# Enhanced Decommissioning, Rehabilitation and Restoration Scheme (EDRRS)

## Annual Monitoring and Verification Report
## EDRRS Year 2
## (April 2022 to March 2023)

# DOCUMENT CONTROL SHEET

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Bord na Móna would like to thank and acknowledge RPS Consultants for their input into this report and associated appendices and the provision of information in relation to the hydrogeological monitoring.

# Contents

**List of Abbreviations**

| | |
|---|---|
| AA | Appropriate Assessment |
| ARA | Annual Relative Abundance |
| BOCCI | Birds of Conservation Concern in Ireland |
| BTO | British Trust for Ornithology |
| CBS | Countryside Bird Survey |
| $CO_2$ | Carbon dioxide |
| $CH_4$ | Methane |
| DECC | Department of Environment, Climate and Communications |
| DIC | Dissolved inorganic carbon |
| DOC | Dissolved organic carbon |
| EDRRS | Enhanced Decommissioning, Rehabilitation and Restoration Scheme |
| EPA | Environmental Protection Agency |
| ETB | Education and Training Board |
| GHG | Greenhouse gas |
| GIS | Geographic Information System |
| GPP | Gross primary production |
| GPR | Ground Penetrating Radar |
| IPC | Integrated Pollution Control |
| IWeBS | Irish Wetland Bird Survey |
| LAI | Leaf Area Index |
| LiDAR | Light Detection and Ranging |
| $N_2O$ | Nitrous Oxide |
| NEE | Net Ecosystem Exchange |
| NIS | Natura Impact Statement |
| NPWS | National Parks and Wildlife Service |
| PAR | Photosynthetic Active Radiation |
| PCAS | Peatlands Climate Action Scheme |
| PE | Potential Evapotranspiration |
| PPFD | Photosynthetic Photon Flux Density |
| POC | Particulate organic carbon |

# 1. Executive Summary and Introduction

## 1.1 Executive Summary

This report addresses the monitoring and verification of the Enhanced Decommissioning, Rehabilitation and Restoration Scheme (EDRRS), also referred to as the Peatlands Climate Action Scheme (PCAS). This report covers the second year of the scheme, from April 2022 to March 2023, and in particular the rehabilitation of twenty bogs referred to in this report as Year 2 Bogs. The purpose of the monitoring on EDRRS is to quantify (where possible) the changes in the bog following the implementation of the rehabilitation measures. Eighteen bogs were rehabilitated in Year 1 as planned under the scheme with rehabilitation commencing on a further twenty bogs in Year 2. A total of eighty-two bogs are required to be rehabilitated under the scheme. Preparation and planning was carried out for Year 3 bogs during this period. Summary information on the various monitoring streams is set out in the report with more detailed bog by bog information and data provided in the Appendices.

### Hydrological Monitoring

The report outlines a summary of key hydrological findings to the end of March 2023 with the focus of the analysis on the Year 1 bogs where rehabilitation has been substantially completed by summer 2022. A network of monitoring wells (measuring water table levels) and piezometers (measuring hydraulic head at depth) have been installed across each of the Year 1, Year 2 and Year 3 bogs.

As set out in Section 2 of this report, analysis of water table responses across all Year 1 bogs reveals a widespread rise in water table levels in rehabilitated areas in line with expectations. However, this only provides a broad indication of the trend of water table levels. Indeed, these increases in water table levels are likely to be an underestimate of the response to rehabilitation, given the post-rehabilitation (Summer 2022) data includes several wells where measures were not fully complete. As further monitoring is completed, it will be possible to increase the confidence of these assessments and address the issue of under-estimating impact on water table levels.

Analysis of overall water table response for Year 2 bog does not indicate significant differences in water table levels between summer 2021 and summer 2022. This is likely to reflect the timing of rehabilitation measures, many of which were only implemented towards the end of summer 2022, during the prolonged dry spell of July and August 2022. Future iterations of the annual monitoring report will be able to provide increased confidence of the impact of rehabilitation on the Year 2 bogs.

### Biodiversity

This document reports on the additional terrestrial biodiversity monitoring carried out on Year 1 and Year 2 bogs for the period April 2022 to March 2023 inclusive, and on the surveys which were 'in scope' for these periods in respect of each individual bog.

The objectives of Biodiversity monitoring on EDRRS has been previously set out per target domain (Bord na Móna, 2023[1]) and are to quantify (where possible) the improvements in Biodiversity following the implementation of the rehabilitation measures. Objectives are summarised below in

[1] Bord na Móna (2023). Enhanced Decommissioning, Restoration and Rehabilitation Scheme (EDRRS) Annual Monitoring and Verification Report EDRRS Year 1 Bogs (Rehabilitation commenced in 2021). Bord na Móna, Leabeg, Co. Offaly.

respect of target domains, but we also refer readers to the above report in addition to other available reporting such as the EDRRS methodology paper (Bord na Móna, 2022) [2].

Details on the methods and materials in respect of the various monitoring techniques are provided in the present report and these cover the broad domains of habitats (habitat mapping and vegetation quadrats), birds (wintering and breeding) and invertebrates (pollinators). Summary tables are provided in the report and the appendices under each of these headings.

*Vegetation quadrats*

The general objective of quadrat monitoring is to '*Measure longer-term **finer scale** changes in vegetation following rehabilitation under the scheme' as outlined in other reporting such as the published EDRRS methodology paper*'.

In total, 74 permanent fixed monitoring quadrats are now installed across 14 of the subject bogs, with an average of 5 quadrats per bog. Two bogs have now had consecutive years of quadrat monitoring within the current reporting period. The permanent quadrats installed in 2021 reflected the baseline conditions pre-rehabilitation. These areas were dominated by dry bare peat (2021). Following a second year of monitoring at these fixed quadrats post-rehabilitation (2022), the areas were noted to have been transformed hydrologically, though not vegetatively, with significant cover (76-90% cover) of standing water noted in some quadrats following successful alteration in the water table. These areas still lacked any vegetation establishment, and more time is needed to record any changes in vegetation. However, based on ecological survey of the surface conditions, the recorded step change in water levels could be equated with rewettings. Where quadrats did not support areas of open water, these quadrats were similarly dominated by bare peat (91-100%) one year later (2022).

*Wintering Birds*

The general objective is to '*Establish quality of effects on relative abundance or proportion of species of conservation concern, following scheme implementation'*. A total of 15 bogs were surveyed for wintering wildfowl over the winter period 2022/23 with a summary table provided in Appendix D1. As the winter period 2022/23 constitutes the first winter of monitoring for 8 Year 2 Bogs it is too soon to establish any increase in species richness or abundance directly attributable to the scheme. Although 7 Year 1 Bogs now have 2 winters of data there is still little evidence of changes in range or abundance outside the expected influence of interannual variation, but we would note that there was some evidence of positive quality changes in species range and abundance at 1 bog (Derrycolumb).

*Breeding Birds*

The general objective is to '*Establish quality of effects on relative abundance or proportion of species of conservation concern, following scheme implementation as outlined in other reporting such as the published EDRRS methodology paper'*. A total of 81 species have now been recorded, with the addition of baseline data from 6 further bogs for which 2022 comprised the first year of monitoring, an increase of 8 species (from a total of 21 bogs). To investigate species richness, a transect methodology is being utilised to generate a representative sample of breeding birds at each study location. Of the 81 species of bird recorded, 79 have been assigned a BOCCI4 conservation status of either Green, Amber or Red (Gilbert et al. 2021). For those assigned a BOCCI4 conservation status, they comprise 56% Green listed

[2] Bord na Móna (2022). Methodology Paper for the Enhanced Decommissioning, Rehabilitation and Restoration on Bord na Móna Peatlands – Preliminary Study. Bord na Móna, Leabeg, Co. Offaly. Available online at:

https://www.bnmpcas.ie/wp-content/uploads/sites/18/2022/11/Methodology%20Report%20v19%20For%20issue.pdf species, 26% Amber listed species and 16% Red listed species. Species benefitting from the creation of wetlands continue to be from the same suite as identified in the previous reporting period namely Black-headed Gull *Chroicocephalus ridibundus*, Ringed Plover *Charadrius hiaticula*, Little Grebe *Tachybaptus ruficollis* and Lesser black-backed Gull *Larus fuscus*. See Section 3.4 for further information.

*Pollinators*

The general objective is to '*Show change in species abundance and diversity post-restoration following vegetation establishment/change'*. The addition of Year 2 Bogs has resulted in an increased baseline which now includes 14 sites compared to 11 in Year 1 of the scheme. On average (across all bogs to date) 7 species of Butterfly were recorded per study site (range = 1-12). 9 species of Bee and 5 species of Moth have now been recorded from transects with the addition of Scheme Year 2 Bogs to baseline data. Whilst affinities with open water are generally limited in respect of butterfly species; some species recorded such as Orange Tip *Anthocharis cardamines*, Wall Brown *Lasiommata megera* and Small Copper *Lycaena phlaeas* are associated with cutover bog habitats, including wetlands, (Regan *et al.* 2010[3]) and may be benefitting from pioneering vegetation which occurs in mosaic with areas of newly created shallow, open water.

Similar to last year, it is known that some of the bogs for which data is presented have additional species of Butterfly which have not to date been recorded 'on transect'. The present monitoring is effectively the first study to potentially look at Pollinator diversity in this scenario and it is hoped the evidence base produced will demonstrate benefits to Pollinators post rehabilitation/commencement of a return to a naturally functioning ecosystem, including the spread to rehabilitated areas of other species known to already occur at subject sites.

## Carbon

As set out in Section 4 of this report, research to date found that industrially extracted bogs are large sources of (gaseous and dissolved?) Carbon Dioxide ($CO_2$), Disolved Organic Carbon (DOC) and Particulate Organic Carbon (POC) while Methane ($CH_4$) Nitrous Oxide ($N_2O$) and Dissolved Inorganic Carbon (DIC) are usually found to be insignificant except in very shallow peat. In rewetted bogs, the emission of $CO_2$, DOC and POC is reduced due to the high-water table levels while due to anaerobic conditions, $CH_4$ emissions increase. Given these dynamics, the aim of this monitoring and verification program is to quantify the most significant Green House Gases (GHGs) that are associated with industrially extracted bogs (bare peat) and to quantify the impact of rewetting on GHGs emanating from peatlands.

The carbon monitoring and verification program addresses these requirements via the establishment of the following four monitoring campaigns to address the variation of GHG emissions in current and future habitats:

1. Chamber measurement program, designed to estimate emission factors for $CO_2$ and $CH_4$ from 22 different vegetation communities.
2. Establishment of two Eddy Covariance towers.
3. Installation of flumes and continuous DOC and POC measurements
4. Monitoring of DOC and POC grab samples across EDRRS bogs.

[3] Regan, E.C., Nelson, B., Aldwell, B., Bertrand, C., Bond, K., Harding, J., Nash, D., Nixon, D., & Wilson, C.J. (2010) Ireland Red List No. 4 – Butterflies. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Ireland.

Sites for chamber monitoring were selected based on geospatial analysis and site inspection to ensure that they had the correct vegetation and peat depth, and that piezometers were in proximity. Sites which did not have piezometers installed were added to the piezometer installation programme. Closed static chamber measurements will be carried out at these locations at fortnightly intervals.

Two Eddy Covariance flux towers have been installed, measuring emissions from peatlands within a c. 250 metre radius. Two flumes have been installed at one of the flux tower sites to measure aquatic carbon losses with two additional flumes to be installed at separate bogs.

### Surface Water Monitoring

During this reporting period, over 4,000 monthly samples were obtained from suitable sampling locations at silt pond outlets (SW's). An observed downward trend in suspended solids post completion of the rehabilitation was observed (initially) on all Scheme Year 1 and Scheme Year 2 bogs.

. Total Ammonia (N) is produced through natural microbial action when organic compounds decompose in peatlands during anaerobic conditions; these are then mobilised during drainage and associated peat extraction. Ammonia concentrations in water samples across all Year 1 and 2 bogs had mixed trends with no obvious trends.

As monitoring of these bogs continues in 2023 and on into the next monitoring cycle, any identifiable trends post rehabilitation will be tracked to validate expected improving trends and any establishing trajectories in water quality from these bogs.

### Flow Monitoring

Flow monitoring of surface water discharge from the peatlands is not an integral part of the monitoring programme for EDRRS bogs, however some flow monitoring of bogs is underway and includes the provision of flumes, monitoring of flow using probes and the monitoring of flow using composite samplers.

### Aerial Imagery/ LiDAR

Post rehabilitation aerial imagery demonstrates the location of peat drain blocks, rehabilitated cells and also gives an indication of the standing water on the bog. The LiDAR provides updated elevations across each of the bogs, and also maps berm and bunded cell heights. This data has been captured for the Year 1 bogs and it is the intention to capture the same for the Year 2 bogs in Year 4.

### Archaeology

In advance of the commencement of the rehabilitation, Bord na Móna engaged a Project Archaeologist to undertake a desk-based study of all available surveys and excavations on the EDRRS bogs in question. The main recommendations from these assessments were that these locations should be preserved *in situ* and be avoided by the rehabilitation works with a 20m buffer zone. In addition, should any previously unknown archaeological material be uncovered during the rehabilitation works, it should also be avoided and reported to the Bord na Móna Archaeological Liaison Officer and the National Museum of Ireland.

## Interactions between Ecology, Hydrology and Carbon

The main objective of the EDRRS monitoring programme is to monitor and verify trajectories of change within defined 'Core Topics' such as Carbon, Hydrology, Biodiversity, Water Quality etc in response to the proposed re-wetting or rehabilitation, with a view towards a defined Climate Outcome. As peat is re-wetted, some broad domains within these core areas can respond quickly to the new environment, whilst others may be slower or require more time before measurable changes attributable to the implemented measures can be evaluated.

From an Ecological perspective, the monitoring programme will aim to investigate change in ecosystem functioning and the trajectory of the cutaway bog towards the development of a naturally functioning peatland ecosystem. However, this also interacts with other Scheme objectives such as reductions in Carbon emissions to water, and also Hydrological objectives. Generally, a step change in water table height commensurate with creating conditions optimal for climate impact.

Results across respective Biodiversity domains suggest that vegetation succession for instance can be slow, and not immediately detectable. It is clear from the Vegetation Quadrat data that vegetation quadrats are a useful proxy for detecting changes in water table, based on recorded increases between years in percentage cover of water (percentage cover being the amount of standing water estimated as covering the surface of the ground enclosed within each sample 4m by 4m quadrat). On this basis, as vegetation succession appears to be slow, data would support an assertion that a better surrogate for 'success' would be achieved or delivered target levels in water table height (measured with piezometers) as opposed to vegetation cover, at least within the current proposed lifetime of the Scheme.

In regard to interactions with Carbon the slower rate of succession as evidenced by vegetation monitoring data suggests it is too soon currently to consider the application of derived emission factor estimates for instance to the data that has been collected, and it may well be nearer the end of the scheme or beyond it before vegetation on re-wetted bogs begins to align with the climax vegetation communities for which emission factors are being derived.

## Lessons Learned/ Initial Observations

Experience was gained and lessons were learned as the monitoring and verification of the EDRRS scheme was implemented and the report lists some of these learnings. Some lessons learned include the value of a piezometer dashboard, the importance of selecting accessible monitoring locations, the scale and challenges of the monitoring required and the value of new technologies.

Significant time and resources have been inputted into the monitoring of the Year 1 and Year 2 bogs and the data collected will be utilised to verify the benefits of the scheme. While these benefits and their verification will take time to determine, the data collected on an annual basis can be used to assess the trajectory of each bog in terms of hydroogy, carbon emissions, biodiversity benefits and surface water quality.

Further data over the lifetime of the scheme (and if possible, beyond the scheme) will continue to provide information in this regard, in particular as the availability of sites with both climate action measures and other effective conservation measures becomes more important at a National and International level.

## 1.2 Introduction

This Annual Monitoring and Verification Report for the Enhanced Decommissioning, Rehabilitation and Restoration Scheme (EDRRS), also referred to as the Peatlands Climate Action Scheme (PCAS), is prepared in accordance with Clause 11.6 of the EDRRS Regulatory Controls which states the following:

> *"Within six months of the end of each year that the Scheme is in operation, the Operator will submit an annual report on the Scheme to both DECC and NPWS/DHLGH. This report will include data on the Greenhouse Gas and biodiversity indicators agreed for the Scheme by all parties, on any future indicators agreed for the Scheme, the area restored under each Enhanced Rehabilitation Bog Plan, and the overall area restored in the year in question*."

In addition, Clause 9.2 of the EDRRS Funding Agreement states the following:

> *"An annual report prepared by BNM in respect of each calendar year in which the Agreement subsists shall be submitted to the Minister by 30th September of the following year ("the Annual Report"). The Annual Report shall detail the work done to further the aims and objectives and deliver the Scheme outcomes and outputs. For the avoidance of doubt the first calendar year end shall not be before the 31st of December 2021."*

This report addresses the monitoring and verification of Year 2 of the scheme and should be read in conjunction with the EDRRS Annual Report - Year 2, which details the Rehabilitation and Decommissioning carried out and other aspects of the scheme, and the *Methodology Paper for the Enhanced Decommisioning, Rehabilitation and Restoration Scheme – Preliminary Study.*

Apart from initial trials, rehabilitation of Bord na Móna bogs under EDRRS commenced in April 2021 and rehabilitation was carried out on eighteen bogs from the launch of the scheme to the end March 2022, referred to as Year 1 bogs. This report covers the second year of the scheme and in particular the rehabilitation of an additional twenty bogs referred to in this report as Year 2 Bogs.

The Bord na Móna financial year runs from April to March and the first year of EDRRS is considered to run from the commencement of the scheme to March 2022. This report covers the monitoring and verification carried out in the second year of the scheme from April 2022 to March 2023.

The Bord na Móna website and other documentation refers to this scheme as the Peatlands Climate Action Scheme (PCAS). However, EDRRS will be used to describe this scheme throughout this document.

The EDRRS Year 1 and Year 2 bogs are listed in tables 1.1 and 1.2 below.

*Table 1.1 EDRRS Year 1 Bogs*

| Bog Unit | County |
|---|---|
| Belmont | Offaly |
| Garryduff | Galway |
| Kellysgrove | Galway |
| Kilmacshane | Galway |
| Boora | Offaly |
| Derries | Offaly |
| Oughter | Offaly |
| Pollagh | Offaly |
| Turraun | Offaly |
| Castlegar | Galway |
| Cavemount | Offaly |
| Clonad | Offaly |
| Esker | Offaly |
| Mountlucas | Offaly |
| Ummeras | Offaly / Kildare |
| Derrycashel | Roscommon |
| Derrycolumb | Longford |
| Edera | Longford |

*Table 1.2 EDRRS Year 2 Bogs*

| Bog Unit | County |
|---|---|
| Bunahinly | Westmeath |
| Clooneeny | Longford |
| Killaranny | Offaly |
| Begnagh | Longford |
| Carranstown | Meath/ Westmeath |
| Derrinboy | Offaly |
| Prosperous | Kildare |
| Lodge | Kildare |
| Derraghan | Longford |
| Clooncreen | Offaly |
| Timahoe South | Kildare |
| Bloomhill | Offaly |
| Derryfadda | Galway |
| Glenlough | Longford / Westmeath |
| Noggusboy | Offaly |
| Derrybrat | Offaly |
| Knappogue | Longford |
| Ballycon | Offaly |
| Blackwater | Offaly |
| Clooniff | Roscommon |

## 1.3 Purpose of EDRRS Monitoring

The purpose of the monitoring on EDRRS is to quantify (where possible) the changes in the bog following the implementation of the rehabilitation measures. This is done by developing a baseline, where possible, monitoring various parameters pertaining to hydrology, ecology and carbon emissions during the rehab implementation and post – rehabilitation. In some cases, observations made during the initial characterisation of bogs will inform the rehabilitation design for subsequent bogs.

It should be noted however that many of the parameters being monitored such as elements of biodiversity - notably habitats and/or vegetation succession - may show little if any change over the lifetime of the scheme and further monitoring extending past the lifetime of EDRRS will be required to fully determine the trajectory of the bogs.

## 1.4 Description of the EDRRS Monitoring

The monitoring carried out as part of EDRRS is set out below:

1. Hydrological Monitoring
2. Biodiversity
3. Carbon Flux
4. Surface water Quality
5. Flow Monitoring
6. Archaeology (by National Museum of Ireland)
7. Aerial Imagery / LiDAR

Summary information on the various monitoring streams is set out below with more detailed bog by bog information and data provided in the Appendices.

## 1.5 Research Projects

A number of research projects are currently being carried out on Bord na Móna bogs that will supplement and / or complement the EDRRS monitoring programme. These projects, many of which are funded from a variety of sources including the Environmental Protection Agency (EPA), iCRAG and Science Foundation Ireland, are in the areas of hydrogeology, hydrology, biodiversity, carbon emissions, and peatland mapping, among others. These projects are supported by third level institutions including Trinity College Dublin, University of Galway, University College Dublin, University of Limerick and include the SmartBog, RePeat, WaterPeat, WetPeat, Peat Hub and Swamp projects.

Bord na Móna have endeavored to facilitate these and other research projects by providing information and facilitating access to our bogs as requested.

# 2. Hydrological Monitoring

## 2.1 Monitoring regime

Hydrological conditions are one of the most important drivers of ecological functioning of peatlands. A core objective of the Enhanced Decommissioning, Rehabilitation and Restoration Scheme is to improve hydrological conditions to reduce carbon emissions, and where feasible establish conditions suitable for the development of peat-forming vegetation types. The following section outlines a summary of key hydrological findings covering the period to the end of March 2023. The focus of current analysis is on the Year 1 (FY22) bogs where rehabilitation has been substantially complete by summer 2022.

Monitoring of baseline water table levels (i.e., prior to implementation of rehabilitation measures) and water table levels post-implementation of rehabilitation measures provides a means to assess the impact of restoration/rehabilitation measures. However, it is important to ensure that appropriate baseline and post-restoration periods are compared to ensure analysis is reliable. A common approach is to assess the changes in water table levels over a hydrological year (1st October – 30th September) or across a summer period when rates of evapotranspiration are typically greatest (1st April – 30th September). In the case of EDRRS, comparison of summer periods proves most suitable, since the constraints of the scheme does not typically permit baseline monitoring over a full hydrological year prior to restoration/rehabilitation being implemented. Additionally, research on Irish raised bogs has shown that summer water levels, are the key driver for ecological processes (Cushnan, 2017). While comparisons over a single summer period can provide an indication of the trajectory of water table levels, it is important to highlight that variations in meteorological conditions between summer periods, as well as timing of implementation of restoration/rehabilitation measures has an influence on water tables, making interpretation over short-term difficult. However, as the scheme progresses the confidence in assessment of results can improve.

A network of monitoring wells (measuring water table levels) and piezometers (measuring hydraulic head at the base of the peat) have been installed across each of the Year 1 (FY22), Year 2 (FY23) and Year 3 (FY24) bogs. A subset of the locations has also been instrumented with automated data loggers, recording groundwater levels at hourly intervals. For the Year 1 (FY22) bogs, data collected to the end of March 2023 includes a baseline summer (summer 2021) and post-restoration summer (summer 2022).[4] Similarly, a partial baseline summer is available for the Year 2 (FY23) bogs (summer 2021) and post-rehabilitation summer (summer 2022). Only a partial baseline summer dataset is available for the Year 3 (FY24) bogs. Therefore, there is no reporting of changes in water table levels at these bogs. Further details of the water table levels at each of the monitoring locations can be found on the hydrological monitoring dashboard.

Monitoring locations were selected to meet a range of criteria, including:

a) Collect baseline data on the hydrological setting of each site to inform rehabilitation design and establish appropriate target rehabilitation measures (through improved characterisation of hydrological conditions).

b) Collect data prior to, during and post-rehabilitation to assist in determining the impact of specific rehabilitation measures on groundwater levels and flow direction within the bog (to inform future rehabilitation measure design).

[4] Note: In some bogs rehabilitation had started within the baseline period

c) Collect data prior to, during and post-rehabilitation which can be extrapolated across representative sections of the site to ensure that the site is on the correct anticipated trajectory.

The hydrological monitoring network has been designed to consider several key factors including rehabilitation measure, peat thickness and anticipated water levels post-rehabilitation, while also ensuring adequate spatial coverage across the site to assist in characterising the hydrological profile in transects across each bog. Loggers have been targeted towards locations where the measures represent areas with larger footprints, while also targeting specific features of interest (e.g., mineral mounds or targeted placement in areas anticipated to become wetlands).

Several practical considerations have also been included in the decision-making process, including the ability to access and undertake routine monitoring into the future and targeting monitoring locations in-combination with ecological quadrats and associated monitoring of greenhouse gas emissions. As a result, most of the monitoring points are located adjacent to high fields, or slightly more elevated areas within bunded cells. This should be taken into account when interpreting results as in some instances the water table level may be slightly deeper than target conditions at the monitoring location, yet the wider area may have ideal target conditions. This is particularly relevant for wetland areas, but also relevant to some bunded areas. Therefore, analysis focuses on the increase in water table height as a key parameter. This is important as research by Evans et al. (2021) highlights that water table levels are the key control on greenhouse gas emissions from peatlands. Indeed, the authors report that, for every 10cm increase in the mean annual effective water table level, the net warming impact of CO2+CH4 emissions (based on 100 year Global Warming Potentials) will reduce by at least 3t CO2e ha-1 yr-1, until the water table is within 30cm of the ground surface. Increasing the water table height further continues to have a net cooling impact until the mean annual effective water table level is within 10cm of the ground surface.

While manual monitoring takes place at all wells installed across the scheme, it is important to highlight that, in wells that do not have loggers installed, data is only collected once in summer and once in winter prior to rehabilitation and then repeated a minimum of once after rehabilitation. Therefore, while the data is useful in baseline characterisation and reviewing the impact of measures at individual locations in combination with site-specific logger data, the manual data alone is not of sufficient resolution to carry out any statistical analysis (since baseline and post-rehabilitation measurements may be taken during very different meteorological conditions). Research (Cushnan, 2017) has shown that manual measurements collected at intervals greater than 2 weeks start to show inaccuracies, when compared that obtained through logger data. As a result, the focus of this high level review of the impact of rehabilitation measures is on analysis of the logger data. As further data becomes available in future years, the confidence in the assessment will increase further.

The following key water table statistics were calculated for summer periods:

- **Summer D90 (S-D90)** = water table level, measured in centimetres relative to ground surface, that is equalled or exceeded for 90% of the relevant summer monitoring period.
- **Summer Mean (S-Mean)** = average water table during the relevant summer monitoring period.
- **Summer Median (S-Med)** = water table equalled or exceeded for 50% of the relevant summer monitoring period.

Comparison of each of these key statistics between baseline periods and post-restoration periods provides a way to assess changes in water table characteristics.

## 2.2 Meteorological conditions

As outlined previously, meteorological conditions have a strong influence on water table dynamics. Therefore, direct comparison of water table statistics from two summer periods needs to consider how these conditions varied and how this may have influenced depth to water table. To address this issue, metrological records from Met Éireann weather stations at Mullingar, Co. Westmeath and Gurteen, Co Tipperary are presented in Figures 2.1 and 2.2 below. These graphs illustrate monthly rates of effective rainfall for 2021 and 2022, based on monthly total rainfall minus monthly rates of potential evapotranspiration (PE). PE has been calculated by Met Éireann using the Penman/Monteith formulae (for grass). In addition, the long-term average monthly rate of effective rainfall is presented for Mullingar (long-term PE data is not available for Gurteen) to provide a comparison with data from summer 2021 and summer 2022.

At Mullingar, there was a 47mm deficit in effective rainfall across the entire summer period in (April - September) in 2022, which was 99mm lower than the recorded long- term (30 year) climatic average. This contrasts with summer 2021 when there was a surplus rate of effective rainfall of 17mm (36mm lower than the long-term average). While summer 2021 had the largest monthly effective rainfall deficit (-67mm in June 2021), summer 2022 had two large monthly deficits in July (-53mm) and August (-48mm). Overall, the data highlights that summer 2022 was a drier summer period, with larger declines in water table levels anticipated compared to summer 2021.

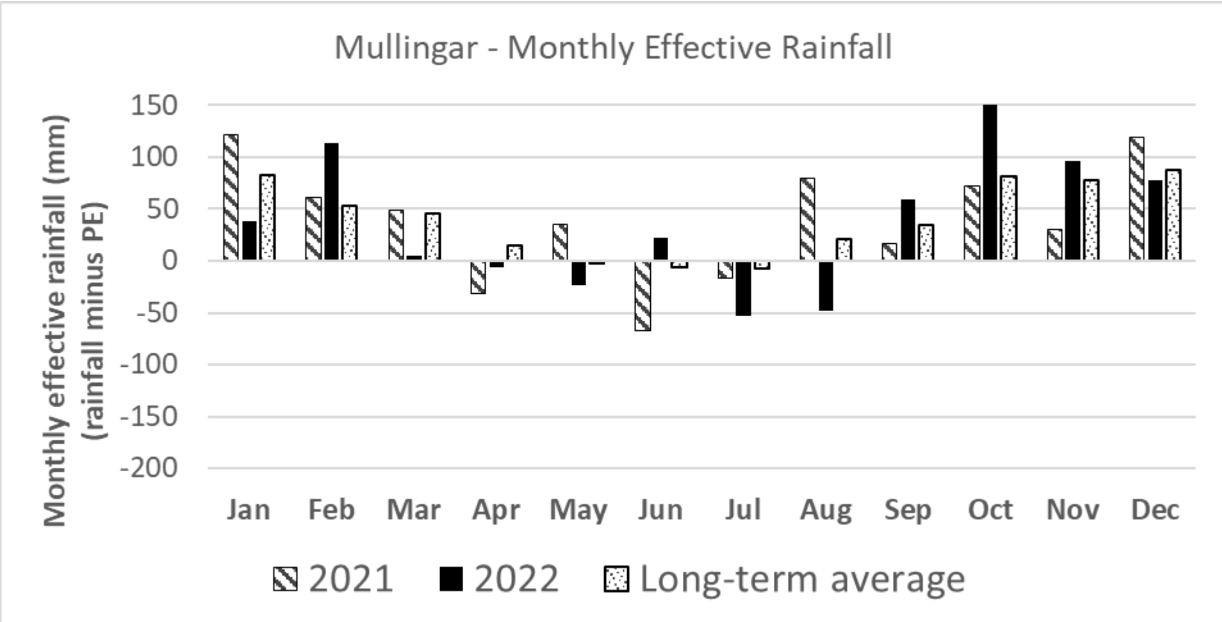


*Figure 2.1: Monthly rates of effective rainfall (rainfall minus potential evapotranspiration) at Mullingar weather station*

At Gurteen, there was a 67mm deficit in effective rainfall across the entire summer period (April - September) in 2022 which was similar to summer 2021 (64mm deficit). However, while summer 2021 had the largest monthly effective rainfall deficit (-61.9mm in June 2021), summer 2022 had two large monthly deficits in July (-54mm) and August (-61.5mm). Overall, the data from Gurteen supports the findings from Mullingar which suggests that summer 2022 was a slightly drier summer period, with larger declines in water table levels anticipated compared to summer 2021.

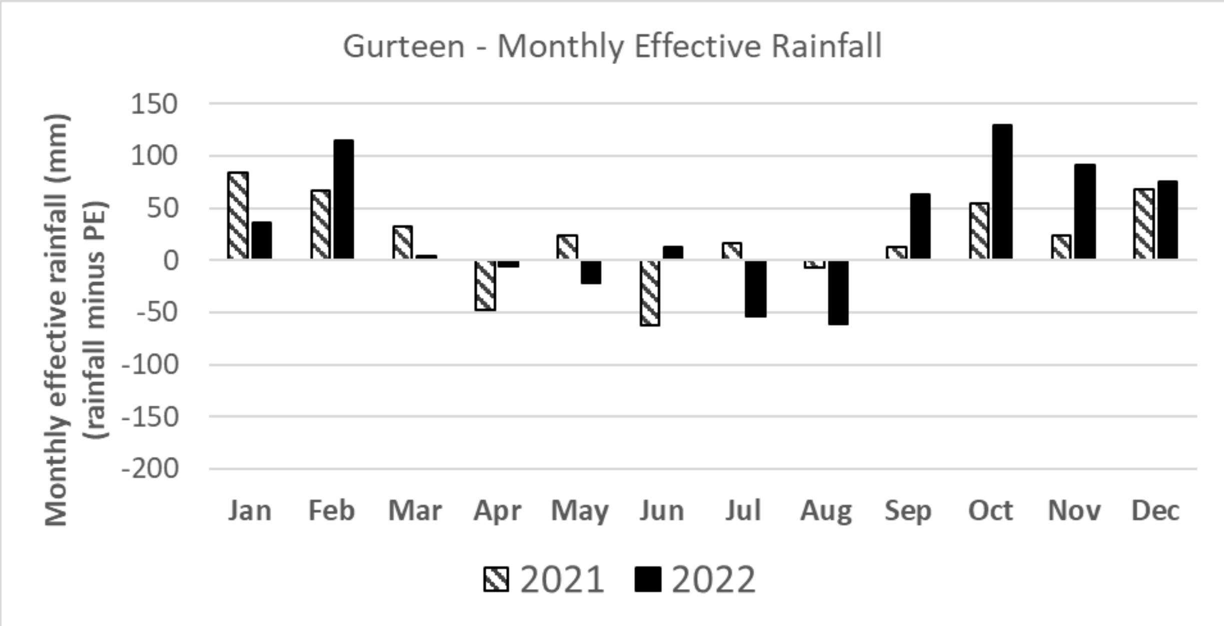


*Figure 2.2: Monthly rates of effective rainfall (rainfall minus potential evapotranspiration) at Gurteen weather station*

## 2.3 Year 1 (FY22) Bogs: Interpretation of Monitoring

Analysis of water table responses across all Year 1 (FY22) bogs reveals a widespread increase in water table height. All key water table statistics have increased between summer 2021 and summer 2022, with median increases in S-Med, S-Mean and S-D90 of 12cm, 13cm and 12cm respectively, despite the generally drier weather. However, this only provides a broad indication of the trend of water table levels. Indeed, these increases in water table levels are likely to be an underestimate of the response to rehabilitation, given the post-rehabilitation (summer 2022) data includes several wells where measures were not fully complete. As further monitoring is completed, it will be possible to increase the confidence of these assessments and address the issue of under-estimating change on water table levels. This will be particularly evident following the completion of analysis of summer 2023 data which will be available for the Year 1 (FY22) bogs after the next round of monitoring (scheduled for summer 2024).

Analysis of changes in S-Med levels considering peat thickness reveals widespread increases in water table height regardless of peat thickness. Small, yet significant increases are apparent at locations where very deep peat occurs, including some high bog areas, where peat thickness exceeds 6m. These small increases are likely to result in areas of sub-marginal vegetation developing into sub-central vegetation types. Relatively small increases have been reported in areas of very shallow peat (<50cm), although many of these areas are likely to correspond to wetland areas where final measures have not yet been implemented. As further data becomes available it will be possible to carry out enhanced analysis of the wider environmental variables and identify whether there are trends associated with parameters including peat thickness, substrate type and rehabilitation measure type.

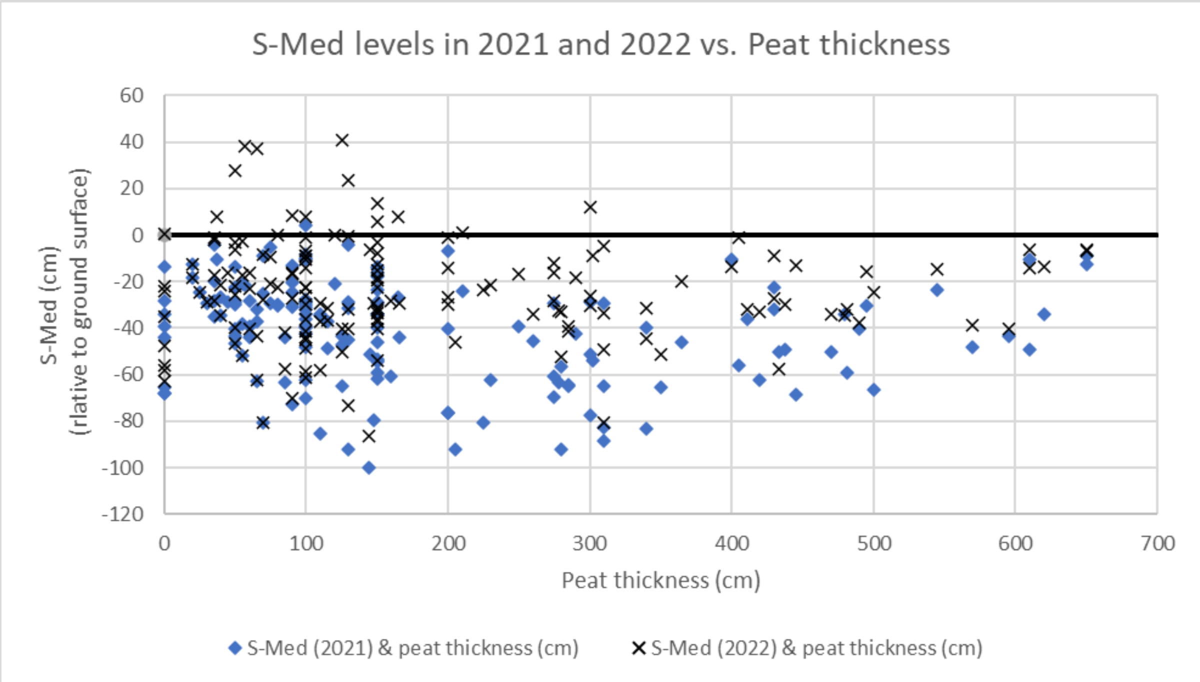


*Figure 2.3: S-Med levels and peat thickness for 2021 and 2022. Note the general shift towards higher water table levels.*

To provide a clearer indication of responses at Year 1 (FY22) sites a selection of monitoring wells were identified where a range of rehabilitation measures have been fully implemented. This comprises a sample of Year 1 (FY22) monitoring wells, covering a range of rehabilitation types, where it has been confirmed that rehabilitation measures were fully completed in summer 2022. As a result, comparisons of water table levels between summer 2021 and summer 2022 for these locations is considered to give a clearer representation of the initial impact of rehabilitation types. In some cases, the measures may not have been complete until mid-2022, therefore, this data should be used to understand the trajectory of water table levels with monitoring in future years providing a better understanding of hydrological impacts of rehabilitation.

At the selected wells, all key water table statistics, where measures are fully complete have increased between summer 2021 and summer 2022, with **median increases in S-Med, S-Mean and S-D90 of 24cm, 23cm and 19cm respectively (Figure 2.4)**. At these wells, located in areas where measures have been completed, median S-Med levels have increased to within 16cm of the ground level. These increases in water table further highlight that the overall data is likely to underestimate the actual impact of restoration.

Types of Rehabilitation Measures and Water Table Height

**Deep Peat**

The largest increases in water table height were associated with deep peat measures, which resulted in **median increases in S-Med, S-Mean and S-D90 of 21cm, 19cm and 16cm respectively at wells where deep peat measures were implemented (Figure 2.5)**. At the selected wells where deep peat measures were applied, median S-Med levels across areas with deep peat measures was increased to within 15cm of the ground surface.

**Wetland**

Areas where wetland measures were applied show the second greatest increase in water table levels. **Median increases in S-Med, S-Mean and S-D90 were 16cm, 12cm and 8cm respectively at locations where wetland measures were implemented (Figure 2.7)**. Median S-Med levels across selected wells where wetland measures were applied were increased to within 21cm of ground level.

**Dry Cutover**

Baseline water tables were lower in areas where dry cutaway measures were applied, with increases in water table levels proving less than those observed at locations where deep peat measures were applied. **Median increases in S-Med, S-Mean and S-D90 were 3cm, 4cm and 13cm respectively at locations where dry cutaway measures were implemented (Figure 2.6).** Median S-Med levels across selected wells where dry cutaway measures were applied were increased to within 44cm of ground level.

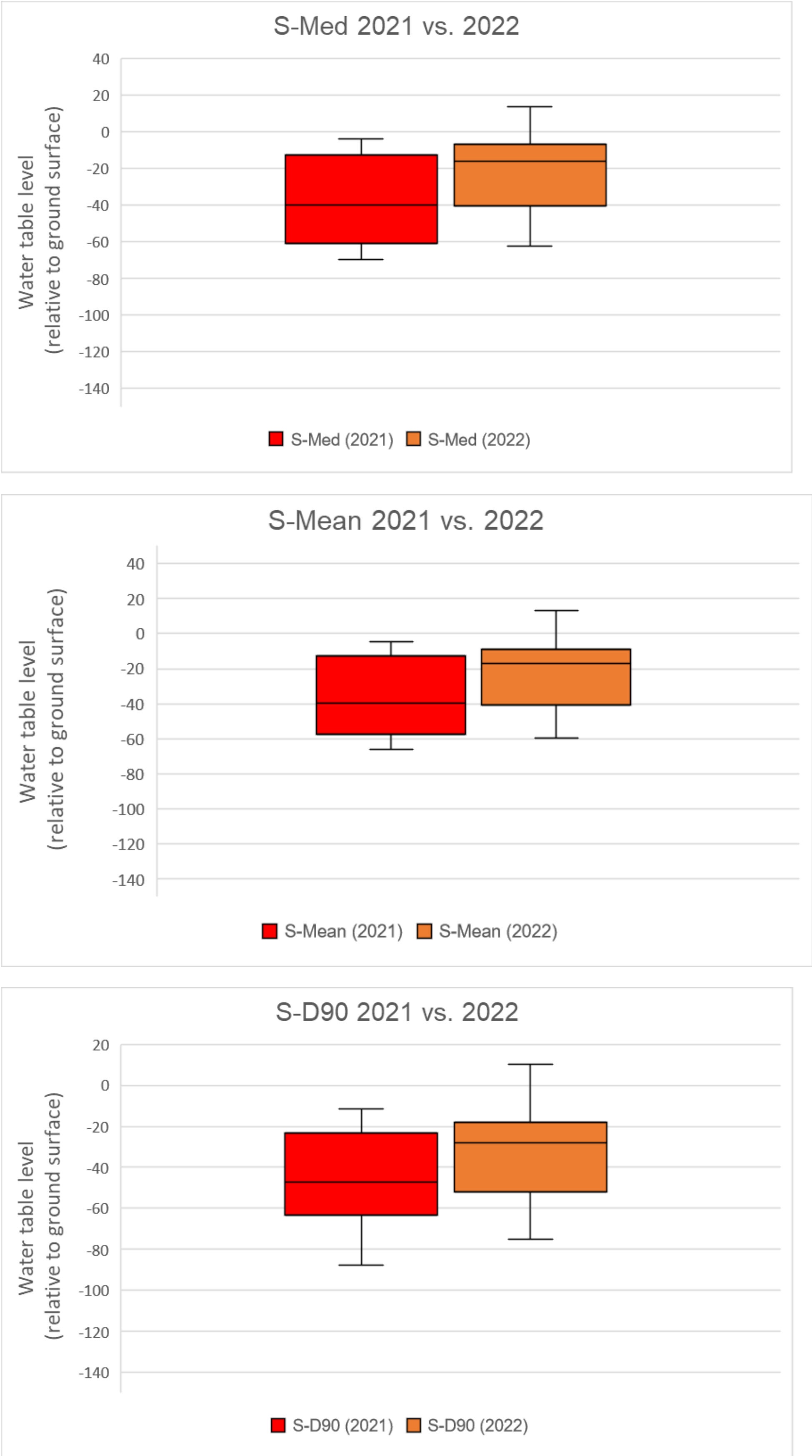


*Figure 2.4: Overall comparison of water table levels between summer 2021 and summer 2022 for sites where rehabilitation measures have been implemented (sample size 24).*

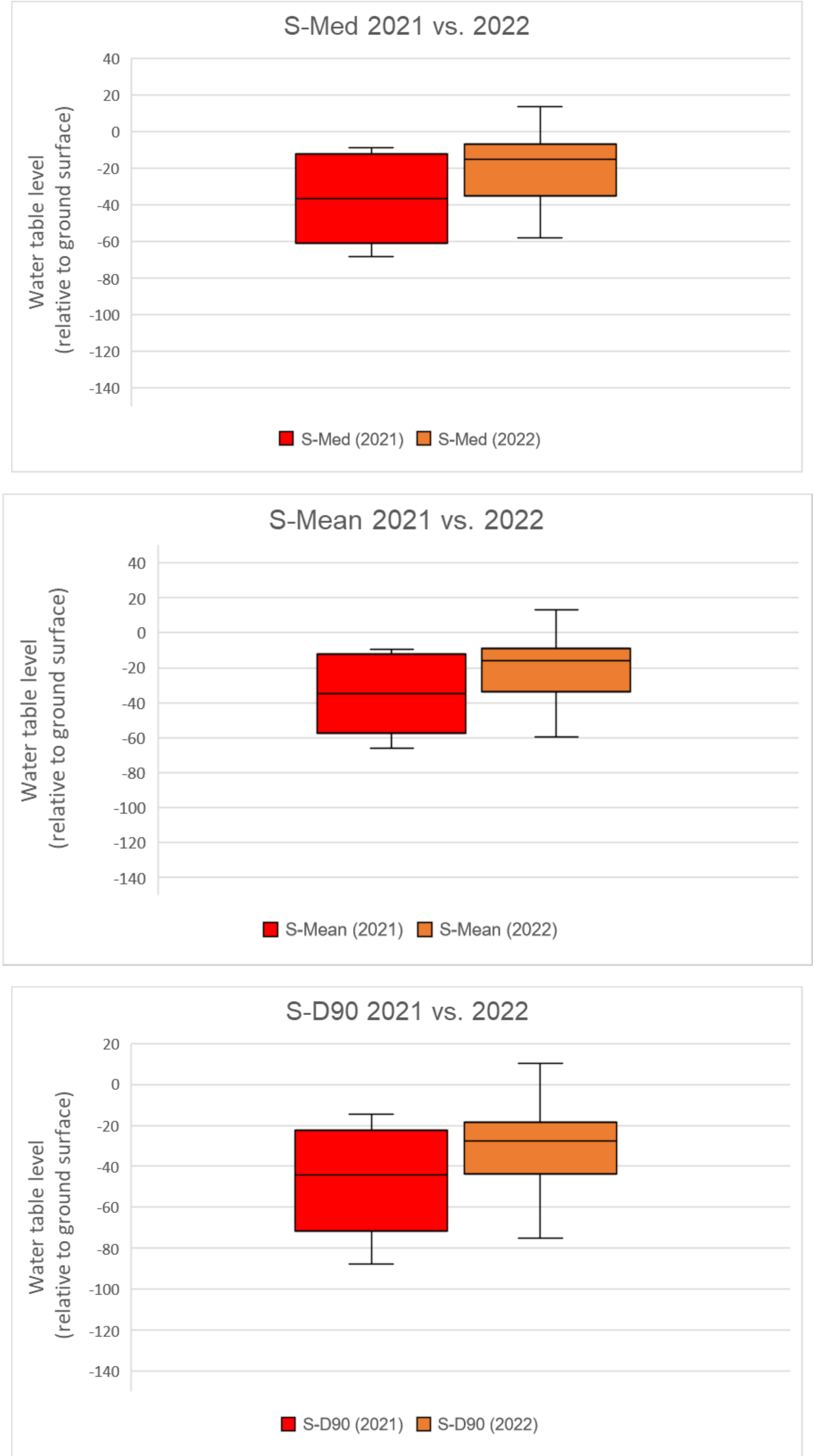


*Figure 2.5: Comparison of water table levels between summer 2021 and summer 2022 where deep peat rehabilitation measures have been implemented (sample size 14).*

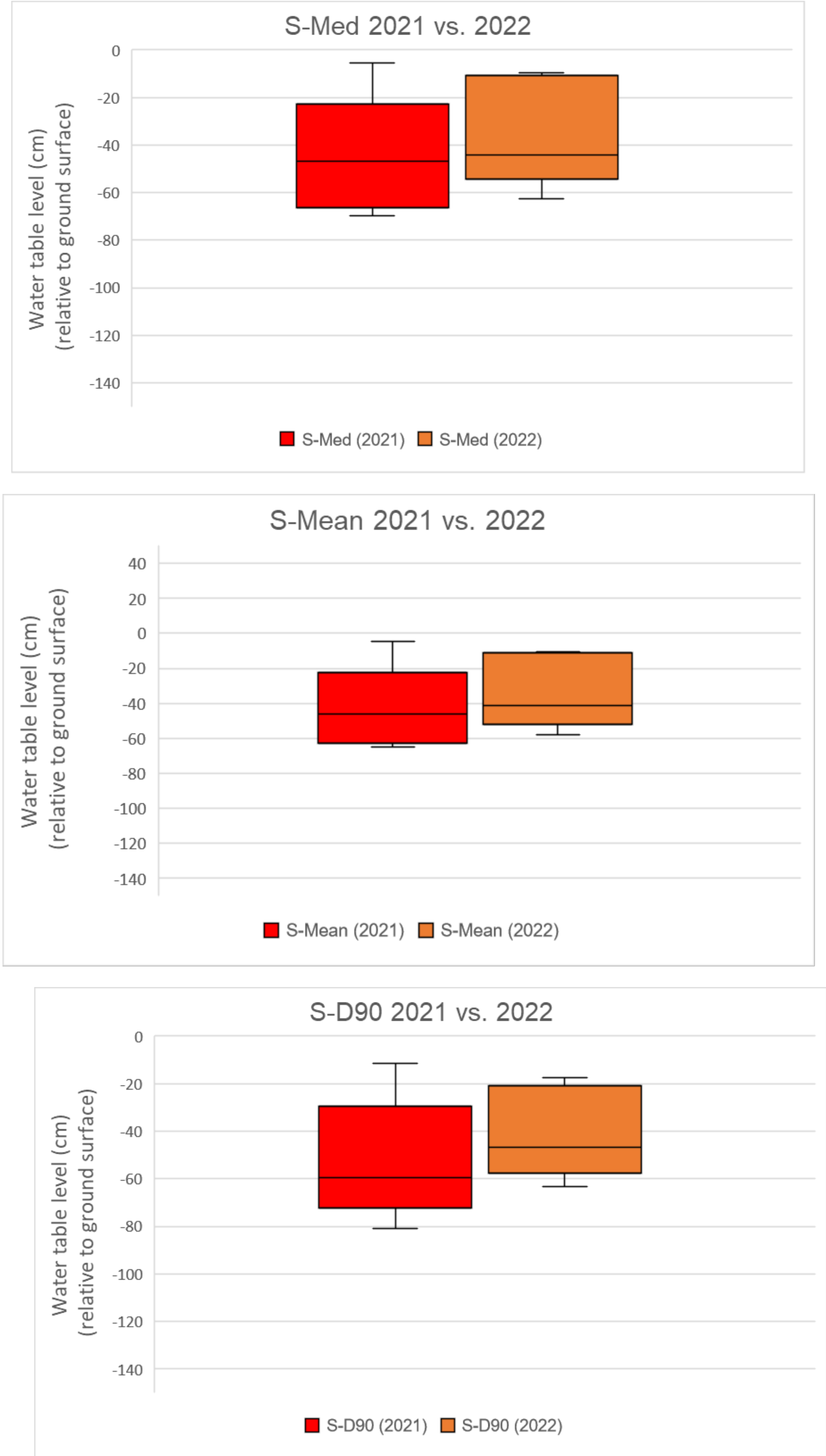


*Figure 2.6: Comparison of water table levels between summer 2021 and summer 2022 where dry cutaway rehabilitation measures have been implemented (sample size 5).*


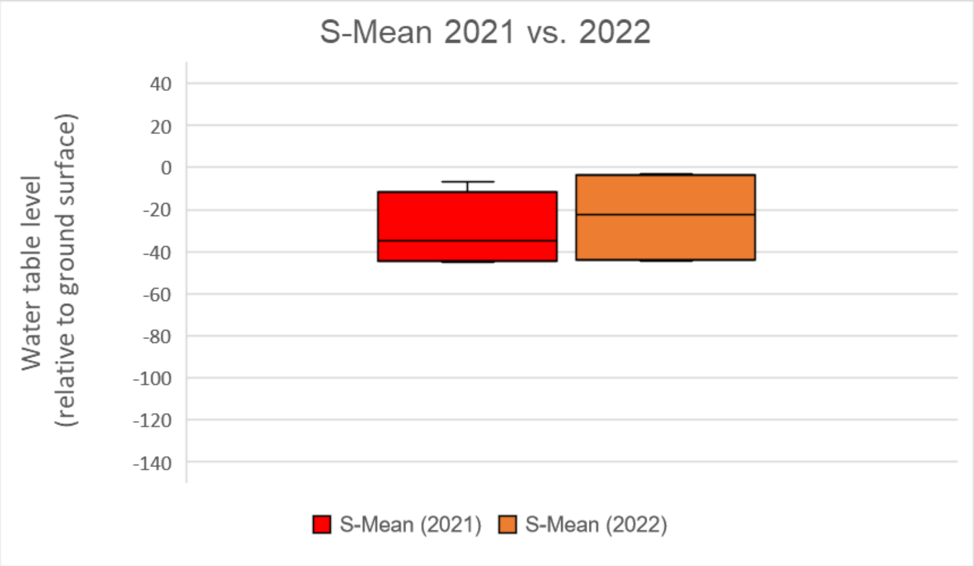



*Figure 2.7: Comparison of water table levels between summer 2021 and summer 2022 where wetland rehabilitation measures have been implemented (sample size 4)*

## 2.4 Year 2 (FY23) Bogs: Interpretation of Monitoring

Analysis of overall water table response for Year 2 bog (FY23) data, does not indicate statistically significant differences in water table levels between summer 2021 and summer 2022. There were slight increases in median values for S-Med and S-Mean between summer 2021 and summer 2022 of 3cm and 2cm respectively. However, median S-D90 was 1cm deeper in summer 2022 compared to summer 2021 across all Year 2 (FY23) wells (reflecting the drier summer period, as illustrated by meteorological data). This is likely to reflect the timing of rehabilitation measures, many of which were only implemented towards the end of summer 2022, during the prolonged dry spell of July and August 2022. Given the positive response observed from the Year 1 (FY22) bogs, it is recommended that monitoring up to the end of summer 2023 is used to provide a more accurate assessment of the impact of restoration on Year 2 (FY23) bogs. This data will be available for Year 2 (FY23) bogs following the next round of monitoring on these bogs (scheduled for summer 2024). Therefore, future iterations of the annual monitoring report will be able to provide increased confidence of the impact of rehabilitation on Year 2 (FY23) bogs.

### Further information

Detailed examples of changes in water table levels for specific wells have been provided in Appendix C1 and C2. This sets out analysis of particular wells that are broadly representative of wider conditions on a site-by-site basis. Furthermore, all available groundwater monitoring data collected by the project to date, is available to view and analyse using the hydrological dashboard developed by RPS. This enables users to select individual wells and provides hydrographs and a summary of key water table statistics to enable more detailed analysis as required.

# 3. Biodiversity Summary

Background information on biodiversity and summary metrics in respect of biodiversity-related monitoring under the current scheme has been set out previously in the EDRRS report titled 'Methodology Paper for the Enhanced Decommissioning, Rehabilitation and Restoration of Bord na Móna Peatlands' available on the Bord na Móna scheme website[5]. The main objective of the EDRRS monitoring programme is to monitor and verify trajectories of change in response to the proposed re-wetting. As peat is re-wetted, some individual species can or may respond quickly to the new environment. The monitoring programme will ultimately demonstrate change in ecosystem functioning and the trajectory of the cutaway bog towards the development of a naturally functioning peatland ecosystem.

The current document reports on the additional biodiversity monitoring carried out on the EDRRS Scheme Year 1 Bogs (rehabilitated in 2021) for the period August 2022 to March 2023 inclusive (comprising 1 additional winter of monitoring), as well as the Scheme Year 2 Bogs (rehabilitated in 2022) for the period April 2022 to March 2023 inclusive (comprising one breeding season and one winter season of monitoring), and reports on the surveys which were 'in scope' for these periods in respect of each individual bog. In a change from the previous report format, updated individual Bog Accounts in respect of the Scheme Year 1 Bogs are included in Appendix D2, whilst individual Bog Accounts in respect of Scheme Year 2 Bogs are included in Appendix D3. Any references in the main text to 'individual bog accounts' should be read as referring to the contents of these appendices as relevant.

Biodiversity is treated as a core secondary area for monitoring and as such different monitoring methods/approaches have been included in the EDRRS monitoring programme. The overall monitoring programme is stratified insofar as not every unique group (broad domain) was surveyed at every rehabilitation site. Different data (target domain outcomes) will also be collected at different scales over different timeframes (e.g. to monitor vegetation and habitat change, all scheme sites will have at minimum baseline habitat maps, and some have permanent vegetation quadrats that will be surveyed at the start and end of EDRRS, whilst others will have permanent vegetation quadrats that will be surveyed each year of the programme). Different locations (i.e., bogs subject to rehabilitation under the scheme) were selected to provide samples of the wide environmental variation of Bord na Móna peatlands (vegetated sites vs bare peat sites, different peat depths, different drainage regimes) and geographical variation across the Bord na Móna estate (east vs west for instance).

Note: Following consultation with the scheme regulator (NPWS), an updated summary table in respect of the EDRRS Scheme Year 1 (2022) and Scheme Year 2 (2023) Bogs is included as Table 1 in Appendix D1 to reflect the overall monitoring requirements for these bogs across the EDRRS scheme lifetime.

Detail on the methods and materials in respect of the various monitoring techniques have been provided previously in the 2022 Annual Monitoring Report[6], but are again provided here for completeness. These cover the broad domains of habitats (habitat mapping and vegetation quadrats), birds (wintering and breeding) and invertebrates (pollinators). Citations are provided throughout as to the Best Practice methods which have been selected to measure the outcomes of rehabilitation and a list of full references is provided subsequently. A summary table of the scheme sites along with

[5] Supporting Material – Bord na Móna Peatlands Climate Action Scheme (bnmpcas.ie)

[6] bnmpcas.ie/wp-content/uploads/sites/18/2023/04/Annual Report to Mar 2022 .pdf

associated monitoring year and respective period covered in the present report is provided as Table 2 of Appendix D1.

## 3.1 Errata and Revisions

Several errata have been corrected in the present report. Note that the abbreviated term 'YR1' or YR2' is utilised to distinguish between different monitoring years post rehabilitation.

1. Bird species BOCCI Conservation status in individual Bog Accounts (See Appendices D2 and D3 in this regard). We note that overall analysis was correctly presented in last year's report, but species codes differed on occasion within individual bog accounts. This has now been corrected.
2. Updated Pollinator overview tables in respect of Scheme Year 1 Bogs are presented in this report. This covers monitoring YR1 and monitoring YR2 with revised Species Index ratings and abundance levels and should be taken as superseding the previously presented tables.
3. We note that some EDRRS Year 2 Bogs were included in the previous report's Pollinator overview & analysis section inadvertently. However, the presentation of this data is now pertinent for the current reporting period and remains in place.
4. For two Scheme Year 1 Bogs (Ummeras and Castlegar), the previous AMR did not include the second summer of quadrat data in the relevant appendix; this is now provided in Appendix D4 and referenced in Appendix D2 under the individual bog accounts.
5. Regarding Derrycolumb Bog, the record of 3 Grey Wagtail in YR1 CBS surveys has been corrected to Pied Wagtail. The updated Bird summaries presented in Section 3.3. reflect this.

The following revisions have been made:

1. A revised approach to the assignment of bird habitat association codes has been undertaken in the present report. See below under methods in this regard. Previous bog accounts for Scheme Year 1 Bogs as presented in Appendix D2 of this document now also reflect this change.
2. Regarding Derrycolumb Bog, the calendar year 2022 has been re-assigned as YR1 of monitoring, in terms of breeding birds. This is because only one breeding bird survey on a single date was conducted in 2021. The revised monitoring schedule is reflected in Table 1 of Appendix D1.
3. Regarding Oughter Bog, the calendar year 2022 has been re-assigned as YR1 of monitoring, in terms of breeding birds. This is because only one breeding bird survey on a single date was conducted in 2021. The revised monitoring schedule is reflected in Table 1 of Appendix D1.

## 3.2 Constraints

Any constraints as pertinent are dealt with within individual bog accounts see Appendix D2 and Appendix D3 in this regard.

## 3.3 Methods

Monitoring methods per target domain and, where relevant, the associated Best Practice guidelines are presented below in respect of habitats, vegetation community monitoring via quadrats, wintering and breeding bird assemblage monitoring and pollinator diversity monitoring.

## Habitats

The approach to planning and management of habitat surveys followed Best-Practice guidance in the Irish context from Smith (*et al.* 2011). Map outputs including all habitat maps and target notes were produced using GIS software application packages (ArcGIS) and a handheld tablet. Habitat mapping consisted of ground truthing previous habitat maps and adding data in the form of point data to represent the habitats encountered. Habitat types were classified and digitised according to the Bord na Móna habitat classification system (see Table 3 of Appendix D1). Digitisation involves review and manipulation of field point data so that one habitat data point is present on each recorded polygon. Using the ARC GIS spatial join tool, the point data is then subsumed into the polygon attribute tables to create the final maps and shape files. General marginal habitats and other habitats that had not been modified significantly by industrial peat extraction were classified using Fossitt (*et al.* 2000) (hereafter Fossitt). Plant nomenclature where referenced for vascular plants follows Stace (2019), while moss and liverwort nomenclature, again where referenced, follows identification keys published by the British Bryological Society (2010). A more detailed Bord na Móna classification system has previously been developed for classifying pioneer cutaway habitats, as Fossitt categories were deemed not to be detailed enough for cutaway bog (much of cutaway bog could be classified as Cutover Bog - PB4). See individual bog accounts in Appendix D3 for further information. We note that a further vegetation classification system for cutaway habitats, to be published as an 'Irish Wildlife Manual' is currently under development and will be used to inform scheme analysis when available.

Note 1: Habitat Maps are still being produced in respect of Scheme Year 2 Bogs habitat surveys. These maps will be provided in due course once available.

Note 2: Regarding Quadrat data presented in the standalone bog appendices, we note that abbreviated scientific names are utilised within the tables presented for plant species. This follows the established drop-down menu utilised in field data collection via a tablet. Full scientific names of any species referenced are utilised in the primary text (Appendices D2 and D3) where relevant.

## Vegetation Quadrats

Vegetation monitoring quadrat locations were aligned with piezometer monitoring locations as previously set out in agreed EDRRS Monitoring and Verification. Each quadrat was visited by a single ecologist and data plus target notes were produced using GIS software application packages (ArcGIS) and a handheld tablet. Variables recorded included surveyor name and data, Bord na Móna classification code, a cutover habitat description code, and then percentage cover respectively of *Sphagnum* species, bare peat, and open water. If vegetation was present, then vegetation height and a full list of species was recorded. See individual bog accounts for clarification on number of quadrats surveyed along with representative sample photographs (Appendices D2 and D3).

## Wintering Birds

Fixed counts, following I-WeBS (Irish Wetland Bird Survey) methods, were used to count wintering waterfowl. Counts were targeted at the period September to March inclusive. I-WeBS uses the well-established technique of counting the numbers of water birds at wetland sites by the 'look-see' method (Bibby *et al.* 1992). This involves counters recording the number of individuals of each water bird species on survey visits to pre-defined wetland sites. The main objective was to establish a baseline for monitoring at a single site which has been subject to rehabilitation. See individual bog accounts for clarification on number of visits undertaken.

Note: For the purposes of the current report, we define wintering water bird species richness on the following scale; 'High'=16-20 species, 'Medium'=11-15 species, 'Low'=6-10 species and 'Very low' = 0-5 species. Non water bird species are excluded. Site importance where discussed is aligned with thresholds as set in the Irish context for the wildfowl monitoring scheme the Irish Wetland Bird Survey (IWeBS).

## Breeding Birds

Breeding bird surveys utilised a transect method generally following the existing Countryside Bird Survey (CBS) (Lewis *et al.* 2019). Each transect was placed along an existing high field, 'headland' or rail line corridor for ease of use but also because these locations will continue to be accessible post rehabilitation, allowing the same route to be repeated. Either two visits, comprising an early and late season visit in the period April to June, or four visits in the period April to July were carried out on a per bog basis. Each transect was walked by a single observer equipped with binoculars and bird species were recorded in line with CBS Guidelines (e.g., no juvenile birds were recorded, any colonies were recorded separately etc.). See individual bog accounts for clarification on number of visits undertaken.

Where a bespoke breeding wader survey was also scoped for Monitoring and Verification, this was carried out in line with O'Brien & Smith (1992) and comprised walking a predefined route or transect across the bog on each of 4 visits in the period April to July inclusive. The route aligned with the CBS transects for ease of implementation. Per visit the total number of adult wading birds observed from the transect, wading young observed, and the estimated total number of pairs were recorded by a single observer equipped with binoculars. See individual bog accounts for clarification on required survey scope and number of visits undertaken along with any constraints on a per bog basis.

*Breeding Birds- Habitat Association Criteria*

Species recorded during the period April to June inclusive have been assigned a habitat association code from one of three categories namely 'OPEN', 'NON-OPEN' or 'OPEN & NON-OPEN'. Associations were interpreted in line with Nairn & O'Halloran (2012) but adapted to reflect the described occurrence of these species within a highly heterogenous cutaway habitat mosaic. Hooded Crow, for instance may typically utilise single isolated trees within a larger unenclosed cutaway raised bog landscape and is considered best placed in the 'OPEN' category. Whitethroat, which does occur in larger open or unenclosed areas, but within which is associated with scrub, is assigned to the 'NON-OPEN' category. Wren has been assigned to 'OPEN & NON-OPEN'; this species is known to breed in cutaway vegetation as low as between 25-50cm (Bracken *et al.* 2008), right up to closed canopy woodland (Cramp *et al.* 1979), both of which occur within the study sites, with extremely low likelihood that birds have not been recorded from either. Similarly, Sedge Warbler may occur in fen (Bracken *et al.* 2008) along with rough vegetation and wet scrub (Copland 2009) and has been assigned to the 'OPEN & NON-OPEN' category. Reed Bunting which is documented as occurring in fen habitat (Bracken *et al.* 2008) but also Willow plantation (Kavanagh 1990a) is similarly assigned to 'OPEN & NON-OPEN'. Eurasian Crane which typically nests in wetlands (Cramp *et al.* 1979) but also appears to rely on pioneering birch woodland (Copland *et al.* 2022) is also considered best placed in the 'OPEN & NON-OPEN' category.

In general terms however, the category 'OPEN' was applied to those species most strongly associated with open pioneering habitats or mosaics thereof found on cutaway bog (or raised bog) whilst species generally associated with scrub (typically birch, willow or gorse) and closed-canopy woodland (typically birch or willow but also other broadleaf mixes and/ or conifer spp.) are assigned to the 'NON-OPEN' category.

*Breeding Birds- Derivation of Annual Relative Abundance Index (ARA)*

To derive the ARA per bog, the maximum number of individuals per species within the period April to June inclusive of the relevant monitoring year is used. This excludes visits from the period July onwards. Notable species recorded in July or other months may be referenced in text but are not included in the index.

*Breeding Birds- Nomenclature*

Bird nomenclature follows the names most broadly used in Ireland[7][8], but with occasional modification. For readability, we have not always used the 'Common' preface before some species (e.g., Snipe) but in instances where paired species occurred (Snipe and Jack Snipe), we have expanded names used to 'Common' Snipe and Jack Snipe, but then revert to the shorter name. In some instances, the IOC World List name (Gill *et al.* 2022) may be used e.g. Great Egret rather than Great White Egret where the IOC name is now commonly used. In each table of bird data species common names are prefaced with the British Trust for Ornithology (BTO) single or two letter code [9] and followed with the scientific name. All references to Redpoll infer 'Lesser' Redpoll *Acanthis cabaret*.

### Pollinators

A transect, of varying length, was established across part of the relevant bog to record pollinators, indicator species (Butterflies) and other taxa. Pollinator recording followed guidelines set out by the National Biodiversity Data Centre Bumblebee Monitoring Scheme. Where possible the same transect route was walked per visit (any amendments to transect routes, such as between years, are described under individual bog accounts) and species recorded 2.5 m either side of and 5 m in front (a 5 m3 recording 'box') of the observer. Each visit was undertaken by a single observer. Counts were targeted to be completed between 11:00 and 17:00hrs, when the temperature was at least 13°C and during good weather conditions. See individual bog accounts for clarification on number of visits undertaken and any constraints (Appendix D2 and Appendix D3). Species Index ratings are based on overall number of species recorded across all counts in any season, whilst abundance estimates reflect the maximum count per individual species across all survey dates.

## 3.4 Findings Summaries

Relevant findings summaries are presented below. We refer to individual bog accounts (Appendix D2 and Appendix D3) for more detailed information and discussion, along with tables as presented in Appendix D1. See also summary metrics in respect of biodiversity-related monitoring under the current scheme as set out previously in the EDRRS report titled '*Methodology Paper for the Enhanced Decommissioning, Rehabilitation and Restoration of Bord na Móna Peatlands'* and the previous Annual Monitoring Report produced in 2022[10].

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[7] List-of-Irish-Birds-v12.0(JH).pdf (southdublinbirds.com)

[8] checklist-Ireland 14.5.1 with IOC9.1 Rev-nossp 2018IRBR-2 by S Enright (irbc.ie)

[9] species_codes.pdf (bto.org)

[10] bnmpcas.ie/wp-content/uploads/sites/18/2023/04/Annual Report to Mar 2022 .pdf

## Habitats

The general objective of habitat mapping is to '*Measure longer-term **broad scale** changes in vegetation following rehabilitation under the scheme'* as outlined in other reporting such as the published EDRRS methodology paper.

The Habitats findings summary table, see Table 4 of Appendix D1, summarises findings for the current reporting period and associated bogs. Regarding trajectory, evaluations apply to measurable evidence of changes to constituent habitat characteristics, attributable to rehabilitation.

Following consultation with the Scheme Regulator (NPWS), Table 4 of Appendix D1 now includes a breakdown of predicted future habitats against which trajectory can be compared. Future habitat area calculations are sourced from the individual Site Characterization Reports previously produced, and are summarised in Table 3-1, below. Across the 38 Scheme Year 1 and Scheme Year 2 bogs under consideration, and excluding the 'Marginal Lands' category (lands around the margins of cutaway areas- deemed to benefit from adjacent rewetting but generally not comprising lands where peat extraction took place); the dominant future habitats comprise Bog Woodland (Fossitt Code WN7 – and not Annex I 'Bog Woodland'), followed by mosaics of open water, poor fen, reedbeds, and emergent scrub and woodland (generally on shallower peat depths) and then regenerating areas of deeper peat vegetation (on deeper peat).

In terms of trajectory towards these future habitats, broad scale general habitat changes post rehabilitation (which we note exludes finer scale conditions within the smaller subset of area sampled by vegetation monitoring quadrats) are linked to changes in hydrological conditions across targeted rehabilitation areas, which, as per previous Scheme bogs, are radically changed since re- wetting. In respect of a corresponding step change in habitat extent to date however there are generally limited measurable indications of recent corresponding changes in habitat response in line with rising water tables. Many bogs appear to have very little fresh pioneer vegetation and the trajectory is appraised as 'Yellow' (See Table 4 of Appendix D1) indicating no measurable evidence of changes in vegetation following rehabilitation, in the current reporting period. This is potentially attributable to a natural lag period in which the hydrology regime must stabilise prior to vegetation acceleration. Many of the bogs under consideration had only relatively recently received fertiliser application within the present reporting period, also suggesting further time must possibly elapse before measurable results are detectable from vegetation succession on headlands, high fields and drier open areas of bare peat. Results of the scheduled second habitat survey post rehabilitation will provide more indication of the impacts of rehabilitation on habitat change and trajectory towards the final predicted climax vegetation. Slower, more linear responses in respect of vegetation succession are to be expected based on published literature (see Fallon 2013 for instance or Kreyling et al.).

Table 3.1 Summary of predicted future habitats as outlined in Table 4 of Appendix D1.*

| Future Habitat Description | Estimated Area (ha) |
|---|---:|
| Marginal Land | 6255 |
| Bog Woodland and/or Bog Woodland Mosaic | 5637 |
| Open Water, Reedbeds, Poor Fen & Scrub/Woodland mosaic | 4459 |
| Regenerating Wet Deep Peat Vegetation | 4154 |
| Constrained Areas | 992 |
| Conifer Plantation | 842 |
| Mosaic of Rich or Poor Fen with Scrub or Wetland | 535 |
| Limestone/Marl lake | 44 |

| Future Habitat Description | Estimated Area (ha) |
|---|---|
| Agricultural lands | 43 |
| Built Surfaces | 40 |
| Wet Willow-Alder-Ash Woodland | 35 |
| Broad-leaved woodland | 33 |
| Artificial Water Body | 31 |
| Mixed broad-leaved/conifer woodland | 15 |
| Rich Fen and Flush | 15 |
| Poor Fen and Flush | 13 |

* Areas are presented for EDRRS Year 1 and EDRRS Year 2 Bogs covered in the present report only. Some habitat categories have been amalgamated for ease of reading and habitat polygons greater than 10 ha only are shown. The category 'Regenerating Wet Deep Peat Vegetation' includes both deep peat on 'high bog' and regenerating wet deep peat on cutaway.

*Vegetation Quadrats*

The general objective of quadrat monitoring is to 'Measure longer-term finer scale changes in *vegetation following rehabilitation under the scheme'* as outlined in other reporting such as the published EDRRS methodology paper.

In total, 74 permanent fixed monitoring quadrats are now installed across 14 of the subject bogs, with an average of 5 quadrats per bog (see Table 5 of Appendix D1). There are a total of 55 quadrats installed across the eleven Scheme Year 1 bogs, with a total of 19 quadrats installed across the three Scheme Year 2 Bogs. For some bogs, more than 5 quadrats were taken to reflect variables in vegetation. For example, eight quadrats were recorded at Glenlough to account for the variation in vegetation across this drained but vegetated raised bog. In all but one instance, these were linked with piezometers to allow for future correlation with changes in, and establishment of, vegetation communities. One quadrat was located away from a piezometer at Glenlough bog in order to monitor change in an area of sub-central ecotope vegetation.

Given the distribution of piezometers and the largely bare peat nature of many of the cutover bogs within the Scheme, a large proportion of the quadrats are dominated by bare peat.
Data analysis shows 38 of the 74 monitoring quadrats installed had percentage cover of 91-100% bare peat. 15 of the permanent monitoring quadrats were installed on restored raised bog (i.e., 5 at Kellysgrove bog, 1 at Clonad, 1 at Ummeras bog and 8 at Glenlough).

Of the quadrats installed on cutover bog (n=59), 45 quadrats were on vegetation communities classified as bare peat (i.e., greater than 50% bare peat cover), 6 located within poor fen type vegetation (within habitats of "*pioneering open habitats and scrub*") and 3 quadrats in pioneering open habitats and scrub type vegetation, with varying degrees of coverage of Downy Birch (*Betula pubescens*) or Willow (*Salix* spp.). See Table 5 of Appendix D1 for a summary of permanent monitoring quadrats deployed per bog. Raw quadrat data is presented in Appendix D4

Only two Bogs have now had consecutive years of quadrat monitoring within the current reporting period, Castlegar and Ummeras. The permanent quadrats installed in 2021 reflected the baseline conditions pre-rehabilitation. These areas were dominated by dry bare peat (2021). Following a second year of monitoring (2022) at these fixed quadrats, post-rehabilitation, the areas were noted to have been transformed hydrologically (but not vegetatively, with significant cover (76-90% cover) of standing water noted in some quadrats following successful alteration in the water table. These areas still lacked any vegetation establishment, and more time is needed to record any changes in vegetation. Where quadrats did not support areas of open water, these quadrats were similarly dominated by bare peat (91-100%) one year later (2022). However, successful rewetting of the peat was noted.

The rate and extent of revegetation of these permanent fixed monitoring quadrats will be monitored during the scheme and provide an insight into the vegetation changes post rehabilitation. In many instances, it will also be possible to correlate vegetation changes with rehabilitation measures i.e., wetland measures and drain blocking (Dry Cutaway Type 2, Deep Peat Type 2/3) and associated changes in hydrological regimes. In some instances, i.e., Deep Peat Type 4/5, significant alteration of the receiving environment has occurred during the formation of the cell bunding. Although fixed monitoring quadrats located in these areas were dominated by bare peat pre-rehabilitation, there may be some initial reductions in species diversity or vegetation cover, although insignificant in the long term.

Future permanent fixed monitoring quadrats will aim to cover a greater diversity of vegetation types, building on those installed to date, and will further help to inform responses in vegetation post-rehabilitation.

## Wintering Birds

*General Objective*

The general objective is to '*establish quality of effects on relative abundance or proportion of species of conservation concern, following scheme implementation'* as outlined in other reporting such as the published EDRRS methodology paper.

*Species Richness*

A total of 15 bogs were surveyed for wintering wildfowl over the winter period 2022/23. Species richness is presented in Table 6 of Appendix D1 in respect of winter bird surveys across all these bogs – which includes the second winter monitoring period of 7 Scheme Year 1 bogs (Castlegar, Cavemount, Clooniff, Derrycolumb, Edera, Ummeras and Oughter) and the first winter monitoring period for 8 Scheme Year 2 bogs (Begnagh, Derryfadda, Derrybrat, Knappogue, Noggusboy, Bloomhill, Bunahinly-Kilgarvan and Blackwater).

In respect of Scheme Year 2 Bogs for which the winter period 2022/23 comprised the first winter of monitoring post rehabilitation, species richness was highest at Knappogue Bog (n=20), followed by Noggusboy (n=19), then Blackwater (n=16). Both Knappogue and Blackwater are known to be subject to annual inundation during the winter periods and occur proximal to other wetland sites (the River Shannon north of Lough Ree in the case of Knappogue and the River Shannon south of Clonmacnoise in the case of Blackwater) both locations with established wildfowl presence. Noggusboy has an established waterbody onsite for several years. These factors may account for the species richness recorded and it is too soon to assign any measurable increase in species to EDRRS rehabilitation measures.

Seven Scheme Year 1 Bogs have now had two winter periods in which wildfowl have been monitored. Only one study bog, Derrycolumb, has had a positive quality increase between monitoring years, improving from 'Very low' to 'Low'.[11] Species richness at Castlegar and Edera has declined from 'Low' to 'Very Low'. Variation in timing, weather conditions, observers, along with natural interannual

[11] 7 species were recorded in winter period 2022/2023 compared to 5 species in the winter period 2021/2022.

variation in bird occurrence may be contributing factors to this however and further time is required to establish an accurate trend reflective of rehabilitation impact.

*Relative Abundance*

Table 7 of Appendix D1 illustrates the relative abundance of water bird species during EDRRS monitoring for both the winter period 2021/22 and the winter period 2022/23. Note the winter period 2022/23 included the second winter period of monitoring in respect of 7 Scheme Year 1 Bogs (Castlegar, Cavemount, Clooniff, Derrycolumb, Edera, Ummeras and Oughter) and the first winter period of monitoring in respect of 8 Scheme Year 2 Bogs (Begnagh, Derryfadda, Knappogue, Noggusboy, Bloom Hill, Bunahinly-Kilgarvan and Blackwater).

Across all survey visits in the winter period 2022/23, the most abundant wildfowl species was Teal *Anas crecca* (n=455), followed by Whooper Swan *Cygnus cygnus* (n=357), then Golden Plover *Pluvialis apricaria* (n=350). Most Whooper Swan and Teal were concentrated at Blackwater Bog in Co. Offaly, a site which is known to already support substantial wildfowl numbers in the winter. Golden Plover numbers were highest at Derrycolumb Bog, again a site which is close to a known, important wildfowl area (Lough Ree). Proximity to existing concentrations of wintering wildfowl may be causal to the recorded occurrence of these species at rehabilitated bogs. Regarding frequency of occurence, to date Golden Plover has occurred on 17 counts, whilst Whooper Swan has been recorded on 20 different counts. See Table 6 of Appendix D2 for overall abundance totals.

When the Scheme Year 1 Bogs are considered in isolation, a comparison of species between the first and second winter of monitoring indicates that Golden Plover is still the most abundant species on these 7 bogs during the winter. The predominance of Golden Plover may reflect the extent of bare peat during the (still) early post rehabilitation stage as this species utilises open areas of bare peat during the winter months for diurnal roosting, with most feeding taking place at night on farmland. Over time, as vegetation succeeds or habitats become more enclosed at these bogs, it is possible that usage by Golden Plover may reduce.

*Summary and Trajectory*

A summary table, provided as Table 8 of Appendix D1, summarises findings for the current reporting period and associated bogs. Regarding trajectory, evaluations apply to measurable evidence of changes to the water bird species assemblage characteristics (proportion of species & relative abundance), attributable to rehabilitation. Cognisance is made in this regard to whether water bird usage was known to Bord na Mona in the period prior to rehabilitation under the current scheme (established) and further to whether this was long term in duration or recognised publicly (long established). The latter includes recognition of sites under national monitoring schemes such as the Irish Wetland Bird Survey (IWeBS). Numerical targets have not been set for any potential increases in species richness or relative abundance due to the potential for natural interannual variation thus requiring longer term monitoring data beyond the lifetime of the scheme to dampen fluctuations and produce a realistic trend interpretation, to compare against any previously defined target. As the winter period 2022/23 constitutes the first winter of monitoring for 8 Scheme Year 2 Bogs it is too soon to establish any increase in species richness or abundance directly attributable to EDRRS. Although 7 Scheme Year 1 Bogs now have 2 winters of data, there is still little evidence of changes in range or abundance outside the expected influence of interannual variation. However, we note that there was some evidence of positive quality changes in species range and abundance at 1 bog (Derrycolumb).

## Breeding Birds

The general objective is to '*Establish quality of effects on relative abundance or proportion of species of conservation concern, following scheme implementation as outlined in other reporting such as the published EDRRS methodology paper*'.

*Species Richness*

Eighty one species were recorded across 7 Scheme Year 1 bogs and 6 Scheme Year 2 bogs during the period April to June 2022. This represents an increase of 8 species compared to the same period in 2021.[12]Newly recorded species comprise Common Tern *Sterna hirundo*, Whinchat *Saxicola rubetra*, Jack Snipe *Lymnocryptes minimus*, Collared Dove *Streptopelia decaocto*, Shoveler *Anas clypeata*, Herring Gull *Larus argentatus*, Crossbill *Loxia curvirostra*, and Siskin *Carduelis spinus*.

*Relative Abundance*

To investigate species richness, a transect methodology is being utilised to generate a representative sample of breeding birds at each study location. Data is then compiled, and an abundance index derived based on maximum transect counts per species during the period April to June inclusive. In 2022, at the subject sites covered herein, we recorded 73 different species across 15 cutaway bogs included in EDRRS, within the April-June inclusive period. As noted above this increased to 81 species with the addition of Scheme Year 2 Bog data. Relative abundance is still highest for Willow Warbler *Phylloscopus trochilus* overall (n=616 recorded in total). Another species for which relative abundance is still considered noteworthy is Meadow Pipit *Anthus pratensis* (still ranked 2nd overall; n=442 recorded). Sand Martin *Riparia riparia* which was ranked 6th overall previously is now ranked 10th overall due to increases in the numbers of other species with the addition of data from the first year of monitoring of Scheme Year 2 Bogs. Meadow pipit is still the most abundant species on the two 'High Bog' sites monitored in 2022.

Overall relative abundance for species recorded whose index value is 10 or more individuals is shown in Figure 3.1, below.

*Proportion of Species of Conservation Concern*

Of the 81 species of bird recorded, 79 have been assigned a BOCCI4 conservation status of either Green, Amber or Red. The two exceptions are Pheasant *Phasianus colchicus* and Eurasian Crane *Grus grus.* For those assigned a BOCCI4 conservation status they comprise by percentage 56% Green listed species, 26% Amber listed species and 16% Red listed species. Two Red listed species which have been added from data in respect of Scheme year 2 Bogs include Whinchat *Saxicola rubetra* and Shoveler *Anas clypeata*. Habitats at the study sites could be considered to currently support a substantial number of species of conservation concern directly or indirectly during the breeding season, including within rehabilitated areas such as cells and bunded wetlands. It is hoped that ongoing monitoring will establish whether the proportions of these species change following completion of rehabilitation.

[12] Scheme Year 2 Bogs were not monitored in 2021.

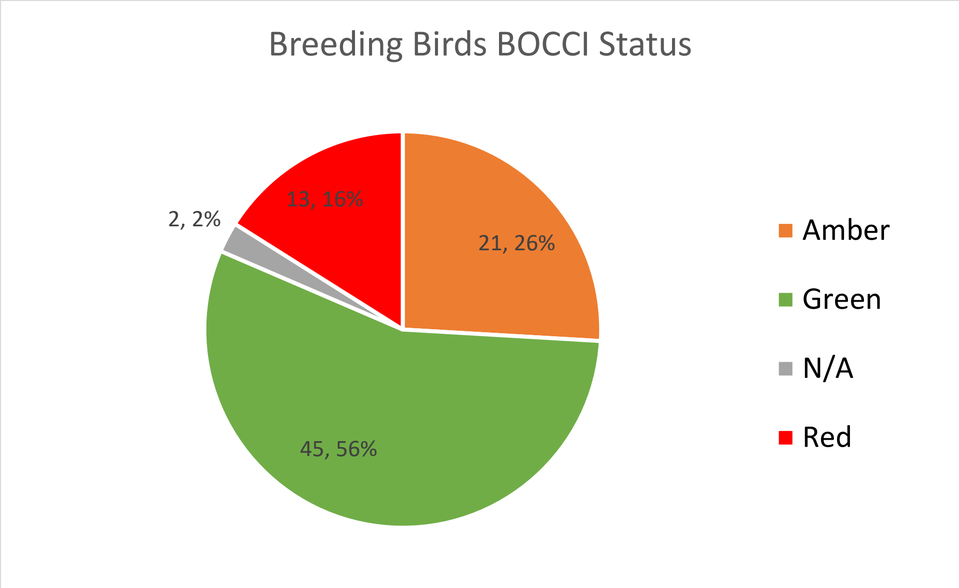


*Figure 3.1. Numbers of Breeding Bird Species (to date) by BOCCI status*

*Habitat Associations*

Species recorded during the period April to June inclusive have been assigned a habitat association code from one of three categories namely 'OPEN', 'NON-OPEN' or 'OPEN & NON-OPEN'. See previous Methods text in Section 3.3 regarding the revision of categorisation.

As noted previously 81 species have now been recorded across the baseline breeding bird transect methodology. 'OPEN' habitat species i.e. species associated with unenclosed areas comprise 60% (n=49) by percentage of the total. 'NON-OPEN' species or species which associated with enclosed areas comprise 35% by percentage of the total (n=28). Three remaining species are categorised as 'OPEN&NON-OPEN' and comprise 5% by percentage of the total. As previously reported the importance of unenclosed areas for species of conservation concern is clearly evident. For instance, all Red listed species fall into the 'OPEN' category and 18 of 21 (or 85% of) Amber species fall into the 'OPEN' category.

The present data continues to inform the potential importance of unenclosed cutaway for species of conservation concern in Ireland. Further sampling of 'High Bog' habitats over the scheme lifetime may provide a more rounded appraisal of secondary benefits to birds overall. This will support evaluations of the importance of rehabilitated cutaway/raised bog habitats in contributing to future Biodiversity or Nature Restoration initiatives.

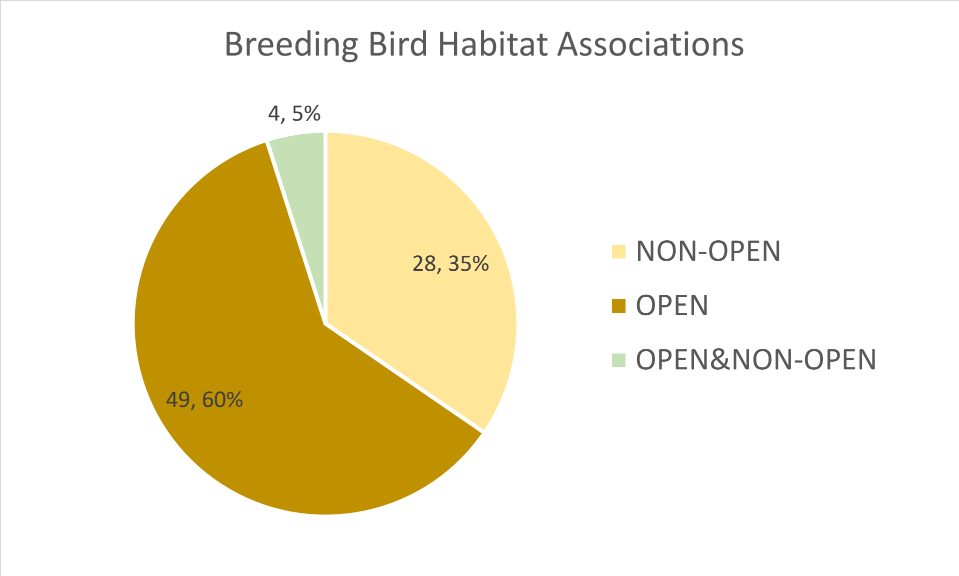


*Figure 3.2 Breeding Monitoring Summary.   of bird species recorded (to date) by Habitat Association Category (OPEN, NON-OPEN or 'OPEN&NON-OPEN')*

*Summary and Trajectory*

Table 9 of Appendix D1, summarises updated findings for the current reporting period and associated bogs. Regarding trajectory, evaluations apply to measurable evidence of changes to the breeding bird species assemblage characteristics (relative abundance or proportion of species of conservation concern), attributable to rehabilitation. It is also noted where emerging links to protected sites (i.e. European Sites designated under the Habitats or Wild Birds Directives) have been observed. Cognisance is made in this regard to whether breeding bird usage was known to Bord na Mona in the period prior to rehabilitation under the current scheme (established).

Numerical targets have not been set for any potential increases in relative abundance or proportion of species of conservation concern due to the potential for natural interannual variation thus requiring longer term monitoring data beyond the lifetime of the scheme to dampen fluctuations and produce a realistic trend interpretation, to compare against any previously defined target. It is generally too soon (even for sites where data for 2 breeding seasons is available) to qualify any long term, permanent change in species richness or abundance directly attributable to EDRRS.

Following on from documented increases in the previous reporting period in respect of Black-headed Gull *Chroicocephalus ridibundus*, Ringed Plover *Charadrius hiaticula*, Little Grebe *Tachybaptus ruficollis* and Lesser black-backed Gull *Larus fuscus* (Edera Bog) which were considered attributable to rehabilitation or rise in water tables- there are no obvious increases in species range or abundance from the 6  additional bogs under consideration within the current reporting period, which are attributable to rehabilitation, although an increase in the baseline species richness has been noted. Noggusboy which had the most species of the 6 Scheme Year 2 Bogs has an existing, extensive wetland with an established species assemblage.

It is notable however that CBS transects have a limiting sample range in respect of the size of certain bogs (the EDRRS extent at Blackwater for instance is over 500Ha of which only 20% is sampled). It is known for instance that a Black-headed Gull colony has become established at Blackwater since rehabilitation was completed, additionally species such as Redshank and Shoveler have been observed 'Off transect' in the 2023 calendar year., indicating that benefits may be further reaching on certain bogs than representative sampling may suggest.

## Pollinators

The general objective is to '*Show change in species abundance and diversity post-restoration following vegetation establishment/change'* as outlined in other reporting such as the published EDRRS methodology paper[13]. Individual bog reports are provided in Appendix D2 and D3. The below analysis has been revised to include comparison between Scheme Year 1 and Scheme Year 2 Bogs with regard to pollinators.

*Abundance and Diversity*

Abundance in terms of overall numbers of Butterfly species are presented below in respect of the 11 EDRRS sites[14] in Scheme Year 1 (Table 3-2) and 3 EDRRS sites in Scheme Year 2 (Table 3-3). On average (across all bogs to date) 7 species of Butterfly were recorded per study site (range = 1-12). Species diversity was highest at Cavemount (2021/YR1) and Clonad Bog (2021/YR1) and Blackwater Bog (YR1/2022).

*Table 3-2 Pollinator Survey Butterfly Index Values Scheme Year 1 Bogs*

| EDRRS Site | Species Index Value |
|---|---|
| Cavemount Year 1 | 11 |
| Cavemount Year 2 | 8 |
| Edera Year 1 | 1 |
| Castlegar Year 1 | 5 |
| Oughter Year 1 | 8 |
| Oughter Year 2 | 7 |
| Clooniff Year 1 | 7 |
| Clonad Year 1 | 11 |
| Clonad Year 2 | 3 |
| Derrycolumb Year 1 | 10 |
| Ummeras Year 1 | 4 |

*Table 3-3 Pollinator Survey Butterfly Index Values Scheme Year 2 Bogs*

| EDRRS Site | Species Index Value |
|---|---|
| Begnagh Year 1 | 4 |
| Blackwater Year 1 | 11 |
| Lodge Year 1 | 12 |

9 species of Bee and 5 species of Moth have now been recorded from transects with the addition of Scheme Year 2 Bogs to baseline data. See individual bog reports for further information and details of any additional casual observations.

For Scheme Year 1 Bog surveys, abundance was highest overall for Small Tortoiseshell *Aglais urticae*, followed by Common Blue *Polyommatus icarus* and then Meadow Brown *Maniola jurtina*, see Table 3-4. For Scheme Year 2 Bogs the order varied slightly with the highest abundance recorded for Meadow Brown *Maniola jurtina*. The additional bogs included in Scheme Year 2, namely Begnagh,

[13] Supporting Material - BNM Peatlands Climate Action Scheme (bnmpcas.ie)

[14] For the purposes of the present report each year of survey at any given bog is treated as a separate 'site'.

Blackwater and Lodge resulted in one additional species being added to effectively the baseline, Dark Green Fritillary *Speyeria aglaja.* No further data from 'High Bog' sites has been collected to compare with the high count of 23 Large Heath *Coenonympha pamphilus* butterfly which was recorded from Kellysgrove Bog in June of 2022- this high count remains outstanding. The below updated Table 3-3 details the (corrected) total species abundance recorded for Scheme Year 1 Bogs. Table 3-5 provides the updated species abundance with the addition of Scheme Year 2 Bogs to the Scheme Year 1 Bog dataset, namely Begnagh, Blackwater and Lodge.

*Table 3-4 Pollinator species abundance Scheme Year 1 Bogs*

| Species | Total |
|---|---|
| Small tortoiseshell *Aglais urticae* | 74 |
| Common Blue *Polyommatus icarus* | 66 |
| Meadow Brown *Maniola jurtina* | 55 |
| Ringlet *Aphantopus hyperantus* | 34 |
| Small White *Pieris rapae* | 32 |
| Orange Tip *Anthocharis cardamines* | 19 |
| Green-veined White *Pieris napi* | 18 |
| Speckled Wood *Pararge aegeria* | 15 |
| Small Copper *Lycaena phlaeas* | 12 |
| Small Heath *Coenonympha pamphilus* | 8 |
| Large White *Pieris brassicae* | 7 |
| Peacock *Aglais io* | 4 |
| Cryptic Wood White *Leptidea juvernica* | 3 |
| Brimstone *Gonepteryx rhamni* | 2 |
| Red Admiral *Vanessa atalanta* | 2 |
| Wall Brown *Lasiommata megera* | 2 |
| Painted Lady *Vanessa cardui* | 1 |

*Table 3-5 Pollinator species abundance Scheme Year 1 & Scheme Year 2 Bogs*

| Species | Total |
|---|---|
| Meadow Brown *Maniola jurtina* | 130 |
| Small tortoiseshell *Aglais urticae* | 84 |
| Common Blue *Polyommatus icarus* | 68 |
| Ringlet *Aphantopus hyperantus* | 51 |
| Small White *Pieris rapae* | 46 |
| Green-veined White *Pieris napi* | 28 |
| Orange Tip *Anthocharis cardamines* | 25 |
| Speckled Wood *Pararge aegeria* | 18 |
| Small Copper *Lycaena phlaeas* | 14 |
| Large White *Pieris brassicae* | 14 |
| Small Heath *Coenonympha pamphilus* | 8 |
| Peacock *Aglais io* | 6 |
| Cryptic Wood White *Leptidea juvernica* | 5 |
| Red Admiral *Vanessa atalanta* | 3 |
| Wall Brown *Lasiommata megera* | 3 |
| Brimstone *Gonepteryx rhamni* | 2 |
| Painted Lady *Vanessa cardui* | 1 |
| Dark Green Fritillary *Speyeria aglaja* | 1 |

*Summary and Trajectory*

The addition of Scheme Year 2 Bogs has resulted in an increased baseline which now includes 14 sites compared to 11 in Year 1 of the scheme. With the addition of the three bogs, there has been a notable increase of 136% in Meadow Brown *Maniola jurtina* abundance. A number of other species have also seen an increase e.g. Ringlet abundance increased by 50%. One additional species, Dark Green Fritillary *Speyeria aglaja* has also been recorded for the first time which has increased the baseline number of species from 16 to 17. Numerical targets have not been set for any potential increases in relative abundance or proportion of species of pollinators due to the heterogenous nature of cutaway, potential for natural interannual variation, and the absence of published baseline data on comparative invertebrate diversity of cutaway bogs (no precedent is known which derives say invertebrate diversity indexes for cutaway either pre- or post rehabilitation). Given anticipated vegetation succession rates longer term monitoring data beyond the lifetime of the scheme is required to effectively produce a realistic trend interpretation, to compare against any previously defined target. On this basis a simple increase in species diversity (Index Value) and/or the establishment of species of known conservation concern post rehabilitation is seen as indicative of a successful trend.

At present however, it is still generally too soon (only the first year of monitoring for 3 additional sites is now added to the dataset) to quantify any further long term, permanent change in species richness or abundance directly attributable to EDRRS. On this basis the overall trajectory evaluation is still in line with last year insofar as there is still no objective trajectory evidence of measurable increases in Pollinators which can be attributed to EDRRS measures.

Similar to last year, it is known that some of the bogs for which data is presented have additional species of Butterfly which have not to date been recorded 'on transect' (Blackwater Bog for instance has a colony of Grayling *Hipparchia semele* which would be notable in the County Offaly context). The present monitoring is effectively the first study to potentially look at Pollinator diversity in this scenario and it is hoped the evidence base produced will demonstrate benefits to Pollinators post rehabilitation/commencement of a return to a naturally functioning ecosystem, including the spread to rehabilitated areas of other species known to already occur at subject sites. Table 10, in Appendix D1 provides a summary of pollinator monitoring to date.

# 4. Carbon

## 4.1 Carbon Monitoring (General)

Research to date, found that industrially extracted bogs are large sources of carbon dioxide ($CO_2$), Disolved Organic Carbon (DOC) and Particulate Organic carbon (POC) while methane ($CH_4$) nitrous oxide ($N_2O$) and dissolved inorganic carbon (DIC) are usually found to be insignificant (Evans *et al.* 2017), (Wilson *et al*. 2022), (Swenson *et al*. 2019) except in shallow peat. In rewetted bogs, the emission of $CO_2$, DOC and POC is reduced due to the high-water table levels and ensuing anaerobic conditions, $CH_4$ emissions temporarily increase (Evans *et al.* 2017), (Wilson *et al.* 2022), (Swenson *et al.* 2019). Given these dynamics, the aim of this monitoring and verification program is to quantify the most significant Green House Gases (GHGs). GHG flux dynamics are also likely to vary over time starting with bare peat emissions which are often complicated by the need to account for inter-annual variability. The sites are outlined in table 4.1. Following rewetting, the short-term change in morphology such as the creation of bunding and drain blocking resulting in pooling water on bare peat, are likely to influence GHG flux dynamics resulting in potentially elevated $CO_2$ and $CH_4$ emissions. The longer-term impact of habitat regeneration such as where rewetted peatlands reach a climax state will also have GHG flux dynamics that are unique to that new peatland state albeit closer to natural peatland GHG fluxes (Kreyling *et al.* 2021).

The carbon monitoring and verification program addresses these requirements via the establishment of four monitoring campaigns. Table 4.1 lists the sites that are included in the monitoring plan. The overall aim of these campaigns is to address the variation of GHG emissions in current and future habitats. A second aim is to account for the different time scales where GHG fluxes may have particular dynamics (short term and long-term variation). These four monitoring campaigns are described as follows:

1. The first campaign is a chamber measurement program, designed to estimate emission factors for $CO_2$ and $CH_4$ from 22 different vegetation communities that are frequently present or expected to be present on Bord na Móna bogs.
2. The second monitoring campaign involves the establishment of two Eddy Covariance towers that will be used to estimate baseline emissions from peat and the short-term impact of rewetting and habitat rehabilitation. This option has the potential to measure long term changes. However, this is currently outside the scope of this project.
3. Thirdly, flumes and continuous DOC and POC estimated using spot samples, will be measured at the flux tower sites. This will provide emission factors for baseline bare peat and the short turn impact of rewetting.
4. Lastly, under the EDRRS enhanced surface water monitoring program, DOC and POC grab samples across EDRRS bogs will be used to estimate emission factors for current and future climax habitats that are present following both rewetting and habitat regeneration.

## 4.2 Desktop/Geospatial Review

Upon request by NPWS, vegetation communities were used to develop emission factors instead of habitats. This involved amending the work completed and described in the *Annual Monitoring and Verification Report – EDRRS Year 1 Bogs*. This included adding new chamber locations and changing the locations of those installed. The monitoring campaign is to be completed over two monitoring periods. Each monitoring campaign will last for two years and focus on different vegetation communities. To assist in the targeting of important vegetation communities, a decision tree was developed to represent current Bord Na Móna land cover characteristics and the likely succession pathways. This involved conducting a geospatial analysis to identify the zonal statistics per habitat types within Bord na Móna peatlands and these were quantified using ArcGIS Map 10.6. Initially, this analysis was completed using Bord na Móna General Habitat Maps.

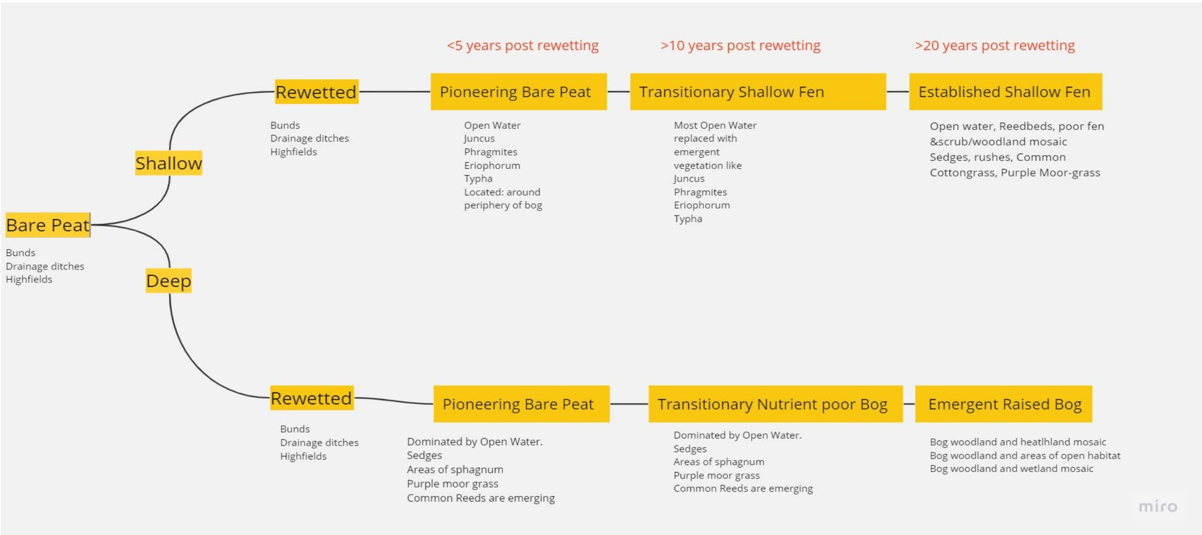


*Figure 4.1 Flow chart illustrating habitats and vegetation communities for carbon monitoring.*

This decision tree identified that two factors needed to be considered when choosing habitat locations. First, considering the large number of habitats and vegetation types present on Bord na Móna bogs, only habitat types that contributed significantly to the overall area were included for monitoring.  Second, that vegetation alone was insufficient to identify chamber locations and that hydrology, peat depth and water chemistry, where possible, should be used to select chamber locations. This conclusion was reached in conjunction with feedback from the NPWS at Ecology Workshops in July and October 2022. Monitoring began in April 2023. Vegetation communities (Table 4.1)are monitored and the data collected is used to develop emission factors for each vegeatation type.  On completion of the monitoring period on sites this will be then integrated into Bord Na Móna habitat classifications based upon spatial data collected during ecological surveys.

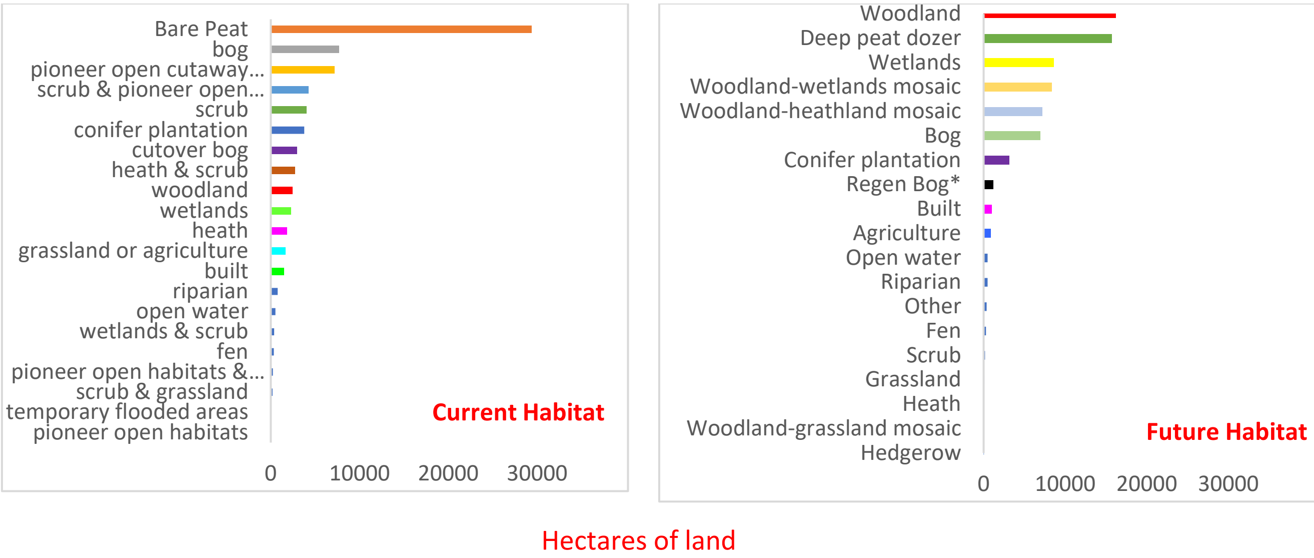


*Figure 4.2: Zonal Statistics on Bord na Móna bogs. These habitat types are classified by Bord na Mona under the General Habitat Classifications. Future iterations of this analysis will be conducted using detailed habitat classification. Chamber measurements are conducted using individual vegetations communities and combined to account for the mosaic nature of Bord na Móna Bogs.*

## 4.3 Collar Installation

Based on the geospatial analysis, sites were first inspected to ensure that they had the appropriate vegetation and peat depth, and where piezometers were in proximity. Where no piezometers were installed, these were added to the piezometer installation programme.

Sites were required to be isolated and no obvious security issues were present. Collars were inserted into the study site to a depth of 12cm using a root saw or spade to clear roots to enable collar insertion. Collars were levelled to ensure that the chamber could achieve a tight seal. A measurement was not taken on the collar for at least one week and in most cases several weeks.

Chamber sites were protected from trampling using both supported boardwalks and non-supported boardwalks. This involved the construction of boardwalks either on site or on Bord na Mona premises and then transported to site. Figure 4.3 shows the collars installed by March 2023. Specific details regarding the sites can be found in Table 4.1.

*Table 4.1: Locations selected for chamber measurements selected following geospatial analysis of Bord na Móna land bank and modelled future habitats.*

| Bog | Depth | Vegetation Community | Rewetted | Rewetting | pH | Scenario |
|---|---|---|---|---|---|---|
| Ballycon | Shallow | Carex rostrata | Y | 17 Years | Basic | Future |
| Derries | Shallow | Carex rostrata | Y | 17 Years | Basic | Future |
| Ballycon | Shallow | Eriophorium | Y | 17 Years | Basic | Future |
| Blackriver | Shallow | Eriophorium | Y | 40 Years | Basic | Future |
| Mouds | Deep | Heather | N | | Acidic | Baseline |
| Clonad | Shallow | Heather | N | | Basic | Baseline |
| Ballycon | Shallow | Juncus | Y | 17 Years | Basic | Future |
| Blackriver | Shallow | Juncus | Y | 40 Years | Acidic | Future |
| Ballycon | Shallow | Molinia Grass | Y | 17 Years | Basic | Future |
| Clonad | Shallow | Molinia Grass | N | | Basic | Baseline |
| Ballycon | Shallow | Open Water | Y | 17 Years | Basic | Future |
| Derries | Shallow | Open Water | Y | 10 Years | Basic | Future |
| Ballycon | Shallow | Phragmites | Y | 17 years | Basic | Future |
| Derries | Shallow | Phragmites | Y | 10 Years | Basic | Future |
| TBC | TBC | Purple Moor grass | | | | |
| TBC | TBC | Purple Moor grass | | | | |
| Mouds | Deep | Sphagnum - Dry | N | | Acidic | Baseline |
| Clonad | Shallow | Sphagnum - Dry | N | | Acidic | Baseline |
| Ballycon | Shallow | Sphagnum - Wet | Y | 17 years | Basic | Future |
| Blackriver | Shallow | Sphagnum - Wet | Y | 40 Years | Acidic | Future |
| Ballycon | Shallow | Typha | Y | 17 Years | Basic | Future |
| Derries | Shallow | Typha | Y | 17 Years | Basic | Future |

Examples of collars installed in vegetation communities are shown in Figure 4.3 below. The chamber monitoring program has four collars installed across two bogs. It is anticipated that this will increase to 6 collars.

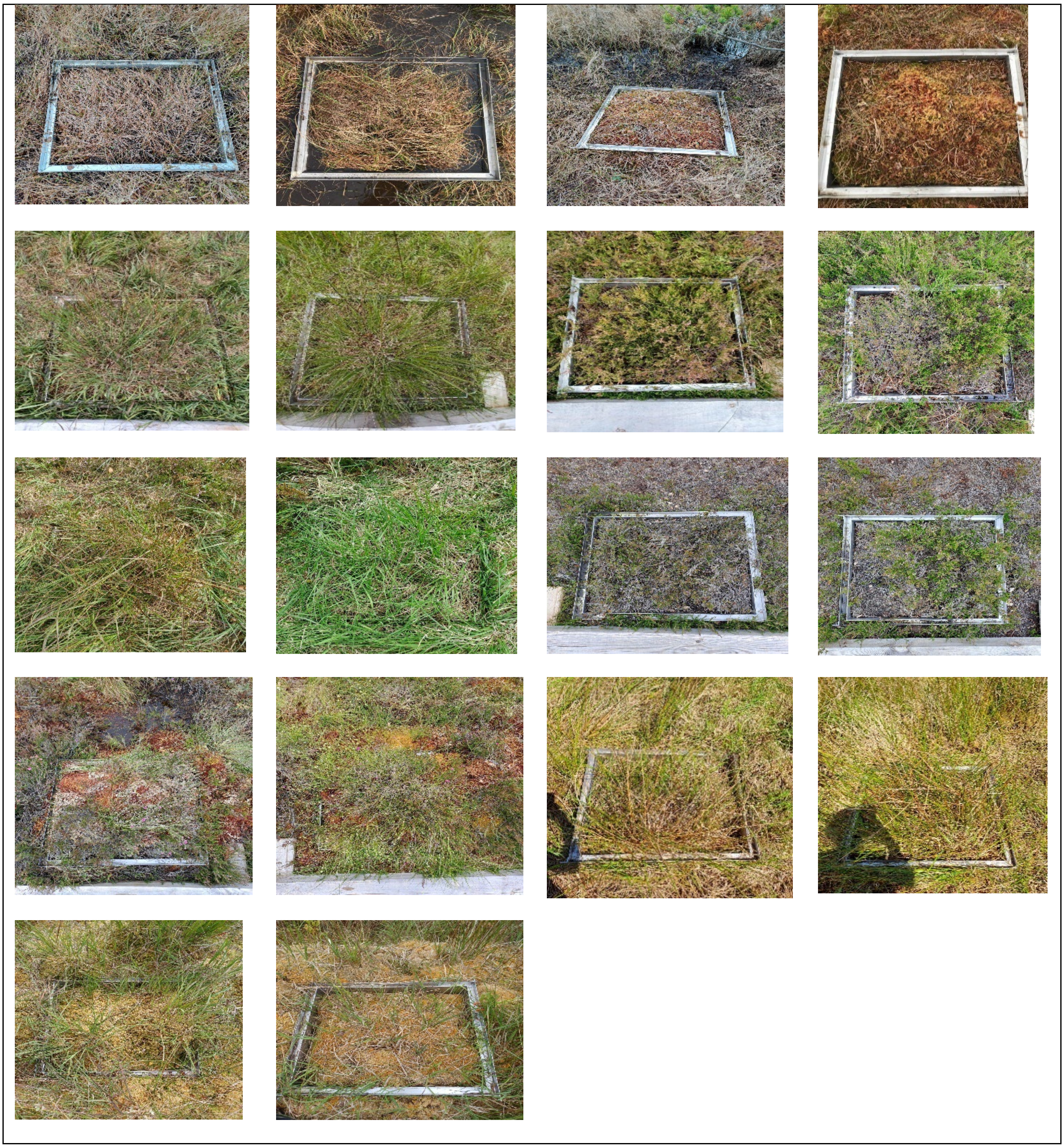

*Figure 4.3 Vegetation communities from left to right include Eriophorium X 2, Sphagnum X 2, Molina Grasses X 2, Calluna Vulgaris X2, Molina Grasses X 2, Calluna Vulgaris X2, Sphagnum X 2, Juncus EffususX2, Sphagnum X2. These are collars installed up to March 2023.*

## 4.4 Closed Static Chamber Field Measurements

Closed static chamber measurements on all monitoring sites are measured at fortnightly intervals during the growing season and monthly intervals during the non-growing season. The Net Ecosystem Exchange (NEE), Ecosystem Respiration (Rs) and Methane ($CH_4$) fluxes are measured using a LICOR 7810 trace gas analyser. The standard chamber consists of polycarbonate sheets (Maier *et al.* 2022)

(60cm*60cm*50cm), an internal fan to ensure mixing and an Apogee SQ-520 Photosynthetic Active Radiation (PAR) Sensor to measure Photosynthetic Photon Flux Density (PPFD). The internal temperature of the chamber is measured using a temperature probe. Temperature is monitored during the chamber closure time and if temperatures vary greater than 4ºC the measurement will be discarded and re-taken (Wilson *et al*. 2016). During warm periods, a cooling system will be used (e.g. ice packs) to maintain temperature at ambient levels (Wilson *et al*. 2022). To ensure enough fluxes are recorded at different light levels, three chamber measurements will be taken per collar. One measurement will be taken with the clear chamber, a semi-transparent sheath will be used for a second measurement and a third measurement will be taken using a dark sheath to simulate night-time respiration (Maier *et al*. 2022). In addition, to ensure that chamber measurements are taken at higher light levels, measurements will be taken different times of the day. Specifically, measurements will coincide where peak sunlight is anticipated to ensure that sufficient model accuracy can be achieved.

A second type of floating chamber is used to measure fluxes from aquatic environments. Three floating chambers were built from polycarbonate sheets (25cm*25cm*25cm). To simulate different light levels, one chamber will be clear, one opaque and one will be covered in aluminium foil (to simulate night-time respiration). The same set-up will be used as described already (Maier *et al*. 2022)

A third type of chamber has been constructed for tall vegetation. This chamber consists of modular stackable chambers that can be constructed up to 1.5m in height. This chamber is fitted with two brush fans to ensure mixing and has a temperature probe and PAR.

*Figure 4.4 Stackable Chamber*

Chamber measurements are taken over 1 minute and 30 seconds with the first 30 seconds for mixing (Maier *et al*. 2022). In certain conditions, the chamber closure period will be amended to shorter time periods (where excess water vapour or pressure increases are present) or longer closure times where fluxes are smaller (Maier *et al*. 2022). A python script is used to automate the measurement protocol where measurements are taken every 2 seconds from the LICOR 7810 and averaged depending on the closure period. Each averaged measurement is automatically plotted to assess the linearity of the measurement and is viewable on a laptop tablet. (Maier *et al*. 2022).

## 4.5 Closed Chamber Flux Calculation

Chamber field measurements that have a co-efficient of determination of 0.90 or greater are accepted. Where a field measurement is accepted, it is input into a flux calculation (Fc):

Equation 1: $$F_c = \frac{10VP_0(1-\frac{W_0}{1000})}{RS(T_0+273.15)} \frac{\partial C\prime}{\partial t}$$ (LICOR,2019)

Where V is the chamber Volume ($m^3$), P is the Air Pressure (Hpa) (taken from nearest Met Eireann Station), W0 is the initial H2O concentration (mmol/mol), R is the ideal gas constant (8.3144), T0 is air temperature taken from the temperature probe (Kelvin), ∂C' is the change in $CO_2$ or $CH_4$ concentration and ∂t is the time elapsed (seconds).

## 4.6 Site Configuration

Each chamber monitoring site will include a boardwalk to prevent disturbance, a piezometer with continuous measurements (Rugged Troll 100 loggers), and continuous monitoring of soil temperature and PAR sensors (Hobo Direct). In addition, spot measurements of water table levels via dip-well method, soil water pH (YSI Pro 10 Professional Plus), soil moisture, temperature, and conductivity (PICO 64 200mm temperature, moisture content & electrical probe) at each collar and Leaf Area Index (LAI) were also taken using a Licor 2200C. Peat depth was also taken using a peat depth probe stick.

## 4.7 Modelling Flux Measurements to Annual Fluxes

To model annual GHG fluxes, closed static chamber flux measurements are used in conjunction with soil temperature, moisture and PPFD data as inputs into carbon models that can estimate annual fluxes from that location.

The NEE is the net exchange of $CO_2$ from an ecosystem or habitat and consists of two terms as shown in Equation 2:

Equation 2: $$NEE = -GPP + R_s$$ (Billet *et al*. 2010)

Where NEE is the net ecosystem exchange, GPP is gross primary production and $R_s$ is the ecosystem respiration. Negative values indicate sequestration while positive values indicate an emission.

As both NEE and Rs are directly measured, GPP is estimated by re-arranging Equation 2 to:

Equation 3: -GPP = Rs – NEE

To take these spot measurements and convert them into annual fluxes, the $CO_2$ and $CH_4$ fluxes are related to environmental variables monitored at the site and the annual fluxes are then extrapolated based on this. In this case, soil temperature at 5cm and PAR are used in addition to water table level. It is anticipated that several models will be used to estimate each parameter and the best performing model will be selected.

### Gross Primary Production (GPP)

GPP can be related to PAR using the Michaelis–Menten-type relationship that describes the saturating response of photosynthesis to light and soil temperature (Tuittila *et al*. 1999, Wilson *et al*. 2016). This involved developing a light response curve that characterises the relationship between GPP and changes in light levels. Coefficients are used to describe this relationship, and these will be obtained using Python Scipy optimize module using the Levenberg–Marquardt multiple nonlinear regression technique (Wilson *et al*. 2016). PAR sensors located at each bog takes measurements at hourly intervals where chamber measurements are occurring will be used to estimate GPP measurements. Equation 4 - 7 was used to model GPP fluxes:

Equation 4: $GPP = GPP_{max}\left(\frac{PPFD}{PPFD + k_{PPFD}}\right) * (\exp(a * T5))$ (Wilson et al., 2022)

Equation 5: $GPP = -GPP_{max}\left(\frac{PPFD}{PPFD + k_{PPFD}}\right)$

(Laine et al., 2006)

Equation 6: $GPP = -\left(a + c * \sin\left(\frac{JD}{365} * \pi\right)\right) * \left(\frac{PPFD}{PPFD + b}\right) * (1 + T5cm * d) * (1 + WT * e)$

(Swenson et al., 2019)

Equation 7: $GPP = -\left(a1 + c * \sin\left(\frac{JuilanDay + 215}{365} * \pi\right)\right) * \left(\frac{PPFD}{PPFD + b}\right) * exp(T5cm * d) * (1 + WT * e)$

(Swenson et al., 2019)

where GPP is gross primary production, GPPmax is maximum photosynthesis, PPFD is photosynthetic photon flux density, kPPFD is the PPFD value at which GPP reaches half its maximum, and T5 is the soil temperature at 5 cm depth, the a1 term is equivalent to the average annual GPPmax, and the c term is the relative seasonal variation in GPPmax throughout the year, d is a linear coefficient between soil temp and GPP, WT is water table while e is the linear coefficient between WT and GPP

## Ecosystem Respiration (Rs)

Ecosystem respiration is the exchange of CO2 from plant derived processes (Autotrophic respiration) and from microbial breakdown of organic material (Heterotrophic respiration). Like GPP, a temperature response curve was used to identify coefficients that enabled the relationship between soil temperature and Rs to be described and then used to model annual fluxes using Equation 8 - 11 used in.

Equation 8: $R_s = a * \exp\left[b\left(\frac{1}{T_{REF-}T_0} - \frac{1}{T5 - T_0}\right)\right]$ (Wilson *et al*. 2022)

Equation 9 : $RS = a1 * e^{b1*T5cm}$ (Piechl et al., 2014)

Equation 10: $RS = a1 * e^{b1*T5cm} - c*WT$ (Swenson et al., 2019)

Equation 11: $Rs = a1 * T5cm - (b1 * WT + c1)$

(Strack et al., 2014)

where Rs is ecosystem respiration, $T_{REF}$ is reference temperature set at 283.15 K, $T_0$ is the (minimum) temperature at which respiration reaches zero and is set here at 227.13 K, T5 and T10 are the soil temperature at 5 cm, respectively, and a and b are fitted model parameters. Coefficients a1, b1 and c1 are obtained via line fitting

Using modelled GPP and Rs, the NEE will be calculated as the difference between the two processes using Equation 2.

### Methane (CH4) Fluxes

Methane fluxes occur because of anaerobic breakdown of organic material within the peat profile. The emission of methane is mediated by ebullition processes (sudden and large emissions), plant mediated transport pathways and diffusive transport processes like concentration gradients (Maier *et al*. 2015). Methane fluxes are estimated using Equations 12-14.

Equation 12: $CH_4 = (\exp\ (a * T_{5cm}))$ (Wilson et al.,2022)

Equation 13: $CH_4 = \left(\exp\ (a * T_{5cm})\right) * \left(b + (c * WT)\right)$ (Wilson et al., 2016)

Equation 14: $CH_4 = \left[0.205 * \sin\left(\frac{Juilian\ Day + 216}{365} * 4\pi\right) + 0.729\right] * e^{\left(213.1 * \left(\frac{1}{283.15} - \frac{1}{T5cm + 273.15 - 227.13}\right)\right)}$

(Swenson et al., 2019)

where $T_{5cm}$ is soil temperature at 5 cm depth, and a, b and c are model parameters.

### Radiative Forcing Models.

Radiate forcing models like Wilson (*et al*. 2022) are currently being investigated. Bord na Móna are in discussions with the experts in this area and will report back in the next report. A significant concern in rewetting bogs is the impact that strong radiative forcing gases may have on the overall GHG balance. Wilson (*et al*. 2022) and Günther (*et al*. 2019) both found that despite the radiative warming influence of $CH_4$, the avoided $CO_2$ emissions, and in time sequestration, offset the net warming effect. Bord na Móna will seek to follow a similar approach to these studies and provide further evidence to the benefits of peatland rehabilitation.

## 4.8 Eddy Covariance Towers

The overall aim of using Eddy covariance towers is to evaluate the real-time impact of rehabilitation measures on carbon fluxes. Bord na Móna peatlands can be characterised by depth given the homogeneous nature of bare peat and it is therefore appropriate to categorise these peatlands based on depth. This distinction is important because peat depth is likely to be an important indicator of its future rehabilitation trajectory whether it be towards a nutrient poor raised bog or fen, or alternatively towards nutrient rich fen. Therefore, flux tower placement needs to account for the most frequently occurring peat depths on Bord na Móna bogs.

To achieve this, ground penetrating radar (GPR) and LiDAR survey data indicating peat depths was used to estimate peat depths for two broad categories: shallow/ intermediate peat (<2.5 depth) and deep peat (2.5m+). This analysis conducted over 25,000 hectares found that the most frequently occurring peat depth was shallow/ intermediate peat which accounted for 61% of Bord na Mona peatlands followed by deep peat which accounted for the remainder, as illustrated in Figure 4.5 below.

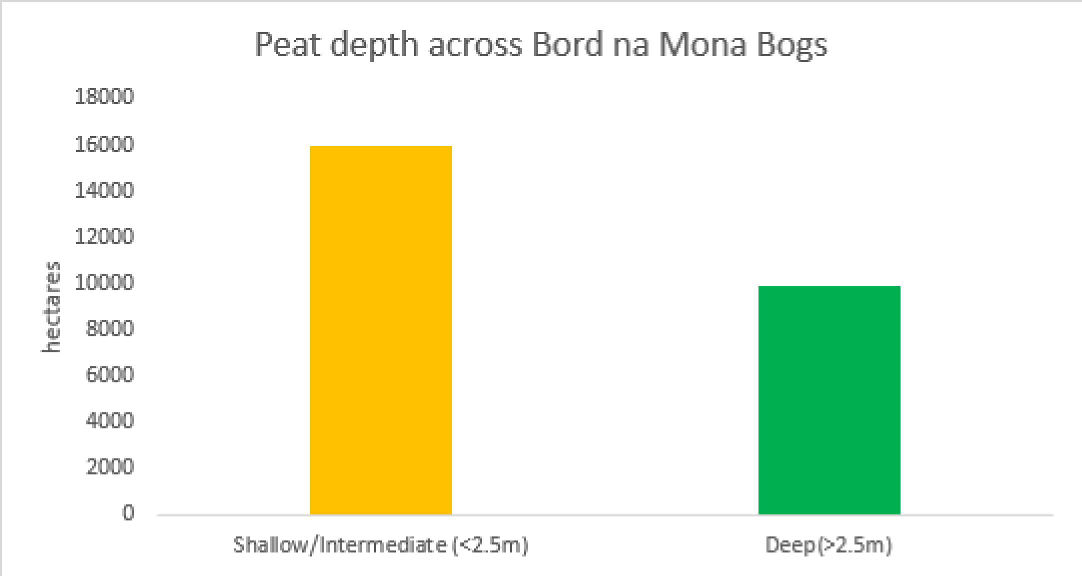


*Figure 4.5 Bar plot showing peat depths over 25,000 hectares of Bord na Mona peatlands. The plot indicated that the most frequently occurring peat depth is shallow/Intermediate peat (depth < 2.5m)*

Several sites were investigated to locate the eddy covariance flux towers with consideration given to factors like security, internet access, presence of peat stock, access to electrical grid and schedule of rehabilitation works (at least one year of baseline data was required before rewetting). Sites that were examined included [redacted]

### Eddy Covariance Tower Location 1 [redacted]

The selected bog [redacted]
The bog represents a shallow/intermediate cutaway peatland with an average of less than 2.5 meters peat depth. The eastern section of the bog was the chosen site location for the Eddy Covariance tower.

[redacted] The tower is set up to measure emissions from peatland within a 270 metre radius of the tower. The peat depths within that footprint are on average 1.9 metres deep (Std. Dev = 1.05m). The maximum peat depth within the tower footprint is 3.65 metres depth, and the minimum is 0.0 metres. The prevailing wind direction (West, North-West as shown in Figure 4.6) indicates that the footprint is likely to focus on shallow peat. Deeper peat in located to the south of the flux tower. The flux tower is located to ensure it is a safe distance from the roadside. Contingency plans are in place to amend the site setup should the prevailing wind direction change, or the footprint is outside our area of interest in which case the tower will be moved. Alternatively, the height of the tower can be increased therefore increasing the footprint size. The eddy covariance software is capable of extracting areas of interest from within the footprint.

The eddy covariance tower was first set up in a laboratory to ensure that all parts were received and in working order. It was subsequently installed [redacted] on the 25th of September 2022. The tower is powered by four 12V batteries connected in parallel which are in turn powered by two arrays of five 350W solar panels connected in serial.

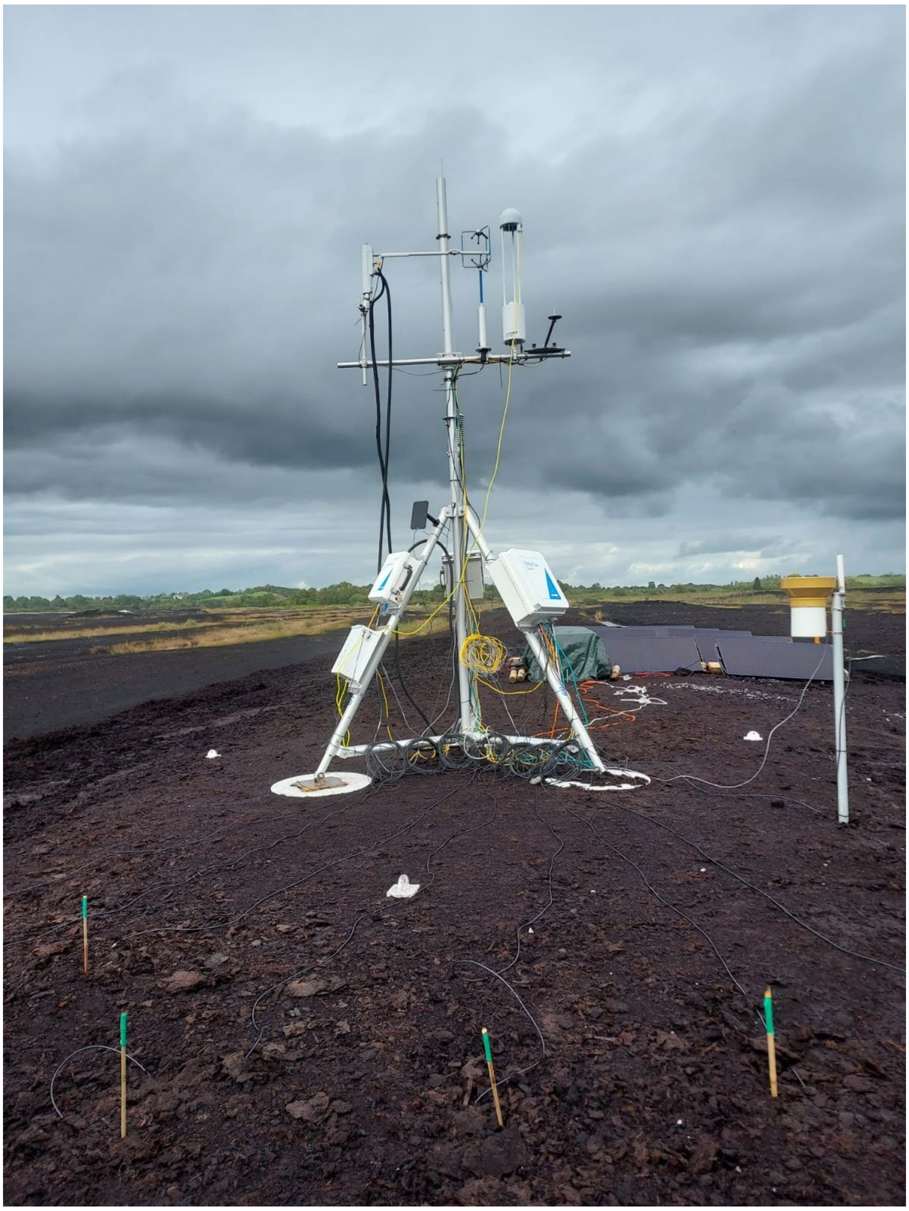

*Figure 4.6: The Eddy Covariance tower capable of measuring $CO_2$, $CH_4$, meteorological Variables, surface energy balance components*

*Figure 4.7: The Eddy Covariance tower showing signage and solar panel set up.*

Initial data from this carbon Eddy covariance tower is included in Appendix E. However, it is too early to interpret this data and this interpretation will be carried when more data has been gathered.

### Eddy Covariance Tower Location 2 [redacted]

The second tower was installed in March 2023 in [redacted] This is a deep peat bog with average of greater than 2.5 meter peat depth located [redacted] Peat production on the site ceased in 2020 in line with other Bord na Mona production bogs. The tower is set up to measure emissions from peatland within a 250 metre radius of the tower and the area has an average peat depth of 4.36m (Std Dev = 0.9m).

As the tower was installed in March 2023 data for the reporting period is not available. This will be reported on in the next Annual Monitoring Report.

*Figure 4.8: Flux tower tower in operation at site 2 location was selected because of the presence of deep peat, location away from stockpiles and presence of a significant footprint.*

## 4.9 Aquatic Carbon Losses

Previous studies have estimated that organic aquatic losses are significant contributors to the overall GHG balance of industrially extracted bogs (Evans *et al.* 2017). In addition, significant reductions were found upon rewetting, indicating that measurement of aquatic losses is valuable in quantifying the overall carbon benefit of the Bord na Móna EDRRS rehabilitation program (Evans *et al.* 2017).

The monitoring and verification program aims to monitor DOC and POC at the bogs where the Eddy Covariance towers are located. Two RBC type flumes were installed in [redacted] and placed in bare peat catchments. The aim of this monitoring program is to develop baseline DOC and POC emission factors for bare peat and for rewetted peatlands following rehabilitation in the short term. DOC is measured using a Photonic Measurements UV254 Probe while POC will be measured via grab samples and analysed via loss on ignition techniques in an external accredited laboratory (in procurement process) following the methods outlined in (Ryder *et al.* 2014). These flumes and probes were installed in December 2022.

*Figure 4.9: RBC Flume located in bare peat catchment of 42 hectares.*

The Site 1 flumes are located in deep and shallow peat catchments. The first flume is located at the southwestern region of the bog in a catchment of approximately 42 hectares. The second flume is located in a 25-hectare catchment in the northeast of the site in shallow peat. Two additional flumes are to be installed in separate bogs post March 2023 and the locations for these flumes will be confirmed in the next Annual monitoring report.

# 5. Surface Water Monitoring

Surface water monitoring is required under Bord an Móna's Integrated Pollution Control (IPC) Licences issued by the Environmental Protection Agency (EPA). The licence obligation of a quarterly sampling regime on a selected number of locations was not considered sufficient to appropriately track the changing water chemistry that will occur as part of this enhanced rehabilitation programme. The frequency and extent of sampling has been increased under the scheme so that circa 70% of each bog's drainage catchments are monitored monthly. The parameters monitored are as per condition 6.2 of the IPC Licence and include monitoring for pH, Suspended Solids, Total Solids, Total Phosphorus, Total Ammonia, Colour & COD (chemical oxygen demand). In addition, DOC (dissolved organic carbon) has been included as a parameter to identify changes in carbon in the surface water.

## 5.1 Surface Water Quality – Data

Surface water monitoring results for the Year 1 and Year 2 bogs are contained in Appendix F. This appendix contains monitoring results from the monthly water sampling programme commenced in most cases in November 2020 for Year 1 bogs and Year 2 bogs. Some additional bogs in Year 2 that were not originally scheduled for the year 2 programme, commenced monitoring in January 2023, but in 90% of cases all monitoring commenced in late 2020 or early 2021.

Monitoring returns 2020 – 2022, as required under the applicable condition of the IPC Licence were submitted to the EPA for calendar years 2021 and 2022, in August of this year. Environmental monitoring performance is reported in the Annual Environmental Report submitted in March each year, for the preceding calendar year, so reporting as part of this monitoring and verification report is up until December 2022.

During this reporting period, over 4000 samples were obtained from suitable sampling locations from these bogs. In some events, sampling was not achieved where downstream rivers and streams were in Winter flood, with associated outlets backed up and not discharging. This was also the case during prolonged periods of dry weather, where bog outlets were not discharging.

The pertinent parameters to consider in analysis of water quality impacts from previous industrial extracted peatlands would be suspended solids (mobilised milled peat particles), ammonia and Chemical Oxygen Demand. Another parameter worth observing would be pH changes that might arise as rehabilitation measures block drainage systems, either gravity or pumping.

The relevant IPC Licence emission limit values are 35mg/l for suspended solids and for Ammonium it ranges from 1.42 to 4.53mg/l, with the higher range of the limit associated with deeper younger bogs that would have been last used in 2019 for horticultural peat. Chemical Oxygen Demand factors that could influence the water quality also include if the bog was drained but not extracted and if it was used for horticultural peat or fuel peat. The drainage characteristics of the bog post rehabilitation will also influence water quality i.e., gravity versus pumped.

From an analysis of the monitoring results and associated trends or changes in the measured water parameters in Appendix F, the following has been determined:

*Table 5.1 – Observed result concentrations based on EDRRS Surface Water monitoring*

| Year | Bog | Suspended Solids | Ammonia | COD | pH | Drainage, gravity or pumped (G, P) | Drained only, Fuel or Horticultural Peat bog (D, F, H) |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/l | mg/l | units | | |
| | | Trends | | | | | |
| 1 | Castlegar | ↔ | ↓ | ↓ | ↔ | G | F |
| 1 | Kellysgrove | ↓ | ↑ | ↑ | ↓ | G | D |
| 1 | Garryduff | ↔ | ↓ | ↔ | ↔ | P | F |
| 1 | Kilmacshane | ↑ | ↔ | ↔ | ↓ | P | F |
| 1 | Belmont | ↓ | ↔ | ↓ | ↑ | G | F |
| 1 | Derries | ↑ | ↑ | ↔ | ↔ | G | F |
| 1 | Turraun | ↓ | ↔ | ↓ | ↔ | G | F |
| 1 | Pollagh | ↓ | ↔ | ↓ | ↔ | P | F |
| 1 | Oughter | ↓ | ↓ | ↓ | ↔ | P | F |
| 1 | Boora | ↓ | ↓ | ↓ | ↑ | G | F |
| 1 | Clonad | ↔ | ↑ | ↑ | ↓ | G | F |
| 1 | Mountlucas | ↑ | ↔ | ↑ | ↓ | G | F |
| 1 | Cavemount | ↓ | ↓ | ↓ | ↔ | G | F |
| 1 | Esker | ↓ | ↓ | ↓ | ↑ | G | F |
| 1 | Ummeras | ↔ | ↓ | ↑ | ↑ | G | H |
| 1 | Derrycashel | ↔ | ↑ | ↓ | ↓ | P | F |
| 1 | Derrycolumb | ↓ | ↔ | ↑ | ↔ | P | F |
| 1 | Edera | ↔ | ↓ | ↔ | ↓ | G | F |
| | | | | | | | |
| 2 | Derryfadda | ↓ | ↑ | ↓ | ↓ | G | F |
| 2 | Clonniff | ↓ | ↓ | ↓ | ↔ | P | F |
| 2 | Bloomhill | ↓ | ↓ | ↔ | ↔ | P | F |
| 2 | Blackwater | ↓ | ↓ | ↑ | ↔ | P | F |
| 2 | Bunahinly | ↓ | ↑ | ↔ | ↑ | G | F |
| 2 | Noggusboy | ↓ | ↓ | ↓ | ↔ | P | F |
| 2 | Derrybrat | ↓ | ↑ | ↑ | ↓ | G | F |
| 2 | Kilaranny | ↓ | ↔ | ↔ | ↔ | G | F |
| 2 | Derrinboy | ↑ | ↔ | ↔ | ↔ | P | H |
| 2 | Carranstown | ↑ | ↑ | ↑ | ↔ | G | H |
| 2 | Cloncreen | ↓ | ↓ | ↓ | ↓ | P | F |
| 2 | Ballycon | ↓ | ↔ | ↓ | ↔ | G | F |
| 2 | Lodge | ↓ | ↓ | ↓ | ↑ | P | F |
| 2 | Timahoe Sth | ↑ | ↑ | ↓ | ↑ | G | F |
| 2 | Prosperous | ↑ | ↓ | ↑ | ↔ | G | H |
| 2 | Knappogue | ↔ | ↓ | ↓ | ↑ | P | F |
| 2 | Begnagh | ↓ | ↓ | ↓ | ↑ | P | F |
| 2 | Clooneeny | ↔ | ↑ | ↔ | ↔ | P | F |
| 2 | Glenlough | ↓ | ↑ | ↓ | ↓ | G | D |
| 2 | Derraghan | ↔ | ↔ | ↓ | ↔ | P | F |

| | |
|---|---|
| ↓ | Improving trajectory |
| ↔ | No obvious trajectory |
| ↑ | Disimproving trajectory |

| | | |
|---|---|---|
| ↔ No Change | ↑Increasing concentration | ↓decreasing concentration |

The initial positive trends in year 1 & 2 bogs were an observed downward trend in suspended solids post completion of the rehabilitation, as indicated by the green downward arrows. While all peatlands had an existing silt control infrastructure during peat extraction activities for the last 23-30 years, which were maintained during the rehabilitation programme, these results were well under the 35mg/l limit and continuing in a downward trend in concentration. Any outlets which had no discernible trajectory indicated in yellow, or had an increasing trend in red, these peatlands were still well below the emission limit value. It is expected that post rehabilitation, when all rehabilitation has been completed and associated hydraulic controls in place, the peat surface will stabilise and any solids still available to be mobilised during rainfall events will be retained within the bog.

Ammonia is produced through natural microbial action when organic compounds are decomposing during peatlands anaerobic conditions, which are then mobilised during drainage and associated peat extraction. Ammonia trends across all Year 1 and 2 bogs had mixed trends with no obvious differences. It might have been expected that Year 1 bogs might indicate a downward trend ahead of Year 2 bogs, but this does not seem to be the case. 27% of bogs showed a slight increase in Ammonia concentrations, but this increase was not evident in all the monitored outlets of these applicable bogs. It is expected that these positive trends will continue as the rehabilitation starts to stabilise, all be it that peatlands will always have a natural background Ammonia base concentration due to this naturally occurring process and normal seasonal fluctuations.

Chemical oxygen demand is again a measure of the peatlands organics that can be present in runoff from peatlands, with trigger levels of 100mg/l set as part of licence regulation, but with 99% of surfacewater outlets being well under this limit. 78% of bogs indicated a downward positive or neutral trend. As above, lack of ongoing drainage and arresting of previous drainage systems is expected to return the bog to its natural water retention capacity which will in turn reduce mobilisation of organics.

pH can also be another indicator of changes in a bog's hydrology, with intact bogs primary water supply coming from rainfall. Drained peatlands and peatlands where extraction and lowering of drainage has been ongoing, gravity and/or pumped drainage, groundwater can become influential. Rehabilitated peatlands hydrology will retain more rainwater and will therefore be more acidic. Previously drained peatlands will have less retention of rainwater and a possible introduction of groundwater where the peat depth is shallow and may have pumping/active drainage. The pH measured during the monitoring period from these bog regions, i.e., Shannon upper, mid Shannnon and Barrow catchments bogs, was 7.33 to 7.34 with a typical intact bog, with no drainage, having a pH of 4.0.

As monitoring of these bogs continues in 2023 and on into the next monitoring cycle, any identifiable trends post rehabilitation will be tracked to validate expected improving trends and any establishing trajectories in water quality, from these bogs.

# 6. Flow Monitoring

Monitoring of surface water discharge from the peatlands is not an integral part of the monitoring programme for EDRRS bogs, however some flow monitoring of bogs is underway as set out below.

## 6.1 Provision of Flumes

The installation of flumes is discussed in Section 4 above. While the purpose of these flumes is to quantity carbon aquatic losses, they will also provide a record of the flow from these bogs. The two flumes installed by the end of March 2023 are located on a bog with a carbon flux towers and rainfall is also measured on this bog. These readings, combined with the catchment size, will give an indication of the run-off from bare peat bogs before rehabilitation is carried out and after rehabilitation has been implemented.

## 6.2 Monitoring of flow using probes

Three flow monitoring probes have been installed on bogs to be rehabilitated under EDRRS. One of these probes is located in [redacted]

The 2150 velocity flow module installed at each location measures liquid level and average stream velocity and calculates the flow rate and total flow. The liquid level and velocity measurements are read from an attached AV Sensor that is placed in the flow stream within a pipe. Power supply is provided using a solar panel and a rain gauge is also provided at each location.

[redacted] Flow data for the period January 2020 to August 2021 is available, the majority of which is prior to the commencement of the rehabilitation measures. Work was required on the probe and following re-installation, flow monitoring commenced again in June 2022 and is ongoing. The flow data from these probes is exported and can be viewed and downloaded remotely using Flowlink software.

The velocity probe in [redacted] was installed in June 2022 and the probe [redacted] was installed in May 2022. Due to the dry summer there was no flow in [redacted] pipe during the summer period, however data has been available from this probe since September 2022.

This data will be useful to analyse the impact of rehabilitation on flow and this analysis can be carried out ost rehabilitation completion on each bog and in conjunction with other flow monitoring data gathered as part of the scheme.

The location of these flow monitoring probes is shown in Figure 6.1 below and an example of the set up for these probes is shown on Figure 6.2 below.

*Figure 6.1: Location of three flow monitoring probes*

*Figure 6.2: Flow Monitoring Velocity probe- Probe is installed in the pipe with the rain gauge, solar panel and container with data logger visible in the background.*

## 6.3 Monitoring of flow - Composite Samplers

Composite samplers have been installed in the following Year 1 EDRRS Bogs

[redacted]

In addition, composite samplers have also been installed in the following EDRRS bogs where rehabilitation has commenced or is due to commence in future years:

[redacted]

While these composite samplers have been installed to sample the surface water discharging from the bog, these samplers also automatically measure the flow. Downloading of this flow data has commenced in recent months.

# 7. Aerial Imagery/ LiDAR

Aerial imagery from 2017/2020 was available for the Bord na Móna bogs included in EDRRS, and this imagery was purchased at the commencement of the scheme. In order to determine the range of elevations across the bogs prior to the commencement of rehab measures, LiDAR (Light Detection and Ranging) was used. LiDAR is a remote sensing system that uses light from an aircraft to measure distance and generates a topographical survey of the land. This information was gathered from aircraft over flying the bogs and as aerial imagery was already available, the bogs could be flown at night for this purpose.

Following the completion of the first year of the scheme implementation, the EDRRS Year 1 bogs were flown in Summer 2022 to capture new aerial imagery and also updated LiDAR information. It is the intention to obtain similar imagery for the Year 2 bog in late Summer/ Early Autumn 2023, depending on the availability of suitable weather conditions and clear skies.

The aerial imagery aims to demonstrate the location of peat drain blocks, rehabilitated cells and also gives an indication of the standing water on the bog. The figures below show an example of the imagery pre-rehabilitation and post – rehabilitation.

The LiDAR provides updated elevations across each of the bogs, and also maps berm and bunded cell heights. A summary of the aerial imagery and LiDAR survey dates are referenced for the Year 1 bogs in Table 7.1 below:

| Bog | Pre-Rehab LiDAR | Post Rehab LiDAR | Pre-Rehab Imagery | Post Rehab Imagery |
|---|---|---|---|---|
| Belmont | 22/12/2020 | 21/06/2022 | 15/04/2020 | 21/06/2022 |
| Boora | 04/11/2020 | 18/07/2022 | 15/04/2020 | 18/07/2022 |
| Castlegar | 22/11/2020 | 21/06/2022 | 17/07/2017 | 21/06/2022 |
| Cavemount | 06/11/2020 | 21/06/2022 | 15/04/2020 | 21/06/2022 |
| Clonad | 06/11/2020 | 21/06/2022 | 15/04/2020 | 21/06/2022 |
| Derries | 04/11/2020 | 18/07/2022 | 15/04/2020 | 18/07/2022 |
| Derrycashel | 26/09/2020 | 21/06/2022 | 21/04/2020 | 21/06/2022 |
| Derrycolumb | 26/09/2020 | 21/06/2022 | 13/05/2020 | 21/06/2022 |
| Edera | 26/09/2020 | 21/06/2022 | 14/05/2020 | 21/06/2022 |
| Esker | 06/11/2020 | 21/06/2022 | 15/04/2020 | 21/06/2022 |
| Garryduff | 22/12/2020 | 21/06/2022 | 15/04/2020 | 21/06/2022 |
| Kellygrove | 22/12/2020 | 21/06/2022 | 18/07/2017 | 21/06/2022 |
| Kilmacshane | 22/12/2020 | 21/06/2022 | 15/04/2020 | 21/06/2022 |
| Mountlucas | 06/11/2020 | 21/06/2022 | 15/04/2020 | 21/06/2022 |
| Oughter | 04/11/2020 | 18/07/2022 | 15/04/2020 | 18/07/2022 |
| Pollagh | 04/11/2020 | 18/07/2022 | 15/04/2020 | 18/07/2022 |
| Turraun | 04/11/2020 | 18/07/2022 | 15/04/2020 | 18/07/2022 |
| Ummeras | 26/09/2020 | 21/06/2022 | 15/04/2020 | 21/06/2022 |

*Table 7.1: Summary of Aerial Imagery and LiDAR dates for Year 1 Bogs*

*Figure 7.1: Aerial imagery of a section of Clonad Bog prior to rehabilitation*

*Figure 7.2: Aerial imagery of the same section of Clonad Bog post rehabilitation (Summer 2022)*

A dashboard showing the rehabilitation status across each bog in the scheme is now available and this aerial imagery can be viewed on this dashboard. The imagery for the Year 2 bogs will be added to this dashboard as it becomes available.

# 8. Archaeology

In advance of the commencement of the rehabilitation, Bord na Móna engaged a Project Archaeologist to undertake a desk-based study of all available surveys and excavations on the EDRRS bogs in question. These archaeological impact assessment (AIA) reports were prepared by Dr. Charles Mount to fulfil this characterisation in relation to archaeological heritage. It represents the results of a desk-based assessment of the impact of proposed bog rehabilitation on the known archaeological heritage of the bog. This assessment includes a collation of existing written and graphic information to identify the likely archaeological potential of each bog. These areas were examined using information from:

1. The IAWU Peatland Survey 1991
2. Bord na Mona Re-assessment survey 1999
3. The Sites and Monuments Record that is maintained by the Dept of Housing, Local Government and Heritage
4. The topographical files of the National Museum of Ireland 39
5. Archaeological monitoring
6. The Excavations database
7. Previous assessments

Monitoring of Archaeology is outside the scope of EDRRS however the National Monuments Service commissioned a programme to carry out site monitoring at a number of the bogs while the rehabilitation measures were implemented.

Bord na Móna operates under an agreed Code of Practice regarding archaeology with the Department of Arts, Heritage and the Gaeltacht and the National Museum of Ireland. Under the Code, Bord na Móna, the Minister and Director work together to ensure that appropriate archaeological mitigation is carried out in advance of peat extraction. While this activity is not peat extraction, Bord na Móna, National Museum of Ireland and National Monuments Service continue to operate under the relevant good archaeological practice elements of this code.

1. Bord na Móna must ensure that any monuments or archaeological objects discovered during peat extraction are protected in an appropriate manner by following the Archaeological Protection Procedures.
2. Bord na Móna must ensure that any newly discovered monuments on Bord na Móna lands are reported in a timely manner to the National Monuments Service of the Department of Arts, Heritage and the Gaeltacht.
3. Bord na Móna must ensure that any archaeological objects discovered on Bord na Móna lands are reported immediately to the Duty Officer of the National Museum of Ireland. Bord na Móna will adhere to the Archaeology Code of Practise relating to management of any archaeological finds that may arise during cutaway peatland rehabilitation and decommissioning. Details of any such finds on the EDRRS Year 1 and 2 bogs are recorded in Section 2 below.

## 8.1 Archaeology Impact Assessments

Archaeological Impact Assessments (AIA) were carried out on Year 1 and 2 bogs, a total of 41 bogs with 173 features defined as potentially being impacted.

This is a desk-based archaeological assessment and includes a collation of existing written and graphic information to identify the likely archaeological potential of the proposed rehabilitation area. In total

106 sites were identified as potentially being impacted by the reposed rehabilitation measures in the Year 1 bogs and 67 in the Year 2 bogs. The main recommendations from these assessments were that to avoid any possible impacts these locations should be preserved *in situ* and be avoided by the rehabilitation works with a 20m buffer zone. In addition, should any previously unknown archaeological material be uncovered during the rehabilitation works, it should also be avoided and reported to the Bord na Móna Archaeological Liaison Officer and the National Museum of Ireland.

During the period of this report, three archaeological finds were uncovered and reported to the National Museum of Ireland. These included a wooden togher trackway at Mountlucas Bog, and bog butter at both Derryfadda and Derraghan Bogs.

# 9. Interactions between Ecology, Hydrology and Carbon Monitoring

As noted previously, the main objective of the EDRRS monitoring programme is to monitor and verify trajectories of change within defined 'Core Topics such as Carbon, Hydrology, Biodiversity, Water Quality etc in response to the proposed re-wetting or rehabilitation, with a view towards a defined Climate Outcome. As peat is re-wetted, some broad domains within these core areas can respond quickly to the new environment, whilst others may be slower or require more time before measurable changes attributable to the implemented measures can be evaluated. This aligns with the general synthesis on monitoring application which has identified differing responses such as either a step change (initial sharp increases or response) versus a linear change (more gradual, over time response) or non-linear, or indeed combinations of the above. The interaction of the trajectories per Core Topic can provide insight into the efficacy of implemented rehabilitation measures and lead to learnings which might inform Best Practice in the future such as in the development of a methodological framework for implementing monitoring.

From an Ecological perspective, the monitoring programme which has been set out for Biodiversity will ultimately demonstrate change in ecosystem functioning and the trajectory of the cutaway bog towards the development of a naturally functioning peatland ecosystem. . However, this also interacts with other Scheme objectives such as reductions in Carbon, emissions to water (Water quality) and also Hydrological objectives (generally a step change in water table height commensurate with creating conditions optimal for climate impact). Broad domains for Biodiversity include Habitats (and within this vegetation succession), Birds and Pollinators for instance.

To date, the current reporting period (covering the period from Scheme commencement in April 2021 to the end of March 2023) comprises 23 months in total. Results across respective Biodiversity domains suggest that vegetation succession for instance has been slow, and not immediately detectable (i.e. not a step change), whereas changes in bird species richness, in particular water obligates can be more noticeable or detectable within months even of rewetting. It is clear from the Vegetation Quadrat data (See Section 3 and relevant Appendices) for instance that vegetation quadrats are a useful proxy for detecting changes in water table, based on recorded increases between years in percentage cover of water. On this basis, as vegetation succession appears to be slow, data would support an assertion that a better surrogate for 'success' would be achieved or delivered target levels in water table rise (using installed piezometers) as opposed to vegetation, or an increase in wetland footprint (which could be measured using aerial photography), at least within the current proposed lifetime of the Scheme.

In regard to interactions with Carbon the slower rate of succession as evidenced by vegetation monitoring data suggests it is too soon currently to consider the application of derived emission factor estimates for instance to the data that has been collected, and it may well be nearer the end of the scheme or beyond it before vegetation on re-wetted bogs begins to align with vegetation communities for which emission factors are being derived. Similarly, regarding water quality, it is difficult to determine any measurable correlation between biodiversity data currently and changes in water quality. Nonetheless one could point out that the increasing database of bird species of conservation concern, utilising rehabilitated sites, could be seen as indicative of at least sufficient water quality to support these species.

# 10. Lessons Learned & Recommendations

Experience was gained and lessons were learned as the monitoring and verification of the EDRRS scheme was implemented. Some of these lessons learned since the commencement of the scheme are set out below.

### Development of Dashboards to monitor Piezometer network

There is a significant piezometer network installed throughout the bogs within the scheme to monitor groundwater levels which in turn informs future design and the efficacy of the rehabilitation measures. To streamline this reporting process a web-based dashboard was developed which was not initially proposed. This dashboard provides an aid to all stakeholders where all the piezometer data is available in a format that will assist with future design and reporting. In addition, this dashboard and the actual piezometer network can be utilised to monitor the ground water results into the future beyond the timeline of EDRRS if deemed necessary.

### Location of Piezometers

Several practical considerations need to be considered when locating piezometers, including the ability to access and undertake routine monitoring into the future and targeting monitoring locations in-combination with ecological quadrats and associated monitoring of greenhouse gas emissions. As a result, most of the monitoring points are located adjacent to high fields, or slightly more elevated areas within bunded cells. Proximity to known archaeology should also be considered when locating the piezometers.

### Scale of Biodiversity Monitoring

The current reporting period (covering the period from Scheme commencement in April 2021 to the end of March 2023) comprises 23 months in total. This has included an expansive monitoring program on Biodiversity as a Core Topic and within it various broad domains with survey requirements in line with Best Practice. Implementation of such monitoring is challenging particularly in relation to the levels of ‘person power’ required to implement the necessary ecological monitoring for a project of this size and scale. From a sustainability perspective for instance significant travel across several counties is required to implement the full scope of the scheme monitoring and consideration should be given as to how best to implement this for any similar schemes with comparable size and scale.

Whilst adherence to Best Practice is ideal, the availability of resources can be a constraint and may lead to an inability to fulfil the recommended suite of surveys (for instance only achieving 5 out of 6 targeted winter bird counts at a site). Significant effort and planning is required to achieve a robust dataset but flexibility should be built in monitoring study design to account for uncontrollable constraints (such as bad weather events for instance, and then lack of resources to carry out re-scheduled surveys concurrently with other monitoring requirements).

### Use of New Technologies for Biodiversity Monitoring

Technological improvements should also be embraced such as the use of Best Available Techniques for Habitat Mapping for instance. The use of bespoke all weather tablets and dedicated software which allows for polygon processing in the field reduces subsequent Ecologist processing time for large datasets and should be encouraged. Similarly, the use of Drones or bespoke commissioned aerial surveys of habitat should be considered for larger schemes, where costs allow, as the application of machine learning or other techniques to these datasets may be equally as viable as collected field data.

## Carbon Monitoring- Challenges Identified

The following key take aways can be understood from the carbon monitoring program:

1. Resource Intensive: Carbon flux measurements demand significant resources. They entail substantial equipment, time, and manpower.
2. Equipment Intensive: The process involves the use of various instruments and tools, necessitating a substantial investment in equipment.
3. Engineering Works: Setting up measurement sites often requires substantial engineering work. Infrastructure and groundwork are essential to create suitable environments for accurate measurements.
4. Custom Chambers: Custom chambers had to be developed to ensure precise measurements. This bespoke equipment was tailored to specific measurement needs.
5. Increased Collar Requirements: The number of collars needed per site exceeded initial estimates. This resulted in additional resource allocation and planning.
6. Challenging Terrain: Some sites posed difficulties due to challenging terrain, especially in boggy areas. Specialized equipment like quads and Hilux vehicles were essential for navigating such environments.

In summary, conducting carbon flux measurements is a resource-intensive endeavour, demanding a range of equipment, engineering efforts, and specialized solutions to overcome site-specific challenges. The above should be considered in the development of any future similar schemes.

## Value of Annual Aerial imagery

The EDRRS financial model only included for the provision of aerial imagery at the commencement of the scheme and also on completion of all the rehabilitation. Following discussions between NPWS and Bord na Móna it was agreed to procure aerial imagery of the Year 1 EDRRS bogs in Spring/ Summer of 2022 and the Year 2 Bogs in the Summer of 2023. This imagery is of very high resolution and is very useful in providing evidence of the rehabilitation completed and allowing for comparison of this completed rehabilitation against the original design. This imagery also provides information on the extent of standing water on the bogs and in the cells, however this should be viewed cautiously as it is a snapshot at a particular point in time.

Subject to costs it is agreed by both NPWS and Bord na Móna that high resolution aerial imagery should be procured each summer for the bogs that have been rehabilitated the previous year.

## Verification Timeframe

Following the completion of the majority of the Year 1 and Year 2 rehabilitation, it is evident that while the bogs do appear to have re-wetted, the scientific evidence for this will take some time to develop.

Fluctuations due to weather conditions will be more evident immediately after rehabilitation measures are completed and it will take some time for the bog conditions to stabilise. Monitoring results over a period of time will be required to determine the success of the scheme. This will vary depending on the parameter considered but is likely to be a number of years.

# 11. Initial observations on EDRRS Monitoring to date

Significant time and resources have been inputted into the monitoring of the Year 1 and Year 2 EDRRS bogs and the data collected will be utilised to verify the benefits of the scheme. While these benefits and their verification will take time to determine, the data collected on an annual basis can be used to assess the trajectory of each bog in terms of hydrogeology, carbon emissions, biodiversity benefits and surface water quality.

To summarise the information presented in section 3 of this report, and to build on the previous analysis presented in the 2022 Annual Monitoring report, monitoring in the core area of Biodiversity has established a robust baseline for which target domain trajectories can be measured against over time, including beyond the lifetime of the scheme if necessary. Most responses (such as for example in respect of vegetation succession) to rehabilitation are expected to be linear (see Fallon 2013 or Kreyling et al.) requiring time to elapse before measurable changes scientifically correlate with implemented measures. Nonetheless, even after 23 months of monitoring it appears that the emergent importance of rehabilitated bogs in respect of some target domains such as bird species of conservation concern is notable and likewise the potential for rehabilitated bogs to act as refugium or support the coherence of the Natura 2000 network in many locations.

Further data over the lifetime of the scheme (and if possible beyond the scheme) will continue to provide information in this regard, in particular as the availability of sites with both climate action measures and other effective conservation measures becomes more important at a National and International level.

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