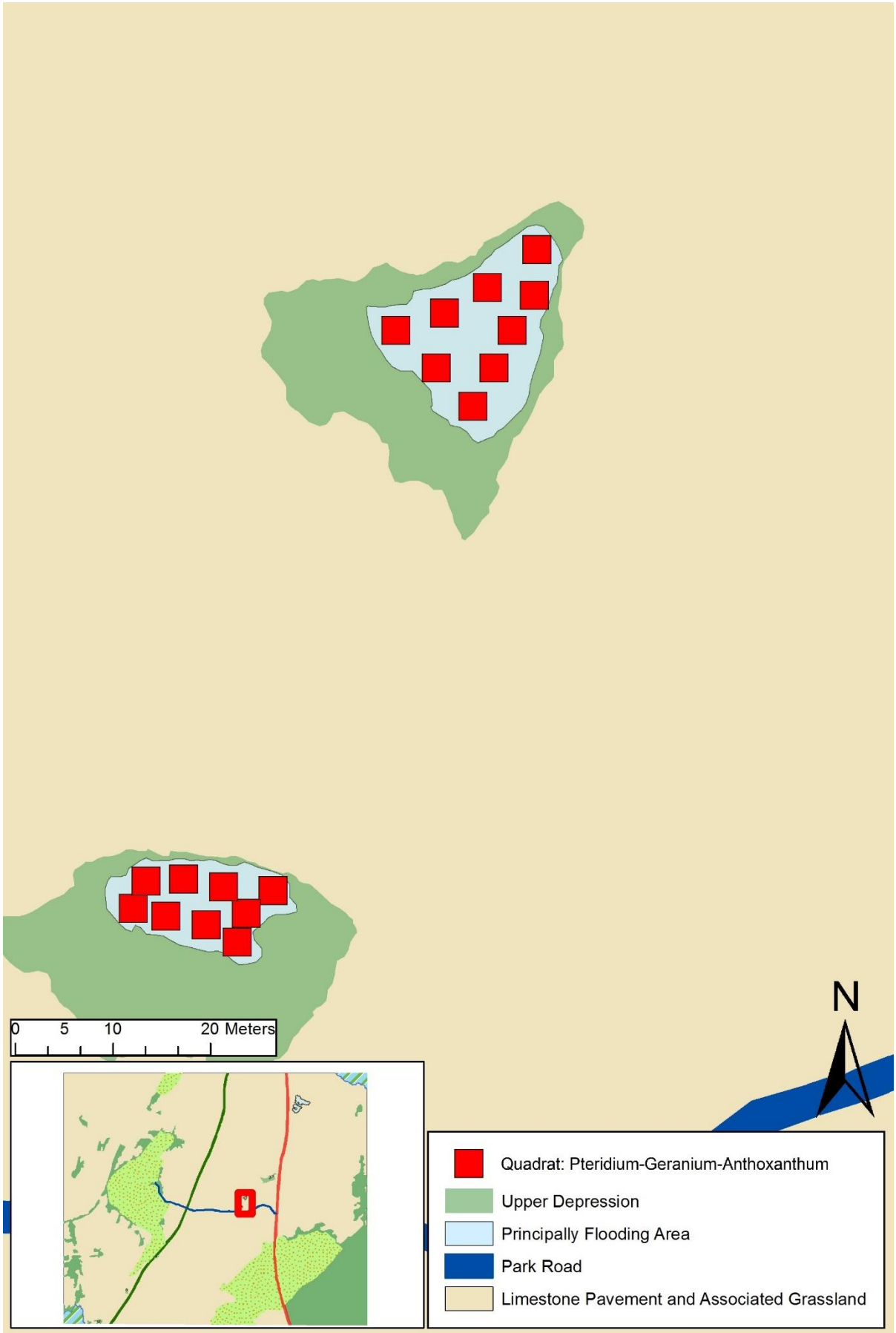

Figure 20. Map of feature #3 with vegetation community and proximal landforms. Note proximity to feature #4 (south)

iv. Feature #4

The principally flooding area of this feature was 143 m^2 and less than 1 meter in depth. The feature was flooded for less than a single day during the survey period, drying out before noon on the day following significant rainfall. No permanent standing water was present in the feature and soil was well-drained. The feature is a shallow pan with exposed limestone pavements surrounding it on all sides. There are significant signs of heavy modification to the limestone pavements in and around the feature. *Coenagrion* sp. and a small community of other invertebrates were observed within the feature.

This feature was represented in 9 quadrats and 48 species. The exclusive vegetation community identified within this feature was the *Pteridium-Geranium-Anthoxanthum* community. Mean species richness was 14.67 species per quadrat. This is the highest value of the study features and is a high alpha diversity value relative to ACST turloughs (Sharkey 2012; Hanley 2014). Average sward height was 27.8 cm (+/- 13.1 cm). Percent cover of bare ground was 7.8% (+/- 14.1%).

Table 16. Constant/near constant species in feature #4 and percent cover

Frequency Class V	Percent Cover	Frequency Class IV	Percent Cover
Carex flacca	2.8%	*Anthoxanthum odoratum*	23.3%
Geranium sanguineum	8.3%	*Briza media*	11.7%
Potentilla erecta	3.3%	*Calluna vulgaris*	3.9%
Pteridium aquilinum	23.1%	Moss	20.8%
Succisa pratensis	15.3%	*Rosa pimpinellifolia*	4.7%
		Seslaria caerulea	7.7%

Achillea millefolium II
Agrostis stolonifera 0
Anemone nemorosa 0
Anthyllis vulneraria I
Brachypodium sylvaticum 0
Carex hostiana I
Carex nigra 0
Centaurea nigra 0
Cirsium dissectum I
Conopodium majus III
Corylus avellana 0
Crataegus monogyna 0
Dactylis glomerata II
Dactylorhiza fuchsii III
Daucus carota I
Festuca rubra 0
Galium palustre III
Galium verum 0
Gymnadenia conopsea II
Helictotrichon pubescens 0
Hieracium pilosella I
Holcus lanatus III
Hypericium pulchrum I
Hypochaeris radicata 0
Lathyrus pratensis 0
Leontodon autumnalis I
Listera ovata III
Lotus corniculatus II
Molinia caerulea 0
Plantago lanceolata III
Polygala serpyllifolia II
Potentilla anserina 0
Ranunculus bulbosus I
Ranunculus flammula II
Teucrium scorodonia II
Trifolium pratense II
Trifolium repens 0
Vicia cracca 0

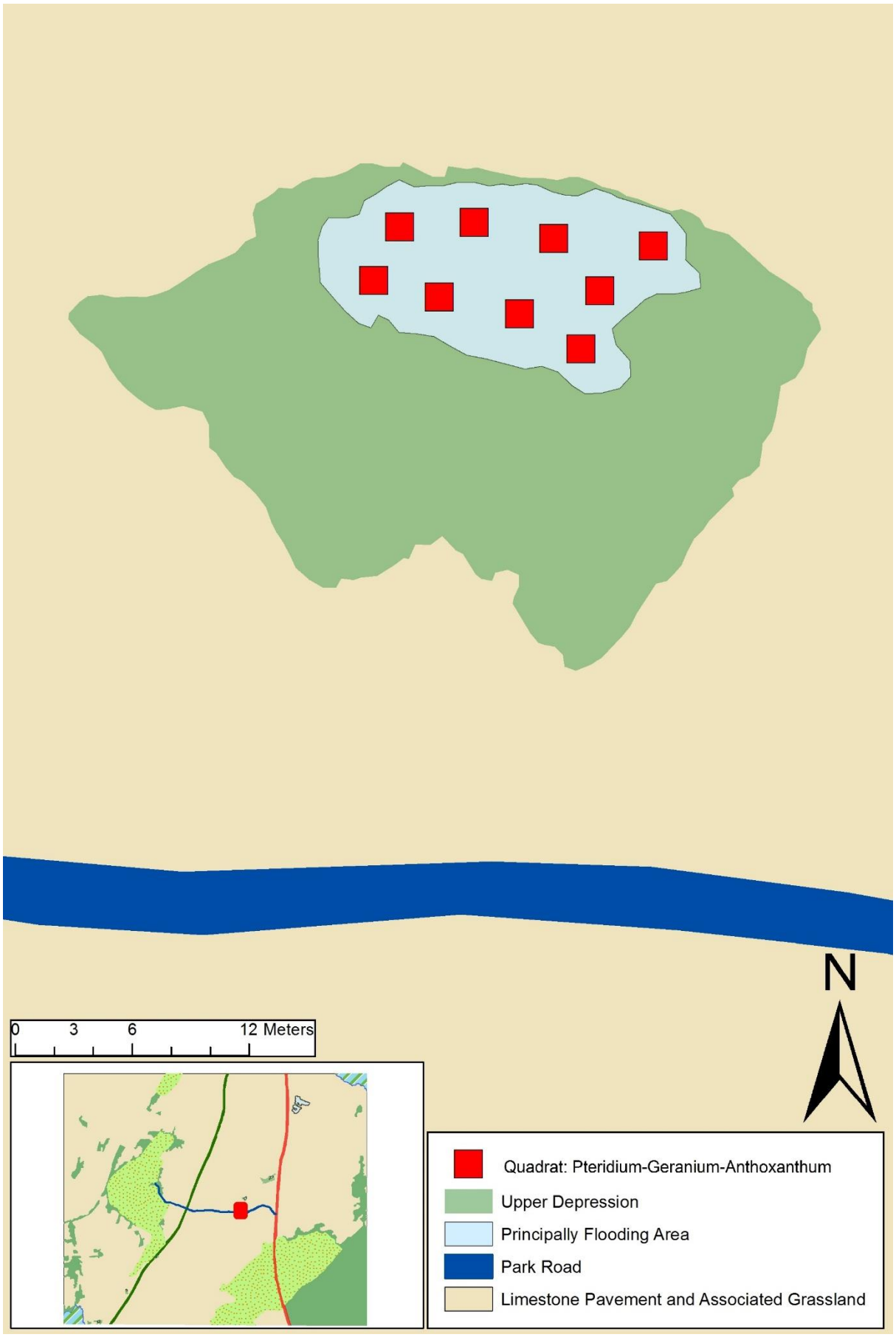

Figure 21. Map of feature #4 with vegetation community and proximal landforms

v. Feature #6

The principally flooding area of this feature was 114 m^2 and roughly 1 meter in depth. The feature was flooded for less than a single day during the survey period, drying out before noon on the day following significant rainfall. No permanent standing water was present in the feature and soil was well-drained. The feature is a sloping pan with a wooded patch in the lowest zone, exposed limestone pavements on three sides, and limestone grassland leading south to the green road. There are significant signs of heavy modification to the limestone pavements in and around the feature. The feature did not appear to support a significant faunal community.

This feature was represented in 9 quadrats and 47 species. The exclusive vegetation community identified within this feature was the *Pteridium-Geranium-Anthoxanthum* community. Mean species richness was 12.67 species per quadrat. Average sward height was 22.8 cm (+/- 8.3 cm). This was the lowest average sward height of each feature. Percent cover of bare ground was 6.9% (+/- 11.1%).

Table 17. Constant/near constant species in feature #6 and percent cover

Frequency Class V	Percent Cover	Frequency Class IV	Percent Cover
Geranium sanguineum	13.9%	*Carex flacca*	6.9%
Moss	32.8%	*Potentilla erecta*	2.2%
Pteridium aquilinum	30.8%	*Succisa pratensis*	6.7%
Seslaria caerulea	23.3%	*Teucrium scorodonia*	5.6%

Achillea millefolium I
Agrostis stolonifera 0
Anemone nemorosa 0
Anthoxanthum odoratum III
Brachypodium sylvaticum 0
Briza media II
Calluna vulgaris II
Carex hostiana I
Carex nigra I
Carex pulicaris 0
Centaurea nigra 0
Cirsium dissectum III
Crataegus monogyna 0
Dactylis glomerata I
Dactylorhiza fuchsii II
Deschampsia cespitosa I
Festuca rubra 0
Galium verum I
Hetera helix II
Hieracium pilosella III
Holcus lanatus III
Hypericium pulchrum I
Leontodon autumnalis II
Leontodon hispidus 0
Molinia caerulea 0
Plantago lanceolata II
Polygala serpyllifolia II
Prunus spinosa II
Ranunculus bulbosus I
Rosa pimpinellifolia III
Rubia peregrina I
Rubus saxatilis 0
Sagina nodosa I
Sanicula vulgaris 0
Senecio jacobea 0
Sonchus asper 0
Thymus polytrichus II
Trifolium pratense II
Vibernum opulus I
Viola canina 0

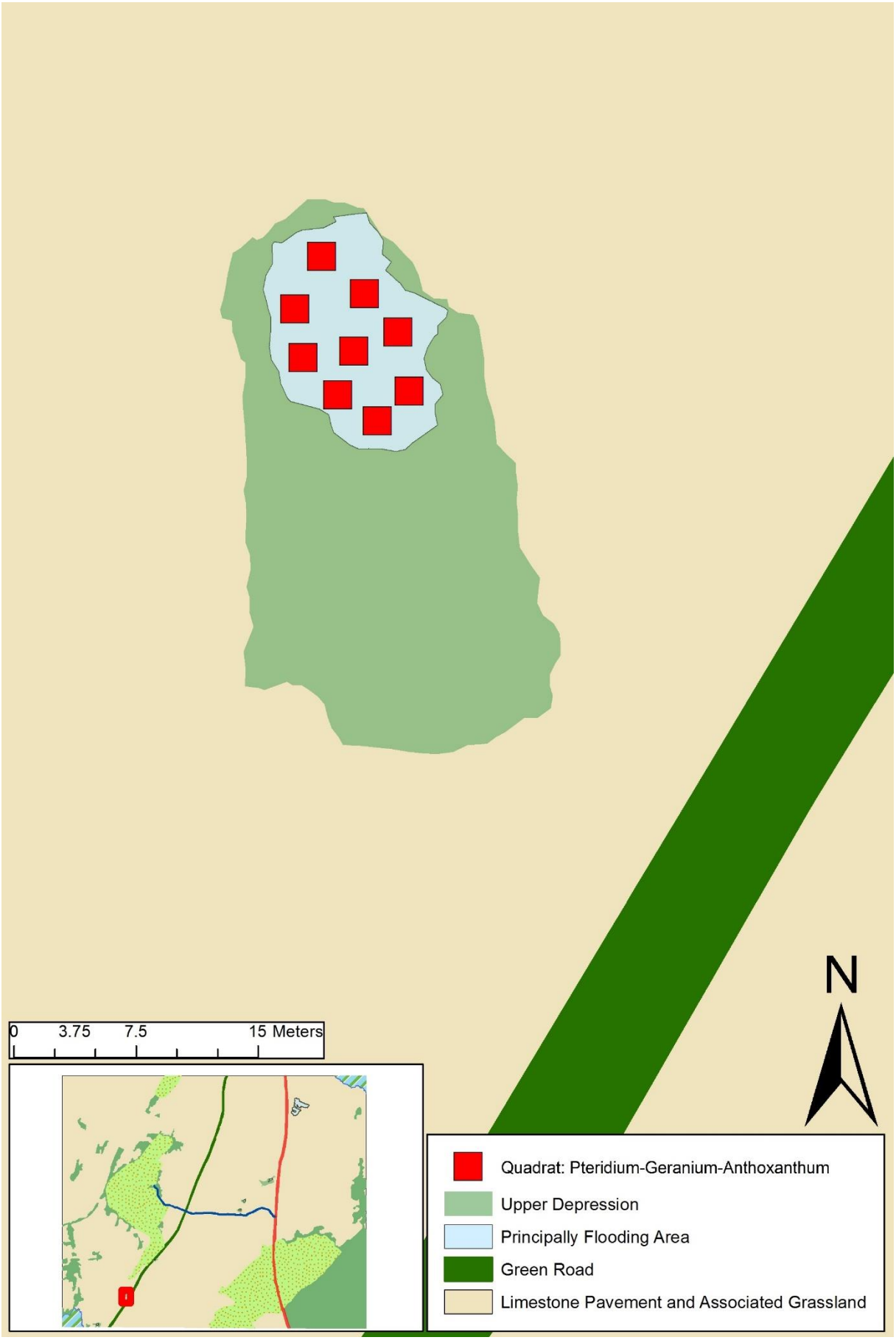

Figure 22. Map of feature #6 with vegetation community and proximal landforms

vi. Feature #7

The principally flooding area of this feature was 161 m^2 and roughly 1 meter in depth. The feature was flooded for one day during the survey period, following significant rainfall. No permanent standing water was present in the feature and soil was well-drained. The feature is a sloping basin making up a small proportion of the total depression, and surrounded by a wooded patch, exposed limestone, and limestone grassland. *Coenagrion* sp., a diverse assemblage of invertebrates, and a sizeable population of *Rana temporaria*, consisting of at least 10 individuals, were observed within the feature.

This feature was represented in 13 quadrats and 53 species. Vegetation communities found within this feature were identified as primarily *Carex flacca* and *Pteridium-Geranium-Anthoxanthum* communities, while the *Molinia* community was also present in a single quadrat. The lowest zone of the feature contained a distinctively uniform branch of the *Carex flacca* community, with roughly 10m^2 of dense *Potentilla anserina* coverage. Mean species richness was 11.62 species per quadrat. Average sward height was 29.2 cm (+/- 8.4 cm). Percent cover of bare ground was 0.6% (+/- 1.1%).

Table 18. Constant/near constant species in feature #7 and percent cover

Frequency Class V	Percent Cover	Frequency Class IV	Percent Cover
Carex flacca	15.4%	*Cirsium dissectum*	8.3%
Plantago lanceolata	14.4%	*Galium boreale*	5.2%
Potentilla erecta	5.4%	*Potentilla anserina*	36.2%
		Rubus saxatilis	5.4%

Anthoxanthum odoratum II
Anemone nemorosa 0
Briza media I
Calluna vulgaris I
Carex hostiana 0
Carex nigra I
Carex panicea II
Carex viridula agg. 0
Centaurea nigra I
Dactylorhiza fuchsii I
Danthonia decumbens 0
Festuca arundinacea 0
Festuca rubra 0
Filipendula ulmaria II
Galium palustre 0
Galium sp. I
Galium verum II
Geranium sanguineum I
Hieracium pilosella I
Holcus lanatus I
Hypericium pulchrum II
Isolepsis setacea 0
Juncus articulatus 0
Juncus bufonius 0
Lathyrus pratensis I
Leontodon autumnalis II
Lotus corniculatus III
Mentha aquatica III
Molinia caerulea II
Ophioglossum vulgatum I
Plantago maritima II
Polygala serpyllifolia I
Potentilla fruticosa 0
Prunus spinosa II
Pteridium aquilinum 0
Ranunculus flammula II
Ranunculus repens III
Rhamnus catharticum 0
Rosa pimpinellifolia II
Rubus saxatilis 0
Sagina nodosa 0
Schoenus nigricans I
Succisa pratensis 0
Trifolium repens 0
Vibernum opulus 0
Vicia cracca 0

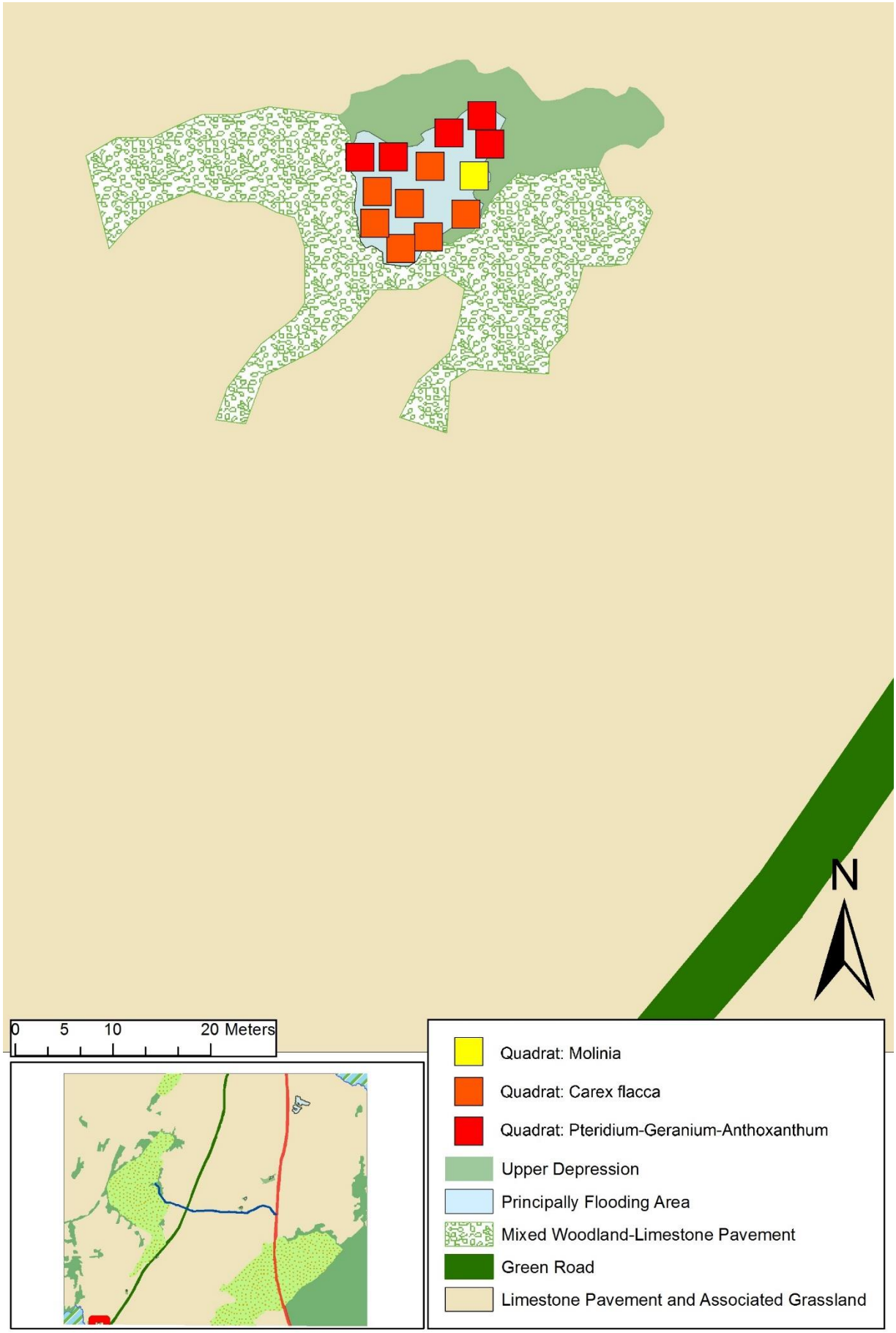

Figure 23. Map of feature #7 with vegetation communities and proximal landforms

vii. Feature #8

The principally flooding area of this feature was 39 m^2. The feature was flooded for two days during the survey period, following significant rainfall. A small amount of standing water (<5 m^2 in area) was present at all times in the lowest zone of the feature. Soil was well-drained only in the margins of the principally flooding area, with the majority of the feature holding significant amounts of water in its soil at all times. The feature is steep-sided to the north and bounded by a woody patch, a limestone wall, and the green road, and sloping into limestone grassland to the south. No exposed limestone is immediately adjacent to this feature. While there were no signs of grazing, a significant amount of livestock dung was present in the feature. The feature appears to be under significant agricultural pressure and is susceptible to anthropogenic pressure, should the green road be utilized to a greater extent, due to its immediate proximity. *Coenagrion* sp., a diverse assemblage of invertebrates, and a sizeable population of *Rana temporaria*, consisting of at least 15 individuals, were observed within the feature.

This feature was represented in 9 quadrats and 58 species. Vegetation communities found within this feature were identified as primarily the *Pteridium-Geranium-Anthoxanthum* community, while the *Carex flacca* community was also present in a single quadrat. Mean species richness was 13.11 species per quadrat. Average sward height was 26.7 cm (+/- 10 cm). No bare ground was recorded in a quadrat within this feature.

Table 19. Constant/near constant species in feature #8 and percent cover

Frequency Class V	Percent Cover	Frequency Class IV	Percent Cover
Plantago lanceolata	13.6%	*Carex flacca*	13.1%
		Leontodon autumnalis	5.6%
		Moss	16.1%
		Ranunculus bulbosus	5.0%
		Succisa pratensis	8.6%

Achillea millefolia III
Agrostis stolonifera 0
Alchemilla xanthochlora 0
Anthoxanthum odoratum II
Bellis perennis II
Briza media III
Calluna vulgaris I
Carex hostiana II
Carex nigra 0
Carex panicea 0
Centaurea nigra 0
Cirsium dissectum II
Conopodium majus I
Crataegus monogyna 0
Cynosurus cristatus II
Dactylis glomeratus II
Dactylorhiza fuchsii II
Daucus carota 0
Filipendula ulmaria III
Galium verum II
Geranium robertianum 0
Geranium sanguineum I
Hieracium pilosella II
Holcus lanatus III
Juncus articulatus 0
Juncus effusus 0
Koelaria macrantha 0
Lathyrus pratensis 0
Leontodon hispidus 0
Leucanthemum vulgare 0
Listera ovata I
Lolium perenne II
Lotus corniculatus I
Mentha aquatica II
Potentilla anserina I
Potentilla erecta III

Primula vulgaris I
Prunella vulgaris 0
Prunus spinosa 0
Pteridium aquilinum III
Ranunculus acris 0
Ranunculus repens II
Rhinanthus minor II
Rosa pimpinellifolia II
Rubus fruticosus 0
Samolus valerandi I
Taraxacum officinale 0
Trifolium campestre II
Trifolium pratense I
Trifolium repens III
Triglochin palustris I
Valeriana officinalis 0
Vicia cracca 0

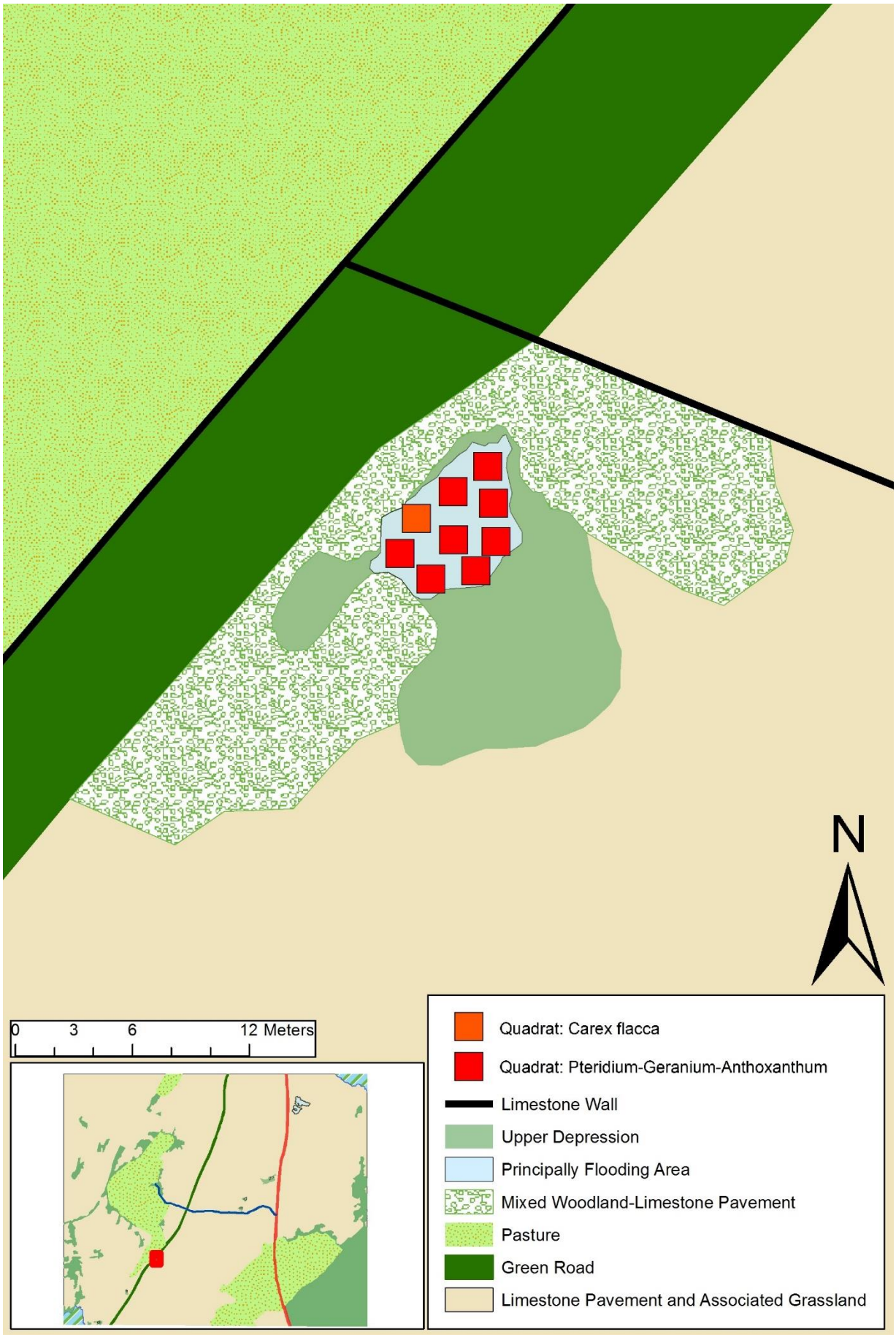

Figure 24. Map of feature #8 with vegetation communities and proximal landforms

e. Hypothesized Hydroperiod and Nutrient Status

Table 20 details the expected hydroperiod and nutrient status for a given species' habitat, as outlined by Sharkey (2012) and Sharkey *et al*. (2015), and the corresponding frequency class of the species in a given study feature. The below stated hypotheses are a synthesis of observed function of the study features and correlation with the Sharkey (2012) and Sharkey *et al*. (2015) observations.

Table 20. Species indicative of hydroperiod and water TP by frequency within a given feature (Sharkey et al*. 2015)*

Species	**Predicted hydroperiod (days/year)**	**Predicted nutrient status (µg l^{-1} water TP)**	**Ft. #1**	**Ft. #2**	**Ft. #7**
Baldellia ranunculoides	221.3+	4.04-7.38	I		
Bellis perennis	5-221.3	24.60-44.98			
Briza media	5-149.2	4.04-7.38	I	II	I
Carex flacca	5-221.3	7.38-13.49	III	V	V
Carex hostiana	5-221.3	4.04-7.38	I		
Carex panicea	5-221.3	7.38-13.49	I		II
Cirsium dissectum	5-221.3	4.04-7.38	I	IV	IV
Galium verum	5-149.2	Non-Indicative	I	III	II
Molinia caerulea	5-221.3	4.04-7.38	IV	II	II
Plantago lanceolata	5-149.2	Non-Indicative	I	V	V
Plantago maritima	5-221.3	4.04-7.38	II	V	II
Potentilla erecta	5-221.3	4.04-7.38	III	IV	V
Potentilla fruticosa	5-149.2	4.04-7.38	0	0	0
Prunus spinosa	5-149.2	4.04-7.38			II
Ranunculus flammula	149.2+	4.04-7.38	I	II	II
Schoenus nigricans	5-149.2	4.04-7.38	IV	I	I
Succisa pratensis	5-221.3	4.04-7.38	III	I	
Trifolium pratense	5-149.2	Non-Indicative			
Trifolium repens	5-221.3	24.60-44.98	I		

i. Feature #1

The feature was flooded for six consecutive days at the end of the 17 day survey period, and was observed as being flooded twice more after the survey period, in late July and late August. The feature has not been observed as being in non-flooded conditions since mid-June. This feature contained 4 estavelles that each maintained a pool of permanent standing water, each less than 10 m^2 in area. The soil immediately proximal to this permanent water was poorly-drained and held significant amounts of water at all times. The upper and middle zones of the feature had well-drained soil when not in flooded conditions. This feature can be predicted to be linked to the nearby Travann Lough hydrologically, with further flash-flooding events.

The vegetation community of this feature as a whole is indicative of having a low nutrient status (4.03-7.38 µg 1^{-1} water TP) and short-medium (5-221.3 days/year) hydroperiod (Sharkey *et al*. 2015). The two species with highest frequency within the feature, *Schoenus nigricans* (IV) and *Molinia caerulea* (IV), are both indicative of low nutrient status, and short and short-medium hydroperiod respectively. While three indicator species (Sharkey *et al*. 2015) found within the feature do not support this hypothesis, these species are very infrequent within the feature and are likely present due to the environmental conditions within the microhabitat for these species. *Baldellia ranunculoides* (I) is indicative of a longer annual hydroperiod, though was found exclusively in lower-middle zone quadrats. *Trifolium repens* (I) indicates a higher nutrient status and was found exclusively in quadrats proximal to the heavily-dunged area along the limestone wall.

In total, the feature can be expected to support a vegetation community tolerant of oligotrophic and relatively dry conditions, as well as flash-flooding events. The feature is not under consistent inundation and cannot support fully aquatic species or reedbeds outside of the immediate proximity of the estavelles. The feature as a whole can be considered a small, relatively dry, oligotrophic turlough, based on its observed hydrological function and vegetation communities. While the two basins are closely related, basin A appears to be drier than basin B, containing the more dry-condition-tolerant *Carex flacca* community and proportionally higher concentration of the *Lotus-Centaurea* community. The ongoing intensive nutrient loading in basin B could contribute to a shift in the nutrient status of the feature and should be monitored.

ii. Feature #2

The feature was flooded for two non-consecutive days during the 17 day survey period, following significant rainfall. This feature did not contain any permanent standing water. During flooded conditions, water levels receded quickly and had dried out within one day. The majority

of the feature had well-drained soil at all times. The lowest zone of the feature (<5 m^2 in area) held water following rainfall, but consistently drained within 24 hours of a flooding event.

The vegetation community of this feature as a whole is indicative of having a low nutrient status (4.04-7.38 µg 1^{-1} water TP) and short-medium (5-221.3 days/year) hydroperiod (Sharkey *et al*. 2015). The two species with highest frequency within the feature, *Carex flacca* (V) and *Plantago maritima* (V), are both indicative of short-medium hydroperiod. While *Carex flacca* is indicative of a low-medium nutrient status, it is the only indicator species to suggest a higher nutrient status than low, and is still within range of low status. *Ranunculus flammula* (II) was the exclusive species to indicate a longer hydroperiod, though it was present in low frequency.

In total, the feature can be expected to support a vegetation community tolerant of oligotrophic and very dry conditions. The feature is infrequently inundated and incapable of supporting fully or mostly aquatic species. The feature as a whole can be considered similar to the upper end of the flooding zone of a turlough.

iii. Feature #7

The feature was flooded for one day during the survey period, following significant rainfall. No permanent standing water was present in the feature and soil was well-drained at all times outside of flooded conditions.

The vegetation community of this feature is primarily indicative of having a low or low-medium nutrient status (4.04-13.49 µg 1^{-1} water TP) and short-medium (5-221.3 days/year) hydroperiod (Sharkey *et al*. 2015). Two of the species with highest frequency within the feature, *Carex flacca* (V) and *Potentilla erecta* (V), are indicative of a short-medium hydroperiod. The third, *Plantago lanceolata* (V), is indicative of a short hydroperiod (5-149.2 days/year). *Ranunculus flammula* (II) indicates a longer hydroperiod, though was present in low frequency.

In total, the feature can be expected to support a vegetation community tolerant of oligotrophic and very dry conditions. The feature is infrequently inundated and incapable of supporting fully or mostly aquatic species. The feature as a whole can be considered similar to the upper end of the flooding zone of a turlough.

5. Discussion

a. Vegetation Communities and Features

The features discussed in this study are best described on a wet-dry gradient from turlough system to limestone grassland, and are most effectively split into three groups as described below.

i. Feature #1

Feature #1 is composed primarily of the *Schoenus, Molinia*, and *Lotus-Centaurea* vegetation communities, with the *Carex flacca* community present in low frequency. The lower basin is made up of primarily the more aquatic *Schoenus* community, with the *Molinia* community in the middle basin and edges, and the *Lotus-Centaurea* community in the upper zones. These vegetation communities are representative of a relatively dry, oligotrophic turlough, with permanent standing water (Sharkey *et al*. 2015). Fully aquatic species *Callitriche* sp. and *Potamogeton polygonifolius* are present, as well as the lower zone species *Cladium mariscus* and *Baldellia ranunculoides*. The most frequent species identified within the feature are the oligotrophic turlough-indicative species *Schoenus nigricans* and *Molinia caerulea* (Sharkey *et al*. 2015). Lolio-Potentillion assemblages are frequent within the feature, as specified for turloughs within the EU Habitats Directive (EU Habitats Committee 2013). Basin A forms primarily the drier, upper zones of the turlough with proportionally higher frequency of the *Molinia* community, the presence of the *Carex flacca* community, and lower volumes of permanent standing water, while basin B forms primarily the lower zone and includes greater volumes of permanent standing water and a higher frequency of the *Schoenus* community. This feature strongly resembles a small turlough, both in its form and inferred ecological function.

ii. Features #2 and 7

These features were primarily composed of the *Carex flacca* community, with the *Pteridium-Geranium-Anthoxanthum* community in the upper zones of the features. Feature #7 also had a single quadrat represented by the *Molinia* community, and feature #2 with a single quadrat each of the *Schoenus* and *Lotus-Centaurea* communities. Oligotrophic turlough-indicative species *Schoenus nigricans* and *Molinia caerulea* were both present in low frequencies within these features, as well as *Potentilla anserina* in high frequency in feature #7. These features resemble the upper zones of a turlough system in their lowest zones and limestone grassland in their upper zones.

iii. Features #3, 4, 6, and 8

These features were dominated by the *Pteridium-Geranium-Anthoxanthum* community and are not representative of turlough vegetation communities. Turlough indicative species *Molinia caerulea* was infrequent and *Schoenus nigricans* absent from these features. Features #3, 4, and 6, containing exclusively this community, can conclusively be stated to not resemble turloughs. These features are better described as limestone grassland in depressions of the limestone pavement.

Feature #8 contained only one quadrat not resembling this community. While this feature does not resemble a turlough, it has been demonstrated to have wetter conditions than features #3, 4, and 6, and to contain a different vegetation community, with a lower frequency of the strongest indicator species of the community, *Pteridium aquilinum, Geranium sanguineum*, and *Anthoxanthum odoratum.* Feature #8 also contains the EU Habitats Directive (EU Habitats Committee 2013) turlough indicative species *Potentilla anserina* and *Lolium perenne* in low frequencies. As such, this feature functions as a limestone grassland habitat with marginal turlough-like function in its lowest zone.

b. Conservation Value and Status

ACST assessments for features #1, 2, and 7 can be found in Appendices 1, 2, and 3 respectively.

i. Feature #1

The Red Data Book (Curtis & McGough 1988) and Red List-Vulnerable (Wyse Jackson *et al*. 2016) species *Potentilla fruticosa* was identified within this feature. No quadrats intersected its cover, though it grew in low density along the upper zones of the northeast side of basin B. The feature has been further demonstrated to contain vegetation communities resembling a turlough, including *Cladium mariscus, Schoenus nigricans*, and the fully aquatic species *Callitriche* sp. and *Potamogeton polygonifolius*. The faunal community of the feature is also representative of a turlough community, including an apparent breeding population of *Rana temporaria* and a diverse range of Odonata, including *Coenagrion* sp. and *Pyrrhosoma nymphula*.

This feature had three sources of pressure or risk, from overgrazing, nutrient loading and eutrophication, and groundwater pollution.

Feature #1 has two distinct grazing regimes, divided by the limestone wall that dissects basin B. South of this wall in the majority of the feature, there were no signs of under- or over-grazing. Most quadrats, excluding those that intersected exposed limestone pavements, had an average sward height of between 8 and 40 cm, as recommended in ACST assessment. Seven quadrats exceeded this level, with a maximum sward height of 65 cm. These quadrats were dominated by tall stands of *Schoenus nigricans*, and contained or were adjacent to *Cladium mariscus* stands. North of the limestone wall, thirty head of cattle regularly grazed the feature and its adjacent limestone grasslands. Vegetation in this area of the feature had been grazed and trampled excessively, with the majority of the principally flooding area less than 10 cm in average sward height. This portion of the feature was starkly divided from south of the wall in terms of average sward height and visible disturbance to vegetation communities.

The feature is further pressured through the secondary nutrient loading impacts of this grazing population. Basin B of the feature contained significant amounts of cattle dung. Similarly to the signs of over-grazing, north of the limestone wall was starkly more impacted than to the south. The feature is likely further loaded with nutrients from its proximity to the public road. Farmers were observed on two occasions cleaning farm equipment in the road, when water levels had risen sufficiently to connect the feature's upper depression to the road. While no cleaning chemicals were observed in use, nutrients carried on this equipment would wash into the feature. Algae and algal paper were present in 11% of quadrats within the feature, and covered a greater portion of the area north of the limestone wall, estimated at 40% of this area.

The feature's 25m proximity to, and downhill position from, the public road places it at a low level of risk of chemical pollution. This road is uncommonly used and is not utilized by heavy vehicles, apart from farm equipment. The karstified limestone subsoil of the area places this feature, as all other features in the area (GSI 2011), under risk of pollution of the groundwater.

The landscape of the feature had been visibly altered in the past, with the removal and damage of limestone pavements along the margins of the upper depression in the construction of the adjacent and intersecting limestone walls. There does not appear to be any ongoing or recent alteration to the limestone pavements, beyond any damage caused by the grazing cattle in the northern end of basin B.

Due to this feature's conservation value and significant number of threats, the site should be monitored regularly and follow-up studies conducted to establish a greater understanding of the hydrological function of the feature. The grazing patterns and subsequent dunging of basin B places the feature at risk of eutrophication, which has already begun to present in algal paper formation. This pressure should be assessed through water quality testing and active monitoring of grazing and nutrient loading patterns from the livestock grazing population.

ii. Feature #2

The Red List (Wyse Jackson *et al*. 2016) species *Potentilla fruticosa* was identified within the feature. No quadrats intersected its cover, and it grew in extremely low density in the lower zone of the feature. This feature has been demonstrated to have a vegetation community that is similar to the upper zone of a turlough, in its lower zones, including small populations of *Potentilla anserina* and *Schoenus nigricans*. The faunal community of the feature is also representative of turlough-like function, including a population of *Rana temporaria* and the presence of *Coenagrion* sp.

This feature had one source of risk, from groundwater pollution. The feature's 30m proximity to, and downhill position from, the public road places it at a low level of risk. This road is uncommonly used and is not utilized by heavy vehicles, apart from farm equipment. The karstified limestone subsoil of the area places this feature, as all other features in the area (GSI 2011), under risk of pollution of the groundwater.

The landscape of the feature had been visibly altered in the past, with the removal and damage of limestone pavements along the margins of the upper depression in the construction of the adjacent and intersecting limestone walls. There does not appear to be any ongoing or recent alteration to the limestone pavements.

iii. Feature #3

No Red Data Book (Curtis & McGough 1988) or Red List (Wyse Jackson *et al*. 2016) species was identified within the feature. This feature does not contain a vegetation or faunal community resembling a turlough and does not represent the subsequent conservation value. The feature does contain a relatively high level of diversity, with 51 species in a 244 m^2 feature and a mean 10.89 species per quadrat.

This feature has no signs of direct pressure, beyond the vulnerable groundwater of the karstified limestone area (GSI 2011). While the feature did not have any signs of being commonly grazed, no overgrowth had occurred. There were no signs of nutrient loading and the feature is located 200m from the nearest public road. The feature is located 75m from the park road, and this road is very rarely utilized. There are no visible signs of damage to the limestone pavements within or adjacent to the feature.

iv. Feature #4

No Red Data Book (Curtis & McGough 1988) or Red List (Wyse Jackson *et al*. 2016) species was identified within the feature. This feature does not contain a vegetation or faunal community resembling a turlough and does not represent the subsequent conservation value. The feature does contain a high level of diversity, with 48 species in a 143 m^2 feature and a mean 14.67 species per quadrat.

This feature has no signs of direct pressure, beyond the vulnerable groundwater of the karstified limestone area (GSI 2011). While the feature did not have any signs of being commonly grazed, no overgrowth had occurred. There were no signs of nutrient loading and the feature is located 200m from the nearest public road. The feature is located only 20m from the park road, though this road is very rarely utilized.

The landscape of the feature had been visibly altered in the past, with the significant removal of limestone pavements throughout the feature in the construction of the nearby road.

Soil was very shallow and the feature was surrounded on all sides by limestone that had been visibly cracked. The feature appears to have been a primarily artificial landform, created by the removal of limestone pavements.

v. Feature #6

No Red Data Book (Curtis & McGough 1988) or Red List (Wyse Jackson *et al*. 2016) species was identified within the feature. This feature does not contain a vegetation or faunal community resembling a turlough and does not represent the subsequent conservation value. This was the only studied feature to lack an Odonata population and no *Rana temporaria* individuals were observed within the feature. The feature does contain a high level of diversity, with 47 species in a 114 m^2 feature and a mean 12.67 species per quadrat.

This feature has no signs of direct pressure, beyond the vulnerable groundwater of the karstified limestone area (GSI 2011). There were no signs of over- or undergrazing or nutrient loading. While the feature is located only 25m from the green road, this road is not utilized by vehicles and rarely walked upon.

The feature had been visibly altered in the past, with the extreme removal of and damage to limestone pavements throughout the feature in the construction of the nearby road. Soil was very shallow and the feature was surrounded on all sides by limestone that had been visibly cracked. The feature appears to have been a primarily artificial landform, created by the removal of limestone pavements.

vi. Feature #7

No Red Data Book (Curtis & McGough 1988) or Red List (Wyse Jackson *et al*. 2016) species was identified within the feature. This feature has been demonstrated to have a vegetation community that is similar to the upper zone of a turlough, in its lower zones. Most significantly, the feature contains *Schoenus nigricans* and a sizable population of *Potentilla anserina*, with an average 32.5% cover of the feature quadrats. The faunal community of the feature is also representative of turlough-like function, including a population of *Rana temporaria* and the presence of *Coenagrion* sp. The presence of this faunal population could be attributed, however, to the feature's 80m proximity to Lough Cuil Reasc.

This feature has no signs of direct pressure, beyond the vulnerable groundwater of the karstified limestone area (GSI 2011). There were no signs of over- or undergrazing or nutrient loading. The feature is not immediately proximal to any roads. The green road is nearest at 65m from the feature, and separated by a strip of woodland and limestone pavements. There are no visible signs of damage to the limestone pavements within or adjacent to the feature.

vii. Feature #8

No Red Data Book (Curtis & McGough 1988) or Red List (Wyse Jackson *et al*. 2016) species was identified within the feature. While this feature does not contain a vegetation or faunal community resembling a turlough as a whole, it does contain the significant species *Potentilla anserina* and *Lolium perenne* specifically referred to in the EU Habitats Directive (EU Habitats Committee 2013), and maintains permanent standing water. The feature also contains a high level of diversity, with 58 species in a 39 m^2 area and a mean 13.11 species per quadrat. Though this feature does not resemble a turlough, it has formed a distinct and diverse habitat.

This feature has signs of being at risk of nutrient loading and eutrophication, as well as the risks of groundwater pollution in the karstified limestone area. These risks are amplified by the small 39 m^2 area of the feature.

The feature is located at the bottom of the green road, across from grazing pastures. When flooded, water flowed under the green road, connecting the feature to the pastures. Small amounts of dung were present within the feature. There were no signs of eutrophication occurring, with no algae or algal paper present.

The landscape of this feature had been significantly modified in the construction of the green road. The road appears to have been built directly through the depression that connects this feature to the pastures opposite. There are no visible signs of damage to the nearest exposed limestone pavements to the feature.

c. Further Studies

i. Hydrology

This study, due to its summertime data collection period, was unable to collect water samples for nutrient status testing. A follow-up wintertime data collection would be able to ascertain for these features their nutrient status when in winter flooded conditions and identify flooding regimes of the features, for comparison with the hypothesized hydroperiods and nutrient status. This would be most particularly significant for features #1, 2, and 7. Feature #1 holds significant conservation value as having the form and apparent function of a turlough, and should be monitored for nutrient status. This is most particularly significant with the pressure of nutrient loading from the grazing population and the presence of algal paper indicating a shift. Features #2 and 7 should be assessed in the wintertime to determine the extent of flooding and hydroperiod. This will allow for a greater determination of similarity of these features to turloughs. If permanent flooding is found in the wintertime, nutrient status could be evaluated as well. The other features of the study could be similarly surveyed, to establish if any standing water is present in the winter. Ideal data collection periods for these

studies would take place during, or immediately following, the months with highest average precipitation, November through January (Met Éireann 2017).

ii. Impacts of Grazing Regimes and Feature #1

The limestone wall dissecting basin B within feature #1 presents a potential question for investigation regarding the impacts of grazing regimes on turloughs. With the grazing population limited by the limestone wall, the cattle are forced into a smaller area of the feature, which has become heavily dunged and nutrient loaded, leading to large amounts of algae. The vegetation has also been thoroughly trampled and over-grazed. Immediately on the opposite side of the wall, vegetation is thriving, though nutrients have entered the water and algae has developed south of the wall. The more distant from this wall the quadrat was placed, the lower frequency and percent cover of algae was present. The wall has caused one small portion of the feature to be significantly reduced in vegetation cover and average sward height, while protecting the feature south of the wall from these effects to a certain extent. Investigation in larger turloughs of this type of effect in cordoning grazers to confined areas of the turlough could help establish more effective grazing regimes and reduce nutrient loading or improper grazing levels.

iii. Identification of Similar Features

Precedent has been set for the identification of small turlough-like depressions to be investigated further for their conservation value. Feature #1 most particularly was demonstrated to have both the form and inferred function of a turlough, including permanent standing water, fully aquatic species, and a faunal community resembling that of a turlough, despite being half a hectare in area. Features #2 and 7 further demonstrated turlough-like function in dramatically smaller areas and supporting floral communities resembling the upper zones of turloughs. Every one of the study features represented a high level of diversity in a relatively small area, most particularly feature #8 sustaining a community with 58 vascular plant species in an area of 39 m^2. As such, it can be demonstrated that similar depressions in karstic limestone can hold conservation value.

6. Conclusions

This study sought to describe the vegetation ecology of seven small turlough-like features through a vegetation survey, composed of 161 quadrats and 73 species. In ordination and clustering of these findings, trends in the ecology of these features were ascertained to evaluate the conservation value of each individual feature and the vegetation communities within them. Five distinct vegetation communities were identified within these features.

Features #3, 4, and 6 were found to not resemble turlough vegetation communities, but rather limestone grasslands. These small features, however, contained high levels of diversity, with 53, 48, and 48 species present respectively.

Feature #8, while found not to resemble a turlough, was found to be a uniquely diverse community. This feature held aspects of turlough-like function, including the presence of *Lolium perenne, Potentilla anserina*, and permanent standing water. This feature further held the second-highest number of species of the study features, 58, despite being only 39 m^2 in area.

Features #2 and 7 were found to represent the vegetation communities of the upper zones of a turlough, presented primarily as the *Carex flacca* community, as well as the *Lotus-Centaurea* and *Schoenus* communities in feature #2 and the *Molinia* community in feature #7. These features, while relatively dry, contained the characteristic turlough species *Molinia caerulea, Potentilla anserina*, and *Schoenus nigricans*. These features further contained the Red List (Wyse Jackson *et al*. 2016) species *Potentilla fruticosa*.

Feature #1 was demonstrated to hold the vegetation communities and signs of the faunal communities of a turlough, as well as the hydrological function. This feature was represented in the lower zones by the *Schoenus* and *Molinia* communities, and in the upper zones by the *Lotus-Centaurea* and *Carex flacca* communities. The feature contained species characteristic of oligotrophic turloughs, *Schoenus nigricans* and *Molinia caerulea*, as well as aquatic/lower zone species *Baldellia ranunculoides*, *Cladium mariscus*, *Potamogeton polygonifolius*, and *Callitriche* sp. The feature also contained the Red List (Wyse Jackson *et al*. 2016) species *Potentilla fruticosa*.

With this greater understanding of these features' vegetation communities established, conservation threats were assessed. Feature #1 is under significant pressure from the grazing of livestock in its northern basin and requires further monitoring and management to assess the apparent eutrophication from local sources ongoing in the basin. With the feature shown to be a turlough in both form and apparent function, assessment of this possible shift in nutrient status is a necessary future step in the monitoring and conservation of this site.

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8. Appendices

Appendix 1. ACST Assessment of Feature #1

			Feature #	**1**
			Pre-screening A: Mineral soil present (=1)	**0**
			Pre-screening B: flooded pavement community present in turlough (=1)	**1**
			Pre-screening B: limestone pavement occurs within 200m of turlough (=1)	**1**
			Pre-screening B: *Potentilla fruticosa* present (=1)	**1**
			Pre-screening B: *Frangula alnus* present (=1)	**1**
			Pre-screening B: *Schoenus nigricans* present (=1)	**1**
			Pre-screening: sum of pre-screening criteria B	**5**
			ASSESSMENT GROUP [Mineral if A=1; Oligotrophic if A=0 and B>1; Mesotrophic if A=0 and B=0]	**Oligotrophic**
INDICATOR	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #1**
Invert of drainage (any increase or decrease of drainage capacity)	None, or affecting only exceptional flooding=0; Affecting flooding in upper part of basin=1; Affecting flooding in majority of basin=2			**ni**
Consistent or progressive change in flooding depth/ duration/ area of flooding (over 6 year HD reporting cycle)	<5% change=0; 5-20% change=1; >20% change=2			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**ni**
Hydrological function score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**ni**
2. Water quality	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #1**
Floodwater TP	<10 µg l^{-1}=0; 10-20 µg l^{-1}=1; >20 µg l^{-1}=2	<20 µg l^{-1}=0; 20-40 µg l^{-1}=1; >40 µg l^{-1}=2		**ni**
Increase in floodwater TP	>10% increase=0; 10-20%=1; >20% increase=2			**ni**
Maximum recorded Chl*a*	<10 µg l^{-1}=0; >10 µg l^{-1}=1			**ni**
Water color	>30 mg µg l^{-1} PtCo=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**ni**
Water quality score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**ni**
3. Biological responses: terrestrial	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #1**
Agrostis stolonifera-	<5% cover of turlough=0; 5-20%=1; >20%=2			**0**

Glyceria fluitans community cover				
Cover of *Rumex crispus, R. conglomeratus*, and *R. acetosa* either singly or in combination	<5% cover of turlough OR <10% of quadrats surveyed=0; >5% cover OR 10% quadrats=1			**0**
Lolium grassland cover	<5% cover of turlough=0; 10-20% cover=1; >20%=2			**0**
Grass-forb dominated community area	<33% cover of turlough=0; >33% cover=1		N.A.	**1**
Filipendula ulmaria-Potentilla erecta-Viola sp. community	<2% cover of turlough=0; 2-10% cover=1; >10%=2	N.A.	N.A.	**1**
Poa annua-Plantago major community	<2% cover of turlough=0; 2-10% cover=1; >10%=2			**0**
Polygonum amphibium community	<2% cover of turlough=0; 2-10% cover=1; >10%=2	N.A.	N.A.	**0**
Eleocharis acicularis community	N.A.	N.A.	No loss=0; loss of community=1	**N.A.**
Limestone grassland, Flooded pavement, or woodland communities in any combination	>10% of turlough=0; <10% of turlough=1			**0**
Eleocharis palustris-Ranunculus flammula community	>10% of turlough=0; <10% of turlough=1		N.A.	**1**
Eleocharis palustris-Ranunculus flammula community	No loss in area=0; loss of area=1		N.A.	**ni**
Polygonum amphibium community	N.A.	No loss in area=0; loss of area=1		**N.A.**
Molinia caerulea-Carex panicea community	Cover >2% of turlough=0; cover <2%=1		N.A.	**0**
Sward height greater than	Indicates undergrazing: <40cm=0; >40cm=1			**0**

40cm (except reedbeds)				
Sward height less than 8cm	Indicates intensive overgrazing by sheep: >8cm=0; <8cm=1			**0**
Notable species (incl. inverts)	No loss=0; loss of species=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**18**
Terrestrial biological responses score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0.17**
4. Biological responses: aquatic	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #1**
Presence of algal paper	<2% of turlough area=0; >2% area=1			**1**
Absence of fully aquatic vascular plants	Any species present=0; otherwise=1			**0**
Notable species (incl. inverts)	No loss=0; loss of species=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**2**
Aquatic biological responses score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0.5**
5. Other	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #1**
Physical damage to turlough (land clearance, resource extraction, etc.)	<5% of turlough area=0; 5-20%=1; >20%=2			**1**
Maximum score	Sum of maximum possible scores for those indicators assessed			**2**
Other impact score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0.5**

SUMMARY		Feature #1
1. Hydrological function score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)	**ni**
2. Water quality score		**ni**
3. Terrestrial biological responses score		**0.17**
4. Aquatic biological responses score		**0.5**
5. Other impact score		**0.5**
COMBINED S&F INDICATORS	Green: no red, no more than 1 amber; Red: two red, or one red and two or more amber; Amber: any other combination	
PRESSURES		
Number of high impact pressures		**0**
Number of medium impact pressures		**2**
Number of low impact pressures		**1**
OVERALL SITE STRUCTURE & FUNCTION	Green: S&F indicators green AND no high impact pressure; Red: S&F indicators red OR at least 1 high impact pressure and at least 3 medium impact pressure	
ADJUSTMENT TO OVERALL ASSESSMENT	Based on expert judgment. Justification for any adjustment MUST be given and incorporated into the Article 17 Audit Trail document	

Appendix 2. ACST Assessment of Feature #2

			Feature #	**2**
			Pre-screening A: Mineral soil present (=1)	**0**
			Pre-screening B: flooded pavement community present in turlough (=1)	**1**
			Pre-screening B: limestone pavement occurs within 200m of turlough (=1)	**1**
			Pre-screening B: *Potentilla fruticosa* present (=1)	**1**
			Pre-screening B: *Frangula alnus* present (=1)	**0**
			Pre-screening B: *Schoenus nigricans* present (=1)	**1**
			Pre-screening: sum of pre-screening criteria B	**4**
			ASSESSMENT GROUP [Mineral if A=1; Oligotrophic if A=0 and B>1; Mesotrophic if A=0 and B=0]	**Oligotrophic**
INDICATOR	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #2**
Invert of drainage (any increase or decrease of drainage capacity)	None, or affecting only exceptional flooding=0; Affecting flooding in upper part of basin=1; Affecting flooding in majority of basin=2			**ni**
Consistent or progressive change in flooding depth/ duration/ area of flooding (over 6 year HD reporting cycle)	<5% change=0; 5-20% change=1; >20% change=2			**ni**
Maximum score	Sum of maximum possible scores for <u>those indicators assessed</u>			**ni**
Hydrological function score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**ni**
2. Water quality	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #2**
Floodwater TP	<10 µg l^{-1}=0; 10-20 µg l^{-1}=1; >20 µg l^{-1}=2	<20 µg l^{-1}=0; 20-40 µg l^{-1}=1; >40 µg l^{-1}=2		**ni**
Increase in floodwater TP	>10% increase=0; 10-20%=1; >20% increase=2			**ni**
Maximum recorded Chl*a*	<10 µg l^{-1}=0; >10 µg l^{-1}=1			**ni**
Water color	>30 mg µg l^{-1} PtCo=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**ni**
Water quality score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**ni**
3. Biological responses: terrestrial	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #2**
Agrostis stolonifera-Glyceria fluitans community cover	<5% cover of turlough=0; 5-20%=1; >20%=2			**0**

Cover of *Rumex crispus, R. conglomeratus*, and *R. acetosa* either singly or in combination	<5% cover of turlough OR <10% of quadrats surveyed=0; >5% cover OR 10% quadrats=1			**0**
Lolium grassland cover	<5% cover of turlough=0; 10-20% cover=1; >20%=2			**0**
Grass-forb dominated community area	<33% cover of turlough=0; >33% cover=1		N.A.	**0**
Filipendula ulmaria-Potentilla erecta-Viola sp. community	<2% cover of turlough=0; 2-10% cover=1; >10%=2	N.A.	N.A.	**1**
Poa annua-Plantago major community	<2% cover of turlough=0; 2-10% cover=1; >10%=2			**0**
Polygonum amphibium community	<2% cover of turlough=0; 2-10% cover=1; >10%=2	N.A.	N.A.	**0**
Eleocharis acicularis community	N.A.	N.A.	No loss=0; loss of community=1	**N.A.**
Limestone grassland, Flooded pavement, or woodland communities in any combination	>10% of turlough=0; <10% of turlough=1			**0**
Eleocharis palustris-Ranunculus flammula community	>10% of turlough=0; <10% of turlough=1		N.A.	**1**
Eleocharis palustris-Ranunculus flammula community	No loss in area=0; loss of area=1		N.A.	**ni**
Polygonum amphibium community	N.A.	No loss in area=0; loss of area=1		**N.A.**
Molinia caerulea-Carex panicea community	Cover >2% of turlough=0; cover <2%=1		N.A.	**0**
Sward height greater than 40cm (except reedbeds)	Indicates undergrazing: <40cm=0; >40cm=1			**0**

Sward height less than 8cm	Indicates intensive overgrazing by sheep: >8cm=0; <8cm=1			**0**
Notable species (incl. inverts)	No loss=0; loss of species=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**18**
Terrestrial biological responses score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0.11**
4. Biological responses: aquatic	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #2**
Presence of algal paper	<2% of turlough area=0; >2% area=1			**0**
Absence of fully aquatic vascular plants	Any species present=0; otherwise=1			**1**
Notable species (incl. inverts)	No loss=0; loss of species=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**2**
Aquatic biological responses score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0.5**
5. Other	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #2**
Physical damage to turlough (land clearance, resource extraction, etc.)	<5% of turlough area=0; 5-20%=1; >20%=2			**1**
Maximum score	Sum of maximum possible scores for those indicators assessed			**2**
Other impact score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0.5**

SUMMARY		Feature #2
1. Hydrological function score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)	**ni**
2. Water quality score		**ni**
3. Terrestrial biological responses score		**0.11**
4. Aquatic biological responses score		**0.5**
5. Other impact score		**0.5**
COMBINED S&F INDICATORS	Green: no red, no more than 1 amber; Red: two red, or one red and two or more amber; Amber: any other combination	
PRESSURES		
Number of high impact pressures		**0**
Number of medium impact pressures		**0**
Number of low impact pressures		**1**
OVERALL SITE STRUCTURE & FUNCTION	Green: S&F indicators green AND no high impact pressure; Red: S&F indicators red OR at least 1 high impact pressure and at least 3 medium impact pressure	
ADJUSTMENT TO OVERALL ASSESSMENT	Based on expert judgment. Justification for any adjustment MUST be given and incorporated into the Article 17 Audit Trail document	**Feature has poor aquatic biological response, as it is an extremely dry feature and would not be expected to have a significant aquatic community**

Appendix 3. ACST Assessment of Feature #7

			Feature #	**7**
			Pre-screening A: Mineral soil present (=1)	**0**
			Pre-screening B: flooded pavement community present in turlough (=1)	**0**
			Pre-screening B: limestone pavement occurs within 200m of turlough (=1)	**1**
			Pre-screening B: *Potentilla fruticosa* present (=1)	**1**
			Pre-screening B: *Frangula alnus* present (=1)	**0**
			Pre-screening B: *Schoenus nigricans* present (=1)	**1**
			Pre-screening: sum of pre-screening criteria B	**3**
			ASSESSMENT GROUP [Mineral if A=1; Oligotrophic if A=0 and B>1; Mesotrophic if A=0 and B=0]	**Oligotrophic**
INDICATOR	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #7**
Invert of drainage (any increase or decrease of drainage capacity)	None, or affecting only exceptional flooding=0; Affecting flooding in upper part of basin=1; Affecting flooding in majority of basin=2			**ni**
Consistent or progressive change in flooding depth/ duration/ area of flooding (over 6 year HD reporting cycle)	<5% change=0; 5-20% change=1; >20% change=2			**ni**
Maximum score	Sum of maximum possible scores for <u>those indicators assessed</u>			**ni**
Hydrological function score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**ni**
2. Water quality	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #7**
Floodwater TP	<10 µg l^{-1}=0; 10-20 µg l^{-1}=1; >20 µg l^{-1}=2	<20 µg l^{-1}=0; 20-40 µg l^{-1}=1; >40 µg l^{-1}=2		**ni**
Increase in floodwater TP	>10% increase=0; 10-20%=1; >20% increase=2			**ni**
Maximum recorded Chl*a*	<10 µg l^{-1}=0; >10 µg l^{-1}=1			**ni**
Water color	>30 mg µg l^{-1} PtCo=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**ni**
Water quality score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**ni**
3. Biological responses: terrestrial	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #7**
Agrostis stolonifera-Glyceria fluitans community cover	<5% cover of turlough=0; 5-20%=1; >20%=2			**0**

Cover of *Rumex crispus, R. conglomeratus*, and *R. acetosa* either singly or in combination	<5% cover of turlough OR <10% of quadrats surveyed=0; >5% cover OR 10% quadrats=1			**0**
Lolium grassland cover	<5% cover of turlough=0; 10-20% cover=1; >20%=2			**0**
Grass-forb dominated community area	<33% cover of turlough=0; >33% cover=1		N.A.	**0**
Filipendula ulmaria-Potentilla erecta-Viola sp. community	<2% cover of turlough=0; 2-10% cover=1; >10%=2	N.A.	N.A.	**1**
Poa annua-Plantago major community	<2% cover of turlough=0; 2-10% cover=1; >10%=2			**0**
Polygonum amphibium community	<2% cover of turlough=0; 2-10% cover=1; >10%=2	N.A.	N.A.	**0**
Eleocharis acicularis community	N.A.	N.A.	No loss=0; loss of community=1	**N.A.**
Limestone grassland, Flooded pavement, or woodland communities in any combination	>10% of turlough=0; <10% of turlough=1			**0**
Eleocharis palustris-Ranunculus flammula community	>10% of turlough=0; <10% of turlough=1		N.A.	**0**
Eleocharis palustris-Ranunculus flammula community	No loss in area=0; loss of area=1		N.A.	**ni**
Polygonum amphibium community	N.A.	No loss in area=0; loss of area=1		**N.A.**
Molinia caerulea-Carex panicea community	Cover >2% of turlough=0; cover <2%=1		N.A.	**0**
Sward height greater than 40cm (except reedbeds)	Indicates undergrazing: <40cm=0; >40cm=1			**0**

Sward height less than 8cm	Indicates intensive overgrazing by sheep: >8cm=0; <8cm=1			**0**
Notable species (incl. inverts)	No loss=0; loss of species=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**18**
Terrestrial biological responses score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0.06**
4. Biological responses: aquatic	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #7**
Presence of algal paper	<2% of turlough area=0; >2% area=1			**0**
Absence of fully aquatic vascular plants	Any species present=0; otherwise=1			**1**
Notable species (incl. inverts)	No loss=0; loss of species=1			**ni**
Maximum score	Sum of maximum possible scores for those indicators assessed			**2**
Aquatic biological responses score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0.5**
5. Other	**OLIGOTROPHIC GROUP**	**MESOTROPHIC GROUP**	**MINERAL SOIL GROUP**	**FEATURE #7**
Physical damage to turlough (land clearance, resource extraction, etc.)	<5% of turlough area=0; 5-20%=1; >20%=2			**0**
Maximum score	Sum of maximum possible scores for those indicators assessed			**2**
Other impact score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)			**0**

SUMMARY		Feature #7
1. Hydrological function score	Sum of scores divided by maximum possible score (0-0.33=good; >0.33-0.66=intermediate; >0.66-1=poor)	**ni**
2. Water quality score		**ni**
3. Terrestrial biological responses score		**0.06**
4. Aquatic biological responses score		**0.5**
5. Other impact score		**0**
COMBINED S&F INDICATORS	Green: no red, no more than 1 amber; Red: two red, or one red and two or more amber; Amber: any other combination	
PRESSURES		
Number of high impact pressures		**0**
Number of medium impact pressures		**0**
Number of low impact pressures		**1**
OVERALL SITE STRUCTURE & FUNCTION	Green: S&F indicators green AND no high impact pressure; Red: S&F indicators red OR at least 1 high impact pressure and at least 3 medium impact pressure	
ADJUSTMENT TO OVERALL ASSESSMENT	Based on expert judgment. Justification for any adjustment MUST be given and incorporated into the Article 17 Audit Trail document	

Appendix 4. Vascular plant species list

**Denotes species present in study features, but absent from quadrats*

Achillea millefolia
*Agrostis stolonifera**
*Alchemilla xanthochlora**
*Anemone nemorosa**
*Antennaria dioica**
Anthoxanthum odoratum
Anthyllis vulneraria
Baldellia ranunculoides
Bellis perennis
*Brachypodium sylvaticum**
Briza media
Callitriche sp.***
Calluna vulgaris
Carex flacca
Carex hostiana
Carex nigra
Carex panicea
Carex pulicaris
*Carex viridula agg. **
Centaurea nigra
Cirsium dissectum
Cladium mariscus
Conopodium majus
*Corylus avellana**
*Crataegus monogyna**
Cynosurus cristatus
Dactylis glomerata
Dactylorhiza fuchsii
*Danthonia decumbens**
Daucus carota
Deschampsia cespitosa
*Eriophorum angustifolium**
*Euonymus europaeus**
*Festuca arundinacea**
*Festuca rubra**
Filipendula ulmaria
*Filipendula vulgaris**
*Frangula alnus**
Galium boreale
Galium palustre
Galium sp.
Galium verum
*Geranium robertianum**
Geranium sanguineum
Gymnadenia conopsea
*Helictotrichon radicata**
Hetera helix
Hieracium pilosella
Holcus lanatus
Hypericium pulchrum
*Ilex aquifolium**
*Isolepis setacea**
*Juncus acutiflorus**
*Juncus articulatus**
*Juncus bufonius**
*Juncus effusus**
*Juniperus communis**
*Koelaria macrantha**
Lathyrus pratensis
Leontodon autumnalis
*Leontodon hispidus**
*Leucanthemum vulgare**
*Linum catharticum**
Listera ovata
Lolium perenne
Lotus corniculatus
Mentha aquatica
*Minuartia verna**
Molinia caerulea
Ophioglossum vulgatum
Parnassia palustris
Plantago lanceolata
Plantago maritima
*Platanthera bifolia**
Polygala serpyllifolia
Potamogeton polygonifolius***
Potentilla anserina
Potentilla erecta
*Potentilla fruticosa**
Primula vulgaris
*Prunella vulgaris**
Prunus spinosa
Pteridium aquilinum
*Ranunculus acris**
Ranunculus bulbosus
Ranunculus flammula
Ranunculus repens
*Rhamnus catharticum**
Rhinanthus minor
Rosa pimpinellifolia
Rubia peregrina
*Rubus fruticosus**
Rubus saxatilis
Sagina nodosa
*Salix aurita**
*Salix cinerea**
*Salix repens**
Samolus valerandi
*Sanicula vulgaris**
Schoenus nigricans
Sedum acre
*Senecio jacobea**
Seslaria caerulea
*Sonchus asper**
Succisa pratensis
*Taraxacum officinale**
Teucrium scorodonia
Thymus polytrichus
Trifolium campestre
Trifolium pratense
Trifolium repens
Triglochin palustris
*Valeriana officinalis**
*Veronica sp.**
Vibernum opulus
*Vicia cracca**
*Vicia hirsuta**
*Viola canina**