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Scoping Study and Pilot Survey of Fens

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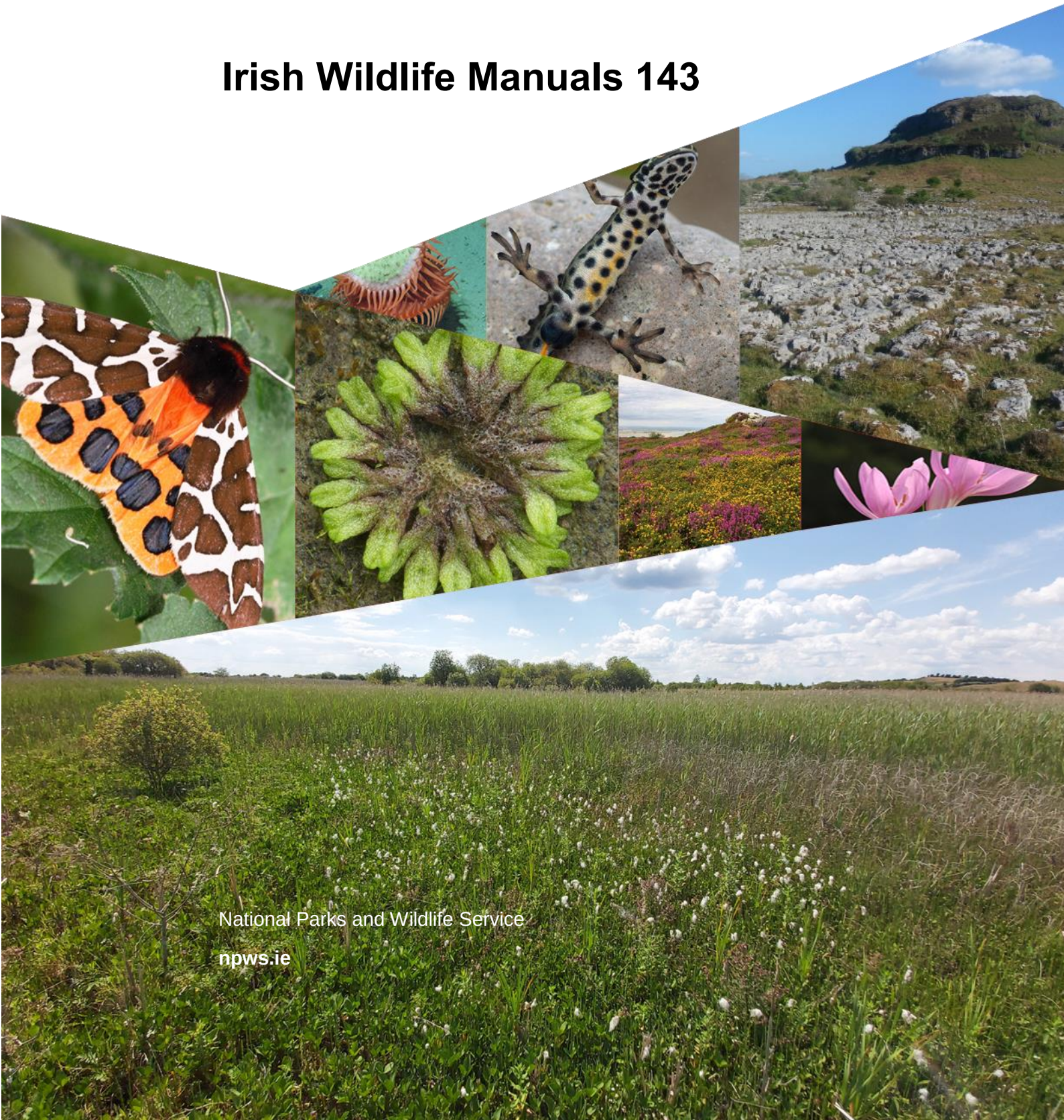

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Front cover, small photographs from top row:

A deepwater fly trap anemone *Phelliactis* sp., Yvonne Leahy; **Common Newt** *Lissotriton vulgaris,* Brian Nelson; **Limestone pavement**, Bricklieve Mountains, Co. Sligo, Andy Bleasdale; **Garden Tiger** *Arctia caja,* Brian Nelson; **Violet Crystalwort** *Riccia huebeneriana*, Robert Thompson; **Coastal heath**, Howth Head, Co. Dublin, Maurice Eakin; **Meadow Saffron** *Colchicum autumnale*, Lorcan Scott

Bottom photograph: **Transition mire and reed swamp**, Fin Lough, Offaly, James Martin

Scoping Study and Pilot Survey of Fens

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Contents

Executive Summary

This report describes the findings of a scoping study for a national survey of fen habitats in Ireland and also the results of a pilot field survey of seven sites conducted in 2019-2020. Fens are peat-forming wetland ecosystems that tend to be dominated by sedges and bryophytes (mosses and liverworts). They can be broadly divided into topogenous fens, which are fed predominantly by vertical water movement (*e.g.,* basins, hollows and open water transitions), and soligenous fens, which are fed predominantly by horizontal water movement (*e.g.,* upland flushes, valley fens and the laggs of raised bogs). Fen habitats range from relatively nutrient-poor and acidic to more nutrient-rich and moderately or highly calcareous. Ireland has special obligations to conserve three types of fen listed under Annex I of the EU Habitats Directive: Transition mires (habitat code 7140), *Cladium* fens (habitat code 7210) and Alkaline fens (habitat code 7230).

Fen habitats are important to a wide range of invertebrate groups, including butterflies, moths, dragonflies, damselflies, snails, spiders, beetles, true flies and caddisflies. Invertebrate communities deserve attention when assessing the conservation status of Annex I fen habitats, but surveying for invertebrates at each of the sites covered by a national fen survey is unlikely to be feasible. It is instead recommended that baseline surveys be conducted by specialists at a selection of important sites. The results of these surveys should be used to establish site-specific assessment criteria for each Annex I fen habitat, focusing on a subset of characteristic species chosen from each site's invertebrate assemblage.

Understanding fen hydrology is critical to successful fen management. To this end, the proposed survey protocol includes measures for mapping ditches and collecting water data in the field (pH and conductivity). For each site, data on groundwater vulnerability and recharge, subsoil types and permeability, bedrock, aquifers, soil types and karst features should be collated from existing Environmental Protection Agency (EPA) and Teagasc Geographic Information System (GIS) datasets. Combined with data and observations from the field, this information should be used in a first attempt to characterise each site using the Wetland Framework approach.

The distribution of Annex I fen habitats in Ireland has previously been mapped for reporting under Article 17 of the Habitats Directive. A review of available datasets was conducted to identify any sources which have hitherto not been utilised for this purpose. GIS data sources were also used to compile a list of suitable sites for inclusion in a national fen survey. All 58 SACs that have an Annex I fen habitat as a Qualifying Interest were selected as a matter of priority. A further 347 other sites were selected on the basis of site area, possible presence of Annex I habitats, and our knowledge about fen distribution on a county basis.

As new information is gathered during the National Survey, 100 additional sites will be chosen for survey. This is to account for the imperfect nature of the available data used for site selection and is based on the assumption that there will be areas of good fen habitat encountered that were not initially selected. The resources required to conduct a national survey have been estimated and presented.

Methodologies for the survey of selected sites has been proposed, including the preparation of field maps, required equipment, health and safety protocols, habitat mapping, monitoring stop recording, recording of impacts and data management. The assessment procedure for Annex I habitats is outlined and both the definitions and assessment criteria for the three Annex I fen habitats have been amended. A conservation scoring system for fen systems has been devised to allow comparison between sites.

Across the seven pilot sites, which totalled 679 ha in area, 259 ha of Annex I fen habitat were mapped and 60 monitoring stops were recorded. Of the six sites in which 7140 habitat was recorded, one was assessed as Favourable, four were Unfavourable-Inadequate and one was Unfavourable-Bad. Of the three sites in which 7210 was assessed, one was Favourable and

two were Unfavourable-Inadequate. Of the six sites in which 7230 was assessed, one was Favourable, three were Unfavourable-Inadequate and two were Unfavourable-Bad. The main impacts recorded were drainage and scrub encroachment. Site reports following a standard template have been compiled for each site including mapping of habitats, water data, target notes and drains.

Measures which would benefit a national fen survey have been recommended regarding bryophyte training, species nomenclature, recording of nutrient enrichment and the potential use of UAV (unmanned aerial vehicle) surveys.

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The authors would like to thank: Maurice Eakin and Shane Regan of NPWS for their advice and feedback on this project, and Fernando Fernandez Valverde and Brian Nelson for additional comments on an earlier draft of this report; Rory Hodd, Kate McNutt and George Smith for conducting the field surveys of Pollardstown Fen and Scragh Bog; and several landowners for kindly permitting access to their sites.

1 Introduction

1.1 Fen Habitats in Ireland

Fens are peat-forming ecosystems with high water tables, which tend to be dominated by sedges and bryophytes. Unlike bog habitats, they are not usually dominated by *Sphagnum* and are generally more alkaline. The term 'fen' does, however, encompass a wide range of peat-forming habitats: from relatively oligotrophic, acidic Poor fen and flush (PF2) (Fossitt, 2000) to mesotrophic, moderately to highly calcareous rich fen and flush (PF1). Transition mires and quaking bogs (PF3) tend to be influenced by acid to mildly mineral or base-rich water sources.

Fen systems can be large and highly complex, supporting a mosaic of different wetland habitats, such as reed and large sedge swamps (FS1), tall-herb swamps (FS2), wet grassland (GS4), calcareous springs (FP1) and open water. They can be fed by predominantly vertical (topogenous) water movement (*e.g.,* basins, hollows and open water transitions), or horizontal (soligenous) water movement (*e.g.,* upland flushes, valley fens and the laggs of raised bogs). In complex systems such as large floodplain fens, both types of water movement may be present. Fens can support species-rich flora, with the highest diversity being found in rich fen and flush small sedge and bryophyte communities. In contrast, habitats such as Poor fen and flush or mono-dominant stands of *Cladium mariscus* tend to have lower plant species diversity.

The most extensive fen areas in Ireland occur in lowland basins associated with limestone groundwater, such as those found in the midlands. Flushes and open water fens tend to be smaller but can be more widespread and can extend into upland areas.

1.2 Rationale for the Current Project

1.2.1 Previous Fen Surveys in Ireland

Fens have been surveyed in an *ad hoc* fashion in Ireland. Some fen surveys were carried out with a focus on specific species or taxonomic groups (*e.g., Hamatocaulis vernicosus*, *Saxifraga hirsuta,* insect surveys), with fen habitats not being the primary focus of the survey. Other fen habitats have been surveyed as part of larger habitat surveys such as the Galway City Transport Project (Barron *et al.*, 2015) or through various county wetland surveys conducted by Wetlands Survey Ireland (*e.g.,* Foss *et al.*, 2014; Foss & Crushell, 2015). Fens and upland flushes were often mapped among bog, heath and grassland habitats during the National Survey of Upland Habitats (Perrin *et al.*, 2014). However, there has never been a national survey dedicated to fen habitats carried out in Ireland.

Foss & Crushell (2008a) carried out a desktop study of fens for the National Parks and Wildlife Service (NPWS) and completed a comprehensive manual on conducting a national fen survey. Despite this preparatory work, field surveys were not carried out. However, in 2019, NPWS commissioned BEC Consultants to carry out a scoping study and a pilot baseline survey of seven fens in Ireland. These sites were surveyed during 2019 and 2020.

1.2.2 Article 17 of the EU Habitats Directive

Annex I habitats are habitats of European importance which are listed in Annex I of the EU Habitats Directive (92/43/EEC). Under Article 17 of the Habitats Directive, all EU Member States that are signatories of the Directive have a legal obligation to report on the conservation status of the Annex I habitats that occur within their boundaries. These national conservation status assessment reports are produced every six years. The next round of reporting, covering the period 2019-2024, is due in 2025. This will be the fourth round of reporting carried out under Article 17.

IWM 143 (2023) Pilot fen survey
The outputs of this Pilot Fen Survey (PFS) will form the basis for a proposed National Fen Survey (NFS). This will in turn feed into Ireland's 2025 Article 17 report for three Annex I fen habitats (see Appendix 1 for more detailed descriptions from Long *et al*., 2018):

- 7140 Transition mires and quaking bogs – physically unstable peat-forming communities, typically occurring as swards or floating mats over saturated peat or open water, encompassing a broad range of plant communities that are characteristic of ombrotrophic to soligenous waters
- 7210 Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae – *Cladium mariscus* beds which are in contact with species-rich vegetation of small sedge fens, fen meadows and tall-herb fens
- 7230 Alkaline fens – groundwater-fed, generally peat-forming systems with extensive areas of species-rich small sedge and brown moss communities

1.3 Project Objectives

1. The main tasks of the scoping and PFS were to: Review, collate and analyse existing scientific/survey reports, publications and other data to establish a contemporary understanding of fen distribution in Ireland and to identify information gaps

2. Review the existing knowledge of invertebrates of fens in Ireland and how invertebrates are dealt with in the assessment procedures of Annex I fen habitats in other Member States; to collate available information on invertebrate fauna of the pilot sites and to make recommendations on the inclusion of an invertebrate survey within the wider, national survey

3. Review and update the National Fen Survey Manual (Foss & Crushell, 2008a)

4. Conduct pilot field surveys within a selection of fen sites

5. Record relevés within the range of vegetation communities at each of the pilot sites

6. Characterise fens based on hydrogeological and hydrochemistry attributes

7. Devise a national monitoring programme for the purposes of reporting under Article 17 of the EU Habitats Directive with a standardised and appropriate methodology, applicable to the above three Annex I fen habitats

8. Review and recommend revisions for the site-specific Conservation Objectives, Site Synopses and Natura 2000 Standard Data Forms relevant to the pilot survey sites based on information gathered

9. Establish criteria to evaluate the conservation value of fens at a site level to allow a full NFS to rank surveyed sites at a national scale

10. Estimate the expected time schedule for the completion of a national fen survey and identify, quantify and cost the necessary resources

11. Prepare an overarching report describing the above tasks, plus individual brief site reports

12. Produce a Microsoft Access database and other appropriate data files, such as ESRI shapefiles and a Turboveg (Alterra, NL) database, to hold survey and monitoring data

The scope of the PFS was to survey seven sites located in designated sites for which Annex I fen habitats were documented as being present. Six of these sites were located in a Special Area of Conservation (SAC), for which at least one Annex I fen habitat was listed as a qualifying interest (QI); the seventh site, Lough Garr, was within a Natural Heritage Area (NHA) in which an area of Annex I fen habitat was mapped for Article 17 reporting (NPWS, 2019). The PFS

was not limited to Annex I habitats; however, there was a particular focus on the three Annex I fen habitats mentioned in section 1.2.2.

1.4 Structure of the Report

This report is divided into a number of parts to address the tasks outlined in section 1.3.

Part I: Literature review and background information

- Review of fen habitat definitions and classification systems
- Literature review of the existing knowledge of invertebrates of fens in Ireland, particularly the seven pilot study sites
- Characterise the hydrogeological and hydrochemistry attributes of fens

Part II: Working towards a National Fen Survey

- Literature review of current fen distribution in Ireland
- Identify the sites and resources required to complete a National Fen Survey
- Methodology for the NFS, including habitat mapping, relevé recording, data management and assessments for Article 17 reporting
- Criteria to evaluate the conservation value of fens at site level to allow ranking of surveyed sites at a national scale

Part III: The Pilot Fen Survey 2019-2020

- Tests the survey and assessment methodology in pilot sites
- Presents the results of the PFS
- Makes recommendations for the NFS based on the experience gained during the PFS

Task 3, the review of the National Fen Survey Manual (Foss & Crushell, 2008a) is addressed in Appendix 2. Tasks 8 and 12 produce digital outputs which do not form part of the report.

Part I: Literature Review and Background Information

2 Review of Fen Habitats

2.1 Fen Habitat Classification Systems

Fens receive nutrients from surface water or groundwater in addition to rainfall, and are considered minerotrophic. Bogs, on the other hand, are considered to be ombrotrophic (rain-fed) but bog and fen habitats can occur in the same system and the division between them may not always be clear. Fens can be classified in various ways, based on, for example, topography (*e.g.,* valley or basin), hydrological characteristics (water movement through the fen), water chemistry (nutrients and pH) or floristics (vegetation type). Certain wetland habitats are included or excluded depending on which criteria or classification system is used. These are reviewed below and some guidance notes are provided.

2.1.1 System Approach

The 'system' approach to fen classification uses hydrology and topography to classify fen systems. These may support a range of different vegetation types. As an example, Foss & Crushell (2008a) included information on the following for Irish fens in the section 'Fen topography and hydrological classification scheme':

- Topogenous fens:
    - Open-water transition fens
    - Flood plain fens
    - Basin fens
- Soligenous fens:
    - Valley fens
    - Flush fens
    - Calcareous spring fens

Topogenous fens are those in which there is vertical water movement. The groundwater level is high due to local landscape features, such as being at the edge of a floodplain, in a basin or at the edge of a waterbody. Water movement in topogenous fens is usually slow (Šefferová Stanová *et al.*, 2008) and they are usually peat-forming. In soligenous fens, the water movement is horizontal and there is usually surface flowing water (Šefferová Stanová *et al.*, 2008). Soligenous fens include springs, upland flushes and valley fens and they may or may not be peat-forming. Some systems can have elements of both topogenous and soligenous fen; for instance, a floodplain may be largely topogenous (high groundwater level) but there may be some soligenous input of water from alluvial flooding.

This 'system' approach is used in the UK for Common Standards Monitoring of lowland, non-coastal wetlands (JNCC, 2004). The scheme recognises the following types:

- Lowland raised bog and blanket bog
- Lowland fen, including:
    - Flood-plain fen
    - Basin fen
    - Open-water transition fen

- Valley fen
- Springs and flushes
- Fen woodland
- Fen meadow

The JNCC guidance also lists the various hydrotopographical elements that may occur within such wetlands, including alluvial wetland, waterfringe wetland, sump wetland, percolating wetland, water track, spring-fed wetland, run-off wetland, soakway, topogenous bog and hill bog. The system approach will be looked at further when considering the hydromorphology of fens in section 4.

2.1.2 Hydrochemistry Approach

The division between rich and poor fens is related to water chemistry rather than topography or hydrology. Rich fens include fen habitats where the water source is alkaline, *e.g.,* from groundwater arising through limestone bedrock. Poor fens occur where the source water is more acidic. They differ from bog habitats in that they have a minerotrophic water source which brings additional nutrients into the system. These fen types can occur in both topogenous and soligenous hydrological conditions. The hydrochemistry approach will be looked into further in section 4.

2.1.3 Habitat Approach

Another approach to fen and wetland classification uses habitat categories. Criteria such as vegetation structure, soil type and management are taken into account, in addition to some species information.

Detailed botanical data are not usually incorporated. Some examples of this approach are EUNIS, EU Habitats Directive Annex I habitats, and *A Guide to Habitats in Ireland* (Fossitt, 2000).

2.1.3.1 EUNIS (European Nature Information System)

The EUNIS habitat classification is a pan-European system, details of which can be found online (https://eunis.eea.europa.eu/habitats.jsp). The categories most relevant to fens are:

- D -Mires, bogs and fens
  - D1 - Raised and blanket bogs
  - D2 - Valley mires, poor fens and transition mires
    - D2.1 - Valley mires
    - D2.2 - Poor fens and soft-water spring mires
    - D2.3 - Transition mires and quaking bogs
  - D3 - Aapa, palsa and polygon mires
  - D4 - Base-rich fens and calcareous spring mires
    - D4.1 - Rich fens, including eutrophic tall-herb fens and calcareous flushes and soaks
    - D4.2 - Basic mountain flushes and streamsides, with a rich arctic-montane flora

In this system, ombrotrophic bogs (D1) are separated from minerotrophic fens with neutral to acidic pH (D2) and those with an alkaline influence (D4). Aapa, palsa and polygon mires (D3) are not found in Ireland, being restricted to boreal, subarctic and arctic regions. While this

system can be applied in Ireland, the category descriptions are often too sparse to be easily interpreted.

2.1.3.2 Annex I Habitats

In the 'Guidelines for a National Fen Survey of Ireland' (Foss & Crushell, 2008a), four Annex I fen habitats were included (*indicates priority Annex I habitat) (see definitions in Appendix 1 for three of these habitats):

- 7140 Transition mire and quaking bogs
- 7210 *Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae
- 7220* Petrifying springs with tufa formation (Cratoneurion)
- 7230 Alkaline fens

Subsequently, priority habitat 7220 Petrifying springs was the subject of separate monitoring and reporting in Ireland and so was not a focus of the proposed NFS. Additional Annex I habitats related to fen habitats include:

- 6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae) – usually surveyed and assessed with grasslands
- 6430 Hydrophilous tall-herb fringe communities of plains and of the montane to alpine levels – occasionally surveyed and assessed with grasslands
- 3180* Turloughs – usually surveyed and assessed separately
- 21A0* Machairs – usually surveyed and assessed with coastal or grassland habitats
- 2170 Dunes with *Salix repens* ssp. *argentea* (Salicion arenariea) – usually surveyed and assessed with coastal habitat
- 2190 Humid dune slacks – usually surveyed and assessed with coastal habitats

Sometimes, separation of these related habitats from fen habitats is not easy. Guidance in this regard is provided in section 2.3. Annex I habitats are of central importance to the proposed NFS but they cannot be used alone to categorise fens as not all fen habitats have affinity to Annex I habitats, *e.g.,* poor fens and mesotrophic fens.

Depressions on peat substrates of the *Rhynchosporion* (7150) occurs within valley fens in southern England (*e.g.,* the New Forest and Dorset) but in Ireland this habitat is essentially restricted to raised bogs and lowland blanket bogs and is not considered an Annex I fen habitat.

2.1.3.3 A Guide to Habitats in Ireland

In Ireland the main habitat classification scheme that is used is 'A Guide to Habitats in Ireland' (Fossitt, 2000). Three types of fen habitat are recognised:

- PF1 Rich fens and flushes (can correspond with habitats 6410, 7210 or 7230, or be non-Annex I)
- PF2 Poor fen and flush (does not correspond with an Annex I habitat)
- PF3 Transition mire and quaking bog (corresponds with habitat 7140)

In addition, several habitat types are likely to be frequently found in association with fens:

- GM1 Marsh
- GS4 Wet grassland (can correspond with habitat 6410)
- HH3 Wet heath

- FP1 Calcareous springs (both tufa-forming and non-tufa-forming examples)
- FP2 Non-calcareous springs
- FS1 Reed and large sedge swamps (can also correspond with habitat 7210)
- FS2 Tall-herb swamps
- PB1 Raised bog (which can contain fen or flush systems)
- PB2 Lowland blanket bog (which can contain fen or flush systems)
- PB3 Upland blanket bog (which can contain fen or flush systems)
- WN6 Wet willow-alder-ash woodland (in the form of fen carr)

This habitat classification system is not intended to capture all of the variation in vegetation communities that is important for the detailed survey and evaluation of sites. However, the categories usually work well for the identification and mapping of wetland sites, and vegetation communities can be used in conjunction with this classification to provide a further level of detail.

2.1.4 Vegetation Community Approach

When mapping and monitoring fen communities, a vegetation community approach provides the best level of detail and consistency between surveyors. Hájek *et al.* (2006), in a paper addressing standardised fen terminology when classifying fens according to environmental gradients, stated their belief that 'fen classification based exclusively on floristic data is necessary to avoid circular argumentation and provides the best basis for the characterisation of habitats.'

2.1.4.1 Phytosociological Classification

Ó Críodáin & Doyle (1994) and White & Doyle (1982) classified Irish fen vegetation using classical central European phytosociology. Their work was summarised by both Foss & Crushell (2008a) and Foss (2007) in sections on 'Fen floristic and phytosociological classification'. Part of their scheme is presented here, updated with the recent nomenclature of Mucina *et al.* (2016):

- Scheuchzerio palustris-Caricetea fuscae Tx. 1937
    - Caricetalia davallianae Br.-Bl. 1950 nom. conserv. propos.
        - Carici nigrae-Juncetum articulati
        - Campylio-Caricetum dioicae
        - Schoenetum nigricantis
        - Juncetum subnodulosi
    - Caricetalia fuscae Koch 1926
        - Carici curtae-Agrostidetum caninae
        - Caricetum magellanicae
        - Sphagneto-Juncetum effusi
        - Drepanoclado exannulati-Caricetum aquatilis
- Scheuchzerietalia palustris Nordhagen ex Tx. 1937
        - Sphagneto-Caricetum lasiocarpae
        - Calliergo-Caricetum diandrae
- Phragmito-Magnocaricetea Klika in Klika et Novák 1941

- Magnocaricetalia Pignatti 1953
  - Cladietum marisci

While classical phytosociology provides a detailed categorisation, it is impractical for survey purposes due to the awkward nomenclature, lack of detailed and consolidated descriptions at the association (community) level, and often the absence from the Irish flora of diagnostic species.

2.1.4.2 National Survey of Upland Habitats Provisional Classification

The National Survey of Upland Habitats (NSUH) sought to record vegetation at a more detailed level than that provided by Fossitt (2000). A provisional upland classification was created, derived largely from the British National Vegetation Classification. This was a subjective classification that was not based on analysis of floristic data but proved very useful in an upland context.

The classification was designed so that there were direct correlates with both Fossitt (2000) and Annex I habitats. Several of the NSUH categories covered fen habitats and are listed here, with their correlates in parentheses:

- PO1a *Menyanthes trifoliata* - *Carex limosa* pool community: infilling pool sub-community (7140/PF3)
- SW1 *Potamogeton polygonifolius* soakway (PF2)
- PFLU1 *Carex nigra/echinata* - *Sphagnum denticulatum* flush (PF2)
- PFLU2 *Juncus effusus* - *Sphagnum cuspidatum/palustre* flush (PF2)
- PFLU4a *Molinia caerulea* - *Sphagnum palustre* flush: typical sub-community (PF2)
- PFLU4b *Molinia caerulea* - *Sphagnum palustre* flush: *Erica erigena* sub-community (PF2)
- PFLU5 *Carex rostrata* - *Sphagnum* spp. flush (7140/PF3)
- RFLU1a *Carex viridula* subsp. *oedocarpa* - *Pinguicula vulgaris* - *Juncus bulbosus* flush: brown moss sub-community (7230/PF1)
- RFLU1b *Carex viridula* subsp. *oedocarpa* - *Pinguicula vulgaris* - *Juncus bulbosus* flush: species-poor sub-community (PF1)
- RFLU2 *Eleocharis quinqueflora* - *Carex viridula* flush (7230/PF1)
- RFLU3 *Carex panicea* - *Carex viridula* subsp. *oedocarpa* flush (PF1) (a rare, high-altitude community)
- RFLU4 *Schoenus nigricans* – *Scorpidium scorpioides* flush (7230/PF1)
- RFLU1a *Carex rostrata* fen: brown moss sub-community (7230/PF1)
- RFEN1b *Carex rostrata* fen: species-poor sub-community (7140/PF3)
- HW1iii *Sphagnum denticulatum/cuspidatum* hollow: flush variant (FP2)
- HW4ii *Eleocharis multicaulis* hollow: flush variant (PF2)

2.1.4.3 Irish Vegetation Classification

A recent development has been the ‘Irish Vegetation Classification’ (IVC) system (see overview in Perrin *et al.*, 2018). This is based on the National Vegetation Database (NVD), which holds data on over 30,000 relevés, many of which are from NPWS national vegetation surveys. This is a statistically-based and validated vegetation classification system which provides an online application (ERICA) for the objective assignment of vegetation sample data. It is a hierarchical classification system with the following structure: Class > Formation >

Division > Group > Community > Sub-community. An excerpt from the hierarchy is shown in Table 1.

Table 1 Excerpt from the Irish Vegetation Classification (IVC) hierarchy showing the groups relevant to fens.

Class	Formation	Division	Group
Shrub and Herb vegetation	Inland Shrub and Herb vegetation	Grasslands (GL)	*Juncus acutiflorus – Holcus lanatus* group (GL1)
		Fens and Mires (FE)	*Schoenus nigricans – Campylium stellatum* group (FE1)
			Menyanthes trifoliata – Potentilla palustris group (FE2)
			Agrostis stolonifera – Carex nigra group (FE3)
Aquatic Vegetation	Freshwater Vegetation	Freshwater Habitats	*Phragmites australis – Cladium mariscus* group (FW3)

This approach is based on a large data set, thus reducing judgement bias in assigning categories, and facilitating the determination of affinities to Annex I habitats, EUNIS and UK vegetation classification systems.

The IVC is still under development and it is likely that additional fen communities will be described as more detailed relevé data are collected. It is hoped that the NFS will facilitate such additions.

The fen types that are currently included in the IVC (excluding those restricted to coastal and turlough habitats) are summarised in Table 2, and the affinities to Annex I fen and related habitats are shown in Table 3. The IVC largely supersedes the NSUH classification.

Table 2 Irish Vegetation Classification of major fen communities and main affinities with Fossitt (2000). Notes: [1]Also has affinity to GM1 where brown mosses absent (not 7230) and habitat not quaking (not 7140); [2]Also has possible affinity to FL6 (where it occurs in turlough basins) and CD5 (in coastal dune slacks).

Code	Community	FP1	FP2	FS1	FS2	PF1	PF2	PF3
FE1A	*Schoenus nigricans – Campylium stellatum* fen					x		
FE1B	*Schoenus nigricans – Succisa pratensis* fen					x		
FE1C	*Carex panicea – Carex viridula* fen					x	x	
FE2B	*Carex limosa – Menyanthes trifoliata* mire						x	x
FE2C	*Carex lasiocarpa – Menyanthes trifoliata* mire							x
FE2D	*Carex rostrata – Menyanthes trifoliata* mire			x				x
FE2E	*Menyanthes trifoliata – Sphagnum recurvum* agg.							x
FE2F	*Menyanthes trifoliata – Calliergonella cuspidata* mire[1]					x		x
FE3A	*Carex nigra – Ranunculus flammula* fen[2]					x		
FE3D	*Carex nigra – Calliergonella cuspidata* fen					x		

FW3C	*Carex rostrata* swamp/fen	x		x	
FW3H	*Cladium mariscus – Phragmites australis* swamp	x			

Table 3 Irish Vegetation Classification of major fen communities and main affinities with Annex I habitats.

Code	Community	7140	7210*	7230	Other
FE1A	*Schoenus nigricans – Campylium stellatum* fen			x	
FE1B	*Schoenus nigricans – Succisa pratensis* fen			x	6410
FE1C	*Carex panicea – Carex viridula* fen			x	
FE2B	*Carex limosa – Menyanthes trifoliata* mire	x			
FE2C	*Carex lasiocarpa – Menyanthes trifoliata* mire	x			
FE2D	*Carex rostrata – Menyanthes trifoliata* mire	x			
FE2E	*Menyanthes trifoliata – Sphagnum recurvum* agg.	x			
FE2F	*Menyanthes trifoliata – Calliergonella cuspidata* mire	x		x	
FE3A	*Carex nigra – Ranunculus flammula* fen			x	2190/ *3180
FE3D	*Carex nigra – Calliergonella cuspidata* fen	x			2190
FW3C	*Carex rostrata* swamp/fen	x			
FW3H	*Cladium mariscus – Phragmites australis* swamp		x		

2.1.4.4 Conclusions on Fen Classification

Based on this review it is proposed that:

- the NFS should use the Fossitt scheme (covers all habitats) and the IVC scheme (provides important detail at the community level), in addition to the mandatory use of Annex I habitats
- in addition to three Annex I fen habitats (7140, 7210 and 7230), the NFS should cover PF2 Poor fens and flushes, PF1 Rich fen and flush that corresponds with habitat 6410 (fen meadows), and non-Annex I examples of PF1 (mesotrophic fens lacking brown mosses)
- Both upland and lowland fen habitats should be included in the NFS, and coastal fens of humid dune slacks and machair should be excluded as they are already being monitored under a separate project

2.2 Gradients in Wetlands

The previous sections have described the classification systems for fen habitats. In practice, fens are not always discrete habitats with distinct vegetation communities and topographical and hydrological characteristics. They often grade into other fen habitats and frequently occur in mosaics. In many cases they can grade into non-fen habitats such as wet grassland, marsh and bog.

Vegetation differs along physical, chemical and biological gradients such as water level, water movement, nutrient supply, pH and vegetation succession. Understanding where different

types of fen occur along these gradients is crucial for consistently identifying them. For example:

- Fertility gradient: dystrophic > oligotrophic > mesotrophic > eutrophic; *e.g*., dystrophic bog pool > ombrotrophic raised/blanket bog > mesotrophic poor fen > mesotrophic fen > eutrophic grassland/marsh/swamp
- pH gradient: acidic > neutral > alkaline/calcareous; *e.g*., acidic raised/blanket bog/non-calcareous spring > acidic to neutral poor fen > transition mire (elements of acidic and alkaline vegetation) > alkaline rich fen and flush > calcareous (petrifying) spring
- Water level: damp soil but no inundation > seasonal/periodic inundation > standing water throughout year; *e.g.,* wet grassland > marsh > fens and flushes/swamp
- Water source/movement: ombrotrophic > topogenous > soligenous; *e.g*., raised/blanket bog > basin poor fen > valley mire rich fen > upland flushes/ springs

Vegetation will vary along these gradients with different species composition and species richness. Species composition can be used to indicate the physical and biological parameters summarised above and to identify wetland types. Important species composition characters which can help to separate wetland habitats include:

- Proportion of nutrient-demanding species (particularly bryophytes); *e.g., Sphagnum papillosum*, which is typical of low-nutrient, rain-fed bogs > *Sphagnum palustre*, which requires some nutrient input in poor fens > *Calliergonella cuspidata*, which is typical of higher-nutrient wet grassland and fens
- Presence and abundance of pH gradient indicators; *e.g., Sphagnum cuspidatum*/*S. papillosum*, indicators of highly acid bogs > *Calliergonella cuspidata*, which can occur in neutral to basic wet grassland > indicators of high alkalinity such as brown mosses (*e.g., Scorpidium cossonii*) in fens
- Percentage cover of bryophytes; low cover in wet grassland > high cover in fen/marsh/poor fen (following wetness gradient)
- Bryophyte species richness; low in grassland/marsh > moderate in poor fen/non-calcareous springs > high in transition mire/fen/calcareous springs (follows pH and fertility gradient)
- Vegetation height; low in calcareous springs > moderate in grassland/marsh/fen/poor fen/ flush > high in swamps/tall-herb fen
- Cover of low- to medium-height sedges (indicates nutrient status and water level); high cover in low-nutrient, wet habitats (*e.g.,* transition mire, fen) > low cover in high-nutrient, drier habitats (*e.g.,* wet grassland)
- Graminoid-to-broadleaved herb proportion; high graminoid proportion in wet grassland (grasses), rich fen/poor fen/transition mire (small to medium sedges) and reed and large sedge swamps (reed and tall sedges) > high forb proportion in marsh/tall-herb fen
- Proportion of wetland species; Low to moderate in wet grassland > dominant in marsh, rich fen and flush, poor fen, transition mire, calcareous spring, non-calcareous spring, reed and large sedge swamp and tall-herb fen. This helps to separate grassland/fen meadow from fen habitats.

Table 4 summarises the primary characteristics of four key fen types.

Table 4 Primary characteristics (pH, nutrients, species richness and composition) of key fen types.

Character	**PF2 Poor Fens and Flushes**	**7140 Transition Mires and Quaking Bogs**	**7210 Calcareous Fens with *Cladium* mariscus**	**7230 Alkaline Fens**
Acidity	Acid	Acid-neutral	Alkaline	Alkaline
Nutrient richness	Low	Low-moderate	Moderate	Moderate
Species richness	Low	Moderate	Moderate-high	High
Bryophytes	Usually dominated by *Sphagnum* species (acid indicators). Brown mosses absent	*Sphagnum* may be present and can be abundant (may include some of the most base-tolerant species such as *S. teres*) and brown mosses may be present	*Sphagnum* absent. Brown mosses locally dominant, but will be of low cover/absent where water levels are persistently high	*Sphagnum* absent. Brown mosses abundant to dominant
Graminoids	Rushes (*Juncus* spp.) and medium-height sedges often frequent	Low- to medium-height sedges often frequent	Tall sedges (*Cladium mariscus*) prominent	Low to medium sedges frequent to dominant
Broadleaved herbs	May be present but not usually abundant	Can be low to high cover (*e.g.*, *Menyanthes trifoliata*, *Comarum palustre*)	Usually not prominent	Usually not prominent

2.3 Identifying Fen Habitats

In order to survey, map and assess fen habitats, they need to be identified in the field. This section provides detailed notes and guidance on the identification of Annex I and non-Annex I fen types in the field and how to separate them from similar vegetation communities. The reader should refer to the descriptions of Annex I fen types in Appendix 1 in conjunction with these notes. A comparison of the typical species found in key fen types is presented in Table 5.

Table 5 Comparison of typical species found in the three Annex I fen habitats (according to Long *et al*., 2018) and habitat 6410 (Martin *et al.*, 2018). High quality indicators are omitted for fens.

Species	7140	7210	7230	6410
Vascular Plants				
Achillea ptarmica				+
Agrostis stolonifera	+			
Briza media			+	
Caltha palustris	+	+		
Cardamine pratensis	+			
Carex demissa	+	+	+	
Carex diandra	+	+		
Carex dioica		+	+	
Carex echinata		+		+
Carex flacca		+	+	+
Carex hostiana		+	+	
Carex lasiocarpa	+	+	+	
Carex lepidocarpa	+	+	+	
Carex limosa	+			
Carex nigra	+	+	+	+
Carex panicea		+	+	+
Carex paniculata		+		
Carex pulicaris	+	+	+	+
Carex riparia		+		
Carex rostrata	+	+	+	
Carex viridula s.l.				+
Carum verticillatum				+
Chara spp.			+	
Cirsium dissectum		+		+
Cladium mariscus		+		
Comarum palustre	+	+		
Crepis paludosa				+
Eleocharis multicaulis		+		
Eleocharis quinqueflora		+	+	
Epilobium palustre	+			
Equisetum fluviatile	+	+		

Species	7140	7210	7230	6410
Equisetum palustre			+	+
Eriophorum angustifolium	+			
Eriophorum latifolium	+	+	+	
Filipendula ulmaria	+			+
Galium palustre	+	+	+	+
Galium uliginosum				+
Hydrocotyle vulgaris	+	+	+	
Juncus acutiflorus				+
Juncus articulatus		+	+	+
Juncus bulbosus		+	+	
Juncus conglomeratus				+
Juncus subnodulosus		+	+	
Lathyrus palustris				+
Linum catharticum			+	
Lotus pedunculatus				+
Lysimachia tenella		+	+	
Lysimachia vulgaris	+			
Lythrum salicaria	+	+		
Luzula multiflora				+
Mentha aquatica	+	+	+	+
Menyanthes trifoliata	+	+		
Molinia caerulea	+	+	+	+
Myrica gale	+			
Ophioglossum vulgatum				+
Orchid species				+
Parnassia palustris		+	+	
Pedicularis palustris	+	+	+	
Phragmites australis	+	+		
Pinguicula grandiflora			+	
Pinguicula vulgaris		+	+	
Potamogeton polygonifolius	+			
Potentilla anglica				+
Potentilla erecta				+
Ranunculus flammula	+	+	+	+
Rhynchospora alba	+			
Schoenus nigricans		+	+	
Selaginella selaginoides		+	+	
Silene flos-cuculi	+	+		
Succisa pratensis	+	+	+	+
Triglochin palustre			+	
Valeriana officinalis	+			
Viola palustris	+			+

Species	7140	7210	7230	6410
Viola persicifolia				+
Bryophytes				
Aneura pinguis	+	+	+	
Aulacomnium palustre	+			
Blindia acuta			+	
Bryum pseudotriquetrum	+	+	+	
Calliergon giganteum	+	+	+	
Calliergonella cuspidata		+	+	
Campylium stellatum	+	+	+	
Ctenidium molluscum		+	+	
Fissidens adianthoides	+	+	+	
Palustriella commutata		+	+	
Palustriella falcata		+	+	
Philonotis calcarea		+	+	
Philonotis fontana	+			
Plagiomnium elatum		+	+	
Polytrichum commune	+			
Rhizomnium pseudopunctatum			+	
Sarmentypnum exannulatum	+			
Sarmentypnum sarmentosum			+	
Scorpidium cossonii	+	+	+	
Scorpidium revolvens	+	+	+	
Scorpidium scorpioides	+		+	
Sphagnum spp.	+			

2.3.1 Some Notes on 7140 Transition Mire

2.3.1.1 7140 Transition Mire *vs* 7230 Alkaline Fen

These two habitats can co-occur at sites and may sometimes be difficult to distinguish. In particular, communities that are dominated by *Carex rostrata*, that tend to have a high water table and can often be quaking, can be hard to separate. The vascular plant layer can be similar, but the key difference is in the bryophyte layer. *Sphagnum* species may be present in 7140 Transition mire but are typically absent from 7230 Alkaline fen. The so-called 'brown mosses' (see list of species under 7230 habitat in Appendix 3) may be a small component of 7140 Transition mire but typically are not dominant and will tend to include mainly those species which are tolerant of lower pH conditions such as *Calliergon giganteum, Bryum pseudotriquetrum* and *Campylium stellatum*. Brown mosses of higher pH conditions such as *Palustriella commutata* and *P. falcata* are usually absent from 7140 Transition mire. When brown mosses are present in habitat 7140, for example where alkaline spring water flushes over acidic peat in the uplands, *Sphagnum* species present are likely to be those that are more base-tolerant such as *Sphagnum contortum, S. teres* and *S. warnstorfii*. *Sphagnum* species that can tolerate more acid conditions such as *Sphagnum denticulatum, S. inundatum* and *S. fallax* are often present at the edges of such flushes in at least small quantities.

2.3.1.2 7140 Transition Mire *vs* 6410 *Molinia* Meadow

6410 *Molinia* meadow can sometimes occur at the edges of waterbodies or on cutover peat over limestone, situations where 7140 Transition mire can also occur. *Molinia* meadow (6410) differs from 7140 Transition mire in that grasses and rushes are prominent and small to medium sedges may be present but not abundant. The most frequent bryophyte is usually *Calliergonella cuspidata.*

2.3.1.3 7140 Transition Mire *vs* FS1 and FS2 Swamps

FS1 Reed and large sedge swamps and FS2 Tall-herb swamps can also occur at the edges of waterbodies and are sometimes mistakenly mapped as 7140 Transition mire as they occupy the transitional zone between open water and dry land. Transition mire (7140) has shorter vegetation, small to medium sedges are characteristic, and large reed and sedges are absent or of low cover. *Sphagnum* species may be present in 7140 Transition mire, but these will typically be absent from FS1 and FS2.

2.3.2 Some Notes on 7210 *Cladium* Fen

Cladium mariscus is a distinctive species, but 7210 *Cladium* fen has proven a difficult habitat to define and this may have led to both under-recording and over-recording in the past.

The current definition of habitat 7210, provided by Long *et al.* (2018) (Appendix 1), includes both "open swards of *Cladium mariscus* with elements of small-sedge fen, fen meadow and tall-herb fen" and "species-poor or mono-dominant stands of *Cladium mariscus* [which] transition to species-rich alkaline fen vegetation types at their margins". An amendment and some clarifications is proposed to this definition.

In the context of the species-poor stands, the current definition only alludes to habitat 7230 Alkaline fen but it alludes to a wider variety of habitat types in the context of open swards. The *Interpretation Manual of European Union Habitats* (European Commission, 2013) states that the habitat occurs "in contact with calcareous fens (7230), but also with acid fens, extensive wet meadows, other reed beds and tall sedge communities". To make the Irish definition more consistent, both internally and with the European Commission (2013) guidance, it is desirable to widen the scope of the possible contact habitats. However, to continue to limit the

occurrences of habitat 7210 to ecosystems with high conservation value, it is proposed that this scope extends only to other Annex I habitats. It is thus proposed that the definition be amended such that habitat 7210 consists of open *Cladium* swards with species characteristic of habitats 7230 (*e.g.,* small-to-medium sedges, brown mosses), 7140 (*e.g.,* small-to-medium sedges), 6410 (fen meadow plants) or 6430 (tall herbs) and species-poor beds of *Cladium* adjacent to areas of habitats 7230, 7140, 6410 and 6430. It is thought that most instances of 7210 will be associated with 7230 Alkaline fens. Foss (2007) noted that 7210 *Cladium* fen occurred in contact with reed beds and tall sedge communities and as stands in blanket bog. These stands are now not regarded as the Annex I habitat unless they also meet the above criteria. Note that in the German interpretation of habitat 7210, adjacent fen communities are "irrelevant for the identification and delimitation of this habitat type" (BfN 2012).

There are different dynamics that underpin these different stand types. Ellmauer (2005) makes a distinction between 'primary stands' of *Cladium*, which occur in the siltation zones of ponds and lakes, and 'secondary stands', where *Cladium* has spread into other herb-dominated habitats such as 7230 Alkaline fens and 6410 *Molinia* meadows following abandonment of cutting, mowing or grazing. With this distinction, primary stands are usually stable systems with a consistently high water table in which no regular management is required, whereas secondary stands could be converted back to the previous habitat if succession were to be reversed. The density of *Cladium* in both primary and secondary stands may vary depending on limiting conditions, so they may not map directly to species-poor stands and open swards respectively.

The distinction between primary and secondary stands is obviously important when weighing up management options, especially as habitat 7210 is a priority habitat, unlike habitats 7140, 7230, 6410 and 6430. Mowing and grazing will reduce the dominance of *Cladium* and favour other vegetation such as alkaline fen. This has been shown at Cors Goch (Anglesey), where cutting of firebreaks and horse grazing led to the development of species-rich alkaline fen from a species-poor *Cladium* stand within 10 years (McBride *et al.*, 2011). This could make mapping potential *Cladium* fen-alkaline fen transitions difficult as the boundaries may change with habitat management. Anon. (2014) suggests that secondary stands which have become established on abandoned 7230 Alkaline fens or 6410 *Molinia* meadows should be regarded as those habitat types when it is feasible to re-establish the original habitat types by proper land management within five years. The feasibility of such management in Ireland has yet to be investigated.

A minimum cover of 25% *Cladium mariscus* is proposed to define habitat 7210 (Anon., 2014). Where cover of *Cladium* is less than 25%, the habitat should not be regarded as habitat 7210. It may instead be regarded as habitat 7230, 7140, 6410, 6430, or as none of these. In some regions of Europe (*e.g.,* Norfolk Broads, UK), a lower threshold of >10% cover of *Cladium mariscus* is used to define 7210 *Cladium* fen (OHES Environmental, 2012).

In Northern Ireland, where there is overlap between *Cladium* fen and alkaline fens at a site, *Cladium* fens are mapped where there is a zone of closed, species-poor *Cladium* with a transition to species-rich, short-sedge mire vegetation at the margins (DEARA, 2015).

Both 7210 *Cladium* fen and 7230 Alkaline fen can also occur as recolonising vegetation on cutover peatlands where the groundwater is alkaline. In these situations, there need to be enough typical species of either habitat present and reasonable vegetation cover, *e.g.*, less than 25% bare peat. In the 2019 Article 17 data review (Long *et al.*, 2018), few recolonising peatland sites were considered to support Annex I fen habitats, but this is likely to change as vegetation develops at these sites.

There is currently only one main IVC community associated with habitat 7210: FW3H *Cladium mariscus – Phragmites australis* swamp, which refers to species-poor stands of *Cladium mariscus*. Species-rich stands of *Cladium* currently do not have their own IVC category but

those in association with base-rich fens can be accommodated under the FE1A *Schoenus nigricans – Campylium stellatum* fen where *Cladium* is described as a rare component. Collection of more plot data may help elucidate further communities with affinities for habitat 7210.

Some examples of *Cladium* fen communities in Ireland are described in the County Monaghan Fen survey II (Foss & Crushell, 2008a, b). Species recorded include the FW3H vascular plant species *Carex disticha, C. rostrata, C. viridula* (ssp. *brachyrrhyncha* and ssp. *oedocarpa*, now *Carex lepidocarpa* and *C. demissa* respectively), *Cladium mariscus, Epilobium hirsutum Epilobium palustre, Filipendula ulmaria, Hydrocotyle vulgaris, Mentha aquatica, Menyanthes trifoliata, Molinia caerulea, Phragmites australis, Succisa pratensis*, *Valeriana officinalis* and the bryophyte *Calliergonella cuspidata*.

Additional non-FW3H species recorded include the bryophytes *Calliergon stramineum* (= *Straminergon stramineum*), *Campylium stellatum sensu lato*, *Ctenidium molluscum, Drepanocladus revolvens* (likely to be *Scorpidium cossonii*), *Fissidens adianthoides*, *Hylocomium splendens* and the vascular plants *Briza media, Carex flacca, C. nigra, C. panicea, C. pulicaris, Cicuta virosa, Cirsium palustre, Juncus effusus, Parnassia palustris, Pedicularis palustris, Pinguicula vulgaris, Plantago lanceolata, Potentilla erecta, Ranunculus lingua, Schoenoplectus lacustris* and *Typha angustifolia*.

2.3.3 Some Notes on 7230 Alkaline Fen

Three main types of alkaline fen were recognised in the latest Article 17 review (Long *et al.*, 2018). The IVC fen communities were not available for that review and the fen descriptions were based on other published sources and expert opinion, including consultation with a number of Irish wetland ecologists. Based on this, the fen descriptions in Table 6 were compiled. These have now been compared with the published IVC fen communities. There is no IVC community that has clear affinity with the *'Carex rostrata* fen' community, and the division with lowland topogenous small-sedge fen and upland soligenous small-sedge fen/flush is not as clearly defined in the IVC. Further detailed floristic data from alkaline fen surveys will help to clarify whether or not the variation in alkaline fen communities has been sufficiently described. Alkaline fen is usually easy to recognise and identification of brown mosses is important in the survey and assessment of 7230. It occurs in both upland and lowland situations and includes some large lowland sites.

There will be some counties where there have not been thorough wetland surveys where additional alkaline fen sites may be recorded by the proposed NFS. 7230 Alkaline fen may have been under-recorded on re-vegetating cutover peat sites, but it is likely that many of these sites are still only starting to develop fen vegetation.

Table 6 7230 Alkaline fen types (Long *et al.*, 2018) and affinity with IVC communities.

Alkaline Fen Type	Typical Species	Affinity with IVC community(s)
Small-sedge fen with species of the Caricion-davalliana alliance	*Schoenus nigricans* and/or *Juncus subnodulosus*, with small sedges such as *Carex lepidocarpa, C. dioica, C. hostiana, C. panicea and C. nigra* and *Eriophorum* spp. Prominent brown moss layer, *e.g., Palustriella falcata, Philonotis calcarea, Campylium stellatum* and *Bryum pseudotriquetrum*.	FE1A *Schoenus nigricans – Campylium stellatum* fen FE1B *Schoenus nigricans – Succisa pratensis* fen FE3A *Carex nigra – Ranunculus flammula fen*
Carex rostrata fen	*Carex rostrata* dominant. Other frequent vascular plants include *Carex nigra, Equisetum fluviatile, Menyanthes trifoliata* with species typical of small-sedge fen. Prominent brown moss layer, *e.g., Calliergon giganteum, Scorpidium scorpioides, Campylium stellatum, Bryum pseudotriquetrum* and *Fissidens adianthoides*.	FE2F *Menyanthes trifoliata – Calliergonella cuspidata* mire (although this has higher affinity with 7140)
Upland base-rich flushes	Dominated by small sedges and other Cyperaceae such as *Carex demissa*, *C. panicea*, and/or *Schoenus nigricans with Juncus bulbosus* and *Pinguicula vulgaris* (replaced *by P. grandiflora* in the south-west) often prominent. Brown moss layer is usually dominated by *Campylium stellatum, Scorpidium revolvens* and *Scorpidium scorpioides*.	FE1C *Carex panicea – Carex viridula* fen

2.3.3.1 7230 Alkaline Fen *vs* 6410 *Molinia* Meadow

Molinia meadow (6410) can manifest as wet grassland (GS4) or fen meadow (GS4/PF1) habitat. *Molinia* meadow (6410) can occur in mosaics with 7230 Alkaline fen and also transition into it on drier ground (Šefferová Stanová *et al.*, 2008). In these situations, it is not always easy to separate the wetter variants of 6410 *Molinia* meadow from 7230 Alkaline fen. *Molinia* meadow (6410) is usually a drier habitat type than 7230 Alkaline fen and will not have standing water for much (if any) of the year. *Molinia caerulea* is dominant or abundant in 6410 *Molinia* meadow. In Alkaline fen (7230), *M. caerulea* may be frequent but it is not usually dominant. Also, in 6410 *Molinia* meadow, *Calliergonella cuspidata* is usually the main bryophyte and brown mosses are rare or absent. Alkaline fen (7230) in contrast has a prominent brown moss layer (Table 5).

2.3.3.2 7230 Alkaline Fen *vs* GM1 Marsh

Some fen areas may transition into GM1 Marsh, either at their edges or where the fen is in poor condition, *e.g.*, from nutrient enrichment or overgrazing. GM1 Marsh can potentially be peat-forming but differs from fen habitat in nutrient availability (Hájek *et al*., 2006). Usually, the difference between marsh and fen is fertility, but water level may also be lower in marsh (Hájek *et al*., 2006). The presence of abundant *Calliergonella cuspidata* usually indicates higher nutrient levels and a deterioration of fen into marsh habitat (Hájek *et al*., 2015). *Calliergonella cuspidata* can also tolerate fluctuating water levels, which typical brown mosses are more sensitive to. Generally, sedge cover is higher in alkaline fen. Greater than 50% cover of grasses and sedges in a peat-forming system is attributable to fen, according to Fossitt (2000),

while broadleaf forb cover is higher (>50%) in marsh. See Fossitt (2000) for other distinctions between PF1 Rich fen and flush (to which habitat 7230 correlates) and GM1 Marsh.

2.3.3.3 7230 Alkaline Fen *vs* 6430 Hydrophilous Tall-herb Fringe

Lowland stands of 6430 Hydrophilous tall-herb fringe associated with wetland systems can contain some similar species to 7230 Alkaline fen and they can co-occur. Such examples of 6430 Hydrophilous tall-herb fringe correlate with FS2 Tall-herb swamp, which is relatively species-rich vegetation that occurs where the water table is above the ground surface for most of the year, or where water levels fluctuate regularly, *e.g.,* tidal situations (Fossitt, 2000). This can be in topogenous and soligenous lowland situations, such as adjacent to watercourses or at the edges of lakes. Habitat 6430 can be distinguished from 7230 Alkaline fen, in that tall broadleaved herbs, typical of relatively high nutrients (nitrophilous), are dominant, brown mosses are absent and small to medium-size sedges are absent or rare.

The positive indicator species for this lowland type of 6430 Hydrophilous tall-herb fringe (described by O'Neill *et al.*, 2013) include vascular plants only: *Alisma lanceolatum, Alisma plantago-aquatica, Angelica sylvestris, Calystegia sepium, Cicuta virosa, Crepis paludosa, Epilobium hirsutum, Epilobium palustre, Epilobium parviflorum, Equisetum fluviatile, Equisetum palustre, Eupatorium cannabinum, Filipendula ulmaria, Galium palustre, Hypericum tetrapterum, Iris pseudacorus, Lysimachia vulgaris, Lythrum salicaria, Mentha aquatica, Myosotis scorpioides, Persicaria amphibia, Rumex hydrolapathum, Sium latifolium, Solanum dulcamara, Stachys palustris, Symphytum officinale, Trollius europaeus* and *Valeriana officinalis.*

2.3.4 Some Notes on Non-Annex I Fens

Non-Annex I fens comprise PF2 Poor fens and flushes and non-Annex I examples of PF1, the latter type consisting of mesotrophic fens lacking brown mosses. They are also likely to be similar to examples of 7230 Alkaline fens.

PF2 Poor fens and flushes occur on acidic, usually peaty soils. They are minerotrophic (Hájek *et al.*, 2006), differing from ombrotrophic bogs in being fed by surface/groundwater and hence being classed with fen habitats. Poor fens can be soligenous, for example, where there is flushing of upland slopes, or where there is water movement on a raised or blanket bog; or topogenous, *e.g*., base-poor basin fen. They tend to be relatively species-poor (Hájek *et al.*, 2006). They can be dominated by rushes (usually *Juncus effusus* or *J. articulatus*), small sedges (*e.g., Carex echinata* or *C. nigra* with *Eriophorum angustifolium*) or medium sedges (*Carex rostrata*) (JNCC, 2004; Rodwell *et al.*, 1991). Tall grasses such as *Molinia caerulea* can be prominent, particularly in poor fen flushes on raised bogs. The bryophyte layer is dominated by minerotrophic, acid-tolerant *Sphagnum* species such as *S. palustre, S. fallax*, *S. denticulatum* and *S. inundatum* and, often prominent, *Polytrichum commune.* Ericoid species and *Potentilla erecta* are the most frequent associates. Table 7 summarises the typical species.

Within poor fen there is some variation across vegetation communities. The NSUH (Perrin *et al.*, 2014a) recognises seven poor fen communities (see section 2.1.4.2) and the IVC recognises three communities with affinity to PF2 Poor fen and flush (Table 2). There is currently no IVC community that describes the poor fen vegetation that is dominated by *Juncus* spp. With *Sphagnum fallax, S. palustre* and *Polytrichum commune*, which is common in upland areas (NSUH community PFLU2). This is due to under-recording of this habitat. *Juncus effusus*-dominated flushes are currently best accommodated at present within the GL2D *Juncus effusus – Rumex acetosa* grassland community.

PF2 Poor fen and flush is usually relatively easy to identify. There may be some over-recording as 7140 Transition mire is sometimes mistakenly mapped as PF2 Poor fen and flush.

However, it is more common that this habitat is not mapped as it does not have affinity to any Annex I habitat and rarely supports rare or protected vascular or bryophyte flora. It is frequent in upland areas, which may be less well surveyed. In lowland areas it may not always be recognised as it may be assumed to be more of an upland habitat. However, it can be frequent in lowland areas in the west and north.

Table 7 Summary of typical species of PF2 Poor fen and flush, compiled from a range of sources including Fossitt (2000), Hájek *et al.* (2006), JNCC (2004), Perrin *et al.* (2014a) and Rodwell *et al.* (1991).

Graminoid Species	Broadleaved Herbs	Ericoid and Woody Shrubs	Bryophytes
Agrostis canina	*Cardamine pratensis*	*Calluna vulgaris*	*Aulacomnium palustre*
Agrostis stolonifera	*Cirsium palustre*	*Erica tetralix*	*Hylocomium splendens*
Anthoxanthum odoratum	*Comarum palustre*	*Myrica gale*	*Plagiomnium undulatum*
Carex canescens	*Drosera rotundifolia*		*Polytrichum commune*
Carex demissa	*Epilobium palustre*		*Rhytidiadelphus loreus*
Carex echinata	*Galium palustre*		*Rhytidiadelphus squarrosus*
Carex lasiocarpa	*Galium saxatile*		*Sarmentypnum exannulatum*
Carex limosa	*Hypericum elodes*		*Sphagnum capillifolium*
Carex nigra	*Lysimachia tenella*		*Sphagnum cuspidatum*
Carex panicea	*Menyanthes trifoliata*		*Sphagnum fallax*
Carex rostrata	*Narthecium ossifragum*		*Sphagnum denticulatum*
Eleocharis multicaulis	*Potentilla erecta*		*Sphagnum divinum*
Equisetum fluviatile	*Ranunculus flammula*		*Sphagnum flexuosum*
Eriophorum angustifolium	*Rumex acetosa*		*Sphagnum fimbriatum*
Eriophorum vaginatum	*Silene flos-cuculi*		*Sphagnum palustre*
Holcus lanatus	*Stellaria alsine*		*Sphagnum papillosum*
Juncus acutiflorus	*Succisa pratensis*		*Sphagnum squarrosum*
Juncus articulatus	*Vaccinium oxycoccos*		*Sphagnum subnitens*
Juncus bulbosus	*Viola palustris*		*Sphagnum teres*
Juncus effusus			*Straminergon stramineum*
Juncus squarrosus			*Warnstorfia fluitans*
Molinia caerulea			
Nardus stricta			

2.3.4.1 PF2 Poor Fen and Flush *vs* 7140 Transition Mire

In some instances, PF2 Poor fen and flush fen may be confused with 7140 Transition mire. Transition mire (7140) can sometimes be dominated by small to medium sedges with acid-tolerant *Sphagnum* species over floating water.

In these instances, the species composition of PF2 Poor fen and flush and 7140 Transition mire may be very similar but the habitat (floating vegetation over open water) will distinguish 7140 Transition mire. Aquatic and semi-aquatic species are usually more prominent in 7140 Transition mire than in PF2 Poor fen and flush. The NSUH vegetation community *Potamogeton polygonifolius* soakways were considered by the NSUH to correspond to PF2

Poor fen and flush. They differ, however, from other PF2 communities in that base-tolerant species are sometimes present. In these situations, these soakways may be better regarded as 7140 Transition mire, with which they often occur in mosaic.

2.3.4.2 PF2 Poor Fen and Flush *vs* Habitats 7210 and 7230

Poor fen can be separated from 7210 *Cladium* fen and 7230 Alkaline fen in that *Sphagnum* cover in poor fen is usually high. Where poor fen is dominated by small to medium sedges (*e.g., Carex rostrata*) rather than rushes, it can be separated from 7230 Alkaline fen by the absence of calcicolous sedges (*e.g., Carex flacca* and *C. lepidocarpa*) and brown mosses (Rodwell *et al*., 1991).

2.3.4.3 Poor Fen *vs* Bog Habitats

Poor fen can occur in flushes, cutover areas or sloping edges of raised and blanket bogs. It can be separated from raised bog or blanket bog vegetation by the presence of *Molinia caerulea*, minerotrophic *Sphagnum* species such as *S. fallax* and *S. palustre*, and bryophytes *Polytrichum commune*, *Straminergon stramineum*, *Sarmentypnum exannulatum* and *Warnstorfia fluitans*, which are rare in ombrotrophic bogs.

2.4 Floral Nomenclature

A review of the recent flora name changes for typical fen species (vascular plants and bryophytes) was undertaken (Appendix 4). Vascular plant nomenclature follows that of the 'New Flora of the British Isles' 4th edition (Stace, 2019). The bryophyte nomenclature adopted by Blockeel *et al.* (2014a, b) is used; this is based on the 'Checklist of British and Irish bryophytes' (Hill *et al.*, 2008) with minor modifications to reflect recent taxonomic changes. A recent paper (Hassel *et al*., 2018) has shown that the species formerly known as *Sphagnum magellanicum* actually comprises three separate species and that, of these, *S. magellanicum* is actually restricted to South America. Material from Ireland is most likely to be *S. medium* (confirmed from a number of Irish locations), although *S. divinum* has also been found to occur in flushes/transition zones in at least two Irish sites. These new names are used throughout this report. A new European checklist of bryophytes has recently been published (Hodgetts and Lockhart, 2020), but not all of these revisions may be accepted into the British and Irish checklist, which is due in 2021.

3 Review of Fen Invertebrates

Fens provide important habitat for a wide range of terrestrial and aquatic invertebrates for a number of reasons. Firstly, fens often represent a patch of undisturbed or less disturbed natural habitat in a landscape that has been greatly changed by anthropogenic activity. This reduced level of disturbance allows the development and maintenance of more stable and complex communities. Secondly, the environmental and ecological variability of fen habitats in terms of vegetation structure, litter, specialised plants, groundwater pH, nutrients, and the variation in ground wetness from open water to dry ground, both spatially and temporally, all combine to provide a wide range of niches that invertebrates can exploit.

3.1 Irish and European Fen Invertebrates

Due to the wide range of niches available in fen habitats, representatives of most, if not all, invertebrate orders will be found in a well-developed fen. However, many of the species recorded in fens are not obligate fen-dwellers, but rather are found in a range of habitats, of which fens are only one type. For this reason, invertebrate species assemblage data from a fen site can be more informative when assessing the status of the fen. The invertebrate species groups that can be found in fens in Britain and Ireland, survey methods, recommendations for monitoring and assessment, as well as management recommendations to maintain or improve fen suitability for invertebrates, are discussed in Drake *et al*. (2007), Foster and Proctor (1995), Lott *et al*. (2002), McBride *et al*. (2011) and Nelson (1998, 2001, 2005). Šefferová Stanová *et al.* (2008) discuss three noteworthy groups of invertebrates that have representatives dependent on fens in Europe: butterflies (Lepidoptera), dragonflies/damselflies (Odonata) and snails (Mollusca). Other important groups that are represented in fen species assemblages include spiders (Araneae), true flies (Diptera), beetles (Coleoptera) and caddisflies (Trichoptera).

3.1.1 Butterflies and Moths

The two species of butterfly listed by Šefferová Stanová *et al.* (2008) as being dependent on fens are *Coenonympha oedippus* and *Lycaena dispar*, neither of which is found in Ireland. A number of attempts were made to reintroduce *L. dispar* to Ireland and Britain in the 1900s, but failed (Duffey, 1968). The scarcity of its host plant, *Rumex hydrolapathum*, at potential British sites is thought to be at least partially responsible for the failure of *L. dispar* to become established (Duffey, 1968). Seasonal flooding and competition are also considered factors (Martin & Pullin, 2004; Nicholls & Pullin, 2003). *Euphydryas aurinia*, an EU HD Annex II species, may be found in Irish fen meadows and other habitats in which its food plant *Succisa pratensis* grows.

The British subspecies *Papilio machaon britannicus* is a fen specialist, in contrast to its continental counterpart *Papilio m*. *gorganus*, which is considerably more catholic in terms of its habitat preference (Dempster, 1995). The British subspecies is restricted to the Norfolk Broads and its distribution is limited by the occurrence of its larval food plant *Peucedanum palustre*, found only in fens (Dempster, 1995); this plant does not occur in Ireland.

Many moth species are found in fens, utilising the range of herbaceous and woody species as food plants (McBride *et al*., 2011). Of the five moth species assessed under the Irish macro-moth red list that include fen among their habitat preferences, *Adscita statices* and *Idaea muricata* are Endangered, *Clostera pigra* and *Amphipyra tragopoginis* are Near Threatened, and *Earias clorana* is Regionally Extinct (Allen *et al*., 2016).

3.1.2 Dragonflies/Damselflies

Odonata inhabit a range of habitats where there is permanent or near-permanent open water, including fens. Examples of dragonflies and damselflies that inhabit fens and mires in Europe include *Leucorrhinia pectoralis*, *Coenagrion ornatum*, *Coenagrion mercuriale*, *Ceriagrion tenellum* and *Nehalennia speciosa* (Buchwald & Schiel, 2002; Šefferová Stanová *et al.*, 2008). Again, none of these odonates are found in Ireland; however, in Ireland, oligotrophic fen systems may support *Sympetrum danae*, *Libellula quadrimaculata*, *Pyrrhosoma nymphula* and *Aeshna juncea* (Nelson & Thompson, 2004). Mesotrophic fen species include *Coenagrion pulchellum*, *Coenagrion lunulatum*, *Brachytron pratense*, *Sympetrum sanguineum* and *Aeshna grandis*, while *Coenagrion puella* may dominate communities in eutrophic fens (Nelson & Thompson, 2004). *Ischnura pumilio* is a species of seepages and flushes, such as those associated with fens (Nelson *et al*., 2011). The population of *C. puella* on the island of Ireland is one of the largest in Europe outside Finland, and is of international importance (McBride *et al*., 2011). Of these species, *C. lunulatum* and *I. pumilio* are listed as Vulnerable on the red list of Irish odonates, while the rest are of Least Concern (Nelson *et al*., 2011).

3.1.3 Snails

Given snails' requirement for calcium in shell-building, it is unsurprising that they form an important part of the fen invertebrate fauna. Typical mollusc fauna in European fens may include three Annex II snail species: *Vertigo geyeri*, *Vertigo moulinsiana* and *Vertigo angustior*, each of which has differing habitat requirements, and all of which occur in Ireland (Moorkens & Killeen, 2011; Šefferová Stanová *et al.*, 2008). Of these three species, *V. moulinsiana* is listed as Endangered, while *V. angustior* and *V. geyeri* are both listed as Vulnerable (Byrne *et al*., 2009). An additional Annex II *Vertigo* species found in fens in a number of European countries, but not in Ireland, is *Vertigo genesii* (Cameron *et al*., 2003). Other snails strongly associated with calcareous wetlands that are found in Ireland include *Zonitoides nitidus*, *Columella edentula*, *Euconulus alderi* and the very rare *Pupilla pratensis* (Moorkens & Killeen, 2009, 2011).

As well as providing habitat for these more specialist species, fens can support numerous other snail species that inhabit a much broader niche.

Horsák & Hájek (2003) reported on the mollusc communities of fens from the border areas of the Czech Republic and Slovakia, separating the studied fens into five clusters, ranging from rich fens with tufa formation to poor *Sphagnum* fens. Among the findings of this study was that vegetation explains the mollusc community along the poor-rich spring fen gradient better than water chemistry.

3.1.4 Spiders

Spiders (Araneae) form a large component of the invertebrate fauna generally, and also in fens. In studying the spiders of fens in East Anglia in the UK, Duffey & Feest (2009) recorded 231 species. Duffey & Feest (2009) described three groupings of spiders based on the species' ability to exploit different breadths of habitat and environmental variation: 'Stenotopic' species have narrow ranges; 'Mesotopic' species can have preferred habitats, but occur elsewhere with lower frequency; and 'Eurytopic' species can be found in a wide range of habitats and environmental conditions. Of those species that are described as stenotopic in fens, *Carorita paludosa*, *Sitticus caricis*, *Hypomma fulvum* and *Donacochara speciosa* are found in Ireland (Anderson *et al*., 2017; Duffey, 1971; Van Helsdingen, 1996).

Štokmane & Cera (2018) recorded 149 species of spider from calcareous fens in the coastal lowlands of Latvia, using pitfall trapping and sweep netting. As expected, most of the species recorded were hygrophilous (water-loving) or photophilous (light-loving), or both; however, the varied microhabitats, and the effect of adjacent habitats, resulted in species adapted to dry

(xerophilous), shaded (sciophilous) and acid (sphagnophilous) habitats also being recorded within the fens. It is notable that, of the 149 species recorded by Štokmane & Cera (2018), only five were recorded in all three years of survey (*Dolomedes fimbriatus*, *Evarcha arcuata*, *Tibellus maritimus*, *Xysticus ulmi* and *Kaestneria pullata*).

Another study of the spider fauna of Latvia, which included calcareous fen habitat, found the dominant species of the habitat to be *Tetragnatha* sp., *Metellina segmentata*, *M. mengei* and *Larinioides cornutus*, with only *Tetragnatha* sp. and *Tibellus maritimus* found in nine or more of the 12 years of survey (Cera *et al*., 2010). Štokmane *et al.* (2013) showed that vegetation is an important factor influencing the spider community of fens, with soil pH also being important.

In Britain and across much of Europe, *Dolomedes plantarius* is a typical species of fen (Šefferová Stanová *et al.*, 2008; Štokmane & Cera, 2018; Van Helsdingen, 1993). This species is absent from Ireland, with the genus represented by the morphologically similar *D. fimbriatus*, which is more associated with marshes and bogs, requiring open water only during mating season (April-May) (Van Helsdingen, 1993).

3.1.5 True Flies

The Order Diptera contains numerous families and thousands of species, and forms an important component of the fen invertebrate community, benefiting from the mix of aquatic and terrestrial habitats. Syrphidae (Hoverflies) is a large dipteran family with 185 species present in Ireland (Speight & Gittings, 2020). The group has been well studied and it is known that a number of hoverflies have a habitat preference that includes fens, such as *Sericomyia silentis*, *Trichopsomyia flavitarsis*, *Platycheirus scambus*, *Melanogaster aerosa* and *Anasimyia lineata* (Speight, 2014). Salmela *et al.* (2007) surveyed the Suborder Nematocera of 14 wetlands in southern Finland and found a rich fen site to be the most species-rich of those surveyed, with 69 nematoceran species recorded. This lends weight to the view that oligotrophic sites support a lower nematoceran diversity than sites with a higher trophic status (Ibid.).

3.1.6 Beetles

Given the diversity of beetles around the world, it is unsurprising that they form an important part of the fen invertebrate community, both aquatic and terrestrial. Ground beetles (Carabidae), rove beetles (Staphylinidae) and water beetles (numerous families) are all found in European fen habitats, with the level of specialisation varying by species (Foster *et al*., 1992; Good, 2005; Holmes *et al*., 1993; Lott, 2003). Holmes *et al.* (1993) characterised 18 species of ground beetle as being specialists in one of the surveyed habitat groups, with *Blethisa multipunctata*, *Elaphrus uliginosus*, *Loricera pilicornis*, *Bembidion lunulatum*, *Agonum moestum*, *Agonum muelleri*, *Agonum viduum*, *Chlaenius nigricornis* and *Oodes helopioides* all considered specialists of managed rich fen, while *Agonum fuliginosum* was considered a specialist of species-rich rich fen. The water beetles *Hydaticus seminiger*, *Hydroporus scalesianus*, *Laccornis oblongus* and *Rhantus grapii* were recorded from fen habitat in counties Armagh and Down, and are considered to be relict fen species (Nelson, 2005). Foster *et al*. (1992) identified 10 water beetle assemblages for Ireland, including ones representing natural minerotrophic fens and base-flushed cutover bogs.

3.1.7 Caddisflies

Caddisflies have been recorded within fen habitat across Europe (Hannigan *et al*. 2009; Kubiak *et al*., 2014; Petruželová *et al*., 2020; Tempelman *et al*., 2013). Of the 156 species of caddisfly in Ireland, around 20 show an affinity to fen habitats to a greater or lesser extent. Species such as *Erotesis baltica*, *Limnephilus pati* and *Limnephilus tauricus* show a

particularly strong connection with fen habitat (Barnard & Ross, 2012; O'Connor, 2015). The hydroptilids *Hydroptila angulata*, *Hydroptila valesiaca* and *Oxyethira simplex* are all associated with streams in fens, while *Beraea pullata* is found in seepage areas, including those in fens (O'Connor, 2015). The habitat for *Tricholeiochiton fagesii* is described by Barnard & Ross (2012) as weedy ponds and lakes, and its discovery at Lough Garr in the course of the current project shows that this can include ponds within fens (Brophy & O'Connor, 2020). Other caddisfly species can be found in fens, but also in a wider range of habitats, including *Limnephilus ignavus*, *Limnephilus fuscinervis*, *Limnephilus binotatus*, *Limnephilus lunatus* and *Holocentropus dubius* (Barnard & Ross, 2012; O'Connor, 2015).

3.1.8 Other Groups

Some other invertebrate groups found in European fens include mites (Acarina) (Kagainis & Spuņģis, 2013; Więcek *et al.,* 2013; Wisdom *et al*., 2011), water bugs (Heteroptera) (Kment & Baňař, 2011; Morris, 1969) and centipedes (Chilopoda) (Zapparoli, 2010).

3.2 Invertebrate Fauna of the Fen Pilot Sites

As part of the current pilot project, an extensive desk study was carried out to collate the existing data on the invertebrate fauna of the seven fen pilot sites (Pollardstown Fen, Co. Kildare; Scragh Bog, Lough Owel and Lough Garr, Co. Westmeath; Fin Lough, Co. Offaly; River Moy (Mannin Lake/Island Lake), Co. Mayo and Liskeenan Fen, Co. Tipperary). The following sections contain brief descriptions of the invertebrate fauna at each fen site, while Table 8 provides a breakdown of species by order across the sites. A full list of species records found for each site is presented in Appendix 5.

Table 8 Number of invertebrate species recorded at each of the pilot fen sites by order. Note: Numbers are not directly comparable across sites due to varying survey effort. Liskeenan Fen was omitted as no invertebrate records were found for this site.

Class	Order	Pollardstown Fen	Scragh Bog	Fin Lough	Lough Owel	Moy River (Island Lake)	Lough Garr
Hirudinea	Arhynchobdellida	-	3	-	-	-	-
	Rhynchobdellida	-	3	-	-	-	-
Mollusca	Bivalvia	2	3	3	-	1	-
	Gastropoda	35	23	30	1	20	-
Malacostraca	Amphipoda	-	-	1	-	-	-
	Isopoda	-	4	-	-	-	-
Chilopoda	Lithobiomorpha	-	1	-	-	-	-
Diplopoda	Julida	-	4	-	-	-	-
	Polydesmida	-	1	-	-	-	-
Insecta	Coleoptera	171	84	10	33	37	-
	Dermaptera	-	1	-	-	-	-
	Diptera	171	86	26	18	-	-
	Ephemeroptera	-	2	-	-	-	-
	Hemiptera	16	34	10	6	6	-
	Hymenoptera	31	7	3	2	-	-
	Lepidoptera	161	13	38	2	-	-
	Megaloptera	-	1	-	-	-	-
	Neuroptera	6	3	-	-	-	-
	Odonata	15	14	6	3	1	-
	Orthoptera	-		-	2	-	-
	Psocoptera	1		-	-	-	-
	Trichoptera	36	16	5	24	-	1
Arachnida	Acarina	19	-	-	-	-	-
	Araneae	58	114	-	-	-	-
	Opiliones	-	2	-	-	-	-
Total		**722**	**419**	**132**	**91**	**65**	**1**

3.2.1 Pollardstown Fen

The invertebrate community of Pollardstown Fen (often referred to as Newbridge Fen in the literature) has received substantial attention, with records reported for a wide range of groups including: spiders (Araneae), true flies (Diptera; in particular, hoverflies (Syrphidae)), butterflies and moths (Lepidoptera), snails (Gastropoda), caddisflies (Trichoptera) and beetles (Coleoptera) (Aukema *et* al., 2007; Ashe *et al*., 1991a, 1995, 2007a, b, 2012; Balfour Browne Club, 2020; Barnard *et al*., 1991; Blackith, 2020; Bond, 1991; Buhl & O'Connor, 2008, 2010; Chandler, 1986; De Courcy Williams, 1989; Good, 1991, 1994, 2005; IBS, 2020a, b, c; Ismay *et al*., 2001; Lott & Foster, 1990; Menzel *et al*., 2006; Moorkens & Killeen, 2011; Nash *et al*., 2001; NBDC, 2020b, c, d, e, f; Nelson, 2020; NMI, 2020; O'Connor, 2015; O'Connor & Ashe,

2004; O'Connor & Buhl, 2016; O'Connor & Chandler, 2000, 2006; O'Connor & O'Connor, 2013, 2019; O'Connor & Thuróczy, 2009; O'Connor *et al*., 1990, 1997, 2007a, b; Ronayne & O'Connor, 2003; Smithers & O'Connor, 1991; Speight, 1982, 1983, 1986, 2002; Speight & Chandler, 1983; Speight & Gittings, 2020; Speight *et al*., 1992; Thuróczy & O'Connor, 2009; Van Helsdingen, 1997; Wisdom *et al*., 2011; Withers, 1992; Withers & O'Connor, 1992).

Some of the more notable species that have been recorded within Pollardstown Fen include three species of *Vertigo* snail listed under Annex II of the Habitats Directive: *V. angustior*, *V. geyeri* and *V. moulinsiana* (Moorkens & Killeen, 2011). These species have differing habitat requirements and so occur in different parts of the site. However, all three species have shown reductions in population size between the 2007-2012 and the 2013-2018 monitoring periods (Long & Brophy, 2019).

Apart from these three *Vertigo* spp., a further 35 mollusc species have been recorded from Pollardstown Fen (Moorkens & Killeen, 2011).

Euphydryas aurinia, also listed under Annex II of the Habitats Directive, has been recorded within Pollardstown Fen over a substantial period of time, with the species recorded by Bond (1991) and larvae also observed during the current survey (J.T. Brophy, pers. obs.). The work of Bond (1991) established a comprehensive baseline of the moths and butterflies found in Pollardstown Fen, recording 158 species, with a further three species added by others (NBDC 2020c, d; NMI, 2020).

A total of 171 species of beetle have been recorded from Pollardstown Fen, with the vast majority of these being rove beetles (Staphylinidae) recorded by Good (2005). The rove beetles were recorded using various techniques, including malaise trapping, suction sampling, Tullgren funnel extraction, pitfall traps and hand collecting, and include fen species, such as *Erichsonius cinerascens*, *Euaesthetus ruficapillus*, *Myllaena dubia*, *Myllaena infuscata* and *Philonthus fumarius* (Good, 2005; Lott, 2003).

Many families of true flies have been recorded in Pollardstown Fen, including biting midges (Ceratopogonidae), mosquitoes (Culicidae), fungus gnats (Sciaridae), flesh flies (Sarcophagidae), moth flies (Psychodidae) and, most notably, hoverflies (Syrphidae) (Ashe *et al*., 1991a, 2012; Blackith, 2020; Menzel *et al*., 2006; Speight, 2002; Speight & Gittings, 2020; Withers & O'Connor, 1992). A total of 86 hoverfly species have been recorded from Pollardstown Fen, and many of these species include fen among their habitat preferences (Speight, 2002, 2014; Speight & Gittings, 2020).

Van Helsdingen (1997) reported on the spider fauna of Pollardstown Fen, recording 58 species. A number of the species recorded have a preference for wetland habitats, including fens. Examples of the species typical of fens are *Ozyptila brevipes*, *Baryphyma gowerense*, *Baryphyma trifrons*, *Clubiona stagnatilis*, *Clubiona subtilis*, *Microlinyphia impigra* and *Tallusia experta* (BAS, 2020; Van Helsdingen, 1997).

Dragonflies and damselflies have been recorded from Pollardstown Fen, with 15 species listed for the site. Species known to include fens among their habitat preferences that have been found in Pollardstown Fen are *Aeshna grandis*, *Brachytron pratense*, *Sympetrum sanguineum* and *Coenagrion pulchellum* (CEDaR, 2020; NBDC, 2020e; Nelson & Thompson, 2004).

3.2.2 Scragh Bog

Of the seven pilot fen sites, Scragh Bog has received the most attention from invertebrate zoologists after Pollardstown Fen. Invertebrate surveys have recorded species from groups including spiders, true flies (particularly hoverflies), terrestrial and aquatic beetles, caddisflies, snails and slugs, and butterflies and moths (Anderson *et al*., 2017; Ashe *et al*., 1991b, 2012; Balfour Browne Club, 2020; Barnard *et al*., 1991; Bilton, 1992; CEDaR, 2020; Hannigan & Kelly-Quinn, 2012; Hannigan *et al*., 2009; Lott & Bilton, 1991; Lott & Foster, 1990; Menzel *et*

al., 2006; Moorkens, 2004; NBDC, 2020c, d, e; Nelson, 2020; NMI, 2020; O'Connor, 2015; O'Connor & Nelson, 2012; Owen, 1997; Ronayne, 2006; Speight & Cogan, 1979; Speight & Gittings, 2020; Speight & Legrand, 1984; Van Helsdingen, 1998; Withers & O'Connor, 1992).

The spider fauna of Scragh Bog has been the subject of two comprehensive surveys, which, between them, have recorded 114 spider species within the site (Anderson *et al*., 2017; Van Helsdingen 1998). Some of the more fen-related species recorded include *Aphileta misera*, *Baryphyma gowerense*, *Clubiona stagnatilis*, *Dismodicus bifrons*, *Kaestneria pullata*, *Oedothorax gibbosus*, *Sitticus caricis*, *Tallusia experta* and *Xysticus ulmi* (Anderson *et al.*, 2017; BAS, 2020; Van Helsdingen 1998).

Many families of true flies have been recorded from Scragh Bog, including biting midges (Ceratopogonidae), dung flies (Scathophagidae), snail-killing flies (Sciomyzidae) and, most notably, hoverflies (Syrphidae) (Ashe *et al*., 2012; Speight & Gittings, 2020; Speight & Legrand, 1984). A total of 52 hoverfly species have been recorded in Scragh Bog, and many of these species include fen among their habitat preferences, such as *Anasimyia lineata*, *Chrysogaster cemiteriorum*, *Helophilus hybridus*, *Lejogaster metallina*, *Platycheirus occultus*, *Platycheirus perpallidus* and *Sericomyia silentis* (Speight, 2002, 2014; Speight & Gittings, 2020).

The beetle fauna of Scragh Bog has received particular attention with 84 species recorded, predominantly water beetles (Balfour Browne Club, 2020; Bilton, 1992; Hannigan & Kelly-Quinn, 2012; Lott & Bilton, 1991; Lott & Foster, 1990; Owen, 1997). The water beetles *Hydroporus glabriusculus* and *Hydroporus scalesianus* are found at the site and are considered indicative of very old wetlands (Bilton, 1992; Hannigan & Kelly-Quinn, 2012; NPWS, 2015). *H. glabriusculus* is considered Endangered in the Irish water beetle red list, while *H. scalesianus* is Near Threatened (Foster *et al.,* 2009). Some of the fen-associated rove beetles found in Scragh Bog include *Philonthus fumarius*, *Philonthus nigrita*, *Stenus cicindeloides*, *Stenus juno* and *Stenus palustris* (Lott, 2003; Lott & Bilton, 1991; Lott & Foster, 1990).

A total of 14 dragonfly and damselfly species have been recorded from Scragh Bog (CEDaR, 2020; Speight & Legrand, 1984). A number of species found in Scragh Bog include fens among their habitat preferences, such as *Aeshna grandis*, *Brachytron pratense*, *Sympetrum sanguineum* and *Coenagrion pulchellum* (CEDaR, 2020; Nelson & Thompson, 2004; Speight & Legrand, 1984).

Particularly notable among the odonates of Scragh Bog is *C. puella*, which was first discovered in Ireland in 1981 by Cotton (1982), with the second colony being discovered at Scragh Bog in 1982 by Speight & Legrand (1983).

A total of 26 species of mollusc have been recorded in Scragh Bog; however, none of the three Annex II listed *Vertigo* are present (Anderson *et al*., 2017; Hannigan & Kelly-Quinn, 2012; Moorkens, 2004).

Several caddisfly (Trichoptera) species have been recorded from Scragh Bog, with 16 species reported for the site (Hannigan & Kelly-Quinn, 2012; O'Connor, 2015). The most notable discovery among the caddisflies of Scragh Bog is *Erotesis baltica*, which was added to the Irish list after being discovered in Scragh Bog (Hannigan *et al*., 2009). Other species of caddisfly known to include fen among their habitat preferences recorded at this site include *Anabolia brevipennis*, *Limnephilus binotatus* and *L. fuscinervis* (Hannigan & Kelly-Quinn, 2012; O'Connor, 2015).

3.2.3 Fin Lough

Two invertebrate groups found at Fin Lough have been studied in detail: molluscs and butterflies/moths with a number of records for other groups also made (Bond, 1989; CEDaR,

2020; Good, 1989; Johnson & Halbert, 1902; Long & Brophy, 2019; Moorkens & Killeen, 2011; Moorkens, 1998; NBDC, 2020b; Nelson, 2020; NPWS, 2013a; O'Connor, 2015; O'Connor & O'Hanrahan, 1988; O'Connor *et al*., 1997; Speight & Gittings, 2020).

Some of the more notable species that have been recorded within Fin Lough include two species of *Vertigo* snail listed under Annex II of the Habitats Directive: *V. geyeri* and *V. moulinsiana* (Moorkens & Killeen, 2011). These species have differing habitat requirements and so occur in different parts of the site. Apart from these two *Vertigo* spp., a further 31 mollusc species have been recorded from Fin Lough (Moorkens & Killeen, 2011).

A total of 26 hoverfly species have been recorded from Fin Lough, the most notable of which is *Melanogaster aerosa* (previously *Chrysogaster macquarti*), which is a wetland species of acid fen and valley bog lagg, and flushes (Speight, 2014; Speight & Gittings, 2020). Some of the other hoverfly species found at the site that include fen among their habitat preferences are *Anasimyia lineata*, *Helophilus hybridus*, *Lejogaster metallina*, *Platycheirus perpallidus* and *Sericomyia silentis* (Speight, 2002, 2014; Speight & Gittings, 2020).

A small number of true bug (Heteroptera) species have been recorded from Fin Lough, mainly aquatic species, including *Callicorixa praeusta*, *Hesperocorixa sahlbergi* and *Sigara falleni* (Nelson, 2020). A notable species of the site is *Zicrona caerulea* (J.T. Brophy, pers. obs.); however, this species can be found in low vegetation in many habitats (British Bugs, 2020).

The butterflies and moths of Fin Lough have been surveyed, with 38 species recorded (Bond, 1989; J.T. Brophy, pers. obs.). Some of the species recorded are considered local or rare, fen or lake-shore species, including *Erynnis tages*, *Hipparchia semele*, *Limnaecia phragmitella*, *Clepsis senecionana*, *Cochylimorpha straminea* and *Mompha locupletella* (Bond, 1989).

There are a handful of beetle records from Fin Lough, the most notable of which is the *Panagaeus cruxmajor*, which is a species of litter in fen and dunes (J.T. Brophy, pers. obs.).

A total of six species of odonate have been recorded from Fin Lough, with *Coenagrion pulchellum* and *Pyrrhosoma nymphula* both present (CEDaR, 2020).

Only two species of caddisfly have been recorded in Fin Lough, *Tricholeiochiton fagesii* and *Limnephilus binotatus*, the latter of which is a species of ponds, fens, turloughs and reed swamps (O'Connor, 2015; O'Connor & O'Hanrahan, 1988).

3.2.4 Lough Garr

The only published invertebrate record found for Lough Garr is the caddisfly *Tricholeiochiton fagesii,* which was recorded in the course of the current survey (Brophy & O'Connor, 2020).

3.2.5 Lough Owel

Invertebrate studies at Lough Owel have tended to focus on the lake itself, rather than the adjacent habitat, including the fen habitat (Balfour Browne Club, 2020; CEDaR, 2020; Long & Brophy, 2019; Moorkens & Killeen, 2011; NBDC, 2020a, b, c; Nelson, 2020; O'Connor, 2015; Speight & Gittings, 2020). O'Connor (2015) lists caddisflies taken along the shore of the lake, many of which are likely to be associated with the lake itself rather than the fen, while Moorkens & Killeen (2011) and Long & Brophy (2019) both report *Vertigo moulinsiana* just outside the target fen habitat to the south of the lake.

A total of 18 species of hoverfly have been reported for Lough Owel, including species associated with fens, such as *Helophilus hybridus*, *Platycheirus manicatus*, *Neoascia tenur*, *Neoascia meticulosa* and *Lejogaster metallina* (Speight, 2014; Speight & Gittings, 2020).

Of the three odonates recorded for Lough Owel, *Aeshna grandis* and *Brachytron pratense* are associated with fens, while the third, *Enallagma cyathigerum*, is common and widespread across Ireland, reflecting its broad habitat range (CEDaR, 2020; Nelson & Thompson, 2004).

There are records for 33 species of water beetle from Lough Owel and its immediate surrounds, with *Agabus affinis* described as being taken from 'swamp/fen', while *Haliplus fulvus*, *Hydrobius fuscipes,* and *Hydroporus striola* recorded in a 'bog pool in area of clear fell' (Balfour Browne Club, 2020).

3.2.6 Liskeenan Fen

The literature review did not reveal any records for invertebrates present within the Liskeenan Fen site.

3.2.7 River Moy (Island Lake)

Island Lake has received limited attention with regard to the invertebrate community present, with only two groups, Coleoptera and Mollusca, subject to dedicated surveys (Holyoak, 2005; Moorkens & Killeen, 2011; Regan & Anderson, 2004). The impetus behind the mollusc survey of Island Lake was the discovery of the Annex II snail species *Vertigo geyeri* by Holyoak (2005). The site was revisited by Moorkens & Killeen (2011), who recorded *V. geyeri* in low numbers, and added another 20 mollusc species for the site.

Although *V. geyeri* was recorded at the site, the population and habitat present was not deemed to be of sufficient value for the species to be included as a Qualifying Interest for the River Moy SAC, within which the site is situated.

A total of 37 beetle species, including water beetles and rove beetles, were recorded for Island Lake (Balfour Browne Club, 2020; Regan & Anderson, 2004), along with a small number of aquatic true bugs (Heteroptera) (Nelson, 2020).

A single species of dragonfly has been recorded at Island Lake: *Aeshna juncea*, a species of bogs, heaths and moor, as well as fen pools (Nelson, 2020; Nelson & Thompson, 2004).

3.3 Invertebrates and Fen Habitat Assessment

The majority of EU Habitats Directive Annex I habitats are defined by the plant species present and a list of characteristic plant species is provided for these habitats in the Interpretation Manual of Annex I habitats (European Commission, 2013). However, characteristic animal species are provided for a number of habitats, indicating that they may, or should, be included in any assessment of the conservation status of that habitat. Ellwanger *et al*. (2018) reviewed the process of assessing Annex I habitat structure and functions, as required under Article 17 of the Habitats Directive. This review found that there were few examples where animal species were incorporated into the assessment of structure and functions, and therefore into the overall conservation status, with those examples limited to Germany, Sweden and the Netherlands (Ellwanger *et al*., 2018).

For example, Odonata are listed as characteristic species under 3160 Natural dystrophic lakes and ponds in the Interpretation Manual (European Commission, 2013) and in Germany the number of dragonfly species present is used in assessing the status of 3160 (BfN, 2017). However, there are numerous other habitats with invertebrates or other animal species listed as characteristic species in the Interpretation Manual for which animal species are not used in the German Article 17 reporting.

Annex I habitat descriptions in Sweden refer to characteristic species ('K-Art') and typical species ('T-Art') of plants and animals for a number of habitats (Dušek *et al*., 2012). These

include Annex I habitats 3160, 3260, 6210, 6450, 6510, 6530, 9070 and 1630 (Dušek *et al*., 2012).

While the Interpretation Manual (European Commission, 2013) lists characteristic invertebrate species for a range of different habitats, none are listed for any of the Annex I fen habitats (7140, 7210, 7230). With only plants (including mosses) being listed as characteristic species for these three fen habitats, it is unsurprising that the focus of conservation assessments has been vegetation and associated environmental data.

The use of invertebrates as bioindicators has received a lot of attention, and much of their power lies in the fact that, due to their generally rapid lifecycle, invertebrate populations can react faster to changing conditions than plants (Hodkinson & Jackson, 2005). Despite this, difficulties exist in the use of invertebrates as bioindicators. Rosenberg *et al*. (1986) noted that the use of terrestrial invertebrates as environmental indicators lags behind aquatic invertebrates, which form part of well-established water quality monitoring and eco-toxicological assessments, and this is still true today. The lack of detailed information on the environmental requirements of so many invertebrate species, and their response to changes in these environmental parameters, limits the use of invertebrate species and groups as biological indicators (Andersen, 1999). Even where the knowledge exists for a group, it may not represent the best approach to assessing habitat change.

For example, Koivula (2011) notes that "although carabids also have the potential to reflect soils, wetness and habitat type variation, they cannot currently compete with plants as environmental indicators for these factors." Koivula (2011) discussed the definition of 'indicator' and the importance that it is used correctly, *i.e.,* the response is not just relevant to indicator species, but to other species/environmental factors as well. The monitoring of fen habitats would require species that react to changes in parameters such as moisture, light and nutrients (Andersen *et al*., 2013). While relationships between environmental factors and invertebrate communities do exist, the invertebrate community often relates better to the vegetation than to parameters such as water chemistry.

Horsák & Hájek (2003) found that vegetation explains the mollusc community along the poor-rich spring fen gradient better than water chemistry, and while calcium concentration correlates with mollusc species richness in poor fens (<100 mg/l Ca), no such correlation exists for rich fens, where species richness depends on other abiotic and biotic factors, such as iron concentration and water regime.

While invertebrate species and groups may not represent the best bioindicators for habitat quality and change, that does not negate their importance in the proper functioning of many habitats. At a higher level, invertebrate assemblages can provide information on the presence of a range of habitat features that can inform the assessment of a habitat or mosaic of habitats at a site. In England, the database tool 'Pantheon' (www.brc.ac.uk/pantheon), developed by Natural England and the Centre for Ecology and Hydrology, can be used to assess the invertebrates of a site and return information on the habitats and resources, assemblage types and habitat fidelity of the species recorded. While Pantheon is less applicable in Ireland, due to a reduced invertebrate species richness and biogeographical factors, a similar approach can be used in the absence of such a tool. The use of species assemblages can provide useful information on a site and can allow targets to be set against which the conservation status of the site can be measured. Foster *et al*. (1992) identified 10 water beetle assemblages for Ireland, including ones representing natural minerotrophic fens (G) and base-flushed cutover bogs (H). These groups were similar, but separated by the presence in Group H of acidophilic species, such as *Hydroporus gyllenhalii*, *H. tristis*, *Ilybius aenescens* and *Gyrinus minutus*, as well as species usually regarded as indicators of eutrophic conditions, *e.g., Noterus clavicornis*, *Laccophilus minutus*, *Hyphydrus ovatus* and *Enochrus testaceus*.

Drake *et al*. (2007) provide a comprehensive approach to the survey of freshwater and terrestrial invertebrates for conservation evaluation in the UK, which could be used as the basis for the development of such a programme in Ireland. It covers survey types, timing, data analysis, sampling methods, target groups, species assemblages and laboratory techniques, among other topics.

Given the large number of invertebrate orders that can be found in fens, it is unlikely that all could be sampled in sufficient detail to provide a comprehensive assessment of the invertebrate community, and certainly not in a cost-effective manner. For this reason, it is necessary to select for invertebrate groups that provide sufficient information that can be used to assess the conservation status of the invertebrate community as a whole. For fen habitats, both acid mire and calcareous fens, Drake *et al*. (2007) recommend selecting from Carabidae (ground beetles), Staphylinidae (rove beetles), water beetles (several families), Diptera families, such as Athericidae, Rhagionidae, Stratiomyidae, Tabanidae, Chloropidae, Dolichopodidae, Ephydridae (shore flies), Sciomyzidae (snail-killing flies), Syrphidae (hoverflies), Tephritidae (picture-wing flies), Tipuloidea and Ptychopteridae (crane flies), as well as water bugs (several families), Odonata (dragonflies) and Araneae (spiders). These groups are considered to be essential for a realistic evaluation, while other groups such as Trichoptera (caddisflies), Mollusca (snails and bivalves) and Lepidoptera (moths and butterflies), among others, would add noticeably to the survey (depending on the habitat), but need not all be included. Amendments could be made to the list of target groups to meet the specific conditions of the site, with characteristic species known from the site added (Drake *et al.*, 2007). Gerlach *et al.* (2013) review the use of terrestrial invertebrates as bioindicators and the information presented therein could further assist in the selection of target groups.

Due to the variability in their form, behaviour and microhabitat preferences, there is a wide range of methods available to sample invertebrates generally, and also in fens. In carrying out monitoring surveys, some level of standardisation is required to allow a comparison of results, which eliminates some methods, while the nature of the habitats and the groups to be targeted further narrows the options. For example, pitfall traps are not favoured for wetland surveys due to the risk of flooding and interference, as well as selectivity issues (Drake *et al*. 2007; Duffey & Feest, 2009). For fen habitats, Drake *et al*. (2007) recommend pond-netting for water beetles and bugs, ground searching for terrestrial beetles and sweeping (spring and summer) for fly species, all carried out in a standard, timed manner. Timed hand collecting has also been recommended for spiders (Duffey & Feest, 2009). When recording species data, presence/absence is usually sufficient to identify species assemblages; however, additional information on abundance can allow the use of a broader range of analytical techniques (Drake *et al*., 2007).

The current usefulness of invertebrates in the conservation assessment of Annex I fen habitats is hampered by a number of factors, including gaps in the ecological understanding of many invertebrate species, the uncertainty of links between the condition of defined fen habitats and invertebrate species/assemblages, and limited availability of entomological expertise available in Ireland. However, raising the profile of invertebrates in assessing the structure and functions of Annex I habitats would begin the process of addressing these issues in the future.

3.4 Conclusion

Annex I fen habitats are important to a wide range of invertebrate groups, both terrestrial and aquatic. Equally, invertebrates provide important services in supporting the proper functioning of fen habitats, such as pollination and the breakdown of litter. For this reason, the invertebrate communities of fen habitats deserve attention when assessing the conservation status of these habitats.

Currently, there are limitations to using invertebrates in the assessment of Annex I fen habitats, and invertebrates are likely to be more useful at site level rather than for the national conservation assessment of a specific habitat.

Further study of the relationships between Annex I fen habitats and the invertebrates found in them may pave the way for the development of well-defined survey and assessment methodologies that relate the invertebrate assemblages recorded within Annex I fen habitats to the conservation status of that habitat.

The approach recommended by Mantell & Anderson (2020), whereby an initial baseline survey identifies the species assemblage, and a subset of characteristic species are selected for regular monitoring, may be the best way forward. Given the site-specific nature of this approach, the invertebrate community status of those Annex I fen habitat areas that have had their baseline invertebrate assemblage described, and characteristic species monitored, could be included in the *Structure and functions* assessment for the habitat. Such an assessment would require pass/fail criteria and thresholds to be set for the invertebrate community to fit within the overall *Structure and functions* assessment. Fen sites that have not had the same level of invertebrate survey work carried out could have this element of the *Structure and functions* assessment omitted.

4 Hydromorphological and Hydrochemical Characterisation of Fens

Understanding fen hydromorphology and hydrochemistry is critical to successful fen management. Being able to categorise Irish fen sites on the basis of these two parameters would be a first step to restoring impacted sites to a favourable conservation status.

As noted in section 2.1.1, Foss & Crushell (2008a) divided Irish fens into two major categories based on the dominant topographic and hydrological conditions: topogenous fens, in which vertical water table fluctuations predominate because of impeded drainage; and soligenous fens, where the horizontal movement of water is more important.

1. **Topogenous fens** are formed where the topography results in a basin type water collection system with little water movement out of the system and water fluctuations are in a vertical direction, as in shallow depressions, or in transitional zones of vegetation bordering open waters. The three main types of topogenous fen recognised in Ireland comprise:
    - basin fens
    - floodplain fens
    - open-water transition fens
2. **Soligenous fens** are formed on sloping terrain where an adequate supply of water provides a continuous throughflow of water. Smaller areas of soligenous fen may also occur within bogs or mires associated with routes of moving drainage water. The three main types of soligenous fen recognised in Ireland comprise:
    - valley fens
    - flush fens
    - calcareous spring fens

While these broad groupings are useful, they do not capture all the variability within these habitats. Fens often have different water transfer mechanisms operating in different parts of the site (McBride *et al.,* 2011; Wheeler *et al.* 2009a). Therefore, for the purposes of the NFS it is proposed that an adapted version of the more detailed 'Wetland Framework' by Wheeler *et al.* (2009a) be utilised to characterise fen systems. The Wetland Framework is not a classification system *per se*. Instead, it records generic units which can, in combination, be used to categorise wetland sites or parts of sites.

The Wetland Framework (see Table 9) records:

(i) landscape type

(ii) WETland water supply MEChanisms (WETMECs)

(iii) base-richness (pH)

(iv) fertility (trophic status)

(v) management

Landscape types are likely to be constant across wetland complexes, but WETMEC, base-richness, fertility and management all have the potential to vary across a site.

WETMECs summarise how wetlands function hydrologically and are conceptual units that describe the supply and distribution of water in wetlands (Wheeler *et al.*, 2009a). Although they were originally developed from wetland data collected from England and Wales, Kimberley & Coxon (2013) noted that the WETMECs relating to fens and bogs should be broadly applicable to the Irish situation. An additional WETMEC (WETMEC 21 Inflow from karst conduits) was added by Kimberley & Coxon (2013) as this type of water supply

mechanism is characteristic of some Irish wetlands but was not covered in Wheeler *et al.* (2009a). It is not clear how WETMEC 21 differs from WETMEC 12, which covers seasonal wetlands. A summary of each WETMEC is presented in Appendix 6. Detailed accounts and diagrams of each WETMEC and their sub-types are presented in Wheeler *et al.* (2009a, b).

In the selection of appropriate WETMEC types, geological datasets and maps from Geological Survey Ireland and Teagasc should be consulted and combined with observations made in the field (see section 9 for further recommendations). An experienced hydrologist should be involved in the survey. To review WETMEC calls for accuracy and consistency. It may not always be possible to select a sub-type with confidence during a single site visit in the NFS; in these instances, it would be satisfactory to record at the type level. Usefully, Wheeler *et al*. (2009a) lists the WETMECs that they found to be associated with Annex I fen habitats:

- 7140 Transition mire and quaking bogs - WETMECs: 2, 3, 5, 6, 15, 16, 17, 18, 19, 20
- 7210 Calcareous fens with *Cladium mariscus* - WETMECs: 5, 6, 7, 8, 9, 12, 13
- 7230 Alkaline fens - WETMECs: 6, 8, 9, 10, 11, 12, 13, 15, 17

From a hydrochemical perspective, the two most important factors determining the ecological composition of fens are base-richness and fertility (McBride *et al.,* 2011).

The base-richness categories used by Wheeler *et al.* (2009a) are shown in Table 9. Where surface water occurs, pH can easily be recorded in the field.

However, where surface water is lacking (this may be a temporal effect), it is proposed for the NFS that Ellenberg R (reaction) values derived from plot data be used as a proxy for pH (Hill *et al.,* 2004).

An overview of Ellenberg R values is presented in Table 10. Plots could then be assigned to a base-richness category based on their mean weighted abundance Ellenberg R value as calculated by the ERICA tool (Perrin, 2018). Ranges of R corresponding to base-richness categories are proposed in Table 9. However, the use of Ellenberg R values is an imperfect substitute for pH, which should always be recorded where possible.

Table 9 Layers of the 'Wetland Framework' (adapted from Wheeler *et al*., 2009a).

Landscape Type	Description
Basin	Associated with discrete basins and ground hollows
Floodplain	Associated with river floodplains, including active and inactive examples (when their inactivity is largely a product of drainage and water management)
Lakeside	Associated with large lakes or smaller water bodies when these represent the only or main situation in which wetland occurs. Where comparatively small water bodies occur within other situation types (such as pools within basin wetlands, ox-bow lakes within floodplain wetlands), they are subsumed within these
Valleyhead	Associated with the upper reaches of valleys; mainly soligenous
Valleyhead Trough/ Basin	Peat-filled troughs in broadly valleyhead contexts. Includes some former basin, or valleyhead basin, sites where peat has accumulated sufficiently to obscure the underlying basin topography
Trough (or valley-bottom)	Associated with the bottoms of valleys or other depressions, in contexts that are not really floodplains, or where the floodplain forms only a small proportion of the site, and often with a visibly sloping bottom. Includes some sites that are spatially transitional between the valleyhead and floodplain zones of rivers, and usually have many topographical similarities with valleyheads, but in a location well downstream of the actual valleyhead
Coastal plain	Associated with coastal plains
Plateau-plain	On flat or slightly undulating ground without close association with lakes, rivers or discrete, shallow basins; kept wet by high rainfall, impermeable substratum, high groundwater level and so on.

WETMEC		Sub-types					
1	Domed Ombrogenous Surfaces ('raised bog' *sensu stricto*)						
2	Buoyant Ombrogenous Surfaces (quag bogs)	2a	2b	2c			
3	Buoyant, Weakly Minerotrophic Surfaces ('transition bogs')	3a	3b				
4	Drained Ombrotrophic Surfaces (in bogs and fens)	4a	4b				
5	Summer-Dry Floodplains	5a	5b	5c	5d		
6	Surface Water Percolation Floodplains	6a	6b	6c	6d	6e	6f
7	Groundwater Floodplains	7a	7b	7c			
8	Groundwater-Fed Bottoms with Aquitard	8a	8b				
9	Groundwater-Fed Bottoms	9a	9b				
10	Permanent Seepage Slopes	10a	10b				
11	Intermittent and Part-Drained Seepages	11a	11b				
12	Fluctuating Seepage Basins	12a	12b	12c	12d	12e	
13	Seepage Percolation Basins	13a	13b	13c	13d		
14	Seepage Percolation Troughs						
15	Seepage Flow Tracks	15a	15b				
16	Groundwater-Flushed Bottoms	16a	16b	16c			
17	Groundwater-Flushed Slopes	17a	17b	17c	17d		
18	Percolation Troughs						

Landscape Type	Description		
19	Flow Tracks		
20	Percolation Basins	20a	20b
21*	Inflow from karst conduits		

Base-richness (pH or Ellenberg R values)			
Acidic	**Base-poor**	**Sub-neutral**	**Base-rich**
pH <4.0 / R 1-3.5	pH 4.0-5.5 / R 3.6-4.5	pH 5.6-6.5 / R 4.6-5.5	pH >6.5 / R 5.6-9

Fertility (Ellenberg N values)			
Oligotrophic	**Mesotrophic**	**Eutrophic**	**Hypertrophic**
N 1-2.5	N 2.6-5.5	N 5.6-7.5	N 7.6-9

Management					
Unmanaged	Winter grazed	Winter mown	Summer grazed	Summer mown	Burnt

Succow (1988) defined three main fertility categories based on the C:N ratio of peat in the upper acrotelm (the living actively-growing upper layer of a bog): oligotrophic (C/N ratio 33-50), mesotrophic (C/N ratio 20-33) and eutrophic (C/N ratio 10-20). However, Wheeler *et al.* (2009a) adopted the use of phytometric tests, as the authors regarded P and N data derived from soil analysis to be of limited use in the assessment of fertility. Phytometric tests involve measuring biomass of a test species (*e.g., Phalaris arundinacea*) grown on soil samples under controlled conditions. Wheeler *et al.* (2009a) defined four fertility categories based on phytometric data: oligotrophic (< 8 mg phytometer), mesotrophic (8–18 mg phytometer), eutrophic (18–38 mg phytometer) and hypertrophic (>38 mg phytometer); values represent mean dry weight of the shoot (mg).

Although phytometric tests are considered reliable indicators of fertility, they are time- and resource-intensive.

As a practical solution, it is again proposed that, in the NFS, Ellenberg values derived from plot data be used. This time N would be used as a proxy for soil fertility (Hill *et al.,* 2004). An overview of Ellenberg N values is presented in Table 11. Plots would be assigned to a fertility category based on their mean weighted abundance Ellenberg N value, again calculated by the ERICA Tool (Perrin, 2018). Van Wirdum (1990) identified three fertility categories based on Ellenberg N values: oligotrophic (Ellenberg: N 1-3), mesotrophic (Ellenberg N 4-6) and eutrophic (Ellenberg: N 7-9). Following a review of field data (plots from two of the pilot sites) and the mean fertility scores of the fen communities within the IVC, the following provisional fertility categories are proposed: oligotrophic (Ellenberg: N 1-2.5), mesotrophic (Ellenberg N 2.6-5.5), eutrophic (Ellenberg: N 5.6-7.5) and hypertrophic (Ellenberg: N 7.6-9).

For both reaction (R) and fertility (N), category thresholds can be refined once additional survey data have been collated. As there is likely to be some noise in the data for both the pH and fertility layers, it may be practical to utilise only the most frequently recorded categories.

The management types listed obviously do not relate directly to hydromorphology or hydrochemistry, but they do provide a further means by which different units within a site can be identified. Note that more than one management type can be selected; for example, if a site is grazed all year round, both winter and summer grazing can be selected.

Using this Wetland Framework approach, sites, or sections of larger sites, could be categorised as, for example:

- Basin, WETMEC 3, Base-poor, Oligotrophic, Unmanaged (in the case of some transition mires); or
- Valleyhead, WETMEC 17, Sub-neutral, Mesotrophic, Summer grazing (in the case of some upland flushes)

Table 10 Ellenberg R values with explanations derived from Hill *et al*. (2004). Example species compiled for this project with their assigned R value have also been presented.

N Values	Explanation	Example Species
1	Indicator of extreme acidity, never found on weakly acid or basic soils	*Kurzia pauciflora, Sphagnum papillosum, Sphagnum cuspidatum*
2	Between 1 and 3	*Calluna vulgaris, Drosera rotundifolia, Erica tetralix, Eriophorum vaginatum, Hypnum jutlandicum, Polytrichum strictum, Sphagnum capillifolium, Vaccinium oxycoccos*
3	Acidity indicator, mainly on acid soils, but exceptionally also on nearly neutral ones	*Aulacomnium palustre, Carex echinata, Hypericum elodes, Myrica gale, Sphagnum palustre, Viola palustris*
4	Between 3 and 5	*Carex limosa, Carex rostrata, Cirsium dissectum, Dichodontium palustre, Eleocharis multicaulis, Juncus acutiflorus, Juncus effusus, Menyanthes trifoliata, Potamogeton polygonifolius, Sphagnum squarrosum, Utricularia minor*
5	Indicator of moderately acid soils, only occasionally found on very acid or on neutral to basic soils	*Carex diandra, Carex vesicaria, Comarum palustre, Epilobium palustre, Hamatocaulis vernicosus, Hookeria lucens, Lysimachia tenella, Montia fontana, Plagiomnium ellipticum, Ranunculus flammula, Sphagnum contortum*
6	Between 5 and 7	*Calliergon giganteum, Caltha palustris, Campylium stellatum, Carex flava* group*, Carex lasiocarpa, Equisetum fluviatile, Eupatorium cannabinum, Iris pseudacorus, Saxifraga hirculus, Scorpidium scorpioides, Silene flos-cuculi, Valeriana officinalis*
7	Indicator of weakly acid to weakly basic conditions; never found on very acid soils	*Agrostis stolonifera, Calliergonella cuspidata, Campyliadelphus elodes, Carex riparia, Lycopus europaeus, Mentha aquatica, Palustriella commutata, Schoenus nigricans*
8	Between 7 and 9	*Cladium mariscus, Filipendula vulgaris, Juncus subnodulosus, Philonotis calcarea*
9	Indicator of basic reaction, always found on calcareous or other high-pH soils	*Ophrys insectifera*

Table 11 Ellenberg N values with explanations derived from Hill *et al*. (2004). Example species compiled for this project with their assigned N value have also been presented.

N Values	Explanation	Example Species
1	Indicator of extremely infertile sites	*Carex limosa, Erica tetralix, Eriophorum angustifolium, Eriophorum vaginatum, Vaccinium oxycoccos*
2	Between 1 and 3	*Aulacomnium palustre, Calluna vulgaris, Ctenidium molluscum, Campylium stellatum, Carex echinata, Carex flacca, Carex nigra, Carex panicea, Carex pulicaris, Carex rostrata, Carex flava* group*, Cirsium dissectum, Juncus acutiflorus, Molinia caerulea, Palustriella commutata, Pinguicula vulgaris, Lotus corniculatus, Potentilla erecta, Schoenus nigricans, Scorpidium cossonii Scorpidium revolvens, Scorpidium scorpioides, Sphagnum palustre, Succisa pratensis, Vaccinium myrtillus*
3	Indicator of more or less infertile sites	*Anthoxanthum odoratum, Briza media, Carex diandra, Carex lasiocarpa, Epilobium palustre, Equisetum palustre, Hydrocotyle vulgaris, Hypericum pulchrum, Juncus articulatus, Lysimachia tenella, Menyanthes trifoliata, Potentilla palustris, Ranunculus flammula, Salix aurita, Salix repens, Sphagnum squarrosum*
4	Between 3 and 5	*Betula pubescens, Calliergonella cuspidata, Caltha palustris, Cardamine pratensis, Cirsium palustre, Cladium mariscus, Deschampsia cespitosa, Equisetum fluviatile, Galium palustre, Galium uliginosum, Juncus subnodulosus, Plagiomnium elatum, Quercus robur, Ranunculus acris, Rhytidiadelphus squarrosus, Silene flos-cuculi, Thuidium tamariscinum*
5	Indicator of sites of intermediate fertility	*Angelica sylvestris, Brachythecium rivulare, Centaurea nigra, Chrysosplenium oppositifolium, Epilobium parviflorum, Festuca rubra, Filipendula ulmaria, Holcus lanatus, Juncus inflexus, Lathyrus pratensis, Mentha aquatica, Salix cinerea, Valeriana officinalis, Vicia cracca.*
6	Between 5 and 7	*Alnus glutinosa, Agrostis stolonifera, Brachythecium rutabulum, Carex hirta, Carex paniculata, Carex remota, Cirsium arvense, Cirsium vulgare, Dactylis glomerata, Drepanocladus aduncus, Equisetum arvense, Geranium robertianum, Glyceria fluitans, Iris pseudacorus, Myosotis scorpioides, Phragmites australis, Poa trivialis, Potentilla anserina, Rubus fruticosus* agg.*, Rumex crispus, Taraxacum officinale* agg.*, Trifolium repens*
7	Plant often found in richly fertile places	*Helosciadium nodiflorum, Arrhenatherum elatius, Calystegia sepium, Epilobium hirsutum, Eupatorium cannabinum, Oenanthe crocata, Oxyrrhynchium speciosum, Phalaris arundinacea, Ranunculus repens, Rumex conglomeratus, Salix caprea, Senecio vulgaris, Stachys palustris, Typha latifolia*
8	Between 7 and 9	*Bromus racemosus, Galium aparine, Glyceria maxima, Persicaria minor, Salix alba, Stachys sylvatica, Urtica dioica*
9	Indicator of extremely rich situations, such as cattle resting places or near polluted rivers	*Rumex obtusifolius*

Part II: Working Towards a National Fen Survey

5 Sites and Resources for the National Fen Survey

5.1 Fen Distribution in Ireland

5.1.1 Current Known National Fen Distribution

The most up-to-date distribution maps of Annex I fen sites are those from the latest Article 17 report (NPWS, 2019). The three habitats have different distributions in Ireland, which reflects their different ecological requirements. Alkaline fens (7230) are relatively widespread in Ireland as there are large areas of limestone bedrock. The most extensive areas of alkaline fen occur in lowland basins associated with limestone groundwater bodies, often in midland areas. Alkaline fens associated with upland flushes and open water transitions tend to be smaller but may be more widespread than those in lowland basins. *Cladium* fens (7210) are found throughout Ireland, most commonly in lowland areas in the midlands, west and south-east. They are occasional elsewhere. Transition mires (7140) are widespread but localised in Ireland. This habitat has been recorded most frequently in blanket bog regions in the north and west, limestone regions in the north-west and midlands, and in inter-drumlin hollows and lakes in the border counties, although the overall distribution is thought to be much wider. In the Connemara region, transition mires develop in the infilling margins of coastal lakes. Transition mires are probably under-recorded as they are not always recognised, particularly where they have been formed by the complete infilling of lakes, and there has been no standardised definition until recently. Poor fens are frequent throughout Ireland but most common in western, upland counties such as Donegal, Mayo, Galway, Kerry and Cork (Foss, 2007). Poor fen is likely to be very under-recorded as it is a non-Annex I fen community and less species-rich than the three Annex I fen habitats.

5.1.2. Data Sources Used for Review

A review of each county was undertaken to assess whether any additional fen sites could be added to the Article 17 dataset (NPWS, 2019). The most informative fen survey data have been derived from county wetland surveys, usually commissioned by a local authority. These typically comprise an initial desktop data review and GIS mapping exercise, followed in some cases by a number of field surveys. Some counties have had several wetland field survey projects conducted and most sites will have been mapped and surveyed. For example, in County Monaghan there has been the County Monaghan Wetland Survey (Barron, 2006), Monaghan Fen Survey II (Foss & Crushell, 2008b), The County Monaghan Wetlands Map (Foss & Crushell, 2010), Monaghan Wetland Survey (Foss & Crushell, 2011) and Monaghan Wetland Survey II (Foss & Crushell, 2012).

A large number of counties, however, have had no county wetland review, and some have had a desktop review only. Therefore, the target fen habitats are likely to be under-represented in the current distribution maps.

The aim of the county review was to identify potential sources of information on additional fen sites and to highlight counties which have had little survey effort or review to date. The first task was to review the data available for each county and to assess which data sources have already been assessed in the Article 17 reports (NPWS, 2008, 2013b, 2019). This focused on large-scale wetland datasets such as county wetland surveys, surveys for infrastructure projects, species records and habitat surveys.

The second task was to review GIS data on potential additional fen sites. Wetland Surveys Ireland (WSI) maintains an online Map of Irish Wetlands (MIW)[1], the aim of which is to "show the location and provide information on a range of freshwater wetlands around Ireland". The GIS data for this map were obtained from WSI and compared with the data from the Article 17 dataset (NPWS, 2019) to identify any potential additional fen sites that had not been included in the Article 17 dataset.

The GIS data were put through a number of pre-processing steps before they could be reviewed:

1. The 2019 Article 17 point shapefiles for habitats 7140, 7210 and 7230 were merged and converted to a polygon layer by giving each point a nominal buffer of 100 m
2. The polygon layer from step 1 was merged with the 2019 Article 17 polygon shapefiles for habitats 7140, 7210 and 7230
3. A new polygon layer was created that comprised all 1 km grid squares (ITM95 grid) that did not intersect with the polygon layer produced in step 2
4. The MIW Locations point shapefile was converted to a polygon layer by giving each point a nominal buffer of 10 m
5. The polygon file from step 4 was merged with the MIW Site Boundaries polygon shapefile
6. Features in the polygon layer from step 5 were extracted if they intersected with the grid square polygon layer produced in step 3

The features yielded by this process represented potential new fen sites not included in the Article 17 dataset (NPWS, 2019). Features derived from the MIW Locations shapefile had been categorised according to the 'Site Evaluation' by WSI.

- A Rating: Internationally Important
- B Rating: Nationally Important
- C+ Rating: County Conservation value
- C Rating: Local conservation value (high value)
- D Rating: Local conservation value (moderate value)
- E Rating: Local conservation value (low value)
- F Rating: Unknown value - survey required
- Blank: no evaluation rating (or habitat) information provided

Most sites evaluated as A or B were protected sites that had already been assessed during the Article 17 data review. If these sites had not been mapped then it is probable that they were considered not to support mappable Annex I fen habitat.

The B category does include some proposed Natural Heritage Area (pNHA) sites that were not reviewed for Article 17. Where these were considered to have potential to support fen habitat, they were highlighted for review and further survey.

For sites evaluated as C+, C, D or E, the site description included in the shapefile attribution was checked for comments such as 'no fen habitat', 'site destroyed', *etc.*, to decide if the site supported mappable fen habitat. The source of the data was then checked. If the site was from a survey such as a county wetland survey (CWS) which had been reviewed for Article

[1]https://www.wetlandsurveysireland.com/wetlands/map-of-irish-wetlands--/map-of-irish-wetlands---map/index.html

17, then it was considered that the site had already been assessed and considered not to support mappable fen habitat. If the source data had not been reviewed, were not available, or the site contained non-Annex I fen habitat, then it was highlighted for review and further survey.

The sites evaluated as F often had little available information and usually require a survey to assess fen habitats. If habitat information was available then this was checked, and sites which fell predominantly into another wetland category (such as turlough or wet woodland) were excluded. Where an Annex I fen habitat type or poor fen was listed, the site was highlighted for review.

Features derived from the MIW Site Boundaries shapefile had no 'Site Evaluation' data. The attribution for these sites usually consisted of just a site name with no additional data. The site name was checked to see if it was an obvious pond, calcareous spring, turlough or protected site which did not need reviewing. If there had been a thorough county wetland survey or review in that county, then it was considered that it was unlikely these points would contain additional fen sites and they were not marked for review or further survey. For less well-surveyed counties, the non-rated sites which were not obviously non-fen were highlighted for review or further survey, but many are unlikely to support additional fen habitat.

5.1.3 County Fen Distribution Review

The data from the county fen distribution review are summarised in Appendix 7. Each of the 26 counties has been reviewed. The Appendix table includes the following information:

- County name;
- Large-scale datasets assessed for Article 17: Large-scale datasets which are known to have been reviewed for the Article 17 2013 and/or 2019 assessment;
- Large-scale datasets not assessed for Article 17: Large-scale datasets which have not been reviewed or where it is unknown if they were reviewed for the Article 17 2013 and/or 2019 assessment. Some of these were completed after the 2019 Article 17 assessment or were not available for review during that process. Some earlier surveys or reports may have been overlooked and not reviewed in earlier Article 17 assessments;
- Potential new sites from MIW: Sites from the MIW which do not appear to have been included in the Article 17 fen maps but which are considered to have some potential to support additional fen habitats. Most of these sites will require further survey to assess but some may have additional data in county wetland reports;
- CWS field survey: Indicates whether a dedicated county wetland survey with a field survey element has been undertaken. Most (but not all) counties have had a desktop review of wetlands but this has not always been followed by field surveys;
- Summary of known fen distribution in county: Brief notes on the known distribution of fens in the county, the coverage of available field survey data and potential additional fen sites;
- Level of knowledge gaps: Based on the review of available data the county is rated as being 'High', 'Medium' or 'Low' in terms of gaps in our knowledge of the distribution of fen sites. High-rated counties have considerable knowledge gaps and are those where there are very limited field survey data to date and limited additional data sources (*e.g.,* bryophyte records). Medium-rated counties have some field survey data, possibly including one or more county wetland surveys, but geographic coverage is limited. The review of these counties highlighted that there are additional potential fen sites to check and that some habitats, *e.g.,* poor fen, are likely to be under-recorded. Low-rated counties have relatively few knowledge gaps are those where there is a range of

field and desktop data on fens for the county, there is a good geographic coverage of fen sites and additional data, *e.g.,* bryophyte records, are available. In these counties the review did not highlight many additional potential fen sites and the different fen types are well represented. High-rated counties = Carlow, Cavan, Clare, Cork, Donegal, Galway, Kilkenny, Laois, Leitrim, Limerick, Mayo, Meath, Offaly, Roscommon and Tipperary; Medium-rated counties = Sligo, Waterford, Westmeath, Wexford and Wicklow; Low-rated counties = Dublin, Kerry, Kildare, Longford, Louth and Monaghan.

5.2 Selecting Sites

5.2.1 Aims

The previous section identified counties where there are gaps in our knowledge of the distribution of Annex I fen sites. While filling in gaps in the Article 17 distribution and range is one of the outputs from the proposed NFS, the survey will have a much broader remit. . The following section reports on the selection of suitable sites for the NFS. The aims of the selection process were as follows:

- to adequately represent the geographical range of fen and flush habitats within Ireland; a minimum number of sites should be surveyed within every county
- to adequately sample the three Annex I fen habitats (EU codes 7140, 7210 and 7230) and non-Annex I fen habitats; these latter habitats may comprise both Rich fen and flush (Fossitt code PF1) and Poor fen and flush (Fossitt code PF2)
- to include sufficient examples of fens and flushes associated with different landscape features (*e.g.,* lakes, uplands, rivers, bogs)
- to focus on known examples of fen and flush, and areas where examples are not known, but where there is a high probability of their occurrence

The process did not aim to select sites for fen woodlands, fen vegetation in turlough basins or fen vegetation in dune slacks. Calcareous springs were used to aid site selection, based on the premise that fen habitats such as alkaline fen could also be located in the vicinity of calcareous springs.

5.2.2 Selection Procedure

All 58 SACs which have an Annex I fen habitat as a Qualifying Interest (QI) were selected. Working with the combined 2019 Article 17 layer produced in section 5.1.2 (step 2), the features which intersect with these SACs were identified and used to calculate an area of potential fen habitat for each site. There were 3,041 such areas totalling 7,509 ha. Based on these figures the average potential area of fen habitat within each of the 58 SACs was estimated to be 129 ha. Of these 58 sites, six have already been surveyed during the PFS. For Pollardstown Fen only a subset of the fen habitat was surveyed and it is recommended that the rest of the site be surveyed during the NFS. Consequently, 53 SAC sites should be surveyed during the NFS. For the larger SACs that include many non-fen habitats, such as the river, lake and upland SACs, it will be important to focus the fen survey on selected areas (sub-sites) within them.

Working with the remaining features in the combined 2019 Article 17 layer, each feature was scored using the criteria in Table 12.

From the polygonised MIW Locations layer produced in section 5.1.2 (step 4), all features which intersected with the combined 2019 Article 17 layer were deleted to avoid duplication. This MIW layer contains habitat information but has only nominal areas. Next, from the MIW Site Boundaries layer all features which intersected with the combined 2019 Article 17 layer

were deleted, again to avoid duplication. This MIW layer has real areas but no habitat information.

These two MIW layers were then intersected and where features in the Locations layer overlapped with features in the Site Boundaries layer, habitat information was transferred. This procedure allowed habitat and area information to be combined. Each feature in the amended Site Boundaries layer was then scored using the criteria in Table 13. Any feature which failed to score for 'target habitat' was eliminated from the selection procedure.

Using the original polygonised MIW Locations layer produced in section 5.1.2, all features which intersected with either the combined 2019 Article 17 layer or the MIW Site Boundaries layer were deleted. This also ensured that no duplicated sites would be selected. Each feature in this amended Locations layer was then scored using the criteria in Table 12.

Table 12 Criteria and scoring used to select National Fen Survey sites. The county criterion is based on the review in section 5.1.3.

Criteria	Scoring	
Area (ha)	> 50 = 4, >20 to 50 = 3, >10 to 20 = 2, ≥5 to 10 = 1, <5 = 0	
County (level of knowledge gaps)	High priority = 2	Carlow, Cavan, Clare, Cork, Donegal, Galway, Kilkenny, Laois, Leitrim, Limerick, Mayo, Meath, Offaly, Roscommon and Tipperary
	Medium priority = 1	Sligo, Waterford, Westmeath, Wexford and Wicklow
	Low priority = 0	Dublin, Kerry, Kildare, Longford, Louth and Monaghan
Target Habitats	All features in the combined 2019 Article 17 layer = 3 Features in the MIW layers with keywords fen, transition mire or spring = 1	

Features that scored ≥ 5 points were selected, as were features greater than 10 ha in area. This resulted in the selection of 335 further sites with an average area of 55 ha.

Of the 3,376 potential fen areas selected at this point, some of the largest were reviewed using aerial imagery and it appeared that a proportion of these areas were non-fen habitats such as raised bogs and cutover bog. It is still important that these large areas are surveyed during the NFS so that the area of fen and flush habitat within them can be studied.

It should be noted that there is a relatively large degree of error in the estimates of potential fen area. A brief review of selected sites using aerial imagery showed that there were many sites that included large areas of non-fen habitat, and conversely there were many sites where areas of potential fen habitat had been missed or were inaccurately mapped. However, the expectation is that the average figures are credible.

Following this procedure, three counties (Carlow, Cork and Wexford), had either one or no areas selected for survey. To ensure a minimum number of selected sites of three per county, an additional 12 sites were selected within these counties by manually reviewing the lists of unselected features. This brought the number of selected sites up to 400.

Since the procedure outlined above is based on imperfect data, it is likely that there are areas of fen habitat that have not been selected. To allow for this discrepancy, it is proposed that 100 additional sites be selected as the NFS progresses. These will include areas of fen that are observed using remote imagery, such as aerial photographs, and potential sites that are observed in the field or learned about from other sources. Some of these may have been considered in the selection process but scored poorly based on available data.

Without investigating each potential fen area individually, it is difficult to accurately assess the landscape context for the selected sites. For the 58 fen QI SAC sites that represent 29% of

the potential fen area, the main landscape features are listed in Table 13. As the NFS proceeds, the landscape features associated with each site should be recorded and these data monitored to ensure that all of the main landscape features are being adequately surveyed and no one feature dominates. The 100 additional sites allow the flexibility to redress any imbalance.

Table 13 Dominant landscape features associated with the 58 SACs selected for survey during the National Fen Survey due to an Annex I fen habitat being listed as a Qualifying Interest.

Landscape feature	% of SACs
Fen and bog	34
Lake edge	31
Uplands	10
River side	7
Other	18

Currently, the selected sites are strongly biased towards Leinster, which accounts for 68% of the area due to large areas of fen being selected in Kildare (6,011 ha) and Westmeath (8,859 ha) (Figure 1).

Leinster does hold a significant number of the known areas of fen habitat, including 22 (38%) of the 58 SACs where fen habitat is listed as a QI. However, the number of selected sites within Leinster is probably too high and the province should probably represent approximately 40% of the survey effort. Twenty-four (41%) of the 58 SACs are within Connacht and this province is currently under-represented within the selected sites, accounting for 18% of the area. Munster and Ulster are expected to contain relatively smaller areas of fen habitat. They currently account for 12% and 6% of the sites respectively, and 17% and 10% of the 58 SACs respectively. As the NFS proceeds, the geographical spread of surveyed sites should be monitored to ensure that the minimum number of three fen sites per county is surveyed and to ensure that all provinces are surveyed in proportion to their estimated fen resource. The quota of 100 additional sites allows the flexibility to redress any imbalance. It is expected that a number of additional sites in Connacht will need to be selected.

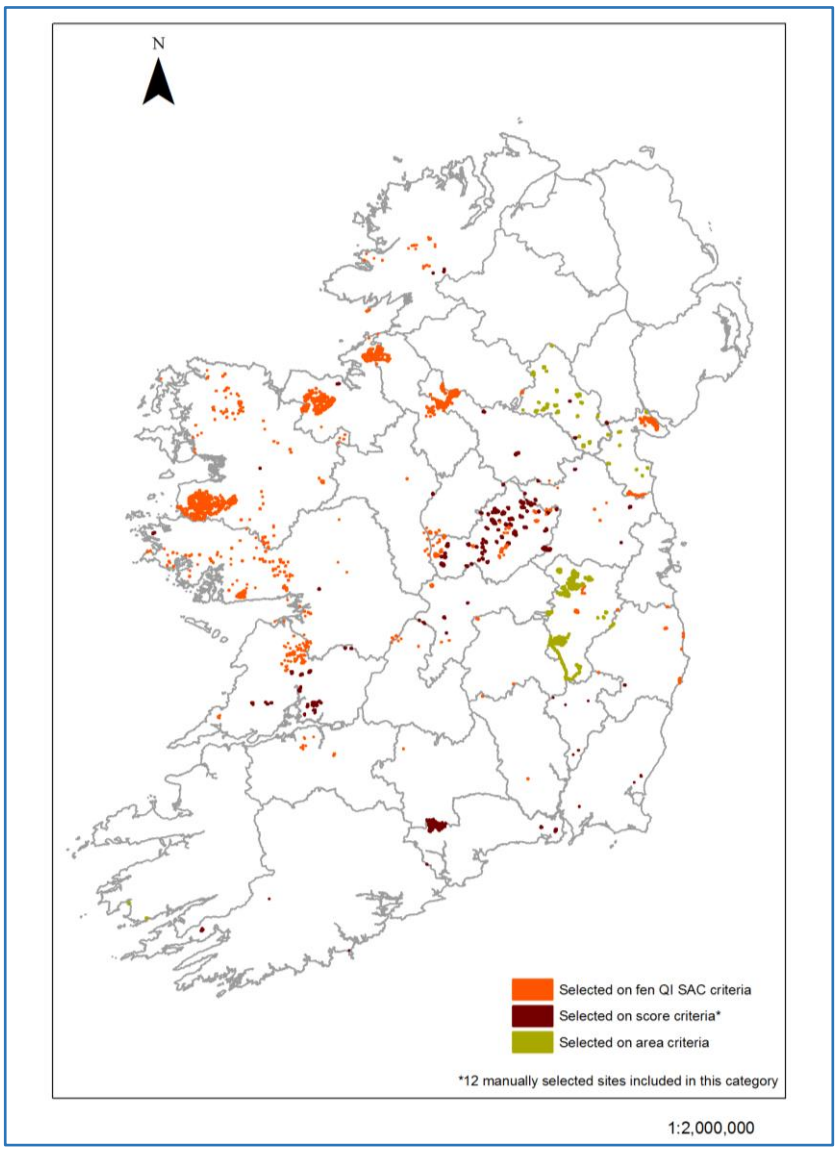

Figure 1 Map of selected sites for the National Fen Survey.

5.3 Strategy and Resources

The estimate for the number of person days required to conduct the NFS field surveys is shown in Table 14. The survey rate for the SAC areas is based on experience gathered from the PFS. These areas are approximately 129 ha each. The survey rate for the other, smaller fen sites (approximately 55 ha each) is similar. It is expected that a two-person team will survey an average of four sites in five days.

Table 14 Estimate of the number of person days to survey the remaining 53 fen QI SAC sites and 447 other fen sites.

Target	Area (ha)	Daily Survey Rate	No. Person Survey Days
Area within 53 fen QI SACs	6,837	19 ha per person per day	359
Area within 447 other fen sites	24,585	0.4 sites per person per day	1,117
Total of 500 sites	31,422	-	1,476

Capacity issues, that is, the problem of securing the services of enough suitably qualified and experienced ecologists, are likely to be a limiting factor for the NFS. These capacity issues can be overcome to a certain degree by training, which can be on-the-job by pairing an experienced ecologist with a less experienced team member, but training will reduce the daily survey rates in Table 14. Unless the NFS includes a significant additional training component, it is realistic for the NFS to aim for 150-300 person-survey-days per field season. It will thus require between four and seven full field seasons to complete the survey.

It is advisable to approach the NFS in phases. For example, phase 1 could aim to survey the remaining 53 fen QI SACs over three field seasons, together with 147 of the other fen sites, which would involve 489 person days based on the estimates presented in Table 14. This would then leave the remaining 300 fen sites to be surveyed during the second phase of the project.

Annual reporting for the NFS should be an integral part of the project, with the annual submission of updated GIS shapefiles and Turboveg data required to ensure that the surveying is progressing at an agreed rate and that data are being collected and stored according to NPWS data standards. A brief written report should also accompany the data collected each year; this report should list all sites surveyed, highlighting the most notable sites any issues that arose during the year.

To ensure that the survey team monitor and report on the national status of fen habitats on an annual basis, it is proposed that four geographical blocks of sites are chosen each year (one from each province). Leinster and Connacht will then each represent approximately 40% of the survey effort, and Munster and Ulster together representing the remaining 20% of the survey effort.

Geographical blocks of sites will make surveying more efficient, although there will inevitably be some geographical outliers. To assist organisation, sites should be numbered with numbers starting at 1001 for Leinster, 2001 for Munster, 3001 for Connacht and 4001 for Ulster. If a site straddles a provincial boundary, it should be assigned to the province in which the largest proportion of the site occurs.

It should also be noted that the sensitivity of habitats to multiple surveys will be an issue for some of the potential fen areas. If there is evidence that a potential fen area has recently been surveyed, *e.g.,* for *Vertigo*, Marsh Fritillary or rare plants, these sites should be scheduled for the end of the NFS.

6 Proposed Methodology for the National Fen Survey

6.1 Summary

- This methodology is for a baseline national survey of fens in Ireland
- Both Annex I and non-Annex I fen habitats in a range of sites will be surveyed and mapped
- Relevés will be recorded in different fen vegetation communities
- Assessment data will be collected to assist in the assessment of *Structure and functions*, *Future prospects* and *Overall Conservation Status* of three Annex I fen habitats: 7140 Transition mires and quaking bogs; 7210 Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae; and 7230 Alkaline fens
- To assist in the assessment of *Future prospects*, information will be gathered on the impacts and activities taking place in the fen habitats at the surveyed sites
- Some other site-level data will also be gathered, including water pH and electrical conductivity, mapping drainage features and recording possible signs of N deposition

6.2 Review of Selected Sites

Site selection (see section 5.2) will need to be individually reviewed using remote imagery and available ecological information. A minimum site size of 0.5 ha of fen habitat is proposed for the NFS. Consequently, some sites may be dropped at this stage because they do not meet the minimum site area requirement. This review may also highlight groups of nearby or adjacent sites that for practical purposes should be coalesced into one survey site. Site boundaries should be defined that encompass not only potential areas of fen habitat but also other habitats within the same wetland system. Data on SACs held on file by NPWS should be accessed to assist with locating the occurrence of fen habitats within SAC sites, and for any other information that may be useful.

6.3 Survey Preparation

Prior to the field survey, a polygon shapefile should be created to hold a habitat mapping framework. The minimum attributes for this shapefile are Fen_ID (unique identifier for the site; see section 5.3 on site numbering), Polygon_ID (unique identifier for the polygon within the site) and Area_m2. This framework should be manually digitised for each selected site, with each polygon representing an area of consistent patterning, based on interpretation of recent aerial imagery. The minimum mapping unit for polygons is 400 m^2, *e.g.,* 20 m × 20 m.

Each polygon in a site should be assigned a unique number, stored in Polygon_ID. This ID number links the polygon to the surveyor's recorded data (see section 6.7.1.1 on habitat mapping). The polygon framework should be made available to surveyors as a shapefile uploaded onto a hand-held computer with the polygon numbers displayed on the screen. This aids with navigation around the site and helps the surveyor to identify what polygon they are in at any time. The framework should also be printed on a paper field map, with the polygon numbers displayed, using aerial photographs or satellite imagery as background mapping, so that any amendments to polygon boundaries can be made on paper in the field, then digitised later when back in the office.

Pre-survey digitisation of drainage features should also be carried out by aerial photograph interpretation and using six-inch maps available on GeoHive (http://map.geohive.ie/

mapviewer.html) or from NPWS via MapGenie as an additional aid to tracing the course of drains. As for polygons, these features can be made available as a digital shapefile or displayed on paper field maps.

Permission from the owner of the site should be sought before entering, unless a site is within State ownership. In addition to granting access to a site, owners can provide information on the land management history of a site. Online resources such as www.landdirect.ie are useful for tracing landowners. Bord na Móna sites are not publicly accessible and should be contacted in advance for details of on-site contact, completion of Health and Safety documents and safety induction. While Coillte sites are publicly accessible under their Open Forest policy as long as forestry operations are not in progress, a permit may be required to conduct a survey on Coillte property. The local NPWS Conservation Ranger should be contacted in advance as a courtesy and to garner any information they may have on a site. Rangers may also be able to help surveyors make contact with landowners.

A site pack should be prepared for each site, either digitally or on paper, comprising the following elements:

- Front sheet for entering overall site data including site description, impacts and activities (digital and paper)
- Printed field maps displaying the numbered polygon framework and drainage features overlaid on colour aerial photographs
- Form for entering habitat data for each polygon (digital and paper)
- Form for entering assessment data for each assessment stop (digital and paper)

6.4 Recommended Survey Equipment

The following equipment is required for carrying out the survey:

- Site pack – for each selected site, as detailed above
- GPS-enabled tablet or ruggedised hand-held computer set to Irish Transverse Mercator projection, with GIS and spreadsheet software installed and the following files:
    - polygons shapefile; outlines and numbers must match those on field maps
    - drains shapefile
    - waypoint shapefile for recording target notes and relevé locations
    - Excel spreadsheet for recording polygon habitat data, using the site number and polygon number as a unique reference for each row of the spreadsheet
    - Excel spreadsheets for recording Annex I assessment data, one per Annex I fen habitat
    - Turboveg database for recording relevé data. The use of Turboveg, a storage database for vegetation data, is recommended as it ensures species names are recorded in a standardised fashion. NPWS now accepts relevé data in a Turboveg database without the need for conversion to an Excel spreadsheet or Access database. Furthermore, the National Biodiversity Data Centre uses

Turboveg as its standard method of holding relevé data, so the task of uploading relevé data from the NFS to the National Vegetation Database is made simpler, faster and more accurate

- Compass/clinometer
- Details of fen Annex I and Fossitt (2000) habitats
- Plant identification guides; *e.g.*, Atherton *et al*. (2010) for bryophytes; Jermy *et al*. (2007) for sedges; Parnell & Curtis (2012); Rose & O'Reilly (2006); Poland & Clement (2020) for vascular plants.
- 2 m × 2 m rope quadrats
- Hand lens ×10 or ×20
- pH and conductivity meters
- Telescopic rod with sampling cup; to assist collection of water data from pools and ditches
- 5 m carpenter's tape measure
- A peat probe of at least 300 cm; avalanche probes are not a satisfactory alternative as they can be exceedingly difficult to extract from deep peat
- Camera
- Small plastic bags for vascular plant samples
- Envelopes for bryophyte samples
- Markers/pens for annotating map and labelling sample bags
- Spare batteries for electronic equipment in waterproof bag
- A4 weatherwriter clipboard
- Paper copies of recording sheets in event of equipment failure, plus pencils and eraser
- Waterproof paper

The following equipment must be carried for safety purposes (see also section 6.5 below for other health and safety considerations):

- Mobile phone, or satellite transponder when in areas with no mobile phone coverage
- Trekking pole
- Water
- Emergency food rations (high-energy snacks such as nuts)
- First aid kit
- Whistle
- High visibility vest
- Sunscreen
- Insect repellent
- Printed copies of phone numbers of all team members, the project coordinator, Mountain Rescue (if appropriate) and regional NPWS staff
- Letter of authorisation from NPWS
- Identity card

- Certificate of insurance

6.5 Health and Safety Aspects of Fen Survey

Perrin *et al*. (2014) gave a detailed account of the health and safety issues to be considered when surveying in upland habitats. Many of the issues addressed are relevant also when surveying in fens, even though the majority of the fens to be surveyed in the NFS are likely to be in a lowland setting. This section uses the guidelines of Perrin *et al*. (2014) as a basis for addressing the health and safety concerns that may arise when surveying in fen areas, with the emphasis here on lowland fen surveying.

There may also be a number of upland flushes and fens included in the national survey; for these, the guidance of Perrin *et al*. (2014) is directly relevant and should be consulted.

Health and safety is a serious consideration for field surveyors working in fens. Soft or quaking ground and deep ditches present hazards that surveyors should treat with respect. Vegetation may have sharp edges or leaf tips. All staff members have a responsibility for their own safety and common sense is advised at all times, but it is incumbent on senior staff to establish a culture of avoiding and reducing risks. Problems can be prevented through appropriate training (particularly of staff new to the project), risk assessments, adherence to health and safety protocols, the use of the correct equipment kept in good condition, and attention to weather forecasts and local weather conditions.

Fieldwork should be conducted either:

- in pairs, when two people work together at a site and stay working together for the duration of the fieldwork, or
- as part of a field team where team members work in different parts of the site, checking in with each other at regular intervals.

Working in pairs creates the safest working environment but on larger sites, the second option may be more practical.

6.5.1 Specific Risks in Fens and Swamps

- Transition mire (7140) will often consist of rafts of vegetation overlying water (swaying or quaking movement when walked on). Bogbean (*Menyanthes trifoliata*) is indicative of such areas and should be approached with caution
- Bogs with extensive pool systems should be avoided if possible
- Take care when traversing reed swamps and use a walking pole to probe ahead
- Take care when stooping down to look at plants such as rushes or reeds, due to the risk of eye injury. Eye protection (*e.g.,* safety glasses, goggles) should be worn to minimise risk of injury from reed or rush vegetation
- Take care when walking through *Cladium mariscus* swamp as the edges of the leaves are very sharp and can cause cuts to skin and could damage eyes. Eye protection is advisable

6.5.2 Before Survey Season Starts

- A comprehensive assessment of potential risks, together with identification of the appropriate courses of action, should be made at the start of each field season

- All staff should familiarise themselves with the company safety statement, particularly the fieldwork safety awareness section
- Specific training in Health and Safety protocols (*e.g.,* how to stay safe, what to do in case of emergency) should be given to all project staff
- First aid training/refreshers should be attended, if appropriate
- Tetanus booster shots should be obtained if necessary
- Supplies of field kit should be inventoried and checked to make sure that they are sufficient and in good working order
- First aid kits should be supplied for surveyors' cars; contents should be checked to ensure that they are in date
- Survey vehicles should be serviced and regularly checked for road-worthiness throughout the field season

6.5.3 Daily Routines

- Check weather forecast; amend fieldwork plans if necessary
- Familiarise yourself beforehand with site, access, *etc.*
- Carry out site-specific risk assessment on arrival at site
- Notify off-site contact of survey details, including location, vehicle details and members of survey team, before fieldwork starts for the day. The information provided must be sufficient for them to identify the survey site with minimum effort in an emergency situation
- Surveyors should plan in advance which specific polygons they will survey and ensure that other surveyors on the same site are aware of their plans. This ensures that there is no duplication of effort, but permits fieldworkers to work in relatively close proximity for safety reasons
- When working as part of a field team, regular contact between team members is important. The frequency of this must be established and agreed upon at the beginning of the day and should take into consideration the weather conditions, phone coverage and site conditions. A contingency plan, such as meeting back at the cars or at a particular landmark by a specific time, should be agreed at the outset
- Notify off-site contact when survey work is finished for the day
- Charge batteries of all electronic equipment (hand-held computers, phones, cameras)
- Check equipment is in good working order for the next day
- Replenish any used first aid stocks, *e.g.,* plasters

6.5.4 Equipment

Section 6.4 includes a checklist of safety equipment that is strongly recommended to be carried by fieldworkers at all times. Additional equipment may be required in upland areas (see Perrin *et al*. (2014) for further details). Where appropriate, items must be checked regularly to ensure that they are fit for purpose. Clothing is dealt with separately in section 6.5.5 below.

Equipment weight should be minimised where possible to prevent fatigue and for efficiency, but a balance must be struck to ensure that surveyors are well prepared. Therefore, the lightest forms of reliable equipment should be used.

All electronic equipment (mobile phones, cameras, hand-held computers and GPS units) must be fully charged each morning prior to field work. Waterproof covers must be used with non-ruggedised electronic equipment. Spare batteries for equipment should be carried if the main battery is insufficient for a full day's usage.

6.5.5 Clothing

- Must be adequate for the type of weather and terrain
- Suitable footwear should be worn such that adequate ankle support and surface grip are obtained; waders may be advisable, especially for wetter fen sites
- Jackets should be windproof, waterproof, breathable, quick-drying and brightly coloured if possible
- Wool or cotton trousers are preferable to denim jeans, which have little warmth and, once wet, tend to stay wet
- Waterproof over-trousers are useful in bad weather and also provide some protection against ticks; bright colours are good for safety
- Gloves should be worn as necessary
- Socks: wear one or two pairs; wool socks stay warm even when wet
- Extra top layer; bring spare clothing if you can, or leave a change of clothes in the vehicle
- Headgear (*e.g.,* warm hat or balaclava) and scarves are important in cold weather; however, a sun hat is essential in open areas in hot weather to prevent heat stroke or sunburn
- High-visibility clothing should be worn if surveying along a road, or walking along a road when returning to your car

6.5.6 Navigation

As a primary method of navigation during data recording, it is recommended to use ArcPad, or a similar program, on the hand-held computer.

With the polygon shapefile open, the constantly updated real-time position of the surveyor in relation to polygon boundaries is available at a glance, as is the direction of travel. This greatly increases the accuracy of data recorded and makes navigation around the site easier.

In case of technical difficulties with the hand-held navigation device (*e.g.,* flat battery, poor satellite coverage) surveyors must be prepared to fall back on using a standard GPS, map and compass to safely navigate around and off site. Care should be taken to ensure that the compass bearing is not affected by magnetic sources, such as a magnetic personal digital assistant (PDA) stylus or mobile phone.

The use of waypoints is recommended when navigating through difficult terrain; for example, when a good point for crossing a stream is located, it should be waypointed, making it easier to locate on the return journey. Waypointing the location of the vehicle(s) is also advisable if parked on a featureless track or road.

6.5.7 Safety/Accident/Emergency Procedures

- If sharing cars, a spare key should be left at a pre-agreed spot near the vehicles so that members of the survey team can get immediate access to shelter if they return early, are unwell or fatigued

- In case of thunder or lightning nearby, surveyors in an exposed location should lie down in the nearest concavity until the danger has passed; metal poles should be discarded away from the body
- Experience has shown that most accidents occur towards the end of the day, when surveyors are tired, cold or hungry. Extra care should be taken by surveyors, even on level terrain, as evening draws near, and sufficient food and drink should be consumed to maintain energy levels until the vehicle is reached
- In the event of a surveyor being late to a meeting point, they should not rush to get there as hurrying may result in an injury. Instead, they should contact their colleagues to inform them that they will be late and proceed at a normal pace, paying due diligence to potential hazards
- In the event of a surveyor being late to a meeting point and being uncontactable, their colleague should wait at the meeting point for at least an hour. They should not go looking for the latecomer. It is vital to remain available for communication, so if there is no mobile phone reception, surveyors should move to a location with a better signal, leaving a conspicuous note or sign to show where they have gone. In upland situations, mountain rescue services should only be alerted 2 to 3 hours after failure to return unless it is after 20:00 hrs, in which case, call immediately. Dial 999/112 and ask for “Mountain Rescue”. You will be put through to the local Garda station where the situation will be assessed and the rescue team alerted
- In the event of an accident, exhaustion or ill-health, six blasts on an emergency whistle should be sounded, followed by a pause and another six blasts. The response to this signal is three blasts followed by a pause and another three blasts. This procedure is repeated until the responding party has located the person in distress. Surveyors should only seek to respond to distress signals if conditions are good and they can confidently do so without endangering themselves, otherwise they should notify the rescue services. Shouts, torch flashes or waves of brightly-coloured cloth can be used instead of a whistle
- Any accidents or incidents/near-misses should be reported using the appropriate reporting form

6.6 Arrival at a Fen Site

A decision should be made upon arrival in the field on the validity of surveying a site, based on the presence of fen habitat and the area it covers. Sites will have been pre-selected based on the following criteria, and a site should only be surveyed if these criteria are found to have been met on visiting the site:

- A minimum survey area of 0.5 ha of fen habitat applies. However, this does not all have to be contiguous; neither does it have to be Annex I habitat.
- Sites at which recent habitat loss has reduced the area of the target fen habitats to less than 0.5 ha should be rejected. Notes should be taken as to why the site is not being surveyed, including reasons for the loss of habitat and approximately when it occurred, if this can be ascertained.

Habitats that are regarded as fen habitats for this survey comprise the following:

- Annex I fen habitats 7140, 7210 and 7230 under the EU Habitats Directive
- Non-Annex I fen habitat (PF1 or PF2 under Fossitt, 2000), including upland flushes

- Fen meadow that is classified as PF1 under Fossitt (2000), but as 6410 under the EU Habitats Directive. This will be surveyed, mapped and will have relevés recorded, but it will not be assessed as part of the NFS

Habitats that are not regarded as fen habitats within the remit of the NFS include:

- Fen habitats that form part of turloughs (Annex I habitat 3180). While fen vegetation is often a component of turloughs, there will be no selection or assessment of fen that occurs in a turlough basin. However, if it forms part of the larger fen complex that is the main focus of the survey, then the boundary of the turlough as a whole should be mapped as 3180 habitat but it should not be assessed or surveyed further
- Fen habitats that form part of dune systems, *e.g.,* dune slacks. Such fen-like habitats would be surveyed separately as part of a coastal or sand dune survey
- Fen woodland/carr such as alder swamp with a closed canopy in a fen situation; however, scattered or invading scrub on fen is included
- Mono-dominant stands of *Cladium* swamp (FS1 under Fossitt, 2000) that are not in contact with another Annex I fen habitat (see section 2.3.2). If this type of habitat occurs within a fen site, it will be mapped as FS1 but no relevé data will be recorded, and it will not be assessed or mapped as 7210 habitat

6.7 Site Survey

There are five main parts to the site survey:

1. Habitat and drain mapping
2. Relevé and assessment stop recording
3. Water data recording
4. Waypoint recording
5. Completion of site pack front sheet

6.7.1 Habitat and Drain Mapping

6.7.1.1 Habitat Mapping

The boundary of the area to be surveyed and the pre-digitised polygon framework (see section 6.3) will be printed on the surveyors' field maps. Fieldworkers should navigate in the field relative to the pre-digitised polygon framework and record habitat data for each polygon, even non-fen habitats.

Polygons are surveyed by walking a zigzag transect through them. The aim is to visit each polygon and record its habitat(s), according to both Fossitt and Annex I habitat classification, by assigning a percentage cover to each habitat. Habitat data should be recorded in an Excel spreadsheet on the hand-held device, one row per polygon, using its unique polygon number as identifier (see example in Table 15).

Despite each polygon in the framework appearing homogeneous on the computer screen, it should be noted that the reality on the ground is frequently more complex, and habitat mosaics are common.

A cover score should be recorded for every habitat in the polygon to the nearest 5% except for covers less than 10%; these should be recorded as 7%, 5%, 3%, 1%, 0.7%, 0.5%, 0.3% or 0.1%. After each polygon is surveyed, the cover scores should be added up to ensure that they total exactly 100% in each classification system; *i.e.,* covers of all Fossitt habitats

recorded in a polygon should add up to 100%, and all Annex I and non-Annex I habitats together add up to 100%. This method allows the consistent recording of habitats that occur as small patches, even if they are below the minimum mapping area of 400 m^2.

Based on observations in the field, polygon boundaries can be amended on the field map by splitting (*e.g.,* a polygon consists of two different blocks of habitat, easily mapped separately), merging with adjacent polygons (*e.g.,* habitat of two polygons is the same), or moving part of one polygon to an adjacent polygon (*i.e.,* the habitat of part of one polygon is the same as the adjacent polygon); see Figure 2. Where new polygons are created by splitting existing polygons, they should be relabelled by suffixing A, B, C, *etc.*, to the original polygon number rather than labelling with a new number.

Hence, if polygon 15 is split in two, the two new polygons are labelled 15A and 15B on the map and recorded as such on the Excel recording sheet. If two or more whole polygons are merged, then the new polygon takes the lowest number of the merged polygons; such merges should be marked on the paper maps with double-headed arrows. Single-headed arrows are used to indicate where part of a one polygon is being moved to an adjacent one. Surveyors should make amendments clearly on their own paper maps in the field. These can then be referred to after fieldwork when amending the GIS polygon data layer digitally. On some hand-held devices, these amendments can be made in the field, but it is often more efficient and more accurate to leave this task until later.

While traversing the site during habitat mapping, surveyors should also look out for the following:

- Impacts and activities that positively or negatively affect the Annex I fen habitats: this information is required for the *Future prospects* assessment. Photographs should be taken and a waypoint recorded in the waypoint shapefile on the hand-held device
- Springs: all springs and up-wellings, including non-Annex I instances, should be waypointed, photographed and a target note recorded. There is no requirement to record relevés in springs
- Signs of nutrient enrichment: these may include slime or algae on trees, woody shrubs or soil. Where there is significant algal cover, a target note and photograph should be taken

Table 15 Sample of completed polygon habitat spreadsheet.

Fen ID	Poly ID	Notes	Total Fossitt	Total Annex	PF 1	PF 2	PF 3	FS1	GS4	7140	7210	7230	6410	Non-Annex
1001	1		100	100		75		25						100
1001	2a		100	100	65			35			100			
1001	2b		100	100	50		50			50		50		
1001	3	Merged with poly 4	100	100					100					100
1001	4	Merged with poly 3												
1001	5	SE corner moved to poly 6	100	100	100							50	50	

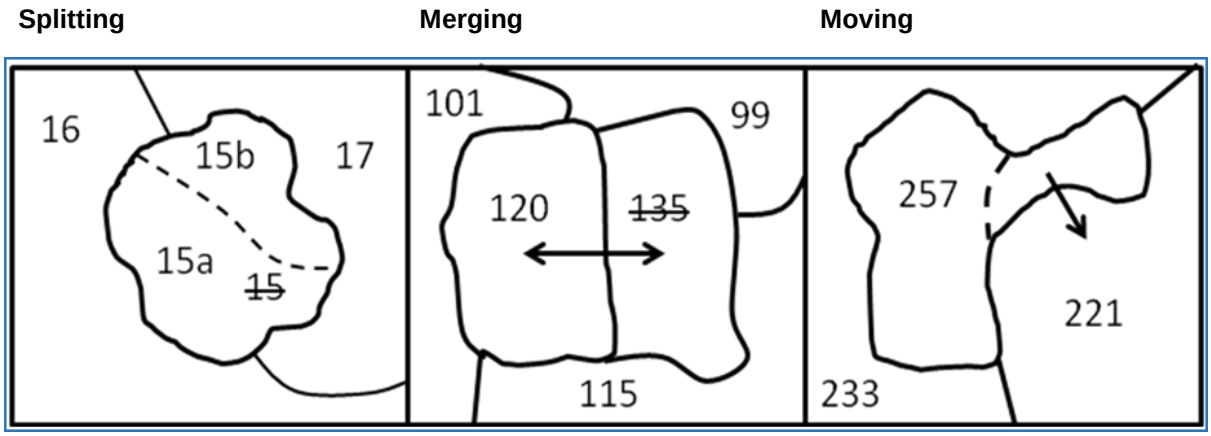

Figure 2 Recommended annotations for amendment of polygon boundaries in the field. From Perrin *et al*. (2014).

6.7.1.2 Drain Mapping

The main drainage features, both natural and anthropogenic, should be mapped within and adjacent to each site. All drains visible on aerial photographs will have been digitised prior to the survey, printed on the surveyors' maps, and the drains shapefile copied on to the hand-held recording device. These features should be verified in the field and corrected or added to as necessary. Where an extensive drain network is present, it may not be possible to walk the entire network, so the main focus should be on the larger drains. After the survey is complete, the drainage features shapefile should be updated based on the field notes. Target notes

should be recorded to characterise the drainage feature (*e.g.,* width, depth, infilling or open, substrate exposure), photographs should be taken and map annotations made as necessary. Water data should also be recorded at a selection of drains (see section 6.7.3).

6.7.2 Relevé / Assessment Stop Recording

A number of assessment stops should be made at which data are recorded for the habitat assessment for habitats 7140, 7210 and 7230 (see section 6.10.2). Table 16 shows the recommended number of assessment stops to be recorded in each Annex I fen habitat as area increases. The assessment criteria for each of the three Annex I fen habitats are given in Appendix 3. Relevés (full list of vascular and bryophyte species, and percentage cover occupied by each) should be recorded at each assessment stop if time permits. Where time does not permit, assessment data may be recorded with no associated relevé. However, at least one relevé should be recorded in each different fen vegetation community identified within a site (this does not include swamps and springs). Relevés without assessment stops should be recorded in non-Annex I fens (PF1 or PF2) and fen meadow (PF1) examples of habitat 6410.

Table 16 Scale for number of assessment stops to be recorded in Annex I fen habitats**.**

Area (ha)	No. of Stops
<0.5	0-1
0.5 – 1	2
>1 – 5	4
>5 – 20	6
>20 – 50	8
>50 – 100	10
>100	12

The standard plot size of 2 m × 2 m should be used for recording relevés and assessment stop data in all fen habitats for this survey, even for taller stands of 7210 *Cladium* fen where *Cladium mariscus* is abundant; see sidebar discussion of this in Box 1.

Box 1: Plot sizes

Foss & Crushell (2008a) recommended that "a relevé size of 2 m x 2 m should be used for the majority of medium or small stature fen vegetation, unless local topographic features restrict the communities to smaller areas. For taller communities, *e.g.,* those with *Phragmites* or *Cladium*, a quadrat size of 4 m x 4 m should be used". The potential difficulty with this approach is that species-poor, tall 7210 *Cladium* fen frequently occurs in a mosaic with or transitions to species-rich 7210 *Cladium fen*, 7230 Alkaline fen or other habitats. The cover of *Cladium mariscus* and vegetation species richness are strongly linked to habitat management (*e.g.,* Broads Authority, 2012; McBride *et al.*, 2011; section 2.3.2). Where the *Cladium mariscus* stands are mown or grazed, they are of smaller stature and accompanied by species-rich vegetation. This can make mapping potential *Cladium* fen transitions difficult as the boundaries may change with habitat management. If a larger relevé size (4 m × 4 m) is used for species-poor, tall *Cladium mariscus* stands and subsequent habitat management is undertaken which leads to the development of species-rich vegetation, repeat relevé surveys would need to use a 4 m × 4 m size relevé to be consistent. This is also the case in reverse where a species-rich site is not managed and *Cladium mariscus* becomes dominant. For this reason, it is recommended that 2 m × 2 m be used for all *Cladium* fen stands. The number of relevés undertaken should be increased to capture the variation present in the vegetation, rather than increasing the relevé size. This also makes all the *Cladium* fen data comparable for subsequent data analysis. Different indicator species may be needed for the different types of *Cladium* fen, as used in Wales where three *Cladium* fen 'types' are recognised: species-poor swamp, tall-herb fen/*Molinia*-*Cladium* fen meadow, and species-rich *Cladium* fen (McBride *et al.*, 2011).

When placing and recording the plots, for either relevés or assessment stops or both, the following guidelines should be followed:

- For each Annex I habitat the series of assessment stops should be positioned to proportionately encompass the variation that exists in that habitat
- When recording relevés, the aim is to represent the range of fen vegetation types on site
- Relevés are not to be recorded in non-fen habitats such as grassland, woodland or heath
- The Annex I assessment form should be completed while surveying each assessment stop, even if a full relevé has been recorded. This is because some information, such as level of scrub encroachment, will not be captured by recording relevé data alone

The procedure for recording relevés is as follows:

- Take a close-up photograph of the relevé's vegetation and a general photograph of the relevé in the context of the landscape. Note the photograph numbers or photograph the hand-held computer screen showing the relevé number, to facilitate correct labelling when back at base
- For all vascular, bryophyte and macro-lichen species, record abundance as percent cover in vertical projection in Turboveg. Any species not identified in the field should be collected, clearly labelled and subsequently identified in the laboratory
- For each relevé, record the following data in a Turboveg database, with the following as header data fields:
    - Date
    - Site code (see front sheet of the site pack)
    - Relevé number (number sequentially, 1..*n*)
    - Ecologist/s (record initials)
    - Grid reference (record in ITM projection)

- Fossitt habitat (in most cases this will be PF1, PF2 or PF3)
- Annex I habitat (use 'No' if non-Annex I)
- Substrate depth (the depth in cm of peat/soft sediment determined using a peat probe of at least 300 cm)
- Substrate stability (see Box 2)
- Slope (in degrees)
- Aspect (N, SE, *etc*.)
- % surface water (should be scored at 100% if relevé is fully inundated, even if emergent vegetation accounts for some of this cover; but scores less than 100% if hummocks of vegetation and soil are above the surface of the water)
- % bare soil
- % bare rock
- % total vegetation (includes bryophytes and vascular plants)
- % algal cover
- Vegetation height 1-4 (*i.e.,* four separate fields); maximum height of field layer in each of the four quadrants of the plot, not trees or shrubs
- Remarks (any additional relevant information such as grazing, or if a change in substrate was encountered when probing and at what depth)

6.7.3 Water Data

Using a portable meter, pH and electrical conductivity (µS/cm) should be recorded from each relevé if sufficient standing water is present. These data should also be recorded from other waypointed locations around the sites, including the major drainage features.

Box 2: Wetness scale (adapted from Foss &and Crushell, 2008a)

Firm in this context implies not quaking or floating.

1. Firm and dry (FD): water table not at surface on day of survey and no significant flooding (standing water in plot < 25%)
2. Firm and wet (FW): water collects around boots if you stand still and no significant flooding
3. Firm and flooded (FF): > 25% of the plot covered in standing water
4. Quaking (Q): Quaking surface but able to support weight of surveyor
5. Floating (FL): Surface assessed that it would not be able to support weight of surveyor

6.7.4 Target Notes

Target notes, recorded as waypoints using customised forms on the hand-held device, should be taken for specific habitats and species of note, other features of interest and any activities (beneficial or otherwise) in Annex I habitats. At least 10 waypoints should be recorded from across each site in addition to those recorded at springs and drainage features. Photographs should be taken to accompany target notes wherever possible. Target notes will be included in site reports to provide additional information.

6.7.5 Completion of General Site Data Form

6.7.5.1 Negative and Positive Impacts

After finishing the survey for each site, the impacts and activities – both positive and negative – occurring in each Annex I fen habitat should be recorded. Standard EU codes should be used to record the impacts, together with their intensity (high, medium or low) and effect (positive, negative or neutral). The percentage of Annex I habitat affected should also be estimated. The list of EU impact codes from DG Environment (2017) is provided in Appendix 8. Additional information not provided by the impact description should be recorded as a separate note; for example, record the species of grazing livestock for the impact *A09 Intensive grazing or overgrazing by livestock.*

6.7.5.2 Site Description

A brief site description should be written after the site has been surveyed, ideally before driving away from the site. If this is not written on the day of survey, relevant notes should be made on the field sheet at the time of survey to assist in the completion of the site description at a later date, particularly where landowners have given information on management.

The habitats on the site should be described, together with current management (if any), or constraints on access or traversing the site. Other points of note could include rare or unusual species of flora or fauna seen during the survey.

6.7.5.3 Indicators of Nutrient Enrichment

A note should be made on the site pack if signs of nutrient enrichment, such as algal deposition, were observed. A tick-box on the front of the site pack is useful to easily pick out affected sites; additional information can be included in the site description.

6.7.5.4 General Site Information

WETMECs operating at the site should be described as far as possible. It is acknowledged that this may not be possible if underlying hydrological processes or water sources are unknown; however, aerial imagery, six-inch maps and Geological Survey Ireland spatial data can provide additional information on hydrology. This task may be best carried out beforehand in the office, where these GIS layers are to hand.

6.8 Data Management

6.8.1 Photographs

- Photographs provide a valuable record of vegetation and landscape at the time of survey. Each photograph should be associated with a grid reference. Most photographs will probably be of relevés and their context in the landscape, so they will always have a grid reference recorded. For other photographs, a waypoint should be taken, and the details noted on the waypoint shapefile or paper form.
- Ensure the date and time of your camera is correct as these details assist when compiling the image catalogue for photographs
- Photographs should be relabelled as soon as possible, preferably on the same day as the survey
- Photograph names should be according to the following template:

For relevé photos (including context photos taken from relevés):

[Site code]_R[relevé_number]_[habitat code]_[photographer_initials],

e.g. *1001_R1_7210_FON*

1001_R2_PF2_JM

For waypointed photos:

[Site code]_WP[Waypoint_no]_[photographer_initials]

e.g. 1001_WP346_JD

Where multiple photos are taken at the same relevé or waypoint, they should be distinguished by suffixes

e.g., 1001_WP346_PP(1)

1001_WP346_PP(2)

6.8.2 Backups

Daily backups of all files updated in the field should be made on return to the field base each night. This includes shapefiles, Excel spreadsheets, photographs and Turboveg database export files. Off-site backups via email or to the cloud should also be carried out.

6.9 Post-survey Data Processing

After fieldwork, the polygon shapefile should be updated so that the digitised polygon outlines correspond to the annotated field maps. Importantly, polygon numbers must also be updated if they have changed because of a split or a merge. To prevent the creation of gaps and slivers, cut and merge type functions should be used rather than reshaping polygons.

The Excel spreadsheet containing the polygon habitat data should be checked for consistency and accuracy (*e.g.,* cover of all Fossitt habitats in a polygon should add up to 100%).

Habitat data in the Excel spreadsheet should be appended to the polygon shapefile using a join function, using the unique polygon number field as the key to join corresponding rows.

Polygon areas should be calculated in GIS and the data exported back to Excel. The area of each habitat within the polygon can then be calculated by multiplying its percentage cover by the area of the polygon. The overall coverage of a habitat within a site can thus be obtained by summing up the areas of the habitat from each polygon.

As soon as unidentified specimens collected in the field have been determined and the Turboveg database updated, all relevé data should be analysed using ERICA to determine the range of IVC communities occurring at each site.

6.10 Assessment of Annex I Habitats

Annex I habitats are assessed under four parameters of conservation status: *Range*, *Area*, *Structure and functions* and *Future prospects*. Guidance on assessment is provided by the EU (DG Environment, 2017). Evaluation of conservation status requires the separate

assessment of the four parameters. Each parameter can receive an assessment of Favourable (green), Unfavourable-Inadequate (amber) or Unfavourable-Bad (red). The individual parameter assessments are then combined, with the aid of an evaluation matrix (Table 17), to give an overall national assessment of conservation status for the habitat.

The NFS should assess three parameters for each Annex I habitat at each site: *Area*, *Structure and functions* and *Future prospects*. *Range* should be assessed separately at the national level for the next Article 17 report.

Table 17 General evaluation matrix for assessment of Conservation Status (CS) (adapted from DG Environment, 2016).

Parameter	Conservation Status			
	Favourable ('green')	**Unfavourable – Inadequate ('amber')**	**Unfavourable - Bad ('red')**	***Unknown***
Range	Stable or increasing AND not smaller than the 'favourable reference range'	Any other combination	>1% decline in range per year over specified period OR More than 10% below 'favourable reference range'	*No or insufficient reliable information available*
Area	Stable or increasing AND not smaller than the 'favourable reference area' AND without significant changes in distribution pattern within range (if data available)	Any other combination	>1% decline in area per year over specified period OR With major losses in distribution pattern within range OR More than 10% below 'favourable reference area'	*No or insufficient reliable information available*
Structure and Functions	Structure and functions in good condition and no significant deteriorations / pressures	Any other combination	> 25% of the area is unfavourable as regards its specific structures and functions	*No or insufficient reliable information available*
Future Prospects	The habitat's prospects for its future are excellent / good, no significant impact from threats expected; long-term viability assured	Any other combination	The habitat's prospects are bad, severe impact from threats expected; long-term viability not assured.	*No or insufficient reliable information available*
Overall Assessment of CS	All 'green' OR three 'green' and one 'unknown'	One or more 'amber' but no 'red'	One or more 'red'	Two or more 'unknown' combined with green or all 'unknown'

6.10.1 Area (Extent)

Area is assessed by mapping the current extent of a habitat and comparing it with that mapped in previous surveys (if available), or visible on earlier aerial photographs or satellite imagery.

For example, an earlier aerial photograph series could be examined to detect if an area currently mapped as improved agricultural grassland was formerly fen habitat.

Losses in habitat should be quantified by comparing the current mapping with previous mapping or aerial imagery and digitising the area lost. Area loss is expressed as annual percentage loss of the original (pre-loss) area, and is calculated as follows:

[(Area lost / (Current area + Area lost)) × 100] / Interval of years between compared maps/imagery

The most accurate results are obtained if there is good baseline mapping available for comparison with the latest survey. If no previous habitat mapping is available for comparison, aerial photograph interpretation must be used to compare areas across different years. It should be noted that, by this means, only gross changes in habitat will be detected, such as soil exposure through excavation; gradual change due to succession, such as a change from fen to rank wet grassland (*e.g.,* due to drainage), will be more difficult to detect and may be overlooked.

6.10.2 Structure and Functions

To assess the *Structure and functions* of each Annex I fen habitat at the surveyed sites, the survey methodology follows what has now become standard practice in Ireland in using assessment stops (also called monitoring stops or monitoring plots). *Structure and functions* are assessed by means of several criteria (devised by each EU Member State to assess the habitat according to local conditions) that examine key attributes of the habitat and compare the current values with set benchmarks or thresholds that reflect the habitat when it is in Favourable condition.

Structure and functions assessment data are recorded at assessment stops. The criteria used to assess the condition of the three Annex I fen habitats are given in Appendix 3. The criteria for habitat 7210 presented in Barron *et al.* (2014) have been amended to reflect the proposed new definition, and criteria for habitats 7140 and 7230 from Perrin *et al*. (2014a).

The criteria are examined and assessed at a monitoring stop, which focuses on a plot of fixed size delimited on the ground using a measuring tape or quadrat square. The dimensions of the plot and the number of monitoring stops recorded vary depending on the type and extent of the habitat. However, for fens, the guidance in section 6.7.2 should be followed. Some criteria require examination of conditions in the local vicinity, within approximately 20 m of the assessment stop.

All criteria must normally pass for a stop to pass. Marginal fails may be examined and a decision can be made using expert judgement as to whether or not the stop should fail. As a general rule, discretionary passes should only be granted where one criterion is failing. If two or more criteria are failing, even marginally, the stop should fail the assessment.

6.10.3 Future Prospects

EU guidance states that a habitat's *Future prospects* parameter…

"…should be evaluated by individually assessing the expected future trends and subsequently future prospects of each of the other three parameters [*Range, Area* and *Structure and functions*], taking primarily into account the current conservation status of the parameter, threats (related to the parameter assessed) and the conservation measures being taken or planned for the future. Once the future prospects of each of the other three parameters have been evaluated, they should be combined to give the overall assessment of *Future prospects*" (DG Environment, 2017).

At a site level, the *Future prospects* assessment of an Annex I fen habitat requires an examination of the habitat's stability in terms of two parameters, *Area* and *Structure and functions*, in the context of the impacts and activities taking place in that Annex I habitat across the site. The balance between positive measures (beneficial management practices) and negative impacts (current pressures, future threats) is weighed up and the future prospects of the habitat at that site over the next two reporting periods (12 years) are evaluated. Guidance provided by the EU (DG Environment, 2017) should be followed to determine the future trends and then the future prospects of each parameter (see Tables 18 and 19).

Table 18 Assessing the future prospects of a parameter (Steps 1 and 2) (reproduced from DG Environment, 2017).

Step 1 Future Trends of Parameters			**Step 2 Future Prospects of a Parameter**	
Balance between threats and measures	Predicted future trend reflects balance between threats and measures	Current conservation status of parameter	Resulting future prospects of parameter (over next 12 years)	
Balance between threats acting on the parameter (mostly threats with insignificant impact and/or Medium impact threats) and conservation measures; no real change in status of the parameter expected	Overall Stable	Favourable	Good	
		Unfavourable-Inadequate	Poor	
		Unfavourable-Bad	Bad	
		Unknown	Unknown	
Threats expected to have negative influence on the status of the parameter (mostly High or Medium impact threats), irrespective of measures taken	Negative / Very Negative	Favourable	Poor (Negative)	Bad (Very Negative)
		Unfavourable-Inadequate	Poor (Negative)	Bad (Very Negative)
		Unfavourable-Bad	Bad	
		Unknown	Poor (Negative)	Bad (Very Negative)
None (or only threats with insignificant impact) and/or effective measures taken: positive influence on the status of the parameter expected	Positive / Very Positive	Favourable	Good	
		Unfavourable-Inadequate	Poor (Positive)	Good (Very Positive)
		Unfavourable-Bad	Poor (Positive)	Good (Very Positive)
		Unknown	Poor (Positive)	Good (Very Positive)
Threats and/or measures taken unknown or interaction not possible to predict	Unknown	Favourable	Unknown	
		Unfavourable-Inadequate		
		Unfavourable-Bad		
		Unknown		

Table 19 Combining the evaluation of parameters to give *Future prospects* for a habitat (reproduced from DG Environment, 2017). Note that only *Area* and *Structure and functions* are relevant for assessment at the site level.

Assessment of Future Prospects	Favourable	Unfavourable-Inadequate	Unfavourable-bad	Unknown
Prospects of parameter: *Range, Area* and *Structure and functions*	All parameters have 'good' prospects OR prospects of one parameter 'unknown', the other prospects' good'	Other combination	One or more parameters have 'bad' prospects	Two or more 'unknown' and no parameter with 'bad' prospects

For any Annex I habitat to be assessed as having Favourable *Future prospects*, its prospects must be judged to be good, with no severe impacts expected from threats, and the habitat is expected to be stable or improving in the long term. For it to be assessed with Unfavourable-Bad *Future prospects*, its prospects must be judged to be bad, with severe impacts expected from threats, and the habitat is expected to decline or disappear in the long term. An assessment of Unfavourable-Inadequate *Future prospects* is between these two extremes.

To help evaluate *Future prospects* according to the above guidance, the pressures, threats and positive activities occurring on each site should be recorded according to the 2017 impact codes available from DG Environment and reproduced in full in Appendix 8. The magnitude of the impact (high, medium or low), influence (positive, negative or neutral) and percentage area of habitat affected should also be noted. This can help to gain an overall understanding of how the positive activities and negative pressures balance out across the site.

6.10.4 Overall Conservation Assessment

The overall conservation status assessment for the habitat at each site is evaluated based on the results of all three parameters, according to the evaluation matrix in Table 17 and using the guidance provided by the EU (DG Environment, 2017).

6.11 Conservation Scoring System for Fen Sites

Conservation of habitats is often best achieved on a site-by-site basis, with specific management plans based on the individual characteristics of a given habitat at a particular site, *e.g.,* management, history, rarity (O'Neill *et al*., 2013). Nevertheless, it can also be useful to be able to evaluate sites in the context of others, with well-known sites serving as yardsticks to gauge the value of previously little-known sites. Management resources can then be focused on the more valuable sites.

A site evaluation system for the NFS with 15 criteria was proposed by Foss & Crushell (2008a), with most of the criteria taken from the ASI (Area of Scientific Interest) evaluation guidelines of Lockhart *et al*. (1993), who in turn had drawn directly on the UK criteria of Ratcliffe (1977):

- Naturalness
- Non-recreatability
- Potential value
- Typicality
- Educational value
- Size
- Diversity
- Fen value
- Rarity of species
- Rarity of habitats
- Viability
- Recorded history
- Management needs
- Intrinsic appeal
- Expert opinion

As summarised by Smith *et al*. (2011), naturalness, size and diversity were generally considered by Lockhart *et al*. (1993) to be the more important criteria for most habitats, with rarity of species also being of overriding importance in many cases. However, these 1993 guidelines pre-dated the EU Habitats Directive coming into force in Ireland and, arguably, an appreciation of the broader ecological importance of habitats; rarity of habitats would now be regarded as of high importance.

The scoring system detailed in Table 20 can be used to quantify the conservation value of each fen site surveyed by the NFS and will permit the comparison and ranking of sites. Similar scoring systems have been used by the National Survey of Native Woodland (Perrin *et al*., 2008) and the Irish Semi-natural Grasslands Survey (O'Neill *et al*., 2013) and these were of influence in the development of the present system. Criteria have been selected which (i) minimise double-scoring any aspects of conservation value, (ii) can be more objectively and therefore consistently assessed, and (iii) place greater weighting on size, diversity, rarity and naturalness. The system has been tested using the seven sites in the PFS (see section 7.3). With the much larger sample size that would be produced by the NFS, it is entirely possible that deficiencies may become apparent, in which case the scoring and weighting will need to be adjusted.

Foss & Crushell (2008a) proposed that total site evaluation scores be used to assign to each site a conservation status: international value, national value, county value, high local value, moderate local value or low local value. While providing an informative status for each site is a good idea, the difficulty with assigning status in this fashion is that there are other obvious measures of what constitutes internationally or nationally important sites (for example designation as an SAC or National Park) and these will not necessarily be consistent with the status derived from a scoring system. Furthermore, what constitutes a site of 'county value', should no doubt differ depending upon the county in question, especially given the uneven distribution of fens sites across Ireland. Sites with moderate scores may be the best sites in some counties and among the worse in others. It is therefore proposed that sites be independently assessed by the NFS using the widely used qualitative guidelines in the National Roads Authority (NRA) (2009) publication as being of international importance, national importance, county importance, local importance (high value) or local importance (low value).

Table 20 Criteria to be used in the calculation of the conservation score for each fen site.

Criterion		Scoring		Maximum Score
1.	Area (ha) of Fen Habitats	Based on the total area in hectares (*x*) of fen habitats (Fossitt code PF but also FS1 where it corresponds with habitat 7210) within the site.		12 points
		0.5 ≤ *x* < 5 = 1 point	40 ≤ *x* < 80 = 6 points	
		5 ≤ *x* < 10 = 2 points	80 ≤ *x* < 160 = 9 points	
		10 ≤ *x* < 20 = 3 points	x ≥ 160 = 12 points	
		20 ≤ *x* < 40 = 4 points		
2.	Rarity of Habitats	Based on number of Annex I habitats present on the site. 3 points per habitat for representative examples of habitats 7140, 7120 or 7230 1 point per habitat for representative examples of up to three other Annex I habitats.		12 points
3.	Rarity of Plant Species	Based on number of plant species observed during the survey that are listed on the Flora (Protection) Order, 2015 and/or are assessed as Vulnerable, Endangered, Critically Endangered or Extinct by Lockhart *et al*. (2012) or by Wyse Jackson *et al*. (2016). 3 points for each species up to a maximum of 3 species.		9 points
4.	Hydrological Naturalness	Based on the naturalness of the hydrology and hydrochemistry of the fen system. Lack of naturalness could manifest as presence of artificial systems or drainage channels, manipulation of water levels, water extraction operations, evidence of eutrophication, *etc.* Artificially-created systems = 0 points Heavily-modified systems = 3 points Systems with minor modifications = 6 points Near natural systems = 9 points		9 points
5.	Landscape Diversity	Based on number of non-fen semi-natural habitat groups (determined by Fossitt code) within the site or adjacent to the site. GS/GM Semi-natural grassland or marsh = 0.5 points FL1-6/FW1-2 Natural lakes, ponds or watercourses = 0.5 points FS Swamp (not including Annex I habitat 7210) = 0.5 points FP Springs (not including Annex I habitat 7220) = 0.5 points WS/WL Woodland or scrub = 0.5 points HH/PB1-3 Heath or intact bog = 0.5 points		3 points
6.	Restoration Requirements	Based on the degree of intervention required to maintain/restore the ecological value of the site. Interventions could comprise changes in grazing regimes, drain blocking, improvement in water quality, removal of trees or invasive species, *etc.* Site requires large-scale active restoration works coupled with significant changes in the management regime = 0 points		2 points

Criterion		Scoring	Maximum Score
		Site requires small-scale active restoration works coupled with some changes in the management regime = 1 point Site requires no active restoration works and minor or no changes to the management regime = 2 points	
7.	Non-recreatability	Based on the difficulty of replacing or simulating the fen system within a site. All fens are dependent on specific hydrological conditions, so few sites should be deemed to be easy to recreate. Easy to moderately hard to recreate in the short to medium term = 0 points Difficult to recreate in the short to medium term = 1 point Near impossible to recreate in the short to medium term = 2 points	2 points
8.	Recorded History	Based on access to previously recorded information on the ecology, conservation or management of fens at a site, which in combination with newly gathered data can be used to elucidate ecological processes and consequences of management. Information must be of sufficiently high quality. Suitable information unavailable = 0 points Suitable information available = 1 point	1 point
9.	Educational Value	Based on the current suitability of a site for educational purposes. Factors to consider include location, parking, access, ownership and, due to both the treacherous and fragile nature of most fens, the presence of, or feasibility of constructing, boardwalks and viewing platforms. Sites should support good examples of fen habitats or important populations of fen species, or demonstrate ecological processes or restoration techniques. Site unsuitable for educational purposes = 0 points Site suitable for educational purposes = 1 points	1 point
Total			**52 points**

Part III: The Pilot Fen Survey 2019-2020

7 Methods

The proposed methodology described in section 6 for the NFS was generally followed for the Pilot Fen Survey (PFS). Any deviations from that methodology are set out in this section.

7.1 Site Selection

Sites were selected by NPWS. Table 21 lists the sites and the features of interests for which they were selected.

Table 21 Name, area and features of interest of the seven sites surveyed during the Pilot Fen Survey 2019-2020.

PFS Code	Site Name	SAC Code	County	Area (ha)	Features
1001	Pollardstown Fen SAC	000396	Kildare	34.29	7210 Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae 7230 Alkaline fens
1002	Scragh Bog SAC	000692	Westmeath	26.46	7140 Transition mires and quaking bogs 7230 Alkaline fens
1003	Fin Lough (Offaly) SAC	000576	Offaly	77.20	7230 Alkaline fens
1004	Lough Garr NHA	001812	Westmeath	18.14	7140 Transition mires and quaking bogs
1005	Lough Owel SAC	000688	Westmeath	101.68	7140 Transition mires and quaking bogs 7230 Alkaline fens
2001	Liskeenan Fen SAC	001683	Tipperary	43.68	7210 Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae
3001	River Moy SAC	002298	Mayo	374.26	7230 Alkaline fens

7.2 Survey Equipment

The recommended survey equipment was carried on all site visits. The site pack consisted of a colour map overlaid with the pre-digitised polygon network. A front sheet (Appendix 9) was included for recording data such as impacts and activities for the *Future prospects* assessment, the site description, presence of signs of nutrient enrichment, including nitrogen deposition, and the dates on which the site was surveyed.

7.3 Site Survey

7.3.1 Ecometrics Relevé Recording

For the two pilot sites surveyed in 2019 (Scragh Bog and parts of Pollardstown Fen), the project had an additional task. At each site the Trinity College Dublin (TCD) Ecometrics project had established a series of piezometers. It was a requirement of the contract that a relevé was recorded in close proximity to each of these piezometers. There were 15 such locations at Scragh Bog and 12 at Pollardstown Fen. At one of the Scragh Bog locations two relevés were recorded, one in a drain next to the piezometer and one adjacent to the drain. Therefore, in total 28 relevés were recorded for this task. These relevés sampled not only fen habitat but also bog woodland, scrub, marsh, grassland, swamp and ditches. No assessments were conducted at any of these relevés. Data from these relevés are included in a separate Turboveg database.

7.3.2 Water Data

The water chemistry of the fen sites (pH and electrical conductivity) was sampled using a Hanna Instruments Waterproof Tester (HI98129). The probes were calibrated following the manufacturer's directions using the official calibration solutions (HI7031, HI70004 and HI70007) prior to the field survey.

In 2019, water data were collected from locations close to each of the piezometers, from drainage features and from the general location of relevés/stops on a visit subsequent to their recording. In 2020, water data were collected from relevés simultaneously with their recording, where surface water occurred. A small number of drains were also sampled in 2020.

7.3.3 Target Notes / Waypoints

Target notes / waypoints were not recorded in 2019. In 2020, target notes were recorded mostly from drains, or from locations of rare/scarce plants such as *Pyrola rotundifolia*. Unusual communities were occasionally waypointed.

7.3.4 Completion of General Site Data Form

The general site data form was expanded in 2020 to include other topics such as nutrient enrichment.

7.4 Assessment of Annex I Habitats

To assist with assessment of the *Area* parameter, notes were taken in the field of any recent (<6 years) losses in habitat evident during the survey. Google Earth time-series images were also consulted in the office to view the habitats over a number of different years, to see if other changes had taken place prior to the survey that might indicate loss of fen habitat. The earliest dates in the series that could be checked varied by location and are listed in Table 22.

The *Structure and functions* and *Future prospects* parameters were assessed as in the proposed NFS methodology.

Table 22 Earliest Google Earth imagery available for Area change investigations

Site Name	Earliest Imagery
Pollardstown Fen	18/04/2009
Scragh Bog	20/11/2005
Fin Lough	02/04/2013
Lough Garr	18/04/2014
Lough Owel	20/11/2005
Liskeenan Fen	01/03/2010
River Moy:	20/02/2006

8 Results

8.1 Annex I Fen Habitats Recorded

8.1.1 Extent

Seven sites were surveyed in the PFS 2019-20. Two sites were surveyed in 2019 and five sites were surveyed in 2020. Site reports for each of these sites are presented as separate documents. A selection of field photographs is presented in Appendix 10. Survey dates are given in Table 23, together with the area in hectares surveyed at each site, the total area of Annex I fen that was recorded, and the percentage of the total area in each site that was made up of Annex I fen.

Table 23 Area in hectares surveyed in each of the seven pilot fen sites, the area of Annex I fen recorded, and the percentage of the area surveyed that was Annex I fen habitat.

PFS Code	Site Name	Survey Date	Total Area Surveyed (ha)	Area Of Annex I Fen (ha)	% Annex I Fen in Area Surveyed
1001	Pollardstown Fen	20-21/08 and 05/09/2019	34.17	22.80	66.7
1002	Scragh Bog	02-04/09 and 06/09/2019	26.77	11.38	42.5
1003	Fin Lough	15-17/06/2020	77.30	15.27	19.8
1004	Lough Garr	26-27/05/2020	18.14	14.35	79.1
1005	Lough Owel	28/05, 10/06 and 12/06/2020	104.19	3.50	3.4
2001	Liskeenan Fen	15-16/07/2020	43.68	8.50	19.5
3001	River Moy	21-24/07/2020	374.40	183.08	48.9
	Total		**678.65**	258.88	38.2

It can be seen that the sites varied with regard to the proportion of fen habitat at each of them. For example, a subset of Lough Owel SAC was selected for survey, focusing on areas most likely to contain fen habitat; but although over 100 ha were surveyed, only 3.5% of this was found to contain Annex I fen, most of the remainder being fen carr (largely Annex I habitat 91E0 Alluvial woodlands).

In contrast, a subset of Lough Garr NHA was selected for survey, covering the area of Lough Garr itself, an infilling lake. Of this, the majority (79.1%) was found to be fen habitat, with the remainder mainly fen carr and raised bog (Annex I habitat 7110 Active raised bogs).

A subset of the large River Moy SAC was selected for survey, in the areas around the former Mannin Lake (the larger area to the north-west) and Island Lake (smaller area to the south-east). The cutover bog between the two former lakes was not included in the survey. The area surveyed covered 374 ha, and almost half of it (49%) was found to be Annex I fen. Therefore, this site represents the largest area of fen habitat surveyed during the PFS. Much of the area not mapped as fen was wet grassland.

A subset of Pollardstown Fen SAC was surveyed, with 66.7% of the area surveyed being Annex I fen. Most of the remainder was rank wet grassland, with pockets also of scrub, wet

woodland and reed swamp. A small area of the Annex I grassland habitat 6410 *Molinia* meadows was recorded in the northern section.

The whole of Scragh Bog SAC was surveyed and 42.5% was found to be Annex I fen. The remainder was mostly non-Annex I wet woodland, with reed swamp also present towards the north-west.

Fin Lough and Liskeenan Fen SACs were also surveyed in their entirety. However, both had relatively low proportions of Annex I fen habitat present, with less than 20% of their areas found to be Annex I fen. In Fin Lough, most of the habitat was either reed swamp or wet heath (Annex I habitat 4010 Wet heaths). At Liskeenan Fen there were large areas of non-Annex I woodland, reed swamp and wet grassland, with the fen habitat mostly concentrated in the centre-west of the site.

8.1.2 Proportion

Overall, habitat 7230 was the most abundant fen habitat recorded (Figure 3). However, this was because the largest site surveyed (River Moy SAC), had a high proportion of 7230.

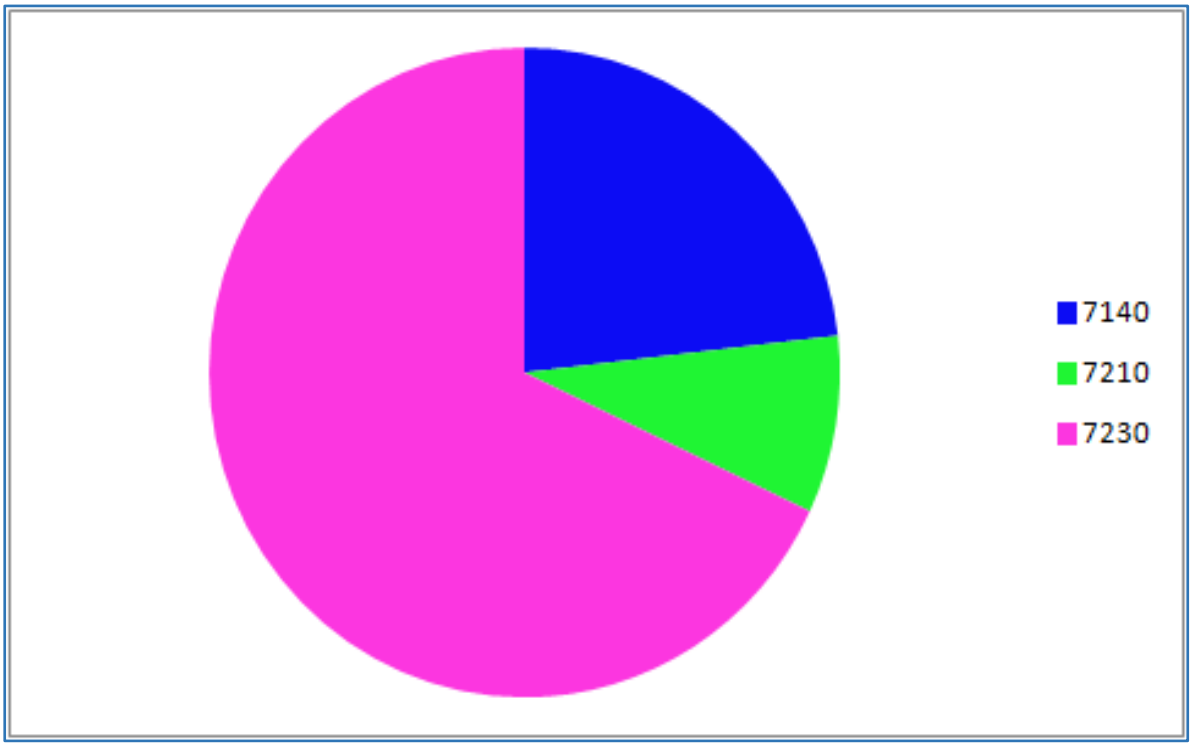

Figure 3 Proportion of each Annex I fen habitat recorded in the Pilot Fen Survey 2019-20.

When the breakdown of fen habitat is examined on a site-by-site basis (Table 24), it can be seen that the sites varied in terms of which was the most abundant fen habitat present. Note that the following discussion relates to 7140, 7210 and 7230 habitat as a proportion of the total area of Annex I fen habitat; non-Annex fen and non-fen habitats are excluded from this analysis.

Pollardstown Fen had a high proportion of 7210 habitat but no 7140, whereas Scragh Bog, Fin Lough and Lough Garr all had high proportions of 7140, with 7210 almost or completely absent. Liskeenan Fen, like Pollardstown Fen, had a high proportion of 7210 habitat. In both cases, the main type of 7210 habitat recorded was the closed stand type, with both sites featuring large swathes of *Cladium* swamp which were contiguous with small-sedge fen

habitats. The section of the River Moy SAC surveyed had a very high proportion of 7230 habitat but a significantly lower proportion of 7140 and virtually no 7210 habitat.

Table 24 Breakdown of area (in hectares) of Annex I fen habitats across the seven pilot fen sites, and overall.

PFS code	Site name	7140	7210	7230	Total Area of Fen in Site
1001	Pollardstown Fen	-	17.00	5.80	22.80
1002	Scragh Bog	9.62	0.26	1.50	11.38
1003	Fin Lough	13.82	-	1.44	15.27
1004	Lough Garr	14.35	-	-	14.35
1005	Lough Owel	1.31	0.01	2.18	3.50
2001	Liskeenan Fen	0.39	5.29	2.82	8.50
3001	River Moy	20.52	0.07	162.50	183.08
	Overall Total	**60.01**	**22.62**	**176.25**	**258.88**

8.1.2.1 7140 Transition Mire and Quaking Bogs

Table 25 shows the area of 7140 recorded in the pilot fen sites in 2019-2020, and the proportion that this made up of the Annex I fen habitat recorded on site.

Table 25 Area (in hectares) of 7140 habitat and Annex I fen recorded on the seven pilot fen sites, and the percentage of Annex I fen habitat that is 7140.

PFS code	Site Name	Area of 7140 (ha)	Area of Annex I Fen (ha)	% of Annex I Fen 7140
1001	Pollardstown Fen	-	22.80	-
1002	Scragh Bog	9.62	11.38	84.5
1003	Fin Lough	13.82	15.27	90.5
1004	Lough Garr	14.35	14.35	100.0
1005	Lough Owel	1.31	3.50	37.4
2001	Liskeenan Fen	0.39	8.50	4.6
3001	River Moy	20.52	183.08	11.2
	Total	**60.01**	**258.88**	**23.2**

7140 was recorded at six of the seven sites. No 7140 habitat was recorded at Pollardstown Fen. The largest area of 7140 habitat was recorded in the River Moy SAC, with 20.8 ha recorded. This was a particularly large site (see Table 23), and although the area was large compared to the other sites, the proportion was relatively low, with only 11.2% of the Annex I fen habitat recorded at this site being 7140.

The highest proportion of 7140 habitat was found at Lough Garr, where all of the Annex I fen habitat recorded was 7140. Fin Lough and Scragh Bog also had a high proportion of 7140 habitat (90.5% and 84.5% respectively), Lough Owel had a medium proportion (37.4%), whereas Liskeenan Fen had a very low proportion of 7140, only 4.6% of the Annex I fen recorded at the site.

8.1.2.2 7210 *Cladium* Fens

Table 26 shows the area of 7210 recorded in the pilot fen sites in 2019-2020, and the proportion that this made up of the Annex I fen habitat recorded on site.

Table 26 Area of 7210 habitat and Annex I fen recorded on the seven pilot fen sites, and the percentage of Annex I fen habitat that is 7210.

PFS Code	Site Name	Area of 7210 (ha)	Area of Annex I fen (ha)	% of Annex I fen 7210
1001	Pollardstown Fen	17.00	22.80	74.6
1002	Scragh Bog	0.26	11.38	2.3
1003	Fin Lough	-	15.27	-
1004	Lough Garr	-	14.35	-
1005	Lough Owel	0.01	3.50	0.3
2001	Liskeenan Fen	5.29	8.50	62.2
3001	River Moy	-	183.08	0.04
	Total	**22.62**	**258.88**	**8.7**

As discussed in section 2.3.2, two general types of 7210 may be encountered: a more species-rich, open sward type and a less species-rich, closed sward type. Because *Cladium mariscus* can occur in large swathes, the closed sward type of the Annex I habitat can, if it is contiguous with species-rich communities, cover large areas. This was the situation in Pollardstown Fen and Liskeenan Fen, where the closed sward type was the main habitat recorded on site. Small areas of the open sward type also occurred. Apart from those two sites, however, the incidence of 7210 habitat was very low, and it was not recorded from Fin Lough, Lough Garr or the River Moy.

8.1.2.3 7230 Alkaline fens

Table 27 shows the area of 7230 recorded in the pilot fen sites in 2019-2020, and the proportion that this made up of the Annex I fen habitat recorded on site.

Table 27 Area of 7230 habitat and Annex I fen recorded at the seven pilot fen sites, and the percentage of Annex I fen habitat that is 7230.

PFS code	Site Name	Area of 7230 (ha)	Area of Annex I fen (ha)	% of fen 7230
1001	Pollardstown Fen	5.80	22.80	25.4
1002	Scragh Bog	1.50	11.38	13.2
1003	Fin Lough	1.44	15.27	9.4
1004	Lough Garr	-	14.35	-
1005	Lough Owel	2.18	3.50	62.3
2001	Liskeenan Fen	2.82	8.50	33.2
3001	River Moy	162.50	183.08	88.8
	Total	**176.25**	**258.88**	**68.1**

Alkaline fen 7230 habitat was absent from Lough Garr and was present at a relatively low level at four of the sites, ranging from 9.4% to 33.2% of the Annex I fen habitat recorded. At the River Moy site, however, 7230 was by far the most abundant of the fen habitats, making up 88.8% of the Annex I fen recorded there and covering a significant 183.1 hectares.

8.1.3 Habitats Recorded by Fossitt (2000) Category

While the focus of this study is on Annex I habitats rather than Fossitt (2000) habitats, a brief analysis of Fossitt (2000) habitats is included here as it shows the context in which fen habitats occurred in the pilot sites. Table 28 shows the breakdown of habitats by Fossitt (2000) category.

When this table is examined, it can be seen that the context of adjacent habitats varied by site. The three most abundant habitats recorded at Pollardstown Fen were FS1 Reed and large sedge swamp, GS4 Wet grassland and PF1 Rich fen and flush. In this case, although FS1 is not usually regarded as a fen habitat, it conformed to the definition of 7210 *Cladium* fen by virtue of being in contact with species-rich, small-sedge fen. The wet grassland recorded on site was mostly found to be rank, non-Annex I grassland, although a small amount of Annex I 6410 *Molinia* meadow was recorded here.

At Scragh Bog, PF3 Transition mire and quaking bog, WN7 Bog woodland and WN6 Wet willow-alder-ash woodland were the main habitats recorded. While most of this was PF3, significant areas of both woodland habitats made up the majority of the rest of the site.

The main habitat at Fin Lough was HH3 Wet heath, with the community largely comprised of *Myrica gale* and rank *Molinia caerulea*. This was followed by FS1 Reed and large sedge swamp, which covered large swathes, most of which was *Phalaris arundinacea*-dominated and none of which corresponded to the 7210 habitat. After PF3 Transition mire and quaking bog, WN6 Wet willow-alder-ash woodland was the next most abundant habitat, with small patches of *Salix cinerea* scrub / woodland occurring in the site.

Table 28 Area in hectares of all Fossitt habitats recorded during the Pilot Fen Survey 2019-2020. Habitats are listed in alphabetical order. Note that value of 0.00 denotes an area <0.005 ha, whereas '-' means the habitat was absent.

Habitat	1001	1002	1003	1004	1005	2001	3001	Total
ED2	-	0.03	-	-	-	-	0.35	0.38
ED3	-	-	-	-	-	-	0.65	0.65
FL3	-	0.02	0.14	-	2.67	-	3.46	6.29
FL6	-	-	-	-	-	0.09	-	0.09
FL8	-	-	-	-	-	-	0.01	0.01
FS1	15.26	0.26	14.04	0.26	12.82	5.51	6.40	54.54
FS2	-	2.68	1.13	0.13	0.29	-	12.91	17.14
FW2	-	0.05	-	-	-	-	2.73	2.78
FW4	-	-	0.01	-	-	-	0.00	0.01
GA1	-	-	-	-	-	-	0.66	0.66
GM1	-	-	-	-	0.52	-	4.16	4.68
GS1	0.14	-	1.38	-	-	5.93	3.66	11.11
GS2	0.02	-	-	-	-	-	12.15	12.17
GS4	8.82	0.73	0.01	-	23.14	8.34	75.03	116.07
HD1	-	-	-	-	-	-	1.42	1.42
HH3	-	-	6.32	-	8.09	6.64	9.39	50.44
PB1	0.21	-	-	1.20	-	1.62	-	3.04
PB4	-	-	2.68	-	-	-	6.69	9.37
PF1	8.15	1.50	6.30	-	4.16	3.49	85.84	209.44
PF2	-	-	-	-	-	-	-	-
PF3	-	9.62	3.82	14.35	1.31	0.39	20.52	60.01
WD1	-	-	-	-	1.61	0.02	-	1.64
WD2	-	-	-	0.00	0.00	-	-	0.01
WD3	-	-	-	-	-	2.74	-	2.74
WD4	-	2.57	-	-	-	-	-	2.57
WL1	-	-	-	-	-	-	0.03	0.03
WL2	0.44	0.05	0.01	-	0.64	0.30	0.11	1.54
WN2	-	-	-	-	-	-	2.26	2.26
WN6	0.57	3.64	6.93	1.60	48.84	1.91	3.01	66.50
WN7	-	5.42	3.80	0.60	0.07	5.84	1.20	16.94
WS1	0.58	0.20	0.73	-	0.00	0.87	21.76	24.14
Site Area	**34.17**	**26.77**	**77.30**	**18.14**	**104.19**	**43.68**	**374.40**	**678.65**

Lough Garr was almost entirely PF3 Transition mire and quaking bog, with small amounts of other habitats such as PB1 Raised bog and WN6 Wet willow-alder-ash woodland occurring in mosaic with the fen, or in small discrete patches.

The areas surveyed in Lough Owel had been selected as those most likely to contain fen. However, most of the site was found to consist of WN6 Wet willow-alder-ash woodland, particularly in the northern and south-western areas. GS4 Wet grassland and FS1 Reed and large sedge swamp were also significant habitats, and HH3 Wet heath was more abundant than PF1 and PF3.

In Liskeenan Fen, PF1 Rich fen and flush habitat ranked only in sixth place in abundance, after GS4 Wet grassland, HH3 Wet heath, GS1 Dry calcareous and neutral grassland, WN7 Bog woodland and FS1 Reed and large sedge swamp. Other modified woodland habitats were also present in the eastern half of the site.

The River Moy site was large and unsurprisingly featured the highest number of habitats of all the sites. Despite this, there were two overwhelmingly abundant habitats here: PF1 Rich fen and flush, and GS4 Wet grassland, with the remaining 22 habitats in total covering just 30%.

Also of some note is the fact that the non-fen habitats frequently occurred around the periphery of the sites, with the fen habitats usually occupying the centre of the site. This is not unexpected, given the propensity for fens to develop in hollows or lake basins, surrounded by higher land or drier habitats.

The last point to note from Table 28 is the fact that PF2 Poor fen and flush was not recorded at any of the seven pilot fen sites. All seven sites were generally neutral or highly calcareous in nature, making the occurrence of the more acidic PF2 habitat less likely

8.2 Assessment of Annex I Habitats

The assessments of the three Annex I fen habitats are discussed in turn from sections 8.2.1 to 8.2.3 below. Table 29 summarises which sites were assessed for each habitat.

Table 29 Occurrence of Annex I fen habitats at the seven pilot fen sites, and whether or not they were assessed.

PFS Code	Site Name	7140		7210		7230	
		Present	Assessed	Present	Assessed	Present	Assessed
1001	Pollardstown Fen	×	×	✓	✓	✓	✓
1002	Scragh Bog	✓	✓	✓	✓	✓	✓
1003	Fin Lough	✓	✓	×	×	✓	✓
1004	Lough Garr	✓	✓	×	×	×	×
1005	Lough Owel	✓	✓	✓	×	✓	✓
2001	Liskeenan Fen	✓	✓	✓	✓	✓	✓
3001	River Moy	✓	✓	✓	×	✓	✓

In most cases, the habitat was assessed if it was recorded on site. For 7210 habitat at Lough Owel and River Moy, however, the habitat covered only a small area and was not considered large enough to warrant an assessment.

8.2.1 7140 Transition Mires

8.2.1.1 Area

No obvious losses of 7140 habitat, such as those due to disturbance, afforestation or other recent land-use change, were noted during the field survey in any of the six sites in which it was recorded. Google Earth was viewed over several time series, to attempt to discern any other habitat changes but none were detected. Therefore, as far as can be ascertained in the absence of baseline mapping, no changes in 7140 habitat area have occurred since 2005.

As this is a baseline survey, the aim would be to determine if any habitat losses had occurred since the EU Habitats Directive came into force in 1994, with the area extant in 1994 taken to be the Favourable Reference Area (FRA). However, due to the difficulty of detecting subtle changes in fen habitats from aerial imagery, and in the absence of baseline mapping with which to compare the current extent of habitat, this was not possible to ascertain with any degree of certainty, so the current area was deemed to be the FRA.

The *Area* parameter for habitat 7140 in the six pilot fen sites in which it was recorded was therefore assessed as Favourable.

8.2.1.2 Structure and Functions

The individual assessment criteria listed in Appendix 3 were assessed at 30 assessment stops recorded at six sites. Table 30 shows the pass rates of the individual criteria, while Table 31 shows the assessment stop pass rates and *Structure and functions* assessment results for each of the six sites in which 7140 habitat was recorded.

Table 30 Pass rates of criteria used in *Structure and functions* assessments for habitat 7140. *n*=30. All criteria are investigated within the 2 m x 2 m monitoring stop unless 'local vicinity' is specified (up to 20 m from stop).

	Assessment Criterion	% Pass rate across stops
1	No. of positive indicator species (Groups i and ii)	87
2	No. of positive indicator species (Group i)	100
3	Cover of positive species	100
4	Cover of negative species	93
5	Cover of non-native species	100
6	Vegetation structure	100
7	Disturbed bare ground	100
8	Disturbed bare ground (local vicinity)	100
9	Signs of drainage (local vicinity)	100
	Pass rate for monitoring stops before expert judgement applied	**80**
	Pass rate for monitoring stops after expert judgement applied	**87**

The criteria that assessed vegetation structure, nativeness and habitat damage due to drainage and trampling were met in all cases. The criteria that were not met were related to typical species (insufficient number of typical species recorded or insufficient cover) or negative species that indicate drying out or some other impact that may not otherwise be apparent. Four stops (one each from Fin Lough, Lough Garr, Liskeenan Fen and River Moy) failed the assessment for number of positive indicator species, although some failures were

marginal and were passed on expert judgement. Two stops (one in Fin Lough and the other in River Moy), had too high a cover of negative species.

In terms of the sites' *Structure and functions* assessments, two sites (Scragh Bog and Lough Garr) received a Favourable result for 7140 habitat, three sites (Lough Owel, Liskeenan Fen and River Moy) were assessed as Unfavourable-Inadequate, and one site (Fin Lough) was assessed as Unfavourable-Bad.

Table 31 Pass rates of assessment stops and assessment result for *Structure and functions* (S&F) for the six sites in which habitat 7140 was assessed. An assessment stop fails if even one criterion is not met unless expert judgement is exercised to override marginal failures. * Discretionary pass awarded to one stop where fail was marginal and all other criteria in all other stops were met.

PFS Code	Site Name	No. of Stops	% Pass Rate (Initially)	% Pass Rate (After Expert Judgement)	S&F Assessment Result
1002	Scragh Bog	5	100	100	Favourable
1003	Fin Lough	6	67	67	Unfavourable-Bad
1004	Lough Garr	6	83	*100	Favourable
1005	Lough Owel	2	100	100	Favourable
2001	Liskeenan Fen	4	75	75	Unfavourable-Inadequate
3001	River Moy	7	71	*86	Unfavourable-Inadequate

8.2.1.3 Impacts, Activities and Future Prospects

Table 32 shows the impacts recorded in habitat 7140 in the sites in which it was assessed. Table 33 summarises these impacts (not broken down by site) according to the intensity, impact and percentage of habitat 7140 affected.

Pollution, manifested as algal deposition, was recorded at Fin Lough, Lough Garr and Lough Owel, but was of a low intensity and affected less than 1% of the habitat at each site. The source of the pollution was not always obvious, but there was one incidence of direct inflow of poor-quality water into the fen which appeared to have an agricultural or possibly domestic origin. However, the area of habitat affected was very small.

Abstraction of water for domestic purposes was recorded as an impact at Lough Owel as this lake is a water supply reservoir. There are therefore fluctuations in water level, depending on demand. The exact effect of this on the 7140 habitat is not clear but is assumed to be negative. Drainage, occurring as drainage ditches, was noted at two sites (Lough Garr and Fin Lough). In Lough Garr, the effect was deemed to be slight as the drains were long-standing and had not been recently maintained, so removal of water from the site was low. In Fin Lough, however, the ditch had been newly dug, thus having greater potential to remove significant amounts of water from the site.

Natural succession was the most frequent impact noted, being recorded in four of the six sites (Scragh Bog, Fin Lough, Lough Garr and Lough Owel). Succession to scrub or woodland was the main type recorded. It varied in the extent to which it affected the Annex I habitat, ranging from 1-5% in Scragh Bog and Fin Lough, to 90% of the habitat at Lough Garr. Flooding was recorded at three sites. The impact of this is assumed to be beneficial to the 7140 habitat but this depends to some extent on the quality of the floodwaters. Nutrient-enriched floodwaters would have a damaging effect on the habitat. Lough Owel, Liskeenan Fen and River Moy were the sites at which definite signs of flooding were seen, although it is possible that the other

sites may be intermittently flooded also. There were no indications that the floodwaters were particularly nutrient-rich, as indicators of enrichment such as algal deposition were low, at least in this habitat.

Table 32 Impacts recorded in 7140 habitat at each site in which it was recorded during the Pilot Fen Survey.

Impact Code	Impact Description	1002	1003	1004	1005	2001	3001
A26	Agricultural activities generating diffuse pollution to surface or ground waters	✓	✓	✓	✓		
H07	Intrusive research and monitoring activities	✓					
K01	Abstractions from groundwater, surface water or mixed water				✓		
K02	Drainage		✓	✓			
L02	Natural succession resulting in species composition change	✓	✓	✓			
M08	Flooding (natural)				✓	✓	✓

Table 33 Summary of impacts recorded in 7140 habitat. Frequency within categories of influence (positive, negative or neutral), intensity (high medium or low) and percentage of 7140 habitat affected are shown. Impact codes are according to DG Environment (2017).

Impact Code	Impact Description	Influence			Intensity			% Habitat Affected				
		Pos	Neu	Neg	H	M	L	<1	1-5	25	90-100	Freq
A26	Agricultural activities generating diffuse pollution to surface or ground waters		1	3		1	3	3	1			4
H07	Research and monitoring activities			1		1		1				1
K01	Abstractions from groundwater, surface water or mixed water			1			1				1	1
K02	Drainage			2	1		1	1	1			2
L02	Natural succession resulting in species composition change (scrub encroachment)		1	2		1	2		1	1	1	3
M08	Flooding (natural)	3			3						3	3

The results of the *Future prospects* assessment of 7140 are shown in Table 34. Two sites, Liskeenan Fen and River Moy, had no negative impacts recorded in the 7140 habitat, and the *Future prospects* assessment was as for the *Structure and functions* assessment, *i.e.,*

Unfavourable-Inadequate. In Fin Lough a number of negative impacts were recorded, including creation of a new drain and some scrub encroachment, but they only impacted a small area of the 7140 habitat. However, as the *Structure and functions* of 7140 at this site had been assessed as Unfavourable-Bad, the *Future prospects* assessment was also Unfavourable-Bad. In Lough Owel, the positive and negative effects from flooding and water abstraction were deemed to be in balance, and the *Future prospects* of the 7140 at the site were deemed to be Favourable.

The two other sites that received a Favourable *Structure and functions* assessment (Scragh Bog and Lough Garr), were judged by the surveyors to have issues with scrub encroachment. While the 7140 habitat otherwise appeared to be in good condition, it was considered that the continuation of such scrub encroachment could, in time, lead to shading, drying out of the habitat, or other negative impacts associated with woodland in this context. Therefore, the *Future prospects* of the 7140 habitat at Scragh Bog and Lough Garr could not be regarded as good over the next 12 years and were instead assessed as Unfavourable-Inadequate.

Table 34 *Future prospects* (FP) assessment of 7140 habitat at six sites surveyed in the Pilot Fen Survey. S&F=*Structure and functions*, Fav=Favourable, U-I=Unfavourable-Inadequate, U-B=Unfavourable-Bad.

PFS Code	Site Name	FP of Area	FP of S&F	FP of Site	Rationale
1002	Scragh Bog	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Scrub encroachment
1003	Fin Lough	Favourable	Unfavourable-Bad	Unfavourable-Bad	Unfavourable S&F (not enough positive species, high cover of negative species)
1004	Lough Garr	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Scrub encroachment
1005	Lough Owel	Favourable	Favourable	Favourable	Positive and negative impacts in balance
2001	Liskeenan Fen	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Unfavourable S and F (not enough positive species)
3001	River Moy	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Unfavourable S and F (high cover of negative species)

8.2.1.4 Overall

For the reasons outlined above, of the six sites in which the 7140 habitat was assessed, one was deemed to be in Favourable condition, four were in Unfavourable-Inadequate condition, and one was Unfavourable-Bad. The assessment results across all parameters are summarised in Table 35.

Table 35 Summary of assessment results for 7140 habitat at the six Pilot Fen Survey sites in which it was recorded.

PFS Code	Site Name	Area	Structure and Functions	Future Prospects	Overall
1002	Scragh Bog	Favourable	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate
1003	Fin Lough	Favourable	Unfavourable-Bad	Unfavourable-Bad	Unfavourable-Bad
1004	Lough Garr	Favourable	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate
1005	Lough Owel	Favourable	Favourable	Favourable	Favourable
2001	Liskeenan Fen	Favourable	Unfavourable - Inadequate	Unfavourable - Inadequate	Unfavourable - Inadequate
3001	River Moy	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Unfavourable-Inadequate

8.2.2 7210 *Cladium* Fens

8.2.2.1 Area

No obvious losses of 7210 habitat, such as those due to disturbance, afforestation or other recent land-use change, were noted during the field survey in any of the five sites in which it was recorded. Google Earth was viewed over several time series to attempt to discern any other habitat changes but none were detected. Therefore, as far as can be ascertained in the absence of baseline mapping, no changes in 7210 habitat area have occurred since 2005.

As this is a baseline survey, the aim would be to determine if any habitat losses had occurred since the EU Habitats Directive came into force in 1994, with the area extant in 1994 taken to be the Favourable Reference Area (FRA). However, due to the difficulty of detecting subtle changes in fen habitats from aerial imagery, and in the absence of baseline mapping with which to compare the current extent of habitat, this was not possible to ascertain with any degree of certainty, so the current area was deemed to be the FRA.

The *Area* parameter for habitat 7210 in the five pilot fen sites in which it was recorded was therefore assessed as Favourable.

8.2.2.2 Structure and Functions

The individual habitat 7210 assessment criteria listed in Appendix 3 were assessed at 10 monitoring plots recorded at three sites. Table 36 shows the pass rates of the individual criteria, while Table 37 shows the assessment stop pass rates and *Structure and functions* assessment results for the sites in which 7210 habitat was recorded.

Table 36 Pass rates of criteria used in *Structure and functions* assessments for habitat 7210. *n*=10. All criteria are investigated within the 2 m x 2 m monitoring stop unless 'local vicinity' is specified (up to 20 m from stop). * All stops were from dense primary stands. ** Tufa was not present at any stops.

	7210 Assessment Criterion	**% Pass Rate Across Stops**
1	*Cladium mariscus* cover	100
2	No. of positive vascular indicator species (n/a for dense primary stands)	***n/a**
3	Total cover of *Anthoxanthum odoratum, Epilobium hirsutum, Holcus lanatus* & *Ranunculus repens*	100
4	Cover of non-native species	100
5	Cover of scattered native trees and shrubs (local vicinity)	80
6	Total cover of *Juncus effusus, Typha latifolia* & *Phragmites australis*	100
7	Live shoots/leaves > 1 m high	100
8	Cover of disturbed bare ground	100
9	Cover of disturbed bare ground (local vicinity)	100
10	Area showing signs of drainage resulting from heavy trampling or tracking or ditches (local vicinity)	100
11	Disturbed vegetation (if tufa present)	**n/a
	Pass rate for monitoring stops	*100*

All stops were carried out in dense stands of *Cladium mariscus*, *i.e.,* primary stands. Therefore, the criterion requiring a certain number of positive vascular indicator species was not assessed at any stop. Similarly, tufa deposition was not noted at any stops, so disturbance of vegetation was not assessed.

Eight of the 10 stops passed on all criteria. The examples of 7210 recorded during the two years of the PFS were dense stands of *Cladium mariscus* in contact with smaller-stature fen habitats, both 7140 and 7230. Structure of the vegetation was found to be satisfactory, with little or no disturbance, apart from a minor amount of trespass from cattle in Liskeenan Fen, and cover of negative species was well below the thresholds applied. Scrub encroachment was an issue at two stops at Liskeenan Fen, mainly by *Salix cinerea* or *Alnus glutinosa*.

In terms of the *Structure and functions* assessment for the sites, Pollardstown Fen and Scragh Bog received a Favourable result for 7210 habitat. Liskeenan Fen was assessed as Unfavourable-Inadequate. The areas of 7210 habitat in Lough Owel and the River Moy were both too small for a *Structure and functions* assessment to be carried out on the habitat.

Table 37 Pass rates of assessment stops and assessment result for *Structure and functions* (S&F) for the five sites in which 7210 habitat was recorded. *n*=10. An assessment stop fails if even one criterion is not met unless expert judgement is exercised to override marginal failures.

PFS Code	Site Name	No. of Stops	% Pass Rate	S&F Assessment Result
1001	Pollardstown Fen	3	100	Favourable
1002	Scragh Bog	3	100	Favourable
1005	Lough Owel	n/a	n/a	Not assessed
2001	Liskeenan Fen	4	50	*Unfavourable-Inadequate
3001	River Moy	n/a	n/a	Not assessed

* Following a review of scrub encroachment on aerial photographs, expert judgement was used to amend the original result from Unfavourable-Bad to Unfavourable-Inadequate.

8.2.2.3 Impacts, Activities and Future prospects

Table 38 shows the impacts recorded in 7210 habitat in the three sites in which it was assessed, *i.e.,* Pollardstown Fen, Scragh Bog and Liskeenan Fen. Table 39 summarises these impacts (not broken down by site) according to the intensity, impact and percentage of 7210 habitat affected.

Abandonment of management was noted as a problem at Pollardstown Fen. Here, cessation of grazing regimes is thought to have contributed to successional changes in habitats (Maurice Eakin, pers. comm.). During the survey, approximately 10% of the total area of 7210 at Pollardstown Fen was thought to consist of secondary stands (see section 2.3.2) of *Cladium* that would benefit from management by grazing or mowing, to open up the stand and increase diversity. However, the majority of the *Cladium*-dominated stands at Pollardstown Fen, as well as those at Scragh Bog and Liskeenan Fen, are thought to be stable, primary stands, formed as a natural consequence of the site's hydrology rather than as a result of abandonment of management. A small number of grazing cattle were noted breaking out of agricultural grassland into the *Cladium* beds at Liskeenan Fen, but this was a sporadic rather than a regular occurrence, and caused neither benefit nor harm to the habitat.

Drainage was recorded as a damaging impact at Pollardstown Fen and there were signs that the fen at this site is drying out. Drainage was also recorded at Liskeenan Fen.

Flooding was recorded at Liskeenan Fen. The impact of this is assumed to be beneficial to the 7210 habitat but as noted in section 8.2.1.3, this depends to some extent on the quality of the floodwaters, as nutrient-enriched floodwaters would be damaging.

The results of the *Future prospects* assessment of 7210 at the sites is shown in Table 40. Lack of management and the issue of drainage were flagged as concerns at Pollardstown Fen, with the habitat showing signs of drying out and a lack of diversity in formerly managed and now abandoned areas. Therefore, in the absence of management practices that seek to correct the problems, the *Future prospects* parameter was assessed as Unfavourable-Inadequate. The 7210 habitat at Scragh Bog received a Favourable *Structure and functions* assessment. While some scrub encroachment was recorded, this was not deemed to be a significant impact. Therefore, the *Future prospects* parameter was assessed as Favourable for Scragh Bog. Liskeenan Fen contains large areas of 7210 habitat and for the most part this is in reasonable condition. However, scrub cover was an issue and the *Future prospects* of 7210 at Liskeenan Fen were assessed as Unfavourable-Inadequate. Lough Owel and River Moy were not assessed for 7210 as the area of the habitat was too small for assessment. Therefore, *Future prospects* could not be reliably assessed.

Table 38 Sites surveyed during the PFS in which impacts were recorded in 7210 habitat.

Impact Code	Impact Description	1001	1002	2001
A06	Abandonment of grassland management	✓		
A10	Extensive grazing or undergrazing by livestock			✓
H07	Intrusive research and monitoring activities	✓		
K02	Drainage	✓		✓
L02	Natural succession resulting in species composition change (scrub encroachment)		✓	✓
M08	Flooding (natural)			✓

Table 39 Summary of impacts recorded in 7210 habitat. Frequency within categories of influence (positive, negative or neutral), intensity (high, medium or low) and percentage of 7210 habitat affected are shown. Impact codes are according to DG Environment (2017).

Impact Code	Impact Description	Influence			Intensity			% habitat affected			
		Pos	Neu	Neg	H	M	L	1-5	10	95-100	Freq
A06	Abandonment of grassland management			1			1		1		1
A10	Extensive grazing or undergrazing by livestock		1				1	1			1
H07	Intrusive research and monitoring activities		1				1	1			1
K02	Drainage		1	1		1	1			2	2
L02	Natural succession resulting in species composition change			2			2	1	1		2
M08	Flooding (natural)	1			1					1	1

Table 40 *Future prospects* (FP) assessment of 7210 habitat at five sites surveyed in the PFS. Fav=Favourable, U-I=Unfavourable-Inadequate. n/a=Not assessed

PFS Code	Site Name	FP of Area	FP of S&F	FP of Site	Rationale
1001	Pollardstown Fen	Fav	U-I	U-I	Lack of management a problem in some areas. Drying out due to drainage may affect future prospects.
1002	Scragh Bog	Fav	Fav	Fav	No significant negative impacts were noted.
1005	Lough Owel	n/a	n/a	n/a	Insufficient area to assess
2001	Liskeenan Fen	Fav	U-I	U-I	Scrub encroachment an issue
3001	River Moy	n/a	n/a	n/a	Insufficient area to assess

8.2.2.4 Overall

The 7210 habitat at Scragh Bog was assessed as Favourable overall. 7210 at Pollardstown Fen and Liskeenan Fen were assessed as Unfavourable-Inadequate due to issues with drying out and scrub encroachment, respectively. The assessment results of all three parameters are summarised in Table 41.

Table 41 Summary of assessment results for 7210 habitat at the five sites in which it was recorded.

PFS Code	Site Name	Area	Structure & Functions	Future Prospects	Overall
1001	Pollardstown Fen	Favourable	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate
1002	Scragh Bog	Favourable	Favourable	Favourable	Favourable
1005	Lough Owel	Favourable	Not assessed	Not assessed	Not assessed
2001	Liskeenan Fen	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Unfavourable-Inadequate
3001	River Moy	Favourable	Not assessed	Not assessed	Not assessed

8.2.3 7230 Alkaline Fens

8.2.3.1 Area

No obvious losses of 7230 habitat, such as those due to disturbance, afforestation or other recent land-use change, were noted during the field survey in any of the six sites in which it was recorded. Google Earth was viewed over several time series to attempt to discern any other habitat changes but none were detected. Therefore, as far as can be ascertained in the absence of baseline mapping, no changes in 7230 habitat area have occurred since 2005.

As this is a baseline survey, the aim would be to determine if any habitat losses had occurred since the EU Habitats Directive came into force in 1994, with the area extant in 1994 taken to be the Favourable Reference Area (FRA). However, due to the difficulty of detecting subtle changes in fen habitats from aerial imagery, and in the absence of baseline mapping with which to compare the current extent of habitat, this was not possible to ascertain with any degree of certainty, so the current area was deemed to be the FRA.

The *Area* parameter for 7230 in the six pilot fen sites in which it was recorded was therefore assessed as Favourable.

8.2.3.2 Structure and Functions

The individual assessment criteria for habitat 7230 listed in Appendix 3 were assessed at 36 monitoring plots recorded at six sites. Table 42 shows the pass rates of the individual criteria. Table 43 shows the assessment stop pass rates and *Structure and functions* assessment results for the sites in which 7230 habitat was recorded.

The criteria that assessed vegetation structure, nativeness and vegetation disturbance in tufa areas were met in all cases (only the six stops that had tufa present were assessed for the last criterion). All of the other criteria failed their assessment in at least one stop. The criterion that failed its assessment most often was the test for the number of positive indicator species, with eight of the stops across three sites (Scragh Bog, Fin Lough and River Moy) failing to reach the threshold, although most failures were marginal, and in some cases positive indicator species were found growing close to the monitoring stop. Cover of positive indicators was a cause for failure in five stops at three sites (Pollardstown Fen, Liskeenan Fen and River Moy). Cover of negative species, including *Phragmites australis*, was too high at three stops (two in Pollardstown Fen and one in Liskeenan Fen), while shrub encroachment was also noted at three stops, one each in Fin Lough, Liskeenan Fen and River Moy. Drainage and a lack of brown mosses were both recorded as a problem at one stop in Pollardstown Fen, while disturbed, bare ground was an issue at one stop in River Moy.

In terms of the site *Structure and functions* assessments, two sites (Scragh Bog and Lough Owel) received a Favourable result for 7230 habitat, two sites (Fin Lough and Liskeenan Fen) were assessed as Unfavourable-Inadequate, and two sites (Pollardstown Fen and River Moy) were assessed as Unfavourable-Bad.

Table 42 Pass rates of criteria used in *Structure and functions* assessments for habitat 7230. *n*=36. All criteria are investigated within the 2 m x 2 m monitoring stop unless 'local vicinity' is specified (up to 20 m from stop). *Tufa present at only five stops, therefore *n*=6 for this criterion.

	Assessment Criterion	% Pass Rate across stops
1	Brown mosses	97
2	Positive vascular indicator species	78
3	Cover of positive indicator species	86
4	Cover of negative species	94
5	Cover of non-native species	100
6	Cover of native trees and scrub (local vicinity)	92
7	Cover of *Juncus effusus* and *Phragmites australis* (local vicinity)	97
8	Vegetation structure	100
9	Disturbed bare ground	97
10	Disturbed bare ground (local vicinity)	97
11	Signs of drainage (local vicinity)	97
12	Disturbed vegetation (if tufa is present) (local vicinity)	100*
	Pass rate for monitoring stops before expert judgement applied	*56*
	Pass rate for monitoring stops after expert judgement applied	*72*

Table 43 Pass rates of assessment stops and assessment result for *Structure & functions* (S&F) for the six sites in which 7230 habitat was recorded. An assessment stop fails if even one criterion is not met unless expert judgement is exercised to override marginal failures.

PFS Code	Site Name	No. of Stops	% Pass Rate	% Pass After Expert Judgement	S&F Assessment Result
1001	Pollardstown Fen	5	40	60	Unfavourable-Bad
1002	Scragh Bog	5	60	100	Favourable
1003	Fin Lough	4	50	75	Unfavourable-Inadequate
1005	Lough Owel	4	100	100	Favourable
2001	Liskeenan Fen	5	80	80	Unfavourable-Inadequate
3001	River Moy	13	38	54	Unfavourable-Bad

8.2.3.3 Impacts, Activities and Future prospects

Table 44 shows the impacts recorded in 7230 habitat in the six sites in which it was assessed. Table 45 summarises the impacts (not broken down by site) according to the intensity, impact and percentage of 7230 habitat affected.

Balancing grazing management of this habitat is difficult. Abandonment of management (primarily a lack of grazing) was seen as a problem at Pollardstown Fen and River Moy. Rank swathes of *Schoenus nigricans* in the River Moy site in particular were extensive, and leaf litter was high. While it is acknowledged that the ground is wet underfoot and could be sensitive to damage by grazing animals, it was nonetheless the surveyors' opinion that the stands of *Schoenus* were in need of some activity, such as livestock grazing, to break up the tussocks and allow less competitive species to thrive.

Table 44 Sites surveyed during the PFS in which impacts were recorded in 7230 habitat.

Impact Code	Impact Description	1001	1002	1003	1005	2001	3001
A06	Abandonment of grassland management	✓					✓
A09	Intensive grazing or overgrazing by livestock			✓			
A10	Extensive grazing or undergrazing by livestock					✓	
A26	Agricultural activities generating diffuse pollution to surface or ground waters						✓
H07	Intrusive research and monitoring activities	✓					
K01	Abstractions from groundwater, surface water or mixed water				✓		
K02	Drainage	✓					
L02	Natural succession resulting in species composition change	✓		✓	✓	✓	
M08	Flooding (natural)				✓	✓	✓
Xxp	No pressures		✓				

A low level of grazing by cattle was recorded in Liskeenan Fen, where cattle were prone to breaking through fenced agricultural grassland into the 7230 and 7210 habitat. Although this grazing is seen as a benefit to the habitat, the level is too low and the frequency too inconsistent at present to be of lasting benefit to the habitat. Conversely, overgrazing by livestock was a problem at Fin Lough in the area of 7230 habitat recorded at the edge of the site.

At the River Moy site, there appeared to be a severe problem with algal deposition on the marl surface of the 7230 fen. In places it appeared to be preventing brown mosses and other typical fen species from achieving any significant cover. The impact has been recorded here as 'Agricultural activities generating diffuse pollution to surface or ground waters', but in fact the source of the pollution is unknown. It could be coming in through enriched floodwaters, caused by nitrogen deposition in the air, or via some other pathway at present unknown. Given the large extent of the habitat at this site, and recognising that this large area is assessed to have bad *Future prospects* as a result, it is a problem that merits further investigation.

Abstraction of water for domestic purposes was recorded as an impact at Lough Owel as this lake is a water supply reservoir. There are therefore fluctuations in water level, depending on demand. The exact effect of this on the 7230 habitat is not clear but is assumed to be negative.

As noted in section 8.2.2.3, drainage at Pollardstown Fen is regarded as a problem.

Table 45 Summary of impacts recorded in 7230 habitat. Frequency within categories of influence (positive, negative or neutral), intensity (high, medium or low) and percentage of 7230 habitat affected are shown. Impact codes are according to DG Environment (2017).

Impact Code	Impact Description	Influence			Intensity			% habitat affected			
		Pos	Neu	Neg	H	M	L	1-5	50-60	90-100	Freq
A06	Abandonment of grassland management			2		2			2		2
A09	Intensive grazing or overgrazing by livestock			1	1				1		1
A10	Extensive grazing or undergrazing by livestock	1					1	1			1
A26	Agricultural activities generating diffuse pollution to surface or ground waters			1		1			1		1
H07	Intrusive research and monitoring activities		1				1	1			1
K01	Abstractions from groundwater, surface water or mixed water			1			1			1	1
K02	Drainage			1		1				1	1
L02	Natural succession resulting in species composition change			4		2	2	3	1		4
M08	Flooding (natural)	3			3					3	3

Succession to scrub was noted as being a problem at Lough Owel. Scrub encroachment can lead to habitats drying out, and as the area of 7230 habitat recorded at Lough Owel was relatively low, this could result in the habitat disappearing from this part of the site completely. Encroachment by birch scrub and reed swamp was also noted at 7230 fen in Fin Lough.

Flooding was recorded at three of the six sites, judged to occur at a high intensity and affecting the entire habitat. The influence of this is assumed to be beneficial to the 7230 habitat but as previously noted, this is dependent on the quality of the floodwaters.

Indications of nutrient enrichment could be seen at River Moy in the form of algal deposition. Whether this was due to nutrient-enriched floodwaters or some other impact is unknown. However, enriched floodwaters would unquestionably have a damaging effect on the habitat, and the fact that flooding impacts the whole habitat is also significant.

The results of the *Future prospects* assessment of 7230 are shown in Table 46. The two sites that received a Favourable *Structure and functions* assessment, Scragh Bog and Liskeenan Fen, were judged by the surveyors not to have any obvious issues to threaten the 7230 habitat here.

The 7230 habitat at Fin Lough failed a number of assessment stops for *Structure and functions*, due to insufficient positive indicator species and encroachment by scrub and reed

swamp. No other obvious impacts were seen, so its *Future prospects* were also assessed as Unfavourable-Inadequate.

Three sites (Pollardstown Fen, Lough Owel and River Moy) were all given Unfavourable-Bad assessments for *Structure and functions*. It follows that the *Future prospects* assessment will also be Unfavourable-Bad, particularly in light of the fact that there are no obvious positive activities taking place to counteract the damaging ones.

Table 46 *Future prospects* (FP) assessment of 7230 habitat at six sites surveyed in the Pilot Fen Survey 2019-2020. Fav=Favourable, U-I=Unfavourable-Inadequate; U-B=Unfavourable-Bad.

PFS Code	Site Name	FP of Area	FP of S&F	FP of site	Rationale
1001	Pollardstown Fen	Fav	U-B	U-B	Drainage, lack of management
1002	Scragh Bog	Fav	Fav	Fav	No negative impacts noted
1003	Fin Lough	Fav	U-I	U-I	Some issue with overgrazing but no other major problems
1005	Lough Owel	Fav	U-I	U-I	Scrub encroachment, water extraction
2001	Liskeenan Fen	Fav	U-I	U-I	Scrub encroachment
3001	River Moy	Fav	U-B	U-B	Severe problems due to algal deposition and lack of management

8.2.3.4 Overall

The overall results for the 7230 habitat assessment at the six PFS sites in which it was recorded is shown in Table 47. The 7230 habitat at two of the six sites in which it was recorded was deemed to be in Favourable condition. These were Scragh Bog and Liskeenan Fen. Fin Lough was assessed as Unfavourable-Inadequate overall. The 7230 habitat at three sites, Pollardstown Fen, Lough Owel and River Moy, was assessed as being in Unfavourable-Bad condition overall.

Table 47 Summary of assessment results for 7230 habitat at the six PFS sites in which it was recorded.

PFS Code	Site Name	Area	Structure & functions	Future prospects	Overall
1001	Pollardstown Fen	Favourable	Unfavourable-Bad	Unfavourable-Bad	Unfavourable-Bad
1002	Scragh Bog	Favourable	Favourable	Favourable	Favourable
1003	Fin Lough	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Unfavourable-Inadequate
1005	Lough Owel	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Unfavourable-Inadequate
2001	Liskeenan Fen	Favourable	Unfavourable-Inadequate	Unfavourable-Inadequate	Unfavourable-Inadequate
3001	River Moy	Favourable	Unfavourable-Bad	Unfavourable-Bad	Unfavourable-Bad

8.3 Conservation Evaluation of Sites

The conservation scoring system described in section 6.11 was implemented for the seven sites surveyed during the PFS. Table 48 shows the results.

Table 48 Conservation scores for the seven pilot fen sites surveyed in 2019-2020.

Criterion	Pollardstown Fen	Scragh Bog	Fin Lough	Lough Garr	Lough Owel	Liskeenan Fen	River Moy
1. Area of fen habitats	4	3	4	3	2	2	12
2. Rarity of habitats	7	10	9	6	9	9	9
3. Rarity of plant species	3	6	0	0	0	0	0
4. Landscape diversity	2	2	3	2	2.5	2	2.5
5. Hydrological naturalness	3	9	3	6	6	6	3
6. Restoration requirements	1	2	1	2	1	2	0
7. Non-recreatability	2	2	2	2	2	2	2
8. Recorded history	1	1	1	0	1	1	1
9. Educational value	1	1	1	0	0	0	1
Total	24	36	24	21	23.5	24	30.5
Rank	=3	1	=3	7	6	=3	2

Of the sites surveyed, Scragh Bog was deemed the best, scoring highly on rarity of habitats (7140, 7210, 7230 and 91D0), rarity of species (*Tomentypnum nitens* and *Hamatocaulis vernicosus*) and hydrological naturalness. Lough Garr was ranked last, scoring less well on rarity of habitats (only one Annex I fen type, habitat 7140).

9 Recommendations

On the basis of observations made both during the scoping study and during the Pilot Fen Survey some recommendations can be made for actions concerning the proposed NFS. A separate discussion of the potential use of UAVs (unmanned aerial vehicles) by the NFS is presented in Box 3.

1. Bryophytes play a critical role in characterising fen habitats and communities. Brown mosses and *Sphagnum* species in particular are of diagnostic value and often abundant. While specimens can always be collected (and often need to be), confident field identification of these plants is far more efficient. All fieldworkers on the NFS should have better-than-average bryological identification skills. Where necessary, training and workshops should be held prior to work commencing to bring all fieldworkers up to the required skill level.

2. The Wetland Framework is a very useful pre-constructed scheme but WETMEC types use a number of specialist terms and concepts that many experienced ecologists will not be altogether confident with. It is recommended that, prior to fieldwork, workshops be organised engaging a knowledgeable hydrologist who can go through each WETMEC and provide examples of the landscape contexts in which they are usually encountered. The limitations of attempting to identify water supply mechanisms from a single site visit must always be acknowledged, particularly for sites on karst geology; thus, this approach should be seen as a preliminary rather than definitive characterisation of each site. For NFS sites deemed to be of high conservation value and/or where serious issues have been identified, follow-up hydrological surveys are recommended.

3. Fens are vulnerable to anthropogenic enrichment via groundwater, surface runoff, floodwaters and atmospheric deposition. Enrichment may manifest as changes in the abundance of graminoids, bryophytes or algal cover (APIS, 2016; Hájek *et al.*, 2015). It is recommended that, prior to fieldwork, workshops be organised to train fieldworkers on the signs of nutrient enrichment. While possible pathways for enrichment in different landscape contexts can be surmised, it may not be possible that a one-off site visit for the NFS will be able to ascertain these pathways. Where significant nutrient enrichment is suspected, sites should be flagged for follow-up, on-site water nutrient monitoring (Farr *et al*., 2019). Vegetation data from future site monitoring should be compared with the NFS baseline to see if there are changes in plant species abundances that may be attributable to nutrient enrichment.

4. Currently, there appears to be insufficient knowledge of invertebrate fen ecology to incorporate invertebrates into the conservation assessment of Annex I fen habitats. To address this deficiency, it is recommended to:

- establish standard methodologies to be employed in surveying invertebrates in fen habitats;
- carry out dedicated baseline surveys covering a broad range of invertebrate groups within fen sites;
- separate sampling effort among Annex I habitats to attempt to more tightly define a species assemblage associated with each specific Annex I fen habitat; and
- establish site-specific assessment criteria for invertebrates by Annex I habitat based on a subset of characteristic species chosen from the site's invertebrate assemblage; these to be included in the *Structure and functions* assessment.

The baseline surveys required in this approach involve repeated visits over a period of several months from a team of specialist entomologists. It is not feasible to conduct such surveys over the large number of sites envisaged for the NFS. Rather it is recommended that a subset of NFS sites, deemed to be of high conservation value and/or where serious pressures have been identified, be selected for a separate follow-up invertebrate survey. This task has not been priced in section 5.3.

5. None of the Annex I fen habitats have a *Structure and functions* assessment criterion addressing algal cover, which may be a symptom of excessive nitrogen deposition or groundwater enrichment. It is recommended that a criterion with an appropriate threshold (*e.g.,* 1 or 2%) be added to the assessment protocols.

6. There is currently no *Structure and functions* assessment criterion for habitat 7140 addressing scrub encroachment, although there is for both habitats 7210 and 7230. Instances of scrub encroachment were observed during the Pilot Fen Survey and it is recommended that such a criterion be added to the assessment protocol.

7. Distinction should be made in management plans between primary and secondary stands of 7210 *Cladium* fen. Primary stands should need no regular maintenance from mowing or grazing. Management at some intermediate level of intensity may be required in some secondary stands to retain species richness, whereas high-intensity grazing or mowing in secondary stands could reduce *Cladium* cover to below the 25% threshold, meaning that they no longer qualify as habitat 7210. Site-specific targets are needed for the areas of the relevant habitats; these may need to reflect the priority status of habitat 7210. To better inform management options, it is recommended that field experiments into the effects of reintroducing grazing and/or mowing to dense secondary *Cladium* stands be commissioned by NPWS.

8. Vegetation assemblages were encountered which appeared to be genuine examples of Annex I fen habitats, but for which the current sets of indicator species were not altogether suitable. Having only surveyed seven sites, it is difficult at this stage to know if these examples are genuinely unusual and best addressed using site-specific criteria, or if they reflect more widespread variations best addressed by changes to the default list. Examples include: fen meadow-type instances of 7230 Alkaline fen, ascribable to the IVC GL1 *Juncus acutiflorus – Holcus lanatus* group; instances of habitat 7210 at interface between short sedge vegetation and tall *Cladium mariscus* stands; infilling pool instances of habitat 7140 with *Carex rostrata* and *Equisetum fluviatile*. This issue is understandable as these criteria have yet to be widely applied. More plot data are required to address this issue.

9. The strategy of the NFS with regard to fen habitat in turloughs needs to be clarified. A preliminary proposal was that turlough fens should be excluded as, like fens of dune slack and machair, they are already included and assessed under a different Annex I habitat (in this case habitat 3180*). However, at Liskeenan Fen, one of the pre-selected sites for the pilot survey, a turlough basin was noted in the south of the site and the NPWS site synopsis states that the site floods from a swallow-hole in the northwest of the site. Similarly, the River Moy site was noted to have some characteristics of turloughs.

10. Small but distinct stands of 7230 Alkaline fen with abundant *Juncus subnodulosus* were noted during the survey. This species is rhizomatous and can form dense stands. Plot data have not been frequently recorded in this community in the past so it does not have its own IVC category but adding one would be a useful addition to the IVC. Such a community would correlate with the phytosociological association Juncetum subnodulosi.

11. Areas dominated by *Molinia caerulea* and *Myrica gale* on substrates of various depths were regarded by this survey as lowland variants of 4010 Wet heath rather than a type

of fen or flush (which are characterised by an abundance of sedges or rushes). Cover of ericaceous species was often low, however. These areas were not assessed by the current project. Were they to be assessed in the future, site-specific amendments to the *Structure and functions* criteria for 4010 Wet heath may be required.

12. The NFS should output brief site reports for each site surveyed. These site reports should consist of a text section and map section. A template for the text section is provided in Appendix 11. The site description should describe the landscape context and include a brief account of the main habitats found on the site and main plant species within each of the fen habitats, together with notes on impacts. Hydrogeological information on groundwater vulnerability, groundwater recharge rates, subsoil permeability, karst features, bedrock, bedrock aquifers and gravel aquifers should be derived from Geological Survey Ireland shapefiles (https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#Per), whereas information of soils and subsoils (parent material) should be derived from Teagasc shapefiles (https://gis.epa.ie/GetData/Download). The management recommendation section should address how the conservation status of the site can be improved and/or what further research is required to address management issues. As a large number of these reports may need to be produced, for efficiency and to reduce inconsistencies, it is recommended that production of these text sections is semi-automated. This can be done either as reports from a Microsoft Access database, or using a Microsoft Word template connected to a Microsoft Excel worksheet with the Mail Merge functionality. The map section of a site report should include: an Annex I habitat map; a Fossitt habitat map; a map showing assessment stops symbolised according to Annex I habitat and pass/fail status; a map showing numbered target notes locations; a map displaying pH and Electrical conductivity (EC) data.

13. While it has been recommended to use Turboveg for recording plot data (section 6.7.2), it is also recommended that NFS general reports and site reports use the much more up-to-date nomenclature of Stace (2019) for vascular plants. If the new checklist from the British Bryological Society is published before the NFS starts in earnest, this should be used as the nomenclatural reference for bryophytes. Failing this, Blockeel *et al*. (2014a, b) should be adopted as the main reference.

Box 3: Potential use of UAVs in the National Fens Survey.

Unmanned aerial vehicles (UAVs) can be used in ecological surveys to obtain a bird's-eye view of sites, providing high-resolution imagery and video. This is particularly useful where access on the ground is difficult and there are health and safety issues for field surveyors. However, far more can be done with a UAV survey than just the provision of contemporary aerial visible light (RGB) imagery.

Photogrammetry techniques based on Structure from Motion Multi-View Stereo (SfM-MVS) of images acquired by UAVs can be used to derive both Digital Elevation Models (DEMs) and Digital Surface Models (DSMs); this approach is a valid low-cost alternative to piloted airborne LiDAR technology (Escobar Villanueva *et al*., 2019). These data can then be used to estimate vegetation height (Hassan *et al*., 2019) and model hydrological processes (Briggs *et al*., 2018). In addition to RGB sensor data, UAVs can also collect data using hyperspectral, multispectral and thermal (infrared) sensors. Datasets can be classified using Random Forest algorithms or artificial neural networks to produce maps of vegetation communities (Beyer *et al*., 2019; Palace *et al*., 2018). There is also potential to use UAV-mounted ground-penetrating radar (GPR) modules (García-Fernández *et al*., 2020) to collect peat depth data which could be used to produce peat depth maps (Plado *et al*., 2011).

Collection of RGB imagery alone may not be enough to justify the expense of commissioning a UAV survey when satellite imagery is widely available as a lower-resolution alternative. Use of the techniques outlined above would provide considerably more information at a site level. Hydrological modelling could be used to plan restoration initiatives, estimates of vegetation height could be used to monitor the impact of grazing regimes, and classification algorithms could allow habitat extent at a site level to be regularly mapped. Peat depth maps would be particularly useful for basin fen sites and for estimates of carbon budgets (Comas *et al*., 2017). However, these techniques also require specialist equipment and considerable data processing expertise and hence come with additional expense.

Alongside invertebrate surveys and hydrological investigations, UAV surveys of fen sites are likely to be too resource-demanding to be conducted at every site in the NFS. However, at selected sites deemed to be of high conservation value and/or where serious pressures have been identified, a UAV survey could provide valuable data to aid in the understanding of ecological or hydrological processes and to inform the development of management options.

10 Bibliography & Relevant Literature

Allen, D., O'Donnell, M., Nelson, B., Tyner, A., Bond, K.G.M., Bryant, T., Crory, A., Mellon, C., O'Boyle, J., O'Donnell, E., Rolston, T., Sheppard, R., Strickland, P., FitzPatrick, Ú. & Regan, E. (2016) Ireland Red List No. 9: Macro-moths (Lepidoptera). National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Andersen, A.M. (1999) My bioindicator or yours? Making the selection. *Journal of Insect Conservation*, **3:** 61–64.

Andersen, D.K., Nygaard, B., Fredshavn, J.R., & Ejrnæs, R. (2013) Cost-effective assessment of conservation status of fens. *Applied Vegetation Science*, **16:** 491-501.

Anderson, R., Mantell, A. & Nelson, B. (2017) An invertebrate survey of Scragh Bog, Co Westmeath. *Irish Wildlife Manuals*, No. **96**. National Parks and Wildlife Service, Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs, Dublin, Ireland.

Anonymous (2014) Natura 2000 Action Plans for Habitat Groups 7210* and 7230. http://www.southeast-europe.net/document.cmt?id=654. Accessed 15th February 2021.

APIS (2016) Nitrogen deposition: fen, marsh and swamp. http://www.apis.ac.uk/node/975. Accessed 8th February 2021.

Ashe, P., O'Connor, J.P. & Casey, R.J. (1991a) Irish Mosquitoes (Diptera: Culicidae): A checklist of the species and their known distribution. *Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science*, **91B**: 21-36.

Ashe, P., O'Connor, J.P., Chandler, P.J., Stubbs, A.E., Vane-Wright, R.I. & Blackith, R.E. (1991b) Craneflies new to Ireland (Diptera: Cylindrotomidae, Limoniidae, Tipulidae). *Bulletin of the Irish Biogeographical Society*, **14**: 54-59.

Ashe, P., O'Connor, J.P., Chandler, P.J., Stubbs, A.E., Vane-Wright, R.I. & Blackith, R.E. (1995) The craneflies (Diptera) of Ireland. Part 1. Limoniidae: Pediciinae. *Bulletin of the Irish Biogeographical Society of Ireland*, **18**: 136-147.

Ashe, P., O'Connor, J.P., Chandler, P.J., Stubbs, A.E., Vane-Wright, R.I. & Alexander, N.A. (2007a) The craneflies (Diptera) of Ireland. Part 5. Tipulidae. *Bulletin of the Irish Biogeographical Society*, **31**: 296-357.

Ashe, P., O'Connor, J.P., Chandler, P.J., Stubbs, A.E., Vane-Wright, R.I. & Alexander, N.A. (2007b) The craneflies (Diptera) of Ireland. Part 6. Limoniidae. *Bulletin of the Irish Biogeographical Society*, **31**: 358-408.

Ashe, P., O'Connor, J.P. & Chandler, P.J. (2012) A revised list of the biting midges (Diptera: Ceratopogonidae). *Bulletin of the Irish Biogeographical Society of Ireland*, **36**: 190-231.

Atherton, I.D.M., Bosanquet, S.D.S. & Lawley, M. (eds) (2010) *Mosses and Liverworts of Britain and Ireland: A Field Guide.* British Bryological Society, UK.

Aukema, B., Hermes, D.J., Nelson, B. & O'Connor, J.P. (2007) Eleven land and water bugs new to the Irish list (Insecta: Heteroptera). *Irish Naturalists' Journal*, **28**: 327-333.

Balfour Browne Club (2020) Water Beetles of Ireland, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/58. Accessed 5th March 2020,

Barnard, P. & Ross, E. (2012) The Adult Trichoptera (Caddisflies) of Britain and Ireland. RES Handbook Volume 1, Part 17.

Barnard, P.C., O'Connor, J.P. & Speight, M.C.D. (1991) A review of published distribution data for Irish Neuroptera (Insecta), together with additional records and a check-list of the Irish species. *Bulletin of the Irish Biogeographical Society*, **14**: 109-123.

Barron, S. (2006) County Monaghan Wetland Survey. Unpublished report for Monaghan County Council and The Heritage Council.

Barron, S.J. & Daly, O.H. (2015) Surveys of possible Marsh Fritillary sites and habitat in Cos. Clare (outside the Burren) and Kerry, Final report. Unpublished report to National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Barron, S.J., O'Neill, F.H. & Martin, J.R. (2015) N6 Galway City Transport Project – Habitat mapping and assessment of a section of Lough Corrib cSAC and surrounding areas. Unpublished report by BEC Consultants Ltd.

BAS (2020) Spider and Harvestman Recording Scheme website. British Arachnological Society. http://srs.britishspiders.org.uk/portal.php. Accessed March 2020.

Beyer, F., Jurasinski, G., Couwenberg, J. & Grenzdörffer, G. (2019) Multisensor data to derive peatland vegetation communities using a fixed-wing unmanned aerial vehicle, *International Journal of Remote Sensing*, **40**: 9103-9125, https://doi.org/10.1080/01431161.2019.1580825.

BfN (2012) *Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae. https://www.bfn.de/en/lrt/natura-2000-code-7210.html. Accessed 15th February 2021.

BfN (2017) Bewertungsschemata für die Bewertung des Erhaltungsgrades von Arten und Lebensraumtypen als Grundlage für ein bundesweites FFH-Monitoring Teil II: Lebensraumtypen nach Anhang I der FFH-Richtlinie (mit Ausnahme der marinen und Küstenlebensräume). Herausgegeben von Bundesamt für Naturschutz (BfN) und dem Bund-Länder-Arbeitskreis (BLAK) FFH-Monitoring und Berichtspflicht.

Bilton, D.T. (1992) Genetic population structure of the postglacial relict diving beetle *Hydroporus glabriusculus* Aubé (Coleoptera: Dytiscidae). *Heredity*, **69**: 503-511.

Blackith, R. (2020) Flesh Flies (Sarcophagidae) of Ireland, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/277. Accessed 26th February 2020.

Blockeel, T.L., Bosanquet, S.D.S. Bosanquet, Hill, M.O. & Preston, C.D. (2014a) *Atlas of British and Irish bryophytes.* Volume 1. British Bryological Society (Pisces Publications, Newbury).

Blockeel, T.L., Bosanquet, S.D.S. Bosanquet, Hill, M.O. & Preston, C.D. (2014b) *Atlas of British and Irish bryophytes.* Volume 2. British Bryological Society (Pisces Publications, Newbury).

Bond, K.G.M. (1989) Clonmacnoise Heritage Zone, Co. Offaly, Ireland: Assessment of conservation value based on Lepidoptera recorded from 1983 to 1987. *Bulletin of the Irish Biogeographical Society*, **12**: 63-89.

Bond, K.G.M. (1991) A preliminary survey of the Lepidoptera of Pollardstown Fen, Co. Kildare, including a record of *Cosmopterix lienigiella* (Lienig & Zeller, 1839), a species new to Ireland. *Bulletin of the Irish Biogeographical Society*, **14**: 24-47.

Briggs, M. A., Dawson, C. B., Holmquist-Johnson, C. L., Williams, K. H., & Lane, J. W. (2018) Efficient hydrogeological characterization of remote stream corridors using drones. *Hydrological Processes*, **33**: 316-319. https://doi.org/10.1002/hyp.13332.

British Bugs (2020) British Bugs: An online identification guide to UK Hemiptera. https://www.britishbugs.org.uk. Accessed 28th April 2020.

Brophy, J.T. & O'Connor, J.P. (2020) A new site for *Tricholeiochiton fagesii* (Guinard, 1879) (Trichoptera: Hydroptilidae) in Ireland. *Entomologist's Record and Journal of Variation*, **132**: 244-248.

Buchwald, R. & Schiel, F.-J. (2002). Chances and limits of different management measures in mires presented for three fen-typical endangered Odonata species in Southwest Germany. *Telma,* **32**: 161-174.

Buhl, P.N. & O'Connor, J.P. (2008) Records of Irish Platygastridae (Hymenoptera) including seventeen species new to Ireland. *Irish Naturalists' Journal*, **29**: 27-29.

Buhl, P.N. & O'Connor, J.P. (2010) Distributional records of Irish Platygastridae with corrections and additions to the Irish list. *Bulletin of the Irish Biogeographical Society of Ireland*, **34**: 3-17.

Byrne, A., Moorkens, E.A., Anderson, R., Killeen, I.J. & Regan, E.C. (2009) Ireland Red List No. 2 – Non-Marine Molluscs. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.

Cameron, R.A.D., Colville, B., Falkner, G., Holyoak, G.A., Hornung, E., Killeen, I.J., Moorkens, E.A., Pokryszko, B.M., Von Proschwitz, T., Tattersfield, P. & Valovirta, I. (2003) Species accounts for snails of the genus *Vertigo* listed in Annex II of the Habitats Directive: *V. angustior*, *V. genesii*, *V. geyeri*, and *V. moulinsiana*. *Heldia*, **5**: 151-170.

CEDaR (2020) Dragonfly Ireland, Centre for Data and Environmental Recording, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/187. Accessed 11th March 2020

Chandler, P.J. (1986) The Irish lance flies (Diptera: Lonchaeidae): a preliminary account. *Irish Naturalists' Journal*, **22**: 147-149.

Comas, X., Terry, N., Hribljan, J. A., Lilleskov, E. A., Suarez, E., Chimner, R. A. & Kolka R. K. (2017) Estimating below-ground carbon stocks in peatlands of the Ecuadorian páramo using ground-penetrating radar (GPR), *Journal of. Geophysical Research: Biogeosciences*, **122**: 370-386. https://doi:10.1002/2016JG003550

Cotton, D.C.F. (1982) *Coenagrion lunulatum* (Charpentier) (Odonata: Coenagrionidae) new to the British Isles. *Entomologist's Gazette*, **33**: 213.

Crushell, P., Foss, P.J. & Kirwan, B. (2014) County Kerry Wetland Survey. Report prepared for Kerry County Council.

Crushell, P., Foss, P.J. & Kirwan, B. (2015) Kerry Wetland Survey II. Report prepared for Kerry County Council.

DAERA (2015) Magheraveely Marl Loughs SAC Conservation Objectives. Unpublished report.

Daly, O.H. (2016) Surveys of possible Marsh Fritillary sites and habitat in the mid-west (Roscommon and Longford), Draft report. Unpublished Report to National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Daly, O.H. & Barron, S.J. (2014) Surveys of possible Marsh Fritillary sites and habitat in Cos Louth, Meath and Monaghan, Final report. Unpublished Report to National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Daly, O.H. & Barron, S.J. (2015) Surveys of possible Marsh Fritillary sites and habitat in Cos. Galway and Mayo, Final report. Unpublished Report to National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

De Courcy Williams, M. (1989) *Idiocerus stigmaticalis* Lewis and *Metidiocerus elegans* (Flor) (Homoptera: Auchenorrhyncha), leafhoppers new to Ireland. *Irish Naturalists' Journal*, **23**: 32.

Dempster, J.P. (1995) The ecology and conservation of *Papilio machaon* in Britain. *In*: Pullin A.S. (eds) *Ecology and Conservation of Butterflies*. Springer, Dordrecht.

DG Environment (2016) Reporting under Article 17 of the Habitats Directive: Report format for the period 2013-2018. Brussels. Pp 29. http://cdr.eionet.europa.eu/help/habitats_art17. Accessed October 2017.

DG Environment (2017) Reporting under Article 17 of the Habitats Directive: Explanatory notes and guidelines for the period 2013-2018. Brussels. Pp 188. http://cdr.eionet.europa.eu/help/habitats_art17. Accessed October 2017.

Drake, C.M. Lott, D.A., Alexander, K.N.A. & Webb, J. (2007) Surveying terrestrial and freshwater invertebrates for conservation evaluation. Natural England Research Report NERR005. Natural England, Sheffield, UK.

Duffey, E. (1968) Ecological Studies on the Large Copper Butterfly *Lycaena dispar* Haw. Batavus Obth. at Woodwalton Fen National Nature Reserve, Huntingdonshire. *Journal of Applied Ecology*, **5**: 69-96. doi: 10.2307/2401275.

Duffey, E. (1971) *Carorita paludosa* n.sp., a new Linyphiid spider from Ireland and eastern England. *Bulletin (British Arachnological Society)*, **2**: 14-15.

Duffey, E. & Feest, A. (2009) A comparative ecological study of the spider (Araneae) faunas of East Anglian fens, England: regional differences and conservation. *Bulletin (British Arachnological Society)*, **14**: 317-333.

Dušek, J., Vokasová, L., Finne, A., Carská, H., Janák, M., Marhoul, P. & Sundseth, K. (2012) Workshop document for the pilot Boreal Natura 2000 Workshop. VERSION 11/01/2012. http://www.ceeweb.org/wp-content/uploads/2012/02/Final_Background_Document.pdf.

EC (2013) Interpretation Manual of European Union Habitats. Version EUR28, European Commission, Brussels.

Ellmauer, T. (ed.) (2005) Entwicklung von Kriterien, Indikatoren und Schwellenwertenzur Beurteilung des Erhaltungszustandes der Natura 2000-Schutzgüter. Band 3: Lebensraumtypendes Anhangs I der Fauna-Flora-Habitat-Richtlinie. Im Auftrag der neun österreichischen Bundesländer, des Bundesministerium f. Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft und der Umweltbundesamt GmbH, [Federal Environment Agency, Austria.]

Ellwanger, G., Runge, S., Wagner, M., Ackermann, W., Neukirchen, M., Frederking, W., Müller, C., Ssymank, A. & Sukopp, U. (2018) Current status of habitat monitoring in the European Union according to Article 17 of the Habitats Directive, with an emphasis on habitat structure and functions and on Germany. *Nature Conservation*, **29**: 57-78. https://doi.org/10.3897/natureconservation.29.27273.

Escobar Villanueva, J.R., Iglesias Martínez, L., & Pérez Montiel, J.I. (2019) DEM Generation from Fixed-Wing UAV Imaging and LiDAR-Derived Ground Control Points for Flood Estimations. *Sensors*, **19**: 3205. https://doi.org/10.3390/s19143205.

Farr, G., Hall, J., Jones, L., Whiteman, M., Haslam, A., Phillips, N., Tang, S., Williams, H., Davison, P. & Lapworth, D. (2019) Atmospheric deposition at groundwater dependent wetlands Phase 2: nutrient source apportionment case studies from England and Wales. Unpublished internal report OR/17/021. British Geological Survey Keyworth, Nottingham.

Foss, P.J. (2007) National Parks & Wildlife Service Study of the Extent and Conservation Status of Springs, Fens and Flushes in Ireland 2007. Internal report for the National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Ireland.

Foss, P.J. & Crushell, P. (2008a) Guidelines for a National Fen Survey of Ireland, Survey Manual. Report for the National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Ireland.

Foss, P.J. & Crushell, P. (2008b) Monaghan Fen Survey II. Volumes 1-3. Report for Department of the Environment, Heritage and Local Government, Ireland and Monaghan County Council.

Foss, P.J. & Crushell, P. (2010) The County Monaghan Wetlands Map Desk Survey & GIS Preparation. Unpublished report for Monaghan County Council and The Heritage Council.

Foss, P.J. & Crushell, P. (2011) Wetland Survey County Monaghan. Unpublished report for Monaghan County Council and The Heritage Council.

Foss, P.J. & Crushell, P. (2012) Wetland Survey County Monaghan II. Unpublished report for Monaghan County Council and The Heritage Council.

Foss, P.J. & Crushell, P. (2013) County Kildare Wetland Survey II. Report prepared for Kildare County Council and The Heritage Council.

Foss, P.J. & Crushell, P. (2014) County Kildare Wetland Survey III. Report prepared for Kildare County Council and The Heritage Council.

Foss, P.J., Crushell, P., Kirwan, B., O'Loughlin, B. & Wilson, F. (2014) Louth Wetland Survey III. Report prepared for Louth County Council and The Heritage Council.

Foss, P.J., Crushell, P. & Kirwan, B. (2015) County Waterford Wetland Survey. Report prepared for Waterford City and County Council.

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

Foster, A.P. & Procter, D.A. (1995) The occurrence of some scarce East Anglian fen invertebrates in relation to vegetation management. *In* Wheeler, B.D., Shaw, S.C., Fojt, W.J. & Robertson, R.A, eds. Restoration of temperate wetlands. pp. 223-240. Chichester: Wiley.

Foster, G. N., Nelson, B. H., Bilton, D. T., Lott, D. A., Merritt, R., Weyl, R. S. & Eyre, M. D. (1992) A classification and evaluation of Irish water beetle assemblages. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **2**: 185–208. doi:10.1002/aqc.3270020205.

Foster, G.N., Nelson, B.H. & O'Connor, Á. (2009) Ireland Red List No. 1 Water beetles. National Parks and Wildlife Service, Department of Environment Heritage and Local Government, Dublin, Ireland.

García-Fernández, M., López, Y.Á. & Andrés, F. L.-H. (2020) Airborne Multi-Channel Ground Penetrating Radar for Improvised Explosive Devices and Landmine Detection. *IEEE Access*, **8**: 165927-165943. https://doi:10.1109/ACCESS.2020.3022624.

Gerlach, J., Samways, M. & Pryke, J. (2013) Terrestrial invertebrates as bioincidators: an overview of available taxonomic groups. *Journal of Insect Conservation*, **17**: 831-850.

Good, J.A. (1989) *Stenus palustris* Erichson (Coleoptera: Staphylinidae): a reed marsh beetle new to Ireland. *Irish Naturalists' Journal*, **23**: 32.

Good, J.A. (1991) *Atheta aeneicollis* (Sharp) (Coleoptera: Staphylinidae), a mycetophilous beetle new to Ireland. *Irish Naturalists' Journal*, **23**: 506.

Good, J.A. (1992) *Atheta strandiella* Brundin (Coleoptera: Staphylinidae), a necrophilous beetle new to Ireland. *Irish Naturalists' Journal*, **24**: 79.

Good, J.A. (1994) *Atheta liliputana* (Brisout) (Coleoptera: Staphylinidae), a marsh beetle new to Ireland. *Irish Naturalists' Journal*, **24**: 413.

Good, J.A. (2005) Spring-fed fen as a habitat for Staphylinidae (Coleoptera) at Pollardstown Fen, Co. Kildare, Ireland, with an assessment of staphylinid sampling by malaise traps. *Bulletin of the Irish Biogeographical Society of Ireland*, **29**: 213-241.

Hájek, M., Horsák, M., Hájková, P. & Dítě, D. (2006) Habitat diversity of central European fens in relation to environmental gradients and an effort to standardise fen terminology in ecological studies. *Perspectives in Plant Ecology, Evolution and Systematics*, **8**: 97–114

Hájek, M., Jiroušek, M., Navrátilová, J., Horodyská, E., Peterka, T., Plesková, Z., Navrátil, J., Hájková, P. & Hájek, T. (2015) Changes in the moss layer in Czech fens indicate early succession triggered by nutrient enrichment. *Preslia,* **87**: 279–301.

Hannigan, E. & Kelly-Quinn, M. (2012) Composition and structure of macroinvertebrate communities in contrasting open-water habitats in Irish peatlands: implications for biodiversity conservation. *Hydrobiologia* **692**: 19–28. https://doi.org/10.1007/s10750-012-1090-4.

Hannigan, E., Kelly-Quinn, M. & O'Connor, J.P. (2009) Notable Caddisflies (Trichoptera) from Scragh Bog, Co. Westmeath, including *Erotesis baltica* McLachlan new to Ireland. *Bulletin of the Irish Biogeographical Society*, **33**: 76-80.

Hassan, M.A., Yang, M., Fu, L., Rasheed, A., Zheng, B., Xia X., Xiao, Y. & He, Z. (2019) Accuracy assessment of plant height using an unmanned aerial vehicle for quantitative genomic analysis in bread wheat. *Plant Methods*, **15**: 37. https://doi.org/10.1186/s13007-019-0419-7

Hassel, K., Kyrkjeeide, M.O., Yousefi, N., Prestø, T., Stenøien, H.K., Shaw, A.J. & Flatberg, K.I. (2018) *Sphagnum divinum* (sp. nov.) and *S. medium* Limpr. and their relationship to *S. magellanicum* Brid., *Journal of Bryology*, **40**: 197-222.

Hill, M.O., Preston, C.D. & Roy, D.B. (2004) PLANTATT Attributes of British and Irish plants: Status, size, life history, geography and habitats, Centre for Ecology & Hydrology, Huntingdon, UK.

Hill, M.O., Blackstock, T.H., Long, D.G. & Rothero, G.P. (2008) *A checklist and census catalogue of British and Irish Bryophytes*. British Bryological Society, UK.

Hodgetts, N. & Lockhart, N. (2020) Checklist and country status of European bryophytes – update 2020*. Irish Wildlife Manuals*, No. 123. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.

Hodkinson, I.D. & Jackson, J.K. (2005) Terrestrial and Aquatic Invertebrates as Bioindicators for Environmental Monitoring, with Particular Reference to Mountain Ecosystems. *Environmental Management*, **35**: 649-666. https://doi.org/10.1007/s00267-004-0211-x.

Holmes, P.R., Fowles, A.P. & Boyce, D.C. (1993) The ground beetle (Coleoptera: Carabidae) fauna of Welsh peatland biotopes – species assemblages in relation to peatland habitats and management. *Biological Conservation*, **65**: 61-67.

Holyoak, G.A. (2005) Widespread occurrence of *Vertigo geyeri* (Gastropoda: Vertiginidae) in north and west Ireland. *Irish Naturalists' Journal*, **28**: 141-150.

Horsák, M. & Hájek, M. (2003) Composition and species richness of molluscan communities in relation to vegetation and water chemistry in the western Carpathian spring fens: the poor–rich gradient. *Journal of Molluscan Studies*, **69**: 349-357.

IBS (2020a) Anisopodidae and Thaumaleidae (Diptera: Nematocera) of Ireland, Irish Biogeographical Society, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/2. Accessed 26th February 2020.

IBS (2020b) Lacewings (Neuroptera) of Ireland, Irish Biogeographical Society, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/64. Accessed 26th February 2020.

IBS (2020c) Meniscus midges (Dixidae) of Ireland, Irish Biogeographical Society, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/16. Accessed 26th February 2020.

Ismay, J.W., Chandler, P.J., O'Connor, J.P. & Nash, R. (2001) Additions to the Irish list of Chloropidae (Diptera), with notes on the A.H. Haliday collection. *Dipterists Digest*, **8**: 53-64.

Jermy, A.C., Simpson, D.A., Foley, M.J.Y. & Porter, M.S. (2007) *Sedges of the British Isles*. BSBI Handbook No. 1, 3rd edition. BSBI, London.

JNCC (2004) Common Standards Monitoring Guidance for Lowland Wetlands Habitats. Version August 2004. ISSN 1743-8160 (online).

JNCC (2019) Article 17 Habitats Directive Report 2019: Habitat Conservation Status Assessments. https://jncc.gov.uk/our-work/article-17-habitats-directive-report-2019-habitats/#natural-and-semi-natural-grassland-formations. Published online Friday, October 18, 2019.

Johnson, W.F. & Halbert, J.N. (1902) A List of the Beetles of Ireland. *Proceedings of the Royal Irish Academy*, **6**: 535-827.

Jones, P.S., Stevens, J., Bosanquet, S.D.S., Turner, A.J., Birch, K.S. & Reed, D.K. (2013) Distribution, extent and status of Annex I wetland habitats in Wales: Supporting material for the 2013 Article 17 assessment. CCW Staff Science Report No 13/7/1.

Joosten, H., Tanneberger, F. & Moen, A. (eds.) (2017) *Mires and peatlands of Europe: Status, distribution and conservation*. Schweizerbart Science Publishers, Stuttgart.

Kagainis, U. & Spuņģis, V. (2013) Moss mite (Acari, Oribatida) communities in the Apšuciems calcareous fen, Latvia. *Acta Biologica Universitatis Daugavpiliensis*, **13**: 39-53.

Kimberley, S. & Coxon, C. (2013) Evaluating the Influence of Groundwater Pressures on Groundwater-Dependent Wetlands. Environmental Supporting Conditions for Groundwater-Dependent Terrestrial Ecosystems (2011-W-DS-5) STRIVE Report. Prepared for the Environmental Protection Agency by the Department of Geology, School of Natural Sciences, University of Dublin, Trinity College, College Green, Dublin 2.

Kment, P. & Baňař, P. (2011) True bugs (Hemiptera: Heteroptera) of the Bílé Karpaty Protected Landscape Area and Biosphere Reserve (Czech Republic). In: Malenovský, I., Kment, P. & Konvička, O. (eds.): Species inventories of selected insect groups in the Bílé Karpaty Protected Landscape Area and Biosphere Reserve (Czech Republic). *Acta Musei Moraviae*, *Scientiae biologicae* (*Brno*) **96**: 323–628.

Koivula, M.J. (2011) Useful model organisms, indicators, or both? Ground beetles (Coleoptera, Carabidae) reflecting environmental conditions. In: Kotze DJ, Assmann T, Noordijk J, Turin H, Vermeulen R (eds.) Carabid Beetles as Bioindicators: Biogeographical, Ecological and Environmental Studies. *ZooKeys*, **100**: 287–317. doi:10.3897/zookeys.100.1533.

Kubiak, M., Stotzem, H.C., Schütte, K. & Peters, R.S. (2014) A commented historic inventory of the caddisfly fauna (Trichoptera) of the fen complex "Eppendorfer Moor" in Northern Germany, based on material collected by G. Ulmer 1896–1907. *Lauterbornia*, **77**: 201-217.

Kyrkjeeide, M.O., Hassel, K., Stenøien, H.K., Prestø, T., Boström, E., Shaw, A.J. & Flatberg, K.I. (2015) The dark morph of *Sphagnum fuscum* (Schimp.) H.Klinggr. in Europe is conspecific with the North American *S. beothuk*, *Journal of Bryology*, **37(4):** 251-266.

Lockhart, N., Madden, B., Wolfe-Murphy, S., Wymer, E. & Wyse Jackson, M. (1993) National ASI Survey Guidelines for Ecologists. National Parks and Wildlife Service, unpublished report.

Long, M.P. & Brophy, J.T. (2019) Monitoring of sites and habitat for three Annex II species of whorl snail (*Vertigo*). Irish Wildlife Manuals, No.

104. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.

Long, M.P., Crowe, O., Kimberley, S. & Denyer, J. (2018) Backing document – National Conservation Status Assessments (NCAs) for three fen habitat types: 7140 – Transition mires and quaking bogs, 7210 – Calcareous fens with *Cladium mariscus* and species of Caricion davallianae, 7230 – Alkaline fens. Unpublished report to National Parks and Wildlife Service.

Lott, D.A. (2003) An annotated list of wetland ground beetles (Carabidae) and rove beetles (Staphylinidae) found in the British Isles including a literature review of their ecology. English Nature Research Reports 488.

Lott, D.A. & Bilton, D.T. (1991) Records of Coleoptera from Irish wetland sites in 1989. *Bulletin of the Irish Biogeographical Society*, **14**: 60-72.

Lott, D.A. & Foster, G.N. (1990) Records of Terrestrial Coleoptera from wetland sites in 1987, including *Stenus glabellus* Thomson (Staphylinidae) new to the British Isles. *Irish Naturalists' Journal*, **23**: 280-282.

Lott, D.A., Proctor, D.A. & Foster, A.P. (2002) East Anglian fen invertebrate survey. Peterborough: English Nature.

Mantell, A. & Anderson, R. (2020) Important Invertebrate Area Surveys: Ballyogan and Slieve Carran, Co. Clare. *Irish Wildlife Manuals*, No. 127. National Parks and Wildlife Service, Department of Housing, Local Government and Heritage, Ireland.

Martin, J.R., O'Neill, F.H. & Daly, O.H. (2018) The monitoring and assessment of three EU Habitats Directive Annex I grassland habitats. *Irish Wildlife Manuals*, No. 102. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.

Martin, L.A. & Pullin, A.S. (2004) Host-plant specialisation and habitat restriction in an endangered insect, *Lycaena dispar batavus* (Lepidoptera: Lycaenidae) II. Larval survival on alternative host plants in the field. *European Journal of Entomology*, **101**: 57-62.

McBride, A., Diack, I., Droy, N., Hamill, B., Jones, P., Schutten, J., Skinner, A. & Street, M. (eds.) (2011) *The Fen Management Handbook*. Scottish Natural Heritage, Perth.

Menzel, F., Smith, J.E. & Chandler, P.J. (2006) The sciarid fauna of the British Isles (Diptera: Sciaridae), including descriptions of six new species. *Zoological Journal of the Linnean Society*, **146**: 1–147.

Moorkens, E.A. (1998) An inventory of Mollusca in potential SAC sites, with special reference to *Vertigo angustior*, *V. moulinsiana* and *V. geyeri*. Unpublished report to Dúchas The Heritage Service, Dublin.

Moorkens, E.A. (2004) Non-marine Mollusca: new and notable records for Ireland. *Bulletin of the Irish Biogeographical Society of Ireland*, **28**: 189-198.

Moorkens, E. & Killeen, I.J. (2009) *Pupilla pratensis* (Clessin, 1871) (Gastropoda: Pupillidae) recognized in Ireland. *Irish Naturalists' Journal*, **30**: 148.

Moorkens, E.A. & Killeen, I.J. (2011) Monitoring and Condition Assessment of Populations of *Vertigo geyeri*, *Vertigo angustior* and *Vertigo moulinsiana* in Ireland. Irish Wildlife Manuals, No. 55. National Parks and Wildlife Service, Department of Arts, Heritage and Gaeltacht, Dublin, Ireland.

Morris, M. (1969) Associations of Aquatic Heteroptera at Woodwalton Fen, Huntingdonshire, and their Use in Characterizing Artificial Aquatic Biotopes. *Journal of Applied Ecology*, **6**: 359-373. doi:10.2307/2401550.

Mucina, L., Bültmann, H., Dierßen, K., Theurillat, J.-P., Raus, T., Čarni, A., Šumberová, K., Willner, W., Dengler, J., García, R.G., Chytrý, M., Hájek, M., Di Pietro, R., Iakushenko, D., Pallas, J., Daniëls, F.J.A., Bergmeier, E., Santos Guerra, A., Ermakov, N., Valachovič, M., Schaminée, J.H.J., Lysenko, T., Didukh, Y.P., Pignatti, S., Rodwell, J.S., Capelo, J., Weber, H.E., Solomeshch, A., Dimopoulos, P., Aguiar, C., Hennekens, S.M. & Tichý, L. (2016) Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Applied Vegetation Science* **19**: 3–264. https://doi.org/10.1111/avsc.12257.

Nash, R., O'Connor, J.P. & Chandler, P.J. (2001) The Irish species of lesser dung flies (Insecta: Diptera, Sphaeroceridae) including a list of type specimens described by Alexander Henry Haliday in Humboldt University Museum, La Specola and the National Museum of Ireland. *Bulletin of the Irish Biogeographical Society of Ireland*, **25**: 180-210.

National Roads Authority (NRA) (2009) Guidelines for Assessment of Ecological Impacts of National Road Schemes. National Roads Authority, Dublin.

NBDC (2020a) Grasshoppers, Crickets and Allied Insects (Orthoptera) of Ireland, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/204. Accessed 26th February 2020.

NBDC (2020b) Bees of Ireland, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/5. Accessed 27th February 2020.

NBDC (2020c) Butterflies of Ireland, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/116.Accessed 27th February 2020

NBDC (2020d) Irish Butterfly Monitoring Scheme, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/28. Accessed 27 February 2020.

NBDC (2020e) Dragonfly Records, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/239. Accessed 27th February 2020.

NBDC (2020f) Ladybirds of Ireland, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/255. Accessed 27th February 2020.

Nelson, B. (1998) A survey of the invertebrates of fens of counties Armagh and Down. A report to Environment and Heritage Service. Contract No. CP1149/94/3/2/.

Nelson, B. (2001) An invertebrate survey of fen sites in County Tyrone. A report to Environment and Heritage Service. Contract No. Con 2/1(76)

Nelson, B. (2005) Surveys of the insects, spiders and other invertebrates of fens in counties Armagh, Down and Tyrone, Northern Ireland. *Bulletin of the Irish Biogeographical Society*, 29: 3–85.

Nelson, B. (2020) True Bugs (Heteroptera) of Ireland, National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/111. Accessed 26th February 2020.

Nelson, B. & Thompson, R. (2004) *The Natural History of Ireland's Dragonflies*. The National Museums and Galleries of Northern Ireland, Belfast.

Nelson, B., Ronayne, C. & Thompson, R. (2011) Ireland Red List No. 6: Damselflies & Dragonflies (Odonata). National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.

Nicholls, C.N. & Pullin, A.S. (2003) The effects of flooding on survivorship in overwintering larvae of the large copper butterfly *Lycaena dispar batavus* (Lepidoptera: Lycaenidae), and its possible implications for restoration management. *European Journal of Entomology*, **100**: 65-72.

NMI (2020) Microlepidoptera collections (National Museum of Ireland), National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/51. Accessed 27th February 2020.

NPWS (2008) The Status of EU Protected Habitats and Species in Ireland. Backing Documents, Article 17 forms, Maps Volumes 1,2 and 3. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Ireland.

NPWS (2013a) Fin Lough SAC [000576] Site synopsis. Department of Arts, Heritage and the Gaeltacht. https://www.npws.ie/sites/default/files/protected-sites/synopsis/SY000576.pdf. Accessed 28 April 2020.

NPWS (2013b) The Status of EU Protected Habitats and Species in Ireland. Habitat Assessments Volume 2. Version 1.0. Unpublished Report, National Parks & Wildlife Service. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

NPWS (2015) Scragh Bog SAC [000692] Site synopsis. Department of Arts, Heritage and the Gaeltacht. https://www.npws.ie/sites/default/files/protected-sites/synopsis/SY000692.pdf. Accessed 28 April 2020.

NPWS (2019) The Status of EU Protected Habitats and Species in Ireland. Volume 2: Habitat Assessments. Unpublished NPWS report. Edited by: Deirdre Lynn and Fionnuala O'Neill.

Ó Críodáin, C. & Doyle, G.J. (1994) An overview of small-sedge vegetation: syntaxonomy and a key to communities belonging to the *Scheuzerio-Caricetum nigrae* (Nordh. 1936) Tx 1937. *Biology and Environment: Proceedings of the Royal Irish Academy*, **94B:** 127-144.

O'Connor, J.P. (2015) A Catalogue and Atlas of the Caddisflies (Trichoptera) of Ireland. *Occasional Publication of the Irish Biogeographical Society*, No. **11**.

O'Connor, J.P. & Ashe, P. (2004) New records of Irish Culicidae and Dixidae (Diptera). *Irish Naturalists' Journal*, **27**: 355-356.

O'Connor, J.P. & Buhl, P.N. (2016) A review of the Irish platygastrids (Hymenoptera: Platygastroidea, Platygastridae) including their known distribution. *Bulletin of the Irish Biogeographical Society of Ireland*, **40**: 43-115.

O'Connor, J.P. & Chandler, P.J. (2000) Distributional records of Irish Diptera. *Bulletin of the Irish Biogeographical Society of Ireland*, **24**: 75-110.

O'Connor, J.P. & Chandler, P.J. (2006) Records of Irish Agromyzidae (Diptera) including two species new to Ireland. *Irish Naturalists' Journal*, **28**: 280-283.

O'Connor, J.P. & Nelson, B. (2012) An Annotated Checklist of the Irish Hemiptera and Small Orders. Macro Series of the Irish Biogeographical Society.

O'Connor, J.P. & O'Connor, M.A. (2013) *Hydroptila valesiaca* Schmid (Trich.: Hydroptilidae) new to Ireland with records of two other notable species. *Entomologist's Record and Journal of Variation*, **125**: 189-193.

O'Connor, J.P. & O'Connor, M.A. (2019) New caddisfly (Trichoptera) data from Ireland including records of *Hydroptila lotensis* Mosely, 1930 and *Hydroptila vectis* Curtis, 1934. *Bulletin of the Irish Biogeographical Society*, **43**: 57-122.

O'Connor, J.P. & O'Hanrahan, B.M. (1988) *Agraylea sexmaculata* new to Ireland with notes on *Tricholeiochiton fagesii* and *Phacopteryx*

brevipennis (Trichoptera). *Irish Naturalists' Journal*, **22**: 478-480.

O'Connor, J.P. & Thuróczy, C. (2009) Records of Irish Chalcidoidea (Hymenoptera) including *Torymus hederae* (Walker, 1833) and *Torymus nitidulus* (Walker, 1833) new to Ireland. *Bulletin of the Irish Biogeographical Society of Ireland*, **33**: 3-13.

O'Connor, J.P., Good, J.A. & Bond, K.G.M. (1990) *Leptocerus tineiformis* Curtis: a caddisfly new to Ireland from Pollardstown Fen, Co. Kildare. *The Entomologist's Record and Journal of Variation*, **12**: 115-116.

O'Connor, J.P., Liston, A.D. & Speight, M.C.D. (1997) A review of the Irish sawflies (Hymenoptera: Symphyta) including a checklist of species. *Bulletin of the Irish Biogeographical Society of Ireland*, **20**: 2-99.

O'Connor, J.P., Chandler, P.J., Ashe, P., Speight, M.C.D. & Nash, R. (2007a) A Review of the Irish Lesser Fruit-Flies (Diptera: Drosophilidae). *Irish Naturalists' Journal*, **28**: 506-516.

O'Connor, J.P., Nash, R. & Fitton, M.G. (2007b) A catalogue of the Irish Ichneumonidae (Hymenoptera: Ichneumonoidea). *Occasional Publication of the Irish Biogeographical Society*, Number 10.

OHES Environmental (2012) Broadland Fens Condition Assessment 2012: Waveney Valley Fens. Unpublished report for Broads Authority, UK.

O'Neill, F.H., Martin, J.R., Devaney, F.M. & Perrin, P.M. (2013) The Irish semi-natural grasslands survey 2007-2012. *Irish Wildlife Manuals*, No. 78. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Ireland.

Owen, J.A. (1997) Beetles (Coleoptera) recorded from various Irish sites in 1993, 1994 and 1996. *Bulletin of the Irish Biogeographical Society of Ireland*, **20**: 136-154.

Palace, M., Herrick, C., DelGreco, J., Finnell, D., Garnello, A.J., McCalley, C., McArthur, K., Sullivan, F. & Varner, R.K. (2018) Determining subarctic peatland vegetation using an unmanned aerial system (UAS). *Remote Sensing*, **10**: 1498. https://doi.org/10.3390/rs10091498.

Parnell, J. & Curtis, T. (2012) *Webb's An Irish flora*, 8th edition. Cork University Press, Cork.

Perrin, P. (2018) Irish Vegetation Classification. Irish Vegetation Classification Technical Progress Report No. 4. Available online: http://www.biodiversityireland.ie/wordpress/wpcontent/uploads/IVC_Technical-Progress-Report-No.4.pdf. Accessed February 2020.

Perrin, P., Barron, S., Martin, J., O'Neill, F., McNutt, K. & Delaney, A. (2008) National Survey of Native Woodlands 2003-2008: Volume I: Main report. Report for National Parks and Wildlife Service, Dublin.

Perrin, P.M., Roche, J.R., Barron, S.J., Daly, O.H., Hodd, R.L., Muldoon, C.S. & Leyden, K.J. (2013a) National Survey of Upland Habitats (Phase 3, 2012 – 2013), Site Report No. 10: Ox Mountains Bogs cSAC (002006), Cos. Mayo and Sligo. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Perrin, P.M., Roche, J.R., Barron, S.J., Daly, O.H., Hodd, R.L., Muldoon, C.S. & Leyden, K.J. (2013b) National Survey of Upland Habitats (Phase 3, 2012 – 2013), Site Report No. 12: Arroo Mountain cSAC (001403), Co. Leitrim. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Perrin, P.M., Roche, J.R., Barron, S.J., Daly, O.H., Hodd, R.L., Muldoon, C.S. & Leyden, K.J. (2013c) National Survey of Upland Habitats (Phase 3, 2012 – 2013), Site Report No. 13: Cuilcagh – Anierin Uplands cSAC (000584), Cos. Cavan and Leitrim. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Perrin, P.M., Roche, J.R., Barron, S.J., Daly, O.H., Hodd, R.L., Muldoon, C.S. & Leyden, K.J. (2013d) National Survey of Upland Habitats (Phase 3, 2012 – 2013), Site Report No. 14: Slieve League cSAC (000189), Co. Donegal. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Perrin, P.M., Barron, S.J., Roche, J.R. & O'Hanrahan, B. (2014a) Guidelines for a national survey and conservation assessment of upland vegetation and habitats in Ireland. Version 2.0. *Irish Wildlife Manuals*, No. 79. National Parks and Wildlife Service, Dublin.

Perrin, P.M., Roche, J.R., Barron, S.J. & Daly, O.H. (2014b) National Survey of Upland Habitats (Phase 2, 2011 – 2012), Site Report No. 7: Mount Brandon cSAC (000375), Co. Kerry (Revision). National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Perrin, P.M., Roche, J.R., Barron, S.J., Daly, O.H., Hodd, R.L. & Devaney, F.M. (2014c) National Survey of Upland Habitats (Phase 4, 2013-2014), Site Report No. 15: Slieve Mish Mountains cSAC (002185), Co. Kerry. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Perrin, P.M., Roche, J.R., Barron, S.J., Daly, O.H., Hodd, R.L. & Devaney, F.M. (2014d) National Survey of Upland Habitats (Phase 4, 2013-2014), Site Report No. 16: Caha Mountains cSAC (000093), Cos. Cork and Kerry. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Perrin, P.M., FitzPatrick, Ú. & Lynn, D. (2018) The Irish Vegetation Classification – an overview of

concepts, structure and tools. *Bulletin of the Chartered Institute of Ecology and Environmental Management – In Practice* **102**: 14–19.

Petruželová, J., Bojková, J., Hubáčková, L., Šorfová, V., Syrovátka, V. & Horsák, M. (2020) Factors explaining community contrast of Trichoptera assemblages at insular Western Carpathian spring fens to the adjacent headwaters. *International Review of Hydrobiology*, **105**: 20– 32. https://doi.org/10 .1002/iroh.201901987.

Plado, J., Sibul, I., Mustasaar, M., & Joeleht, A. (2011). Ground-penetrating radar study of the Rahivere peat bog, eastern Estonia. *Estonian Journal of Earth Sciences*, **60**: 31-42. https://doi:10.3176/earth.2011.1.03

Poland, J. & Clement, E. (2020) *The Vegetative Key to the British Flora. 2nd edition.* John Poland, Southampton.

Ratcliffe, D.A. (ed.) (1977) *A Nature Conservation Review.* Cambridge University Press, Cambridge.

Regan, E.C. & Anderson, R. (2004) Terrestrial Coleoptera recorded in Ireland, May 2003. *Bulletin of the Irish Biogeographical Society of Ireland*, **28**: 85-132.

Roche, J.R., Perrin, P.M., Barron, S.J. & Daly, O.H. (2014a) National Survey of Upland Habitats (Pilot Survey Phase, 2009 – 2010), Site Report No. 2: Corraun Plateau cSAC (000485), Co. Mayo (Revision). National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Roche, J.R., Perrin, P.M., Barron, S.J. & Daly, O.H. (2014b) National Survey of Upland Habitats (Pilot Survey Phase, 2009 – 2010), Site Report No. 3: Comeragh Mountains cSAC (001952) Co. Waterford (Revision). National Parks and Wildlife Service, Department of the Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Roche, J.R., Perrin, P.M., Barron, S.J. & Daly, O.H. (2014c) National Survey of Upland Habitats (Pilot Survey Phase, 2009 – 2010), Site Report No. 4: Carlingford Mountain cSAC (000453), Co. Louth (Revision). National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Roche, J.R., Perrin, P.M., Barron, S.J. & Daly, O.H. (2014d) National Survey of Upland Habitats (Phase 1, 2010 – 2011) Site Report No 1: Mweelrea, Sheeffry, Erriff Complex cSAC (001932) Co. Mayo (Revision). National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.

Roche, J.R., Perrin, P.M., Barron, S.J. & Daly, O.H. (2014e) National Survey of Upland Habitats (Phase 1, 2010 – 2011), Site Report No. 6: Croaghaun/Slievemore cSAC (001955), Co. Mayo (Revision). National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Roche, J.R., Perrin, P.M., Barron, S.J. & Daly, O.H. (2014f) National Survey of Upland Habitats (Phase 2, 2011 – 2012), Site Report No.9: Galtee Mountains cSAC (000646), Cos. Tipperary and Limerick (Revision). National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Rodwell, J.S. (ed.) (1991) *British Plant Communities. Volume 2. Mires and heath*. Cambridge University Press.

Rodwell, J.S. (ed.) (1995) *British Plant Communities. Volume 4. Aquatic communities, swamps and tall-herb fens*. Cambridge University Press.

Ronayne, C. & O'Connor, J.P. (2003) Distributional records of some Aculeata (Hymenoptera) collected in Ireland from 1980-2002. *Bulletin of the Irish Biogeographical Society of Ireland*, **27**: 227-254.

Rose, F. & O'Reilly, C. (2006) *The Wild Flower Key*, 2nd edition. Frederick Warne, UK.

Rosenberg, D.M., Danks, H.V. & Lehmkuhl, D.M. (1986) Importance of insects in environmental impact assessment. *Environmental Management*, **10**: 773–783.

Salmela, J., Autio, O. & Ilmonen, J. (2007) A survey on the nematoceran (Diptera) communities of southern Finnish wetlands. *Memoranda Societatis pro Fauna et Flora Fennica*, **83**: 33–47.

Šefferová Stanová, V., Šeffer, J. & Janák, M. (2008) Management of Natura 2000 habitats. 7230 Alkaline fens. European Commission Technical Report 2008 20/24.

Smith, G.F., O'Donoghue, P., O'Hora, K. & Delaney, E. (2011) *Best Practice Guidance for Habitat Survey and Mapping.* Heritage Council.

Smithers, C.N. & O'Connor, J.P. (1991) New Records of Psocoptera (Insecta) (Booklice, Barklice) from Ireland, including a species previously known from New Zealand. *Irish Naturalists' Journal*, **23**: 477-486.

Speight, M.C.D. (1982) *Acrocera globulus*, *Limnia paludicola* and *Sphaerophoria loewi*: insects new to Ireland. *Irish Naturalists' Journal*, **20**: 369-372.

Speight, M.C.D. (1983) *Cordilura aemula* & *Microprosopa pallidicauda* new to Ireland, *Trichopalpus fraternus* confirmed as an Irish Insect and other Irish records of Scathophagidae (Diptera). *Irish Naturalists' Journal*, **21**: 165-167.

Speight, M.C.D. (1986) *Asaphidion curtum*, *Dorylomorpha maculata*, *Selatosomus melancholicus* and *Syntormon miki*: insects new to Ireland. *Irish Naturalists' Journal*, **22**: 20-23.

Speight, M.C.D. (2002) An annotated list of the Syrphidae (Diptera) of Pollardstown Fen, Co. Kildare, Ireland. *Bulletin of the Irish Biogeographical Society*, **26**: 196-210.

Speight, M.C.D. (2014) Species accounts of European Syrphidae (Diptera), 2014. Syrph the Net, the database of European Syrphidae, vol.78, 321 pp., Syrph the Net publications, Dublin.

Speight, M.C.D. & Chandler, P. J. (1983) Irish Otitidae & Platystomatidae (Diptera) including a key to the genera known in Ireland and/or Great Britain. *Irish Naturalists' Journal*, **21**: 130-136.

Speight, M.C.D. & Cogan, B.H. (1979) *Acrometopia wahlbergi*, *Clusiodes caledonica* and *Stigmella catharticella*: insects new to Ireland. *Irish Naturalists' Journal*, **19**: 401-402.

Speight, M. & Gittings, T. (2020) Hoverflies (Syrphidae) of Ireland. National Biodiversity Data Centre, Ireland. https://maps.biodiversityireland.ie/Dataset/159. Accessed April 2020.

Speight, M.C.D. & Legrand, J. (1984) *Coenagrion lunulatum* (Odonata): Morphology of the female and notes on a second Irish colony. *Irish Naturalists' Journal*, **21**: 237-242.

Speight, M.C.D., Blackith, R.M. & de Courcy Williams, M. (1992) *Calliopum elisae*, *Hercostomus nanus*, *Psacadina verbekei*, *Systenus alpinus* and *Zabrachia tenella* (Diptera), insects new to Ireland. *Irish Naturalists' Journal*, **24**: 147-151.

Stace, C.A. (2019) *New Flora of the British Isles.* 4th Edition. C&M Floristics, Stowmarket, UK.

Štokmane, M. & Cera, I. (2018) Revision of the calcareous fen arachnofauna: habitat affinities of the fen inhabiting spiders. *ZooKeys*, **802**: 67–108. https://doi.org/10.3897/zookeys.802.26449

Štokmane, M., Spuņģis, V. & Cera, I. (2013) Spider (Arachnida: Araneae) species richness, community structure and ecological factors influencing spider diversity in the calcareous fens of Latvia. *Proceedings of the 54th International Scientific Conference of Daugavpils University*: 45–55.

Succow, M. (1988) LandschaftsoÈkologische Moorkunde. Gustav Fischer-Verlag, Jena, Germany.

Tempelman, D., Verdonschot, R.C.M. & Neu, P.J. (2013) *Limnephilus pati* O'Connor, 1980 (Trichoptera: Limnephilidae) new for Poland. *Lauterbornia*, **76**: 139-142.

Thuróczy, C. & O'Connor, J.P. (2009) Records of Irish Chalcidoidea (Hymenoptera) including thirteen species new to Ireland. *Irish Naturalists' Journal*, **30**: 123-126.

Van Helsdingen, P.J. (1993) Ecology and distribution of *Dolomedes* in Europe (Araneida: Dolomedidae). *Bollettino delle sedute della Accademia Gioenia di Scienze Naturali in Catania*, **26**: 181-187.

Van Helsdingen, P.J. (1996) The county distribution of Irish spiders, incorporating revised catalogue of the species. *Irish Naturalists' Journal*, **25**: 1-87, 89-92.

Van Helsdingen, P.J. (1997) The spiders (Araneida) of Pollardstown Fen, Co. Kildare, Ireland. *Irish Naturalists' Journal*, **25**: 396-404.

Van Helsdingen, P.J. (1998) The spider fauna of Scragh Bog in Co. Westmeath, Ireland (Arachnida: Araneae). *Zoologische Verhandelingen Leiden*, **323**: 407-415.

Van Wirdum, G. (1990) Vegetation and hydrology of floating rich-fens. Datawyse, Maastricht.

Wheeler, B.D. (1980) Plant communities of rich-fen systems in England and Wales. I. Introduction. Tall sedge and reed communities. *Journal of Ecology*, **68;** 365-395.

Wheeler, B.D., Shaw, S. & Tanner, K (2009a) A wetland framework for impact assessment at statutory sites in England and Wales. Integrated catchment science programme. Science report: SC030232. Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD.

Wheeler, B.D., Shaw, S. & Tanner, K (2009b) Wetland functional mechanisms: a synopsis of WETMECs. Science report: SC030232/SR2. Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD.

White, J. & Doyle, G.J. (1982) The vegetation of Ireland. A catalogue raisonné. In *Studies on Irish vegetation* (ed. J. White), pp. 289-368. Royal Dublin Society, Dublin.

Więcek, M., Martin, P. & Gąbka, M. (2013) Distribution patterns and environmental correlates of water mites (Hydrachnidia, Acari) in peatland microhabitats. *Experimental and Applied Acarology*, 61: 147-160. DOI 10.1007/s10493-013-9692-8.

Wisdom, R., Arroyo, J. & Bolger, T. (2011) A survey of the Oribatida and Mesostigmata (Acarina) of Irish peatlands. *Journal of the Irish Biogeographical Society*, **35**: 130-149.

Withers, P. (1992) A further occurrence of *Psectra diptera* (Burmeister) (Insecta, Neuroptera) in Ireland. *Irish Naturalists' Journal*, **24**: 79.

Withers, P. & O'Connor, J.P. (1992) A preliminary account of the Irish species of moth fly (Diptera: Psychodidae). *Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science*, **92B**: 61-77.

Woodrow, W. & McNicholas, D. (2014) *Surveys of possible Marsh Fritillary sites and habitats in Co Cavan and Co Leitrim – 2013*. Report to National Parks and Wildlife Service, Dublin.

Zapparoli, M. (2010) Centipedes in relic wetlands of north-eastern Italy: faunistic and ecological

remarks (Chilopoda). *Gortania Botanica, Zoologia*, **32**: 135-166.

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