National Parks & Wildlife Service

All Saints Bog and Esker SAC
(site code 000566)

Conservation objectives supporting document - raised bog habitats

Version 1

March 2016

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 bog' (habitat code 7110) (hereafter referred to as Active Raised Bog (ARB)), for which All Saints Bog and Esker Special Area of Conservation (SAC) has been designated.

All Saints Bog and Esker 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 on the site, then, as a consequence, favourable conservation condition for the other two habitats would also be achieved.

All Saints Bog and Esker Bog SAC is also designated for the priority Annex I habitats '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 based on phytosociological and morphological characteristics (Schouten 1984): 1. Western or intermediate raised bogs, and 2. True midland or eastern raised bogs. 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 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

[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 are used throughout the text together with scientific names.*

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 surface 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, more recent 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).

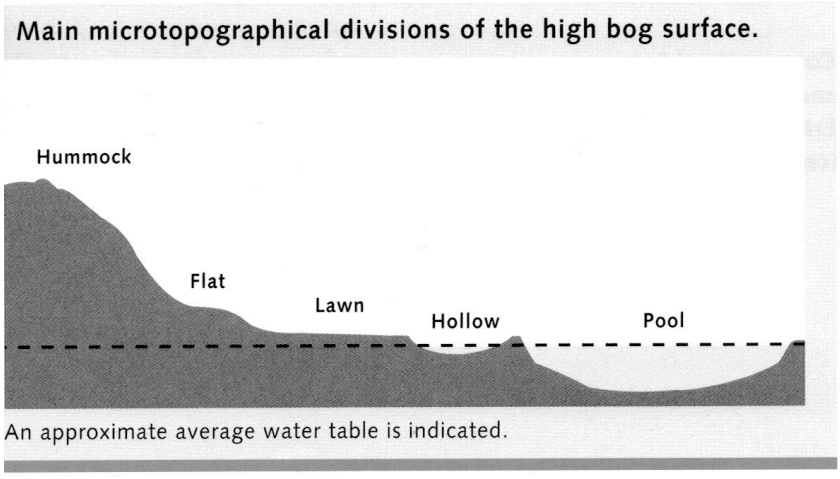


Figure 1 Raised bog microtopographical divisions on the high bog surface (reproduced from Kelly & Schouten 2002).

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 bog.

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 across raised bogs in recent times. BirdWatch Ireland have 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, Nolan 2013). Van Duinen (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)) (Flynn 2014).

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 presented 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 'active raised bogs': "*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 'Active Raised Bog' 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 Active Raised Bog 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 as 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 All Saints Bog SAC

The SAC includes the raised bog, known as All Saints Bog and surrounding areas which include cutover bog, a small area of farmland, and a broken esker ridge which runs through the south of the SAC.

The SAC has been selected for five Annex I habitats. The peatland habitats for which the site has been selected are:

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

All Saints Bog is located 8km north-northwest of Birr and 6km south of Banagher. The Rapemills River borders the northern edge. A gravel ridge runs to the south, south of which the Little Brosna River flows. Over half of the high bog is state-owned. To the south of the bog are the fragmented remains of an esker ridge, which may have an influence on the hydrology of the large flush occurring within the bog. The esker supports species-rich semi-natural grasslands, some of which is a qualifying habitat f(Annex I habitat 6210)or the SAC. This occurs in an area south-east of a now disused.

ARB at All Saints Bog is dominated by bog mosses, both in pools, *and* forming carpets and hummocks. *Calluna vulgaris* occurs on the hummocks. Characteristic species of midland raised bogs, such as *Vaccinium oxycoccos* and *Andromeda polifolia* also occur. In the wettest areas, Rhynchosporion vegetation is relatively well-developed and widespread. Non-active raised bog dominates the drier areas of high bog surface within this site. The *Sphagnum* cover in non-active areas is generally low, typically lying within the range of 5-20% ground cover.

The site contains the largest known stand of bog woodland (91D0) in the country. In the centre of the bog there is an elongated flushed area which is wooded, and this is surrounded by an outer non-wooded area. The rare myxomycete fungus, *Badhamia lilacina*, has been recorded from the site. The woodland supports an interesting invertebrate fauna, with two rare species being recorded.

An extensive area in the north-east corner of the bog, representing about 20% of the bog surface, was industrially milled, with drains running into the eastern edge of the woodland. This appears to be leading to the bog drying out, as the surface is reported to be much drier than when first surveyed in the mid-1980s.

1.3.1 Flora of All Saints Bog

ARB at All Saints Bog includes sub-central ecotope, active flushes and bog woodland. Sub-central ecotope was found at eight locations on the high bog with only two community complex types recorded. The first complex consists of tall and low hummocks and hollows with an absence of pools and *Sphagnum* cover ranging from 51-75%. *Calluna vulgaris*, *Erica tetralix* and *Eriophorum angustifolium* dominate; *Sphagnum magellanicum* and *S. papillosum* dominate the hummock layer which also features *S. capillifolium, S. subnitens*, *S. tenellum*, *S. austinii* and *S. fuscum*. Hollows consist of *S. cuspidatum.* Some sections of this complex feature flush indicator species (e.g. *Aulacomnium palustre*, *Polytrichum commune* var. *commune, Vaccinium oxycoccos*). The second sub-central ecotope complex is characterised by the abundance of *Rhynchospora alba*. The microtopography also consists of hummocks and hollows, and pools are absent. This complex is characterised by a thin *Sphagnum* layer

with abundant *S. papillosum* and other *Sphagnum* species (*S. capillifolium*, *S. magellanicum*, *S. subnitens*, *S. austinii* and *S. fuscum* forming hummocks and *S. cuspidatum* in hollows). Other species recorded include *Menyanthes trifoliata* and *Aulacomnium palustre*.

Four active peat-forming flushed areas are present at All Saints Bog. All but one are wooded flushes dominated by *Betula pubescens* or *Pinus sylvestris* trees with a dense bryophyte cover characterised by abundant *Sphagnum* species. However, their canopy cover is now too open (<30%) to be considered bog woodland. One flush lies in a small depression that is likely to have developed as a result of subsidence associated with peat-cutting. The un-wooded flush was previously mapped as bog woodland (Kelly *et al.* 1995), but a severe fire event in 2003 seriously damaged the woodland canopy and it is now considered to be an active peat forming wooded flush.

Bog woodland is found at four different locations on the high bog at All Saints Bog (Fernandez *et al.* 2014a,b). This is considered the most extensive example of wet birch wood on a raised bog in Ireland (Cross 1987). Either *Betula pubescens* or *Pinus sylvestris* dominate the different sections of the woodland. *Pinus sylvestris* dominates the drier, frequently non-active peat forming, sections of the woodland. The trees are mostly 8-10m tall but some reach 12-15m. *Betula pubescens*, *Pinus sylvestris* and *Salix* spp. dominate the shrub layer. The understorey contains *Molinia caerulea, Calluna vulgaris, Empetrum nigrum, Vaccinium myrtillus, Dryopteris carthusiana, Pteridium aquilinum, Eriophorum vaginatum, Rubus fruticosus, Anthoxanthum odoratum, Holcus lanatus, Hedera helix, Osmunda regalis*, and *Myrica gale*. The abundance of bryophyte species, and particularly Sphagna, is a common feature within the bog woodland. *Sphagnum* species are frequently found forming hummocks and hollows, the most common species being *S. capillifolium, S. fimbriatum S. fallax, S. palustre* and *S. cuspidatum*. Other mosses recorded are *Aulacomnium palustre, Hylocomium splendens, Pseudoscleropodium purum, Polytrichum commune var. commune, Dicranum scoparium* and *Rhytidiadelphus* sp.

At All Saints Bog non-active raised bog habitat includes the sub-marginal, marginal and face bank ecotopes, as well as inactive flushes and dry woodland.

The sub-marginal ecotope features the most developed microtopography. Although pools are mostly absent from the high bog, they are found within the wettest sub-marginal ecotope community complex. However, these pools generally feature a low *Sphagnum* cover and are mostly covered with algae. This sub-marginal ecotope sample featuring pools is found in an area previously classified as sub-central ecotope. The sub-marginal ecotope microtopography generally consists of hummocks, hollows and *Narthecium ossifragum* flats in places. Overall, the *Sphagnum* cover within the sub-marginal ecotope ranges from 11-25%. *Calluna vulgaris*, *Erica tetralix*, *Eriophorum vaginatum, Narthecium ossifragum* and *Carex panicea* are the most common species within this ecotope. The *Sphagnum* hummocks consist of *S. capillifolium, S. papillosum* and *S. magellanicum*. *S. austinii* and *S. fuscum* are also found. The hollows contain *Eriophorum vaginatum, E. angustifolium*, open water and occasionally *Sphagnum cuspidatum*. *Narthecium ossifragum* colonises the hollows in drier sections of the habitat. The non-native and disturbance indicator species *Campylopus introflexus* is abundant in places (Fernandez *et al.* 2014a,b).

Marginal ecotope is slightly drier than sub-marginal ecotope and mainly occurs as a narrow band near the margins of the high bog. The microtopography consists of *Calluna vulgaris* hummocks, low *Sphagnum* hummocks, flats and very occasionally hollows and tear pools. The *Sphagnum* cover is even lower here than in the sub-marginal ecotope (<10%) and the vegetation is characterised by a higher cover of *Carex panicea, Narthecium ossifragum, Trichophorum germanicum,* and *Calluna vulgaris* (Fernandez *et al.* 2014a,b).

Face bank ecotope is characterised by firm ground, tall *Calluna vulgaris*, poor *Sphagnum*

cover and a flat microtopography. This ecotope covers a large area near the area of former moss peat exploitation to the north-east of the high bog where several functional drains continue to discharge water from the high bog.

The high bog also features five inactive flushes. Four flushes are wooded and some of them are classified as dry woodland dominated by *Pinus sylvestris* trees. *Pteridium aquilinum* becomes abundant in some sections and the overall *Sphagnum* cover is low (<25%). One flush appears to have expanded due to further drying out processes. The fifth inactive flush is located on an elevated ridge and is not wooded although some *Betula pubescens* are present (Fernandez *et al.* 2014a,b).

Rhynchosporion vegetation is widespread on All Saints Bog. It is found in both ARB and DRB, but tends to be best developed and most stable in the wettest areas of ARB. In these areas, the Rhynchosporion vegetation occurs within *Sphagnum* hollows and along *Sphagnum* pool edges and on lawns. However, neither pools nor lawns are very common on All Saints Bog. Typical plant species include *Rhynchospora alba*, *Sphagnum cuspidatum, S. magellanicum, S. papillosum*, *Drosera anglica* and *Eriophorum angustifolium*. *Rhynchospora alba* is also found within degraded areas, but always associated with wet features such as hollows and run-off channels (Fernandez *et al.* 2014a,b).

1.3.2 Fauna of All Saints Bog

All Saints Bog supports a rich invertebrate fauna, including several species that are rare in Ireland including some known only from this site, such as the ladybird *Hippodamia tredecimpunctata* and the click beetle *Athous subfuscus* (Speight 1990). Saproxylic species (i.e. those that feed on dead and dying wood), such as *Dictendia bimaculata, Ampedus pomorum*, *Eisenia eiseni* and *Araneus umbraticus* are generally very scarce in Ireland. The presence of a concentration of such species in the bog woodland at All Saints Bog suggests that this woodland is ancient. It is possible that the bog woodland supports a relict Irish biotope, making All Saints Bog of international scientific interest (Speight 1990). The unusual grasshopper *Stethophyma grossum* has also been recorded from bog woodland areas (Foss & Speight 1989).

Viviparous lizard (*Lacerta vivipara*) has been recorded from the site.

Bird species that have been recorded from the in the SAC include Greenland white-fronted geese (*Anser albifrons flavirostris*), merlin (*Falco columbarius*), peregrine falcon (*Falco peregrinus*), golden plover (*Pluvialis apricaria*), mallard (*Anas platyrhynchos*), sparrowhawk (*Accipter nisus*), kestrel (*Falco tinnunculus*), redshank (*Tringa totanus*) and curlew (*Numensis arquata*). Cross (1990) recorded hooded crow (*Corvus corone cornix*), wren (*Troglodytes troglodytes*), robin (*Erithacus rubecula*), willow warbler (*Phylloscopus trochilus*), chaffinch (*Fringilla coelebs*) and redpoll (*Acanthis flammea*) from the bog woodland. (DEHLG 2004).

Irish hare (*Lepus timidus hibernicus*), badger (*Meles meles*), fallow deer (*Dama dama*) and fox (*Vulpes vulpes*) have also been recorded in the SAC (DEHLG 2004).

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 All Saints Bog SAC 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); 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 area of ARB at All Saints Bog in 1994 is estimated to have been 66.6ha, while the area of DRB is estimated to have been 2.1ha 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 All Saints Bog would equate to 68.7ha (sum of ARB and DRB in 1994). However, in setting the site-specific target the current hydro-ecological conditions on the bog (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.

The most recent monitoring survey of the bog estimated the area of ARB to be 39.8ha (Fernandez *et al.* 2014a,b). This represents a decline of 26.8ha (40.3%) during the period 1994-2011. An additional survey undertaken in 2005 confirms that this decrease occurred during the period 1994-2005 and is likely to be attributable to peat cutting, drainage and regular burning (Fernandez *et al.* 2005). Fernandez *et al*. (2014b) reported a slight overall increase (1.7ha) in ARB extent between 2005 and 2011, mostly associated with recovery from fire damage. However, substantial changes in habitat distribution were also reported, along with habitat losses particularly across the northern section. These losses were associated with drying out processes due to drainage and past peat-cutting. 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 33.3ha (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 further refined to 21.2ha 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, it is therefore concluded that the maximum achievable target for ARB on the high bog is 61.0ha. However, it is important to note that this assumes no further decline of ARB due to impacting activities. 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 All Saints Bog in 1994, 2005, and 2011 (Source: Fernandez *et al*. 2005; Fernandez *et al.* 2014a,b).

1994		2005		2011	
ARB (ha)	DRB (ha)	ARB (ha)	DRB (ha)	ARB (ha)	DRB (ha)
66.6	2.1	38.1	Unknown	39.8	21.2

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 10.7ha of ARB could be restored in this area. The long term achievable target for ARB on All Saints Bog is therefore set at 71.7ha which is 3.0ha more than the estimated area of ARB and DRB in 1994.

In conclusion, the site-specific target for the attribute habitat area is: **Restore area of active raised bog to 71.7ha, 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 All Saints Bog as set out in Section 2.1 above will contribute to safeguarding the national range of the habitat.

The ARB habitat at All Saints Bog includes sub-central ecotope, active flush and areas of bog woodland. A map showing the most recent distribution of ecotopes throughout All Saints Bog is presented in Map 2.

The site-specific target for the attribute habitat distribution is: **Restore the distribution and**

[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.

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 the ARB and DRB habitats. High bog is of value in its own right as a refuge for species characteristic of drier bog conditions as well as 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 All Saints Bog SAC in 1994 was mapped as 228.9ha, while the corresponding area in 2011 is 226.8ha (based on interpretation of LiDAR and aerial photography flown in 2012), representing a loss of 2.1ha of high bog (DAHG 2014). The extent of high bog within the SAC 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 level 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 run-off) and encourage sustained waterlogging are the most favourable to achieve these conditions. Such 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 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 All Saints Bog is presented in Fernandez *et al.* (2014a,b) who reported that 27.4km of drains impact upon raised bog habitats. Most of these drains are classified as functional with only 0.03km of reduced functional. A further 1.2km of drains are classified as non-functional, however, these drains have not been blocked and therefore it is possible that they are continuing to have some adverse impacts on the hydrology of the high bog. Most of the functional drains occur within the section of the high bog formerly used for moss peat exploitation.

There are also drains on several sections of cutover bog that are likely to be having on-going impacts on the hydrology of All Saints Bog. Drain maintenance is evident on the 2010 aerial photograph along the north-east margin of high bog, associated with agriculture improvements. Fernandez *et al.* (2014a,b) reported a new T-shaped drain between land reclaimed for agriculture and cutover bog on the south-east of the site. This is part of agricultural improvements in this area that have also included removal of scrub. The drain is 2-3m wide and 1-1.5m deep and was recorded as having 0.5m depth of water in places, with water from the cutover flowing into this deepened drain.

The potential impacts of two quarries that lie close to the bog have not been assessed.Fernandez *et al.* (2014a,b) noted that the 2011 survey showed considerable changes along the southern section of the high bog. There are obvious water flow patterns towards the southern cutover, an expansion of ARB towards the south of the high bog and a decrease and drying out of ARB along the north including in the former bog woodland section (now inactive flush). The authors suggest that the quarrying activity is likely to have altered the hydrology of the high bog and is therefore impacting on high bog habitats.

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 1990's. The only available hydrological study for All Saints is the work carried out by Kelly *et al.* (1995). This study identified that most of the cutover drains surrounding the bog intercept the regional water table, as indicated by relatively high electrical conductivity (EC) measurements. The former area of moss peat exploitation typically had ECs of 400µS/cm with several drains intercepting the underlying substrate (till/shell marl). ECs in the cutover towards the west of the bog ranged from 370-390µS/cm, while at the eastern side of the bog ECs were in excess of 500µS/cm. The Rapemills River which flows north of the bog had an electrical conductivity of 750µS/cm. Drains in the cutover on the south-western side of the cutover had ECs ranging from 90-150µS/cm, the authors suggest that this is a result of recharge occurring in this area.

Kelly *et al.* (1995) note that a study of the area of *Betula* woodland on the high bog was carried out by Cross (1987). Cross (1987) suggested that drying out or a burning event were not satisfactory explanations for the presence of the woodland. The International Mires Conservation Group (Fojt 1988) identified that the occurrence of this woodland type were coincident with ridges of underlying mineral material (4.5 – 5.0m below the peat surface). The EC values for the open bog were 121.4µS/cm while those in the woodland were 139.9µS/cm. It was therefore suggested that mineral rich waters are upwelling under the *Betula pubescens* flush.

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

The flow patterns on All Saints Bog indicate that most of the flow from the bog is towards the northern margin of the bog, with less flow towards the southern or south-western margin. Patterns of converging flow coincide with areas of active flush and bog woodland, while slopes are in general steeper towards the northern margin of the bog. Slopes are particularly steep in the transition between the area of intact high bog and the former area of peat-exploitation. These flow patterns suggest that All Saints Bog is likely to have been affected by subsidence, particularly towards the northern margin. Further changes to flow patterns or slope arising from subsidence associated either with residual effects of peat-exploitation, drainage or nearby quarrying activities are likely to have a significant impact on the area of ARB.

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 species that 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 All Saints Bog include a range of different habitat types (e.g. improved grassland, cutover bog and scrub). The total area of cutover bog within All Saints Bog and Esker SAC is estimated to be circa 84ha. The development of habitats within cutover areas depends on a number of factors including prevailing land-use, topography, up-welling regional groundwater and drainage.

According to Kelly *et al.* (1995) the old cutover areas all around the site support mostly *Eriophorum vaginatum* and *Calluna vulgaris*. At the southern side there are some areas of regenerating peat where a *Sphagnum* layer has developed. A list of species for a typical area of regeneration was taken at the east side of the bog. This included *Molinia caerulea, Sphagnum* sp., *Anthoxanthum odoratum, Carex nigra, Salix spp., Polytrichum spp., Calluna vulgaris* and *Ulex europaeus*. At the wetter facebank edge, *Carex rostrata, Juncus effusus* and *Sphagnum fallax* were noted. *Betula pubescens* scrub and trees and *Ulex* scrub were also seen in many areas of cutover around the site. Two areas of mesotrophic vegetation were noted on the southern side of the bog in the old cutover. The first, a water filled pit

next to the facebank edge featured *Typha latifolia, Lemna, Potamogeton polygonifolius, Carex diandra, Carex rostrata, Equisetum fluviatile* and *Riccardia* sp. In the slightly drier sections the following were noted: *Carex echinata, Juncus effusus, Lycopus europaeus, Osmunda regalis* and *Holcus lanatus.* The second area was also a water-filled pit with *Lemna sp., Nasturtium officinale, Typha latifolia, Carex rostrata, Cardamine pratensis, Lythrum salicaria, Potamogeton polygonifolius* and *Salix sp.* Beyond this the vegetation indicated drier conditions with *Ulex europaeus* dominating.

Kelly *et al.* (1995) also noted two areas of cutover dominated by *Juncus effusus* at the southern and northern sides of the bog. At the southern side of the SAC, north of the gravel pit a hedge on the edge of the high bog was recorded. The tree layer was dominated by *Salix sp., Corylus avellana, Sambucus nigra, Acer pseudoplatanus* and *Fraxinus excelsior*. *Pteridium aquilinum, Rubus fruticosus* and *Urtica dioica* had colonised the clearings with *Molinia caerulea, Ulex europaeus, Holcus lanatus, Anthoxanthum odoratum, Festuca rubra, Briza media, Carex pulicharis, Chamerion angustifolium, Senecio jacobaea, Cirsium palustre, Potentilla erecta, Geranium robertianum, Veronica chamaedrys, Glechoma hederacea, Succisa pratensis, Hyperichum* sp. and *Lotus corniculatus*. Leading from this area onto the high bog, Kelly *et al.* (1995) noted heath vegetation with a lot of *Molinia caerulea* in addition to *Pedicularis sylvatica, Polygala vulgaris* and *Potentilla erecta* with *Luzula, Holcus lanatus, Anthoxanthum odoratum, Stellaria media, Plantanthera bifolia, Dactylorhiza maculata* and *Poa trivialis*.

An area of the high bog has been industrially milled in the past. This area remains largely devoid of vegetation with regular drains occurring throughout.

The site-specific target for the attribute transitional areas is: **Restore adequate transitional areas to support / protect the 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 site level.

The ARB habitat at All Saints comprises sub-central ecotope and active wooded flushes. These wooded flushes are dominated by *Betula pubescens* and correspond with the Annex I priority habitat 'Bog woodland' (91DO), which is listed as a qualifying interest for the SAC. A separate Site-Specific Conservation Objective has been prepared for this habitat.

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 active flush and bog woodland is currently 82%. Comparing this to results of surveys undertaken in 2004 indicates that the proportion of each of the component ecotopes remained relatively static.

The target for this attribute is 35.9ha of high quality ARB (50% of ARB target area (71.7ha)). This requires an increase from the current area of 33.2ha.

Table 4 Extent of ecotopes classified as ARB in 2005 and 2011 (Fernandez *et al.* 2014a,b).

Ecotope	2005		2011	
	ha	% of total ARB	ha	% of total ARB
Sub-central ecotope	6.83	16.4	6.54	17.9
Active flush	16.90	47.6	18.90	44.4
Bog woodland	14.34	36.0	14.34	37.6
Total ARB	**38.07**		**39.8**	

The site-specific target for the attribute vegetation quality is: **Restore 35.9ha of central ecotope/active flush/soaks/bog woodland as appropriate.**

2.3.6 Vegetation quality: microtopographical features

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

Hummock and hollow microtopography is well developed on All Saints Bog although pools are uncommon (Kelly *et al.* 1995; Fernandez *et al.* 2014a,b).

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

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 2.3.6 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.

Kelly *et al.* (1995) and Fernandez *et al.* (2014a,b) provide information on the occurrence of *Sphagnum* species throughout All Saints Bog.

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

All Saints Bog supports the full complement of plant species typically associated with a true midland raised bog (see Section 1.1.2 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 All Saints Bog with the exception of *Sphagnum denticulatum* (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.

All Saints Bog is likely to support a wide 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 relatively extensive area of bog woodland is the main feature of local distinctiveness on All Saints Bog.

2.3.10.2 Rare flora

No rare flora records have been reported from All Saints Bog. However, the presence of the liverwort *Pleurozia purpurea*, a western species, is notable. While not a rare plant in the Irish context, it is a rare occurrence on raised bogs east of the River Shannon.

2.3.10.3 Rare fauna

As mentioned above, there is limited current documented site-specific data relating to species that are particularly associated with ARB, including rare species.

The bog woodland supports a rich invertebrate fauna, including several species that are rare in Ireland or known only from this site, *e.g*. the ladybird *Hippodamia tredecimpunctata* and the click beetle *Athous subfuscus* (Speight 1990).

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.

Fernandez *et al.* (2014a,b) found that habitat losses have taken place particularly along the northern section of All Saints Bog. They also found expansion of ARB habitat across the southern high bog and attributed this partially to vegetation recovery after a severe fire event of 2002/3. Fernandez *et al.* (2014a,b) report that these changes may also be due to subsidence which may be associated with falling water table levels in the underlying mineral subsoil layers associated with the quarrying activity taking place adjacent to the high bog. Falling water tables are likely to be causing changes in the hydrological functioning of the high bog (more water running towards the south) with unpredictable negative consequences on the ARB and bog woodland.

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 Fernandez *et al.* (2014a,b) survey of 2011 noted the spread of *Pinus sylvestris* on many sections across the entire high bog and particularly within inactive flushes and the drier sections of active flushes and bog woodland. Many plants were less than 2m high and likely to have germinated after the severe fire event that took place in 2002/3. The rapid spread of *Pinus sylvestris* is likely to be an indication of further drying out of the high bog.

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). There are no records for non-native invasive species on All Saints Bog.

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 All Saints Bog 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 vicinity of All Saints Bog as reported by Henry & Aherne (2014) is 12.6kg 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. 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, run-off from surrounding mineral soils, and the release of nutrients through oxidation of peat resulting from reduced water levels.

Kelly *et al.* (1995) reported hydrochemistry from different sections of the bog. Many of the cutover drains around the site had relatively high electrical conductivity (EC) measurements suggesting mineralized groundwater influence. However, drains in the cutover on the south-western side had lower EC values more typical of bog conditions, the authors suggest that this is a result of recharge occurring in this area. As previously mentioned, Fojt (1988) identified that the occurrence of bog woodland is coincident with ridges of underlying mineral material (4.5-5.0m below the peat surface) and the EC values for the open bog were slightly less than those in the woodland, suggesting that mineral-rich waters are upwelling

under the wooded flush. However, further research into the origin, development and functioning of the woodland area is warranted.

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. & 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).

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.

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.

Cross, J.R. (1987) Unusual stands of Birch on Bogs. Irish Naturalists Journal, Vol. 22, No. 7, pp. 305-310.

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 Duinan, 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.

DEHLG (2004) National Parks and Wildlife Service Conservation Plan. All Saints Bog and Esker cSAC & SPA: Site Code 566 & 4103, County Offaly.

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.

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, F., MacGowan, F., Crowley, W., Farrell, M., Croal, Y., Fanning, M. & McKee M. (2006) Assessment of the impacts of turf cutting on designated raised bogs 2003-06. Unpublished report, National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, 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 – All Saints Bog – site report. National Parks and Wildlife Service, Department of Arts, Heritage and Gaeltacht, Dublin, Ireland.

Flynn, C. (2014) Nocturnal Lepidoptera of Midland Raised Bogs. A thesis submitted to the National University of Ireland, Maynooth for the Degree of Master of Science (MSc.).

Foss, P.J. & Speight, M.C.D. (1989) Stethophyma grossum (L.): a further Midland record with comment on the status of this grasshopper in Ireland (Orthoptera: Acrididae). Bulletin of the Irish Biogeographical Society, No. 12, pps. 90-93.

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.

Fojt, W. (1988) *Field excursion to Ireland*. International Mires Group, Nature Conservancy Council, pps 15-22.

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

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

Hannigan, E., and 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. and 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. & 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, 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, 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.

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

Nolan, M. (2013) Spiders (Araneae) of Irish raised bogs: Clara bog, Co. Offaly and Carrowbehy bog, Co. Roscommon. Bulletin of the Irish Biogeographical Society 37: 172-203.

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.

O Connor, J.P. & Speight, M.C.D., (1987) *Macrosiphum albifrons, Dictenidia bimaculata, Callaspidia defonscolombei* and *Xyalaspis petiolata*: Insects new to Ireland. Irish Naturalists Journal, Vol. 22, No. 5, pps. 199 – 201

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.

Speight, M.C.D. (1990) *Hippodamia 13-punctata (*Coleoptera: Coccinellidae*)* and other insects from All Saints Bog, Co. Offaly, Ireland. Bulletin of the Irish Biogeographical Society, No. 13, p200-212.

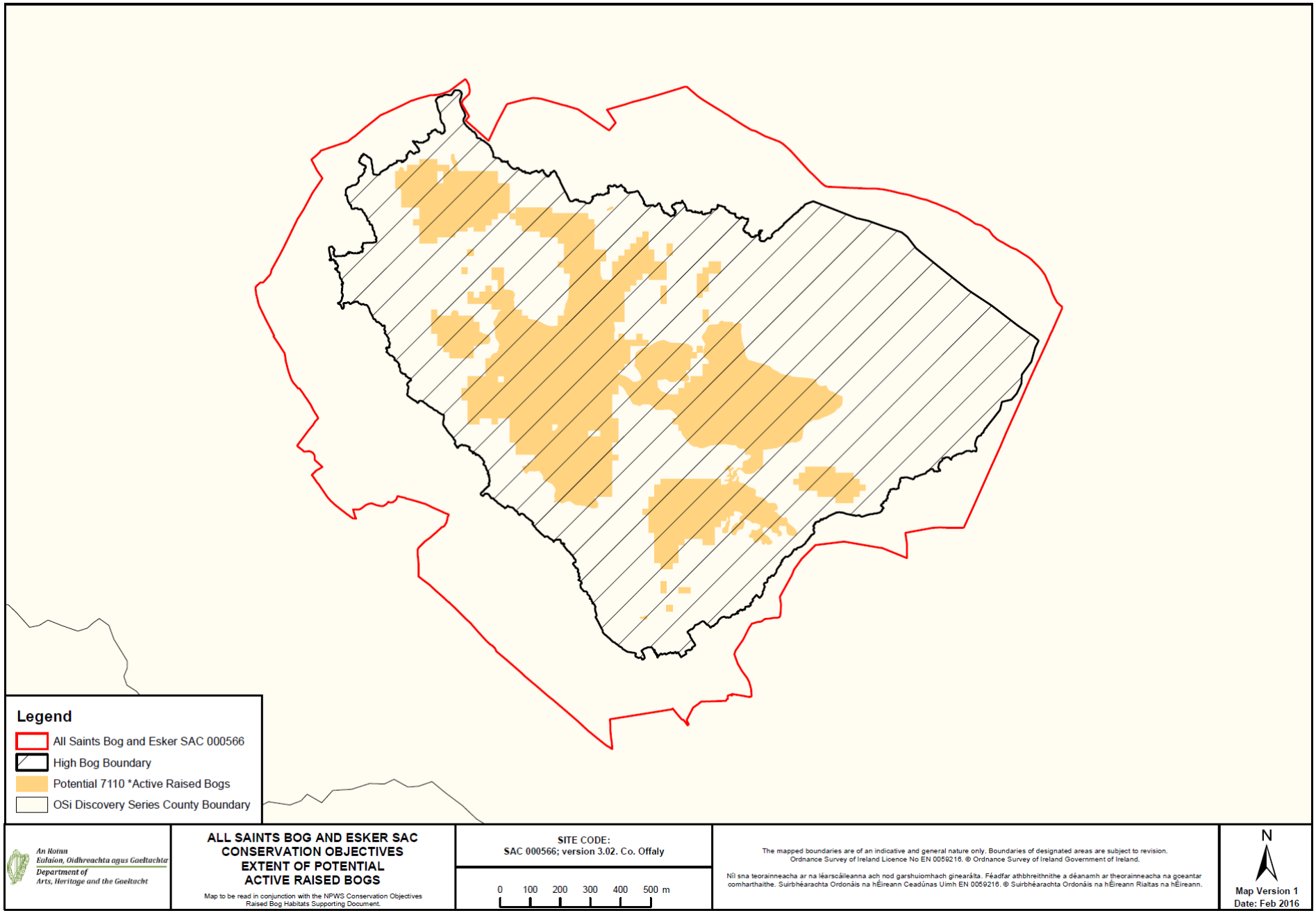
Turunen, J., Roulet, N.T., Moore, T.R. & Richard, P.J.H. (2004) Nitrogen deposition and increased carbon accumulation in ombrotrophic peatlands in eastern Canada. Global Biogeochemical Cycles. 18 (3): GB3002.

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

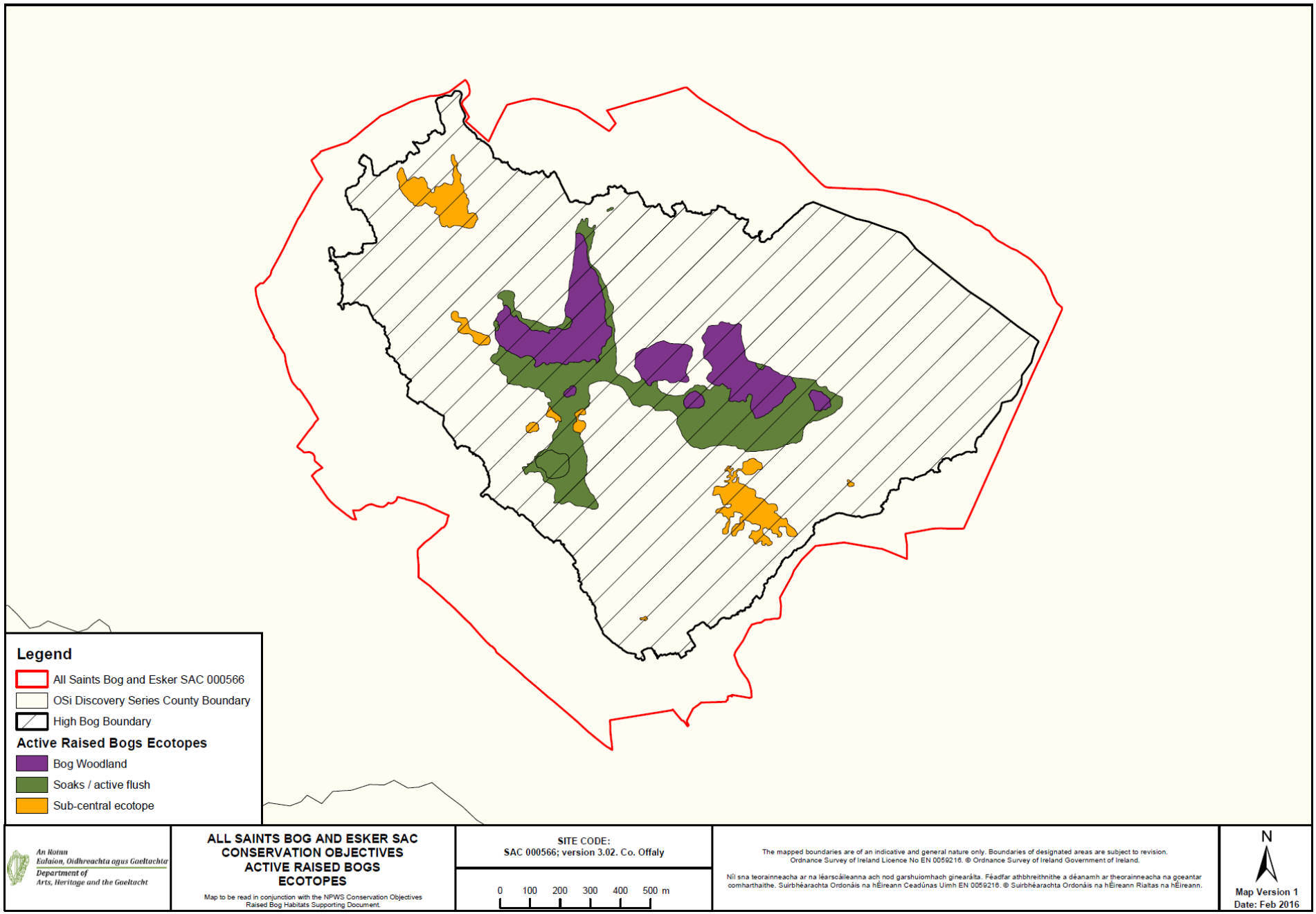
Wilson, H.J. (1990) Birds of raised bogs. pp. 29-36. In: Cross, J. (ed.) The Raised Bogs of Ireland, their ecology, status and conservation. Report to the Minister of State at the Department of Finance. The Stationery Office, Dublin.

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 on All Saints Bog.



Map 2: Distribution of raised bog ecotopes on All Saints Bog.



Map 3: Digital elevation model and drainage patterns at All Saints Bog.