NPWS

Ballynamona Bog and Corkip Lough SAC

(site code 2339)

Conservation objectives supporting document-
Turloughs

Version 1

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Contents

1. Introduction

1.1 Turloughs

"Turloughs" (habitat code 3180) is a priority habitat in Annex I of the Habitats Directive. A turlough is a topographic depression in karst which is intermittently inundated on an annual basis, mainly from groundwater, and which has a substrate and/or ecological communities characteristic of wetlands (Working Group on Groundwater, 2005; Tynan *et al.*, 2007). Turloughs are semi-natural habitats that are virtually unique to Ireland. They generally flood in winter and dry out in summer, but there may be other sporadic rises in response to high rainfall. Turloughs are considered to be of high conservation value for their plant, invertebrate (both terrestrial and aquatic) and bird communities (Goodwillie, 1992, 2003; NPWS, 2007, 2008; Sheehy Skeffington, 2006). They are grass- or sedge-dominated habitats, often with areas of fen, marsh or permanent pond. Many turloughs show a distinctive zonation of herbaceous perennials which relates to the depth and duration of flooding. Turloughs intergrade into many other wetland types, from marl lakes and ponds to swamp, to fen and even to coastal lagoons and marine habitats.

The interpretation manual of EU habitats gives the following description: *"Temporary lakes principally filled by subterranean waters and particular to karstic limestone areas. Most flood in the autumn and then dry up between April and July. However, some may flood at any time of the year after heavy rainfall and dry out again in a few days; others, close to the sea, may be affected by the tide in summer. These lakes fill and empty at particular places. The soils are quite variable, including limestone bedrock, marls, peat, clay and humus, while aquatic conditions range from ultra oligotrophic to eutrophic. The vegetation mainly belongs to the alliance Lolio-Potentillion anserinae Tx. 1947, but also to the Caricion davallianae Klika 1934."* (CEC, 2013).

In Ireland, turloughs are considered to be in poor/inadequate conservation status as a result of nutrient enrichment, inappropriate grazing and drainage pressures (NPWS, 2007, 2008, 2013).

1.2 Ballynamona Bog and Corkip Lough SAC

Ballynamona Bog and Corkip Lough SAC is situated in Co. Roscommon approximately 9 km west of Athlone. The site comprises a raised bog and the turlough, Corkip Lough. It is selected for five habitats listed on Annex I of the EU Habitats Directive, three of which are priority habitats (turloughs*, active raised bogs* and bog woodland*).

Corkip Lough is in the north-west of the SAC. There are limited data available on the turlough, which is considered important owing to its hydrological linkage to the raised bog and the presence of interesting plant and invertebrate species.

1.3 Conservation objectives

A site-specific conservation objective aims to define the favourable conservation condition of a habitat or species at site level. The maintenance of habitats and species within sites at favourable condition will contribute to the maintenance of favourable conservation status of those habitats and species at a national level.

Conservation objectives are defined using attributes and targets that are based on parameters as set out in the Habitats Directive for defining favourable status, namely area, range, and structure and functions.

Grazing is integral to the ecology of turloughs and it is important that appropriate grazing levels are maintained. Over-grazing and, in particular, under-grazing are considered significant threats to turlough conservation status. Turlough diversity will benefit from within-site spatial variations in grazing regime. Both the timing (post flood-recession) and intensity of grazing are important. Various attributes set out below and various authors (e.g. Goodwillie, 1992, 2003; Bond, 1997; Ní Bhriain *et al*., 2002; Moran, 2005; Regan, 2005; Ryder *et al*., 2005; Sheehy Skeffington *et al*., 2006; Moran *et al*., 2008; Kimberley *et al*., 2012) provide further information on the importance of grazing.

Attributes and targets may change/become more refined as further information becomes available.

2. Area

The full extent of flooding and wetland vegetation within Corkip Lough turlough is currently unknown. Jim Ryan (pers. comm.) estimated the area of Corkip Lough as approx. 60 ha. He also advised that the turlough was affected by drainage in the 1860s. Duigan (1988) estimated the area as 77 ha. The location of the turlough is indicated in the conservation objective map with a point. Appendix II shows the SAC boundary overlying 2010 orthophotography, and indicates wetland vegetation and marl deposition. Further investigation is required to map the extent of turlough vegetation and flooding at Corkip Lough. It is possible that the full extent is not contained within the SAC boundary.

The **target** for habitat area is: stable or increasing, subject to natural processes.

3. Range

As the full extent of the turloughs habitat in Ballynamona Bog and Corkip Lough SAC is unknown, the approximate centre of the habitat is indicated on the map in Appendix 1.

The **target** for the habitat distribution attribute is: no decline, subject to natural processes.

4. Structure and functions

Structure and functions relates to the physical components of a habitat (“structure”) and the ecological processes that drive it (“functions”). For turloughs these include attributes such as hydrology, soils and various water quality attributes.

4.1 Hydrological regime

Hydrology is the key driver of turlough ecology. The different turlough communities, assemblages and species are affected by various hydrological attributes. The most important of these are described below.

Little is known about the hydrological regime of Corkip Lough. As noted above, it was affected by drainage in the 1860s (Jim Ryan, pers. comm.; Goodwillie and Fahy, 1974). On the first edition six inch map, Corkip Lough is a permanent (presumably shallow) lake of approximately 70 ha, that stretched to the south-south-east of the current turlough and along the edge of Ballynamona Bog. In the second edition six inch maps, the area of permanent water is significantly reduced and some surrounding areas are mapped as 'liable to flood'. The pattern of drains in the turlough appears unchanged since the second edition six inch map, however the drains appear to have been widened and deepened over time, and changes to the vegetation are evident in aerial images since the mid-1990s. Goodwillie and Fahy (1974) recorded significant open water, but these are not evident in the aerial imagery since 1995. All of this evidence suggests that the pattern of flooding at Corkip turlough has varied between the 1970s and 2012.

In restoring the hydrological regime of the raised bog, consideration should be given to turlough hydrological regime and, particularly, to supporting and restoring transitional vegetation between these two priority habitats.

4.1.1 Hydrological regime: groundwater contribution

Turloughs flood mainly as a result of rising groundwater levels. The groundwater contribution exerts a strong influence on turlough ecology, notably through mineral contributions (e.g. calcium carbonate). It is, therefore, important that groundwater makes a high percentage contribution to turlough floodwaters. At Corkip turlough, there may be a significant contribution of base-poor surface run-off from areas of raised bog, however it is uncertain to what extent the natural groundwater : surface-water ratio has been altered by drainage of the peatland.

The **target** for the attribute hydrological regime, groundwater contribution is: Maintain/restore appropriate groundwater contribution necessary for the natural functioning of the habitat.

4.1.2 Hydrological regime: flood duration

Flood duration is considered to be the dominant hydrological driver of turlough vegetation. Flood duration is also important for turlough invertebrates. Both terrestrial and aquatic species and communities must be considered when investigating the influence of flood duration. A number of hydrological indicators of flood duration have been used in turlough studies. The recession constant (k) characterises the rate at which floodwaters recede, with a low k indicating a more gradual recession and, hence, longer flood duration (Paul Johnston, pers. comm., Tynan, *et al.*, 2007; Naughton, 2011). The usefulness of other hydrological functions, such as gamma function, for characterising turlough hydrology is also being investigated (Paul Johnston, pers. comm.; Naughton, 2011). It should also be possible to use plant species as indicators of the extent and duration of flooding in turloughs (see Goodwillie, 1992; Goodwillie *et al*., 1997; Waldren, 2015). Consequently, both hydrological and vegetation indicators should be considered when measuring this attribute. Little is known about the flood duration of Corkip Lough. There was no flooding evident in the 1995, 2005 or 2010 OSi ortho-imagery, or in the 2012 Bing imagery. Limited flooding is apparent in the lower parts of the turlough in the 2000 OSi ortho-imagery. This may suggest a relatively short flood duration that may be natural or the result of historic drainage.

The **target** for the attribute hydrological regime, flood duration is: Restore appropriate hydrological regime necessary for the natural functioning of the habitat.

4.1.3 Hydrological regime: flood frequency

Hydrological regime is highly variable among turloughs. Some turloughs demonstrate a characteristically low flood frequency (flooding just once most years for six months or more), whilst others have more dynamic water levels with higher flood frequencies (Naughton, 2011).

The **target** for the attribute hydrological regime, flood frequency is: Maintain/restore natural annual temporal patterns in flood frequency.

4.1.4 Hydrological regime: flood area

The extent of flooding determines the overall area of wetland vegetation, as well as the area of each characteristic vegetation community. Flood area is also important to aquatic invertebrate communities, determining the extent of the available habitat and influencing competitive and predation interactions. A number of hydrological indicators might be used to measure the flood area, such as the average annual maximum flood area, the stage (level):area relationship, or the areal (flood) reduction rate (Porst, 2009; Naughton, 2011; Naughton *et al.*, 2012). Drainage activities in the area may have affected the natural flood area.

The **target** for the attribute hydrological regime, flood area is: Restore natural temporal pattern in flood area.

4.1.5 Hydrological regime: flood depth

Flood depth is directly related to the other measures of hydrological regime (duration, area etc.) and basin morphology. The depth (and area/duration) of flooding could be impacted by increases or decreases in the discharge to the turlough (resulting in changes to the water level/stage) or by re-contouring the land (changing ground elevation and topography). Changes to flood depth will affect flood duration and, therefore, the vegetation communities. A number of hydrological indicators might be used to measure the flood depth, such as average annual maximum flood depth, the stage/depth:time series, or the average depth. Duigan (1988) said Corkip Lough was ‘very shallow, less than 1 m’.

The **target** for the attribute hydrological regime, flood depth is: Maintain/restore natural temporal and spatial patterns in flood depths.

4.1.6 Hydrological regime: permanently flooded/wet areas

Most turloughs have areas of permanent or semi-permanent flooding or saturated soils (i.e. areas that do not dry out every year). These may reflect the presence of aquitards (low permeability deposits such as peat or marl) rather than the local groundwater level during the turlough’s ‘dry phase’. These ponds and wet areas act as refuges for aquatic invertebrate species during the dry phase. They are particularly important to high conservation value species and assemblages, such as the moss-edge dwelling aquatic coleopteran community (Bilton, 1988; Bilton and Lott, 1991; Foster *et al.*, 1992; Bradish *et al.*, 2002). These areas also support important aquatic macrophyte communities, notably charophytes. Goodwillie and Fahy (1974) said there is a small area of open water throughout the summer, but that it is smaller than it was pre-drainage. Open water is not evident on aerial imagery since the 1990s.

The **target** for the attribute hydrological regime, permanently flooded/wet areas is: Restore any areas of permanent or semi-permanent flooding or water-logging.

4.2 Soil type

Turloughs are characterised by a broad range of wetland soils from mineral alluvium to peat and marl (Coxon, 1987b; Goodwillie, 1992; Kimberley, 2008; Waldren, 2015). Turlough soil type is largely determined by geology, morphology and hydrology (MacGowran, 1985; Coxon, 1986). Soil type is an important driver of vegetation and influences grazing and other land management practices (Moran *et al.*, 2008; Kimberley *et al.*, 2012). Little is known about the soils of Corkip Lough, but the presence of fen species suggests some peat occurs.

The **target** for the attribute soil type is: Maintain variety, area and extent of soil types necessary to support turlough vegetation and other biota.

4.3 Soil nutrient status

Nutrient concentrations are typically low in turlough soils, but are highly variable (temporally, among soil types, and with flood duration and land-use) and exert an influence on vegetation communities (Sarah Kimberley, pers. comm.; Waldren *et al.*, 2002; Kimberley, 2008; Kimberley *et al.*, 2012; Kimberley and Waldren, 2012). Maintenance of the natural nutrient status is important, as increases in soil nutrient status can significantly alter the vegetation communities and impact on sensitive aquatic assemblages.

The **target** for the attribute soil nutrient status is: Maintain/restore nutrient status (phosphorus and nitrogen concentrations) appropriate to soil types and vegetation communities.

4.4 Physical structure: Bare ground

Bare ground in turloughs occurs naturally in areas with long flood duration and late drying and where fine sediments (alluvium) are deposited by the floodwaters. Trampling by grazers can also result in areas of bare ground. Bare ground is important for certain vegetation communities, such as *Chenopodion rubri* (Habitats Directive Annex I habitat 3270), which is dominated by short-lived annuals, including the rare *Callitriche palustris*, *Limosella aquatica* and *Rorippa islandica*. It is also important to invertebrate communities, notably ground beetles (Regan, 2005a; Sheehy Skeffington *et al.*, 2006).

The **target** for the attribute Physical structure, bare ground is: Maintain sufficient wet bare ground, as appropriate.

4.5 Chemical processes: Calcium carbonate deposition

Calcium carbonate ($CaCO_3$) deposition is a feature of very many turloughs (Coxon, 1994; Goodwillie, 2003). Both physical and biological processes clearly play a part in precipitating $CaCO_3$ from saturated/ super-saturated groundwater, as evidenced by deposits on turlough vegetation after flood recession (Goodwillie, 2003; Jim Ryan, pers. comm.). While it may appear difficult to change $CaCO_3$ precipitation, it could be affected by drainage activities in the turlough or the zone of contribution (groundwater catchment) impacting the $CaCO_3$ concentration in the floodwater, or by changes to biological communities, impacting the precipitation processes. Goodwillie and fahy (1974) found calcareous deposits on the plants at Corkip Lough. Grey-white colouration evident from aerial imagery indicates that $CaCO_3$ precipitation is still a feature of Corkip Lough.

The **target** for the attribute chemical processes, Calcium carbonate deposition is: Maintain $CaCO_3$ deposition rate and/or soil concentration.

4.6 Water quality

Turloughs, being groundwater fed, are typically associated with high water quality. This is demonstrated by naturally low dissolved nutrients, clear water and low algal growth. Water quality can be measured by the following attributes:

4.6.1 Water quality: nutrients

The WFD Working Group on Groundwater developed a methodology to assess the risk to turloughs from phosphorus pollution, which established provisional phosphorus thresholds for turlough flood waters and the up-gradient groundwater (Working Group on Groundwater, 2005). Two total phosphorus (TP) thresholds were used for the turlough water, depending on the site's fertility and sensitivity to phosphorus enrichment. A threshold of ≤10µg/l TP was set for the least fertile ('extremely sensitive') turloughs as defined by the vegetation communities, and a threshold of ≤20µg/l TP for all other turloughs. These values were based on the Phosphorus Regulations' standards for TP in Irish lakes, which indicate that when mean TP is ≤10µg/l a lake is oligotrophic and >10 to ≤20µg/l mesotrophic (McGarrigle *et al.*, 2002, Appendix I).

Work undertaken by TCD clearly demonstrated that turloughs behave like lakes in terms of their phytoplankton biomass and their TP:phytoplankton biomass (chlorophyll *a*) relationship (Norman Allott, pers. comm.; Cunha Pereira *et al.*, 2010; NPWS, 2013; Waldren 2015). The TCD team considered that the natural background levels for all turloughs were likely to be <10µg/l (Norman Allott and Catherine Coxon, pers. comm.). Waldren (2015) concluded that <10µg/l TP indicates 'Very good' quality, 10-20µg/l TP indicates 'Good' quality, 20–50µg/l TP 'Intermediate' quality, and >50µg/l P indicates 'Bad' quality.

While it may ultimately be necessary to set site-specific TP targets for turloughs, a target of ≤10µg/l TP is here used for more oligotrophic sites dominated by fen and other sedge-rich vegetation of low-fertility and high species diversity, and a target of ≤20µg/l TP for less oligotrophic sites and there should be no deterioration in mean TP values.

The Working Group on Groundwater (2005) categorised Corkip Lough turlough as naturally highly sensitive to nutrient enrichment, and considered that it is likely to have been impacted by groundwater enrichment. Based on this assessment, the appropriate target for Corkip Lough turlough is ≤20µg/l TP, however this should be confirmed through investigation of the phosphorus concentration of the flood waters and evidence of eutrophication responses in the biota. Where the average annual TP concentration is ≤10µg/l TP, there should be no deterioration, i.e. the target should be revised to≤10µg/l TP.

The **target** for the attribute water quality, nutrients is: Maintain average annual TP concentration of ≤10µg/l TP, or ≤20µg/l TP, as appropriate.

4.6.2 Water quality: colour

Colour is typically low in turlough floodwaters, however drainage of peatland in the Slieve Aughty Mountains is believed to have increased the colour in Blackrock, Lough Coy, Garryland and Caherglassaun turloughs and to have altered the nutrient-algal biomass relationship and phytoplankton species composition (Norman Allott, pers. comm.; Cunha Pereira *et al.*, 2010). Reduced light penetration is the most likely causative factor, although sequestration of ions can also affect phytoplankton growth (Norman Allott, pers. comm.; Cunha Pereira *et al.*, 2010). Increased water colour could also impact on the primary productivity of rooted plants, either the truly aquatic plants or those wetland species that can grow even when flooded. All TCD study turloughs, other than those on the Gort-series (72-85 mg/L PtCo), had colour of <48 mg/L PtCo, with the Burren turloughs all ≤14 mg/L PtCo (Cunha Pereira *et al.*, 2010; Waldren, 2015). Drainage of adjacent raised bog may have artificially increased water colour at Corkip Lough.

The **target** for the attribute water quality, colour is: Maintain/restore appropriate water colour.

4.6.3 Water quality: phytoplankton biomass

Phytoplankton biomass as chlorophyll *a* is not significantly lower in turloughs than that found in permanent lakes (Cunha Pereira *et al.* 2010). Peak chlorophyll *a* concentration was recorded in winter in the TCD study turloughs (Norman Allott, pers. comm.; Cunha Pereira *et al.*, 2010). It is probable that the decline in phytoplankton biomass in spring in turloughs is, at least in part, the result of grazing by zooplankton, whose development is likely dependent on temperature triggers.

The targets below are based on the OECD fixed boundary system for annual mean and annual peak chlorophyll *a* (OECD, 1982). Lower thresholds apply for the more oligotrophic and sensitive sites. Waldren (2015) used maximum recorded Chlorophyll *a* >10 µg/l as a negative indicator for conservation condition in turloughs. See also Section 4.6.1 above, water quality: nutrients and the Working Group on Groundwater (2005) for more information on categorising the sensitivity of turloughs.

The chlorophyll *a* standards in the European Communities Environmental Objectives (Surface Water) Regulations (S.I. 272 of 2009) could not be adopted as they are based on "growing season (March to October) mean values[1]", which includes a turlough's 'dry phase'. In addition S.I. 272 of 2009 states

[1] a minimum of four samples is required, distributed throughout the growing season.

that the EQR boundary conditions are not yet developed for shallow calcareous lakes, which is the lake type most similar to turloughs.

The **target** for the attribute water quality, phytoplankton biomass is: Maintain appropriate cholorophyll *a* concentrations (annual mean <2.5 or <8µg/l, annual maximum values ≤8 and <25µg/l, as appropriate).

4.6.4 Water quality: epiphyton biomass

Patches of filamentous algae are a common occurrence in turloughs, however extensive algal mats are only found in turloughs with high average TP concentrations (i.e. ≥20µg/l) (Normal Allott, pers. comm.). The filamentous forms recorded include *Oedogonium*, *Spirogyra* and *Mougeotia* species (Normal Allott, pers. comm.). A few turloughs with high TP did not develop extensive algal mats, at least partly because of high water colour (Normal Allott, pers. comm.). Waldren (2015) used the 'Presence of filamentous algal mats covering at least 2% of turlough area on at least one occasion over three years of observation' as a negative indicator for turlough conservation condition

As a general rule, therefore, higher TP concentrations increase epiphyton production in turloughs. Owing to the fact that epiphyton is typically deposited onto the vegetation as the floodwaters recede, the decomposition of these algae is a pathway for nutrients from water to soil and rooted vegetation.

The **target** for the attribute water quality, epiphyton biomass is: Maintain trace/ absent epiphyton as algal mats (<2% cover).

4.7 Active peat formation

Peat formation is not a feature of all turloughs, but is associated with sedge-rich, fen-type vegetation communities. The duration of flooding is the key determinant of peat formation in turloughs. The water level needs to be slightly below to above the soil surface for approximately 90% of the time for peat to form (Jim Ryan, pers. comm.). Active peat formation can be threatened by drainage and other earth movements, as well as changes in hydrological regime. Note: peat formation in turloughs can be affected by natural changes in hydrology (Coxon and Coxon, 1994).

The **target** for the attribute active peat formation is: Restore active peat formation, where appropriate.

4.8 Vegetation composition: vegetation communities

The vegetation of turloughs has been described and classified a number of times, notably by Goodwillie (1992, 2003), Goodwillie *et al.* (1997), O'Connell *et al.* (1994), MacGowran (1985), Regan *et al*. (2007) and Sharkey (2012). The conservation value of the described vegetation communities was considered by most of these authors (e.g. Goodwillie, 1992; O'Connell *et al.*, 1994; Regan, 2005a; Sharkey, 2012; Waldren, 2015). The WFD Working Group on Groundwater classified sensitive vegetation communities by assigning Ellenberg N (fertility) values (Hill *et al.*, 1999) to data from Goodwillie (1992), Goodwillie *et al.* (1997) and NPWS surveys (Working Group on Groundwater, 2005). Waldren (2015) developed positive and negative indicator communities for turloughs. The characteristic turlough communities identified as positive indicators (turlough-type dependent) included the *Eleocharis acicularis* community, *Carex* fen (*Molinia caerulea-Carex panicea* community), *Schoenus nigricans* fen and flooded woodland and pavement communities (Waldren, 2015).

Turlough vegetation communities also support invertebrate species and assemblages. The association between the turlough moss-edge water beetle assemblage and moss-rich fen vegetation communities is particularly notable.

Goodwillie and Fahy (1974) recorded *Carex rostrata, C. elata, Schoenoplectus lacustris, Ranunculus lingua, Alisma plantago-aquatica* and *Hippuris vulgaris* fringing the area of permanent, open water, and noted that *Potamogeton natans* and *Chara sp.* characterised the open water with *Menyanthes trifoliata* and *Potentilla palustris* in places. The grassland vegetation surrounding the open water and fringing swamp was dominated by *Carex nigra* and *C. panacea* (Goodwillie and Fahy, 1974). Patches of fen vegetation with *Parnassia palustris* and *Eleocharis quinqueflora* were also recorded.

The **target** for the attribute vegetation composition, vegetation communities is: Maintain area of sensitive and high conservation value vegetation communities/units.

4.9 Vegetation composition: vegetation zonation

Sheehy Skeffington *et al*. (2006) provide a good commentary and summary of the studies on turlough vegetation zonation. Praeger (1932) was one of the first to record the zonation from dry soil species at the turlough margins to amphibious and aquatic species in the areas with the longest flood duration. This zonation has been recorded by many authors (Ivimey-Cook and Proctor, 1966; O'Connell *et al*., 1984; Goodwillie, 1992; Goodwillie *et al*., 1997). Goodwillie (2003) discusses the influence of flood duration, the timing of flooding and other hydrological characteristics on vegetation zonation.

Maintaining a diversity of vegetation zones (community patches) also helps support invertebrate diversity.

Goodwillie and Fahy (1974) recorded distinct zonation from open water to drier grassland at Corkip Lough (see Section 4.8), however it is uncertain that these vegetation patterns persist.

The **target** for the attribute vegetation composition, vegetation zonation is: Maintain the vegetation zonation/mosaic characteristic of the site.

4.10 Vegetation structure: sward height

Vegetation height varies over time in turloughs, as a result of the timing of flood recession and the plants' growth periods, as well as the grazing regime. Vegetation diversity can be maximised by employing a variable grazing regime across the turlough. Variation in vegetation height is also important to invertebrate communities, with some species being dependent on bare soil, some associated with grazed, short vegetation, whilst others, notably Diptera and Lepidoptera, require taller herbaceous vegetation and scrub, respectively (Bond, 1997; Good and Butler, 2001; Ní Bhriain *et al*., 2002; Moran, 2005; Regan, 2005a; Ryder *et al*., 2005; Sheehy Skeffington *et al*., 2006).

Moran *et al*. (2008) state "Given that different species of both plants and animals will respond differently to differing management conditions, maintenance of heterogeneity is vital for the maintenance of maximum biodiversity".

The **target** for the attribute vegetation structure, sward height is: Maintain sward heights appropriate to the vegetation unit, and a variety of sward heights across the turlough.

4.11 Typical species

As wetlands with distinct terrestrial and aquatic phases, turloughs have a range of typical species that can broadly be divided into wetland and aquatic species. In listing the typical species for the various groups below, strong emphasis has been placed on those that are indicative of good condition in turloughs (positive indicator species) and/or are known to be restricted to or have most occurrences in turloughs (characteristic species). The species lists highlight the rare and threatened species found in turloughs.

4.11.1 Typical species: terrestrial, wetland and aquatic plants

Table 1 lists the typical turlough plant species (NPWS, 2013). Various botanical and review studies list characteristic turlough plants (e.g. Goodwillie, 1992, 2003; Goodwillie *et al*., 1997; Sheehy Skeffington *et al*, 2006; Sharkey, 2012; Waldren, 2015). Table 2 lists other more widespread vascular plant species that are commonly encountered in turloughs, often at high cover abundance.

Table 1 The typical plant species of turloughs. Species indicated by * are considered turlough specialists, though not necessarily restricted to turloughs. † indicates typical species of habitat 3270. Regional Red List status is given, where relevant, as a superscript (bryophytes only).

Angiosperms:
Dicots: *Callitriche palustris**†, *Frangula alnus* (prostrate form*), *Galium boreale*, *Limosella aquatica*†*, *Persicaria minor*†, *Plantago maritima*, *Potentilla fruticosa**, *Ranunculus repens* (form with highly dissected leaves*), *Rhamnus cathartica*, *Rorippa islandica**†, *Teucrium scordium**, *Viola persicifolia**
Monocots: *Alopecurus aequalis*†, *Carex viridula* agg., *Eleocharis acicularis*†, *Schoenus nigricans*
Bryophytes:
Mosses: *Cinclidotus fontinaloides, Drepanocladus sendtneri* [NT], *Pseudocalliergon lycopodioides* [VU], *Pseudocalliergon trifarium* [VU]
Liverworts: *Riccia cavernosa*†
Pteridophytes:
Ophioglossum vulgatum

The TCD integrated turlough project identified the following as positive turlough indicator species: *Potentilla fruticosa, Viola persicifolia, Teucrium scordium, Limosella aquatica, Plantago maritima, Rorippa islandica* and *Frangula alnus* (Steve Waldren, pers. comm.; Waldren, 2015).

The plant list in Table 1 includes species typical of the Annex I habitat 'Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation' (3270), which is a community of short-lived annual species associated with turloughs in Ireland (NPWS, 2013). Other species associated with habitat 3270 include *Atriplex prostrata*, *Gnaphalium uliginosum*, *Rorippa palustris*, *Persicaria hydropiper*, *Chenopodium rubrum*, *Juncus bufonius* and, *Bidens tripartita*. It should be noted that habitat 3270 was not recorded in Corkip Lough turlough.

Waldren (2015) said "many of the characteristic plant species encountered in turloughs also occur in other wetlands, or indeed in well-drained calcareous habitats; what is unique about turlough vegetation is the juxtaposition of ecologically different species along short but strong ecological gradients." Rather than recommending a revised list of typical species, the authors identified plant indicator species that are indicators for flood duration and nutrient status (Waldren, 2015).

Lockhart *et al*. (2012) noted that *Cinclidotus fontinaloides* is characteristic of turloughs and that the rare *Pseudocalliergon lycopodioides* and *Drepanocladus sendtneri* can be locally abundant in turloughs. Some of the best, fen-vegetation-rich turloughs support *Pseudocalliergon trifarium* (Lockhart *et al*., 2012).

Table 2 Widespread plant species commonly found in turloughs, frequently at high abundance. Species indicative of oligotrophic conditions are given a ‡.

Angiosperms:
Dicots: *Baldellia ranunculoides‡, Filipendula ulmaria, Hydrocotyle vulgaris*, *Leontodon hispidus*, *Littorella uniflora‡, Mentha aquatica*, *Myosotis scorpioides, Persicaria amphibia*, *Persicaria hydropiper, Potamogeton gramineus, Potamogeton polygonifolius‡*, *Potentilla anserina*, *Potentilla reptans*, *Prunus spinosa*, *Ranunculus flammula*, *Ranunculus trichophyllus*, *Rumex acetosa*, *Scorzoneroides autumnalis*, *Thymus polytrichus*, *Trifolium repens*, *Viola canina*
Monocots: *Agrostis stolonifera, Carex hirta, Carex hostiana, Carex nigra, Carex panicea, Deschampsia caespitosa, Eleocharis multicaulis‡, Eleocharis palustris, Eleogiton fluitans‡, Festuca arundinacea, Festuca rubra, Glyceria fluitans, Juncus articulatus, Juncus bulbosus‡*, *Molinia caerulea, Phalaris arundinacea, Poa annua*
Bryophytes:
Fontinalis antipyretica, Scorpidium revolvens

Further investigation into the charophyte flora and other aquatic macrophytes of turloughs is required.

Teucrium scordium was found at Corkip Lough (Goodwillie and Fahy, 1974; Anonymous, 1981). They also recorded *Ranunculus lingua*, an unusual occurrence in turloughs (Goodwillie and Fahy, 1974). Goodwillie and Fahy (1974) recorded a range of typical and common turlough species including *Agrostis stolonifera, Carex nigra, Carex panicea, Eleocharis palustris, Hydrocotyle vulgaris, Persicaria amphibia, Potentilla anserina* and *Ranunculus repens*.

The **target** for the attribute typical species, terrestrial, wetland and aquatic plants is: Maintain typical species within and across sites

4.11.2 Typical species: aquatic invertebrates

NPWS (2013) provided an updated list of typical aquatic invertebrate species of turloughs (see Table 3), and the available information on this group is reviewed by Sheehy Skeffington *et al*. (2006) and Reynolds (2016). The species of greatest conservation importance in turloughs include the rare chydorid, *Eurycercus glacialis* (see Duigan and Frey, 1987a, b; Reynolds, 1997, 2000; Reynolds and Marnell, 1999; Reynolds et al., 2004), the copepod *Diaptomus castor* (see Ali et al., 1987; Reynolds, 1997), the near threatened odonate *Lestes dryas* (see Nelson and Thompson, 2004; Nelson *et al.*, 2011), and the characteristic water beetle species *Agabus labiatus* (nt), *Graptodytes bilineatus* (nt), *Berosus signaticollis* (EN) and *Dryops similaris* (nt) (see Bilton, 1988; Bilton and Lott, 1991; Foster *et al.*, 1992; Bradish *et al.*, 2002; Foster *et al.*, 2009). As well as these rare and threatened water beetle species, typical aquatic coleopteran species include: *Haliplus obliquus, Agabus nebulosus, Rhantus frontalis, Hygrotus impressopunctatus, Helophorus minutus, Laccobius colon, L. minutus,* and *Ochthebius minimus* (Garth Foster, pers. comm.). *Bagous brevis* is a critically endangered (CR) aquatic weevil that feeds on *Ranunculus flammula*. The only recent records for this species are from Knockaunroe turlough (Morris, 1985; Bilton and Lott, 1991; Foster *et al.*, 2009). *Siphlonurus armatus* is a critically endangered (CR) mayfly, the only recent record of which is from a turlough (Kelly-Quinn and Regan, 2012). Both these species and their potential association with turloughs require further study.

Table 3 Typical aquatic invertebrate species of turloughs. The species included are characteristic and/or indicative of good quality in turloughs. Those species indicated by * have a strong association with turloughs, with most/all records for that species in Ireland coming from turloughs. Regional Red List status is given, where relevant, as a superscript.

Aquatic invertebrates:
Plathyhelminthes, Turbellaria: *Polycelis nigra;* **Crustacea, Cladocera:** *Alonella excisa, Alona rustica, Alonopsis elongate, Alona affinis, Eurycercus glacialis*,* **Crustacea, Copepoda;** *Diaptomus castor;* **Insecta, Odonata:** *Lestes dryas**, *Sympetrum sanguineum*; **Insecta, Coleoptera:** *Agabus labiatus** ^{NT}, *Agabus nebulosus, Bagous limosus* ^{CR}, *Berosus signaticollis** ^{EN}, *Dryops similaris** ^{NT}, *Graptodytes bilineatus** ^{NT}, *Haliplus obliquus, Haliplus variegates* ^{VU}, *Helophorus minutus, Helophorus nanus* ^{VU}, *Hygrotus impressopunctatus, Laccobius colon, Laccobius minutus, Ochthebius minimus, Rhantus frontalis*.

Characteristic turlough molluscan species include: *Stagnicola fuscus*, *Galba truncatula*, *Radix balthica*, *Anisus leucostoma*, *Oxyloma elegans* and *Pisidium personatum* (Evelyn Moorkens, pers. comm.). High quality turloughs contain a good mixture of these species in relatively even abundance (i.e. no one species dominating) (Evelyn Moorkens, pers. comm.). *Valvata cristata* and *Armiger crista* may also be present but restricted to the more stable areas of water (Evelyn Moorkens, pers. comm.).

Duigan (1988) found *Eurycercus glacialis* and *E. lamellatus* with seven other cladoceran species at Corkip Lough. The turlough spreadwing, *Lestes dryas*, was also recorded at Corkip Lough in 2002 (Dragonfly Ireland database).

The **target** for the attribute typical species, aquatic invertebrates is: Maintain typical species within and across sites.

4.11.3 Typical species: other invertebrates

NPWS (2007, 2013) provides a list of typical terrestrial invertebrate species of turloughs (see Table 4). The EU Interpretation Manual (CEC, 2013) lists the following terrestrial invertebrate species as characteristic of turloughs: *Agonum lugens, A. livens, Badister meridionalis, Blethisa multipunctata* and *Pelophila borealis* (dry phase).

The available information on terrestrial invertebrates was reviewed by Sheehy Skeffington *et al*. (2006). They state “The terrestrial invertebrate fauna of turloughs includes several rare species and communities. Yet to date only some faunal groups have received much attention. The beetles and butterflies have been described to some extent, but the remaining terrestrial orders are poorly documented.”

Terrestrial Coleoptera have been recorded by a number of authors (e.g. Speight, 1976, 1977; Lott and Foster, 1990; Lott and Bilton 1991; Anderson, 1997; Owen, 1997; Good and Butler, 2001; Ní Bhriain *et al*., 2002; Lott, 2003; Moran *et al*., 2003; Regan and Anderson, 2004; Moran, 2005; Regan, 2005 a and b; Regan and Moran, 2005).

Bond (1997) noted that no lepidopteran species were exclusively associated with turloughs, but that the upper turlough zones and, especially, fringing scrub had high diversity and hosted some scarce and rare species. The frequency and longevity of flooding is probably a limiting factor for many of the terrestrial species and many of the claimed associations of species with turloughs remain unverified. For example, several species of Lepidoptera feed on *Rhamnus,* which tends to grow on pavement near and at the upper margins of turloughs, and so have been associated with the habitat. There is no evidence, however, that these species have any requirement for the turlough habitat itself. The Lepidoptera species listed in Table 4 are those which have been associated with turloughs and which feed on wetland species of plant. A possibly un-described species of micromoth of the genus *Elachista* (Elachistidae) was recently found at Coolorta Turlough in the Burren, the caterpillars of which were feeding on *Cladium mariscus* (Phil Sterling, pers. comm.).

Insufficient and lack of comprehensive survey of other groups limits selection of other typical species to a few. Morris (1974) provides an account of the Auchenorrhyncha (Hemiptera) of the Burren which refers to species associated with wetlands. However, work such as this needs to be repeated before definitive turlough associations can be made.

Table 4 The typical terrestrial invertebrate species of turloughs (NPWS, 2007, 2013). Species indicated by * have a strong association with turloughs, i.e. most/all records for that species in Ireland are from turloughs.

Terrestrial invertebrates:
Diptera, Sciomyzidae: *Pherbellia nana, Colobaea distincta, Ilione albiceta, Pherbina coryleti*; **Lepidoptera, Crambidae:** *Paraponyx stratiotata*; **Lepidoptera, Tortricidae:** *Bactra furfurana;* **Lepidoptera, Gelechiidae** *Monochroa lutulentella;* **Lepidoptera, Noctuidae:** *Deltote uncula;* **Coleoptera, Carabidae:** *Blethisa multipunctata, Chlaenius nigricornis, Pelophila borealis, Agonum piceum, Carabus granulatus, Loricera pilicornis, Pterostichus nigrita, Bembidion clarkii, Agonum muelleri, Bembidion aeneum, *Agonum lugens, *Platynus livens, *Badister meridionalis, *Badister peltatus*; **Coleoptera, Staphylinidae:** *Philonthus furcifer;* **Coleoptera, Silphidae**: *Thanatophilus dispar.* **Orthoptera, Tetrigidae** *Tetrix subulata*; **Orthoptera, Acrididae** *Chorthippus albomarginatus* **Heteroptera, Saldidae** *Saldula opacula*

The **target** for the attribute typical species, other invertebrates is: Maintain typical species within and across sites.

4.11.4 Typical species: birds

The aquatic phase of turloughs has long been recognised as of importance for wintering waterbirds (Buckley and McCarthy, 1987; Buckley, 1993; Madden and Heery, 1997; Crowe, 2005). Turloughs can provide rich feeding grounds, and can also be important roosting areas. Waterbird usage may also contribute to the colonisation or re-colonisation of turloughs by certain invertebrate species (see Frisch *et al*., 2007). Turloughs near the coast and those near large lakes, generally have higher numbers of waterbirds than the Burren or land-locked turloughs. Coastal turloughs can be particularly important for feeding and roosting during high tides and stormy seas. The more oligotrophic turloughs, however, tend to host fewer birds.

Goodwillie and Fahy (1974) said Redshank, Lapwing and Snipe nested at Corkip Lough and in winter large numbers of Golden Plover, Curlew and Lapwing were found. Smaller songbirds such as Reed Bunting and Sedge Warblers also frequented the site (Goodwillie and Fahy, 1974). Corkip Lough is an IWeBS sub-site, however data are available for January 2009 only, when four Whooper Swan and eight Lapwing were counted. It is possible that wintering waterbird usage has varied with changes in the flooding regime of Corkip Lough between 1970s and the present day.

The **target** for the attribute typical species, birds is: Maintain typical species within and across sites.

4.12 Fringing habitats

Marginal woodland and scrub, as well as fringing limestone pavement and semi-natural grasslands are important for terrestrial invertebrates, particularly Lepidoptera (see also Section 4.11.3 above). *Rhamnus cathartica* (Purging Buckthorn) appeared to be of special significance (Bond, 1997). The Irish Annulet (*Odontognophos dumeteta*) is one such rare species that could have an association with the fringing habitats of turloughs, as it feeds on *Rhamnus cathartica*. These fringing habitats are also important over-wintering sites for many terrestrial coleopteran species that occupy the turlough during the dry phase (Good and Butler, 2001; Lott, 2003).

Semi-natural and natural fringing habitats are also likely to act as seed/propagule source areas for turlough plant species.

Fringing grasslands may also be important feeding areas for wintering waterbirds.

Raised bog is an important and less common fringing habitat for some turloughs, such as Corkip Lough, in east Galway and Roscommon. The co-occurrence of and the maintenance/restoration of transitional vegetation between these two priority habitats is of high conservation value. Further investigation is required of the use of these habitats where they co-occur by invertebrate, bird and mammal species.

The **target** for the attribute fringing habitats is: Maintain marginal fringing habitats that support turlough vegetation, invertebrate, mammal and/or bird populations.

4.13 Vegetation structure: turlough woodland

The natural climax vegetation for at least the upper margins of turloughs is wet-woodland. Goodwillie (2003) notes "Without grazing, a 'wet' turlough would have a central area of wetland vegetation made up of aquatic or amphibious plants that could start development when still water-covered, and be surrounded by small trees and shrubs, especially willows." "A 'dry' turlough would be totally covered by trees though the trees in the centre would be relatively small because of periodic kills caused by spring or summer flooding." Owing to traditional grazing of turloughs, turlough woodland is now quite rare. Some turloughs, however, notably those in the Coole-Garryland complex, have areas of mature, native woodland that floods most years. Perrin *et al*. (2008) identified a variant of their *Alnus glutinosa – Filipendula ulmaria* group, *Crataegus monogyna – Geranium robertianum* woodland (3 d) from the upper margins of turlough basins. They described this as a very rare type of stand of low scrub woodland dominated by *Crataegus monogyna* and *Rhamnus cathartica* (Perrin *et al.*, 2008). This, and possibly other not yet described turlough woodland sub-types, are important elements of the natural variation of turloughs in Ireland.

The **target** for the attribute vegetation structure, woodland structure is: Maintain appropriate turlough woodland diversity and structure.

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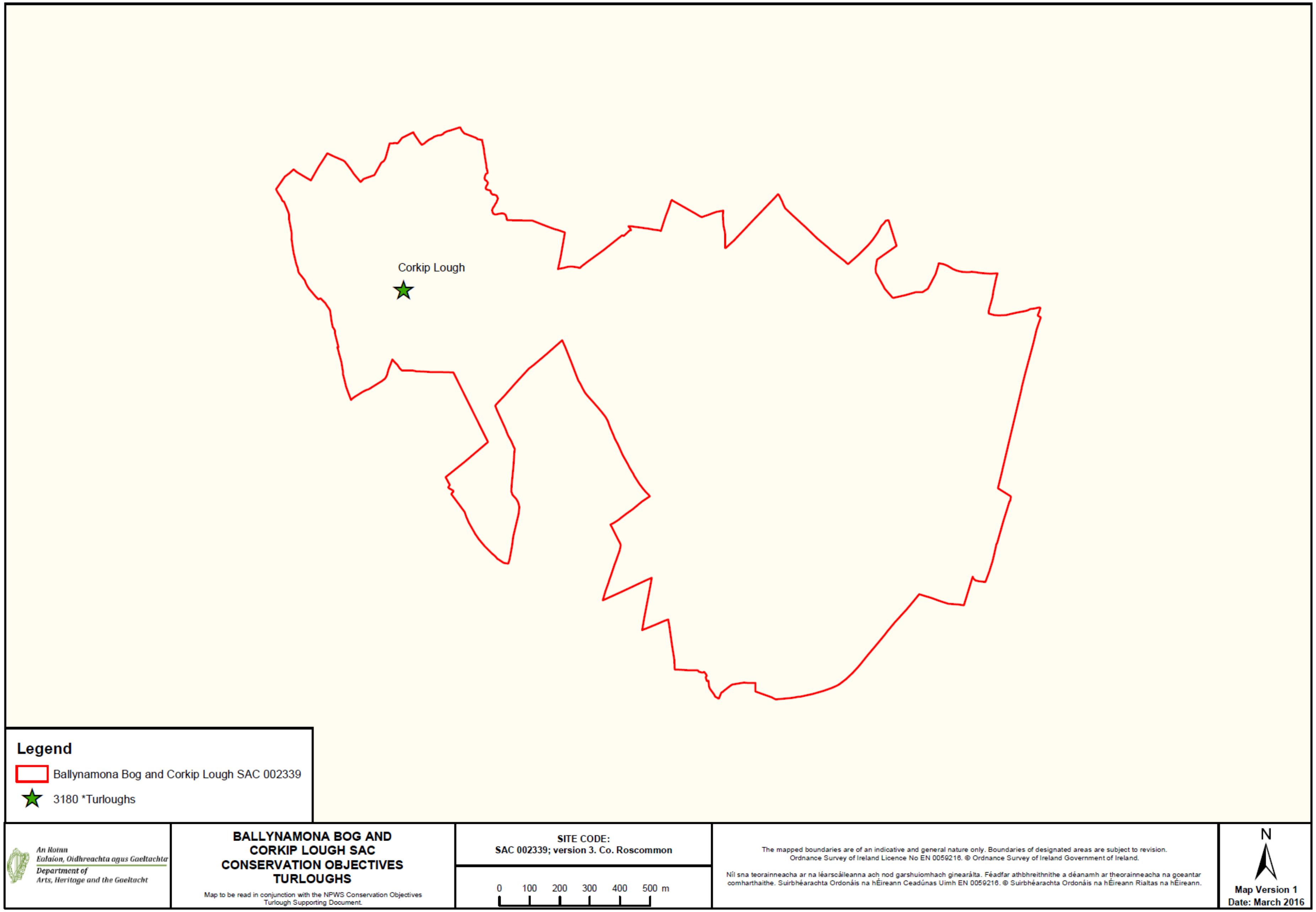
Appendix I Map of Corkip Lough Turlough



Appendix II Orthophotograph of Corkip Lough Turlough