TURLOUGH VEGETATION COMMUNITIES – LINKS WITH HYDROLOGY, HYDROCHEMISTRY, SOILS AND MANAGEMENT

Thesis submitted for the Degree of

Doctor of Philosophy

by

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based on research carried out under the supervision of

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Declaration

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work.

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SUMMARY

This thesis documents the vegetation communities of 22 turloughs from Counties Galway, Clare, Roscommon and Mayo. In total, 28 vegetation communities were identified, classified and described. These communities ranged from the fully aquatic to mostly terrestrial, with a range of intermediate vegetation types in between. There was a degree of overlap between the species composition of many of the plant communities; few species were faithful to a single plant community.

The communities found fell within the phytosociological classes of the Molinio-Arrhenatheretea, the Scheuchzerio-Caricetea fuscae, the Phragmitetea, the Potametea, the Littorelletea uniflorae and the Polygono-Poetea annuae, and the Ranunculo-Potentilletum anserinae association. The small sedge communities of the Scheuchzerio-Caricetea fuscae and the Ranunculo-Potentilletum anserinae are described in the literature as being typical of turloughs, and these communities are well-represented here. The remainder of the plant communities either belong to classes that are similar to those found just outside the turlough boundary, such as the Molinio-Arrhenatheretea, or to classes such as the Phragmitetea or Potametea which contain communities which require permanent water throughout the year. A number of communities were identified as being of high conservation value, due either to the rare species contained therein, or to the unusual combination of plant species.

The strongest drivers of turlough vegetation were identified. Of the hydrological variables, duration of flooding was a more important factor than any other. The timing of the recession of floodwaters was also found to be important, as was maximum depth of flooding. Water total phosphorus concentration was shown to be one of the variables with the strongest association with turlough vegetation communities, water total nitrogen was also influential. Soil nutrient status did not show a strong relationship with vegetation type, but soil type was identified as an important explanatory variable – some vegetation types were recorded on only one soil type. Land use was also identified as influential; i.e. whether a land-parcel was grazed or not was important.

Plant species were assigned to different categories in four different plant functional trait groupings; perennation, life form, clonality and growth form. There was a general trend for increased number of annual species as the duration of flooding increased. There was a marked decrease in the number and cover of hemicryptophyte species as the mean duration of inundation increased, with a concomitant increase in the number and cover of perennial hydrophyte species. Likewise, the number and cover of species with little or no clonal growth decreased, as mean duration of inundation increased. Rhizomatous species were the most common of those with clonal growth, and the number and cover of species in this category increased with increased duration of inundation.

The classification and description of turlough vegetation communities presented here provides the first semi-quantitative survey of turlough vegetation from a wide range of turloughs. The large number of relevés recorded as part of this study lends great weight to the findings, and allows confidence in the results. Vegetation communities were recorded in turloughs with a wide range of geomorphology, hydrological regime and management, and provide important baseline information for turlough conservation and monitoring.

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1 GENERAL INTRODUCTION

1.1 Turloughs

Turloughs are seasonal wetlands predominantly found in karstic regions of the Irish Carboniferous Limestone in central and western Ireland (Coxon 1987a). A clue to the temporary status of these wetlands can be found in their name: the word "turlough" is commonly thought of as an Anglicisation of the Irish "tuar loch", which translates as "dry lake" (Praeger 1932). An alternative interpretation can be made from the current Irish spelling of the word – "turlach" meaning 'a dried up place' (Royal Irish Academy 1998). Figure 1.1 and Figure 1.2 show Coolorta turlough, Co. Clare, flooded in winter, and the same turlough empty in the summer. Turloughs require a combination of moist climate and low-lying limestone which is not commonly found outside of Ireland (Drew 1990). However, turlough-like systems have been identified elsewhere; in Wales (Campbell 1992, Blackstock et al. 1993), Catalonia (Reynolds et al. 1998), eastern Canada (Cote et al. 1990) and Slovenia (Sheehy Skeffington and Scott 2008). Nevertheless, turloughs are certainly most frequent within Ireland, notably concentrated in counties Galway, Clare, Mayo and Roscommon (Goodwillie and Reynolds 2003). Approximately 480 turloughs have been recorded (Mayes 2008) and are shown in Figure 1.3, of which 300 have been identified as active (Sheehy Skeffington et al. 2006). The majority of these, however, have not been studied in any detail.

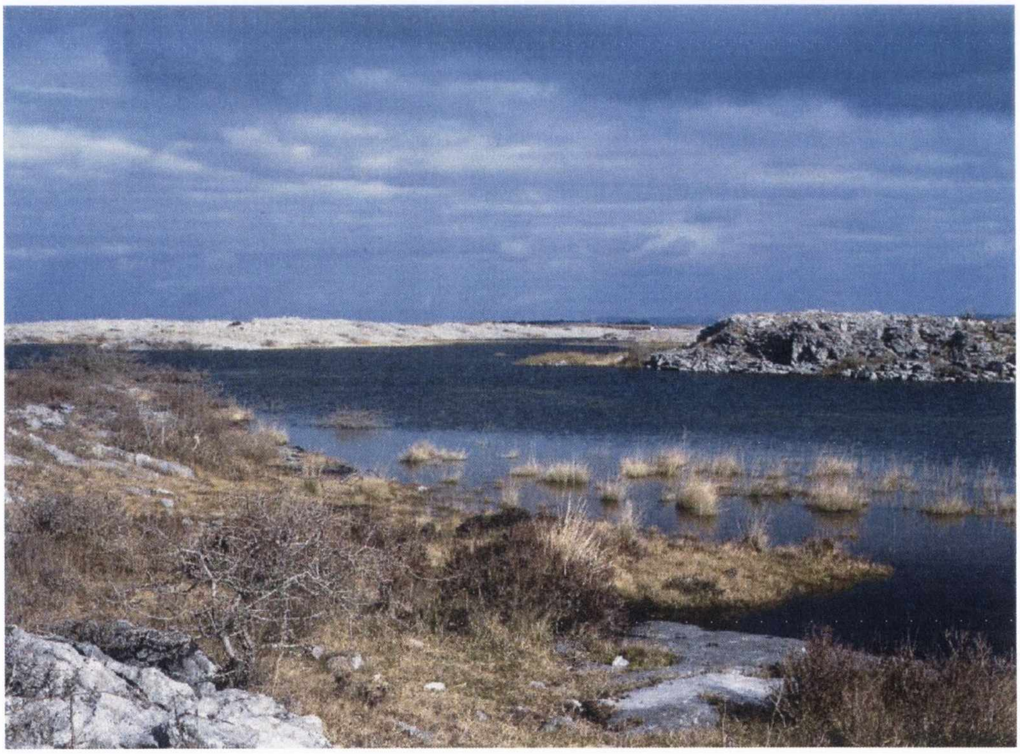


Figure 1.1 Coolorta turlough, Co. Clare, in winter (Photo: S. Waldren).

Figure 1.2 Coolorta turlough, Co. Clare, in summer (Photo: S. Waldren).

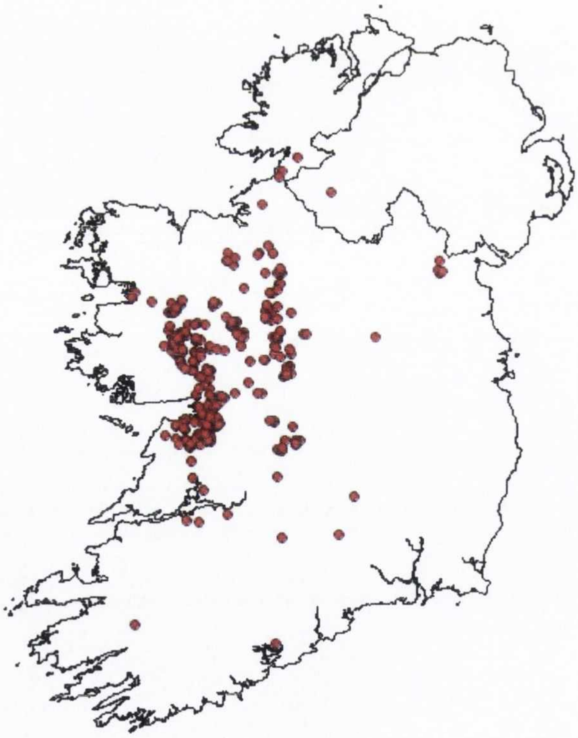


Figure 1.3 Geographical distribution of 480 turloughs according to the NPWS turlough database (Mayes 2008).

The continually changing environment of turloughs means that they are considered as ecotones rather than ecosystems; that is, they are transitional zones between aquatic and terrestrial systems (Reynolds 1996), and can be thought of as the shores of underground lakes or the callows of underground rivers (Goodwillie 2003). The fundamental premise of the ecotone concept, with respect to turloughs, lies in recognising that turloughs are not simply static zones where two communities join but are dynamic, constantly changing, have unique properties and must be understood in the spatial and temporal context of the changing ecological units (Risser 1990).

The majority of turloughs occur on Dinantian pure bedded limestone (Coxon 1987b). The bedding planes and purity of this limestone mean that it is highly porous and easily dissolved by rainwater in a process known as karstification, which can lead to the formation of underground caves and passageways. These underground networks can be very extensive, and can link different turloughs in the same catchment area, although it can be difficult to delineate the 'catchment area' of a turlough because inflow can come from diffuse epikarst recharge or point recharge from sinking streams (Drew 2003). The extent of the area contributing to the catchment may also vary over time, depending on the amount of precipitation and the level of the water table. Groundwater can travel very rapidly through karstified limestone; while normal rates of groundwater flow are slow (ranging from a few centimetres to a few metres per day), flow through subterranean channels and fissures in limestone can be up to 100 metres per hour or more (Coxon and Drew 1986, Drew 1990). When the water table has been recharged to a sufficient degree, subterranean waters flow from the ground through springs or estavelles into depressions or hollows that constitute the turlough basin, thereby creating the flooded phase of the turlough (Coxon and Drew 1986). Since turloughs have no overground outlet for drainage, they remain flooded until the water table subsides and the floodwaters drain back into the water table through swallow holes, estavelles or swallets (Coxon 1986, Reynolds et al. 1998). Some turloughs may retain standing water when the flooding subsides, either in channels, pools or small lakes. A diagram showing a schematic cross-section of a turlough is presented in Figure 1.4.

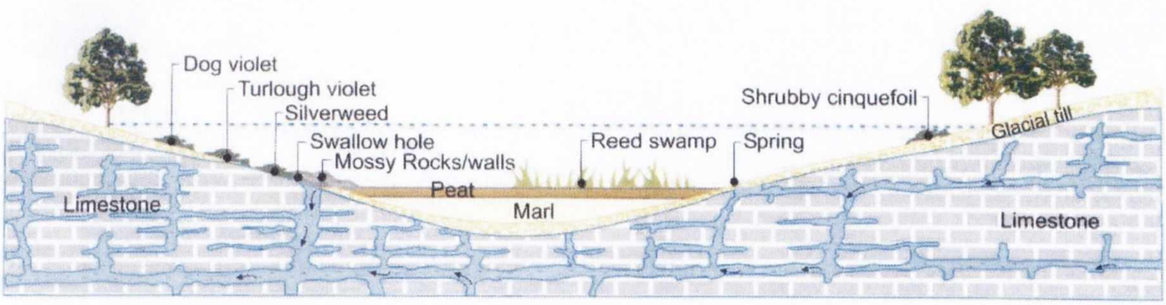


Figure 1.4 Schematic cross section of a turlough (Karst Working Group 2000).

While turloughs are often referred to as temporary or seasonal lakes or wetlands, they are not strictly seasonal; they fill and empty in response to local weather conditions in the catchment area to which they belong (Goodwillie and Reynolds 2003). Since they are almost entirely dependent on local precipitation, however, there is an element of seasonality to their flooding, and as a general rule they are usually flooded for periods between October and April, dry in May and June, and may be variably wet from July through to September (Coxon 1986, Goodwillie and Reynolds 2003). The hydrological regime of a turlough may vary from year to year, depending on the amount and timing of precipitation (Moran et al. 2008b). Turlough size can vary considerably, ranging from diameters of tens of metres to areas of several square kilometres (Coxon 1987a). Depth can vary independently of the size of the turlough (O'Connell et al. 1984); the deepest recorded turlough, Blackrock, can flood to depths of 13m (Goodwillie 2003). As they are wetland systems, turlough function is dependent on the hydrological regime. While Coxon found 90 large (>10 ha) turloughs in a 1986 survey of Ordnance Survey maps, she considered only 60 of these to be functioning 'naturally', the remainder having had their hydrology disrupted by anthropological sources, namely arterial drainage for agriculture. The hydrological regime of turloughs may also change naturally over time; some turloughs have an abundance of limnic deposits which suggest the one-time presence of a permanent lake, e.g. Carron turlough, Co. Clare (Crabtree 1982). Approximately half of the 90 turloughs surveyed by Coxon (1987a) contained lacustrine chalk or pure calcareous marl, also indicating that these sites were once permanent lakes. These shifts in the hydrological regime, from lake to turlough, may be due to changes in the drainage system; fissures and swallow holes connecting the turlough to the groundwater may become open, or blocked by marl deposition (Goodwillie 1992).

Turloughs vary in their topography, underlying soil type and hydrologic regime. A number of attempts have been made to distinguish between, and define, turlough types (Williams 1970, Drew 1976, Coxon 1986, Goodwillie and Reynolds 2003). The large amount of variation in hydrology, morphology and geology between turloughs, however, has made this a difficult task. There is also a lack of detailed knowledge about hydrology and the mechanisms of flooding; while some turloughs have been studied in detail, there is little or only cursory information available for the vast majority. Visser et al. (2006), proposed bypassing typology, instead assigning turloughs a place on a wet-dry continuum based on the hydrological regime. Visser et al.'s continuum ranges from the dry extreme, with a short (3 months or less) period of inundation, where the soils dry out quickly after recession of flooding, to the wet extreme, with a long hydroperiod (6 months or longer), where the soils retain water throughout the year. Turloughs containing permanent waterbodies can belong anywhere on this continuum, as this definition refers only to the temporarily flooded areas.

The amount of variation inherent in turlough ecotones has great implications for their conservation. An effective turlough typology, driven by Water Framework Directive (EC 2000) requirements, could have great implications for turlough conservation, as the only real alternative is to consider turloughs individually in a site-by-site approach.

1.2 Conservation

Turlough ecosystems are particularly vulnerable to impacts through drainage and intensification of land use both in the turlough basin and in the surrounding farmland (Sheehy Skeffington et al. 2006). They are of conservation importance because they can contain plant and animal species which are rare in an Irish context, but occur frequently within turloughs, and the communities of plant and animal species found may not occur commonly elsewhere.

Several plant species listed in the Red Data Book (Curtis and McGough 1988) occur in turloughs, including *Filipendula vulgaris, Potentilla fruticosa, Frangula alnus, Viola persicifolia, Rorippa islandica, Limosella* *aquatica* and *Nitella tenuissima*. While none of these species are confined only to turloughs, the conservation value of a turlough in which they occur is increased. In addition, *Callitriche palustris* has only been recorded at one location in Ireland, in a turlough in Coole (Goodwillie 2003). While many of the plant communities found in turloughs can be found elsewhere, the small sedge communities may be specific to turloughs (Sheehy Skeffington et al. 2006).

A number of rare aquatic invertebrate species have been found, some of which only occur in turloughs in Ireland, for example the damselfly *Lestes dryas* (Nelson and Thompson 2004), the copepod *Daptomus castor* (Reynolds 1997), and the glacial relict cladoceran *Eurycercus glacialis* (Reynolds and Marnell 1999). Turloughs are the only habitat in the British Isles where the fairy shrimp *Tanymastix stagnalis* is found (Young 1976). Turloughs are also important over-wintering grounds for migratory birds (Sheehy Skeffington et al. 2006), including whooper swans and Greenland white-fronted geese (de Buitléar 1995).

1.2.1 Threats

The primary threats to turlough ecosystems have been defined as drainage, grazing and nutrient input (Reynolds 1996, Sheehy Skeffington et al. 2006). Climate change will inevitably have an impact on turlough vegetation and faunal communities, the rate and direction of climate change will affect the size of this impact. Peat cutting has also been carried out on some turloughs (Proctor 2010).

Drainage has historically been the greatest threat to the function of turloughs. Turloughs, once emptied, provide good grazing land for livestock. Due to seasonal inundation, however, turloughs are accessible for only a few months of the year. In an attempt to maximise grazing pasture, major drainage works have been carried out on a number of turloughs. Coxon (1986) found that approximately one third of the turloughs over 10 hectares were damaged by drainage. The Arterial Drainage Act (1945) had a massive impact on the hydrology of karst lowlands in Ireland, and in particular on turloughs. An estimated 50% of flooded turlough area was lost (Coxon 1986, Goodwillie 2001). A number of studies have investigated the impacts of arterial drainage, and the potential loss of biodiversity that accompanies it, for example, the potential loss of *Viola persicifolia* (Lockhart 1985), a species which is known to favour areas of temporary flooding (Pullin and Woodell 1987). The maintenance of existing drains, i.e. maintaining or widening drainage channels in or adjacent to turloughs, can either be detrimental to turlough ecology or have no discernible effect (Ní Bhroin 2008). Recent extensive flooding events may result in a renewed consideration of drainage within the landscape. Drainage, and the subsequent loss of or reduction in seasonal inundation, results in the loss of the unique flora and fauna of turloughs, as they cannot survive outside of their ecological niche.

Turloughs, by their very nature, are intrinsically linked with the hydrology of the surrounding area. Eutrophication of surface waters is perhaps the most significant water pollution issue in Ireland at present, and this is primarily caused by elevated levels of phosphorus from both agricultural and sewage sources (Daly 2004). While the overland transfer pathways of phosphorus to surface water have been extensively studied, few have examined the transfer to surface waters via groundwater discharge (Kilroy and Coxon 2005). Some 50% of Ireland is underlain by karstified or partly karstified limestone, and in the most highly karstified regions in the west of the country, complex interactions between surface water and groundwater are to be found (Coxon and Drew 2000). The rapid movement of water throughout the karst region means that inputs from throughout the catchment can end up influencing the nutrient status of turloughs. This type of input is very difficult to quantify, particularly as turlough catchment areas are so difficult to define. Although groundwater bodies are normally considered to be more stable than surface water bodies, due to higher residence times, this is not always true, as illustrated in the case of turloughs and karstic aquifers, which are characterised by rapid flow (Goodwillie and Reynolds 2003). The high permeability of limestone, together with the increased flow rate through features such as sinkholes, means that groundwater-surface water interactions in karstic regions have specific aspects which need to be addressed in terms of management; because of rapid and point recharge, aquifers overlain by karstified limestone, and hence turloughs, can be very vulnerable to pollution. Pollutants entering these aquifers at one point, therefore, can be very rapidly relocated to the surface at another point unrelated by surface water flow (Kilroy and Coxon 2005). In this way, silage effluent, septic tank overflow and fertiliser application throughout the catchment can all have a detrimental effect on groundwater quality and hence on turlough biota (Reynolds 1996). On a smaller scale, one of the most important localised sources of excess nutrients is the run-off from overwintering livestock (Goodwillie 2003), especially if feedlots are on or near limestone pavement, as this contributes a concentrated source of nutrients to groundwater. Localised inputs such as silage pits and manure and fertiliser spreading can also affect vegetation, while grazing animals can be another source of nutrient input. It has been estimated that only 5% of turloughs remain oligotrophic (Goodwillie 2003).

Studies on flood-meadows have shown a significant decrease in species richness when fertilization at rates typical of intensive agriculture is used (Joyce 2001). While the use of fertilisers within the turlough or its buffer zone is a notifiable action, this may be difficult to enforce in practice. Turlough boundaries, i.e. the upper limit of flooding, may also be inaccurate.

Turloughs can be classified as marginal grazing land (Visser et al. 2007). As such the vegetation is very sensitive to grazing pressure, and the maintenance of appropriate stocking densities is important in conserving turlough plant communities. Either over- or under-stocking can result in changes to the vegetation, although ascribing appropriate stocking densities can be difficult. The stocking density recommended by the National Parks and Wildlife Service (NPWS) is 1.5 livestock units per hectare, while some studies have suggested an upper limit of 1 livestock unit per hectare is more appropriate (Ní Bhriain et al. 2002, Ní Bhriain et al. 2003). Sheehy-Skeffington et al. (2006) suggest that the more intensively managed turloughs show a shift towards mesotrophic grasslands rather than the sedge-dominated communities of oligotrophic turloughs. Conversely, a lack of grazing may be one of the greater threats facing turloughs today; as marginal land, they are of reduced financial value and are at risk of abandonment. If this lack of grazing occurs throughout the turlough, the vegetation could be seriously affected, with a knock-on effect on the fauna (Sheehy Skeffington et al. 2006).

Recent investigations into the impact of global climate change on the Irish climate (McElwain and Sweeney 2003) indicate that the Irish climate is following similar trends to those apparent worldwide, and that the major effects to impact the Irish climate will be warmer winters and increased precipitation, particularly in the winter months. An increase in precipitation will undoubtedly impact upon the turlough environment.

Increased precipitation in the winter months may result in deeper inundation occurring earlier in the flooded phase and continuing for longer than heretofore, which will impact on vegetation communities, shifting their location within the turlough basin and reducing the density of those communities which normally occupy the upper reaches of basins.

Increased precipitation may also lead to more flooding of local farmland and residential land, which may result in drainage initiatives being employed, as farmers seek to preserve both their farmland and their homes. An increase in precipitation may also result in increased rates of nutrient loss from the surrounding agricultural lands to turloughs.

1.2.2 Legislation

At a national level, there are two main pieces of environmental legislation which protect turloughs; the Wildlife Act (1976) and the Wildlife (Amendment) Act (2000). The aim of the Wildlife Act was to protect areas with ecologically interesting habitats, which are designated Natural Heritage Areas (NHAs). Turloughs occur within 67 of 630 proposed NHAs (pNHAs), but, as yet, only one of these has been formally designated as a NHA (Sheehy Skeffington et al. 2006). The Wildlife (Amendment) Act was passed in order to enforce the protection of NHAs and pNHAs from the date of formal proposal.

There are three important pieces of European environmental legislation which encompass turlough conservation: the EU Birds Directive (EEC 1979), the EU Habitats Directive (EEC 1992) and the EU Water Framework Directive (EC 2000). EU Member States were obliged to designate Special Protection Areas (SPAs) under the Birds Directive, and Special Areas of Conservation (SACs) under the Habitats Directive. Together, SPAs and SACs make up a network of protected sites in the EU called Natura 2000. Turloughs have been designated as one of 16 priority habitats under Annex I of the Habitats Directive, and as such must be protected within SACs. As a result, many turloughs have been proposed for designation as Candidate Special Areas of Conservation (cSACs); 44 cSACs have been designated within Ireland, encompassing approximately 70 turloughs (Sheehy Skeffington and Gormally 2007). Member States are required to ensure the 'maintenance or restoration at a favourable conservation status' of cSACs, and furthermore are required to monitor and report on their conservation status to the EU. Landowners whose land falls within a cSAC are required to restrict certain activities within the 'buffer zone'; this is that area of their land which occurs within 50 metres of the high water level of the turlough. These activities, or 'notifiable actions', include grazing above a 'sustainable level' or fertiliser application within the buffer zone (Goodwillie 2001, Ní Bhriain et al. 2003).

The EU Water Framework Directive (WFD) (EC 2000) requires Member States to maintain "good water status" for all waters by 2015, and this will require extensive monitoring and assessment, and integrated management of both groundwater and surface water within defined geographical units, or river basin districts (RBDs) (Mostert 2003). Under the WFD, turloughs are considered Groundwater Dependent Terrestrial Ecosystems (GDTEs) because of their temporary nature (Kilroy et al. 2005). In order to achieve this, turloughs must meet their Habitats Directive objective of 'favourable conservation status', where this is dependent on their water needs (Working Group on Groundwater 2004). The EU Groundwater Directive (GWD; (European Parliament and Council 2006) complements the WFD, setting quality standards for groundwater and introducing new measures aimed at preventing or limiting inputs of pollution to groundwater. This is important for many waterbodies and ecosystems, but especially for turloughs, given that they are almost entirely dependent on groundwater for their function. An interim classification of the status of groundwater bodies in Ireland has resulted in 14.2% of the land area being classified as 'poor'; this is likely to be low in a European context (Daly 2009).

Agri-environmental policy can also have implications for turloughs. Turloughs are generally classified as marginal grazing land, and low intensity grazing and/or haymaking are essential to maintaining their biodiversity (Bignal and McCracken 1996, Bignal 1998).

1.3 Turlough vegetation ecology

Plant communities established in ecotones tend to be more diverse and of a higher density than in adjacent ecosystems (Risser 1990). Previous studies on turlough vegetation have found a trend for increasing species diversity with increased elevation (Caffarra 2002), or increased species diversity at intermediate elevations (O'Rourke 2009), which is in accordance with the intermediate disturbance hypothesis (Smith and Huston 1989, Pollock et al. 1998). Turlough ecotones are highly variable with respect to their size, depth, groundwater connections and inundation patterns, and as a result of these specific environmental characteristics, they play host to unique floral and faunal communities. Traditional successional concepts may not be appropriate for the turlough environment (Gopal 1986, Niering 1989); many wetlands, including turloughs, have plant communities which are kept in 'permanent successional stages' due to the fluctuating water level (Hejny and Segal 1998).

1.3.1 Vegetation communities

A number of studies of turlough vegetation communities have been conducted (Ivimey-Cook and Proctor 1966, O'Connell et al. 1984, MacGowran 1985, Goodwillie 1992, Regan et al. 2007, Moran et al. 2008a). Turlough vegetation generally exhibits regular zonation, with woodland and grassland communities at the edge, sedge and wet grassland communities in the middle zones, and fen and aquatic communities in the wettest parts (Goodwillie 1992, Moran et al. 2008a). O'Connell et al. (1984) analysed a number of relevés from the studies of Ivimey-Cook and Proctor (1966) and MacGowran (1985), to come up with two overarching turlough plant communities: a *Potentilla anserina* sward (Class Plantaginetea majoris) and a sedge-dominated community (Class Scheuchzerio-Caricetea fuscae), each of which can be further subdivided. Goodwillie (1992), in a survey of 60 turloughs, described 32 vegetation communities, while in a later study (2003) he described 24 communities from turloughs within a single catchment. Goodwillie's plant communities, however, are qualitative rather than quantitative; relevés were taken in the preliminary stages of his survey, but were not statistically analysed to produce the vegetation communities. Regan et al. (2007) analysed relevés from 30 turloughs using statistical methods, but only 3 relevés were taken in each turlough, so that the variety of turlough vegetation within turloughs was not comprehensively assessed. These studies on turlough vegetation will be explored in more detail in Chapter 2.

1.3.2 Drivers of vegetation community dynamics

The hydrology of seasonally flooded wetlands has been shown to be the main factor affecting vegetation community composition (Keddy 2000, Gowing et al. 2002). Previous studies have indicated that turlough hydrological regime is the main factor influencing turlough vegetation communities, especially the depth of submergence and duration of flooding (O'Connell et al. 1984, Goodwillie 1992, Regan et al. 2007, Moran et al. 2008a). Given that the water level of turloughs can change so dramatically, the vegetation is predominantly composed of species that can tolerate intermittent flooding *in situ*, and those that can rapidly recolonise the habitat after flooding has passed (O'Connell et al. 1984, Goodwillie 2003).

Apart from hydrology, there are a number of factors that can affect vegetation in wetlands. Wheeler and Proctor (2000), in a study of ecological gradients and floristic variation of north-west European mires, found that most of the variation was accounted for by just three ecological gradients: pH, the availability of nitrogen and phosphorus, and the hydrological gradient. They also note the importance of land use as a factor affecting vegetation. Moran et al. (2008a) found that plant communities can vary within areas with similar hydrological regimes, which may be due to differences in soil moisture, soil depth, proximity to swallow holes and differences in management. Other studies have also identified similar drivers affecting turlough plant communities, such as differing substrates and trophic status, as well as the intensity of grazing (Ní Bhriain et al. 2003, Regan et al. 2007, Moran et al. 2008b). The environmental factors affecting turlough vegetation will be explored in greater detail in Chapter 3.

1.3.3 Plant responses to flooding

Flooded or waterlogged soils are a vastly different environment for plant roots to well-aerated, relatively dry soils. Waterlogged soils quickly become hypoxic or anoxic, as gaseous exchange is severely retarded, resulting in rapidly decreasing levels of oxygen and decreased nutrient availability (Blom and Voesenek 1996). There is also a reduced rate of gaseous exchange in water, and inundated plant shoot systems must also exhibit some form of adaptation or at least tolerance in order to survive flooding. Because flood tolerance and adaptation varies between and within plant species (Blom and Voesenek 1996), groundwater inundation has a profound effect on the composition of vegetation communities in turloughs. As a result of the reducing conditions created by flooding, nitrogen, sulphur, iron, manganese and carbon are reduced (Mitsch and Gosselink 2000). High iron concentrations and the solubilisation of ferrous iron are associated with waterlogged soils (Ponnamperuma 1972). This reducing atmosphere results in the relatively insoluble ferric iron (Fe^{3+}) being reduced to ferrous iron (Fe^{2+}), which is then absorbed by roots (Chaney et al. 1972) which can then be toxic to many non-adapted organisms at much lower concentrations than ferric iron.

Waterlogging also causes physical changes in soil structure; it can cause the breakdown of large aggregates into smaller particles, which leads to smaller soil pore size, reduced O^2 concentrations and increases the resistance of the soil to root penetration (Engelaar et al. 1993).

There has been much research into the adaptations shown by terrestrial plant communities and species when subjected to flooding (Blom and Voesenek 1996, Mony et al. 2010, Raulings et al. 2010). There are a variety of ways in which plants can adapt to the flooded environment, including life history adaptations (e.g. the timing of important life history events, such as germination), short-term metabolic adaptation, long-term responses in the root, long-term responses in the shoot and the hormonal adaptation of adaptive responses.

Blom and Voesenek (1996) recognise that vegetation zonation along a flooding gradient often reflects differences in flooding stress at the level of the individual plant. This is a phenomenon that can be readily observed in turloughs, where vegetation communities vary along the flooding gradient of the turlough (Caffarra 2002). Some species occur from the edge of the basin almost to the floor, while others are restricted by their tolerance to flooding. MacGowran (1985) postulated that the duration and depth of flooding during the winter period was of lesser importance than the height above the summer water table and the drainage properties of the substrate. Flooding may also confer protection from erosion through grazing on turlough soils, and provide nutrient input from the flood waters (MacGowran 1985).

A number of physiological and morphological survival strategies have been identified in plants as a response to flooding. *Ranunculus repens*, for example, has demonstrated complete tolerance of flooding, together with a slightly improved photosynthetic rate in the genotype typical of flooded turlough basins when compared to genotypes of non-flooded areas (Lynn and Waldren 2002). Responses such as these may be selected for in areas which experience intermittent inundation; Voesenek et al. (2004), in a study on 22 plant species growing in the floodplain of the Rhine, found the capacity for stem and petiole elongation was positively correlated with flooding duration experienced. The root systems of reeds such as *Phragmites australis* and *Schoenoplectus lacustris* can tolerate anoxia throughout the winter as the dead shoots aerate the roots; when wind blows across the top of broken stems, oxygen is introduced to the roots through venturi-induced convection (Armstrong et al. 1992). Some wetland plants have physiological adaptations to waterlogging and instead of accumulating ethanol (which can be toxic) during anaerobic respiration, they accumulate relatively benign compounds, such as malate, instead (Otte 2003). Rhizomatous plants, such as *Potentilla anserina*, exhibit a number of adaptations which allow them to tolerate the turlough environment. The formation of a rhizome offers protection for the plant in a number of ways; providing anchorage for shoots during light disturbance or grazing, carbohydrate storage during periods unsuitable for photosynthesis, and enabling the plant to begin growing immediately after heavier disturbances (Lenssen et al. 2000). Some turlough plants respond to flooding through the elongation of stems or petioles in order to maintain a relationship with the air, and this is a well-recognised response in flood-resistant plants (van der Sman et al. 1993).

Post-anoxic injury is a risk to plants when flooding recedes. A number of compounds that may accumulate during anoxia undergo oxidation, e.g. ethanol can be oxidised to form acetaldehyde, which may be more damaging to plant tissues than the ethanol (Crawford 2008). Plants which are morphologically or physiologically adapted to waterlogged conditions may also be at a competitive disadvantage when turloughs empty.

The water of turloughs characteristically has high alkalinity and high levels of calcium carbonate ($CaCO_3$), as a result of $CaCO_3$ dissolution and enrichment as the groundwater flows through the limestone bedrock before upwelling into the turlough. This high $CaCO_3$ concentration creates a number of phenomena; there can be a high rate of marl or calcite deposition as the turlough drains, while high $CaCO_3$ levels can also render some nutrients less bioavailable through the formation of compounds that are inaccessible to plants (e.g. calcium phosphates). Indeed, the more calcareous turloughs are often the more oligotrophic ones, for example those in the eastern Burren (Goodwillie 1992).

1.3.4 Soils

The large degree of hydrological, hydrochemical and geomorphological variation among turloughs means that turlough soils are highly variable (MacGowran 1985, Coxon 1986, Kimberley 2007), and there is a wide range of soil types within turloughs in comparison to other wetlands (Goodwillie 2001). Soil composition in turloughs, like so much else in this habitat, is intrinsically linked with the hydrological regime of the turlough. The formation of new soils is related to the length and inundation of flooding; for example peats are formed in flat, shallow turloughs which tend to remain wet (MacGowran 1985, Goodwillie 2003).

A number of studies have been conducted on turlough soils. MacGowran (1985), in a study of 16 turloughs in Galway, Clare, Roscommon and Mayo found that the substrate at the base of turlough basins is often underlain by marl, which is commonly thought to have been deposited during the Pleistocene era (Drew 1976, Crabtree 1982). MacGowran found four principal soil types: rendzinas and rendzina-like soils, gleys, river silts and marl, although he also mentions recording peat soils. He found the soils in the upper reaches of turloughs to be generally light, freely draining rendzinas and rendzina-like soils, transitioning to more strongly gleyed soils and finally to silty or marly substrates at the base. Peaty soils were found to be relatively extensive, but generally shallow (usually less than 30cm). He mentions that where peats are now found, extensive peat-cutting may have occurred in the past, which has lead to mosaics of peat banks and pools scattered throughout the basin.

Coxon (1986) examined the deposit/sediment types of 90 turloughs, dividing them into six categories based on colour, organic matter content, calcium carbonate content, and non-calcareous inorganic content. The categories defined were peat, marl, peat-marl, silt/clay, sand/silt and diamicton. Individual turloughs can contain one or more of these sediment types.

A more recent study (Kimberley and Waldren 2005) examined the soil types and nutrient status of turloughs in two catchments with different types of karstic flow systems, and found that the parent materials, hydrology and hydrochemistry of a catchment can affect soil type within that catchment. Turloughs in the East Burren were associated with highly organic and calcareous soils, while turloughs within the Coole Garryland catchment were of a more mineral nature, and moderately calcareous. Vegetation types were found to be more strongly associated with soil moisture and alkalinity than with soil nutrient status. Soils within all turloughs had relatively low concentrations of nitrogen, phosphorus and potassium, in agreement with previous studies on the nutrient status of turloughs.

1.3.5 Grazing and management

Pre-agriculture, turloughs were surrounded by woodland (Goodwillie 2003). Nowadays, however, the majority of turloughs occur on land that has been 'improved' or farmed in some way; and many are used as grazing pastureland during their drained phase. In many turloughs, the central basin is managed as commonage; adjacent landowners, whose fields radiate from the centre, possessing grazing rights. In some cases, there is no commonage, and fields stretch right across the basin, encompassing different vegetation types (Sheehy Skeffington and Gormally 2007, Moran et al. 2008a). This pattern of field boundaries was related to water requirements for livestock. Landowners with adjacent fields within the same turlough may have very different management strategies, which can result in differences in vegetation even when the soil type and hydrological regime are similar (Ní Bhriain et al. 2003), and this variation in management within and between turloughs effects a heterogeneity in plant communities that is important and valuable in and of itself, but also provides diverse habitats for turlough faunal communities (Sheehy Skeffington and Gormally 2007).

Turloughs are important grazing land for cattle, sheep, horses and sometimes domestic geese (Sheehy Skeffington et al. 2006), and this can have a number of implications for turlough ecology. Grazing animals affect plant community composition in a number of ways. Grazing removes biomass, reduces sward height, creates gaps in vegetation, and may reduce the proportion of certain species within the community, since livestock will preferentially graze the more palatable species (Tanner 1992, Moran et al. 2008a). Turlough soils are generally relatively thin, delicate and easily eroded through overstocking. Grazing when the soil is very wet can result in poaching, thereby degrading the soil structure, damaging vegetation and altering plant community composition. Bare and trampled ground, however, with an associated ruderal component to the vegetation, is often a feature of turloughs with mineral soils (Goodwillie 1992). The defecation and urination of livestock can also introduce nutrients into these oligotrophic habitats.

While there has been much research on the effects of grazing on species composition and diversity (Olff and Ritchie 1998, Del-Val and Crawley 2005, Marty 2005), when grazing is required to maintain a habitat, such as a turlough, a delicate balance needs to be reached between overstocking and understocking of livestock. Turloughs generally require quite light grazing, but recommended stocking levels are sometimes ignored (Ní Bhriain et al. 2003), to the detriment of the vegetation communities. Stocking levels and grazing intensity are often governed by the hydrological regime, with the landowner releasing livestock into fields as the flooding recedes (Sheehy Skeffington and Gormally 2007).

1.4 Aims and thesis structure

The overarching aim of this thesis is to provide a better understanding of the plant communities in turloughs and the ecological drivers which create them. The thesis is divided into five chapters, three of which are relatively self-contained results chapters:

Chapter 1 is an introduction to turloughs and the challenges faced by plants which inhabit them.

Chapter 2 describes and classifies the vegetation communities found in the turloughs in this study.

Chapter 3 examines the ecological conditions associated with each vegetation type, and identifies the most important drivers of turlough vegetation communities.

Chapter 4 looks at the functional types of the species which compose turlough plant communities.

Chapter 5 summarises the findings of the previous chapters, drawing the information together into one place. This chapter also contains recommendations for future investigations into turlough vegetation communities, as well as recommendations on utilising the information in this thesis for turlough conservation and monitoring.

2 TURLOUGH VEGETATION

2.1 Introduction

The turlough habitat is strikingly dynamic. The transformation from lake to dry, vegetated basin, and back again, creates a number of challenges for the biota of turloughs. As a result, the water regime (i.e. depth, duration and frequency of flooding) is considered the primary factor affecting plant species distribution, and hence the composition of plant communities, in wetlands such as turloughs (Casanova and Brock 2000).

2.1.1 Vegetation classification

Phytosociology is the science of "recognising and defining plant communities" (Kent and Coker 1992). Early methods of classification, such as those of the Braun-Blanquet school, were subjective, based on ordering floristic tables by hand so as to place vegetation units that were similar to each other close together. Modern numerical classification techniques are considered more objective, as the methods are based on numerical values and therefore should be repeatable by different users (Kent and Coker 1992).

Nomenclature in phytosociology follows strict rules. Associations are usually named by using one or two of the species thought to be typical, adding the suffix –etum to the generic name of one (usually the one considered dominant), followed by the author(s) who first published a description of the association (Weber et al. 2000). Similar rules are followed for higher levels of phytosociological units, or syntaxa. There are four principle ranks of syntaxa, these are arranged in a hierarchy, with Class being the largest unit, and Association generally the basic rank. For a list of suffixes and the phytosociological units to which they refer, see Table 2.1.

Table 2.1 Nomenclature followed in naming of phytosociological units (Weber et al. 2000).

Phytosociological unit	Suffix used
Class	-etea
Order	-etalia
Sub-order	-enalia
Alliance	-ion
Sub-alliance	-enion
Association	-etum
Sub-association	-etosum

The most wide-ranging review of Irish vegetation communities to date, *The Vegetation of Ireland: A Catalogue Raisonné* (White and Doyle 1982), collated available published and unpublished data in order to give an account of the vegetation types in Ireland according to phytosociological principles. The paper included plant associations which have been recorded in Ireland, associations believed to be in Ireland based on species lists, and associations not yet recorded in Ireland but which the authors suspected must be present. This review, however, did not attempt to define new plant communities, relying instead on fitting communities to those in the existing literature. Fossitt's *A Guide to the Habitats of Ireland* (2000) sets forth a hierarchical classification of Irish habitats, and is the most recent of the reviews of Irish habitats. In this classification, habitats are defined based on characteristics of the vegetation, the physical environment and management (where applicable), and as such this is not a phytosociological classification system. The National Vegetation Classification (NVC) (Rodwell 1991a, b, 1992, 1995, 2000) is a comprehensive classification of the terrestrial and aquatic vegetation of Great Britain, based on phytosociological principles. The NVC is widely used throughout the United Kingdom (Rodwell et al. 2000).

Ireland's flora lacks a number of species commonly found in Great Britain and continental Europe (Webb 1983). This has resulted in a lesser amount of interspecific competition in a wide range of communities, and may also mean some species can tolerate a wider or different range of ecological conditions (Mooney and O'Connell 1990). Ireland's climate also has an effect on plant life – the mild oceanic climate can result in a longer growing season, and a more widespread occurrence of Atlantic and sub-Atlantic species than might otherwise be predicted (Cross 2006). These factors mean that it is likely that plant communities will be found in Ireland that will not be found elsewhere (White and Doyle 1982), and that some NVC communities may not correspond with those found in Ireland.

2.1.2 Ecotones

The continually changing environment of turloughs means that they are considered as ecotones rather than ecosystems; that is, they are transitional zones between aquatic and terrestrial systems (Reynolds 1996), and can be considered as the shores of underground lakes or the callows of underground rivers (Goodwillie 2003). The fundamental premise of the ecotone concept, with respect to turloughs, lies in recognising that turloughs are not simply static zones where two communities join but are dynamic, constantly changing, have unique properties and must be understood in the spatial and temporal context of the changing ecological units (Risser 1990).

Plant communities established in ecotones tend to be more diverse than those in adjacent ecosystems (Odum 1971, Risser 1990), although since they are neither stable nor mature, sudden perturbations in the environment can induce the opposite effect (Juge and Lachavanne 1996). This second scenario is more typical of turloughs due to rapid fluctuations in water level, and indeed, they display relatively low species diversity (Goodwillie 2003). Turloughs are highly variable with respect to their size, depth, groundwater connections and inundation patterns, and as a result of these specific environmental characteristics, they play host to unique assemblages of flora and fauna.

2.1.3 Turlough vegetation

Turlough vegetation is intrinsically linked to hydrology. During the 'dry' hydroperiod, turloughs are generally grass- or sedge-dominated basins, the base of which can, depending on the turlough, run the gamut from dry grassland to a permanent, but fluctuating, waterbody (Goodwillie 1992). Some species can tolerate a range of soil moisture/flooding, and are usually found almost throughout the basin, for example *Agrostis* *stolonifera*, *Potentilla anserina* and *Ranunculus repens*. Others have a more restricted range due to stricter habitat requirements, such as aquatic species which occur only in permanent water at the base of turloughs.

While many turloughs can dry out completely during the dry period, some can retain water, even when the level of the water table has lowered significantly, as 'perched ponds' on impermeable substrates such as marl or glacial deposits. The presence of permanent waterbodies such as these enables the persistence of aquatic vegetation throughout the year in some turloughs.

Trees and shrubs are notably absent from the main basin, confined to the fringes of the turlough by both inundation and grazing pressures (Praeger 1932, Goodwillie 1992). The flora of turloughs changes along the flooding gradient, so that at the bottom of the turlough more aquatic plants are found. The composition of the vegetation gradually changes from wetland species to dry habitat species towards the upper boundaries. This zonation of vegetation was first reported by Praeger (1932), who described the shift in vegetation from aquatic species to terrestrial species in three turloughs. There have since been many studies conducted on turlough vegetation; some of these will be explored in Section 2.1.4. Along the edges of the turlough, the vegetation resembles that of the surrounding non-flooded land (Goodwillie 1992), as these upper areas are subjected to least inundation. The upper margins of the turloughs are also where shrubby and woody species such as *Frangula alnus, Prunus spinosa* and *Rhamnus cathartica* can be found. In some ungrazed turloughs, *Salix* spp. can be found at lower levels than would be expected, but in general, woody species will be killed by frequent flooding.

2.1.4 Phytosociology of turlough plants

There have been a number of previous vegetation studies on turloughs. Praeger (1932) was among the first to describe the vegetation communities of turloughs, in a note on the flora of three turloughs in Counties Clare and Galway. In an account of the plant communities of the Burren (Ivimey-Cook and Proctor 1966), turloughs are described as 'dry and carpeted with a green turf closely grazed by cattle in summer, but sheets of water in winter or after a period of heavy rain'. Relevés were recorded in a number of turloughs in the area, compiled into plant communities, and these communities were then compared to those previously published in the literature. The turlough communities were found to belong to a number of different phytosociological classes, ranging from aquatic to dry woodland.

O'Connell et al. (1984) conducted a phytosociological review of wetland communities in Ireland, including turlough communities. Relevés from a number of surveys were included in this review; the data were then classified in accordance with the Braun-Blanquet tabular method. Two main turlough plant communities were described; a *Potentilla anserina*/*Agrostis stolonifera*-dominated sward and a *Carex panicea*-dominated community. The forb-dominated community was related to higher trophic status and/or higher levels of disturbance, while the sedge-dominated community generally occurred at more oligotrophic sites.

MacGowran's study of turlough vegetation and pedology (1985) was a comprehensive survey of turlough plant communities of 16 turloughs in counties Galway, Clare and Mayo. He identified the major vegetation type as the 'turlough sward', a community which can be classified in the Lolio-Potentillion anserinae and in the Caricion davallianae. He also described the vegetation of the bottom of the turlough basin, which included communities of the Phragmitetea, Potametea, Littorelletea and Bidentetea.

In a review of turlough vegetation, Goodwillie (2003) described 24 turlough vegetation communities. These communities were based on two previous surveys, one which was conducted on 61 turloughs over 10ha (Goodwillie 1992), and one carried out in the Gort area (Goodwillie et al. 1997). Each of these 24 communities can generally be assigned to one of two major phytosociological classes: the Scheuzerio-Caricetea fuscae, or the Plantaginetea majoris (Sheehy Skeffington and Gormally 2007). These communities are also summarised in Table 2.2.

Proctor (2010) compared the turlough, fen and lake communities of Ivimey-Cook and Proctor (1966) and Goodwillie (2003) with those of White and Doyle (1982) and the NVC (1991a, b, 1992, 1995, 2000). The relevant parts of this table (i.e. those concerning turloughs) are reproduced in Table 2.2.

A recent study of turlough plant communities in southeast Galway/north Clare distinguished nine plant communities (Regan et al. 2007). This survey omitted extremely wet areas and limestone pavement in order to place the relevés adjacent to pitfall traps, which were used in a survey of invertebrates. The nine communities could be broadly divided into three groups; a sedge-dominated group and a forb-dominated group, with an intermediate *Carex nigra*-dominated group in between. Species were not found to be 'faithful', often occurring in more than one group.

This broad division between grass- and forb-dominated vegetation and sedge-dominated vegetation has been reported throughout the literature (for example O'Connell et al. 1984, MacGowran 1985, Goodwillie 1992, Regan et al. 2007, Moran et al. 2008a). The sedge-dominated communities have been found to be associated with lower trophic status, later release date of inundation, longer period of inundation and shallow or absent glacial deposits. In contrast, the forb-dominated communities were recorded in areas with increased nutrient availability, deeper mineral deposits and decreased soil moisture (O'Connell et al. 1984, Regan et al. 2007, Moran et al. 2008a).

Wet grasslands are another feature of turlough vegetation. They are subjected to more anthropogenic disturbance than some of the more permanently wet vegetation types. Characteristic species include rushes, such as *Juncus articulatus* and *Juncus acutiflorus*, a small number of grass species, such as *Agrostis stolonifera,* and small sedges such as *Carex flacca, C. nigra* and *C. panicea.* A number of forb species can also be characteristic of wet grasslands, such as *Cardamine pratensis, Galium palustre, Mentha aquatica* and *Ranunculus repens* (Fossitt 2000).

Table 2.2 Comparison of the fen and turlough communities from Ivimey-Cook and Proctor (1966), and Goodwillie (2003). The communities are arranged in the order of the phytosociological higher vegetation units in White and Doyle (1982). Table adapted from Proctor (2010).

White and Doyle (1982)	Ivimey-Cook and Proctor (1966)	Goodwillie (2003)	British National Vegetation Classification equivalents
Class: Potametea. Vegetation of rooted, floating or submerged aquatic plants	*Nymphaea alba-Nuphar luteum* nodum. [Table ix* includes various other aquatics]	8a. *Oenanthe aquatica/Hippuris* 8b. *Potamogeton/Elodea*	A3, A4, A5, A8, A10, A11 (1995)
Class: Littorelletea uniflorae. Vegetation of rooted plants in oligotrophic and dystrophic still or weakly flowing fresh clear waters	*Littorella uniflora-Baldellia ranunculoides* association (Table x). *Eleocharis multicaulis-Scorpidium scorpioides* association (Table x).	6a. *Baldellia/Littorella*	[A22] (1995)
Class: Bidentetea tripartiti. Vegetation mostly of summer annuals, weakly to strongly nitrophilous, especially on wet ground or in shallow water with a fluctuating water table	Five samples from sink-holes of turloughs in Table vii and two in Table xii probably belong here.	5b. *Persicaria amphibium, P. minus, Alopecurus geniculatus* etc. 6b. *Eleocharis acicularis/Limosella*	OV29-OV31 (2000)
Class: Plantaginetea majoris. Vegetation mostly of perennial plants (rosette and creeping hemicryptophytes) in disturbed environments; typical of ecotones or 'tension zones'	*Rumex crispus-Alopecurus geniculatus* nodum (Table vii). *Carex nigra-Potentilla anserine* association (Table xxxv).	3c. Tall herb 4a. *Potentilla reptans/Viola canina* 4b. *P. reptans/Carex nigra* 4c. Dry *Carex nigra* 4d. Wet *Carex nigra*	[MG11], MG13 (1992) SD17 (2000) ?MG8 (1992)
Class: Phragmitetea; Reedswamps and allied communities –			
Order: Nasturtio-Glycerietalia. Relatively short vegetation (<1m) in the contact zone between land and still or running water in relatively stable fertile habitats.	Table xvi lists one sample from a turlough west of Gort.	5a. Floodgrass; *Glyceria fluitans, Eleocharis palustris*	S22, S23 (1995)
Order: Phragmitetalia. Vegetation of tall emergent aquatics often monodominant in stagnant or slowly flowing water	*Scirpus lacustris-Phragmites communis* nodum (Table ix).	8c. *Schoenoplectus/Phragmites*	S4, S8 (1995)
Order: Magnocaricetalia. Vegetation dominated by large sedges. Often in a zone around open water behind reed swamps of *Phragmites* etc	*Cladium mariscus-Utricularia intermedia* nodum (Table xv). *Carex elata* and *Juncus subnodulosus* stands (Table xv).	8d. Magnocaricion 8e. *Cladium mariscus*	[S1], S9, S28 S2 (1995)

* Tables referred to here are those in Ivimey-Cook and Proctor (1966). NVC communities are approximate equivalents, where communities comparable with those in the Burren have been described in Britain. Square brackets indicate incidental associations as per Proctor (2010).

Table 2.2(contd.) Comparison of the fen and turlough communities from Ivimey-Cook and Proctor (1966), and Goodwillie (2003). The communities are arranged in the order of the phytosociological higher vegetation units in White and Doyle (1982). Table adapted from Proctor (2010).

White and Doyle (1982)	**Ivimey-Cook and Proctor (1966)**	**Goodwillie (2003)**	**British National Vegetation Classification equivalents**
Class: Parvocaricetea. Vegetation of swamps and acid and calcareous fens, typically dominated by short (<50cm) *Carex* spp. or other small sedges, with water generally near the surface through most or all of the growing season	*Carex nigra-Acrocladium gigateum* association (Table xxxi). *Schoenus nigricans-Cirsium dissectum* association (Table xxxii). Burren *Carex demissa* nodum (Table xxxiv). *Potentilla anserine-Drepanocladus lycopodioides* nodum (Table xxxiv).	7a. Peaty *Carex nigra* 7b. *Schoenus/ Cirsium dissectum*	M9 M13 (1991b) [M10] (1991b)]SD17 (2000)
Class: Festuco-Brometea. Open or closed, species-rich, grazed vegetation on calcium-rich, dry, warm soils	*Antennaria dioica-Hieracium pilosella* nodum (Table xxviii). [Other dry calcareous grasslands described by Ivimey-Cook and Proctor occur on dunes or in the high Burren.]	2c. Limestone Grassland	CG9, [CG8] (1992)
Class: Molinio-Arrhenatheretea; Anthropogenic lowland meadows and pastures. Replacement communities of deciduous woodland on a variety of soils	*Potentilla fruticosa* stands (Table xxiv). *Juncus acutiflorus-Senecio aquaticus* nodum (Table xxv). Centaureo-Cynosuretum (Table xxvi).	2d. *Lolium* grassland 2e. Damp grassland 3a. Sedge heath 3b. *Carex hostiana/Molinia*	MG5-MG7 MG8-MG10 M23 M24 (1992)
Class: Rhamno-Prunetea. Vegetation of bushes and shrubs, often spiny; essentially degraded woodland or woodland-margin communities	[*Crataegus-Prunus spinosa* scrub was seen by these authors as fragmentary woodland; samples from *Potentilla fruticosa* stands (Table xxiv) include *Prunus spinosa, Rhamnus catharticus* and *Frangula alnus*.]	2a. Turlough scrub	W21, W22 (1991a)
Class: Querco-Fagetea. Stratified deciduous forests with a species-rich herbaceous layer on mineral-rich well-drained soils	*Corylus avellana-Oxalis acetosella* association (Table xxxviii).	1a. Dry woodland	W9, [W8] (1991a)
Unclassified		2b. Flooded Pavement	

* Tables referred to here are those in Ivimey-Cook and Proctor (1966). NVC communities are approximate equivalents, where communities comparable with those in the Burren have been described in Britain. Square brackets indicate incidental associations as per Proctor (2010).

2.2 Aims

This chapter has three main aims:

1. To identify, classify and describe the vegetation communities recorded in the turloughs included in the study. This will feed into the project 'Assessing the Conservation Status of Turloughs'.

2. To compare the vegetation communities defined here with those in the literature.

3. To conduct an initial exploration of the factors affecting vegetation communities, using Ellenberg and Grime's C-S-R values derived from the floristic data.

2.3 Methods

2.3.1 Site selection

Of the >300 active turloughs known in Ireland, there is hydrogeological and ecological information for about 90 (Coxon 1986, 1987b, Goodwillie 1992, Southern Water Global 1998). From this subset of 90, twenty-two turloughs were selected for study using the existing hydrological data in order to choose turloughs representative of the range of hydromorphology and geographical location. Hydrological regime was chosen as the main criterion for selection based on the hypothesis of Mitsch and Gosselink (2000), i.e. hydrology is the key factor in the establishment and maintenance of wetland ecosystems. The Karstic Flow System hypothesis of Tynan et al. (2006) associates specific ecological conditions with specific types of karst (shallow epikarst or conduit) and groundwater flow. In cases where specific information on karstic flow was unavailable, selection was based on hydrological data from Coxon (1986), Southern Water Global (1998) and David Drew (pers. comm.). The mosses *Cinclidotus fontinaloides* and *Fontinalis antipyretica* were used as a measure of duration of inundation, and the height of *Clinclidotus fontinaloides* within the basin was used as a surrogate for the depth of flooding. Where applicable, information on swallow holes, soils and groundwater tracing data was used as a secondary selection criterion. Prior to the start of the project, and before finalisation of the selection process, permission for access to turloughs was sought from landowners.

This selection process was carried out by the Project Management and Steering Committee of the overall project 'Assessing the Conservation Status of Turloughs' (Turlough Conservation Project: http://www.tcd.ie/Botany/turlough_conservation/). All of the turloughs in the study, with the exception of Brierfield, Carrowreagh and Rathnalluleagh, are currently designated as candidate Special Areas of Conservation (cSAC) under the EU Habitats Directive (EEC 1992). The study sites, their location and size are described in Table 2.3 and their geographical distribution is shown in Figure 2.1.

Table 2.3 The twenty-two turloughs included in this study, along with their ID code, location, reference to source of hydrological information used for selection, and description of karstic flow system.

Turlough	Site Code	County	Size (ha)[1]	Hydrological Data Source	Karstic Flow System	Irish National Grid
Ardkill	ARD	Mayo	23.3	Coxon (1986), Drew (pers. comm.)	N/A	127360 262500
Ballindereen	BAL	Galway	69.5	Coxon (1986)	N/A	141060 214920
Blackrock	BLA	Galway	59.3	Tynan et al. (2005)	Conduit	149780 208130
Brierfield	BRI	Roscommon	54.1	Coxon (1986), Drew (pers. comm.)	N/A	181600 276560
Caherglassaun	CAH	Galway	62.6	Tynan et al. (2005)	Conduit	141235 206225
Caranavoodaun	CARA	Galway	34.6	Southern Water Global (1998), Tynan et al. (2005)	Shallow epikarst	145314 215421
Carrowreagh	CARR	Roscommon	28.3	Coxon (1986), Drew (pers. comm.)	N/A	178420 275080
Coolcam	COO	Galway/ Roscommon	78.1	Coxon (1986), Drew (pers. comm.)	N/A	157420 271390
Croaghill	CRO	Galway	38.6	Coxon (1986), David Drew (pers. comm.)	N/A	159631 270711
Garryland	GAR	Galway	42.1	Southern Water Global (1998)	Conduit	141750 204050
Kilglassan	KIL	Mayo	51.0	Coxon (1986), Drew (pers. comm.)	N/A	127860 264550
Knockaunroe	KNO	Clare	78.8	Drew (1990)	Shallow epikarst	131317 193982
Lisduff	LIS	Roscommon	53.7	Coxon (1986), David Drew (pers. comm.)	N/A	184250 255500
Lough Aleenaun	ALE	Clare	13.7	Southern Water Global (1998), Drew (pers. comm.)	Shallow epikarst	127740 195440
Lough Coy	COY	Galway	25.3	Southern Water Global (1998), Tynan et al. (2005)	Conduit	149000 207500
Lough Gealain	GEA	Clare	35.8	Drew (pers. comm.)	Shallow epikarst	131502 194828
Rathnalulleagh	RAT	Roscommon	29.5	Coxon (1986), Drew (pers. comm.)	N/A	177710 273760
Roo	ROO	Galway/Clare	41.0	Tynan et al. (2005)	Shallow epikarst	138630 202210
Skealoghan	SKE	Mayo	32.7	Coxon (1986), Drew (pers. comm.), Moran (2000)	N/A	124737 262878
Termon	TER	Galway/Clare	42.0	Southern Water Global (1998)	Shallow epikarst	140941 197346
Tullynafrankagh	TUL	Galway	12.0[2]	Southern Water Global (1998), Tynan et al. (2005)	Shallow epikarst	143210 215340
Turloughmore	TUR	Clare	30.8	Coxon (1986)	N/A	134950 199480

1. This is the maximum flooded area recorded by Owen Naughton as part of the research for his PhD between 2006 and 2009.
2. Area of Tullynafrankagh turlough estimated from aerial photograph as this turlough was not fully topographically surveyed.

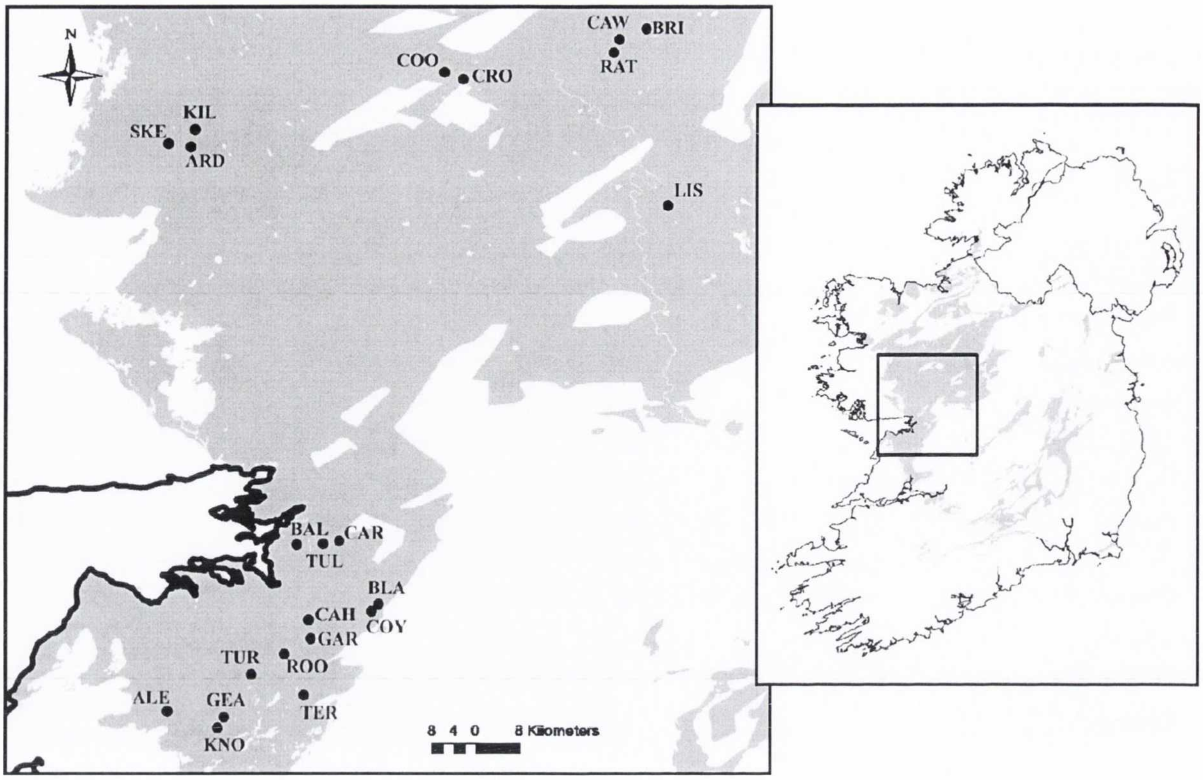


Figure 2.1 Geographical distribution of the 22 turloughs studied (abbreviations are explained in Table 2.3). Shaded areas correspond to areas of pure bedded limestone (geological data from the Geological Survey of Ireland Database: http://www.gsi.ie/Mapping.html).

2.3.2 Vegetation recording

Field work was conducted over three field seasons; 2006, 2007 and 2008. A small number of additional relevés were recorded in May of 2009.

Species area curves were used to determine optimum quadrat size. The majority of the vegetation was grassland or short herbaceous vegetation, and a species curve found 1m x 1m quadrats to be satisfactory – this quadrat size would also allow comparison with previous turlough vegetation studies which had used 1m x 1m quadrats (MacGowran 1985, Caffarra 2002, Lynn and Waldren 2003).

Aerial photographs, taken during the summer of 2001 (OSI material, accessed via NPWS), and vegetation maps (Goodwillie 1992) were consulted prior to field work, in order to have an initial understanding of the spread and position of vegetation types across the habitat.

Each turlough was walked over to determine (by eye) the range of vegetation types present. Each quadrat was placed so as to obtain a representative sample of the vegetation type. A minimum of five relevés were recorded in each vegetation type. Within each relevé, the vascular plant species present and their cover-abundance were recorded using the Domin (Table 2.4). At the beginning of field work, a 25cm x 25cm quadrat was used to mark off one quarter of the larger quadrat to aid visual estimation of cover. Vascular plant nomenclature follows Stace (2010). Total bryophyte cover-abundance was recorded, but species were not determined. Information on mean vegetation height and type of herbivores present was also recorded. The amount of grazing was estimated, and given a score of 0-3, where 0 = no grazing (all growing tips on vegetation intact, no dung evident) and 3 = very heavy grazing, all vegetation cropped close to the ground. Poaching was recorded using a similar scale, where 0 = no poaching, 3 = 75% or more of the quadrat consisting of poached soil. The location of each relevé was recorded using a hand held Garmin Etrex GPS receiver (5m accuracy).

Table 2.4 Domin scores and corresponding range of abundance used for recording relevés (after Kent and Coker 1992).

Domin score	Range of abundance
+	Single individual (small unobtrusive individual)
1	1-2 individuals (larger, more obvious individual(s) than '+'
2	<1%
3	1-4%
4	4-10%;
5	11-25%;
6	26-33%
7	34-50%
8	51-75%
9	76-90%
10	91-100%

Identification of turlough vegetation can be problematic; hydrological stresses, shortened growing seasons and sometimes intensive grazing mean that specimens are often stunted (MacGowran 1985, Goodwillie 1992). The *Carex viridula* group was identified to subspecies where flowers were present, but since this distinction could not always be made in vegetative specimens, all were assigned to *C. viridula* agg. for analysis. *Viola persicifolia* readily hybridises with *Viola canina*, producing offspring with a range of traits from either parent. Identification of non-flowering specimens was therefore very difficult, and some were recorded as *Viola* sp. All species of *Viola* were assigned to *Viola* sp. for analysis. *Euphrasia* and *Taraxacum* were identified to genus level only, as these are generally acknowledged to be very difficult groups.

The time of surveying can also affect vegetation recording; both length of time since last inundation and stage within the growing season will affect the presence/absence of certain species. This is a common issue in ecological recording. One way in which this effect can be lessened is to sample at the same time each year. When sampling in the turlough environment, however, it is often necessary to time sampling according to the hydrology of the turlough rather than the calendar.

2.3.3 Data Analysis

Over the summer periods of 2006, 2007 and 2008 688 relevés were recorded. An additional 25 relevés were recorded in May 2009. The dataset was supplemented by the inclusion of relevés from a previous study on two turloughs within the group (Feeney 2007); 100 relevés were included from this study. These relevés did not include information on bryophyte presence/absence. The analysed data set consisted of 813 relevés. To make all data points compatible, bryophyte cover/abundance information was omitted, as per the Feeney quadrats. To reduce noise within the dataset, species occurring in less than three relevés were omitted

(McCune and Grace 2002). This brought the total number of species down from 239 to 177. The data were then analysed using PC-ORD 5 (MjM Software, Oregon). The methodology followed was adapted from Perrin et al. (2006).

Hierarchical, polythetic, agglomerative cluster analysis was used to group the data into vegetation types. This procedure calculates a distance matrix by measuring the dissimilarity or similarity between each pair of samples in the data matrix. The most similar samples are grouped together, and their attributes combined. This process is repeated until only two groups remain. The results can then be displayed as a dendrogram (McCune and Grace 2002). The Quantitative Sørensen (Bray-Curtis) distance measure was selected, as this has been shown to be one of the most effective measures for ecological community analysis, and appropriate for use with ordinal (i.e. Domin scale) data (McCune and Grace 2002). The Flexible Beta linkage method was used, with parameter β set to -0.25, as this gives the best approximation of 'natural' clusters (McCune and Grace 2002).

To determine objectively the optimum level of clustering (i.e. the number of groupings which give the most information), Indicator Species Analysis (ISA) was used (Dufrêne and Legendre 1997). ISA produces percentage indicator values for species, based on the premise that an ideal indicator species will be found in all samples within a predefined group, and that this indicator species will only occur within this group. At any given level of clustering, an indicator value is assigned to each species. The significance of this assignment is tested using Monte Carlo randomisations. Dufrêne and Legendre (1997) proposed that indicator values could be used as a stopping rule for clustering, i.e. indicator values would be low when groups are either too finely or too broadly defined. ISA, however, is not appropriate for ordinal data, i.e. Domin scores (Podani 2006). In order to overcome this, the Domin 2.6 transformation (Currall 1987), which is more accurate than direct averaging, was applied to the data. ISA was run on the output from the hierarchical clustering cycles yielding 2-30 groups with 1,000 randomisations used in the Monte Carlo tests. The criteria used to determine the optimum number of clusters were number of significant indicators ($p \leq 0.05$) and the sum of significant indicator values at each stage of grouping. The optimum number of groups is arrived at by comparing the average p-value across all species (McCune and Grace 2002).

Non-metric Multidimensional Scaling (NMS) was used for ordination. Ordination techniques can be used to examine complex data sets by simplifying the factors affecting the data into a reduced number of dimensions that explain the majority of the variation. The distance between objects in the ordination space is a function of how similar they are; generally those objects which are close together are more similar than those which are far apart. This means that ordination can be a useful way in which to compare individual and groups of relevés. Environmental variables can also be overlaid on these plots to enable an examination of the relationships between relevés and environmental data. NMS is an iterative ordination technique which has been recommended over other methods of ordination for ecological community data, as it is flexible and is less prone to artefacts than other methods such as PCA and DCA (McCune and Grace 2002). Species data were relativised before conducting the NMS. The 'slow and thorough' autopilot mode, with the Quantitative Sørensen (Bray-Curtis) distance measure was used. This mode uses a random starting configuration, with a stability criterion of 0.0001 and 15 iterations to evaluate stability. 250 randomised runs were used for a Monte Carlo test to determine the probability of the final stress value being obtained by chance.

Outlier analysis was carried out in PC-ORD; outliers can greatly affect the outcome of analysis (McCune and Grace 2002). No relevés fell beyond 3 standard deviations from the grand mean; all relevés were therefore included in the analysis.

Synoptic tables were used to describe the floristic composition of the groups identified using the cluster analysis, following the style of the British National Vegetation Classification (Rodwell 1991a). Frequency and range of Domin scores (for each species in that community) are indicated in the tables. 'Frequency' is taken here to mean how often the species is found in samples within a community.

The presence or absence of a plant species can be a useful bioindicator, and can provide information on the environmental conditions in the habitat in which it is found. The presence of a plant in a certain habitat can, therefore, be used to describe the environmental conditions which prevailed over the lifetime of that plant. A number of ecologists have attempted to quantify this relationship between plant species and their environment by assigning species indicator values for various environmental variables to a plant species. The most well-known of these is Heinz Ellenberg, who has published a number of lists of indicator values for plants in central Europe (Ellenberg 1979, 1988, Ellenberg et al. 1991). These values have been adjusted to be relevant for plants in the British Isles by Hill et al. (1999).

The C-S-R model was proposed by Grime (1974, 1977, 1979) to describe the 'strategies' by which plant species and vegetation can survive in varied habitats. The basic premise is that there are two main external factors which affect vegetation; *stress*, factors which affect the growth of the plant through limiting photosynthetic ability, such as water stress, nutrient shortage, etc., and *disturbance*, which can be natural or anthropogenic in origin, such as flooding, drought, mowing, etc. In areas of low stress and high disturbance, plants which adopt a short, opportunistic life cycle, such as ruderal species, gain the advantage. Where both stress and disturbance are low, those plants which can out-compete their neighbours become most successful. The third strategy is that of stress toleration, where stress is high but disturbance is low (Grime et al. 1988).

Modular Analysis of Vegetation Information System (MAVIS) (Smart 2000) was used to objectively assign the vegetation types to the British National Vegetation Classification group to which they were most similar. Programmes such as MAVIS, however, must be used with caution. While MAVIS provides an objective comparison with existing communities, affinities suggested may not always concur with those an experienced ecologist might suggest. The presence or absence of key species may result in the community that is actually the best ecological fit getting a 'goodness-of-fit' score which is lower than some other communities which may not correspond so closely (Kirby 2001). This software was also used to calculate weighted averages of Ellenberg indicator values for each quadrat. Using averaged data in this way gives a more reliable indicator of environmental conditions than data for individual species, as there is less overlap of ecological tolerances when a number of species are considered together than the overlap of ecological tolerances of a single species (Diekmann 2003). The Ellenberg indicator values and the range of environmental conditions to which they refer are presented in Table 2.5.

Table 2.5 Ellenberg indicator values used in the analysis.

Parameter	Range	Minimum value	Maximum value
L – Light	1-9	Plant in deep shade	Plant in full light
F – Moisture (Wetness)	1-12	Extreme dryness	Submerged plant
R – Reaction (soil pH or water pH)	1-9	Extreme acidity	Extremely calcareous
N – Nitrogen (Fertility)	1-9	Extremely infertile sites	Eutrophic sites

As well as Ellenberg indicator values, MAVIS also generates C-S-R values for each quadrat. These are values based on the triangular C-S-R model which classifies vegetation based on three established plant strategies; Competitors, Stress-tolerators and Ruderal species (Grime et al. 1988). Both Ellenberg and C-S-R values were used in analyses to help elucidate differences between turlough vegetation communities.

The non-parametric Spearman's rank correlation coefficient was calculated for the ordination axes and Ellenberg and CRS values using SPSS (Release 18.0.0).

2.4 Results

2.4.1 Cluster analysis

Hierarchical, polythetic, agglomerative cluster analysis was used to arrange the species data into groups with similar vegetation. Indicator species analysis (Dufrêne and Legendre 1997) indicated that the optimum cut-off in the cluster analysis was at the eight group stage (this was the level of clustering at which the p-value was lowest and the number of significant indicators was highest). However, this resulted in groups which were deemed too large and diverse to be informative. The next-best level of clustering was at the 28-group stage (Figure 2.2). This gave clusters which made ecological sense, and so it was decided to use this as the cut-off point for the cluster analysis. To avoid confusion, the word 'cluster' will be used to refer to the eight initial clusters, while 'group' will refer to the further division of 28 communities. Figure 2.3 shows the relationship between each of the 28 vegetation communities or groups and the eight initial clusters.

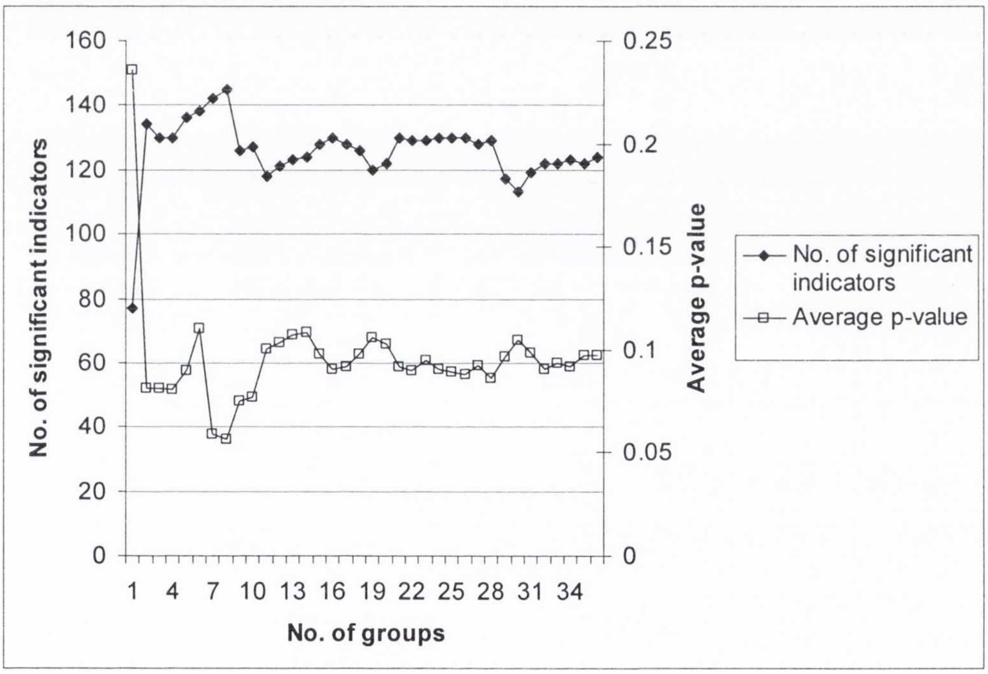


Figure 2.2 – Variation in the number of significant indicators identified by ISA and the average p-value of all species at each stage of the cluster analysis.

The dendrogram produced from the cluster analysis, which is too large to present here, can be seen in Appendix I.

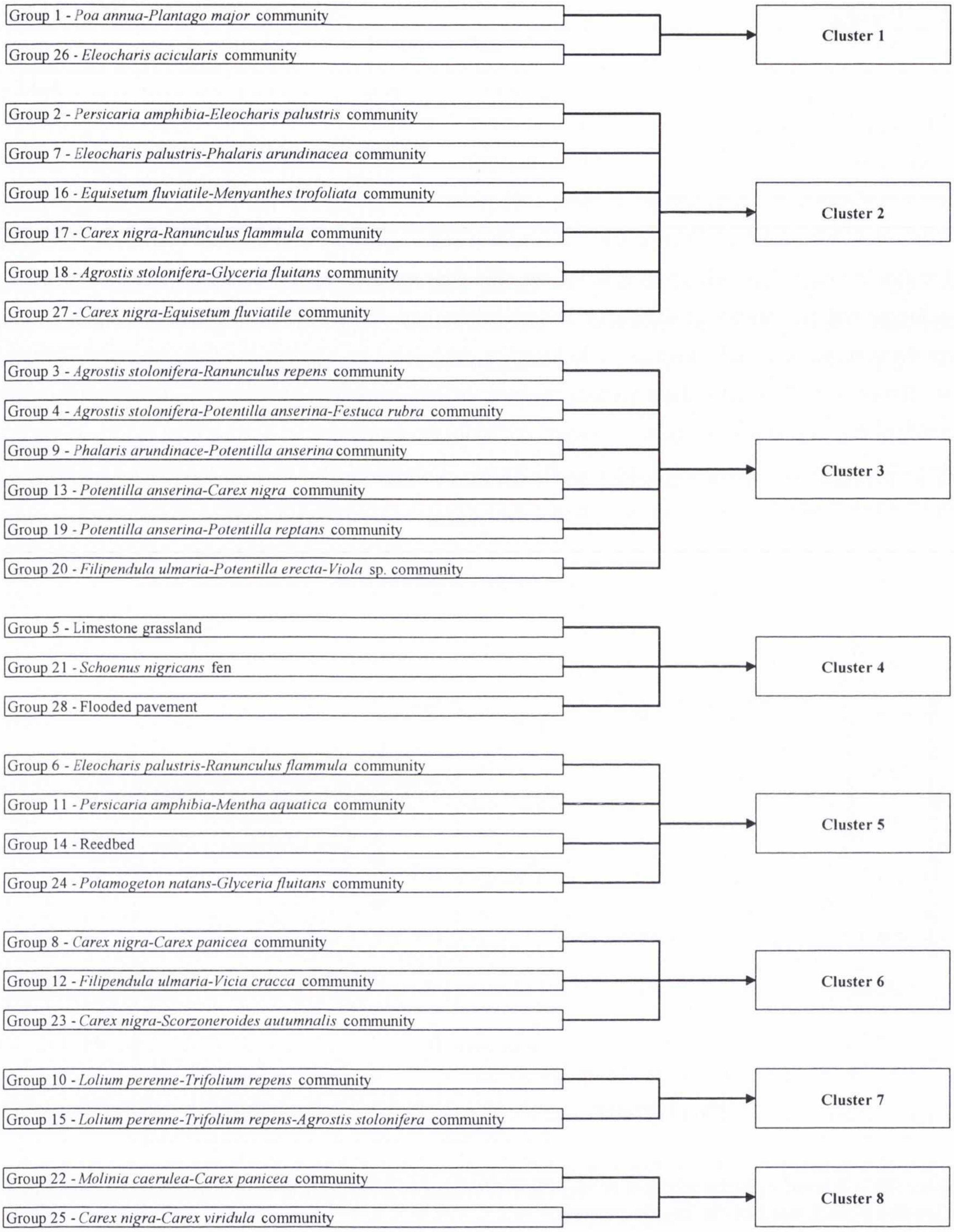


Figure 2.3 – Flowchart showing the relationships between the 28 vegetation communities identified (denoted ‘groups’) and the eight major clusters.

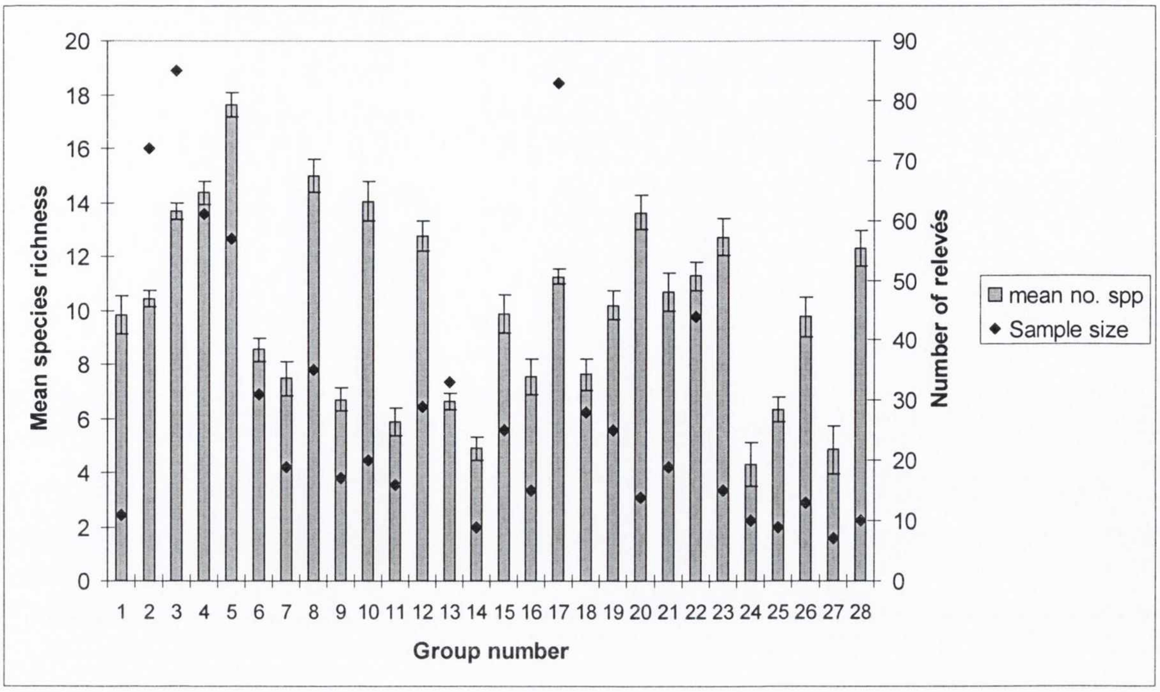


Figure 2.4 – Mean species richness (± standard error) and sample size for each of the twenty eight communities indicated by cluster analysis.

The mean number of species per relevé (a measure of species richness) was calculated for each community/group. See Figure 2.4 for a graph comparing these results between relevés. The mean number of species varied from just four for Group 24, to 18 for Group 12.

2.4.2 Non-metric Multidimensional Scaling (NMS)

NMS recommended a 3-dimensional solution with a final stress of 20.9%. Clarke's 'rule of thumb' suggests that values exceeding 20 are difficult to interpret with confidence (Clarke 1993). Stress tends to increase when large datasets are used, however, and given the size of the dataset used in this instance, the final stress is probably indicative of a good solution (McCune and Grace 2002, Perrin et al. 2006). A Monte Carlo test showed that the probability of a similar stress value being obtained by chance was low ($p=0.0040$). The final instability was very low ($p<0.00000$), indicating that the ordination was a stable solution.

With so many groups and relevés, both presentation and interpretation of an ordination can be difficult. To facilitate both, ordination diagrams showing only the eight major clusters are presented here. Refer to Figure 2.3 for a flowchart detailing which of the 28 vegetation communities described here belong to which of the eight major clusters shown in the ordination diagrams.

Ellenberg values for Light, Wetness, Fertility and pH, and C-S-R values (Grime et al. 1988) and species data were overlaid on the ordination as a joint plot. The major correlation vectors were aligned with the axes by rotating the axes; this improves ease of interpretation (McCune and Grace 2002). The species and derived variables which are displayed in the joint plot on the ordination diagrams are those which had a Pearson's correlation coefficient of greater than 0.2. This is useful for visualising the relationship between the relevés and the variables, but Spearman rank correlations are a more appropriate measure for non-parametric data. Spearman rank correlation coefficients were calculated for the derived variables and the species in SPSS Release 18.0.0 (Table 2.6).

The eight main clusters identified corresponded reasonably well to defined areas on the ordinations. Axis 1, which represented the largest proportion of variance in the data ($r^2 = 0.181$; Figure 2.5), is highly negatively correlated with Wetness ($r = -0.906$, $p \leq 0.001$); quadrats located on the left-hand side of the ordination diagram have a higher mean Ellenberg value for Wetness than those on the right-hand side. Cluster 5, represented by the open blue diamonds on the far left-hand side of the diagram, contains vegetation communities which require permanent water, such as the Reedbed community and the *Potamogeton natans-Glyceria fluitans* community. Cluster 2, represented by the green triangles, contains quadrats with a lower Wetness value; these are also water-dependent communities, such as the *Equisetum fluviatile-Menyanthes trifoliata* community. At the other end of Axis 1 are Clusters 4 and 7, examples of which are the Limestone Grassland community and the *Lolium perenne-Trifolium repens* community, respectively. These communities occur at higher levels within the turlough basin, thereby experiencing relatively little inundation. Axis 1 is also negatively correlated with two water-dependent species: *Mentha aquatica* ($r = -0.553$, $p \leq 0.001$) and *Eleocharis palustris* ($r = -0.561$, $p \leq 0.001$).

Axis 2 corresponds negatively with Ellenberg Fertility values ($r = -0.818$, $p \leq 0.001$), pH values ($r = -0.667$, $p \leq 0.001$) and positively with the Grimes 'S' or stress-tolerator values ($r = 0.536$, $p \leq 0.001$). Quadrats which occur towards the bottom of Axis 2 tend to contain species which require higher soil fertility, a higher pH, or are 'R' strategists. Cluster 1, for example, contains the *Poa annua-Plantago major* community, which is characterised by a high proportion of ruderal species. At the opposite end of Axis 2 are the clusters representing communities which occur on limestone (Cluster 4) or contain higher proportions of stress-tolerating species which occur on more eutrophic substrates, i.e. the *Carex*-dominated communities of Cluster 6.

Axis 3, which represents the smallest amount of variance at $r^2 = 0.112$, was not significantly correlated with any of the derived variables or the species.

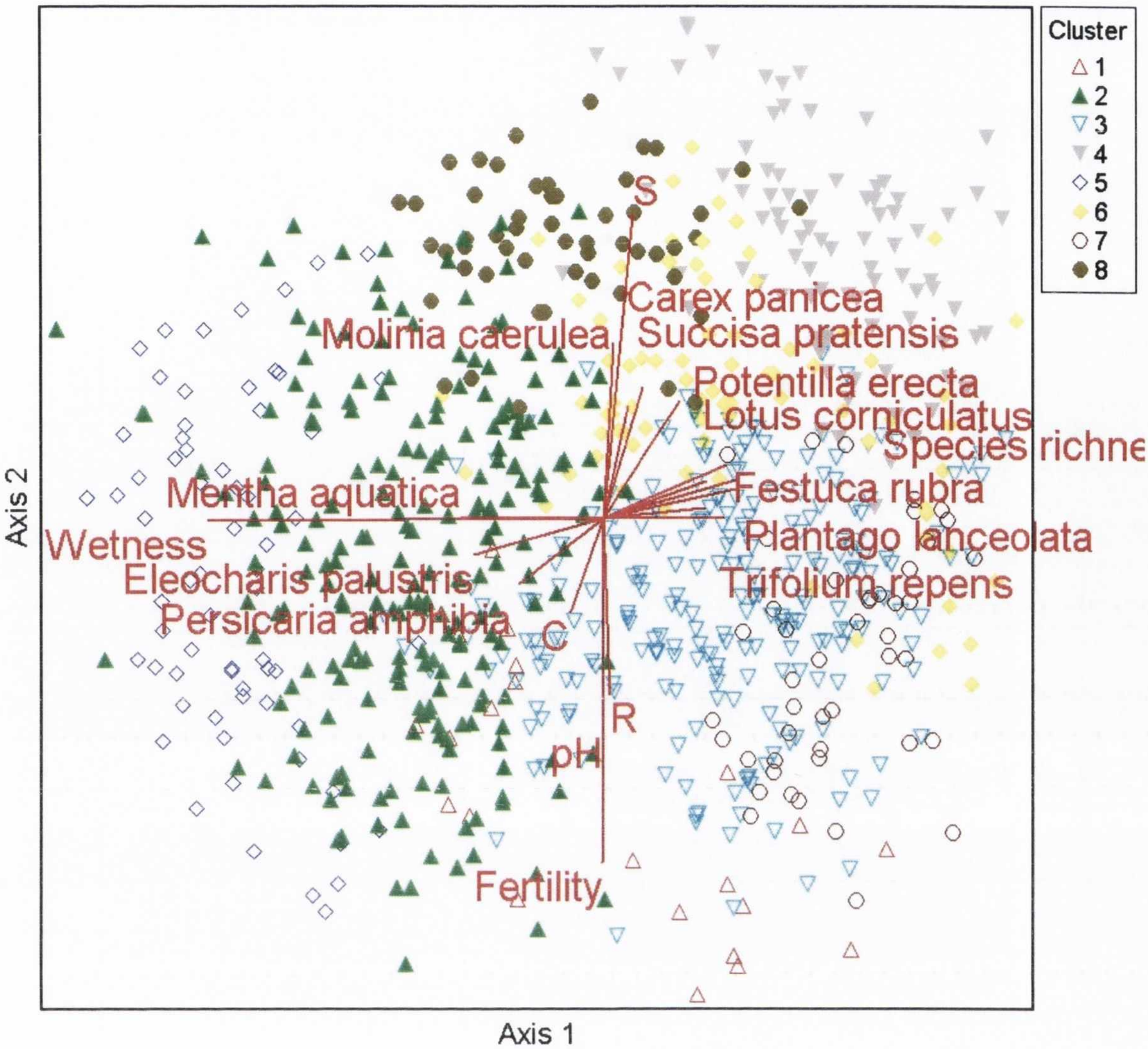


Figure 2.5. – Non-metric Multidimensional Scaling ordination of relevés, showing Axes 1 and 2 ($r^2 = 0.320$). The eight major clusters derived by cluster analysis are shown, along with a biplot of derived variables. Species that were strongly correlated ($r > 0.2$) with the axes are also plotted. r^2 values of axes: 1 = 0.181, 2 = 0.139, 3 = 0.112; total = 0.432.

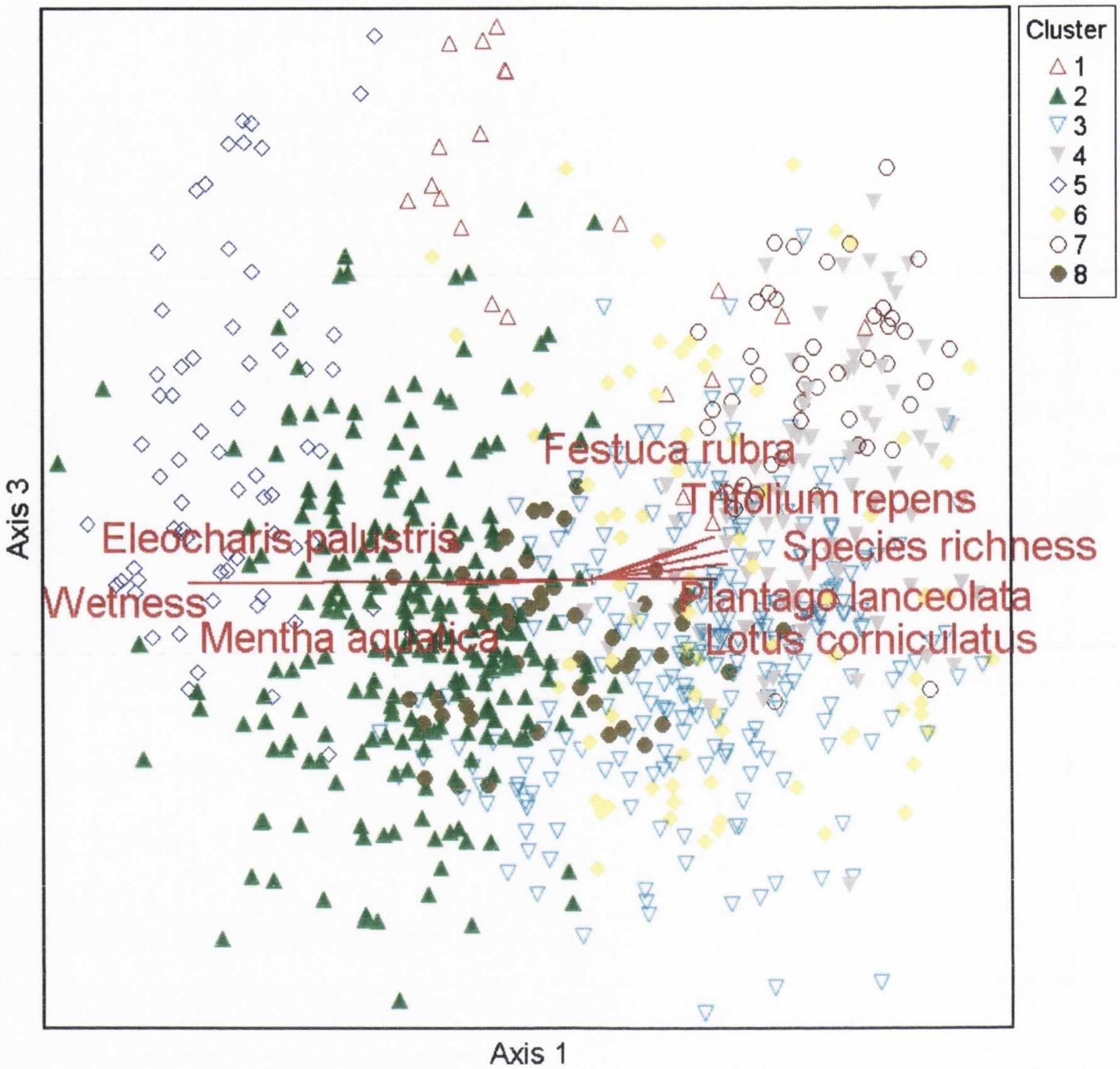


Figure 2.6. – Non-metric Multidimensional Scaling ordination of relevés, showing Axes 1 and 3 (r^2 = 0.293) The eight major clusters derived by cluster analysis are shown, along with a biplot of derived variables. Species that were strongly correlated (r > 0.2) with the axes are also plotted. r^2 values of axes: 1 = 0.181, 2 = 0.139, 3 = 0.112; total = 0.432.

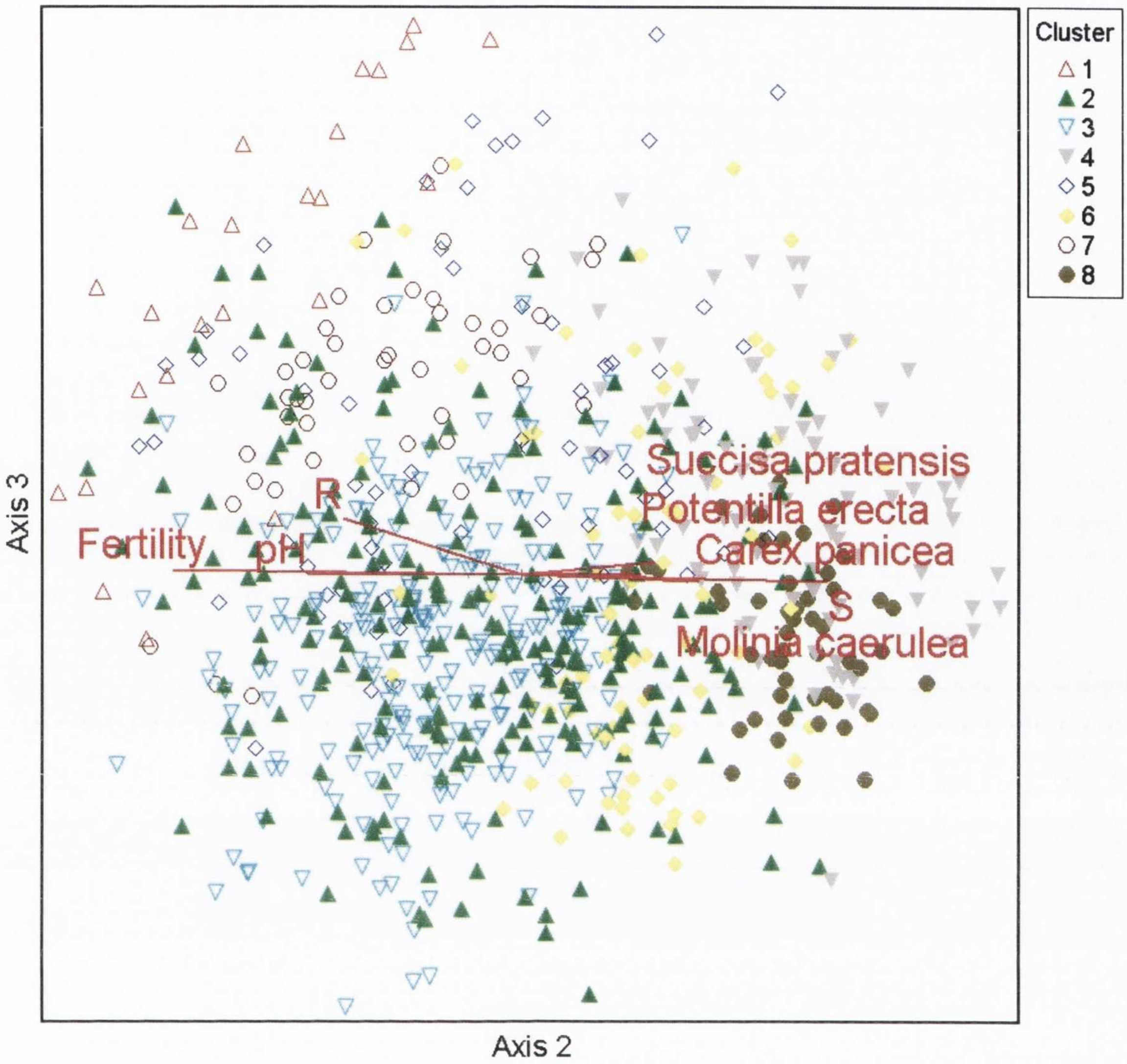


Figure 2.7 – Non-metric Multidimensional Scaling ordination of relevés, showing Axes 2 and 3 (r^2 = 0.251) The eight major clusters derived by cluster analysis are shown, along with a biplot of derived variables. Species that were strongly correlated (r > 0.2) with the axes are also plotted. r^2 values of axes: 1 = 0.181, 2 = 0.139, 3 = 0.112; total = 0.432.

Table 2.6 Spearman rank correlation coefficients between the NMS ordination axes and the variables in the second matrix (the species presented here are those which had a Pearson's correlation coefficient of >0.2 and were displayed on the ordination diagram)

Variable	Axis 1	Axis 2	Axis 3
Wetness	**-0.906***	-0.047	-0.156*
Light	-0.179*	0.226*	-0.083
Fertility	-0.065	**-0.818***	0.234
pH	-0.060	**-0.667***	0.116
C	-0.293*	-0.466*	-0.089
S	0.275*	**0.758***	-0.257*
R	0.099	**-0.536***	0.460*
Species richness	**0.529***	0.305*	0.248
Carex panicea	0.245*	**0.504***	0.004
Eleocharis palustris	**-0.561***	-0.287*	0.038
Festuca rubra	**0.500***	0.298*	0.273*
Lotus corniculatus	**0.544***	0.354*	-0.073
Mentha aquatica	**-0.553***	0.108	-0.081
Molinia caerulea	0.157*	**0.587***	-0.206*
Persicaria amphibia	-0.451*	-0.406*	-0.039
Plantago lanceolata	0.493*	0.182*	0.169*
Potentilla erecta	0.423*	0.484*	-0.059
Succisa pratensis	0.327*	**0.500***	0.088
Trifolium repens	0.532*	0.028	0.351*

* Significant correlation ($p \leq 0.05$) when corrected for multiple comparisons.
Those correlation coefficients which are both significant and greater than 0.5 are highlighted in bold.

2.4.3 Vegetation description and floristic tables

In this section, the 28 communities identified in the cluster analysis are described. Communities are presented in order of position on the flooding gradient, beginning at the top of the gradient. Because there are floristic similarities between the groups within each of the initial eight clusters, these clusters will be used to group the communities for description.

For each vegetation community or group, a short description of the species present, location on the flooding gradient (upper, middle or lower zone) and land use will be given. Where a species has an indicator value of ≥ 20%, this is also presented. Floristic tables giving species abundance and frequency information are presented for each community.

Floristic tables for each vegetation community are presented in the following section. 'Frequency' refers the percentage of relevés assigned to the community that contained a given species, and is not related to the abundance of that species in the samples. The frequency classes used in the tables are those used in the NVC, and are denoted by Roman numerals: I = 1-20% frequency, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%. Following the terminology of the NVC (Rodwell 1991a), for a given community, species which occur at frequency classes IV to V are referred to as constants. The other classes are described as: III – common/frequent, II – occasional and I – scarce. In the tables, the species are sorted according to frequency, and then alphabetically.

Agrostis stolonifera was the only species which was constant across the data set, with a frequency of 68%. *Potentilla anserina, Galium palustre, Ranunculus repens* and *Carex nigra* were common species across the whole data set.

2.4.4 Comparison with communities described in the literature

Vegetation communities were identified to class level using White's (1982) key for the identification of Irish plant communities. Where possible, the communities described in this chapter are compared with communities described by Ivimey-Cook and Proctor (1966), O'Connell et al. (1984), O'Sullivan (1982), Goodwillie (1992, 2003) and Regan et al. (2007). Goodwillie gave detailed descriptions of the vegetation communities in his earlier work on turloughs (1992), while in his more recent review of turlough vegetation (2003), he only lists the diagnostic species for each vegetation type. Furthermore, in the later work, only 24 communities were described, as opposed to 32 from the 1992 study, and some were renumbered and/or renamed. In this comparison of the plant communities with previous work, both names will be given if they differ between the works. Comparison with NVC communities was made by using the keys provided in the texts (Rodwell 1991a, b, 1992, 1995, 2000). Affinities to NVC communities were also generated by MAVIS, and these too are presented in the text. Comparisons will be made directly after the description of the community; a summary of the comparisons drawn is presented in Table 2.51.

Some plant communities are named in the literature using species names which have fallen out of use. Where these are referenced in this text, the original name will be given, with the current name (Stace 2010) given in parentheses, e.g. *Polygonum amphibium (Persicaria amphibia).*

When classifying vegetation, a number of caveats need to be considered. It can be difficult to assign a sample unit, or relevé, to an existing phytosociological classification, as individual units rarely show an exact match. In addition, Ireland's biogeographical isolation has resulted in a relatively depauperate flora, lacking many of the species used in the NVC classifications, which can make direct comparisons problematic.

2.4.5 Cluster 7

Cluster 7 consists of two grassland communities, both with frequent *Lolium perenne, Agrostis stolonifera* and *Trifolium repens*. These are communities which occur around the upper fringes of the turlough. Mean values for Ellenberg and Grime's C-S-R values for these communities are presented in Table 2.7.

Table 2.7 Mean Ellenberg and Grime's C-S-R values for the groups in Cluster 7 (± standard deviation).

Group	Light	Wetness	pH	Fertility	C	S	R
10	7.3 ± 0.1	5.5 ± 0.3	6.0 ± 0.1	5.1 ± 0.4	2.85 ± 0.12	2.25 ± 0.28	3.01 ± 0.18
15	7.3 ± 0.2	5.9 ± 0.5	6.3 ± 0.3	5.8 ± 0.3	3.02 ± 0.24	1.66 ± 0.24	2.94 ± 0.30

Group 10 – *Lolium perenne-Trifolium repens* community (Table 2.8)

Recorded in eight turloughs, number of relevés in each indicated in brackets – Ardkill (1), Brierfield (2), Carrowreagh (2), Lough Aleenaun (5), Rathnalulleagh (3), Skealoghan (1), Tullynafrankagh (1), Turloughmore (5)

Description

This was a relatively short (c. 20cm) species-rich sward, with a mean species richness of 14 (Figure 2.4). The total number of species recorded in this community was 62. *Lolium perenne* and *Trifolium repens* were present with the highest frequency, and both were relatively abundant in all relevés. Other constant species, albeit at generally lower abundance, were *Agrostis stolonifera, Bellis perennis, Cardamine pratense, Festuca rubra, Scorzoneroides autumnalis, Plantago lanceolata* and *Prunella vulgaris. Ranunculus acris, Ranunculus repens* and *Taraxacum officinale* agg. were frequent.

Bellis perennis, Lolium perenne and *Prunella vulgaris* were all indicator species, with indicator values of 51%, 37% and 25% respectively.

Location on flooding gradient

This community was located in the upper zones of the turlough basins, generally fringing the turlough, and as such it experiences the least amount of inundation. The mean Ellenberg value for wetness is 5.5 for this community (Table 2.7), which is a value associated with moist sites (Hill et al. 1999).

Land use

This vegetation type is found around the edges of the more eutrophic turloughs. The mean Ellenberg indicator value for Fertility, is 5.1 (Table 2.7), which is indicative of a site of intermediate fertility (Hill et al. 1999). Some of the species found here, such as *Lolium perenne* and *Trifolium repens* are indicative of semi-improved grassland. These areas are grazed when the flooding level permits.

Table 2.8 – Floristic table for the *Lolium perenne-Trifolium repens* community.

No. of relevés	20		
No. of species	62		
Group	10		
Lolium perenne	V (3-7)	*Cirsium vulgare*	I (3-4)
Trifolium repens	V (3-9)	*Danthonia decumbens*	I (3)
Agrostis stolonifera	IV (3-4)	*Elytrigia repens*	I (4)
Bellis perennis	IV (2-5)	*Schedonorus arundinaceus*	I (3)
Cardamine pratensis	IV (0.1-5)	*Schedonorus pratensis*	I (4)
Festuca rubra	IV (3-5)	*Filipendula ulmaria*	I (3)
Scorzoneroides autumnalis	IV (3-5)	*Galium palustre*	I (2-3)
Plantago lanceolata	IV (3-6)	*Hydrocotyle vulgaris*	I (4)
Prunella vulgaris	IV (3-5)	*Hypochoeris radicata*	I (2)
Ranunculus acris	III (3-4)	*Juncus acutiflorus*	I (3)
Ranunculus repens	III (2-6)	*Juncus articulatus*	I (4)
Taraxacum officinale agg.	III (2-4)	*Leontodon hispidus*	I (2)
Carex hirta	II (3-4)	*Lotus corniculatus*	I (2-3)
Cerastium fontanum	II (0.1-4)	*Phleum bertolonii*	I (4)
Cirsium arvense	II (0.1-5)	*Phleum pratensis*	I (3-4)
Cynosurus cristatus	II (3-4)	*Poa pratensis*	I (3)
Holcus lanatus	II (2-4)	*Poa trivialis*	I (4)
Plantago major	II (2-4)	*Potentilla anserina*	I (3)
Rumex acetosa	II (2-4)	*Potentilla erecta*	I (3)
Achillea millefolium	I (1-4)	*Potentilla reptans*	I (3-4)
Agrostis capillaris	I (4)	*Rumex crispus*	I (3-4)
Alchemilla filicaulis	I (3)	*Rumex obtusifolius*	I (3)
Carex disticha	I (3)	*Sagina procumbens*	I (2)
Carex flacca	I (3-4)	*Senecio aquaticus*	I (2)
Carex hostiana	I (2)	*Succisa pratensis*	I (3)
Carex nigra	I (2-3)	*Teucrium scordium*	I (2)
Carex panicea	I (3)	*Trifolium pratense*	I (2-4)
Cirsium dissectum	I (4)	*Urtica dioica*	I (3)
Cirsium palustre	I (3-4)	*Veronica serpyllifolia*	I (3)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 15 – *Agrostis stolonifera-Trifolium repens-Lolium perenne* community (Table 2.9)

Recorded in nine turloughs, number of relevés in each indicated in brackets – Ardkill (5), Ballindereen (1), Carrowreagh (2), Coolcam (3), Croaghill (2), Lough Aleenaun (2), Rathnalulleagh (2), Tullynafrankagh (1), Turloughmore (8)

Description

This community also consists of grassy sward, and is broadly similar to Group 10. The mean vegetation height was c. 20cm, and *Agrostis stolonifera, Trifolium repens* and *Lolium perenne* were constant, with frequent *Potentilla anserina* and *Ranunculus repens. Lolium perenne* was the only species with an indicator value of greater than 20%, at 22%.

While similar to the *Lolium perenne-Trifolium repens* community, and occurring in many of the same turloughs (section 2.4.5), this community shows more evidence of disturbance. A lower total number of species were found in this vegetation type (a mean of 10 species per relevé, compared with 14 for the *Lolium perenne-Trifolium repens* community), along with a greater number of ruderal species, such as *Matricaria discoidea* and *Capsella bursa-pastoris*. The total number of species recorded was 57. It is possible that grazing animals poached these areas when the turloughs are flooded, thereby creating the disturbance required by ruderal species to colonise the area. It is common to see paths worn by cattle around the level of winter flooding in turloughs in the summer.

Location on flooding gradient

This vegetation community is located in the upper zone of the turlough basin, and has a mean Ellenberg Wetness value of 5.9 (Table 2.7), which is indicative of a slightly wetter environment than that of the *Lolium perenne-Trifolium repens* community.

Land use

As with the previous vegetation type, this community occurs around the upper fringes of turloughs, and is grazed when the water level permits. It has a similar mean Ellenberg Fertility value as Group 10, at 5.8 (Table 2.7).

Table 2.9 – Floristic table for the *Agrostis stolonifera-Trifolium repens-Lolium perenne* community.

No. of relevés	26		
No. of species	57		
Group	15		
Agrostis stolonifera	V (3-9)	*Juncus bufonius*	I (2)
Trifolium repens	V (3-8)	*Lathyrus pratensis*	I (5)
Lolium perenne	IV (3-9)	*Scorzoneroides autumnalis*	I (2-4)
Potentilla anserina	III (2-8)	*Leontodon saxatilis*	I (3)
Ranunculus repens	III (3-6)	*Linum catharticum*	I (3)
Alopecurus geniculatus	II (3-6)	*Lotus corniculatus*	I (2)
Cardamine pratensis	II (1-4)	*Matricaria discoidea*	I (1)
Cerastium fontanum	II (2-4)	*Phalaris arundinacea*	I (3)
Cirsium arvense	II (1-5)	*Phleum bertolonii*	I (2-3)
Holcus lanatus	II (1-4)	*Phleum pratensis*	I (3-5)
Myosotis scorpioides	II (2-4)	*Plantago lanceolata*	I (3)
Rumex crispus	II (1-5)	*Plantago major*	I (1-5)
Agrostis capillaris	I (3-4)	*Poa annua*	I (4)
Bellis perennis	I (3-4)	*Poa pratensis*	I (2-4)
Capsella bursa-pastoris	I (2)	*Persicaria lapathifolia*	I (1)
Carex disticha	I (2-4)	*Potentilla reptans*	I (3)
Carex hirta	I (2-3)	*Prunella vulgaris*	I (2)
Cirsium palustre	I (1-4)	*Ranunculus acris*	I (3-4)
Cirsium vulgare	I (1-3)	*Rorippa amphibia*	I (3)
Cynosurus cristatus	I (3-4)	*Rumex acetosa*	I (1-4)
Deschampsia cespitosa	I (5)	*Rumex obtusifolius*	I (1-5)
Elytrigia repens	I (3-5)	*Sagina procumbens*	I (0.1)
Festuca rubra	I (3-4)	*Senecio aquaticus*	I (3)
Galium palustre	I (1-3)	*Stellaria media*	I (2-3)
Hydrocotyle vulgaris	I (3)	*Taraxacum officinale* agg.	II (2-3)
Iris pseudacorus	I (2)	*Urtica dioica*	I (1-4)
Juncus acutiflorus	I (2)	*Veronica serpyllifolia*	I (1)
Juncus articulatus	I (2)	*Vicia cracca*	I (2-5)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

2.4.6 Comparison with previous studies

These communities both belong to the Molinio-Arrhenatheretea, anthropogenic lowland meadows and pastures (White and Doyle 1982), and both contain *Lolium perenne, Cirsium arvense* and a little *Achillea millefolium*, which would seem to place both communities within the Cynosurion cristati alliance.

Group 10 – *Lolium perenne-Trifolium repens* community

Class: Molinio-Arrhenatheretea

This community was similar to the Lolio-Cynosuretum described by O'Sullivan (1982). Both this community and Group 15 contain the differential species *Cirsium palustre* and *Carex hirta*, which seems to place them in the cirsietosum sub-association.

This community is very similar to Goodwillie's *Lolium* grassland (1992, 2003). He describes it as occurring around the fringes of the more eutrophic turloughs, which fits with where this community was recorded in the present study. Proctor (2010) places Goodwillie's *Lolium* grassland into White and Doyle's Molinio-Arrhenatheretea (White and Doyle 1982).

Table 2.10 shows the goodness-of-fit scores for these communities with the NVC classifications, as calculated by MAVIS. MG6a and MG6, the *Lolium perenne-Cynosurus cristatus* grassland and the typical sub-community of same emerged as the strongest comparison with Group 10, with goodness-of-fit scores of 59.73% and 58.44% respectively.

Group 15 – *Lolium perenne-Trifolium repens-Agrostis stolonifera* community

Class: Molinio-Arrhenatheretea

This community was recorded in some of the same turloughs as the *Lolium perenne-Trifolium repens* community, albeit at lower elevations, and as such is subjected to a longer duration of inundation. It is very similar to Group 10, but also has some elements of Goodwillie's 2B Poor Grassland (1992) or Damp Grassland (Goodwillie 2003). There was a slightly lower number of species overall in this community when compared to Group 10. It seems to be a wetter/more disturbed variant of the *Lolium perenne-Trifolium repens* community.

The NVC communities MG11 *Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland and MG11a *Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland – *Lolium perenne* sub-community emerge as the NVC communities to which Group 15 has the strongest affinity using MAVIS (Table 2.10). Rodwell (1992) states that MG11 and MG11a are often subjected to inundation, and can grade into the Lolio-Cynosuretum (e.g. Group 10), on drier ground.

Table 2.10 Affinities with NVC communities as produced by MAVIS.

Group	NVC	Percentage	Community
10	MG6a	59.73	*Lolium perenne-Cynosurus cristatus* grassland
	MG6	58.44	*Lolium perenne-Cynosurus cristatus* grassland Typical sub-community
	MG11a	57.52	*Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland *Lolium perenne* sub-community
15	MG11	65.89	*Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland
	MG11a	65.84	*Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland – *Lolium perenne* sub-community
	SD17a	59.39	*Potentilla anserina-Carex nigra* dune slack – *Festuca rubra-Ranunculus repens* sub-community

2.4.7 Cluster 6

Cluster 6 contains communities with a mix of grasses, sedges and forbs. All communities contain constant *Filipendula ulmaria*, as well as at least some *Carex nigra, Carex flacca,* and *Carex panicea.* These communities have slightly higher mean Ellenberg Wetness values than those in Cluster 7 (Table 2.11).

Table 2.11 Mean Ellenberg and Grime's C-S-R values for the groups in Cluster 6 (± standard deviation).

Group	Light	Wetness	pH	Fertility	C	S	R
8	7.2 ± 0.2	7.3 ± 0.5	5.2 ± 0.4	3.5 ± 0.6	2.64 ± 0.35	2.95 ± 0.46	1.92 ± 0.34
12	7.1 ± 0.2	6.6 ± 0.4	5.9 ± 0.4	4.5 ± 0.4	3.15 ± 0.29	2.54 ± 0.29	2.08 ± 0.30
23	7.1 ± 0.3	6.8 ± 0.5	6.1 ± 0.3	4.6 ± 0.6	2.98 ± 0.42	2.48 ± 0.41	2.11 ± 0.36

Group 8 – *Carex nigra-Carex panicea* community (Table 2.12)

Recorded in ten turloughs, number of relevés in each indicated in brackets – Ardkill (3), Brierfield (6), Ballindereen (1), Carrowreagh (7), Croaghill (5), Coolcam(1), Knockaunroe (2), Lisduff (3), Skealoghan (5), Tullynafrankagh (1)

Description

This is a small-sedge community, with a sward height of c. 45cm. *Carex nigra, Hydrocotyle vulgaris, Carex panicea, Filipendula ulmaria, Molinia caerulea* and *Potentilla erecta* are all constant species. *Agrostis stolonifera, Galium palustre, Lotus corniculatus, Ranunculus repens* and *Trifolium repens* are frequent.

This community has a high level of species diversity; a total of 82 species were recorded, and the mean number of species per relevé was 15.

Location on flooding gradient

This vegetation community is located in the upper zone of the turlough basins. It has a mean Ellenberg Wetness value of 7.3 (Table 2.11), which suggests this community occurs on soils which remain damp but are not constantly wet (Hill et al. 1999).

Land use

This community is little grazed, as indicated by the sward height; it seems to occur on minimally managed land. The low mean Ellenberg Fertility value of 3.5 (Table 2.11) is indicative of 'more or less infertile sites' (Hill et al. 1999).

Table 2.12 – Floristic table for the *Carex nigra-Carex panicea* community.

No. of relevés	35		
No. of species	82		
Group	8		
Carex nigra	V (3-6)	*Dactylorhiza incarnata*	I (2-4)
Hydrocotyle vulgaris	V (3-5)	*Deschampsia cespitosa*	I (3-4)
Carex panicea	IV (3-5)	*Elytrigia repens*	I (2)
Filipendula ulmaria	IV (3-8)	*Equisetum fluviatile*	I (1-3)
Molinia caerulea	IV (3-8)	*Equisetum palustre*	I (3)
Potentilla erecta	IV (2-5)	*Eriophorum angustifolium*	I (3-4)
Agrostis stolonifera	III (2-7)	*Schedonorus arundinaceus*	I (3-4)
Galium palustre	III (2-4)	*Galium boreale*	I (3-4)
Lotus corniculatus	III (2-6)	*Galium verum*	I (3)
Ranunculus repens	III (2-6)	*Glyceria fluitans*	I (3)
Trifolium repens	III (3-6)	*Holcus lanatus*	I (2-3)
Cardamine pratensis	II (1-4)	*Iris pseudacorus*	I (3)
Carex flacca	II (3-5)	*Juncus articulatus*	I (3-4)
Carex hostiana	II (3-6)	*Juncus bulbosus*	I (2-4)
Festuca rubra	II (2-4)	*Juncus conglomeratus*	I (4)
Juncus acutiflorus	II (2-7)	*Juncus inflexus*	I (4)
Scorzoneroides autumnalis	II (2-4)	*Lathyrus pratensis*	I (3)
Mentha aquatica	II (2-4)	*Leontodon saxatilis*	I (2)
Potentilla anserina	II (3-7)	*Lolium perenne*	I (4)
Prunella vulgaris	II (2-4)	*Lythrum salicaria*	I (4)
Senecio aquaticus	II (3-4)	*Menyanthes trifoliata*	I (4)
Succisa pratensis	II (3-6)	*Myosotis scorpioides*	I (2)
Vicia cracca	II (2-6)	*Parnassia palustris*	I (3-4)
Achillea ptarmica	I (3)	*Persicaria amphibia*	I (2-3)
Alopecurus geniculatus	I (3)	*Phalaris arundinacea*	I (3-4)
Anagallis tenella	I (2-4)	*Plantago lanceolata*	I (3-6)
Bellis perennis	I (3)	*Plantago maritima*	I (2)
Briza media	I (3-4)	*Comarum palustre*	I (3)
Caltha palustris	I (4-5)	*Ranunculus acris*	I (2-5)
Cardamine flexuosa	I (2-3)	*Ranunculus flammula*	I (2-4)
Carex disticha	I (4)	*Rumex acetosa*	I (3-4)
Carex leporina	I (3)	*Sagina procumbens*	I (2)
Carex pulicaris	I (3-4)	*Stellaria palustris*	I (4)
Carex viridula agg.	I (2-4)	*Taraxacum officinale* agg.	I (3)
Centaurea nigra	I (4)	*Trifolium pratense*	I (3-5)
Cirsium arvense	I (2)	*Triglochin palustris*	I (2-3)
Cirsium dissectum	I (2-6)	*Valeriana officinale*	I (3-4)
Crataegus monogyna	I (1)	*Viola* species	I (1)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 12 – *Filipendula ulmaria-Vicia cracca* community (Table 2.13)

Recorded in nine turloughs, number of relevés in each indicated in brackets – Ardkill (9), Brierfield (6), Caranavoodaun (1), Carrowreagh (1), Coolcam (1), Croaghill (1), Kilglassan (1), Rathnalulleagh (6), Tullynafrankagh (2)

Description

This was an ungrazed community, easily distinguished by the height of the vegetation (mean vegetation height 70cm) and the presence of *Vicia cracca* growing up through the long grasses and other herbs. This was a relatively diverse community, with a mean species richness of 13 species.

Constant species were *Filipendula ulmaria, Vicia cracca, Agrostis stolonifera* and *Potentilla anserina*, with frequent *Lotus corniculatus, Molinia caerulea, Trifolium repens, Potentilla erecta* and *Schedonorus arundinaceus*.

Vicia cracca was an indicator species, with an indicator value of 26%.

Location on flooding gradient

This community is located in the upper zones of the turlough basins; the mean Ellenberg Wetness values is 6.6 (Table 2.11), suggesting this community occurs on soils which are slightly damp (Hill et al. 1999).

Land use

This community is usually ungrazed, as evidenced by the height of the sward. It occurs on moderately fertile sites; with a mean Ellenberg indicator value for Fertility of 4.5 (Table 2.11).

Table 2.13 – Floristic table for the *Filipendula ulmaria-Vicia cracca* community.

No. of relevés	28		
No. of species	73		
Group	12		
Filipendula ulmaria	V (4-9)	*Danthonia decumbens*	I (3-4)
Agrostis stolonifera	IV (4-5)	*Eleocharis palustris*	I (3)
Potentilla anserina	IV (3-7)	*Equisetum fluviatile*	I (3)
Vicia cracca	IV (3-7)	*Equisetum palustre*	I (3-5)
Schedonorus arundinaceus	III (4-8)	*Schedonorus pratensis*	I (4-5)
Lotus corniculatus	III (3-6)	*Fraxinus excelsior*	I (1)
Molinia caerulea	III (4-7)	*Galium boreale*	I (4-5)
Potentilla erecta	III (2-6)	*Galium verum*	I (4)
Trifolium repens	III (3-7)	*Hydrocotyle vulgaris*	I (3-5)
Carex flacca	II (3-5)	*Iris pseudacorus*	I (5-7)
Carex nigra	II (3-5)	*Juncus acutiflorus*	I (2)
Carex panicea	II (4-5)	*Juncus articulatus*	I (4)
Deschampsia cespitosa	II (4-6)	*Juncus conglomeratus*	I (6)
Elytrigia repens	II (4-5)	*Juncus effusus*	I (6-7)
Festuca rubra	II (4-6)	*Juncus inflexus*	I (5-6)
Galium palustre	II (3-6)	*Scorzoneroides autumnalis*	I (4)
Holcus lanatus	II (4-5)	*Leontodon saxatilis*	I (3)
Lathyrus pratensis	II (3-5)	*Lolium perenne*	I (4-5)
Phleum pratense	II (5)	*Mentha aquatica*	I (5)
Plantago lanceolata	II (4-7)	*Myosotis scorpioides*	I (4-5)
Ranunculus acris	II (4-5)	*Phalaris arundinacea*	I (4-7)
Valeriana officinalis	II (4-6)	*Plantago major*	I (4)
Caltha palustris	I (3)	*Poa pratensis*	I (4)
Cardamine pratensis	I (3-4)	*Potentilla reptans*	I (4-5)
Carex disticha	I (3-5)	*Prunus spinosa*	I (4-7)
Carex viridula	I (3-5)	*Rubus caesius*	I (5)
Carex hirta	I (4)	*Rubus fruticosus* agg.	I (5)
Carex hostiana	I (4)	*Rumex acetosa*	I (3-5)
Carex leporina	I (4)	*Salix aurita*	I (5)
Centaurea nigra	I (4)	*Schoenus nigricans*	I (6)
Cirsium arvense	I (4)	*Senecio aquaticus*	I (3-5)
Cirsium dissectum	I (2)	*Stellaria media*	I (3-4)
Cirsium palustre	I (3)	*Stellaria palustris*	I (3-4)
Cirsium vulgare	I (2)	*Succisa pratensis*	I (3-6)
Cynosurus cristatus	I (3)	*Taraxacum officinale* agg.	I (1-4)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 23 – *Carex nigra-Scorzoneroides autumnalis* community (Table 2.14)

Recorded in three turloughs , number of relevés in each indicated in brackets – Ballindereen (6), Kilglassan (2), Knockaunroe (7)

Description

This vegetation type was dominated by forbs and sedges. The sward was relatively tall, at 40cm, and the constant species are *Scorzoneroides autumnalis, Potentilla anserina, Carex nigra, Filipendula ulmaria, Phalaris arundinacea, Agrostis stolonifera* and *Hydrocotyle vulgaris*. *Carex flacca, Carex panicea, Galium* *palustre, Lotus corniculatus, Plantago lanceolata* and *Ranunculus repens* were all frequent in the community. There is relatively high species richness; the mean number of species per relevé is 13.

Indicator species are *Rubus fruticosus* agg. (27%) and *Teucrium scordium* (25%).

Location on flooding gradient

This community occurs in the upper middle of the flooding gradient. The mean Ellenberg value for Wetness is 6.8 (Table 2.11).

Land use

This community is lightly grazed, if at all. The mean Ellenberg value for Fertility is 4.6 (Table 2.11).

Table 2.14 – Floristic table for the *Carex nigra-Scorzoneroides autumnalis* community.

No. of relevés	15		
No. of species	47		
Group	23		
Scorzoneroides autumnalis	V (1-4)	*Cynosurus cristatus*	I (4)
Agrostis stolonifera	IV (2-6)	*Deschampsia cespitosa*	I (2-4)
Carex nigra	IV (2-5)	*Fraxinus excelsior*	I (0.1-1)
Filipendula ulmaria	IV (2-4)	*Galium boreale*	I (3)
Hydrocotyle vulgaris	IV (2-6)	*Holcus lanatus*	I (7)
Phalaris arundinacea	IV (3-8)	*Juncus acutiflorus*	I (2)
Potentilla anserina	IV (2-6)	*Juncus conglomeratus*	I (4)
Carex flacca	III (2-5)	*Knautia arvensis*	I (4)
Carex panicea	III (2-5)	*Leontodon hispidus*	I (1-3)
Galium palustre	III (1-3)	*Littorella uniflora*	I (2-4)
Lotus corniculatus	III (3-4)	*Lythrum salicaria*	I (3)
Plantago lanceolata	III (2-4)	*Molinia caerulea*	I (3-4)
Ranunculus repens	III (3)	*Ophioglossum vulgatum*	I (2)
Achillea ptarmica	II (2-3)	*Phleum bertolonii*	I (3)
Mentha aquatica	II (2-5)	*Poa annua*	I (3)
Potentilla reptans	II (2-3)	*Potentilla erecta*	I (2)
Rhamnus cathartica	II (2-7)	*Prunus spinosa*	I (2-3)
Rubus fruticosus	II (2-4)	*Rumex acetosa*	I (3)
Teucrium scordium	II (2-4)	*Samolus valerandi*	I (4)
Carex hostiana	I (3)	*Taraxacum officinale* agg.	I (3)
Cirsium palustre	I (3)	*Trifolium repens*	I (2-4)
Crataegus monogyna	I (2)	*Viola* species	I (1-2)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

2.4.8 Comparison with previous studies

The three groups in this cluster appear to belong to the Plantaginetalia majoris (White and Doyle 1982). All three of the groups also show some affinity with the SD17 *Potentilla anserina-Carex nigra* dune slack community, and associated sub-communities, of the NVC (Rodwell 2000) (Table 2.15). Dune slack communities share some characteristic species with these turlough communities, and are subjected to similar environmental conditions. Dune slacks can experience flooding in the winter, and remain wet in the summer as the water regime is linked to the water table (Ranwell 1959). They are also likely to be relatively oligotrophic, as nutrients may be leached from the sandy soils (Rodwell 2000).

Group 8 – *Carex nigra-Carex panicea* community

Class: Scheuchzerio-Caricetea fuscae

Of the communities described by Ivimey-Cook and Proctor (1966), this community corresponds most closely with the *Carex demissa* nodum of the Scheuchzerio-Caricetea fuscae. This community seems to belong to the species-rich variant of the *Carex panicea-Carex flava* agg. community described by O'Connell et al. (1984). Group 8 is most similar to Goodwillie's 5B Sedge Fen (Goodwillie 1992), but did not fall easily into any of the communities described by Regan et al. (2007).

Group 8 shows the highest affinity for SD17 *Potentilla anserina-Carex nigra* dune slack community; however, there is no *Molinia caerulea* listed in the floristic table for SD17, while it occurs as a constant in Group 8. The second-best fit, according to MAVIS, is with M23a, the *Juncus acutiflorus* sub-community of the *Juncus effusus/acutiflorus-Galium palustre* rush-meadow. On inspection of the floristic tables, however, this is not a good match; *Juncus effusus* and *Holcus lanatus* are both present at very high frequencies in M23a, but absent or present at a very low frequency in Group 8. Proctor (2010) likewise gives M23 as the NVC equivalent to Goodwillie's 3B Sedge Heath, although the four dominant species in M23 are missing from 3B Sedge Heath.

Group 12 – *Filipendula ulmaria-Vicia cracca*

Class: Molinio-Arrhenatheretea

Ivimey-Cook and Proctor (1966) describe a *Juncus acutiflorus-Senecio aquaticus* nodum of the Filipendulo-Petasition that is dominated by *Filipendula ulmaria* to which this community seems related.

This community did not seem to correspond too closely with any of those described by O'Connell et al. (1984), although there were some similarities with the Ranunculo-Potentilletum anserinae.

This community was very similar to Goodwillie's Tall Herb (1992, 2003). Some species were notably absent, however, namely *Persicaria amphibia, Lysimachia vulgaris,* and *Caltha palustris*, all of which Goodwillie describes as 'water-demanding'. *Phalaris arundinacea* was found in Group 12, though not to the extent described in the Tall Herb community.

Group 8 seemed most similar to Regan et al.'s Group 6 (2007), which they regard as a vegetation community representing a transition between sedge- and forb-dominated vegetation.

There are some similarities with the NVC community SD17 *Potentilla anserina-Carex nigra* dune slack community, as well as M27 *Filipendula ulmaria-Angelica sylvestris* mire (Table 2.15).

Group 23 – *Carex nigra-Scorzoneroides autumnalis* community

Class: Plantaginetea majoris

This community is similar to the *Carex nigra-Potentilla anserina* association described by Ivimey-Cook and Proctor (1966).

Group 23 is part of the Ranunculo-Potentilletum anserinae (O'Connell et al. 1984), and seems to belong to the *Carex nigra* variant.

This community does not seem to correspond very closely with any of those described by Goodwillie (1992). There is some affinity with 5B *Potentilla reptans* (species-poor), although relatively little *P. reptans* was recorded.

Group 23 seemed most similar to Regan et al.'s Group 7 (2007), one of their forb-dominated communities.

Of the NVC communities, this is most similar to the SD17 *Potentilla anserina-Carex nigra* dune slack community (Table 2.15).

Table 2.15 Affinities with NVC communities for Cluster 6.

Group	NVC	Percentage	Community
8	SD17	58.11	*Potentilla anserina-Carex nigra* dune slack community
	M23a	51.08	*Juncus effusus/acutiflorus-Galium palustre* rush-pasture – *Juncus acutiflorus* sub-community
	SD17b	51.07	*Potentilla anserina-Carex nigra* dune slack – *Carex flacca* sub-community
12	SD17	53.35	*Potentilla anserina-Carex nigra* dune slack
	M27	51.74	*Filipendula ulmaria-Angelica sylvestris* mire
	MG9	50.72	*Holcus lanatus-Deschampsia cespitosa* grassland
23	SD17	44.64	*Potentilla anserina-Carex nigra* dune slack
	SD17d	43.91	*Potentilla anserina-Carex nigra* dune slack – *Hydrocotyle vulgaris-Ranunculus flammula* sub-community
	SD15b	40.67	*Salix repens-Calliergon cuspidatum* dune slack – *Equisetum variegatum* sub-community

2.4.9 Cluster 4

Cluster 4 contained relevés from a seemingly diverse group of habitats; Limestone Grassland, *Schoenus nigricans* fen and Flooded Pavement. There were, however, similarities between all three in relation to the suite of species they support. All contained frequent *Succisa pratensis* and at least some *Festuca rubra, Galium verum, Lotus corniculatus, Molinia caerulea, Potentilla erecta* and *Plantago maritima.* All communities in this cluster have a relatively low mean Ellenberg value for Fertility (Table 2.16).

Table 2.16 Mean Ellenberg and Grime's C-S-R values for the groups in Cluster 4 (± standard deviation).

Group	Light	Wetness	pH	Fertility	C	S	R
5	7.3 ± 0.2	5.9 ± 0.5	5.4 ± 0.5	3.3 ± 0.6	2.21 ± 0.43	3.50 ± 0.54	2.02 ± 0.41
21	7.3 ± 0.2	7.2 ± 0.6	4.9 ± 0.7	2.3 ± 0.3	2.33 ± 0.29	3.52 ± 0.25	1.42 ± 0.20
28	7.1 ± 0.3	5.7 ± 0.6	5.5 ± 0.4	3.2 ± 0.6	1.96 ± 0.34	3.86 ± 0.35	1.42 ± 0.34

Group 5 - Limestone Grassland (Table 2.17)

Recorded in thirteen turloughs, number of relevés in each indicated in brackets – Ardkill (1), Ballindereen (5), Brierfield (1), Caranavoodaun (16), Carrowreagh (1), Coolcam (2), Knockaunroe (6), Lough Gealain (1), Rathnalulleagh (3), Roo West (8), Skealoghan (2), Tullynafrankagh (8), Turloughmore (3)

Description

This was a species-rich vegetation type, with the highest number of species per community (117), and the highest species richness (18; Figure 2.4). The sward was relatively short, at c. 15cm. Constant species were *Lotus corniculatus, Potentilla erecta, Plantago lanceolata, Festuca rubra, Carex flacca, Trifolium repens, Succisa pratensis and Carex panicea.* Frequent species were *Leontodon hispidus, Prunella vulgaris, Scorzoneroides autumnalis, Agrostis stolonifera, Molinia caerulea, Galium verum* and *Plantago maritima.*

Indicator species were *Leontodon hispidus* (43%) and *Plantago maritima* (22%).

Location on flooding gradient

The Limestone Grassland community occurs on the upper fringes of turloughs with shallow soils, which are generally underlain with limestone. This community has a mean Ellenberg Wetness value of 5.9 (Table 2.16), which is suggestive of a somewhat damp, though not constantly wet, substrate (Hill et al. 1999).

Land use

This community occurs in a range of turloughs, and is generally lightly grazed, either by livestock or by wild and feral grazers, as in the case of Knockaunroe. The low mean Ellenberg value for Fertility of 3.3 (Table 2.16) is associated with infertile sites (Hill et al. 1999).

Table 2.17 – Floristic table for the Limestone Grassland community.

No. of relevés	57		
No. of species	117		
Group	5		
Festuca rubra	V (4-8)	*Schedonorus arundinaceus*	I (3-7)
Lotus corniculatus	V (4-6)	*Schedonorus pratensis*	I (5)
Plantago lanceolata	V (1-7)	*Filipendula vulgaris*	I (4-5)
Potentilla erecta	V (3-6)	*Fraxinus excelsior*	I (1-5)
Carex flacca	IV (2-6)	*Galium boreale*	I (4)
Carex panicea	IV (3-7)	*Galium palustre*	I (3)
Succisa pratensis	IV (2-7)	*Geranium sanguineum*	I (4)
Trifolium repens	IV (2-6)	*Geum rivale*	I (5)
Agrostis stolonifera	III (3-8)	*Glechoma hederacea*	I (3)
Galium verum	III (2-6)	*Holcus lanatus*	I (2-5)
Scorzoneroides autumnalis	III (2-7)	*Hydrocotyle vulgaris*	I (1-6)
Leontodon hispidus	III (3-7)	*Hypochoeris radicata*	I (4)
Molinia caerulea	III (3-7)	*Juncus acutiflorus*	I (4)
Plantago maritima	III (4-6)	*Juncus articulatus*	I (3-4)
Prunella vulgaris	III (2-7)	*Knautia arvensis*	I (5)
Bellis perennis	II (1-5)	*Lathyrus pratensis*	I (5)
Carex hostiana	II (3-7)	*Leontodon saxatilis*	I (3-6)
Centaurea nigra	II (3-6)	*Leucanthemum vulgare*	I (2-5)
Danthonia decumbens	II (3-5)	*Linum catharticum*	I (1-5)
Filipendula ulmaria	II (2-6)	*Mentha aquatica*	I (1-3)
Lolium perenne	II (2-5)	*Odontites vernus*	I (2)
Trifolium pratense	II (1-5)	*Parnassia palustris*	I (3-4)
Viola species	II (1-5)	*Phalaris arundinacea*	I (2-5)
Achillea millefolium	I (3-6)	*Phleum bertolonii*	I (3-5)
Achillea ptarmica	I (1-5)	*Phleum pratense*	I (4)
Agrostis capillaris	I (4-6)	*Plantago major*	I (1-2)
Alchemilla filicaulis	I (5)	*Poa pratensis*	I (4-6)
Alopecurus geniculatus	I (3)	*Poa trivialis*	I (3)
Anagallis tenella	I (2)	*Potentilla anserina*	I (1-8)
Antennaria dioica	I (3-4)	*Potentilla fruticosa*	I (4)
Briza media	I (3-5)	*Potentilla reptans*	I (1-5)
Calluna vulgaris	I (5-7)	*Prunus spinosa*	I (1-4)
Campanula rotundifolia	I (3-4)	*Ranunculus acris*	I (2-5)
Cardamine pratensis	I (1-4)	*Ranunculus flammula*	I (1-4)
Carex hirta	I (4-5)	*Ranunculus repens*	I (1-4)
Carex nigra	I (3-7)	*Rhamnus cathartica*	I (2-3)
Carex pulicaris	I (4)	*Rhinanthus minor*	I (2-4)
Carex viridula agg.	I (3-6)	*Rosa spinosissima*	I (2-3)
Cerastium fontanum	I (1-4)	*Rubus fruticosus* agg.	I (5)
Cirsium arvense	I (3-6)	*Rumex acetosa*	I (3)
Cirsium dissectum	I (1-6)	*Salix repens*	I (5)
Cirsium palustre	I (5)	*Schoenus nigricans*	I (3-5)
Crataegus monogyna	I (1-4)	*Senecio aquaticus*	I (4)
Cynosurus cristatus	I (3-6)	*Stellaria media*	I (3)
Dactylorhiza incarnata	I (1-4)	*Taraxacum officinale* agg.	I (1-5)
Deschampsia cespitosa	I (4-5)	*Thymus polytrichus*	I (3-5)
Elytrigia repens	I (3)	*Veronica serpyllifolia*	I (5)
Equisetum palustre	I (4)	*Vicia cracca*	I (3-5)
Euphrasia species	I (2-5)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 21 – *Schoenus nigricans* fen (Table 2.18)

Recorded in five turloughs, number of relevés in each indicated in brackets – Ballindereen (5), Knockaunroe (2), Lough Gealain (5), Roo West (6), Tullynafrankagh (1)

Description

This vegetation type was one of the more easily distinguishable in the field, due to conspicuous tufts of *Schoenus nigricans*. The mean vegetation height was 35 cm.

The constant species were *Schoenus nigricans, Molinia caerulea, Potentilla erecta* and *Succisa pratensis*. Frequent species were *Carex flacca, Galium boreale* and *Lotus corniculatus*. Indicator species were *Schoenus nigricans* (43%), *Succisa pratensis* (26%) and *Molinia caerulea* (20%). A total of 44 species were recorded in 19 relevés, with a mean number of species per relevé of 11.

Location on flooding gradient

This community is located in the upper zone of the turlough basin. The mean Ellenberg value for Wetness (7.2, Table 2.16) suggests that this community occurs on damp, but not constantly wet, soils (Hill et al. 1999).

Land use

This community is generally grazed, or at least accessible by cattle. Many of the species are tough and unpalatable, however, and do not seem to be favoured for grazing. The very low mean Ellenberg Fertility value, 2.3 (Table 2.16), is associated with very infertile sites (Hill et al. 1999).

Table 2.18 – Floristic table for the *Schoenus nigricans* fen.

No. of relevés	19		
No. of species	44		
Group	21		
Molinia caerulea	V (5-8)	*Carex hostiana*	I (3-5)
Potentilla erecta	V (4-5)	*Dactylorhiza incarnata*	I (1)
Schoenus nigricans	V (3-8)	*Euphrasia* species	I (3)
Succisa pratensis	V (4-5)	*Filipendula ulmaria*	I (4)
Carex flacca	III (4-5)	*Galium palustre*	I (3)
Galium boreale	III (3-4)	*Geranium sanguineum*	I (3-5)
Lotus corniculatus	III (3-5)	*Hydrocotyle vulgaris*	I (4)
Agrostis stolonifera	II (3-5)	*Linum catharticum*	I (3-4)
Carex viridula agg.	II (4)	*Mentha aquatica*	I (3)
Carex nigra	II (3-4)	*Plantago lanceolata*	I (4)
Carex panicea	II (4-5)	*Plantago major*	I (5)
Cirsium dissectum	II (4-5)	*Prunella vulgaris*	I (3)
Festuca rubra	II (4-5)	*Prunus spinosa*	I (1-4)
Galium verum	II (4-5)	*Ranunculus flammula*	I (4)
Scorzoneroides autumnalis	II (3-4)	*Ranunculus repens*	I (4)
Parnassia palustris	II (3-5)	*Rhinanthus minor*	I (4)
Plantago maritima	II (3-4)	*Rubus fruticosus* agg.	I (3)
Potentilla fruticosa	II (4-7)	*Salix repens*	I (5)
Achillea ptarmica	I (3-4)	*Thymus polytrichus*	I (3-4)
Calluna vulgaris	I (5-6)	*Trifolium repens*	I (3-4)
Campanula rotundifolia	I (2)	*Viola* species	I (1-4)
Cardamine pratensis	I (3)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 28 – Flooded Pavement (Table 2.19)

Recorded in Knockaunroe, ten relevés.

Description

This community occurs on exposed limestone pavement at the fringes of Knockaunroe. *Viola canina, Potentilla fruticosa, Festuca rubra* and *Succisa pratensis* were the constant species. Other species included scrubby ones such as *Prunus spinosa* and *Rhamnus cathartica*, with occasional *Fraxinus excelsior*, as well as plants typical of the Burren region such as *Thymus polytrichus* and *Geranium sanguineum*. The clints and grikes in limestone pavement provides a variety of habitats, and this community is relatively diverse (mean no. of species per relevé is 13).

Indicator species were *Potentilla fruticosa* (59%), *Thymus polytrichus* (46%), *Prunus spinosa* (37%), *Rhamnus cathartica* (24%) and *Viola* species (20%).

This community was recorded in a number of other turloughs in Goodwillie's survey (1992). Uncertainty as to the boundary of some of the turlough basins, as well as a lack of time in the field, meant that this vegetation type was only recorded in Knockaunroe during the course of this study. In addition, the limestone pavement areas fringing turloughs often grade into scrubby vegetation and woodland, the surveying of which was beyond the scope of this project.

Location on flooding gradient

This community is located in the upper zones of the turlough basin, where open limestone pavement abuts the flood zone. The mean Ellenberg Wetness value of 5.7 (Table 2.16) is indicative of slightly damp soils (Hill et al. 1999).

Land use

This vegetation type is not intensively managed, although feral goats are probably important grazers (Dunford 2002). The low mean Ellenberg Fertility value (3.2; Table 2.16) is associated with infertile sites (Hill et al. 1999).

Table 2.19 – Floristic table for the Flooded Pavement community.

No. of relevés	10		
No. of species	42		
Group	28		
Viola species	V (3-5)	*Rhinanthus minor*	II (2-3)
Festuca rubra	IV (4-7)	*Vicia cracca*	II (2-4)
Potentilla fruticosa	IV (5-8)	*Achillea ptarmica*	I (3)
Succisa pratensis	IV (3-6)	*Carex viridula*	I (3)
Carex flacca	III (3-4)	*Carex hostiana*	I (3)
Carex nigra	III (3-5)	*Crataegus monogyna*	I (6)
Carex panicea	III (3-5)	*Danthonia decumbens*	I (3)
Galium boreale	III (3-4)	*Euphrasia species*	I (4)
Scorzoneroides autumnalis	III (2-4)	*Geranium sanguineum*	I (4)
Molinia caerulea	III (3-6)	*Glechoma hederacea*	I (2)
Prunus spinosa	III (3-6)	*Linum catharticum*	I (3)
Rhamnus cathartica	III (2-5)	*Phleum pratense*	I (5)
Thymus polytrichus	III (4)	*Plantago lanceolata*	I (4)
Agrostis stolonifera	II (2-4)	*Plantago maritima*	I (4)
Fraxinus excelsior	II (2-4)	*Potentilla erecta*	I (4)
Galium verum	II (3-4)	*Rubus caesius*	I (5)
Lotus corniculatus	II (2-4)	*Rubus fruticosus* agg.	I (2)
Prunella vulgaris	II (3-4)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

2.4.10 Comparison with previous studies

Group 5 – Limestone Grassland

Class: Molinio-Arrhenatheretea

This community seems to belong to the Cynosurion cristati, as described by O'Sullivan (1982). The presence of *Carex flacca, Lotus corniculatus* and *Centaurea nigra* place this community in the Centaureo-Cynosuretum, more specifically the galietosum sub-association.

This community is very similar to Goodwillie's (2003) 2C Limestone Grassland.

Of the NVC communities, this is most similar to CG10 *Festuca ovina-Agrostis capillaris-Thymus polytrichus* grassland (Rodwell 1992), in particular the *Carex pulicaris-Carex panicea* sub-community.

Filipendula vulgaris, a red data book species, was found within this community.

Group 21 – *Schoenus nigricans* fen

Class: Parvocaricetea (White & Doyle) Scheuchzerio-Caricetea fuscae (O'Connell, and Rodwell)

This community was similar to the *Schoenus nigricans-Cirsium dissectum* association of Ivimey-Cook and Proctor (1966). It corresponds well with O'Connell et al.'s Cirsio-Schoenetum nigricantis molinietosum, especially the Typicum and *Plantago maritima* variants (1984); however, *Pinguicula vulgaris* is included in the floristic table by O'Connell et al., but was not recorded in this study, and was not reported by Goodwillie or MacGowran in their descriptions of the community.

This community is very similar to Goodwillie's 4D *Schoenus* fen (1992)/7B *Schoenus/Cirsium dissectum* (2003). It also corresponds very well with Regan et al.'s Group 1 (2007), which also has abundant *Schoenus nigricans* and *Molinia caerulea.*

Subjectively, this community seems most similar to the NVC community M13 *Schoenus nigricans-Juncus subnodulosus* mire, and this is one of the top three NVC communities MAVIS calculated as having a good fit (Table 2.20).

Group 28 – Flooded Pavement

More a habitat than a vegetation community, this was not previously described by O'Connell et al. (1984), nor did it seem to be described in the NVC (1991a, b, 1992, 1995, 2000). In a review of the coverage of the NVC, Limestone pavement is described as a combination of various vegetation communities, rather than a community itself, i.e. the vegetation of grikes should be considered apart from the rest of the pavement, etc. (Rodwell et al. 2000). This approach was not adopted for this study; the pavement was surveyed as a whole.

Ivimey-Cook and Proctor (1966) describe *Potentilla fruticosa* stands occurring around lakes in the Burren; they go on to say that in open *P. fruticosa* scrub of this sort, the species lists are similar to fens and grasslands occurring at similar levels, and indeed, the species list for this community is similar to that of Group 5. This community was most similar to Goodwillie's 3C Flooded Pavement (1992) or 2A Turlough scrub (Goodwillie 2003).

Table 2.20 MAVIS-generated goodness-of-fit scores for the three communities in Cluster4.

Group	NVC	Percentage	Community
5	CG3	46.7	*Bromus erectus* grassland
	MG5b	46.18	*Cynosurus cristatus-Centaurea nigra* grassland
	MG5	46.09	*Cynosurus cristatus-Centaurea nigra* grassland
21	MC10c	43.68	*Festuca rubra-Plantago* spp. maritime grassland
	M25	39.94	*Molinia caerulea-Potentilla erecta* mire
	M13a	39.93	*Schoenus nigricans-Juncus subnodulosus* mire
28	MC10b	33.98	*Festuca rubra-Plantago* spp. maritime grassland
	MC10c	33.06	*Festuca rubra-Plantago* spp. maritime grassland
	H7c	32.89	*Calluna vulgaris-Scilla verna* heath

2.4.11 Cluster 1

Cluster 1 contains two groups – the *Poa annua-Plantago major* community and the *Eleocharis acicularis* community. Both of these groups are characterised by a high proportion of bare ground (median Domin scores were 3.5 and 6 respectively) and a high degree of poaching (median Domin scores were 2 and 3 respectively), as well as a high proportion of ruderal species. Both groups contain at least some *Polygonum aviculare* and *Rorippa islandica.* Although these two groups are somewhat similar floristically, they differ in their location within the turlough; the *Poa annua-Plantago major* community occurs on trampled ground and is not strictly confined to a certain place on the flooding gradient, while the *Eleocharis acicularis* community occurs on wet mud near permanent water, and is therefore located at the bottom of the flooding gradient. The difference in mean Ellenberg values for Wetness between these two communities reflects this (Table 2.21).

Table 2.21 Mean Ellenberg and Grime's C-S-R values for the groups in Cluster 1 (± standard deviation).

	Light	Wetness	pH	Fertility	C	S	R
1	7.2 ± 0.1	5.9 ± 0.6	6.3 ± 0.2	6.4 ± 0.3	2.04 ± 0.42	1.37 ± 0.22	3.93 ± 0.41
26	7.2 ± 0.2	7.3 ± 0.9	6.4 ± 0.2	5.8 ± 0.4	2.39 ± 0.66	1.31 ± 0.27	3.39 ± 0.75

Group 1 – *Poa annua-Plantago major* community (Table 2.22)

Recorded in six turloughs, number of relevés in each indicated in brackets – Ardkill (2), Blackrock (1), Carrowreagh (3), Coolcam (2), Lough Aleenaun (1), Turloughmore (2)

Description

This community was found in areas where the integrity of the soil had been damaged through poaching, allowing the large proportion of ruderal species found in this type to colonise. Constant species were *Plantago major, Polygonum aviculare, Agrostis stolonifera, Poa annua* and *Matricaria discoidea*, with frequent *Potentilla anserina, Stellaria media* and *Ranunculus repens*. The species list consists of perennials that can rapidly colonise from the surrounding grassland (e.g. *Agrostis stolonifera* and *Potentilla anserina*) and opportunistic ruderals (e.g. *Capsella bursa-pastoris*). The vegetation was generally short in stature, with an average height of c. 10cm.

Indicator species were *Matricaria discoidea* (62%), *Polygonum aviculare* (62%), *Plantago major* (36%), *Poa annua* (34%), *Stellaria media* (23%) and *Capsella bursa-pastoris* (22%).

Location on flooding gradient

This community was found on trampled ground in the upper reaches of the turlough basins; as suggested by the mean Ellenberg Wetness value of 5.9 (Table 2.21).

Land use

This community was frequently found in very poached areas, especially along paths and near to gates. The highest mean Ellenberg Fertility value (6.4) is found in this community (Table 2.21); this is approaching a value of 7 which is indicative of 'richly fertile' sites (Hill et al. 1999). Areas experiencing a high degree of poaching, such as those where this community is found, are also likely to have relatively concentrated nutrient inputs through dunging.

Table 2.22 – Floristic table for the *Poa annua-Plantago major* community.

No. of relevés	11		
No. of species	33		
Group	1		
Plantago major	V (3-6)	*Schedonorus arundinaceus*	I (4-5)
Polygonum aviculare	V (4-7)	*Gnaphalium uliginosum*	I (4)
Agrostis stolonifera	IV (4-7)	*Juncus articulatus*	I (3)
Matricaria discoidea	IV (2-6)	*Scorzoneroides autumnalis*	I (4)
Poa annua	IV (4-7)	*Lolium perenne*	I (4-5)
Potentilla anserina	III (4-8)	*Persicaria amphibia*	I (3-5)
Ranunculus repens	III (2-5)	*Phalaris arundinacea*	I (2-4)
Stellaria media	III (4-5)	*Poa pratensis*	I (4-5)
Alopecurus geniculatus	II (3-6)	*Persicaria hydropiper*	I (5)
Capsella bursa-pastoris	II (2-4)	*Potentilla reptans*	I (4)
Carex hirta	II (3-5)	*Rorippa islandica*	I (4)
Juncus bufonius	II (3-6)	*Rorippa palustris*	I (5)
Myosotis scorpioides	II (4-5)	*Rumex crispus*	I (3-4)
Persicaria maculosa	II (3-4)	*Rumex obtusifolius*	I (3-5)
Agrostis capillaris	I (5)	*Senecio aquaticus*	I (3)
Cirsium palustre	I (2)	*Trifolium repens*	I (4-5)
Cirsium vulgare	I (2)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 26 - *Eleocharis acicularis* community (Table 2.23)

Recorded in Garryland, 13 relevés.

Description

This community was recorded in only one turlough; Garryland. It corresponds very closely with the *Eleocharis acicularis* community identified by Goodwillie (Goodwillie 1992). *Eleocharis acicularis* is not a common turlough plant, and in Goodwillie's survey this vegetation community occupied just 0.2% of the surveyed land area, occurring only in turloughs around Gort and in Rahasane. It has previously been recorded in 5 of the turloughs included in this survey; Blackrock, Caherglassaun, Garryland, Lough Aleenaun and Lough Coy (Goodwillie 1992). It forms relatively small patches on drying mud near water, usually at the very base of the turlough, and as such its presence/absence during a survey is very dependent on water levels. The mean vegetation height is 5cm. Timing of survey work in different turloughs is likely to have resulted in under-sampling of this community; however, this community was subsequently located and mapped in other turloughs.

The constant species were *Eleocharis acicularis, Agrostis stolonifera, Rorippa islandica, Lythrum portula, Callitriche* sp. and *Ranunculus trichophyllus. Gnaphalium uliginosum, Mentha aquatica, Persicaria hydropiper* and *Persicaria minor* were common.

Indicator species were *Eleocharis acicularis* (100%), *Rorippa islandica* (64%), *Lythrum portula* (53%), *Persicaria minor* (46%), *Persicaria hydropiper* (38%), *Limosella aquatica* (31%), *Gnaphalium uliginosum* (27%) and *Callitriche* sp. (25%).

Location on flooding gradient

This community occurred around a permanent pool in the southern end of Garryland basin, on a muddy, silty substrate that appeared to have been recently flooded. Interestingly, while this community occurs at the base of the turlough, the mean Ellenberg Wetness value for the group is 7.3 (Table 2.21), associated with constantly moist, but not wet, soils. The Grime's R value is high, at 3.39, suggesting a large ruderal component to this community. This community, therefore, seems to consist of species which complete their life-cycle while the flooding has subsided.

Land use

Garryland turlough is located in Coole Park, and is surrounded by woodland. The turlough basin is very closely grazed by sheep and cattle. Cattle come to drink at the permanent pools when the turlough is in the dry phase, which means that the soil there can be extremely poached. The high level of disturbance from this poaching and the fluctuating water levels seems to result in a high frequency of opportunistic annuals in this community type, such as *Rorippa islandica* and *Gnaphalium uliginosum*. The mean Ellenberg Fertility value of 5.8 suggests that this is a relatively fertile site (Hill et al. 1999).

Table 2.23 – Floristic table for the *Eleocharis acicularis* community.

No. of relevés	13		
No. of species	27		
Group	26		
Agrostis stolonifera	V (3-6)	*Persicaria maculosa*	II (3-4)
Eleocharis acicularis	V (3-9)	*Polygonum aviculare*	II (4-5)
Callitriche species	IV (1-3)	*Potentilla anserina*	II (1-4)
Lythrum portula	IV (1-4)	*Rorippa amphibia*	II (1-2)
Ranunculus trichophyllus	IV (1-4)	*Bellis perennis*	I (1)
Rorippa islandica	IV (1-3)	*Juncus articulatus*	I (2)
Gnaphalium uliginosum	III (1-4)	*Persicaria amphibia*	I (3)
Mentha aquatica	III (1-4)	*Poa annua*	I (3)
Persicaria hydropiper	III (4-5)	*Ranunculus repens*	I (1)
Persicaria minor	III (3-5)	*Sparganium emersum*	I (4)
Eleocharis palustris	II (3-5)	*Trifolium repens*	I (3)
Galium palustre	II (2-3)	*Urtica dioica*	I (2)
Limosella aquatica	II (1-4)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

2.4.12 Comparison with previous studies

Group 1 – *Poa annua-Plantago major* community

Class: Polygono-Poetea annuae

The *Poa annua-Plantago major* community is also quite similar to the *Lolium perenne-Plantago major* association of the Plantaginetalia majoris described by Ivimey-Cook and Proctor (1966). *Lolium perenne*, however, is recorded as 'constant' in their community while 'scarce' here.

This community is not included in Goodwillie's most recent review of turlough vegetation (2003), although it is present as 'Dry weed' in the survey of turloughs over 10 ha (Goodwillie 1992).

The *Poa annua-Plantago major* community is most similar to Group 9 of Regan et al. (2007), although they recorded little or no *Matricaria discoidea*.

This community corresponds very well with the NVC OV21 *Poa annua-Plantago major* community as well as the *Polygonum aviculare-Ranunculus repens* sub-community and the *Lolium perenne* sub-community (Rodwell 2000) (Table 2.24).

Group 26 – *Eleocharis acicularis* community

Class: Littorelletea uniflorae

An *Eleocharis acicularis*-dominated community was recorded by Ivimey-Cook and Proctor (1966), with a similar suite of species. This community is identical to that described by Goodwillie as 9B *Eleocharis acicularis* (1992) or 6B *Eleocharis acicularis/Limosella* (2003). White and Doyle also mention an *Eleocharis acicularis* community.

Of the NVC communities, the *Eleocharis acicularis* community was most similar to OV31 *Rorippa palustris-Filaginella uliginosa* community, at 41.67% goodness-of-fit (Table 2.24). While the two communities share a large number of species, the proportions are quite different, and *Eleocharis acicularis* does not occur in OV31.

Table 2.24 Affinities with NVC communities for Cluster 1.

Group	NVC	Percentage	Community
1	OV21	63.2	*Poa annua-Plantago major* community
	OV21c	62.1	*Poa annua-Plantago major* community – *Polygonum aviculare-Ranunculus repens* sub-community
	OV21b	59.2	*Poa annua-Plantago major* community – *Lolium perenne* sub-community
26	OV31	41.67	*Rorippa palustris-Filaginella uliginosa* community
	OV28	36.17	*Agrostis stolonifera-Ranunculus repens* community
	OV28a	34.32	*Agrostis stolonifera-Ranunculus repens* community – *Polygonum hydropiper-Rorippa sylvestris* sub-community

2.4.13 Cluster 3

Cluster 3 contained mostly wet grassland communities. All contained constant *Potentilla anserina,* with all communities containing at least some *Carex nigra, Agrostis stolonifera, Filipendula ulmaria* and *Ranunculus repens.* These communities all seem to belong to the classic 'turlough sward', O'Connell et al.'s Ranunculo-Potentilletum anserinae (1984). The various derived variables show some variation between the groups (Table 2.25).

Table 2.25 Mean Ellenberg and Grime's C-S-R values for the groups in Cluster 3 (± standard deviation).

Group	Light	Wetness	pH	Fertility	C	S	R
3	7.2 ± 0.2	6.7 ± 0.6	6.1 ± 0.3	5.2 ± 0.6	3.00 ± 0.32	2.04 ± 0.36	2.57 ± 0.39
4	7.3 ± 0.2	6.2 ± 0.4	6 ± 0.3	4.7 ± 0.7	2.67 ± 0.28	2.41 ± 0.43	2.67 ± 0.36
9	7.1 ± 0.2	7.3 ± 0.6	6.7 ± 0.3	5.9 ± 0.4	3.79 ± 0.40	1.80 ± 0.32	1.83 ± 0.43
13	7.4 ± 0.3	7.4 ± 0.6	6.0 ± 0.7	4.8 ± 1.1	2.82 ± 0.34	2.38 ± 0.67	2.25 ± 0.66
19	7.3 ± 0.2	6.1 ± 0.5	6.5 ± 0.3	5.2 ± 0.4	2.83 ± 0.14	2.07 ± 0.21	2.88 ± 0.18
20	7.3 ± 0.1	6.2 ± 0.4	5.9 ± 0.3	4.0 ± 0.4	2.71 ± 0.24	2.56 ± 0.27	2.42 ± 0.40

Group 3 – *Agrostis stolonifera-Ranunculus repens* community (Table 2.26)

Recorded in 15 turloughs, number of relevés in each indicated in brackets – Ardkill (16), Brierfield (7), Caherglassaun (8), Carrowreagh (12), Coolcam (4), Garryland (5), Kilglassan (5), Lisduff (1), Lough Coy (7), Rathnalulleagh (5), Skealoghan (1), Termon (1), Tullynafrankagh (1)

Description

This was a widespread community, found in 15 of the 22 turloughs surveyed. The community was a relatively short (c. 25cm) forb-dominated sward, with a mean number of species per relevé of 14. The vegetation type was comprised of a high number of constant species; *Potentilla anserina, Agrostis* *stolonifera, Ranunculus repens, Galium palustre, Filipendula ulmaria, Carex nigra, Scorzoneroides autumnalis, Carex hirta* and *Trifolium repens*, with frequent *Phalaris arundinacea.*

Location on flooding gradient

This community is found in the upper to middle zones of the turlough basins, and the mean Ellenberg Wetness value (6.7; Table 2.25) is indicative of damp but not wet soils (Hill et al. 1999).

Land use

This vegetation type is generally moderately grazed, and the mean Ellenberg Fertility value (5.2; Table 2.25) suggests intermediate site fertility.

Table 2.26 – Floristic table for the *Agrostis stolonifera-Ranunculus repens* community.

No. of relevés	85		
No. of species	100		
Group	3		
Agrostis stolonifera	V (3-9)	*Galium boreale*	I (3-4)
Potentilla anserina	V (3-8)	*Galium verum*	I (4)
Ranunculus repens	V (3-8)	*Geum rivale*	I (4-5)
Carex hirta	IV (3-6)	*Glyceria fluitans*	I (3)
Carex nigra	IV (3-8)	*Holcus lanatus*	I (5)
Filipendula ulmaria	IV (1-7)	*Hypochoeris radicata*	I (4)
Galium palustre	IV (1-5)	*Iris pseudacorus*	I (5-7)
Scorzoneroides autumnalis	IV (1-7)	*Juncus acutiflorus*	I (4-5)
Trifolium repens	IV (1-9)	*Juncus articulatus*	I (3-5)
Phalaris arundinacea	III (2-8)	*Juncus effusus*	I (4-5)
Cardamine pratensis	II (1-5)	*Knautia arvensis*	I (5)
Hydrocotyle vulgaris	II (3-6)	*Lathyrus pratensis*	I (3)
Lotus corniculatus	II (3-7)	*Leontodon hispidus*	I (4)
Mentha aquatica	II (2-5)	*Lolium perenne*	I (4-5)
Myosotis scorpioides	II (1-5)	*Lysimachia vulgaris*	I (5)
Plantago major	II (3-7)	*Molinia caerulea*	I (4-6)
Potentilla reptans	II (3-7)	*Oenanthe aquatica*	I (1-3)
Rumex acetosa	II (3-6)	*Ophioglossum vulgatum*	I (2-5)
Rumex crispus	II (2-5)	*Persicaria amphibia*	I (2-6)
Agrostis capillaris	I (4-8)	*Persicaria maculosa*	I (4-5)
Alopecurus geniculatus	I (3-5)	*Phleum bertolonii*	I (3-5)
Apium inundatum	I (4)	*Phleum pratense*	I (4-5)
Apium nodiflorum	I (5)	*Plantago lanceolata*	I (4-7)
Bellis perennis	I (4-5)	*Poa annua*	I (3-7)
Briza media	I (3)	*Poa pratensis*	I (4)
Cardamine flexuosa	I (3)	*Persicaria hydropiper*	I (1)
Carex disticha	I (4-7)	*Potentilla erecta*	I (3-4)
Carex flacca	I (4)	*Comarum palustre*	I (5)
Carex viridula agg.	I (3-5)	*Prunella vulgaris*	I (4-6)
Carex hostiana	I (3)	*Ranunculus acris*	I (4)
Carex leporina	I (4)	*Ranunculus flammula*	I (5)
Carex panicea	I (3-6)	*Rhinanthus minor*	I (3)
Carex rostrata	I (8)	*Rorippa amphibia*	I (2)
Centaurea nigra	I (4)	*Rorippa palustris*	I (7)
Cerastium fontanum	I (1-4)	*Senecio aquaticus*	I (4-5)
Cirsium arvense	I (4)	*Stellaria media*	I (1-5)
Cirsium dissectum	I (2)	*Stellaria palustris*	I (4)
Cirsium vulgare	I (2)	*Succisa pratensis*	I (2-4)
Deschampsia cespitosa	I (3-6)	*Taraxacum officinale* agg.	I (1-5)
Eleocharis palustris	I (3-5)	*Trifolium pratense*	I (5-6)
Elytrigia repens	I (3-5)	*Valeriana officinalis*	I (3)
Equisetum fluviatile	I (3-4)	*Veronica scutellata*	I (2-4)
Equisetum palustre	I (3)	*Veronica serpyllifolia*	I (4)
Schedonorus arundinaceus	I (4-6)	*Vicia cracca*	I (3-8)
Schedonorus pratensis	I (3-5)	*Viola* species	I (4-6)
Festuca rubra	I (5-7)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 4 – *Agrostis stolonifera-Potentilla anserina-Festuca rubra* community (Table 2.27)

Recorded in 13 turloughs, number of relevés in each indicated in brackets – Ardkill (1), Ballindereen (3), Blackrock (10), Caherglassaun (10), Coolcam, Croaghill (2), Garryland (6), Kilglassan (4), Knockaunroe (4), Lough Aleenaun (4), Lough Coy (8), Rathnalulleagh (3), Skealoghan (2), Turloughmore (4)

Description

This vegetation type is widespread, and was recorded in 13 of the 22 turloughs. The community is generally moderately grazed, and the sward is quite short (c. 15cm). The constant species are *Agrostis stolonifera, Scorzoneroides autumnalis, Potentilla anserina, Ranunculus repens, Trifolium repens, Lotus corniculatus* and *Filipendula ulmaria.* Frequent species are *Galium palustre, Plantago lanceolata, Carex panicea* and *Festuca rubra.*

This is a diverse community, with 86 species recorded overall, and the mean number of species per relevé is high (14; Figure 2.4).

Location on flooding gradient

This community was generally found in the middle to upper zones of the turlough basin, and has a mean Ellenberg Wetness value of 6.2 (Table 2.25).

Land use

Grazed when the flooding allows, this community has an Ellenberg indicator value for Fertility indicating moderate fertility (4.7; Table 2.25).

Table 2.27 – Floristic table for the *Agrostis stolonifera-Potentilla anserina-Festuca rubra* community.

No. of relevés	61		
No. of species	96		
Group	4		
Agrostis stolonifera	V (2-8)	*Glechoma hederacea*	I (1)
Scorzoneroides autumnalis	V (3-7)	*Gnaphalium uliginosum*	I (4)
Filipendula ulmaria	IV (0.1-7)	*Holcus lanatus*	I (3-4)
Lotus corniculatus	IV (1-6)	*Hydrocotyle vulgaris*	I (2-5)
Potentilla anserina	IV (3-8)	*Juncus acutiflorus*	I (3)
Ranunculus repens	IV (2-7)	*Juncus articulatus*	I (2-4)
Trifolium repens	IV (2-8)	*Juncus bufonius*	I (4)
Carex panicea	III (2-8)	*Juncus conglomeratus*	I (4)
Festuca rubra	III (3-6)	*Leontodon hispidus*	I (2-4)
Galium palustre	III (2-4)	*Leontodon saxatilis*	I (2-3)
Plantago lanceolata	III (3-6)	*Lolium perenne*	I (2-5)
Cardamine pratensis	II (0.1-3)	*Mentha aquatica*	I (1-4)
Carex nigra	II (2-5)	*Molinia caerulea*	I (4-5)
Cerastium fontanum	II (1-3)	*Myosotis scorpioides*	I (3)
Elytrigia repens	II (3-5)	*Odontites vernus*	I (4)
Galium verum	II (2-6)	*Oenanthe aquatica*	I (2)
Plantago major	II (1-5)	*Persicaria maculosa*	I (1)
Potentilla erecta	II (1-5)	*Phalaris arundinacea*	I (2-4)
Rumex acetosa	II (2-6)	*Phleum bertolonii*	I (2)
Rumex crispus	II (1-4)	*Phleum pratense*	I (2-4)
Viola species	II (0.1-3)	*Plantago maritima*	I (3)
Achillea millefolium	I (3)	*Plantago media*	I (4-5)
Achillea ptarmica	I (0.1-3)	*Poa annua*	I (3-5)
Agrostis capillaris	I (3-4)	*Poa pratensis*	I (3-4)
Alchemilla filicaulis	I (3)	*Poa trivialis*	I (2-5)
Alopecurus geniculatus	I (2-3)	*Potentilla fruticosa*	I (5)
Apium inundatum	I (4)	*Potentilla reptans*	I (1-4)
Bellis perennis	I (4)	*Prunella vulgaris*	I (0.1-4)
Capsella bursa-pastoris	I (2)	*Prunus spinosa*	I (4)
Carex disticha	I (3-4)	*Ranunculus acris*	I (3-4)
Carex flacca	I (3-7)	*Ranunculus flammula*	I (1-4)
Carex hirta	I (1-4)	*Rhinanthus minor*	I (2)
Carex hostiana	I (2-5)	*Rumex obtusifolius*	I (2-5)
Carex viridula agg.	I (2-4)	*Sagina nodosa*	I (2-3)
Cirsium arvense	I (1)	*Salix aurita*	I (2)
Cirsium dissectum	I (2-3)	*Senecio aquaticus*	I (3-4)
Cynosurus cristatus	I (3-4)	*Stellaria media*	I (1-4)
Deschampsia cespitosa	I (4-7)	*Succisa pratensis*	I (1-3)
Eleocharis palustris	I (4)	*Taraxacum officinale* agg.	I (0.1 4)
Euphrasia sp	I (2-3)	*Teucrium scordium*	I (3-4)
Schedonorus arundinaceus	I (3-6)	*Trifolium pratense*	I (3)
Schedonorus pratensis	I (3-4)	*Veronica serpyllifolia*	I (2-3)
Galium boreale	I (1-4)	*Vicia cracca*	I (3)
Geum rivale	I (1-4)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 9 – *Phalaris arundinacea-Potentilla anserina* community (Table 2.28)

Recorded in five turloughs, number of relevés in each indicated in brackets – Ardkill (10), Brierfield (3), Rathnalulleagh (2), Skealoghan (1), Tullynafrankagh (1)

Description

This vegetation type was generally tall, with a mean height of 85cm. *Phalaris arundinacea* and *Potentilla anserina* were the constant species in this vegetation community, with frequent *Filipendula ulmaria, Vicia cracca, Ranunculus repens* and *Carex hirta*. This seems to be a *P. arundinacea*-dominated variant of the tall herb community. *Phalaris arundinacea* was an indicator species for this vegetation community (20%).

Location on flooding gradient

This vegetation type is located in the middle of the flooding gradient; the Ellenberg Wetness value for this group of 7.3 (see Table 2.25) indicates this community occurs on damp sites (Hill et al. 1999).

Land use

As evidenced by the tall height of the vegetation, this community occurs in ungrazed turloughs, or in ungrazed portions of turloughs. The mean Fertility value is approaching 6 (Table 2.25) indicating this community may occur on sites with relatively high fertility.

Table 2.28 – Floristic table for the *Phalaris arundinacea-Potentilla anserina* community.

No. of relevés	17		
No. of species	29		
Group	9		
Phalaris arundinacea	V (4-9)	*Carex nigra*	I (5)
Potentilla anserina	V (2-9)	*Eleocharis palustris*	I (8)
Carex hirta	III (3-7)	*Equisetum fluviatile*	I (5)
Filipendula ulmaria	III (3-7)	*Galium palustre*	I (2-3)
Ranunculus repens	III (4-5)	*Hypochoeris radicata*	I (1)
Vicia cracca	III (3-9)	*Iris pseudacorus*	I (5)
Elytrigia repens	II (3-7)	*Lathyrus pratensis*	I (4-5)
Hydrocotyle vulgaris	II (4-5)	*Lysimachia vulgaris*	I (3-5)
Persicaria amphibia	II (2-6)	*Lythrum salicaria*	I (6)
Rubus caesius	II (5-8)	*Rorippa amphibia*	I (3)
Agrostis stolonifera	I (3-5)	*Rubus fruticosus* agg.	I (6)
Cardamine flexuosa	I (1)	*Stellaria media*	I (3-5)
Carex disticha	I (4)	*Urtica dioica*	I (3-6)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 13 – *Potentilla anserina-Carex nigra* community (Table 2.29)

Recorded in eleven turloughs, number of relevés in each indicated in brackets – Ardkill (3), Blackrock (2), Brierfield (2), Caherglassaun (1), Carrowreagh (2), Coolcam (1), Croaghill (2), Garryland (8), Lisduff (2), Lough Coy (7), Turloughmore (3)

Description

This community occurs in a number of turloughs, it was found in half of the 22 turloughs surveyed. The sward is short (c. 20cm) and relatively homogeneous; from the 33 relevés made, 36 species were recorded. The mean species richness is among the lowest found in this study, at 7 (Figure 2.4). *Potentilla anserina, Agrostis stolonifera* and *Carex nigra* are constants, with frequent *Persicaria amphibia.*

Location on flooding gradient

This community is found in the middle of the flooding gradient, with a mean Ellenberg Wetness indicator value of 7.4 (Table 2.25), which suggests this community occurs on damp soil (Hill et al. 1999).

Land use

This vegetation type is moderately to heavily grazed. The Ellenberg Fertility score is approaching 5 (Table 2.25), which indicates this community occurs in areas with intermediate fertility (Hill et al. 1999).

Table 2.29 – Floristic table for the *Potentilla anserina-Carex nigra* community.

No. of relevés	33		
No. of species	36		
Group	13		
Potentilla anserina	V (5-9)	*Glyceria fluitans*	I (3-4)
Agrostis stolonifera	IV (3-7)	*Hydrocotyle vulgaris*	I (3-6)
Carex nigra	IV (5-9)	*Juncus acutiflorus*	I (3)
Persicaria amphibia	III (2-7)	*Juncus bulbosus*	I (4)
Carex hirta	II (4-6)	*Scorzoneroides autumnalis*	I (4)
Eleocharis palustris	II (3-7)	*Matricaria discoidea*	I (2)
Galium palustre	II (3-5)	*Molinia caerulea*	I (4)
Mentha aquatica	II (3-4)	*Myosotis scorpioides*	I (2-4)
Phalaris arundinacea	II (4-7)	*Oenanthe aquatica*	I (4)
Ranunculus repens	II (1-5)	*Persicaria maculosa*	I (4)
Stellaria media	II (3-5)	*Polygonum aviculare*	I (4-5)
Cardamine pratensis	I (3-4)	*Potentilla reptans*	I (4-6)
Carex hostiana	I (3-7)	*Prunella vulgaris*	I (1)
Carex panicea	I (3-5)	*Rumex crispus*	I (3-4)
Cerastium fontanum	I (2)	*Rumex obtusifolius*	I (4-5)
Elytrigia repens	I (4-6)	*Taraxacum officinale* agg.	I (2-4)
Equisetum fluviatile	I (3-5)	*Trifolium repens*	I (4)
Filipendula ulmaria	I (3-6)	*Viola* species	I (1)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 19 – *Potentilla anserina-Potentilla reptans* community (Table 2.30)

Recorded in two turloughs, number of relevés in each indicated in brackets – Blackrock (21), Garryland (4)

Description

This was a herb-dominated community, with a mean sward height of c. 10cm and with constant and abundant *Potentilla reptans*, usually occurring near the bottom of the turlough basin. Alongside *P. reptans*, *Agrostis stolonifera, Potentilla anserina* and *Ranunculus repens* were constant species. *Carex nigra, Rumex crispus, Trifolium repens, Cerastium fontanum, Lotus corniculatus, Galium palustre* and *Scorzoneroides autumnalis* were all frequent in this vegetation type.

The indicator species for this cluster was *Potentilla reptans* (37%).

Location on flooding gradient

This community is generally located in the middle to the bottom of the flooding gradient. The mean Ellenberg value for Wetness (6.1, Table 2.25) is indicative of a damp site (Hill et al. 1999).

Land use

This community is generally grazed. The Ellenberg value for Fertility (5.2, Table 2.25) suggests that this community occurs on sites of intermediate fertility (Hill et al. 1999).

Table 2.30 – Floristic table for the *Potentilla anserina-Potentilla reptans* community.

No. of relevés	25		
No. of species	41		
Group	19		
Agrostis stolonifera	V (3-8)	*Cirsium arvense*	I (2)
Potentilla anserina	V (4-10)	*Cirsium dissectum*	I (2-3)
Potentilla reptans	V (3-10)	*Elytrigia repens*	I (4)
Ranunculus repens	IV (2-5)	*Schedonorus arundinaceus*	I (4)
Carex nigra	III (2-4)	*Festuca rubra*	I (4)
Cerastium fontanum	III (2-4)	*Galium boreale*	I (1-5)
Galium palustre	III (2-4)	*Galium verum*	I (4)
Scorzoneroides autumnalis	III (0.1-3)	*Geum rivale*	I (3)
Lotus corniculatus	III (3-7)	*Gnaphalium uliginosum*	I (2)
Rumex crispus	III (2-5)	*Leontodon saxatilis*	I (3)
Trifolium repens	III (2-5)	*Mentha aquatica*	I (0.1-4)
Filipendula ulmaria	II (2-5)	*Phalaris arundinacea*	I (2-4)
Plantago lanceolata	II (3-5)	*Poa annua*	I (3-5)
Plantago major	II (3-4)	*Polygonum aviculare*	I (3)
Rumex acetosa	II (3-4)	*Prunella vulgaris*	I (2-3)
Viola species	II (2-8)	*Rorippa palustris*	I (4)
Cardamine pratensis	I (3)	*Rumex obtusifolius*	I (3)
Carex flacca	I (3-4)	*Stellaria media*	I (2)
Carex hirta	I (2-4)	*Succisa pratensis*	I (2)
Carex panicea	I (3-4)	*Trifolium pratense*	I (4)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 20 – *Filipendula ulmaria-Potentilla erecta-Viola* community (Table 2.31)

Recorded in Blackrock, 14 relevés.

Description

This was a herb-rich community, recorded in Blackrock turlough, in which *Viola* sp., *Filipendula ulmaria, Potentilla anserina, Lotus corniculatus* and *Potentilla erecta* were constant. *Carex nigra, Galium palustre, Rumex acetosa* and *Plantago media* were all frequent.

Indicator species were *Plantago media* (61%), *Sagina nodosa* (54%), *Viola* species (45%) and *Rumex acetosa* (22%).

Location on flooding gradient

This community occurs in the middle of the flooding gradient, and has an Ellenberg Wetness score of 6.2 (Table 2.25), indicating that this is a damp area.

Land use

This community is well grazed. The mean Ellenberg Fertility value of 4 (Table 2.25) suggests that this community occurs on sites with slightly less than moderate fertility (Hill et al. 1999).

Table 2.31 – Floristic table for the *Filipendula ulmaria-Potentilla erecta-Viola* community.

No. of relevés	14		
No. of species	30		
Group	20		
Filipendula ulmaria	V (4-7)	*Ranunculus repens*	III (3-4)
Lotus corniculatus	V (4-6)	*Sagina nodosa*	III (0.1-4)
Potentilla anserina	V (4-7)	*Carex panicea*	II (3-4)
Potentilla erecta	V (3-7)	*Cerastium fontanum*	II (0.1-4)
Viola species	V (4-5)	*Juncus bufonius*	II (3)
Carex nigra	IV (4-7)	*Plantago lanceolata*	II (3-4)
Galium palustre	IV (3-5)	*Cardamine pratensis*	I (3)
Plantago media	IV (3-5)	*Festuca rubra*	I (2)
Rumex acetosa	IV (3-4)	*Mentha aquatica*	I (4)
Agrostis stolonifera	III (2-5)	*Ophioglossum vulgatum*	I (2-3)
Galium boreale	III (3-4)	*Plantago major*	I (3-4)
Galium verum	III (4)	*Rhamnus cathartica*	I (0.1)
Scorzoneroides autumnalis	III (3-4)	*Rorippa palustris*	I (2)
Poa annua	III (3-5)	*Rumex crispus*	I (4)
Potentilla reptans	III (4-7)	*Trifolium repens*	I (4)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

2.4.14 Comparison with previous studies

All of the groups in this cluster belong to the class Plantaginetea majoris, more specifically to the *Ranunculo-*Potentilletum anserinae association. Each of the groups in this cluster show at least some affinity with the NVC SD17 *Potentilla anserina-Carex nigra* dune slack community, apart from Group 9.

Group 3 – *Agrostis stolonifera-Ranunculus repens* community

Class: Plantaginetea majoris

This community is very similar to the *Carex nigra-Potentilla anserina* association of Ivimey-Cook and Proctor (1966). It belongs to the typical variant of O'Connell et al.'s Ranunculo-Potentilletum anserinae (1984).

This community corresponds well with Goodwillie's 6A Dry *Carex nigra* (1992) or 4C Dry *Carex nigra* (2003). It was most similar to Regan et al.'s Group 7, a forb-dominated community.

The highest goodness-of-fit score given by MAVIS for this community was for the SD17 *Potentilla anserina-Carex nigra* dune slack community (Table 2.32).

Group 4 – *Agrostis stolonifera-Potentilla anserina-Festuca rubra* community

Class: Plantaginetea majoris

This community was similar to the *Potentilla anserina-Drepanocladus lycopodioides* nodum of Ivimey-Cook and Proctor (1966), with the caveat that moss species were not identified. There are also similarities with O'Connell et al.'s *Drepanocladus lycopodioides* variant of the Ranunculo-Potentilletum anserinae (1984), but again, since mosses were not identified during this survey, the characteristic species *Drepanocladus lycopodioides* was not recorded.

This community does not correspond very well with any single Goodwillie community. There are similarities with Goodwillie's 2B Poor Grassland (1992) or 2E Damp Grassland (2003), and also with 3B Sedge heath (Goodwillie 1992).

The *Agrostis stolonifera-Potentilla anserina-Festuca rubra* community seems to be most similar to Regan et al.'s Group 7, although no *Festuca rubra* was recorded in any of their communities. There are also similarities with Group 8.

This community was most similar to the NVC SD17a *Potentilla anserina-Carex nigra* dune slack community, *Festuca rubra-Ranunculus repens* sub-community.

Group 9 – *Phalaris arundinacea-Potentilla anserina* community

Class: Plantaginetea majoris

There are some similarities to the *Potentilla anserina-Drepanocladus lycopodioides* nodum of the Caricion davallianae as described by Ivimey-Cook and Proctor.

There are similarities to the Ranunculo-Potentilletum anserinae, although *Phalaris arundinacea* is never present at the high frequency found in this community in any of the sub-communities described by O'Connell et al. (1984).

Group 9 did not correspond well with any of the communities described by Regan et al. (2007); in none of their communities was *Phalaris arundinacea* recorded at a greater frequency than 40%, and the average percentage cover was just 1% in these communities.

This vegetation type, as well as Group 20, had similarities with Goodwillie's 3A Tall Herb (Goodwillie 1992). Group 9, however, had more of the 'water-demanding' species described by Goodwillie, such as *Phalaris arundinacea*, *Persicaria amphibia* and *Lysimachia vulgaris*, suggesting that this was perhaps a wetter variant of Group 20. The two communities were, in fact, recorded in many of the same turloughs, and the mean Ellenberg Wetness score for Group 20 was 6.2, while it was 7.3 for Group 9. This may suggest that Group 9 experiences a wetter environment than Group 20.

There are some similarities with the NVC S28 *Phalaris arundinacea* tall-herb fen (Rodwell 1995) (Table 2.32), but also with M27 *Filipendula ulmaria-Angelica sylvestris* mire.

Group 13 – *Potentilla anserina-Carex nigra* community

Class: Plantaginetea majoris

Ivimey-Cook and Proctor's *Carex nigra-Potentilla anserina* association (Ivimey-Cook and Proctor 1966) is very similar to this community. This is another community that belongs to the Ranunculo-Potentilletum anserinae, and is most similar to the *Polygonum amphibium (Persicaria amphibia)* variant (O'Connell et al. 1984), although *Persicaria amphibia* does not achieve the dominance reported by O'Connell et al.

This vegetation type corresponds reasonably well with Goodwillie's 6B Wet *Carex nigra* (1992), or 4D Wet *Carex nigra* (Goodwillie 2003). It is also very similar to Regan et al.'s (2007) Group 5, a *Carex nigra*-dominated community.

This community had the greatest affinity for SD17d *Potentilla anserina-Carex nigra* dune slack community – *Hydrocotyle vulgaris-Ranunculus flammula* sub-community (Table 2.32).

Group 19 – *Potentilla anserina-Potentilla reptans* community

Class: Plantaginetea majoris

Ivimey-Cook and Proctor do not seem to explicitly describe this community, although there are some similarities with some of the relevés in their *Carex nigra-Potentilla anserina* association (Ivimey-Cook and Proctor 1966).

This community is part of the Ranunculo-Potentilletum anserinae (O'Connell et al. 1984), and is similar to the species-poor *Potentilla reptans* variant. O'Connell et al. suggest that the large ruderal component of this community (mainly *Potentilla anserina* and *Rumex crispus*) may be due to nutrient enrichment. This community was very similar to Goodwillie's 5B *Potentilla reptans* (species-poor) community (1992), or 4B *Potentilla reptans/Carex nigra* (2003), although there was less *Phalaris arundinacea* and more *Potentilla reptans*.

The *Potentilla anserina-Potentilla reptans* community was most similar to Regan et al.'s (2007) Group 7.

There were similarities between this community and the NVC SD17 *Potentilla anserina-Carex nigra* dune slack community – *Hydrocotyle vulgaris-Ranunculus flammula* sub-community, but also with MG11a, the *Lolium perenne* sub-community of the *Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland (Table 2.32).

Group 20 – *Filipendula ulmaria-Potentilla erecta-Viola* sp. community

Class: Plantaginetea majoris

This community seems to fit well with the species-rich variant of O'Connell et al.'s Ranunculo-Potentilletum anserinae (1984).

Group 20 also corresponds well with Goodwillie's 4B *Potentilla reptans* (species rich) (1992), also known as 4A *Potentilla reptans/Viola canina* (2003). There are some similarities with Regan et al.'s Group 7 (2007).

The highest goodness-of-fit score produced by MAVIS for this community was for the SD17 *Potentilla anserina-Carex nigra* dune slack community (Table 2.32).

Table 2.32 Affinities with NVC communities generated by MAVIS for Cluster 3.

Group	NVC	Percentage goodness-of-fit	Community
3	SD17	53.58	*Potentilla anserina-Carex nigra* dune slack community
	SD17a	50.16	*Potentilla anserina-Carex nigra* dune slack community – *Festuca rubra-Ranunculus repens* sub-community
	M27	47.24	*Filipendula ulmaria-Angelica sylvestris* mire
4	SD17a	53.21	*Potentilla anserina-Carex nigra* dune slack community – *Festuca rubra-Ranunculus repens* sub-community
	SD17	52.75	*Potentilla anserina-Carex nigra* dune slack community
	SD17b	47.78	*Potentilla anserina-Carex nigra* dune slack community – *Carex flacca* sub-community
9	S28	41.79	*Phalaris arundinacea* tall-herb fen
	M27	41.45	*Filipendula ulmaria-Angelica sylvestris* mire
	OV26	41.41	*Epilobium hirsutum* community
13	SD17d	55.03	*Potentilla anserina-Carex nigra* dune slack community – *Hydrocotyle vulgaris-Ranunculus flammula* sub-community
	SD17	51.48	*Potentilla anserina-Carex nigra* dune slack community
	S19	50.75	*Eleocharis palustris* swamp
19	SD17a	50.11	*Potentilla anserina-Carex nigra* dune slack community – *Festuca rubra-Ranunculus repens* sub-community
	MG11a	49	*Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland – *Lolium perenne* sub-community
	MG11	48.17	*Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland
20	SD17	40.21	*Potentilla anserina-Carex nigra* dune slack community
	SD17a	38.65	*Potentilla anserina-Carex nigra* dune slack community – *Festuca rubra-Ranunculus repens* sub-community
	SD17c	36.74	*Potentilla anserina-Carex nigra dune* slack community – *Caltha palustris* sub-community

2.4.15 Cluster 2

Cluster 2 contained a number of water-dependent communities. These groups all contain at least some species which are obligately aquatic plants. All communities contained at least some *Equisetum fluviatile*, albeit at varying frequencies and abundances. These communities generally have a high mean Ellenberg Wetness score, and a relatively low mean Ellenberg Fertility score (Table 2.33).

Table 2.33 Mean Ellenberg and Grime's C-S-R values for the groups in Cluster 2 (± standard deviation).

Group	Light	Wetness	pH	Fertility	C	S	R
2	7.3 ± 0.2	8.2 ± 0.7	6.2 ± 0.3	5.2 ± 0.7	2.99 ± 0.27	1.81 ± 0.38	2.68 ± 0.30
7	7.3 ± 0.2	8.5 ± 0.5	6.2 ± 0.5	5.2 ± 0.9	3.56 ± 0.65	2.06 ± 0.62	1.71 ± 0.43
16	7.5 ± 0.3	9.0 ± 0.6	5.6 ± 0.8	4.4 ± 0.8	2.83 ± 0.40	2.59 ± 0.71	1.80 ± 0.40
17	7.4 ± 0.2	7.9 ± 0.6	5.7 ± 0.5	4.0 ± 0.7	2.86 ± 0.38	2.49 ± 0.48	2.24 ± 0.38
18	7.2 ± 0.4	8.6 ± 0.9	6.1 ± 0.4	5.4 ± 0.8	2.95 ± 0.34	1.60 ± 0.51	2.71 ± 0.48
27	7.6 ± 0.4	9.3 ± 0.8	4.9 ± 0.6	3.4 ± 0.9	2.60 ± 0.39	3.23 ± 0.54	1.39 ± 0.43

Group 2 – *Persicaria amphibia-Eleocharis palustris* community (Table 2.34)

Recorded in twelve turloughs, number of relevés in each indicated in brackets – Lough Aleenaun (18), Brierfield (7), Carrowreagh (3), Croaghill (7), Coolcam (2), Knockaunroe (11), Kilglassan (8), Lisduff (6), Skealoghan (5), Tullynafrankagh (1), Termon (4)

Description

Persicaria amphibia, as its name suggests, can tolerate aquatic and damp terrestrial habitats. This community was found in areas that retain shallow water during the summer months (the mean water depth at time of sampling was c. 20cm), with the emergent vegetation reaching around 35cm. *P. amphibia, Agrostis stolonifera, Potentilla anserina, Galium palustre, Eleocharis palustris,* and *Ranunculus repens* were the constant species, with frequent *Mentha aquatica* and *Carex nigra.*

Location on flooding gradient

This community occurs in the middle to lower zones of turloughs, and was generally found to have shallow standing water when sampled. The mean Ellenberg Wetness value for this community is 8.2 (Table 2.33), which is intermediate between a damp and wet site (Hill et al. 1999).

Land use

This community was found in the lower zone of turloughs that are generally grazed by cattle. The presence of water throughout the dry period, however, means that grazing of this vegetation type is not extensive, although cattle are likely to water here and this results in poaching and disturbance. The mean Ellenberg Fertility value of 5.2 is indicative of an intermediate level of fertility (Hill et al. 1999).

Table 2.34 Floristic table for the *Persicaria amphibia-Eleocharis palustris* community.

No. of relevés	72		
No. of species	76		
Group	2		
Agrostis stolonifera	V (4-9)	*Filipendula ulmaria*	I (2-6)
Eleocharis palustris	IV (2-8)	*Glechoma hederacea*	I (3)
Galium palustre	IV (1-6)	*Hippuris vulgaris*	I (5-7)
Persicaria amphibia	IV (2-9)	*Iris pseudacorus*	I (3-7)
Potentilla anserina	IV (1-8)	*Juncus acutiflorus*	I (3-5)
Ranunculus repens	IV (2-6)	*Juncus bulbosus*	I (3-4)
Carex nigra	III (3-6)	*Juncus inflexus*	I (6)
Mentha aquatica	III (1-7)	*Lemna trisulca*	I (4)
Cardamine pratensis	II (3-6)	*Scorzoneroides autumnalis*	I (5)
Glyceria fluitans	II (2-6)	*Littorella uniflora*	I (6)
Hydrocotyle vulgaris	II (2-9)	*Lolium perenne*	I (4)
Juncus articulatus	II (3-5)	*Lysimachia vulgaris*	I (6)
Myosotis scorpioides	II (2-7)	*Lythrum salicaria*	I (2)
Oenanthe aquatica	II (3-7)	*Ophioglossum vulgatum*	I (3)
Phalaris arundinacea	II (4-7)	*Persicaria maculosa*	I (3-4)
Ranunculus flammula	II (3-7)	*Plantago lanceolata*	I (5)
Rorippa amphibia	II (3-7)	*Persicaria lapathifolia*	I (2)
Agrostis capillaris	I (6)	*Potamogeton gramineus*	I (4-6)
Alisma plantago-aquatica	I (1-5)	*Potentilla reptans*	I (5)
Alopecurus geniculatus	I (3-6)	*Ranunculus lingua*	I (6)
Apium inundatum	I (3-4)	*Ranunculus trichophyllus*	I (3-4)
Apium nodiflorum	I (5)	*Rumex crispus*	I (3-6)
Baldellia ranunculoides	I (3-5)	*Rumex obtusifolius*	I (4-6)
Caltha palustris	I (5-7)	*Senecio aquaticus*	I (1)
Carex disticha	I (4-7)	*Sparganium emersum*	I (5-6)
Carex elata	I (4-6)	*Sparganium erectum*	I (4-5)
Carex flacca	I (4)	*Stellaria media*	I (2-7)
Carex viridula agg.	I (3-5)	*Stellaria palustris*	I (4-5)
Carex hirta	I (4-5)	*Taraxacum officinale* agg.	I (1-4)
Carex hostiana	I (3-7)	*Teucrium scordium*	I (3-5)
Carex rostrata	I (5)	*Trifolium repens*	I (4-5)
Eleogiton fluitans	I (4)	*Veronica beccabunga*	I (1-5)
Equisetum fluviatile	I (2-4)	*Veronica catenata*	I (3)
Schedonorus arundinaceus	I (4)	*Veronica scutellata*	I (1-4)
Festuca rubra	I (4)	*Veronica serpyllifolia*	I (3-5)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 7 – *Eleocharis palustris-Phalaris arundinacea* community (Table 2.35)

Recorded in three turloughs, number of relevés in each indicated in brackets – Ardkill (8), Brierfield (9), Tullynafrankagh (2)

Description

This is a tall, ungrazed community, with a mean vegetation height 80 cm. This community has a similar suite of species to Cluster 2 but with more frequent *Phalaris arundinacea.*

Constant species are *Eleocharis palustris, Phalaris arundinacea* and *Galium palustre*, with frequent *Carex nigra, Persicaria amphibia, Potentilla anserina, Equisetum fluviatile* and *Agrostis stolonifera. Phalaris arundinacea* was an indicator species (26%).

Location on flooding gradient

This community occurs towards the bottom of the flooding gradient. The mean Ellenberg Wetness score of 8.5 (Table 2.33) is suggestive of a wet site (Hill et al. 1999).

Land use

This community, as shown by the vegetation height, is little grazed. The mean Ellenberg Fertility value of 5.2 (Table 2.33) suggests that this community occurs on sites of intermediate fertility (Hill et al. 1999).

Table 2.35 – Floristic table for the *Eleocharis palustris-Phalaris arundinacea* community.

No. of relevés	19		
No. of species	28		
Group	7		
Eleocharis palustris	V (3-7)	*Caltha palustris*	I (3-4)
Phalaris arundinacea	V (4-9)	*Carex disticha*	I (4)
Galium palustre	IV (2-5)	*Carex hirta*	I (4)
Agrostis stolonifera	III (3-8)	*Filipendula ulmaria*	I (4)
Carex nigra	III (2-7)	*Lysimachia vulgaris*	I (3-5)
Equisetum fluviatile	III (3-6)	*Lythrum salicaria*	I (5)
Persicaria amphibia	III (3-5)	*Menyanthes trifoliata*	I (6-7)
Potentilla anserina	III (2-7)	*Myosotis scorpioides*	I (2)
Cardamine pratensis	II (3-4)	*Ranunculus lingua*	I (5)
Hydrocotyle vulgaris	II (3-4)	*Rorippa amphibia*	I (2)
Mentha aquatica	II (2-6)	*Salix aurita*	I (5-6)
Ranunculus repens	II (2-5)	*Salix repens*	I (7)
Alisma plantago-aquatica	I (6)	*Stellaria media*	I (2)
Apium nodiflorum	I (6)	*Veronica scutellata*	I (3)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 16 – *Equisetum fluviatile-Menyanthes trifoliata* community (Table 2.36)

Recorded in six turloughs, number of relevés in each indicated in brackets – Ardkill (1), Brierfield (7), Kilglassan (3), Lisduff (1), Skealoghan (2), Tullynafrankagh (1)

Description

This community occurs in areas likely to retain shallow standing water during the summer months; the mean water depth was 10cm at time of sampling, while the mean vegetation height is 40cm. *Equisetum fluviatile, Menyanthes trifoliata* and *Agrostis stolonifera* are constant species, with frequent *Mentha aquatica*. Occasional species are *Galium palustre, Hydrocotyle vulgaris, Oenanthe aquatica* and *Veronica catenata.*

Indicator species are *Menyanthes trifoliata* (81%) and *Equisetum fluviatile* (31%).

Location on flooding gradient

This community is located at the bottom of the flooding gradient, generally in areas with shallow standing water. It is also sometimes found in drainage ditches. The mean Ellenberg value for Wetness is 9 for this community (Table 2.33), which is indicative of a wet site (Hill et al. 1999).

Land use

Due to the wetness of this community, it is little grazed. The mean Ellenberg Fertility score is relatively low, at 4.4 (Table 2.33).

Table 2.36 – Floristic table for the *Equisetum fluviatile-Menyanthes trifoliata* community.

No. of relevés	15		
No. of species	37		
Group	16		
Equisetum fluviatile	V (3-7)	*Iris pseudacorus*	I (7)
Menyanthes trifoliata	V (5-9)	*Juncus acutiflorus*	I (3)
Agrostis stolonifera	IV (3-9)	*Juncus articulatus*	I (5)
Mentha aquatica	III (4-5)	*Juncus effusus*	I (5-6)
Galium palustre	II (3-5)	*Lysimachia vulgaris*	I (4)
Hydrocotyle vulgaris	II (3-6)	*Lythrum portula*	I (3)
Oenanthe aquatica	II (4-8)	*Persicaria amphibia*	I (2-4)
Veronica catenata	II (3-7)	*Phalaris arundinacea*	I (5)
Apium nodiflorum	I (4-5)	*Potamogeton natans*	I (4)
Cardamine flexuosa	I (6)	*Potentilla anserina*	I (4)
Cardamine pratensis	I (4-5)	*Ranunculus flammula*	I (3-4)
Carex nigra	I (4-5)	*Ranunculus lingua*	I (4-5)
Carex rostrata	I (4-6)	*Ranunculus repens*	I (4)
Eleocharis palustris	I (4-5)	*Rorippa amphibia*	I (4-5)
Schedonorus arundinaceus	I (2)	*Salix repens*	I (4)
Glyceria fluitans	I (4-5)	*Schoenoplectus lacustris*	I (5-6)
Hippuris vulgaris	I (6-7)	*Veronica serpyllifolia*	I (3)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 17 – *Carex nigra-Ranunculus flammula* community (Table 2.37)

Recorded in twelve turloughs, number of relevés in each indicated in brackets – Ballindereen (2), Brierfield (1), Caranavoodaun (15), Coolcam (8), Croaghill (6), Kilglassan (2), Knockaunroe (9), Lisduff (7), Roo West (9), Skealoghan (4), Termon (10), Tullynafrankagh (10)

Description

This community was quite widespread, and was recorded in over half of the turloughs surveyed. The sward is lightly grazed, and generally reached a height of 30cm. *Mentha aquatica, Hydrocotyle vulgaris* and *Potentilla anserina* are the constant species. *Agrostis stolonifera, Carex nigra, Ranunculus flammula* and *Galium palustre* are frequent.

Caltha palustris, Comarum palustre and *Salix repens* are notable in this community, the first two for their instantly recognisable leaves and flowers, and *S. repens* for the large size of occasional specimens within the community.

Location on flooding gradient

This community is located towards the bottom of the flooding gradient, and generally had either a few centimetres of surface water or a waterlogged substrate at time of sampling. The mean Ellenberg Wetness value for this community is 7.9 (Table 2.33), indicative of a relatively wet site (Hill et al. 1999).

Land use

This community is sometimes grazed by livestock. The mean Ellenberg Fertility value of 4 (Table 2.33) is relatively low, and indicative of less fertile sites (Hill et al. 1999).

Table 2.37 – Floristic table for the *Carex nigra-Ranunculus flammula* community.

No. of relevés	83		
No. of species	74		
Group	17		
Hydrocotyle vulgaris	V (3-7)	*Filipendula ulmaria*	I (4-7)
Mentha aquatica	V (3-7)	*Glyceria fluitans*	I (3-6)
Potentilla anserina	V (2-9)	*Juncus acutiflorus*	I (3-6)
Agrostis stolonifera	IV (1-7)	*Juncus bulbosus*	I (1-5)
Carex nigra	IV (3-9)	*Juncus effusus*	I (4)
Galium palustre	IV (1-6)	*Lathyrus pratensis*	I (4)
Ranunculus flammula	IV (2-7)	*Leontodon saxatilis*	I (3)
Carex viridula agg.	III (2-8)	*Lysimachia vulgaris*	I (4-7)
Juncus articulatus	III (3-7)	*Menyanthes trifoliata*	I (4-9)
Ranunculus repens	III (2-6)	*Myosotis scorpioides*	I (2-5)
Carex panicea	II (2-7)	*Oenanthe aquatica*	I (4-5)
Scorzoneroides autumnalis	II (1-5)	*Persicaria amphibia*	I (3-6)
Littorella uniflora	II (2-9)	*Phragmites australis*	I (5-8)
Molinia caerulea	II (3-8)	*Potamogeton gramineus*	I (3)
Phalaris arundinacea	II (3-7)	*Potentilla erecta*	I (3-5)
Achillea ptarmica	I (3-4)	*Comarum palustre*	I (3-7)
Agrostis capillaris	I (5)	*Potentilla reptans*	I (4-7)
Alisma plantago-aquatica	I (3-4)	*Prunella vulgaris*	I (4)
Anagallis tenella	I (1)	*Prunus spinosa*	I (5)
Baldellia ranunculoides	I (2-5)	*Ranunculus trichophyllus*	I (3)
Caltha palustris	I (4-6)	*Salix repens*	I (4)
Cardamine pratensis	I (3-6)	*Samolus valerandi*	I (1-6)
Carex elata	I (4-6)	*Schoenus nigricans*	I (4)
Carex flacca	I (3-8)	*Senecio aquaticus*	I (5-6)
Carex hirta	I (4-5)	*Stellaria palustris*	I (4-5)
Carex hostiana	I (3-4)	*Succisa pratensis*	I (5)
Carex rostrata	I (5)	*Teucrium scordium*	I (3-6)
Cirsium dissectum	I (2-5)	*Trifolium repens*	I (3-5)
Eleocharis multicaulis	I (5-8)	*Triglochin palustris*	I (4)
Eleocharis palustris	I (3-8)	*Veronica beccabunga*	I (3)
Equisetum fluviatile	I (3-5)	*Veronica scutellata*	I (1-4)
Equisetum palustre	I (6)	*Vicia cracca*	I (3-6)
Eriophorum angustifolium	I (5)	*Zannichellia palustris*	I (3-5)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 18 – *Agrostis stolonifera-Glyceria fluitans* community (Table 2.38)

Recorded in twelve turloughs, number of relevés in each indicated in brackets – Ballindereen (2), Brierfield (1), Carrowreagh (3), Croaghill (5), Garryland (1) Kilglassan (1), Knockaunroe (2), Lisduff (1), Lough Aleenaun (3), Rathnalulleagh (3), Skealoghan (3), Tullynafrankagh (3)

Description

This community was generally aquatic; the mean water depth across all the relevés was 20cm (at time of sampling), with the some of the vegetation emerging slightly above that. *Agrostis stolonifera* and *Glyceria fluitans* are the constant species, with frequent *Eleocharis palustris* and *Galium palustre. Glyceria fluitans* had an indicator value of 31%.

Location on flooding gradient

This community is located at the base or near the bottom of the turloughs, in areas that are likely to retain some standing water throughout the season, as was recorded during sampling. The mean Ellenberg value for Wetness is 8.6 (Table 2.33), which suggests that this community occurs on wet sites.

Land use

Although this community occurs in areas which are accessible by livestock, grazing is limited due to the presence of standing water. The mean Ellenberg Fertility score is 5.4 (Table 2.33), which is indicative of a site moderately high fertility (Hill et al. 1999).

Table 2.38 – Floristic table for the *Agrostis stolonifera-Glyceria fluitans* community.

No. of relevés	28		
No. of species	51		
Group	18		
Agrostis stolonifera	V (3-9)	*Scorzoneroides autumnalis*	I (4)
Glyceria fluitans	IV (4-8)	*Lythrum portula*	I (4)
Eleocharis palustris	III (3-9)	*Molinia caerulea*	I (4)
Galium palustre	III (3-6)	*Oenanthe aquatica*	I (5)
Cardamine flexuosa	II (3-7)	*Persicaria maculosa*	I (4-5)
Equisetum fluviatile	II (4-6)	*Phalaris arundinacea*	I (5-6)
Mentha aquatica	II (3-6)	*Plantago major*	I (1)
Myosotis scorpioides	II (4-7)	*Poa annua*	I (4)
Persicaria amphibia	II (3-8)	*Polygonum aviculare*	I (5)
Ranunculus repens	II (3-6)	*Potentilla anserina*	I (3-5)
Alisma plantago-aquatica	I (3-5)	*Ranunculus flammula*	I (4-5)
Alopecurus geniculatus	I (4)	*Ranunculus trichophyllus*	I (1-5)
Apium inundatum	I (5)	*Rorippa amphibia*	I (4-6)
Apium nodiflorum	I (4-5)	*Rorippa palustris*	I (4-7)
Baldellia ranunculoides	I (4-5)	*Rumex crispus*	I (2)
Callitriche species	I (4)	*Rumex obtusifolius*	I (5)
Caltha palustris	I (4)	*Senecio aquaticus*	I (1)
Cardamine pratensis	I (4)	*Sparganium erectum*	I (5-6)
Carex nigra	I (3-5)	*Stellaria media*	I (3-4)
Gnaphalium uliginosum	I (1-2)	*Trifolium repens*	I (4-5)
Juncus acutiflorus	I (4-5)	*Veronica catenata*	I (4)
Juncus articulatus	I (3-4)	*Veronica scutellata*	I (4-5)
Juncus effusus	I (6)	*Zannichellia palustris*	I (4)
Lemna minor	I (3)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 27 – *Carex nigra-Equisetum fluviatile* community (Table 2.39)

Recorded in three turloughs, number of relevés in each indicated in brackets – Garryland (4), Lisduff (2), Skealoghan (1)

Description

This community has a relatively low number of species, but again, this may be due to the small sample size. The sward is relatively ungrazed, and the mean vegetation height is 30cm. Constant species are *Equisetum fluviatile* and *Carex nigra*, and the community is easily recognised due to the dominance of these two species. Frequent species are *Eleocharis palustris* and *Carex vesicaria*.

Indicator species are *Carex vesicaria* (43%) and *Equisetum fluviatile* (23%).

Location on flooding gradient

This vegetation type is located towards the bottom of the flooding gradient, and when surveyed, usually had some surface water or a waterlogged substrate. The mean Ellenberg value for Wetness is high, at 9.3 (Table 2.33), indicating that this is a community which may occur on wet sites.

Land use

This community occurs in areas accessible by cattle, but is little grazed. The mean Ellenberg Fertility value is low, at 3.4 (Table 2.33), which suggests that this community may occur on infertile sites (Hill et al. 1999).

Table 2.39 – Floristic table for the *Carex nigra-Equisetum fluviatile* community.

No. of relevés	7		
No. of species	16		
Group	27		
Carex nigra	V (5-9)	*Glyceria fluitans*	I (4)
Equisetum fluviatile	V (3-6)	*Juncus acutiflorus*	I (4)
Carex vesicaria	III (7-9)	*Littorella uniflora*	I (5)
Eleocharis palustris	III (3-5)	*Mentha aquatica*	I (4)
Hydrocotyle vulgaris	II (3-4)	*Phalaris arundinacea*	I (3)
Juncus bulbosus	II (5)	*Persicaria hydropiper*	I (3)
Ranunculus flammula	II (5-6)	*Schoenoplectus lacustris*	I (9)
Carex viridula	I (5)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

2.4.16 Comparison with previous studies

Group 2 – *Persicaria amphibia-Eleocharis palustris* community

Class: Plantaginetea majoris

Group 2 is most similar to the *Polygonum amphibium (Persicaria amphibia)* variant of the Ranunculo-Potentilletum anserinae as described by O'Connell et al. (1984). This community was similar to 7A *Polygonum amphibium (Persicaria amphibia)* (grassy) from Goodwillie's 1992 survey, and seems to belong to his 5B *Polygonum amphibium (Persicaria amphibia)* community (2003).

This community appears to belong to the A10 *Polygonum amphibium (Persicaria amphibia)* NVC community (Rodwell 1995), although the NVC community with the highest affinity calculated by MAVIS was SD17d, the *Hydrocotyle vulgaris-Ranunculus flammula* sub-community of the *Potentilla anserina-Carex nigra* dune-slack community.

Group 7 – *Eleocharis palustris-Phalaris arundinacea* community

Class: Plantaginetea majoris

This community was similar to Goodwillie's 7A *Polygonum amphibium (Persicaria amphibia)* (grassy) community (Goodwillie 1992), although *Persicaria amphibia* is not as frequent, while *Eleocharis palustris, Phalaris arundinacea* and *Galium palustre* are all more frequent than in 7A. While this community has a similar suite of species to Group 2, this community is in general much taller, and did not have standing water present at the time of sampling.

The NVC community to which this has the greatest degree of affinity, according to MAVIS, is the S19 *Eleocharis palustris* swamp.

Group 16 – *Equisetum fluviatile-Menyanthes trifoliata* community

Class: Phragmitetea

This community seems to belong to the Glycerio-Sparganion alliance of the Phragmitetea, which was not described in depth by Ivimey-Cook and Proctor (1966). They did, however, present a table with three relevés representing this community, and Group 16 seems to fit here.

O'Connell et al. provide synoptic tables for their reedswamp and tall sedge communities, to which Group 16 seems to belong. The character and differential species listed by them, however, were not present in Group 16 in sufficient quantities to allow a distinction between the groups.

This community was most similar to Goodwillie's 11B Peaty Pond (1992), who also placed this community in the Glycerio-Sparganion.

This community was very similar to the NVC S10 *Equisetum fluviatile* swamp (Rodwell 1995), although the NVC community for which the highest goodness-of-fit score that was generated by MAVIS was S19 the *Eleocharis palustris* swamp, as shown in Table 2.40.

Group 17 – *Carex nigra-Ranunculus flammula* community

Class: Plantaginetea majoris

Group 17 is most similar to the Typical *Carex nigra* variant of the Ranunculo-Potentilletum anserinae as described by O'Connell et al. (1984). This community is most similar to 6D Peaty *Carex nigra* (Goodwillie 1992) or 7A Peaty *Carex nigra* (Goodwillie 2003).

The *Carex nigra-Ranunculus flammula* community was similar to Groups 3 and 4 from Regan et al. (2007).

Proctor (2010) gives the NVC equivalent of this community as M9 *Carex rostrata-Calliergon cuspidatum/giganteum* mire (Rodwell 1991b), and there are similarities, but Group 17 has 'scarce' *Carex rostrata*, while it is listed as 'constant' in the floristic table for M9.

Group 18 – *Agrostis stolonifera-Glyceria fluitans* community

Class: Phragmitetea

This community was most similar to Goodwillie's 9A Temporary Pond (1992), which seems to be renamed later as 5A Floodgrass (2003).

On comparison with the floristic tables describing NVC communities, the *Agrostis stolonifera-Glyceria fluitans* community was found to be similar to the NVC S22 *Glyceria fluitans* water margin vegetation (Rodwell 1995), although *Agrostis stolonifera,* one of the constant species in this vegetation type, is listed as 'scarce' in the floristic table for S22. It may be that the fluctuating water levels allow *A. stolonifera* a competitive edge. There were also similarities with NVC vegetation type S23 – 'Other water-margin vegetation' (Rodwell 1995). MAVIS, however, did not give high goodness-of-fit scores for either of these communities, and instead found affinity with S19 *Eleocharis palustris* swamp.

Group 27 – *Carex nigra-Equisetum fluviatile* community

Class: Phragmitetea

This community also had similarities to Goodwillie's 11B Peaty Pond (1992), although in this case there was no *Menyanthes trifoliata* and abundant and frequent *Carex nigra.* These two species also confound any comparison with the NVC S10 *Equisetum fluviatile* swamp (Rodwell 1995). A relatively low number of relevés were recorded for this community (7), and it is possible that these represent a transition zone between the *Equisetum fluviatile-Menyanthes trifoliata* community and a more *Carex nigra*-dominated community. The NVC community with the highest goodness-of-fit score was S19; the *Eleocharis palustris* swamp (Table 2.40).

Table 2.40 Affinities with NVC communities for Cluster 2.

Group	NVC	Percentage	Community
2	SD17d	51.52	*Potentilla anserina-Carex nigra* dune slack
	SD17	48.94	*Potentilla anserina-Carex nigra* dune slack
	SD17a	44.89	*Potentilla anserina-Carex nigra* dune slack
7	S19	54.93	*Eleocharis palustris* swamp
	SD17d	51.9	*Potentilla anserina-Carex nigra* dune slack
	S19a	48.47	*Eleocharis palustris* swamp
16	S19	49.59	*Eleocharis palustris* swamp
	S27a	49.48	*Carex rostrata-Potentilla palustris* tall-herb swamp
	S12	48.84	*Typha latifolia* swamp
17	SD17d	54.62	*Potentilla anserina-Carex nigra* dune slack
	SD15	48.92	*Salix repens-Calliergon cuspidatum* dune slack
	SD17	48.91	*Potentilla anserina-Carex nigra* dune slack
18	S19	50.78	*Eleocharis palustris* swamp
	S19a	46.51	*Eleocharis palustris* swamp
	S12	45.14	*Typha latifolia* swamp
27	S19	50.54	*Eleocharis palustris* swamp
	S8c	46.58	*Scirpus lacustris* swamp
	S19a	46.24	*Eleocharis palustris* swamp

2.4.17 Cluster 8

Cluster 8 contains Groups 22 and 25, both of which have a high frequency of *Molinia caerulea,* and both also contain at least some *Carex hostiana, Cirsium dissectum* and *Ranunculus flammula.* Both of these communities have low mean Ellenberg Fertility values (Table 2.41).

Table 2.41 Mean Ellenberg and Grime's C-S-R values for the groups in Cluster 8 (± standard deviation).

Group	Light	Wetness	pH	Fertility	C	S	R
22	7.5 ± 0.3	7.7 ± 0.6	5.0 ± 0.7	2.7 ± 0.6	2.17 ± 0.4	3.56 ± 0.53	1.60 ± 0.38
25	7.6 ± 0.2	8.3 ± 0.2	5.6 ± 0.7	2.1 ± 0.1	2.08 ± 0.26	3.80 ± 0.36	1.23 ± 0.20

Group 22 - *Molinia caerulea-Carex nigra* community (Table 2.42)

Recorded in six turloughs, number of relevés in each indicated in brackets – Ballindereen (6), Caranavoodaun (10), Knockaunroe (18), Lisduff (5), Roo West (4), Tullynafrankagh (1)

Description

This community has a relatively short sward (25cm) comprised of a mix of sedges, grasses and forbs. The constant species are *Carex panicea, Molinia caerulea, Carex hostiana* and *Mentha aquatica. Agrostis stolonifera, Carex flacca, Cirsium dissectum, Hydrocotyle vulgaris, Scorzoneroides autumnalis, Lotus corniculatus, Potentilla anserina, Potentilla erecta* and *Ranunculus flammula* are all frequent.

Carex hostiana is an indicator species (24%).

Location on flooding gradient

This community is generally located in the middle to the bottom of the flooding gradient. The mean Ellenberg Wetness value of 7.7 (Table 2.41) is indicative of damp to wet soils (Hill et al. 1999).

Land use

This community occurs on Fen peat or peat marl, and is little grazed. The mean Ellenberg Fertility value is low, at 2.7 (Table 2.41), which is indicative of infertile sites (Hill et al. 1999).

Table 2.42 – Floristic table for the *Molinia caerulea-Carex panicea* community.

No. of relevés	44		
No. of species	59		
Group	22		
Carex panicea	V (2-8)	*Galium boreale*	I (3)
Molinia caerulea	V (2-9)	*Hypochoeris radicata*	I (0.1)
Carex hostiana	IV (1-9)	*Juncus acutiflorus*	I (2)
Mentha aquatica	IV (0.1-4)	*Juncus articulatus*	I (1-5)
Agrostis stolonifera	III (1-6)	*Juncus bulbosus*	I (2)
Carex flacca	III (2-5)	*Leontodon hispidus*	I (2)
Cirsium dissectum	III (0.1-5)	*Linum cathartica*	I (2-3)
Hydrocotyle vulgaris	III (0.1-6)	*Lythrum salicaria*	I (2)
Scorzoneroides autumnalis	III (1-4)	*Ophioglossum vulgatum*	I (2)
Lotus corniculatus	III (2-5)	*Parnassia palustris*	I (3)
Potentilla anserina	III (1-7)	*Persicaria amphibia*	I (3)
Potentilla erecta	III (2-5)	*Phalaris arundinacea*	I (1-3)
Ranunculus flammula	III (0.1-4)	*Phleum bertolonii*	I (1-2)
Carex nigra	II (2-8)	*Plantago lanceolata*	I (1-4)
Carex viridula agg.	II (2-7)	*Plantago maritima*	I (2-4)
Galium palustre	II (0.1-4)	*Potentilla reptans*	I (1-4)
Succisa pratensis	II (1-5)	*Prunella vulgaris*	I (4)
Achillea ptarmica	I (1-3)	*Prunus spinosa*	I (0.1-5)
Alopecurus geniculatus	I (2)	*Ranunculus repens*	I (0.1-5)
Anagallis tenella	I (1)	*Salix repens*	I (2-6)
Carex hirta	I (3)	*Samolus valerandi*	I (2)
Cirsium arvense	I (4)	*Schoenus nigricans*	I (0.1-6)
Danthonia decumbens	I (2)	*Teucrium scordium*	I (1-2)
Eleocharis palustris	I (3)	*Trifolium pratense*	I (2)
Elytrigia repens	I (2)	*Trifolium repens*	I (1-4)
Equisetum fluviatile	I (1)	*Veronica beccabunga*	I (1-2)
Schedonorus arundinaceus	I (3)	*Viola* species	I (0.1-3)
Fraxinus excelsior	I (0.1-3)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 25 – *Carex nigra-Carex viridula* community (Table 2.43)

Recorded in two turloughs, number of relevés in each indicated in brackets – Caranavoodaun (7), Knockaunroe (2)

Description

The mean vegetation height of this community is 35cm. Relatively few species were recorded, just 16 in 9 relevés. This is quite a small sample number, however, and further relevés may be required to further define this vegetation type. *Carex nigra, Carex viridula* agg., *Molinia caerulea, Ranunculus flammula* and *Schoenus nigricans* are all constant species, and in fact dominated the vegetation. There are no frequent species in this community. *Carex hostiana, Hydrocotyle vulgaris, Mentha aquatic* and *Phalaris arundinacea* are all occasional species.

Indicator species are *Carex viridula* agg. (41%), and *Schoenus nigricans* (28%).

Location on flooding gradient

This community is located towards the bottom of the flooding gradient, and the mean Ellenberg value for Wetness, at 8.3 (Table 2.41), is indicative of a damp to wet site (Hill et al. 1999).

Land use

This is a community which is only lightly grazed. The mean Ellenberg Fertility value is the lowest found, at 2.1 (Table 2.41), and suggests this community occurs on infertile sites.

Table 2.43 – Floristic table for the *Carex nigra-Carex viridula* community.

No. of relevés	9		
No. of species	16		
Group	25		
Carex nigra	V (4-7)	*Phalaris arundinacea*	II (2)
Carex viridula agg.	V (2-8)	*Agrostis stolonifera*	I (2)
Molinia caerulea	V (3-6)	*Cirsium dissectum*	I (3)
Ranunculus flammula	V (0.1-5)	*Galium palustre*	I (2)
Schoenus nigricans	IV (3-9)	*Juncus articulatus*	I (3)
Carex hostiana	II (2-6)	*Scorzoneroides autumnalis*	I (3)
Hydrocotyle vulgaris	II (2)	*Menyanthes trifoliata*	I (3)
Mentha aquatica	II (2)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

2.4.18 Comparison with previous studies

Group 22 – *Molinia caerulea-Carex panicea* community

Class: Scheuchzerio-Caricetea fuscae

Of the communities described by O'Connell et al. (1984), this community seems to correspond best with the *Carex panicea-Carex flava* agg. community. This community seems to be identical to Goodwillie's 5D Sedge Fen (1992) or 3B *Carex hostiana/Molinia* (2003). Of the communities described by Regan et al. (2007), the *Molinia caerulea-Carex panicea* community was most similar to Group 2, although Regan et al. did not record *Carex hostiana* in any of their communities.

This community was also very similar to the NVC M24 *Molinia caerulea-Cirsium dissectum* fen-meadow (Rodwell 1991b), although the NVC communities with which it has the greatest affinity according to MAVIS are dune slack communities (Table 2.44).

Group 25 – *Carex nigra-Carex viridula* agg. community

Class: Scheuchzerio-Caricetea fuscae

This community seems to belong to the *Carex demissa* nodum of the Caricion davallianae (Ivimey-Cook and Proctor 1966). It also has similarities with the species-poor variant of the *Carex panicea-Carex flava* agg. community of O'Connell et al. (1984), although *Carex panicea* is not present.

This community seems similar to Goodwillie's 5E *Carex flava (Carex viridula* agg.*)* community (Goodwillie 1992). The community represented only 1% of the surveyed area in that report, however, and was not described in the 2003 review of turlough vegetation.

There are some similarities with Group 1 as described by Regan et al. (2007).

According to MAVIS, the community to which Group 25 has the greatest affinity is SD17d, the *Hydrocotyle vulgaris-Ranunculus flammula* sub-community of the *Potentilla anserina-Carex nigra* dune slack community (Table 2.44). This was given a very low goodness-of-fit score, however, and does not correspond that well with this community.

Table 2.44 Affinities with NVC for Cluster 8.

Group	NVC	Percentage	Community
22	SD15	48.13	*Salix repens-Calliergon cuspidatum* dune slack community
	SD14	46.53	*Salix repens-Campylium stellatum* dune slack community
	SD14b	44.08	*Salix repens-Campylium stellatum* dune slack community – *Rubus caesius-Galium palustre* sub-community
25	SD17d	37.28	*Potentilla anserina-Carex nigra* dune slack community – *Hydrocotyle vulgaris-Ranunculus flammula* sub-community
	M13a	33.01	*Schoenus nigricans-Juncus subnodulosus* mire – *Festuca rubra-Juncus acutiflorus* sub-community
	M29	31.92	*Hypericum elodes-Potamogeton polygonifolius* soakway

2.4.19 Cluster 5

Cluster 5 contains communities that seem to be the most reliant on permanent water during the dry phase of the turlough; all communities had an average water depth at time of sampling of 20cm. All of the communities contain aquatic plants, and all contain at least some *Potamogeton natans* and *Glyceria fluitans*. The mean Ellenberg Wetness score is high in all cases, while the mean Fertility score is relatively low (Table 2.45)

Table 2.45 Mean Ellenberg and Grime's C-S-R values for the groups in Cluster 8 (± standard deviation).

Group	Light	Wetness	pH	Fertility	C	S	R
6	7.4 ± 0.3	9.5 ± 0.5	6.1 ± 0.3	4.7 ± 0.9	3.08 ± 0.14	1.96 ± 0.54	2.53 ± 0.41
11	7.1 ± 0.1	9.2 ± 0.5	6.3 ± 0.2	5.7 ± 0.3	3.24 ± 0.27	1.24 ± 0.22	2.64 ± 0.32
14	7.5 ± 0.4	9.4 ± 0.6	6.3 ± 0.6	4.8 ± 0.7	3.34 ± 0.30	2.23 ± 0.55	1.98 ± 0.56
24	7.0 ± 0.0	10.3 ± 0.5	6.0 ± 0.0	4.3 ± 0.4	3.83 ± 0.21	1.87 ± 0.18	1.34 ± 0.43

Group 6 – *Eleocharis palustris-Ranunculus flammula* community (Table 2.46)

Recorded in eight turloughs, number of relevés in each indicated in brackets – Ardkill (3), Coolcam (3), Croaghill (2), Kilglassan (3), Knockaunroe (10), Lisduff (2), Skealoghan (2), Termon (6)

Description

This is one of the more water-dependent communities sampled. In contrast with group 2, which also features *Persicaria amphibia,* this community is weighted more towards the aquatic, with such constant species as *Mentha aquatica, Eleocharis palustris and Ranunculus flammula.* The aforementioned *Persicaria amphibia* is frequent, along with *Glyceria fluitans, Galium palustre* and *Juncus articulatus.* When surveyed, this community had an average water depth of 20cm, with the emergent vegetation generally rising 30cm above this.

Elodea canadensis, an invasive aquatic alien, is found in this community, although not very frequently.

Location on flooding gradient

This community is found in the lower zones of turloughs, usually in shallow water. It can form large stands, especially in shallower basins or those with a flat bottom. The high mean Ellenberg Wetness score (9.5, Table 2.45) is indicative of a wet site, that may lack standing water for some of the year (Hill et al. 1999).

Soil type

The substrate this community grows on is generally marl and silt.

Land use

Due to the wet nature of this community, it is not intensively grazed. Several of the plant species appear to be palatable to livestock, however. It is often subject to poaching by cattle seeking water, and subsequent enrichment through dunging. The mean Ellenberg value for Fertility is almost 5 (Table 2.45), which suggests this community occurs on sites of intermediate fertility.

Table 2.46 – Floristic table for the *Eleocharis palustris-Ranunculus flammula* community.

No. of relevés	31		
No. of species	45		
Group	6		
Eleocharis palustris	V (3-9)	*Hippuris vulgaris*	I (4-5)
Mentha aquatica	V (3-7)	*Hydrocotyle vulgaris*	I (3-5)
Ranunculus flammula	IV (2-6)	*Juncus bulbosus*	I (5)
Galium palustre	III (3-5)	*Lemna minor*	I (4)
Glyceria fluitans	III (4-7)	*Littorella uniflora*	I (3-8)
Juncus articulatus	III (3-8)	*Lythrum portula*	I (3)
Persicaria amphibia	III (3-5)	*Myosotis scorpioides*	I (3-4)
Agrostis stolonifera	II (3-7)	*Persicaria maculosa*	I (4)
Alisma plantago-aquatica	II (2-7)	*Phalaris arundinacea*	I (2)
Baldellia ranunculoides	II (3-6)	*Potamogeton gramineus*	I (4-6)
Equisetum fluviatile	II (4-6)	*Potentilla anserina*	I (3)
Oenanthe aquatica	II (4-7)	*Ranunculus repens*	I (3)
Potamogeton natans	II (3-6)	*Ranunculus trichophyllus*	I (3-5)
Apium inundatum	I (3)	*Rorippa amphibia*	I (2-9)
Cardamine flexuosa	I (4)	*Samolus valerandi*	I (3-4)
Carex elata	I (7)	*Schoenoplectus lacustris*	I (9)
Carex viridula	I (4-6)	*Sparganium emersum*	I (3-5)
Carex hostiana	I (4)	*Sparganium erectum*	I (4-5)
Carex nigra	I (3-6)	*Teucrium scordium*	I (3)
Chara species	I (4)	*Veronica beccabunga*	I (4)
Eleocharis multicaulis	I (4)	*Veronica scutellata*	I (4)
Eleogiton fluitans	I (7)	*Zannichellia palustris*	I (6)
Elodea canadensis	I (5-8)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 11 – *Persicaria amphibia-Mentha aquatica* community (Table 2.47)

Recorded in three turloughs, number of relevés in each indicated in brackets – Ardkill (7), Croaghill (4), Lough Aleenaun (5)

Description

This community occurs in areas likely to retain shallow water during the dry phase; when surveyed the water was generally around 20cm deep. The average vegetation height is 25cm, though *Oenanthe aquatica* can grow much taller. Constant species are *Persicaria amphibia* and *Mentha aquatica*, with frequent *Eleocharis palustris* and *Oenanthe aquatica.*

Persicaria amphibia has an indicator value of 28% in this community.

Location on flooding gradient

This vegetation type occurs at the bottom of the flooding gradient, and has a mean Ellenberg indicator value for Wetness of 9.2, suggesting that this occurs on very wet sites (Hill et al. 1999).

Land use

As with all of the communities found in standing water, this one is not intensively managed. Cattle come to drink from the water, and this causes disturbance to the substrate, resulting in turbid water which reduces the light available to submerged plants. There is also nutrient input to the habitat via dunging of cattle. The mean Ellenberg Fertility value is 5.7 (Table 2.45), indicating that this is a community which occurs on relatively fertile sites (Hill et al. 1999).

Table 2.47 – Floristic table for the *Persicaria amphibia-Mentha aquatica* community.

No. of relevés	16		
No. of species	39		
Group	11		
Persicaria amphibia	V (5-8)	*Hydrocotyle vulgaris*	I (5)
Mentha aquatica	IV (4-8)	*Lemna minor*	I (4)
Eleocharis palustris	III (3-5)	*Lemna trisulca*	I (3)
Oenanthe aquatica	III (2-7)	*Myosotis scorpioides*	I (4)
Agrostis stolonifera	II (3-5)	*Phalaris arundinacea*	I (4-5)
Callitriche species	II (4-5)	*Persicaria hydropiper*	I (2)
Glyceria fluitans	II (4-5)	*Potamogeton natans*	I (7)
Ranunculus repens	II (4-5)	*Potentilla anserina*	I (2)
Ranunculus trichophyllus	II (6-7)	*Rorippa palustris*	I (4)
Rorippa amphibia	II (3-5)	*Rumex obtusifolius*	I (4-5)
Cardamine pratensis	I (3-4)	*Sparganium emersum*	I (4-6)
Carex nigra	I (3)	*Sparganium erectum*	I (4)
Galium palustre	I (2-4)	*Veronica catenata*	I (4-6)
Hippuris vulgaris	I (4)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 14 - Reedbed (Table 2.48)

Recorded in three turloughs, number of relevés in each indicated in brackets – Ardkill (1), Knockaunroe (2), Termon (6)

Description

The constant species in this community are *Schoenoplectus lacustris* and *Mentha aquatica*, with frequent *Carex elata* and *Eleocharis palustris*. Both *S. lacustris* and *C. elata* are tall plants, and the former can reach heights of up to 1-2m.

Indicator species are *Schoenoplectus lacustris* (48%), *Carex elata* (46%) and *Chara* sp. (30%).

Location on flooding gradient

This community is located at the very bottom of the flooding gradient, and when surveyed standing water was present. The mean Ellenberg value for Wetness is 9.4 for this community (Table 2.45), indicating it occurs on wet sites (Hill et al. 1999).

Land use

This community is not grazed. The mean Ellenberg value for Fertility is 4.8 (Table 2.45), which indicates this community occurs on sites of intermediate fertility.

Additional notes

It should be noted that this community was under sampled due to physical difficulties in getting to the vegetation – the water was often too deep and/or the substrate too soft to safely record the vegetation. Stands of *S. lacustris* and *Phragmites australis* have been recorded in a number of turloughs (O'Connell et al. 1984, Goodwillie 1992).

Table 2.48 – Floristic table for the Reedbed community.

No. of relevés	9		
No. of species	21		
Group	14		
Mentha aquatica	IV (3-4)	*Baldellia ranunculoides*	I (4)
Schoenoplectus lacustris	IV (5-9)	*Equisetum fluviatile*	I (3)
Carex elata	III (4-9)	*Galium palustre*	I (3)
Eleocharis palustris	III (4-7)	*Glyceria fluitans*	I (4)
Chara species	II (4)	*Hippuris vulgaris*	I (4)
Lythrum salicaria	II (4-5)	*Hydrocotyle vulgaris*	I (3)
Persicaria amphibia	II (3-5)	*Lemna trisulca*	I (3)
Potamogeton gramineus	II (3-4)	*Phragmites australis*	I (4)
Ranunculus flammula	II (3-4)	*Potamogeton natans*	I (3)
Agrostis stolonifera	I (3)		

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

Group 24 – *Potamogeton natans-Glyceria fluitans* community (Table 2.49)

Recorded in three turloughs, number of relevés in each indicated in brackets – Croaghill (3), Caranavoodaun (6), Termon (1)

Description

This is the most water-dependent of the vegetation types recorded. The mean water depth of the areas surveyed was 20cm, though some of the ponds (which appear to be permanent waterbodies during the 'dry' phase of the turlough) can be quite large. The mean vegetation height is 25cm.

Potamogeton natans and *Glyceria fluitans* are constant species, with occasional *Baldellia ranunculoides, Oenanthe aquatica* and *Sparganium emersum.* Indicator species for this community are *Potamogeton natans* (82%) and *Sparganium emersum* (20%).

Location on flooding gradient

This community occurs in permanent pools at the very bottom of the flooding gradient. At 10.3, the mean Ellenberg Wetness value for this community is the highest found (Table 2.45), and is indicative of a shallow water site which may have drier periods (Hill et al. 1999).

Land use

Permanent pools in turloughs are often utilised as water sources for grazing livestock; this can result in poaching at the perimeter of the water body. The mean Ellenberg value for Fertility is relatively low, at 4.3 (Table 2.45), which is indicative of sites with low to intermediate fertility (Hill et al. 1999).

Table 2.49 – Floristic table for the *Potamogeton natans-Glyceria fluitans* community.

No. of relevés	10		
No. of species	16		
Group	24		
Potamogeton natans	V (7-9)	*Eleocharis palustris*	I (3-4)
Glyceria fluitans	IV (3-8)	*Galium palustre*	I (4)
Baldellia ranunculoides	II (1-4)	*Hippuris vulgaris*	I (5)
Oenanthe aquatica	II (2-6)	*Juncus acutiflorus*	I (4)
Sparganium emersum	II (4-7)	*Lemna minor*	I (3-4)
Agrostis stolonifera	I (3)	*Mentha aquatica*	I (4)
Alisma plantago-aquatica	I (3-4)	*Persicaria amphibia*	I (4)
Apium inundatum	I (4)	*Sparganium erectum*	I (3-4)

Species frequency within the vegetation type is indicated by Roman numeral (I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80% and V = 81-100%). The numbers in parentheses indicate the range of Domin scores within the community for each species to give an indication of abundance.

2.4.20 Comparison with previous studies

Group 6 – *Eleocharis palustris-Ranunculus flammula* community

Class: Littorelletea uniflorae

Ivimey-Cook and Proctor (1966) describe a *Littorella uniflora-Baldellia ranunculoides* association to which this community may belong; however they did not record *Eleocharis palustris* at as high a frequency as it is found in Group 6.

This community was very similar to Goodwillie's 9C Marl Pond (1992), or 6A *Baldellia/Littorella* (2003).

This community was most similar to the NVC S19 *Eleocharis palustris* swamp (Rodwell 1995) (Table 2.50).

Group 11 – *Persicaria amphibia-Mentha aquatica* community

Class: Plantaginetea majoris

This community seems to belong to the *Polygonum amphibium (Persicaria amphibia)* variant of the Ranunculo-Potentilletum anserinae as described by O'Connell et al. (1984), although it is a more aquatic community, with little *Potentilla anserina.*

This community was similar to Goodwillie's 8A *Polygonum amphibium (Persicaria amphibia)* community. His 10A *Oenanthe aquatica* (1992) may also be represented here, although *Oenanthe aquatica* was not present at the same frequency reported by him. It showed the greatest affinity for the NVC S19 *Eleocharis palustris* swamp (Rodwell 1995) (Table 2.50).

Group 14 – Reedbed

Class: Phragmitetea

Reedswamp communities are usually defined by a single dominant reed or sedge species (O'Connell et al. 1984). The Reedbed community described here seems to contain relevés from two reedswamp associations; the Scirpetum lacustris and the Cladietum marisci (Ivimey-Cook and Proctor 1966, O'Connell et al. 1984). There is also possibly one relevé from the Phragmitetum communis.

Goodwillie (2003) also describes reedswamp communities to which these relevés could belong; 8C *Schoenoplectus/Phragmites*, 8D *Magnocaricion* and 8E *Cladium mariscus.*

The greatest affinity with the NVC communities according to MAVIS were to S8 *Scirpus lacustris* swamp, S19a the *Eleocharis palustris* sub-community of the *Eleocharis palustris* swamp, and S4 *Phragmites australis* reed bed and swamp (Table 2.50).

Group 24 – *Potamogeton natans-Glyceria fluitans*

Class: Potametea OR Phragmitetea

This is a community which occurs in and around seemingly permanent water at the base of turloughs. It may represent a transition between two communities, and as such was difficult to assign to published communities in some cases.

Ivimey-Cook and Proctor (1966) describe similar communities within the Eu-Potamion alliance, although no *Glyceria fluitans* was recorded. There were also similarities with the Glycerio-Sparganion alliance of the Phragmitetea, although Ivimey-Cook and Proctor state that this alliance is not well represented within the Burren, and only three relevés are presented. O'Connell et al. (1984) also describe a Glycerietum fluitantis association within the Glycerio-Sparganion into which this community may fit; there are, however, no records for *Potamogeton natans* in these relevés.

This community is most similar to Goodwillie's 12 Open Water community (Goodwillie 1992) or the 8B *Potamogeton/Elodea* (2003). Goodwillie (1992) places this community within the Potametea, and states that it seems to be an amalgam of associations.

This community showed the greatest affinity for the NVC communities S22 and S22a, the *Glyceria fluitans* water margin vegetation and the *Glyceria fluitans* sub-community of same (Table 2.50). There is also some similarity with the NVC A9 *Potamogeton natans* community (Rodwell 1995) given the dominance of *P. natans*. The associated flora, however, do not conform rigidly to any of the sub-groups, and in this case Rodwell recommends regarding the vegetation as a mosaic of the *P. natans* community and other aquatic communities.

Table 2.50 Affinities with NVC for Cluster 5.

Group	NVC	Percentage	Community
6	S19	50.1	*Eleocharis palustris* swamp
	S19a	47.77	*Eleocharis palustris* swamp – *Eleocharis palustris* sub-community
	S12b	43.52	*Typha latifolia* swamp – *Mentha aquatica* sub-community
11	S19	44.94	*Eleocharis palustris* swamp
	S19a	40.82	*Eleocharis palustris* swamp – *Eleocharis palustris* sub-community
	S12	39.11	*Typha latifolia* swamp
14	S8	49.69	*Scirpus lacustris* swamp
	S19a	45.69	*Eleocharis palustris* swamp – *Eleocharis palustris* sub-community
	S4	44.8	*Phragmites australis* swamp and reed beds
24	S22	50	*Glyceria fluitans* water margin vegetation
	S22a	46.51	*Glyceria fluitans* water margin vegetation – *Glyceria fluitans* sub-community
	A9b	45.57	*Potamogeton natans* community – *Elodea canadensis* sub-community

2.4.21 Summary of plant communities

A summary of the plant communities identified in this chapter and the communities from the literature with which they have the strongest affinities is presented in Table 2.51.

Table 2.51 Summary table of plant communities from this study, compared with those previously published in the literature.

Cluster	Group	Name	Class (White & Doyle, 1984)	Ivimey-Cook & Proctor (1966)	O'Connell et al. (1984)	Goodwillie (1992)	Regan et al. (2007)	NVC
1	1	*Poa annua-Plantago major* community	Polygono-Poetea annuae	*Lolium perenne-Plantago major* association	NA	5A Dry annuals	NA	OV21 *Poa annua-Plantago major* community
2	2	*Persicaria amphibia-Eleocharis palustris* community	Plantaginetea majoris		Ranunculo-Potentilletum anserinae, *P. amphibium* variant	7A *P. amphibium*	NA	A10 *Polygonum. amphibium*, SD17
3	3	*Agrostis stolonifera-Ranunculus repens* community	Plantaginetea majoris	*Carex nigra-Potentilla anserina* association	Ranunculo Potentilletum anserinae, typical variant	6A Dry *Carex nigra*	Group 7	SD17 *Potentilla anserina-Carex nigra* dune slack community
3	4	*Agrostis stolonifera-Potentilla anserina-Festuca rubra* community	Plantaginetea majoris	*Potentilla anserina-Drepanocladus lycopodioides* nodum	Ranunculo Potentilletum anserinae, *Drepanocladus lycopodioides* variant	3B Sedge heath?	Group 7/8?	SD17a
4	5	Limestone Grassland	Molinio-Arrhenatheretea	Cynosurion cristati, Centaureo-Cynosuretum (O'Sullivan, 1984)	NA	2C Limestone Grassland	NA	CG10 *Festuca ovina-Agrostis capillaris-Thymus polytrichus*
5	6	*Eleocharis palustris-Ranunculus flammula* community	Littorelletea uniflorae	*Littorella uniflora-Baldellia ranunculoides* association?	NA	9C Marl Pond	NA	S19 *Eleocharis palustris* swamp
2	7	*Eleocharis palustris-Phalaris arundinacea* community	Plantaginetea majoris			7A *P. amphibium* (grassy)	NA	S19 *Eleocharis palustris* swamp
6	8	*Carex nigra-Carex panicea* community	Scheuchzerio-Caricetea fuscae	*Carex demissa* nodum	*Carex panicea-Carex flava* agg.	5B Sedge fen	NA	SD17 *Potentilla anserina-Carex nigra* dune slack community
3	9	*Phalaris arundinacea-Potentilla anserina* community	Plantaginetea majoris	*Potentilla anserina-Drepanocladus lycopodioides* nodum	Ranunculo Potentilletum anserinae?	3A Tall herb	NA	S28, M27
7	10	*Lolium perenne-Trifolium repens* community	Molinio-Arrhenatheretea	Lolio-Cynosuretum (O'Sullivan, 1984)	NA	2A *Lolium* grassland	NA	MG6 *Lolium perenne-Cynosurus cristatus* grassland
5	11	*Persicaria amphibia-Mentha aquatica* community	Plantaginetea majoris		Ranunculo-Potentilletum anserinae, *P. amphibium* variant	8A *Polygonum. amphibium*, 10A *Oenanthe aquatica*?	NA	S19 *Eleocharis palustris* swamp
6	12	*Filipendula ulmaria-Vicia cracca* community	Molinio-Arrhenatheretea	*Juncus acutiflorus-Senecio aquaticus* nodum		3A Tall herb	Group 6?	SD17 *Potentilla anserina-Carex nigra* dune slack community, M27 *Filipendula ulmaria-Angelica sylvestris* mire
3	13	*Potentilla anserina-Carex nigra* community	Plantaginetea majoris	*Carex nigra-Potentilla anserina* association	Ranunculo Potentilletum anserinae, *P. amphibium* variant	6B Wet *Carex nigra*	Group 5	SD17d *Hydrocotyle vulgaris-Ranunculus flammula sub*-community
5	14	Reedbed	Phragmitetea		Scirpetum lacustris, Cladietum marisci	11A Reedbed	NA	S8 *Scirpus lacustris* swamp

Table 2.51 (contd.) Summary table of plant communities from this study, compared with those previously published in the literature.

Cluster	Group	Name	Class (White & Doyle, 1984)	Ivimey-Cook & Proctor (1966)	O'Connell et al. (1984)	Goodwillie (1992)	Regan et al. (2007)	NVC
7	15	*Lolium perenne-Trifolium repens-Agrostis stolonifera* community	Molinio-Arrhenatheretea		NA	2B Poor grassland	NA	MG11 *Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland
2	16	*Equisetum fluviatile-Menyanthes trifoliata* community	Phragmitetea	*Glycerio-Sparganion*	Reedswamp and tall sedge communities	11B Peaty pond	NA	S10 *Equisetum fluviatile* swamp, S19 *Eleocharis palustris* swamp
2	17	*Carex nigra-Ranunculus flammula* community	Plantaginetea majoris		Ranunculo Potentilletum anserinae, *Carex nigra* variant	6D Peaty *Carex nigra*	Group 3/4?	M9 *Carex rostrata-Calliergon cuspidatum/giganteum* mire
2	18	*Agrostis stolonifera-Glyceria fluitans* community	Phragmitetea			9A Temporary pond	NA	S22 *Glyceria fluitans* water margin vegetation, S23 Other water margin vegetation, S19 *Eleocharis palustris* swamp
3	19	*Potentilla anserina-Potentilla reptans* community	Plantaginetea majoris	*Carex nigra-Potentilla anserina* association?	Ranunculo-Potentilletum anserinae, species poor *Potentilla reptans* variant	5B *Potentilla reptans* (species-poor)	Group 7	SD17d *Hydrocotyle vulgaris-Ranunculus flammula* sub-community
3	20	*Filipendula ulmaria-Potentilla erecta-Viola* sp. community	Plantaginetea majoris		Ranunculo-Potentilletum anserinae, species rich *Potentilla anserina* variant	4B *Potentilla reptans* (species rich)	Group 7?	SD17 *Potentilla anserina-Carex nigra* dune slack community
4	21	*Schoenus nigricans* fen	Scheuchzerio-Caricetea fuscae	*Schoenus nigricans-Cirsium dissectum* association	Cirsio-Schoenetum nigricantis molinietosum	4D *Schoenus* fen	Group 1	M13 *Schoenus nigricans-Juncus subnodulosus mire*
8	22	*Molinia caerulea-Carex panicea* community	Scheuchzerio-Caricetea fuscae		*Carex panicea-Carex flava* agg.	5D Sedge Fen	Group 2	M24 *Molinia caerulea-Cirsium dissectum*
6	23	*Carex nigra-Scorzoneroides autumnalis* community	Plantaginetea majoris	*Carex nigra-Potentilla anserina* association	Ranunculo Potentilletum anserinae, *Carex nigra* variant	5B *Potentilla reptans* (species-poor)?	Group7	SD17 *Potentilla anserina-Carex nigra* dune slack community
5	24	*Potamogeton natans-Glyceria fluitans* community	Potametea	*Eu-Potamion* alliance	Glycerietum fluitans?	12 Open water	NA	S22, S22a, A9 *Potamogeton natans*
8	25	*Carex nigra-Carex viridula* community	Scheuchzerio-Caricetea fuscae	*Carex demissa* nodum	*Carex panicea-Carex flava agg.*, species poor variant	5E *Carex flava*	Group 1?	SD17d *Hydrocotyle vulgaris-Ranunculus flammula sub-*community
1	26	*Eleocharis acicularis* community	Littorelletea uniflorae	*Eleocharis acicularis* stands	*NA*	9B *Eleocharis acicularis*	NA	OV31 *Rorippa palustris-Filaginella uliginosa* community
2	27	*Carex nigra-Equisetum fluviatile* community	Phragmitetea			11B Peaty pond?	NA	S19 *Eleocharis palustris* swamp
4	28	Flooded Pavement				3C Flooded Pavement	NA	

2.4.22 Derived variables

Mean Ellenberg values seem to vary by cluster (Table 2.52). For Light, the values range from 7.2 to 7.5, but the standard deviation indicates that this is not a significant difference. The largest range is in Wetness; which ranges from a mean value of 5.7 for Cluster 7 to 9.5 for Cluster 5.

Table 2.52 Mean Ellenberg indicator values and Grimes' C-S-R values for each cluster, ± standard deviation.

Cluster	Light	Wetness	pH	Fertility	C	S	R
1	7.2 ± 0.2	6.6 ± 1.0	6.4 ± 0.2	6.1 ± 0.5	2.23 ± 0.58	1.34 ± 0.24	3.64 ± 0.66
2	7.4 ± 0.3	8.3 ± 0.8	5.9 ± 0.5	4.7 ± 1.0	2.96 ± 0.42	2.15 ± 0.63	2.34 ± 0.53
3	7.2 ± 0.2	6.6 ± 0.7	6.1 ± 0.5	5.0 ± 0.8	2.91 ± 0.41	2.20 ± 0.47	2.52 ± 0.49
4	7.3 ± 0.2	6.2 ± 0.8	5.3 ± 0.6	3.1 ± 0.7	2.21 ± 0.40	3.54 ± 0.48	1.82 ± 0.46
5	7.3 ± 0.3	9.5 ± 0.6	6.2 ± 0.3	4.9 ± 0.8	3.27 ± 0.33	1.81 ± 0.55	2.30 ± 0.61
6	7.2 ± 0.2	6.9 ± 0.5	5.6 ± 0.5	4.1 ± 0.7	2.89 ± 0.41	2.71 ± 0.45	2.02 ± 0.34
7	7.3 ± 0.2	5.7 ± 0.4	6.2 ± 0.3	5.5 ± 0.5	2.95 ± 0.21	1.91 ± 0.39	2.97 ± 0.25
8	7.5 ± 0.2	7.8 ± 0.6	5.1 ± 0.7	2.6 ± 0.6	2.15 ± 0.38	3.60 ± 0.51	1.54 ± 0.38

Wetness, Fertility and Grime's S value had the highest Spearman's correlation coefficients (Table 2.6); these will be examined in more detail.

Wetness

As mentioned above, there is a large degree of variation in mean Ellenberg scores for Wetness among the 8 Clusters; this is represented graphically in Figure 2.8. Cluster 5, which contains communities that occur in the bottom of turloughs, and generally had some standing water when surveyed, has the largest mean Wetness value, at 9.5. At the other end of the scale is Cluster 7, which contains dry grassland communities, and has a mean Wetness value of 5.7.

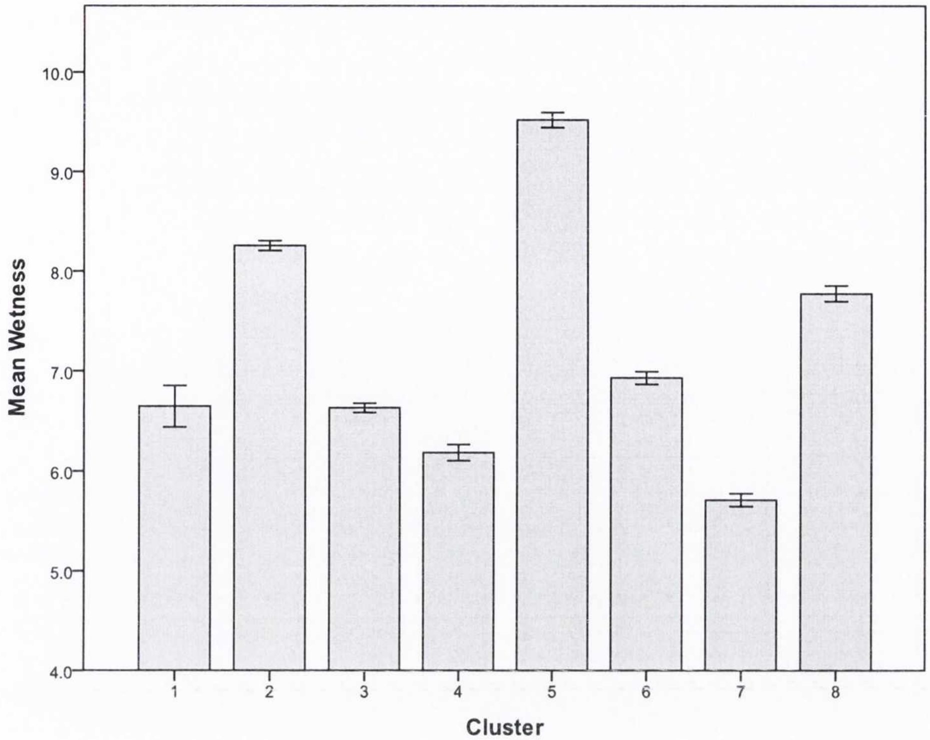


Figure 2.8 Barchart of mean Ellenberg Wetness values per cluster, ± standard error.

From Table 2.53, it can be seen that each cluster has a significantly different mean Wetness value to every other cluster, with the exception of Cluster 1, which is not significantly different to Clusters 3, 4 and 6.

Table 2.53 Mann-Whitney U tests for differences between cluster medians for Ellenberg Wetness values.

Cluster	1	2	3	4	5	6	7
2	**0.000**						
3	0.868	**0.000**					
4	0.041	**0.000**	**0.000**				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	0.032	**0.000**	**0.000**	**0.000**	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
8	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Significant p-values ($p < 0.05$) in bold (corrected for multiple comparisons with Dunn-Šidák correction).

Fertility

The mean Ellenberg value for Fertility ranged from 2.6 for Cluster 8 to 6.1 for Cluster 1 (Table 2.52, Figure 2.9). Cluster 5 is not significantly different to Clusters 2 or 3 (Table 2.54), but each other cluster is significantly different to all other clusters. Clusters 8 and 4 have the lowest mean Fertility values; these are clusters which contain communities within the Scheuchzerio-Caricetea fuscae, and are generally found on less eutrophic soils. By contrast, Cluster 1 has the highest mean Fertility value; this cluster contains a number of ruderal species which are characteristic of highly productive, highly disturbed environments. Cluster 7 also has a high mean Fertility value, this cluster contains two grassland communities which may be influenced by the management of farmland surrounding the turloughs; the presence of such species as *Lolium perenne* and *Trifolium repens* indicate that these are areas with a higher level of available nutrients.

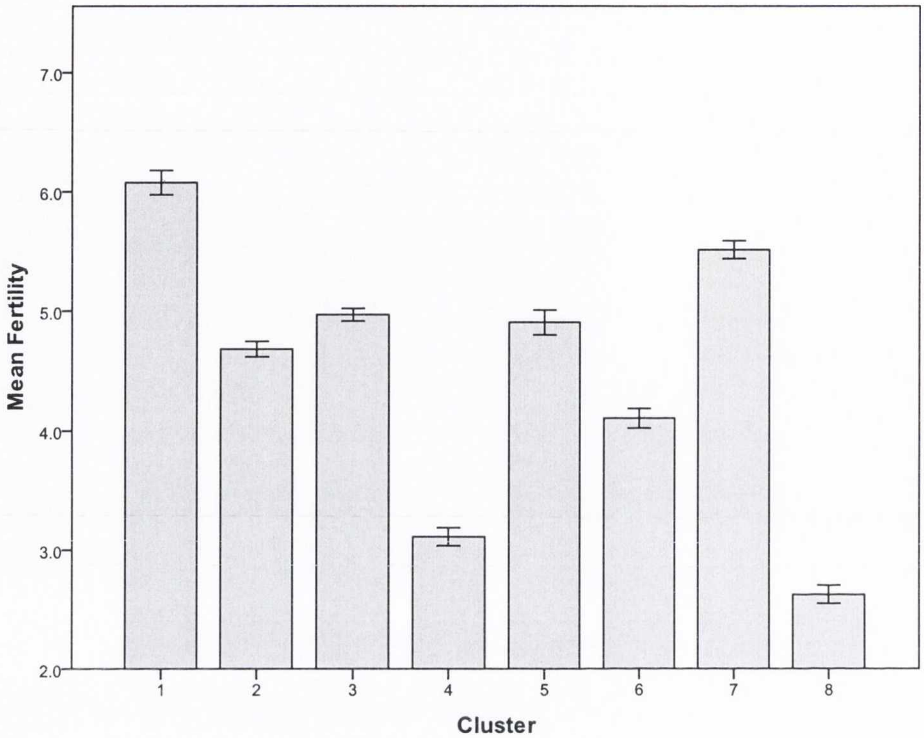


Figure 2.9 Barchart showing mean Ellenberg Fertility values per cluster, ± standard error.

Table 2.54 Mann-Whitney U tests for differences between cluster medians for Ellenberg Fertility values.

Cluster	1	2	3	4	5	6	7
2	**0.000**						
3	**0.000**	**0.001**					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	0.102	0.675	**0.000**			
6	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
8	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Significant p-values ($p < 0.05$) in bold (corrected for multiple comparisons with Dunn-Šidák correction).

Grime's S value

Grime's S value was the derived variable with the third highest level of correlation with the NMS axes. The mean values for Grime's S values are highest for Clusters 4 and 8 (Figure 2.10); these are significantly higher than the other clusters (Table 2.55). These values suggest that these clusters contain a high proportion of species which are stress-tolerators. In contrast, Clusters 1, 5 and 7 have a low proportion of stress-tolerators.

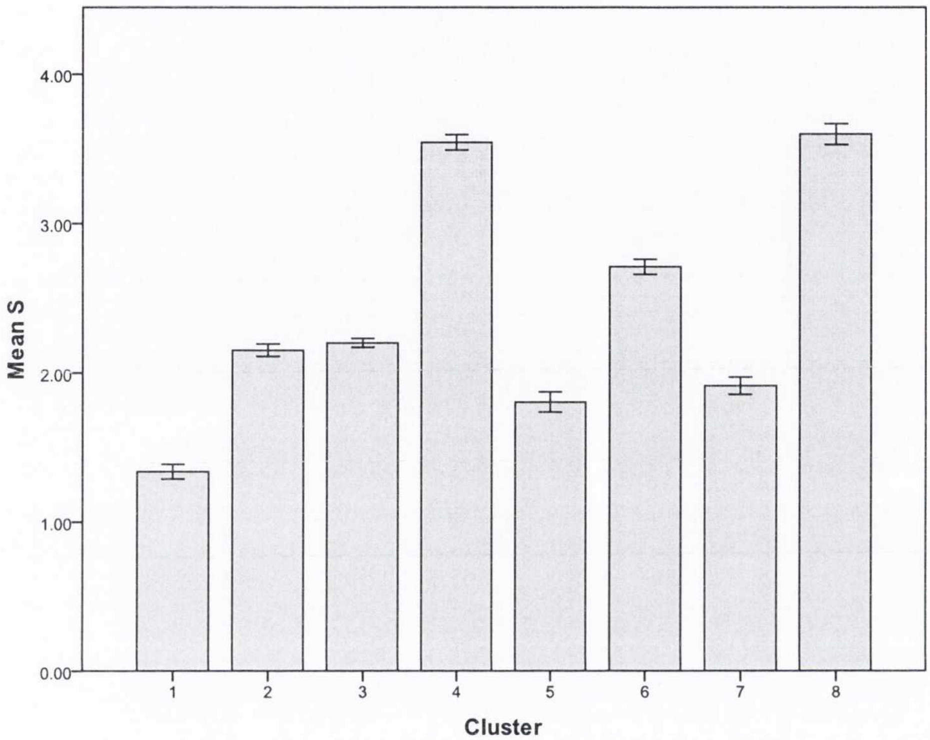


Figure 2.10 Barchart of mean Grime's S values per cluster, ± standard error.

Table 2.55 Mann-Whitney U tests for differences between cluster medians for Grime's S values.

Cluster	1	2	3	4	5	6	7
2	**0.000**						
3	**0.000**	0.223					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**		
7	**0.000**	0.014	**0.000**	**0.000**	0.156	**0.000**	
8	**0.000**	**0.000**	**0.000**	0.765	**0.000**	**0.000**	**0.000**

Significant p-values ($p < 0.05$) in bold (corrected for multiple comparisons with Dunn-Šidák correction).

Mean Ellenberg indicator values, Grime's C-S-R values and species richness are presented in Table 2.56.

Table 2.56 Summary statistics for derived variables for each vegetation group.

Group	Light	Wetness	pH	Fertility	C	S	R	Species richness
1	7.2 ± 0.1	5.9 ± 0.6	6.3 ± 0.2	6.4 ± 0.3	2.04 ± 0.42	1.37 ± 0.22	3.93 ± 0.41	10 ± 2
2	7.3 ± 0.2	8.2 ± 0.7	6.2 ± 0.3	5.2 ± 0.7	2.99 ± 0.27	1.81 ± 0.38	2.68 ± 0.30	10 ± 3
3	7.2 ± 0.2	6.7 ± 0.6	6.1 ± 0.3	5.2 ± 0.6	3.00 ± 0.32	2.04 ± 0.36	2.57 ± 0.39	14 ± 3
4	7.3 ± 0.2	6.2 ± 0.4	6.0 ± 0.3	4.7 ± 0.7	2.67 ± 0.28	2.41 ± 0.43	2.67 ± 0.36	14 ± 3
5	7.3 ± 0.2	5.9 ± 0.5	5.4 ± 0.5	3.3 ± 0.6	2.21 ± 0.43	3.50 ± 0.54	2.02 ± 0.41	18 ± 3
6	7.4 ± 0.3	9.5 ± 0.5	6.1 ± 0.3	4.7 ± 0.9	3.08 ± 0.14	1.96 ± 0.54	2.53 ± 0.41	8 ± 2
7	7.3 ± 0.2	8.5 ± 0.5	6.2 ± 0.5	5.2 ± 0.9	3.56 ± 0.65	2.06 ± 0.62	1.71 ± 0.43	8 ± 3
8	7.2 ± 0.2	7.3 ± 0.5	5.2 ± 0.4	3.5 ± 0.6	2.64 ± 0.35	2.95 ± 0.46	1.92 ± 0.34	15 ± 3
9	7.1 ± 0.2	7.3 ± 0.6	6.7 ± 0.3	5.9 ± 0.4	3.79 ± 0.40	1.80 ± 0.32	1.83 ± 0.43	7 ± 2
10	7.3 ± 0.1	5.5 ± 0.3	6.0 ± 0.1	5.1 ± 0.4	2.85 ± 0.12	2.25 ± 0.28	3.01 ± 0.18	15 ± 3
11	7.1 ± 0.1	9.2 ± 0.5	6.3 ± 0.2	5.7 ± 0.3	3.24 ± 0.27	1.24 ± 0.22	2.64 ± 0.32	6 ± 2
12	7.1 ± 0.2	6.6 ± 0.4	5.9 ± 0.4	4.5 ± 0.4	3.15 ± 0.29	2.54 ± 0.29	2.08 ± 0.30	13 ± 3
13	7.4 ± 0.3	7.4 ± 0.6	6.0 ± 0.7	4.8 ± 1.1	2.82 ± 0.34	2.38 ± 0.67	2.25 ± 0.66	7 ± 2
14	7.5 ± 0.4	9.4 ± 0.6	6.3 ± 0.6	4.8 ± 0.7	3.34 ± 0.30	2.23 ± 0.55	1.98 ± 0.56	5 ± 1
15	7.3 ± 0.2	5.9 ± 0.5	6.3 ± 0.3	5.8 ± 0.3	3.02 ± 0.24	1.66 ± 0.24	2.94 ± 0.30	10 ± 4
16	7.5 ± 0.3	9.0 ± 0.6	5.6 ± 0.8	4.4 ± 0.8	2.83 ± 0.40	2.59 ± 0.71	1.80 ± 0.40	8 ± 3
17	7.4 ± 0.2	7.9 ± 0.6	5.7 ± 0.5	4.0 ± 0.7	2.86 ± 0.38	2.49 ± 0.48	2.24 ± 0.38	12 ± 2
18	7.2 ± 0.4	8.6 ± 0.9	6.1 ± 0.4	5.4 ± 0.8	2.95 ± 0.34	1.60 ± 0.51	2.71 ± 0.48	8 ± 3
19	7.3 ± 0.2	6.1 ± 0.5	6.5 ± 0.3	5.2 ± 0.4	2.83 ± 0.14	2.07 ± 0.21	2.88 ± 0.18	10 ± 3
20	7.3 ± 0.1	6.2 ± 0.4	5.9 ± 0.3	4.0 ± 0.4	2.71 ± 0.24	2.56 ± 0.27	2.42 ± 0.40	13 ± 2
21	7.3 ± 0.2	7.2 ± 0.6	4.9 ± 0.7	2.3 ± 0.3	2.33 ± 0.29	3.52 ± 0.25	1.42 ± 0.20	13 ± 3
22	7.5 ± 0.3	7.7 ± 0.6	5.0 ± 0.7	2.7 ± 0.6	2.17 ± 0.40	3.56 ± 0.53	1.60 ± 0.38	11 ± 3
23	7.1 ± 0.3	6.8 ± 0.5	6.1 ± 0.3	4.6 ± 0.6	2.98 ± 0.42	2.48 ± 0.41	2.11 ± 0.36	12 ± 2
24	7.0 ± 0	10.3 ± 0.5	6.0 ± 0	4.3 ± 0.4	3.83 ± 0.21	1.87 ± 0.18	1.34 ± 0.43	4 ± 2
25	7.6 ± 0.2	8.3 ± 0.2	5.6 ± 0.7	2.1 ± 0.1	2.08 ± 0.26	3.80 ± 0.36	1.23 ± 0.20	6 ± 2
26	7.2 ± 0.2	7.3 ± 0.9	6.4 ± 0.2	5.8 ± 0.4	2.39 ± 0.66	1.31 ± 0.27	3.39 ± 0.75	10 ± 3
27	7.6 ± 0.4	9.3 ± 0.8	4.9 ± 0.6	3.4 ± 0.9	2.60 ± 0.39	3.23 ± 0.54	1.39 ± 0.43	5 ± 2
28	7.1 ± 0.3	5.7 ± 0.6	5.5 ± 0.4	3.2 ± 0.6	1.96 ± 0.34	3.86 ± 0.35	1.42 ± 0.34	13 ± 2

When the mean Ellenberg Wetness and Fertility scores were plotted on a scatterplot, a clear division between clusters can be seen (Figure 2.11). Communities in Cluster 5 (yellow dots), which contains communities such as the Reedbed and *Potamogeton natans-Glyceria fluitans* communities, occur in the top right-hand side of the graph, indicating a high mean Wetness score and a high mean Fertility score. The two *Lolium perenne*-dominated communities (Cluster 7, light blue dots) occur on the top right-hand side of the scatterplot, suggesting that these communities occur in areas with relatively high fertility and experience little inundation. The two clusters with the lowest mean Ellenberg Fertility values (Clusters 4 and 8) occur on the bottom of the Fertility gradient; these represent communities which may occur on poorer soils, such as the *Molinia caerulea-Carex panicea* community.

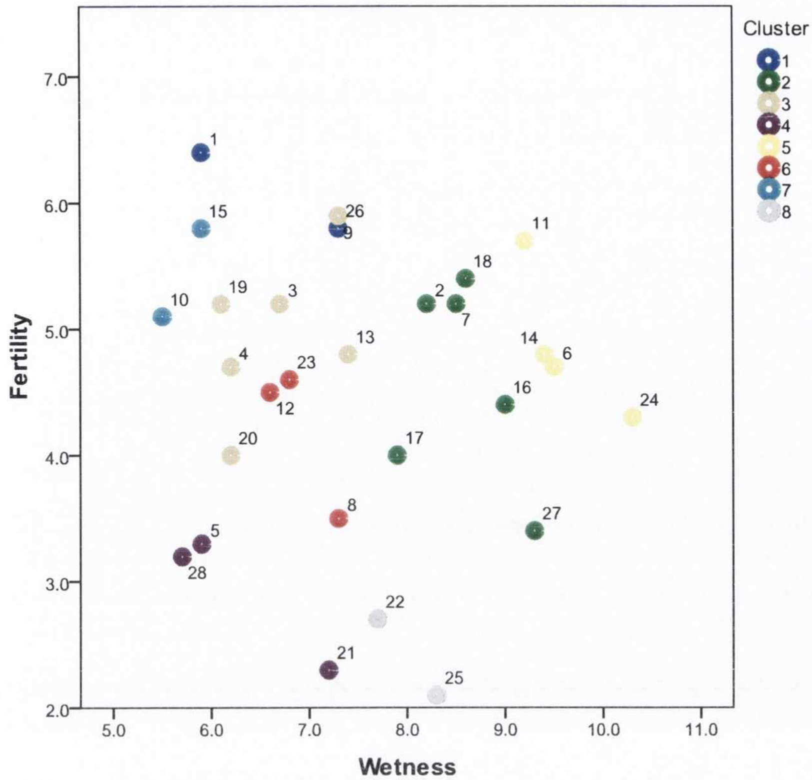
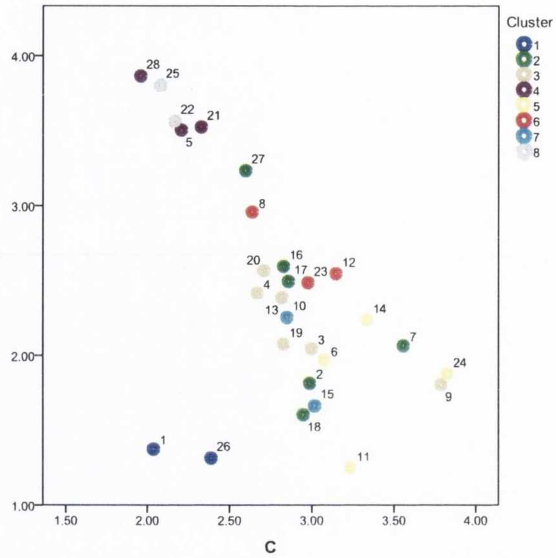


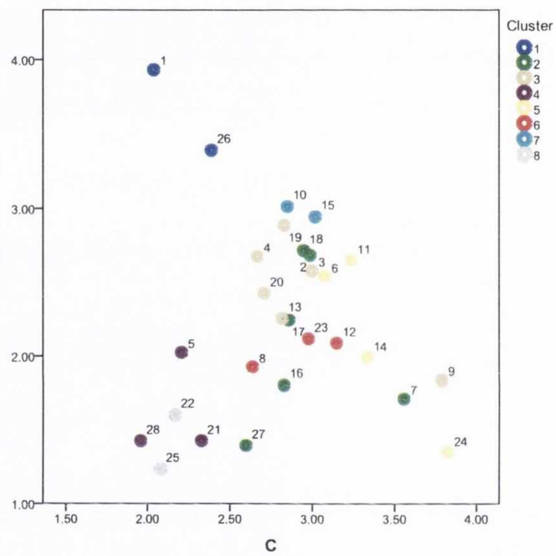
Figure 2.11 Scatterplot of mean Ellenberg Fertility and Wetness indicator value for each vegetation community. Points are labelled with group number, and coloured according to cluster.

When scatterplots were created for the C-S-R scores for the 28 vegetation groups, the different clusters seem to represent different 'strategies' for survival in the turlough environment (Figure 2.12). Cluster 1, for example, represented by dark blue dots, has very low mean scores for 'competitiveness' and 'stress-toleration' (Figure 2.12A), but has the highest scores for 'ruderal' (Figure 2.12B, C). Clusters 4 and 8, represented by dark blue and grey dots, have high mean scores for 'stress-toleration' (Figure 2.12A), but score low on the 'competitive' and 'ruderal' scales (Figure 2.12B, C).

A – Scatterplot of mean C and S values



B – Scatterplot of mean C and R values



C – Scatterplot of mean S and R values

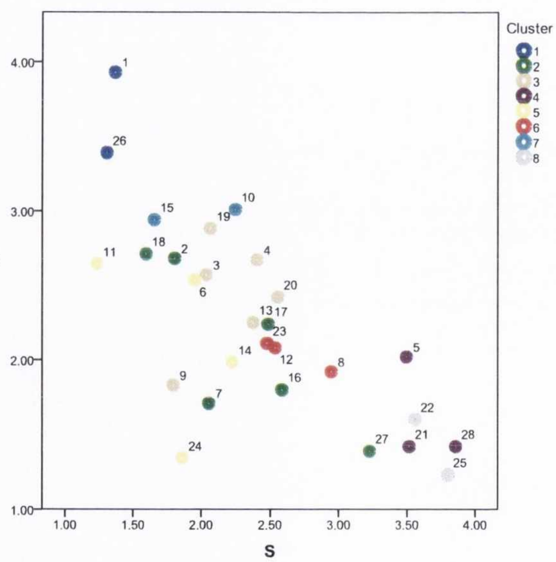


Figure 2.12 Scatterplots showing the relationship between Grime's C-S-R values and the 28 vegetation communities. Points are labelled with group number, and coloured according to cluster

2.5 Discussion

Vegetation surveys were carried out in 22 turloughs, yielding 813 relevés containing 239 species. Twenty eight plant communities were identified by cluster analysis and indicator species analysis. There was overlap between many of the plant communities in terms of species composition; this meant that few species were faithful to any one group. Plant species which were common in this study included *Agrostis stolonifera, Potentilla anserina, Galium palustre, Ranunculus repens* and *Carex nigra.*

Vegetation communities classified and described in this thesis

The communities described in this study occur from the fringes of turloughs right down to the bottom, and range from fully terrestrial grasslands which experience little inundation to aquatic communities.

Molinio-Arrhenatheretea

Grassland communities dominated the upper zones of the turloughs surveyed during this study. The *Lolium perenne-Trifolium repens* community and the *Lolium perenne-Trifolium repens-Agrostis stolonifera* community both show an anthropogenic influence, with species such as *Lolium perenne.* These communities often grade into managed grazing land outside of the turlough boundary.

The Limestone Grassland community was most similar to the other grassland communities described here, although a number of species more typical of calcareous habitats were found.

The Flooded Pavement community was characterised by exposed limestone pavement, and *Potentilla fruticosa* was frequent here. This community was difficult to classify, however, and so was not assigned to a class.

Scheuchzerio-Caricetea fuscae

A number of communities were described which fall within the Scheuchzerio-Caricetea fuscae, or the small sedge communities as described by O'Connell et al. (1984) These were the *Schoenus nigricans* fen, the *Molinia caerulea-Carex panicea* community, the *Carex nigra-Carex panicea* community, and the *Carex nigra-Carex viridula* community.

These are communities that are characterised by species which require the water table to remain near the surface throughout the growing season – *Carex panicea, C. nigra* and *C. flacca* are all species which can compete effectively when the water levels remain consistently high (Gowing and Spoor 1998).

Plantaginetea majoris

Ranunculo-Potentilletum anserinae

A number of communities defined herein correspond to those previously described by O'Connell et al. (1984) as belonging to the Ranunculo-Potentilletum anserinae. These are 'typical' turlough communities, occurring in a wide range of turloughs, and generally characterising the middle to lower zone of the turlough.

Chiefly composed of species such as *Potentilla anserina, Carex nigra* and *Agrostis stolonifera*, there is a large amount of variation between the different variants of this association.

A number of communities show affinity with the *Eleocharis palustris* swamps of the NVC. These occur in areas which seem to retain water until late in the growing season, and have frequent and abundant species such as *Eleocharis palustris* and *Ranunculus flammula.*

Phragmitetea

Group 14, the Reedbed community, represents the tall sedge and reed swamp vegetation of turloughs, but was under sampled in this study. Other communities which seemed to belong to the Phragmitetea were the *Equisetum fluviatile-Menyanthes trifoliata* community, the *Agrostis stolonifera-Glyceria fluitans* community, and the *Carex nigra-Equisetum fluviatile* community.

Potametea

The *Potamogeton natans-Glyceria fluitans* community represents the permanently inundated part of the vegetation of turloughs.

Littorelletea uniflorae

The *Eleocharis palustris-Ranunculus flammula* community and the *Eleocharis acicularis* communities belong to this class.

Polygono-Poetea annuae

The *Poa annua-Plantago major* community was the only community to belong to this class.

Other communities

The *Rumex crispus-Alopecurus geniculatus* nodum of the Plantaginetalia majoris (Ivimey-Cook and Proctor 1966) was not recorded during the field work for this thesis. It was, however, found in Lough Aleenaun during surveying work for mapping. It was found at a level that was not accessible due to flooding during field work.

2.5.1.1 Comparison with previously published vegetation communities

Two associations are repeatedly described in the literature as being typical of turloughs – these are the small sedge communities of the Scheuchzerio-Caricetea fuscae and the Ranunculo-Potentilletum anserinae. Both of these associations were well-represented in the current study. The *Carex nigra-Carex panicea* community (Group 8), the *Schoenus nigricans* fen (Group 21), the *Molinia caerulea-Carex panicea* community (Group 22) and the *Carex nigra-Carex viridula* community all belong to the Scheuchzerio-Caricetea fuscae. The Ranunculo-Potentilletum anserinae is represented by the *Phalaris arundinacea-Potentilla anserina* community (Group 9), the *Potentilla anserina-Carex nigra* community (Group 13), the *Carex nigra-Ranunculus flammula* community (Group 17), the *Potentilla anserina-Potentilla reptans* community (Group 19), the *Filipendula ulmaria-Potentilla erecta-Viola* sp. community (Group 20) and the *Carex nigra-Scorzoneroides autumnalis* community. The remainder of the plant communities either belong to classes which are similar to those found just outside the turlough boundary, such as the Molinio-Arrhenatheretea, or to classes such as the Phragmitetea or Potametea which contain communities which require higher water levels.

The communities in this study could be assigned to previously published communities in most cases. Where there was no clear affinity for previously published communities, it is possible that the vegetation either represents a transition between different communities or a sub-community which was not previously defined, was not sampled in previous studies, or was insufficiently mature when recorded. Regan et al. (2007) suggest that the communities with abundant *Carex nigra* and *Potentilla anserina* represent a transition between the more sedge-dominated communities and the forb-dominated communities.

2.5.1.2 Dune slack communities

It is perhaps initially surprising to see such a high level of affinity for the NVC dune slack communities amongst the turlough vegetation communities. Dune slacks and turloughs, however, share many environmental characteristics, which have lead to the formation of similar vegetation types. The dune slack communities mentioned occur in areas with high winter rainfall, and the water table is not far from the surface, resulting in localised winter flooding, and a damp substrate during the summer. Leaching from the sandy soils results in a relatively oligotrophic habitat, while gleying of the soils occurs in dune slacks as in turloughs (Ranwell 1959). Additionally, dune slacks are often calcareous where shell sand forms the substrate. The similarities between some turlough vegetation communities and sand dune communities are referenced by Ivimey-Cook and Proctor (1966) and by Proctor (2010), but are not dealt with in any great detail.

The use of MAVIS to calculate affinity of the vegetation types defined in this study with those of the NVC was of mixed use. The top goodness-of-fit scores ranged from 33.98% for Group 28 and MC10b to 65.89% for Group 15 and MG11. The former indicates a poor correlation between the communities, while the latter is a good fit; the discrepancies in these scores suggest that care must be taken when relying on these data.

2.5.1.3 Variation between sites

While much of the variation in turlough plant communities seems to be due to hydrological regime, as evidenced by the zonation in vegetation from the fringes of the basin to the bottom, other factors such as soil type, nutrient status and management are also thought to be important drivers of variation in vegetation. There is, therefore, much variability between turloughs, as well as within turloughs. Some vegetation types only occur on certain substrates, for example the Flooded Pavement community occurs on exposed limestone pavement, and is therefore restricted in its range. Similarly, communities such as the *Potamogeton natans-Glyceria fluitans* community can only occur where there is permanent water throughout the year.

2.5.1.4 Communities of high conservation value

A number of the communities found do not commonly occur outside of turloughs, at least in Ireland, and some of these did not seem to fit with communities in the NVC, suggesting that their occurrence is limited, or at least not yet reported, in the rest of the British Isles. Given their restricted distribution, these communities are likely to be of high conservation value. In addition, some communities have been identified as those in which rare species occur. Communities suggested to have high conservation value are listed in Table 2.57.

Table 2.57 Turlough communities of high conservation value

Group	Community
20	*Filipendula ulmaria-Potentilla erecta-Viola* community
23	*Carex nigra-Scorzoneroides autumnalis* community
25	*Carex nigra-Carex viridula* community
26	*Eleocharis acicularis* community
28	Flooded Pavement

Group 20, the *Filipendula ulmaria-Potentilla erecta-Viola* community is important as it often contains *Viola persicifolia*, which is listed as vulnerable in the Irish Red Data Book (Curtis and McGough 1988). *Teucrium scordium* occurs within Group 23, the *Carex nigra-Scorzoneroides autumnalis* community; even though it occurs at a relatively low frequency, it is an indicator species for this community. A revision to the Irish Red Data List for Vascular Plants is in preparation (http://www.botanicgardens.ie/gspc/pdfs/rdboct2005.xls), and it is proposed to add *T. scordium* to the Red Data List. The *Carex nigra-Carex viridula* community (Group 25) did not show a high affinity with any NVC communities, suggesting it may not occur elsewhere in the British Isles. It was similar to communities defined by previous studies on turlough vegetation, suggesting its distribution may be restricted to turloughs. Group 26, the *Eleocharis acicularis* community is of very high conservation value. *Rorippa islandica* and *Limosella aquatica*, both of which are listed as vulnerable in the Red Data Book (Curtis and McGough 1988) occur within this community. The Flooded Pavement community (Group 28) is also of high conservation value, especially as habitat for *Potentilla fruticosa*, a species which is rare throughout the British Isles and largely restricted to the fringes of some turloughs in Ireland (Elkington and Woodell 1963, Webb and Scannell 1983).

2.5.1.5 Initial investigation into environmental factors affecting vegetation

This chapter was primarily concerned with classifying and describing the vegetation of turloughs using floristic data. In an attempt to place the vegetation communities into context, a number of derived variables were calculated in an attempt to relate the differences in vegetation communities to differences in environmental conditions. Mean Ellenberg values were used for this, as they have been shown to be useful in a range of vegetation studies (for example ter Braak and Wiertz 1994, Chytrý et al. 2009, Sullivan et al. 2010). They have also been used in some turlough studies (Regan et al. 2007, Williams et al. 2009).

A number of previous studies have designated flooding as the primary factor driving turlough vegetation (for example O'Connell et al. 1984, Goodwillie 1992, Moran et al. 2008a). An initial investigation into this, based on the separation of communities according to mean Ellenberg Wetness values, backs this up, and there is a clear relationship between Axis 1 and mean Ellenberg Wetness value in the ordination (Figure 2.5, Table 2.6). Furthermore, the mean Ellenberg Wetness value differs significantly between clusters, with the exception of Cluster 1 (Figure 2.8, Table 2.53). Cluster 1, however, contains two very different vegetation communities, the *Poa annua-Plantago major* community, which can occur throughout the turlough, therefore at different flooding durations, and the *Eleocharis acicularis* community, which occurs on wet mud near permanent water at the base of turloughs.

Trophic status is a secondary factor influencing turlough vegetation communities (Goodwillie 1992). Mean Ellenberg Fertility values were shown to have a strong relationship with Axis 2 of the ordination (Figure 2.5, Table 2.6). When this was examined in more detail, it was found that Cluster 5 is not significantly different to Clusters 2 or 3 (Figure 2.9 and Table 2.54), but each other cluster is significantly different to all other clusters. Species found in Cluster 7, which had one of the higher mean Ellenberg Fertility values, such as *Plantago major, Ranunculus repens, Trifolium repens, Lolium perenne, Agrostis stolonifera, Rumex crispus* and *Cerastium fontanum* are generally found in more productive communities (Grime et al. 1988, Rodwell 1992). All of these species, except for *Cerastium fontanum*, have high Ellenberg values (Hill et al. 1999).

Both soil properties and management practice have been determined as important factors for differentiating vegetation types in the Cirsio-Molinietum community in Great Britain (Rodwell 1991). The intensity of grazing is also important; affecting species composition - increased grazing leads to an increase in rosette-forming species, as these can somewhat escape grazing pressure (Rodwell 1991). These factors will be explored in Chapter 3.

Previous studies investigating the relationship between turlough vegetation communities and environmental conditions have concentrated on the 'typical' turlough communities represented by the small sedge-dominated communities and the grass- and forb-dominated communities (Regan et al. 2007, Moran et al. 2008a). In order to compare the communities in this study with those of Regan et al. and Moran et al., just the sedge-dominated (Scheuchzerio-Caricetea fuscae) communities and the forb-dominated (Ranunculo-Potentilletum anserinae) communities were examined in further detail. In Figure 2.13, the sedge- and forb-dominated communities are arranged on a scatterplot according to mean Ellenberg Wetness and Fertility values for each community (this is a subset of the communities presented in Figure 2.11). The sedge-dominated communities cluster to the bottom right-hand side of the scatterplot, indicating that these communities have a high mean Ellenberg Wetness value, and a low mean Ellenberg Fertility value. The forb-dominated groups show a greater spread in Ellenberg Wetness value, but generally have a high mean Ellenberg Fertility value. These are similar results to those reported in the literature. Regan et al. (2007) found that their sedge-dominated communities were associated with higher soil moisture and nutrient concentration than the grass- and forb- dominated communities. Moran et al. (2008) also found that two of their three sedge-dominated communities had a higher percentage of soil moisture than all of the four forb-dominated communities, but did not examine nutrient status of the soil or water. In Skealoghan turlough, the

Cirsio-Molinietum was found at higher elevations (and therefore areas which experience less inundation) while the Ranunculo-Potentilletum anserinae was found at lower elevations (Moran et al. 2008a).

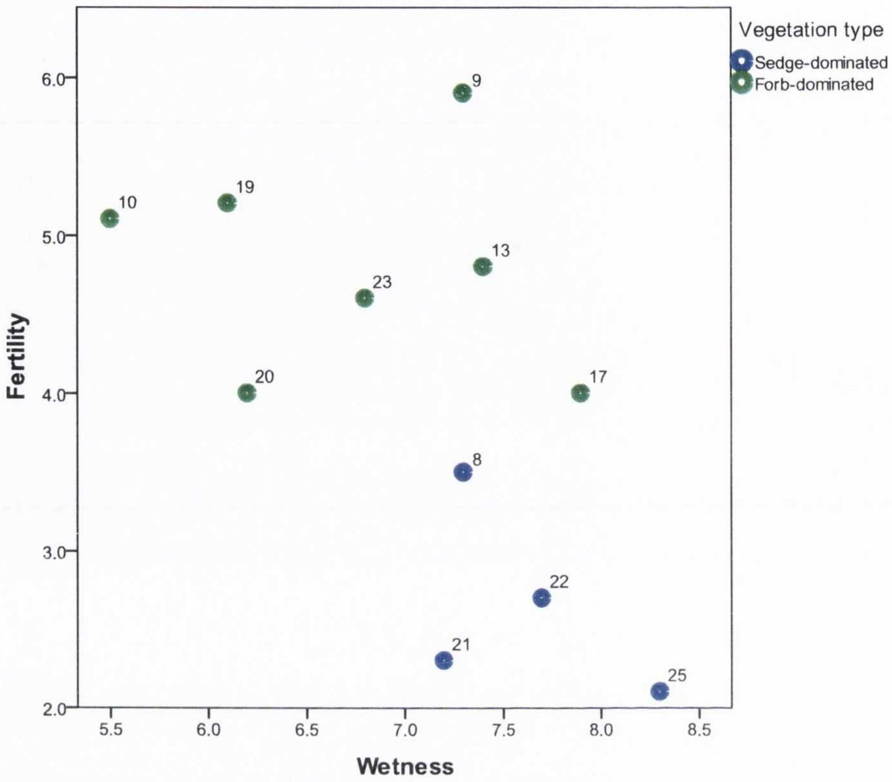


Figure 2.13 Scatterplot of mean Ellenberg Fertility and Wetness indicator value for the sedge-dominated and forb-dominated communities. Points are labelled with group number, and coloured according to sedge- or forb-dominated group.

These results suggest that, while the forb-dominated communities may occur deeper within the turlough basin, they occur on more freely draining soil, whereas the sedge-dominated communities may experience less inundation, but occur on more water-logged soils. This will be explored in greater depth in Chapter 3, using hydrological, soil and water chemistry data.

The scatterplots showing the relationships between the C-S-R scores for the vegetation groups (Figure 2.12) suggest that the vegetation communities are comprised of species which occupy specific ecological niches within turloughs which they inhabit. Some, such as Cluster 1, seem likely to avoid the stresses of turlough life through life-history adaptations (i.e. with a high proportion of ruderal species), while others appear to grow in areas with low nutrient availability, such as Clusters 4 and 8. However, it is important to note that the Ellenberg values are indicators of likely ecological conditions, not direct measurements of nutrient status or waterlogging. The hypotheses put forward above will be explored in more depth in Chapter 4, where plant communities and functional groups will be examined in conjunction with hydrological, soil and water chemistry data.

2.6 Conclusion

In this study, the vegetation communities of 22 turloughs were investigated in detail. 28 vegetation communities were identified and described, and then compared with communities already described in the literature. There was a good degree of correlation between the communities in this study and those previously defined. Some communities did not correspond well with those in the literature, however, and some previously published communities were not recorded due to logistical difficulties.

A number of communities identified were of high conservation value, in particular Group 20, the *Filipendula ulmaria-Potentilla erecta-Viola* sp. community, Group 26, the *Eleocharis acicularis* community and Group 28, the Flooded Pavement community.

Mean Ellenberg values were used as indicators of likely ecological condition; the vegetation communities appear to be aligned along a wet-dry continuum in one axis of the ordination, and along a fertility gradient in the other, suggesting that hydrology and nutrient availability are likely to be important drivers in determining turlough vegetation.

3 Environmental drivers of turlough vegetation

3.1 Introduction

The natural hydrological changes inherent to the turlough ecosystem mean that they are highly dynamic habitats. While the changing water levels are the most obvious of the factors affecting turlough ecology, there is a highly complex relationship between the hydrology, the water quality of the flood waters, the underlying geology and soil type, the management and the associated plant and animal communities of the turlough habitat (Tynan et al. 2006). This chapter will attempt to identify and quantify the relationships between these factors and turlough vegetation.

3.1.1 Hydrology

Seasonally or intermittently flooded wetlands pose a number of challenges for the plants which live there, and hydrology, disturbance, spatial heterogeneity and productivity are all major factors which affect them (Pollock et al. 1998). A constantly changing water regime changes the physical and chemical properties of soils (Ponnamperuma 1984), which affects the relative competitive abilities of plant species, thereby influencing the species composition of vegetation communities (Pollock et al. 1998, Kennedy et al. 2003). Three main aspects of the hydrological regime have been shown to have the greatest effect on the ecology of wetlands; these are duration, depth and frequency of flooding (de Becker et al. 1999, Casanova and Brock 2000, Thompson and Finlayson 2001). These three aspects of the flooding regime are also assumed to be the main drivers of change in turlough vegetation communities, while the level of the summer water table has also been determined to be an important factor (O'Connell et al. 1984, Goodwillie 1992, 2003, Visser et al. 2006, Regan et al. 2007).

Depth of flooding will impact on the species which can survive in an area within a turlough, and therefore on the communities which are found there. Voesenek et al. (2004) found that tolerance to flooding through rapid growth of stems and petioles was a favourable trait in areas with shallow and prolonged flood events; this would not be a profitable use of resources in the bottom of deep turloughs or those which flood and empty rapidly and repeatedly. The rhizomes of some plants, such as *Schoenoplectus lacustris*, can survive months of total anoxia (Crawford 2008). While flooding tolerance gives an advantage to certain plant species, the recession of floodwaters is also a disturbance. Adaptations which allow plants to tolerate inundation may reduce competitive ability in the absence of flooding; for example Koncalova (1990) suggested that the presence of aerenchyma could decrease the capacity for nutrient uptake of graminoids. Very frequent flood events may therefore impose an extra level of stress upon plants.

The timing of flooding may affect how it is tolerated by different plants; summer flooding, for example in response to an unusually heavy precipitation event, may be of a shorter duration than winter flooding, but the higher temperatures of the growing season can mean a greater metabolic oxygen demand, resulting in greater tissue damage under anoxic conditions than would be expected during a cooler season (Crawford 2008).

Turlough vegetation generally exhibits a readily observed zonation, from the unaffected terrestrial communities outside the turlough boundary, to the communities at the bottom of the flooding gradient which experience the longest and deepest inundation (Goodwillie and Reynolds 2003). Plant communities in the upper zones generally have some relationship with the vegetation communities outside the influence of the flooding regime, so that the vegetation in the upper zones of turloughs which occur within managed farmland reflects the vegetation of the managed fields outside it, with large amounts of *Lolium perenne* and *Trifolium repens*, for example.

While flood-tolerant trees are common in tropical areas (e.g. mangrove swamps), the colder winter temperatures of temperate regions place extra stresses on tree root systems, requiring trees to maintain their root systems in anaerobic conditions. Winter conditions in Ireland (long, wet, and mild) appear to be the least hospitable to flood-tolerant trees. Colder winters are less stressful; frozen soils reduce oxygen demand (Crawford 1992), while flooded trees in warmer climes are less likely to become dormant, and can therefore maintain aeration of their roots. Conditions in north-western Europe, however, are such that winter flooding usually occurs before dormancy of tree roots, resulting in damage to the root system. Flooding thereby limits the encroachment of scrub and woody species into wetlands. In a study of the effects of flooding duration, frequency and depth on woody saplings, increasing inundation resulted in decreased presence of hardwoods, and this effect was especially strong if the inundation occurred during the growing season (Vreugdenhil et al. 2006). This can be observed in turloughs; even in sites where grazing is minimal a 'scrub line' is evident, beyond which new scrubby or woody species do not tend to become established. Some authors suggest grazing also plays an important part in limiting the encroachment of scrub into the turlough basin (Goodwillie 2003, Sheehy Skeffington et al. 2006), although duration and extent of flooding would seem to be a more important factor, as noted by Praeger (1932) The life-history of trees and shrubs may also contribute to their vulnerability to flooding; an extreme event once every number of years may kill off any seedlings or saplings that have managed to become established.

3.1.2 Soils

Turloughs occurring in different catchments may also have different soil types; in a study on eight turloughs from two different catchment areas, Kimberley (2007) found that the hydrology, parent materials and hydrochemistry associated with the aquifers in the catchments influenced the soil types of turloughs found therein. Soils in the Coole Garryland catchment area were mineral and moderately calcareous, while those in the East Burren were more organic and highly calcareous. Differences such as these can have huge effects on the species composition of plant communities. Nutrient status also differed between catchments, this may be attributed to differences in soil and underlying geology, but the nutrient content of floodwaters will also have an effect.

As with vegetation, turlough soils can exhibit zonation, with the soil type changing as the duration of flooding increases, i.e. with depth in the turlough basin. MacGowran (1985) found the soils in the upper reaches of turloughs to be generally light, freely draining rendzinas and rendzina-like soils, transitioning through more strongly gleyed soils to silty or marly substrates at the base. Peaty soils were found to be relatively extensive, but generally shallow (usually less than 30cm). The soil in the bottom of a turlough basin can be clay, sand, silt, peat or marl, or a combination of these, and is associated with the hydrological regime of the turlough (Coxon 1987b). Different substrates have different levels of permeability, which affects how quickly water drains from the soil when flooding recedes, and hence how waterlogged (or not) the soil remains. Some areas within turloughs may have impermeable layers of marl underneath other substrates, which can result in the overlying soil retaining water, or even perched water tables which persist throughout the year.

3.1.3 Water chemistry

Turloughs are generally flooded by groundwater, rain and overland flow may also contribute to the hydrology, but are generally thought to be of lesser importance. The chemistry and nutrient status of turlough floodwaters are influenced by the catchment area.

Cunha Pereira et al. (2010) suggest that nutrient leaching from soils in the turlough catchment, rather than soils within the turlough basin, is the main source of nutrient input into turlough waters. Since turloughs are generally surrounded by agricultural land, this can be an important source of nutrients, and the quality of floodwaters is thought to be one of the main factors affecting trophic status of turloughs (Southern Water Global 1998). Aside from inputs from agriculture, the geology and soils of catchments can also influence the nutrient status of floodwaters (Kimberley 2007), and hence the trophic status of turloughs.

3.1.4 Nutrient status

To date, trophic statuses of turloughs in the dry phase have been estimated based on the proportion of terrestrial plant communities with enrichment-sensitive species (Goodwillie 1992, Working Group on Groundwater 2004). Turloughs are generally thought of as oligotrophic, although there are more eutrophic turloughs, more oligotrophic turloughs, and gradations in between (Goodwillie 2001). Even within a single turlough basin, there may be differences in nutrient content of soils; for example there may be richer patches of soil along the winter flood line or near swallow holes.

3.1.5 Management

The management and land use of turloughs, including regulating the amount of grazing which occurs on them, is an important factor in biodiversity maintenance. A number of management practices have been identified as damaging to turlough biota, such as turf cutting, drainage and fertiliser application. These have largely been stopped in turloughs due to legislation. Ní Bhriain et al. (2003) reported that, of ten farmers surveyed at Caherglassaun turlough, eight had applied fertiliser to either land directly adjacent to or within the turlough basin itself.

Many wetlands have been used historically for grazing (Williams 1990), and maintaining certain levels of grazing are likely to be important for maintaining biodiversity (Bignal and McCracken 1996). The response of individual species to grazing differs, and they can be characterised as grazing increasers or grazing decreasers, depending on their shift in relative abundance (Vesk and Westoby 2001). Vesk and Westoby found, however, that the response of a species can shift depending on environmental factors such as rainfall.

Grazing has a number of impacts on plants and plant communities, including defoliation, damage through trampling and the introduction of dung, which result in loss of biomass, seed dispersal and nutrient input (Gibson 1988). These mechanisms can also open up the vegetation, allowing colonization by ruderal and annual species, which may also benefit from the increased nutrient concentration associated with dunging (Goodwillie et al. 1997). Certain life-forms, such as rosette-forming species, may also be favoured by these conditions (Rodwell 1991b). Some species exhibit greater tolerance to herbivory, i.e. capacity for regrowth after grazing (del-Val and Crawley 2004), while others are more palatable, and therefore selectively removed by grazers (Goodwillie 2003). Grazing can have variable effects on plant communities in different circumstances. Through the direct consumption of competitive species and indirect effects on plant competition, herbivores are generally thought to increase plant biodiversity (Marty 2005, Pyke and Marty 2005). A number of factors are important, however, including type of livestock, density of livestock, length of time of grazing period, and when in the growing season grazing takes place.

Vertebrate herbivores are the largest grazers within the turlough ecotone, especially livestock such as cattle and sheep, and due to their size and the amount of biomass they consume, they are particularly influential on the plant communities they graze. Other grazers may also have an important influence, for example molluscs can have an impact on biodiversity (Frank 2003), but in the context of this paper, 'grazing' refers to the use of the land as grazing pasture for livestock. Wild grazers such as hares can be common on turloughs and the surrounding land, but since their impacts are not quantified in this study, these are treated as 'background' grazing.

While a certain level of grazing is required in order to maintain turlough vegetation, overstocking can have detrimental effects on turlough biodiversity. Ní Bhriain et al. (2003) compared the vegetation of two turloughs (Caherglassaun and Caranavoodaun) with differing stocking density, and found that a higher stocking density was correlated with a greater proportion of bare ground and more ruderals in Caherglassaun when compared to an adjacent field with a lower stocking density. The intensity and timing of grazing can vary hugely both within and between turloughs (Ní Bhriain et al. 2003). The timing of grazing affects plant community composition; grazing during sensitive phases in the life cycle of species which are vulnerable to the effects of grazing may disproportionately affect these species (Noy-Meir et al. 1989, Hobbs and Huenneke 1992). If livestock are put out to graze before vegetation regenerates after the recession of floodwaters, the waterlogged soils are more prone to damage through poaching, resulting in the proliferation of ruderal species (Goodwillie 2001).

3.1.6 Interactions between factors

It is important to consider the disturbances that affect the vegetation of turloughs together, rather than separately. Multiple disturbances may act synergistically rather than additively (Hobbs and Huenneke 1992), and in the case of turlough vegetation, the effects of hydrology, soil type and grazing in particular may be difficult to disentangle (Moran et al. 2008a). Flooding levels will dictate availability of grazing land, and some soil types may support vegetation that is not usually grazed, either because it is inaccessible to livestock or unpalatable. The influence of hydrological regime and grazing on Skealoghan turlough was investigated by Moran et al. (2008b). In this study, two main plant associations were found, the Cirsio-Molinietum and the Ranunculo-Potentilletum anserinae, both of which are well-represented in the vegetation communities defined and described in Chapter 2. Moran et al. found that the main factors affecting vegetation within the turlough were flooding regime and grazing, which in combination can influence soil properties such as the proportion of organic matter found within the soil. They found that the Ranunculo-Potentilletum anserinae association occurred at lower elevations within the turlough, and therefore experienced longer and deeper inundation than the Cirsio-Molinietum association. Management of stocking levels was found to influence vegetation composition, as grazing changes the structure of the vegetation and reduces the amount of litter accumulation, thereby affecting the competitive ability of the component species. The effects of soils and grazing on the vegetation could not be separated; peaty soils tend to have communities which are less suitable for grazing than mineral soils, and as a result these areas tend to have a reduced level of grazing by comparison. The Cirsio-Molinietum association was further divided into three groups based on floristic composition, and while the flood duration and depth was broadly similar for the three groups, there were differences in grazing intensity and soil composition between them.

Regan et al. (2007) examined the relationship between turlough vegetation communities and a number of environmental variables. They identified nine plant communities which were broadly divided into sedge-dominated communities characterised by frequent *Carex panicea* and *Carex flava*, and grass- and forb-dominated communities. Two groups with abundant *Carex nigra* and *Potentilla anserina* were said to represent a transitional community between the sedge-dominated and grass- and forb-dominated communities. They found that the sedge-dominated communities were associated with higher soil moisture, thinner or absent glacial deposits, later recession of floodwaters, shallower inundation and lower nutrient status than the grass- and forb-dominated communities.

3.2 Aims

Previous studies relating turlough vegetation to environmental conditions have focused on just one (Moran et al. 2008a) or two (Ní Bhriain et al. 2003) turloughs, or on a relatively small number of vegetation types in a larger number of turloughs (Regan et al. 2007). This study will examine the relationships between 28 vegetation communities from 22 turloughs and their associated environmental conditions in order to give a broader understanding of the environmental drivers of turlough plant community composition.

The specific aims of this chapter are to:

1. Examine the different ecological conditions associated with each vegetation type.

2. Confirm the zonation of vegetation along the flooding gradient.

3. Determine which of duration, depth, frequency or timing of flooding is the main hydrological driver of turlough vegetation.

4. Identify the main environmental drivers of turlough vegetation communities so that indicators of structure and function of turlough biota may be derived.

These findings will aid the understanding of the interactions between turlough vegetation communities and the ecological conditions which determine them. This knowledge will be invaluable in the monitoring and conservation of turlough ecosystems.

3.3 Methods

As this study was part of a multi-disciplinary project assessing a number of aspects of turlough ecology, hydrology and pedology, data were made available from other researchers for use with the vegetation data in order to identify drivers of plant community composition. It should be noted here that data on water and soil chemistry are based on a single mean value for each turlough; while these values may not be strictly associated with each relevé or vegetation community within the turlough, they give an indication of the environmental conditions therein. This also means that in cases where a vegetation community was sampled in only one turlough, e.g. Group 26 *Eleoacic*, there is only one value associated with that community.

3.3.1 Vegetation recording

Details on how the vegetation was recorded and classified can be found in Chapter 2; 8 major clusters were identified, with 28 plant communities in total (Figure 2.3).

3.3.2 Hydrology

Data on the hydrological regime of each turlough were obtained from Owen Naughton, who collected all of the hydrological data described in this section. A brief description of methods are given below, for detailed methodologies please see Naughton (2011).

Water level information was obtained using a variety of Schlumberger Divers®, which were placed at or near the lowest point in each turlough. These divers measure the pressure of the water column, and the air above it, which allows the depth of water to be calculated. Changes in air pressure affect diver readings; this was compensated for using BaroDiver® (DI500) and Met Éireann synoptic station data. Divers were placed and retrieved over a three year period; the longest continuous period for which data for a large number of turloughs was January 2007 to December 2008, and so this was the period used in analyses.

Topographic surveys of the turloughs were conducted while water levels were at their lowest in the summer months, using Trimble R6 and 4700 differential GPS systems. An average of over one thousand topographic points was taken at each site. These points were used to create digital terrain models, allowing the overall volume of the turlough to be calculated. The GPS coordinates for each quadrat were compared with the digital terrain models to give an elevation (metres above ordnance datum) for each quadrat. This allowed detailed hydrological information to be extracted from the dataset, producing figures for number of days spent inundated, maximum depth of flooding, etc.

3.3.2.1 Hydrological variables used

A number of variables were selected to represent the depth, duration, frequency and timing of flooding. Depth was represented by the mean maximum depth of inundation for each turlough (the mean was taken from the winter maxima for two years). Duration of flooding was the number of days over the two year period for which the water level reached the level of the quadrat. A flood event, for the purposes of this study, is defined as a period of ≥ 48 hours where the level of the water is ≥ the level of the quadrat. In waterlogged soils, dissolved O_2 in the soil water can be used up within hours or days (Ponnamperuma 1972, 1984), and previous studies have used 48 hours as the minimum length of time of inundation when considering flood events (Vreugdenhil et al. 2006). Frequency of flooding was therefore the number of flood events experienced by each quadrat over the two year hydrological record. In order to assess the effect of timing of flooding, the end of the longest flooding period, the beginning of the longest flooding period, the longest duration without flooding were all calculated. In order to assess the effect of date of emptying and date of filling on turlough vegetation, the start of the longest continuous wet period and the start of the longest continuous dry period were also calculated for each relevé. The hydrological variables used in analyses and the abbreviations used in this chapter are given in Table 3.1.

Table 3.1 A description of each of the hydrological variables used in this chapter.

Variable name	Description	Abbreviation
Maximum quadrat depth	The mean of two years records of the maximum depth of water recorded for each quadrat.	MDQuad
Duration of flooding	The number of days each quadrat was inundated to 0cm, 10cm, 25cm and 50cm.	DurXcm
Frequency of flooding	The number of flood events (≥ 48 hours) which occurred at each quadrat, at depths of 0cm, 10cm, 25cm and 50cm.	FreqXcm
Length of longest dry period	The length, in days, of the longest continuous dry period.	LongDry
Start of longest dry period	The date, in Julian days, of the start of the longest continuous dry period	DryDate
Start of longest wet period	The date, in Julian days, of the start of the longest continuous wet period	WetDate

3.3.3 Soils

Soil descriptions and soil nutrient analyses were carried out by Sarah Kimberley.

3.3.3.1 Soil descriptions

Soil types were described and classified; methodology is presented in Appendix II. These data were then used by Sarah Kimberley to create soil type maps of each of the turloughs in the study, using the boundaries of parent soil material as a proxy for the boundaries between soil types. In this study, relevés were overlaid on soil type maps using ArcMap Release 9.3 (ESRI 2008), and joined to the soil type map to assign a soil type to each relevé.

3.3.3.2 Soil nutrients

Six soil samples were taken by from each turlough, two each from the upper, middle and lower elevation zones, to a maximum depth of 20cm. Vegetation communities (as defined by Goodwillie (1992)) were used to determine the sampling zones. Samples were then analysed for total phosphorus, total nitrogen, pH, organic matter content, non-calcareous sand/silt/clay fraction and calcium carbonate content. Table 3.2 shows variables measured and abbreviations used.

Table 3.2 Soil variables and abbreviations.

Variable	Abbreviation
Total phosphorus (mg kg^{-1})	Soil TP
Total nitrogen (mg kg^{-1})	Soil TN
pH	Soil pH
Organic matter (% dry weight)	OM
Inorganic matter (% dry weight)	INORG
$CaCO_3$ (% dry weight)	$CaCO_3$

3.3.4 Water chemistry

Water chemistry analysis was carried out by Gwendoline Porst and Helder Cunha Pereira, of the Zoology and Environmental Science Departments of TCD respectively, as part of their PhD research. Of the various water chemistry variables measured by Porst and Cunha Pereira, those detailed in Table 3.3 were used in this chapter.

Turlough water samples were obtained using a weighted 5 litre plastic bottle which was attached to a rope and thrown out from the turlough shore. Sampling was carried out monthly from October 2006 to June 2007. All values presented in this chapter are the means for this period (for details on methodologies used, see Porst and Irvine 2009). The variables measured and abbreviations used are presented in Table 3.3.

Table 3.3 Water chemistry variables and abbreviations.

Variable	Abbreviation
Total phosphorus (µg l^{-1})	Water TP
Molybdate Reactive Phosphorus (µg l^{-1})	Water MRP
Total nitrogen (mg l^{-1})	Water TN
Nitrate (mg l^{-1})	Nitrate
Alkalinity (mg l^{-1} $CaCO_3$)	Alkalinity
Calcium (mg l^{-1})	Calcium

Turloughs were assigned to trophic categories based on thresholds from the Organisation of Economic Co-Operation and Development (1982) lake trophic classifications. Threshold values are given in Table 3.4.

Table 3.4 OECD boundary values for trophic categories (1982).

Trophic category	Mean TP (µg l^{-1})
Ultra-oligotrophic	≤ 4.0
Oligotrophic	≤ 10.0
Mesotrophic	10-35
Eutrophic	35-100
Hypertrophic	≥ 100

3.3.5 Management

Management questionnaires were given to landowners to determine, among other things, which land-parcels were grazed and which were not. A 'land-parcel' here refers to a field or group of fields which are open to livestock and managed in the same way by the land-owner. While grazing affects vegetation, an important caveat to bear in mind is that the grazed or ungrazed designation refers to the whole land-parcel, and not just the relevé. For example, in a large land-parcel which includes grassland, there may also be open water; this is unlikely to be grazed by livestock, but will be included under the 'grazed' heading. Some points within the turlough may also be isolated from the livestock by water, effectively becoming islands, during the wet phase. Some land may be unsuitable for grazing or unattractive to livestock; i.e. a land-parcel may be too wet to allow cattle onto it. Land-parcel maps indicating whether each land-parcel was grazed or not were created by Sarah Kimberley. As for the soil type data, relevés were overlaid on land use maps using ArcMap Release 9.3 (ESRI 2008), and joined to the management data. Each relevé was then assigned to a grazing regime depending on the land-parcel to which they belonged.

3.3.6 Derived variables

Ellenberg indicator values, Grime's C-S-R values and species richness were calculated for each relevé (see Chapter 2 for further details). Initial exploration of the relationships between these derived variables and plant communities was carried out in Chapter 2. In this chapter, the relationships between these variables and the measured environmental variables will be examined, and the relationships between the derived variables and vegetation communities will be explored in greater detail.

3.3.7 Data analysis

3.3.7.1 Environmental variables

For each of the recorded and derived variables, summary statistics were calculated for each vegetation type. These were presented in tabular format and as boxplots.

3.3.7.2 Vegetation data

Twelve relevés were never inundated over the recording period; these were removed from the data set (they were included in the vegetation dataset in Chapter 2 as it is likely they are flooded during extreme events). There was no complete topographic survey for Tullynafrankagh turlough and as a result vegetation data could not be related to hydrological variables. These 34 relevés were also removed from the dataset. The hydrological record for Kilglassan was incomplete; these relevés were therefore deleted. There were no hydrological records for Roo West for 2007 due to a malfunctioning diver; these 27 relevés were deleted. There were no hydrological records for Ballindereen for 2008 due to a malfunctioning diver; these 31 relevés were deleted. Ten relevés had no GPS coordinates; these were deleted. This left 670 relevés with accurate hydrological data for both 2007 and 2008.

Outlier analysis was conducted on this reduced dataset in PC-ORD 5 (MjM Software, Oregon), using the Sorenson distance measure. No relevés had an average distance of more than 3 standard deviations from the mean of the distribution; all relevés were therefore included in the analysis. The analysis was also carried out on the species, and no outlying species (>3 standard deviations) were found.

Non-Metric Multidimensional Scaling (NMS) ordination was carried out using PC-ORD 5, as described in Chapter 2. This analysis was carried out in order to visualise the relationships between vegetation communities and environmental variables, by adding the environmental and derived variables to the second matrix and then overlaying the environmental variables onto the ordination as a biplot. It was also used to give an indication of the strength of the relationships by calculating correlations with the ordination axes. The dataset had 670 quadrats and 176 species. The reduction in the dataset due to incomplete or missing hydrological data resulted in some of the species being present at very low frequencies; to reduce noise, rare species (i.e. those which were present in fewer than 4 quadrats) were deleted, leaving 160 species.

A Multi-Response Permutation Procedure was carried out on the species abundance matrix to confirm differences between groups. A Mantel test was then used to examine the relationship between vegetation and environmental matrices for each quadrat. This test examines the differences between two matrices to test if the relationship between them is more different than would be expected by chance using a randomization procedure (Sokal and Rohlf 1995).

Discriminant analysis is a procedure which tests whether a multivariate data matrix supports the splitting of samples into a series of *a priori* groups. Independent variables are combined into new variables; each relevé is then allocated a score based on these new variables, or discriminant functions (Kinnear and Gray 2006). Discriminant analysis was carried out on the data using SPSS (Release 18.0.0).

The stepwise form of discriminant analysis was used instead of direct (standard) or hierarchical (sequential) discriminant function analysis. Direct and hierarchical discriminant analysis were not used as in direct discriminant analysis, the predictor variables are all analysed simultaneously, while in hierarchical discriminant analysis the variables are analysed in an order chosen by the researcher. In stepwise discriminant function analysis, however, the most highly correlated variable is entered first by the stepwise programme, then the second and so on until an additional variable adds no significant amount to the canonical R^2 value. Given that this is an exploratory study, with no pre-existing information on which variables are most important, assigning an order to the variables was not possible, and so stepwise discriminant analysis was deemed the most appropriate method. Tests of significance are measured by Wilks' lambda. The selection criteria for entry and removal of variables were: F value for entry is 3.84, and F value for removal is 2.71.

BIO-ENV is a permutational procedure that aims to identify the combination of environmental variables that produces the highest correlation between a species matrix and an environmental data matrix (Clarke and Ainsworth 1993). BIO-ENV was carried out using PRIMER v.6. Vegetation data were $\log^{(x+1)}$ transformed, and environmental variables were log transformed before analysis (Clarke and Gorley 2006). All data were also normalised as recommended by Clarke and Gorley prior to analysis. A resemblance matrix was calculated for the species matrix using Bray-Curtis distance. The Spearman rank coefficient was selected for use in BIO-ENV as the measure of correlation between the species abundance matrix and the environmental variables matrix.

3.4 Results

For the sake of brevity, names of the vegetation communities have been abbreviated (Table 3.5), these abbreviations will be used when referencing vegetation groups in this chapter.

Table 3.5 Abbreviations used in this chapter when referring to vegetation communities defined in Chapter 2.

Cluster	Group	Name	Abbreviation
1	1	*Poa annua-Plantago major* community	*PoaPlan*
2	2	*Persicaria amphibia-Eleocharis palustris* community	*PersEleo*
3	3	*Agrostis stolonifera-Ranunculus repens* community	*AgroRanu*
3	4	*Agrostis stolonifera-Potentilla anserina-Festuca rubra* community	*AgroPote*
4	5	Limestone Grassland	LimeGras
5	6	*Eleocharis palustris-Ranunculus flammula* community	*EleoRanu*
2	7	*Eleocharis palustris-Phalaris arundinacea* community	*EleoPhal*
6	8	*Carex nigra-Carex panicea* community	*CareCpan*
3	9	*Phalaris arundinacea-Potentilla anserina* community	*PhalPote*
7	10	*Lolium perenne-Trifolium repens* community	*LoliTrif*
5	11	*Persicaria amphibia-Mentha aquatica* community	*PersMent*
6	12	*Filipendula ulmaria-Vicia cracca* community	*FiliVici*
3	13	*Potentilla anserina-Carex nigra* community	*PoteCare*
5	14	Reedbed	Reedbed
7	15	*Lolium perenne-Trifolium repens-Agrostis stolonifera* community	*LoliAgro*
2	16	*Equisetum fluviatile-Menyanthes trifoliata* community	*EquiMeny*
2	17	*Carex nigra-Ranunculus flammula* community	*CareRanu*
2	18	*Agrostis stolonifera-Glyceria fluitans* community	*AgroGlyc*
3	19	*Potentilla anserina-Potentilla reptans* community	*PotePote*
3	20	*Filipendula ulmaria-Potentilla erecta-Viola* sp. community	*FiliPote*
4	21	*Schoenus nigricans* fen	*Schoenus*
8	22	*Molinia caerulea-Carex panicea* community	*MoliCare*
6	23	*Carex nigra-Scorzoneroides autumnalis* community	*CareScor*
5	24	*Potamogeton natans-Glyceria fluitans* community	*PotaGlyc*
8	25	*Carex nigra-Carex viridula* community	*CareCvir*
1	26	*Eleocharis acicularis* community	*Eleoacic*
2	27	*Carex nigra-Equisetum fluviatile* community	*CareEqui*
4	28	Flooded Pavement	FldPavmt

In this section, environmental variables are summarised and presented graphically in the form of boxplots, to show the median, interquartile range and the smallest and largest values for each group. Outliers are indicated by a circle on the graphs, while extreme outliers are shown by an asterisk.

Investigation into differences between group medians was carried out using Mann-Whitney U tests. With 28 different groups, pairwise testing and subsequent adjustment for multiple comparisons results in an unwieldy table with an extremely low threshold for significance; *post-hoc* testing was, therefore, carried out on clusters (the eight broader groups defined in Chapter 2) rather than each individual vegetation community.

3.4.1 Hydrology

3.4.1.1 Frequency

Frequency of flooding at 0cm, 10cm, 25cm and 50cm (height of flooding above the substrate, for duration of $\geq$ 48 hours) was analysed and is presented in Table 3.6 and Figure 3.1. A Kruskal-Wallis test was carried out to test for differences between group medians which indicated that there were significant differences between the medians of at least two groups for each of the soil chemistry variables. *Post-hoc* Mann-Whitney U tests were therefore carried out to determine which clusters differed from each other (Table 3.7).

Note: the frequency of inundation for some of the quadrats increases as the level of flooding examined increases – this is due to fluctuating water levels above the level being examined – i.e. a flooding event which reaches at or above 10cm can reach 50cm a number of times before receding below 10cm again.

There was a large amount of variation in the frequency of flooding for some of the communities, in particular those of Clusters 2 and 3. There were a number of outliers, especially in Lough Aleenaun (denoted by the code ALE), which is the 'flashiest' turlough of the study, it responds rapidly to rainfall events, filling and emptying frequently. At 50cm, the outliers were mostly relevés from Lisduff and Knockaunroe.

For many of the communities, the range of frequencies of inundation events decreased as the depth of inundation increased (Figure 3.1). Group 1 *PoaPlan* is a striking example of this; at 0cm the frequency of flooding ranged from 2 to 21 flood events, while when only flooding to a depth of 50cm is considered, the range contracted to 2 to 9 events (Table 3.6, Figure 3.1). Cluster 7, which contains Group 10 *LoliTrif* and Group 15 *LoliAgro*, also experienced a wide range of flooding frequencies at 0cm, 10cm and 25cm depth, but this was much reduced at 50cm. These communities occur around the edge of turloughs, and it seems they can experience frequent, but shallow, flooding. The frequency of flood events to 50cm or deeper does not differ significantly between many of the clusters (Table 3.7); at this depth of flooding, only 3 pairs of clusters show significant differences.

Table 3.6 Mean, median and range for frequency of flooding (number of events of duration > 48 hrs) at 0cm, 10cm, 25cm and 50cm above substrate surface.

		Frequency (0cm)		**Frequency (10cm)**		**Frequency (25cm)**		**Frequency (50cm)**	
		Mean	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**
1	*PoaPlan*	8	6 (2-21)	7	6 (1-21)	8	6 (1-25)	4	4 (2-9)
2	*PersEleo*	4	3 (1-20)	4	3 (1-22)	4	3 (1-24)	5	4 (2-25)
3	*AgroRanu*	4	3 (2-9)	4	3 (2-9)	4	3 (2-9)	4	4 (0-9)
4	*AgroPote*	6	5 (2-18)	6	5 (2-18)	6	5 (2-16)	4	3 (0-25)
5	LimeGras	4	4 (1-12)	4	4 (0-12)	4	4 (0-11)	3	3 (0-12)
6	*EleoRanu*	4	4 (1-9)	5	4 (3-16)	4	3 (3-8)	6	4 (2-12)
7	*EleoPhal*	3	3 (2-5)	3	3 (2-4)	3	3 (2-5)	5	5 (2-9)
8	*CareCpan*	3	3 (1-6)	3	3 (1-6)	3	3 (0-5)	3	4 (0-7)
9	*PhalPote*	3	3 (2-5)	3	3 (1-5)	3	3 (1-5)	4	3 (2-8)
10	*LoliTrif*	6	3 (1-18)	5	3 (1-19)	5	3 (0-16)	3	3 (0-7)
11	*PersMent*	6	4 (1-17)	7	4 (3-17)	7	3 (3-18)	3	3 (1-6)
12	*FiliVici*	3	3 (1-4)	2	2 (1-4)	2	2 (0-4)	3	3 (1-9)
13	*PoteCare*	6	5 (1-14)	6	5 (1-12)	6	5 (1-12)	4	4 (0-11)
14	Reedbed	3	3 (1-9)	4	3 (1-8)	3	3 (1-6)	9	5 (1-21)
15	*LoliAgro*	7	3 (1-21)	7	3 (1-21)	6	4 (1-18)	3	3 (1-7)
16	*EquiMeny*	3	4 (1-4)	3	4 (2-5)	3	3 (1-5)	4	3 (1-8)
17	*CareRanu*	4	3 (1-9)	4	3 (2-9)	4	3 (3-9)	6	4 (0-25)
18	*AgroGlyc*	7	4 (1-19)	7	5 (2-19)	6	5 (2-18)	4	4 (0-9)
19	*PotePote*	7	7 (3-11)	7	7 (3-11)	7	7 (4-11)	4	4 (0-13)
20	*FiliPote*	7	7 (5-9)	7	7 (5-9)	7	7 (5-9)	6	7 (0-9)
21	*Schoenus*	4	4 (3-6)	5	5 (3-6)	4	4 (4-5)	4	4 (3-6)
22	*MoliCare*	4	4 (3-9)	4	4 (3-9)	4	4 (3-8)	5	3 (0-27)
23	*CareScor*	5	4 (3-8)	5	4 (3-8)	5	4 (3-8)	3	3 (0-4)
24	*PotaGlyc*	3	3 (1-5)	3	3 (2-5)	6	5 (3-10)	4	3 (1-10)
25	*CareCvir*	5	4 (2-9)	4	4 (2-6)	4	5 (2-5)	3	3 (1-5)
26	*Eleoacic*	7	7 (6-9)	7	7 (5-9)	7	7 (5-9)	4	4 (3-5)
27	*CareEqui*	6	5 (1-11)	6	5 (1-9)	6	5 (4-8)	4	4 (3-5)
28	FldPavmt	5	5 (3-8)	5	4 (3-9)	5	5 (4-8)	4	3 (2-6)

Table 3.7 *Post-hoc* Mann-Whitney U tests for differences between medians of clusters for frequency of flooding at 0cm, 10cm, 25cm and 50cm.

Frequency of flooding to 0cm.

	1	2	3	4	5	6	7
2	**0.000**						
3	**0.001**	**0.000**					
4	**0.000**	0.004	0.225				
5	**0.000**	0.872	**0.002**	0.065			
6	**0.000**	**0.000**	**0.000**	**0.000**	0.015		
7	0.172	0.771	0.540	0.915	0.441	0.027	
8	**0.000**	0.007	0.219	0.809	0.070	**0.000**	0.027

Frequency of flooding to 10cm.

	1	2	3	4	5	6	7
2	**0.000**						
3	**0.002**	**0.000**					
4	**0.000**	0.032	0.166				
5	**0.001**	0.668	0.089	0.254			
6	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**		
7	0.146	0.971	0.409	0.785	0.450	0.018	
8	**0.000**	0.120	0.096	0.382	0.367	**0.000**	0.018

Frequency of flooding to 25cm.

	1	2	3	4	5	6	7
2	**0.000**						
3	**0.002**	**0.000**					
4	**0.000**	0.033	0.094				
5	**0.001**	0.850	0.035	0.183			
6	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**		
7	0.141	0.567	0.274	0.756	0.452	0.066	
8	**0.000**	0.086	0.076	0.567	0.187	**0.000**	0.066

Frequency of flooding to 50cm.

	1	2	3	4	5	6	7
2	0.294						
3	0.956	0.022					
4	0.011	**0.000**	0.005				
5	0.665	0.677	0.269	0.003			
6	0.060	**0.000**	0.023	0.600	0.009		
7	0.014	**0.000**	0.016	0.826	0.005	0.527	
8	0.126	0.009	0.139	0.254	0.080	0.575	0.527

Figures in bold are significant ($p \leq 0.05$) after correction for multiple comparisons using the Dunn-Šidák method.

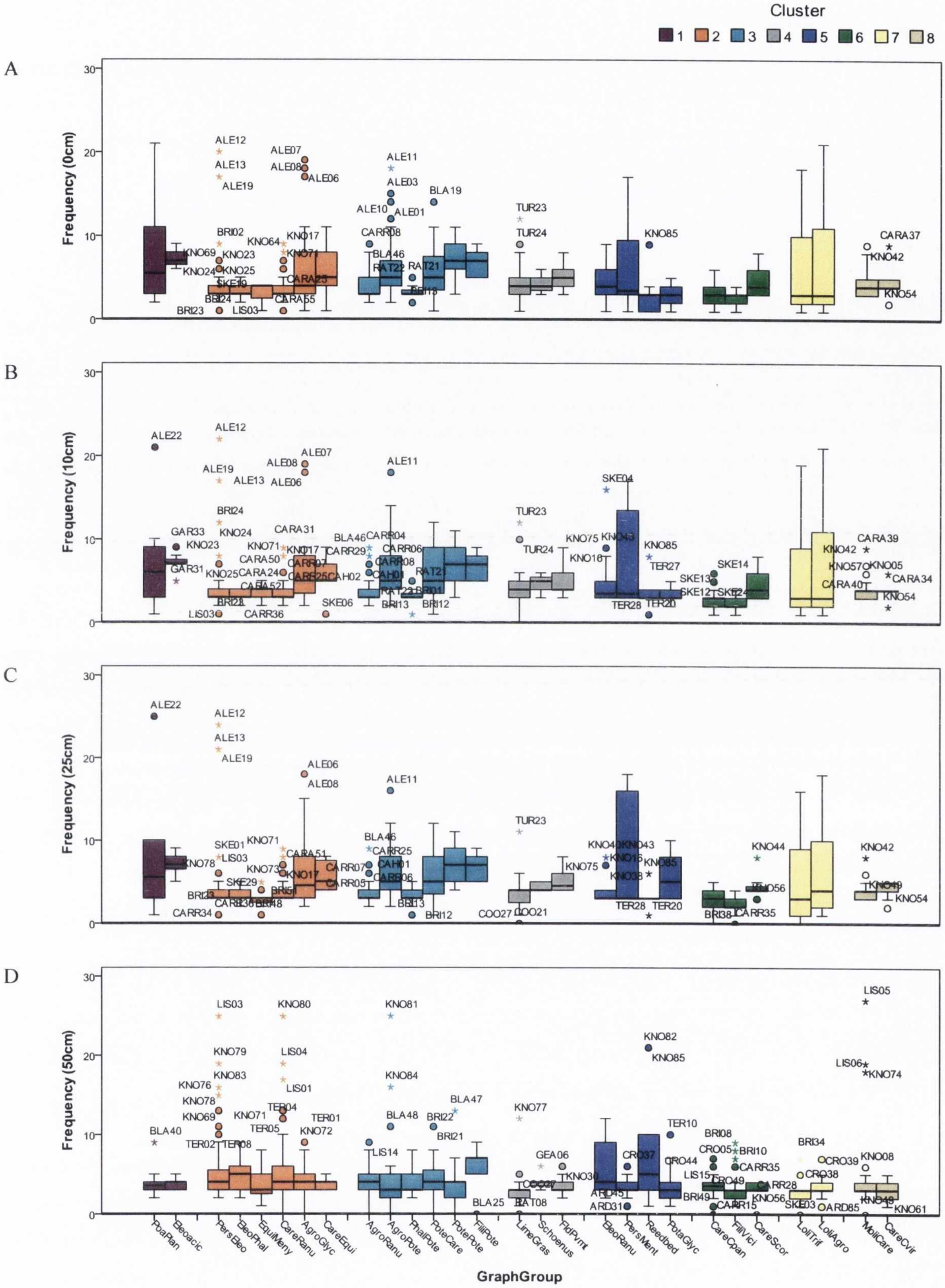


Figure 3.1(A-D) Boxplots showing the median, interquartile range and highest and lowest values for frequency of flooding at 0cm, 10cm, 25cm and 50cm for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

3.4.1.2 Duration of flooding

Summary statistics for the combined duration of flooding for 2007 and 2008 for each of the vegetation communities are presented in Table 3.8 and presented graphically in Figure 3.2. A Kruskal-Wallis test was carried out to test for differences between the medians of the groups, and results indicated that there was a highly significant difference between the medians of at least two groups. *Post-hoc* Mann-Whitney U tests were carried out to determine any statistically significant differences between the medians of clusters (Table 3.9).

A number of communities exhibit a wide range of duration of flooding, for example Group 18 *AgroGlyc* had the greatest range, from 120 days to 547 days (Table 3.8).

The two *Lolium* grassland communities (Group 10 *LoliTrif* and Group 15 *LoliAgro*) had the shortest mean duration of flooding at 0cm, at just 107.3 days and 188.0 days. Group 12 *FiliVici* also had a very short mean duration of flooding, at 193.8 days. At the opposite end of the flooding gradient lie Group 14 Reedbed and Group 24 *PotaGlyc*, with mean duration of flooding of 602.5 days and 640.8 days respectively.

Within each cluster, the median durations of flooding for all groups were similar (Figure 3.2), although there were some exceptions. In Cluster 1, the median duration of flooding for Group 26 *Eleoacic* was greater than the median duration of flooding for Group 1 *PoaPlan* for all levels of flooding. Group 26 *Eleoacic*, however, was only recorded in relevés from one turlough, and so has a lesser range of duration than might be expected if it were recorded in a number of turloughs. However, this is a community which occurs on the fringes of permanent water, on a wet, muddy substrate, and so duration of flooding may well be comparable for this community across different turloughs. Cluster 2 has six different vegetation communities, and the medians for these were similar, with the exception of Group 27 *CareEqui*, for which the median was consistently higher at all levels of flooding. In Cluster 6, the median duration of flooding for Group 23 *CareScor* is consistently higher than the other two communities in that cluster.

Cluster 5 contains the four vegetation communities with the highest median duration of flooding. Only Group 27 *CareEqui* reached a comparable duration of flooding. Group 24 *PotaGlyc* had the highest median duration of flooding at 0cm, 10cm, and 25 cm, but at 50cm Group 11 *PersMent* was highest.

Cluster 7 contained the two *Lolium perenne* grasslands, and of these, Group 10 *LoliTrif* had the lowest median duration of flooding at each level. Group 15 *LoliAgro* and Group 12 *FiliVici* had comparable medians at all levels of flooding. While the median duration of flooding for these communities was similar, when the frequency of flooding is examined (Figure 3.1), the *Lolium* grasslands experienced a much greater range of frequency of flooding events than Group 12 *FiliVici.*

In general, clusters 2 and 3 have the greatest numbers of outliers for duration of flooding at all levels of inundation (Figure 3.2A-D), but especially at 0cm, 10cm, and 25cm. These clusters are comprised of communities with high proportions of amphibious and water-dependent species, such as Group 2 *PersEleo*, and occur in the middle of the duration gradient; these communities might, therefore, be expected to tolerate fluctuations in water level and varying lengths of inundation. These clusters also experience the widest range of frequency of flooding events, with a large number of outliers (Figure 3.1A-D). The ranges of duration of flooding for some of the other clusters are much tighter, with fewer outliers (Figure 3.2A-D). This is especially evident at duration of flooding to 50cm (Figure 3.2D), where the interquartile ranges are much smaller than at other depths of flooding, and there are few outliers.

Table 3.8 Mean, median and range of duration of flooding for each of the 28 vegetation communities.

		Duration 0cm (days)		**Duration 10cm (days)**		**Duration 25cm (days)**		**Duration 50cm (days)**	
		Mean	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**
1	*PoaPlan*	311.7	309.2 (133.0-471.0)	302.1	302.4 (99.0-453.0)	291.2	293.3 (84.0-428.0)	267.0	276.1 (7.0-385.0)
2	*PersEleo*	449.4	464.2 (94.0-731.0)	433.8	451.0 (90.0-731.0)	408.4	410.0 (87.0-731.0)	373.0	388.0 (73.0-731.0)
3	*AgroRanu*	309.6	306.0 (123.0-467.0)	309.2	298.0 (110.0-511.3)	292.3	284.8 (91.0-511.3)	246.1	257.0 (11.0-414.8)
4	*AgroPote*	292.3	321.0 (90.0-446.0)	296.9	317.0 (81.0-473.3)	285.6	303.0 (33.0-463.4)	257.5	290.0 (0.0-410.0)
5	LimeGras	278.8	322.4 (11.0-499.0)	254.4	289.0 (0.0-457.0)	223.2	255.0 (0.0-407.0)	173.3	157.0 (0.0-387.0)
6	*EleoRanu*	559.5	564.0 (345.0-731.0)	531.0	542.0 (329.0-729.0)	484.4	508.0 (288.0-599.0)	421.3	419.5 (234.0-554.0)
7	*EleoPhal*	447.6	464.2 (280.0-525.0)	434.1	446.2 (267.0-515.0)	410.8	423.8 (250.0-508.0)	365.1	393.5 (214.0-490.0)
8	*CareCpan*	235.9	265.7 (85.0-414.0)	217.6	255.3 (41.0-401.0)	188.2	202.5 (0.0-389.0)	132.3	106.0 (0.0-365.0)
9	*PhalPote*	379.9	406.4 (114.0-537.0)	369.2	400.3 (98.0-527.0)	353.7	391.8 (87.0-515.0)	324.9	354.0 (32.0-501.0)
10	*LoliTrif*	107.3	93.0 (10.0-223.0)	96.8	82.0 (7.0-214.0)	75.7	64.0 (0.0-195.0)	58.0	34.0 (0.0-158.0)
11	*PersMent*	553.1	542.9 (315.0-731.0)	531.4	531.5 (297.0-668.0)	511.5	522.2 (273.0-638.0)	487.5	510.7 (208.0-615.0)
12	*FiliVici*	193.8	190.0 (20.0-381.0)	180.8	183.0 (13.0-359.0)	160.3	141.0 (0.0-330.0)	127.7	98.7 (0.0-284.0)
13	*PoteCare*	402.4	419.0 (111.0-731.0)	395.1	417.0 (95.0-731.0)	380.3	399.0 (78.0-731.0)	348.7	389.0 (45.0-546.0)
14	Reedbed	602.5	594.0 (403.0-731.0)	583.4	564.0 (394.0-731.0)	552.9	520.3 (387.0-731.0)	484.6	481.0 (360.0-623.0)
15	*LoliAgro*	188.0	204.0 (26.0-337.0)	175.6	188.0 (21.0-320.0)	156.9	158.0 (12.0-293.0)	123.1	109.0 (0.0-252.0)
16	*EquiMeny*	436.8	479.0 (189.0-731.0)	402.3	460.0 (142.0-555.0)	366.4	414.0 (98.0-507.0)	307.4	313.0 (77.0-468.6)
17	*CareRanu*	479.9	466.0 (331.0-731.0)	449.3	423.0 (314.0-711.0)	406.3	401.0 (274.0-660.0)	352.7	359.0 (214.0-485.0)
18	*AgroGlyc*	385.4	372.5 (135.0-731.0)	358.1	359.5 (120.0-547.0)	332.8	348.5 (102.0-521.0)	298.8	317.0 (82.0-494.0)
19	*PotePote*	357.6	371.0 (271.0-400.0)	355.2	370.0 (269.0-397.0)	351.5	368.0 (261.0-392.0)	345.6	362.0 (255.0-388.0)
20	*FiliPote*	306.8	317.0 (234.0-353.0)	304.2	314.0 (228.0-352.0)	299.5	307.0 (219.0-346.0)	292.9	301.0 (211.0-341.0)
21	*Schoenus*	305.4	312.0 (202.8-394.4)	287.1	286.0 (165.3-386.3)	257.9	270.0 (102.4-373.1)	214.3	248.0 (64.9-349.8)
22	*MoliCare*	422.3	413.0 (277.0-629.0)	399.2	394.0 (258.0-592.0)	371.0	379.0 (225.0-530.0)	318.7	333.0 (108.0-414.0)
23	*CareScor*	438.2	394.0 (364.0-585.0)	419.7	389.0 (355.0-548.0)	387.9	375.0 (342.0-471.0)	350.7	353.0 (286.0-399.0)
24	*PotaGlyc*	640.8	685.0 (391.0-731.0)	611.3	655.0 (371.0-727.0)	537.5	536.0 (337.0-668.0)	443.0	457.0 (293.0-493.0)
25	*CareCvir*	411.9	481.0 (71.0-536.0)	392.9	468.0 (64.0-481.0)	358.1	421.0 (46.0-457.0)	297.8	360.0 (7.0-385.0)
26	*Eleoacic*	449.9	466.5 (311.0-498.0)	441.8	455.0 (305.0-491.0)	428.3	438.0 (297.0-477.0)	411.7	424.5 (288.0-450.0)
27	*CareEqui*	543.6	556.0 (299.0-731.0)	526.1	543.0 (294.0-731.0)	478.7	508.0 (287.0-545.0)	428.1	453.0 (265.0-495.0)
28	FldPavmt	390.3	359.0 (288.0-640.0)	370.7	350.5 (274.0-603.0)	344.8	328.5 (262.0-546.0)	305.9	277.5 (238.0-418.0)

Table 3.9 Mann-Whitney U test results for duration of flooding for 8 clusters.

Duration of flooding to 0cm.

	1	2	3	4	5	6	7
2	0.013						
3	0.005	**0.000**					
4	0.009	**0.000**	0.524				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	**0.000**	**0.000**	**0.000**	0.007	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
8	0.506	0.037	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Duration of flooding to 10cm.

	1	2	3	4	5	6	7
2	0.046						
3	0.017	**0.000**					
4	**0.002**	**0.000**	0.079				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	**0.000**	**0.000**	**0.000**	0.010	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
8	0.910	0.027	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Duration of flooding to 25cm.

	1	2	3	4	5	6	7
2	0.221						
3	0.015	**0.000**					
4	**0.000**	**0.000**	0.006				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	**0.000**	**0.000**	**0.000**	0.020	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	
8	0.365	0.013	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Duration of flooding to 50cm.

	1	2	3	4	5	6	7
2	0.912						
3	**0.002**	**0.000**					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	**0.000**	**0.000**	**0.000**	0.038	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.039	
8	0.024	0.004	0.059	**0.000**	**0.000**	**0.000**	**0.000**

Figures in bold are significant ($p \leq 0.05$) after correction for multiple comparisons using the Dunn-Šidák method.

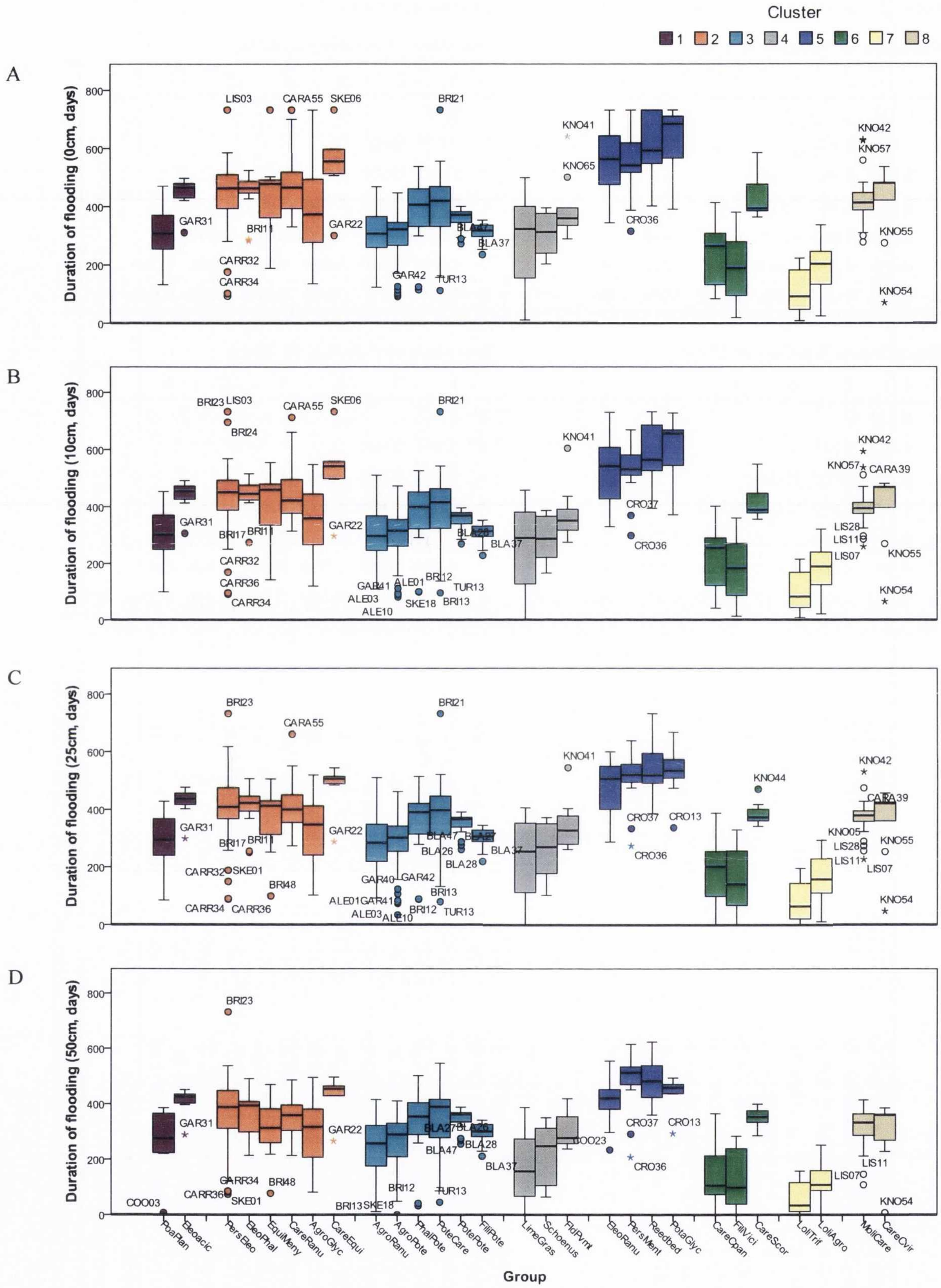


Figure 3.2(A-D) Boxplots showing the median, interquartile range and highest and lowest values for duration of flooding to 0cm, 10cm, 25cm and 50cm for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

There was a large amount of inter-annual variation in duration of flooding (Figure 3.3), as has been reported in other studies on turloughs. In this study, the mean duration over two years was taken to be representative of the hydrological regime, as in other studies (for example Moran et al. (2008) used the mean duration of flooding over three years). Duration of flooding was always greater in 2008 than 2007, but for some clusters there was relatively little difference (Clusters 6 and 7) while the difference was greater for others (Clusters 4, 8 and 9).

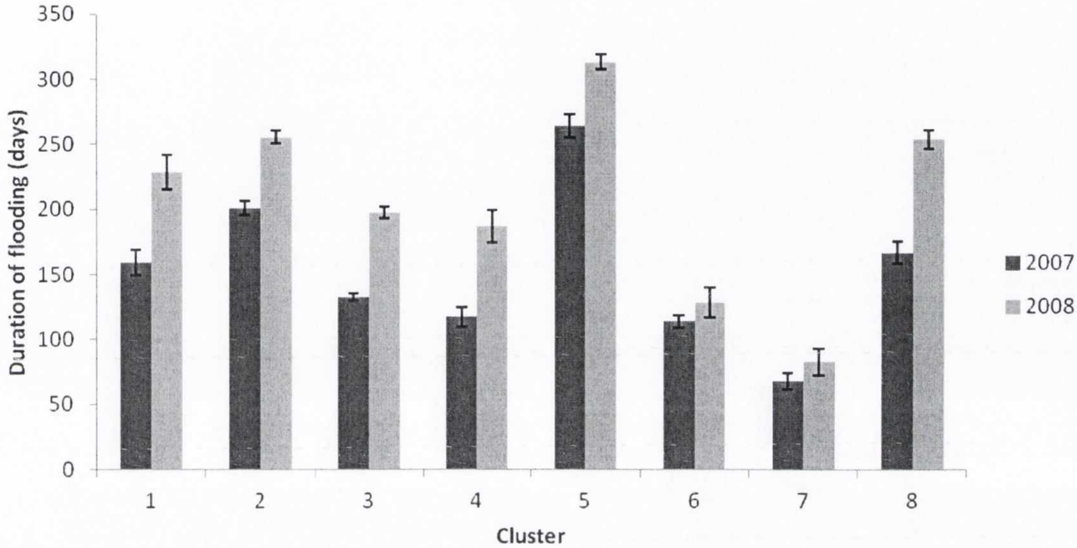


Figure 3.3 Mean duration of inundation to 0cm (± standard error) for 2007 and 2008.

3.4.1.3 Length of longest dry period

This variable is the length of the longest continuous dry period for each relevé over the entire recording period (3 years), presented as a percentage. This extends beyond the time period for the rest of the hydrological data, but was chosen to examine the extremes of hydrological regime to which the vegetation communities may be subjected. Results are presented in Table 3.11 and Figure 3.4. A Kruskal-Wallis test indicated that there were significant differences between the medians of at least two of the groups. *Post-hoc* Mann-Whitney U tests were carried out on the cluster medians (Table 3.12). Group 8 *CareCpan* had the longest mean continuous dry period, at 72.8% of the recorded time, but relevés in this community experienced a wide range of longest dry period, from 11.9% to 84.8%. Group 14 Reedbed, Group 24 *PotaGlyc* and Group 26 *Eleoacic* were the communities with the shortest mean length of continuous dry period (6.2% to 9%; Table 3.11). In general, the interquartile ranges for each of the communities were quite small (Figure 3.4A), although there were also a large number of outliers, mainly from Coolcam, Carrowreagh, Brierfield, Garryland and Rathnalulleagh.

3.4.1.4 Start of longest wet period and longest dry period

The start of the longest wet period and longest dry periods were presented as Julian days (Table 3.11, Figure 3.4). Table 3.10 shows the range of Julian days which correspond to each calendar month. Most communities experienced quite a range of starting dates for longest wet period. A Kruskal-Wallis test indicated that there were significant differences between the medians of at least two of the groups. *Post-hoc* Mann-Whitney U tests were carried out on the cluster medians (Table 3.12). Group 27 *CareEqui* had the earliest median start date for longest wet period, at 214 (early August). Group 10 *LoliTrif* and Group 15 *LoliAgro* had the latest median start date for longest wet period, at 337 and 348 (December) respectively. Cluster 7 (Group 10 *LoliTrif* and Group 15 *LoliAgro*) also had the earliest median start date for longest dry period, at 75 and 82 Julian days (March). Group 26 *Eleoacic* had the latest median start date for longest dry period, at 246 Julian days (September).

Table 3.10 Relationship between Julian days and months.

Julian day	Month
1-31	January
32-59	February
60-90	March
91-120	April
121-151	May
152-181	June
182-212	July
213-243	August
244-273	September
274-304	October
305-334	November
335-365	December

3.4.1.5 Maximum depth

Summary statistics for maximum depth of inundation for each of the 28 vegetation communities are presented in Table 3.11 and Figure 3.4. A Kruskal-Wallis test indicated that there were significant differences between the medians of at least two of the groups. *Post-hoc* Mann-Whitney U tests were carried out on the cluster medians (Table 3.12).

The communities with the greatest median maximum depth were Group 26 *Eleoacic*, Group 19 *PotePote* and Group 20 *FiliPote* (Table 3.11, Figure 3.4). These groups were all found in Garryland and Blackrock turloughs, which are two of the deepest turloughs. Apart from a single outlier, a very narrow range of maximum depths were associated with Group 26 *Eleoacic*; these relevés were all recorded from Garryland turlough, at similar elevations within the turlough. Group 19 *PotePote* was associated with the greatest median maximum depth (10.68m).

The communities with the lowest median maximum depth were Group 8 *CareCpan*, Group 10 *LoliTrif*, and Group 12 *FiliVici*, all of which had median maximum depths of less than one metre.

Table 3.11 Summary statistics for length of longest dry period (%), start of longest wet and dry periods (Julian days) and maximum depth of flooding for each of the vegetation communities.

		Length of longest dry period		Start of longest wet period (Julian days)		Start of longest dry period (Julian days)		Maximum depth (m)	
		Mean	Median (range)	Mean	Median (range)	Mean	Median (range)	Mean	Median (range)
1	*PoaPlan*	26.3	26.1 (6.1-48.3)	296	329 (8-362)	108	111 (75-159)	3.35	3.11 (0.28-6.72)
2	*PersEleo*	24.9	21.5 (0-52.6)	282	292 (221-345)	151	161 (0-274)	2.68	2.74 (0.58-4.67)
3	*AgroRanu*	28.5	24.4 (9.9-51.4)	310	325 (0-352)	116	109 (51-307)	2.87	2.27 (0.41-6.94)
4	*AgroPote*	22.7	23.6 (8.3-50)	290	322 (6-362)	90	85 (56-248)	4.61	4.44 (0.50-10.23)
5	LimeGras	30.1	24.4 (6.1-90.2)	253	284 (7-362)	113	103 (24-352)	1.42	1.55 (0.05-3.10)
6	*EleoRanu*	14.7	9.2 (0-27.8)	246	229 (173-348)	170	194 (0-266)	2.74	2.58 (1.18-5.20)
7	*EleoPhal*	19.9	21.9 (11.7-26.5)	322	323 (307-342)	182	181 (136-222)	2.64	2.38 (1.08-4.28)
8	*CareCpan*	72.8	31 (11.9-84.8)	278	327 (8-350)	98	105 (34-149)	1.05	0.96 (0.02-2.92)
9	*PhalPote*	27.1	25.2 (9.1-52)	277	323 (6-335)	143	153 (45-223)	2.86	3.07 (0.28-4.95)
10	*LoliTrif*	41.4	37.9 (27.1-84.1)	226	337 (8-362)	95	75 (13-351)	0.99	0.93 (0.02-2.48)
11	*PersMent*	11.7	13.4 (0-25)	297	309 (226-320)	150	163 (0-273)	4.33	4.80 (0.98-6.21)
12	*FiliVici*	46.5	36 (21.3-90.5)	234	334 (2-364)	101	102 (34-144)	1.18	0.95 (0.04-2.54)
13	*PoteCare*	20.1	10.3 (0-34.6)	259	225 (7-362)	131	100 (0-258)	5.14	3.70 (0.64-13.33)
14	Reedbed	9	11.8 (0-22.4)	266	245 (215-309)	119	136 (0-218)	2.91	2.85 (2.12-5.11)
15	*LoliAgro*	37	27.7 (15.4-90.2)	282	348 (6-362)	101	82 (37-352)	1.36	1.30 (0.01-2.64)
16	*EquiMeny*	24.9	16.4 (0-46.3)	312	326 (228-364)	161	182 (0-253)	1.77	1.77 (0.44-4.29)
17	*CareRanu*	23.8	14.8 (0-23.9)	253	237 (170-344)	160	160 (0-257)	1.93	1.90 (1.04-3.41)
18	*AgroGlyc*	28.9	23.4 (0-31.2)	283	315 (213-342)	125	109 (0-273)	2.87	2.28 (1.05-10.57)
19	*PotePote*	15.5	13.4 (9.6-27.1)	305	319 (224-322)	114	94 (76-242)	10.23	10.68 (7.19-12.67)
20	*FiliPote*	18.9	15.7 (13.8-27.8)	321	321 (320-322)	81	81 (74-86)	8.56	8.61 (6.17-10.56)
21	*Schoenus*	26.4	24.6 (23.4-30.7)	204	228 (0-362)	95	95 (82-108)	1.84	2.00 (1.07-2.49)
22	*MoliCare*	49.4	12 (3.9-27.6)	238	228 (213-323)	122	117 (96-241)	2.26	2.28 (0.66-3.42)
23	*CareScor*	17.7	22.7 (4.3-23.6)	240	227 (216-283)	114	108 (101-135)	2.82	2.75 (2.40-3.30)
24	*PotaGlyc*	6.2	3.1 (0-21.1)	239	266 (170-283)	150	192 (0-237)	2.25	2.35 (1.35-2.56)
25	*CareCvir*	15.4	8.6 (8.3-52.5)	252	228 (227-344)	122	138 (54-140)	1.80	2.00 (0.54-2.10)
26	*Eleoacic*	9.9	8.4 (8.1-24.2)	231	222 (222-323)	208	246 (88-247)	9.40	9.74 (6.10-10.12)
27	*CareEqui*	25.4	6.9 (0-24.5)	235	214 (186-324)	157	130 (0-266)	6.19	5.88 (2.05-10.59)
28	FldPavmt	20.1	23.8 (3.7-24.7)	276	284 (213-326)	121	100 (94-273)	2.49	2.34 (1.92-3.45)

Table 3.12 Mann-Whitney U test results for lengths of longest dry period, start of longest wet and dry periods and maximum quadrat depth for 8 clusters.

Length of longest dry period.

	1	2	3	4	5	6	7
2	0.886						
3	0.006	**0.000**					
4	0.003	**0.000**	0.127				
5	0.005	**0.000**	**0.000**	**0.000**			
6	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.162	
8	0.538	0.974	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Start of longest wet period (Julian days).

	1	2	3	4	5	6	7
2	0.197						
3	0.020	**0.000**					
4	0.306	0.647	0.018				
5	0.951	0.019	**0.000**	0.377			
6	0.110	0.023	0.523	0.094	0.004		
7	0.034	**0.000**	**0.002**	0.003	**0.000**	0.020	
8	0.620	**0.000**	**0.000**	0.006	0.013	**0.001**	**0.001**

Start of longest dry period (Julian days).

	1	2	3	4	5	6	7
2	0.883						
3	**0.002**	**0.000**					
4	0.009	**0.000**	0.796				
5	0.951	0.221	**0.000**	**0.000**			
6	0.004	**0.000**	0.912	0.762	**0.000**		
7	**0.000**	**0.000**	**0.000**	0.003	**0.000**	0.004	
8	0.270	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**

Maximum depth.

	1	2	3	4	5	6	7
2	**0.000**						
3	0.016	**0.000**					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	**0.000**	0.005	**0.000**			
6	**0.000**	**0.000**	**0.000**	0.010	**0.000**		
7	**0.000**	**0.000**	**0.000**	0.004	**0.000**	0.688	
8	**0.000**	0.647	**0.000**	0.003	**0.000**	**0.000**	**0.000**

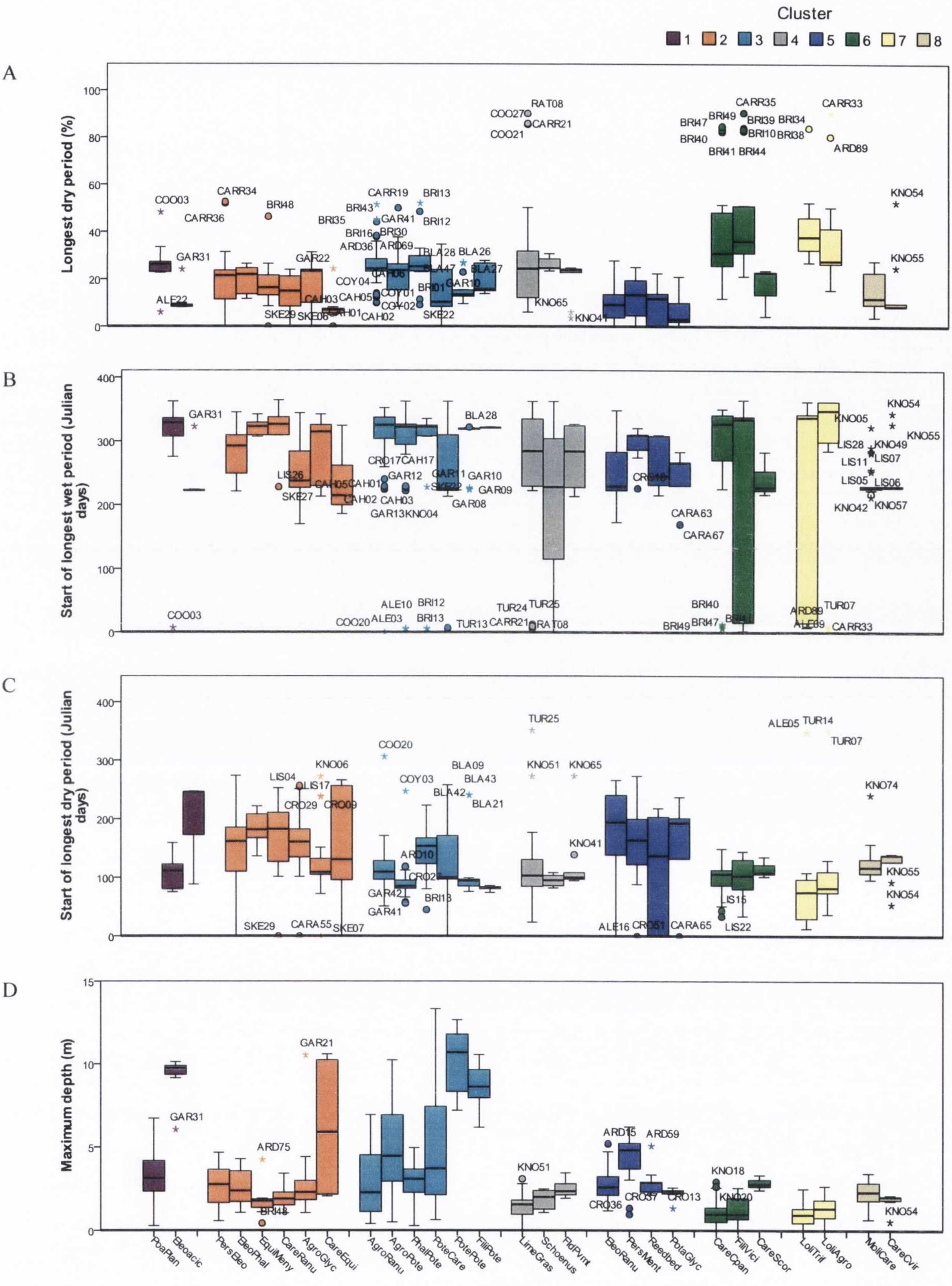


Figure 3.4(A-D) Boxplots showing the median, interquartile range and highest and lowest values for the length of the longest dry period, and the beginning of the longest dry and wet periods and maximum depth of inundation for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

3.4.2 Soils

3.4.2.1 Soil chemistry

Soil chemistry data for each turlough are presented in Table 3.13; these are the means of the soil chemistry of the upper middle and lower zones within the turlough (see Section 3.3.3 for details). Summary statistics for each of the variables for each vegetation community are shown in Table 3.14, Figure 3.5 and Figure 3.6. A Kruskal-Wallis test was carried out to test for differences between group medians, which indicated that there are significant differences between the medians of at least two groups, for each of the soil chemistry variables. Mann-Whitney U tests were then carried out to test for significant differences in median values between clusters (Table 3.15).

Lough Aleenaun had the highest mean total phosphorus (1594 mg kg^{-1}; Table 3.13), while Coolcam had the lowest (245 mg kg^{-1}). These two turloughs can be seen as outliers on the boxplot of soil total phosphorus for each vegetation community (Figure 3.5A). Group 14 Reedbed had the lowest median total phosphorus, at 475.5 mg kg^{-1}, while Group 19 *PotePote* and Group 20 *FiliPote* had the highest median total phosphorus, at 1123.0 mg kg^{-1}.

Mean soil total nitrogen ranged from 4,983 mg kg^{-1} (Coolcam turlough) to 24,233 mg kg^{-1} for Knockaunroe and 22,383 mg kg^{-1} for Skealoghan (Table 3.13). Knockaunroe and Skealoghan can be seen as outliers towards the top of the nitrogen gradient on the boxplot of soil total nitrogen for each vegetation community (Figure 3.5B), while relevés from Coolcam are evident outliers towards the bottom of the gradient. Group 19 *PotePote* and Group 20 *FiliPote* have the lowest total nitrogen (7050 mg kg^{-1}; Table 3.14, Figure 3.5B), while Group 22 *MoliCare*, Group 23 *CareScor* and Group 28 FldPavmt had the highest median total nitrogen (24233 mg kg^{-1}).

Mean soil pH ranged from 5.9 for Garryland to 8.3 for Termon (Table 3.13). Group 26 *Eleoacic* and Group 27 *CareEqui* were associated with a low median pH (5.9; Table 3.14, Figure 3.5C), while the community with the highest median pH was Group 14 Reedbed (8.3).

There was a wide range of mean soil organic matter, ranging from 10.2% in Coolcam to 69.1% in Knockaunroe (Table 3.13). Group 19 *PotePote* and Group 20 *FiliPote* had the lowest median organic matter content (14.6; Table 3.14, Figure 3.6A), while Group 22 *MoliCare*, Group 23 *CareScor* and Group 28 FldPavmt had the highest organic matter content (69.1). Mean soil inorganic matter content ranges from 25.7% in Knockaunroe to 85.0% in Coolcam (Table 3.13). Group 22 *MoliCare*, Group 23 *CareScor* and Group 29 FldPavmt all had the lowest median inorganic matter content (25.7%; Table 3.14, Figure 3.6B), while Group 19 *PotePote* and Group 20 *FiliVici* had the highest (80.4%).

Mean soil $CaCO_3$ ranged from 2.5% dry weight in Turloughmore to almost half of the dry weight of the soil (42.5%) in Lisduff (Table 3.13). Group 4 *AgroPote*, Group 19 *PotePote* and Group 20 *FiliPote* all had low median $CaCO_3$ content (5.0% dry weight; Table 3.14, Figure 3.6C), while Group 14 Reedbed had the highest (42.4% dry weight).

Table 3.13 Soil nutrient variables (mean and standard deviation) for each of the 22 turloughs.

		Total phosphorus (mg kg^{-1})		Total nitrogen (mg kg^{-1})		pH		Organic matter (% dry weight)		Inorganic matter (% dry weight)		$CaCO_3$ (% dry weight)	
Turlough	**Abbreviation**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Lough Aleenaun	ALE	1594	670	12077	5042	7.6	0.5	24.1	9.8	38.2	25.8	37.7	30.3
Ardkill	ARD	844	121	15400	4042	7.8	0.3	36.2	10.3	31.0	4.4	32.8	12.3
Ballindereen	BAL	761	137	9708	1231	8.0	0.2	21.5	4.3	39.9	11.4	38.6	14.5
Blackrock	BLA	1123	618	7050	1388	6.6	0.2	14.6	2.6	80.4	3.1	5.0	0.7
Brierfield	BRI	939	237	19458	10574	7.2	0.9	44.6	23.9	35.8	29.1	19.6	22.5
Caherglassaun	CAH	1016	449	6263	884	6.4	0.7	13.8	1.7	81.8	2.3	4.4	1.7
Caranavoodaun	CARA	814	365	15893	7540	8.0	0.2	38.0	18.5	27.5	16.2	34.6	31.4
Carrowreagh	CARR	1056	304	11783	5105	6.1	0.4	27.4	13.0	66.6	19.7	6.0	8.2
Coolcam	COO	245	36	4983	1191	7.8	0.6	10.2	3.3	85.0	4.4	4.8	4.7
Lough Coy	COY	1163	402	7069	2234	6.6	0.6	14.5	4.6	81.5	5.6	4.0	1.1
Croaghill	CRO	896	391	15883	11881	6.8	0.8	41.6	27.8	54.6	28.8	3.8	2.4
Garryland	GAR	920	270	9756	3379	5.9	0.6	22.6	8.4	71.6	8.6	5.8	0.4
Lough Gealain	GEA	578	220	21917	8630	7.5	0.8	38.1	18.3	41.9	23.6	20.0	28.4
Kilglassan	KIL	1226	495	17450	4918	7.4	0.5	34.0	10.4	44.5	8.0	21.5	11.9
Knockaunroe	KNO	1080	410	24233	9468	7.1	0.6	69.1	15.5	25.7	13.4	5.2	2.5
Lisduff	LIS	432	187	9234	2204	8.0	0.2	23.7	5.6	33.8	31.1	42.5	26.9
Rathnalulleagh	RAT	713	352	7958	3572	6.2	0.6	18.4	6.8	78.0	8.3	3.5	1.5
Roo West	ROO	716	193	14000	2945	7.2	0.7	29.1	10.5	55.1	19.4	15.8	21.0
Skealoghan	SKE	1059	288	22383	10719	7.0	0.7	53.4	25.4	39.9	26.2	6.7	6.2
Termon	TER	476	165	8217	2785	8.3	0.1	23.0	5.1	34.6	27.8	42.4	26.3
Tullynafrankagh	TUL	616	222	10050	4917	7.9	0.2	29.7	12.8	26.6	10.3	43.7	10.3
Turloughmore	TUR	915	328	8233	1725	6.6	0.5	18.8	2.6	78.7	2.8	2.5	0.4

Table 3.14 Summary statistics for soil chemistry variables.

		Total phosphorus ($mg\ kg^{-1}$)		Total nitrogen ($mg\ kg^{-1}$)		pH		Organic matter (% dry weight)		Inorganic matter (% dry weight)		$CaCO_3$ (% dry weight)	
		Mean	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**
1	*PoaPlan*	964.9	985.6 (244.7-1594.3)	10673	11783 (4983-15400)	6.9	6.6 (6.1-7.8)	24.1	25.8 (10.2-36.2)	62.3	66.6 (31.0-85.0)	13.6	6.0 (2.5-37.7)
2	*PersEleo*	902.5	895.6 (244.7-1594.3)	16590	15400 (4983-24233)	7.4	7.2 (6.1-8.3)	41.6	36.2 (10.2-69.1)	38.0	33.8 (25.7-85.0)	20.4	19.6 (3.8-42.5)
3	*AgroRanu*	899.6	919.9 (244.7-1163.4)	12027	11783 (4983-22383)	6.9	6.8 (5.9-8.3)	28.5	27.4 (10.2-53.4)	59.1	66.6 (31.0-85.0)	12.5	5.8 (3.5-42.5)
4	*AgroPote*	1071.6	1080.3 (713-1594.3)	10230	7958 (6263-24233)	6.6	6.6 (5.9-7.8)	23.9	18.4 (13.8-69.1)	68.3	78.7 (25.7-81.8)	7.9	5.0 (2.5-37.7)
5	LimeGras	842.3	814.3 (244.7-1080.3)	15774	15893 (4983-24233)	7.4	7.8 (6.1-8.0)	38.9	38.0 (10.2-69.1)	41.5	27.5 (25.7-85.0)	19.5	20.0 (2.5-34.6)
6	*EleoRanu*	774.9	869.8 (244.7-1080.3)	15992	15642 (4983-24233)	7.5	7.4 (6.8-8.3)	43.1	38.9 (10.2-69.1)	38.2	33.8 (25.7-85.0)	18.7	5.2 (3.8-42.5)
7	*EleoPhal*	894.4	939.2 (844.1-939.2)	17549	19458 (15400-19458)	7.5	7.2 (7.2-7.8)	40.6	44.6 (36.2-44.6)	33.5	35.8 (31.0-35.8)	25.9	19.6 (19.6-32.8)
8	*CareCpan*	891.6	939.2 (244.7-1080.3)	15865	15883 (4983-24233)	7.0	7.0 (6.1-8.0)	38.8	41.6 (10.2-69.1)	46.3	39.9 (25.7-85.0)	14.9	6.7 (3.8-42.5)
9	*PhalPote*	859.0	844.1 (713.0-1059.3)	15667	15400 (7958-22383)	7.4	7.8 (6.2-7.8)	36.6	36.2 (18.4-53.4)	38.3	31.0 (31.0-78.0)	25.1	32.8 (3.5-32.8)
10	*LoliTrif*	1063.0	939.2 (713.0-1594.3)	12081	11783 (7958-22383)	6.9	6.6 (6.1-7.8)	27.1	24.1 (18.4-53.4)	57.5	66.6 (31.0-78.7)	15.4	6 (2.5-37.7)
11	*PersMent*	1091.4	895.6 (844.1-1594.3)	14482	15400 (12077-15883)	7.5	7.6 (6.8-7.8)	33.8	36.2 (24.1-41.6)	39.1	38.2 (31.0-54.6)	27.1	32.8 (3.8-37.7)
12	*FiliVici*	819.1	844.1 (244.7-1056.2)	13923	15400 (4983-19458)	7.2	7.2 (6.1-8.0)	32.7	36.2 (10.2-44.6)	48.6	35.8 (27.5-85.0)	18.7	19.6 (3.5-34.6)
13	*PoteCare*	931.9	919.9 (244.7-1163.4)	10312	9756 (4983)	6.7	6.6 (5.9-8.0)	23.8	22.6 (10.2-44.6)	65.5	71.6 (31.0-85.0)	10.7	5.8 (2.5-42.5)
14	Reedbed	650.9	475.5 (475.5-1080.3)	12574	8217 (8217-24233)	8.0	8.3 (7.1-8.3)	34.7	23.0 (23.0-69.1)	32.3	34.6 (25.7-34.6)	33.1	42.4 (5.2-42.4)
15	*LoliAgro*	916.5	915.0 (244.7-1594.3)	11022	8233 (4983-15883)	7.0	6.6 (6.1-7.8)	25.6	18.8 (10.2-41.6)	60.9	78.0 (31.0-85.0)	13.6	3.8 (2.5-37.7)
16	*EquiMeny*	906.3	939.2 (432.1-1059.3)	18692	19458 (9234-22383)	7.3	7.2 (7.0-8.0)	43.5	44.6 (23.7-53.4)	35.9	35.8 (31.0-39.9)	20.6	19.6 (6.7-42.5)
17	*CareRanu*	708.4	814.3 (244.7-1080.3)	14207	15883 (4983-24233)	7.7	8.0 (6.8-8.3)	36.5	38.0 (10.2-69.1)	40.6	33.8 (25.7-85.0)	22.9	34.6 (3.8-42.5)
18	*AgroGlyc*	1020.4	1056.2 (432.1-1594.3)	14859	12077 (7958-24233)	6.8	6.9 (5.9-8.0)	36.2	27.4 (18.4-69.1)	51.2	47.3 (25.7-78.0)	12.6	6.0 (3.5-42.5)
19	*PotePote*	1090.5	1123.0 (919.9-1123.0)	7483	7050 (7050-9756)	6.5	6.6 (5.9-6.6)	15.9	14.6 (14.6-22.6)	79.0	80.4 (71.6-80.4)	5.1	5.0 (5-5.8.0)
20	*FiliPote*	1123.0	1123.0 (1123)	7050	7050 (7050)	6.6	6.6 (6.6)	14.6	14.6 (14.6-14.6)	80.4	80.4 (80.4)	5.0	5.0 (5.0)
21	*Schoenus*	721.3	577.7 (577.7-1080.3)	22579	21917 (21917-24233)	7.4	7.5 (7.1-7.5)	47.0	38.1 (38.1-69.1)	37.3	41.9 (25.7-41.9)	15.7	20.0 (5.2-20.0)
22	*MoliCare*	901.5	1080.3 (432.1-1080.3)	19433	24233 (9234-24233)	7.5	7.1 (7.1-8.0)	52.8	69.1 (23.7-69.1)	27.5	25.7 (25.7-33.8)	19.7	5.2 (5.2-42.5)
23	*CareScor*	1080.3	1080.3 (1080.3)	24233	24233 (24233)	7.1	7.1 (7.1)	69.1	69.1 (69.1)	25.7	25.7 (25.7)	5.2	5.2 (5.2)
24	*PotaGlyc*	794.7	814.3 (475.5-895.6)	15038	15893 (8217-15893)	7.8	8.0 (6.8-8.3)	37.1	38.0 (23.0-41.6)	34.3	27.5 (27.5-54.6)	28.6	34.6 (3.8-42.4)
25	*CareCvir*	873.4	814.3 (814.3-1080.3)	17747	15893 (15893-24233)	7.8	8.0 (7.1-8.0)	44.9	38.0 (38.0-69.1)	27.1	27.5 (27.5)	28	34.6 (5.2-34.6)
26	*Eleoacic*	919.9	919.9 (919.9)	9756	9756 (9756)	5.9	5.9 (5.9)	22.6	22.6 (22.6-22.6)	71.6	71.6 (71.6)	5.8	5.8 (5.8)
27	*CareEqui*	800.4	919.9 (432.1-1059.3)	11411	9756 (9234-22383)	6.7	5.9 (5.9-8.0)	27.3	22.6 (22.6-53.4)	56.3	71.6 (33.8-71.6)	16.4	5.8 (5.8-42.5)
28	FldPavmt	1080.3	1080.3 (1080.3)	24233	24233 (24233)	7.1	7.1 (7.1)	69.1	69.1 (69.1)	25.7	25.7 (25.7)	5.2	5.2 (5.2)

Table 3.15 *Post-hoc* Mann-Whitney U tests for differences between clusters for soil variables.

Total phosphorus (mg kg^{-1})

	1	2	3	4	5	6	7
2	0.186						
3	0.184	**0.000**					
4	0.173	0.698	**0.000**				
5	0.021	0.640	**0.000**	0.577			
6	0.625	0.299	**0.000**	0.728	0.230		
7	0.093	0.235	0.033	0.258	0.032	0.815	
8	0.561	0.309	**0.002**	0.416	0.520	0.607	0.618

Total nitrogen (mg kg^{-1})

	1	2	3	4	5	6	7
2	**0.000**						
3	0.432	**0.000**					
4	**0.000**	**0.000**	**0.000**				
5	**0.002**	0.354	**0.000**	**0.000**			
6	**0.000**	0.938	**0.000**	0.003	0.520		
7	0.597	**0.000**	0.026	**0.000**	0.004	**0.000**	
8	**0.000**	**0.000**	**0.000**	0.358	**0.000**	**0.000**	**0.000**

pH

	1	2	3	4	5	6	7
2	**0.000**						
3	**0.000**	**0.000**					
4	**0.000**	0.585	**0.000**				
5	**0.000**	0.052	**0.000**	0.038			
6	**0.000**	**0.001**	**0.000**	0.025	**0.000**		
7	**0.000**	**0.000**	0.082	**0.001**	**0.000**	0.146	
8	**0.000**	0.097	**0.000**	0.026	0.968	**0.000**	**0.000**

Organic matter (% dry weight)

	1	2	3	4	5	6	7
2	**0.000**						
3	0.493	**0.000**					
4	**0.000**	0.023	**0.000**				
5	**0.000**	0.436	**0.000**	0.021			
6	**0.000**	0.683	**0.000**	0.079	0.314		
7	0.768	**0.000**	0.044	**0.000**	**0.000**	**0.000**	
8	**0.000**	**0.000**	**0.000**	0.358	**0.000**	0.003	**0.000**

Inorganic matter (% dry weight)

	1	2	3	4	5	6	7
2	**0.000**						
3	0.404	**0.000**					
4	**0.000**	0.020	**0.000**				
5	**0.000**	0.065	**0.000**	0.083			
6	**0.000**	0.181	**0.000**	**0.002**	0.012		
7	0.630	**0.000**	0.031	**0.000**	**0.000**	**0.000**	
8	**0.000**	**0.000**	**0.000**	0.017	**0.000**	**0.000**	**0.000**

$CaCO_3$ (% dry weight)

	1	2	3	4	5	6	7
2	0.006						
3	0.098	**0.000**					
4	0.635	0.085	**0.000**				
5	0.031	0.284	**0.000**	0.018			
6	0.172	0.008	**0.002**	0.545	0.004		
7	0.630	**0.000**	0.239	0.050	**0.000**	0.045	
8	0.216	0.485	**0.000**	0.039	0.968	0.016	**0.001**

Figures in bold are significant ($p \leq 0.05$) after correction for multiple comparisons using the Dunn-Šidák method.

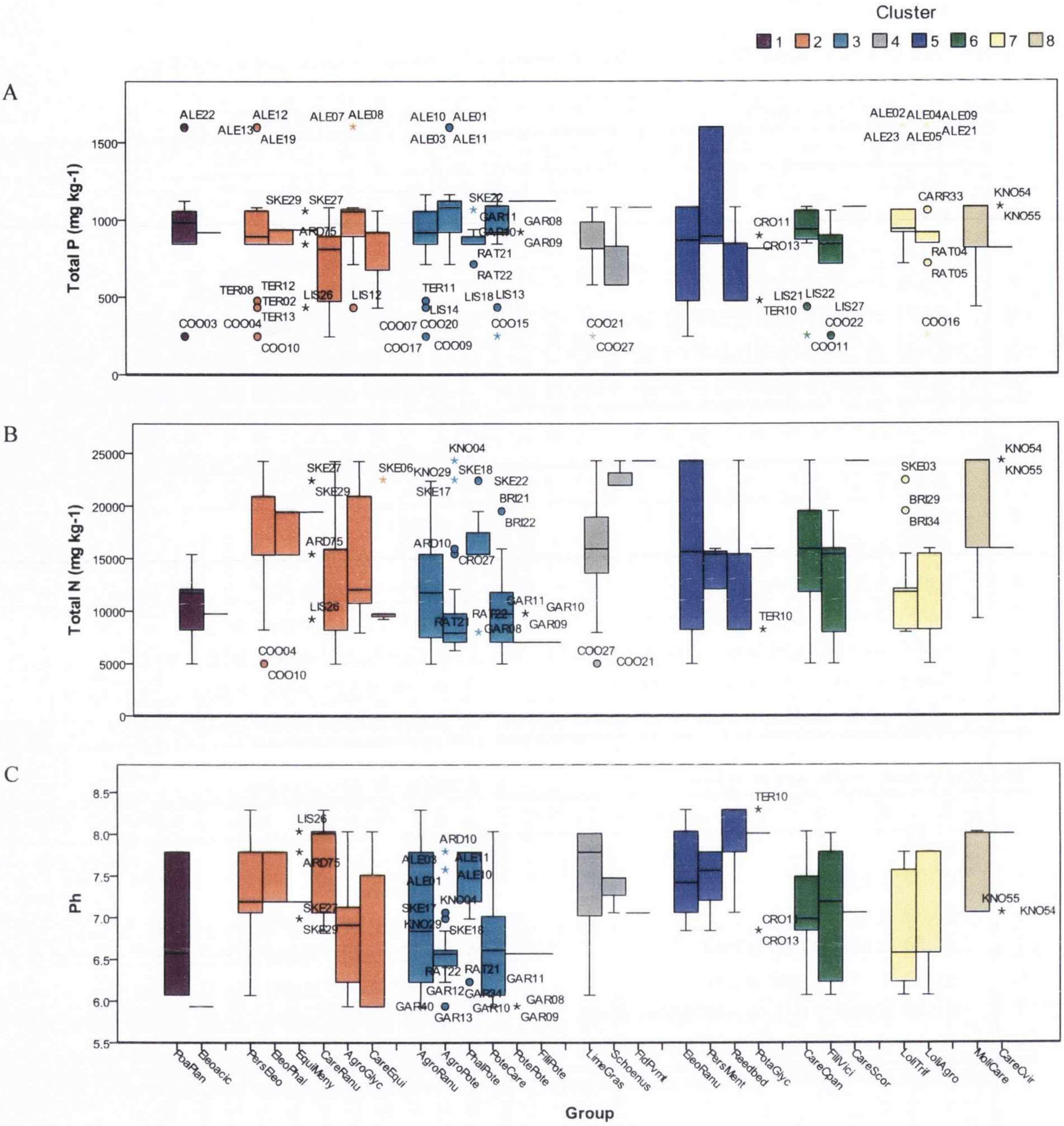


Figure 3.5(A-C) Boxplots showing the median, interquartile range and highest and lowest values for total phosphorus, total nitrogen and pH (soil chemistry) for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

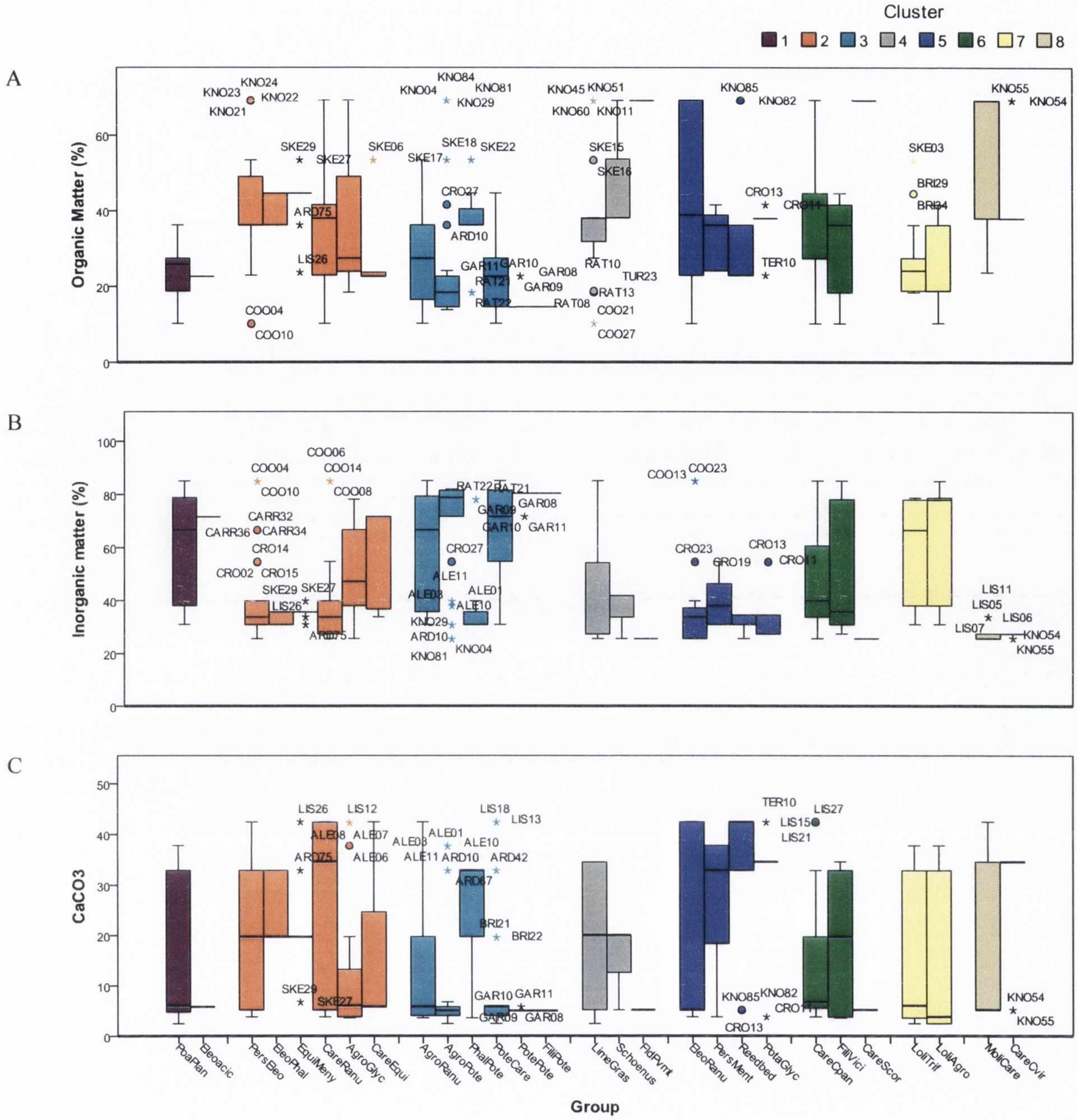


Figure 3.6 (A-C) Boxplots showing the median, interquartile range and highest and lowest values for soil organic matter, inorganic matter and $CaCO_3$ content for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

3.4.2.2 Soil types

A total of 13 soil types were found to be associated with the relevés recorded in this study (Table 3.16). For each vegetation community, the number of relevés occurring in each soil type (as mapped) were calculated (Table 3.17). For ease of interpretation, each specific soil type was assigned to one of the general soil types, these are shown in Figure 3.7.

Four vegetation communities were recorded only on one general soil type. Group 28 FldPavmt and Group 23 *CareScor* were recorded only on Alluvium, Group 26 *Eleoacic* was recorded only on PDM, and Group 20 *FiliPote* was only recorded on WDM. Twelve communities occurred on two soil types; of these, 10 were recorded on both Alluvium and PDO (Figure 3.7), while Group 27 *CareEqui* was recorded on both PDM and PDO, and Group 19 *PotePote* was recorded on both PDM and WDM. The remainder of the vegetation communities occurred on a variety of soil types, suggesting that these communities are not restricted by soil type.

Table 3.16 General (in bold) and specific soil types found in the 22 turloughs in this study.

Soil type	Code	Characteristics
Well-drained mineral (WDM)		
Very shallow well drained mineral	BminVSW	Soil depth <25cm; well drained mineral soils derived principally from calcareous parent materials. Generally have medium textures (sandy loam, loam, sandy clay loam) with semi-fibrous organic material.
Shallow well drained mineral	BminSW	Soil depth 25-76cm well drained mineral soils; derived principally from calcareous parent materials. Generally have medium textures (sandy loam, loam, sandy clay loam) with semi-fibrous organic material.
Poorly-drained mineral (PDM)		
Very shallow poorly drained mineral	BminVSP	Soil depth < 25 cm; poorly drained mineral soils derived principally from calcareous parent materials. Generally have medium textures (sandy loam, loam, sandy clay loam) with semi-fibrous organic material.
Shallow poorly drained mineral	BminSP	Soil depth 25-76cm; poorly drained mineral soils derived principally from calcareous parent materials. Generally have medium textures (sandy loam, loam, sandy clay loam) with semi-fibrous organic material.
Deep poorly drained mineral	BminDP	Soil depth >76cm; poorly drained mineral soils derived principally from calcareous parent materials. Generally have medium textures (sandy loam, loam, sandy clay loam) with semi-fibrous organic material.
Shallow poorly drained mineral soils with peaty topsoil	BminSPPT	Soil depth 25-76cm; poorly drained mineral soils derived principally from calcareous parent materials. Distinct peaty topsoil present with organic texture and dark (10 YR 3/1, 3/2, 3/3, 2/1or 2/2) colouration. Lower horizons generally have silty clay, clay loam textures with semi-fibrous organic material.
Well drained organic (WDO)		
Very shallow well drained organic	BorgVSW	Soil depth <25cm; well drained organic soils derived principally from calcareous parent materials. Generally have organic or loamy textures with fibrous organic material.
Poorly drained organic (PDO)		
Very shallow poorly drained organic	BorgVSP	Soil depth <25cm; poorly drained organic soils derived principally from calcareous parent materials. Generally have organic or loamy textures with fibrous organic material. M/SM not significant.
Fen Peat	FenPt	Soil depth >30cm; poorly drained organic soils derived principally from calcareous parent materials. Generally have organic or organic silty clay textures with fibrous organic material. Dark (10 YR 3/1, 3/2, 3/3, 2/1or 2/2) or Dusky red (10 R 3/2, 3/3or 3/4) colouration. 0-20% marl or shell marl may or may not be present.
Alluviums		
Peat-marl	Pt-MRL	Mid-point of the continuum from marl to peat and has a characteristic calcium carbonate content of 55-70% and an organic matter content of 10-25% (Coxon, 1986). Dark (10 YR 3/1, 3/2, 3/3, 2/1, 2/2) or greyish brown (10 YR 5/2) soil matrix with abundant flecks of snail shell marl and/or marl deposition. Profile generally undifferentiated into horizons. Depths range from very shallow to deep.
Marl with peaty topsoil	AlluvMRLPT	Profile generally has two distinct horizons consisting of peaty topsoil with organic texture and dark (10 YR 3/1, 3/2, 3/3, 2/1, 2/2) colouration and a grey (10 YR 5/1, 6/1, 7/1 or 8/1) marl horizon with of clay, silty clay or silty clay loam texture. Distinct mottling is often present.
Marl alluvium	AlluvMRL	Generally grey (10 YR 5/1) or greyish brown (10 YR 5/2), very shallow or shallow, often stony soils. Abundant marl and/or shell marl evident. Semi-fibrous organic matter. Deeper lacustrine type soils
Mineral alluvium	AlluvMIN	Generally dark, very shallow, often stony soils with silty textures and semi-fibrous organic material. Marl and/or shell marl often common but not abundant.

Table 3.17 Number of relevés belonging to each community occurring in each soil type (descriptions are presented in Table 3.16).

		Alluvium				PDM				PDO		WDM		WDO
		AlluvMIN	AlluvMRL	AlluvMRLPT	Pt-MRL	BminDP	BminSP	BminSPPT	BminVSP	BorgVSP	FenPt	BminSW	BminVSW	BorgVSW
1	*PoaPlan*	1					4		1	2			1	1
2	*PersEleo*	2	4	8	8		3			19	18			1
3	*AgroRanu*	4	1	5		1	22		14	12	18	1	1	
4	*AgroPote*				2		14		12	7		2	10	2
5	LimeGras				3		2	2	1	5	8	2		12
6	*EleoRanu*	3	6		10					3	6			
7	*EleoPhal*			9						4	4			
8	*CareCpan*	1		5	1		6		1	3	14			1
9	*PhalPote*			3			2			10	1			
10	*LoliTrif*			2			3		2	5	1	3		1
11	*PersMent*			4						8	4			
12	*FiliVici*	1		4		1	5			9	2	2		1
13	*PoteCare*	1		2		1	8		12	1	6			
14	Reedbed		6		2					1				
15	*LoliAgro*	1					9			7		2		1
16	*EquiMeny*			7							4			
17	*CareRanu*	8	9	1	8					2	31			
18	*AgroGlyc*			1	2		7			3	7			
19	*PotePote*						11		3			4	7	
20	*FiliPote*											2	11	
21	*Schoenus*				2					5				
22	*MoliCare*				16					2	15			
23	*CareScor*				7									
24	*PotaGlyc*		1								8			
25	*CareCvir*				2						7			
26	*Eleoacic*					8			4					
27	*CareEqui*					4					3			
28	FldPavmt				10									

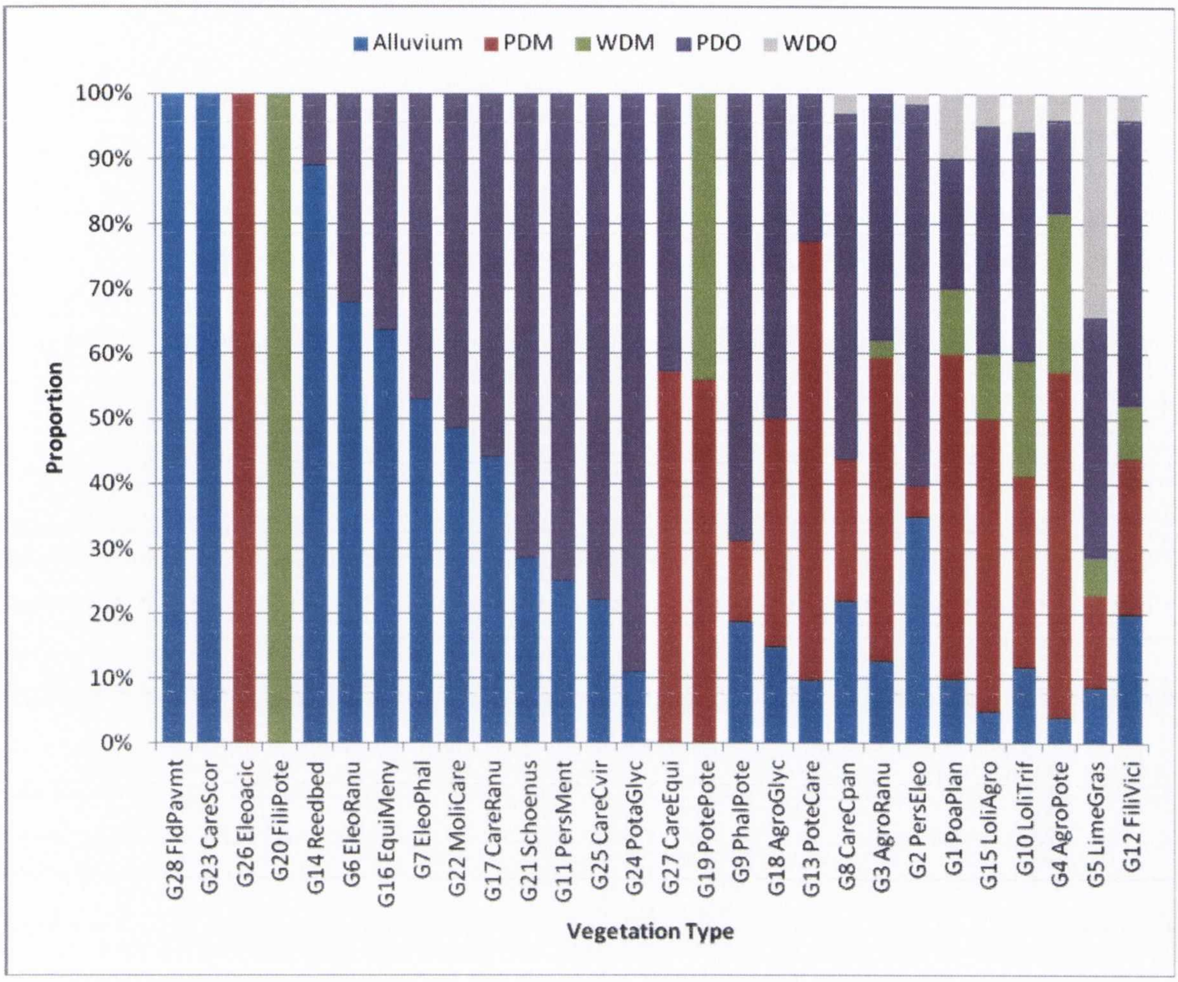


Figure 3.7 Stacked bar chart showing the proportions of each general soil type for each vegetation community. See Table 3.16 for explanation of the codes used.

3.4.3 Water chemistry

Water chemistry results for each turlough are presented in Table 3.18. Water chemistry results were summarised for each vegetation community and are presented in Table 3.19, and displayed graphically in Figure 3.8 to Figure 3.9. A Kruskal-Wallis test was conducted on the data to test for differences between group medians indicated that there were significant differences between the medians of at least two groups for each of the water chemistry variables. *Post-hoc* Mann-Whitney U tests were carried out to determine which clusters differed (Table 3.20).

3.4.3.1 Nutrient concentrations and turloughs

There was considerable variation in nutrient levels between turloughs; mean values for the sampling period (October 2006 to June 2007) are presented in Table 3.18. Mean TP ranged from 4.0 to 82.1 $\mu g\ l^{-1}$. Four turloughs had mean TP values of $< 12\ \mu g\ l^{-1}$, indicating oligotrophic status (see Table 3.4 in Methods section for threshold values), twelve had mean TP values indicating they were mesotrophic, while six had mean TP levels making them eutrophic. Mean MRP also spanned a large range of values, from 42.1 $\mu g\ l^{-1}$ in Ardkill to 0.71 $\mu g\ l^{-1}$ in Knockaunroe. Caranavoodaun and Tullynafrankagh had the highest mean TN, at 2.3 and 2.1 mg l^{-1}, while Knockaunroe had the lowest (0.55 mg l^{-1}). Mean nitrate concentrations showed a similar pattern to TN; Caranavoodaun, Tullynafrankagh and Lisduff had the highest levels (1.49 – 1.86 mg l^{-1}). Knockaunroe was among the turloughs with the lowest mean MRP values, at 0.3 mg l^{-1}, but Brierfield had the lowest, at 0.1 mg l^{-1}. Mean alkalinity values ranged from 112.3 mg l^{-1} in Brierfield to 236.4 mg l^{-1} in Rathnalulleagh. There was relatively little temporal variation in alkalinity; standard deviations were low. Unsurprisingly, mean calcium concentrations varied in a similar fashion to mean alkalinity. As with alkalinity, Brierfield was the turlough with the lowest mean calcium concentration (44.41 mg l^{-1}), while Rathnalulleagh had the highest mean concentration (99.17 mg l^{-1}).

3.4.3.2 Nutrient concentrations and vegetation communities

Many of the vegetation communities were associated with a wide range of median TP values (Figure 3.8A). While some of the vegetation communities occurred in turloughs with a range of TP concentrations (e.g. Group 2 *PersEleo*), others seemed to occur in turloughs with a lower concentration (e.g. Group 5 *LimeGras*, Group 21 *Schoenus*). Group 21 *Schoenus*, Group 22 *MoliCare*, Group 23 *CareScor* and Group 28 FldPavmt had the lowest median TP concentrations. Group 9 *PhalPote* had by far the highest median TP concentration, at 82.12 $\mu g\ l^{-1}$. Ardkill was the turlough with the highest mean TP (Table 3.18), and at 82.1 $\mu g\ l^{-1}$ this was almost 30 $\mu g\ l^{-1}$ higher than the next highest mean, in Blackrock. There was also significant temporal variation in the TP concentrations found in Ardkill, as evidenced by the large standard deviation. There are a large number of positive outliers present in Figure 3.8A and B; most of these are quadrats that were recorded in Ardkill, suggesting higher TP at Ardkill than were usual for the plant communities found there.

Table 3.18 Mean and standard deviations of water chemistry variables for each of the 22 turloughs.

Turlough	Abbreviation	TP (μg l^{-1}) Mean	TP SD	MRP (μg l^{-1}) Mean	MRP SD	TN (mg l^{-1}) Mean	TN SD	Nitrate (mg l^{-1}) Mean	Nitrate SD	Alk (mg l^{-1} $CaCO_3$) Mean	Alk SD	Calcium (mg l^{-1}) Mean	Calcium SD	OECD trophic status based on TP*
Lough Aleenaun	ALE	30.7	13.8	9.1	6.3	1.3	0.3	1.0	0.3	160.2	25.2	67.1	11.8	Mesotrophic
Ardkill	ARD	82.1	32.6	42.1	26.6	1.7	1.0	1.3	1.0	220.2	25.0	90.9	15.6	Eutrophic
Ballindereen	BAL	12.4	8.5	1.1	0.4	0.7	0.4	0.2	0.2	183.6	20.2	71.9	7.4	Mesotrophic
Blackrock	BLA	52.4	15.7	27.3	9.5	1.7	0.3	1.2	0.4	166.9	58.4	71.0	28.6	Eutrophic
Brierfield	BRI	19.8	9.5	1.9	0.8	0.6	0.2	0.1	0.1	210.2	25.9	85.3	15.7	Mesotrophic
Caherglassaun	CAH	43.2	12.1	18.8	6.9	1.2	0.2	0.7	0.2	112.4	28.1	44.4	7.0	Eutrophic
Caranavoodaun	CARA	11.0	3.8	1.5	0.7	2.3	1.4	1.9	1.4	217.1	30.0	87.4	16.9	Mesotrophic
Carrowreagh	CARR	42.8	7.7	8.2	7.5	0.9	0.5	0.4	0.4	218.8	14.7	92.5	8.4	Eutrophic
Coolcam	COO	34.0	21.3	3.7	4.1	1.3	0.7	0.9	0.6	214.0	29.0	87.1	17.7	Mesotrophic
Lough Coy	COY	43.4	15.9	20.6	9.9	1.4	0.3	1.0	0.3	142.7	26.1	56.5	8.4	Eutrophic
Croaghill	CRO	25.0	16.6	3.5	2.3	1.2	0.7	0.7	0.7	220.2	21.3	90.7	13.5	Mesotrophic
Garryland	GAR	24.6	6.8	10.9	3.8	1.1	0.4	0.6	0.2	122.1	23.5	47.9	7.5	Mesotrophic
Lough Gealain	GEA	4.0	1.2	0.8	0.4	0.6	0.2	0.4	0.1	134.9	4.9	55.4	3.9	Oligotrophic
Kilglassan	KIL	27.2	11.6	4.6	3.6	1.5	1.0	1.1	1.0	216.2	39.4	91.9	17.7	Mesotrophic
Knockaunroe	KNO	4.2	1.8	0.7	0.4	0.6	0.2	0.3	0.2	138.5	3.1	56.5	3.3	Oligotrophic
Lisduff	LIS	7.4	2.0	1.5	0.5	1.9	0.8	1.8	0.8	227.8	43.8	96.0	23.4	Oligotrophic
Rathnalulleagh	RAT	44.6	22.0	3.4	1.9	1.3	0.5	0.7	0.5	236.4	38.9	99.2	16.4	Eutrophic
Roo West	ROO	9.8	4.1	1.1	0.5	0.6	0.3	0.3	0.2	141.0	26.3	58.6	11.2	Eutrophic
Skealoghan	SKE	20.4	6.2	5.8	5.9	0.9	0.7	0.5	0.7	197.8	26.6	79.2	14.8	Mesotrophic
Termon	TER	19.5	10.9	3.3	1.8	0.6	0.4	0.3	0.4	167.5	19.1	68.0	6.9	Mesotrophic
Tullynafrankagh	TUL	33.0	17.9	3.3	1.9	2.1	1.2	1.5	1.3	233.8	22.2	91.5	15.9	Mesotrophic
Turloughmore	TUR	15.0	7.9	2.3	1.1	0.6	0.3	0.3	0.3	225.6	30.7	88.3	13.9	Mesotrophic

* as presented in Cunha Pereira et al. (2010).

Table 3.19 Mean, median and range of water chemistry variables for each of the 28 vegetation communities.

		TP (μg l^{-1})		MRP (μg l^{-1})		TN (mg l^{-1})		Nitrate (mg l^{-1})		Alkalinity (mg l^{-1} $CaCO_3$)		Calcium (mg l^{-1})	
		Mean	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**
1	*PoaPlan*	44.9	42.8 (19.5-82.1)	15.6	8.2 (3.3-42.1)	1.17	1.08 (0.63-1.74)	0.74	0.64 (0.33-1.25)	197.3	216.4 (160.2-220.2)	82.1	89.0 (67.1-92.5)
2	*PersEleo*	36.7	25.0 (4.2-82.1)	14.4	3.5 (0.7-42.1)	1.13	1.17 (0.55-1.9)	0.73	0.7 (0.06-1.75)	200.6	220.2 (138.5-227.8)	82.2	88.3 (56.5-96.0)
3	*AgroRanu*	44.0	42.8 (7.4-82.1)	15.7	8.2 (1.5-42.1)	1.24	1.22 (0.57-1.9)	0.75	0.7 (0.06-1.75)	195.1	218.8 (112.4-236.4)	80.2	90.7 (44.4-99.2)
4	*AgroPote*	36.3	43.2 (4.2-82.1)	15.0	18.8 (0.7-42.1)	1.23	1.25 (0.55-1.74)	0.80	0.69 (0.30-1.25)	155.7	160.2 (112.4-236.4)	63.7	67.1 (44.4-99.2)
5	LimeGras	18.0	11.0 (4.04-82.1)	3.4	1.5 (0.7-42.1)	1.52	1.27 (0.55-2.3)	1.12	0.92 (0.30-1.86)	197.5	217.1 (134.9-236.4)	80.3	87.4 (55.4-99.2)
6	*EleoRanu*	20.9	15.0 (4.2-82.1)	6.4	2.3 (0.7-42.1)	0.94	0.62 (0.55-1.9)	0.61	0.30 (0.28-1.75)	190.4	214.0 (138.5-227.8)	77.2	87.1 (56.5-96.0)
7	*EleoPhal*	49.2	19.8 (19.84-82.1)	20.8	1.9 (1.9-42.1)	1.12	0.57 (0.57-1.74)	0.62	0.06 (0.06-1.25)	214.9	210.2 (210.2-220.2)	87.9	85.3 (85.3-90.9)
8	*CareCpan*	29.5	22.7 (4.2-82.1)	7.9	3.63 (0.7-42.1)	1.09	0.92 (0.55-1.9)	0.66	0.50 (0.06-1.75)	210.4	218.8 (138.5-227.8)	86.9	90.7 (56.5-96.0)
9	*PhalPote*	61.9	82.1 (19.84-82.1)	27.5	42.1 (1.9-42.1)	1.41	1.74 (0.57-1.74)	0.91	1.25 (0.06-1.25)	218.9	220.2 (197.8-236.4)	90.1	90.9 (79.2-99.2)
10	*LoliTrif*	33.1	30.7 (19.5-82.1)	7.5	3.4 (1.9-42.1)	0.99	0.92 (0.57-1.74)	0.58	0.50 (0.06-1.25)	193.8	197.8 (160.2-236.4)	80.2	79.2 (67.1-99.2)
11	*PersMent*	51.8	30.7 (25.0-82.1)	22.1	9.1 (3.5-42.1)	1.44	1.25 (1.17-1.74)	1.04	1.01 (0.7-1.25)	201.4	220.2 (160.2-220.2)	83.4	90.7 (67.1-90.9)
12	*FiliVici*	49.7	44.6 (11.0-82.1)	17.2	3.5 (1.5-42.1)	1.31	1.25 (0.57-2.3)	0.80	0.7 (0.06-1.86)	221.6	220.2 (210.2-236.4)	91.5	90.9 (85.3-99.2)
13	*PoteCare*	35.5	25.0 (7.4-82.1)	14.1	10.7 (1.5-42.1)	1.22	1.17 (0.57-1.9)	0.78	0.7 (0.06-1.75)	169.8	166.9 (112.4-227.8)	69.0	68.0 (44.4-96.0)
14	Reedbed	20.1	15.0 (4.2-82.1)	6.4	2.3 (0.7-42.1)	0.73	0.62 (0.55-1.74)	0.39	0.28 (0.28-1.25)	205.6	225.6 (138.5-225.6)	81.5	88.3 (56.5-90.9)
15	*LoliAgro*	40.2	30.7 (19.5-82.1)	13.4	3.5 (3.3-42.1)	1.11	1.17 (0.63-1.74)	0.71	0.66 (0.33-1.25)	195.6	214.0 (160.2-236.4)	80.6	87.1 (67.1-99.2)
16	*EquiMeny*	30.4	19.8 (7.4-82.1)	10.9	1.9 (1.5-42.1)	1.07	0.92 (0.57-1.9)	0.61	0.50 (0.06-1.75)	202.6	210.2 (166.9-227.8)	83.1	85.3 (71.0-96.0)
17	*CareRanu*	15.6	11.0 (4.2-34.0)	2.3	1.5 (0.7-5.79)	1.33	1.17 (0.55-2.3)	0.98	0.7 (0.06-1.86)	206.1	217.1 (138.5-227.8)	83.4	87.4 (56.5-96.0)
18	*AgroGlyc*	27.5	25.0 (4.2-44.6)	5.3	4.7 (0.7-10.7)	1.06	1.13 (0.55-1.9)	0.64	0.62 (0.06-1.75)	196.9	214.5 (122.1-236.4)	81.4	88.0 (47.9-99.2)
19	*PotePote*	48.0	52.4 (24.6-52.4)	24.7	27.3 (10.7-27.3)	1.62	1.72 (1.08-1.72)	1.11	1.21 (0.57-1.21)	159.8	166.9 (122.1-166.9)	67.3	71.0 (47.9-71.0)
20	*FiliPote*	52.4	52.4 (52.4)	27.3	27.3 (27.3)	1.72	1.72 (1.72)	1.21	1.21 (1.21)	166.9	166.9 (166.9)	71.0	71.0 (71.0)
21	*Schoenus*	4.1	4.0 (4.04-4.2)	0.7	0.75 (0.7-0.75)	0.58	0.59 (0.55-0.59)	0.34	0.35 (0.3-0.35)	135.9	134.9 (134.9-138.5)	55.7	55.4 (55.4-56.5)
22	*MoliCare*	6.7	4.2 (4.2-11.0)	1.1	0.7 (0.7-1.5)	1.28	0.55 (0.55-2.3)	0.99	0.30 (0.3-1.86)	175.8	138.5 (138.5-227.8)	71.8	56.5 (56.5-96.0)
23	*CareScor*	4.2	4.2 (4.2)	0.7	0.7 (0.7)	0.55	0.55 (0.55)	0.30	0.30 (0.3)	138.5	138.5 (138.5)	56.5	56.5 (56.5)
24	*PotaGlyc*	14.6	11.0 (11.0-25.0)	2.1	1.5 (1.5-3.5)	1.86	2.3 (0.62-2.3)	1.43	1.86 (0.28-1.86)	218.7	217.1 (217.1-225.6)	88.2	87.4 (87.4-90.7)
25	*CareCvir*	9.5	11.0 (4.2-11.0)	1.4	1.5 (0.7-1.5)	1.91	2.3 (0.55-2.3)	1.51	1.86 (0.3-1.86)	199.6	217.1 (138.5-217.1)	80.5	87.4 (56.5-87.4)
26	*Eleoacic*	24.6	24.6 (24.6)	10.9	10.7 (10.7)	1.08	1.08 (1.08)	0.57	0.57 (0.57)	122.1	122.1 (122.1)	47.9	47.9 (47.9)
27	*CareEqui*	19.1	24.6 (7.4-24.6)	7.5	10.7 (1.5-10.7)	1.29	1.08 (0.92-1.9)	0.90	0.57 (0.5-1.75)	163.1	122.1 (122.1-227.8)	66.1	47.9 (47.9-96.0)
28	FldPavmt	4.2	4.2 (4.2)	0.7	0.7 (0.7)	0.55	0.55 (0.55)	0.30	0.30 (0.30)	138.5	138.5 (138.5)	56.5	56.5 (56.5)

Table 3.20 Mann-Whitney U tests for water chemistry variables.

TP (μg l^{-1})

	1	2	3	4	5	6	7
2	0.019						
3	0.003	**0.000**					
4	**0.000**	**0.000**	**0.000**				
5	0.027	0.436	**0.000**	**0.000**			
6	0.698	0.067	**0.000**	**0.000**	0.048		
7	0.950	0.009	0.006	**0.000**	**0.001**	0.709	
8	**0.000**	**0.000**	**0.000**	0.302	**0.000**	**0.000**	**0.000**

MRP (μg l^{-1})

	1	2	3	4	5	6	7
2	**0.000**						
3	0.254	**0.000**					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	0.763	**0.000**	**0.000**			
6	**0.000**	0.532	**0.000**	**0.000**	0.455		
7	**0.001**	0.009	**0.000**	**0.000**	0.012	0.173	
8	**0.000**	**0.000**	**0.000**	0.046	**0.000**	**0.000**	**0.000**

Nitrate (mg l^{-1})

	1	2	3	4	5	6	7
2	0.890						
3	0.007	0.054					
4	0.310	0.436	0.051				
5	0.870	0.793	0.257	0.303			
6	0.742	0.363	0.007	0.516	0.403		
7	0.792	0.718	0.009	0.754	0.946	0.864	
8	0.794	0.014	0.264	0.897	0.016	0.030	0.445

TN (mg l^{-1})

	1	2	3	4	5	6	7
2	0.873						
3	0.006	0.014					
4	0.264	0.394	0.023				
5	0.886	0.832	0.053	0.595			
6	0.780	0.354	0.005	0.810	0.644		
7	0.761	0.874	0.005	0.325	0.699	0.804	
8	0.749	0.658	0.572	0.897	0.515	0.392	0.710

Alkalinity (mg l^{-1} $CaCO_3$)

	1	2	3	4	5	6	7
2	**0.000**						
3	0.018	**0.000**					
4	0.015	**0.000**	0.257				
5	**0.000**	0.343	**0.000**	**0.000**			
6	**0.000**	0.320	**0.000**	**0.000**	0.876		
7	**0.000**	0.331	0.005	0.003	0.402	0.114	
8	0.010	0.005	0.481	0.350	**0.002**	**0.001**	0.011

Calcium (mg l^{-1})

	1	2	3	4	5	6	7
2	**0.000**						
3	0.026	**0.000**					
4	0.017	**0.000**	0.599				
5	**0.002**	0.886	0.023	**0.000**			
6	**0.000**	0.023	**0.000**	**0.000**	0.018		
7	**0.002**	0.766	0.113	0.003	0.490	0.119	
8	0.010	0.005	0.757	0.350	**0.002**	**0.001**	0.011

Figures in bold are significant ($p \leq 0.05$) after correction for multiple comparisons using the Dunn-Šidák method.

When Mann-Whitney U-tests were carried out to gauge the statistical significance of differences between median TP concentrations for clusters, clusters 4 and 8 were not significantly different from each other, but were significantly different from every other cluster. These are clusters which contain vegetation communities associated with lower nutrient levels, such as Group 21 *Schoenus*, while the vegetation communities in the other clusters are composed of species which are associated with higher levels of soil nutrients. Cluster 1 was significantly different from clusters 4 and 8, but no others. Cluster 2 was significantly different from Clusters 3, 4 and 8, but no others.

A similar pattern was evident with MRP. Many communities occurred in turloughs with wide ranges of MRP concentrations, but as described above, some communities seemed to be restricted to turloughs with high MRP concentrations while others occurred in turloughs with low concentrations. Group 21 *Schoenus*, Group 22 *MoliCare*, Group 23 *CareScor* and Group 28 FldPavmt had the lowest concentrations, while Group 9 *PhalPote* had the highest (Figure 3.8B).

Many of the positive outliers for TP and MRP were from Ardkill turlough (Figure 3.8). Ardkill had by far the highest mean TP and MRP of all turloughs sampled (Table 3.18). This suggests that there is some nutrient input to the turlough, either via overland flow from surrounding farmland or via the recharge water from the catchment.

Knockaunroe had the lowest mean total nitrogen concentration Table 3.18, and there were a number of outliers from this turlough (Figure 3.8C). Group 28 FldPavmt, Group 6 *EleoRanu*, Group 14 Reedbed and Group 23 *CareScor* all had very low median total nitrogen concentration (Figure 3.8C). Some communities had very low total phosphorus concentrations, but high total nitrogen concentrations, i.e. Group 5 LimeGras and Group 25 *CareCvir*.

It is interesting to note that total nitrogen concentration across communities seemed to be less variable than total phosphorus concentration; most communities occurred in turloughs with a wide range of total nitrogen concentration in turlough waters, with a few exceptions. This may suggest that total phosphorus concentrations in turlough waters are a stronger driver of turlough plant communities than total nitrogen.

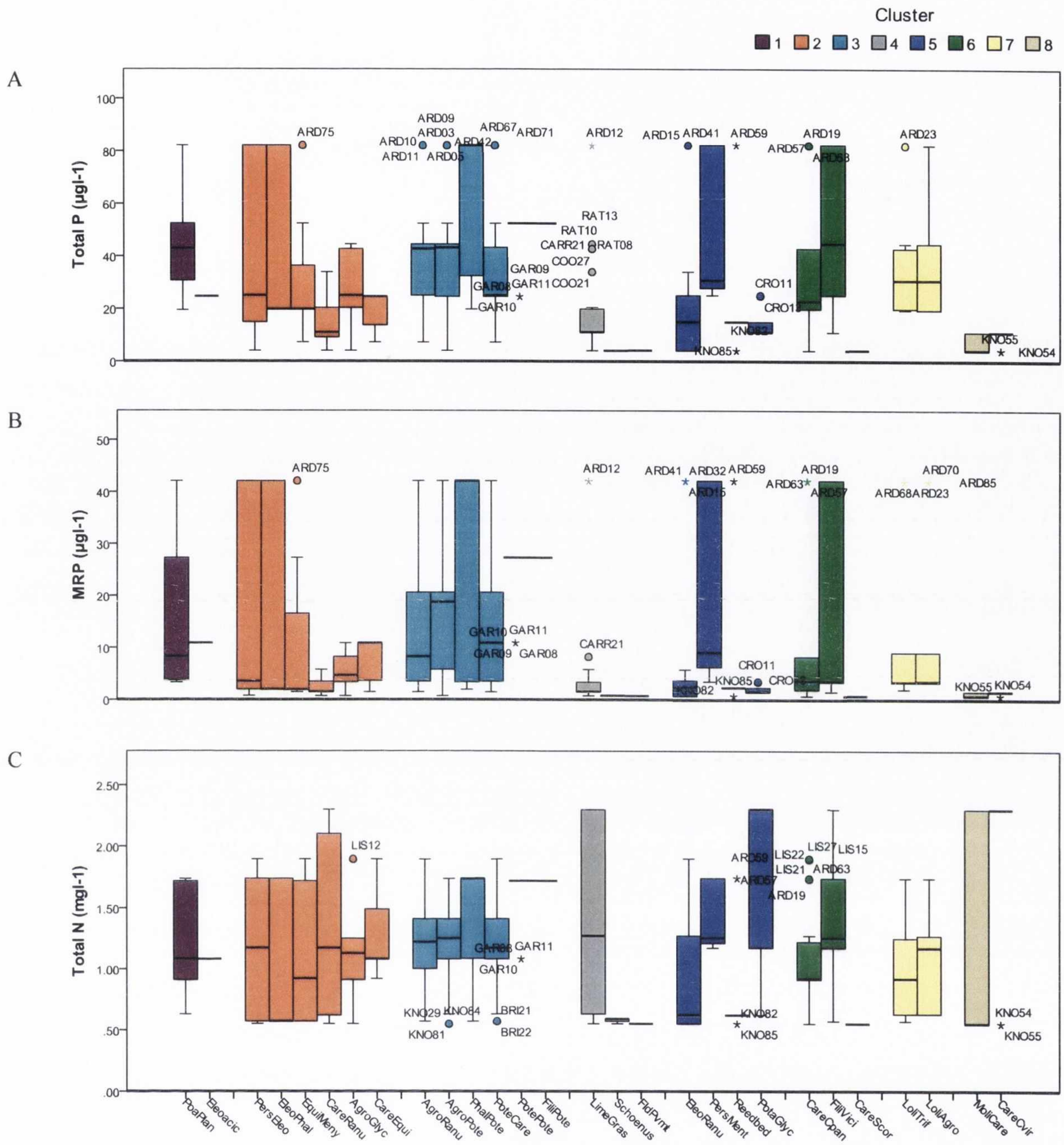


Figure 3.8(A-C) Boxplots showing the median, interquartile range and highest and lowest values for total phosphorus, molybdate reactive phosphorus and total nitrogen (water chemistry) for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

There was a wide range of median nitrate concentration associated with turlough vegetation communities (Table 3.19, Figure 3.9A). The pattern of nitrate concentrations for each vegetation community closely resembled that of TN concentrations (Figure 3.8C). As with TN, Ardkill and Lisduff feature in the outliers seen in the boxplots. While the turlough values for these were at the higher end of the range (Table 3.18), neither was the highest value recorded for TN or nitrate in any turlough. This might indicate that these communities are at the edge of their range when they occur in Ardkill and Lisduff, or alternatively that the mean water TN and nitrate concentrations are not highly associated with specific vegetation types.

A number of vegetation communities were associated with turlough water with low alkalinity, i.e. Group 21 *Schoenus*, Group 23 *CareScor*, Group 26 *Eleoacic*, Group 27 *CareEqui* and Group 28 FldPavmt all had low median alkalinity (Figure 3.9B). Group 2 *PersEleo*, Group 9 *PhalPote*, Group 11 *PersMent* and Group 12 *FiliVici* are all communities which seem to be associated with a high level of alkalinity; all of these groups had a high median alkalinity (220.2).

The distribution of calcium concentration followed a pattern similar to that of alkalinity – Group 21 *Schoenus*, Group 23 *CareScor*, Group 26 *Eleoacic*, Group 27 *CareEqui* and Group 28 FldPavmt all had low median concentrations of calcium (47.9 – 56.5;Table 3.19, Figure 3.9C). Group 3 *AgroRanu*, Group 8 *CareCpan*, Group 9 *PhalPote*, Group 11 *PersMent* and Group 12 *FiliVici* all had high median alkalinity concentrations (90.7 – 90.9;Table 3.19, Figure 3.9C).

There were a number of outliers in the boxplots for Alkalinity and Calcium (Figure 3.9B & C). At the upper end of the range these were mainly relevés recorded in Rathnalulleagh and Lisduff, both of which were among the most highly alkaline and had the highest mean calcium concentrations (Table 3.18). Outliers occurring towards the lower end of the range were quadrats from Knockaunroe and Garryland.

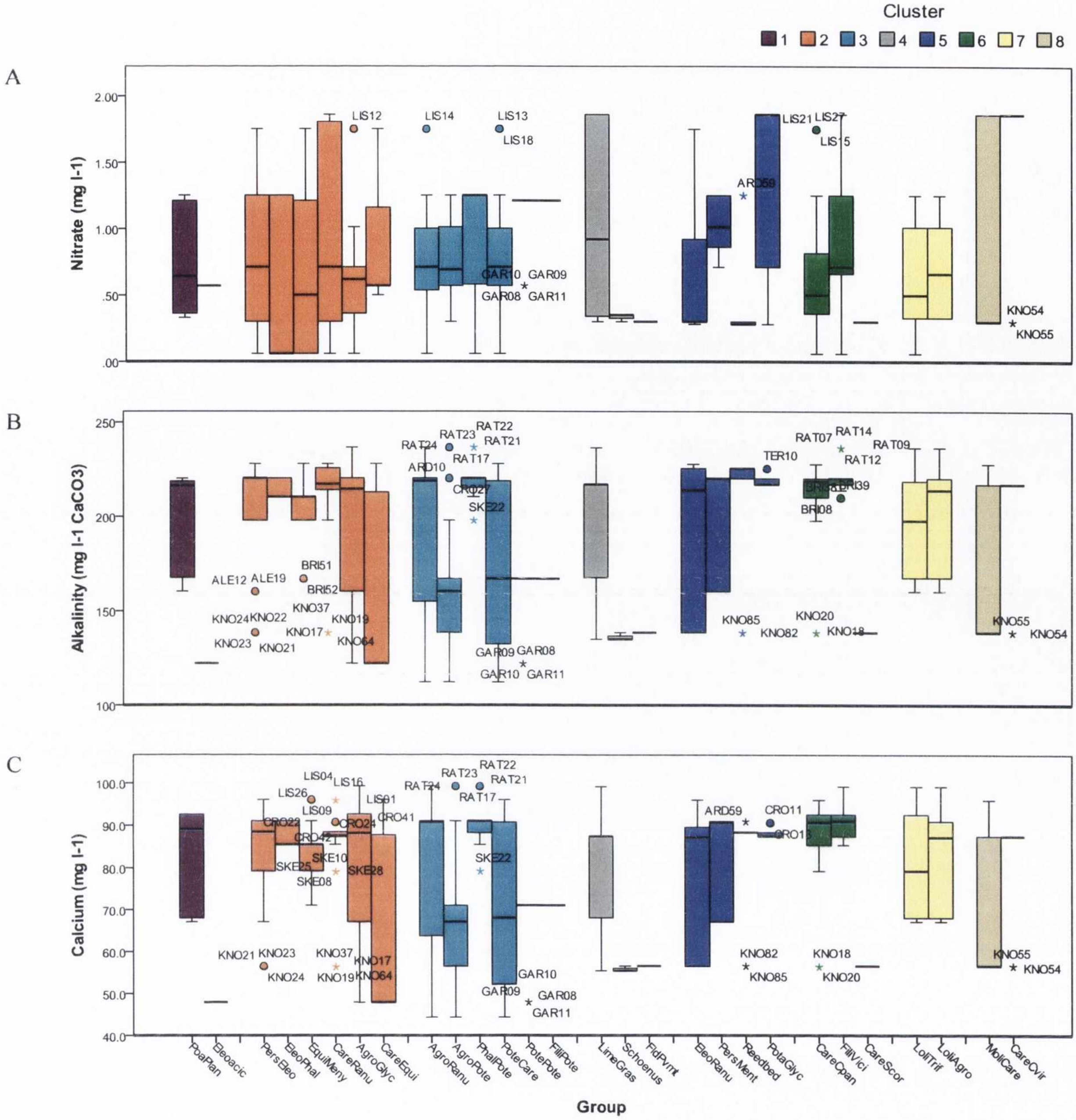


Figure 3.9 (A-C) Boxplots showing the median, interquartile range and highest and lowest values for nitrate, alkalinity and calcium (water chemistry) for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

3.4.4 Management

The numbers of grazed and ungrazed relevés in each vegetation type were calculated, and are presented in Table 3.21. The proportion of grazed:ungrazed relevés is presented in Figure 3.10. Four vegetation types were only recorded in relevés from ungrazed land-parcels; these were Group 14 Reedbed, Group 21 *Schoenus*, Group 23 *CareScor* and Group 28 FldPavmt. Six vegetation communities were recorded only in grazed land-parcels; these were Group 1 *PoaPlan*, Group 10 *LoliTrif*, Group 19 *PotePote*, Group 20 *FiliPote*, Group 24 *PotaGlyc*, and Group 26 *Eleoacic*. The remaining vegetation types were found in both grazed and ungrazed land-parcels, although some, such as Group 7 *EleoPhal* and Group 9 *PhalPote* were found mostly in ungrazed land-parcels, while Group 3 *AgroRanu*, Group 4 *AgroPote* and Group 15 *LoliAgro* were found mostly in grazed land-parcels.

Group 12 *FiliVici* - of the 25 relevés recorded in this vegetation type that were retained in this analysis, a 'low' level of grazing was recorded for 6 of these, so that even though c. 50% of the relevés occurred in 'grazed' land-parcels, grazing was not evident in the majority of them.

Table 3.21 Number of relevés in each vegetation type occurring in grazed and ungrazed land-parcels.

		Grazed	Ungrazed	Total
1	*PoaPlan*	10	0	10
2	*PersEleo*	38	25	63
3	*AgroRanu*	71	8	79
4	*AgroPote*	45	4	49
5	LimeGras	28	7	35
6	*EleoRanu*	10	18	28
7	*EleoPhal*	1	16	17
8	*CareCpan*	19	13	32
9	*PhalPote*	3	13	16
10	*LoliTrif*	17	0	17
11	*PersMent*	8	8	16
12	*FiliVici*	12	13	25
13	*PoteCare*	25	6	31
14	Reedbed	0	9	9
15	*LoliAgro*	20	1	21
16	*EquiMeny*	7	4	11
17	*CareRanu*	29	30	59
18	*AgroGlyc*	16	4	20
19	*PotePote*	25	0	25
20	*FiliPote*	13	0	13
21	*Schoenus*	0	7	7
22	*MoliCare*	11	22	33
23	*CareScor*	0	7	7
24	*PotaGlyc*	9	0	9
25	*CareCvir*	7	2	9
26	*Eleoacic*	12	0	12
27	*CareEqui*	6	1	7
28	FldPavmt	0	10	10

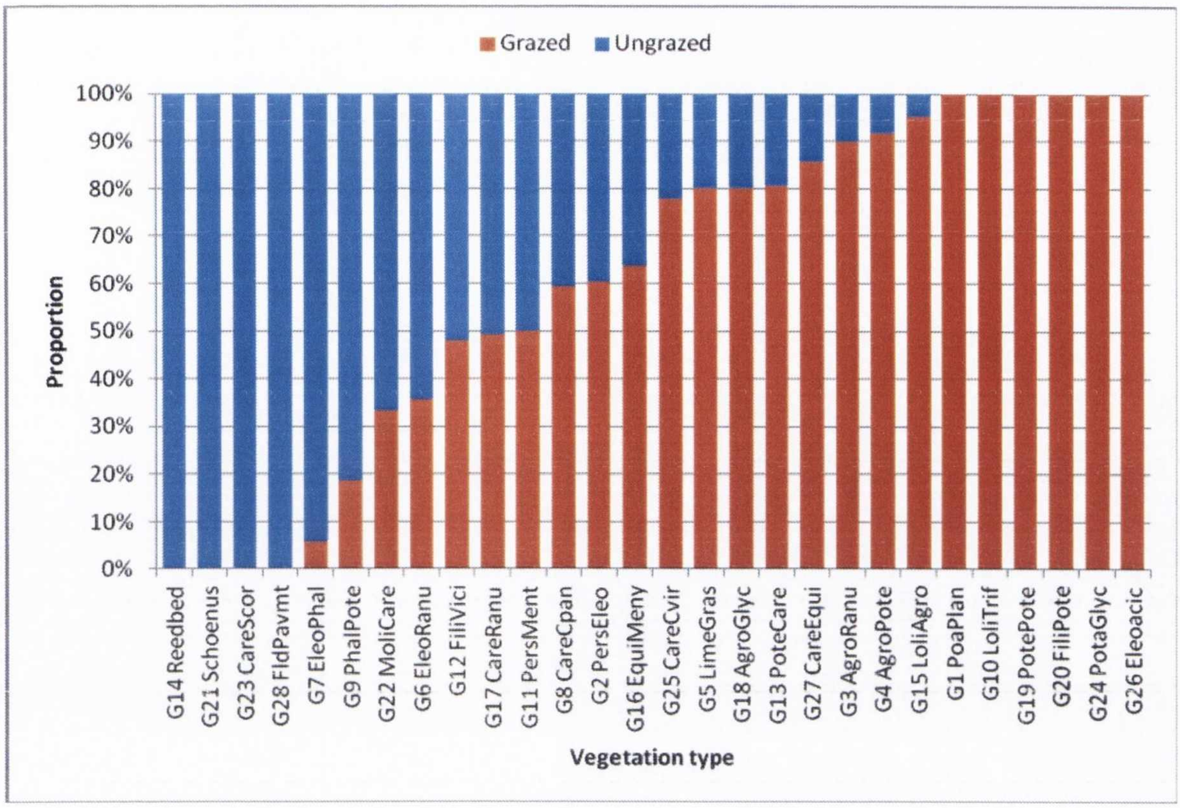


Figure 3.10 Stacked bar chart showing the proportion of relevés for each vegetation community occurring in grazed or ungrazed land-parcels.

3.4.5 Derived variables

Summary statistics and boxplots for Ellenberg values, Grime's C-S-R values and species richness for each of the 28 vegetation types are presented in Table 3.22, Table 3.23, Figure 3.11 and Figure 3.12. (These variables were previously examined in Chapter 2, but are presented here again to facilitate comparison with the other variables, and are discussed in greater detail). A Kruskal-Wallis test was carried out to test for differences between the medians of the clusters. This gave Chi-square values of 330.16-542.37, with p-values of 0.000, indicating that there was a highly significant difference between the medians of at least two clusters. *Post-hoc* Mann-Whitney U tests for differences between the medians of clusters are presented in Table 3.24 and Table 3.25.

Table 3.22 Mean, median and range of Ellenberg Wetness, Fertility and pH values for each community.

		Wetness		Fertility		pH	
		Mean	Median (range)	Mean	Median (range)	Mean	Median (range)
1	*PoaPlan*	6.0	6.0 (5.2-6.7)	6.4	6.4 (6.0-6.9)	6.3	6.3 (6.1-6.7)
2	*PersEleo*	8.2	8.1 (6.4-9.7)	5.2	5.3 (3.8-6.9)	6.2	6.3 (5.0-6.8)
3	*AgroRanu*	6.7	6.6 (5.5-8.0)	5.1	5.2 (3.7-6.7)	6.1	6.1 (5.3-6.9)
4	*AgroPote*	6.2	6.1 (5.5-7.4)	4.7	4.6 (3.5-6.0)	6.0	6.0 (5.1-6.7)
5	LimeGras	6.0	6.0 (4.8-6.9)	3.3	3.1 (2.2-4.9)	5.4	5.5 (4.2-6.3)
6	*EleoRanu*	9.4	9.6 (7.6-10.0)	4.6	4.3 (3.1-6.7)	6.1	6.0 (5.4-6.7)
7	*EleoPhal*	8.6	8.5 (8.0-9.5)	5.1	4.8 (3.8-6.9)	6.1	6.2 (5.1-7.0)
8	*CareCpan*	7.3	7.2 (6.2-8.2)	3.5	3.5 (2.4-4.5)	5.2	5.3 (4.3-5.9)
9	*PhalPote*	7.3	7.5 (6.2-8.7)	5.9	6.0 (5.2-6.7)	6.7	6.8 (6.2-7.0)
10	*LoliTrif*	5.5	5.5 (5.2-6.1)	5.1	5.0 (4.5-5.7)	6.0	6.0 (5.8-6.3)
11	*PersMent*	9.2	9.1 (8.4-10.0)	5.7	5.7 (4.7-6.1)	6.3	6.4 (6.0-6.7)
12	*FiliVici*	6.7	6.7 (5.8-7.2)	4.6	4.7 (3.9-5.2)	5.9	5.9 (5.1-6.5)
13	*PoteCare*	7.4	7.5 (5.6-8.2)	4.7	4.9 (2.8-6.3)	5.9	5.9 (4.6-6.9)
14	Reedbed	9.4	9.3 (8.3-10.0)	4.8	4.7 (3.7-6.0)	6.3	6 (5.7-7.4)
15	*LoliAgro*	5.9	5.9 (5.1-7.1)	5.8	5.9 (5.1-6.4)	6.4	6.4 (5.9-6.8)
16	*EquiMeny*	9.2	9.4 (8.1-10.0)	4.4	4.7 (3.1-6.0)	5.5	5.7 (4.0-6.5)
17	*CareRanu*	8.0	8.1 (7.0-9.4)	3.9	3.9 (2.5-5.6)	5.6	5.7 (4.5-6.6)
18	*AgroGlyc*	8.6	8.8 (6.8-9.8)	5.5	5.8 (4.0-6.7)	6.1	6.2 (5.0-6.7)
19	*PotePote*	6.1	6.0 (5.2-6.8)	5.2	5.2 (4.3-6.0)	6.5	6.6 (5.9-7.0)
20	*FiliPote*	6.2	6.2 (5.5-7.0)	4.0	3.9 (3.2-4.8)	5.9	6.0 (5.2-6.2)
21	*Schoenus*	6.9	7.1 (6-7.3)	2.3	2.4 (2.0-2.7)	4.5	4.7 (3.1-5.5)
22	*MoliCare*	7.8	7.7 (6.3-8.7)	2.7	2.6 (2.0-4.0)	5.1	5.2 (3.7-6.2)
23	*CareScor*	6.7	6.6 (5.9-7.4)	4.5	4.3 (3.9-5.5)	6.1	6.1 (5.8-6.6)
24	*PotaGlyc*	10.3	10.0 (10.0-11.0)	4.2	4.2 (4.0-4.9)	6.0	6.0 (6)
25	*CareCvir*	8.3	8.4 (7.9-8.5)	2.1	2.1 (2.0-2.4)	5.6	5.8 (4.4-6.6)
26	*Eleoacic*	7.3	6.9 (6.3-9.0)	5.8	6.0 (5.0-6.4)	6.4	6.4 (6.1-6.8)
27	*CareEqui*	9.3	9.7 (8.1-10.0)	3.4	3.7 (2.2-4.7)	4.9	5.0 (4.1-5.9)
28	FldPavmt	5.7	5.7 (4.9-6.5)	3.2	3.2 (2.5-4.5)	5.5	5.4 (5.1-6.4)

3.4.5.1 Wetness

Communities had a wide range of mean Ellenberg Wetness values. Group 10 *LoliTrif*, Group 15 *LoliAgro*, and Group 28 FldPavmt had the lowest median values for Wetness (5.5-5.9; Table 3.22, Figure 3.8A). These are all communities which occur around the fringes of the turlough basin, and so they would be expected to experience relatively little flooding. Group 6 *EleoRanu*, Group 24 *PotaGlyc* and Group 27 *CareEqui* had the highest median values for Wetness (9.6-10). These are communities which generally occur towards the bottom of the turlough basin, and would be expected to experience more flooding than communities at higher levels. Group 2 *PersEleo* and Group 18 *AgroGlyc* had the largest ranges of values, with quadrats in these communities ranging from a mean Ellenberg Wetness value of 6.4 to 9.7 and 6.8 to 9.8 respectively.

3.4.5.2 Fertility

There was a wide range of mean Ellenberg Fertility values, from 2.1 to 6.4 (Table 3.22). Group 21 *Schoenus*, Group 22 *MoliCare* and Group 25 *CareCvir* had the lowest median Ellenberg Fertility values (2.1-2.6; Table 3.22, Figure 3.11). The highest median values for Fertility were for Group 1 *PoaPlan*, Group 9

PhalPote and Group 26 *Eleoacic* (6.0-6.4). While some communities contained species with a wide range of Ellenberg Fertility values, for example Group 13 *PoteCare*, others had quadrats containing species with a tighter range of values. Group 26 *Eleoacic*, Group 15 *LoliAgro*, Group 9 *PhalPote* and Group 1 *PoaPlan* were all communities with high mean Fertility values and low ranges, suggesting that these communities occur in areas with relatively high nutrient loading. Group 22 *MoliCare*, Group 8 *CareCpan*, Group 28 FldPavmt, Group 21 *Schoenus* and Group 25 *CareCvir* all had low mean Ellenberg Fertility values, and low ranges of values, which suggest that these more sedge-dominated communities occur in more oligotrophic areas.

3.4.5.3 pH

The lowest median pH values were for Group 21 *Schoenus*, Group 22 *MoliCare* and Group 27 *CareEqui* (4.7-5.2; Table 3.22, Figure 3.11C). Group 9 *PhalPote*, Group 11 *PersMent*, Group 15 *LoliAgro*, Group19 *PotePote* and Group 27 *Eleoacic* all had the highest median pH values (6.6-6.8). Mean Ellenberg pH values were generally basic to very acidic, which is surprising given the karstic bedrock on which turloughs occur.

3.4.5.4 Species richness

Group 14 Reedbed, Group 24 *PotaGlyc* and Group 27 *CareEqui* had the lowest median number of species (3-5; Table 3.23, Figure 3.12A). Group 4 *AgroPote*, Group 5 LimeGras and Group 8 *CareCpan* had the highest median number of species (15-18).

3.4.5.5 Grime's C-S-R values

The communities with the lowest medians for Grime's C value are Group 1 *PoaPlan*, Group 5 LimeGras, Group 25 *CareCvir* and Group 28 FldPavmt (1.86-2.07; Table 3.23, Figure 3.12B). Group 7 *EleoPhal*, Group 9 *PhalPote* and Group 24 *PotaGlyc* have the highest median Grime's C values (3.53-3.89).

Group 1 *PoaPlan*, Group 11 *PersMent*, Group 18 *AgroGlyc* and Group 26 *Eleoacic* have the lowest median Grime's S values (1.25-1.38; Table 3.23, Figure 3.12C), suggesting that these communities occur in sites with relatively high fertility. Group 5 LimeGras, Group 22 *MoliCare,* Group 25 *CareCvir* and Group 28 FldPavmt have the highest median Grime's S values (3.65-3.91); these are communities with high proportions of 'stress-tolerators'.

The communities with the lowest median Grime's R values are Group 24 *PotaGlyc*, Group 25 *CareCvir*, Group 27 *CareEqui* and Group 28 FldPavmt (1.16-1.30; Table 3.23, Figure 3.12D). Group 1 *PoaPlan*, Group 10 *LoliTrif*, Group 15 *LoliAgro* and Group 26 *Eleoacic* have the highest median Grime's R values (3.04-3.95).

Table 3.23 Mean, median and range for number of species and Grime's C-S-R values for each group.

		No. of species		C		S		R	
		Mean	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**	**Mean**	**Median (range)**
1	*PoaPlan*	10	10 (6-15)	2.09	2.04 (1.41-2.71)	1.38	1.34 (1.04-1.77)	3.88	3.95 (3.29-4.53)
2	*PersEleo*	10	11 (5-19)	2.98	2.99 (2.10-3.98)	1.8	1.88 (1.00-2.69)	2.69	2.73 (1.73-3.83)
3	*AgroRanu*	14	14 (9-21)	2.98	2.88 (2.54-3.97)	2.06	2.03 (1.29-2.96)	2.58	2.68 (1.62-3.40)
4	*AgroPote*	14	15 (7-20)	2.66	2.69 (1.79-3.13)	2.39	2.33 (1.70-3.55)	2.69	2.72 (1.95-3.39)
5	LimeGras	18	18 (10-24)	2.12	2.07 (1.27-2.95)	3.6	3.65 (2.72-4.59)	1.98	2.00 (1.19-2.73)
6	*EleoRanu*	8	8 (3-14)	3.07	3.08 (2.69-3.39)	1.99	2.20 (1.10-2.70)	2.53	2.63 (1.47-3.31)
7	*EleoPhal*	8	8 (3-12)	3.59	3.53 (2.62-4.96)	2.11	2.31 (1.04-3.09)	1.65	1.61 (1.02-2.60)
8	*CareCpan*	15	15 (10-23)	2.66	2.69 (2.07-3.29)	2.95	2.78 (2.16-3.89)	1.92	1.94 (1.15-2.55)
9	*PhalPote*	7	7 (4-9)	3.80	3.86 (3.16-4.44)	1.78	1.75 (1.28-2.38)	1.81	1.76 (1.12-2.77)
10	*LoliTrif*	15	14 (10-21)	2.85	2.84 (2.61-3.12)	2.25	2.18 (1.88-2.77)	2.99	3.06 (2.46-3.18)
11	*PersMent*	6	6 (3-10)	3.24	3.22 (2.90-3.73)	1.24	1.25 (1.00-1.54)	2.64	2.69 (1.74-3.00)
12	*FiliVici*	13	13 (6-18)	3.17	3.16 (2.63-3.62)	2.5	2.47 (2.04-3.03)	2.05	2.07 (1.51-2.62)
13	*PoteCare*	7	7 (3-11)	2.81	2.90 (2.19-3.57)	2.38	2.49 (1.25-3.55)	2.23	2.19 (1.01-3.10)
14	Reedbed	5	5 (4-8)	3.34	3.37 (3.02-4.00)	2.23	2.28 (1.50-2.92)	1.98	2.20 (1.10-2.62)
15	*LoliAgro*	10	10 (6-21)	3.03	2.96 (2.71-3.67)	1.63	1.62 (1.20-2.09)	2.92	3.04 (1.87-3.21)
16	*EquiMeny*	8	8 (3-12)	2.72	2.64 (2.30-3.49)	2.73	2.72 (1.58-3.70)	1.8	1.75 (1.00-2.43)
17	*CareRanu*	12	12 (8-17)	2.82	2.87 (1.87-3.48)	2.55	2.46 (1.82-4.01)	2.25	2.26 (1.40-2.98)
18	*AgroGlyc*	8	8 (2-16)	2.99	3.00 (2.01-3.43)	1.56	1.38 (1.00-2.87)	2.69	2.66 (1.93-3.87)
19	*PotePote*	10	11 (4-14)	2.83	2.83 (2.31-3.05)	2.07	2.04 (1.77-2.59)	2.88	2.86 (2.49-3.21)
20	*FiliPote*	13	14 (8-16)	2.74	2.75 (2.45-3.2)	2.56	2.48 (2.09-3.14)	2.4	2.41 (1.73-3.04)
21	*Schoenus*	13	13 (8-17)	2.35	2.38 (2.02-2.74)	3.54	3.57 (3.26-3.89)	1.34	1.41 (1.13-1.58)
22	*MoliCare*	11	12 (6-20)	2.10	2.13 (1.22-2.77)	3.64	3.63 (2.71-4.71)	1.56	1.52 (1.04-2.45)
23	*CareScor*	12	12 (8-16)	2.79	2.66 (2.26-3.52)	2.55	2.80 (1.84-2.92)	1.91	1.98 (1.35-2.24)
24	*PotaGlyc*	4	3 (1-9)	3.87	3.89 (3.44-4.00)	1.91	1.92 (1.63-2.05)	1.25	1.22 (1.00-2.16)
25	*CareCvir*	6	6 (5-10)	2.08	2.00 (1.79-2.54)	3.8	3.91 (3.25-4.14)	1.23	1.16 (1.00-1.62)
26	*Eleoacic*	10	10 (5-15)	2.44	2.38 (1.31-3.74)	1.28	1.25 (1.00-1.74)	3.36	3.34 (1.52-4.68)
27	*CareEqui*	5	4 (3-9)	2.60	2.78 (2.08-3.00)	3.23	3.06 (2.52-3.91)	1.39	1.24 (1.00-2.00)
28	FldPavmt	13	14 (8-15)	1.96	1.86 (1.51-2.66)	3.86	3.86 (3.30-4.40)	1.42	1.30 (1.07-2.13)

Table 3.24 *Post-hoc* Mann-Whitney U tests for differences between the medians of clusters for Ellenberg Wetness, Fertility and pH values.

Wetness

	1	2	3	4	5	6	7
2	**0.000**						
3	0.868	**0.000**					
4	0.041	**0.000**	**0.000**				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	0.032	**0.000**	**0.000**	**0.000**	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
8	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Fertility

	1	2	3	4	5	6	7
2	**0.000**						
3	**0.000**	**0.001**					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	0.102	0.675	**0.000**			
6	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
8	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

pH

	1	2	3	4	5	6	7
2	**0.000**						
3	0.005	**0.000**					
4	**0.000**	**0.000**	**0.000**				
5	**0.001**	0.003	0.945	**0.000**			
6	**0.000**	**0.000**	**0.000**	0.055	**0.000**		
7	0.010	0.002	0.419	**0.000**	0.343	**0.000**	
8	**0.000**	**0.000**	**0.000**	0.510	**0.000**	0.020	**0.000**

Table 3.25 *Post-hoc* Mann-Whitney U tests for differences between the medians of clusters for Species Richness and Grime's C-S-R values.

Species Richness

	1	2	3	4	5	6	7
2	0.562						
3	0.012	**0.000**					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	**0.000**	**0.000**	**0.001**	**0.001**	**0.000**		
7	0.049	0.040	0.897	**0.000**	**0.000**	0.011	
8	0.789	0.895	0.006	**0.000**	**0.000**	**0.000**	0.064

C

	1	2	3	4	5	6	7
2	**0.000**						
3	**0.000**	0.015					
4	0.276	**0.000**	**0.000**				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	**0.000**	0.413	0.966	**0.000**	**0.000**		
7	**0.000**	0.575	0.128	**0.000**	**0.000**	0.436	
8	0.258	**0.000**	**0.000**	0.964	**0.000**	**0.000**	**0.000**

S

	1	2	3	4	5	6	7
2	**0.000**						
3	**0.000**	0.223					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	**0.000**	**0.000**	**0.000**			
6	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**		
7	**0.000**	0.014	**0.000**	**0.000**	0.156	**0.000**	
8	**0.000**	**0.000**	**0.000**	0.765	**0.000**	**0.000**	**0.000**

R

	1	2	3	4	5	6	7
2	**0.000**						
3	**0.000**	**0.000**					
4	**0.000**	**0.000**	**0.000**				
5	**0.000**	0.951	0.016	**0.000**			
6	**0.000**	**0.000**	**0.000**	0.015	**0.000**		
7	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
8	**0.000**	**0.000**	**0.000**	0.004	**0.000**	**0.000**	**0.000**

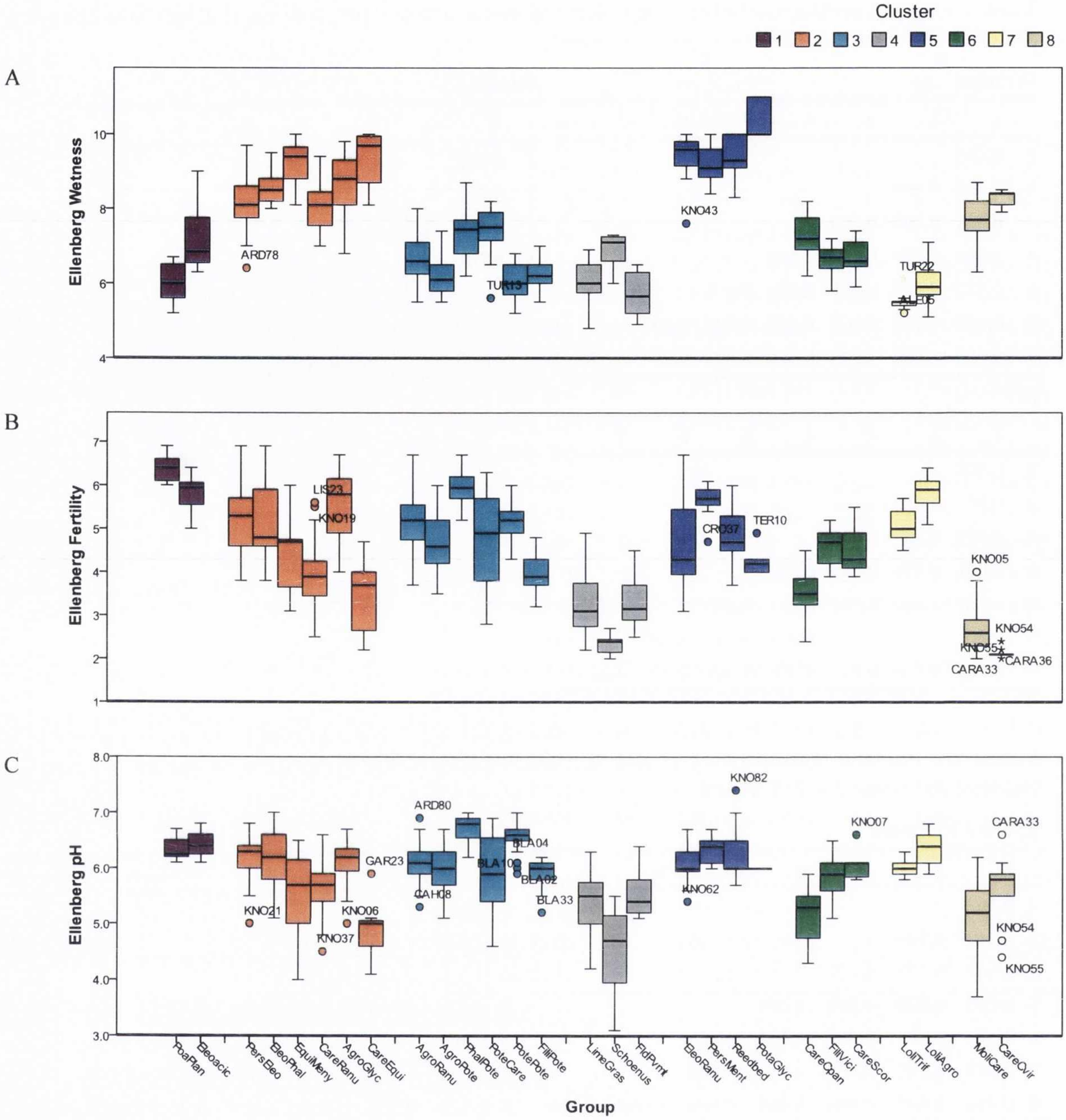


Figure 3.11 (A-C) Boxplots showing the median, interquartile range and highest and lowest values for Ellenberg Wetness, Fertility and pH values for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

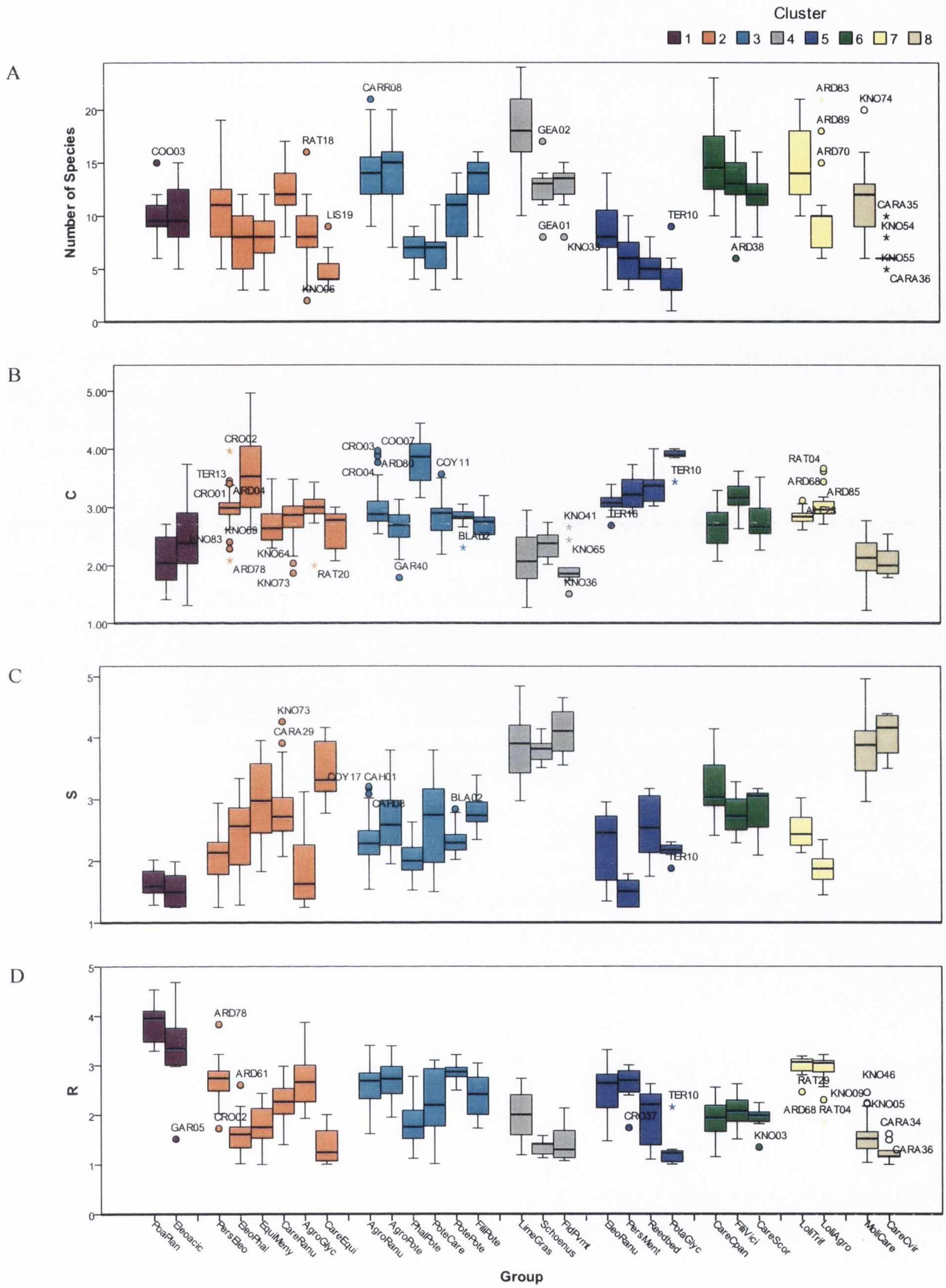


Figure 3.12 (A-D) Boxplots showing the median, interquartile range and highest and lowest values for number of species and Grime's C-S-R values for each of the 28 groups. Groups are colour-coded and divided into clusters as shown in the legend.

3.4.6 Multicollinearity

The measured and derived environmental variables were tested for multicollinearity in order to allow further analyses of the data. Since there were so many variables, initial testing was done for each category to rule out variables which were highly correlated within the same category, before testing the remainder. Variables which had correlation values of ≥ 0.800 were considered very highly correlated, and one of the variables was removed before proceeding.

3.4.6.1 Hydrological variables

For duration, all levels of inundation were highly correlated (Table 3.26). Frequency 0cm was highly correlated with Frequency 10cm, but not with Frequency 25cm or Frequency 50cm, while Frequency 10cm was highly correlated with Frequency 25cm. Maximum quadrat depth was moderately correlated with all duration and frequency variables (0.442-0.660) except for Frequency 50cm.

Duration 0cm was retained; other levels of inundation were discarded. Frequency 0cm and 50cm were retained, other levels were discarded. The length of the longest dry period (LongDry) was highly significantly negatively correlated with Dur0cm and Dur10cm, and so was not retained. All other hydrological variables were retained.

Table 3.26 Spearman's rank correlation coefficients for hydrological variables.

	DryDate	Dur0cm	Dur10cm	Dur25cm	Dur50cm	Freq0cm	Freq10cm	Freq25cm	Freq50cm	LongDry
Dur0cm	**0.604**									
Dur10cm	**0.571**	**0.986**								
Dur25cm	**0.550**	**0.970**	**0.993**							
Dur50cm	**0.525**	**0.936**	**0.952**	**0.973**						
Freq0cm	-0.032	0.096	0.101	0.113	**0.145**					
Freq10cm	-0.083	**0.199**	0.209	**0.214**	**0.240**	**0.843**				
Freq25cm	-0.127	**0.201**	0.220	**0.229**	**0.244**	**0.766**	**0.835**			
Freq50cm	0.116	**0.163**	0.141	0.132	0.126	0.000	0.026	0.012		
LongDry	**-0.354**	**-0.821**	**-0.810**	**-0.795**	**-0.769**	**-0.266**	**-0.357**	**-0.333**	-0.121	
WetDate	**-0.251**	**-0.435**	**-0.428**	**-0.415**	**-0.386**	-0.080	-0.110	-0.110	-0.104	**0.531**
MDQuad	.073	**.442**	**.499**	**.564**	**.660**	**.497**	**.536**	**.538**	-.022	**-.435**

Figures in bold are significant to p=0.05 when corrected for multiple comparisons using the Dunn-Šidák correction. Correlations ≥ 0.800 are highlighted in grey.

3.4.6.2 Soil variables

Organic matter and soil total nitrogen were very highly correlated (Table 3.27). Based on this, organic matter was removed before proceeding, as total nitrogen is more widely used in the literature.

Table 3.27 Spearman's rank correlation coefficients for soil variables.

	Soil TP	Soil TN	Soil pH	OM	INORG
Soil TN	**.214**				
Soil pH	**-.494**	**.247**			
OM	**.195**	**.985**	**.259**		
INORG	**.120**	**-.732**	**-.535**	**-.726**	
CACO3	**-.272**	**.251**	**.729**	**.235**	**-.513**

Figures in bold are significant to p=0.05 when corrected for multiple comparisons using the Dunn-Šidák correction. Correlations ≥ 0.800 are highlighted in grey.

3.4.6.3 Water chemistry

Total phosphorus and MRP were very highly correlated (Table 3.28). Nitrate was very highly correlated with total nitrogen, and calcium was very highly correlated with alkalinity, as was expected.

Total phosphorus, total nitrogen and alkalinity were retained while MRP, nitrate, and calcium were removed; the former are much more widely used in the literature than the latter, and this will allow comparison with other studies.

Table 3.28 Spearman's rank correlation coefficients for water chemistry variables.

	TP	MRP	TN	Nitrate	Ca
MRP	**0.936**				
TN	**0.505**	**0.482**			
Nitrate	**0.444**	**0.442**	**0.973**		
Ca	**0.374**	**0.176**	**0.463**	**0.388**	
Alkalinity	**0.324**	**0.142**	**0.459**	**0.365**	**0.957**

Figures in bold are significant to p=0.05 when corrected for multiple comparisons using the Dunn-Šidák correction. Correlations ≥ 0.800 are highlighted in grey.

3.4.6.4 Derived variables

Mean Ellenberg pH value was highly significantly correlated with mean Ellenberg Fertility value (Table 3.29). Fertility was also highly negatively correlated with Grime's S value. On this basis, Ellenberg pH and Grime's S values were removed before proceeding.

Table 3.29 Spearman's rank correlation coefficients for derived variables.

	Wetness	pH	Fertility	C	S	R
pH	**-.061**					
Fertility	-.048	**.839**				
C	**.348**	**.505**	**.525**			
S	-.077	**-.710**	**-.831**	**-.551**		
R	**-.270**	**.552**	**.657**	**.095**	**-.609**	
Number of species	**-.467**	**-.227**	**-.195**	**-.295**	**.328**	.117

Figures in bold are significant to p=0.05 when corrected for multiple comparisons using the Dunn-Šidák correction. Correlations ≥ 0.800 are highlighted in grey.

Spearman's rank correlation coefficients were then calculated for the remaining variables (Table 3.30). None of these remaining variables were highly (≥ 0.800) correlated; all were therefore retained for further analyses.

Dur0cm was highly significantly correlated with DryDate and Wetness (0.604, 0.672), moderately correlated with MDQuad (0.442), and moderately negatively correlated with WetDate (-0.435). Wetness was also positively correlated with DryDate (0.479), and moderately negatively correlated with species richness (-0.409). Freq0cm was moderately negatively correlated with Alkalinity (-0.435), and positively correlated with MDQuad and SoilTP (0.497, 0.458).

Ellenberg Fertility was correlated with Grime's R value and WaterTP (0.657, 0.489).

INORG was negatively correlated with $CaCO_3$ and SoilTN (-0.513, -0.732) and positively correlated with, Grime's R value and WaterTP (0.647, 0.405, 0.501). SoilTN was also moderately negatively correlated with WaterTP (-0.499).

Table 3.30 Spearman's rank correlation coefficients for the retained variables from all categories.

	Alkalinity	C	CACO3	DryDate	Dur0cm	Fertility	Freq0cm	Freq50cm	INORG	MDQuad	No. Species	R	SoilTN	SoilTP	WaterTN	WaterTP	WetDate
C	**0.369**																
$CACO_3$	**0.313**	0.067															
DryDate	**0.280**	**0.216**	**0.311**														
Dur0cm	0.038	**0.156**	**0.330**	**0.604**													
Fertility	**0.192**	0.525	-0.057	0.031	-0.049												
Freq0cm	**-0.435**	**-0.194**	**-0.180**	-0.032	0.096	0.070											
Freq50cm	0.035	0.050	-0.019	0.116	**0.163**	-0.022	0.000										
INORG	-0.053	0.091	**-0.513**	**-0.279**	**-0.317**	**0.295**	**0.223**	0.094									
MDQuad	**-0.372**	-0.005	-0.101	0.073	**0.442**	**0.223**	**0.497**	-0.022	**0.161**								
No. Species	0.008	**-0.295**	-0.078	**-0.220**	**-0.317**	**-0.195**	-0.041	-0.025	0.084	**-0.247**							
R	0.050	0.095	-0.132	-0.105	**-0.155**	**0.657**	**0.194**	0.027	**0.405**	**0.178**	0.117						
SoilTN	**-0.136**	-0.056	**0.251**	**0.188**	**0.248**	**-0.221**	-0.116	0.035	**-0.732**	**-0.223**	0.037	**-0.335**					
SoilTP	**-0.652**	**-0.165**	**-0.272**	**-0.315**	-0.1	0.076	**0.458**	0.020	0.120	**0.396**	0.101	**0.162**	**0.214**				
WaterTN	**0.459**	0.095	**0.346**	**0.155**	0.117	0.085	0.001	**-0.194**	0.105	0.123	-0.021	0.046	**-0.346**	**-0.381**			
WaterTP	**0.324**	**0.314**	-0.111	-0.006	**-0.197**	**0.489**	-0.047	**-0.197**	**0.501**	**0.283**	0.035	**0.338**	**-0.499**	0.034	**0.505**		
WetDate	**0.282**	**0.144**	-0.056	**-0.251**	**-0.435**	**0.282**	-0.080	-0.104	**0.259**	-0.097	**0.196**	**0.215**	**-0.194**	-0.025	**0.139**	**0.453**	
Wetness	**0.211**	**0.348**	**0.320**	**0.479**	**0.672**	-0.048	**-0.162**	**0.198**	**-0.274**	0.050	**-0.467**	**-0.270**	**0.309**	**-0.191**	0.009	**-0.174**	**-0.247**

Figures in bold are correlations with $p<0.001$. Correlations ≥ 0.400 are highlighted in grey.

3.4.7 Relationships between measured and derived variables

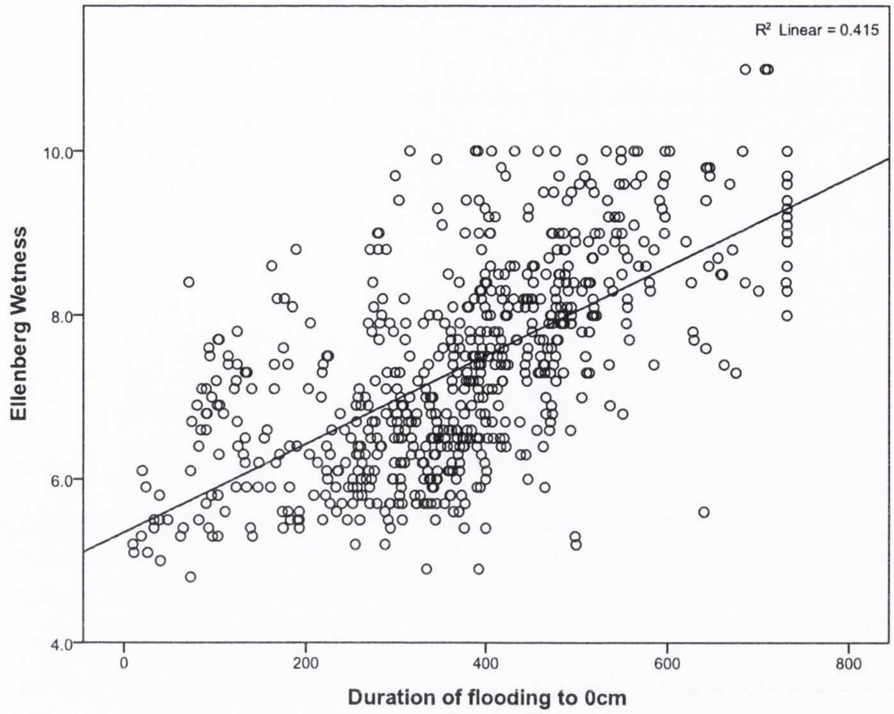
Ellenberg values have been used in the literature as indicators for environmental conditions (e.g. Hawkes et al. 1997). In this study, Spearman rank correlations infer relationships between Ellenberg values and Water TP and Dur0cm (Table 3.30). In order to further explore these relationships, scatterplots and regression equations were used.

3.4.7.1 Ellenberg Wetness

A strong positive relationship was evident between duration of flooding to 0cm and Ellenberg Wetness (Figure 3.13A). The regression equation is Ellenberg Wetness = (0.005 x Ellenberg Wetness) + 5.348; $F = 474.781$, $p<0.001$; $R^2 = 41.5\%$.

There was a much weaker relationship between duration of flooding to 50cm and Ellenberg Wetness (Figure 3.13B). Regression equation: Ellenberg Wetness = (0.005 x Ellenberg Wetness) + 5.909; $F = 263.539$, $p<0.001$; $R^2 = 28.3\%$.

A



B

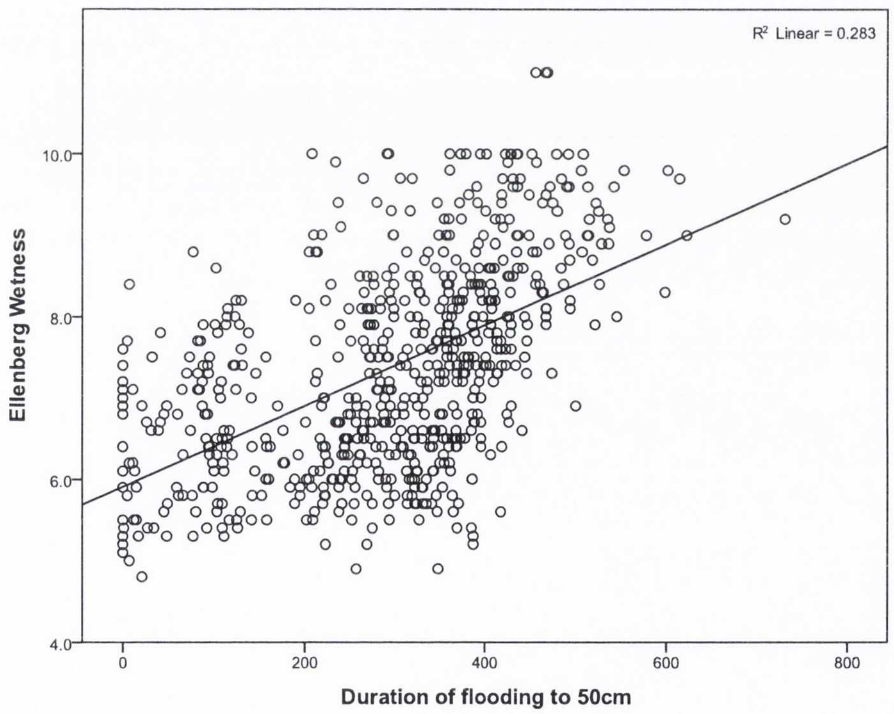


Figure 3.13 Scatterplots of Ellenberg Wetness values and duration of flooding.

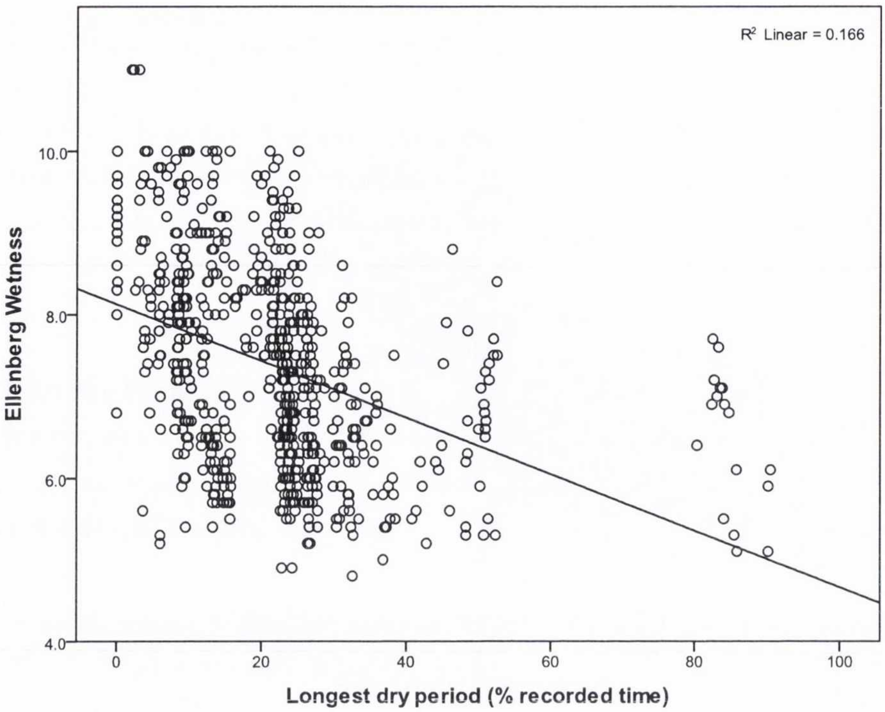


Figure 3.14 Scatterplot showing the relationship between Ellenberg Wetness value and the longest dry period.

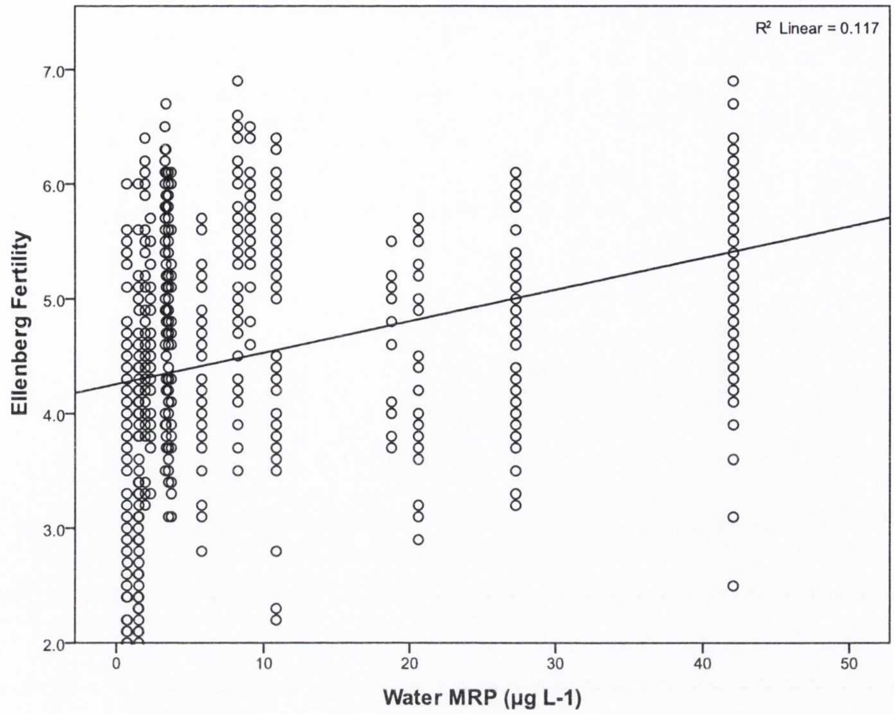
3.4.7.2 Ellenberg pH

Ellenberg pH showed no relationship with either water pH or soil pH.

3.4.7.3 Ellenberg Fertility

There was no relationship between Ellenberg Fertility and water TN or nitrate. There was a slight positive relationship between Ellenberg Fertility values and Water MRP and Water TP (Figure 3.15).

A



B

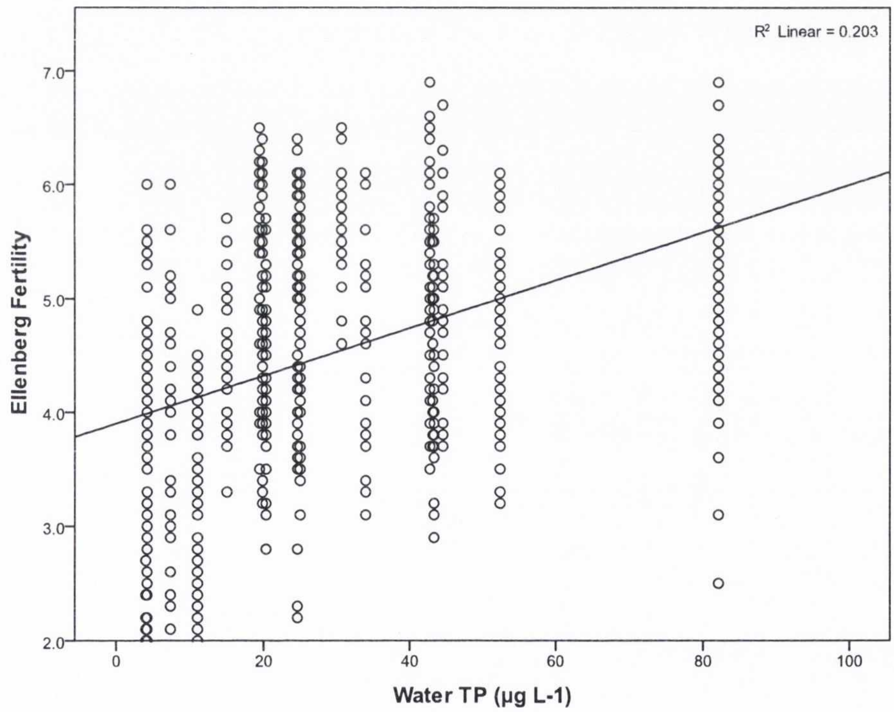


Figure 3.15 Scatterplots showing the relationships between Ellenberg Fertility values and water MRP and TP.

A

B

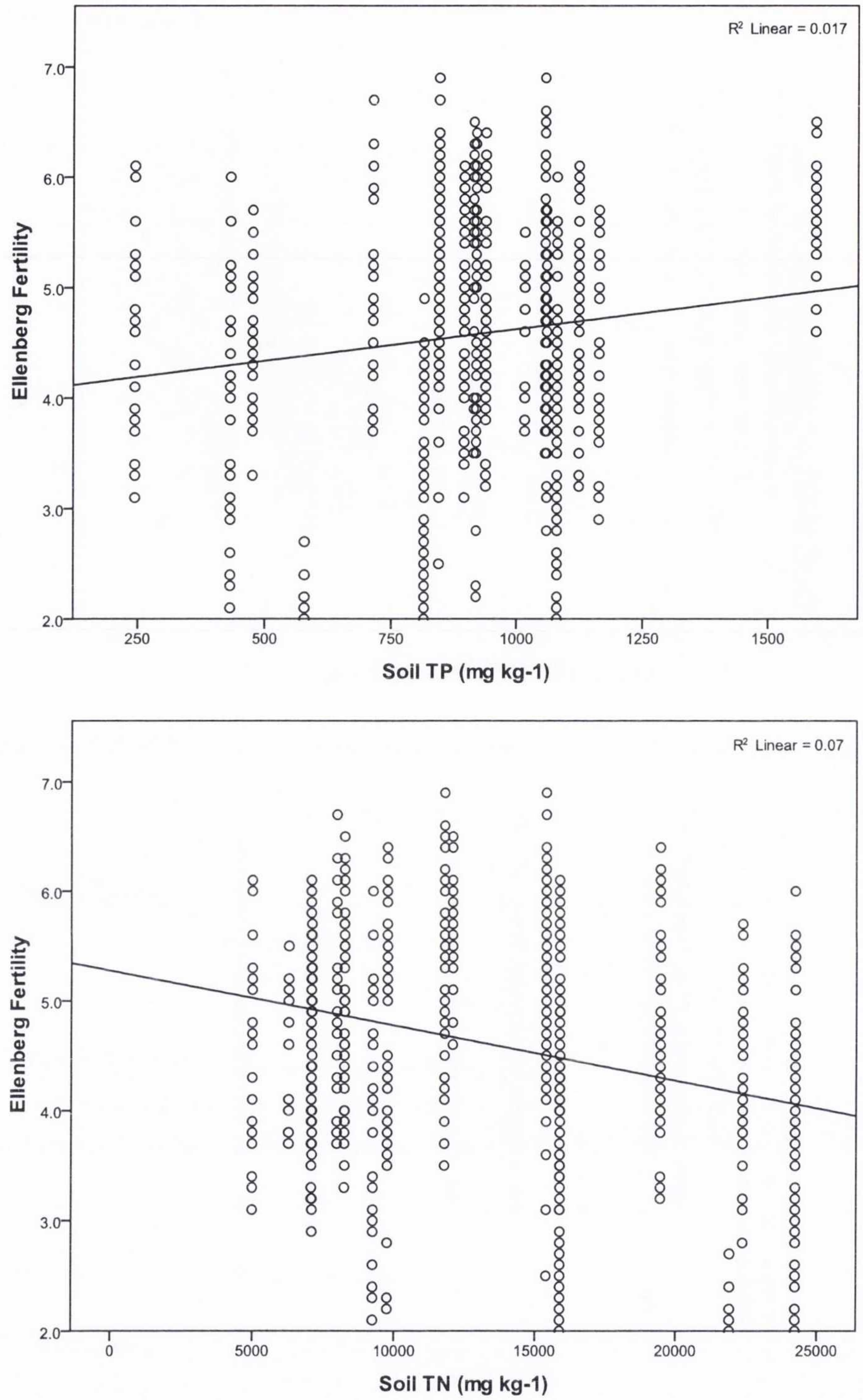


Figure 3.16 Scatterplots showing the relationships between Ellenberg Fertility values and soil TP and TN.

3.4.8 Relationships between all variables and vegetation types

An ordination of the species abundance in quadrats was carried out on this reduced dataset using Non-Metric Multidimensional Scaling (NMS) as per Chapter 2. A 3-dimensional solution was chosen for the ordination by PC-ORD, with a final stress of 21.3. This is a high stress value, but given the large dataset, acceptable (McCune and Grace 2002). The probability of finding a similar final stress by chance, with 250 randomised runs, was calculated using a Monte Carlo test as 0.004. A plot of stress vs. iteration number was used to assess stability; a final instability of 0.00032 was calculated after 500 iterations. Environmental data were added to the second matrix and overlaid on the ordination as a biplot; the threshold for displaying environmental variables as a biplot was $r^2 > 0.200$. The major correlation vectors were visually aligned with Axes 2 and 3 by rotating the axes until the biplots were aligned with the ordination axes, both to improve ease of interpretation (McCune and Grace 2002) and to allow comparison with the ordination diagrams presented in Chapter 2. This is a type of rigid rotation which does not change the geometry of the points in ordination space or the cumulative variance represented by the axes, but does affect the correlation of variables with the ordination axes and the variance represented by an individual axis (McCune and Grace 2002); correlations and variance were calculated after rotation. Ordination diagrams are presented in Figure 3.17. Axis 2 explained the largest amount of variation, ($r^2 = 0.301$), Axis 3 the next largest amount ($r^2 = 0.197$), while Axis 1 explained the least ($r^2 = 0.139$). The cumulative amount of variance represented by all three axes was 63.7% ($r^2 = 0.637$). This ordination corresponds well with that carried out in Chapter 2. When Figure 3.17C is compared with Figure 2.7 in Chapter 2, the scatter of clusters is broadly similar.

The mean Ellenberg Wetness score was highly negatively correlated with Axis 2 ($r^2 = -0.863$, $p \leq 0.001$). Duration of flooding was also highly negatively correlated with this axis ($r^2 = -0.643$, $p \leq 0.001$). This indicates that the clusters towards the negative end of Axis 2 are associated with a longer duration of flooding, and contain species with a higher Ellenberg value for wetness, than those on the positive end of the axis. As can be seen in Figure 3.17C, Clusters 5 and 2, both of which contain very water-dependent communities, are located towards the negative end of Axis 2. Conversely, Clusters 4 and 7, which contain vegetation communities associated with drier habitats, occur on the opposite end of Axis 2. Species richness is positively correlated with Axis 2 ($r^2 = 0.589$, $p \leq 0.001$), which indicates that communities that experience least inundation have a greater number of species.

Axis 3 was highly negatively correlated with the mean Ellenberg value for Fertility (($r^2 = -0.831$, $p \leq 0.001$), as well as Grime's R value ($r^2 = -0.713$, $p \leq 0.001$). Grime's S value was also positively correlated with Axis 3 ($r^2 = 0.793$, $p \leq 0.001$). This suggests that communities occurring towards the negative end of Axis 3 are those that contain a high proportion of species which occur on relatively fertile soil, and which may contain a high number of ruderal species. Cluster 1, which occurs on the negative end of Axis 3, consists of two communities which have a large number of ruderal species (the *Poa annua-Plantago major* community and the *Eleocharis acicularis* community). At the opposite end of the fertility gradient is Cluster 8, which contains sedge-dominated communities, characterised by 'Stress-tolerator' species which can tolerate low levels of soil nutrients.

Maximum quadrat depth and frequency of flooding did not have a sufficiently high Tau value to be displayed on the ordination diagrams when the biplot was overlaid, and indeed these variables were only weakly correlated with the ordination axes (Table 3.31). This suggests that duration of flooding rather than frequency or maximum depth of flooding is the strongest hydrological driver of vegetation, although these may have interactions or effects which are not seen through this type of analysis.

It should be noted here that the vectors on the ordination diagrams indicate the strength of the relationship between the axes and the variables using Kendall's tau, while the values presented in Table 3.31 are the correlations between the axes and the variables using Spearman's rank correlation coefficients. Ordination diagrams displaying the vectors obtained from Kendall's tau are commonly published in the literature (for example Perrin et al. 2006), Spearman's rank correlation coefficients are more appropriate for non-parametric data, and so these are also presented here.

A multi-response permutation procedure (MRPP) was carried out on the species abundance matrix to confirm that there was clear separation between the vegetation communities. A high chance-corrected within-group agreement (A = 0.733), and a highly significant effect of 'group' ($P < 10^8$) were found. The test statistic, T, was large and negative (-149.3), indicating good separation between groups. A describes within-group homogeneity; the highest possible value is 1, when all items are identical within groups. If within-group heterogeneity is as expected by chance, then $A = 0$ (McCune and Grace 2002). An $A > 0.3$ is described by McCune and Grace as 'fairly high'. The results of MRPP therefore support the separation of relevés into groups, and confirm that this reduced dataset still contains well-defined groups.

The Mantel test yielded a small r (0.074), but was statistically significant (p = 0.001).

A

B

C

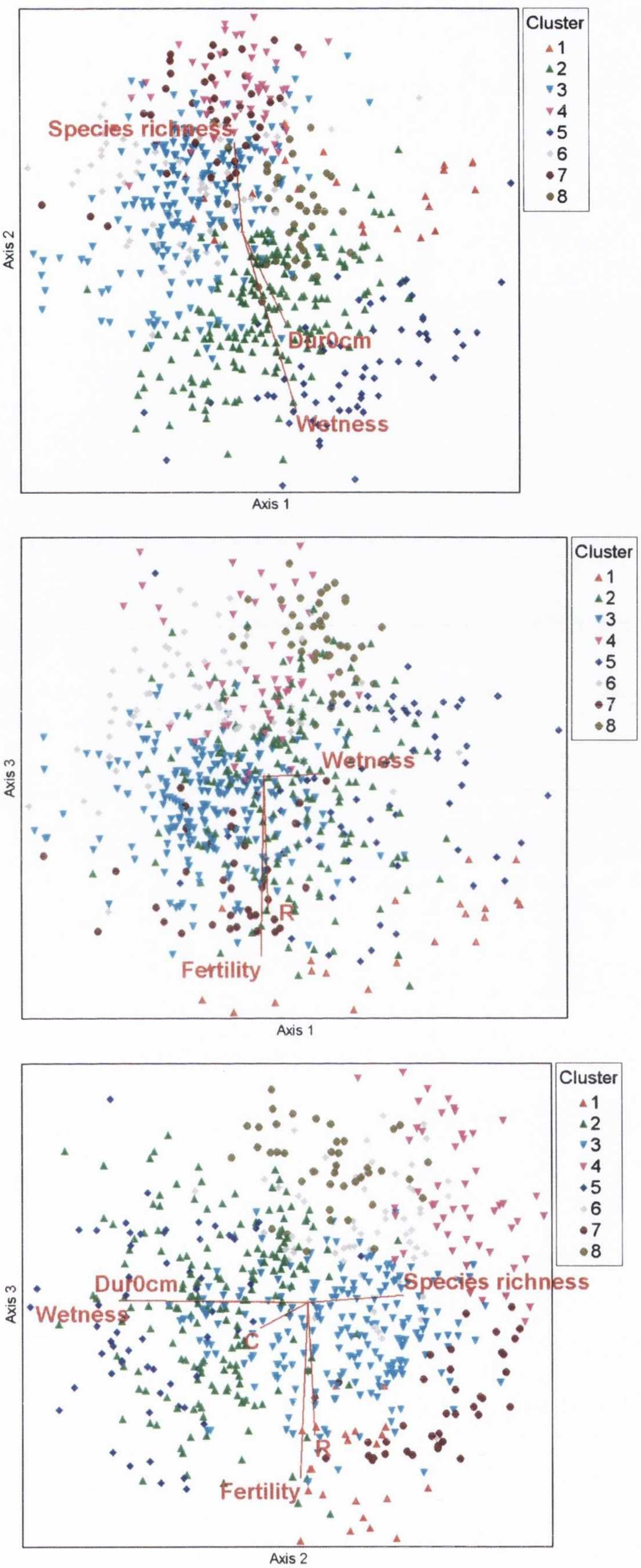


Figure 3.17 - Non-metric Multidimensional Scaling ordination showing the 8 vegetation clusters derived by cluster analysis and a biplot showing duration of flooding, Ellenberg and Grime's indicator values, and species richness (r^2 values of axes: 1 = 0.139, 2 = 0.301, 3 = 0.197, total = 0.637).

Table 3.31 Statistically significant Spearman's rank correlation coefficients between the ordination axes and the measured or derived environmental variables

	Axis1	Axis2	Axis3
C	**-0.175**	**-0.449**	**-0.342**
$CaCO_3$	**0.200**	**-0.215**	**0.173**
DryDate	**0.226**	**-0.485**	0.063
Dur0cm	**0.438**	**-0.643**	0.099
Fertility	**-0.135**	**-0.157**	**-0.831**
Freq0cm	0.089	**0.170**	**-0.163**
Freq50cm	0.113	**-0.169**	0.013
INORG	**-0.266**	**0.154**	**-0.368**
MDQuad	0.052	**-0.128**	**-0.248**
Species richness	**-0.184**	**0.589**	**0.180**
R	0.108	**0.161**	**-0.713**
SoilTN	**0.188**	**-0.137**	**0.319**
SoilTP	-0.072	**0.191**	**-0.144**
WaterTN	-0.100	-0.024	-0.077
WaterTP	**-0.394**	0.003	**-0.463**
WetDate	**-0.319**	**0.173**	**-0.221**
Wetness	**0.457**	**-0.863**	**0.127**

Figures in bold are significant to $p<0.05$, corrected for multiple comparisons with Dunn-Šidák correction

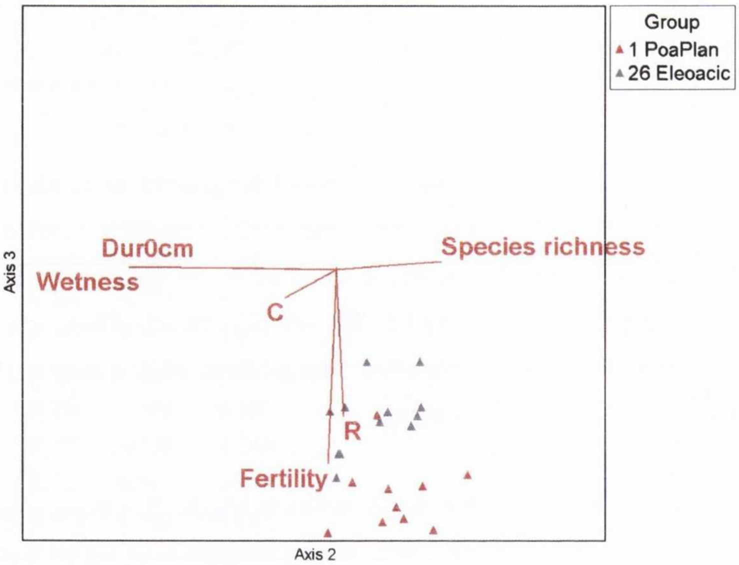
In order to visualise the position of the 28 different vegetation communities in the ordination diagrams, each cluster was graphed individually (Figure 3.18 to Figure 3.20). Axes 2 and 3 are shown, as these represent the greatest amount of variation (48.9%).

Cluster 1 is shown in Figure 3.18A, and occurs at the top of the Fertility, and R gradient. This cluster consists of two vegetation communities, Group 1 *PoaPlan* and Group 26 *Eleoacic*. Both of these communities are characterised by a high proportion of ruderal species, as indicated by the correlation vector for Grime's R value. They also both have a high mean Ellenberg Fertility value. Group 26, *Eleoacic* occurs on wet mud near to standing water, and is higher up the Wetness/Duration gradient, while Group 1, *PoaPlan* occurs on heavily poached soils which experience less inundation.

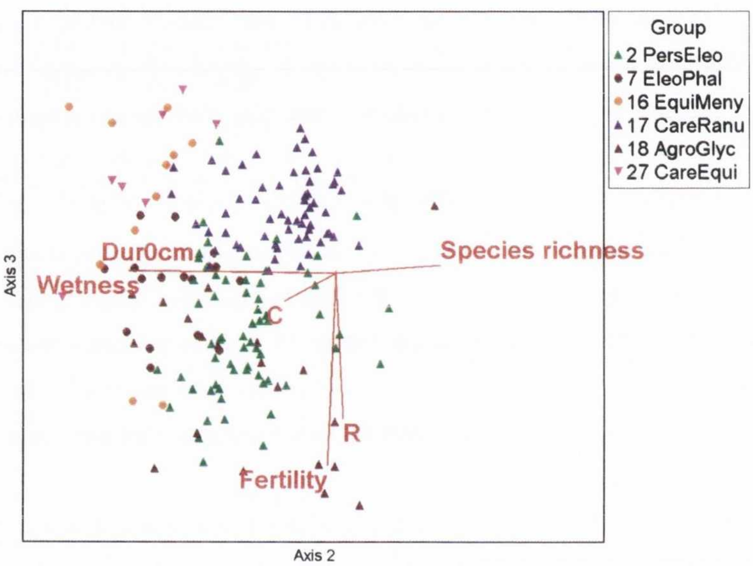
Figure 3.18B shows the position of the vegetation communities in Cluster 2 in the ordination space. These communities all occur towards the wetter end of the Wetness/Duration gradient, but are well spread out along the Fertility gradient. They all occur towards the bottom of the Species Richness gradient, indicating relatively low species diversity. Group 2 *PersEleo* and Group 18 *AgroGlyc* both occur towards the negative end of Axis 3, i.e. at the top of the Fertility gradient, indicating that these communities have a high proportion of species which flourish on relatively fertile soils. Group 7 *EleoPhal*, Group 17 *CareRanu* and Group 27 *CareEqui* all occur towards the top of the Wetness/Duration gradient, indicating that these communities are composed of species which tolerate or require a relatively long duration of inundation. These communities are also aligned at the bottom of the Fertility gradient, which suggests there is a high proportion of stress-tolerator species in these groups. Group 16 *EquiMeny* occurs towards the top of the Wetness/Duration gradient, indicating the requirement for relatively long duration of flooding, but relevés from this group are plotted all along the Fertility gradient, which suggests that nutrient availability is not a driver for this community.

Cluster 3 is represented in Figure 3.18C, and although they occur throughout the Wetness gradient, there is a trend for these communities to occur towards the positive end of Axis 2, suggesting they occur in areas with a shorter duration of flooding. They also seem to be concentrated towards the upper end of the Fertility gradient, suggesting that these communities occur in areas of high fertility. Group 4 *AgroPote* and Group 20 *FiliPote* occur towards the top end of the Species Richness gradient, which indicates that these communities have a high level of species richness, while also occurring in areas with a shorter duration of flooding. Group 9 *PhalPote* and Group 13 *PoteCare*, on the other hand, occur towards the opposite end of this gradient, which suggests these communities require a longer duration of inundation, and that they have a lower species richness.

A – Cluster 1



B – Cluster 2



C – Cluster 3

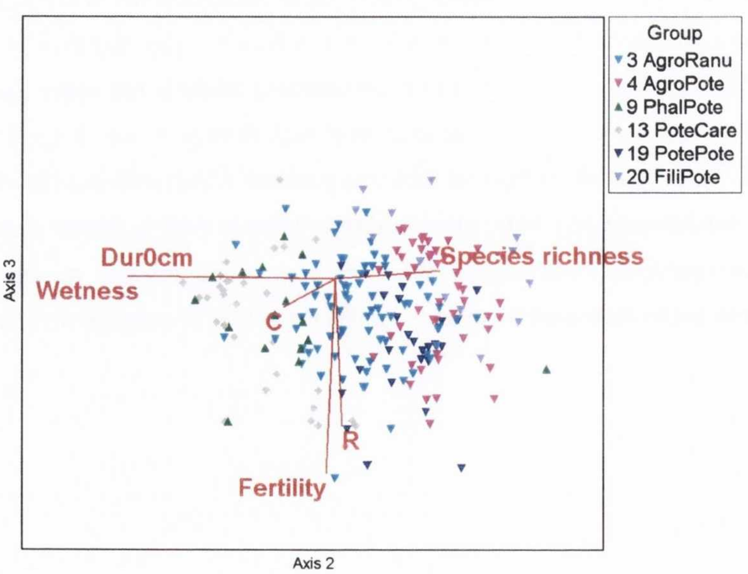


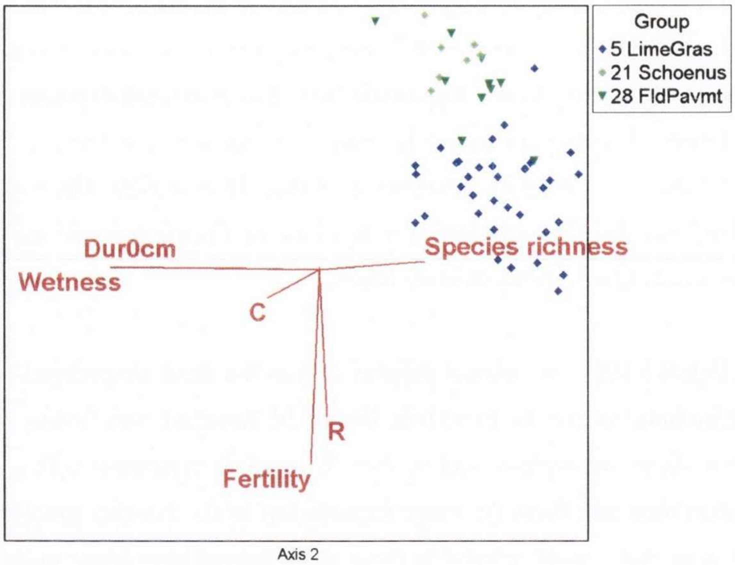
Figure 3.18(A-C) Non-metric Multidimensional Scaling ordination of Axes 2 and 3 (r^2 = 0.498) showing the vegetation communities in clusters 1 to 3, with a biplot showing duration of flooding, Ellenberg and Grime's indicator values, and species richness (r^2 values of axes: , 2 = 0.301 = 0.197).

The location of Cluster 4 on the ordination diagram can be seen in Figure 3.19A. The communities in this cluster all occur at the positive ends of axes 2 and 3, indicating that these communities occur in areas that experience a short duration of flooding, have a high proportion of stress-tolerator species (as suggested by the low Fertility), a high number of species, and occur in areas with relatively low fertility. The communities in this cluster are Group 5 LimeGras, Group 21 *Schoenus* and Group 28 FldPavmt. There is some separation of these communities along the Fertility gradient; the position of Group 5 LimeGras suggests that this community occurs in areas of higher fertility than the others.

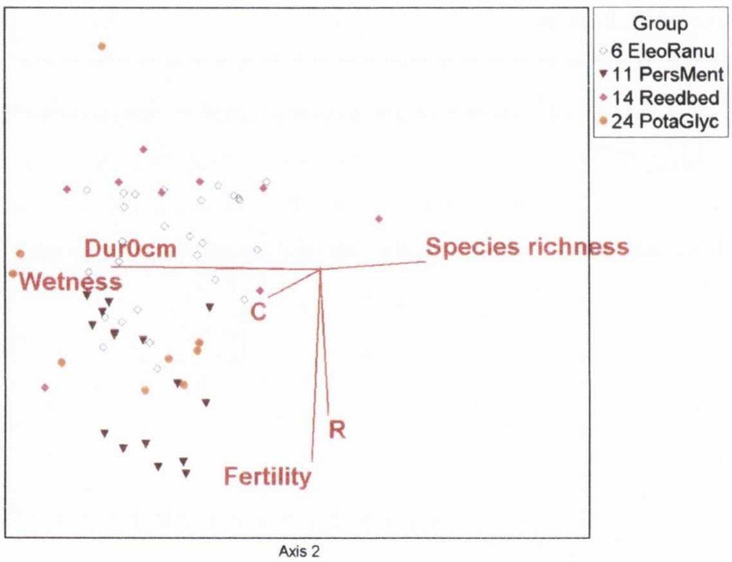
Cluster 5 is shown in Figure 3.19B. This cluster consists of 4 of the more water-dependent communities in this study: Group 6 *EleoRanu*, Group 11 *PersMent*, Group 14 Reedbed, and Group 24 *PotaGlyc*. These communities all occur towards the negative end of Axis 2, which is correlated with a greater duration of duration of flooding. *PersMent* and *PotaGlyc* occur towards top of the Fertility gradient, suggesting these communities occur on more fertile soils, while *EleoRanu* and Reedbed have lower mean Ellenberg Fertility values, and lower mean Grime's R value.

In Figure 3.19C, Cluster 6 is shown. This cluster contains three vegetation communities: Group 8 *CareCpan*, Group 12 *FiliVici*, and Group 23 *CareScor*. As in Cluster 4, these communities all occur towards the positive end of both axes, indicating they experience shorter periods of inundation, and occur in areas with a lower nutrient status. Of the three communities, *FiliVici* occurs along a greater range of Fertility values.

A – Cluster 4



B – Cluster 5



C – Cluster 6

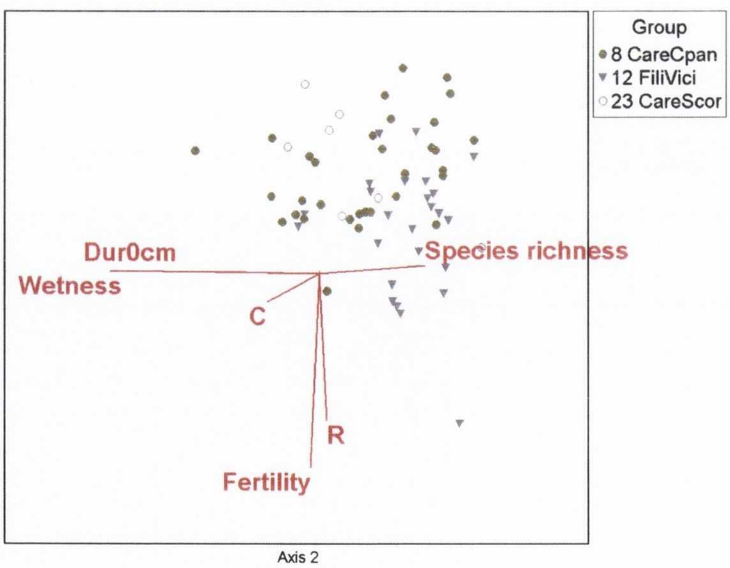
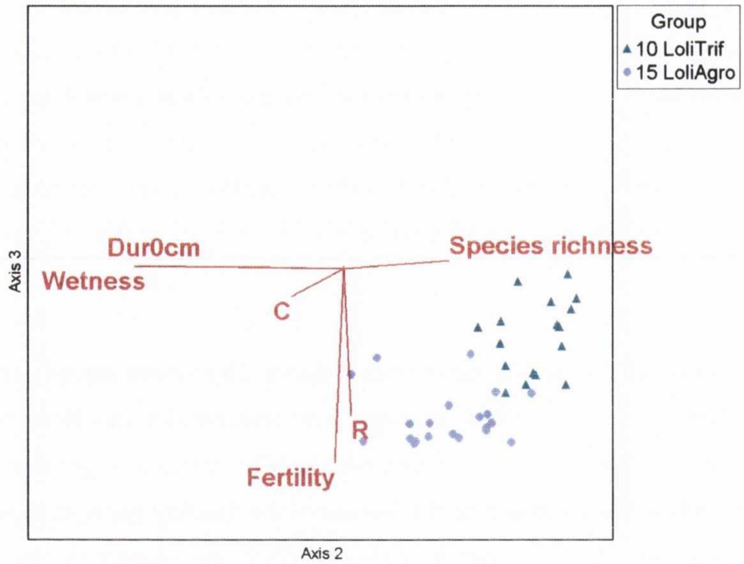


Figure 3.19(A-C) Non-metric Multidimensional Scaling ordination of Axes 2 and 3 ($r^2 = 0.498$) showing the vegetation communities in clusters 4 to 6, with a biplot showing duration of flooding, Ellenberg and Grime's indicator values, and species richness (r^2 values of axes: , 2 = 0.301 = 0.197).

Cluster 7 is represented in Figure 3.20A. This cluster is composed of two vegetation communities: Group 10 *LoliTrif*, and Group 15 *LoliAgro*. These communities are similar floristically, although *LoliAgro* has a higher proportion of ruderal species. Their position on the ordination diagram indicates that these communities are well-drained and occur on relatively fertile soils. They also occur towards the top of the species richness gradient. Group 15 *LoliAgro* is associated with higher Ellenberg Fertility values, and occurs more towards the middle of the duration gradient, while Group 10 *LoliTrif* has shorter flooding duration and higher species richness.

Figure 3.20B shows the location of Cluster 8 in the ordination space. This cluster consists of two vegetation communities: Group 22 *MoliCare* and Group 25 *CareCvir*. These communities are characterised by species with a high stress tolerance – *Molinia caerulea*, for example, usually occurs in vegetation types with low productivity (Grime et al. 1988). Their position at the bottom of the Fertility gradient indicates that these communities occur in areas with low nutrient availability. They are plotted in the middle of the Wetness/Duration gradient, indicating they experience moderate inundation, and have an intermediate level of species richness. There is some separation of these two communities, with the position of Group 25 *CareCvir* on the Fertility gradient suggesting that this community occurs in less fertile areas than Group 22 *MoliCare*. Group 25 *CareCvir* also experiences longer duration of inundation than Group 25 *CareCvir*, as indicated by position on the duration gradient.

A – Cluster 7



B – Cluster 8

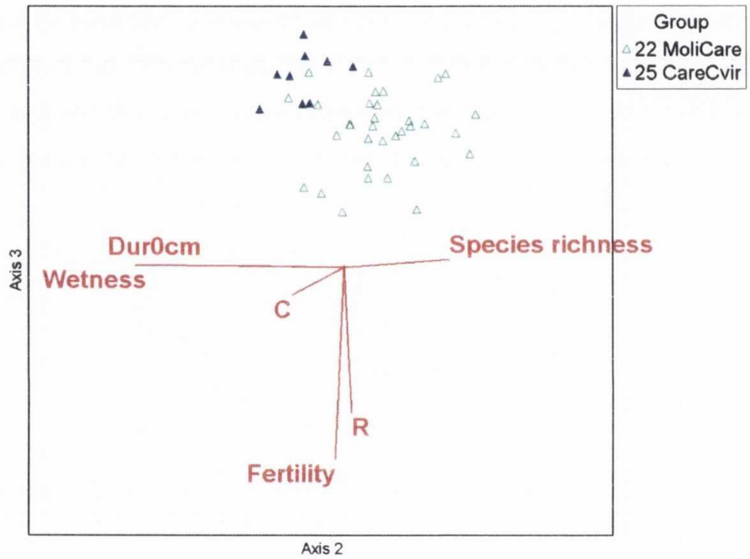


Figure 3.20(A-B) Non-metric Multidimensional Scaling ordination of Axes 2 and 3 (r^2 = 0.498) showing the vegetation communities in clusters 7 to 8, with a biplot showing duration of flooding, Ellenberg and Grime's indicator values, and species richness (r^2 values of axes: 1 = 0.139, 2 = 0.301 = 0.197, total = 0.637)

A Discriminant Analysis was carried out on the quantitative environmental variables, with Vegetation Community as the grouping variable, in order to ascertain which environmental variables were most important in distinguishing between the vegetation groups. MDQuad and WaterTP were log transformed to improve normality prior to analysis.

A Box's M test was carried out to test the null hypothesis that the covariance matrices do not differ between groups. This test was significant, indicating that the null hypothesis should be rejected. However, a significant result is not regarded as too important where sample sizes are large, and non-normality can also affect the result (Leech et al. 2005). Tests of equality of group means showed that all variables were significantly different across groups.

Eigenvalues, percentage of variance explained, cumulative variance and canonical correlations associated with the discriminant analysis for the first eight discriminant functions are presented in Table 3.32. The canonical correlation provides an indication of overall model fit. Function 1 has a canonical correlation of 0.839. Each progressive function explains less of the variation. These results suggest that the first four discriminant functions are most important; the cumulative amount of variation explained by these four functions is 88.2%.

Table 3.32 Eigenvalues, variance explained, and canonical correlations from the stepwise discriminant analysis.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	2.381	41.3	41.3	.839
2	1.353	23.5	64.8	.758
3	.923	16.0	80.8	.693
4	.429	7.4	88.2	.548
5	.297	5.2	93.4	.478
6	.220	3.8	97.2	.424
7	.095	1.7	98.9	.295
8	.066	1.1	100.0	.249

Table 3.33 presents the standardised canonical discriminant function coefficients from the discriminant analysis. These values are the weightings added to each variable to maximise the differences between groups for each function. MDQuad and Dur0cm carry the highest weightings for the first two functions. Water TN and ROCK_CVR are heavily weighted in functions 3 and 4. Table 3.34 gives a different view of the results, in the correlations for the structure matrix. Structure matrix correlations are often used instead of standardised canonical discriminant function coefficients as they are considered to be more accurate (Burns and Burns 2008). These values indicate how important each of the variables is in each of the functions. MDQuad, Dur0cm, WaterTP and WaterTN were the most important variables in the first four functions.

Table 3.33 Standardised canonical discriminant function coefficients from the Discriminant Analysis.

	Function 1	Function 2	Function 3	Function 4
MDQuad	1.072	.438	-.227	.207
Dur0cm	-.606	.783	.532	-.064
WaterTN	.056	-.227	-.865	.597
WaterTP	-.163	-.182	.840	-.577
Alkalinity	.245	.081	.535	.576
SoilTP	.206	-.242	.578	.122
SoilTN	-.175	.090	-.641	-.105
ROCK_CVR	-.018	.106	-.212	-.587

MDQuad and SoilTN were the most important variables in Function 1, with structure matrix correlations of 0.794 and -0.366. Dur0cm was the most important variable in Function 2, with a structure matrix correlation of 0.898, while MDQuad was also important (0.547). WaterTP was the most important variable in Function 3 (0.573), while WaterTN was the most important in Function 4 (0.593). Variables which also contributed but were not as important were ROCK_CVR, Alkalinity, SoilTP and SoilTN.

Table 3.34 Structure matrix correlation coefficients from Discriminant Analysis.

	Function 1	**Function 2**	**Function 3**	**Function 4**
MDQuad	.794	.547	.030	-.064
Dur0cm	-.228	.898	.134	.177
WaterTP	.226	-.189	.573	-.044
WaterTN	.108	-.007	-.038	.593
ROCK_CVR	.036	.077	-.196	-.592
Alkalinity	-.272	-.170	.364	.519
SoilTP	.215	-.082	.028	-.267
SoilTN	-.366	.072	-.263	-.301

Table 3.35 presents the classification results from the discriminant analysis, i.e. the percentage of relevés which were placed in the correct group based only on the environmental variables in the analysis. This table is read from left to right, so that for Group 1 *PoaPlan*, no relevés were correctly classified based only on the environmental variables; 50% of the relevés were placed in Group 3 *AgroRanu* instead, and so on. Discriminant analysis placed 31.2% of the relevés in the correct group.

Some groups were very well classified based only on the environmental variables in the analysis, while others were completely misclassified. For Group 1 *PoaPlan*, it is not surprising that classification based solely on environmental variables was not successful; this community is composed primarily of ruderal species and occurs on heavily poached ground, which could not be predicted with the variables in the analysis.

Groups which were well-classified on the basis of only the quantitative environmental variables were Group 9 *PhalPote*, Group 14 Reedbed, Group 19 *PotePote*, Group 21 *Schoenus*, Group 24 *PotaGlyc*, Group 25

CareCvir and Group 26 *Eleoacic*. These were the groups for which > 60% of relevés were assigned to the correct vegetation group by Discriminant Analysis.

None of the relevés from Group 1 *PoaPlan*, Group 7 *EleoPhal*, Group 16 *EquiMeny*, Group 18 *AgroGlyc* and Group 27 *CareEqui* were correctly assigned by Discriminant Analysis. This suggests that the measured environmental variables associated with these communities do not differ enough from those associated with other communities to distinguish between them.

In some cases, relevés from similar communities were incorrectly classified. For example, Group 19 *PotePote* and Group 20 *FiliPote* are floristically quite similar, but occur at different elevations within the same turlough. 46.2% of relevés in Group 20 *FiliPote* were assigned to Group 19 *PotePote*, and 16% of relevés in Group 19 *PotePote* were assigned to Group 20 *FiliPote*.

45.5% of relevés from Group 16 *EquiMeny* were mis-classified into Group 2 *PersEleo*, while 41.2% of relevés from Group 7 *EleoPhal* were mis-classified into Group 2 *PersEleo*. This suggests that the environmental variables included here are very similar for these groups, and that there is another explanation (i.e. due to variables not used in this analysis) for the floristic differences between them.

Table 3.35 Number of relevés correctly classified by discriminant analysis using only quantitative environmental variables. Figures in bold are those which were correctly classified by discriminant analysis.

G	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1			50.0	10.0					10.0		10.0	10.0	10.0															
2		**23.8**	1.6					4.8	27.0	3.2	4.8			7.9			6.3					17.5	1.6	1.6				
3		5.1	**22.8**	26.6	1.3			19.0	12.7	1.3		5.1	2.5				3.8											
4		2.0	14.3	**40.8**				4.1		6.1		2.0							4.1	14.3		8.2				4.1		
5			2.9		**8.6**			5.7		5.7		14.3			5.7							17.1	2.9		37.1			
6		10.7				**28.6**			7.1					25.0			10.7					17.9						
7		41.2						11.8	47.1																			
8		6.3	12.5		9.4			**40.6**	6.3	12.5		3.1					3.1					3.1						3.1
9		12.5	12.5					12.5	**62.5**																			
10			17.6					17.6		**41.2**		17.6			5.9													
11		12.5				12.5	6.3	6.3	31.3		**31.3**																	
12		4.0	16.0		4.0			24.0	16.0	4.0		**32.0**																
13		6.5	16.1	19.4				3.2	6.5				**9.7**	3.2	3.2		9.7		3.2							19.4		
14						11.1			11.1					**66.7**								11.1						
15		4.8	28.6					4.8		14.3		33.3			**9.5**								4.8					
16		45.5				9.1		27.3	9.1								9.1											
17		16.9				5.1								8.5			**32.2**					11.9		15.3	10.2			
18		20.0	30.0			5.0		5.0		15.0							5.0					10.0	5.0			5.0		
19																			**68.0**	16.0						16.0		
20				7.7															46.2	**46.2**								
21																					**71.4**	14.3						14.3
22					9.1	6.1											6.1					**45.5**		3.0	27.3			3.0
23						14.3																28.6	**42.9**					14.3
24		22.2												11.1										**66.7**				
25					11.1																	11.1			**77.8**			
26				8.3																						**91.7**		
27				14.3		14.3											28.6									42.9		
28						10.0																50.0	20.0					**20.0**

The top ten BIO-ENV results are presented in Table 3.36. The Spearman's rank correlation coefficient was maximised at two combinations of either four or five variables. The combination of variables which explained most variation was Dur0cm, WaterTP, DryDate and whether the relevé occurred in a grazed or ungrazed land-parcel. The addition of Freq0cm did not improve the correlation.

Table 3.36 BIO-ENV results showing top ten combinations of variables (see Table 3.37 for variable names).

Number of Variables	Spearman's rank correlation	Variables
4	0.307	1,4,9,12
5	0.307	1,4,6,9,12
3	0.305	1,9,12
3	0.303	1,4,9
4	0.303	1,5,9,12
6	0.302	1,4,6,9,11,12
5	0.300	1,4,9,11,12
6	0.299	1,4,5,6,9,12
4	0.298	1,4,6,9
5	0.296	1,4,9,12,18

Table 3.37 Variables included in BIO-ENV analysis (variables in bold are those that were found to be important in BIO-ENV analysis).

Variable number	Variable name
1	**Dur0cm**
2	Group
3	Alkalinity
4	**WaterTP**
5	**WaterTN**
6	**Freq0cm**
7	Freq50cm
8	MDQuad
9	**DryDate**
10	WetDate
11	**Soil Type**
12	**Grazed/Ungrazed**
13	Turlough
14	SoilTP
15	SoilTN
16	INORG
17	CACO3
18	**BARE_GRND**
19	ROCK_CVR
20	DUNG_CVR
21	GrazInten
22	PoachScale

3.4.9 Summary of important drivers of turlough vegetation

The important environmental variables affecting turlough vegetation, as identified through NMS, Discriminant Analysis and BIO-ENV are summarised and presented in Table 3.38.

Table 3.38 Summary of important environmental variables (means are presented here) affecting turlough vegetation communities, as determined by NMS, Discriminant Analysis and BIO-ENV.

		Duration	MDQuad	Water TP	Water TN	DryDate	Freq0cm	Grazing	Soil Type
1	*PoaPlan*	311.7	3.35	44.9	1.3	108	8	Grazed	Alluvium, PDM, PDO, WDM, WDO
2	*PersEleo*	449.4	2.68	36.7	1.7	151	4	Mixed	Alluvium, PDM, PDO, WDO
3	*AgroRanu*	309.6	2.87	44.0	0.7	116	4	Mixed, mostly grazed	Alluvium, PDM, PDO, WDM
4	*AgroPote*	292.3	4.61	36.3	1.7	90	6	Mixed, mostly grazed	Alluvium
5	LimeGras	278.8	1.42	18.0	0.6	113	4	Mixed, mostly grazed	Alluvium
6	*EleoRanu*	559.5	2.74	20.9	1.2	170	4	Mixed	Alluvium, PDO
7	*EleoPhal*	447.6	2.64	49.2	2.3	182	3	Mixed, mostly ungrazed	Alluvium, PDO
8	*CareCpan*	235.9	1.05	29.5	0.9	98	3	Mixed	Alluvium, PDM, PDO, WDO
9	*PhalPote*	379.9	2.86	61.9	1.3	143	3	Mixed, mostly ungrazed	Alluvium, PDM, PDO
10	*LoliTrif*	107.3	0.99	33.1	1.4	95	6	Grazed	Alluvium, PDM, PDO, WDM, WDO
11	*PersMent*	553.1	4.33	51.8	1.2	150	6	Mixed	Alluvium, PDO
12	*FiliVici*	193.8	1.18	49.7	1.1	101	3	Mixed	Alluvium, PDM, PDO, WDM, WDO
13	*PoteCare*	402.4	5.14	35.5	0.6	131	6	Mixed, mostly grazed	Alluvium, PDM, PDO
14	Reedbed	602.5	2.91	20.1	1.5	119	3	Ungrazed	Alluvium, PDO
15	*LoliAgro*	188.0	1.36	40.2	0.6	101	7	Mostly grazed	Alluvium, PDM, PDO, WDM, WDO
16	*EquiMeny*	436.8	1.77	30.4	1.9	161	3	Mixed	Alluvium, PDO
17	*CareRanu*	479.9	1.93	15.6	1.3	160	4	Mixed	Alluvium, PDO
18	*AgroGlyc*	385.4	2.87	27.5	0.6	125	7	Mixed, mostly grazed	Alluvium, PDM, PDO
19	*PotePote*	357.6	10.23	48.0	0.9	114	7	Grazed	PDM, WDM
20	*FiliPote*	306.8	8.56	52.4	0.6	81	7	Grazed	WDM
21	*Schoenus*	305.4	1.84	4.1	2.1	95	4	Ungrazed	Alluvium, PDO
22	*MoliCare*	422.3	2.26	6.7	0.6	122	4	Mixed	Alluvium, PDO
23	*CareScor*	438.2	2.82	4.2	1.3	114	5	Ungrazed	Alluvium
24	*PotaGlyc*	640.8	2.25	14.6	1.7	150	3	Grazed	Alluvium, PDO
25	*CareCvir*	411.9	1.80	9.5	0.7	122	5	Mixed, mostly grazed	Alluvium, PDO
26	*Eleoacic*	449.9	9.40	24.6	1.7	208	7	Grazed	PDM
27	*CareEqui*	543.6	6.19	19.1	0.6	157	6	Mixed, mostly grazed	PDM, PDO
28	FldPavmt	390.3	2.49	4.2	1.2	121	5	Ungrazed	Alluvium

3.5 Discussion

A wide range of hydrology, soil properties, hydrochemistry, and management regimes were found in the turloughs in this study. Many of the plant communities occurred in a range of turloughs with a variety of environmental conditions, thereby showing their adaptability to and tolerance of varied environmental and ecological factors. Other plant communities, however, such as those which were correctly classified by the Discriminant Analysis, were more restricted in their range, either due to a reliance on certain hydrological conditions, nutrient levels, or management, or a combination of factors.

3.5.1 Environmental variables

3.5.1.1 Hydrology

The frequency of flood events for each vegetation community showed a large degree of variation (see Section 3.4.1.1). This demonstrates the dynamic nature of the turlough environment, and highlights the challenges this habitat presents for the plants which live there. The communities occurring around the fringes of the turlough basin, such as Group 10 *LoliTrif* and Group 15 *LoliAgro* can experience a wide range of flooding frequency at shallower depths of flooding, but few at 50cm deep. These flood events are likely to be short in duration, given the overall short inundation period recorded for these communities. Communities which occur in the bottom of turlough basins, such as Group 14 Reedbed and Group 24 *PotaGlyc* experience lower frequencies of flooding; but these flood events last longer, as evidenced by the greater means of duration of flooding found for these communities.

A number of communities experienced a wide range of duration of flooding, for example Group 18 *AgroGlyc* had the greatest range, from 120 days to 547 days (see Section 3.4.1.2). This community contains species such as *Agrostis stolonifera*, which can tolerate a range of environmental conditions, and is found all along the flooding gradient. It may also be the case that flooded grassland is quickly colonised by opportunistic amphibious (or ruderal) species, so the long-term hydrological regime may not have a huge influence on the presence or absence of the community. The two *Lolium* grassland communities in Cluster 7, Group 10 *LoliTrif* and Group 15 *LoliAgro*, were found to have the shortest mean durations of flooding. Group 10 *LoliTrif* had a mean duration of flooding of 107 days, while Group 15 *LoliAgro* had a longer mean duration of flooding, at 188 days. These communities can occur on the same soil types (Figure 3.10) and in the same turloughs (Chapter 2), so it is likely that duration of flooding affects plant community composition in this case. Group 10 *LoliTrif*, which has species more typical of managed grasslands, experienced the least amount of inundation, while Group 15 *LoliAgro* experienced slightly longer inundation and has a greater proportion of ruderal species. Group 14 Reedbed and Group 24 *PotaGlyc* had the longest mean durations of flooding, on the other hand, and these communities are very reliant on retaining water throughout the growing season, with obligate aquatic species such as *Potamogeton natans* and *Glyceria fluitans*.

A reduction in the duration of inundation may result in the loss of some species. A study investigating the effects of water extraction on a Junco-Molinion grassland found that *Parnassia palustris* and *Ophioglossum vulgatum* decreased in abundance following lowering of the water table (ter Braak and Wiertz 1994). It is important to note that vegetation communities, within turloughs as in other wetlands, may not show an immediate response to changes in the hydrological regime; some species may exhibit inertia in response to changes in flooding pattern (Large et al. 2007). The hydrological regime of turloughs can vary widely from year to year, and it is likely be that long-term patterns of flooding, rather than that of a single year or even two years (such as the hydrological data here), may drive the vegetation. Flooding can also affect vegetation communities through the influence it has on the recruitment of plant species. One study has found that the survival of tall forb seedlings is significantly decreased by inundation (Lenssen et al. 1998); while Crawford (2008) states that annual plant species are much underrepresented in wetland vegetation communities.

A wide range of mean maximum depths was found. Vegetation communities usually associated with the fringes of the turlough basin were found to have the lowest mean maximum depth; Group 5 LimeGras, Group 8 *CareCpan*, Group 10 *LoliTrif*, Group 12 *FiliVici* and Group 15 *LoliAgro* all had mean values for maximum depth of < 1.5m. Group 19 *PotePote*, Group 20 *FiliPote* and Group 26 *Eleoacic* were all associated with very high mean values for maximum quadrat depth. These communities were recorded only in Garryland and Blackrock turloughs, which are two of the deepest turloughs in this study. Floodwaters this deep may exert extra pressures on the plants which occur there; at c. 10m deep, only very specialised plants can persist throughout the winter. Plants such as *Potentilla reptans* and *Potentilla anserina* can tolerate these conditions by persisting throughout the flooded period as underground rhizomes; they are then able to grow rapidly on recession of the floodwaters, taking advantage of an initial lack of competition to become established before other species.

Many turloughs have more than one cycle of flooding and emptying, and plant communities experience a range of frequencies of flood events, as evidenced above. In order to give an indication of the timing of important flooding event, therefore, the beginning of the longest wet and longest dry periods were calculated for each relevé. The date of start of the longest dry period showed a large degree of variation even within different groups. As could be expected, communities occurring in the bottom of the turlough basin, which experienced long durations of inundation, had later dates for the start of the longest dry period than those occurring on the periphery.

3.5.1.2 Soils

A wide range of soil nutrient concentrations were found in the turloughs in this study (see Section 3.4.2.1). Mean total phosphorus concentration ranged from 245 mg kg^{-1} (Coolcam) to 1594 mg kg^{-1} (Lough Aleenaun). These two turloughs are visible as outliers in the boxplot for TP (Figure 3.5A). Lough Aleenaun has previously been described as being quite heavily managed, with rock clearance and heavy grazing (Goodwillie 1992); in this study, all land-parcels were designated as 'grazed'. This suggests that there may be nutrient enrichment from grazing livestock. Coolcam, on the other hand, is a very wet turlough and retains water throughout the summer, and while cattle have access to some areas, grazing may be limited. Coolcam turlough also had the lowest mean total nitrogen (4983 mg kg^{-1}), while Knockaunroe had the highest (24233 mg kg^{-1}).

No strong relationships between soil nutrients and turlough vegetation communities were found. In this study, however, the soil nutrient data used were single data points for each turlough, which were amalgamations of soil samples from the upper, middle and lower zones of the turlough basin. While this approach gives a broad indication of the soil nutrient status of a turlough, the highly heterogeneous nature of turlough soil means that point data, ideally related to the relevés, would be more useful, but were beyond the scope of this project.

A total of 13 different soil types were associated with the vegetation communities in this study. Some of the vegetation communities were recorded on only one soil type; Group 28 FldPavmt and Group 23 *CareScor* were found only on Alluvium, Group 26 *Eleoacic* was recorded only on Poorly-drained Mineral, and Group 20 *FiliPote* was recorded only on Well-drained Mineral. This suggests that these communities are restricted to these soil types.

3.5.1.3 Water chemistry

There was a large amount of variation in nutrient levels between turloughs in this study. Mean total phosphorus ranged from 4.0 to 82.1 µg l^{-1}. Four of the turloughs had mean TP concentrations indicating an oligotrophic status, 12 had mean TP values indicative of mesotrophic status, while six had mean TP levels indicating eutrophic status.

While nitrogen is often found to be the limiting nutrient in primary production in aquatic ecosystems, phosphorus is generally the limiting nutrient in terrestrial ecosystems (Smith et al. 1999). TP concentration in turlough floodwaters was found to be the limiting factor in phytoplankton biomass accumulation (Cunha Pereira et al. 2010) and the composition of phytoplankton communities (Cunha Pereira et al. 2011). No clear relationship was found between water nutrient concentrations and turlough invertebrate communities (Porst and Irvine 2009). In this study, however, which was concerned with mostly the terrestrial phase of turlough vegetation, TP seems to be a stronger driver of vegetation communities than TN – this is similar to findings reported in the literature recently (Williams et al. 2011).

3.5.1.4 Grazing

When relevés were assigned to 'grazed' or 'ungrazed' categories, based on their presence in land-parcels, four vegetation communities were found to occur only in ungrazed land-parcels. These communities were Group 14 Reedbed, Group 21 *Schoenus*, Group 23 *CareScor* and Group 28 FldPavmt.

Grazing can exert pressures and affect plant community composition as outlined in the introduction. Grazing has also been found to be an important driver of turlough vegetation in previous studies (e.g. Ní Bhriain et al. 2003).

In this study, however, the level of grazing recorded at individual relevés was not as important as other variables, and did not have significant correlation with any of the ordination axes.

Recording grazing intensity in a relevé may not be the best way to estimate grazing intensity over the growing season. Rotational grazing of cattle can mean that vegetation is grazed intensively for a number of days before the vegetation is allowed to recover for a number of weeks. The timing of relevé recording in this cycle will obviously affect the estimate of grazing intensity. Other studies on grazing intensity in turloughs have been on a smaller scale, e.g. just one turlough (Moran et al. 2008a) or two turloughs (Ní Bhriain et al. 2003). These studies had the advantage of smaller scale, whereby more detailed information could be obtained for the land-parcels they examined, as well as being concerned with a smaller number of vegetation communities, which may show differences more easily. Even these smaller scale studies, however, found it difficult to disentangle the effects of the underlying geomorphology and trophic status on vegetation types. Moran et al. (2008b) state "It appears that the management practices are regulated by the inherent grazing potential of the site and soil properties, which in turn are shaped by the hydrological regime", while Ni Bhriain et al. said, of the differences in vegetation found in two different turloughs "...as substrate and hydrology differ between the sites, it is not possible to attribute these differences to management alone." Experimental manipulation of grazing intensity, through for example the erection of long-term grazing exclosures, may be necessary to properly examine the effects of grazing in isolation on vegetation communities.

Some vegetation communities, such as Group 14 Reedbed and Group 21 *Schoenus* were only recorded in ungrazed land-parcels. It is likely that these communities grow on very marginal land which is either very wet (Reedbed) and/or low in nutrients (*Schoenus*) and so supports poor quality forage for grazing animals. Other vegetation communities were only recorded in 'grazed' land-parcels. These consisted of managed grassland (Group 10 *LoliTrif*, Group 15 *LoliAgro*) communities dominated by ruderal species which benefit from the disturbance of grazing animals (Group 1 *PoaPlan*, Group 26 *Eleoacic*) and herb-rich communities with a short sward height which may benefit from grazing to keep the vegetation open (Group 19 *PotePote*, Group 20 *FiliPote*). The other communities occurred in both grazed and ungrazed areas.

3.5.2 Most important drivers of turlough vegetation

Building on the understanding of the relationships between ecological and management variables developed in the previous sections, NMS, Discriminant Analysis and BIO-ENV were then used to identify the variables with the strongest relationships to the vegetation communities. These results are summarised in Table 3.39.
Each of these analyses had strengths and weaknesses, and they were all carried out for different reasons.

NMS was used to give an indication of the relationships between each vegetation type and the environmental variables. The position of the vegetation groups in the ordination space, and how they are arranged upon various axes which are related to the environmental variables gave an indication of which factors were important for which vegetation group. Correlations between the environmental variables and the ordination axes were also carried out; while these give a statistical value for the relationship, care must be taken when interpreting these results.

Discriminant analysis was carried out in order to determine which of the quantitative variables explained most of the differences between vegetation groups. A drawback of this analysis is that categorical data are not appropriate, and so only continuous data were included.

BIO-ENV was then carried out to determine the combination of environmental variables (both quantitative and categorical) which explained most of the variation in the biotic assemblage (i.e. the species abundance matrix).

When correlations between variables were calculated, maximum quadrat depth was correlated with duration of flooding (0.422) – this is unsurprising, as the deeper a point is within a turlough, the more likely it is to be flooded for a longer duration. Maximum quadrat depth was also correlated with frequency of flooding (at 0cm, but not at 50cm). Frequency of flooding was also negatively correlated with water alkalinity (-0.435), suggesting that those turloughs with more alkaline water may experience less changeable water levels. Frequency of flooding was positively correlated with soil total phosphorus.

Water TP was negatively correlated with Axis 3 of the NMS ordination (Table 3.31) and less strongly negatively correlated with Axis 1. Water TP was also positively correlated with Fertility (Table 3.30), this suggests that Water TP is an important driver of turlough vegetation communities. Total phosphorus concentrations in water have been found to be the limiting factor in phytoplankton growth (Cunha Pereira et al. 2010), and it seems that the same may hold true for plant communities. Species richness was negatively correlated with duration of flooding, indicating that a limited number of species can tolerate long periods of inundation.

Discriminant Analysis indicated that Dur0cm, MDQuad, WaterTP and Water TN were the most important environmental variables. However, as categorical variables cannot be used in Discriminant Analysis, such as whether or not a land-parcel was grazed, and soil type were not included. On the basis of the quantitative variables, just 31.2% of relevés were placed into the correct vegetation groups by discriminant analysis. While this is a very low number, when the classification table was examined (Table 3.35), some of the vegetation groups were well-classified; others were completely mis-classified. This suggests that, for the well-classified groups, the environmental variables included in the analysis are enough to predict, with varying degrees of confidence, which vegetation type will occur. For others, more information is likely needed.

The BIO-ENV procedure found that a combination of five variables gave the highest correlation with the vegetation data, at 0.307; Dur0cm, Water TP, Freq0cm, DryDate and whether or not the land-parcel was grazed. While this is not a very high degree of correlation, relatively low correlations have been reported in the literature (e.g. 0.470; King and Buckney 2000, 0.288; Gioria et al. 2010).

The results presented here from all three multivariate analyses demonstrate that duration of flooding and water total phosphorus concentration were the variables which most clearly influence turlough vegetation. The start date of the dry period and frequency of flooding were also shown to be important. The other hydrological variables recorded do not seem to have the same degree of effect.

Table 3.39 Summary of important variables associated with turlough vegetation as determined by NMS, Discriminant Analysis and BIO-ENV.

Analysis	Most important variables	Notes
NMS	Dur0cm WaterTP DryDate	These are the variables with the highest correlations with the ordination axes.
Discriminant analysis	Dur0cm MDQuad Water TP Water TN	These are the variables identified by Discriminant Analysis as most important in distinguishing between vegetation groups.
BIO-ENV	Dur0cm Water TP DryDate Grazed/Ungrazed Freq0cm	This is the combination of five variables identified by BIO-ENV as explaining most variation in the species matrix.

3.5.2.1 Comparison with previous studies

The findings presented here are similar to those from other studies on wetlands. Wheeler and Proctor (2000), in a study of ecological gradients and floristic variation of north-west European mires, found that most of the variation was accounted for by just three ecological gradients: pH, the availability of nitrogen and phosphorus, and the hydrological gradient. Similar findings were reported by de Becker et al. (1999), who concluded that water regime and soil type/management were the main drivers of vegetation community change in a floodplain mire.

Similar findings have also been presented on turloughs; Regan et al. (2007) determined that date of emptying of the turlough (corresponding to DryDate here) and water phosphorus and nitrogen were among the most important drivers of turlough vegetation communities. Moran et al. (2008b) found that the main factors affecting turlough plant community composition were hydrological regime and grazing.

3.5.3 Communities which are restricted in their range/show an association with certain variables

Discriminant Analysis highlighted those groups with restricted range, i.e. those which were classified correctly based on the variables included in the analysis. These were Group 9 *PhalPote*, Group 14 Reedbed, Group 19 *PotePote*, Group 21 *Schoenus*, Group 24 *PotaGlyc*, Group 25 *CareCvir* and Group 26 *Eleoacic*. These groups were those for which > 60% of relevés were assigned to the correct vegetation group by Discriminant Analysis.

For other groups, however, none of the relevés were correctly classified. These were Group 1 *PoaPlan*, Group 7 *EleoPhal*, Group 16 *EquiMeny*, Group 18 *AgroGlyc* and Group 27 *CareEqui*. In some cases, relevés were assigned to similar communities, e.g. Group 19 *PotePote* and Group 20 *FiliPote* are floristically quite similar, but occur at different locations on the flooding gradient within the same turlough. Almost half of the relevés belonging to Group 20 FiliPote were incorrectly assigned to Group 19, and a number of relevés belonging to Group 19 *PotePote* were incorrectly assigned to Group 20 *FiliPote*. This suggests that, based solely on the variables included in the analysis, there is not sufficient difference in the environmental conditions between these communities to distinguish between them. They were both found on Well-Drained Mineral soils, but Group 19 *PotePote* was also found on Poorly-Drained Mineral soils – this suggests that Group 19 *PotePote* may be more tolerant of wetter conditions than Group 20 *FiliPote*.

3.5.4 Implications for Conservation

Large et al. (2007) outline a number of issues and knowledge gaps encountered in attempts at predicting the response of fen species to restoration, many of which might apply to turloughs. These include the tolerance of wetland species to wet conditions, the effect of species interactions on the response of plant communities to hydrology, how changes in the hydrology affect vegetation (e.g. summer vs. winter flooding), previous site history (i.e. the vegetation community may reflect historical hydrological regimes), the role of seed banks in enabling the regeneration of wetland vegetation after a dry period.

Ireland has obligations under a number of EU directives (see Section 1.2.2) to conserve turlough ecosystems. The identification of drivers of vegetation communities is critically important in this context, as specific relationships between vegetation communities and environmental and ecological conditions have not been examined on this wide scale before. Vegetation communities are vital components of turlough ecosystems, so the contribution of ecological and environmental drivers to the structure and function of turloughs is important.

3.5.4.1 Use of derived variables as bioindicators of turlough ecological conditions

The Ellenberg Wetness indicator value and Duration of inundation were the variables which had the highest degree of correlation with the ordination axes. The Ellenberg Fertility indicator value was the variable associated with the second most important axis.

The mean Ellenberg Wetness indicator value was very highly correlated with the duration of inundation ($r^2 = 0.661$, $p \leq 0.001$); this suggests that calculating the mean Ellenberg Wetness value for a quadrat may be a useful proxy for duration of inundation when surveying turloughs, without the need to conduct extensive hydrological investigations. Williams et al. (2011) also examined the relationship between Ellenberg Wetness values and hydroperiod; they found a stronger relationship, but this was based on only one turlough. It may be that the derived mean Ellenberg value more accurately reflects the effects of the hydrological regime over a number of years, rather than the two-year average which was used as a measure of duration of inundation for this study. The mean Ellenberg value for Wetness may also indicate the presence of soil moisture, rather than inundation; communities which occur on soils which retain water may have a high mean Ellenberg Wetness value.

Mean Ellenberg Fertility values may also be of use in monitoring the trophic status of turloughs. While some communities contained species with a wide range of Ellenberg Fertility values, for example Group 13 *PoteCare*, others had species with a tighter range of values. Group 26 *Eleoacic*, Group 15 *LoliAgro*, Group 9 *PhalPote* and Group 1 *PoaPlan* were all communities with high mean Fertility values and low ranges, suggesting that these communities occur in areas with relatively high nutrient loading. Group 22 *MoliCare*, Group 8 *CareCpan*, Group 28 FldPavmt, Group 21 *Schoenus* and Group 25 *CareCvir* all had low mean Ellenberg Fertility values, and low ranges of values, which indicate that these more sedge-dominated communities occur in more oligotrophic areas.

3.6 Conclusion

The specific aims of this chapter were all addressed:

1. To confirm the zonation of vegetation along the flooding gradient.

   Duration of flooding, i.e. position on the flooding gradient, is one of the strongest drivers of turlough vegetation. This confirms that location on the flooding gradient is one of the main factors which determines the species composition of the vegetation in turloughs.

2. To examine the different ecological conditions associated with each vegetation type.

   The ecological conditions associated with each vegetation type were examined. Some communities were found to be associated with a restricted range of environmental conditions through Discriminant Analysis, while others were associated with a range of conditions. A table with the most important ecological conditions associated with each vegetation type was compiled and presented in Table 3.38.

3. To determine which of duration, depth or frequency is the main hydrological driver of turlough vegetation.

   Duration of flooding is the strongest hydrological driver of turlough vegetation, followed by depth and then frequency.

4. To identify the main drivers of turlough vegetation communities.

   The most important drivers affecting turlough vegetation were identified as duration of flooding and the concentration of total phosphorus in flood waters.

In summary, a wide range of environmental and management factors were found to affect the species composition of turlough vegetation. Soil type, nutrient status, grazing and hydrology were all found to affect turlough vegetation, and the conditions associated with each vegetation community were identified. Duration of flooding and nutrient status were found to be the most important drivers of turlough vegetation. Maintenance of the hydrological regime of turloughs and the protection of floodwaters from eutrophication are therefore essential for the preservation of the vegetation communities which occur in these unique habitats.

4 PLANT FUNCTIONAL TRAITS OF TURLOUGH VEGETATION COMMUNITIES

4.1 Introduction

All plant species require the same resources – light, nutrients, water, CO_2 and space. Unlike animals, which may turn to different foodstuffs in the face of competition, plants are in direct competition with their neighbours for the same resources. This has lead to ecological differentiation among plant species, as different methods of resource acquisition and exploitation are employed by different plants. Some differences are obvious and readily observable, such as life form or life span, while others, such as variation in physiology, are more subtle.

Understanding the ecological variation among species can help in understanding why certain species are restricted to a range of ecological conditions, and thereby aid understanding of the distribution of plant communities along ecological gradients, such as a flooding gradient. This chapter will investigate traits and attributes associated with the plant species recorded in turlough vegetation.

4.1.1 Plant Functional Traits

Plant functional traits can be used to group plant species, not necessarily taxonomically related, which share ecological traits and occupy similar ecological niches (Diaz and Cabido 2001, Westoby et al. 2002, Ramsay et al. 2006). Plant functional traits can be described based either on a single characteristic (e.g. Raunkiaer 1934) or on a number of physiological, morphological and/or life-history traits (Diaz et al. 2004). Plant functional traits based on traits measured in the field or in the laboratory were beyond the scope of this project, and so those based on morphological and life history attributes were used.

4.1.2 Perennation

There are three characteristic life histories of plants – annuals, biennials and perennials. Annual species have a key advantage in continuously disturbed conditions (Grime 1979); they can endure unfavourable conditions in a dormant state, as seeds. This strategy may be a risky one; however, as during germination and establishment, seedlings are very vulnerable. This risk can be mitigated by the persistence of seeds in the seed bank, and staggered germination so that at least some individuals are likely to survive (Andersson 1990). Perennial species, on the other hand, must utilise a different strategy to tolerate unfavourable conditions, but are then at an advantage once conditions become favourable again, as they are already established plants. Biennial species may be well suited to disturbed habitats due to their dispersal characteristics (Van der Meijden et al. 1992).

4.1.3 Life forms

One of the more well-known of these classification systems is that of Raunkiaer (1934), which is primarily based on the position of the vegetative buds during the unfavourable season. In this way, observable traits, such as method of vegetative propagation or life form were used to distinguish between groups. A number of other traits can be considered as important to the ecological niche a plant fills. For example: traits associated with the ability to withstand disturbance (grazing, flooding etc.), traits associated with competition with other plants, and the ability to find and assimilate nutrients are all important factors (Boutin and Keddy 1993).

The majority of amphibious herbaceous plants in temperate regions are those with underground perennating organs, such as rhizomes or tubers (Crawford 2008). Reproduction of these plants is more often through vegetative propagation than seed germination; fluctuating water levels can make seed germination and seedling establishment uncertain.

4.1.4 Clonal growth

Reproduction through clonal growth may provide a number of advantages in a wetland environment, and clonal plants are abundant in wetlands (Klimeš et al. 1997). Clonal individuals that become established in a habitat produce genetically identical offspring (ramets) that can become established in the immediate vicinity of the parent plant. The clonal offspring of an already successful individual is therefore likely to have a phenotype suited to the environment in which it occurs, increasing chances of success for that ramet. Rhizomes, turions (detachable winter bud, used for perennation in some aquatic plants) and fragmenting stems can allow plants to reproduce rapidly (Klimesova and Klimes 2006). Wetter habitats tend to support species with greater lateral spread (i.e. the distance between parent and daughter ramet) and clones which split more easily from the parent plant (Van Groenendael et al. 1996, Sosnová et al. 2011). Sosnová et al. (2011) found that clonal growth traits differed depending on the type of wetland in which they occurred. Open water was associated with species which produce freely dispersing propagules, whereas fens and floodplains (the categories in that study most closely related to turlough habitats) were associated with medium lateral spread and long-lived connections between ramets.

4.1.5 Growth form

Studies have found that plant growth form in wetlands varies with elevation (and hence flooding), and that grasses and sedges are most abundant at intermediate levels of flooding, while forbs are dominant at higher levels (e.g. Menges and Waller 1983). Others, however, report that sedges are found in wetter areas within wetlands, while grasses are found in relatively drier areas (Sieben et al. 2010). These differences may be due to differences in the habitats being studied. Sieben et al. (2010) also found shrubs to be confined to the drier areas of wetlands.

Grasses and sedges generally differ in morphology; grasses usually have open leaf sheaths with leaves attached to nodes on the stem, while sedges usually have closed leaf sheaths which are attached to the base of the stem, resulting in a rosette growth form (Sieben et al. 2010).

4.2 Aims

The classification of plants into functional groups can be used to explain vegetation patterns due to environmental conditions (Sieben et al. 2010).

The main aims of this chapter were to:

1. Investigate the attributes of plant species comprising each vegetation community.

2. Examine the relationship between attributes of plant species and environmental conditions, in order to develop an understanding of the strategies adopted in order to tolerate the variations inherent in the turlough environment.

4.3 Methods

Various attributes of the plant species recorded in turloughs were examined. These were obtained from PLANTATT (Hill et al. 2004). The attributes of interest for this study were perennation, life form and clonality, which are described below. Each species was also assigned to a growth form category, i.e. grasses, forbs, sedges, rushes, shrubs/trees.

4.3.1 Perennation

The categories of perennation used were annual, biennial (including monocarpic short-lived perennials) and perennial.

4.3.2 Life form

This category is based on Raunkiear's life forms (Clapham et al. 1962), but was revised in PLANTATT (Hill et al. 2004), due to inconsistencies in classification. The main changes are that the helophyte category (marsh plants) was removed, and an additional life form of aquatic annuals has been added (aquatic therophytes). Categories are based on the position of overwintering buds, and are presented in Table 4.1.

Table 4.1 Life form attributes, descriptions and codes.

Code	Attribute	Description
Ch	Chamaephyte	Perennial woody plant, overwintering buds at or just above ground level
Gn	Non-bulbous geophyte (rhizome, corm or tuber)	Perennial herbaceous plant with dormant parts underground
Hc	Hemicryptophyte	Herbaceous perennial in which the perennating parts are at soil level
Hy	Perennial hydrophyte	Perennial water plant
Hz	Annual hydrophyte	Annual water plant
Ph	Mega-, meso- and microphanerophyte	Tree or shrub with aerial dormant buds (2 – 8m tall)
Pn	Nanophanerophyte	Tree or shrub with aerial dormant buds (< 2m tall)
Th	Therophyte	Annual land plant

4.3.3 Clonality

Hill et al. (2004) describe clonal growth as "vegetative reproduction combined with lateral spread". They categorised plant species based on whether or not clonal growth occurs, and devised categories for different types of clonal growth. The categories used in this chapter are presented in Table 4.2.

Table 4.2 Categories of clonal growth

Attribute	Description
0	Little or no vegetative spread
0gr	Tussock-forming graminoid, may slowly spread
DRa	Detaching ramets above ground (often axillary)
DRg	Detaching ramets at or below ground
DRi	Detaching ramets on inflorescence
Frag	Fragmenting as part of normal growth
Irreg	Irregularly fragmenting (mainly water plants)
Leaf	Plantlets formed on leaves
Node1	Shortly creeping and rooting at nodes
Node2	Extensively creeping and rooting at nodes
Rhiz1	Rhizome shortly creeping
Rhiz2	Rhizome far creeping
Root	Clones formed by suckering from roots
Stol1	Shortly creeping, stolons in illuminated medium
Stol2	Far-creeping by stolons in illuminated medium
Tip	Tip rooting (the stems often turn downwards)

Notes on species excluded

Some species which were only identified to genus level were omitted, as reliable information could not be calculated – *Callitriche* sp. *Epilobium* sp., *Luzula* sp. and *Primula* sp. were assigned to the 'perennial' category, as all species in either genus listed in PLANTATT are perennial. *Chara* sp. was omitted as Hill et al. (2004) did not provide information for Charophytes.

4.3.4 Growth form

Species were assigned to categories based on their growth form; these categories were Grasses, Sedges, Rushes, Forbs and Shrubs/Trees.

Non-Metric Multidimensional Scaling (NMS) was used to examine the relationships between the vegetation communities and environmental variables and the various attributes. An ordination was carried out using the abundance of different attributes, but this did not yield a useful solution, and so the ordination from Chapter 3 was used. The mean number of species within each functional grouping was added to the second matrix of the NMS ordination carried out in Chapter 3. This ordination was used as it contained all of the relevés for which detailed hydrological data were available, allowing the interpretation of the plant functional traits in the context of all of the environmental variables available.

4.4 Results

The abbreviations for vegetation communities introduced in Chapter 3 will also be used here, they are repeated in Table 4.3.

Table 4.3 Abbreviations used in this chapter when referring to vegetation communities defined in Chapter 2

Cluster	Group	Name	Abbreviation
1	1	*Poa annua-Plantago major* community	*PoaPlan*
2	2	*Persicaria amphibia-Eleocharis palustris* community	*PersEleo*
3	3	*Agrostis stolonifera-Ranunculus repens* community	*AgroRanu*
3	4	*Agrostis stolonifera-Potentilla anserina-Festuca rubra* community	*AgroPote*
4	5	Limestone Grassland	LimeGras
5	6	*Eleocharis palustris-Ranunculus flammula* community	*EleoRanu*
2	7	*Eleocharis palustris-Phalaris arundinacea* community	*EleoPhal*
6	8	*Carex nigra-Carex panicea* community	*CareCpan*
3	9	*Phalaris arundinacea-Potentilla anserina* community	*PhalPote*
7	10	*Lolium perenne-Trifolium repens* community	*LoliTrif*
5	11	*Persicaria amphibia-Mentha aquatica* community	*PersMent*
6	12	*Filipendula ulmaria-Vicia cracca* community	*FiliVici*
3	13	*Potentilla anserina-Carex nigra* community	*PoteCare*
5	14	Reedbed	Reedbed
7	15	*Lolium perenne-Trifolium repens-Agrostis stolonifera* community	*LoliAgro*
2	16	*Equisetum fluviatile-Menyanthes trifoliata* community	*EquiMeny*
2	17	*Carex nigra-Ranunculus flammula* community	*CareRanu*
2	18	*Agrostis stolonifera-Glyceria fluitans* community	*AgroGlyc*
3	19	*Potentilla anserina-Potentilla reptans* community	*PotePote*
3	20	*Filipendula ulmaria-Potentilla erecta-Viola* sp. community	*FiliPote*
4	21	*Schoenus nigricans* fen	*Schoenus*
8	22	*Molinia caerulea-Carex panicea* community	*MoliCare*
6	23	*Carex nigra-Scorzoneroides autumnalis* community	*CareScor*
5	24	*Potamogeton natans-Glyceria fluitans* community	*PotaGlyc*
8	25	*Carex nigra-Carex viridula* community	*CareCvir*
1	26	*Eleocharis acicularis* community	*Eleoacic*
2	27	*Carex nigra-Equisetum fluviatile* community	*CareEqui*
4	28	Flooded Pavement	FldPavmt

4.4.1 Perennation

The majority of plant species (191) recorded in this study were perennials (Table 4.4), with 31 annual species and just 6 biennials.

Table 4.4 Total number of plant species in each category of perennation

Attribute	N1	Explanation
a	31	Annual
b	6	Biennial, including monocarpic perennials
p	191	Perennial

Group 1 *PoaPlan* and Group 26 *Eleoacic* had the highest mean numbers of annual species (Table 4.5; 4.2, 4.9). Group 5 LimeGras had the highest mean number of perennial species, at 17.8. For each vegetation community, the mean number of perennial species was higher than either of the other categories, except for Group 26 *Eleoacic*, which had a higher mean number of annuals than either perennials or biennials. The mean number of annuals was less than one in most communities, with the exceptions of the aforementioned Group 26 *Eleoacic*, Group 1 *PoaPlan* (4.2) and Group 18 *AgroGlyc* (1.3).

Table 4.5 Mean number of species (± standard deviation) in each category of perennation recorded in each vegetation type.

	Group	Mean no. species	Annual	Biennial	Perennial
1	*PoaPlan*	9.8	4.2 ± 1.6	0.2 ± 0.4	5.5 ± 2.5
2	*PersEleo*	10.4	0.6 ± 0.9		9.8 ± 2.7
3	*AgroRanu*	13.7	0.3 ± 0.5	0.1 ± 0.3	13.5 ± 2.7
4	*AgroPote*	14.4	0.3 ± 0.6	0.1 ± 0.2	13.7 ± 3.1
5	LimeGras	17.6	0.3 ± 0.7	0.3 ± 0.6	17.8 ± 3.3
6	*EleoRanu*	8.5	0.4 ± 0.6		8 ± 2.1
7	*EleoPhal*	7.5	0.1 ± 0.2		7.5 ± 2.9
8	*CareCpan*	15.0		0.3 ± 0.5	15 ± 3.4
9	*PhalPote*	6.7	0.3 ± 0.4		6.5 ± 1.5
10	*LoliTrif*	14.1	0.1 ± 0.3	0.5 ± 0.8	14.1 ± 3
11	*PersMent*	5.9	0.8 ± 0.4		4.6 ± 2.1
12	*FiliVici*	12.8	0.1 ± 0.3	0.3 ± 0.5	12.6 ± 3.1
13	*PoteCare*	6.6	0.5 ± 0.7		6.2 ± 1.4
14	Reedbed	4.9			4.8 ± 1.3
15	*LoliAgro*	9.9	0.2 ± 0.5	0.4 ± 0.6	9.3 ± 3
16	*EquiMeny*	7.5	0.8 ± 1.1		7 ± 2.2
17	*CareRanu*	11.3	0.1 ± 0.2		12 ± 2.2
18	*AgroGlyc*	7.6	1.3 ± 2.2	0.1 ± 0.2	6.8 ± 2.6
19	*PotePote*	10.2	0.3 ± 0.6		9.9 ± 2.7
20	*FiliPote*	13.6	0.7 ± 0.9		11.8 ± 2
21	*Schoenus*	10.7	0.3 ± 0.5		12 ± 2.3
22	*MoliCare*	11.3			11.2 ± 3
23	*CareScor*	12.7			12 ± 2.4
24	*PotaGlyc*	4.3	0.4 ± 0.5		3.4 ± 2.2
25	*CareCvir*	6.3			6.4 ± 1.6
26	*Eleoacic*	9.8	4.9 ± 2.2		4.3 ± 1.3
27	*CareEqui*	4.9	0.3 ± 0.5		4.7 ± 2.4
28	FldPavmt	12.3	0.5 ± 0.8	0.2 ± 0.4	11.5 ± 2.3

Figure 4.1 shows the percentage frequency of each category of perennation, this chart is ordered according to increasing mean duration of inundation. From this chart it becomes obvious that biennials occurred only in vegetation communities which experienced less inundation. The number of annuals tended to increase with increasing inundation, with the exception of the large numbers of annuals found in Group 1 *PoaPlan* and Group 26 *Eleoacic*.

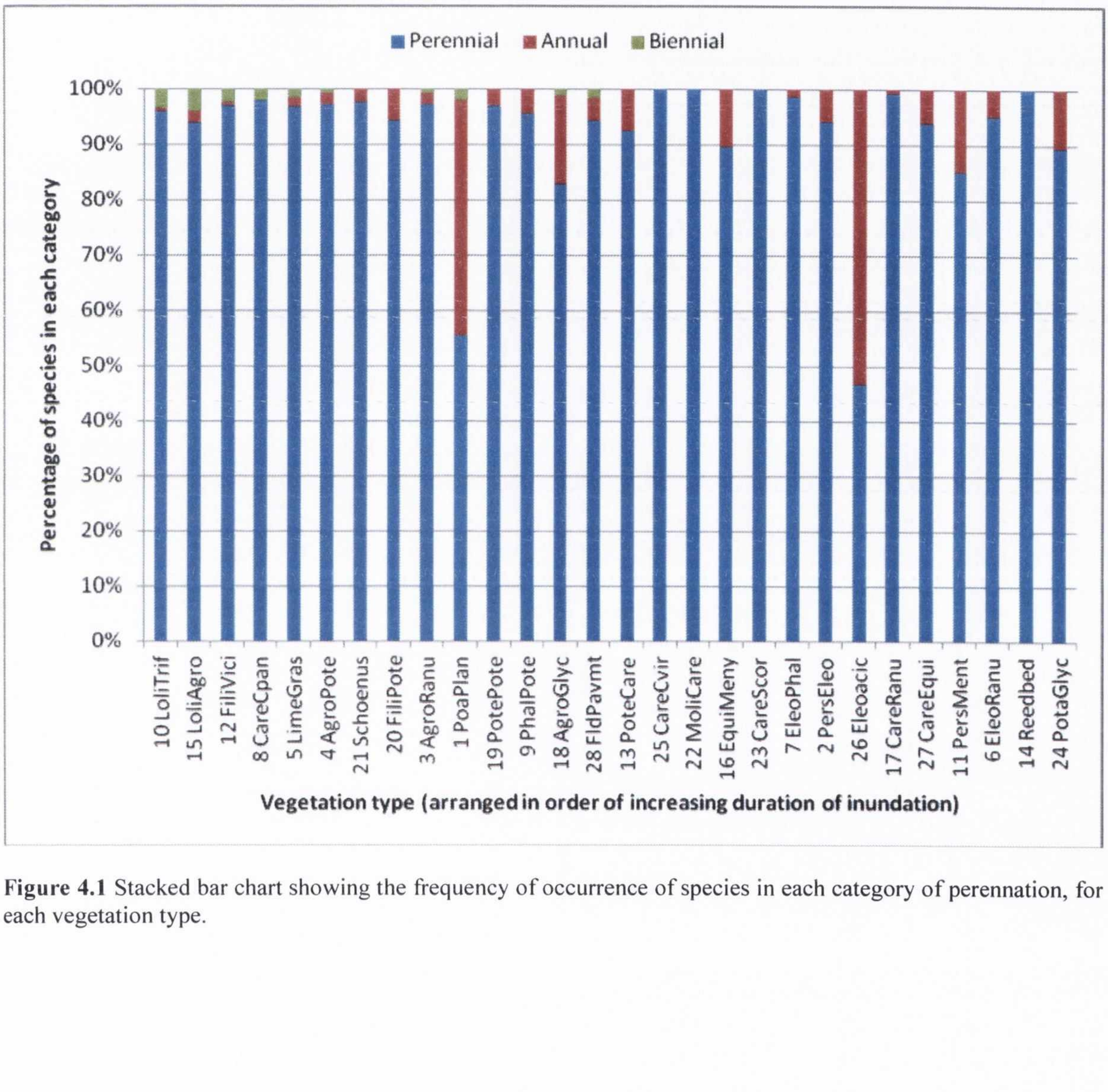


Figure 4.1 Stacked bar chart showing the frequency of occurrence of species in each category of perennation, for each vegetation type.

When the summed percentage cover for each category of perennation was examined, similar trends were evident. Perennial species comprised the majority of cover in each vegetation type (Table 4.6). Group 1 *PoaPlan* was the community with the highest percentage cover of annual species (32.9). Biennials again were poorly represented, making up only a small percentage of the cover in each of the communities in which they were present.

Table 4.6 Mean percentage cover of species (± standard deviation) in each category of perennation recorded in each vegetation type.

	Group	Annual	Biennial	Perennial
1	*PoaPlan*	32.9 ± 19.6	0.2 ± 0.5	40.2 ± 23.1
2	*PersEleo*	3.6 ± 6.8		76.9 ± 29.4
3	*AgroRanu*	1.2 ± 3.3	0.9 ± 2.5	105.8 ± 28.1
4	*AgroPote*	1.5 ± 4.2	0.4 ± 1.5	97.7 ± 28.4
5	LimeGras	0.8 ± 2	1.8 ± 4.6	121.6 ± 36.3
6	*EleoRanu*	3.3 ± 6.1		69.9 ± 25.5
7	*EleoPhal*			71.7 ± 36.5
8	*CareCpan*		2.3 ± 4.4	119.1 ± 31.6
9	*PhalPote*	1.5 ± 3.2		70.9 ± 30.4
10	*LoliTrif*	0.3 ± 1.1	3 ± 6.1	111.4 ± 45.9
11	*PersMent*	5.6 ± 7.2		40.9 ± 21.3
12	*FiliVici*	0.2 ± 0.9	1.2 ± 2.7	109.5 ± 23.7
13	*PoteCare*	2.3 ± 4.5		64.3 ± 33.4
14	Reedbed			40.8 ± 35
15	*LoliAgro*	0.4 ± 1	1.3 ± 2.7	76 ± 24.6
16	*EquiMeny*	5.9 ± 9.2		63.7 ± 32.3
17	*CareRanu*	0.3 ± 1.4	0.3 ± 2.1	107.6 ± 33.7
18	*AgroGlyc*	8.1 ± 14.2		57 ± 25.4
19	*PotePote*	1.9 ± 4.5		95.9 ± 45.9
20	*FiliPote*	5.8 ± 7.6		109.8 ± 28
21	*Schoenus*	0.8 ± 1.6		79.9 ± 21.3
22	*MoliCare*			77.9 ± 29.2
23	*CareScor*			68.9 ± 21.2
24	*PotaGlyc*	3 ± 5.8		57.9 ± 35.7
25	*CareCvir*			61.3 ± 25.7
26	*Eleoacic*	13.1 ± 6.1		52.8 ± 32.1
27	*CareEqui*	0.2 ± 0.6		69.2 ± 40.3
28	FldPavmt	1.2 ± 2.4	0.3 ± 0.6	53.1 ± 14.5

In Figure 4.2, the same general trends can be seen as in Figure 4.1. Biennials made up a very small percentage of the cover of those communities in which they were found, and the percentage cover of annual species showed an increasing trend as duration of inundation increased. Interestingly, while Group 1 *PoaPlan* and Group 26 *Eleoacic* had similar mean numbers of species, the mean percentage cover of these groups differed quite markedly; in Group 1 *PoaPlan* annual species comprised almost 50% of cover, while for Group 26 *Eleoacic* annuals made up just 13%.

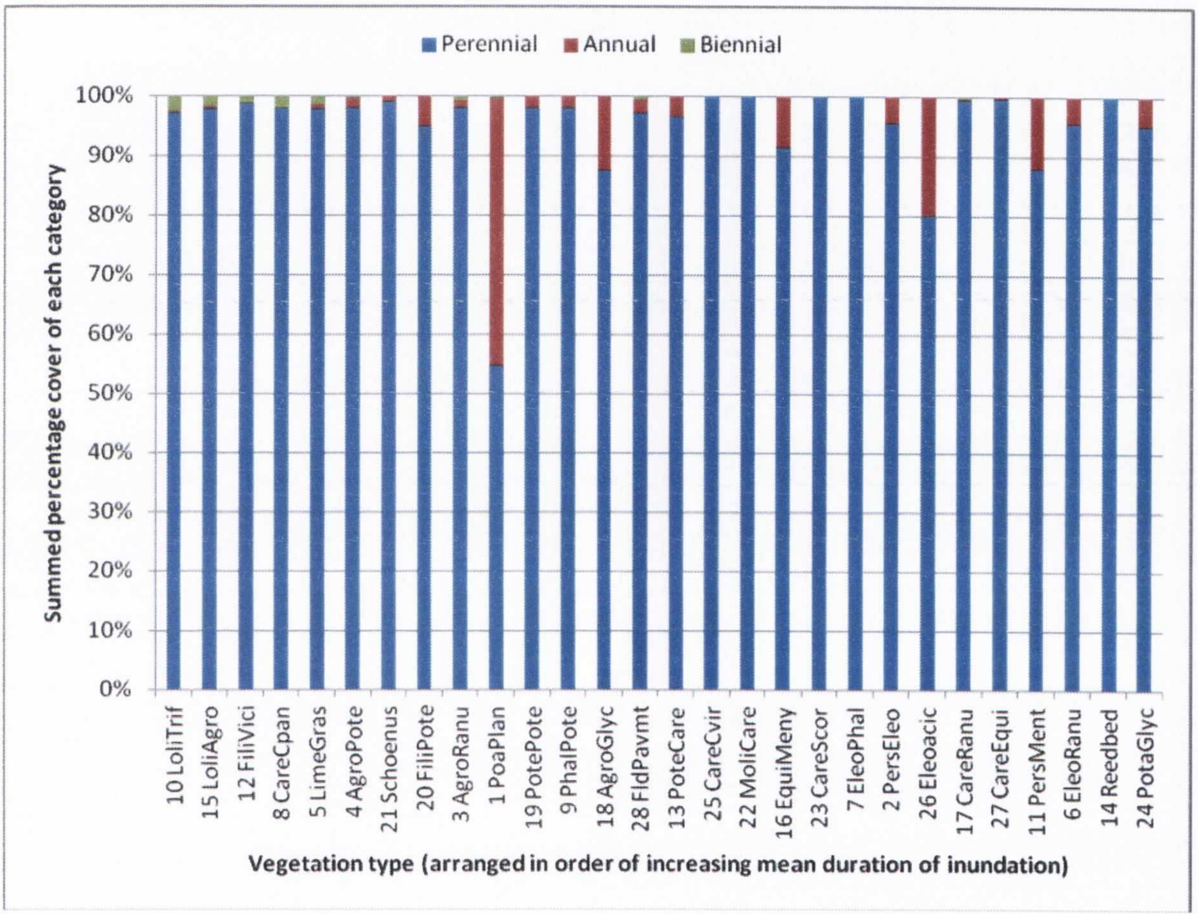


Figure 4.2 Stacked bar chart showing the summed percentage cover of species in each category of perennation, for each vegetation type.

4.4.2 Life-form

Hemicryptophytes were by far the most frequent life-form, at 130 species (Table 4.7). Perennial hydrophytes and therophytes were the next most common categories, at 36 and 27 species respectively. Annual hydrophytes and nanophanerophytes were the least well-represented, with just 4 species in each category.

Table 4.7 Total number of plant species in each category of life form.

Attribute	N	Explanation
Ch	11	Chamaephyte
Gn	10	Non-bulbous geophyte (rhizome, corm or tuber)
Hc	130	Hemicryptophyte
Hy	36	Perennial hydrophyte (perennial water plant)
Hz	4	Annual hydrophyte (aquatic therophyte)
Ph	7	Mega-, meso- and microphanerophyte
Pn	4	Nanophanerophyte
Th	27	Therophyte (annual land plant)

When the mean number of species in each category was examined by vegetation type (Table 4.8), the vegetation types with the highest mean numbers of chamaephytes were Group 20 *FiliPote*, Group 21 *Schoenus* and Group 28 FldPavmt, although these were all relatively low (0.8-0.9). Group 16 *EquiMeny* had the highest mean number of non-bulbous geophytes, at 2; indicator species for this group, *Equisetum fluviatile* and *Menyanthes trifoliata* are both categorised as non-bulbous geophytes. As shown in Table 4.7, the hemicryptophytes were the most frequent category of life form, and they were the only category to be represented in each of the vegetation types (Table 4.8). Group 5 LimeGras had the highest mean number of hemicryptophyte species, at 17.2. Perennial hydrophytes were also very well represented, occurring in 24 of the 28 groups. Amphibious species such as *Persicaria amphibia* and *Phalaris arundinacea* are included in this category, which explains why perennial hydrophytes were found in so many vegetation groups. Group 4 *EleoRanu* had the highest mean number of perennial hydrophytes, at 4. Annual hydrophytes were much less frequent, and Group 11 *PersMent* and Group 26 *Eleoacic* had the highest mean number of species, at 0.7. The phanerophytes were relatively infrequently found; Group 28 FldPavmt had the highest mean number of species at 1.6. Group 21 *Schoenus* had the highest number of nanophanerophytes (1.1). Therophytes were found in a range of vegetation types, but at low frequencies. Group 1 *PoaPlan* and Group 26 *Eleoacic* had the highest mean numbers of therophytes (4.2, 4.3).

Table 4.8 Mean number of species (± standard deviation) in each category of life form recorded in each vegetation type. Life form codes are explained in Table 4.7.

		Mean no. species	Ch	Gn	Hc	Hy	Hz	Ph	Pn	Th
1	*PoaPlan*	9.8			5.3 ± 2.3	0.4 ± 0.5				4.2 ± 1.6
2	*PersEleo*	10.4		0.3 ± 0.4	6.8 ± 2.8	2.8 ± 1.2	0.4 ± 0.6			0.2 ± 0.5
3	*AgroRanu*	13.7	0.2 ± 0.4	0.2 ± 0.4	12.6 ± 2.9	0.7 ± 0.7				0.3 ± 0.5
4	*AgroPote*	14.4	0.4 ± 0.5		13.2 ± 3.1	0.1 ± 0.3				0.3 ± 0.6
5	LimeGras	17.6	0.4 ± 1	0.1 ± 0.3	17.2 ± 3.2	0.2 ± 0.4		0.1 ± 0.4	0.1 ± 0.2	0.3 ± 0.7
6	*EleoRanu*	8.5		0.2 ± 0.4	3.8 ± 1.8	4 ± 1.4	0.3 ± 0.4			0.2 ± 0.4
7	*EleoPhal*	7.5		0.6 ± 0.7	4.1 ± 2.5	2.7 ± 0.6			0.2 ± 0.4	0.1 ± 0.2
8	*CareCpan*	15.0		0.5 ± 0.7	14.4 ± 3.7	0.3 ± 0.5				
9	*PhalPote*	6.7	0.3 ± 0.5	0.2 ± 0.4	4.6 ± 1.6	1.4 ± 0.8				0.3 ± 0.4
10	*LoliTrif*	14.1	0.5 ± 0.6	0.4 ± 0.5	13.6 ± 3.1					0.1 ± 0.3
11	*PersMent*	5.9			1.8 ± 1.5	2.8 ± 1	0.7 ± 0.5			0.1 ± 0.3
12	*FiliVici*	12.8		0.2 ± 0.5	12.2 ± 3.3	0.2 ± 0.5		0.1 ± 0.3		0.1 ± 0.3
13	*PoteCare*	6.6		0.1 ± 0.3	4.8 ± 1.7	1.3 ± 0.7				0.4 ± 0.7
14	Reedbed	4.9		0.1 ± 0.3	1.6 ± 1.1	3.1 ± 1.3				
15	*LoliAgro*	9.9	0.3 ± 0.5	0.4 ± 0.5	9 ± 3.2	0.1 ± 0.3				0.2 ± 0.5
16	*EquiMeny*	7.5		2 ± 0.0	3.1 ± 1.6	1.8 ± 1.5	0.6 ± 0.8		0.1 ± 0.3	0.2 ± 0.6
17	*CareRanu*	11.3		0.4 ± 0.9	10.2 ± 2.1	1.3 ± 1	0.1 ± 0.2			
18	*AgroGlyc*	7.6		0.3 ± 0.4	4 ± 2.2	2.6 ± 1.5	0.4 ± 0.8			0.9 ± 1.6
19	*PotePote*	10.2	0.5 ± 0.5		9.3 ± 2.7	0.1 ± 0.3				0.3 ± 0.6
20	*FiliPote*	13.6	0.9 ± 0.9	0.2 ± 0.4	10.6 ± 1.6			0.1 ± 0.3		0.7 ± 0.9
21	*Schoenus*	10.7	0.9 ± 0.4	0.3 ± 0.5	9.4 ± 1.7			0.3 ± 0.5	1.1 ± 0.4	0.3 ± 0.5
22	*MoliCare*	11.3		0.1 ± 0.2	10.8 ± 2.8	0.2 ± 0.4		0.1 ± 0.2		
23	*CareScor*	12.7			9.7 ± 2.7	0.3 ± 0.5		1.3 ± 1.4	0.7 ± 0.5	
24	*PotaGlyc*	4.3			0.3 ± 1	3.1 ± 1.6	0.4 ± 0.5			
25	*CareCvir*	6.3		0.1 ± 0.3	6.1 ± 1.6	0.2 ± 0.4				
26	*Eleoacic*	9.8		0.1 ± 0.3	2.5 ± 1.1	1.7 ± 0.5	0.7 ± 0.5			4.3 ± 2.1
27	*CareEqui*	4.9		1 ± 0	2.1 ± 2.5	1.6 ± 1				0.3 ± 0.5
28	FldPavmt	12.3	0.8 ± 0.8		8.4 ± 2.4			1.6 ± 1.4	0.9 ± 0.6	0.5 ± 0.8

The percentage frequencies of species in each vegetation type are shown in Figure 4.3; vegetation types are arranged in order of increasing mean duration of inundation, so that communities on the left hand side of the chart experienced the shortest duration of inundation while those on the right hand side were flooded for longest. A clear trend can be seen of decreasing proportion of hemicryptophytes with increasing duration of inundation. Some vegetation types stand out as not conforming to this trend; Group 25 *CareCvir*, Group 22 *MoliCare,* Group 23 *CareScor* and Group 17 *CareRanu*. These are all vegetation types with a high number of *Carex* species, such as *Carex nigra,* which are classed as hemicryptophytes and can withstand prolonged inundation. The proportion of perennial hydrophytes also clearly increased as duration of inundation increased. Group 1 *PoaPlan* and Group 26 *Eleoacic* stand out as having the highest proportion of therophytes.

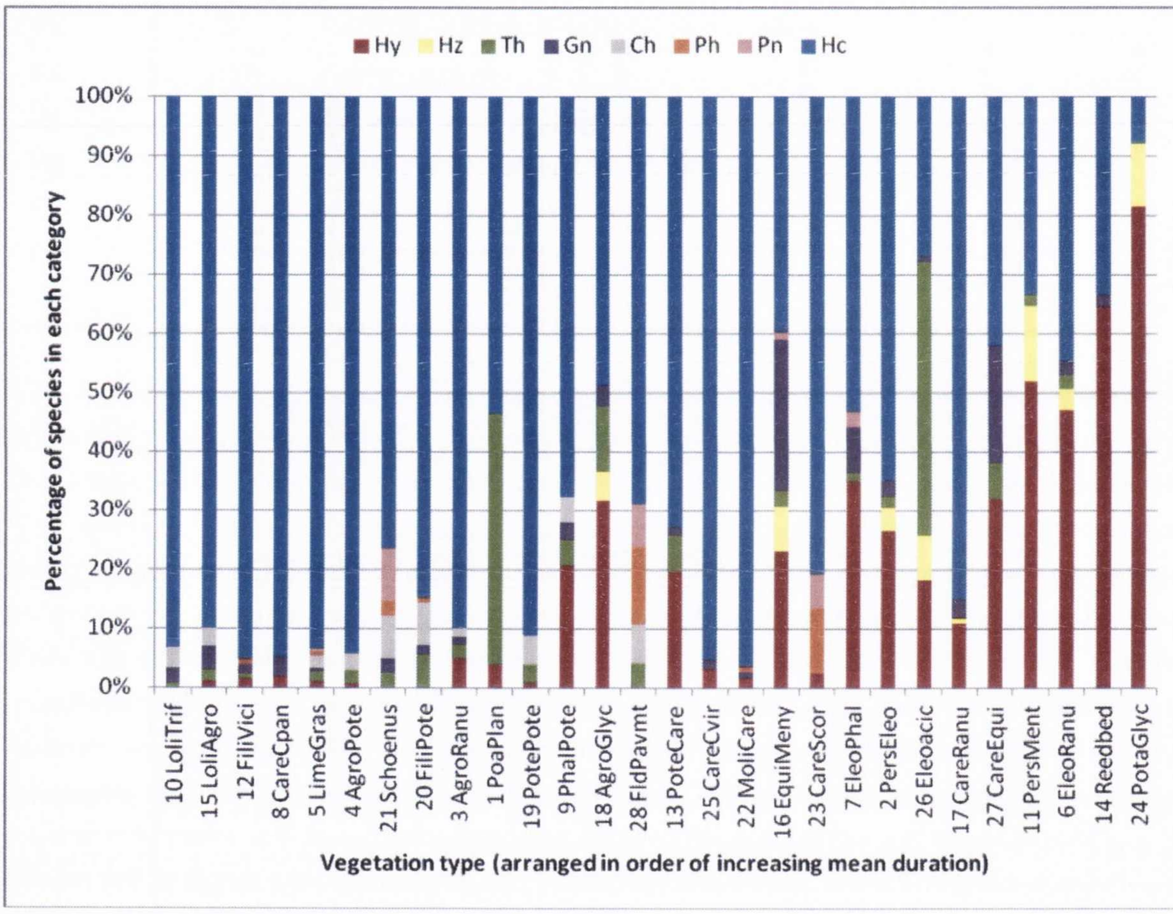


Figure 4.3 Stacked bar chart showing the frequency of occurrence of species in each category of life form, for each vegetation type. Life form codes are explained in Table 4.7.

When the summed percentage cover of each species was examined (Table 4.9), this gives an indication of the composition of the vegetation, although there was a large amount of variation, as evidenced by the large standard deviations. While Group 20 *FiliPote*, Group 21 *Schoenus* and Group 28 FldPavmt all had similar numbers of chamaephytes species (Table 4.8), Group 21 *Schoenus* had the highest percentage cover of species in that category (Table 4.9; 7%), while Group 20 *FiliPote* and Group 28 FldPavmt had mean percentage cover of chamaephytes of 3.3 and 3.7%. Group 16 *EquiMeny* had the highest percentage cover of non-bulbous geophytes. Group 5 LimeGras and Group 8 *CareCpan* had the highest mean percentage cover of hemicryptophytes (119.7%, 117.9%), while Group 14 Reedbed and Group 24 *PotaGlyc* had the lowest mean cover of hemicryptophytes (5.4%, 1.1%). Group 24 *PotaGlyc* had the highest mean cover of perennial hydrophytes, and Group 16 *EquiMeny* had the highest mean cover of annual hydrophytes (5.7%).

Table 4.9 Mean percentage cover of species (± standard deviation) in each category of life form recorded in each vegetation type. Life form codes are in Table 4.7.

		Ch	Gn	Hc	Hy	Hz	Ph	Pn	Th
1	*PoaPlan*			38.9 ± 23.1	1.5 ± 3				32.9 ± 19.6
2	*PersEleo*		1.3 ± 3.8	52.1 ± 28.9	23.5 ± 16.7	3.1 ± 6.3			0.5 ± 2.1
3	*AgroRanu*	0.6 ± 1.4	0.8 ± 2.5	101.2 ± 30.7	4.1 ± 5.4				1.2 ± 3.3
4	*AgroPote*	1 ± 1.9		95.6 ± 27.2	1.1 ± 4.3			0.3 ± 2.3	1.5 ± 4.2
5	LimeGras	2.1 ± 4.6	0.4 ± 1.7	119.7 ± 38	0.4 ± 1.6		0.3 ± 1.1	0.4 ± 1.7	0.8 ± 2
6	*EleoRanu*		2.8 ± 5.9	27.3 ± 17.8	39.8 ± 26.5	2.7 ± 6.2			0.6 ± 1.4
7	*EleoPhal*		6.8 ± 10.8	23.8 ± 22.3	39.2 ± 25.2			1.9 ± 4.6	
8	*CareCpan*		2.1 ± 3.2	117.9 ± 31.6	1.3 ± 2.8				
9	*PhalPote*	3.2 ± 5.2	1.7 ± 3.7	46 ± 26.4	20 ± 20.2				1.5 ± 3.2
10	*LoliTrif*	2.2 ± 3.6	3.1 ± 5	109.1 ± 47.9					0.3 ± 1.1
11	*PersMent*			14.3 ± 15.4	26.6 ± 11.3	5.3 ± 7.3			0.3 ± 1.1
12	*FiliVici*	0.4 ± 1.8	1.9 ± 5.8	105.8 ± 23	1.8 ± 5.7		0.5 ± 1.6	0.4 ± 1.8	0.2 ± 0.9
13	*PoteCare*		0.5 ± 1.8	55.5 ± 33.5	8.4 ± 7.7	0.1 ± 0.8			2.1 ± 4.5
14	Reedbed		0.2 ± 0.5	5.4 ± 3.5	35.3 ± 35.9				
15	*LoliAgro*	1.3 ± 2.4	2.6 ± 5.2	73 ± 26	0.4 ± 1.3				0.4 ± 1
16	*EquiMeny*		22.5 ± 22.1	27.4 ± 22.3	13.4 ± 14.8	5.7 ± 8.8		0.4 ± 1.3	0.2 ± 0.5
17	*CareRanu*		4.9 ± 15	91.1 ± 32.9	11.7 ± 15.5	0.3 ± 1.4	0.2 ± 1.2	0.1 ± 0.6	
18	*AgroGlyc*		1.9 ± 4.2	26.9 ± 17.1	28.2 ± 19	1.8 ± 3.7			6.3 ± 11.6
19	*PotePote*	1.4 ± 2.2	0.1 ± 0.3	94 ± 45.5	0.4 ± 1.9				1.9 ± 4.5
20	*FiliPote*	3.3 ± 4.6	0.4 ± 1.2	106 ± 26.2					5.8 ± 7.6
21	*Schoenus*	7 ± 7.1	0.2 ± 0.6	59.6 ± 22.9			1.5 ± 3.4	11.5 ± 4.9	0.8 ± 1.6
22	*MoliCare*		0.3 ± 1.6	76.3 ± 27.9	0.5 ± 1.3			0.8 ± 4.6	
23	*CareScor*			54.5 ± 26.4	4.7 ± 8		4.9 ± 5.5	4.8 ± 4.4	
24	*PotaGlyc*			1.1 ± 3.4	56.7 ± 35.6	3 ± 5.8			
25	*CareCvir*		0.5 ± 1.4	60.5 ± 26.4	0.3 ± 0.7				
26	*Eleoacic*		0.4 ± 1.2	8.9 ± 6.1	43.5 ± 34.3	0.9 ± 1.3			12.2 ± 6.4
27	*CareEqui*		5.2 ± 5.1	35.3 ± 34	28.7 ± 39.4				0.2 ± 0.6
28	FldPavmt	3.7 ± 4.2		33.6 ± 13.4			7.4 ± 9.5	8.8 ± 7.8	1.2 ± 2.4

As with Figure 4.3, a clear trend was evident in Figure 4.4, with percentage cover of hemicryptophytes decreasing as mean duration of inundation increased. Percentage cover of hydrophytes, both perennial and annual, also increased as mean duration of inundation increased.

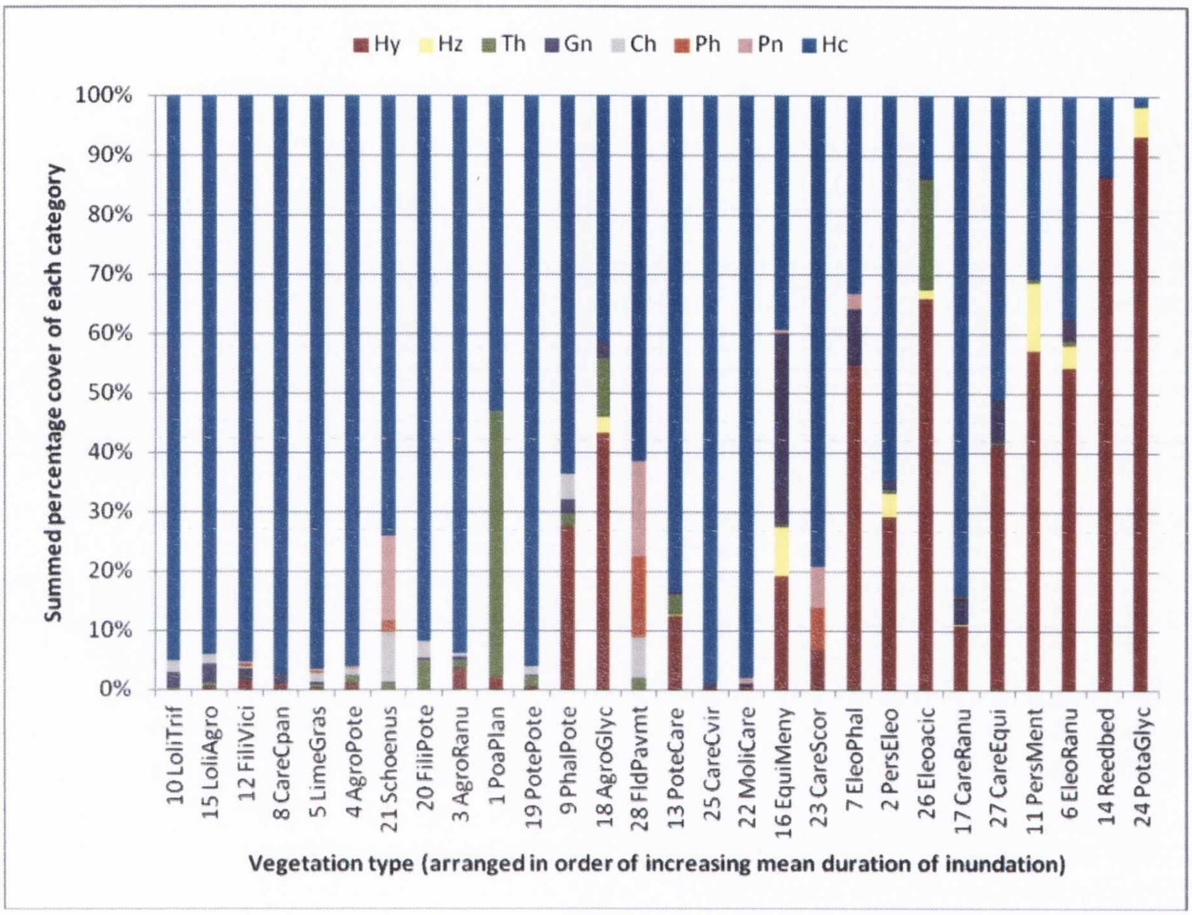


Figure 4.4 Stacked bar chart showing the summed percentage cover of species in each category of life form, for each vegetation type. Life form codes are explained in Table 4.7.

4.4.3 Clonality

The most common form of clonality was rhizomatous; 68 species have either shortly or far creeping rhizomes (Table 4.10). There were 87 species with little or no vegetation spread, and 24 that form tussocks and may slowly spread.

Table 4.10 Total number of plant species in each category of clonality.

Attribute	N	Explanation
0	87	Little or no vegetative spread
0gr	24	Tussock-forming graminoid, may slowly spread
DRa	1	Detaching ramets above ground (often axillary)
Frag	2	Fragmenting as part of normal growth
Irreg	8	Irregularly fragmenting (mainly water plants)
Node1	6	Shortly creeping and rooting at nodes
Node2	12	Extensively creeping and rooting at nodes
Rhiz1	21	Rhizome shortly creeping
Rhiz2	47	Rhizome far creeping
Root	4	Clones formed by suckering from roots
Stol1	2	Shortly creeping, stolons in illuminated medium
Stol2	7	Far-creeping by stolons in illuminated medium
Tip	2	Tip rooting (the stems often turn downwards)

Species which do not reproduce using clones were present in each of the vegetation types (Table 4.11). Node2, Rhiz2 and Stol2 also occurred in each of the vegetation types. Some categories contained only a small number of the species recorded in this study; DRa, Frag, Irreg, Root, Stol1 and Tip all had very low mean numbers of species, and occurred in relatively few of the vegetation types. Group1 *PoaPlan* and Group 5 LimeGras had the highest mean numbers of not-clonal species (Table 4.11; 5.8, 6.8). Group 14 Reedbed, Group 25 *CareCvir* and Group 27 *CareEqui* all had low mean numbers of not-clonal species (0.1-0.3). Species of tussock-forming graminoids were most frequent in Group 25 *CareCvir*. For those plants which creep and root at nodes or with creeping rhizomes or stolons, in almost every case there were more species in the 'far-creeping' than the 'shortly-creeping' categories.

Table 4.11 Mean number of species (± standard deviation) in each category of clonality recorded in each vegetation type. Clonality codes are explained in Table 4.10.

		Mean no. sp.	0	0gr	DRa	Frag	Irreg	Node1	Node2	Rhiz1	Rhiz2	Root	Stol1	Stol2	Tip
1	*PoaPlan*	9.8	5.8 ± 1.8	0.3 ± 0.7					0.5 ± 0.7		1.1 ± 0.9		0.3 ± 0.5	1.9 ± 1.1	
2	*PersEleo*	10.4	1.1 ± 1.1	0.3 ± 0.7			0.1 ± 0.3	1 ± 0.6	0.9 ± 0.8	0.8 ± 0.6	3.5 ± 1.3		0.3 ± 0.5	2.4 ± 0.7	
3	*AgroRanu*	13.7	3.1 ± 1.6	0.7 ± 0.8				0.1 ± 0.3	1.1 ± 0.7	1.4 ± 0.9	4.2 ± 1.6		0.4 ± 0.5	2.9 ± 0.6	
4	*AgroPote*	14.4	4.6 ± 1.3	0.8 ± 1				0.2 ± 0.4	0.9 ± 0.7	1.6 ± 0.9	3.3 ± 1.6		.1	2.7 ± 0.8	
5	LimeGras	17.6	6.8 ± 2.1	2.7 ± 1.3				0.7 ± 0.6	1.2 ± 0.6	1.9 ± 1.1	3.8 ± 1.3	0.1 ± 0.3	0.1 ± 0.2	1.1 ± 0.9	
6	*EleoRanu*	8.5	1.1 ± 1	0.4 ± 0.7			0.8 ± 0.8	0.9 ± 0.6	0.6 ± 0.7	0.4 ± 0.5	3.5 ± 1		0.1 ± 0.3	0.6 ± 0.8	
7	*EleoPhal*	7.5	0.8 ± 0.8					0.2 ± 0.4	0.4 ± 0.5	0.6 ± 0.5	4.5 ± 1.5		0.1 ± 0.2	1.2 ± 1	
8	*CareCpan*	15.0	3.7 ± 1.6	1.6 ± 1				0.4 ± 0.7	1.7 ± 1	1.4 ± 1	5 ± 1.3			1.4 ± 0.8	
9	*PhalPote*	6.7	0.4 ± 0.9					0.1 ± 0.3	0.3 ± 0.5	0.7 ± 0.5	3.4 ± 1.3			1.5 ± 0.9	0.3 ± 0.5
10	*LoliTrif*	14.1	4.7 ± 1.7	2.3 ± 1.3				0.6 ± 0.5	0.9 ± 0.5	1.9 ± 1	2.3 ± 1.1	0.4 ± 0.5		1.4 ± 1.2	
11	*PersMent*	5.9	0.9 ± 0.6			0.2 ± 0.4	0.1 ± 0.3	0.5 ± 0.6	0.3 ± 0.5	0.1 ± 0.3	2.6 ± 1		0.1 ± 0.3	0.6 ± 0.9	
12	*FiliVici*	12.8	2.8 ± 1.5	2.6 ± 1.4					0.6 ± 0.6	1.6 ± 0.8	3.6 ± 1.3	0.1 ± 0.3	0.1 ± 0.3	1.4 ± 0.6	
13	*PoteCare*	6.6	1 ± 1.3	0.1 ± 0.3					0.3 ± 0.5	0.4 ± 0.5	2.8 ± 1		0.1 ± 0.2	2 ± 0.7	
14	Reedbed	4.9	0.3 ± 0.5	0.6 ± 0.5		0.1 ± 0.3	0.3 ± 0.5	0.3 ± 0.5	0.2 ± 0.4	1 ± 0.5	1.8 ± 1.1			0.1 ± 0.3	
15	*LoliAgro*	9.9	2.6 ± 2	1.2 ± 0.8				0.1 ± 0.3	1.4 ± 0.8	0.6 ± 0.8	1.3 ± 1.3	0.3 ± 0.5	0.2 ± 0.4	2.2 ± 0.7	
16	*EquiMeny*	7.5	0.6 ± 0.9	0.1 ± 0.3			0.3 ± 0.5	0.8 ± 0.9	0.6 ± 0.5	0.5 ± 0.5	4 ± 1.2			0.8 ± 0.9	
17	*CareRanu*	11.3	0.9 ± 0.9	1.1 ± 0.9			0.1 ± 0.3	0.8 ± 0.5	1.2 ± 0.7	0.8 ± 0.6	4.3 ± 1.7		0.1 ± 0.2	2.7 ± 0.8	
18	*AgroGlyc*	7.6	1.9 ± 2.4	0.1 ± 0.3		0.1 ± 0.3	0.2 ± 0.5	0.5 ± 0.6	1.2 ± 1	0.4 ± 0.5	2.2 ± 1.7		0.4 ± 0.5	1.3 ± 0.7	
19	*PotePote*	10.2	2.9 ± 1.2	0.1 ± 0.3				0.1 ± 0.3	0.6 ± 0.5	1.2 ± 1	1.8 ± 1.3			3.5 ± 0.5	
20	*FiliPote*	13.6	4.5 ± 1.8						0.1 ± 0.3	2.1 ± 1	3.3 ± 1.2	0.2 ± 0.4		2.4 ± 1	
21	*Schoenus*	10.7	5.1 ± 1.2	2.4 ± 0.5					0.4 ± 0.5	0.4 ± 0.8	3.4 ± 1.3			0.3 ± 0.5	0.1 ± 0.4
22	*MoliCare*	11.3	2.2 ± 1.7	2.3 ± 1				0.7 ± 0.6	0.8 ± 0.6	0.6 ± 0.7	3.5 ± 1.2	0.1 ± 0.2		1 ± 0.9	
23	*CareScor*	12.7	3 ± 1.2						0.6 ± 0.5	1 ± 0	4.9 ± 2.4	0.3 ± 0.5		1.6 ± 0.5	0.7 ± 0.5
24	*PotaGlyc*	4.3	0.9 ± 0.8			0.1 ± 0.3	1 ± 0		0.7 ± 0.5	0.1 ± 0.3	1 ± 1.2			0.1 ± 0.3	
25	*CareCvir*	6.3	0.1 ± 0.3	3.1 ± 0.8				0.9 ± 0.3	0.2 ± 0.4	0.1 ± 0.3	1.9 ± 1.1			0.1 ± 0.3	
26	*Eleoacic*	9.8	4.6 ± 2.1					0.3 ± 0.5	0.1 ± 0.3	0.4 ± 0.5	2.2 ± 0.8			1.7 ± 0.8	
27	*CareEqui*	4.9	0.3 ± 0.5	0.1 ± 0.4				0.3 ± 0.5	0.7 ± 1	0.6 ± 0.8	2.9 ± 0.9			0.1 ± 0.4	
28	FldPavmt	12.3	5 ± 1.4	1.4 ± 0.8				0.3 ± 0.5	0.8 ± 0.6	0.5 ± 0.5	3.1 ± 0.9	0.6 ± 0.5		0.3 ± 0.5	0.2 ± 0.4

A stacked bar chart showing percentage frequency of species in each category of clonality for each vegetation type is presented in Figure 4.5; vegetation types are arranged in order of increasing mean duration of inundation. A general trend can be seen of decreasing proportion of species with limited or no clonal growth (0gr and 0), and a concomitant increase in the proportion of species with clonal growth forms with increasing duration of inundation.

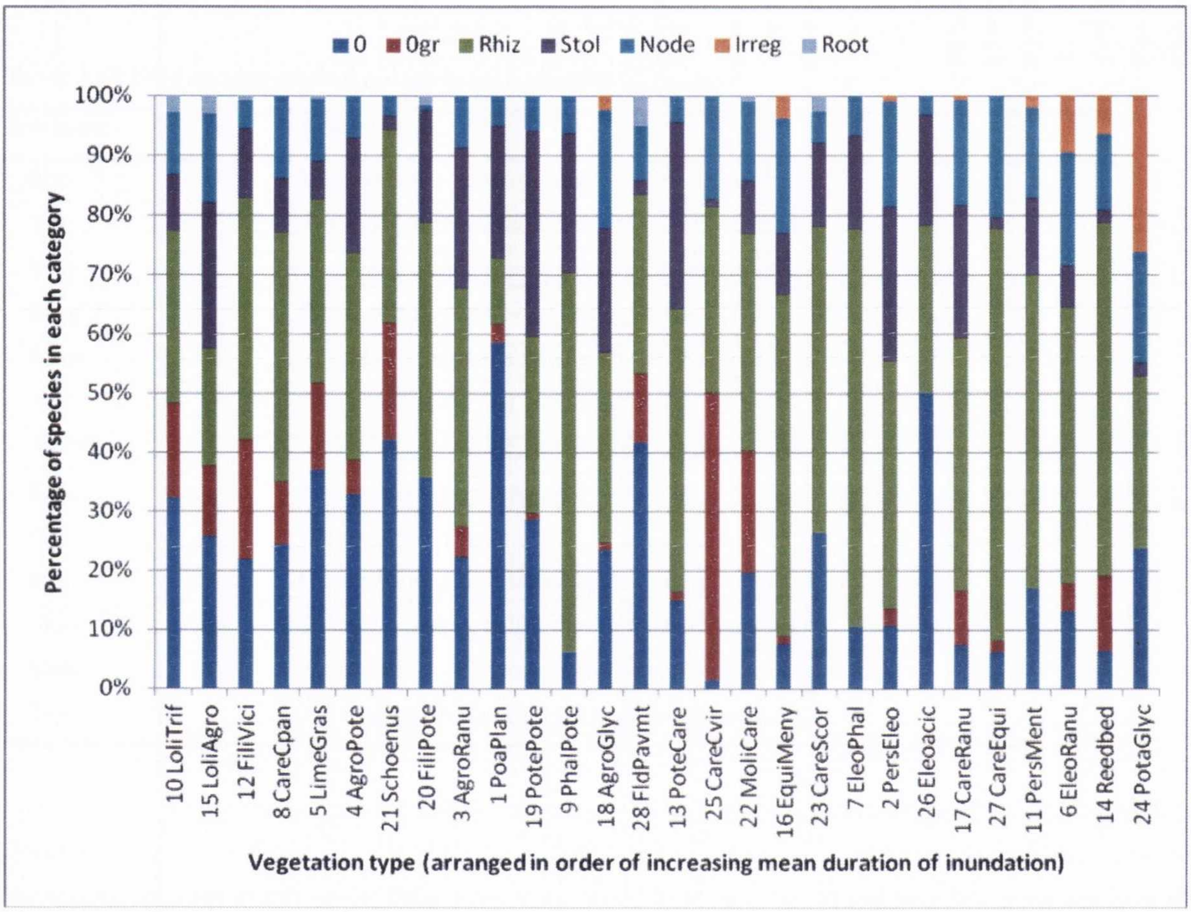


Figure 4.5 Stacked bar chart showing the frequency of occurrence of species in each category of clonality, for each vegetation type. Rhiz1 and Rhiz2, Stol1 and Stol2, and Node1 and Node2 were amalgamated for this graph; DRa, Frag and Tip were omitted as they occurred very infrequently. Clonality codes are explained in Table 4.10.

When the mean percentage covers of species in each category of clonality were examined, a similar trend unfolds (Table 4.12, Figure 4.6). Group 1 *PoaPlan* and Group 5 LimeGras had the highest mean percentage cover of not clonal species (41.9%, 43.3%), while Group 20 *FiliPote* and Group 21 *Schoenus* also had high percentage covers (40.9%, 38.6%). Group 25 *CareCvir*, which had the highest number of tussock-forming graminoid species (Table 4.11) also had the highest mean percentage cover of these species (42.6%; Table 4.12). Group 26 *Eleoacic* had the highest mean percentage cover of Rhiz2 (far-creeping rhizomatous species), at 44.9%. Group 19 *PotePote* had the highest cover of Stol2 (far-creeping stoloniferous species; 58.5%). Group 24 *PotaGlyc* had by far the highest cover of Irreg (irregularly fragmenting species), at 45.5. As with the numbers of species, there was also higher cover of those species with far-creeping and rooting nodes, rhizomes and stolons than there were shortly-creeping.

Table 4.12 Mean percentage cover of species (± standard deviation) in each category of clonality recorded in each vegetation type. Clonality codes explained in Table 4.10.

		0	0gr	DRa	Frag	Irreg	Node1	Node2	Rhiz1	Rhiz2	Root	Stol1	Stol2	Tip
1	*PoaPlan*	41.9 ± 23.6	2.3 ± 4.9					3.6 ± 5.7		5.5 ± 6.1		2.3 ± 3.9	17.8 ± 11.7	
2	*PersEleo*	7 ± 9	2.1 ± 7.3		0.1 ± 0.8	0.6 ± 2.5	5.7 ± 6.1	6.3 ± 8.1	5.3 ± 5	28.8 ± 18.1		1.1 ± 3.6	23.4 ± 14.6	
3	*AgroRanu*	18.9 ± 13.6	5.3 ± 6.8			0.2 ± 1.1	0.8 ± 2.8	10.7 ± 11.3	7.6 ± 6.7	30.6 ± 14.3	0.2 ± 1.1	1.3 ± 2.3	32.5 ± 12.3	
4	*AgroPote*	28.7 ± 12.3	5.7 ± 8.2				0.4 ± 1.5	6.4 ± 7.2	9 ± 7.5	25.3 ± 16.2		0.1 ± 0.6	24.2 ± 9.5	
5	LimeGras	43.3 ± 19.1	22.2 ± 15.6				4.5 ± 6	7.1 ± 5.7	11.4 ± 7.8	29.4 ± 13.6	0.2 ± 0.8	0.2 ± 0.8	5.5 ± 7.1	0.3 ± 1.6
6	*EleoRanu*	9.7 ± 13.9	3.1 ± 6.4		0.2 ± 0.8	6 ± 8.1	8.2 ± 14.2	4.4 ± 6.6	4.6 ± 14.2	33.1 ± 21.8		0.2 ± 0.9	3.7 ± 6.9	
7	*EleoPhal*	4.2 ± 6.5					0.2 ± 0.5	1.4 ± 2	1.8 ± 2.5	57.6 ± 29.6			6.6 ± 9.1	
8	*CareCpan*	26.1 ± 14.6	15.6 ± 12.2				2.2 ± 3.7	14.9 ± 11.1	10 ± 9.6	41.7 ± 13.7			10.8 ± 7.5	
9	*PhalPote*	2.6 ± 5.2					0.2 ± 0.5	1.7 ± 2.8	12.6 ± 25.1	36.5 ± 25.2			15.7 ± 18.6	3.2 ± 5.2
10	*LoliTrif*	25.9 ± 12.2	20.6 ± 11.7				4.4 ± 4.5	20.8 ± 22.7	14.7 ± 10.8	14.8 ± 9.3	3.1 ± 5		10.4 ± 12.3	
11	*PersMent*	5.5 ± 7.2			0.5 ± 1.1	1.7 ± 6.6	3.7 ± 5.2	2.6 ± 4.1	0.3 ± 1.1	28.7 ± 16.7		0.3 ± 1.1	3.5 ± 5.4	
12	*FiliVici*	17 ± 11.1	24.1 ± 12.7					6.5 ± 7.8	15.9 ± 9.6	32.8 ± 18.3	0.6 ± 1.8	0.7 ± 2.1	12.9 ± 8.7	0.4 ± 1.8
13	*PoteCare*	4.2 ± 6.5	1.2 ± 4.8					1.2 ± 3.8	1.6 ± 2.7	25.2 ± 19.6		0.1 ± 0.8	33 ± 32.1	
14	Reedbed	2 ± 3.3	6 ± 9.4		0.2 ± 0.5	0.8 ± 1.5	1.1 ± 1.9	0.6 ± 1.5	22.1 ± 31.5	7.8 ± 5.3			0.2 ± 0.5	
15	*LoliAgro*	12 ± 9.6	11.5 ± 11.2				0.3 ± 1	11.9 ± 7.7	2.7 ± 4.8	9 ± 12.8	2.2 ± 5.1	0.9 ± 2.2	27.4 ± 20.1	
16	*EquiMeny*	3.3 ± 6.1				1.6 ± 3	5.9 ± 10	4.2 ± 5.3	4.1 ± 5.4	36.5 ± 25.5			13.9 ± 22.2	
17	*CareRanu*	4.5 ± 6.3	11.1 ± 11.5	0.1 ± 0.6		0.2 ± 1.4	5.3 ± 6	11 ± 8.8	4.7 ± 5.7	40 ± 21.8	0.2 ± 1.2	0.2 ± 1.3	30.8 ± 27	
18	*AgroGlyc*	10.7 ± 13.8	1 ± 3.7		0.2 ± 0.5	1.1 ± 2.8	2.4 ± 3.7	11.5 ± 9.8	1.5 ± 2.5	21.4 ± 20.9		4.8 ± 7.5	10.4 ± 8.1	
19	*PotePote*	17.5 ± 11.4	0.7 ± 2.5				0.2 ± 0.9	3.6 ± 4.3	5.8 ± 5.1	11.3 ± 9.8	0.1 ± 0.3		58.5 ± 41.7	
20	*FiliPote*	40.9 ± 19.5						0.7 ± 2.6	19.9 ± 11.8	29.2 ± 12	0.4 ± 1.2		24.5 ± 12.5	
21	*Schoenus*	38.6 ± 10.4	22.2 ± 11.9					1 ± 1.6	0.5 ± 0.8	16.9 ± 11			1.2 ± 2.1	0.2 ± 0.6
22	*MoliCare*	10.1 ± 11	29 ± 20.3				1.8 ± 2.5	4.5 ± 5.8	0.9 ± 1.8	25 ± 13.4	0.3 ± 1.6		6.4 ± 7.4	
23	*CareScor*	11.4 ± 4.3						1.7 ± 1.9	1.6 ± 1.3	33.3 ± 20	0.8 ± 1.6		15.5 ± 10.6	4.8 ± 4.4
24	*PotaGlyc*	3.7 ± 5.7			0.5 ± 1.4	45.5 ± 35.8		3.9 ± 4.2	0.5 ± 1.4	6.7 ± 12.7			0.2 ± 0.5	
25	*CareCvir*	0.5 ± 1.4	42.6 ± 25.2				3.9 ± 5.5	0.3 ± 0.7	0.2 ± 0.5	13.7 ± 7.4			0.2 ± 0.5	
26	*Eleoacic*	12.5 ± 6						0.1 ± 0.4	0.4 ± 0.7	44.9 ± 33.7			7.9 ± 4.6	
27	*CareEqui*	0.2 ± 0.6	1.3 ± 3.5				3.7 ± 6.6	4.1 ± 5.8	23.8 ± 38	35 ± 33.7			1.3 ± 3.5	
28	FldPavmt	23.2 ± 7	10.7 ± 8.5				0.7 ± 1.4	2.8 ± 2.4	1.2 ± 1.7	10.7 ± 2.5	3.5 ± 5		0.9 ± 1.8	1 ± 2.9

When these data are presented in a stacked bar chart, and the communities are ordered according to increasing mean duration of inundation, the trend seen in Figure 4.5 of an increasing proportion of clonal plants with increasing duration is also evident (Figure 4.6). The cover of Irreg (irregularly fragmenting) plants was most evident in the communities which experienced the longest duration of inundation, and Group 24 *PotaGlyc* in particular had high cover of plants from this category. Group 25 *CareCvir*, as noted above, had the highest cover of tussock-forming graminoids, and species from this category comprise almost 70% of the summed percentage cover of this community. Group 22 *MoliCare* also had a relatively high proportion of cover from species from this category.

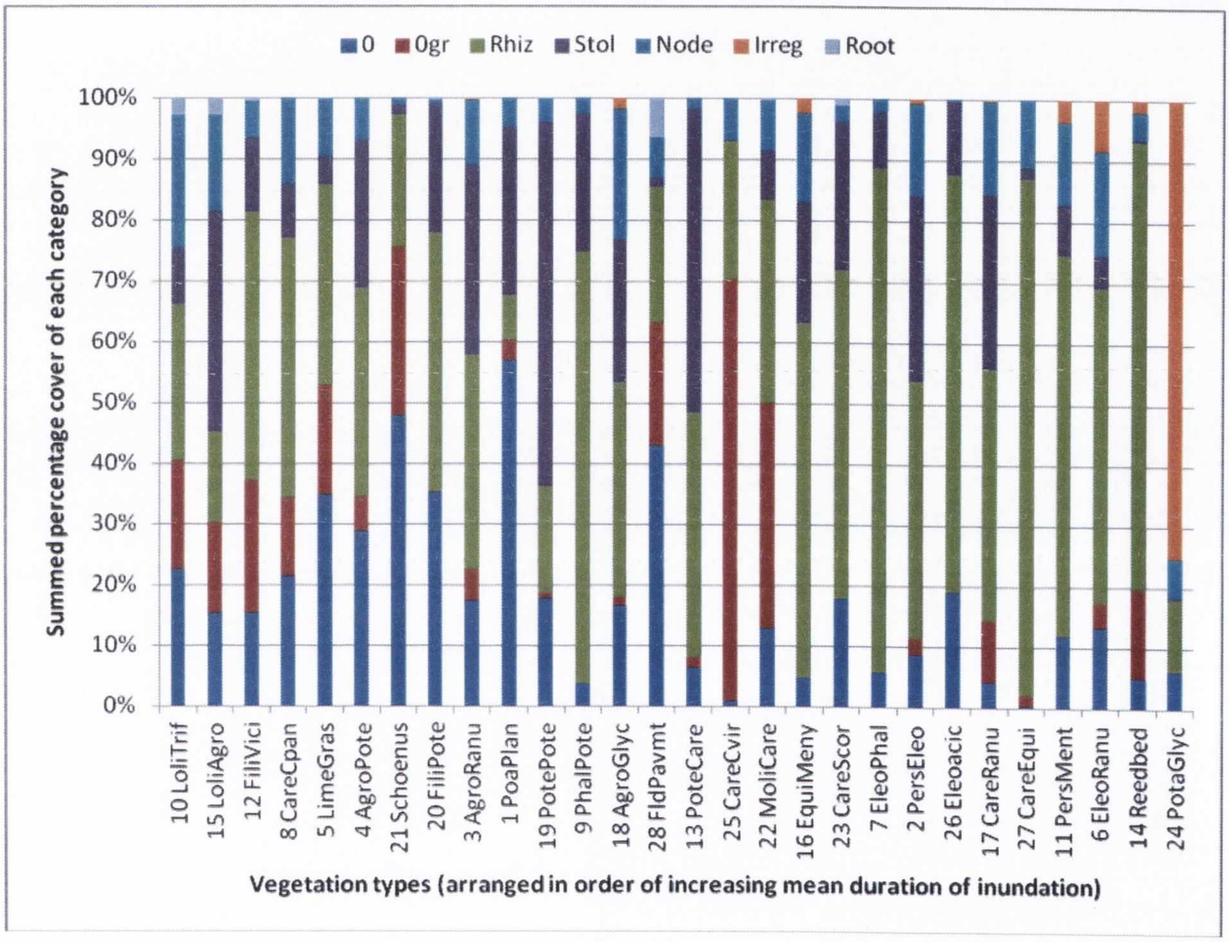


Figure 4.6 Stacked bar chart showing the summed percentage cover of species in each category of clonality, for each vegetation type. Rhiz1 and Rhiz2, Stol1 and Stol2, and Node1 and Node2 were amalgamated for this graph; DRa, Frag and Tip were omitted as they occurred very infrequently. Clonality codes are explained in Table 4.10.

4.4.4 Growth forms

When species were categorised according to growth form, species which belong to the forb category were by far the most frequent, at 162 (Table 4.13). Grasses were the next most frequent, at 27 species.

Table 4.13 Total number of plant species in each category of growth form.

Attribute	N
Grasses	27
Rushes	11
Shrubs/Trees	15
Sedges	19
Forbs	162

The mean number of species in each category is presented according to vegetation community in Table 4.14. Group 5 LimeGras had the highest number of forbs (12.0), while Group 25 *CareCvir* had the lowest number (1.9). Group 10 *LoliTrif* had the highest number of grass species, at 3.9, while Group 14 Reedbed and Group 27 *CareEqui* had the lowest (0.3). The mean number of rush species did not show much variation across vegetation types, ranging from 2.0 (Group 19 *PotePote*, Group 21 *Schoenus*, Group 23 *CareScor* and Group 28 FldPavmt) to 3.4 (Group 6 *EleoRanu* and Group 26 *Eleoacic*). Group 24 *PotaGlyc* and Group 26 *Eleoacic* did not contain any sedges, while Group 25 *CareCvir* had the highest mean number of sedges (3.1). Shrubs were not common in the vegetation types in this study; Group 21 *Schoenus* and Group 28 FldPavmt had the highest mean numbers of species, at 1.9 and 2.0.

Table 4.14 Mean number of species (± standard deviation) in each category of growth form recorded in each vegetation type.

	Group	Forbs	Grasses	Rushes	Sedges	Shrubs/Trees
1	*PoaPlan*	6.4 ± 2.0	2.7 ± 1.3	2.5 ± 0.7	0.3 ± 0.5	
2	*PersEleo*	7.1 ± 2.3	1.5 ± 0.7	3.1 ± 0.8	0.8 ± 0.9	
3	*AgroRanu*	9.4 ± 2.4	2.4 ± 1.2	2.3 ± 0.6	1.8 ± 0.9	
4	*AgroPote*	10.3 ± 2.4	2.4 ± 1.2	2.2 ± 0.5	1.2 ± 0.9	
5	LimeGras	12.0 ± 2.6	3.7 ± 1.3	2.2 ± 0.4	2.3 ± 0.9	0.2 ± 0.7
6	*EleoRanu*	5.8 ± 2.0	0.8 ± 0.6	3.4 ± 0.6	0.4 ± 0.7	
7	*EleoPhal*	4.4 ± 2.1	1.4 ± 0.5	3.0 ± 0	0.7 ± 0.6	0.2 ± 0.4
8	*CareCpan*	9.7 ± 2.3	2.3 ± 1.0	2.6 ± 0.7	2.6 ± 1.3	
9	*PhalPote*	4.5 ± 1.4	1.3 ± 0.7	2.1 ± 0.3	0.6 ± 0.6	0.3 ± 0.5
10	*LoliTrif*	9.9 ± 3.2	3.9 ± 1.2	2.1 ± 0.2	0.8 ± 0.9	
11	*PersMent*	4.6 ± 1.3	0.7 ± 0.6	2.6 ± 0.5	0.1 ± 0.3	
12	*FiliVici*	7.8 ± 1.8	3.4 ± 1.3	2.4 ± 0.6	1.2 ± 1.1	0.1 ± 0.3
13	*PoteCare*	3.8 ± 1.7	1.4 ± 0.5	2.3 ± 0.5	1.2 ± 0.7	
14	Reedbed	2.9 ± 1.7	0.3 ± 0.7	3.2 ± 0.8	0.6 ± 0.5	0.1 ± 0.3
15	*LoliAgro*	6.4 ± 3.1	3.3 ± 0.8	2.1 ± 0.3	0.2 ± 0.5	
16	*EquiMeny*	5.7 ± 2.1	1.0 ± 0.8	2.6 ± 0.7	0.4 ± 0.7	0.1 ± 0.3
17	*CareRanu*	7.4 ± 2.2	1.6 ± 0.8	3.2 ± 1	1.9 ± 1.1	
18	*AgroGlyc*	5.1 ± 2.9	2.2 ± 0.7	2.9 ± 0.9	0.1 ± 0.3	
19	*PotePote*	7.9 ± 2.5	1.4 ± 0.5	2.0 ± 0	0.9 ± 0.8	
20	*FiliPote*	10.9 ± 2.3	1.1 ± 0.8	2.2 ± 0.4	1.2 ± 0.8	0.1 ± 0.3
21	*Schoenus*	6.1 ± 2.3	1.7 ± 0.5	2.0 ± 0	2.9 ± 0.7	1.9 ± 0.7
22	*MoliCare*	6.3 ± 2.9	1.6 ± 0.7	2.4 ± 0.6	2.9 ± 0.9	0.1 ± 0.2
23	*CareScor*	7.0 ± 2.4	1.1 ± 0.7	2.0 ± 0	2.1 ± 0.7	1.7 ± 1.5
24	*PotaGlyc*	2.9 ± 1.9	0.8 ± 0.7	2.2 ± 0.4		
25	*CareCvir*	1.9 ± 0.8	1.3 ± 0.5	2.1 ± 0.3	3.1 ± 0.8	
26	*Eleoacic*	7.4 ± 2.5	1.0 ± 0.4	3.4 ± 0.7		
27	*CareEqui*	2.1 ± 1.5	0.3 ± 0.5	3.1 ± 0.7	1.4 ± 0.5	
28	FldPavmt	7.1 ± 1.7	1.8 ± 1.1	2.0 ± 0	1.8 ± 1.1	2.0 ± 1.2

Figure 4.7 is a stacked barchart showing the proportion of species from each growth form in each vegetation community, arranged in order of increasing mean duration of inundation. A trend can be seen of decreasing number of grass and forb species with increasing duration of inundation. The number of rush species seemed to increase with increasing duration of inundation, while no clear pattern was evident for sedges and shrubs/trees.

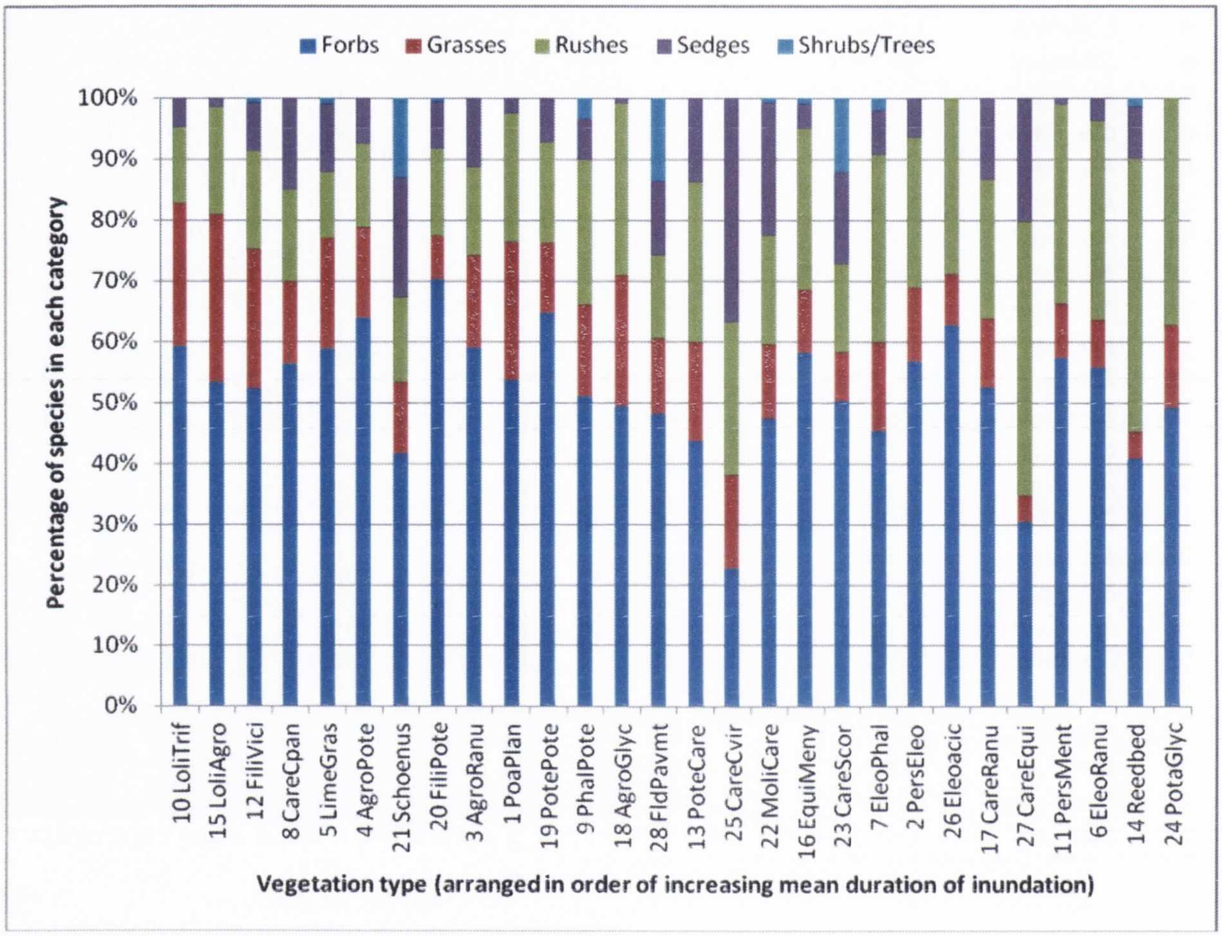


Figure 4.7 Stacked bar chart showing the frequency of occurrence of species in each category of growth form, for each vegetation type.

The summed mean percentage covers of species in each category of growth form for each vegetation type are presented in Table 4.15. Group 20 *FiliPote* had the highest cover of forbs, at 106.3%, while Group 25 *CareCvir* had the lowest, at just 6.3%. Group 10 *LoliTrif* and Group 15 *LoliAgro* had the highest cover of grasses, at 33.3% and 36.8%, while Group 27 *CareEqui* had the lowest (0.8%). Group 25 *CareCvir* and Group 27 *CareEqui* had the highest cover of sedges, at 40% and 39.9%. The community with the highest cover of shrubs/trees was Group 21 *Schoenus*, at 19%.

Table 4.15 Mean percentage cover of species (± standard deviation) in each category of growth form recorded in each vegetation type.

	Group	Forbs	Grasses	Rushes	Sedges	Shrubs/Trees
1	*PoaPlan*	45.1 ± 23.4	24.1 ± 14.1	2.5 ± 5.1	1.5 ± 3	
2	*PersEleo*	50.7 ± 23.4	15.8 ± 11.8	8.2 ± 6.8	6 ± 8.9	
3	*AgroRanu*	70.1 ± 25.4	22 ± 12.6	1.7 ± 3.5	14.2 ± 8.7	
4	*AgroPote*	68.5 ± 24.4	20.8 ± 10.4	0.9 ± 3.2	9 ± 7.6	0.3 ± 2.3
5	LimeGras	73.6 ± 28.5	26 ± 12.3	0.8 ± 1.6	22.6 ± 16	1.1 ± 3.6
6	*EleoRanu*	44.2 ± 26.3	5.9 ± 7.3	19.6 ± 22.8	3.6 ± 8	0 ± 0
7	*EleoPhal*	24 ± 20.3	23.5 ± 26.2	13.9 ± 8.8	8.4 ± 9.8	1.9 ± 4.6
8	*CareCpan*	75.1 ± 26.9	19.2 ± 9.2	4.7 ± 5.8	22.3 ± 11.3	0 ± 0.1
9	*PhalPote*	44.3 ± 23.9	19.1 ± 18.1	0.5 ± 2	5.3 ± 7.8	3.2 ± 5.2
10	*LoliTrif*	77.2 ± 40.1	33.3 ± 12.6	0.3 ± 1	4 ± 5.6	
11	*PersMent*	43 ± 17.7	4.6 ± 4.6	2.6 ± 2.7	0.1 ± 0.4	
12	*FiliVici*	69.1 ± 22.8	30 ± 10	3.7 ± 7.5	7.4 ± 7.8	0.7 ± 2.5
13	*PoteCare*	38.1 ± 33.1	12.3 ± 8.5	1.1 ± 2	15.2 ± 18.9	0 ± 0
14	Reedbed	10.9 ± 8.1	1.1 ± 2.8	21.2 ± 33.2	6 ± 9.4	2.9 ± 8.8
15	*LoliAgro*	39.9 ± 19.4	36.8 ± 16.3	0.1 ± 0.5	0.9 ± 2.3	
16	*EquiMeny*	47.8 ± 28.1	14.8 ± 21.4	4.9 ± 6.8	1.8 ± 3.2	0.4 ± 1.3
17	*CareRanu*	66.9 ± 35.6	12.9 ± 10.4	8.1 ± 8	20.2 ± 18.4	0.1 ± 0.6
18	*AgroGlyc*	35.2 ± 19.3	19.5 ± 10.5	10.2 ± 18.3	0.5 ± 2.1	
19	*PotePote*	82.4 ± 44.2	9.7 ± 5.1		5.7 ± 5	
20	*FiliPote*	106.3 ± 29.3	9.6 ± 8.5	1 ± 1.9	9.5 ± 6	
21	*Schoenus*	28.9 ± 10.6	15.3 ± 10		18 ± 11.7	19 ± 8.7
22	*MoliCare*	28.2 ± 14.8	16.9 ± 18.9	1.8 ± 4.2	30.2 ± 19.1	0.8 ± 4.6
23	*CareScor*	30.4 ± 19.9	13.6 ± 9.2		16 ± 10.6	8.9 ± 8
24	*PotaGlyc*	56.2 ± 29.9	4 ± 4.5	0.6 ± 1.5		
25	*CareCvir*	6.3 ± 5	14.5 ± 6.9	0.5 ± 1.4	40 ± 26	
26	*Eleoacic*	16 ± 6.7	6.9 ± 4.8	43.4 ± 34.5		
27	*CareEqui*	11.9 ± 17.7	0.8 ± 1.6	16.8 ± 30.4	39.9 ± 34	
28	FldPavmt	23.4 ± 6	12.9 ± 7.5		6.5 ± 3	13.6 ± 9.3

Figure 4.8 shows a general trend for decreasing cover of forbs and grasses as duration of inundation increased. Some communities, however, did not conform to this trend, Group 11 *PersMent* and Group 24 *PotaGlyc* both had very high cover of forbs, for example, even though they occurred at the longer end of the duration gradient. The cover of rushes seemed to increase with increasing duration, while sedge cover reached a peak at an intermediate duration of inundation before seeming to decrease again.

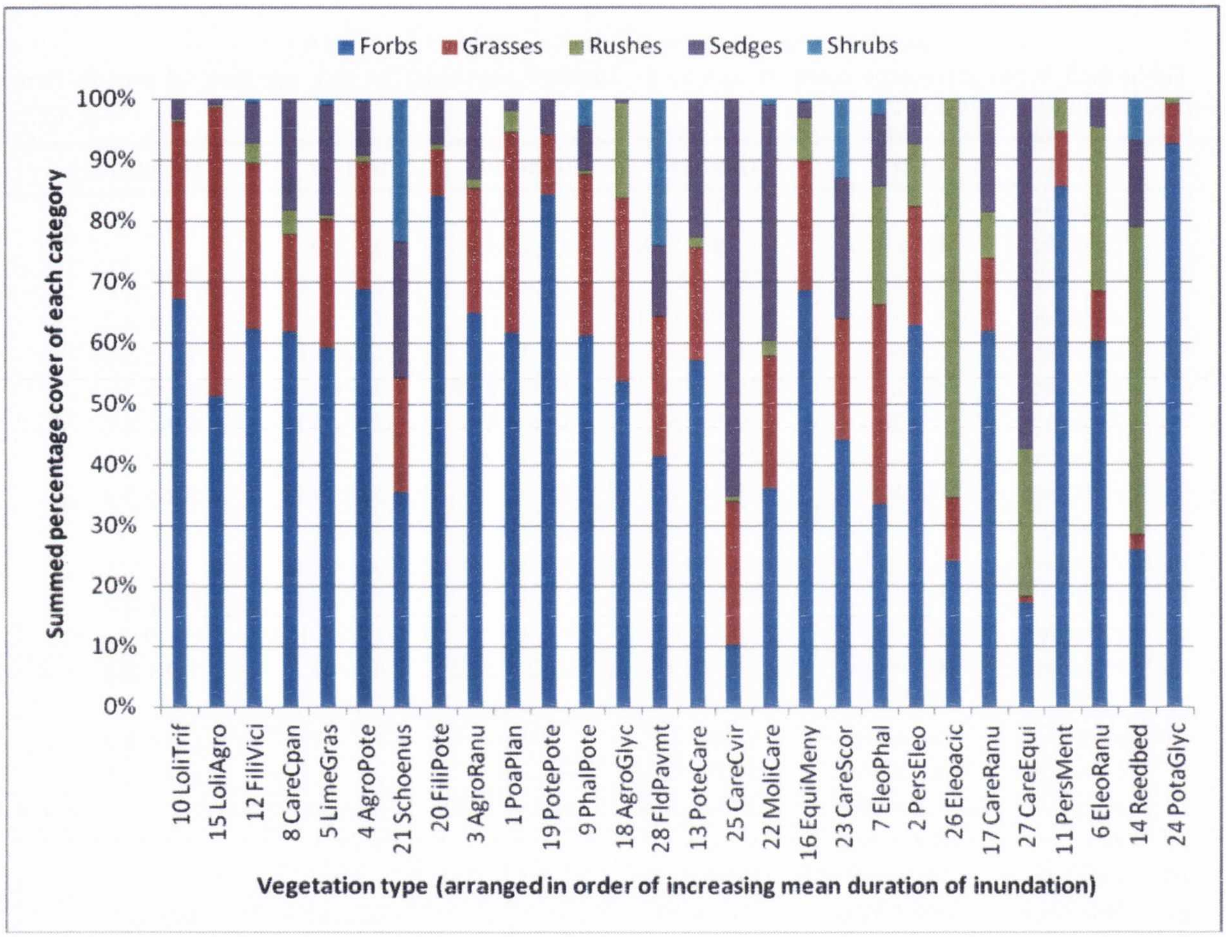


Figure 4.8 Stacked bar chart showing the summed percentage cover of species in each category of growth form, for each vegetation type.

4.4.5 Relationships between plant functional traits and environmental and derived variables

The number of species in each category of perennation, life-forms, clonality and growth forms in each relevé were added to the second matrix of the NMS ordination from Chapter 3, and variables with a significant relationship were overlaid on the ordination as biplots. The ordination diagrams for all three axes are presented in Figure 4.9 A-C. These ordinations are in the same orientation and have the same important environmental variables as in Chapter 3. Figure 4.9C displays the ordination along axes 2 and 3, which together represent the greatest amount of variation (r^2 = 0.498). Along the wet-dry gradient, the perennial hydrophytes were most strongly associated with greater duration of inundation and Ellenberg Wetness values.

Correlations with the ordination axes

Spearman rank correlations between the axes and the variables were calculated (Table 4.16). Axis 1 was moderately correlated with Node1 (0.468), but there were no other significant correlations.

A number of variables were correlated with Axis 2 (which represents the wet-dry gradient); of the perennation category, perennial species were positively correlated (0.567). Of the life forms, chamaephytes were moderately correlated (0.421), while hemicryptophytes were strongly positively correlated (0.702). Perennial hydrophytes were very strongly negatively correlated (-0.801) with Axis 2. Of the categories of clonality, 'None' was strongly positively correlated (0.745) with Axis 2, while Rhiz1 (species with shortly creeping rhizomes) and Tussockgram (tussock-forming graminoids) were positively correlated (0.422, 0.479). Forbs, grasses and sedges were positively correlated with Axis 2 (0.516, 0.547, 0.309), while rushes were negatively correlated (-0.438). Annual species were moderately negatively correlated (-0.405) with Axis 3, while Tussockgram and sedges were positively correlated (0.487, 0.583).

Axis 3, which is aligned with the Fertility gradient, was moderately negatively correlated with annuals (-0.405). Tussockgram and sedges were also positively correlated with this axis.

Correlations with environmental and derived variables

Spearman rank correlation coefficients were calculated between the attribute variables and the measured and derived variables which showed the strongest relationship with the ordination, i.e. Duration of flooding, Ellenberg Fertility value, species richness and Ellenberg Wetness value (Table 4.17). Duration of flooding was moderately negatively correlated with Perennials (-0.443) and hemicryptophytes (-0.542), and positively correlated with perennial hydrophytes (0.563). Duration was also negatively correlated with the 'None' category of clonality (-0.518), and with the number of grass species (-0.548). Fertility was negatively correlated with Tussockgram (-0.498) and sedges (-0.572). Species richness was very strongly correlated with perennial species (0.960), hemicryptophytes (0.909) and forbs (0.909). Of the categories of clonality, species richness was moderately correlated with Node2, and more strongly correlated with Rhiz1 and 'None' (0.583, 0.712). There were also correlations between species richness and grasses (0.537) and sedges (0.440). Ellenberg Wetness was negatively correlated with perennial species (-0485), chamaephytes (-0.461) and the 'None' category of clonality, and very strongly positively correlated with perennial hydrophytes (0.718). Ellenberg Wetness was also negatively correlated with numbers of forb species (-0.489) and grass species (-0.531), and positively correlated with number of rush species (0.474).

A

B

C

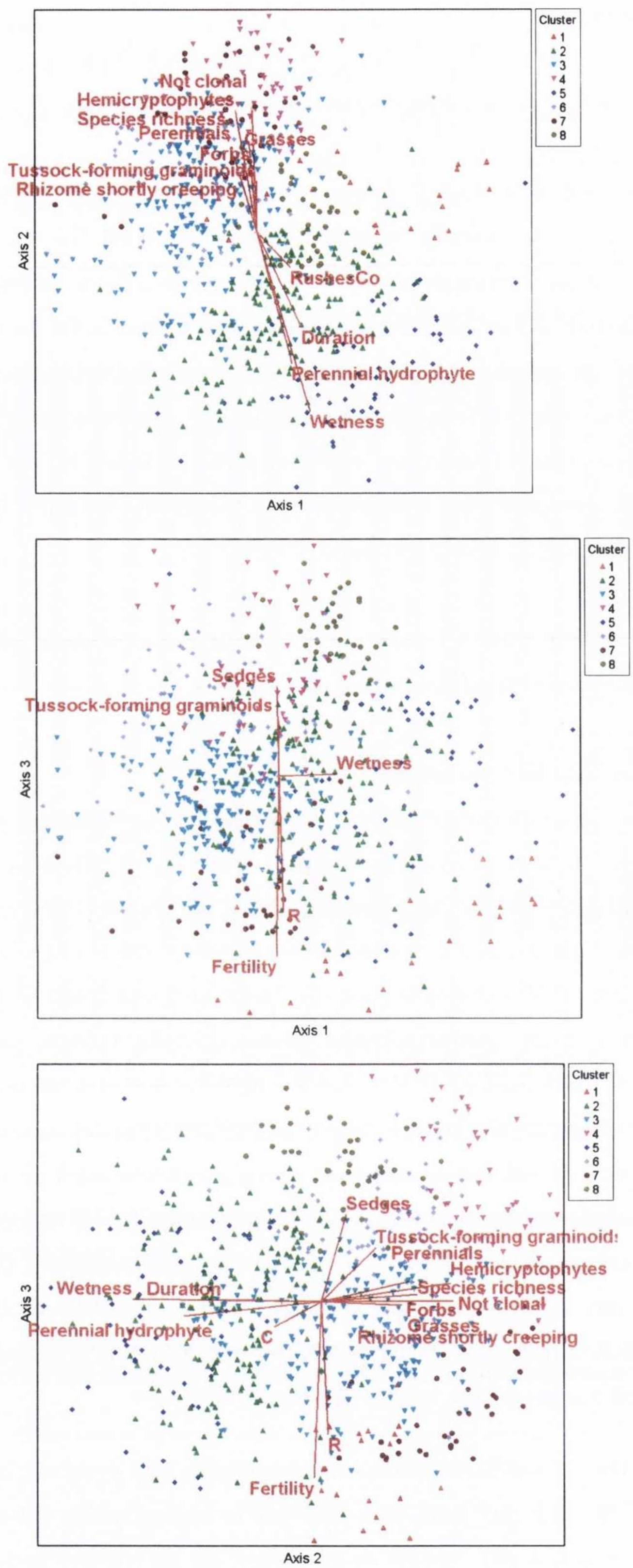


Figure 4.9 Non-metric Multidimensional Scaling ordination of Axes 2 and 3 (r^2 = 0.498) showing the 8 vegetation clusters derived by cluster analysis and a biplot showing duration of flooding, Ellenberg and Grime's indicator values, species richness and some functional groups. (r^2 values of axes: 1 = 0.139, 2 = 0.301 = 0.197, total = 0.637

Table 4.16 Correlations with the ordination axes.

	Axis1	Axis2	Axis3
Perennation			
Annual	**0.149**	-0.085	**-0.405**
Biennial	-0.088	**0.276**	-0.004
Perennial	**-0.233**	**0.567**	**0.283**
Life-form			
Annual hydrophyte	**0.289**	**-0.309**	**-0.258**
Chamaephyte	**-0.192**	**0.421**	-0.064
Hemicryptophyte	**-0.281**	**0.702**	**0.273**
Nanophanerophyte	-0.052	**0.148**	**0.271**
Non-bulbous geophyte	-0.073	**-0.225**	0.087
Perennial hydrophyte	**0.303**	**-0.801**	**-0.232**
Phanerophyte	-0.102	**0.199**	**0.256**
Therophyte	0.011	0.12	**-0.323**
Clonality			
Detachingramabove	0.047	-0.031	0.05
Frag	0.12	**-0.155**	**-0.135**
Irreg	**0.313**	**-0.313**	-0.005
Node1	**0.468**	**-0.172**	**0.147**
Node2	0.097	**0.149**	0.069
None	**-0.201**	**0.745**	-0.039
Rhiz1	**-0.27**	**0.422**	0.051
Rhiz2	**-0.222**	-0.095	**0.354**
Root	-0.101	**0.255**	0.045
Stol1	-0.011	-0.061	**-0.239**
Stol2	**-0.195**	**0.149**	**-0.331**
Tip	**-0.13**	0.067	0.109
Tussockgram	0.032	**0.479**	**0.487**
Growth form			
Forbs	**-0.167**	**0.516**	0.024
Grasses	**-0.312**	**0.547**	-0.119
Rushes	**0.386**	**-0.438**	0.016
Sedges	-0.079	**0.309**	**0.583**
Shrubs/Trees	-0.109	**0.169**	**0.257**

Figures in bold are significant ($p \leq 0.05$) after correction for multiple comparisons using the Dunn-Šidák method.

Table 4.17 Correlations between life forms and main environmental variables.

	Dur0cm	Fertility	Wetness	Species richness
Perennation				
Annual	0.073	**0.351**	0.035	-0.032
Biennial	**-0.303**	-0.03	**-0.206**	**0.288**
Perennial	**-0.443**	**-0.320**	**-0.485**	**0.960**
Life form				
Annual hydrophyte	**0.268**	**0.248**	**0.328**	**-0.137**
Chamaephyte	**-0.275**	-0.015	**-0.461**	**0.240**
Hemicryptophyte	**-0.542**	**-0.319**	**-0.61**	**0.909**
Nanophanerophyte	0.006	**-0.195**	-0.099	0.089
Non-bulbous geophyte	-0.017	-0.040	**0.192**	0.032
Perennial hydrophyte	**0.563**	**0.251**	**0.718**	**-0.384**
Phanerophyte	-0.034	**-0.170**	**-0.165**	0.118
Therophyte	-0.090	**0.276**	**-0.173**	0.071
Clonality				
Detachingramabove	0.056	-0.051	0.035	-0.025
Frag	0.077	**0.129**	**0.161**	-0.094
Irreg	**0.247**	-0.033	**0.365**	**-0.148**
Node1	**0.248**	**-0.193**	**0.302**	**0.099**
Node2	**-0.154**	-0.082	-0.089	**0.470**
None	**-0.518**	-0.051	**-0.682**	**0.712**
Rhiz1	**-0.348**	-0.079	**-0.403**	**0.583**
Rhiz2	-0.053	**-0.279**	0.073	**0.479**
Root	**-0.169**	-0.030	**-0.268**	**0.137**
Stol1	-0.128	**0.249**	0.011	**0.147**
Stol2	**-0.143**	**0.288**	**-0.308**	**0.358**
Tip	0.024	0.027	-0.120	-0.028
Tussockgram	**-0.284**	**-0.498**	**-0.239**	**0.385**
Growth form				
Forbs	**-0.391**	-0.091	**-0.489**	**0.909**
Grasses	**-0.548**	0.089	**-0.531**	**0.537**
Rushes	**0.317**	-0.032	**0.474**	0.005
Sedges	**-0.167**	**-0.572**	**-0.157**	**0.440**
Shrubs/Trees	0.014	**-0.176**	**-0.141**	0.070

Figures in bold are significant ($p \leq 0.05$) after correction for multiple comparisons using the Dunn-Šidák method.

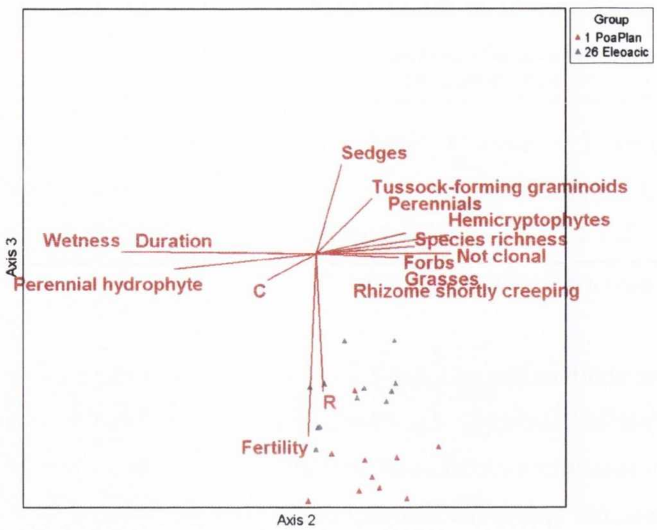
As in Chapter 3, ordination diagrams were also produced showing only the vegetation communities in each cluster, for ease of interpretation. These are presented in Figure 4.10, Figure 4.11 and Figure 4.12.

Cluster 1 is shown in Figure 4.10A. The communities which comprised this cluster were Group 1 *PoaPlan* and Group 26 *Eleoacic*, both of which were communities with high numbers of annual species, as seen in Section 4.3.1. None of the plant functional trait attributes overlaid on the ordination diagram seemed strongly related to the quadrant in which this cluster occurs.

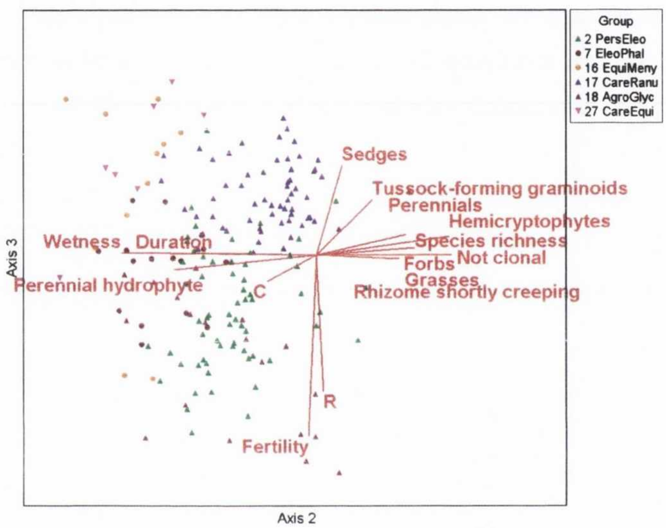
The communities of Cluster 2 are presented in Figure 4.10B, and these were Group 2 *PersEleo*, Group 7 *EleoPhal*, Group 16 *EquiMeny*, Group 17 *CareRanu*, Group 18 *AgroGlyc* and Group 27 *CareEqui*. These communities were all associated with high Ellenberg Wetness values and long duration of flooding, and the perennial hydrophyte category of the life form category. They occurred across a range of Ellenberg Fertility values, and the communities associated with low Ellenberg Fertility values, i.e. Group 16 *EquiMeny*, *CareRanu* and Group 27 *CareEqui* were all communities with relatively large frequencies of sedge species, and so were associated with the sedge functional grouping.

Cluster 3 is represented in Figure 4.10C. The communities which belong to Cluster 3 are Group 3 *AgroRanu*, Group 4 *AgroPote*, Group 9 *PhalPote*, Group 13 *PoteCare*, Group 19 *PotePote* and Group 20 *FiliPote*. These communities all occurred towards the middle of the Fertility and Wetness/Duration gradients.

A – Cluster 1



B – Cluster 2



C – Cluster 3

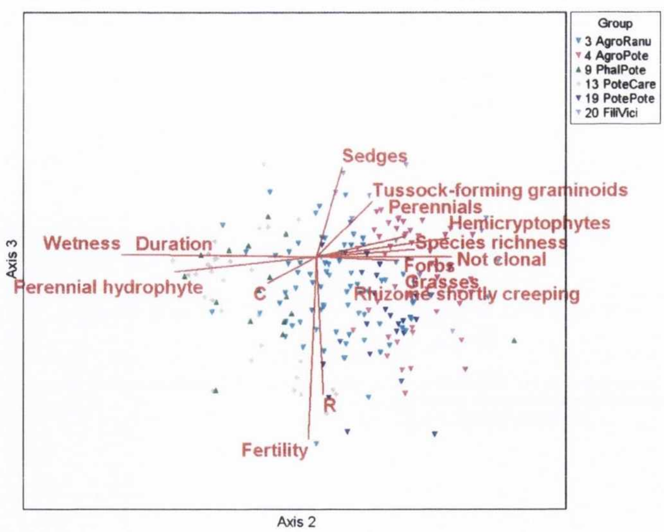


Figure 4.10 A-C Non-metric Multidimensional Scaling ordination of Axes 2 and 3 (r^2 = 0.498) showing the 8 vegetation clusters derived by cluster analysis and a biplot showing duration of flooding, Ellenberg and Grime's indicator values, species richness and some functional groups. (r^2 values of axes: 1 = 0.139, 2 = 0.301 = 0.197, total = 0.637

Cluster 4 is presented in Figure 4.11A. The communities which belong to this cluster are Group 5 LimeGras, Group 21 *Schoenus* and Group 28 FldPavmt. Their position on the ordination axes suggest that Group 21

Schoenus and Group 28 FldPavmt were associated with sedges and tussock-forming graminoids, while Group 5 LimeGras was more associated with perennials, hemicryptophytes, no clonal growth, forbs and grasses.

Cluster 5 is shown in Figure 4.11B. The communities in this cluster are Group 6 *EleoRanu*, Group 11 *PersMent*, Group 14 Reedbed and Group 24 *PotaGlyc*. These communities were all associated with long duration of flooding and perennial hydrophytes.

Figure 4.11C shows the location of Cluster 6 on the ordination diagram. The communities in this cluster are Group 8 *CareCpan*, Group 12 *FiliVici* and Group 23 *CareScor*. Group 8 *CareCpan* and Group 23 *CareScor* occurred towards the top of Axis 3, suggesting that these communities were associated with high numbers of sedges and tussock-forming graminoids, while Group 12 *FiliVici* had more hemicryptophytes, not clonal species, grasses and forbs.

A – Cluster 4

B – Cluster 5

C – Cluster 6

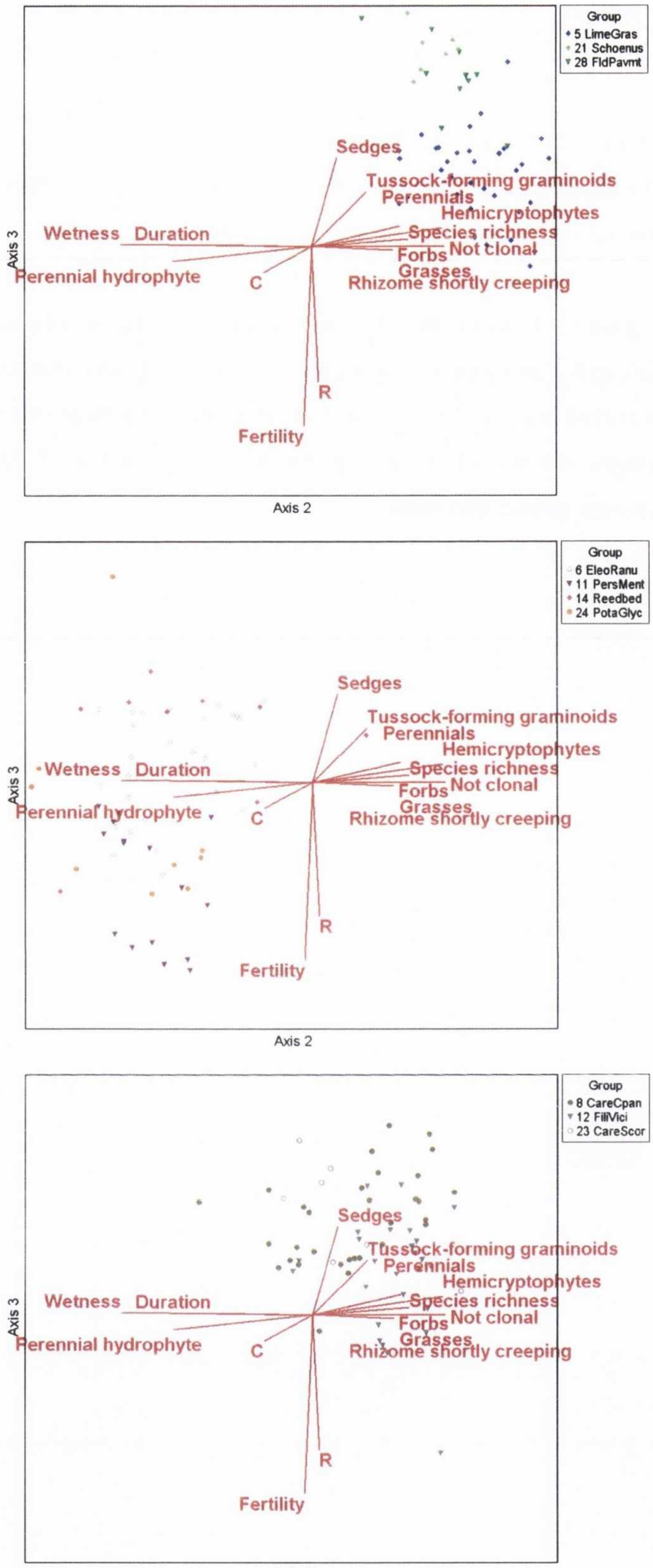


Figure 4.11 A-C Non-metric Multidimensional Scaling ordination of Axes 2 and 3 ($r^2 = 0.498$) showing the **8** vegetation clusters derived by cluster analysis and a biplot showing duration of flooding, Ellenberg and Grime's indicator values, species richness and some functional groups. (r^2 values of axes: 1 = 0.139, 2 = 0.301 = 0.197, total = 0.637

Cluster 7 is shown in Figure 4.12A, the communities in this cluster are Group 10 *LoliTrif* and Group 15 *LoliAgro*. These communities were associated with relatively high fertility, and low duration of inundation.

Cluster 8 is presented in Figure 4.12B. The communities which comprise this cluster are Group 22 *MoliCare* and Group 25 *CareCvir*. These were two communities with a high number of sedge species, as shown by their position on the ordination diagram at the top of the sedge gradient.

A – Cluster 7

B – Cluster 8

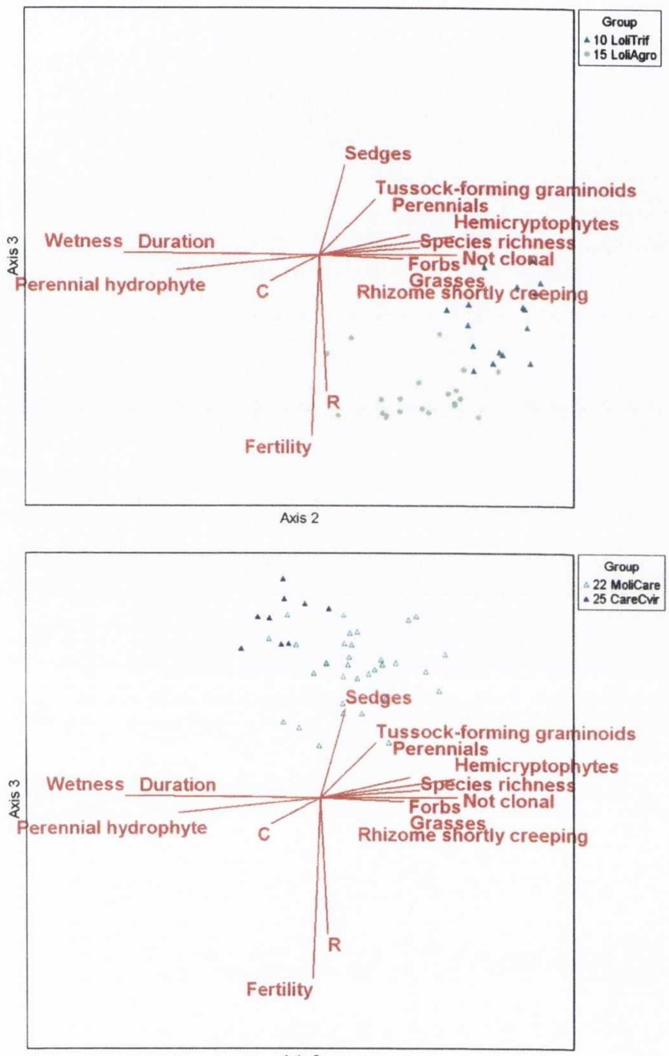


Figure 4.12 A-B Non-metric Multidimensional Scaling ordination of Axes 2 and 3 (r^2 = 0.498) showing the 8 vegetation clusters derived by cluster analysis and a biplot showing duration of flooding, Ellenberg and Grime's indicator values, species richness and some functional groups. (r^2 values of axes: 1 = 0.139, 2 = 0.301 = 0.197, total = 0.637

4.5 Discussion

Assigning plant species to plant functional traits presents a different view of the structure and composition of plant communities, and examining functional groupings in conjunction with the environmental variables associated with the different vegetation communities elucidates the relationships between plants and their environment.

4.5.1 Perennation

Perennial species were the most common in this study, followed by annuals and then biennials. No biennials occurred in the vegetation communities which experienced the longest periods of inundation; it may be that flooding results in too short a growing season so that the plants cannot put on enough biomass to produce flowers. The two communities with the highest numbers of annual species were Group 1 *PoaPlan* and Group 26 *Eleoacic*. These communities experience a large amount of disturbance through poaching, and by being annuals; the species which occur in these communities are able to tolerate this disturbance through avoidance. Annuals were found to be more frequent and at higher mean percentage cover at longer durations of inundation; this is similar to findings reported in other work. Menges and Waller (1983), in a study on floodplain herbs, found that annuals were present throughout the flooding gradient, but important only at lower elevations.

4.5.2 Life form

The most common category of life form recorded in this study was hemicryptophyte, which was the only category in this functional grouping to be represented in each of the vegetation communities, followed by perennial hydrophytes and therophytes. Group 20 *FiliPote*, Group 21 *Schoenus* and Group 28 FldPavmt had the highest numbers of chamaephytes. Perennial hydrophytes, a category which includes amphibious species, were found in 24 of the 28 vegetation types. Therophytes (annual land plants) were relatively well-represented in this study, occurring in 21 of the 28 vegetation types. Skornik et al. (2010) found that increased grazing pressure in North Adriatic Karst pastures was related to decreased proportions of chamaephytes and geophytes in the vegetation, and an increase in the proportion of therophytes. Therophytes are also associated with flooding disturbance (Menges and Waller 1983).

4.5.3 Clonality

Clonal growth forms are common in wetland environments (Klimeš et al. 1997), and were also found to be associated with duration of inundation in this study. Clonal plants have a number of advantages in the turlough environment. Perennating organs, such as rhizomes or stolons, can allow amphibious species to survive under prolonged periods of anoxia, and depending on the time of year, species of plant and condition of the perennating organ, this period can range from days to months (Crawford and Braendle 1996). Clonal integration, or the level of connectedness between parent and daughter ramets, can also confer a competitive advantage on clonal plants; studies have shown that transfer of resources, such as nutrients, can occur between connected clones (Wijesinghe 1994).

Clonal plants in wetlands tend to have greater lateral spread than their counterparts in drier environments (Van Groenendael et al. 1996), and in this study, in almost every community there were a greater number of and cover of species with far-reaching clones than those with shortly creeping clones. This suggests that the 'guerilla' strategy of Lovett Doust (1981) is more successful in this environment than the 'phalanx' strategy.

The most common type of clonality in Dutch wetlands was found to be rhizomatous (Sosnová et al. 2010), a finding which was shared here. The mean percentage cover of rhizomatous species was higher than any other category of clonality in almost all vegetation types.

4.5.4 Growth form

The number of, and mean percentage cover of, species from each growth form category varied across vegetation types. Communities which are found on the edges of the turlough, which experience least inundation, had the highest numbers of and covers of forbs and grasses. While the numbers of rush species did not vary greatly between communities, the mean percentage cover of rushes increased substantially as duration of flooding increased. Šmilauerová and Šmilauer (2010) found that grasses were able to more quickly colonise areas of high nutrient concentration than were forbs, thereby giving grasses a competitive advantage. In areas with inputs of nutrients, for example from dunging of grazing livestock, this could be another mechanism whereby grasses become dominant in areas around the edges of turloughs.

4.5.5 Relationships between plant functional traits and environmental and derived variables

The ecological traits examined in this study were based on morphology and life history rather than physiology, so it must be borne in mind that there is not always a clear relationship between morphology and function (Diaz and Cabido 2001). When the functional groupings in this study were examined in conjunction with the environmental variables, however, some possible links between morphology and function can be seen.

Different strategies for tolerating lack of nutrient availability and flooding were evident when the ordination with biplots representing the plant functional traits added was examined. Axis 1 of the ordination was the wet-dry gradient, and communities on the wet end, which experienced the longest duration of inundation, were associated with a high frequency of perennial hydrophytes. Communities on the other end of this axis experienced less inundation, and were associated with higher species richness, a higher frequency of hemicryptophyte species, a higher frequency of species with no clonal growth and a higher frequency of forbs and grasses. Communities on this end of the axis were also associated with a higher frequency of plant species with shortly creeping rhizomes, i.e. the phalanx strategy of Lovett Doust (1981). The third strategy which was evident from the ordination was related to Axis 3, which was aligned with the Fertility gradient. Communities which occurred at the top of this gradient, i.e. in areas with low fertility (as indicated by Ellenberg Fertility values) tended to have a higher frequency of sedge species.

Cluster 1

Cluster 1 contained Group 1 *PoaPlan* and Group 26 *Eleoacic*, and occurred towards the middle of the wetness gradient, and at the top of the fertility gradient on the ordination. These are two communities which have a high frequency of annual species. Group 1 *PoaPlan*, however, had a much greater cover of annual species than Group 26 *Eleoacic*. Group 1 *PoaPlan* also had a relatively large number of therophytes, while Group 26 *Eleoacic* had a similar number of therophytes, but also more perennial hydrophytes and a number of annual hydrophytes. Group 26 *Eleoacic*, however, had a large percentage cover of perennial hydrophytes. Both Group 1 *PoaPlan* and Group 26 *Eleoacic* had a relatively large number of species with no clonal growth.

Cluster 2

This cluster contained Group 2 *PersEleo*, Group 7 *EleoPhal*, Group 16 *EquiMeny*, G17 *CareRanu*, Group 18 *AgroGlyc* and Group 27 *CareEqui*, and occurred on the wetter end of the Wetness/Duration gradient on the ordination. Group 16 *EquiMeny*, G17 *CareRanu* and Group 27 *CareEqui* occur on the less fertile end of the Fertility gradient, and are associated with higher numbers of sedge species, while the other communities are associated with higher Ellenberg Fertility values. All of these communities had relatively high numbers of perennial hydrophyte species, and high percentage cover of perennial hydrophytes. Group 2 *PersEleo*, Group 16 *EquiMeny*, G17 *CareRanu* and Group 18 *AgroGlyc* all contained annual hydrophytes. Group 16 *EquiMeny* had the highest number of, and percentage cover of, non-bulbous geophytes. Group 2 *PersEleo*, Group 16 *EquiMeny*, G17 *CareRanu* and Group 18 *AgroGlyc* all had species with irregular fragmentation (Irreg), a clonal growth form associated with permanent water (Sosnová et al. 2011). All communities in this cluster also had relatively high numbers of and cover of rush species.

Cluster 3

Cluster 3 contained Group 3 *AgroRanu*, Group 4 *AgroPote*, Group 9 *PhalPote*, Group 13 *PoteCare*, Group 19 *PotePote* and Group 20 *FiliPote*. This cluster occurred in the centre of the ordination, with Group 4 *AgroPote*, Group 19 *PotePote* and Group 20 *FiliPote* occurring on the drier end of the Wetness/Duration gradient, and Group 9 *PhalPote* and Group 13 *PoteCare* occurring on the wetter end of the gradient. Group 3 *AgroRanu* occurred in the middle of this gradient. All communities in this cluster contained annual species, and Group 3 *AgroRanu* and Group 4 *AgroPote* also contained some biennials. Group 9 *PhalPote* and Group 13 *PoteCare* had higher numbers of and cover of perennial hydrophytes than the other communities in this cluster. Group 9 *PhalPote* and Group 13 *PoteCare* also had relatively high numbers of, and percentage cover of, clonal plants compared to other groups in this cluster.

Cluster 4

Cluster 4 contained Group 5 LimeGras, Group 21 *Schoenus* and Group 28 FldPavmt. Group 21 *Schoenus* and Group 28 FldPavmt occurred on the top of the Fertility gradient, indicating that these communities occur in areas with little nutrient availability. They were also associated with higher numbers of sedge species. Group 5 LimeGras occurred on the drier end of the Wetness/Duration gradient, and in the middle of the Fertility gradient, which suggests that this community occurs on slightly more fertile soil than the others in this cluster. All three communities contained annual species, and Group 5 LimeGras and Group 28 FldPavmt also contained biennials. All three communities also contained phanerophytes and nanophanerophytes; Group 21 *Schoenus* and Group 28 FldPavmt had the highest mean percentage covers of nanophanerophytes. All three communities had relatively low numbers of, and mean percentage cover of, clonal plant species. Group 21 *Schoenus* and Group 28 FldPavmt had the highest number of, and highest mean percentage cover of, shrub/tree species.

Cluster 5

Cluster 5 is comprised of Group 6 *EleoRanu*, Group 11 *PersMent*, Group 14 Reedbed and Group 24 *PotaGlyc*. This cluster was at the top of the wetness/duration gradient in the ordination, and contains the four vegetation types with the longest mean durations of inundation. Annual species were found in all of these communities except Group 14 Reedbed. These communities had the highest mean numbers of perennial hydrophytes, and Group 6 *EleoRanu*, Group 11 *PersMent* and Group 24 *PotaGlyc* also contained annual hydrophytes. Group 11 *PersMent*, Group 14 Reedbed and Group 24 *PotaGlyc* all contained species which fragment as part of their normal growth (Frag), while all four communities had species with irregular fragmentation (Irreg). Group 6 *EleoRanu* and Group 14 Reedbed both had relatively large number of rush species. These are all characteristics of plants in open or permanent water; e.g. Sosnová et al. (2011) found that plants which reproduce vegetatively through fragmentation were associated with open water.

Cluster 6

Cluster 6 contains Group 8 *CareCpan*, Group 12 *FiliVici* and Group 23 *CareScor*. Their positions on the ordination diagram suggest that Group 8 *CareCpan* and Group 23 *CareScor* are characterised by relatively high numbers of sedge species, and they occur in the middle of the Wetness/Duration gradient and towards the least fertile end of the Fertility gradient. Group 12 *FiliVici*, by contrast, occurs towards the middle of the Fertility gradient and is more towards the dry end of the Wetness/Duration gradient. Group 12 *FiliVici* contains annual, biennial and perennial species, Group 8 *CareCpan* contains biennial and perennial species, and Group 23 *CareScor* contains only perennial species.

Cluster 7

Group 10 *LoliTrif* and Group 15 *LoliAgro* make up Cluster 7, and both occur at the dry end of the Wetness/Duration gradient, and towards the most fertile end of the Fertility gradient. Both communities contain annual, biennial and perennial species. They both have high numbers of, and high percentage cover of, hemicryptophyte species, and both contain chamaephytes and non-bulbous geophytes. Both communities have relatively high numbers of, and mean percentage cover of, non clonal species. Both communities also contain species which form clones by suckering from the root. Both communities have high numbers of forb and grass species, and they also have very high percentage cover of these categories of growth forms.

Cluster 8

Cluster 8 contains Group 22 *MoliCare* and Group 25 *CareCvir*. Group 22 *MoliCare* occurs on the middle of the Wetness/Duration gradient on the ordination, and towards the least fertile end of the Fertility gradient. The position of Group 25 *CareCvir* on the ordination indicates that it occurs on slightly more fertile soil than Group 22 *MoliCare*, and experiences slightly less inundation. Both communities contain only perennial species. Both communities contain very high numbers of, and have very high mean percentage cover of, hemicryptophytes. Both communities contain high numbers of species with little or no clonal spread, and Group 25 *CareCvir* has relatively high numbers of tussock-forming graminoids, while both communities have very high mean percentage covers of tussock-forming graminoids.

These results increase our understanding of the strategies used by plant species in the turlough environment in order to tolerate the conditions in which they find themselves. The wettest communities (Cluster 5) have high frequencies of perennial and annual hydrophytes, and the most common form of clonal reproduction is through irregular fragmentation, as seen in open water communities elsewhere (Sosnová et al. 2011). Communities which experience a slightly shorter mean duration of inundation, and which may not have standing water throughout the year (Cluster 2) had slightly fewer annual hydrophytes than Cluster 5, but the cover of these species was almost the same in both clusters. Cluster 2 had fewer species which reproduce through irregular fragmentation (a characteristic of species of open water), and more species with the stoloniferous category of clonal growth. Moving further along the flooding gradient, Cluster 3 contains communities which straddle the transition zone between the more amphibious/aquatic communities discussed above, and the communities which occur in drier areas within turloughs. This cluster contains communities typical of the 'turlough sward', and had high numbers, and mean percentage cover, of clonal species. The driest communities were found in Cluster 4 and Cluster 7. Cluster 4 was associated with lower mean Ellenberg Fertility than Cluster 7, and had a higher number of sedge species and tussock-forming graminoids. Cluster 7 was characterised by high numbers of forbs and grasses, and species which were either not clonal, or with shortly creeping rhizomes. Cluster 6 and Cluster 8 were both associated with low mean Ellenberg Fertility values and high numbers of sedge species. Annual species were uncommon in these clusters, and were found in only one vegetation community (Group 12 *FiliVici*). Cluster 1 contained two communities which were characterised by high numbers of annual species; Group 1 *PoaPlan* had high number and cover of therophytes, while Group 26 *Eleoacic* had high number and cover of annual hydrophytes.

4.6 Conclusion

The main aims of this chapter were addressed:

1. Investigate the attributes of plant species comprising each vegetation community.

Groupings based on plant functional traits were used to represent different traits and attributes of plant species, and the mechanisms by which the species of turlough vegetation types tolerate stresses and disturbances were examined.

2. Examine the relationship between attributes of plant species and environmental conditions, in order to develop an understanding of the strategies adopted in order to tolerate the variations inherent in the turlough environment.

The attributes of the plant species in each community were examined, and analysed in conjunction with the environmental variables. Communities associated with longer flooding had higher numbers of perennial and annual hydrophytes, and were often found to contain species which reproduce vegetatively through irregular fragmentation. Communities in the middle of the Wetness/Duration and Fertility gradients contained high numbers of amphibious species and species with clonal growth forms. Those communities which were associated with low nutrient availability and intermediate durations of flooding were characterised by high numbers of sedge and tussock-forming graminoid species, and relatively low numbers of species with clonal growth forms. Communities which experienced least flooding and were in areas of intermediate to high fertility generally had high numbers and cover of forbs and grasses, and low numbers of clonal species, except for shortly creeping rhizomatous species. Communities which occurred on the middle of the flooding gradient and in areas of high nutrient availability were characterised by high numbers of annual plants; the proportion of these plants that were therophytes or annual hydrophytes was dependent on duration of flooding.

5 Discussion

One of the principal aims of this study was to contribute to an improved understanding of turlough vegetation communities. This was achieved through extensive field surveys of the vegetation of 22 turloughs which led to the identification, classification and description of 28 vegetation communities.

The second main aim of this thesis was to investigate the relationships between turlough vegetation communities and the environmental and management conditions which shape them. This was achieved by exploring the environmental variables associated with each vegetation community, and determining which of these variables had the greatest effect on turlough vegetation through a suite of multivariate analyses.

The final aim of this study was to elucidate the strategies utilised by plant species to tolerate the environmental conditions with which they are faced in the turlough environment. This was achieved by assigning plant species to different plant functional traits and analysing these in conjunction with the previously identified important environmental variables in order to develop a greater understanding of the morphological adaptations of turlough plants and plant communities to their habitat.

In this chapter I will summarise the findings of the research, and draw some general conclusions about turlough plant communities and their ecology. I will discuss the limitations of the research, as well as the practical implications and wider relevance of the findings for turlough conservation. I will also outline some of the areas most in need of further research.

5.1 Summary and synthesis

5.1.1 The vegetation communities of turloughs

In Chapter 2, 28 vegetation communities were classified and described, from 22 turloughs. The classification method used was hierarchical, polythetic, agglomerative cluster analysis. The vegetation types identified ranged from the fully aquatic to mostly terrestrial, with a range of intermediate vegetation types in between. There was a degree of overlap between the species composition of many of the plant communities; few species were faithful to a single plant community. This is characteristic of plant communities aligned along environmental gradients, as the responses of individual species to environmental conditions vary.

The communities found fell within the phytosociological classes of the Molinio-Arrhenatheretea, the Scheuchzerio-Caricetea fuscae, the Phragmitetea, the Potametea, the Littorelletea uniflora and the Polygono-Poetea annuae, and the Ranunculo-Potentilletum anserinae association. The communities classified were related to those communities previously described in the literature.

The 'typical turlough sward' - the small sedge communities of the Scheuchzerio-Caricetea fuscae and the Ranunculo-Potentilletum anserinae were well-represented here. The *Carex nigra-Carex panicea* community (Group 8), the *Schoenus nigricans* fen (Group 21), the *Molinia caerulea-Carex panicea* community (Group 22) and the *Carex nigra-Carex viridula* community all belong to the Scheuchzerio-Caricetea fuscae. The Ranunculo-Potentilletum anserinae was represented by the *Phalaris arundinacea-Potentilla anserina* community (Group 9), the *Potentilla anserina-Carex nigra* community (Group 13), the *Carex nigra-Ranunculus flammula* community (Group 17), the *Potentilla anserina-Potentilla reptans* community (Group 19), the *Filipendula ulmaria-Potentilla erecta-Viola* sp. community (Group 20) and the *Carex nigra-Scorzoneroides autumnalis* community (Group 23). The remainder of the plant communities either belonged to classes which were similar to those found just outside the turlough boundary, such as the Molinio-Arrhenatheretea, or to classes such as the Phragmitetea or Potametea which contain communities which require permanent water throughout the year.

Previous studies

Turloughs are extremely variable habitats; the heterogeneity of soil types even within a single turlough basin can mean that one turlough can support a wide variety of plant communities. Management and stocking densities can differ hugely between one land parcel and another, while hydrological regime and water quality can vary among catchments, and even among turloughs within the same catchment. This amount of variation, both between and within turloughs, means that each turlough is unique in terms of its ecology. All of this means that it is difficult to categorise turloughs or turlough vegetation, although a number of attempts have been made in the past.

When comparing the turlough plant communities identified here with those previously reported in the literature, there were some discrepancies. One of the reasons for this is that other studies on turlough vegetation have concentrated on different numbers of turloughs, and on turloughs in different geographical regions. Ivimey-Cook and Proctor (1966), for example, studied some turloughs in the Burren, but their survey was part of a larger vegetation survey which did not focus on turlough vegetation. O'Connell et al. (1984) also examined turloughs in the Burren, and focused on the typical 'turlough sward' vegetation communities. Goodwillie (1992) conducted the largest-scale survey of turlough vegetation, describing 32 plant communities in 60 turloughs, but this was based on a qualitative assessment rather than using relevés. He also described 23 plant communities in a later publication (Goodwillie 2003) from one catchment area. Regan et al. (2007) surveyed 30 turloughs, but took just three relevés in each, from the top, middle and bottom of the flooding gradient, so that it is unlikely that this study is representative of the full range of turlough vegetation. Moran et al (2008b) made a detailed study of the vegetation types of a single turlough, which, though extremely valuable due to its level of detail, may not be representative of turlough vegetation as a whole. This current study is unique both in the number of turloughs studied (22) and the number of relevés recorded (813).

Turlough communities of high conservation value

Some of the communities described in this study do not seem to occur outside of the turlough environment, at least in Ireland, and others have been identified as communities in which rare species occur (Table 5.1).

These communities are therefore of high conservation value, and efforts should be made to preserve the structure and function of the turloughs in which they occur.

Table 5.1 Turlough vegetation communities of high conservation value.

Group	Community
20	*Filipendula ulmaria-Potentilla erecta-Viola* sp. community
23	*Carex nigra-Scorzoneroides autumnalis* community
25	*Carex nigra-Carex viridula* community
26	*Eleocharis acicularis* community
28	Flooded Pavement

Group 20, the *Filipendula ulmaria-Potentilla erecta-Viola* sp. community, is a herb-rich, heavily grazed, open sward community, which often contains *Viola palustris* a Red Data Book species (Curtis and McGough 1988). Another proposed Red Data List species, *Teucrium scordium*, occurs within Group 23, the *Carex nigra-Scorzoneroides autumnalis* community. Group 26, the *Eleocharis acicularis* community has been recorded in a number of turloughs, and two Red Data Book species occur in this vegetation type; *Rorippa islandica* and *Limosella aquatica.* Group 28, the Flooded Pavement community, contains *Potentilla fruticosa*, a species whose range within Ireland is largely restricted to the fringes of some turloughs (Elkington and Woodell 1963, Webb and Scannell 1983). Group 25, the *Carex nigra-Carex viridula* community does not contain any rare species, but was not readily comparable with any of the vegetation communities recorded in the NVC. It was similar, however, to small sedge communities described in previous work on turlough vegetation, and it may therefore have a range restricted to turloughs.

5.1.2 Drivers of turlough plant community composition

Chapter 3 demonstrated that a wide range of soil types, soil chemistry, water chemistry, hydrology and management are associated with the vegetation communities of turloughs. The environmental variables associated with each vegetation type were examined and summarised. Some environmental variables showed a strong relationship to certain communities, while for others there was no discernible relationship.

The strongest drivers of turlough vegetation were identified. Of the hydrological variables, duration of flooding was a more important factor than any other; it was identified as the most important variable by Non-Metric Multidimensional Scaling (NMS) and Discriminant Analysis, and featured in each of the top ten combinations of variables identified by BIO-ENV. The timing of the recession of floodwaters was also found to be important in the NMS and BIO-ENV analyses. Discriminant Analysis also identified maximum depth of flooding as an important variable. Water total phosphorus concentration was shown to be one of the variables with the strongest association with turlough vegetation communities, and was identified by NMS, Discriminant Analysis and BIO-ENV as an important factor affecting turlough vegetation communities. Additionally, WaterTN was identified by BIO-ENV as an important variable.

Soil nutrient status did not show a strong relationship with vegetation type, but BIO-ENV identified soil type as an important explanatory variable – some vegetation types were recorded on only one soil type. Land use was also identified as influential by BIO-ENV; i.e. whether a land-parcel was grazed or not was important.

These findings were similar to those from other studies on turloughs. Date of emptying of the turlough (corresponding to DryDate in this study) and water phosphorus and nitrogen were identified as among the most important drivers of turlough vegetation by Regan et al. (2007). Moran et al. (2008b) found that hydrological regime and grazing were the main factors affecting the vegetation communities of turloughs, while Ní Bhriain et al. (2003) also found that grazing was an important factor affecting the composition of vegetation communities.

5.1.3 Plant functional traits in turlough plant communities

In Chapter 4, plant species were assigned to different functional groupings in four different categories; perennation, life form, clonality and growth form. Biennial species were only associated with those communities which occur at the top of the flooding gradient. There was a general trend for increased number of annual species as the duration of flooding increased. Hemicryptophytes were the most common life form in this study. There was a marked decrease in the number and cover of hemicryptophyte species as the mean duration of inundation increased, with a concomitant increase in the number and cover of perennial hydrophyte species. Likewise, the number and cover of species with little or no clonal growth decreased as mean duration of inundation increased. Rhizomatous species were the most common of those with clonal growth, and the number and cover of species in this category increased with increased duration of inundation. The number and cover of grass and forb species decreased, in general, with increasing duration of inundation, but this trend was not as clear as those seen in the other functional groupings.

These results are important in a turlough conservation context. A number of the rare plant species found in turloughs are annuals (e.g. *Rorippa islandica* and *Limosella aquatica*), and occur towards the bottom of the turlough basin, i.e. they are associated with long mean durations of inundation. An increased understanding of the needs of these species and their susceptibility to change will aid efforts to conserve them.

5.2 Relevance, implications and practical applications of the research

5.2.1 Methodological limitations and considerations

A number of methods were employed in this study to investigate the vegetation communities of turloughs, and the environmental and management conditions which affect them. To allow evaluation of the relevance of the research, the limitations of the methodological approaches are outlined here.

The primary aim of this research was to classify and describe the vegetation communities of 22 turloughs. During the field survey portion of the research, species abundance was estimated and recorded using the Domin scale. While this is a common approach in vegetation recording, and allows for the relatively quick assignation of plant species cover/abundance to the appropriate category, it does limit the statistical analyses which can be carried out on the data. In this study, Domin scores were converted to percentages for some of the analyses using the transformation recommended by Currall (1987). Recording species cover/abundance using a percentage scale would have circumvented the need to do this.

Due to the scale and time-consuming nature of the vegetation recording, it was not possible to take soil samples for nutrient analysis from each relevé. Instead, mean soil nutrient information was calculated for each turlough. Had soil samples been taken at each relevé, however, analyses relating vegetation types to soil conditions would have been more accurate and, perhaps, more informative. Soil types and nutrients are very heterogeneous in turloughs, and so the use of a single soil nutrient value for each turlough has hampered the understanding of the relationships between soil nutrient status and turlough vegetation types.

Water chemistry data were also based on a single mean value for each turlough, based on one field season only. This did not take into account any inter-annual variation that might be present in the nutrient status of turlough flood waters.

Non-normal data can be a problem in ecological research, and this study was no exception. Information on soil nutrient status and turlough floodwater nutrient status were both based on single values for each turlough. This meant that the data were not continuous, and were not normally distributed, which limited the statistical approaches which could be adopted.

The impacts of grazing on turlough vegetation were difficult to quantify. Information on stocking density was difficult to acquire; livestock units per hectare were obtained for only some of the land-parcels. As a result, land-parcels were designated 'grazed' or 'not grazed', and while this was found to be an important driver of turlough vegetation, more detailed information on stocking density would enable a more in-depth investigation of the effects of grazing on turlough vegetation.

Justification of methods used

Non-metric Multidimensional Scaling, which is a type of indirect gradient analysis, was used extensively throughout this study. It was chosen over other ordination methods as it is a robust ordination technique which is particularly appropriate for extracting patterns (which are often non-linear) from non-normal and zero-heavy ecology and community data (McCune and Grace 2002, Perrin et al. 2006)

Discriminant Analysis was employed to give an overview of the important factors affecting turlough vegetation communities, but given the non-normal distribution of soil nutrient and water nutrient data, care must be taken when interpreting these results.

BIO-ENV is a procedure which searches for the best match between the multivariate among-sample patterns of a species matrix and the environmental variables associated with the samples (Clarke and Gorley 2006). It is a method that is widely used to find drivers of community composition in marine research, but has also been used in plant ecology research (e.g. Gioria et al. 2010). One clear advantage of this method is that it gives multiple answers in the form of a list of drivers, and these can be interpreted with some flexibility by ecologists.

5.2.2 Implications and practical applications

The classification and description of turlough vegetation communities presented here provides the first semi-quantitative survey of turlough vegetation from a wide range of turloughs. The large number of relevés recorded as part of this study lend great weight to the findings, and allow confidence in the results. Vegetation communities were recorded in turloughs with a wide range of geomorphology, hydrological regime and management, and provide important baseline information for turlough conservation and monitoring.

Since the baseline vegetation survey, the vegetation in the 22 turloughs in this study has been mapped using the vegetation communities defined herein. This provides invaluable information on the current status of these turloughs, and can be used to monitor any changes in their vegetation.

Conservation

Turloughs are often managed as commonages, which can complicate issues associated with grazing pastures. Presence or absence of grazers, as well as grazing intensity, have been shown to have a large effect on turlough vegetation, both in this study and in other work (e.g. Ní Bhriain et al. 2003). In order to maintain the full variety of turlough vegetation communities, a range of grazing intensities is required.

In many cases, the presence of buffer zones is required between grazing animals and watercourses/waterbodies. In the turlough environment, this is very difficult to implement, as the water level changes regularly. While introducing grazers to waterlogged fields will have a deleterious effect on soil structure and vegetation communities, it is likely that some communities require the disturbance produced by grazing animals to survive. The *Eleocharis acicularis* community, for example, occurs on wet silty mud near permanent water, usually in turloughs with a relatively high level of grazing. Poaching by animals coming to drink at the water may be necessary to prevent encroachment by other vegetation types.

For some of the Red Data List species, for example *Teucrium scordium*, persistence may be encouraged by limiting grazing until after the plant has flowered and set seed. *Viola persicifolia*, on the other hand, seems to flourish in areas with a relatively high level of grazing; the growth form is favoured by grazing.

Use of derived variables as bioindicators of turlough ecological conditions

The mean Ellenberg indicator value for Wetness was strongly correlated with the mean duration of inundation ($r^2 = 0.661, p \leq 0.001$). This suggests that calculating the Ellenberg indicator values for a relevé or community may be a useful proxy for duration of inundation in the absence of detailed hydrological data, but would need further research before it could be used.

5.3 Future research

Turloughs are very complex systems, and the findings of this research present a number of opportunities for further study.

Bryophyte diversity in turloughs

Bryophyte abundance was recorded in this study, but due to time constraints individual species were not identified. An understanding of the contribution of bryophytes to turlough biodiversity would be valuable; targeted bryophyte surveys in vegetation types defined in this study would enhance the knowledge of the function of turlough vegetation communities.

The relationship between soil nutrient status and turlough vegetation communities

Targeted soil surveys in vegetation types defined in this study would also increase understanding of the relationship between soil nutrients and vegetation type. As outlined above, this study used single values per turlough, due to time and resource constraints. The value of having additional detailed soil data is obvious.

The effects of grazing on turlough vegetation communities

As noted above (Section 5.2.1), the detail pertaining to the grazing regimes on turloughs was, in many cases, not picked up using the methodology employed in this survey. One possible remedy would be permanent exclosures. These could be used to examine the effect of grazing on turlough vegetation and provide valuable and detailed experimental data.

Tracking changes in the boundaries of turlough vegetation communities

Long-term monitoring of permanent transects and the hydrological regime (in a range of catchments, and with differing soil types and management) would greatly help to further elucidate the relationship between hydroperiod and vegetation. Additionally, this information may help to identify the lag period, if any, of the vegetation in responding to inter-annual changes in flooding pattern.

5.4 Concluding remarks

Turloughs are of high conservation value, not just because of the rare plants that can be found in them, but also because of the unusual combinations of species in turlough plant communities and their various adaptations to the highly unusual hydrological regimes. This research has made a valuable contribution to the understanding of turlough vegetation communities, generating detailed baseline data on which future monitoring programmes can be based. It used the huge amount of data generated to define the most important drivers of the vegetation of turloughs, which will aid in the formation of guidelines for their protection and conservation.

Conclusions:

- 28 plant communities from 22 turloughs were identified, classified and described.
- Plant communities of high conservation value were identified.
- The main hydrological driver of turlough vegetation was identified as duration of flooding.
- The timing of the recession of floodwaters, frequency of flooding and the maximum depth of flooding were identified as other important hydrological factors affecting turlough vegetation.
- Nutrient status is an important driver of turlough vegetation; phosphorus seems to be the limiting nutrient, rather than nitrogen.
- Grazing was identified as an important factor affecting plant community composition.
- Ellenberg indicator values for Wetness are correlated with duration of flooding, and thus may be used as an indicator of flooding regime in the absence of hydrological data.

Recommendations:

- Maintenance of the existing/'natural' hydrological regime is essential for turlough vegetation communities.
- Grazing is an important factor affecting turlough vegetation communities, and is essential for some communities. Care must be taken, however, with timing and stocking densities.
- Additional studies should be set up, especially to examine in detail the relationship between turlough vegetation communities and soil nutrient status, and to examine the effects of grazing at different stocking densities on turlough plant communities occurring on similar substrates which experience similar hydrological conditions.

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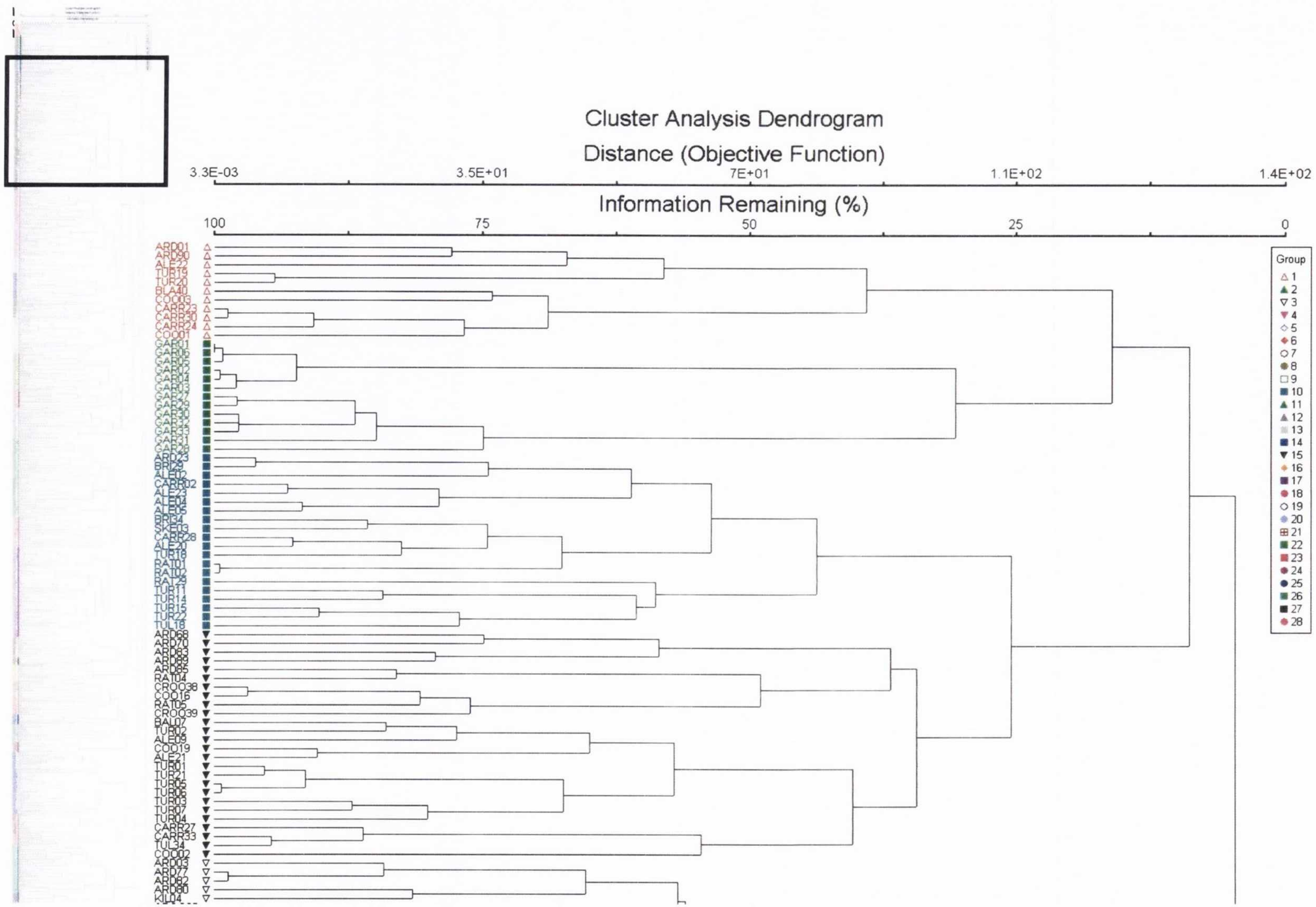
APPENDIX I

Cluster dendrogram showing the 28 vegetation communities identified in Chapter 2.



Cluster Analysis Dendrogram
Distance (Objective Function)
3.3E-03
3.5E+01
7E+01
1.1E+02
1.4E+02
Information Remaining (%)
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75
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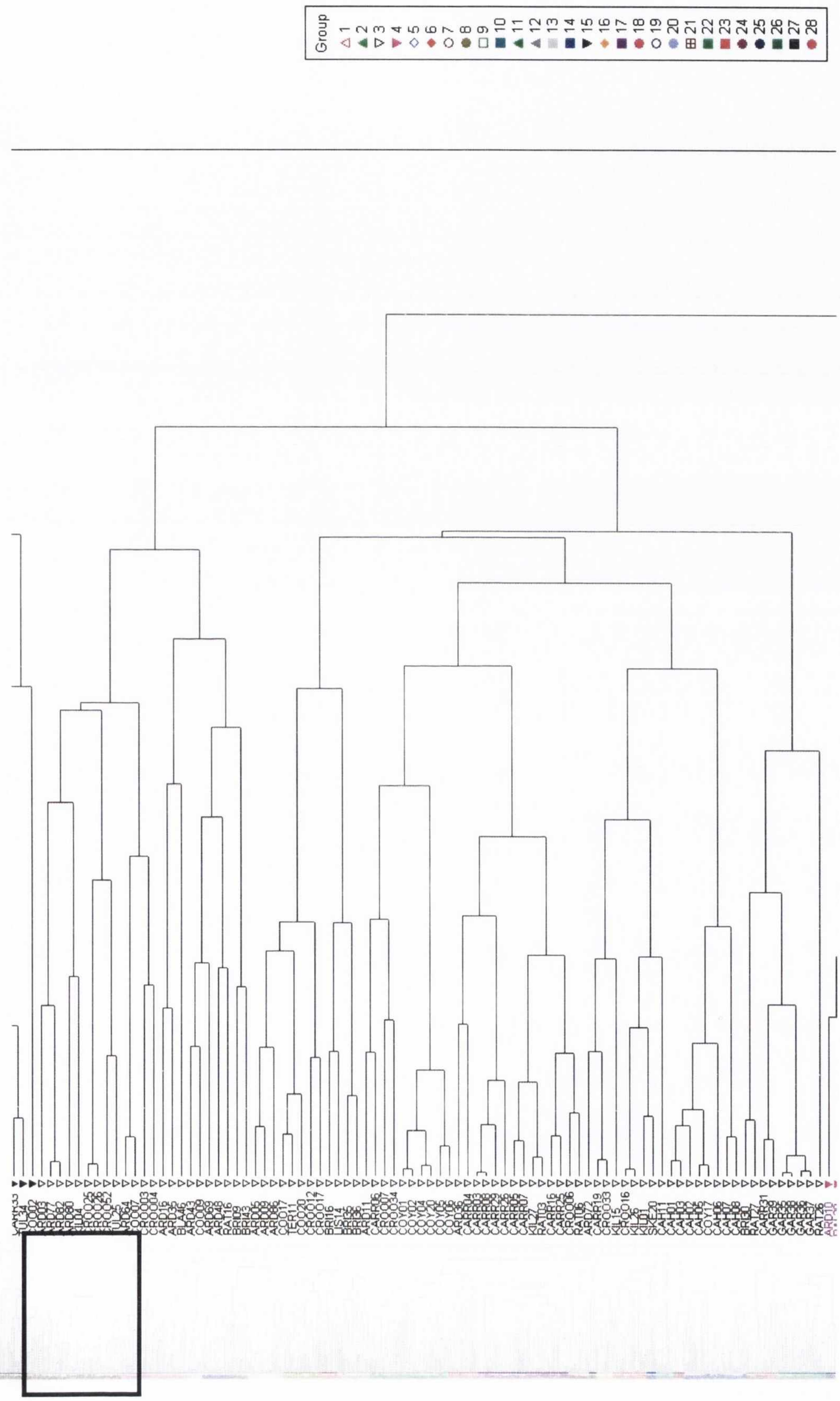
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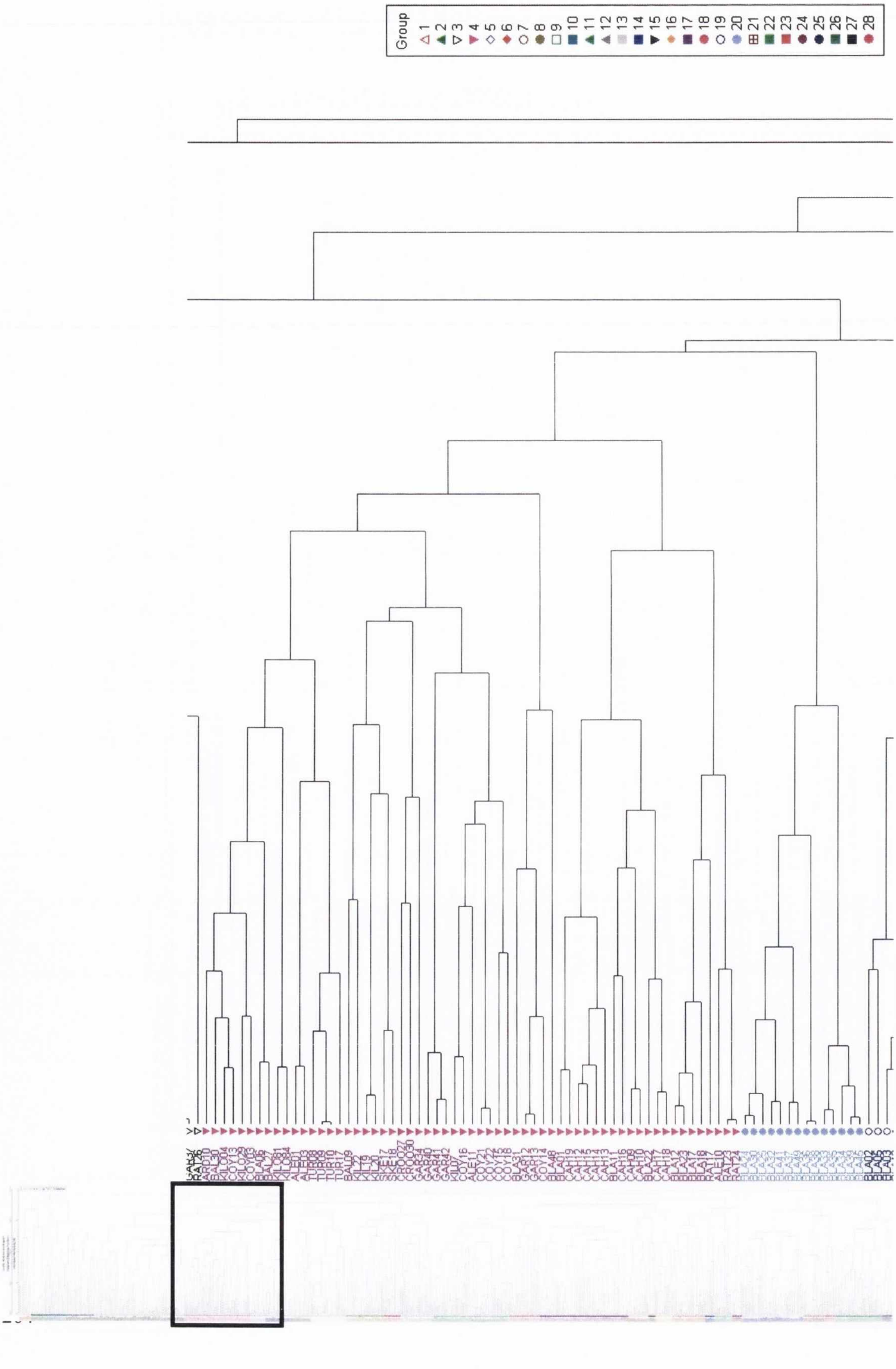
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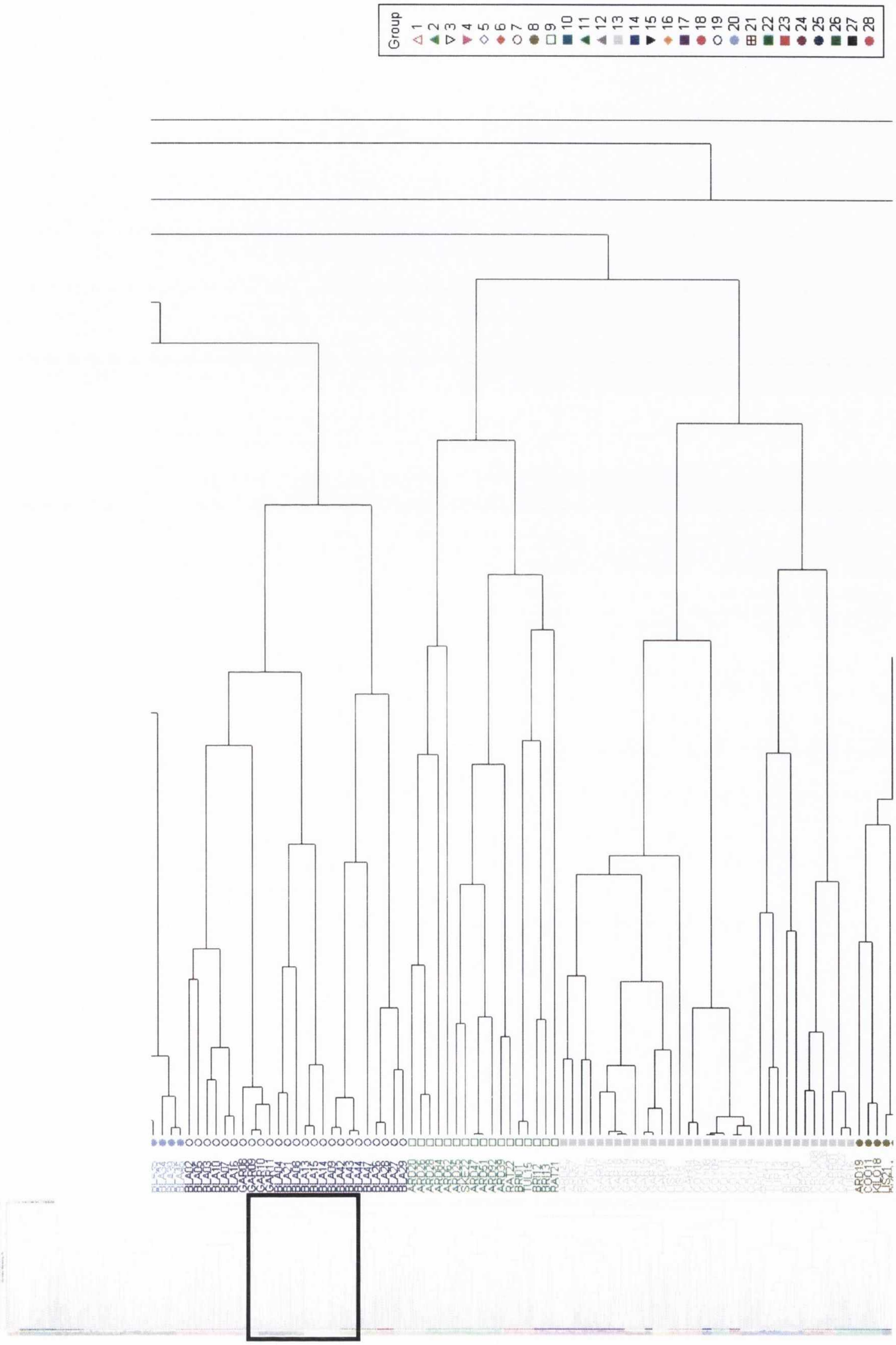
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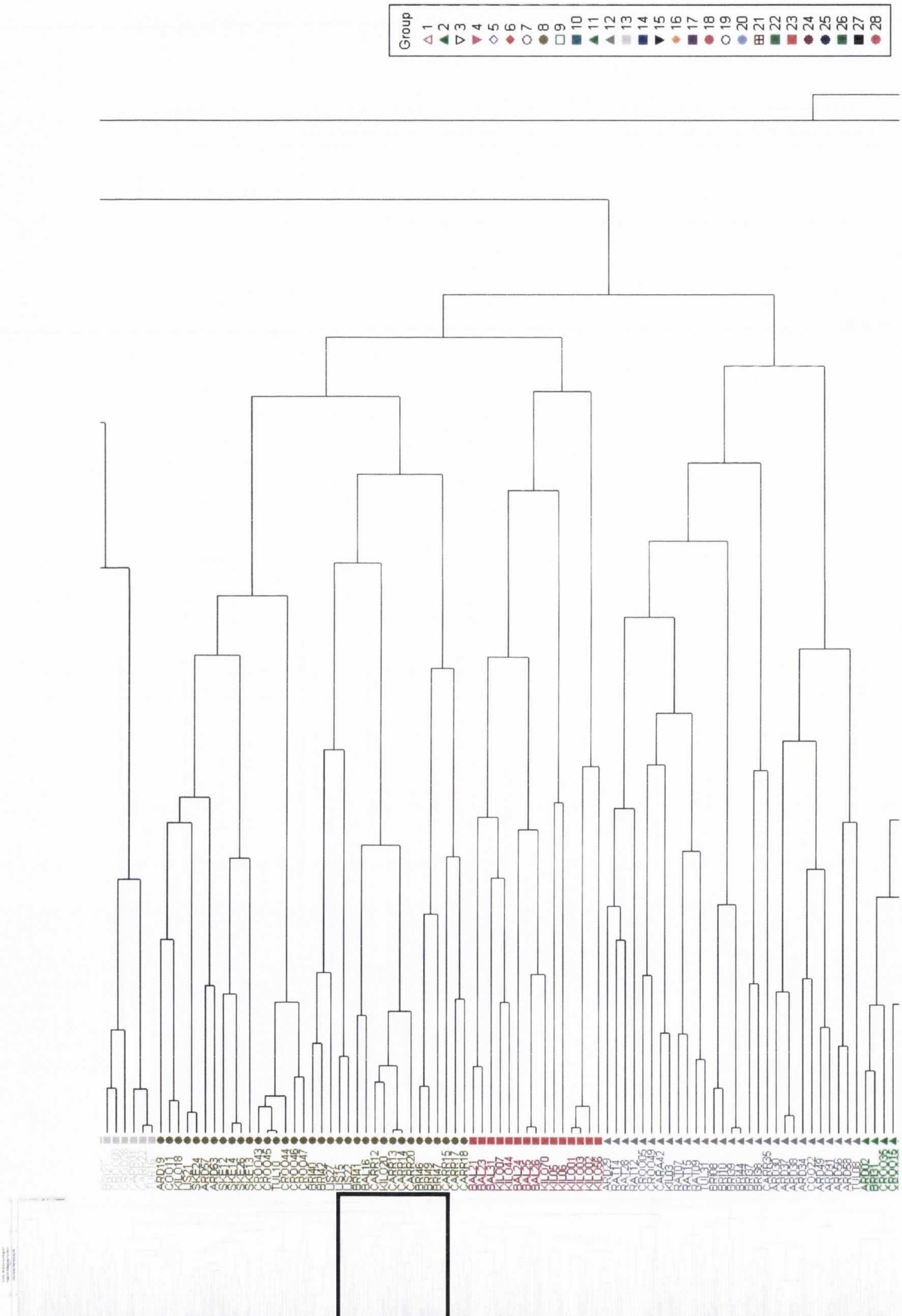
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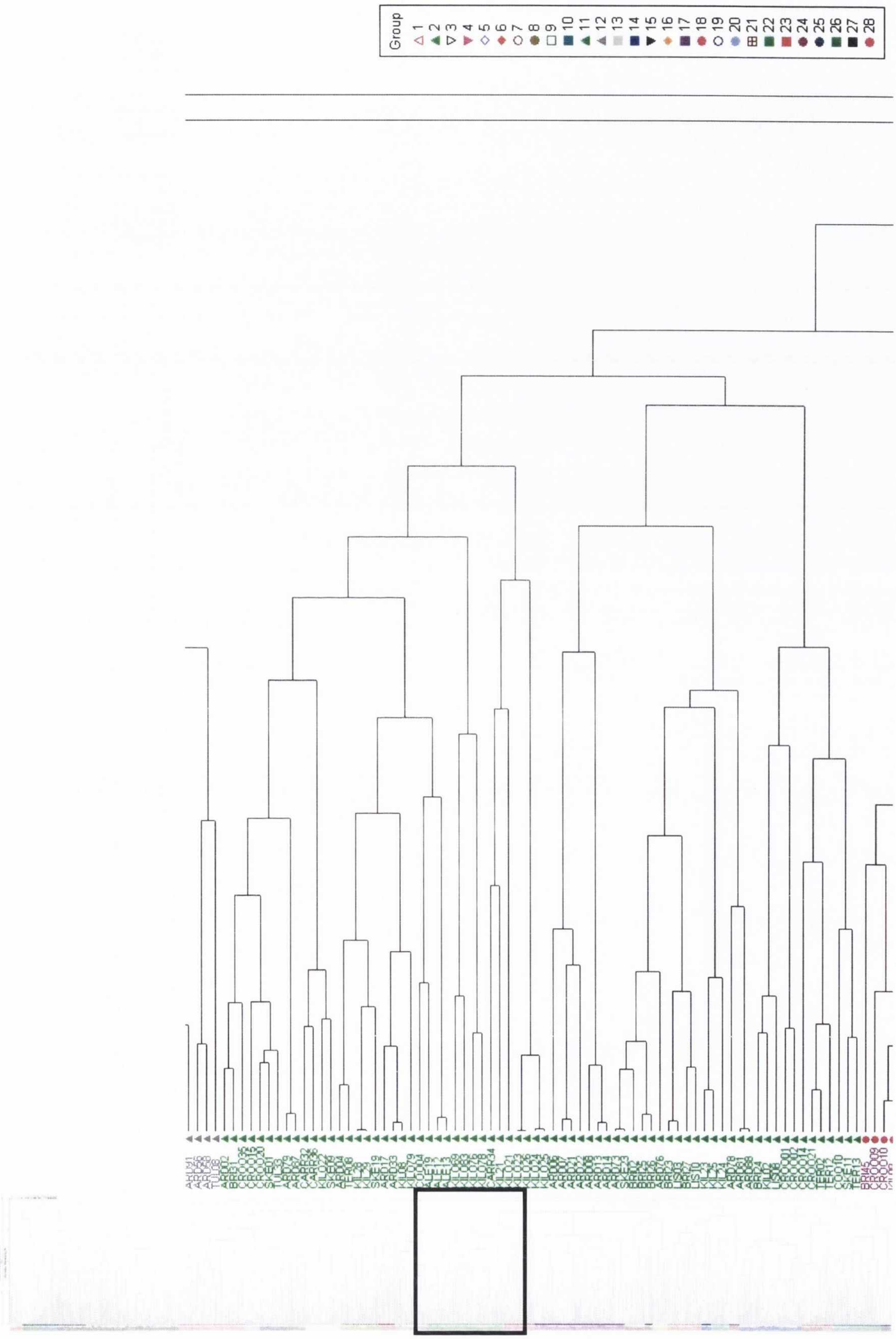
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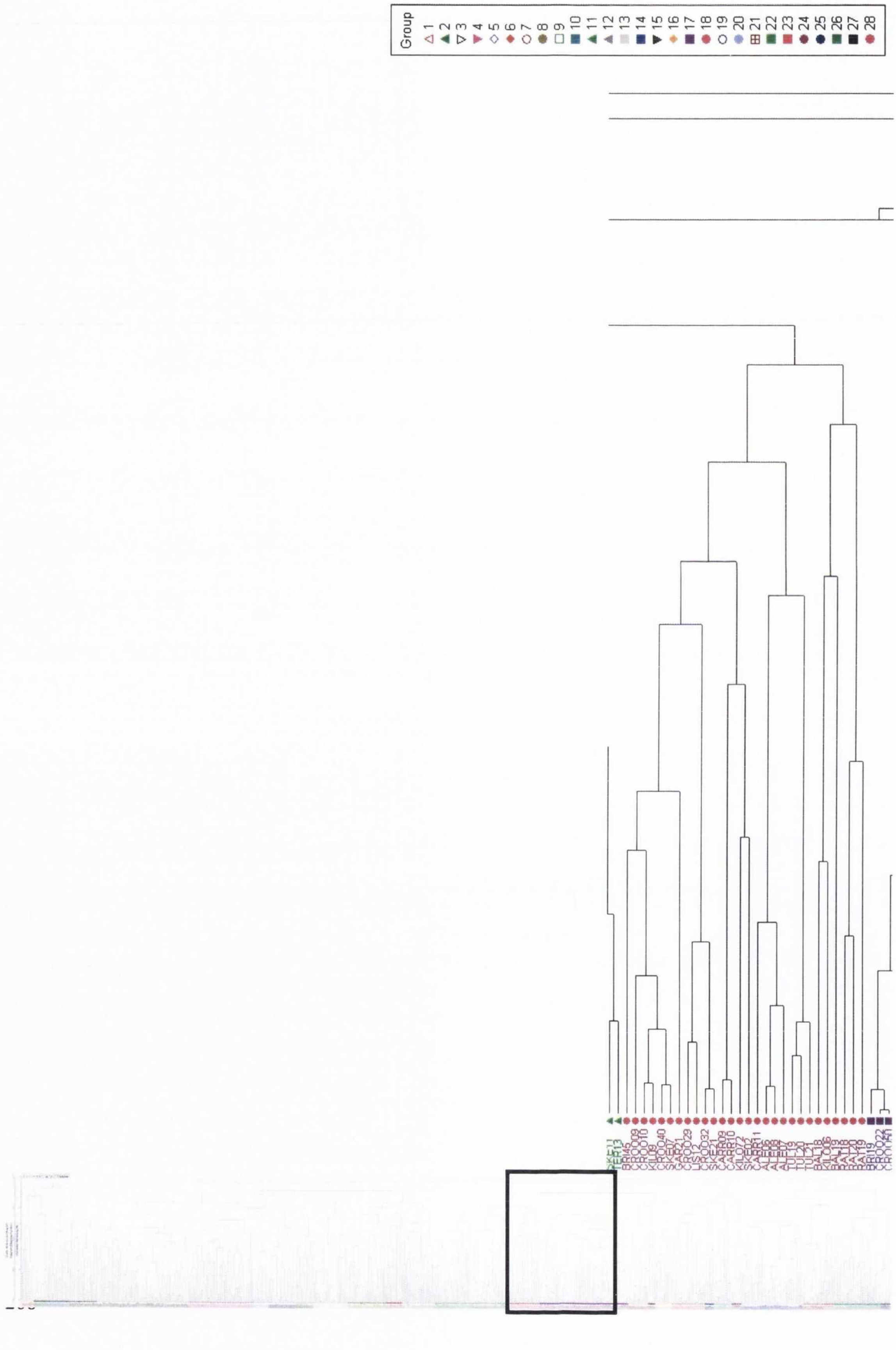
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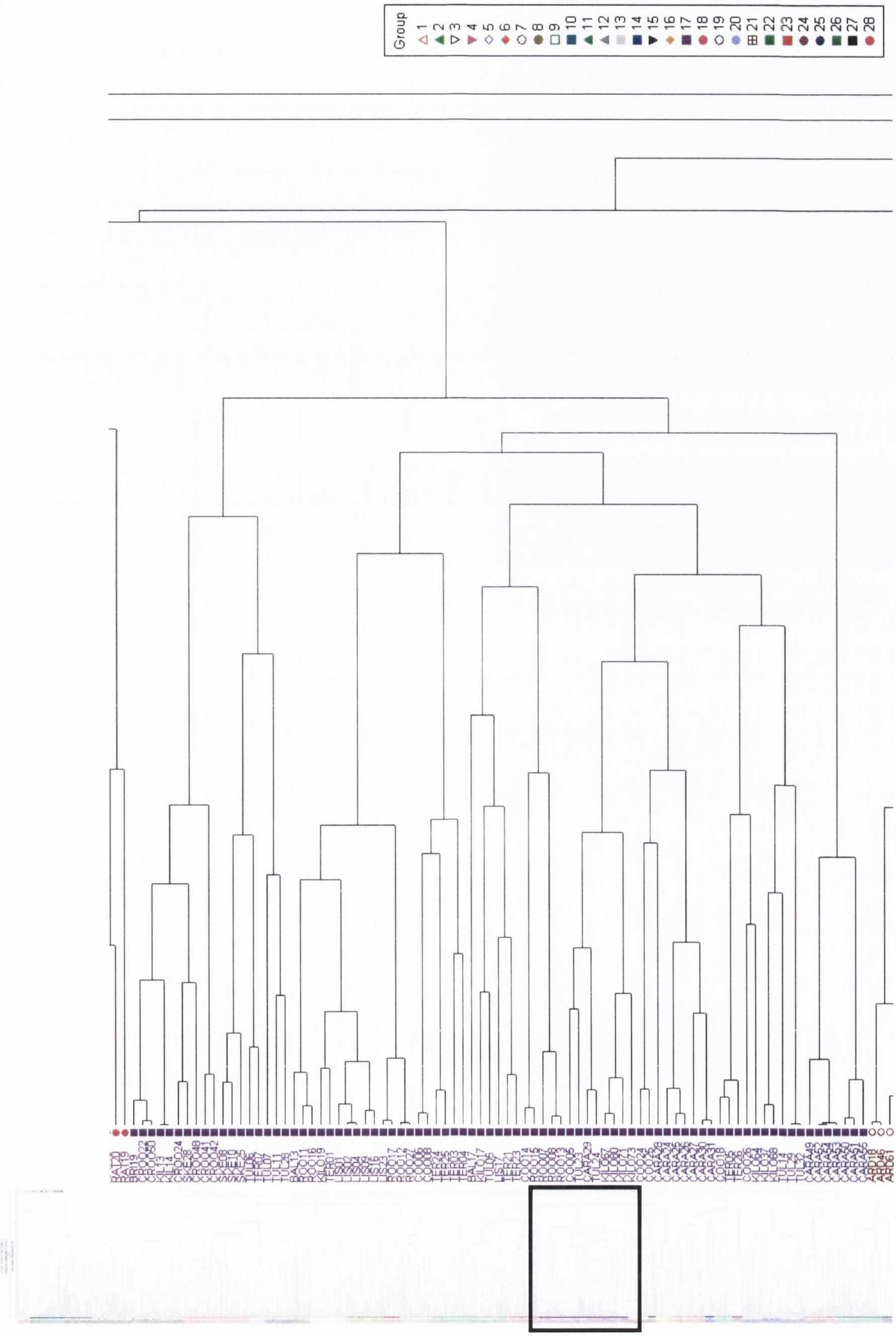
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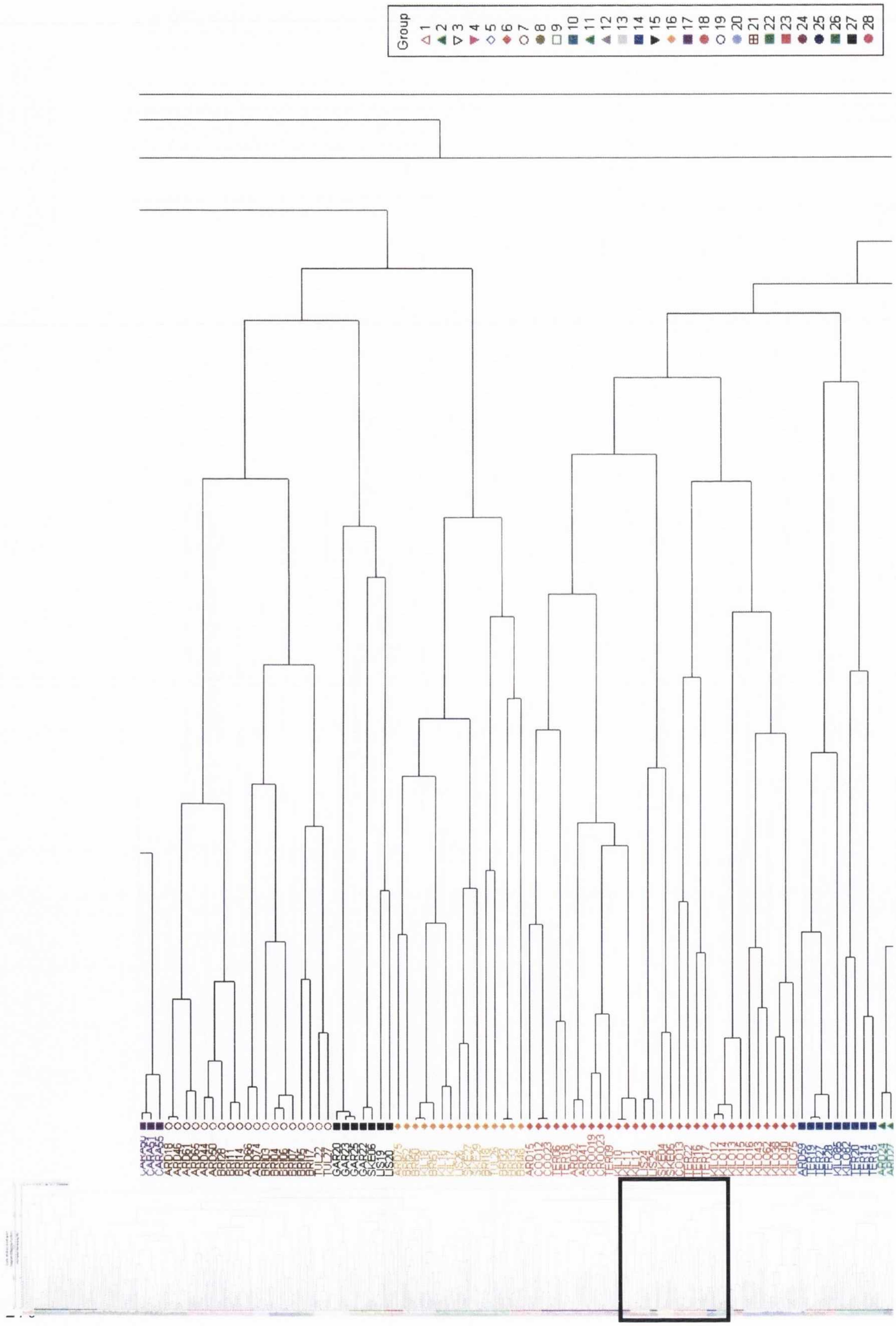
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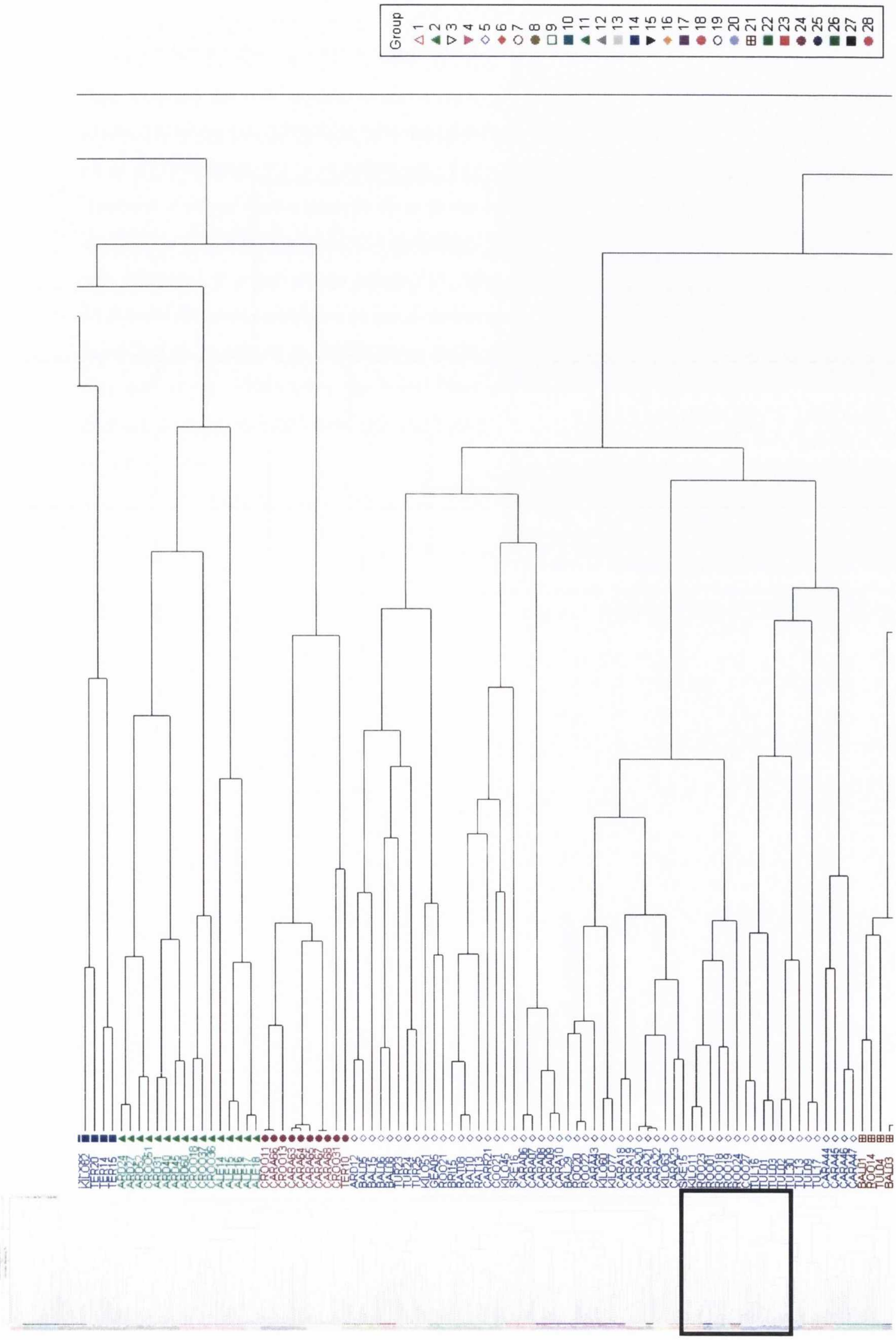
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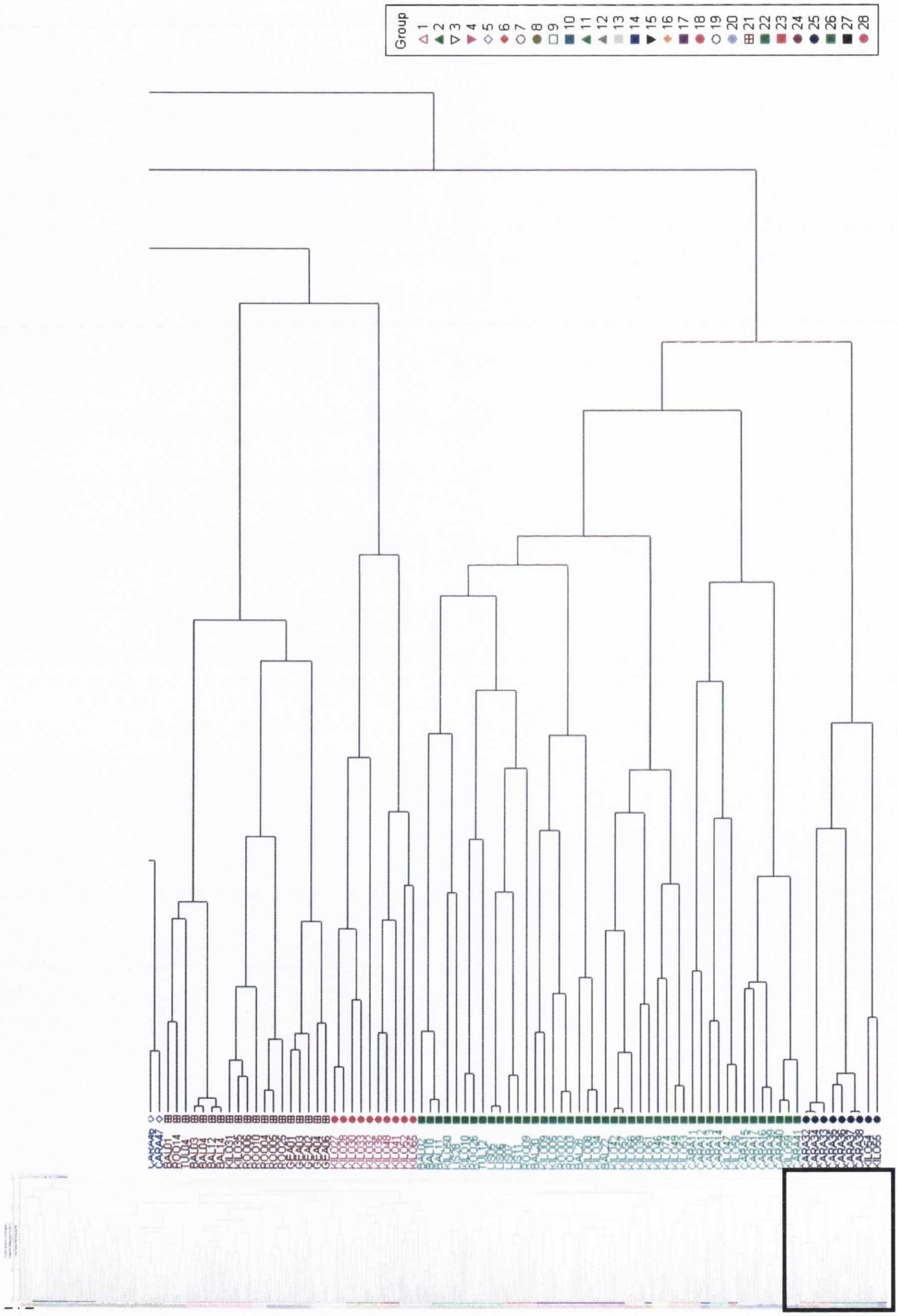
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APPENDIX II

Soil chemistry methodology

Soil nutrient information was determined for each turlough. Six soil samples were taken from each turlough, two each from the upper, middle and lower elevation zones, to a maximum depth of 20cm. Vegetation communities (as defined by Goodwillie (1992)) were used to determine the sampling zones. Samples were then analysed for pH, organic matter content (OM), calcium carbonate content ($CaCO_3$), non-calcareous sand/silt/clay fraction (INORG), total nitrogen (TN) and total phosphorus (TP). Estimations of pH were made on an approximately 1:2 (v:v) suspension of moist soil and double-distilled water (DDW) (Allen, 1989) using a Jenway 3030 calomel electrode. Prior to remaining analyses, samples were air-dried and passed through a 2mm sieve. OM was measured as a percentage weight loss following ignition at 550°C (Allen, 1989). $CaCO_3$ was estimated as a percentage weight loss following loss on ignition by further ignition at 1000°C (Dean, 1974). INORG was calculated as the initial sample weight less OM and $CaCO_3$ fractions. TN was measured according to Verado et al. (1990) using an ELEMENTAR analyser. TP was measured by nitric acid (69%) digestion (Kuo, 1996) using an MDS 2000 microwave digestor followed by ICP (inductively-coupled plasma) analysis. Reference soil material was included during the TP digestion procedure which indicated an 85% P recovery.