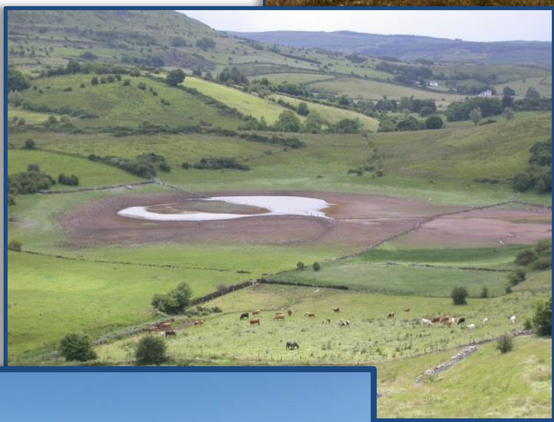
Conservation objectives supporting document

Turloughs*

and

Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation



An Roinn Ealaíon, Oidhreachta, Gnóthaí Réigiúnacha, Tuaithe agus Gaeltachta

Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs

National Parks and Wildlife Service

NPWS

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Version 1.1

Áine O Connor

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Cover photos: From top: Keenagh Turlough, Co. Roscommon; Lough Funshinagh, Co. Roscommon (both Brian Nelson); Lough Gowra, Co. Sligo; Lough Gealain, Co. Clare (both Áine O Connor).

Contents

1. Introduction

1.1 Turloughs

"Turloughs" (EU habitat code 3180) is a priority habitat (denoted by *) on Annex I of the EU 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). The interpretation manual of EU habitats (European Commission, 2013) 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.*

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 *et al.*, 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. A small number with long flood duration have annual communities of the Annex I habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270) (see section 1.2 below).

Turloughs intergrade with many other wetland types, from marl lakes and ponds to swamp, to fen and even to coastal lagoons and other coastal/intertidal habitats. Turloughs are, perhaps, best thought of as a landform or a hydrogeological entity that can contain a range of plant and animal communities. The turlough sites with the highest conservation interest and value include those that contain or are surrounded by other EU Habitats Directive Annex I habitats, notably Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. (3140), Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270) (see section 1.2), Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae* (7210), Petrifying springs with tufa formation (Cratoneurion)* (7220), Alkaline fens (7230), Limestone pavements* (8240) and Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (*important orchid sites) (6210). A small number of turloughs contain a rare woodland type dominated by *Crataegus monogyna* and *Rhamnus cathartica* (Perrin *et al*., 2008). *Juniperus communis* formations on heaths or calcareous grasslands (5130), *Taxus baccata* woods of the British Isles* (91J0) and other heath and woodland communities may also occur on turlough margins.

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, 2013a).

1.2 Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation

"Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation" (EU habitat code 3270) is a habitat on Annex I of the EU Habitats Directive. In Ireland, it is mainly found within turloughs that have areas from which the floodwater recedes late and that are prone to summer flooding. In the rest of Europe, the habitat is found on muddy banks of rivers in late-receding river floodplains (European Commission, 2013). The Gearagh SAC contains the only known Irish example of "Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation" occurring in the floodplain of a 'surface' river. The occurrence of the habitat in some turloughs is perhaps unsurprising when they are considered as the floodplains of underground rivers (Goodwillie, 2003, 2007).

Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is a dynamic habitat found on damp, fine, mineral soils (typically alluvial muds). Typical species are small, short-lived, fast-growing annuals that are poor competitors. Colonisation of the habitat by perennial species is prevented by its exposure late in the growing season for a short period. The persistence of the habitat is dependent on a continuous supply of fine sediment.

Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation forms a vegetation community within the turlough habitat and can, therefore, be considered as a sub-set of the turlough vegetation.

In Ireland, habitat 3270 is considered to be in poor/inadequate conservation status as a result of nutrient enrichment, inappropriate grazing and drainage pressures (NPWS, 2007, 2008, 2013a).

1.3 SACs for Turloughs

A total of 45 SACs (Special Areas of Conservation) have been selected for the priority habitat Turloughs (3180) listed on Annex I of the EU Habitats Directive (see Table 1).

Site-specific conservation objective supporting documents have been produced for turloughs in four SACs (NPWS, 2013b, 2016b, 2016c, 2016d). This supporting document has been prepared for the conservation objectives for the remaining SACs selected for Turloughs (3180).

Table 1 Special Areas of Conservation (SACs) selected for the priority habitat Turloughs (3180) and for Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270). 'Supporting document' indicates that a dedicated conservation objective supporting document has been published for the habitat(s) in the SAC.

Site Code	Site Name	3180	3270	Supporting document
000051	Lough Gash Turlough SAC	3180	3270	
000054	Moneen Mountain SAC	3180		
000108	The Gearagh SAC		3270	NPWS, 2016a
000218	Coolcam Turlough SAC	3180		
000238	Caherglassaun Turlough SAC	3180	3270	
000242	Castletaylor Complex SAC	3180		
000252	Coole-Garryland Complex SAC	3180	3270	
000255	Croaghill Turlough SAC	3180		
000268	Galway Bay Complex SAC	3180		NPWS, 2013b
000295	Levally Lough SAC	3180		
000296	Lisnageeragh Bog and Ballinastack Turlough SAC	3180		NPWS, 2016b
000301	Lough Lurgeen Bog/Glenamaddy Turlough SAC	3180	3270	NPWS, 2016c
000318	Peterswell Turlough SAC	3180	3270	
000322	Rahasane Turlough SAC	3180		
000407	The Loughans SAC	3180		
000448	Fortwilliam Turlough SAC	3180		
000461	Ardkill Turlough SAC	3180		

Site Code	Site Name	3180	3270	Supporting document
000463	Balla Turlough SAC	3180		
000475	Carrowkeel Turlough SAC	3180		
000480	Clyard Kettle-holes SAC	3180		
000492	Doocastle Turlough SAC	3180		
000503	Greaghans Turlough SAC	3180		
000504	Kilglassan/Caheravoostia Turlough Complex SAC	3180		
000525	Shrule Turlough SAC	3180		
000541	Skealoghan Turlough SAC	3180		
000588	Ballinturly Turlough SAC	3180		
000606	Lough Fingall Complex SAC	3180		
000609	Lisduff Turlough SAC	3180		
000610	Lough Croan Turlough SAC	3180		
000611	Lough Funshinagh SAC	3180	3270	
000612	Mullygollan Turlough SAC	3180		
000637	Turloughmore (Sligo) SAC	3180		
000996	Ballyvaughan Turlough SAC	3180		
001285	Kiltiernan Turlough SAC	3180		
001321	Termon Lough SAC	3180		
001625	Castlesampson Esker SAC	3180		
001637	Four Roads Turlough SAC	3180		
001656	Bricklieve Mountains and Keishcorran SAC	3180		
001926	East Burren Complex SAC	3180		
002117	Lough Coy SAC	3180		
002293	Carrowbaun, Newhall and Ballylee Turloughs SAC	3180		
002294	Cahermore Turlough SAC	3180		
002295	Ballinduff Turlough SAC	3180		
002296	Williamstown Turloughs SAC	3180		
002303	Dunmuckrum Turloughs SAC	3180		
002339	Ballynamona Bog and Corkip Lough SAC	3180		NPWS, 2016d

1.4 SACs for Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation

A total of seven SACs have been selected for the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270) listed on Annex I of the EU Habitats Directive (see Table 1).

Site-specific conservation objectives supporting documents have been produced for Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation in two SACs (NPWS, 2016a, 2016c). This supporting document has been prepared for the conservation objectives for the remaining five SACs selected for the habitat.

1.5 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. Overgrazing and, in particular, undergrazing 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, 2005a; 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.

Little if any grazing is required for the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270). It is important that this high conservation value habitat, dominated by rare species, is not confused with the wet annual community of common, 'weedy' species found on damp tracks and trampled/poached mineral soil. Natural disturbance by flooding and sediment deposition is the main ecological driver of habitat 3270.

Attributes and targets may change/become more refined as further information becomes available. Note that while the targets below are given as 'maintain', a target of 'restore' may apply for one or more attributes within an individual SAC. This will be indicated in the site-specific conservation objectives document.

2. Area

Mapping turlough area is challenging. Coxon (1986, 1987a) measured turlough area from the lines of inundation on the OSi 6" maps, but where such lines were not available, used field survey of vegetation (*Cinclidotus fontinaloides*) to estimate the 'area normally flooded in winter'. Naughton (2011) mapped turlough flooded areas based on water level measurements and detailed topographic mapping (see also Naughton *et al*., 2012 and Waldren, 2015). These hydrological maps, where the area is determined by the maximum water level recorded during the survey period, may underestimate or overestimate the extent of wetland communities. Goodwillie (1992) and Goodwillie *et al*. (1997) mapped the 'topmost edge' of turloughs based on vegetation and flood debris. The variation in the areas of turloughs mapped during both surveys clearly illustrates the complexity of mapping and measuring turlough area (Goodwillie, 1992; Goodwillie *et al*., 1997). Goodwillie (2003) stated 'the plant community is constantly adjusting to the previous flood event', 'holly is a rough guide to the normal top levels of flooding' and *Cinclidotus fontinaloides* indicates the 'top water height'. He also explained that *Ranunculus bulbosus* indicates areas that 'flood for a few weeks and probably not every year' and that epiphytic lichens in woodland are a useful indicator as they 'seem to be killed by only a few days of flooding' (Goodwillie, 2003).

Estimating the area of a turlough requires that all available mapped and estimated data be collated and compared to contemporary field-survey data based on vegetative indicators. This provides some interrogation of the natural variation in turlough area over time (in response to natural flood variation). The aim is to maintain or increase the area of wetland communities of conservation value (without compromising the condition of surrounding, high conservation value non-wetland communities).

Mapping the area of Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270) is even more challenging. The area of habitat 3270, unlike that of the turlough as a whole, is expected to vary significantly, inter-annually, with flooding regime. The timing of observations will also significantly influence measurement of the area of habitat 3270.

The **TARGET** for the habitat area attribute for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Area stable or increasing, subject to natural processes.

3. Range

The known distribution of Turloughs* and/or Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is mapped in each site-specific conservation objective document. The full, national distribution of each habitat is not yet known (see, for example, O'Neill and Martin, 2015) and, in larger SACs (e.g. East Burren Complex SAC, site code 001926), knowledge of the range of each habitat may be incomplete.

The **TARGET** for the habitat distribution attribute for Turloughs* and Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation 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* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation these include attributes such as hydrology, soils and various water quality attributes.

4.1 Hydrological regime

Hydrology is the key driver of the ecology of Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation. The different turlough communities, assemblages and species are affected by various hydrological attributes. The most important of these are described below. Derivation of hydrological indicators will often require high frequency monitoring of water level, as well as detailed topographic mapping (see Naughton, 2011; Naughton *et al*., 2012; Waldren, 2015).

Groundwater enters turloughs mainly through estavelles and springs, and turloughs also empty through estavelles and swallow-holes (Naughton, 2011; Naughton *et al*., 2012; Waldren, 2015). There is also some inflow of water to turloughs through direct rainfall, surface runoff and diffuse shallow groundwater flow. Turloughs are at the interface between groundwater and surface water, and flooding results from high rainfall and, accordingly, high groundwater levels in topographic depressions in karstified limestone terrain (Naughton *et al*., 2012). Turlough flooding regimes form a continuum, from short-duration flooding in basins with a rapid response to rainfall events, to long-duration flooding in response to longer term precipitation patterns (Naughton *et al*., 2012; Waldren, 2015). Goodwillie (2003) provides detailed information on the effects of inundation of plant species. Waldren (2015) found that the turlough communities are shaped primarily by the depth, duration and rate of areal reduction in flooding. Maintenance of the hydrological functioning of turloughs is key to achieving favourable conservation condition (Waldren, 2015). As the ecology of each turlough is a response to the local hydrological regime, conservation objectives and management must be site-specific (Waldren, 2015).

Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is flooded for an extended period of time each year, becoming exposed late in summer. Most turloughs with the habitat (3270) are fed by streams or underground conduits and these may supply fine sediment. Wave action may also be important in maintaining bare mud through erosion, re-suspension and deposition of sediment within the basin. The soils of habitat 3270 usually remain saturated for a significant period of time after becoming exposed, through a combination of local water table level and the water retention capacity/permeability of the soils (NPWS, 2013a).

Site-specific data and observations on individual turloughs may be available from the sources listed in Section 5.

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. Groundwater mainly enters turloughs through estavelles and springs.

The **TARGET** for the attribute hydrological regime, groundwater contribution for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain 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 is also possible to use plant species as indicators of the extent and duration of flooding in turloughs (see Goodwillie, 1992, 2003; Goodwillie *et al*., 1997; Waldren, 2015). Consequently, both hydrological and vegetation indicators should be considered when measuring this attribute.

As noted above, the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270), is flooded for an extended period each year, becoming exposed in summer, and this allows the annual, short-lived species that typify the habitat to grow, while preventing perennial species from completing their life-cycles. Data for habitat 3270 at Coole indicates that it is continuously flooded for around 250 days/year (Owen Naughton, pers. comm.).

The **TARGET** for the attribute hydrological regime, flood duration for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain appropriate natural spatial and temporal patterns in flood duration.

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 habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation must flood at least once per year; however, it is likely that a second, summer flood is required at lower frequency (perhaps once every five years) in order to exclude perennials (NPWS, 2013a).

Alternatively, persistent, year-round flooding every few years could prevent the establishment of perennials.

The **TARGET** for the attribute hydrological regime, flood frequency for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain 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 (including the area of Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation). Flood area is also important to aquatic invertebrate communities by 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).

The **TARGET** for the attribute hydrological regime, flood area for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain natural temporal and spatial 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.

As the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270) generally occurs at the base of the turlough, it is associated with the maximum flood depth. It is also generally found in relatively deep turloughs. The depth of water level fluctuations (likely to be from 2m up to 6m plus) and average water depth during flooding may be significant factors in limiting the colonisation of habitat 3270 by perennial species (NPWS, 2013a).

The **TARGET** for the attribute hydrological regime, flood depth for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain 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.

The **TARGET** for the attribute hydrological regime, permanently flooded/wet areas for Turloughs* and Rivers with muddy banks *with Chenopodion rubri p.p. and Bidention p.p*. vegetation is: Maintain 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 ranging from mineral alluvium to peat and marl (Coxon, 1987a; 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).

Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270) is found on damp, fine, mineral soils (typically alluvial muds). When floodwaters recede, relatively fertile, bare mud is exposed and rapidly colonised (NPWS, 2013a). The on-going development of the habitat depends on a continuous supply of fine sediment, which may be derived from an external source and delivered through groundwater or surface water, or from an internal supply resulting from natural sediment dynamics within the turlough. The soils of habitat 3270 usually remain saturated for a significant period of time after exposure, allowing the characteristic species to become established, but can dry out showing superficial cracking in late summer/autumn. Moisture is retained in the soils through a combination of local water table level and the water retention capacity/permeability of the soils.

The **TARGET** for the attribute soil type for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain variety, area and extent of soil types necessary to support turlough vegetation and other biota.

4.3 Soil nutrient status: nitrogen and phosphorus

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.

Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation appears to be associated with relatively fertile soils (relative to other turlough communities).

The **TARGET** for the attribute soil nutrient status, nitrogen and phosphorus for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain 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. It is important for certain vegetation communities, such as Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p.

vegetation. Bare ground in turloughs is also important for invertebrate communities, notably ground beetles (Regan, 2005a; Sheehy Skeffington *et al*., 2006).

Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is a dynamic habitat dominated by short-lived annuals, including the rare *Callitriche palustris*, *Limosella aquatica* and *Rorippa islandica,* that is found on the damp, bare ground resulting from naturally long flood duration and late recession. Sediment flux is also an important driver. It is not associated with areas of bare ground created by trampling by grazers.

The **TARGET** for the attribute Physical structure, bare ground for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain sufficient wet bare ground, as appropriate.

4.5 Chemical processes: calcium carbonate deposition and concentration

Calcium carbonate ($CaCO_3$) deposition is a feature of very many turloughs (Coxon, 1994; Goodwillie, 2003). Base-rich mineral soils appear to be typical of Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation, and precipitation of $CaCO_3$ from the water column may be an important contributor. 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. Changes in the hydrochemistry of water entering the turlough through inflowing streams and surface run-off (particularly those draining peat), require particular consideration.

The **TARGET** for the attribute chemical processes, calcium carbonate deposition and concentration for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain calcium carbonate ($CaCO_3$) deposition rate and/or concentration in soil.

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. Turlough water quality can be measured by the following attributes:

4.6.1 Water quality: nutrients

The Water Framework Directive (WFD) Working Group on Groundwater developed a methodology to assess the risk to turloughs from phosphorus pollution, which established provisional phosphorus thresholds for turlough floodwaters 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 indicated that when mean TP is ≤10µg/l a lake is oligotrophic and >10µg/l to ≤20µg/l is mesotrophic (McGarrigle *et al*., 2002, Appendix I). The Working Group on Groundwater (2005) categorised the 'natural trophic sensitivity' of 70 SAC turloughs as extremely high sensitivity to enrichment (1), high sensitivity (2) or medium sensitivity (3).

Work undertaken by Trinity College Dublin (TCD) 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, 2013a; 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 indicates 'Intermediate' quality and >50µg/l TP indicates 'Bad' quality.

While it may ultimately be necessary to set site-specific TP targets for turloughs, a target of ≤10µg/l TP is used here for more oligotrophic sites containing marl lake communities and/or dominated by fen and other sedge-rich vegetation of low-fertility and high species diversity. For less oligotrophic turloughs, where study demonstrates it can maintain favourable condition for the long-term, a target of ≤20µg/l TP can be applied. Where nutrient concentrations are lower than the targets, there should be no upward trend in concentrations.

The **TARGET** for the attribute water quality, nutrients for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain average annual total phosphorus (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 (72–85mg/l PtCo), had colour of <48mg/l PtCo, with the Burren turloughs all ≤14mg/l PtCo (Cunha Pereira *et al*., 2010; Waldren, 2015). A number of SAC turloughs are adjacent to raised bogs and may also have artificially increased water colour owing to drainage and exploitation of the peatland.

The **TARGET** for the attribute water quality, colour for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain 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 to be 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* >10µg/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 that the Ecological Quality Ratio (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 for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain appropriate chlorophyll *a* concentrations (annual mean <2.5µg/l or <8µg/l, annual maximum values ≤8µg/l 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) (Norman Allott, pers. comm.). The filamentous forms recorded include *Oedogonium*, *Spirogyra* and *Mougeotia* species (Norman Allott, pers. comm.). A few turloughs with high TP did not develop extensive algal mats, at least partly because of high water colour (Norman 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 for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation 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).
Active peat formation is not a feature of the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270).

The **TARGET** for the attribute active peat formation for Turloughs* is: Maintain active peat formation, where appropriate.

4.8 Vegetation composition: area of 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

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

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). Mapping and classification of turlough communities in practice can be challenging, as they can grade very gradually from one type to another (Goodwillie, 1992; Waldren, 2015; O'Neill and Martin, 2015).

The vegetation community of Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is composed of small, short-lived, fast-growing annuals that are poor competitors and includes a number of rare species (see typical species, Section 4.11). Goodwillie (1992) describes the community in his 'Wet annual' vegetation unit (8B). In conducting the conservation assessment, Goodwillie (2007) examined the phytosociological context of the habitat and concluded the following: "Schaminée *et al.* 1998 divide the ***Bidention tripartitae*** in the Netherlands into the ***Polygono-Bidentetum*** (3–110 days of inundation), the ***Chenopodietum rubri*** (50–250 days) and the ***Eleocharito acicularis – Limoselletum*** (130–300). This system has definite parallels in Ireland. All three communities may be recognized in turloughs and at the Gearagh . . .".

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.

In addition to the above listed turlough vegetation classifications, rare flora surveys and other sources listed in Section 5 may contain site-specific data on turlough vegetation communities. As discussed in Section 1.1, turloughs can contain plant communities that are associated with other habitats, such as hard water lakes and fens. Consideration should therefore be given to vegetation communities classified under other relevant surveys (e.g. Foss and Crushell, 2008; Perrin *et al*., 2008; Murphy and Fernández, 2009; O'Neill *et al*., 2013; Roden and Murphy, 2013; Wilson and Fernández, 2013; Perrin *et al*., 2014; Lyons and Kelly, 2016; see also http://www.biodiversityireland.ie/projects/national-vegetation-database/irish-vegetation-classification/).

The **TARGET** for the attribute vegetation composition, area of vegetation communities for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation 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) helps support invertebrate diversity.

The **TARGET** for the attribute vegetation composition, vegetation zonation for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation 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 for 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) stated "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".

As noted above, little if any grazing is required for the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270). Natural disturbance by flooding and sediment deposition is the main ecological driver of the habitat and it should not be confused with the wet annual community of common, 'weedy' species found on damp tracks and trampled/poached mineral soil.

The **TARGET** for the attribute vegetation structure, sward height for Turloughs* 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 2 lists the typical turlough plant species (NPWS, 2013a). 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 3 lists other more widespread vascular plant species that are commonly encountered in turloughs, often at high cover abundance.

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 2 includes species typical of the Annex I habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270) (NPWS, 2013a). Other species associated with habitat 3270 include *Atriplex prostrata*, *Gnaphalium uliginosum*, *Rorippa palustris*, *Persicaria hydropiper*, *Chenopodium rubrum*, *Juncus bufonius* and *Bidens tripartita*.

Table 2 **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 (Lockhart *et al*., 2012a; Wyse Jackson *et al*., 2016) is given, where relevant, as a superscript.

	Angiosperms
Dicots	*Callitriche palustris**† [VU], *Frangula alnus* (prostrate form*), *Galium boreale*, *Limosella aquatica*†*, *Persicaria minor*†, *Plantago maritima*, *Potentilla fruticosa** [VU], *Ranunculus repens* (form with highly dissected leaves*), *Rhamnus cathartica*, *Rorippa islandica**†, *Teucrium scordium**, *Viola persicifolia** [NT]
Monocots	*Alopecurus aequalis*† [NT], *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

Waldren (2015) stated “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*. (2012b) noted that *Cinclidotus fontinaloides* is characteristic of turloughs and that the Vulnerable *Pseudocalliergon lycopodioides* and Near Threatened *Drepanocladus sendtneri* can be locally abundant in turloughs. Some of the best, fen-vegetation-rich turloughs support the Vulnerable *Pseudocalliergon trifarium* (Lockhart *et al*., 2012b).

Table 3 **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
Mosses	*Fontinalis antipyretica, Scorpidium revolvens*

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

The **TARGET** for the attribute typical species, terrestrial, wetland and aquatic plants communities for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation is: Maintain typical species within and across the habitats

4.11.2 Typical species: aquatic invertebrates

NPWS (2013a) provided an updated list of typical aquatic invertebrate species of turloughs (see Table 4), 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, 1987b; 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 (NT) 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* (Endangered) 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 4 **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, i.e. most/all records for that species in Ireland are from turloughs. Regional Red List status (Foster *et al*., 2009) is given, where relevant, as a superscript.

	Plathyhelminthes
Turbellaria	*Polycelis nigra*
	Crustacea
Cladocera	*Alonella excisa, Alona rustica, Alonopsis elongate, Alona affinis, Eurycercus glacialis**
Copepoda	*Diaptomus castor*
	Insecta
Odonata	*Lestes dryas*, Sympetrum sanguineum*
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.).

No specific linkages have yet been made between aquatic invertebrates and the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270).

The **TARGET** for the attribute typical species, aquatic invertebrates for Turloughs* is: Maintain typical species within and across turloughs.

4.11.3 Typical species: other invertebrates

NPWS (2007, 2013a) provides a list of typical terrestrial invertebrate species of turloughs (see Table 5). The EU Interpretation Manual (European Commission, 2013) lists the following terrestrial invertebrate species as characteristic of turloughs: *Agonum lugens, A. livens, Badister meridionalis, Blethisa multipunctata* and *Pelophila borealis* (dry phase).

Table 5 **The typical terrestrial invertebrate species of turloughs (NPWS, 2007, 2013a).** Species indicated by * have a strong association with turloughs, i.e. most/all records for that species in Ireland are from turloughs.

	Diptera
Sciomyzidae	*Pherbellia nana, Colobaea distincta, Ilione albiceta, Pherbina coryleti*
	Lepidoptera
Crambidae	*Paraponyx stratiotata*
Tortricidae	*Bactra furfurana*
Gelechiidae	*Monochroa lutulentella*
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 peltatu*
Staphylinidae	*Philonthus furcifer*
Silphidae	*Thanatophilus dispar*
	Orthoptera
Tetrigidae	*Tetrix subulata*
Acrididae	*Chorthippus albomarginatus*
	Heteroptera
Saldidae	*Saldula opacula*

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, 2005a, 2005b; 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 5 are those which have been associated with turloughs and which feed on wetland species of plant. A possibly undescribed 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.

No specific linkages have yet been made between terrestrial invertebrates and the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270); however, the habitat is likely to be used by terrestrial wetland invertebrates when dry.

The **TARGET** for the attribute typical species, other invertebrates for Turloughs* is: Maintain typical species within and across turloughs.

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 have fewer waterbirds.

The **TARGET** for the attribute typical species, birds for Turloughs* is: Maintain typical species within and across turloughs.

4.12 Fringing habitats: area

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.

While the relationship between fringing habitats and the habitat Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation (3270), has not yet been established, it is likely that terrestrial invertebrates associated with habitat 3270 in late summer are reliant on fringing habitat for over-wintering.

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

Raised bog is a less common and important fringing habitat for some turloughs. The co-occurrence of and the maintenance/restoration of transitional vegetation between these two priority habitats is of high conservation value. See Sections 1.1 and 4.13 for information on more common turlough fringing habitats of conservation importance. Further investigation is required of the use of these fringing habitats where they co-occur by turlough invertebrate, bird and other vertebrate species.

The **TARGET** for the attribute fringing habitats, area for Turloughs* and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation 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” and “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 Coole-Garryland Complex SAC, 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, turlough woodland for Turloughs* is: Maintain appropriate turlough woodland diversity and structure.

5. Bibliography

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