

National Parks & Wildlife Service

Lough Ree SAC
(site code 000440)

**Conservation objectives supporting document -
raised bog habitats**

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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 Habitats Directive Annex I habitat 'Active raised bogs' (habitat code 7110) (hereafter referred to as Active Raised Bog (ARB)), for which Lough Ree Special Area of Conservation (SAC) has been designated. Within the SAC, the raised bog habitat for which the site has been selected occurs at Clooncraff and Cloonlarge Bogs in the north-west of the SAC within the Co. Roscommon section.

Lough Ree SAC is also designated for one other related Annex I habitat, namely; 'Degraded raised bogs still capable of natural regeneration' (habitat code 7120) (hereafter referred to as Degraded raised bog (DRB)). Based on the close ecological relationship between these two habitat types, it is not necessary to set specific Conservation Objectives for both 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 DRB would also be achieved.

Lough Ree SAC is also designated for the 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 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 tend to stay more confined to the depressions in which they were formed, western raised bogs tend to grow out beyond their original basin, presumably a result of the higher rainfall levels (Cross, 1990). In terms of vegetation, 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 low-level Atlantic blanket bogs and their presence in western raised bogs is presumed to be due to 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 (NPWS,

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.*

2017), see Section 1.2 for an explanation of Habitats Directive Annex I raised bog habitats. 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 lags 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 relatively low in species number and comprise of unique 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, pools 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 (or lost) 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, more recent semi-industrial peat extraction, and associated drainage effects caused by these activities (NPWS, 2007; 2013; 2019). The lowering of regional groundwater levels is also known to have had an effect on some sites. Fires associated with turf cutting, dumping, forestry or agricultural activities may also adversely affect the condition of the habitat.

1.1.1 Raised Bog 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 round 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

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

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

Flats

Flat areas which are intermediate between hollow and hummock communities. They tend to be drier than pools, hollows or lawns.

Hummocks

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 medium*, *S. rubellum*, *S. austinii* and *S. beothuk* 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 and Schouten, 2002).

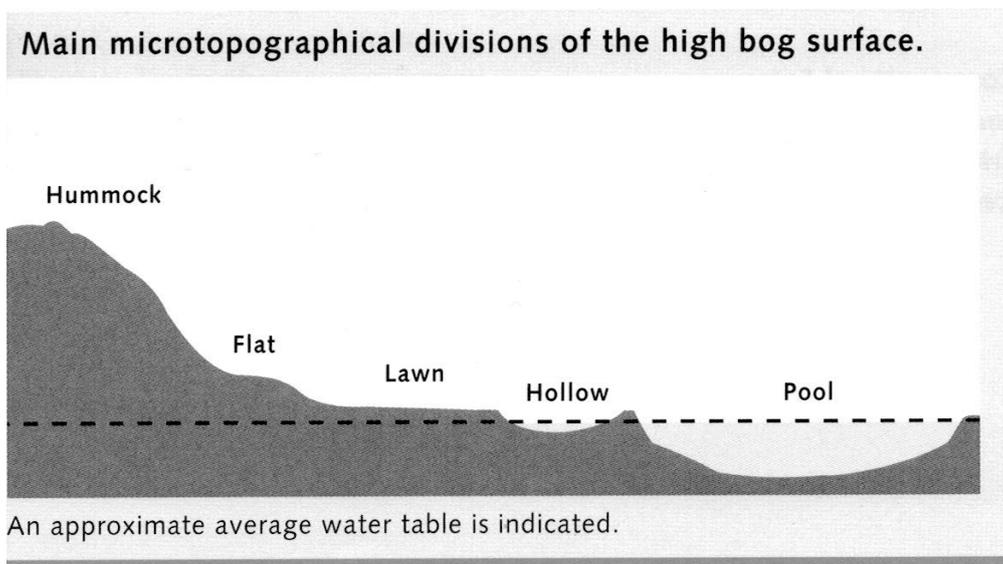


Figure 1 Raised bog microtopographical divisions on the high bog surface (reproduced from Kelly and Schouten, 2002).

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., *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 on both the bog surface and epiphytes on the stems of dwarf shrubs and on 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*, *Narthecium ossifragum* 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 rubellum*, *S. austinii*, *S. beothuk*, *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. medium*).

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 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 and Schouten (2002).*

Common name	Scientific Name
Bog-rosemary	<i>Andromeda polifolia</i>
Bog Bead-moss	<i>Aulacomnium palustre</i>
Bristly Swan-neck Moss*	<i>Campylopus atrovirens*</i>
Lichen	<i>Cladonia ciliata</i>
Lichen	<i>Cladonia portentosa</i>
Long-leaved Sundew	<i>Drosera anglica</i>
Intermediate-leaved Sundew*	<i>Drosera intermedia*</i>
Round-leaved Sundew	<i>Drosera rotundifolia</i>
Common Cottongrass	<i>Eriophorum angustifolium</i>
Hare's-tail Cottongrass	<i>Eriophorum vaginatum</i>
Large White Moss	<i>Leucobryum glaucum</i>
Bogbean	<i>Menyanthes trifoliata</i>
Bog Asphodel	<i>Narthecium ossifragum</i>
Purple Spoonwort*	<i>Pleurozia purpurea*</i>
Woolly Fringe-moss*	<i>Racomitrium lanuginosum*</i>
White Beak-sedge	<i>Rhynchospora alba</i>
Austin's Bog-moss	<i>Sphagnum austinii</i>
Red Bog-moss	<i>Sphagnum rubellum</i>
Feathery Bog-moss	<i>Sphagnum cuspidatum</i>
Cow-horn Bog-moss*	<i>Sphagnum denticulatum*</i>
Rusty Bog-moss	<i>Sphagnum beothuk</i>
Magellanic Bog-moss	<i>Sphagnum medium</i>
Papillose Bog-moss	<i>Sphagnum papillosum</i>
Golden Bog-moss*	<i>Sphagnum pulchrum*</i>
Lustrous Bog-moss	<i>Sphagnum subnitens</i>
Bladderwort	<i>Utricularia minor</i>
Cranberry	<i>Vaccinium oxycoccos</i>

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. Otter use bogs as foraging sites. 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. A few bird species, including Meadow Pipit (*Anthus pratensis*), Skylark (*Alauda arvensis*) and Curlew (*Numenius arquata*) complete their full breeding cycle in bog habitat; the first two species are the commonest species occurring (Bracken *et al.*, 2008). Meadow Pipit and Curlew are both listed as Red (most endangered) and Skylark as amber on the most

recent list of Birds of Conservation Concern in Ireland (BoCCI) (Gilbert *et al.*, 2021). Red Grouse (*Lagopus lagopus*), (also red listed) 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). These are listed in Table 2 below. Snipe (*Gallinago gallinago*) and Kestrel (*Falco tinnunculus*) have recently been added to the red list of BoCCI (Gilbert *et al.*, 2021).

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 and Kelly-Quinn, 2011; Wisdom and 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 study of Lepidoptera associated with raised bogs identified two species that appear to be characteristic of higher quality raised bog habitat, namely the moth species, Bordered Grey (*Selidosema brunnearia* (Villers, 1789)) and Light Knot Grass (*Acrionicta 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. This deficiency in data could be addressed by further research into the topic. 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 and Smiddy, 2012).

Common name	Scientific name
Mammal species	
Irish Hare	<i>Lepus timidus hibernicus</i>
Otter	<i>Lutra lutra</i>
Pygmy Shrew	<i>Sorex minutes</i>
Fox	<i>Vulpes vulpes</i>
Bird species	
Skylark	<i>Alauda arvensis</i>
Mallard	<i>Anas platyrhynchos</i>
Greenland White-fronted Goose	<i>Anser albifrons flavirostris</i>
Meadow Pipit	<i>Anthus pratensis</i>
Hen Harrier	<i>Circus cyaneus</i>
Cuckoo	<i>Cuculus canorus</i>
Merlin	<i>Falco columbarius</i>
Kestrel	<i>Falco tinnunculus</i>
Snipe	<i>Gallinago gallinago</i>
Red Grouse	<i>Lagopus lagopus</i>
Curlew	<i>Numenius arquata</i>
Golden Plover	<i>Pluvialis apricaria</i>
Lapwing	<i>Vanellus vanellus</i>
Reptiles and amphibians	
Common Lizard	<i>Lacerta vivipara</i>
Common Frog	<i>Rana temporaria</i>
Typical invertebrates	
Black Slug	<i>Arion ater</i>
Large Heath Butterfly	<i>Coenonympha tullia</i>
Marsh Fritillary Butterfly	<i>Euphydryas aurinia</i>
Bog-pool Spider	<i>Dolomedes fimbriatus</i>
Water Striders	<i>Gerris</i> and <i>Velia</i> species
Oak Eggar Moth	<i>Lasiocampa quercus</i>
Four-spotted Chaser Dragonfly	<i>Libellula quadrimaculata</i>
Fox Moth	<i>Macrothylacia rubi</i>
Ant	<i>Myrmica ruginodis</i>
Emperor Moth	<i>Saturnia pavonia</i>
Great Green Bog Grasshopper	<i>Stethophyma grossa</i>
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)
	Odonata (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, 2013).

Up until very recently, ARB was defined in Ireland as only occurring on the high bog. However, a growing acknowledgement of the occurrence of peat-forming vegetation on cutover areas at some sites led to an appraisal of these habitats. A methodology was developed by Smith and Crowley (2020) for assessing whether an area of high *Sphagnum* on the cutover corresponds with ARB based on numbers of positive indicator species, *Sphagnum* cover and absence or low levels of negative indicator species (Crushell *et al.*, in prep). This was the first time that ARB had been recognised as occurring on cutover in the Irish context. However, it should be realised that ARB on cutover constitutes a small percentage of the overall extent of ARB in Ireland, with <1% of the most recent national estimate of 1,843ha of the Annex habitat, occurring on cutover (Crushell *et al.*, in prep). In general, regenerating ombrotrophic vegetation on cutover does not correspond with ARB as even where it is characterised by a high *Sphagnum* cover, it lacks the diversity of *Sphagnum* species, micro-topographical features and good quality indicators that are usually associated with the Annex habitat. Nonetheless, over the long term these areas may develop into ARB.

DRB is described in the interpretation manual as “*raised bogs where there has been disruption (usually anthropogenic) to the natural hydrology of the peat body, leading to surface desiccation and/or species change or loss. Vegetation on these sites usually contains species typical of active raised bog as the main component, but the relative abundance of individual species is different. Sites judged to be still capable of natural regeneration will include those areas where the hydrology can be repaired and where, with appropriate rehabilitation management, there is a reasonable expectation of re-establishing vegetation with peat-forming capability within 30 years....*” (CEC, 2013).

In Ireland, the identification of ARB is made at ecotope level, based on the vegetation classification developed by Kelly (1993) and Kelly and 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 and 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 area of Annex I DRB is estimated using an ecohydrological model that was developed based on LiDAR (Light Detection and Ranging) data (NPWS, 2019). The model predicts where there is potential to restore active conditions on the high bog (Mackin *et al.*, 2017a and 2017b; NPWS, 2017). As a result, only those areas with the right combination of physical conditions (including surface shape, slope and drainage patterns) ultimately capable of supporting ARB are now considered as DRB. These are the areas of raised bogs whose hydrology has been disturbed so that their surfaces have dried out and suffered some species change or loss. Bog species of drier conditions now dominate, and peat formation has ceased. The water level is generally 10cm or more below the surface and drops to 30+cm below during dry summer weather. To qualify as DRB, these areas must still be capable of natural regeneration to active bog within 30 years if their hydrology is repaired (usually after restoration works, particularly blocking of drains). The remainder of the high bog that is neither ARB nor DRB is now referred to as 'Supporting Raised bog habitat'.

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. medium*, *S. papillosum*, *Menyanthes trifoliata*, and *Eriophorum angustifolium*. In raised bogs in Ireland, *Rhynchospora* vegetation communities are only considered Annex I type (*sensu stricto*) when they occur in their most developed form in the wettest sections of the Active raised bog (7110), which correspond with pools, *Sphagnum* lawns and hollows.

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, usually with *Polytrichum* mosses and occasional lichens. 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

ARB is currently considered to be in Unfavourable-Bad Conservation Status in Ireland (see Section 1.1). 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.

Up until recently most of the restoration works undertaken in Ireland were concentrated on high bog (e.g. Clara Bog, Mongan Bog, Sharavogue Bog and Raheenmore Bog), and restricted to drain blocking to prevent further losses as well as to restore areas to ARB with limited restoration works undertaken on cutover areas such as at Ballykenny and Fisherstown Bogs and Killyconny Bog (Crowley *et al.*, 2021). 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. More recently NPWS are employing enhanced restoration works (see Mackin *et al.*, 2017a; Cushman *et al.*, 2022) both on high bog and cutover, using techniques such as cell bunding on sites such as Cloncrow Bog (New Forest) NHA and Scohaboy Bog NHA.

Works undertaken by 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 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 ($\leq 0.3\%$ 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 Ree SAC

Lough Ree is the third largest lake in Ireland and is situated in an ice-deepened depression in Carboniferous limestone on the River Shannon system, between Lanesborough and Athlone. The site spans Counties Longford, Roscommon and Westmeath. Some of its features (including the islands) are based on glacial drift. It has a very long, indented shoreline and hence has many sheltered bays. Although the main habitat, by area, is the lake itself, interesting shoreline, terrestrial and semi-aquatic habitats also occur. Raised bog is found at Clooncraff and Cloonlarge, at the north-western corner of Lough Ree between the Clooneigh and Hind rivers.

The SAC has been selected for eight Annex I habitats and one Annex II species. The raised bog habitats for which the site has been selected are:

- [7110] Active raised bogs*
- [7120] Degraded raised bogs still capable of natural regeneration
- [91D0] Bog woodland*

The SAC is also selected for:

- [3150] Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation
- [6210] Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)
- [7230] Alkaline fens
- [8240] Limestone pavements*
- [91E0] Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)*

- [1355] *Lutra lutra* (Otter)

1.3.1 Clooncruff and Cloonlarge Bogs

Clooncruff and Cloonlarge Bogs formed on the River Shannon floodplain at Lough Ree and therefore are examples of floodplain type raised bog. The bog area is a complex shape with numerous lobes broken up by peat-cutting. It was part of a much larger raised bog complex, now mostly lost, due to past peat-cutting and reclamation for agriculture. There are three main sections, Kiltteevan to the north, Clooncruff to the west and Cloonlarge to the east. Of these, Kiltteevan has the most regular shape, with little peat-cutting occurring due to past afforestation (recently felled as part of Coillte LIFE Restoration Project (see Derwin (2008) for further details). Clooncruff and Cloonlarge have a complex shape as they are divided by tracks and peat-cutting (Fernandez *et al.*, 2006).

Clooncruff and Cloonlarge Bogs comprises a large area of high bog, situated along the north-western shore of Lough Ree. In general, the vegetation is dominated by species such as *Erica tetralix*, *Calluna vulgaris*, *Eriophorum vaginatum*, *Narthecium ossifragum*, and *Trichophorum germanicum*. Typically, the degraded bog areas have a low cover of peat-forming bog mosses (*Sphagnum* spp.). There are areas of pools, wet flushes, and Bog woodland associated with the high bog. The area between Cloonlarge Bog and Lough Ree contains a mixture of old cutover, grassland and woodland, which often floods (Fernandez *et al.*, 2006).

Associated with the extensive raised bog system at Clooncruff and Cloonlarge Bogs are areas of Bog woodland. At least two small areas of woodland occur on the raised bog domes. However, it would appear that this habitat is in the early stages of development. The largest area is dominated by low trees of *Betula pubescens* and *Pinus contorta*. Occasional trees of *Pinus sylvestris* also occur. The ground layer is wet and quaking with a lush carpet of mosses present.

1.3.1.1 Flora of Clooncruff and Cloonlarge Bogs

Due to the size and the compartmentalisation of the bog, Fernandez *et al.* (2006) divided it into 16 sections to facilitate their vegetation description. ARB was recorded in Sections B, G, I (Kiltteevan Bog), and M, L and O as part of the survey.

Fernandez *et al.* (2006) described a single central ecotope area on Cloonlarge Bog. This small area (40m x 40m) is confined to a depression on the bog surface. The ground is quaking and the microtopography is well developed. There are well developed hummocks of *Sphagnum papillosum*, *S. tenellum*, *S. subnitens*, and *S. rubellum* interspersed with pools of *S. cuspidatum* and *S. denticulatum*. *Menyanthes trifoliata*, *Drosera rotundifolia* and *Andromeda polifolia* are common in the pools. *Rhynchospora alba* is frequent and *Vaccinium oxycoccos* is found growing on the *Sphagnum*, along with *Aulacomnium palustre*, indicating the presence of some flushing. *Calluna vulgaris* and *Erica tetralix* are also present, as well as *Narthecium ossifragum*. This area is bordered to the west by an active flush.

Fernandez *et al.* (2006) recorded a flushed bog woodland on high bog at Clooncruff Bog as the main feature of interest, with *Betula pubescens*, *Pinus sylvestris* and some *Ilex aquifolium*. There is a high-quality area of ARB associated with the wooded flush, with some quaking areas surrounding the woodland. In general, the remainder of the western part of the bog is of poor quality, moderately wet to dry, damaged by drainage and burning, with a large percentage of the site dominated either by *Calluna vulgaris* or bare algal patches. Two small patches of sub-central ecotope that display evidence of desiccation occur. The sub-marginal ecotope here was recorded as of good quality towards the south and mid-west, where the microtopography improved and the ground was moist with a good, diverse *Sphagnum* cover.

The eastern part of Cloonlarge Bog is mostly dominated by sub-marginal ecotope vegetation. Two extensive patches of dispersed *Sphagnum* lawns were recorded in this area. The ground is wet and spongy and low hummocks are frequent. A thin acrotelm characterises this area, which may be explained by water flowing across the surface down towards the lakeshore (Fernandez *et al.*, 2006).

Two well-developed sub-central areas were recorded in the Kiltieven section of the bog, near the inactive wooded flush, where *Sphagnum pulchrum* was recorded in hollows (Fernandez *et al.*, 2006).

A small *Betula pubescens* active flush surrounds the only central complex in the bog and an area of sub-central ecotope is found just to the north-east of this complex. The central and sub-central ecotopes lie within depressions on the high bog. A small sub-central area was recorded in Section B, with scattered pools and lawns of *Sphagnum* spp. (Fernandez *et al.*, 2006).

Crowley and Crushell (2015) undertook a targeted vegetation survey of parts of the site during early 2015, with a view to determining the ecotopes present in these areas. The parts of the site that were targeted in this survey include Sections A, C, D, J, K and N as labelled by Fernandez *et al.*, (2006). The results of the survey confirmed the absence of ARB from all of these areas.

1.3.1.2 Fauna of Clooncraff and Cloonlarge Bogs

Many of the typical fauna associated with raised bog habitats are likely to occur at Clooncraff and Cloonlarge Bogs (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 the raised bog network of sites (SACs and NHAs) have been published in the National Raised Bog SAC Management Plan (NPWS, 2017). The various attributes and the justification of appropriate targets used to define Favourable conservation condition for ARB relevant to Lough Ree SAC are discussed in the following sections.

As the long-term aim for DRB is that its peat-forming capability is re-established, the conservation objective for this habitat is inherently linked to that of ARB (7110), thus the attributes and targets set for DRB are the same as those for ARB.

2.1 Area

NPWS has commissioned a number of raised bog surveys between 1993 and the present; Kelly *et al.* (1995); Derwin and MacGowan (2000); Fernandez *et al.* (2005); Fernandez *et al.* (2006); Fernandez *et al.* (2014); Crushell *et al.* (2019). Mapping from these surveys has been used to derive the Annex I habitat areas 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.

The national SAC target for the attribute 'habitat area' has been set at 2,590ha (NPWS, 2017). 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 earliest survey of ARB at Clooncraff and Cloonlarge Bogs was undertaken in 2003. Results of that survey estimated that the total extent of ARB was 5.9ha, while the area of DRB at that time is unknown (see Table 3). 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 bog has not been subject to a detailed survey since 2003. However, a survey of part of the site undertaken in 2015 recorded a decline in ARB (Crowley and Crushell, 2015), following which the extent of ARB on the site was estimated to be 5.7ha.

The current extent of DRB, estimated using a recently developed hydrological modelling technique, based largely on Light Detection and Ranging (LiDAR)² data, is 44.7ha (see NPWS, 2017 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). It is estimated that this entire area could be restored by blocking drains on the high bog.

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 50.4ha. However, it is important to

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.

note that this assumes no further decline of ARB due to losses of high bog caused by peat-cutting and drainage activities associated with same (Fernandez *et al.*, 2006). 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 Lough Ree SAC in 2003 and 2015 (Sources: Fernandez *et al.*, 2006 and Crowley and Crushell, 2015).

2003		2015	
ARB (ha)	DRB (ha)	ARB (ha)	DRB (ha)
5.9	Unknown	5.7	44.7

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 19.5ha of ARB could be restored in this area.

The long term target for ARB on Lough Ree is set at 69.9ha, based on figures for DRB on the high bog, along with figures for Bog woodland and estimated restoration potential on the cutover.

In conclusion, the site-specific target for the attribute habitat area is: **Restore area of Active raised bog to 69.9ha, 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 target for the attribute 'Range' has been set as 'not less than current range subject to natural processes' (NPWS, 2017).

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 and potential restoration of ARB within Lough Ree SAC as set out in Section 2.1 above will contribute to safeguarding the national range of the habitat.

The ARB habitat at Lough Ree SAC includes central and sub-central ecotopes, as well as active flushes and Bog woodland. A map showing the most recent distribution of ecotopes throughout Lough Ree SAC 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, as well as, 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 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 national SAC target for the attribute 'Habitat area' has been set at 2,590ha (NPWS, 2017).

The area of high bog within Clooncraff and Cloonlarge Bogs in 1994 was mapped as 501.9ha, while the corresponding area in 2012 was 474.4ha (based on interpretation of LiDAR and Aerial Photography flown in 2012), representing a loss of 27.5ha of high bog (NPWS, 2017). The extent of high bog within Clooncraff and Cloonlarge 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 and 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 Clooncraff-Cloonlarge raised bog complex is presented in Fernandez *et al.* (2006) based on a survey of the bog carried out in 2003. In this study, 25.9km of functional drains were reported as being present on the high bog. A recent estimate of high bog drainage based on interpretation of 2010 aerial photography suggests that there may be up to 40.1km of high bog drains; however, it is not known whether all of these drains are functional. It is likely that most of these drains were present at the time of the last survey but were only identified through the use of higher resolution aerial

photography. Fernandez *et al.* (2006) reported that many of the drains are old and have already caused extensive drying out of the high bog. Many of the drains are associated with bog tracks and peat-cutting and many were dug along townland boundaries. Most of the more recent drains dug since the 1970s are associated with conifer plantations on sections of the high bog. These conifer plantations are likely to be contributing to a lowering of the water levels within the peat. One of the plantations was felled by Coillte as part of an EU LIFE funded raised bog restoration project. Fernandez *et al.* (2006) report that apart from the semi-natural margin by the shore of Lough Ree and the southwest margin of Clooncraff, the whole site is surrounded by cutover, with associated drainage. A review of 2010 aerial photography indicates maintenance of drainage, associated with agricultural improvements along the southern boundary of Clooncraff and at a number of locations to the north of the raised bog complex.

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 studies for Clooncraff-Cloonlarge raised bog complex is based on a survey carried out by RPS in 2015 (unpublished data). Hydrochemistry measurements carried out as part of that survey identified relatively low electrical conductivity (EC) values in most areas of the cutover (generally $<100\mu\text{S}/\text{cm}$) which indicates little groundwater influence, as these values are similar to those of rain water, reflecting the inert properties of the peat. In some of the drains along the tracks and roads, elevated EC values were identified; however, it is likely that this was due to the limestone material used in the construction of these roads. Elevated EC values were identified in the cutover drains to the south-east of the bog, adjacent to the narrow section of high bog remaining in this area. This suggests there may be some upwelling of groundwater into these drains.

The presence of upwelling groundwater suggests that a small number of marginal drains intercept the regional groundwater table. This can result in a decline in groundwater head, which can impact on the surface of the bog through subsidence. The risk of subsidence depends on the permeability of the underlying mineral substrate, which will influence the extent of impacts from changes to groundwater heads. Geological mapping indicates that most of the bog is underlain by a Visean limestone bedrock unit which is a regionally important aquifer, as it is subject to karstification (conduit). A number of other limestone bedrock units appear to underlie sections of the bog. Subsoil mapping indicates that limestone till is the main mineral subsoil in the area. The presence of a productive bedrock unit as well as potentially permeable substrate suggests that a decline in groundwater head is likely to result in subsidence on the high bog.

Deepening of drains is likely to reduce the hydraulic resistance (hydraulic conductivity x peat thickness) making it easier for groundwater to discharge, and thus lowering regional groundwater levels, giving rise to increased vertical infiltration on the uncut bog. Increased vertical infiltration will alter the water balance on the bog and may cause further declines of ARB.

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

The slopes and flow patterns on Clooncraff and Cloonlarge Bogs indicate that the bog has been significantly affected by subsidence. It is clear that the roads and tracks that divide the bog have had a significant impact on the topography, with very steep slopes evident close to these roads and tracks. Furthermore, there is evidence of focused flow towards these roads, suggesting the roads and associated drainage have resulted in subsidence of the high bog surface. Despite the significant impacts on the topography of the bog there are some areas where the topography is relatively flat (slopes <0.3%) indicating there is significant potential for restoration of ARB. Further changes to flow patterns or slopes arising from subsidence due to the effects of peat exploitation and drainage are likely to have a significant impact on raised bog habitats.

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 adjacent mineral soils (including 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 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.

A small area of *Juncus*-dominated wet grassland, which floods from Lough Ree, occurs at the far eastern margin of the bog. A small area of *Betula* scrub lies adjacent to this grassland and is also likely to be subject to flooding. There is a remnant natural margin occurring between the high bog at the southern extent of Cloonlarge and the Hind River. In this area, the bog grades into an area of heath type vegetation, which in turn transitions into wet grassland that occurs along the former floodplain of the river

Apart from the semi-natural margins described above, the whole bog area is surrounded by cutover, with associated drainage. Land uses on the cutover include old and recent peat-cutting, reclaimed agricultural grassland and conifer plantations. Wet grassland occurs on about 10% of the cutover and there are some forestry plantations to the north. Approximately 10% of old cutover to the west and east has been reclaimed for agriculture (Fernandez *et al.*, 2006).

The site-specific target for the attribute transitional areas is: **Restore adequate transitional areas to support/protect the Active raised bog ecosystem 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 beothuk* and *S. austinii*; pool indicators: *S. cuspidatum* and *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.

A summary description of the vegetation of Clooncraff and Cloonlarge Bogs (which lie within Lough Ree SAC) is presented in Section 1.3.1.1 above. The vegetation and habitats of the bog have been described in more detail by Fernandez *et al.*, (2006).

The extent of the different ecotopes that correspond with ARB based on the most recent surveys is presented in Table 4 and Map 2.

The target for this attribute is 35.0ha of high quality ARB (50% of ARB target area (69.9ha)).

Table 4 Extent of ecotopes classified as ARB in 2003 (modified from Fernandez *et al.*, 2006). Note that a partial survey of the site by Crowley and Crushell (2015) estimated that there was 0.2ha less of sub-central habitat present in 2015.

Ecotope	2003	
	ha	% of total ARB
Sub-central ecotope	2.85	48.1
Central ecotope	0.20	3.4
Active flushes	0.76	12.8
Bog woodland	2.12	35.8
Total ARB	5.93	

The site-specific target for the attribute vegetation quality is: **Restore 35.0ha 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.

Well-developed microtopography occurs in the ARB areas of Clooncraff and Cloonlarge Bogs (which lie within Lough Ree SAC) (Fernandez *et al.*, 2006).

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 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 rubellum*, *S. austinii* and *S. papillosum* which form hummocks or low ridges. *Sphagnum beothuk* may also form hummocks (Cross, 1990). On the flats *Sphagnum medium*, *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 Clooncraff and Cloonlarge Bogs, the overall *Sphagnum* cover is high (40-100%) in the ARB areas, and low (5-35%) in DRB areas (Fernandez *et al.*, 2006). Further information on the distribution of *Sphagnum* species throughout the bog is presented by Fernandez *et al.* (2006) and Crowley and Crushell (2015).

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
<i>Sphagnum austinii</i>	Hummock species	High
<i>Sphagnum rubellum</i>	Forms small hummocks and carpets	Moderate
<i>Sphagnum cuspidatum</i>	Pool and hollow species	Low
<i>Sphagnum denticulatum</i>	Pool and hollow species	Low
<i>Sphagnum fallax</i>	Occurs in lawns and carpets, shade tolerant. Indicative of some nutrient enrichment (soaks and active flushes)	Low
<i>Sphagnum beothuk</i>	Forms dense low and wide, and occasionally high hummocks	High
<i>Sphagnum medium</i>	Lawn species forming carpets and low hummocks	Moderate
<i>Sphagnum palustre</i>	Forms hummocks and dense carpets, often in shaded conditions. Indicative of nutrient enrichment (soaks and active flushes)	Low
<i>Sphagnum papillosum</i>	Lawn , hollow, and low hummock species	Moderate
<i>Sphagnum pulchrum</i>	Grows in lawns and hollows, more typical of western bogs	Moderate
<i>Sphagnum squarrosum</i>	Forms carpets and small mounds. Indicative of nutrient enrichment (soaks and active flushes)	Low
<i>Sphagnum subnitens</i>	Occurs as individual shoots or small cushions and lawns. Tolerant of minerotrophic conditions	Moderate
<i>Sphagnum tenellum</i>	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

Clooncraff and Cloonlarge Bogs (within Lough Ree SAC) support the full complement of plant species typically associated with a 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 beothuk* 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 Clooncraff and Cloonlarge Bogs (Fernandez *et al.*, 2006).

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.

Clooncraff and Cloonlarge Bogs (within Lough Ree SAC) are 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 main feature of interest on this bog is the large number of flushes on the high bog, including those that support Bog woodland. Fernandez *et al.* (2006) describe a total of 28 flushes on the bog, of which six are classed as active.

2.3.10.2 Rare flora

No rare flora records have been reported from Clooncraff and Cloonlarge Bogs.

2.3.10.3 Rare fauna

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

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.

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 medium* 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 some areas of sub-central ecotope on Clooncraff and Cloonlarge Bogs (Fernandez *et al.*, 2006). Non-native species associated with the felled forestry on the high bog at Kiltieven include *Rhododendron ponticum* and *Pinus contorta* (Derwin, 2008).

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 and 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 5kg and 10kg N/ha/yr for these ecosystems (Bobbink and Hettelingh, 2011), a level which is exceeded over a significant

portion of their range. An Irish study during the late 1990s undertaken by Aherne and 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 and Farrell (2000) was 10kg N/ha/yr. This is in line with the recommendation by Bobbink and 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.

In the case of on Clooncraff and Cloonlarge Bogs (within Lough Ree SAC), it is recommended 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 Clooncraff and Cloonlarge Bogs as reported by Henry and Aherne (2014) was 14.2kg N/ha/yr.

The site-specific target for the attribute air quality is: **Air quality surrounding bog close to natural reference conditions. The total 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 and 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 Clooncraff and Cloonlarge Bogs was investigated by RPS in 2015. This survey recorded relatively low electrical conductivity (EC) values in most areas of the cutover (generally <100µS/cm) which indicates little groundwater influence, as these values are similar to those of rain water, reflecting the inert properties of the peat. Elevated EC values were identified in the cutover drains to the south-east of the bog, adjacent to the narrow section of high bog remaining in this area. This suggests there may be some upwelling of groundwater in to these drains.

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.**

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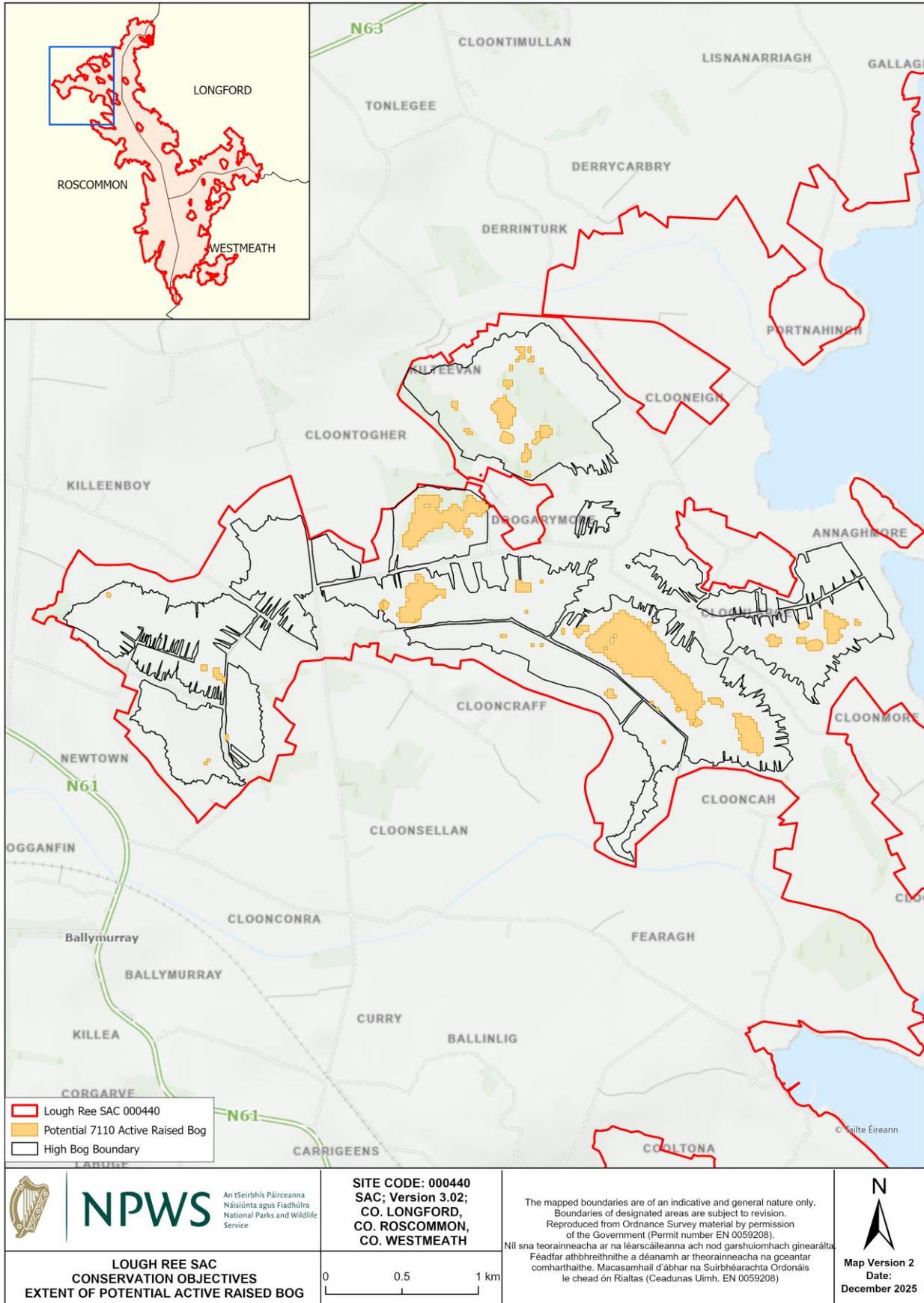
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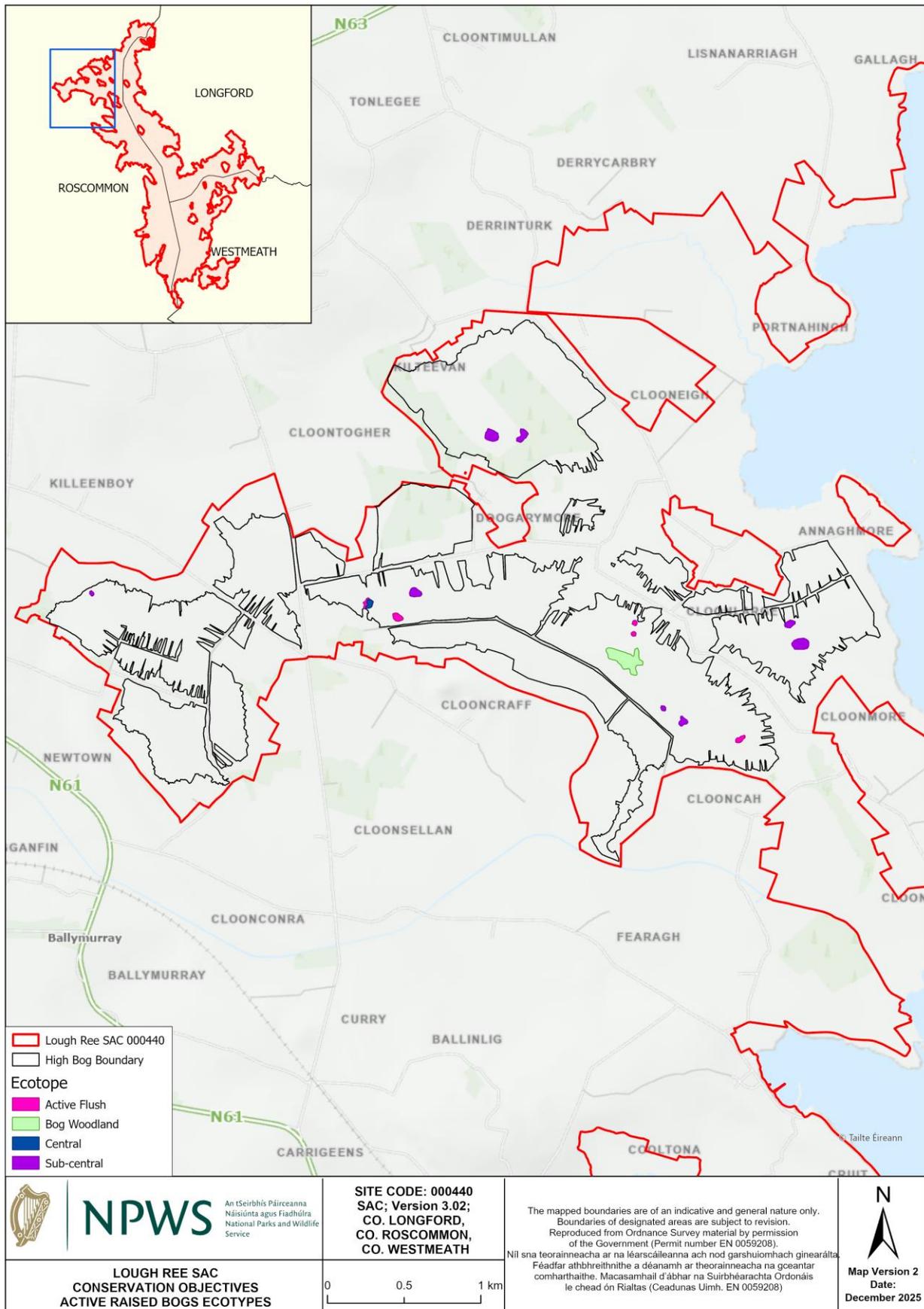
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Map 1: Extent of potential Active raised bog on Clooncraft and Cloonlarge Bogs (within Lough Ree SAC).



Map to be read in conjunction with the NPWS Conservation Objectives Document.

Map 2: Distribution of raised bog ecotopes on Clooncraft and Cloonlarge Bogs (within Lough Ree SAC).



Map to be read in conjunction with the NPWS Conservation Objectives Document.

Map 3: Digital elevation model and drainage patterns at Clooncraft and Cloonlarge Bogs (within Lough Ree SAC).

