National Parks & Wildlife Service

Lough Corrib SAC
(site code 000297)

Conservation objectives supporting document - raised bog habitats

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Contents

1 Introduction

This document presents a summary of the background information that has informed the process of setting the Site-Specific Conservation Objective in relation to the priority Annex I habitat 'active raised bogs' (habitat code 7110) (hereafter referred to as Active Raised Bog (ARB)), for which Lough Corrib Special Area of Conservation (SAC) has been designated. Within the SAC, the ARB for which the site has been selected occurs at Addergoole Bog and Lough Tee Bog. Whilst there are other areas of raised bog within the SAC, they are not considered to be part of the qualifying Annex I ARB habitat.

Lough Corrib SAC is also designated for two other related Annex I habitats, namely; 'degraded raised bogs still capable of natural regeneration' (habitat code 7120) (hereafter referred to as Degraded Raised Bog (DRB)) and 'depressions on peat substrates of the Rhynchosporion' (habitat code 7150). Based on the close ecological relationship between these three habitats types, it is not necessary to set specific Conservation Objectives for all three habitats individually. It is considered, that should favourable conservation condition for ARB be achieved in the SAC, then, as a consequence, favourable conservation condition for the other two habitats would also be achieved.

Lough Corrib SAC is also designated for the priority Annex I habitat 'bog woodland' (habitat code 91D0). A separate site-specific conservation objective has been set for bog woodland and therefore is not considered in this supporting document.

1.1 Raised Bogs

Raised bogs are accumulations of deep peat (typically 3-12m) that originated in shallow lake basins or topographic depressions. The name is derived from the elevated surface, or dome, that develops as raised bogs grow upwards through the accumulation of peat; the domed effect is often exaggerated when the margins of a bog are damaged by turf cutting or drainage, and are drying out. Raised bogs are most abundant in the lowlands of central and mid-west Ireland.

Irish raised bogs are classified into two sub-types (Schouten 1984): 1. Western or intermediate raised bogs, and 2. True midland or eastern raised bogs, based on phytosociological and morphological characteristics. In terms of overall morphology, the main difference between these two raised bog types is that while eastern raised bogs tended to stay more confined to the depressions in which they were formed, western raised bogs tended to grow out beyond their original basin, presumably a result of the higher rainfall levels (Cross 1990). In terms of vegetation differences the most obvious difference between the two bog types is the presence of a number of oceanic plant species on western raised bogs which are absent from the true midland raised bogs. The liverwort species *Pleurozia purpurea*[1] and the moss species *Campylopus atrovirens* grow on western raised bogs but not on eastern raised bogs; similarly, *Carex panicea* is generally more common on the high bog surfaces of western raised bogs (Schouten 1984). All of these plant species are widespread in the low-level Atlantic blanket bogs and their presence in western raised bogs is presumed to be due to the higher rainfall levels and greater rain-derived nutrient fluxes.

Exploitation has been extensive and none of the remaining Irish raised bogs are completely

[1] Note on species nomenclature: *In the case of plant species, only scientific names are used throughout the main text while common English names are included in tables. In the case of faunal species, common English names (where known) are used throughout the text together with scientific names.*

intact (Cross 1990). It is estimated that less than 10% of the original raised bog habitat in Ireland is in a near intact state (uncut), with less than 0.5% continuing to support ARB (DAHG 2014). Excavated face banks, whether active or inactive, are a common feature around the margins. Any areas where part of the bog has been removed are termed cutover bog, with the remaining area referred to as high bog or intact bog. In a natural state, raised bogs are circled by a wetland fringe, known as the lagg zone, which is usually characterised by fen communities. In Ireland, most laggs have been lost through drainage and land reclamation (Fossitt 2000).

The surface of a relatively intact raised bog is typically wet, acid, deficient in plant nutrients, and supports specialised plant communities that are low in overall diversity and comprising species adapted to the biologically harsh conditions. The vegetation is open, treeless and bog mosses or *Sphagnum* species dominate the ground layer. Small-scale mosaics of plant communities are characteristic and reflect the complex microtopography of hummocks and hollows on the bog surface (see Section 1.1.1 below). Raised bogs are driest at the margins and wetness generally increases towards the centre of the peat mass where well-developed pool systems are most likely to occur.

Raised bogs may also contain soaks and flushes (wet 'active' or dry 'inactive') due to the increased supply of nutrients over time through concentrated surface flows, or where there are links with regional groundwater or the underlying mineral substratum. Slight mineral enrichment and / or constant through flow of water provide conditions suitable for a range of species that are not typically associated with other areas of raised bog.

When damaged by peat extraction or drainage, the water table in the peat drops and the bog surface becomes relatively dry; pools are rare or absent, cover of bog mosses is greatly reduced and *Calluna vulgaris* increases in abundance. The drop in water table causes the peat to compress under its own weight causing the bog surface to deform. Greater deformation occurs closest to areas where the water table has dropped. This increases the slope of the bog surface causing rain falling on the ground surface to flow off the bog more quickly. The effect is normally greatest around the margins and in a typical situation wetness increases towards the centre of the bog. Trees such as *Betula pubescens* and *Pinus sylvestris* frequently invade the drier cut margins, but may also occur in flushed areas.

In Ireland, the Annex I habitat ARB is currently considered to be in unfavourable bad conservation status principally as a result of marginal turf cutting, semi-industrial peat extraction, and associated drainage effects caused by these activities (NPWS 2008; 2013). The lowering of regional groundwater levels is also known to have had an effect on some sites. Fires associated with turf cutting, dumping or agricultural activities may also adversely affect the condition of the habitat.

1.1.1 Raised Bogs Microtopography

Raised bogs are typically treeless and are characterised by a distinctive vegetation dominated by bog mosses (*Sphagnum*), sedges and dwarf shrubs, all of which are adapted to waterlogged, acidic and exposed conditions. Bog mosses, which have unique properties, are the principal component of peat, and are largely responsible for the typical surface features of hummocks, hollows, lawns and pools. The wettest bogs, which have extensive pool systems, have the greatest variety of plant and animal life and support a range of specialist species.

The following terms that describe microtopography are generally accepted in the study of mire ecology (Gore 1983). A schematic diagram showing the typical microtopographical divisions is presented in Figure 1.

Pools

Depressions in the bog surface where the water table remains above the surface level all year around or below surface level for only a very short period of time. They are characterised by the presence of aquatic plant species such as *Sphagnum cuspidatum*, *S. denticulatum* and *Cladopodiella fluitans*. In more degraded scenarios, or where high seasonal water fluctuation occurs, the pools contain open water and/or algae. Tear pools are found on bogs where internal tensions, due to mass movement of peat, has taken place within the high bog and has caused the development of elongated pools. These are frequently found on western bogs and may be natural or anthropogenic in origin.

Hollows

These are shallow depressions (less than 5cm deep) on the bog surface where surface water collects, or where the water table reaches or lies just above ground level, depending on seasonal conditions. They are often filled with *Sphagnum* species such as *S. papillosum* and *S. cuspidatum*. They take many forms but are often eye shaped. Marginal hollows tend to be elongated as they are focused points for surface water run-off. They are often dominated by *Narthecium ossifragum*.

Lawns

These are shallow hollows or flat areas where one species dominates to form a lawn. This is frequently a *Sphagnum* species, such as *Sphagnum magellanicum,* or *S. papillosum* which can completely fill in a hollow to form a small lawn.

Flats

These are more or less flat areas which are intermediate between hollow and hummock communities. They tend to be drier than the above situations.

Hummocks

These are mounds on the bog surface which can range from a few centimetres to more than one metre in height. They are usually composed mainly of *Sphagnum* species, such as *Sphagnum magellanicum, S. capillifolium, S. austinii* and *S. fuscum* but other bryophyte species such as *Hypnum jutlandicum* and *Leucobryum glaucum* are also important, especially as the hummock grows taller and becomes drier. *Calluna vulgaris* is another important element, as it flourishes where the water table is not at surface level (Kelly & Schouten 2002).

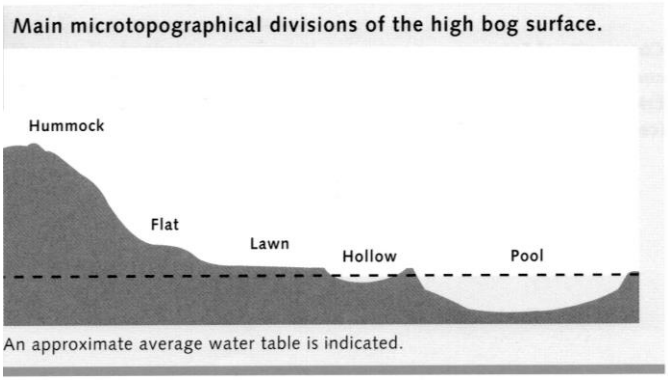


Figure 1 Raised bog microtopographical divisions on the high bog surface (reproduced from Kelly & Schouten 2002).

1.1.2 Typical Flora of Irish Raised Bogs

Raised bogs are characterised by a distinctive vegetation dominated by a variety of mosses (e.g. *Sphagnum* spp*., Hypnum* spp*., Racomitrium* spp.), sedges and grass-like species (e.g. *Eriophorum* spp*., Rhynchospora* spp*., Narthecium ossifragum, Molinia caerulea* and *Carex* spp.), and dwarf shrubs (e.g. *Calluna vulgaris, Erica tetralix, Vaccinium spp.* and *Empetrum nigrum*). In addition to these groups, a number of other species characterise raised bogs including carnivorous plants (e.g. *Drosera spp., Utricularia spp.*), lichens of both the bog surface and epiphytes on the stems of dwarf shrubs and the occasional trees on bogs (e.g. *Cladonia* spp*., Usnea* spp.). Herbaceous plants are not a significant element on raised bogs and include a few commonly occurring species such as *Menyanthes trifoliata, Pedicularis sylvatica*, and *Potentilla erecta* (Cross 1990).

Drier areas and hummocks usually support *Calluna vulgaris*, *Eriophorum vaginatum*, *Trichophorum germanicum*, *Erica tetralix*, lichens (*Cladonia* spp.), bog mosses (*Sphagnum capillifolium*, *S. austinii*, *S. fuscum*, *S. papillosum*), and other mosses (*Dicranum scoparium*, *Leucobryum glaucum*). Wet hollow areas and pools are characterised by *Eriophorum angustifolium*, *Rhynchospora alba*, *Narthecium ossifragum*, *Drosera* spp., *Menyanthes trifoliata*, bladderworts (*Utricularia* spp.), and bog mosses (*Sphagnum cuspidatum, S. denticulatum and S. magellanicum*).

A list of flora species that are regarded as being typical of ARB habitat in Ireland is presented in Table 1. A number of these typical species would have a restricted distribution and do not occur throughout the range of the habitat in Ireland (see above), therefore only a subset of these species would be expected to be present on any individual site.

Table 1 Flora species typically associated with active raised bog in Ireland (after NPWS 2013). *Species list is based on vegetation communities defined by Kelly (1993) and Kelly & Schouten (2002).*

Common name	Scientific Name
Bog rosemary	*Andromeda polifolia*
Bog bead moss	*Aulacomnium palustre*
Bristly Swan-neck moss*	*Campylopus atrovirens**
Lichen	*Cladonia ciliata*
Lichen	*Cladonia portentosa*
Long leaved sundew	*Drosera anglica*
Intermediate leaved sundew*	*Drosera intermedia**
Round leaved sundew	*Drosera rotundifolia*
Common cotton grass	*Eriophorum angustifolium*
Hare's tail cotton grass	*Eriophorum vaginatum*
Large white moss	*Leucobryum glaucum*
Bogbean	*Menyanthes trifoliata*
Bog asphodel	*Narthecium ossifragum*
Purple spoonwort*	*Pleurozia purpurea**
Woolly fringe moss*	*Racomitrium lanuginosum**
White beak-sedge	*Rhynchospora alba*
Austin's bog moss	*Sphagnum austinii*
Red bog moss	*Sphagnum capillifolium*
Feathery bog moss	*Sphagnum cuspidatum*
Cow-horn bog moss*	*Sphagnum denticulatum**
Rusty bog moss	*Sphagnum fuscum*
Magellanic bog moss	*Sphagnum magellanicum*
Papillose bog moss	*Sphagnum papillosum*
Golden bog moss*	*Sphagnum pulchrum**
Lustrous bog moss	*Sphagnum subnitens*
Bladderwort	*Utricularia minor*
Cranberry	*Vaccinium oxycoccos*

*Notes: * Species more typical of western raised bog sites.*

1.1.3 Typical Fauna of Irish Raised Bogs

Raised bogs are extremely nutrient poor ecosystems. Acidic, waterlogged and exposed conditions make them an unattractive habitat for animal life. As a consequence they are relatively poor both in terms of species diversity and population densities. Many species are opportunists, vagrant or temporary rather than specialists, but nonetheless may have an important impact on the ecosystem through nutrient imports and exports or other interactions (Cross 1990). A list of fauna species that would be typically associated with raised bog habitat in Ireland is presented in Table 2. The species listed are not confined to ARB and most, if not all, will use other areas of the bog and surrounding habitats.

Raised bog is unsuitable habitat for many vertebrates due to the lack of available foraging and suitable breeding places. The Irish hare is the only mammal commonly occurring. The common frog is the most common vertebrate predator.

Although 18 species of birds have been reported breeding on raised bogs (Wilson 1990) many of these species utilise the bog as a nesting habitat only. They are dependent on other neighbouring habitats such as open water bodies, callows and wet grassland particularly for

feeding. Just a few species of bird, including meadow pipit (*Anthus pratensis*), skylark (*Alauda arvensis*) and curlew (*Numenius arquata*) complete their full breeding cycle on the bog and the first two species are the commonest species occurring (Bracken *et al.* 2008). Red grouse (*Lagopus lagopus*) must also be included as a typical bog species, occurring year round as a resident. Red grouse and curlew have declined significantly on raised bogs in recent times. BirdWatch Ireland has published an Action Plan for Raised Bog Birds in Ireland which lists 13 species of conservation concern that are associated with Raised Bogs (O'Connell 2011). A recent review of birds of conservation concern in Ireland has since added meadow pipit (*Anthus pratensis*) to the red (most endangered) list of Birds of Conservation Concern in Ireland (BoCCI) (Colhoun & Cummins 2013).

Our knowledge of the invertebrate assemblages associated with Irish raised bogs remains incomplete (particularly micro-invertebrate species) with few studies undertaken (Reynolds 1984a; Reynolds 1984b; Reynolds 1985; De Leeuw 1986; O Connor et al. 2001; Crushell et al. 2008; Hannigan & Kelly-Quinn 2011; Wisdom & Bolger 2011). Van Duinan (2013) highlights the importance of structural diversity at various spatial scales (e.g. micro-scale of hummock hollow topography to macro-scale which would include the landscape setting of the bog, see Schouten (2002)) as a prerequisite for hosting the full species diversity of raised bog landscapes.

A recent study of Lepidoptera associated with raised bogs identified two species that appear to be characteristic of higher quality raised bog habitat, namely bordered grey (*Selidosema brunnearia* (Villers 1789)) and light knot grass (*Acronicta menyanthidis* (Esper, 1789)) (Ciara Flynn pers. comm.).

Recent research on spiders has revealed that a number of species are known to occur in Ireland only on raised bog habitats, all of which are considered local/uncommon or rare across Europe (Myles Nolan pers. comm.). Five of these species that can be considered useful indicators of ARB include: *Glyphesis cottonae* (La Touche 1945), *Walckenaeria alticeps* (Denis 1952), *Satilatlas britteni* (Jackson 1913), *Pirata piscatorius* (Clerck 1757), and *Minicia marginella* (Wider 1834) (Myles Nolan pers. comm.).

The information currently available on other invertebrate groups of peatland systems in Ireland is not sufficient to allow a determination of many species that are typically associated with or may be characteristic of higher quality ARB. A selection of invertebrate species and species groups that are known to be typically associated with raised bogs are included in Table 2.

Table 2 Fauna species typically associated with raised bog ecosystems in Ireland (after O'Connell 1987; Cross 1990; Renou-Wilson *et al.* 2011; Bracken & Smiddy 2012).

Common name	**Scientific name**
Mammal species	
Irish hare	*Lepus timidus hibernicus*
Otter	*Lutra lutra*
Pygmy shrew	*Sorex minutes*
Fox	*Vulpes vulpes*
Bird species	
Skylark	*Alauda arvensis*
Mallard	*Anas platyrhynchos*
Greenland white-fronted goose	*Anser albifrons flavirostris*
Meadow pipit	*Anthus pratensis*
Hen harrier	*Circus cyaneus*
Cuckoo	*Cuculus canorus*
Merlin	*Falco columbarius*
Kestrel	*Falco tinnunculus*
Snipe	*Gallinago gallinago*
Red grouse	*Lagopus lagopus*
Curlew	*Numenius arquata*
Golden plover	*Pluvialis apricaria*
Lapwing	*Vanellus vanellus*
Reptiles and amphibians	
Common lizard	*Lacerta vivipara*
Common frog	*Rana temporaria*
Typical invertebrates	
Black slug	*Arion ater*
Large heath butterfly	*Coenonympha tullia*
Marsh fritillary butterfly	*Euphydryas aurinia*
Bog-pool spider	*Dolomedes fimbriatus*
Water striders	*Gerris* and *Velia* species
Oak eggar moth	*Lasiocampa quercus*
Four-spotted chaser dragonfly	*Libellua quadrimaculata*
Fox moth	*Macrothylacia rubi*
Ant	*Myrmica ruginodis*
Emperor moth	*Saturnia pavonia*
Great green bog grasshopper	*Stethophyma grossa*
Other species groups that are well represented on raised bogs include:	Araneae (spiders and mites)
	Ceratopogonidae (biting-midges)
	Chironomids (non-biting midges)
	Coleoptera (beetles)
	Collembola (springtails)
	Diptera (true flies)
	Dytiscidae (water beetles)
	Hemiptera (true bugs)
	Hymenoptera (bees, wasps, ants and sawflies)
	Lepidoptera (butterflies and moths)
	Odonta (dragonflies and damselflies)
	Orthoptera (grasshoppers)
	Syrphidae (hoverflies)
	Tipulidae (craneflies)
	Tabanidae (horseflies)

1.2 Habitats Directive Raised Bog Habitats in Ireland

Four habitat types listed on Annex I of the EU Habitats Directive are typically associated with raised bogs in Ireland, two of which are priority habitats (*):

- 7110 Active raised bogs* (ARB)
- 7120 Degraded raised bogs still capable of natural regeneration (DRB)
- 7150 Depressions on peat substrates of the Rhynchosporion
- 91D0 Bog woodland*

The interpretation manual of EU habitats gives the following description for ARB: "*Acid bogs, ombrotrophic, poor in mineral nutrients, sustained mainly by rainwater, with a water level generally higher than the surrounding water table, with perennial vegetation dominated by colourful Sphagna hummocks allowing for the growth of the bog (Erico-Sphagnetalia magellanici, Scheuchzerietalia palustris p., Utricularietalia intermedio-minoris p., Caricetalia fuscae p.). The term "active" must be taken to mean still supporting a significant area of vegetation that is normally peat forming, but bogs where active peat formation is temporarily at a standstill, such as after a fire or during a natural climatic cycle e.g., a period of drought, are also included*." (CEC 2007).

DRB should be, according to the interpretation manual capable of regeneration to ARB in 30 years if appropriate measures are put in place (i.e. no major impacting activities are present and any necessary restoration works are implemented).

In Ireland, the identification of ARB is made at ecotope level based on the vegetation classification developed by Kelly (1993) and Kelly & Schouten (2002).

Raised bog vegetation communities are grouped into a series of community complexes and these complexes are then amalgamated into a series of ecotopes characterised by different physical characteristics using the approach outlined by Kelly & Schouten (2002).

The main ecotopes that community complexes are grouped into include:

- Central ecotope
- Sub-central ecotope
- Active flushes and soaks
- Sub-marginal ecotope
- Marginal ecotope
- Inactive flushes
- Face-bank ecotope

Actively accumulating peat conditions occur within the sub-central and central ecotopes, which are the wettest on the bog and an indication of good quality ARB. Active flushes and soaks are also dominated by *Sphagnum* mosses and typically have wet conditions. These features are associated with ARB and contribute to the overall diversity of the habitat.

The adjacent surrounding marginal, sub-marginal, and face-bank bog areas typically have a supporting function for the central and sub-central communities but are not peat accumulating. These drier ecotopes may or may not correspond to the Annex I habitat DRB, as it depends on whether they are capable of regeneration to ARB. Other drier ecotopes recorded on the high bog that do not correspond to ARB include 'inactive flushes' which typically have a low *Sphagnum* cover.

The Annex I habitat Rhynchosporion depressions (7150) typically occurs along pool edges and on flats underlain by deep, wet and quaking peat. Typical plant species include *Rhynchospora alba*, *Drosera anglica*, *Narthecium ossifragum*, *Sphagnum cuspidatum*, *S. denticulatum*, *S. magellanicum*, *S. papillosum*, *Menyanthes trifoliata*, and *Eriophorum angustifolium*.

The priority Annex I habitat bog woodland is also actively peat-forming and overlaps with the ARB habitat. Such woodlands are usually dominated by *Betula pubescens* with a characteristic ground cover dominated by *Sphagnum* moss species, which often form deep carpets, and other mosses including species of *Polytrichum*. A separate conservation objective has been prepared for bog woodland. Woodland areas are occasionally found on raised bogs that have an absence of the characteristic moss layer and are not regarded as peat forming. Such areas do not correspond to the Annex I habitat.

1.2.1 Restoration of Raised Bog habitats in Ireland

As already mentioned in the section 1.1, ARB is currently considered to be in unfavourable bad conservation status in Ireland. In addition, according to its definition, DRB should be capable of regeneration to ARB in a 30-year timescale. Thus, it follows that restoration measures are required in order to halt further losses and increase the area of ARB as well as to improve the condition of existing areas of the Annex I habitat.

Most of the restoration works undertaken so far in Ireland have concentrated on the high bog (e.g. Clara Bog, Mongan Bog, Sharavogue Bog and Raheenmore Bog) to prevent further losses as well as to restore areas to ARB. Nevertheless, some restoration works have also been undertaken on cutover areas such as at Ballykenny and Fisherstown Bogs and Killyconny Bog. Such work aims to do one or more of the following (depending on the bog in question): restore ARB on the high bog; reduce further ARB and DRB loss on the high bog; restore peat forming habitats (such ARB, bog woodland, poor fen) on the cutover.

Works undertaken by the NPWS have indicated that there are significant differences, both ecological and economic, when comparing the effectiveness of works carried out on the cutover with those carried out on the high bog. Positive and significant results (i.e. expansion or development of ARB) can be achieved over a relatively short timeframe (10 years) on favourable areas of the high bog by blocking high bog drains. In contrast, a longer time period (30 years+) is required to achieve active peat formation on cutover areas, and even then the results are generally confined to smaller areas; i.e. flat areas (≤0.3% surface slope) or enclosed depressions that have sufficient water flow (minimum catchment 0.5ha) to maintain wet conditions throughout the year. A longer time period (minimum 50-100 years) is likely to be required for high quality ARB habitat (vegetation structure and species diversity) to develop on such cutover areas. In addition, costs of restoration measures on cutover areas are typically significantly higher than those on high bog areas.

1.3 Lough Corrib SAC

Lough Corrib is situated north of Galway City extending westwards c.35km. It consists of a shallower lake basin to the south and a larger, deeper basin to the north. The bedrock is mostly limestone, with sandstone to the north.

The main area of raised bog in this SAC is found at Addergoole, between the Cregg and Clare rivers that flow along the northern and southern boundary of the bog respectively. Addergoole Bog also includes areas of cutover bog, fen, a bog lake, and a soak system.

Lough Tee Bog, which is located approximately 7km east of Monivea and within the townlands of Ballyglass, Clonkeenkerrill and Gorteen, also includes cutover bog and a conifer

plantation on the high bog and cutover to the east.

The SAC has been selected for 13 Annex I habitats and nine Annex II species. The peatland habitats for which the site has been selected are:

- [7110] Active raised bogs*
- [7120] Degraded raised bogs still capable of natural regeneration
- [7210] Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae*
- [7230] Alkaline fens
- [91D0] Bog woodland*

1.3.1 Addergoole Bog

Addergoole Bog is a good example of a western raised bog located on the eastern shores of Lough Corrib approximately 8km north of Galway city. The Galway to Headford road runs by the east of the present extent of the bog.

At Addergoole a substantial soak system occurs which includes *Betula pubescens* bog woodland, active flush and bog lakes. The open water in this area is infilling with large rafts of Rhynchosporion vegetation.

Hydrological modelling suggests that the largest part of the uncut high bog comprises DRB. Peat cutting threatens Addergoole Bog and already a substantial area of the high bog has been cut particularly along the eastern margin.

Addergoole Bog represents one of the extreme western examples of raised bog in the country and thus the conservation of priority habitats (ARB habitat and bog woodland) at the site is particularly important to ensure the retention of the natural range of these habitats (Kelly *et al.* 1995; Fernandez *et al.* 2005; 2006; 2014a,b).

1.3.1.1 Flora of Addergoole Bog

Addergoole Bog is an example of a western broad floodplain raised bog, characterised by the occurrence of typical western plant species. ARB present on the bog includes central and sub-central ecotope, active flushes, and bog woodland (Kelly *et al.* 1995; Fernandez *et al.* 2014a,b).

Western raised bog indicators, including *Campylopus atrovirens* and *Pleurozia purpurea*, occur throughout the ARB. Species indicative of flushed conditions, such as *Myrica gale, Molinia caerulea, Aulacomnium palustre* and *Empetrum nigrum* are more frequent throughout ARB, especially in the northern half of the bog, than is typical for raised bogs (Kelly *et al.* 1995).Two central ecotope community complex types that have been recorded are characterised by high (51-75%) cover of *Sphagnum* with 11 to 25% cover of interconnected *Sphagnum cuspidatum* and *S. denticulatum* pools. Lawns of *S. papillosum, S. magellanicum,* and *S. cuspidatum* extend from pools. Low and high hummocks of *S. capillifolium, S. austinii, S. fuscum* and *Leucobryum glaucum* were present. In addition very wet lawns of *Sphagnum* (cover c.85%), mainly *S. papillosum* and *S. magellanicum*, with frequent low hummocks of *S. capillifolium, S. austinii, Aulacomnium palustre* and occasionally *S. fuscum* are also present (Fernandez *et al.* 2014a,b).

The highest quality sub-central community complex has a substrate that is very soft to quaking with high (51-75%) *Sphagnum* cover and frequent (11-25% cover) interconnecting pools dominated by *S. cuspidatum* with some *S. denticulatum*. Interpool areas are low, with prominent *Rhynchospora alba* and *Myrica gale*, as well as *Eriophorum* species. *Campylopus*

atrovirens is locally frequent. The most widespread sub-central community complex recorded is characterised by low hummocks and lawns of *Sphagnum papillosum* and *S. magellanicum* with low *Calluna vulgaris*, *Rhynchospora alba,* and *Eriophorum angustifolium*. Small pools are scattered throughout, and these are mainly shallow and filled with *Sphagnum cuspidatum*.

In the north-east of the bog, a very wet and somewhat flushed complex was recorded in which tall *Calluna* is abundant, along with *Eriophorum vaginatum* and lesser amounts of *E. angustifolium*, *Erica tetralix*, *Empetrum nigrum*, and *Aulacomnium palustre*. *Sphagnum capillifolium* and *S. papillosum* are the most abundant *Sphagna*. Another flushed complex type is present in the northern half of the bog, with less *Sphagnum* and more cover of *Eriophorum vaginatum* and *E. angustifolium*. A poor quality complex transitional to sub-marginal ecotope occurs in the southern half of the bog. This complex is characterised by frequent (11-25% cover) *Sphagnum cuspidatum* dominated pools separated by high interpool areas dominated by *Calluna* that are relatively dry and firm underfoot (Fernandez *et al.* 2014a,b).

The active central flush or soak that bisects the bog is extremely wet. It is in effect a large *Sphagnum cuspidatum* dominated pool with abundant islands composed of *Aulacomnium palustre* topped by *Calluna vulgaris*, *Molinia caerulea*, and *Juncus effusus*. *Menyanthes trifoliata* is locally abundant.

The active part of the central flush contains two pool systems. The southern pool system consists of two areas of open water with some emergent *Menyanthes trifoliata*. These are bounded by stands of *Molinia caerulea* and occasional *Juncus effusus* that graded into floating mats of *Sphagnum cuspidatum* with some *S. fallax* and *S. palustre*.

The pool at the north-east end of the flush consists of open water and a floating *Sphagnum cuspidatum* mat with occasional tussocks of *Molinia caerulea*. Away from the pools, the transition from inactive to active flush comprises a seasonally flooded area with frequent pools containing *Sphagnum cuspidatum* and *S. palustre*. *Aulacomnium palustre* hummocks are frequent at the edges of the pools with tall *Calluna vulgaris*, *Eriophorum vaginatum*, and *Myrica gale* abundant between pools.

Bog woodland is found on the high bog at Addergoole within the central flush where it covers 1.22ha (Fernandez *et al.* 2014a,b).

1.3.2 Lough Tee Bog

Lough Tee Bog is a basin bog and a good example of a western raised bog. This bog is part of a much larger bog complex and includes a larger section of bog to the west, which contains small lakes and flushes, but which is not included in the SAC.

The main high bog area is quite flat, allowing for an accumulation of water and ARB areas. Hydrological modelling suggests that much of the uncut high bog comprises DRB. Peat cutting threatens Lough Tee Bog and already a substantial area of the high bog has been cut, particularly along the south-western and northern margins.

Lough Tee Bog represents one of the extreme western examples of raised bog in the country and thus the conservation of priority habitats (ARB habitat) at the site is particularly important to ensure the retention of the natural range of these habitats (Kelly *et al*. 1995; Derwin *et al*. 2002; Fernandez *et al.* 2006).

1.3.2.1 Flora of Lough Tee Bog

As a good example of a western basin raised bog, Lough Tee Bog is characterised by the occurrence of typical western plant species. ARB present on the bog includes central and

sub-central ecotopes and active flushes (Kelly *et al*. 1995; Derwin *et al*. 2002 and Fernandez *et al*. 2006).

ARB is found at four locations on this bog which includes one central ecotope area, two sub-central ecotope areas and an active flush.

The highest quality ARB consists of central ecotope and is found in the north west of the bog. It is very wet and quaking. Many large long pools are present, which are vegetated with *Sphagnum cuspidatum, Menyanthes trifoliata* and *Drosera anglica*. There is about 90% S*phagnum* cover including large hummocks of *S. austinii, S. capillifolium, S. magellanicum, S. papillosum* and *S. fuscum*. *Narthecium ossifragum*, *Erica tetralix*, *Rhynchospora alba* and *Eriophorum vaginatum* were also recorded, as well as small algal-dominated pools.

The Western indicator species *Pleurozia purpurea* was reported by Derwin *et al*. (2002) at the edges of pools as well as *Rhynchospora fusca* and *Sphagnum denticulatum* in the pools.

Two sub-central ecotope areas were described by Fernandez *et al*. (2006), including a small section in the north-east of the bog which was described as very wet and quaking but with poorly developed micro-topography. Scattered *Sphagnum austinii*, *Calluna vulgaris and Hypnum jutlandicum* hummocks were recorded within it. Large pools dominated by S. *cuspidatum*, S. *papillosum* as well as *S. magellanicum* and *Drosera anglica* were noted. *Menyanthes trifoliata* was also recorded within the pools. The inter-pool areas were dominated by *Narthecium ossifragum, Rhynchospora alba* lawns and scattered *Eriophorum angustifolium.* Low *Calluna vulgaris* hummocks were also recorded as well as small algal-dominated pools. A larger section of sub-central ecotope is found in the middle section of the bog. This area supports better quality vegetation than the one above with larger pools and abundant *Sphagnum magellanicum* lawns.

An active peat forming flush is found to the north-west of the bog. *Sphagnum* cover, mostly *S. capillifolium* and S. *papillosum,* reaches 100% in places. Hummocks of *S*. *austinii* and *S. fuscum* were also recorded. *Eriophorum angustifolium* and *Empetrum nigrum* were abundant and *Calluna vulgaris, Erica tetralix* and *Vaccinium oxycoccos* were also present, as well as *Cladonia portentosa and C. uncialis*.

The remaining high bog consists of non-active vegetation: sub-marginal, marginal ecotopes and a conifer plantation along the east. Sub-marginal ecotope is characterised by the abundance of *Narthecium ossifragum* up to 60 % in places, tussocky *Trichophorum germanicum, Calluna vulgaris* and *Erica tetralix*. *Sphagnum* cover reaches 30-40% in places and mostly consists of *S. papillosum* and *S. capillifolium*. Tear pools are also present in places and although *Sphagnum cuspidatum, Menyanthes trifoliata* and *D. anglica* were recorded within them, the inter-pool areas are very low in *Sphagnum* cover. Low *S. austinii* and *S. capillifolium* hummocks with *Vaccinium oxycoccos, Empetrum nigrum* and *Hypnum jutlandicum* were also found, as well as *Huperzia selago*.

1.3.3 Fauna of Addergoole and Lough Tee Bogs

Many of the typical fauna associated with raised bog habitats are likely to occur at both Addergoole Bog and Lough Tee Bog (see Section 1.1.3 above). However, there is a lack of documented site-specific data relating to the fauna of the bog.

2 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 for habitats 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. Attributes and targets may change or become more refined as further information becomes available.

National Conservation Objectives for raised bog SACs have recently been published in the Draft National Raised Bog SAC Management Plan (DAHG 2014). The various attributes and the justification of appropriate targets used to define favourable conservation condition for ARB relevant to Addergoole and Lough Tee Bogs are discussed in the following sections.

2.1 Area

NPWS has commissioned a number of raised bog surveys between 1993 and the present - Kelly *et al*. (1995); Derwin & MacGowan (2000); Derwin *et al*. (2002); Fernandez *et al*. (2005); Fernandez *et al*. (2006); Fernandez *et al*. (2014). Mapping from these surveys has been used to derive the area of ARB for each bog as shown in Table 3. More recent surveys have been able to employ more precise and detailed mapping techniques and more standardised ecotope descriptions. NPWS undertook a review of data from earlier surveys in 2014 taking into account these improved techniques with the aim of providing more accurate figures for ARB. This in some cases has resulted in a change in ARB area for these earlier time periods (NPWS, unpublished data).

The national SAC target for the attribute 'habitat area' has been set at 2,590ha (DAHG 2014). This target is based on the estimated area of ARB (1,940ha) and DRB (650ha) present within the SAC network in 1994 (when the Habitats Directive came into effect).

The total area of ARB in Lough Corrib SAC in 1994 is not known as the high bog at Lough Tee was first surveyed in 2003 (Fernandez *et al*. 2006). The area of ARB at Addergoole Bog in 1994 is estimated to have been 59.0ha, while the area of DRB is estimated to have been 2.6ha at that time (see Table 3). Using the same approach that has been adopted in setting the national SAC target, the site-specific target for Addergoole Bog would equate to 61.6ha (sum of ARB and DRB in 1994). However, due to a lack of data it is not possible to set such a target for Lough Tee Bog.

In setting the site-specific target, the current hydro-ecological conditions on the bogs (including cutover) have been considered in order to ensure that the target being set is based on a realistic appraisal of what is achievable as set out below.

As there is an absence of more recent data for Lough Tee Bog, the 2003 area figure has been used for the ARB target (see Table 3 below).

The most recent monitoring surveys of Addergoole Bog estimated the area of ARB to be 39.2ha (Fernandez et al. 2014a,b). This represents a decline of 19.8ha (33.6%) during the period 1994 - 2012. An additional survey undertaken in 2005 shows that most of this decline occurred during the period 1994-2005 and that in fact, the area of ARB only decreased slightly during the period 2004-2012 as a result of drying out of areas in the north-east caused by peat cutting activities, and cracking and slumping of the bog in the east (see Table 3) (Fernandez *et al*. 2014a,b).

The current extent of DRB as estimated using a recently developed hydrological modelling

technique, based largely on Light Detection And Ranging (LiDAR)[2] data, is 72.0ha (see DAHG 2014 for further details of the technique). This represents the area of the high bog, which does not currently contain ARB but has topographical conditions deemed suitable to support ARB (see Map 1 which shows the total area of current and modelled potential ARB). This area was refined to 24.1ha by estimating the area that could be restored by blocking drains on the high bog. This refinement was based on applying an efficacy factor (see DAHG 2014).

Based on the current assessment of the bog above, it is therefore concluded that the maximum achievable target for ARB on the high bog is 69.3ha. However, it is important to note that this assumes no further decline of ARB due to losses of high bog caused by turf cutting and drainage activities associated with same (Fernandez *et al*. 2014a,b). Similarly, should the bog be significantly dependent on regional groundwater levels then any deepening of drains in the cutover could further impact the potential restoration of ARB on the high bog.

Table 3 Area of ARB and DRB recorded on the high bog at Addergoole and Lough Tee Bogs in 1994, 2005 and 2012 (Source: Fernandez *et al*., 2014a,b).

	1994		**2003/2005**		**2012**	
	ARB (ha)	DRB (ha)	ARB (ha)	DRB (ha)	ARB (ha)	DRB (ha)
Addergoole Bog	59.0	2.6	39.7	Unknown	39.2	17.7
Lough Tee Bog	Unknown	Unknown	6.0	Unknown	6.0[3]	6.4
Lough Corrib SAC	**Unknown**	**Unknown**	**45.7**	**Unknown**	**45.2**	**24.1**

A recent eco-hydrological assessment of the cutover surrounding the high bog undertaken as part of the restoration planning process estimates that, by implementing appropriate management, an additional 9.5ha of ARB could be restored in these areas. The long term achievable target for ARB in Lough Corrib SAC is therefore set at 78.8ha.

In conclusion, the site-specific target for the attribute habitat area is: **Restore area of active raised bog to 78.8ha, subject to natural processes.**

2.2 Range

At a national scale, range represents the geographic range that encompasses all significant ecological variations of the ARB habitat. The national SAC target for the attribute 'range' has been set as 'not less than current range, subject to natural processes'.

However, range, in the form of habitat distribution, may also be important at the site level, particularly within larger SACs, including those containing a number of individual bogs (i.e. complexes). The attribute therefore under the parameter of range is 'habitat distribution'. At the local level, it is important to conserve the variability and distribution of ARB across a raised bog SAC. This will help to ensure the diversity of the habitat is maintained while lessening the impact of localised damaging activities such as fire.

The conservation of ARB within Addergoole and Lough Tee Bogs as set out in Section 2.1 above will contribute to safeguarding the national range of the habitat.

[2] LiDAR is a remote sensing technology that measures vertical surface elevation by illuminating a target with a laser and analysing the reflected light. This provides much more detailed topographical maps than can be collected by traditional surveying techniques.

[3] This data is based on the most recent vegetation survey of the bog (in this case 2003). Based on the trend recorded at other sites, the extent of ARB in 2012 is likely to be less.

The ARB habitat at Addergoole Bog includes central and sub-central ecotopes, as well as active flush and soaks, and bog woodland. Lough Tee Bog supports central, sub-central ecotopes and active flush vegetation. A map showing the most recently surveyed distribution of ecotopes throughout Addergoole Bog and Lough Tee Bog is presented in Map 2.

The site-specific target for the attribute habitat distribution is: **Restore the distribution and variability of active raised bog across the SAC.**

2.3 Structure and functions

Structure and functions relates to the physical components of a habitat ("structure") and the ecological processes that drive it ("functions"). For ARB these include attributes such as the hydrological regime, water quality, habitat quality, species occurrence, elements of local distinctiveness, marginal habitats, negative physical indicators, and negative species occurrence. As several of these attributes are inter-connected, they are all included in order to better define habitat quality in a meaningful way. In some cases, attribute targets are not quantified; however, as more detailed information becomes available (for example through further research), more measurable site-specific targets may be developed. Structure and functions attributes are expanded on in the sections below.

2.3.1 High bog area

On individual raised bogs adequate high bog is required to support the development and maintenance of ARB. Raised bog habitat that is classified as neither ARB nor DRB is still important particularly as a supporting habitat for those listed in Annex I of the Habitats Directive. It is an essential part of the hydrological unit which supports ARB and DRB habitats. High bog is of value in its own right as a refuge for species characteristic of drier bog conditions and for providing a transitional zone between the Annex I habitats of the high bog and surrounding areas. Additional values for the maintenance of high bog include the preservation of its record of past environmental conditions and carbon storage. The area of high bog in the entire SAC network in 1994 was 10,740ha. The corresponding area in 2012 is 10,515ha – indicating that there has been a 225ha loss of high bog since 1994.

The national target for the attribute 'high bog' habitat is to ensure no decline in extent of high bog to support the development and maintenance of ARB.

The area of high bog within Addergoole Bog in 1994 was mapped as 161.4ha, while the corresponding area in 2012 is 157.4ha (based on interpretation of LiDAR and aerial photography flown in 2012), representing a loss of 4.0ha of high bog. Using the same methodology, the area of high bog within Lough Tee Bog in 1994 was mapped as 79.8ha and 79.6ha in 2012, representing a loss of 0.2ha of high bog (DAHG 2014). The extent of high bog within Addergoole and Lough Tee Bogs in 2012 is illustrated on Map 1.

The site-specific target for the attribute high bog is: **No decline in extent of high bog necessary to support the development and maintenance of active raised bog**.

2.3.2 Hydrological regime: water levels

Hydrological processes are key drivers of raised bog ecology. The different raised bog communities, assemblages and species are affected by various hydrological attributes. For ARB, mean water levels need to be near or above the surface of bog lawns for most of the year. Seasonal fluctuations should not exceed 20cm, and water levels should be within 10cm of the surface, except for very short periods of time (Kelly & Schouten 2002). Gentle slopes that limit intermittent lateral losses of water (through surface runoff) and encourage

sustained waterlogging are the most favourable to achieve these conditions. These conditions may be maintained on steeper slopes in areas of focused flow (flushes).

The traditional view of water flowing across the bog laterally has been recently refined to also consider that water flows vertically through peat into the underlying mineral substrate. Water loss by this route depends on the permeability of the material through which the water must flow and the difference in head (water level elevation) in the bog and underlying mineral substrate; larger differences encountered in higher permeability materials will result in greater losses. Although the proportion of water lost in this manner may be small, the sustained loss during prolonged dry periods may be sufficient to impact bog ecotopes. Drains extending into the mineral substrate in marginal areas surrounding the bog can lead to an increased gradient between the head in the peat and the head in the underlying substrate, resulting in increased vertical water losses from the bog.

The most recent description of drainage at Addergoole is presented in Fernandez *et al.* (2014a,b). This reports that 5.4km of high bog drains are considered to be having an impact upon raised bog habitats. Drains associated with either currently active or former peat cutting facebanks are present along the entire bog perimeter, with the exception of the northern margin, which grades naturally into fen. A 1.5km long, wide drainage system is located to the west of the high bog on cutover bog; it flows mainly northwards into the Cregg River and eventually into Lough Corrib. It is likely that this drain is actively maintained. No drains have been blocked either on the high bog or on the surrounding cutover.

There are a number of drains crossing the high bog at Lough Tee Bog, most of which were already present in the 1970s. However, there are newer drains associated with an area of coniferous forestry on the east margins of the high bog. Although 2012 aerial images do not indicate drainage maintenance has taken place on the original drains since the 1970s, they are likely to be having some effects on the hydrology of the bog. There are many drainage ditches around the bog margin in association with peat-cutting. There are also new drains associated with the forestry that has been planted on the cutover.

Much of the knowledge regarding the hydrological requirements of raised bog communities in Ireland stems from the extensive ecological and hydrological work undertaken on Clara Bog since the early 1990s. The only available hydrological study for Addergoole is the work carried out by Kelly *et al.* (1995). This study identified that the bog lies in a regional groundwater discharge zone with the hydrochemistry in the cutover drains indicative of widespread groundwater discharge around the bog margins. The bog formed in the floodplain between the rivers Clare and Cregg with Lough Corrib to the west. It is likely that the level of Lough Corrib was higher in the past and has since been lowered by arterial drainage. These changes would suggest that human activity has increased the rate of vertical water loss from Addergoole Bog, contributing to ecological impacts. Further deepening of these drains will result in further vertical water losses. In addition, lowering of regional groundwater levels will also impact on the hydrology of the fen adjacent to the bog.

The site-specific target for the attribute hydrological regime – water levels is: **Restore appropriate water levels throughout the site.**

2.3.3 Hydrological regime: flow patterns

As outlined above, ARB depends on water levels being near or above the surface of bog lawns for most of the year. Long and gentle slopes are the most favourable to achieve these conditions. Changes to flow directions due to subsidence of bogs can radically change water regimes and cause drying out of high quality ARB areas and soak systems.

A map illustrating the slopes and drainage patterns on Addergoole Bog and Lough Tee Bog

based on a digital elevation model generated from LiDAR imagery flown in 2012 is presented in Map 3.

The map suggests that the flow patterns at Addergoole are likely to have been altered as a result of subsidence. Addergoole Bog does not display a typical domed structure characteristic of an un-impacted raised bog. The western side of the bog appears to have been impacted by subsidence which has resulted in a shift in the sub-catchment divide with most of the flow from the bog discharging to the north-west and western side of the bog. The impact of reduced regional groundwater levels may have caused subsidence in the vicinity of the soak system thus helping to maintain its functioning. Further fieldwork would be necessary to establish the degree of subsidence in this area.

The main high bog area at Lough Tee is quite flat, allowing for an accumulation of water and active bog areas. The old cutting to the west has resulted in the subsidence of the high bog and an increase in the water flowing towards this direction.

The site-specific target for the attribute hydrological regime – flow patterns is: **Restore, where possible, appropriate high bog topography, flow directions and slopes.**

2.3.4 Transitional areas between high bog and surrounding mineral soils (includes cutover areas)

Transitional zones between raised bogs and surrounding mineral soils are typically cutover bog and drained lagg zones. The maintenance / restoration of these areas will help to maintain hydrological integrity of ARB and DRB, and support a diversity of other wetland habitats (e.g. wet woodland, swamp, and fen), as well as the species they sustain. In some cases, these areas may assist in reducing further losses of ARB / DRB on the high bog and in time could develop into active peat forming habitats (including ARB - see Section 2.1 above). These transitional zones, once restored, can provide ecosystem services through flood attenuation and water purification to downstream areas and potentially increase the carbon storage / sink function of the bog. The estimated extent of such transitional areas within the SAC network is 3,000ha (DAHG 2014). The national target for these transitional areas is to maintain / restore semi-natural habitats with high water levels around as much of the bog margins as necessary.

The transitional areas at Addergoole Bog include a range of different habitat types (e.g. cutover bog, fen, swamp, river, lake, scrub, woodland). The transition from the high bog into these different wetland habitats is of particular interest at Addergoole. The total area of cutover bog is estimated to be circa 269ha. The development of habitats within cutover areas depends on a number of factors including prevailing land-use, topography, up-welling regional groundwater, and drainage.

Along its north north-western edge the bog grades into rich fen vegetation dominated by *Juncus subnodulosus*, *Cladium mariscus, Phragmites australis* and *Molinia caerulea.* Increased abundance of *Ulex europaeus, Phragmites australis*, *Juncus subnodulosus*, *Cladium mariscus,* and *Schoenus nigricans* is seen on the bog as it grades into this area. It is therefore difficult to define where the bog ends and the fen begins. Between this and the river further north, new drains have been excavated and some of the plots are grazed. To the north-northeast of the bog the old cutover is dominated by *Phragmites australis* with tall *Calluna vulgaris* nearer the bog edge (Kelly *et al.* 1995).

The vegetation of the cutover, which extends around three sides of this bog is dictated by the type and intensity of peat cutting. To the east-north-east of the bog, the cutover is extensive and there are recently re-excavated drains and active peat cutting continues (Fernandez *et al.* 2014a,b). The vegetation consists mainly of small amounts of *Phragmites*

australis, Molinia caerulea and *Calluna vulgaris.* South of this area the peat cutting is mainly by hand and there is a greater vegetation cover with abundant *Calluna vulgaris, Eriophorum angustifolium*, some *Molinia caerulea* and large patches of *Phragmites australis.* Clumps of *Salix* spp. and *Ulex europaeus* are also present.

Mooney (1990) mapped the area of vegetation between Lough Corrib and the deep drains to the east of the high bog. This area is shown to be dominated by a community of *Sphagnum subnitens* and *Myrica gale* with patches of the *Schoenetum nigricantis*, the *Caricetum elatae* and a *Senecio aquaticus* community.

To the south of the bog where there is a combination of peat harvesting methods there are some large areas bare of vegetation which are associated with Difco and Hopper cutting (Kelly *et al.* 1995). Old peat cuttings are colonised by *Molinia caerulea, Calluna vulgaris* and *Pteridium aquilinum* with willow and bracken along the drains. *Phragmites australis, Typha latifolia, Juncus effusus, Myrica gale, Ranunculus flammula, Osmunda regalis* and *Potamogeton polygonifolius* were also noted. Further west and closer to Lough Corrib there are old wet pits and some re-vegetation. There are indications that there is up-welling in the area and the vegetation is characteristic of mesotrophic conditions, indicative of mixed bog water and regional groundwater. Species recorded within a drain include *Chara* species*, Myriophyllum species, Sparganium minimum, Potamogeton coloratus* and *Calliergonella cuspidata.*

The vegetation along the west edge of the bog is dominated by *Molinia caerulea* and *Phragmites australis* with *Cladium mariscus*, *Pedicularis sylvatica* and *Schoenus nigricans* with some *Calluna vulgaris* in the vicinity of the old turf banks. Iron staining has been recorded, providing evidence of up-welling regional groundwater. Further north in the vicinity of active peat cutting the area is mainly bare of vegetation though there are clumps of *Ulex europaeus* scrub. *Typha latifolia* and *Phragmites australis* were also recorded (Fernandez *et al.* 2006).

Transitional areas between Lough Tee Bog and the adjacent mineral soils mostly correspond with cutover bog at different stages of re-colonisation by vegetation (such as *Eriophorum* species, *Molinia caerulea*, *Calluna vulgaris, Erica tetralix*). Scrub is developing along the northern section where cutting has not taken place in over 40 years. A coniferous plantation is found along the east of the site on cutover. A comprehensive vegetation survey of Lough Tee Bog cutover has never been undertaken and thus more detailed information is not available.

The site-specific target for the attribute transitional areas is: **Restore adequate transitional areas to support / protect active raised bog and the services it provides.**

2.3.5 Vegetation quality: central ecotope, active flush, soaks, bog woodland

A diverse good quality microtopography on raised bogs consists of *Sphagnum* dominated pools, hollows, lawns and hummocks, which support the highest diversity of species including hummock indicators: *Sphagnum fuscum* and *S. austinii*; pool indicators: *S. cuspidatum*, *S. denticulatum*, and indicators of lack of burning events e.g. some lichen species (*Cladonia* spp.) (Cross 1990).

The national target for the attribute vegetation quality has been set as “to maintain / restore sufficient high quality bog vegetation (i.e. central ecotope and / or flushes / soaks). At least 50% of ARB habitat should be central ecotope and / or flush / soaks.” Bog woodland is also regarded as a desirable variant of ARB as it adds species and structural diversity to the habitat and therefore, where relevant, also contributes to the 50% target at a site level.

A summary description of the vegetation of Addergoole Bog and Lough Tee Bog is presented

in Sections 1.3.1 and 1.3.2 above. The vegetation and habitats of the bog have been described in more detail by Kelly (1995), Schouten (2002), Fernandez *et al.* (2005), Fernandez *et al*. (2006) and Fernandez *et al*. (2014a,b).

The active flush ecotope areas mapped on Addergoole are mostly of high quality adding to diversity of the vegetation on the bog and are typically associated with the central flush (soak).

The extent of the different ecotopes that correspond with ARB based on the most recent surveys is presented in Table 4 and on Map 2. It can be seen that the proportion of ARB that comprises central ecotope and soaks / active flush is currently 18.1%. Comparing this to results of surveys undertaken in 2005 indicates that the proportion remained relatively static throughout the period 2005-2012.

The target for this attribute is 39.4ha of central ecotope, active flush and soaks and bog woodland (50% of ARB target area (78.8ha). This requires an increase from the current area of central ecotope and soaks from their current extent of 31.4ha.

Table 4 Extent of ecotopes classified as ARB in 2003/2005 and 2012 (modified from Fernandez *et al.* 2005 & 2014a,b).

Ecotope	**2003/2005**		**2012**[4]	
	ha	**% of total ARB**	**ha**	**% of total ARB**
Addergoole Bog				
Sub-central ecotope	31.6	79.4	31.1	79.1
Central ecotope	2.5	6.3	2.5	6.4
Active flush / soaks	4.5	11.3	4.5	11.5
Bog woodland	1.2	3.0	1.2	3.1
Lough Tee Bog				
Sub-central ecotope	5.0	83.3	5.0	83.3
Central ecotope	0.7	11.7	0.7	11.7
Active flush / soaks	0.3	5.0	0.3	5.0
Total ARB	**45.8**		**45.3**	

The site-specific target for the attribute vegetation quality is: **Restore 39.4ha of central ecotope/active flush/soaks/bog woodland as appropriate. No decline in the extent of soaks.**

2.3.6 Vegetation quality: microtopographical features

The characteristic microtopographical features of raised bogs are described in Section 1.1.1 above.

Well-developed microtopography occurs in the central ecotopes areas on both Addergoole and Lough Tee Bogs. However, evidence of burning was noted on the central ecotope area at Lough Tee in 2003 by Fernandez *et al.* (2006) and much of the south of Addergoole Bog was reported to have been burned prior to a survey in 2005, which impacted the hummock features (Fernandez *et al.* 2006).

The site-specific target for the attribute microtopographical features is: **Restore adequate cover of high quality microtopographical features.**

[4] Note that, as there is no more recent survey data for Lough Tee Bog, the 2003 figures have also been used for 2012

2.3.7 Vegetation quality: bog moss (*Sphagnum*) species

Bog mosses, which have unique properties, are the principal component of peat, and are largely responsible for the typical microtopographical features as described in Section 1.1.1 above.

The vegetation of a typical raised bog that is still hydrologically intact is characterised by the dominance of several species of Sphagna and dwarf, ericoid shrubs. The most abundant species are *Sphagnum capillifolium, S. austinii* and *S. papillosum* which form hummocks or low ridges. *Sphagnum fuscum* may also form hummocks (Cross 1990). On the flats *Sphagnum magellanicum, S. papillosum, S. tenellum,* and *S. subnitens* are the key species. *Sphagnum pulchrum* may also be dominant in flats on western raised bogs. In permanently waterlogged hollows *Sphagnum cuspidatum* and *S. denticulatum* (western bogs) occur. *Sphagnum fallax* is common where there is slight flushing (Cross 1990). The most commonly occurring *Sphagnum* moss species that occur on raised bogs in Ireland are presented in Table 5 along with a summary of their ecology and typical contribution to peat formation.

On Addergoole, the overall *Sphagnum* cover is high (50-75%) in the ARB areas, and low (11-25%) in DRB areas, apart from the pool areas mentioned and around the flush (Fernandez *et al.* 2014a,b; Kelly *et al.* 1995).

Sphagnum cover reaches 90% in central ecotope areas at Lough Tee Bog and decreases across the rest of the bog according to Fernandez *et al*. (2006).

Table 5 *Sphagnum* species typically associated with raised bog ecosystems in Ireland. Ecology as described by Laine *et al.* (2009) with minor modifications.

Species	Ecology	Peat forming capacity
Sphagnum austinii	Hummock species	High
Sphagnum capillifolium	Forms small hummocks and carpets	Moderate
Sphagnum cuspidatum	Pool and hollow species	Low
Sphagnum denticulatum	Pool and hollow species	Low
Sphagnum fallax	Occurs in lawns and carpets, shade tolerant. Indicative of some nutrient enrichment (soaks and active flushes)	Low
Sphagnum fuscum	Forms dense low and wide, and occasionally high hummocks	High
Sphagnum magellanicum	Lawn species forming carpets and low hummocks	Moderate
Sphagnum palustre	Forms hummocks and dense carpets, often in shaded conditions. Indicative of nutrient enrichment (soaks and active flushes)	Low
Sphagnum papillosum	Lawn, hollow and low hummock species	Moderate
Sphagnum pulchrum	Grows in lawns and hollows, more typical of western bogs	Moderate
Sphagnum squarrosum	Forms carpets and small mounds. Indicative of nutrient enrichment (soaks and active flushes)	Low
Sphagnum subnitens	Occurs as individual shoots or small cushions and lawns. Tolerant of minerotrophic conditions	Moderate
Sphagnum tenellum	Occurs as single shoots or weak cushions, typically in disturbed patches of the bog surface	Low

The site-specific target for the attribute bog moss (*Sphagnum*) species is: **Restore adequate cover of bog moss (*Sphagnum*) species to ensure peat-forming capacity.**

2.3.8 Typical ARB species: flora

Addergoole Bog supports the full complement of plant species typically associated with a western raised bog (see Table 1 and Section 1.3.1 above).

The key typical species that are indicative of high quality raised bog include *Sphagnum fuscum* and *S. austinii* which are associated with hummocks and *S. cuspidatum* and *S. denticulatum* which are associated with pools and hollows. All of these species have been reported from Addergoole Bog and Lough Tee Bog (Kelly *et al.* 1995; Fernandez *et al.* 2014a,b).

The site-specific target for the attribute typical bog flora is: **Restore, where appropriate, typical active raised bog flora.**

2.3.9 Typical ARB species: fauna

As mentioned in section 1.1.3, a list of typical fauna specific to ARB has not been developed and the table contains species that use the wider raised bog habitat. This may be refined as more information becomes available.

The bogs are likely to support a range of fauna species that are typically associated with raised bog habitat (see Section 1.1.3 above).

The site-specific target for the attribute typical bog fauna is: **Restore, where appropriate, typical active raised bog fauna.**

2.3.10 Elements of local distinctiveness

A range of features may be associated with raised bogs which add to the scientific, historical, or conservation value of a bog. These can include geological, topographical, archaeological and hydrological features (e.g. soaks, lakes, flushes) and noteworthy species of flora and fauna (Cross 1990). Notable species of flora and fauna include those listed in the Habitats and Birds Directives, Red-listed species and other rare or localised species. For this attribute, features that are particularly associated with ARB are relevant.

2.3.10.1 Site features

The main feature of interest on Addergoole Bog is the large soak which covers approximately 11ha in the centre of the bog. This feature is dominated by *Betula pubescens* woodland with abundant epiphytic lichens. The surface is very wet and *Juncus effusus* is quite common with a well-developed *Sphagnum* layer. Two open water bodies occur towards the east of the soak. A channel leads from the flush westwards into Lough Corrib. The soak is described in further detail in Section 1.3.1 above.

2.3.10.2 Rare flora

No rare flora records have been reported from Addergoole Bog or Lough Tee Bog. However, a number of rare plant species are reported from the Lough Corrib SAC. Some of these species (including *Eriophorum gracile*) may occur within wetland habitats adjacent to the bog.

2.3.10.3 Rare fauna

As mentioned above, there is a lack of documented site-specific data relating to the fauna of these bogs. It is probable that they are utilised by a number of faunal (including birds and mammals) species of conservation concern.

In conclusion, the site-specific target for the attribute elements of local distinctiveness is:

Maintain features of local distinctiveness, subject to natural processes.

2.3.11 Negative physical indicators

Raised bogs that have been damaged by marginal cutting and drainage, reclamation for agriculture, forestry activities, fire, surface drainage, or the lowering of regional water tables show a range of negative physical indicators (Cross 1990). Such negative physical features of ARB include: bare peat, algae dominated pools and hollows, marginal cracks, tear patterns, subsidence features such as dry peat and / or mineral mounds / ridges emerging or expanding, and burning evidence.

Cutting has taken place on all sides of Addergoole bog except for an area in the north where the bog grades into fen. Cutting has mostly taken place along the south-west corner of Lough Tee Bog, with some activity documented along the south-east corner of the bog.

No fire events have been reported on the high bog at Addergoole in the 2005-2011 reporting period (Fernandez *et al.* 2014a,b). Earlier fire events have been reported by Kelly *et al.* (1995) who believed that fire frequently disturbed the high bog vegetation, as there were few large hummocks and the *Cladonia* spp. cover was sparse. Douglas and Grogan (1985) also noted that lichens and hummocks were uncommon and that the bog had been burnt in the past.

Fire events at Lough Tee Bog were reported by Derwin *et al*. (2002) and evidence of burning was also reported again in 2003 by Fernandez *et al*. (2006). Evidence of burning on the high bog is visible on the 2012 aerial images.

The site-specific target for the attribute negative physical indicators is: **Negative physical features absent or insignificant.**

2.3.12 Vegetation composition: native negative indicator species

Indicators of disturbance on a raised bog include species indicative of drying out conditions such as abundant *Narthecium ossifragum* and *Trichophorum germanicum*; *Eriophorum vaginatum* forming tussocks; abundant *Sphagnum magellanicum* in pools previously dominated by species typical of very wet conditions (e.g. *Sphagnum cuspidatum*). Indicators of frequent burning events include abundant *Cladonia floerkeana* and high cover of *Carex panicea* (particularly in the true midlands raised bog type).

The site-specific target for the attribute native negative indicator species is: **Native negative indicator species at insignificant levels.**

2.3.13 Vegetation composition: non-native invasive species

Non-native invasive species that can commonly occur on raised bog habitats include: *Pinus contorta*, *Rhododendron ponticum* and *Sarracenia purpurea* (Cross 1990).

Campylopus introflexus was recorded colonising bare peat in the marginal ecotope of Addergoole Bog and was locally abundant (Fernandez *et al.* 2014a,b).

The site-specific target for the attribute non-native invasive species: **Non-native invasive species at insignificant levels and not more than 1% cover.**

2.3.14 Air quality: nitrogen deposition

Peatlands are highly sensitive to air pollution, particularly nitrogen deposition. Reactive nitrogen from fossil fuel combustion or intensive agriculture can contaminate rain and snow, causing soil acidification, nutrient enrichment, and a decline in species that are sensitive to

these conditions. There is evidence that the combined impact of elevated nitrogen deposition and a warming climate could exceed the sum of the individual stressors and lead to a dramatic decline in the biodiversity of mosses, sensitive vascular plants, and microbes, potentially leading to catastrophic peat loss (PEATBOG project - http://www.sste.mmu.ac.uk).

Air pollution can change both the species composition and the functioning of peatlands. The primary atmospheric pollutant from the Industrial Revolution to the mid 1970s was sulphur deposition, but levels have since greatly declined. Reactive nitrogen (N) deposition (primarily NO3- and NH4+), which can both acidify and eutrophy, became significantly elevated over a widespread area in the early to mid-20th century and is now the major pollutant in atmospheric deposition across most of Europe (Fowler *et al.* 2005).

Nitrogen is commonly a limiting terrestrial nutrient and in un-impacted peatlands it is tightly cycled. With long-term elevated N deposition, vegetation composition typically shifts toward species adapted to higher nutrient levels, with an overall loss of diversity (Malmer & Wallén 2005). In peatlands, field experiments with N additions within the current European range have shown significant declines in bryophyte species-richness and productivity, and shifts in composition toward vascular plants (Bobbink *et al.* 1998; Bubier *et al.* 2007). Community shifts toward more nitrophilous bryophytes in N-enriched regions such as parts of the Netherlands are also well documented (Greven 1992). In the UK, both a general survey of peatlands across the country (Smart *et al.* 2003), and a targeted study of *Calluna* moorland (Caporn *et al.* 2007) showed significant inverse relationships between levels of nitrogen deposition and species richness, with bryophytes particularly impacted. Changes in the vegetation also impact below-ground communities and biogeochemical processes.

Moderate increases in N deposition from a low level may increase *Sphagnum* and vascular plant productivity without an equal increase in decomposition rates, leading to enhanced carbon accumulation (Turunen, *et al.* 2004). However, shifts in species composition from bryophytes to vascular plants may increase the production of easily-decomposable plant material, leading to higher rates of decomposition, and reduced carbon accumulation (Lamers *et al.* 2000; Bubier *et al.* 2007).

The particular sensitivity of nutrient-poor ombrotrophic peatlands to nitrogen enrichment is reflected in the low critical load threshold of between 5 and 10kg N/ha/yr for these ecosystems (Bobbink & Hettelingh 2011), a level which is exceeded over a significant portion of their range. An Irish study during the late 1990s undertaken by Aherne & Farrell (2000) concluded that total N deposition shows a strong east-west gradient, with lowest deposition in the west at 2kg N/ha/yr and highest in the east and south-east at 20kg N/ha/yr. Average N deposition over the Republic of Ireland was estimated to be approximately 12kg N/ha/yr. The study also concluded that the Critical Load Threshold for N was exceeded in at least 15% of ecosystems studied. The critical load applied to peatland ecosystems by Aherne & Farrell (2000) was 10kg N/ha/yr. This is in line with the recommendation by Bobbink & Hettelingh (2011) that the critical load should be set at the high end of the range in areas of high precipitation and at the low end of the range in areas of low precipitation assuming that Ireland represents a high precipitation area.

It is recommended in the case of Addergoole and Lough Tee Bogs that the level of N deposition should not exceed the low end of the range i.e. 5kg N/ha/yr. This recommendation is based on a precautionary approach, as the evidential basis for setting a higher level is not particularly strong as alluded to by Payne (2014). Total N deposition in the area around the bogs in Lough Corrib SAC as reported by Henry & Aherne (2014) is 8.5kg N/ha/yr.

The site-specific target for the attribute air quality is: **Air quality surrounding bog close to**

natural reference conditions. The level of N deposition should not exceed 5kg N/ha/yr.

2.3.15 Water quality

Ombrotrophic peat waters found on the surface of raised bogs are characterised by low pH values (pH < 4.5) (Moore & Bellamy 1974) and also have low values of Electrical Conductivity (EC). This is due to the fact that the raised bog system derives its mineral supply from precipitation, which is usually acidic and low in nutrients. Raised bog vegetation exchanges cations with protons to further reduce the pH.

Hydrochemistry varies in the areas surrounding a raised bog. Locally, conditions may be similar to the high bog due to a dominance of water originating from the bog. However, elsewhere in the marginal areas, there may be increased mineral and nutrient content of the water due to regional groundwater influences, runoff from surrounding mineral soils, and the release of nutrients through oxidation of peat resulting from reduced water levels.

The hydrochemistry of Addergoole Bog has not been studied in any detail. Some research work has been conducted at the Addergoole soak, which indicated an absence of up-welling groundwater (Connolly *et al.* 2002). Two surface water samples collected in 1993 from one of the open water pools and from within the *Betula* woodland confirm this, as they both indicate a water type that originates from precipitation with an ionic dominance of sodium (Na) and chlorine (Cl). Owing to maritime influence, they have slightly higher sodium (Na) values than samples from Shanley's Lough at Clara Bog in county Offaly (eastern raised bog site) (Connolly *et al.* 2002).

A subsequent visit to Addergoole Bog in 1994, identified a small spring associated with the flush which suggests a dilute groundwater influence (Kelly *et al.* 1995). However, the main mechanism for the functioning of this soak is still thought to be water movement through a slightly depressed area (Connolly *et al.* 2002).

There is no hydrochemistry information gathered for Lough Tee Bog.

The site-specific target for the attribute water quality is: **Water quality on the high bog and in transitional areas close to natural reference conditions.**

3 References

Aherne, J., & Farrell, E.P. (2000) Final Report: Determination and mapping of critical loads for sulphur and nitrogen and critical levels for ozone in Ireland. Environmental Protection Agency, Dublin, 212pp.

Bobbink, R., Hornung, M. & Roelofs, J.G.M. (1998) The effects of air—borne nitrogen pollutants on species diversity and semi—natural European vegetation. Journal of Ecology 86: 717–738.

Bobbink, R. & Hettelingh, J.P. (2011) Review and revision of empirical critical loads and dose-response relationships. Proceedings of an expert workshop, Noordwijkerhout, 23-25 June 2010. RIVM report 680359002, Coordination Centre for Effects, National Institute for Public Health and the Environment (RIVM).

Bracken, F. & Smiddy, P. (2012) Lowland bogs, fens and reedswamps, pp. 73-89. In: Nairn, R., and O'Halloran, J. (eds.) Bird Habitats in Ireland. The Collins Press, Cork.

Bracken, F., McMahon, B. & Whelan, J. (2008) Breeding bird populations of Irish Peatlands: capsule peatlands are very important habitats for birds despite low species diversity. Bird Study 55 (2): 169-178.

Bubier, J., Moore, T. & Bledzki, L.A. (2007) Effects of nutrient addition on vegetation and carbon cycling in an ombrotrophic bog. Global Change Biology 13: 1168–1186.

Caporn, S.J.M., Edmondson, J., Carroll, J.A., Pilkington, M. & Ray, N. (2007) Long-term impacts of enhanced and reduced nitrogen deposition on semi-natural vegetation. Report to Defra. Terrestrial Umbrella. Work Package 2: Impacts, Recovery and Processes. Task 4. Defra London.

CEC (2007) Interpretation manual of European Union Habitats. Version EUR 27. European Commission, DG Environment, Brussels. Nature and Biodiversity.

Colhoun, K. & Cummins, S. (2013) Birds of Conservation Concern in Ireland 2014–2019. Irish Birds 9: 523-544.

Connolly, A., Kelly, L., Lamers, L., Mitchell, F.J.G., van der Schaaf, S., Schouten, M.G.C., Streefkerk, J.G. & van Wirdum, G. (2002) Soaks. In: Schouten, M.G.C. (ed.), Conservation and restoration of raised bogs: geological, hydrological and ecological Studies. Dúchas – The Heritage Service of the Department of the Environment and Local Government, Ireland; Staatsbosbeheer, the Netherlands; Geological Survey of Ireland, Dublin. pp. 170-185.

Cross, J. (1990) The Raised Bogs of Ireland, their ecology, status and conservation. Report to the Minister of State at the Department of Finance. The Stationery Office, Dublin.

Crushell, P.H., Schouten, M.G.C., Robroak, B.J.M. & van Duinen, G-J. (2008) The contribution of soak lakes to macroinvertebrate diversity of raised bogs in Ireland. In: Crushell, P.H. (2008). Soak Systems of an Irish Raised Bog: a multidisciplinary study of their origin, ecology, conservation and restoration. PhD thesis, Wageningen University, with a summary in Dutch and Irish

DAHG (2014) National Raised Bog SAC Management Plan. Draft for Consultation. Main report and appendices. Department of Arts, Heritage and the Gaeltacht.

De Leeuw, J.P.M. (1986) Een onderzoek naar het voorkomen en de verspreiding van aquatische macro- en mirofauna in de Ierse hoogvenen. Deel 1: Macrofauna. Aquatische Oecologie, Katholieke Universiteit Nijmegen, Nijmegen, The Netherlands.

Derwin, J. & MacGowan, F. (2000) Raised Bog Restoration Project: A Continuation of the Investigation into the Conservation and Restoration of Selected Raised Bog Sites in Ireland.

Unpublished report, Dúchas the Heritage Service, Dublin.

Derwin, J., Gabbett, M., Keane, S., Long, M. & Martin, J. (2002). *Raised Bog Natural Heritage Areas (NHA) Project 2002*. Unpublished report, Dúchas – The Heritage Service, Dublin.

Douglas, C. & Grogan, H. (1985) *Survey to locate raised bogs of scientific interest in counties Galway (E) and Roscommon. Part II.* Internal report to the Forest and Wildlife Service, Dublin.

Fernandez Valverde, F., Fanning, M., McCorry, M. & Crowley, W. (2005) Raised bog monitoring project 2004-2005. Document 3: Site Reports and Maps Volume 1-5. Unpublished Report. National Parks and Wildlife Service, Dublin.

Fernandez Valverde, F., MacGowan, F., Crowley, W., Farrell, M., Croal, Y., Fanning, M. & McKee, A. (2006) Assessments of impacts of turf cutting on designated raised bogs 2003-2006. A Report to the Research Section of National Parks and Wildlife Service, Dublin.

Fernandez, F., Connolly, K., Crowley, W., Denyer, J., Duff, K. & Smith, G. (2014a) Raised bog monitoring and assessment survey 2013. Irish Wildlife Manuals, No. 81. National Parks and Wildlife Service, Department of Arts, Heritage and Gaeltacht, Dublin, Ireland.

Fernandez, F., Connolly, K., Crowley, W., Denyer, J., Duff, K. & Smith, G. (2014b) Raised Bog Monitoring and Assessment Survey 2013 - Addergoole Bog (SAC 000297), Co.Galway- site report. National Parks and Wildlife Service, Department of Arts, Heritage and Gaeltacht, Dublin, Ireland.

Fossitt, J. (2000) A Guide to Habitats in Ireland. The Heritage Council, Ireland.

Fowler, D., Smith, R.I., Muller, J.B.A., Hayman, G. & Vincent, K.J. (2005) Changes in the atmospheric deposition of acidifying compounds in the UK between 1986 and 2001. Environmental Pollution, 137: 15-25.

Gore, A.J.P. (ed.) (1983) Ecosystems of the world 4A. Mires: Swamp, bog, fen and moor. General studies. Elsevir Scientific Publishing Company, Amsterdam.

Greven, H.C. (1992) Changes in the moss flora of the Netherlands. Biological Conservation 59: 133-137.

Hannigan, E. & Kelly-Quinn, M. (2011) Chapter 2.6 - Aquatic macro-invertebrate diversity. pp. 140-157 In: Renou-Wilson, F. (ed.) BOGLAND: Sustainable Management of Peatlands in Ireland. Environmental Protection Agency, Wexford.

Henry, J. & Aherne, J. (2014) Nitrogen deposition and exceedance of critical loads for nutrient nitrogen in Irish grasslands. Science of the Total Environment 470–471: 216–223.

Kelly, L., Doak, M. & Dromey, M. (1995) Raised Bog Restoration Project: An Investigation into the Conservation and Restoration of Selected Raised Bog Sites in Ireland. Part 1 Summary Reports. National Parks & Wildlife Service, Department of Environment, Heritage and Local Government, Dublin.

Kelly, L. & Schouten, M.G.C. (2002) Vegetation. In: Schouten, M.G.C. (ed.), Conservation and restoration of raised bogs: geological, hydrological and ecological Studies. Dúchas – The Heritage Service of the Department of the Environment and Local Government, Ireland; Staatsbosbeheer, the Netherlands; Geological Survey of Ireland, Dublin. pp. 110-169.

Kelly, M.L. (1993) Hydrology, hydrochemistry and vegetation of two raised bogs in county Offaly. PhD thesis, Trinity College Dublin.

Laine, J., Harju, P., Timonen, T., Laine, A., Tuittila, E.S, Minkkinen, K. & Vasander, H. (2009)

The Intricate beauty of Sphagnum mosses - A Finnish guide to identification. University of Helsinki Department of Forest Ecology Publications, 39: 1–190.

Lamers, L. P. M., Bobbink, R. & Roelofs, J. G. M. (2000) Natural nitrogen filter fails in polluted raised bogs. Global Change Biology, 6: 583–586.

Malmer, N. & Wallén, B. (2005) Nitrogen and phosphorus in mire plants: variation during 50 years in relation to supply rate and vegetation type. Oikos, 109: 539–554.

Mooney, E. (1990) A Phytosociological and Palaeoecological Study of the Wetlands of the Lower Corrib Basin, Co. Galway, Ireland. Ph.D. Thesis. National University of Ireland.

Moore, P.D. & Bellamy, D.J. (1974) Peatlands. Elek Science. London.

NPWS (2008) The Status of EU Protected Habitats and Species in Ireland. National Parks and Wildlife Service, Ireland.

NPWS (2013) The Status of EU Protected Habitats and Species in Ireland. Version 1.0. Unpublished Report, National Parks and Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

O'Connell C. (ed.) (1987) The IPCC Guide to Irish Peatlands. Irish Peatland Conservation Council, Dublin.

O'Connell, P. (2011) Action Plan for Raised Bog Birds in Ireland 2011-2020. BirdWatch Ireland, Kilcoole, Co Wicklow.

O Connor, Á., Reynolds, J.D. & Kavanagh, B. (2001) Aquatic macroinvertebrate colonisation of artificial water bodies in cutaway oceanic raised bog in Ireland. In: Rochfort, L. and Daigle, J.Y. (eds.), Proceedings of the 11th International Peat Congress. pp. 742-750.

Payne, R.J. (2014) The exposure of British peatlands to nitrogen deposition, 1900–2030. Mires and Peat 14: Art. 4.

Renou-Wilson, F., Bolger, T., Bullock, C., Convery, F., Curry, J., Ward, S., Wilson, D. & Müller, C. (2011) BOGLAND: Sustainable Management of Peatlands in Ireland. STRIVE Report Series No.75. Prepared for the Environmental Protection Agency. pp. 181.

Reynolds, J.D. (1984a) Invertebrate survey of Irish midlands raised bogs. Bulletin of the British Ecological Society 15: 81-82.

Reynolds, J.D. (1984b) Invertebrate fauna of Irish raised bogs. Part II: Odonata, aquatic Hemiptera and Trichoptera. Bulletin of the Irish Biogeographical Society 8: 98-102.

Reynolds, J.D. (1985) Invertebrates of Lough Roe, Co. Offaly; a rare and endangered bogland habitat. Bulletin of the Irish Biogeographical Society 9: 41-45.

Schouten, M.G.C. (1984) Some aspects of the ecogeographical gradient in the Irish ombrotrophic bogs, paper presented to 7th Int. Peat Congress, Dublin, vol. 1, pp. 414-432, The International Peat Society, Helsinki.

Schouten, M.G.C. (ed.) (2002) Conservation and Restoration of Raised Bogs – geological, hydrological and ecological studies. Dúchas – The Heritage Service of the Department of the Environment and Local Government, Ireland; Staatsbosheheer, The Netherlands; and The Geological Survey of Ireland. pp. 220.

Smart, S.M., Robertson, J., Shield, E.J. & van de Poll, M.H. (2003) Locating eutrophication effects across British vegetation between 1990 and 1998. Global Change Biology 9: 1763-1774.

Turunen, J., Roulet, N.T., Moore, T.R. & Richard, P.J.H. (2004) Nitrogen deposition and

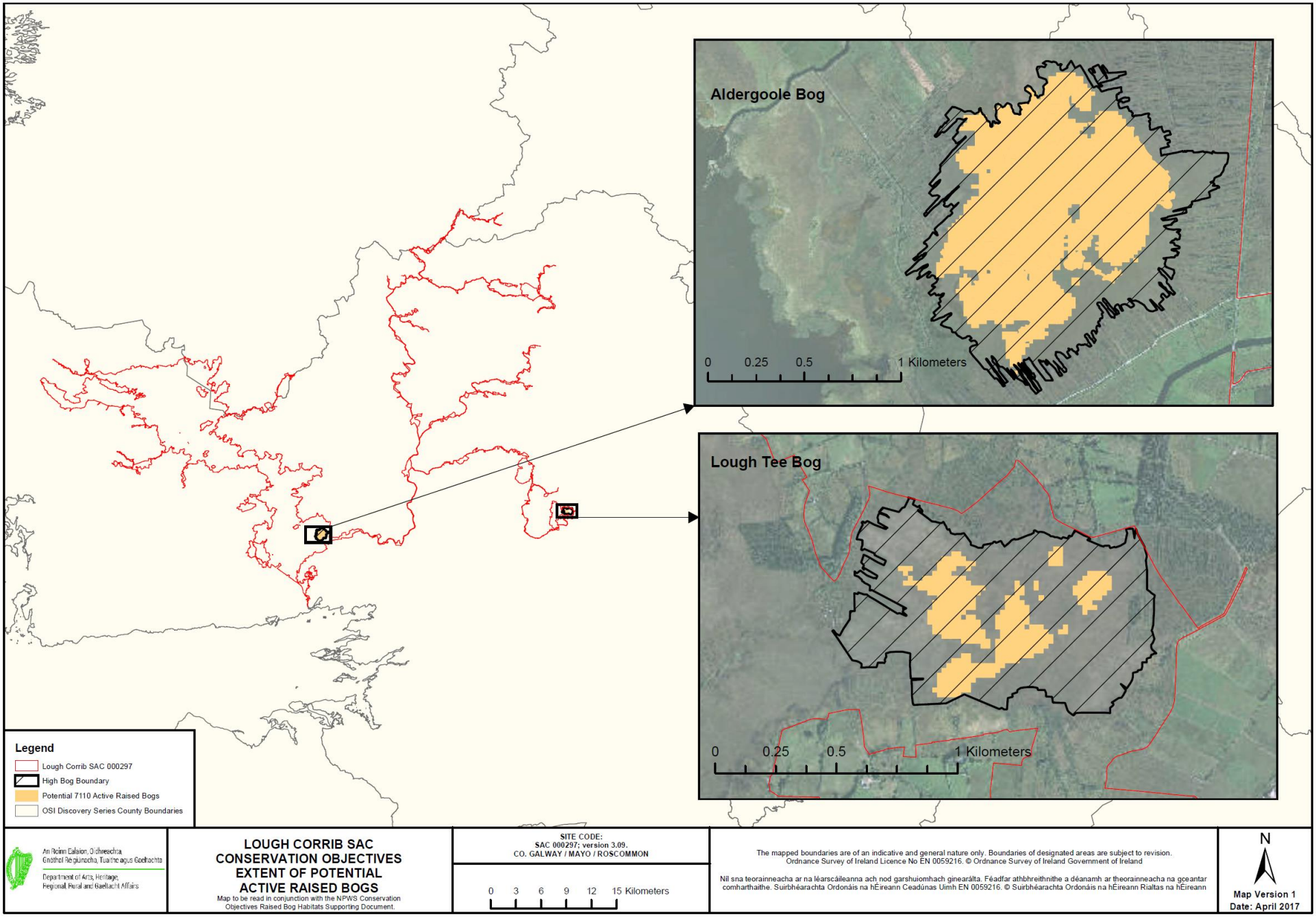
increased carbon accumulation in ombrotrophic peatlands in eastern Canada. Global Biogeochemical Cycles. 18 (3): GB3002.

Van Duinen G.A. (2013) Rehabilitation of aquatic invertebrate communities in raised bog landscapes. PhD thesis, Radboud University Nijmegen, the Netherlands.

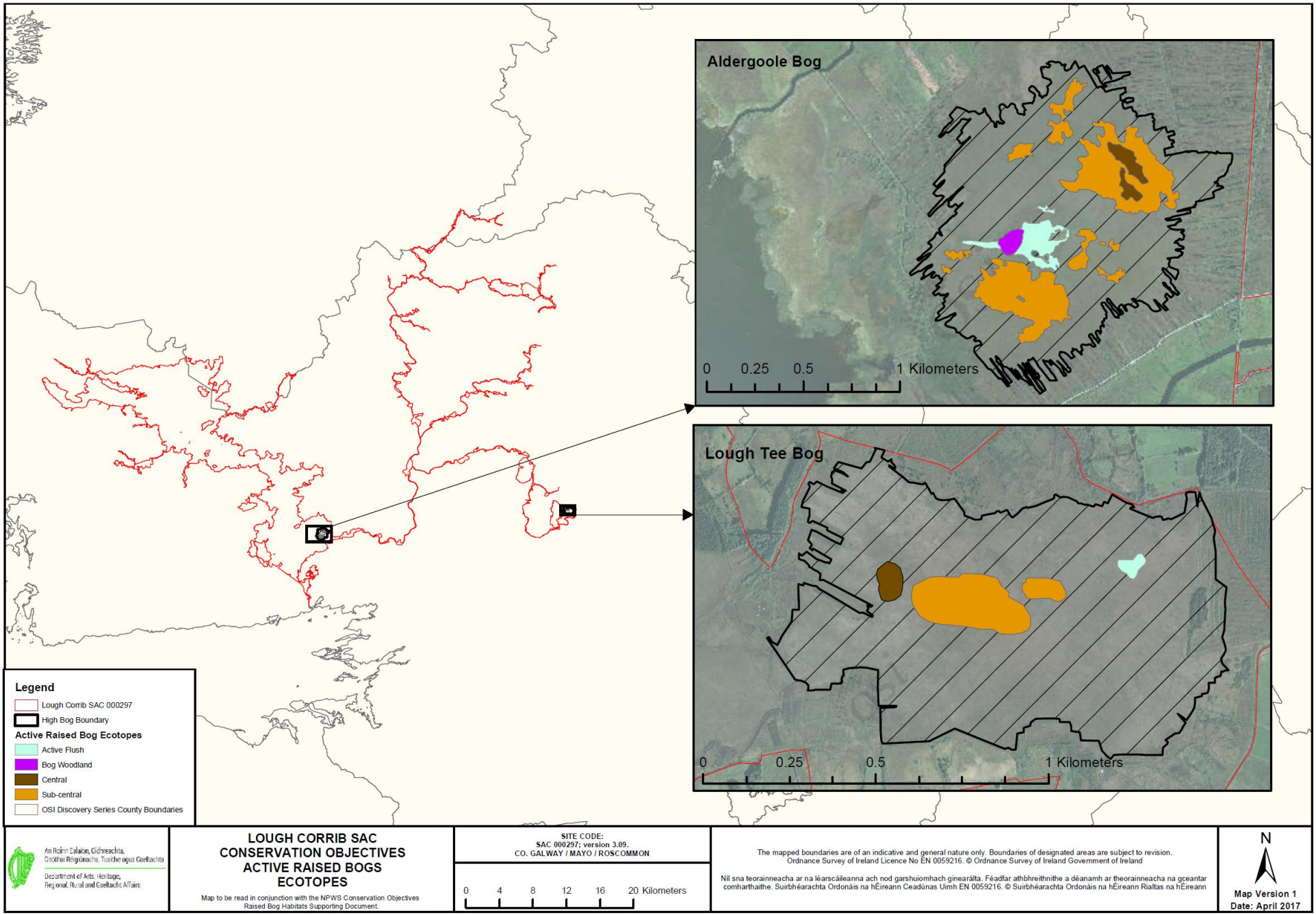
Wilson, H.J. (1990) Birds of raised bogs. pp. 29-36. In: Cross, J. (ed.) The Raised Bogs of Ireland, their ecology, status and conservation. Report to the Minister of State at the Department of Finance. The Stationery Office, Dublin.

Wisdom, R. & Bolger, T. (2011) Chapter 2.4 - Terrestrial invertebrate biodiversity. pp. 103-121 In: Renou-Wilson, F. (ed.) BOGLAND: Sustainable Management of Peatlands in Ireland. Environmental Protection Agency, Wexford.

Map 1: Extent of potential active raised bog in Lough Corrib SAC.



Map 2: Distribution of raised bog ecotopes in Lough Corrib SAC.



Map 3: Digital elevation model and drainage patterns at Lough Corrib SAC bogs.