

# Large Heath Butterfly monitoring within Cors Fochno SAC, 1986 to 2022.



Photo: John Ibbotson

Report No: **715**

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Report series: NRW Evidence Report

Report number: 715

Publication date: June 2023

Title: **Large Heath Butterfly monitoring within Cors Fochno SAC, 1986 to 2022.**

Author(s): J Lyons, NRW

Technical Editor: Dr. M.A. Howe

Quality assurance: Tier 3, Richard Cardwell.

Peer Reviewer(s): Dr Liz Halliwell

Approved By: Dr Liz Halliwell

Restrictions: None

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## Recommended citation for this volume:

Lyons, J. (2022). Large Heath Butterfly monitoring within Cors Fochno SAC, 1986 to 2022.

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## Crynodeb Gweithredol

Mae gweirlöyn mawr y waun, *Coenonympha tullia*, yn cael ei ddsbarthu fel rhywogaeth Mewn Perygl yn y DU a Dan Fygythiad yn Ewrop. Mae'n nodwedd hysbysedig SoDdGA Dyfi lle mae i'w ganfod ar gyforgors iseldir fawr Cors Fochno sy'n Ardal Cadwraeth Arbennig. Er mwyn pennu ei statws cadwraeth ar SoDdGA Dyfi a, lle bo angen, llywio rheolaeth y safle, mae dosbarthiad a statws y glöyn byw wedi'i fonitro'n flynyddol ar Gors Fochno ers 1986 ar hyd trawslun o 2km gan ddefnyddio methodoleg safonol. Mae hyn wedi darparu set ddata anarferol o hir ar gyfer rhywogaeth infertebrat. Yr asesiad presennol, sy'n seiliedig ar fonitro yn ystod 2022, yw bod y boblogaeth yn cael ei chynnal mewn cyflwr ffafriol.

Cynhaliwyd dadansoddiad manwl o wahanol gydrannau'r data dros y cyfnod 1986 i 2022 i benderfynu a yw'r asesiad nodwedd SoDdGA cyfredol yn gywir ac a ellid cael unrhyw wybodaeth bellach am y boblogaeth yng Nghors Fochno. Mae'r canfyddiadau allweddol fel a ganlyn:

- Mae'r indecs poblogaeth blynyddol ar gweirlöyn mawr y waun, fel y'i cofnodwyd ar hyd y trawslun i gyd wedi aros yn sefydlog heb unrhyw ostyngiad na chynnydd ystadegol ar gyfer y cyfnod 1990 i 2022;
- Mae'r amrywiad yn yr indecs poblogaeth rhwng pum adran y trawslun yn dangos bod ardaloedd mwy delfrydol ar gyfer gweirlöyn mawr y waun ar Gors Fochno. Y nodwedd sy'n gwneud yr amodau'n fwy ffafriol ar gyfer y glöyn byw yw ansawdd y cynefin cyforgors a'i strwythur;
- Nid oes unrhyw ostyngiad ystadegol neu gynnydd ym mynegai poblogaeth gweirlöyn mawr y waun ar gyfer y cyfnod 1990 i 2022 i'w gweld mewn pedair adran o'r trawslun. Mae un adran o'r trawslun (Adran 5) yn dangos gostyngiad ystadegol yn y boblogaeth oherwydd dirywiad yn y cynefin sy'n cynnal y rhywogaeth;
- Mae tystiolaeth bod y boblogaeth wedi cyrraedd ei brig yn gynharach yn y tymor rhwng 1998 a 2021 o gymharu â rhwng 1986 a 1997, efallai o ganlyniad i hinsawdd sy'n cynhesu;
- Mae Cors Fochno yn ardal anarferol o helaeth o gyforgors iseldir gyfan sy'n cynnal poblogaeth fawr o dros 10,000 o weirloynod mawr y waun llawndwf bob blwyddyn.

Yn dilyn dadansoddiadau ystadegol amrywiol, dylid adolygu'r priodoledd a ddefnyddiwyd ar gyfer indecs poblogaeth yr asesiad SoDdGA, o isafswm o rhwng 60 a 80 a gosod terfynau isaf unigol ar gyfer pob un o bum adran y trawslun. O wneud newid o'r fath, byddai nodwedd y SoDdGA wedyn yn Anffafriol ac yn Dirywio oherwydd bod un adran (Adran 5) yn dirywio.

O ran dau amcan ar gyfer nodwedd gweirlöyn mawr y waun y SoDdGA ar ACA Cors Fochno.

- Ar y cyfan bu'r boblogaeth yn sefydlog rhwng 1986 a 2022.
- Ar y cyfan mae ansawdd da cynefin cynhaliol y gyforgors actif wedi cael ei chynnal, lle mae rhai ardaloedd wedi elwa o adfer cynefinoedd. Mewn un ardal bu dirywiad yn nifer gweirlöyn mawr y waun oherwydd dirywiad yng nghyfeir y gyforgors ddiraddiedig. Mae angen rheolaeth gadarnhaol yn yr ardal hon i alluogi nodwedd gweirlöyn mawr y waun i fod yn Ffafriol yn y dyfodol.

Mae'n ddymunol parhau â'r gwaith o fonitro gweirlöyn mawr y waun ar Gors Fochno er mwyn deall deinameg ei boblogaeth ymhellach, ei ddewis gynefin, effaith adfer mawndiroedd, ei statws cadwraeth ar y safle ac effaith newid hinsawdd.

## Executive Summary

The Large Heath *Coenonympha tullia* is classified as Endangered in the UK and Vulnerable in Europe. It is a notified feature of the Dyfi SSSI where it is found on the large lowland raised bog of Cors Fochno, a Special Area of Conservation. To determine its conservation status on Dyfi SSSI and, where necessary, to inform site management, the distribution and status of the butterfly has been monitored annually on Cors Fochno since 1986 along a 2km transect using a standardised methodology. This has provided an unusually long data set for an invertebrate species. The current assessment based on 2022 monitoring is that the population is *Favourable Maintained*.

A detailed analysis of various components of the data over the period 1986 to 2022 has been made to determine if the current SSSI feature assessment is accurate and if any further information could be ascertained about the population at Cors Fochno. The key findings are as follows:

- The annual population index for Large Heath as recorded along the transect in total has remained stable with no statistical decline or increase for the period 1990 to 2022;
- The variation in population index between the 5 transect sections indicates that there are more optimal areas for Large Heath on Cors Fochno. The attribute influencing the more favourable conditions for the butterfly is the quality of the raised bog habitat and its structure;
- Four of the transect sections show no statistical decline or increase in population index for Large Heath for the period 1990 to 2022. One transect section (Section 5) shows a statistical decline in population due to deterioration in the habitat that supports the species;
- There is evidence that the population has peaked earlier in the season between 1998 and 2021 compared to between 1986 to 1997, perhaps as a consequence of a warming climate;
- Cors Fochno is an unusually extensive area of intact lowland raised bog that supports a large population of Large Heath in excess of 10,000 adults annually.

Following various statistical analyses, the attribute for population index used for the SSSI assessment should be revised from a **lower threshold of 60 to 80** and individual lower limits set for each of the five transect sections. Under such a change, the SSSI feature would be *Unfavourable Declining* due to one section (Section 5) deteriorating.

For the two objectives for the Large Heath SSSI feature on Cors Fochno SAC.

- Overall, there has been a stable population from 1986 to 2022.
- There has overall been the maintenance of the supporting habitat of good quality active raised bog, where some areas have benefited from habitat restoration. In one area there has been a decline in the Large Heath due to deterioration in the degraded raised bog habitat. Positive management is required in this area to enable the Large Heath feature to be *Favourable* in the future.

Continuation of the monitoring of Large Heath at Cors Fochno is desirable to further understand its population dynamics, habitat preference, the impact of peatland restoration, its conservation status on site and the impact of climatic change.

# 1. Species Description and Conservation Status

The Large Heath *Coenonympha tullia* is normally associated with mires (lowland raised and blanket bogs and acidic moorland) in northern Britain and Ireland, with a few isolated sites in central England and Wales that support its primary host plant, Hare's-tail Cottongrass *Eriophorum vaginatum* (Asher *et al.*, 2001). The colony at Cors Fochno lies at the southern limit of the species' distribution in the UK. Cors Fochno is part of the Dyfi National Nature Reserve and is a Special Area of Conservation (SAC) for active raised bog 402ha (EU Habitats & Species Directive Annex 1, code H7110) and degraded raised bog 216ha still capable of natural regeneration.

There are 3 subspecies of Large Heath present in the UK, with the subspecies *polydama* being found at Cors Fochno and at most Welsh localities. Subspecies *davus* is found on Fenn's and Bettisfield Mosses. There is just one generation a year with adult emergence at Cors Fochno usually in late May to early June, a good 2-3 weeks earlier than most sites in the UK due to it being one of the most southerly sites and close to sea level. The main nectar source of the adult butterfly is Cross-leaved Heath *Erica tetralix* (Joy, 1991; Melling, 1987) although at Cors Fochno this is not normally in flower until the mid-period of its flight season. Nectaring on Bramble flowers has also been seen on one occasion at Cors Fochno. The species is said to be highly colonial and sedentary, hence the Cors Fochno population, although relatively large and well distributed across the site, is an isolated one. The nearest populations are on Cors Caron and Cors Goch Trawsfynydd.

The principal habitats for Large Heath in the UK over the last 200 – 300 years have seen a dramatic reduction and deterioration in their quality. In the UK, 94% of lowland raised bogs in Britain and Ireland have been destroyed by drainage, afforestation, overgrazing and/or peat extraction.

The Large Heath is a notified feature on Dyfi SSSI. This evidence report only references monitoring and surveying of the species within the Cors Fochno SAC part of the Dyfi SSSI; the majority of the area is within the Dyfi NNR with additional areas on common land. The conservation status of the species within Wales, UK and Europe is as follows:

- Listed on Section 7 of the Environment (Wales) Act 2016;
- UK BAP status: Priority Species;
- UK Status – Endangered. A revised Red List of British Butterflies (Fox *et al.*, 2022);
- European Status: Vulnerable;
- Protected under Schedule 5 of the 1981 Wildlife and Countryside Act (for sale only).

It is also a notified feature on Afon Eden – Cors Goch Trawsfynydd SSSI, Cors Caron SSSI, Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses SSSI and Mignenint-Arenig-Dduallt SSSI. Recent counts suggest that Berwyn SSSI also supports a nationally important population but this has yet to be fully evaluated.

## 2. Conservation Objective and Attributes

The Large Heath is scarce in Wales and is mainly confined to suitable patches of bog or wet heath habitat on extensive upland blanket bogs or lowland raised bogs. Cors Fochno is one of the most extensive tracts of habitat capable of supporting this species in lowland Britain. The SSSI feature objective for the butterfly within the Dyfi National Nature Reserve management plan is for:

- The population to be strong, stable or increasing and to be well distributed across the site;
- The maintenance and, where possible, the expansion of the distribution and abundance of the main larval foodplant Hare's-tail Cottongrass growing in close association to extensive sphagnum lawns, will be sought. These conditions are synonymous with a raised bog in favourable condition or one that is recovering following restoration.

The species occurs here close to the southern limit of its European range, making it vulnerable to climate change. Locally the main threats are fire and habitat loss and or deterioration caused by dwarf shrub, reed, Purple Moor-grass *Molinia caerulea* or scrub encroachment in areas of bog disturbed by former drainage and peat cutting. It is probable that some suitable habitat on the fringes of the site closest to sea level will become unsuitable to this species in coming decades due to sea level rise.

### SSSI Feature - Attribute Discussion from Dyfi NNR Management Plan

#### Population Size

Based on an annual total adult population index taken from an established transect (Pollard Walk) using the UK Butterfly Monitoring Scheme methodology, as detailed in Butterfly Conservation website as G2: Field guidance notes for butterfly transects. Due to the open nature of the habitat, the width of the transect where butterflies are recorded is 5m either side of a boardwalk/path and 5m in front. The transect is only walked during the adult flight period, with all species of butterfly recorded. The transect is primarily along a boardwalk that goes across the centre of the raised bog from north to south with a shorter west to east section. It is 2km in length and is split into 5 unequal sections. The transect has been monitored annually since 1986 providing a 37 year dataset. It is worth noting that the monitoring for this period has been undertaken primarily by 3 site-based staff (Paul Burnham, Mike Bailey & Justin Lyons) giving a high level of consistency.

Lower limit: A population index of above 60 (averaged over any 3 consecutive year period) based on the sum of all counts during its flight period. Occasionally, a week may have been missed during the flight period and when this occurred an average figure between the previous and following week was used, this figure was only used for the site population size assessment and was not entered into the UKBMS data.

### Population Distribution

Two or more adults in total recorded from each of the following site compartments, over the current and preceding 2 years. These compartments are separate from the compartments that the population transect traverses and are roughly positioned north, south, east and west of the site.

West of Llwyn -y-garreg: cpts 10 & 13

Ty Hwnt: cpts 14 & 15

Gelli: cpts 4a, 19 a and b & 30

Pant-y-dwn: cpts 32 & 33

### Habitat quality and extent

Vegetation composition and structure of areas designated as active raised bog for the Cors Fochno SAC should be composed of good quality M18 *Sphagnum-Erica* raised mire (National Vegetation Classification – community type), as per attributes set out in the SAC monitoring performance indicators. The monitoring for active raised bog in 2020 reported on the status of this feature to be *Unfavourable Recovering* with core areas approaching *Favourable* condition. The M18 *Sphagnum-Erica* active mire vegetation should remain abundant with the condition assessments for the SAC monitoring plots distributed across the area showing no decline in condition in future monitoring, based on the 2020 monitoring round. The hydrology should be of a natural raised bog as per an active raised bog set out in the site SAC Management Plan.

Vegetation composition and structure of areas designated in the Cors Fochno SAC as degraded raised bog should move from *Unfavourable* to *Unfavourable Recovering* as a minimum for extent and quality in future monitoring rounds based on the 2020 SAC monitoring. In future SAC monitoring areas of degraded raised bog that underwent extensive LIFE Welsh Raised Bog restorations works (2019 – 2023) should preferably be *Favourable* for degraded raised bog and approaching a condition where they can be assessed for active raised bog. For areas designated as degraded raised bog within the SAC where LIFE Welsh Raised Bog restoration works were unable to be carried out there should be no deterioration of this features condition or extent and efforts made to carryout restoration work should be prioritised.

For both SAC features there should be no loss of open mire habitat by the encroachment of scrub, *Molinia* (*Molinia caerulea*) or Common reed (*Phragmites australis*).

## 3. 2022 Report - Attributes

### Population Size

Six weekly transect counts were carried out by the author between 27<sup>th</sup> May and 7<sup>th</sup> July 2022. The maximum weekly total was 37 butterflies, and the annual index was 119 (2 + 34 + 29 + 37 + 11 + 6 = 119). The annual index for 2021 and 2020 was 105 and 102.5 respectively giving a population index of **108.8** for the last 3 years, well above the lower limit of 60. The first count on 27<sup>th</sup> May with just 2 butterflies is likely to have coincided with emergence. The 3 following visits between 7<sup>th</sup> and 17<sup>th</sup> June gave relatively high counts of

between 29 and 37. The weather for the flight period was generally dry and warm except for a period between mid and late June where it became cooler and windier.

Transect details were entered on to the Butterfly Conservation national butterfly monitoring website and added to NRW's internal document management system for the Dyfi NNR.

### Population distribution

Passed with 2 or more adults observed in the specified compartments in the current and preceding 2 years, all from casual records as follows.

- W. of Llwyn -y-garreg cpts: 10b & 13b: **6 individuals**
- Ty Hwnt: cpts 14 & 15: **9 individuals**
- Gelli cpts 19, 30, 4a: **3 individuals**
- Pant-y-dwn: cpts 32 & 33: **2 individuals**

The last 3 years have provided a good many casual records due to staff being out on site during the flight period undertaking preparation for LIFE Welsh Raised Bog works and other monitoring projects. The distribution of these records being widely seen across the site, Figure 1. Presence of Large Heath appears not just to be associated with areas of active raised bog but also areas of degraded raised bog; of particular interest from this year was the unexpected observation of the butterfly in grazed areas of degraded bog to the west of the Afon Leri, an area now hydrologically separate from the main part of Cors Fochno.

The passing of the population size and distribution attributes reported for the SSSI feature for the period 2020 to 2022 indicates the conservation status to be *Favourable Maintained*.



Figure 1. Cors Fochno casual records of Large Heath 2020 – 2022.

## 4. Detailed Assessment and Discussion of Transect Monitoring over the Period 1986 – 2022

Butterfly populations can be subject to considerable annual fluctuations induced by both inherent population dynamics and environmental variation such as weather patterns (Pollard, 1988; Roy *et al.*, 2008). As a consequence, longer time series are typically required to distinguish between such fluctuations and actual temporal trends (Thomas, 2005). The monitoring transect that has been used to assess the population index on Cors Fochno for Large Heath has been undertaken annually for 37 years providing an unusually long dataset for an invertebrate, ideally suited for assessing population trends on site. Various assessments of the data have been made to look at potential changes over this period, the results of which are discussed and suggestion made to inform a more detailed attribute assessment for the feature and management of the SAC/SSSI.

To date, the attribute for population index that has been assessed has been the total annual count from the transect. The following details several parameters of the data for the period 1986 to 2022:

- The earliest date for the first transect sighting has been 19<sup>th</sup> May in 2011;
- The latest date for a transect sighting was 23<sup>rd</sup> July, in both 2011 and 2012;
- The transect is walked weekly and for 34 of the 37 years the transect has recorded a flight period of 6 to 8 weeks;
- The highest annual count was 178 in 2010;
- The lowest annual count was 53 in 1991;
- Peak counts have occurred in week 12 (17<sup>th</sup> – 23<sup>rd</sup> June) for 49% of the years;
- The mean and median for the annual total count were both 104 for the period 1990 - 2022.

For a more balanced assessment of the transect and its sections, further analysis has been based on a population index calculated from the number of butterflies recorded per 100m for each season/year. This was especially necessary for the 5 transect sections as they are unequal in length as shown in Table 1. Figure 2 shows the location of the 2km transect with sections traversing the central dome on Cors Fochno. The data has excluded the period 1986 – 1989 for this analysis as the section data was not available. No estimate of missed weeks was used in the analysis of the data. For the period analysed statistically, there were 10 years where there was one week missed each year (2 years between 1990 and 2000, 3 years between 2001 and 2011 and 5 years between 2012 and 2022), there was 2 years where there were 2 weeks missed (between 1990 and 2000). These records of missed weeks do not include potential missed weeks at the start and end of the flight period when numbers would be very low.

Table 1. Transect lengths.

Transect No.	1	2	3	4	5
Length (m)	354	370	607	370	285

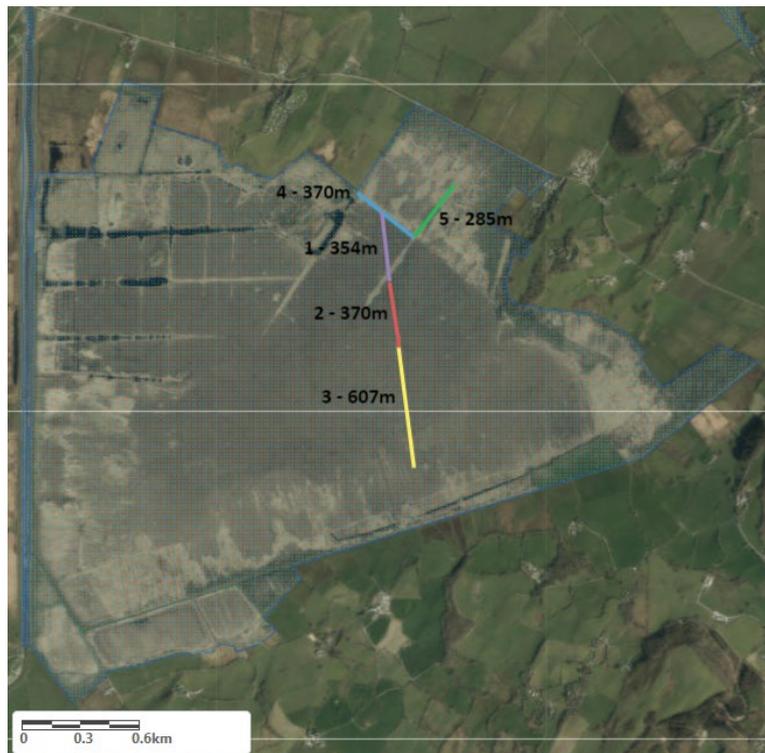


Figure 2. Location of transect sections and lengths. Cors Fochno SAC is shaded in blue.

The first assessment is of the total annual population index for the total length of the transect comparing three equal time periods of 11 years - 1990 to 2000, 2001 to 2011 and 2012 to 2022 as shown in Figure 3. The three time periods had similar median values between 4.6 and 5.4 and similar inter-quartile ranges between 3.7 and 6.7. As expected, there is considerable variation outside of the inter-quartiles due to population dynamics and environmental variation.

The data is not normally distributed so to look for any statistical difference between the 3 samples a Kruskal-Wallis test (H) was carried out. No statistically significant difference was detected between the three samples ( $p > 0.05$ ). The analysis therefore shows that the annual population index as recorded along the transect in total has remained stable with no statistically significant decline or increase for the period 1990 to 2022.

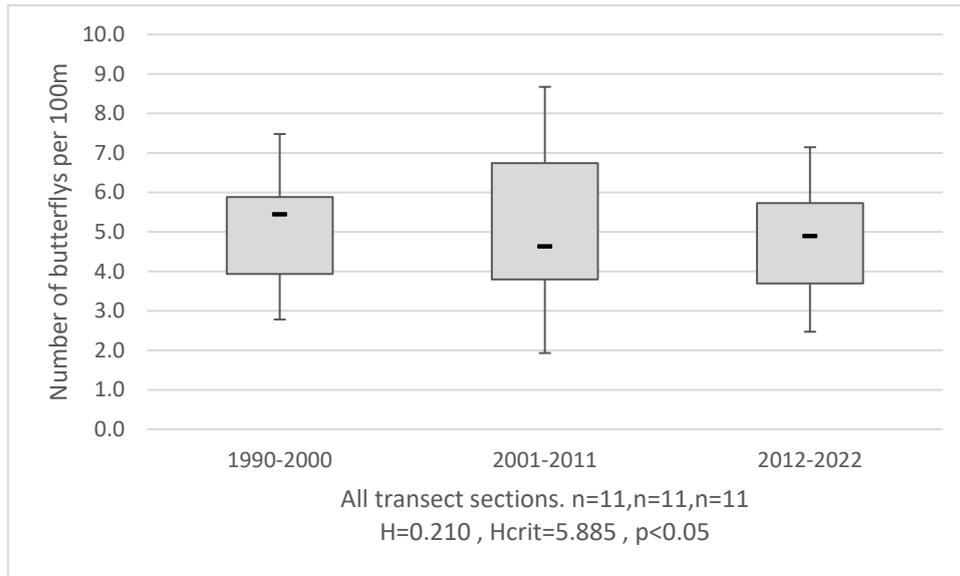


Figure 3. Number of butterflies per 100m for three time periods between 1990 and 2022. The dash shows the median, boxes show inter-quartiles, and the whiskers show range.

The population index of butterflies recorded annually within each of the 5 transect sections was analysed for the period 1990 to 2022. Figure 4 shows that there is variation over the period between the 5 transect sections with respect to median, inter-quartiles and range. Sections 1, 2 and 3 that traverse the central dome of the raised bog have very similar median values between 5.7 and 5.9 and inter-quartile ranges between 4.3 and 7.3. Sections 4 and 5 to the north of Section 1 have lower median values of 4.3 and 2.1, and interquartile ranges of 3.5 to 5.9 and 1.4 to 3.2 respectively.

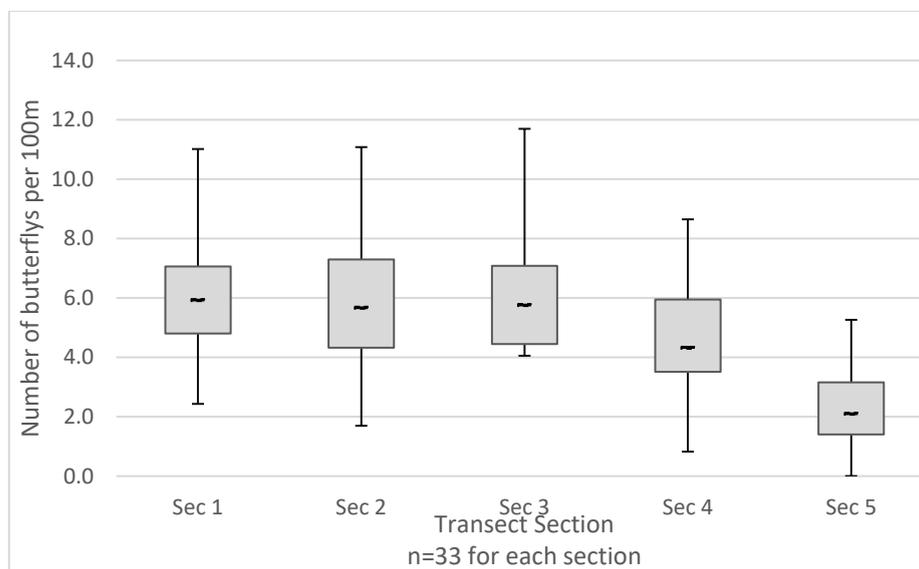


Figure 4. Number of butterflies per 100m for each transect section for period 1990 to 2022. The dash shows the median, boxes show inter-quartiles, and the whiskers show range.

The variation in population index between the 5 sections indicates that there are more optimal areas for Large Heath on Cors Fochno. The attribute most likely influencing the more favourable conditions for the butterfly is the habitat and its structure. Studies of the species at Harelaw Moss and other Northumberland/Cumbria Border Mires (Wainwright,

2011) have indicated that the best conditions for ovipositing (egg laying) are in relatively open vegetation where Heather *Calluna vulgaris* was both stunted and scarce and *Sphagnum* moss usually abundant, this equating to good quality active raised bog. Conversely, Heather-dominated (i.e. relatively dry) vegetation appears to be sub-optimal habitat for the butterfly. The vegetation type found to constitute the best breeding habitat at Harelaw Moss was described as follows: “High percentage cover of Hares-tail cotton grass though occurring in ‘non-tussock’ growth form. Heather was abundant though not as dominant as in drier areas. Hypnoid mosses were present though only on tussocks. Extensive lawns of sphagnum were present between tussocks. Molinia was almost entirely absent”.

The condition of the SAC active raised bog vegetation/habitat on Cors Fochno was most recently assessed for NRW by Matt Sutton in 2020 (unpublished Cors Fochno SAC Monitoring Report). For the SAC condition assessment, within each of seven 100m x 100m plots (100 recording locations per plot) several performance indicators were assessed. For a plot to be in favourable condition, 60 of the 100 locations (60%) are required to pass. Table 2 shows the condition pass scores of the SAC plots where they were within 250m of a butterfly transect section, with the corresponding median for the Large Heath population index for each section shown below. Where more than 1 plot was within 250m of a section an average was taken. No plots across the site are currently in favourable condition for active raised bog although a good number were within 20% of the lower limit, the site was classified as *Unfavourable Recovering* in the SAC assessment. Section 5 is on the boundary of active raised bog and is classified as degraded raised bog.

Table 2. SAC active raised bog vegetation condition score for plots within 250m of transect sections and Large Heath population index median value for transect sections.

Transect No.	1	2	3	4	5
SAC Active raised bog condition score (average)	18% (0 ,36)	44% (36,40,55)	49% (40,52,55)	0%	-
Population Index (median)	5.9	5.7	5.8	4.3	2.1

Transect sections 1, 2 and 3 with the highest condition score for active raised bog vegetation have the highest population index for the species. The vegetation composition and structure of these sections, although not in favourable condition for active raised bog, are the closest to corresponding to it and to that described by Wainwright (2011) to be optimal for Large Heath ovipositing. For Section 4, there is only one plot within 250m with a score of 0% for active raised bog condition, primarily due to low cover of *Sphagnum* and the presence of *Molinia*, both reported as negative feature with respect to optimal conditions for Large Heath by Wainwright (2011). Although no SAC monitoring has taken place further east along Section 4, from personal observation it is noted that the condition of the active raised bog vegetation improves here, particularly adjacent to the neighbouring Section 1 where active raised bog condition score from the monitoring is higher (36%). This may explain the higher population index of this section to the neighbouring Section 5.

No vegetation monitoring occurred within 250m of Section 5 that goes across Llancynfelyn Common. All this section is within an area that has historically been peat cut and drained for this purpose and contains more extensive areas of *Molinia* and Heather with very limited areas of open *Sphagnum* lawns, comparable to suboptimal conditions for Large Heath ovipositing as described by Wainwright (2011) and probably explains the low population index. The photographs in Figure 6 compare vegetation along Section 2 that is optimal for Large Heath to that in Section 5 that is suboptimal. In addition, the following investigation into population index change over time for each transect section shows Section 5 to be deteriorating with respect to supporting Large Heath.

The final assessment undertaken of total annual population index was for three equal time periods of 11 years - 1990 to 2000, 2001 to 2011 and 2012 to 2022 for each of the 5 transect sections as shown in Figure 5. As the data is not normally distributed, a Kruskal-Wallis test (H) was carried out for each transect section to look for any statistical difference between the 3 samples. For sections 1 to 4, there is no significant difference between the three time periods ( $p > 0.05$ ), but a significant decline was detected for Section 5 ( $p < 0.05$ ) highlighting a decline in the population index on this part of the transect.

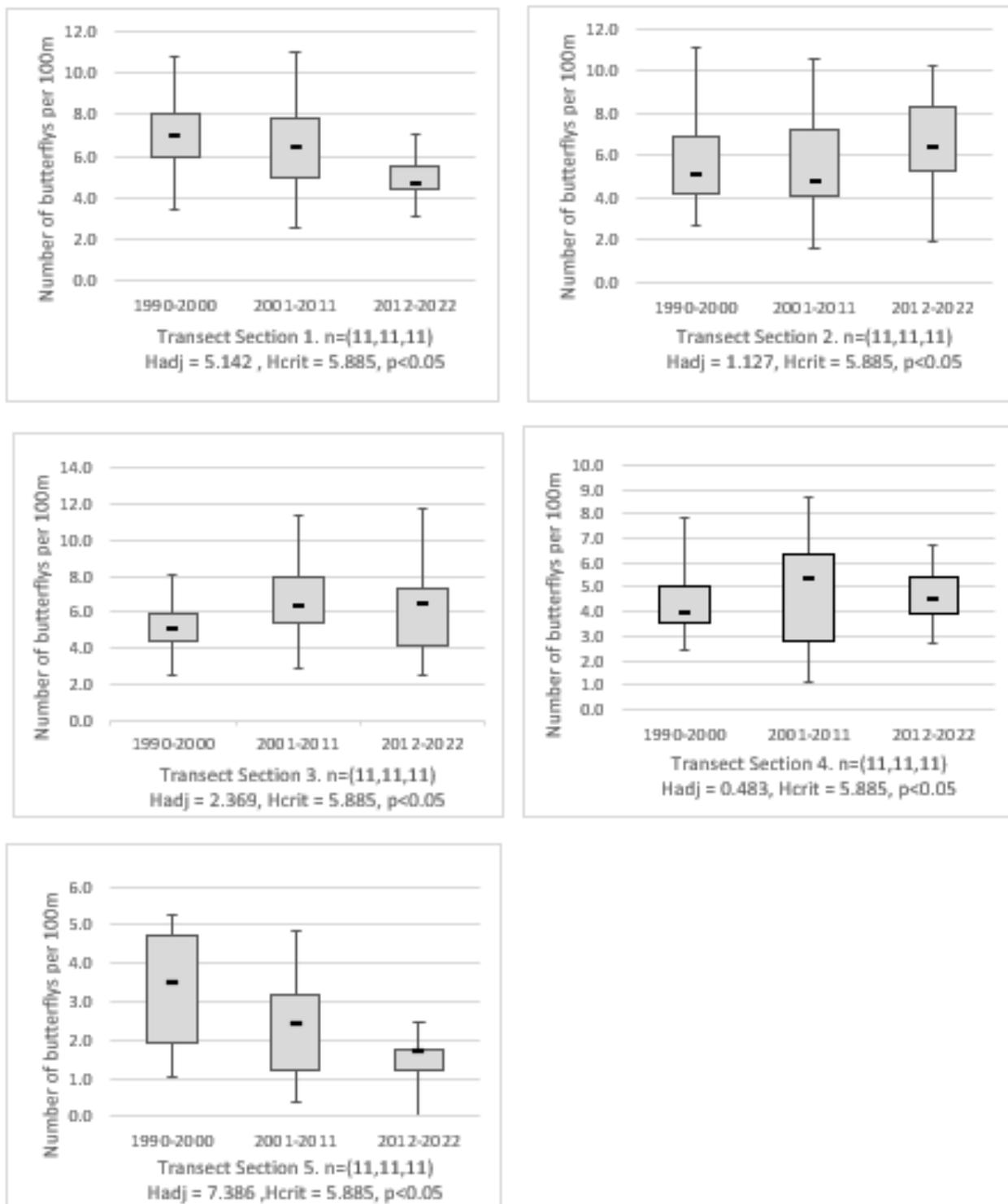


Figure 5. Number of butterflies per 100m for three time periods between 1990 and 2022 for each transect length. The dash shows the median, boxes show inter-quartiles and the whiskers show range.

Sections 1 to 4 show no statistically significant decline or increase in population index for Large Heath. These sections are all within the NNR and since 1990 have seen a variety of peatland restoration techniques to improve conditions for active raised bog following several hundreds of years of peat cutting and drainage particularly around the periphery

and burning over the whole site. Even though there has been no statistically significant increase in the population index for Large Heath for any of these sections, it is reassuring to see no decline. Of note from the assessment, although not statistically significant yet, is that a gradual decline in the population index may be occurring in Section 1, with the median and interquartiles very similar to the more suboptimal Section 4. Recent peatland restoration from the middle to northern parts of Section 1 to improve hydrological supporting conditions will hopefully lead to an improvement in the active raised bog vegetation and subsequently the Large Heath population in this area. Similarly, the southern half of Section 3 has also seen extensive damming of peat cuttings during the period 2003 to 2014 and more recently between 2020 and 2022 with the help of the LIFE for Welsh Raised Bog project and it will be interesting to see if this benefits the Large Heath population in the vicinity.

The only section that statistically shows a statistically significant deterioration in the population index over the time periods is Section 5. Unfortunately, there has been no vegetation assessments of this area. Personal observation has seen a gradual increase since 1996 of less optimal condition for Large Heath in this area with *Molinia* and Heather becoming more dominant following historic cutting and drainage for peat. There has also been a gradual increase of sparse patches of scrub mainly of Downy Birch *Betula pubescens* and Grey Willow *Salix cinerea*, both near the transect and more widely across the neighbouring area. Unlike the rest of the transect, this section is not part of the NNR owned and managed by NRW but is Common land with a complicated and sometimes unknown ownership. For this reason, it has not been possible to date to undertake hydrological management to improve conditions for active raised bog vegetation and the more optimal conditions for Large Heath.

Section 4 runs along the boundary of the Common land and, although it has not seen any statistically significant change, it does have a lower population index than sections 1, 2 and 3. Hopefully in the future, appropriate management of the neighbouring common will happen and improve the active raised bog here also and the population of Large Heath.

Between 2003 and 2014, the restoration of the hydrology on the raised bog of Cors Fochno focussed on damming the extensive peat cuttings on the southern and eastern periphery of the site. The technique used to dam across the cuttings involved the use of plastic piling, see Figure 7. In the year following instillation, there was commonly a rise above the dam in the water table, submerging the vegetation above dams for commonly 3-5m and to a depth of up to 0.25m for several months of the year. In a study of *The effect of flooding on the survival and behaviour of overwintering large heath butterfly*, Joy & Pullin (1999) reported that the *submergence of overwintering C. tullia larvae was found to have a marked impact on their long term survival*. Undoubtedly, the impact of this restoration technique will have had a localised impact on Large Heath larvae at the flooded locations above dams. The butterfly transect only bisects one area treated using this technique, the final third of Section 3.

The piling work was carried out within this area over approximately 10 years allowing for a gradual improvement of the hydrology and colonisation by primarily *Sphagnum* and *Eriophorum* species into the flooded area as can be seen in Figure 7. The improved hydrology of the historically drier adjacent baulks as well as in the cuttings has allowed more favourable active raised bog vegetation to colonise. The SAC vegetation monitoring (Sutton, 2020) included a plot within an area of cuttings and baulks that had been piled as

described, 150m from Section 3. Although unfavourable, the plot had by far the highest pass rate compared to other plots directly impacted by cuttings that at the time had not undergone restoration works. The impact of the hydrological improvements on the population index for the Large Heath population cannot be directly analysed as only a third of Section 3 had been impacted. However, the section 3 analysis shows no statistically significant deterioration in the population index for Large Heath. It may be that the staged raising of the water table has ameliorated any detrimental localised impacts of flooding on Large Heath larvae and this, coupled with the improved hydrology, allowed more optimal vegetation for Large Heath in this area overall and hence no change in population index.



Figure 6. Above - Transect 5 suboptimal condition for Large Heath. Below - Transect 2 optimal conditions for Large Heath.



Figure 7. Above – Cutting one year after piling installed. Below – Cutting ten years after piling installed.

Further extensive hydrological restoration work has occurred on Cors Fochno between 2019 and 2022 as part of a European funded project – LIFE for Welsh Raised Bogs to accelerate the restoration of the SAC active and degraded raised bog habitat to achieve

favourable conservation status. The primary management technique used on Cors Fochno has been to raise water table elevation to desired near surface levels using low contour elevation bunding. The technique involves the construction of a shallow bund (0.3 – 0.4m high) from ombrotrophic peat from up slope of the bund to capture surface and near surface run-off water. The bunds follow the contours of the domed profile of the site and range from 30 to several hundred metres apart depending on the gradient of the area of the raised bog.

Similar to the plastic piling technique, up slope of the bund shallow flashes of water are created commonly 3 to 8m wide as seen in Figure, although occasionally more where the gradient approaches zero and/or within cuttings that are crossed. The desired depth of water is no greater than 0.3m closest to the bund and tapers off up slope. As the LIFE project comes to an end, a total length of 38km of bunding has been installed that influences 200 to 300 hectares of the site with a more desirable water table elevation for supporting active raised bog vegetation. As with the piling, this will have caused some localised losses of Large Heath larvae over an area of 19ha for the total length bunded given the flooding up slope of the bund is on average 5m wide; this amounts to approximately 6 to 10% of the area influenced by bunding. The flashes of water created just as with the piling areas are expected to be colonised by the butterfly over the coming decade and the area influenced by the improved hydrology should start to approach and achieve favourable conservation status for active raised bog.

Given that the more favourable active raised bog vegetation is more optimal for Large Heath (Wainwright, 2011) and confirmed by the sectional analysis seen here on Cors Fochno, this should bode well for the future of Large Heath on Cors Fochno, although the impact of climate change on the species and habitat is of concern. Sections 1 and 3 are directly impacted by several bunds and future analysis of the annual transect data should be undertaken to assess the impact of the bunding works alongside vegetation analysis.



Figure 8. Impact of water level rise up slope of bund, one year after instillation.

An analysis of butterfly emergence time recorded on the transect was compared for three time periods of 12 years between 1986 to 1997, 1998 to 2009 and 2010 to 2021. From the data, there is very little difference between the time periods, with the majority of first counts

being in either weeks 9,10 or 11,see Figure 9. The range of first counts for the period is between 1 and 30, with 86% of first counts being 10 or less, the unusually high first count of 30 in 2020 was due to a delay in the start time because of Covid 19 restrictions. It is likely that for some of the years, the timing of the first transect count doesn't always coincide with the butterfly's emergence.

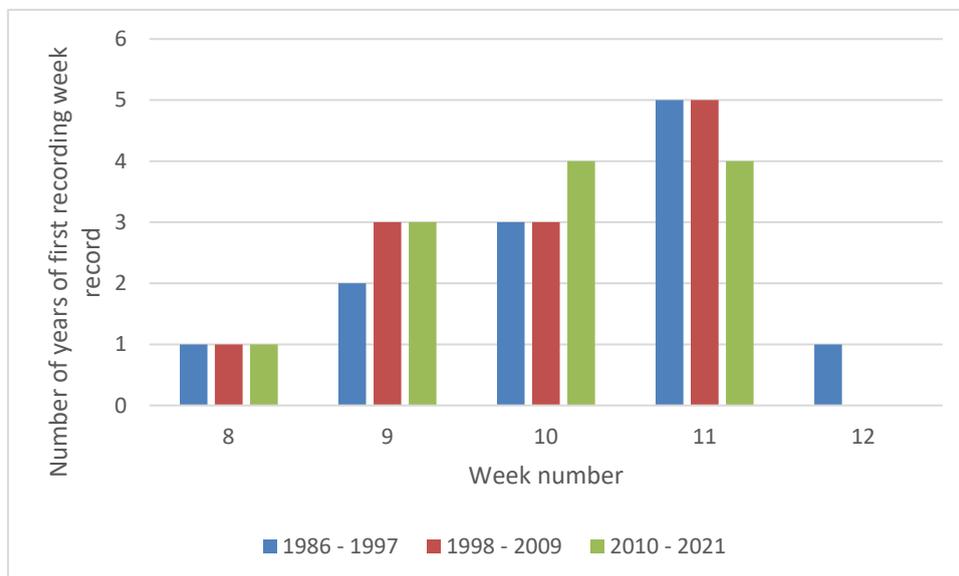


Figure 9. Week number of annual first record for transect.

Due to this potential difficulty in pinpointing actual emergence time from the data, an analysis of the week number that the peak count occurs annually was made as a potential proxy for emergence time due to the greater likelihood that the transect count would capture this, Figure 10. For the 12-year period 1986 to 1997, the peak count time occurred on or before week 12 on 6 occasions i.e., 50% of occasions. For the periods 1998 to 2009 and 2010 to 2021, the peak count occurred on or before week 12 on 11 (92%) and 10 (83%) occasions respectively. This may suggest an earlier emergence time for the two more recent periods and/or possibly that the population attains peak abundance over a shorter time period. This may be due to the impact of a warming climate. Unfortunately, Large Heath is predicted to contract its range northwards in the UK with a 73% decline in the period 2070 to 2099 as a response to climate change (Hill *et al.*, 2002). Cors Fochno being at the southern limit of its range will be highly vulnerable to this change.

Attempts at estimating the total population of a butterfly on a site are difficult due to several factors including unknown information on the lifespan of an individual butterfly, variations on life span relative to weather conditions, probability of detection along a transect and fragmentation of the quality of the habitat that supports the species. A very conservative estimate of population has been made based on the length, width and the mean of the week with the annual peak count for the transect for the period 1986 to 2022. The life expectancy of adult Large Heath has been calculated at 3-5 days, with some individuals living as long as 21 days (Joy, pers. comm.; Melling, 1987), so this is indeed a conservative calculation with the flight period on Cors Fochno being 6 to 8 weeks. From this, a metric of 18.27 butterflies per hectare has been calculated. The total area of active and degraded raised bog on Cors Fochno is 618ha giving a total population estimate of 11,289 adults for the mean of peak weeks. Due to the loss or deterioration of lowland

raised bogs in the UK, it is apparent that Cors Fochno supports a significantly large population of this endangered butterfly.

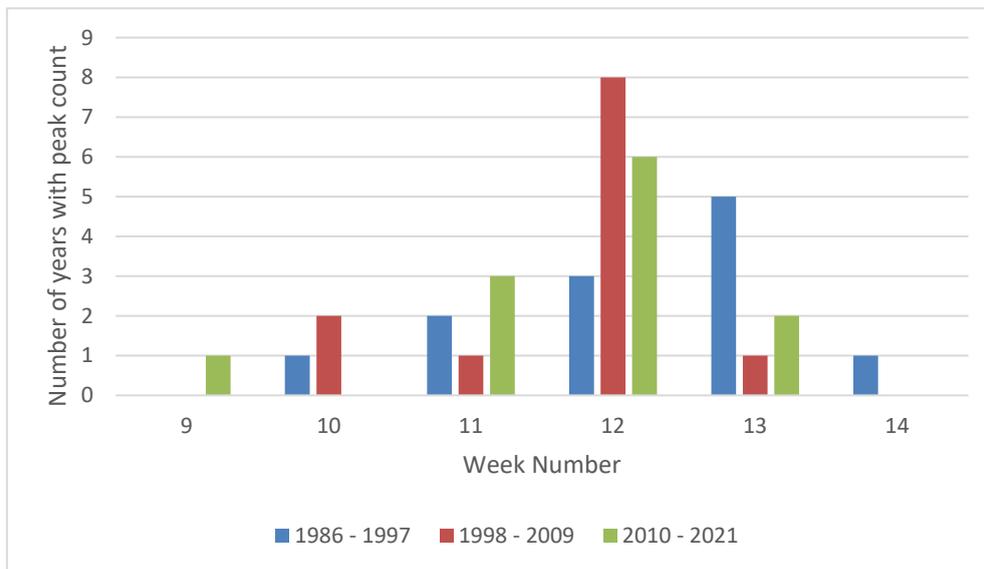


Figure 10. Week number for peak annual count.

In view of the analysis above, it would be timely to review the population size attribute that the Large Heath SSSI feature is assessed against. Currently the lower limit is for the population index to be above 60 (averaged over any 3 consecutive year period) based on the sum of all counts during its flight period. As it has been shown that the population has undergone no statistical change over the period 1990 to 2022, is this lower threshold accurate enough to alert us to change? The interquartile range of annual population index for annual counts including averaged weeks has the lower quartile of 80.5. Perhaps this would be a more appropriate lower limit to trigger concern that the population may be changing. If three consecutive year annual totals are looked at for the period 1986 to 2022, there are three occasions when it would be below 80.5, the lowest average being 76.8 between 1991 and 1993. It is therefore recommended that the lower limit of annual population index be 80.

From the statistical analysis of change over time for the population index of the 5 transect sections, there is one (Section 5) that is declining. This wasn't picked up in the similar analysis of the transect in total. For this reason, it would be advisable to set lower limits for population for each transect section. This could easily be done for each of the 4 sections where there is no statistical change to date using a similar process to the one described in the previous paragraph. For the section that has seen a decline, it should be decided whether the area can support more optimal conditions for Large Heath if appropriate management was undertaken and then set the target based on this. If suitable habitat is subsequently provided, one would expect Section 5 to have a similar population index to the other sections.

## 5. Conclusions

Annual population monitoring along a transect and ad-hoc recording of distribution across Cors Fochno SAC show the conservation status of the Large Heath notified SSSI feature for the period 2020 to 2022 continues to be *Favourable Maintained*. Statistical analysis of the population index from the monitoring transect for annual totals for the period 1990 to 2022 confirms this assessment for the butterfly's population, with no statistical change in the population index over this period. Assessment of the population index for the 5 transect sections show variation between the sections over the period 1990 to 2022. The transect sections (Sections 1, 2, 3 & 4) that are on areas of active raised bog that are tending towards more favourable condition for this habitat have a higher population index.

A statistical assessment undertaken of total annual population index for three equal time periods of 11 years between 1990 and 2022 of each of the 5 transect sections showed there to be no statistically significant increase or decrease in the population index for Sections 1 to 4. Some of these sections have benefitted from peatland restoration works undertaken since 1990 to improve the condition of the active raised bog habitat. For one of the sections (Section 5) on common land, there was a statistically significant decline, this is most likely due to a gradual and continual deterioration of the active and degraded raised bog habitat here for the monitoring period, following historic peat cutting and drainage over 100 years ago. There has been as, yet no peatland restoration works undertaken on Section 5 to improve habitat conditions, except for limited scrub and Rhododendron control from 2000 to 2019. There should be continued effort to ensure appropriate management of the common land area for the SAC active and degraded raised bog if Large Heath decline is not to continue here.

An analysis of butterfly emergence time recorded on the transect comparing three time periods of 12 years between 1986 to 2021 showed very little difference in emergence time, although it was likely that emergence time was missed in some years. Annual peak counts between 1986 to 1997 were on or before week 12 for 50% of the years whereas for the two later periods of 1998 to 2009 and 2010 to 2021, peak transect counts on or before week 12 were 92% and 83% respectively. This may suggest an earlier emergence time for the two more recent periods and/or possibly that the population attains peak abundance over a shorter time period, both outcomes perhaps due to climatic change.

Statistical analysis suggests that the lower threshold for the population index used for the SSSI assessment should be revised from 60 to 80 and individual lower limits set for the transect sections. Under such a change, the feature's status would be *Unfavourable Declining* due to one section (Section 5) deteriorating.

With respect to the two SSSI feature objectives, Cors Fochno SAC can be said to support overall a stable population of Large Heath over the period 1986 to 2022. Secondly the butterfly numbers are highest where active raised bog habitat is in good condition and it is very likely that when this habitat is in *Favourable* and/or *Unfavourable Recovering* condition, the Large Heath population is also in *Favourable* condition. The current habitat condition of the active raised bog is *Unfavourable Recovering* and for the degraded bog *Unfavourable*. The stable butterfly population may have been sustained by positive peatland restoration over the last 30 years, and further to this the recent LIFE works will undoubtedly benefit further areas of active and degraded raised bog habitat and the Large

Heath population in the future. If positive habitat management can be secured on the failing section, Section 5, this would further benefit the conservation of the butterfly on the site and lead to the feature being *Favourable* in the future.

The value of continuation of the long-term monitoring of Large Heath on Cors Fochno is desirable to further understand its population dynamics, habitat preference particularly with reference to peatland restoration, its conservation status on site and due to its presence at the southern edge of its range in the UK to further understand the impacts of climatic change.

## 6. Acknowledgements

Special thanks are extended to Mike Bailey (Retired NRW Senior Reserve Manager – Dyfi National Nature Reserve) for undertaking the monitoring for many years and inspiring me in the importance of such work and to Paul Burnham (Dyfi NNR Warden) for starting the Large Heath butterfly transect in 1986.

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## Data Archive Appendix

No data outputs were produced as part of this project.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

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