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**Using Coenonympha Tullia
as a specialist indicator
species to evaluate extent
of favourable condition
arising from ecological
restoration of lowland raised
peatbogs at Cors Caron
National Nature Reserve**

**Postgraduate Research
Methods**

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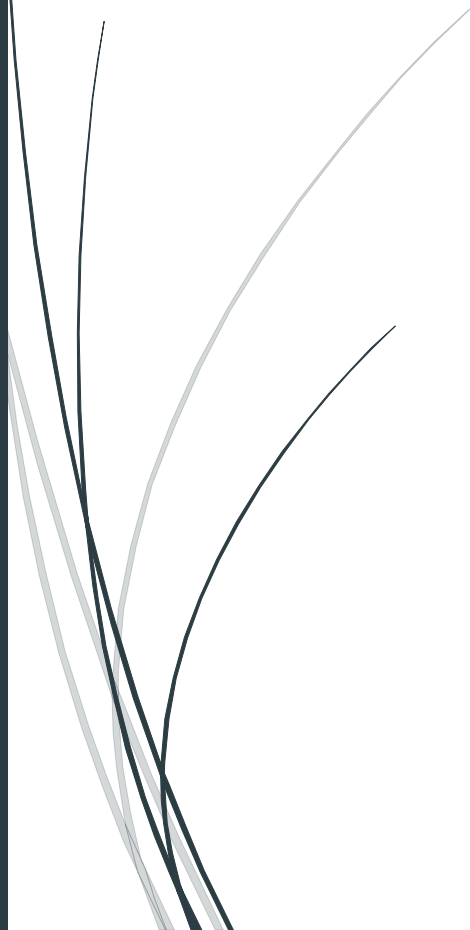


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Abstract

During the last decade increasing attention has been paid to the 'ecosystem services' of peatbogs, which when in 'favourable' condition (FC) sequester large amounts of CO₂ disproportionate to their small global coverage, when in 'unfavourable' condition however, peatbogs are, responsible for releasing GHG's e.g., methane. Consequently, landscape restoration projects are now focused on tackling restoration of degraded bogs and peatlands. Studies have also been carried out to assess the value of using biotic factors i.e., specialist indicator species (e.g., Odonata, Lepidoptera) in addition to abiotic factors (i.e., water level) to evaluate the extent of FC restored after ecosystem management works and subsequent ability to mitigate climate change.

*The purpose of this research is to assess the effectiveness of ecosystems restoration works, using the technique of 'low pressure bunding'(LPB) at Cors Caron National Nature Reserve (CCNNR) utilizing a biotic feature, the lowland acid mire specialist butterfly *Coenonympha Tullia* (CT). This will be the first instance of using CT as a biotic measure to assess efficacy of LPB to restore FC to the macrotopic system CCNNR.*

The research will be achieved by undertaking a survey, using established transect routes for the duration of the 2023 flight season to obtain new baseline data for annual adult numbers for correlating with survey data taken prior to commencement of restoration works.

'Patch quality %' data will also be gathered to quantify the average percentage availability of key larval and nectar sources for CT providing an additional biotic indicator tool to assist future monitoring of SSSI features and restoration management practices at CCNNR.

Additionally, comparisons made between average adult index numbers, pre and post ecosystem restoration management, combined with patch quality % data may also add to the findings of research which has established a quantitative methodology to assess CT patch quality % values

KEYWORDS: *Coenonympha Tullia, Lowland raised bog, Peatland Restoration, Low pressure bunding techniques, Biotic factor, Patch Quality % data*

1.Introduction

1.1 Research Context & study site overview

Natural Resources Wales (NRW) a member of The Nature Recovery Action Plan Implementation Group NRAP(IG)(Wales Biodiversity Partnership,2022) is responsible for implementing projects to manage and restore protected sites via an 'ecosystem' approach, within the context of enhancing connectivity of sites in the wider landscape and managing for resilience and climate change mitigation. An exemplar programme is the 'LIFE for Welsh Bogs Project'(NRW,2022) a programme of hydrological management works, currently being undertaken by NRW to restore functionality to seven key Welsh peatbog sites, including CCNNR. If in favourable condition, peatbogs deliver valuable ecological services by delivering hydrological filtration and flood risk attenuation as described by (Shuttleworth et al,2019) and outlined implicitly at the 'Convention for Wetlands' recently held in Zurich by (Ramsar,2020) . This is due to the significant ability of peatbogs to sequester CO₂ in relation to the 2-3 % of total global land mass covered, as widely described in the literature i.e., (Freeman et al ,2012); with sub-arctic(northerly) latitudes proposed to contain possibly up to 90% of total global peatland carbon stores(Yu,2011)

Consequently, the carbon storage functionality of peatland is considered a priority internationally in the context of funding provision for landscape ecological restoration; consider a recent declaration that 'countries should include peatland conservation and restoration in their commitments to international agreements, including the Paris Agreement on climate change' (IUCN,2021)) Moreover a recent NRW Evidence Report suggests restoration of all peatland areas to rewetted fen or bog could reduce emissions

from NRW peatlands by approximately '78 kt CO₂-e yr⁻¹, with lowland raised bogs sequestering a further 414 t CO₂-C yr⁻¹'(Burden et al,2016) A recent briefing paper (CIEEM,2021) notes 'Potential carbon sequestration of these habitats could double if they were in good order, equivalent to 32% of annual agricultural emissions . Peatbogs, left in degraded or unfavourable condition(UC) ,however, can act against climate change mitigation, by off gassing noted by 'Burden et al(2016); 'Methane emissions, in contrast, are highest from blanket bogs with almost 97 t CH₄C emitted per year.' They also note that 'Raised bogs contributed the second largest emissions of methane at 55 t CH₄-C yr⁻¹'. Following the science NRW has embarked on restoring its peatland sites, using innovative techniques such as' low pressure bunding 'techniques, one of these being CCNNR, A brief overview of the site and ecological restoration works are presented below.

1.2 CCNNR :Structure and Current Ecosystem Restoration management



Fig 1:GIS Map showing CCNNR,mesotopes and bisection of the AfonTeifi Sac and flood plain features(QGIS/ QGIS/ (Lle,2022) 'Phase 1 Habitat Survey'(Lle,2022) / 'QGIS mapping styles for UK habitats'(FSC,2022)/ 'Cors Caron'(RSIS,2022)/'Google Maps Tiled Map Service Link'(Google,2022)

desynchronisation of flood peaks,for nearby towns of Tregaron, Lampeter and Llandysul (NRW ,2015, NRW,2016) respectively. Internationally significant, the site is an intact raised bog system (macrotope) formed 12000 yrs ago, from glacial lake melt ,consisting of three 'mesotope domes'(North East,West and South East)

Nonetheless despite the relative favourable condition of areas of CCNNR, degradation has occurred throughout the macrotope, due to past land management practices such as agricultural drainage and burning to enable stock grazing, industrial processes(i.e. peat cutting, evidence of which can be seen in Fig 2 below) and previous ecological restoration practices such as deep pressure bunding (shown in Fig 3 below)



Fig 2 shown above: Aerial photograph of Cors Caron near Tregaron, 1946.:Copyright: Welsh Government and RA.



**Fig 3 shown below: Satellite image showing peripheral historic bund pools:
Life for Welsh Bog Blog(2022)**

As part of the 'Life for Welsh Bogs' project, NRW is carrying out current hydrological management measures at CCNNR using 'low pressure bunding' pioneered by Natural England at Foulshaw Moss (Cumbrian Wildlife Trust, 2016) and successfully trialled at Cors Fochno (NRW, 2021). The technique enables construction of low bunds in 'finger like' cells, using single bucket diggers (as shown in Fig 4 below), these follow natural contouring around the base of the domes (no more than 30 cm depth) for rewetting, enabling water attenuation, allowing sphagnum moss rafts to re-establish, an essential component for reinterment of peatland. In the case of one 'section' of bunding failing unlike (deep pressure bunding practices) repairs can be achieved with hand tools (spade) without compromising the action of the remaining peat dam section and minimising disturbance to re-established ecology.



Fig 4: Photograph: depicting low pressure bund reprofiling at Cors Caron NNR from 'Life for Welsh Bogs Blog'(2022)

1.3 Research Problem How to evaluate efficacy of 'LPB' ecosystem restoration works at (CCNNR) abiotic vs biotic methodologies

Throughout the project considerable abiotic data has been collated by NRW staff /surveyors via 'Dip wells' measuring water table levels and gas readings to gauge levels of anoxia , which broadly demonstrate that the project is enabling water table levels to remain within 20 cm of the bog dome surfaces, in restored areas, maintaining acceptable limits of hydration for bog mosses to thrive and enabling greater resilience constituent ecosystems. (NRW,2022)

There is however a paucity of biotic data collated to date to directly correlate with current abiotic findings logged to date. Prior to these ecosystem restoration works (Boyce ,2008) and (Polkey,2018) had surveyed all three domes for 'CT' ecology attributes and adult number counts, respectively. Considered a specialist indicator species in the literature(Osbourne et al 2022) the existing data potentially presents an opportunity to use CT 2023 adult number counts for comparison with 2017/2018 data, to evaluate how effective 'LPB' practices (undertaken over 5 years) have been in restoring FC to macro topic

ecology. Furthermore, recommendations in the literature argue the case that studies made in protected areas and other effective area-based conservation initiatives 'OECM's could be helpful in understanding decline in endangered species and in 'developing indicator species for monitoring restoration of recovering ecosystems(Dudley et al, 2021). Attaining adult numbers for CT surveying 'patch quality%' data (for larval and nectar food sources) could also enable further correlation to be made between CT ecology condition and adult numbers for 2023, helping to establish future monitoring methodology for evaluating' FC' arising from ongoing low pressure bunding hydrological restoration management practices undertaken at CCNNR(and other similar sites) .

1.4 Research Hypothesis

Establish a quantifiable basis for evaluating the extent of favourable condition restored to the bog , using a biotic feature(CT), by carrying out annual adult index count for Coenonympha Tullia (CT) (to correlate with existing NRW survey data taken pre -bog hydrological management restoration works.

Additionally gather 'patch habitat quality % data' for CT which, could, in addition to updating attribute data for the feature CT at CCNNR , add to current research models to develop CT as a specialist indicator species for assessment of favourable condition to the mesotope ecology arising from ecological restoration works, e.g., LPB'

Table 1:research objectives for use of CT as biotic indicate to assess efficacy of ecological restoration works at CCNNR

Objective	Description
1	<i>Use current literature to evaluate understanding of the use of CT as a specialist indicator species to evaluate FC of restored /existing peatbog conditions. from annual adult index data and patch quality% surveys of CT ecology</i>
2	<i>Repeat existing transect methodologies as described in(Boyce, 2008 /Polkey, 2018) to collate 2023 adult CT numbers and correlate with existing survey data collated previously at CCNNR to enable evaluation of extent of FC restored arising from LPB' restoration works</i>

3

Using transect methodologies described in point 2, combined with data collection technique from (Osbourne et al,2022) score Patch quality habitat % figures for CT larval /nectar ecology Eriophorum vaginatum(Hares- tail Cotton grass) and Erica Tetralix(Cross leaved Heath).

4

Correlate patch quality habitat % data to establish new baseline for future monitoring and to enable correlation with adult count data to attempt a more in-depth evaluation of ecological restoration works at CCNNR.

2.Literature Review

2.1 Use of invertebrates as specialist indicator biotic markers for evaluation of peatbog restoration works

There is increasing support: in the literature for use of specialist indicator species to evaluate peatbog restoration measures and target methodologies ,e.g recent research carried out. by (Kreiger et al,2019) utilised dragon fly fauna of raised bogs for determining if nutrient rich restored bogs may present secondary habitat for transition bogs species; their findings demonstrated that measures effected had created a viable network of smaller oligo to mesotrophic water bodies capable of supporting a range of macroinvertebrate diversity

(Assandri and Bazzi,2022) have also used peatland dragonfly assemblages to demonstrate that conserving ‘pristine sites’ should be a priority for preserving unique dragonfly assemblages, along with creating heterogeneity in restored sites to effectively support Odonata communities.

(Burkmar,2018) presents extensive research survey data regarding specialist bog indicator species on Cheshire and Lancashire lowland bogs, noting these have ‘the potential to predict overall site quality for invertebrates. (Boyce,2007) also established a conservation objective for Araneid spider Singa hamata at CCNNR and suggests that simultaneous monitoring of

both this feature and CT should be carried out along the same transect routes as they share similar habitat requirements.

It is not in the scope of this research undertake simultaneous studies at this time „but it is recommended that Singa Hamata could be monitored alongside CT, in the future, potentially introducing more efficient SSSI survey methodologies for this feature whilst undertaking ecological restoration monitoring Furthermore, CCW and NRW reporting notes a considerable dragonfly assemblage of ombrotrophic and mesotrophic dragonflies at CCNNR utilising these as specialist indicator species would be also be congruent with current research findings and supportive of prioritising regular species monitoring, providing data on feature health. Also contributes to the assertion of others that this should be a tandem management and research concern alongside ecological restoration as ‘focus on vegetation alone’ could be detrimental to efforts to reverse species decline in these environments. ,(Dudley et al, 2021)

2.2. CT ecology-and context of use as a specialist bioindicator species for peatland restoration assessment

Coenonympha tullia (Large heath Butterfly) is a sedentary, lowland mire specialist (,shown in Fig 5 below.) Preferring northern or ‘holoarctic’ latitudes, habitats are mainly found in the UK in the northwest of Scotland, with additional colonies in Northern England and North/ Mid Wales. First officially counted at CCNNR by Turner, J..R.G., (1963),the CCNNR population is considered the most southern in the UK, providing opportunities to contrast with other indigenous populations as regards “stress induced Climate Change pressures.; recording flight beginning and end times for the 2023 study(Polkey,2018) will enable a new baseline to be set for making comparisons with other UK regional data counts for CT , allowing for regular assessment of climate change pressures at CCNNR.

CT, need lowland bog environments in favourable condition(FC) ; requiring optimum mire conditions as described in classic research by (Bourn and Warren, 1997) internationally it is considered to be declining, due to habitat destruction arising from poor land management practices.(Weking et al, 2013) and has designated 'IUCN Red List' status, Due to its attributes and current status CT has also become a 'favoured ' species for lowland mire restoration, .e.g .following reintroduction at Chat Moss, Manchester, (The Wildlife Trusts,2019) and Heysham Moss, Lancashire(BIAZA, 2017)

In summary researchers and reserve managers, concerned with ecological restoration, increasingly endorse CT's suitability as a potential specialist species indicator of low land bog attribute conditions, backing up assertions from the literature that focussing joint efforts on environmental restoration monitoring, and environmental impacts arising from peatland restoration will foster greater knowledge transfer between academics and managers generating synergistic benefits.' (Vasander et al.,2003).



Fig 5: Coenonympha tullia' adult The Wildlife Trusts(2023)

(Osbourne et al,2022) present an example of such research in an effort to assess the most suitable sites for CT: introduction. Their main premise concerned percentage cover of two habitat resources utilised to provide models to predict C. T presence: i.e. Cross-leaved heath :*Erica tetralix* (shown in Fig 6 below)and hair's-tail cotton sedge: *Eriophorum vaginatum* (shown in Fig 7 below), vital as adult nectar sources and larval food, respectively with the latter also being important for flood buffering/hibernation habitat over winter months.



Figure 6- E Tetralix and CT Habitat (UKBMS,2023)



Figure 7 Eriophorum vaginatum(-UKBMS,2023)

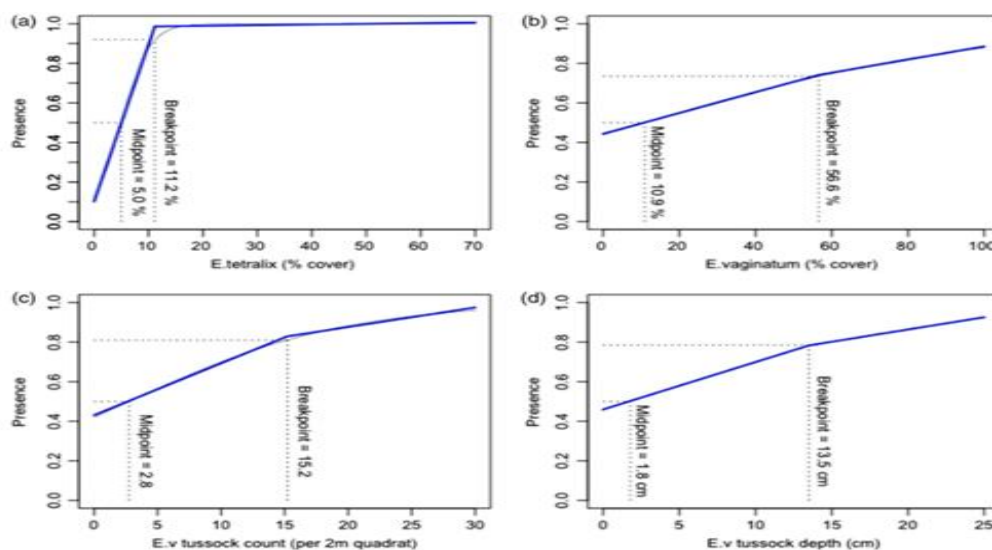


FIGURE 3 Segmented regression lines (blue) for the four Habitat Resources which are important predictors of the presence of *Coenonympha tullia*, overlying their logistic curves (grey). Dotted lines show the calculated values for Midpoint and Breakpoint (Table 6). (a) *Erica tetralix* percentage cover; (b) *Eriophorum vaginatum* percentage cover; (c) *E. vaginatum* tussock count and (d) *E. vaginatum* tussock depth. The Midpoint is the mid-inflection point on the logistic curve when the possibility of a *C. tullia* population is 50%. The Breakpoint is the statistically and biologically significant upper inflection point on the logistic curve when the abundance of Habitat Resource is 'near-optimal'.

Figure 8 Mid and Breakpoint Correlation graphs for E Tetralix/E Vaginatum/Tussock

The methodology provides quantitative assessment of habitat FC prior to CT reintroduction. and corroborates with previous research identifying *E. vaginatum* tussocks height being important to oviposition and overwintering of larvae, described respectively by (Dennis & Eales,1999 and (Joy & Pullin,1999) Crucially for this research proposal, the innovative statistical approach, used (borrowed from clinical medical studies), provided a method to enable proximal values to be suggested for 'near-optimal' habitat conditions for CT (shown in Fig 8 above) .It also provides a means to accurately score patch quality habitat percentage assessments, by demonstrating that abiotic markers'(high peat water level, low nutrient and anoxia) correlated with biotic markers(higher number and depth of *E. vaginatum* tussocks and number of *E. tetralix* inflorescences) indicative of CT absence/presence . This finding could be utilised to assess CT habitat fitness at CCNNR, in addition to making comparison with CT adult count data pre and post restoration works, Potential results from this research could also provide an opportunity to add to the robustness of the model using CT as a biotic factor to assess FC of existing and or restored bogland ecology (Osbourne et al,2022) .

3.Methodology

3.1. Methodological Literature Review

(Boyce ,2008) defined a methodology using sample areas 1-4 (shown in Fig 9 below) to assess conservation objectives for feature and habitat attributes CT at CCNNR (shown in Table 2 below) (Polkey,2018) ,building on methodologies laid down by Boyce expanded the count range to encompass one remnant bog areas., to obtain CT adult count data(2017/2018) prior to commencement of recent LPB works His findings implied a continued stable CT population at CCNNR, whilst confirming anecdotal data that CT

was more widespread than previously supposed ;subsequent comparisons with data collated sporadically from 1987-2001, are summarised in Table 3 below.

Table 2 Showing Conservation Objectives for FC for the feature *Coenonympha Tullia* at CCNR(Boyce,2008)

Conservation Objective for when the feature is in favourable condition	To maintain the large heath butterfly <i>Coenonympha Tullia</i> at Cors Caron SSSI in favourable condition where:
Lower Limit	At least 3 butterflies recorded during 45-minute searches of both stations 1 and 4 and at least 40 butterflies recorded during searches of sample stations 2 and 3 combined.
Habitat extent Lower limit	The current extent of M18 raised bog is maintained on all three domes.
Habitat quality Lower limit	The Western and North eastern raised mires have suitable habitat recorded from 505 of sampling points and 30 % of sampling points are classified as suitable habitat on the South east mire- described below
Definition of suitable large heath habitat	Bog Vegetation with no more than 50 % cover of purple moor grass and at least 5% cover of hare tails 'cotton grass.

Table 3 showing adult count data for CT at CCNNR from 1987-2018

Adult Count Data at CCNNR for CT 1987-2018

Polkey,2017	Polkey,2018	Older Data- 1987-2001
West Bog: Stations 2-3 47 South East Bog: Station 1 7 North East Bog: Station4 12	Large Heath(CT)Population – Adhoc 2018 Timed surveys/full sun/no wind/above 20 degrees West Bog: 49 in 45 mins South East Bog 15 in 30 mins	
Average Index 139	No Average index data	Average Index Amended: 96

Comments		
Well exceed the lower limit of acceptable change for the Large Heath SSSI feature.	Well exceed the lower limit of acceptable change for the Large Heath SSSI feature.	Well exceed the lower limit of acceptable change for the Large Heath SSSI feature. further to the knowledge base to enable further monitoring of CT at CC.

Polkey's subsequent conclusions and recommendations , resulting from his 2017/2018 survey work are summarised in Table 4(shown in Appendix 1 below);it is anticipated that this study will address some of recommendation 6 and aspects of 7 as follows:

1. Establishing a new baseline count for CT adult numbers,
2. Recording flight beginning and end times for the 2023 season (thereby providing a basis for climate change pressures to be assessed)
3. Providing patch habitat quality percentage data

Patch Quality percentage data sampling:

(Fowles & Smith., 2006) stress the importance of monitoring and improving the distribution of habitat patches at landscape scale, in addition to focusing on traditional habitat quality improvements for adults.(Anthes et al ,2003) also observe whilst current management strategies are based on studies regarding habitat requirements of adult individuals, 'we intend to emphasise larval habitat quality and population processes at the landscape level as additional key factors'; the LPB restoration programme at CCNNR being a prime example of the latter approach. Boyce as previously discussed, established a robust technique to sample for CT feature and habitat attributes; using additional sample transects established

by Polkey combined with scoring aspects from the model of(Osbourne et al,2022) I have established an additional protocol measure for determining CT patch quality% data ,presented in Table 5 below:

Table 5 Protocol for assessing CT Patch quality % data using methodologies from(Boyce, 2008), (Polkey, 2018) and (Osbourne et al, 2022)

Patch Quality % Sampling Protocol by (Boyce,2008)/(Polkey,2018),(Osbourne et al, 2022) methodologies	Comments /further recommendations
1)Carry out continuous 2mx2m quadrat sampling in sample areas 1-4,(shown in fig 9 below) a)By setting transects along 4 figure northing/easting/ bearings fixed using a handheld GPS unit b)Note beginning point of each transect Infront of this point (note surveyor's boot marks the 'near left hand corner of each notional point) c)Once completed 25 paces are taken along the set bearing using the GPS unit to regularly maintain position along the transect. At the 25th pace another quadrat is recorded, until end point of the transect is reached	Considered as more for this study rather than capping sampling to '10 randomised patches per study area' ,as per (Osbourne et al, 2022) Also eliminates a measure of variability in that sample area transects areas have been previously used to determine feature and habitat attributes works at CCNNR ,enabling comparisons with previously collated adult Count data for CT. for future monitoring.
2) To enable direct correlation with CT adult data collated by (Polkey, 2017/2018), additional patch quality data will be sampled from section 7 of the adult number count route established by Polkey	Not in current scope of this study but: recommended as per Polkey,2018) that a fifth sample area on remnant bog area be established for future monitoring of CT/habitat attribute alongside

(2018), to count CT numbers in the remnant bog area	annual species and patch quality percentage data collation for assessing restoration work efficacy.
3)Data gathering/scoring of the quadrats will be undertaken using methods to record patch quality % data , for CT larval and nectar food sources, and noting presence /absence of sphagnum/bryophyte assemblages as per(Osbourne et al ,2022),	As opposed to (Boyce,2008) , (Osbourne et al,2022) offers more extensive evaluation of CT patch quality percentage data. providing a viable subset of data to gauge extent of CT ecology restored in along transects.(see Fig 10: below for Result tables 5/6 showing significant p values for CT presence predictor variables , ET/EV for CT and midpoint/breakpoint and values for EV %, tussock count and depth(Osbourne et al,2022)
4)(Osbourne et al,2022): Key indicator species values to use for CT presence E Tetralix (5%/11.2%) E Vaginatum(10.9%/56.6%) E Vaginatum tussocks numbers (3 and 15 tussocks per 2 m × 2 m quadrat) Maximum tussock depth.(1.8 and 13.5 cm) also scored * <i>(*i.e., the distance from the top leaf tips of the tussock to the dry material below the rosette of leaves- as a measure of larval overwintering habitat resource(Joy and Pullin, 1999) and oviposition site availability)</i>	Percentage area cover of common heathers, mixed bryophytes and sphagnum mosses(key- stone species) were recorded along with hummock depth and presence : For the purposes of this study may be pertinent to just record presence/absence for common Sphagnum ,(as per methodology)- using 1 to denote presence/0 to denote absence: due to the fact we are assessing specifically for CT ecology flora , presence of which already. correlates strongly to the presence of sphagnum moss and bryophyte assemblages, vital to contributing to FC of lowland mires (Osbourne et al,2022)

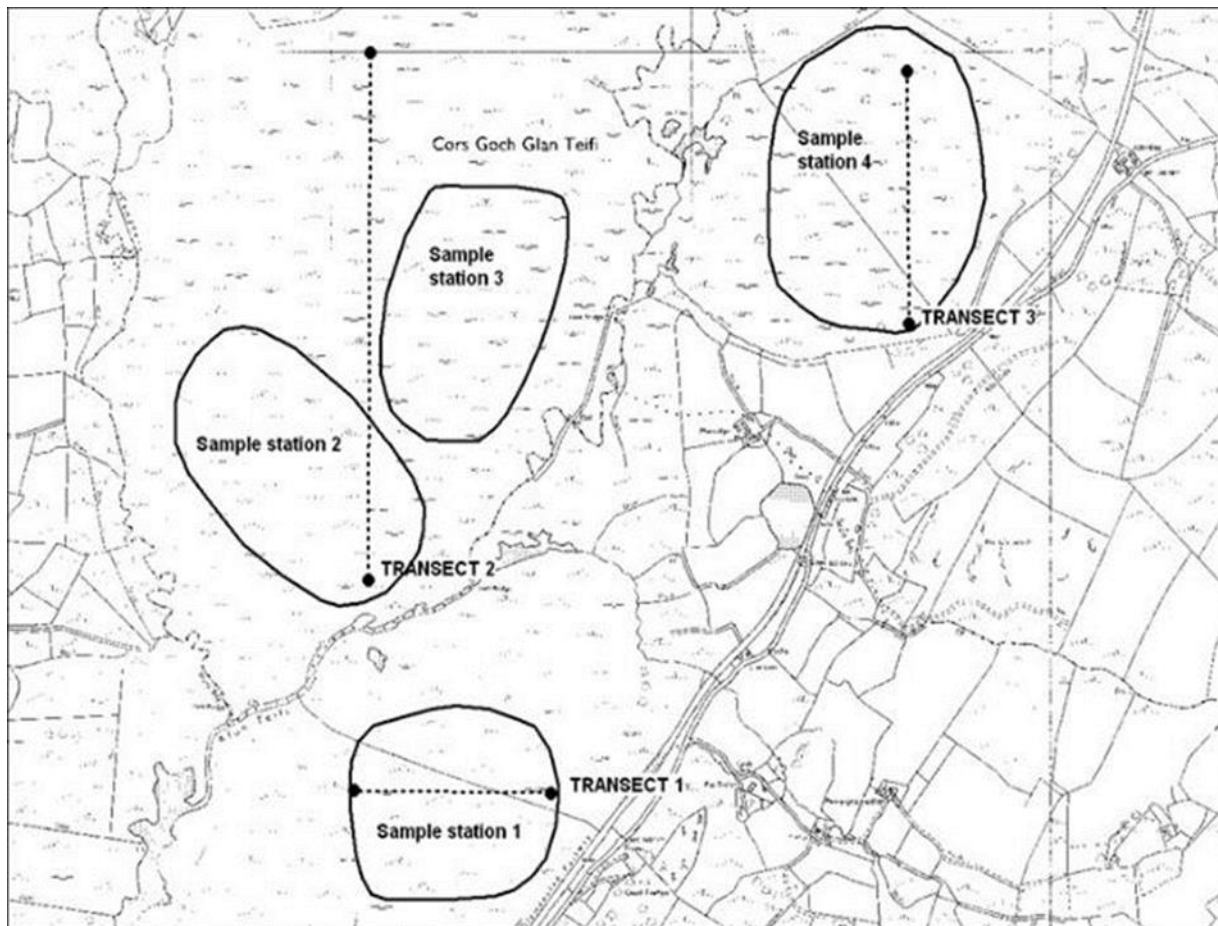


Fig 9:Depicts sample areas used by Boyce for feature attribute determination and across which transects were taken to sample habitat attributes.(Boyce,2008)

TABLE 5 Variable importance, number of models, average and most significant *p*-values for *Coenonympha tullia* presence predictor variables—derived from the GLMMs as part of the multi-model inference approach

Fixed effect	Sum of weights ($\sum w_i$)	Number of models	Average <i>P</i> -value	Most Significant <i>P</i> -value
<i>E. tetralix</i>	0.88	13	0.098	<0.001
<i>C. vulgaris</i>	0.86	9	0.132	<0.001
<i>E. vaginatum</i>	0.63	8	0.542	<0.001
Sphagnum cover	0.52	9	0.560	<0.001
Mixed Bryophytes	0.42	8	0.415	<0.001
Peat water content	0.34	6	0.547	<0.001
<i>E. tetralix</i> × <i>E. vaginatum</i>	0.23	2	0.482	0.003
<i>E.v</i> tussock count	0.20	8	0.671	<0.001
<i>E.v</i> tussock depth	0.16	6	0.603	0.080
EC	0.08	5	0.752	0.665

Note: Importance refers to the sum of 'Akaike weights' for all candidate models in which a specific term was a predictor. The 10 most important predictors are listed, ordered by descending sum of weights ($\sum w_i$). *E. tetralix*, *C. vulgaris*, *E. vaginatum*, Sphagnum cover and Mixed Bryophytes are the most influential significant predictors.

TABLE 6 Calculated values for the Midpoint and Breakpoint for the four Habitat Resources which are strongest predictors of *C. tullia* presence

Habitat resource	Midpoint ± SE	Breakpoint ± SE
<i>E. tetralix</i> (% cover)	4.96 ± 0.99	11.15 ± 0.04
<i>E. vaginatum</i> (% cover)	10.91 ± 9.63	56.57 ± 0.19
<i>E.v</i> tussock count (per 2 m quadrat)	2.76 ± 1.82	15.18 ± 0.07
<i>E.v</i> tussock depth (cm)	1.78 ± 2.29	13.50 ± 0.34

Note: Midpoint represents the 'mathematical' mid-inflection point of the logistic curve, where the probability of *C. tullia* presence is 50%—below this level, a population is vulnerable to extirpation. Breakpoint is a statistically and biologically significant estimate of the upper inflection point of the logistic curve, the 'near-optimal' abundance of each habitat resource.

Fig10: Result tables 5/6 showing significant *p* values for CT presence predictor variables , ET/EV for CT and midpoint/breakpoint and values for EV %, tussock count and depth

Transect methodologies: Comparison Polkey (2018) , UKBMS(2023) and Barkmann et al,2022)

For the purposes of controlling variables(and to enable direct comparison with previous data collated by using similar methodologies) I will be repeating the methodology carried out by (Polkey,2018) using established transect walks 1-7(as shown in Fig11 below) which are situated across all three intact domes and the remnant bog ,these will be conducted in accordance with the methodology described in point 1 of comparison Table 6 below.

Table 6 showing comparisons between Polkey, 2008 and UKBMS, 2023, transect walk methods

Polkey 2018 Transect Methodology	UKBMS Transect Methodology
1) Counts of adult large heaths seen in front of the recorder within a 5-metre boundary were made	2) Walk the transect at a slow, steady pace counting all butterflies seen within a fixed distance - 2.5m either side of the transect line and 5m ahead . In some habitats e.g., along sea cliffs or woodland rides, it is acceptable to record at a width of 5m along one side only of the transect line

Polkey's methodology does not directly compare with that used by UKBMS(2023) guidance, that favours the 'Pollard Walk' methodology, (described in point 2 of the Table 6 above) rather counting numbers observable only 5 meters ahead of the surveyor. This may potentially present a less robust technique for data collation considering earlier critiques of existing European butterfly monitoring methodologies Van Swaay et al(2008) and a recent comparative study by Barkmann et al(2022), of standard transect counts('Pollard Walks') with area time count methodologies. concluding that area time counts provide more thorough assessments, enabling a close connection to 'specific habitat types. Both methods are found to be good indicators of relative butterfly abundance, however area time counts proved better suited than standard transect counts regarding analysis and calculation of international abundance trends. It is not in the scope of this research to carry out a comparable investigation of transect methodologies, but it is recommended with regard to future monitoring that the current transect methodology should be reviewed . Regarding general guidance to conduct transect walks (Polkey, 2018) is in accord with (UKBMS, 2023)

guidelines that will be followed as part of my research protocol is summarised in Table 7
(shown in Appendix 1 below)

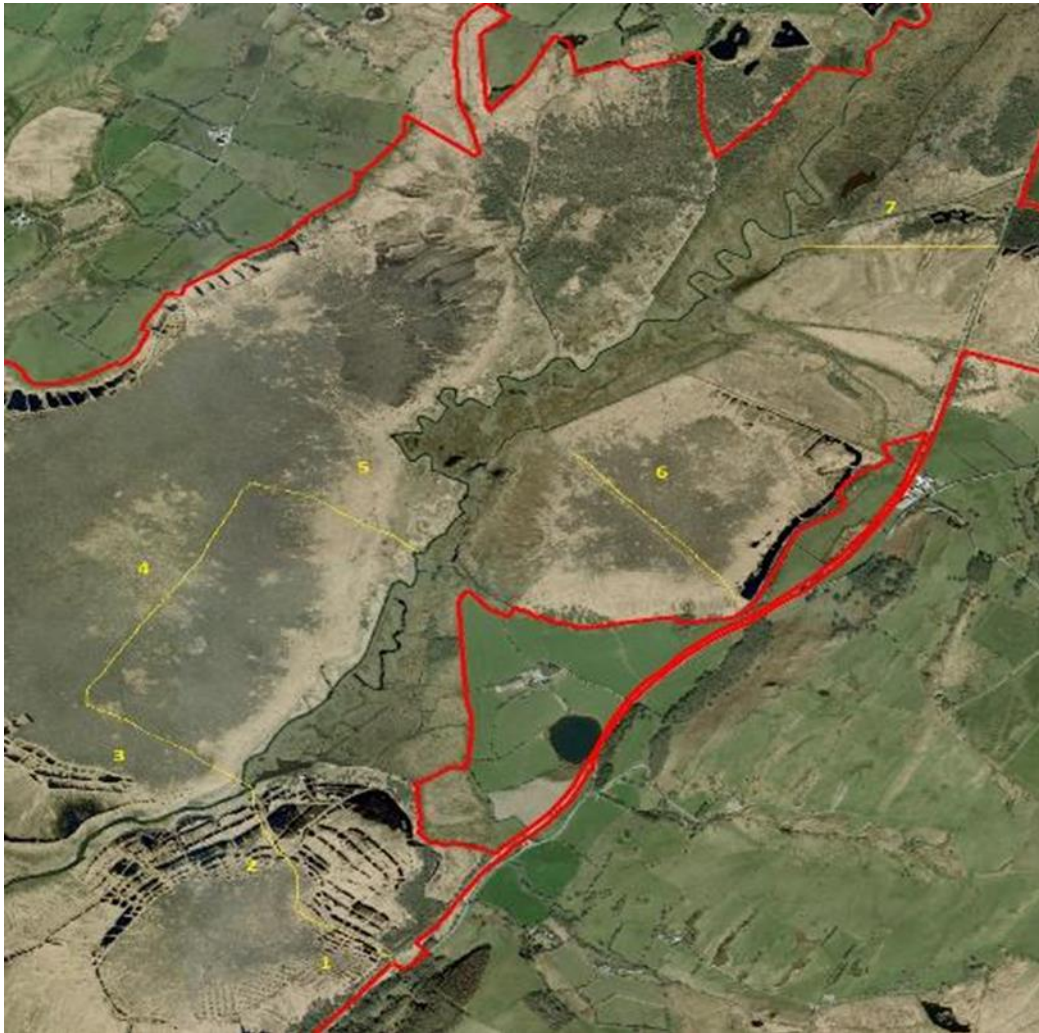


Fig 11 Transect routes (in yellow) for adult CTcounts consisting of 7 sections (Boyce2008, Polkey 2018)

3.2: Method Outline

Primary strategy:

1) Conduct thorough Literature Review

To present complete contextual understanding of the research pertaining to:

- a) Context of other invertebrates being used as specialist indicator species for monitoring bogland ecology condition, with especial reference to monitoring post LPB /similar ecological restoration works.
- b) Low land peatbog habitat/ecology restoration practices and, climate change.
- c) Gain comprehensive knowledge of specific areas of my research inclusive of: CT ecology and its use as a bioindicator specialist data for monitoring efficacy of landscape ecology restoration works, -

Secondary data sources to be used, summarized below:

Secondary Data Source Summary:

- UWTSD interlibrary service for rare UK and International journals
- Original papers/reports:
 - Mid to late 1990's early 2000 period for CT research- contrast and compare, especially for Climate Change indicators/tools of measurement /recommendations for research.
- Online Databases- i.e., Science Direct- Google Scholar- Specialist Entomology/Journals-
- Unpublished/Published reports/data-
- NRW Library resources (Bangor and Cors Caron Office)
- Map and Report data
- LERC/BAP/NBS Atlas/Data Map/FSC
- Butterfly Conservation Charity/UKBMS regional and national reporting.

Se

2) Count average CT Adult numbers for the 2023 Flight season and carry out Patch Quality % Habitat survey for adult nectar and larval food sources for CT.

:

Patch quality percentage data:

Using Boyce 2009, transect walks in sample areas 1-4 and additional transect 7 (Polkey, 2019) aspects of multi modal inference approach of (Osbourne et al, 2022) will be used to assess 2mx2m quadrat samples regarding CT larval and nectar food source and core lowland bog ecological mosses/bryophyte assemblages.

Adult CT number Counts

Adult flight and beginning times to be recorded for the 2023 season and adult number counts taken weekly, walking transects walks, using methodology as per (Polkey, 2018) and guidance (Polkey,2018, UKBMS,2023)

Primary Data to be produced summarized below:

Primary Data:

Adult CT numbers for 2023 flight season

Patch quality quadrat % data following transects established by(Boyce,2008,Polkey 2018)

Original recording sheets: inc weather conditions/and in accordance to protocol, not windy, raining under a certain temperature.

Location data GPS co-ordinate recording for adult recording and times moved along transect for recording adult CT (observed 5 m in front of surveyor), Boyce, Polkey , 2018)

3.3 Ethical Considerations

Primary data gathering/survey work, will not involve direct handling of CT(live animals/invertebrates) via capture, mark and recapture techniques and so it is not deemed that there will be ethical impacts o CT arising monitoring/survey work undertaken as part of

this research. In addition, corresponding reports used from NRW Surveyors are already in the public domain and are not deemed to pose an ethical issue, with respect to use within this research.

However, there will be a requirement to carry out a risk assessment regarding the field, work, aspects of the work i.e., involving lone working , working near bodies of water, livestock, walking across boggy land, and being exposed to ticks/insect bites/sunburn. A full risk assessment form will be completed in accordance to the guidance from UKBMS(2023) , copy of which can be seen in Appendix 2 and will be submitted with the required ethics form documentation.

3.4 Proposed Timeline for Research

Tasks	May 23	Jun 23	Jul 23	Aug 23	Sep 23	Oct 23	Nov 23	Dec 23	Jan 24	Feb 24	Mar 24	Apr 24
Risk assessment complete for UWTSD												
Complete NRW Activity Request Form.												
Preliminary meeting UWTSD Supervisor												
UWTSD Supervisor meetings												
Organise Equipment required for transect and quadrat sampling												
Test timed transect walk/quadrat sample routes												
Flight Begin/end record/												
Transect Counts CT												
Patch Quality Habitat Survey												
Lit Review & write up												
Results/Data Analysis & Write up												

Submission Viva Preparation												
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4.Data Analysis

Two sets of primary data will be supplied from spreadsheets compiled from original field work recording sheets, comprising:

1)Adult number counts and GPS co- ordinates for observation position along the line transects* (* Inclusive of recording conditions for data, temperature, wind speed, other observations)

2)Patch habitat % data of larval/nectar plant sources/presence/absence of sphagnum/bryophyte assemblages and e. vaginatum tussock height and distribution from quadrat sampling.

Suggested preliminary and secondary analysis of data could then be achieved using methods described in Table 8 below

Table 8 summarising suggested preliminary and secondary data analysis methods

Analysis Stage	Description of statistical analysis of data
Preliminary stage: Collation & primary analysis	Analysis of primary data for adult butterfly counts and the Patch habitat % for plant data will be via the Microsoft Office package: 'Excel'; this will then be utilised to organise data to carry out the following initial analysis: a) Look for patterns in the data, including 'outlier' data b) Prepare simple charts. correlation/scatter graphs c) Prepare simple correlation coefficient graphs/'scatter graph' to help interpret potential relationships between variables within for adult numbers(and adult numbers from previous surveys) and/or patch habitat %.

Secondary Stage: Determination of strength of relationship/correlations between data sets	To determine the strength of statistical significance of the data correlated (strength of relationships between data sets) via common statistical analytical tools e.g. a) Paired T tests(for testing difference in means of data sets) b) Pearson's chi-square (χ^2) test for independence(i.e., to formally test statistically significant association between two categorical variables)
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Geographical Information System (GIS)

Adult butterfly numbers for the 2023 season and corresponding GPS co-ordinates will also be mapped using GIS, onto imported satellite map data of the CCNNR. It is envisaged this will produce graphical representation of data such as that shown in Fig12 below, depicting data(in non-GIS format) from Boyce(2008) showing tiger moth and CT adult counts against GPS co-ordinates, the advantage of creating GIS representation of the data in addition to a map of recorded adult numbers. will be the ability to produce a tool where data can be queried.



Fig 12: Map showing counts against GPS co-ordinates for (*Coenonympha tullia* and Tiger Moth data, 2008, Boyce, 2008)

Phase one habitat mapping for the areas sampled will also be completed (as per example in Fig 13 below) showing SED Recreation area) to create a reference tool for comparison of adult survey numbers with recorded existing condition of habitat areas. Additionally Patch quality % data values, will be overlaid to help demonstrate relative abundance levels for larval and nectar sources, and for comparison with adult count data , to help form the basis of developing a future monitoring tool for other surveyors.

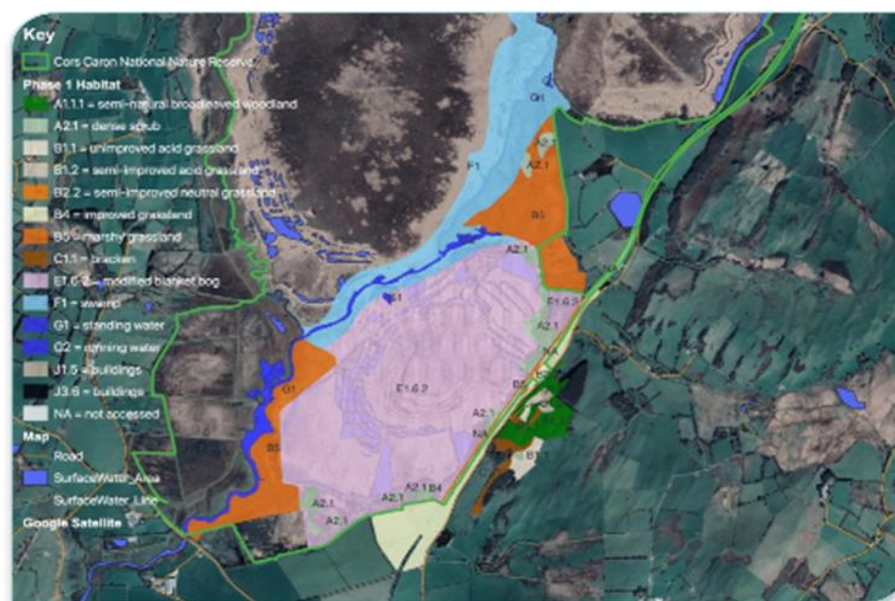


Fig 13 (Zanoni,2022 –PH1 mapping for SED Recreation area, Cors Caron NNR

5. Evaluation

Evaluation of core research outcomes, and potential contribution to existing findings in the literature are presented in Table 9(See Appendix 1 below), preceded by summary overview below:

5.1 Evaluation overview of potential outcomes of research

This will be the first occasion at CCNNR that a specialist indicator species is used to provide biotic data for assessing FC restored post ecological restoration works, using LPB

techniques; evaluation of adult number count comparisons and assessment of patch % quality could also enable targeted adjustment of current and future restoration methodology protocols undertaken at CCNNR (and other sites)

Potentially study findings could also add to those add to those from researchers currently developing protocols for specialist indicator species monitoring to assess increased ecosystem resilience arising from landscape restoration practices(e.g., Kreiger et al,2019, Assandri and Bazzi,2022, Burkmar,2018,Osbourne et al, 2022)

This proposal is therefore deemed congruent with assertions from the literature that research using a specialist indicator species(CT) encompassing both species and ecological restoration, within protected sites e.g., CCNNR, could be useful in terms of understanding mechanisms of biodiversity loss,(and their prevention) in conjunction with contributing further to research into biotic monitoring of ecosystem restoration methodologies(Dudley et al,2021, IUCN,2021)

5.2.Limitations/issues

Provided adult number counts are sufficient and continuous throughout the 2023 season and recommended guidance for carrying out surveys are proficiently followed it is anticipated that accurate, unbiased biotic data will be collated, to allowing biotic survey enable determination of the extent of FC restored to CCNNR . However, insufficient data collation could arise due to adopted transect methodology technique used and/or prolonged windy/cold/adverse weather affecting adult CT flight timings (coinciding with planned weekly survey slots). This could considerably limit the proposed research undertakings; a mitigation measure would be to ensure that additional weekly survey time

could be scheduled during the 2023 flight season, to enable further suitable opportunities to gather data.

Patch Quality % data could potentially be affected by prolonged flooding, though as the survey period will be taking place in the summer, it is anticipated this is a low risk.

6.Conclusion

Provided sufficient adult count data during the 2023 flight season, is obtained, new CT adult baseline data will be provided contributing to existing survey data (Boyce, 2008, Polkey, 2018) and to national monitoring records for the season, Furthermore, accurate recording of the 2023 flight beginning and end timings will also enable a baseline to be set for future monitoring of climate change effects regarding CT at CCNNR.

Comparison of the 2023 CT adult count data(post ecosystem restoration works) with previous survey data (pre-ecosystem restoration works) will also demonstrate ability of using CT ,now and in the future, as a biotic specialist indicator for evaluation of FC restored at CCNNR. It could also to the robustness of current research models, evaluating the use of CT as 'bioindicators' for assessment of attained levels of FC at restored peatbog sites. (Osbourne at al,2022) enabling further understanding of optimum habitat resources required to support specialist invertebrate species reintroductions, and to help monitoring of and targeting of ecosystem restoration methodologies.

Similarly, the Patch quality % data survey collated will provide a new baseline for future monitoring at CCNNR (and similar sites) to correlate with abiotic data collated by NRW project officers potentially enabling more in-depth assessment and better targeting of future works

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Appendix 1

From Section 3 1 Methodology Review:

Table 4 Polkey 2018, Conclusions and Recommendations from 2017/2018 survey with comments regarding range of scope for 2023 survey/research proposal

Polkey(2018):Conclusions and Recommendations from 2017/2018 survey	Comments regarding range of scope for 2023 CTsurvey/research proposal
1. Large heath geographical range across Cors Caron NNR is at least maintained and is greater than previously known and hence may possibly have increased.	Agree but not in scope of this research to explore but should be addressed.
2. The month of peak count (relative to the 1 st week of April, week 1) does not appear to have changed from 1987 to 2017 to the very limited extent that conclusions on trends can be drawn from the current data set.	Agreed- Flight beginning and end times for 2023 season to be recorded to set new baseline for future monitoring with respect to Climate change pressures on this most southern population of CT
3. However, it isn't known how much Large Heath inter-change there is between these three locations.-	4. Agreed but not in scope would need genetic and in depth population studies to be carried out. 5. Also (Melling, 1984) notes Natural colonisation unlikely due to CT's 'poor dispersal ability'
6. Given the apparent absence of any trends in population indices or flight period at Cors Caron the need for annual monitoring should be reviewed - three or five yearly monitoring may be adequate	Agreed- 2023 count will be effectively the first for five years.
7. The current monitoring methodology has the following limitations: - It will not indicate the full distribution of Large Heath across Cors Caron NNR- n- not scope - It will not clearly show changes (if present) in the flight season from year to year due to climate -Y change or other reasons. - it doesn't cover any aspect of large heath habitat at Cors Caron	Agreed: Note:Patch Quait percentage data will address lack of recent evaluation of CT habitat restoration at CCNNR, in addition to any existing data held by NRW.

NNR/SSSI/SAC-Y	
8. The purpose of large heath monitoring at Cors Caron should be revised and redefined in relation to: - feature status. - any requirement to assess distribution & population size on site. - possible climate change effects. - national and/or regional monitoring requirements.-	Agreed, Adult number counts being carried out in accordance with UKBMS guidance and patch quality % counts in accordance with latest research methodologies. Assessment of climate change effects also being addressed(see point ?) Population size on site not in scope of this research see point ?)(

Table 7 Summary of guidelines for conducting Transect Walks, (Polkey,2019,UKBMS,2023)

Guidelines for conducting Transect Walks at:CCNNR (Polkey,2019)
Transect walks should only be carried out in warm (13 °C or more) and at least bright weather. The minimum criteria are 13-17°C with at least 60% sunshine, or over 17°C and not raining.
Transect counts should ideally be made between 10:45 and 15:45 hours. Between 10:00 and 17:00 hours is usually allowable, though butterfly activity may drop off rapidly during the late afternoon so later times should be avoided.
Windspeed should be estimated using the Beaufort scale (0 - no wind, 6 - very strong wind). Avoid counts in if values above 1(light waving of tree branches)
Record butterfly counts 5 m in front of surveyor: record adult numbers,(also GPS values) % sunshine, any other significant variables
Additional guidance (UKBMS,2023)
Do not stop walking and wait at favoured hotspots to improve your count, as this will bias results.
Always follow exactly the same route each time you make a transect walk.- as per advice Boyce,2008 set course each time with GPS tracker

From Section 5: Evaluation: potential outcomes of research

Table 9 Showing comparison of aims and evaluation of perceived outcomes arising from proposed research for the feature Coenonympha Tullia at CCNRR

<i>Core research aims</i>	<i>Evaluation of perceived outcome</i>
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1) Determine if there is a correlation between 2023 adult index data with extent of FC restored(as a result of commencement of low pressure bunding works) in comparison to average adult index data established 2017 & 2018 (pre low pressure bunding(LPB) works)	<i>Will provide updated survey data to enable ongoing monitoring for CT feature at CCNNR.</i> <i>Accurate recording of flight beginning and end timings will also enable comparison/ evaluation of the potential impacts of climate change on CT, in relation to data collated regarding other nationally recorded data for UK populations of this feature.</i> <i>First occasion at CCNNR that CT adult counts will be utilised as a biotic factor for testing efficacy of using the low-pressure bunding technique to restore FC of existing domes.</i> <i>Optimum conditions to support floral ecology of this specialist butterfly is also typical of FC status for lowland bog mires: therefore, could be inferred that good or improved adult counts might indicate good or improved FC for the bog(as a result of the LPB and other restoration measures- scrub clearance/Molina mowing)</i> <i>Will help to corroborate (or not) findings of current NRW abiotic data gathered LPB ecosystem restoration works.</i> <i>Provide data to evaluate and/or enable adjustment of monitoring/methodologies of LPB ecosystem restoration works.</i> <i>Overall, could potentially provide a new combined methodology to combine with existing abiotic protocols for future monitoring/testing of the efficacy of LPB ecosystem restoration for NRW at this site(and similar)</i>
2) Determine strength of correlation with 2023 Patch quality habitat % data and average 2023 adult index data.	<i>Establishing survey data for Patch Quality % will provide the basis of a new baseline for surveying of the feature(CT) at the bog for determining/ monitoring efficacy of restoration of FC as a result of current restoration works.</i> <i>A more robust tool could potentially be developed by further comparison of % counts of key CT larval and nectar source from collated</i>

	<i>patch quality % sample data with 2023 adult number counts species to help establish a future monitoring tool for surveyors at CCNNR and other sites to-measure efficacy of LPB restoration works.</i> <i>Biotic data obtained assessing % of CT ecology flora present in comparison adult CT counts will also contribute to the work of other researchers in the literature(i.e. Osbourne,2022) with respect to measuring. % of key plants present, providing quantifiable measurement of ability of environment to support reintroduced CT populations and/or to assess likelihood of them being present as a result of undertaken ecological restoration works.</i>
3)Extend range Patch quality % data collation to the Bog remnant(Polkey, 2018)	<i>Determine level of FC restored to favoured CT ecology in this area, not previously quantified in 2017/2018 surveys.</i>

Appendix 2



Standard Risk Assessment No. 11/22

Code of Practice	Activity	Location/s	Person/s covered	SEVERITY	LIKELIHOOD		
					Slight	Possible	Highly likely
22	Monitoring and recording	Outdoor sites and reserves	Transect walkers and recorders	Trivial. No action	Low. Control. Notify later	Medium. Control. Notify later	High. Eliminate risk or STOP! and notify now
				Major	Low. Control. Notify later	Medium. Control. Notify later	High. Eliminate risk or STOP! and notify now
				Severe	Medium. Control. Notify later	High. Eliminate risk or STOP! and notify now	High. STOP! and notify now

If working alone or in a remote area set up a buddy system. For emergencies carry first aid kit, mobile phone, OS map, GPS, water, as appropriate

Common Hazards	Risk	Existing controls	Likelihood	Severity	Risk Rating
Long walk and/or arduous conditions	Tiredness leading to fatigue and accident	Take regular breaks	Possible	Slight	Low
Mud, boggy ground	Slipping, injury	Wear appropriate footwear Avoid area if possible especially following inclement weather	Possible	Major	Medium
Steep Slopes	Slipping, falling, injury	Wear appropriate footwear Avoid area if possible especially following inclement weather	Possible	Major	Medium
Gates, stiles, barbed wire fences	Slipping, injury, cuts	Ensure gates opened and closed correctly Avoid climbing over barbed wire fences if possible Ensure firm footing when stepping on wet stiles	Possible	Slight	Low
Uneven ground/tree stumps	Tripping and falling	Avoid where possible	Possible	Major	Medium
Hot sunny weather	Sunburn, sunstroke Exposure, dehydration	Wear appropriate clothing. Apply sunscreen. Seek shade. Drink plenty of water.	Possible	Major	Medium
Plants	Rashes, scratches, infections.	Wear suitable clothing etc Use barrier creams where necessary	Possible	Slight	Low
Dust, pollen, spores	Allergy Asthma attack Hay fever	Known sufferers to take appropriate precautions, have medication with them.	Possible	Slight	Low

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Insects etc	Bites, stings, Lyme disease	Use insect repellents. Cover bare skin. Avoid long vegetation where possible. Check for ticks regularly and remove promptly. Know what to do if bitten or symptoms develop.	Possible	Major	Medium
Adders	Bite	Know any likely sites where adders might be found. Know what to do if bitten	Unlikely	Major	Low
Other people	Threatening or abusive behaviour	Withdraw if confronted	Unlikely	Major	Low
Animals	Dogs – fighting, allergic phobia, tripping Livestock – phobia, injury	Keep on lead. Exclude from transect walk. If possible avoid contact Avoid where possible.	Possible	Major	Medium
Open Water	Slipping, falling. Wells Disease Stomach Upsets	Avoid open water where possible Do not drink water from site Clean hands thoroughly before eating.	Unlikely	Major	Low

Date	01/02/19
Signed	Vikki Webb
Countersigned	Russel Hobson

Assessor: Review specific site conditions and activities and record any additional hazards and controls.					
Site:		Assessor:		Date:	
Common Hazards	Risk	Existing controls	Likelihood	Severity	Risk Rating

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