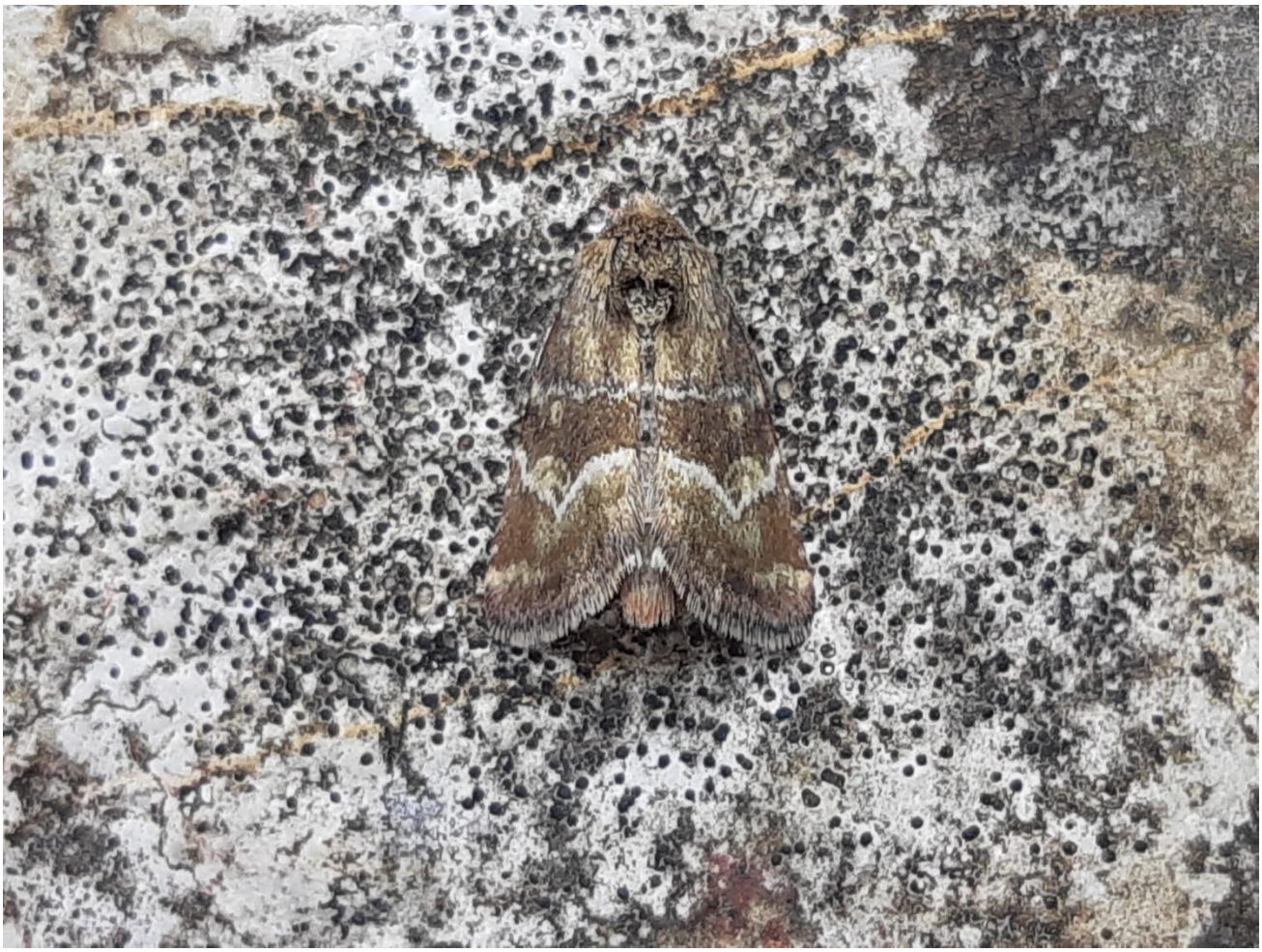
The Status and Distribution of the Endangered Macro-moth Least Minor *Photedes captiuncula* (Treitschke, 1825) (Lepidoptera: Noctuidae) in the Morecambe Bay Limestone Area 2022



A Report for the Tanyptera Project
National Museums Liverpool

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Abstract

The recent re-assessment of the status of Least Minor *Photedes captiuncula* (Treitschke, 1825) has resulted in an updated status to Nationally rare with a threat risk of Endangered. The Morecambe Bay limestone area has been identified as a stronghold for *P. captiuncula*, which highlighted the need for a survey to be conducted. Larval and adult surveys were carried out during suitable weather between late-April and mid-July 2022 within suitable habitat containing the larval foodplants, Blue Moor-grass *Sesleria caerulea* and Glaucous Sedge *Carex flacca* following standardised sampling methods. A total of seven *P. captiuncul*a larvae were found feeding on *S. caerulea* in Lancashire, of which four were successfully reared through to adults and a total of thirty adult moths were caught at known and new sites. An additional seventy-nine moth species were recorded during surveys, some of which with Nationally Scarce status. The surveys identified *P. captiuncula* larval feeding for the first time in the UK, but concerns are raised that the adults of *P. captiuncula* could not be found at historically reliable sites. Recommendations are made regarding the continued monitoring of known sites and surveying new sites along with suggestions for habitat management going forward.

Rationale

It is apparent that there have been no recent (if any at all) systematic landscape-scale surveys of the Morecambe Bay Least Minor *Photedes captiuncula* (Treitschke, 1825) populations despite the importance of the landscape as the UK stronghold for the species and a recent Great Britain threat category assessment of Endangered as a result of national declines (Fox *et al.* 2019). In recent years, the moth has not been found at some formerly well-known local sites despite search efforts with no obvious explanation. There is also limited life history information available, and the early stages of moth have never been recorded in this population (and rarely elsewhere). As a result, the status and distribution of the Morecambe Bay *P. captiuncula* populations, and their micro-habitat requirements are poorly understood.

Aim

To determine the status and distribution of *P. captiuncula* within Lancashire's Morecambe Bay limestone area and provide detailed microhabitat and biological notes associated with each specimen or population.

Introduction

Study area

The Morecambe Bay Limestones National Character Area (NCA) is a lowland landscape that arches around the head of Morecambe Bay and is comprised of limestone hills, scars, screes and limestone pavements exposed by glacial erosion. The prominent limestone geology is interspersed with low-lying arable land. The NCA has a total of 776 ha of limestone pavement, making it significant at both a national and global scale. Almost a fifth of the NCA are designated Sites of Special Scientific Interest (SSSI) for its high-quality habitats and the species they support, including salt marshes, lowland raised bogs, limestone pavements, limestone grasslands, ancient woodlands, reedbeds, rivers and marl tarns (Natural England, 2014).

Within Lancashire, much of the limestone features are found within the Arnside and Silverdale Area of Outstanding Natural Beauty (AONB), which extends to the east of Hutton Roof. In Cumbria, the limestone skirts the coastline and extends northwards toward Kendal, with extensive outcrops at Whitbarrow and Scout Scar. The Morecambe Bay NCA is the main stronghold for the target species, *P. captiuncula*, in north-west England.

Target species

Status and distribution

P. captiuncula was formerly designated a Red Data Book species (RDB) (Waring & Townsend, 2017), however, the Great Britain Rarity status has recently been updated to Nationally Rare with a threat status of Endangered (Fox *et al*., 2019). In Great Britain, *P. captiuncula* (ssp. *expolita* Stainton only) is known from the areas of carboniferous limestone found in the extreme south of Cumbria and extreme north Lancashire, the Malham and Grassington area of north Yorkshire, and restricted sections of the Northumberland coast. As a result of declines in recent decades, the moth has become rare in north-east England.

The open limestone habitats found in the north-west of Lancashire are within the biological recording area of Vice County 60 (VC60) and south Cumbria is within VC69. Within the study area of Lancashire, just 56 records of *P. captiuncula* exist on the local database, 27 of which have been since the year 2000. It was first recorded as an adult in Lancashire near The Row in Silverdale by W. Mansbridge on 26/06/1909. It was not reported again until 1954 by the Reverend Vine Hall at Warton Crag. Since then, it has been recorded sporadically and last seen at Yealand Hall Allotments in 2013, Gait Barrows in 2016, Warton Crag in 2018, and was recorded in the Lancashire section of Hutton Roof for the first time in 2021. There are over 100 records for Cumbria and was first recorded in 1912 at Witherslack. There are recent records from Hutton Roof and Farleton Knott (2021), Arnside Knott (2012), and Whitbarrow (2018). It has also been recorded on the Orton and Great Asby limestone (2013), where a small number were recorded from light traps.

Life history

P. captiuncula is a specialist of open, limestone grassland, including rough fields, usually on south-facing hills and dales where the larval foodplants, Blue Moor-grass *Sesleria caerulea* and Glaucous Sedge *Carex flacca* are present.

In May 2014, final instar larvae of the ssp. *tincta* Kane were found in the wild for the first time at the Burren, Ireland. Larvae were feeding within the stems of both *S. caerulea* and *C. flacca* in close proximity to limestone pavement habitat. These findings were subsequently published in the *Field Guide to the Caterpillars of Great Britain and Ireland* (Henwood & Sterling, 2020).

Larvae feed deep within the stems of the larval foodplant. The underdeveloped flower spikes of *S. caerulea* and *C. flacca* may indicate the presence of a larva feeding within the stem. Larvae overwinter part-grown, and resume feeding the following spring (August to May). Pupation is within a flimsy cocoon on the ground (Waring & Townsend, 2017).

Adult males fly erratically in the afternoon sunshine between late-May and early-August (peak mid-June to mid-July) in a single generation. Adults are also known to fly at night and occasionally far away from suitable breeding habitats (e.g., adults attracted to light at Walmer Bridge, G. Jones 2013 and Middleton Nature Reserve, J. Girdley 2013).

Identification

P. captiuncula is a small species of noctuid with a forewing length of 7-9 mm, with the male being larger than the female (Waring & Townsend, 2017). Forewing colour ranges from light or dark brown to a reddish brown, with a darker central crossband, highlighted by white central cross-lines; the first being straight and the second strongly arched. The kidney and oval are also outlined white, which also varies in intensity between individuals, with the oval being absent in some. Species of a similar size and colour include Cloaked Minor *Mesoliga furuncula* ([Denis & Schiffermüller], 1775) and Middle-barred Minor *Oliga fasciuncula* (Haworth, 1809). Larvae are a pale creamy colour with a brown

head, prothoracic plate and anal plate and may be confused with *M. furuncula* (Henwood & Sterling, 2020).

Method

Larval and adult searches of *P. captiuncula* were carried out at known and new sites containing open limestone habitats of north-west Lancashire (VC60) and south Cumbria (VC69) (Fig. 1). Larval searches were carried out during the day between late-April and mid-May 2022. Adult searches took place when the weather was favourable (light winds and warm) from early-afternoon to early-evening between June and July 2022. As adults are known to come to light, a light trap was left overnight at Gait Barrows National Nature Reserve (NNR) on one occasion. A single battery-powered, Heath-style light trap was left at dusk in a suitable habitat. The contents were checked at dawn the following morning. Any other species observed during searches were noted and records submitted to the relevant County Moth Recorders. Eight-figure grid references were recorded for all moth sightings.

In addition to the main survey, adult searches were carried out at a small number of known and new sites in Yorkshire as part of Butterfly Conservations Limestone Lepidoptera Project (Patton, 2022). Two sites along the Northumberland coast were also visited during the 2022 flight period (pers. comm. Dave Wainwright). Survey methodology conformed to the Morecambe Bay NCA survey. However, due to the limited number of surveys and the disjunction between the Lancastrian/Cumbrian, Yorkshire and Northumbrian populations, it was decided the focus of the results should be limited to the Morecambe Bay area. Details of the searches and the results can be found in the appendices (Appendix 2 & 3).

Permission was granted by all landowners prior to surveys commencing. All photos belong to the author unless stated otherwise.

Figure 1. Map of survey sites and their 6-figure grid references across the Morecambe Bay limestone area.

Larval searches

Prior to starting the survey, existing records for *P. captiuncula* were assessed to determine where searches were most likely to be successful. Larval searches were therefore restricted to a small number of sites located on the Lancashire limestone within VC60 where there had been recent and reliable sightings. The most recent adult sightings prior to survey were at Crag House Allotment, Hutton Roof on 08/07/2021 and 15/07/2021, where three were observed flying rapidly across the path amongst *Sesleria* grassland during the early evening. These were the first records since 2018 where a single adult was sighted during the day at Warton Crag (K. Hughes), which is one of the most reliable sites for the species historically and so selected as the second larval search site. As Gait Barrows has a similarly reliable set of historic sightings, it was chosen as the final site to carry out larval searches.

The larval searches consisted of identifying stunted, and or dead flowering spikes of *S. caerulea* and *C. flacca* following the advice of Henwood and Sterling (pers. comm. 2022). Given that those that were found in Ireland were final instar by mid-May, it was decided that searches starting in late-April would provide a greater window of opportunity to successfully find larvae. The flowering spikes of *S. caerulea* are purple in colour with an almost metallic sheen and begins to flower in late-March/early-April (Streeter, 2009) when the herbaceous layer is still undeveloped, making feeding easy to identify. *C. flacca* flowers a month later between May and June (Streeter, 2009) and so flowering was limited to just one or two flowering spikes beginning to develop.

In order to look for larvae within stems that looked as though they may be occupied, the thumb and forefinger were used to carefully find the base if the stem, as to not crush any potential larva within, and detach from the main plant clump. Once removed, the base of the stem was carefully opened to reveal the contents. If a larva was found then a 50 cm x 50 cm quadrat was used to assess the immediate vegetation surrounding the larval site, with the larval position located centrally within the quadrat (see Fig. 2b & 2c). Seven vegetation variables were measured from within the quadrat, noting the larval foodplant, aspect and altitude of each find (see Appendix 1).

Any larvae that were found were taken from the site in order to attempt to rear through to adults. Soil and live foodplant were put in a plant pot, with the larvae placed amongst this and left to enter new stems and continue their development. A frame was constructed around the edge of the plant pot and a fine net secured around the structure to retain any adults that emerged.

Adult searches

Adult searches consisted of walking through areas of suitable habitat during the flight period when weather conditions were favourable; afternoon or early evening when winds were light to moderate and temperatures warm. Larger areas of suitable habitat were walked through in a zig-zag pattern at a steady pace, covering as much of the available habitat as possible and catching any moths using a hand net (see Appendices 5 to 8 for coverage).

Results

Target species

In total, seven larvae and thirty adult *P. captiuncula* were recorded during surveys across the Morecambe Bay limestone area. Larvae were found at all three target sites: Crag House Allotment, Warton Crag and Gait Barrows (Table 1). In Lancashire, all adults were from Warton Crag on 17/06/22. A total of nineteen adults were recorded between 24/06/2022 and 14/07/2022 in Cumbria from Arnside Knott, Farleton Knott, Hutton Roof, and Cunswick Scar, being recorded at the latter for the first time. Extensive searches at sites with historic sightings, Whitbarrow and Scout Scar, proved unsuccessful.

Table 1. *Photedes captiuncula* records collected across the Morecambe Bay area during the 2022 recording period.

Taxon	Vernacular	Site	Gridref	VC	Recorder	Date	Quantity	Stage
Photedes captiuncula	Least Minor	Crag House Allotment, Hutton Roof	SD55547674	60	J. Patton, G. Hedges, B. Smart & S. Palmer	26/04/2022	2	Larva
Photedes captiuncula	Least Minor	Crag House Allotment, Hutton Roof	SD55547673	60	J. Patton, G. Hedges, B. Smart & S. Palmer	26/04/2022	1	Larva
Photedes captiuncula	Least Minor	Crag House Allotment, Hutton Roof	SD55617693	60	J. Patton, G. Hedges, B. Smart & S. Palmer	26/04/2022	1	Larva
Photedes captiuncula	Least Minor	Warton Crag LNR	SD49217250	60	Justine Patton	29/04/2022	2	Larva
Photedes captiuncula	Least Minor	Gait Barrows	SD48167748	60	Justine Patton	11/05/2022	1	Larva
Photedes captiuncula	Least Minor	Warton Crag LNR	SD49287250	60	Justine Patton	17/06/2022	1	Adult
Photedes captiuncula	Least Minor	Warton Crag LNR	SD49487249	60	Justine Patton	17/06/2022	1	Adult
Photedes captiuncula	Least Minor	Warton Crag LNR	SD49607267	60	Justine Patton	17/06/2022	2	Adult
Photedes captiuncula	Least Minor	Warton Crag LNR	SD49567267	60	Justine Patton	17/06/2022	7	Adult
Photedes captiuncula	Least Minor	Arnside Knott	SD45487740	69	Justine Patton	24/06/2022	1	Adult
Photedes captiuncula	Least Minor	Arnside Knott	SD45547748	69	Justine Patton	24/06/2022	2	Adult
Photedes captiuncula	Least Minor	Arnside Knott	SD45487744	69	Justine Patton	24/06/2022	1	Adult
Photedes captiuncula	Least Minor	Hutton Roof	SD55367850	69	Justine Patton	09/07/2022	1	Adult
Photedes captiuncula	Least Minor	Hutton Roof	SD55237832	69	Justine Patton	09/07/2022	1	Adult
Photedes captiuncula	Least Minor	Hutton Roof	SD55117835	69	Justine Patton	09/07/2022	1	Adult
Photedes captiuncula	Least Minor	Farleton Knott	SD54638015	69	Justine Patton	11/07/2022	2	Adult
Photedes captiuncula	Least Minor	Farleton Knott	SD54568018	69	Justine Patton	11/07/2022	2	Adult
Photedes captiuncula	Least Minor	Farleton Knott	SD54398028	69	Justine Patton	11/07/2022	3	Adult

Photedes captiuncula	Least Minor	Farleton Knott	SD54218022	69	Justine Patton	11/07/2022	1	Adult
Photedes captiuncula	Least Minor	Cunswick Scar	SD49289393	69	Justine Patton	12/07/2022	1	Adult
Photedes captiuncula	Least Minor	Hutton Roof	SD55687723	69	Justine Patton	14/07/2022	2	Adult
Photedes captiuncula	Least Minor	Hutton Roof	SD55847726	69	Justine Patton	14/07/2022	1	Adult

Non-target species

Whilst surveying for adult *P. captiuncula* in Lancashire, any other species that were seen at the time were also recorded. An additional seventy-nine moth species were noted during surveys across the recording area. Several of the non-target species recorded were notable for the area due to their local or national status and include the second record of the Nationally Scarce B species *Elachista adscitella*, *Anania funebris* at Gait Barrows and the pRDB1 species, *Scythris fallasella* at Warton Crag. In Cumbria, *Merrifieldia leucodactyla*, a locally restricted species and *Pyrausta ostrinalis* was recorded at Scout Scar and the Nationally Scarce A species, *Crambus ericella*, was also recorded across Hutton Roof (Appendix 4).

Summary of results from adult searches outside the main survey area

Just five adults were recorded during searches at known sites on the limestone of the Yorkshire Dales as part of Butterfly Conservations Limestone Lepidoptera Project. A single adult was recorded in suitable habitat on the Durham coast (pers. comm. Dave Wainwright). Outside the main survey just one other adult sighting of *P. captiuncula* was made during the 2022 recording period (see Appendix 2).

Discussion

P. captiuncula larva and larval feeding signs

Larval feeding was identified in *S. caerulea* by locating dead, brown looking flowering spikes around the area where the adults had been observed the previous year (Fig. 2b). These were then followed to the base of the stem near the rhizome and checked for the presence of larvae. Larvae were found with their head toward the base of the stem with frass accumulations within the portion of the stem that had been consumed by the larva (Fig. 4b). Older feeding that was observed presented as blackened inner stems and darkened frass. Fresh feeding produced green frass (Fig. 2a). Feeding signs often presented in a number of stems within a single clump of *S. caerulea* and in one case (Warton Crag), two larvae were found in the same clump (Fig. 3a). On one occasion an entrance hole was visible near the base of the flowering stem where larvae had either entered or exited a stem (Fig. 2c). All stems with a larva present were distended at the base. Other feeding signs analogous to those of *P. captiuncula* were seen frequently, however, as a number of other grass-feeding Noctuids and also fly larvae may also feed in a similar fashion, the presence of dead stems alone cannot be attributed to *P. captiuncula* and so any larvae must be observed.

Figure 2. *P. captiuncula* larval feeding signs in *S. caerulea* with a) frass circled in red, b) dead stem indicating that larval feeding had taken place and c) older frass with larval entrance hole circled in red.

Figure 3. The sites where *P. captiuncula* were found at a) Warton Crag, b) Gait Barrows and c) Crag House Allotment.

Larvae were found in a range of conditions across the survey sites. Those found at Warton Crag were in a single, well-developed clump of *S. caerulea* that was growing on the vertical limestone escarpment at the top of the scree slope (Fig. 3a). Warton Crag had a greater proportion of smaller patches of *S. caerulea* that tended not to form clumps, particularly on the scree slope and forester

bank. These smaller plants had tight, thin stems, which were often exposed to the elements and were dry. At Gait Barrows, a single larva was found in the shade of *Betula* scrub (Fig. 3b). At Crag House Allotment, Hutton Roof, *S. caerulea* is extensive and dominates the SSSI unit. The site is exposed to the south and has no shelter. In all cases, larvae were found in healthy and well-formed clumps of *S. caerulea* (Fig. 3c).

The larvae were approximately 15 mm in length and had a creamy yellowy/white body with black spiracles. The head and prothoracic plate are light brown, with darker mandibles. The anal plate is also light brown. The thoracic legs were a darker brown and the prolegs were concolorous with the body (Fig. 4a, 4b & 4c). The features of the larvae found during this survey did not vary between individuals and looked identical to those found by Henwood and Sterling (2021).

All the larvae of *P. captiuncula* that were found were removed in order to try and rear them through to adults. Four of the seven larvae found were successfully reared and emerged as adults (57% success rate). Three were male and one female; all three from Crag House Allotment emerged and one of the two found at Warton Crag. The one suspected female and one of what was assumed to be a male *P. captiuncula* were dissected to confirm by examining the genitalia (see Fig. 5a, 5b & Fig. 6a, 6b). These were the first known larvae to be found in the wild in the UK and to be successfully bred through. The pupae were looked for within the material provided for rearing but could not be located.

C. flacca was still underdeveloped with just one or two plants located during searches. Feeding signs were noted in one of the stems by the presence of frass, which was darker in colour than that seen in *S. caerulea*. As this plant develops and flowers later in the year, further checks in May when the plant has fully developed would be beneficial.

Figure 4*. P. captiuncula* larvae found feeding in *S. caerulea* at a) Gait Barrows and (b & c) Crag House Allotment, Hutton Roof (© Ben Smart, 2022).

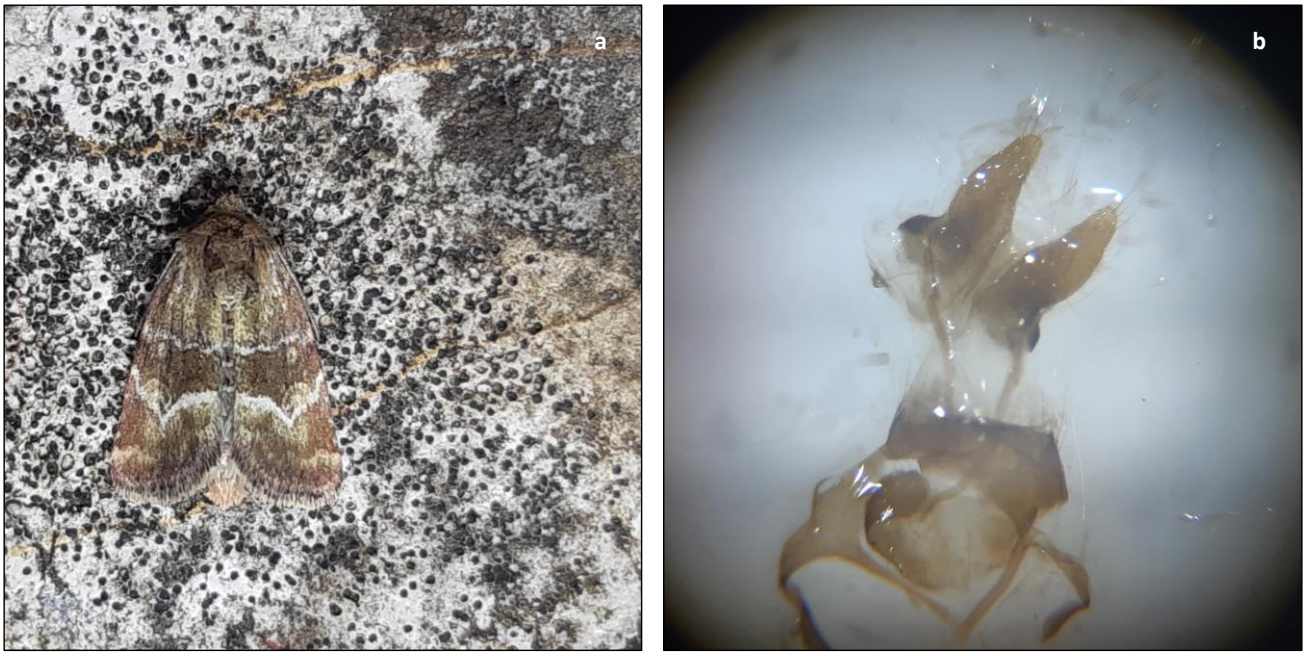

Figure 5. a) Female *P. captiuncula* that emerged on 13/07/2022 from larvae collected from Crag House Allotment, Hutton Roof on 26/04/2022 and b) the genitalia from the specimen.

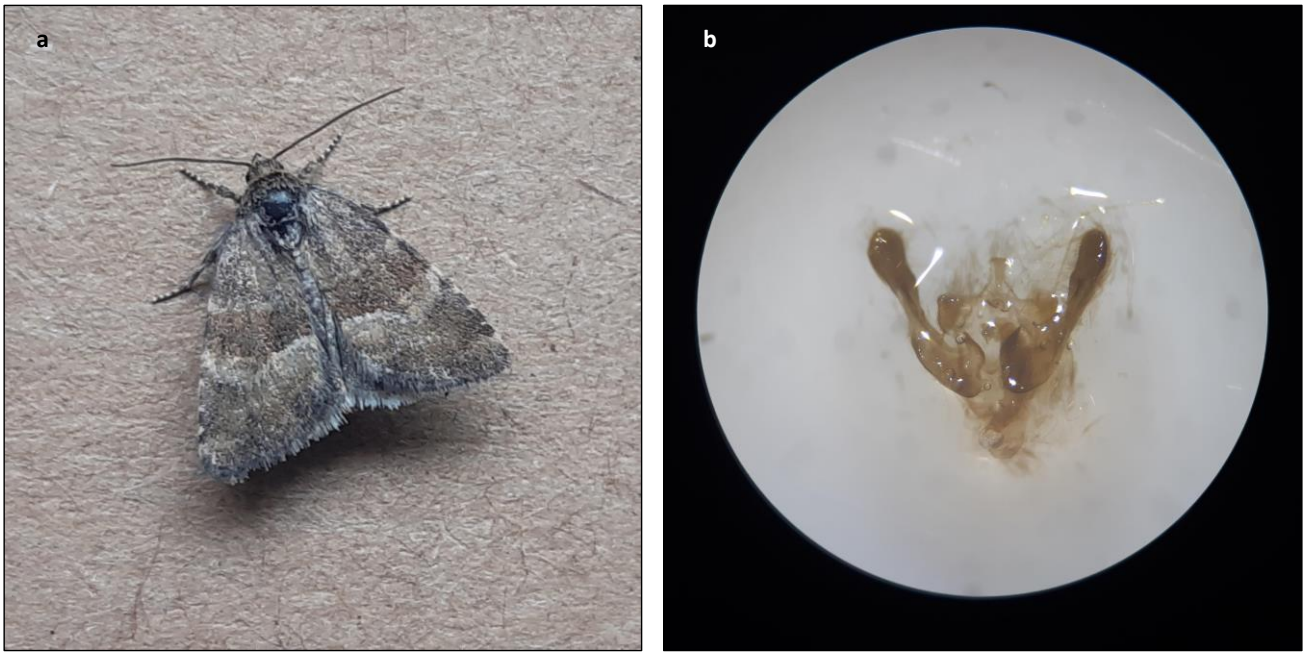

Figure 6. a) Male *P. captiuncula* emerged on 26/06/2022 from larvae collected from Warton Crag, Lancashire on 29/04/2022 and b) the genitalia from the specimen.

Observations of adult *P. captiuncula*

Adult *P. captiuncula* were only recorded at Warton Crag during the Lancashire surveys. The forewing colour ranged from ochreous brown (Fig. 7a) to a deeper brown, which is in-line with the description in Waring and Townsend (2017). The darker central crossband, which is highlighted by a white subterminal line, was seen to be consistent even where individuals were particularly worn, but the

oval appeared to be absent in some specimens. The thorax wears very quickly and was often ‘bald’, but the banded legs remained an obvious feature across individuals.

It was particularly concerning not be able to locate the adult moth at Gait Barrows despite being covered more than any other site during the survey period. The last adult sighting was made in 2016 (Palmer & Young). Similarly at Thang End, where adults had been seen in good numbers until 2013.

In an attempt to locate potentially new sites, the small area of suitable habitat near the summit of Heald Brow and at the Jack Scout headland were searched but proved unsuccessful. Given the difficulties locating adults at known sites it may still be found in there in the future and has the potential to link up with other known sites in the area. The adults were also difficult to locate during searches at known sites in Cumbria and Yorkshire during the same survey period in 2022. It could be that they occur at low densities throughout their range, however, there are double figure records from Yealand Hall Allotment and Warton Crag in Lancashire and over 100 males were observed around a female in Yorkshire (Yorkshire Moths, 2022).

Adults can be confused with some of the other Minor species and some micro-moth species of a similar size such as the Pyraustas. All moths should be temporarily caught for reliable identification as the erratic flight that is often described as being distinctive is not sufficient evidence to support a positive *P. captiuncula* identification. Adults were all disturbed from rest and immediately fly off. Their small size and speed make them difficult to catch.

Whilst adults were only located in areas of scrub containing little of the larval foodplant in Lancashire, they were also found in more open areas with extensive *Sesleria* grassland during searches in Cumbria and so can be found across a gradient of *Sesleria/Carex* presence. Across all survey sites, areas of shelter appeared to be preferential to adults on windy or hot days, with many being found in the transitional habitat between the grassland and scrub. However, some adults were found (Fig. 8a) in the open with no scrub in the immediate vicinity such as Arnside Knott (Fig. 8a) and Farleton Knott. They are able to utilise both open calcareous grasslands and more discrete patches within the limestone matrix, including areas moderately scrubbed-over such as found at Hutton Roof (Fig. 9b).

Figure 7.The a) male *P. captiuncula* caught at Warton Crag LNR on 17/06/2022 at b) the scree slope. All other *P. captiuncula* were recorded from c) the area of limestone pavement on the LNR section of the reserve.

Figure 8. One of the a) male *P. captiuncula* netted during the early evening at Arnside Knott on 24/06/2022 and b) the area near the twisted Larch where all individuals were observed during the visit.

Figure 9. The single a) male *P. captiuncula* netted during a visit on 09/07/2022 and b) the area near the summit of the reserve.

P. captiuncula larval and adult search details

Crag House Allotment, Hutton Roof, 26/04/2022, 14/06/2022, 14/07/2022

Crag House Allotment is part of the Hutton Roof Site of Special Scientific Interest (SSSI), which is notified for its extensive calcareous grassland and limestone pavement (Natural England, 1988). The SSSI unit is dominated by *S. caerulea* with exposed limestone pavement running through the middle of the site and has a south facing aspect.

Larval feeding was identified in *S. caerulea* by locating dead, straw-coloured flowering spikes around the area where adults had been observed the previous year as to maximise the chances of locating them. These were then followed to the base of the stem by the roots and checked for the presence of larvae. Lots of feeding found early on which was noted by the presence of green frass in the stem of the dead and/or stunted flower. Older feeding observed presented as blackened stems and darkened frass. Fresh feeding produced green frass. Feeding signs became easy to identify early in the search as the dead stems stood out amongst the monoculture of purple *S. caerulea* flowers at the site.

C. flacca was still underdeveloped, but one or two plants were located. Feeding signs were noted in one of the stems by the presence of frass, which was darker in colour than that seen in the Blue Moor Grass. As this plant develops and flowers later in the year, further checks in May when the plant has fully developed would be beneficial.

Four larvae were located in four hours between four recorders, all of which were found feeding in the stems of *S. caerulea*. Two of the larvae appeared to be almost fully fed and possibly final instar and the two others were much smaller, possibly third instar. All specimens were removed from site to breed through as potentially the first documented larval records for the United Kingdom.

Larva were approximately 15 mm in length and were all found head toward the base of the stem. Smaller larvae were found higher up in the stem. The body was a creamy yellowy/white with a brown head, looked similar to a tortricid larva (pers. comm. Ben Smart).

A small number of additional moth species emerged from the larval foodplant collected from Cumbria (VC69) to rear the *P. captiuncula* larvae through: Middle-barred Minor *Oliga fasciuncula*, *Elachista adscitella*, *Chrysoteuchia culmella* and *Micropterix calthella*.

A second visit was made to the areas of *Sesleria* grassland at Hutton Roof Commons Pavement and Uberash Plain. Conditions were full sun and 21 degrees from early afternoon with a moderated breeze coming in off Morecambe Bay from a westerly direction. Three adults were located during the search, all of which were at or near the edge of Hazel *Corylus avellana* scrub, two of which were in the shade.

Heald Brow, Silverdale, 27/04/2022, 21/06/2022

A quick walk through the reserve to look at the habitat and to see if *S. caerulea* was present and in good enough quantities to warrant an adult search later in the year. *S. caerulea* was present in small patches concentrated around the summit, but not very vigorous growth on shallow soils. The site was being grazed by cattle during the visit. A small number of plants displayed dead, brown flowers. Upon checking one, frass was present in an identical fashion to that seen the day prior at Hutton Roof, but no larvae could be found. An afternoon search around the foodplant proved unsuccessful.

Warton Crag, Warton, 29/04/2022, 17/06/2022, 20/06/2022

Warton Crag is the southernmost limestone hill in the Arnside and Silverdale AONB. The majority of the nature reserve is wooded, particularly to the rear of the summit. The front has a south-western aspect, which is exposed to Morecambe Bay and is comprised of herb rich grassland, areas of bracken and scrub and screes to the east of the disused quarry.

Warton Crag LNR and RSPB sections were searched for larvae. At the LNR section of the reserve, the main area of *Sesleria* can be found at the scree slope. The scree slope consists of woodland at the base and a mosaic of loose scree with some *Sesleria* grassland and scrub development where sections are more stable. At the top of the slope, the limestone escarpment becomes blocky and supports many forbs and *Sesleria* tussocks. The RSPB section contains *Sesleria* grassland along the escarpment below the summit which is grazed year-round by Redpoll cattle along with more in an area known locally as the forester bank. Adult *P. captiuncula* have been sighted in both areas historically, but more so at the scree slope.

Larval feeding was identified in *S. caerulea* by locating dead, brown looking flowering spikes. These were then followed to the base of the stem by the roots and checked for the presence of larvae. Minimal feeding found, which was noted by the presence of green frass in the stem of the dead and/or stunted flower. *C. flacca* was much more developed here than at Crag House Allotment, Hutton Roof, but no signs of feeding (dead or weak flowering spikes) were noted. Two larvae were found feeding in one small tussock of *S. caerulea* (Fig. 3a) nestled within the limestone escarpment at the top of the scree slope. Several stunted stems with brown flowers were noted, but only two plants were checked, both of which contained larvae of around fourth instar.

An additional three hours of looking for larvae was unsuccessful. The majority of the *Sesleria* patches at Warton Crag are small and grow on shallow soils and/or scree. The root systems on these plants do not appear to be big enough to support the size of larvae observed elsewhere.

A single male emerged on 29/06/2022, confirmed by gen. det (see Fig. 6a).

The site was visited on two occasions to look for adults, the first of which on 17/06/2022. Conditions were initially sunny and humid with a strong breeze coming in from the west. Upon arriving at the scree slope, conditions became hazy. The vegetation structure here varies, but is dictated by the scree and its gradient, with a mosaic of bare ground, herb and scrub.

The first adult, a male, was noted at the top of the scree slope at 12:45pm and the second at the opposite end of the slope, near the top at 1:40pm. The search then moved over to an area of limestone pavement still on the LNR section of the reserve. Cloud had built by this point and the temperature began to drop. However, several adults were seen in this area at around 2pm, which was sheltered from the prevailing wind. The pavement here has some small tress, scrub and is interspersed with grasses and forbs within the broken matrix. Both *S. caerulea* and *C. flacca* was present but only in small quantities. The search was abandoned as a thunderstorm developed.

A second visit was made to Warton Crag on the 20/06/2022 to cover the RSPB and LWT sections of the reserve. Conditions were bright sun and light breeze with the temperature at around 20°C. There are no previous records for the LWT section, but there is an area of potentially suitable habitat at the far end which is not far from suitable areas on the RSPB section of the reserve. No adults were observed here, but this should not be reason to not look again in the future. The forester bank was then searched as there are previous sightings from here, but not for a number of years now. No adults were seen here either.

Gait Barrows, Silverdale, 04/05/22 & 11/5/22, 08/06/2022, 16/06/2022, 30/06/2022, 10/07/2022

Gait Barrows has the best example of lowland limestone pavement in the Arnside and Silverdale AONB but has been marred by extraction. What remains is a blocky matrix with well-developed scrub and trees, but still with extensive areas of *Sesleria* patches that skirts the raised pavement areas, forming healthy clumps across the reserve.

Any open areas of limestone containing *S. caerulea* were searched for larvae. All *Sesleria* looked really healthy, with very little difficulty entering the base of the stems to look for larvae. Lots of feeding

signs found (frass in the stems) but proved difficult to locate. No feeding damage noted on *C. flacca*, which at this point in the season was becoming quite well developed.

A single larva was located after nearly 4 hours of searching near the start of the limestone trail. The area the larva was found feeding was under *Betula* scrub, the first of all the larvae found shaded by taller vegetation. The larva appeared quite small compared to others found previously. The weather had been poor between searches at Warton and Gait Barrows, with some very cold nights and wet days and so feeding may have paused. The clumps of *Sesleria* were very wet inside and humid after the prolonged rain, making them slightly more difficult to search.

The site was searched for adults on four occasions, with focus on areas where larval feeding signs had been found the previous month and also where adults have been observed in the past. No adults were noted during the visits. Moth traps were left overnight close to where the larva was found on the 16/06/22 as adults are known to come to light, however this was not successful.

Thrang End, Yealand Redmayne, 29/06/2022, 08/07/2022

Thrang End is an area of south-facing exposed limestone pavement, surrounded by woodland of an advancing successional stage. Small areas of *Sesleria* occur here, particularly in two hollows that were possible left after extraction. The area of exposed limestone pavement is small, but the broken matrix supports a mix of *Sesleria* and herbaceous plants typical of calcareous habitats.

Two visits were made, with the first during the late afternoon. Conditions were sunny and warm with a light breeze. All suitable grassland and pavement areas were walked during the searches.

The areas previously searched were revisited on a later date. In addition, the private land beyond the summit of Thrang Brow was also searched. Very little suitable habitat can be found here possibly due to excessive sheep grazing, with much of what may be suitable being restricted to the edges of the site and a small patch near a number of scrap vehicles at the rear of the site. It may worthwhile looking for larvae here instead of the adults.

Arnside Knott, Arnside, 22/06/2022, 24/06/2022 (x2 visits on same day)

Arnside Knott is the highest hill in the Arnside and Silverdale AONB, comprised of mix of habitats, with *Sesleria* grassland and extremely steep scree slopes in the upper parts with patchy scrub development. On the north side, extensive Bracken *Pteridium aquilinum* beds dominate, to the south and east, it's scree and to the west down to the coast is extensive woodland.

This site was visited on three separate occasions during suitable conditions over two dates in June. The first visit was to the *Sesleria* slopes above the car park area. Arriving at about 1pm, the temperature was 23°C with a light breeze and no cloud cover. No moths of any species were seen to be flying whilst walking through suitable areas of habitat.

A second visit commenced early afternoon of 24/06/2022 on the scree and *Sesleria* south and east flank of the reserve. Weather conditions were overcast and humid, and an air temperature of 21°C. The area was dominated by *Sesleria*, with some areas of scrub. Toward the top there was a small limestone outcrop/cliff that was herb-rich at the top. One moth was seen that looked to be good for *P. captiuncula*, however, it was not caught and subsequently left unrecorded in this instance. The search was abandoned due to the sudden onset of heavy rain.

A third visit was made to the last area later on the same day during a brief window in the weather. Four individuals were located near the dead twisted Larch at the summit within a 30-minute window from 5:45pm before the wind picked up again and heavy rain set in (Fig. 8b). Conditions were overcast and humid throughout. All were males and flew readily from areas of open *Sesleria* and herb, but also around *Corylus* scrub.

Hutton Roof & Farleton Knott, 14/06/2022, 09/07/2022, 11/07/2022

Farleton Knott is an exposed limestone outcrop connected to Hutton Roof, forming one ecological unit and lies to the east of the Arnside and Silverdale AONB. Conditions were overcast and humid during the first half of the search at Farleton Knott, becoming clear later on. The breeze was moderate throughout as there is no shelter from Morecambe Bay. A total of eight adults were seen, all of which were along the eastern escarpment out of the wind.

The first visit to Hutton Roof was early in the flight period. The main aim was to train recorders to identify the moth in the field in an attempt to generate more records. However, no moths were found during the search. Conditions were cool until lunchtime when the sun came out, but no adults could be found. Conditions were suitable for a number of other species to fly so may have just been early given the altitude.

A second visit was made to the areas of *Sesleria* grassland at Hutton Roof Commons Pavement and Uberash Plain four weeks later. Conditions were full sun and 21°C from early afternoon with a moderated breeze coming from the west. Three adults were located during the search, all of which were at or near the edge of Hazel *Corylus avellena* scrub, two of which were in the shade.

Scout Scar & Cunswick Scar, Kendal, 12/07/2022

Scout Scar and Cunswick Scar are limestone outcrops included in the Morecambe Bay limestone area, situated in south Lakeland, west of Kendal. The undulating topography of Scout Scar is particularly herb rich and is comprised mostly of broken limestone of varying sizes, but mostly within scree range. The *Sesleria* here is comprised of very small patches and almost never dominating. *C. flacca* is widely distributed with some more extensive patch occurring frequently throughout the site. Cunswick Scar is separated from Scout Scar by Underbarrow Road but has a different vegetation structure. The grassland is much more developed, with a taller overall structure, which transitions between mixed, neutral grassland and herb-rich areas to *Sesleria* dominated areas. The *Sesleria* dominance becomes more prominent toward the summit of Cunswick.

The weather during the visit was warm (temperatures around 21°C) and sunny, with a moderate westerly breeze. A single male *P. captiuncula* was disturbed from an area of *Sesleria d*ominated grassland on the western flank of the escarpment at Cunswick mid-afternoon. *C. flacca* was present, but patchy and forbs had a minimal presence, mostly Lady's Bedstraw *Galium verum*.

Whitbarrow Scar, Cumbria, 18/07/2022

Whitbarrow is an expansive limestone prominence at the southern end of the Lakes, Cumbria, which overlooks Morecambe Bay. The site forms part of the Morecambe Bay limestone area and hosts extensive *Sesleria* grasslands on the exposed plateau and woodland surrounding the perimeter of the site. Scrub and bracken are present in patches in what is an extremely exposed site for the most part.

Weather conditions during the survey were extremely hot (29 degrees) and sunny, with a gentle breeze. Very few non-butterfly Lepidoptera were observed during the survey, which may have been in part due to the extreme conditions, however, dozens of Silver-washed Fritillary *Argynnis paphia* patrolled clearings to the east during a brief walk through the woodland. There are recent records of adult *P. captiuncula* from the reserve so the conditions may have just been too hot for them.

Recommendations for future work and habitat management

Sesleria grassland around the Morecambe Bay limestone area is threatened by the loss of traditional management methods and the resulting encroachment of scrub and woodland. Whilst the adults can be found in more heterogenous areas of habitat, scrub encroachment will out-compete the larval foodplant in time. It will be extremely difficult to restore these habitats once scrub is allowed to develop and should currently be considered the main threat to the persistence of *P. captiuncula* in the Morecambe Bay area. Maintaining known sites for *P. captiuncula* will be key to conserving the species, as well as ensuring suitable larval foodplant availability is also maintained at satellite sites without known populations.

As an Endangered species, it is recommended that *P. captiuncula* should be monitored annually at all known sites. However, it has become apparent from this survey that it is an extremely difficult species to locate even during what are thought to be suitable flying conditions. Coupled with the oftentimes tricky terrain this species associates with, it will be a challenge to build an accurate picture of its ecology. The adults are also difficult to identify in the field and should be caught briefly to be certain of the identification. With this in mind, it is suggested that any future monitoring should be carried out by experienced surveyors. It is pertinent that adult surveys are conducted at known sites where they had not been observed during the 2022 searches. Further work is also required to establish whether *P. captiuncula* is present at any other sites within the Morecambe Bay area and additional larval searches are also required to determine if *C. flacca* is being utilised as a larval foodplant. Larval searches may be more effective at sites such as Thrang End, Yealand, where historic adult records exist, but have not been found in recent years.

Similar recommendations apply to the populations in Yorkshire and Northumberland, with the Northumberland sites being prioritised based on the conspicuous lack of modern-day records from the east coast (Randle *et al*., 2019). When considering the differences in the fate of the north-west versus the north-east populations, the pressures experienced by *P. captiuncula* in the east could be appreciably greater there than in the north-west.

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Appendices

Appendix 1. Details of the environmental and vegetation variables recorded at each larval find site.

Site	Instar	Larval foodplant	Altitude (m ASL)	Aspect	Vegetation height (cm)	Cover fern/bracken (%)	Cover forbs (%)	Cover woody (%)	Cover bryo (%)	Cover grass (%)	Bare ground/rock (%)
Crag House Allotment	5	Blue Moor-grass	240	S	8	0	0	0	0	100	0
Crag House Allotment	5	Blue Moor-grass	240	S	5.6	0	0	0	50	50	0
Crag House Allotment	3	Blue Moor-grass	245	S	5.6	0	0	0	15	80	5
Crag House Allotment	3	Blue Moor-grass	250	S	9	0	0	0	0	100	0
Warton Crag LNR	4	Blue Moor-grass	100	S	4.6	0	5	0	5	45	45
Gait Barrows	4	Blue Moor-grass	22	N/A	7.7	0	0	0	10	90	0

Appendix 2. *P. captiuncula* records collected in Yorkshire and Durham during the 2022 recording period.

Taxon	Vernacular	Site	Gridref	VC	Recorder	Date	Quantity	Stage
Photedes captiuncula	Least Minor	Fell Close Sike	SD77497459	64	Justine Patton	26/07/2022	2	Adult
Photedes captiuncula	Least Minor	Fell Close Sike	SD77527441	64	Justine Patton	26/07/2022	1	Adult
Photedes captiuncula	Least Minor	Southerscales NR, Ingleborough	SD74337670	64	Justine Patton	27/07/2022	1	Adult
Photedes captiuncula	Least Minor	Kilnsey	SD96736723	64	Justine Patton	17/07/2022	1	Adult

Photedes captiuncula	Least Minor	Kilnsey, Low Ox Pasture	SD9668	64	Paul Millard	29/07/2022	1	Adult
Photedes captiuncula	Least Minor	Beacon Point	NZ442457	66	Dave Wainwright	30/06/2022	1	Adult

Appendix 3. Adult search details for sites in north Cumbria, Yorkshire and Northumberland, but were not included in the main survey area.

Orton & Asby Scar, Kirkby Stephen, Cumbria, 16/07/2022

Orton Scar and Asby Scar are two connected areas of flat limestone exposed by glacial action. Divided only by drystone walls, the two sites form one ecological unit. The *Sesleria* grassland is extensive from the off, interspersed with some more herb-rich areas. Livestock were present near the road – a mix of sheep and longhorn cattle.

Conditions were sunny and hot (24°C), with a light to moderate breeze. Accessed from the Orton to Appleby Road, 9 km of limestone pavement and grassland were walked, but focussed mainly on the latter as this contains more larval foodplant.

Within the gently undulating topography, there are distinctive transitions between vegetation types. The higher elevations are comprised of *Sesleria* dominated grassland. As Great Asby was approached, the slightly raised and exposed limestone pavement becomes apparent. The pavement here is blocky in nature, but *Sesleria* occurs around the broken matrix at the lower and upper extremes. Within the hollows, Purple moor grass *Molinia caerulea* and a mix of Ericaceous species occur, which are more typical of upland, acid conditions.

No adult *P. captiuncula* were found, but the Nationally Scarce B species, *Elachista adscitella*, was located near the exposed limestone close to *Sesleria*, its larval foodplant.

Smardale Gill, Cumbria, 16/07/2022

There is an area of *Sesleria* on the bank of the Gill as the viaduct is approached, with a smaller quantity located at the limestone quarry and lime kiln on the adjacent bank. Similar weather conditions were observed as the visit was made on the same day as Orton/Asby, but it had become considerably cloudier, with temperatures holding in the mid-20s. Again, *P. captiuncula* were not located, but a number of rare and uncommon moth species were observed. It may be worthwhile carrying out larval searches here as a safer alternative to walking the steep-sided gill.

Malham Tarn and Spiggot Hillside, Malham, West Yorkshire, 13/07/2022

Malham Tarn is situated in the Yorkshire Dales (VC64) and hosts the largest area of open water in the area, which is rare for limestone. Surrounding the tarn are vast limestone mounds carved by glaciers, which have steep, vertical escarpments on the lake side, but gradually slope to the rear. These limestone mounds host *Sesleria* grassland which is populated with a mix of herbaceous plants associated with calcareous grassland.

Spiggot Hill is a small limestone outcrop adjacent to Malham Tarn, accessed at the roadside near the carpark. The grassland is dominated by *Sesleria*, although other grasses do occur in transitional parches, particularly along the lower slopes of the site.

The day was warm and sunny throughout with a moderated breeze from the south west. No adults were located at either site during the visit. Given the nature of the escarpment and the preference of the *Sesleria*, it may prove more productive to conduct a larval search during late-April or early-May.

Kilnsey, West Yorkshire, 17/07/2022

Kilnsey is situated in the upper Wharfedale area of the Yorkshire Dale. The distinctive Kilnsey Crag overhangs at the head of the site, carved out during the last glacial maxima. Surrounding the crag are steep slopes to the sides, with screes and, herb-rich grassland and *Sesleria* dominated grassland. An abandoned quarry sits the rear of Kilnsey Crag.

The weather during the visit was hot (25°C) and sunny, with a gentle to moderate breeze. Just a single female *P. captiuncula* was located at 2:50pm on the slope of Cool Scar. A number of other moth species with restricted distributions that are associated with the limestone habitat were also found during the visit.

High Brae and Selside, Horton-in-Ribblesdale, 26/07/2022

A loop around the southern flank of Ingleborough on the Horton-in-Ribblesdale side was walked in warm sun and light winds during the afternoon, covering over 8 km in total. Initially, Brae Pasture was searched, particularly along the limestone escarpment and the banks of a small ravine below the farm house adjacent the Yorkshire Wildlife Trust Reserve. These areas were particularly herb-rich with *S. caerulea* and *C. flacca* both present but transitioned to upland hay meadow toward the top boundary wall.

Access to Crooke Lane along the Pennine Way was initially blocked by young bullocks grazing the limestone grassland directly in front of the gate. Instead, a direct route up through to the shelf of exposed limestone pavement called Fell Sike Close. This area of pavement is fenced off to restrict access to grazing livestock, which appeared to be predominantly by sheep. The pavement here was extremely dangerous, with loose clints and deep grikes, oftentimes covered with a superficial layer of vegetation. This should be kept in mind for any potential future visits, particularly when working alone. The vegetation was a combination of species associated with drier calcareous grasslands, including *S. caerulea* and *C. flacca* and upland pasture with Angelica, Melancholy Thistle and Greater Burnet being particularly abundant. Scrub was also plentiful, but not dominant. Three adult *P. captiuncula* were located here between 2pm and 2:30pm (two males and one female), all of which were caught (see Fig. 9b). Two additional sightings were made here but were not documented as they could not be caught.

The pavement and grassland above Fell Sike Close was Sheep grazed. The vegetation was closely grazed, even within the pavement matrix and Marsh Thistle *Cirsium palustre* were abundant. Only *Agriphila straminella* were observed here.

Circling back along Crooke Lane, the grassland transitioned again, with *S. caerulea* and *C. flacca* being abundant on the slopes running along the path. A good herb and grass ratio was observed on the route back, but *P. captiuncula* was not picked up.

Southerscales NR, Ingleborough, 27/07/2022

Southerscales is an area of limestone pavement located high up the side of Ingleborough. The fields below the reserve are intensively sheep grazed, whilst Southerscales, is cattle grazed . A small number of Belted Galloway looked to been recently put on to browse. *S. caerulea* and *C. flacca* are abundant on the grassland slopes up to the pavement and also occur within the pavement matrix.

On the limestone pavement, there were small grassy islands containing a mix of *Sesleria* and *Carex*, but also Purple Moor-grass *Molinia caerulea* and Bilberry *Vaccinium myrtillus* and a range of herbaceous plants but had a definite upland feel. A single male was located on the limestone pavement at 2:20pm. It was disturbed from the base of Wild Angelica *Angelica sylvestris* but was not seen to be nectaring and landed a short distance away in the grass where it was potted and photographed.

No other *P. captiuncula* were found during the remainder of the search, but a number of other notable moth species for the area were observed during the visit.

Colt Park, Ribblehead, 29/07/2022

Colt Park forms part of the Ingleborough National Nature Reserve. Woodland has developed on much of the pavement and much of the grassland is either sheep grazed or hay meadow. However, there is a section of pavement beyond the Natural England offices that supports vegetation similar to sites in the area where *P. captiuncula* have been located historically. This area extends toward Ribblehead. Weather conditions were sunny and humid, but thundery rain developed after a couple of hours so the search was abandoned.

Thrislington NNR and Beacon Point, Durham, 18/06/2022, 07/07/2022 & 30/06/2022 (per Dave Wainwright)

Thrislington NNR was surveyed in afternoon with search duration approx. 2 hours each time. Last record from 2012. Thrislington NNR supports a substantial amount of *S. caerulea* and *C. flacca*, all those surveys were 20°C or more and sunny conditions throughout. Winter pony grazing is the current management there with limited control of small scrub.

The only success was met at Beacon Point (most recent record from 1986). Search duration was 1.5 hours, involving myself and 5 volunteers. It was 17°C with a strong breeze during the search and had been really sunny earlier in the day but recorded the sun as being out 30% of the time when *P. captiuncula* was observed.

Much of the coast south of there was also covered, where *C. flacca* was widespread and abundant and *S. caerulea* present also, albeit more localised. The grasslands are both species rich and ungrazed. I also surveyed a couple more stretches of the coast to the south of this, no previous records but habitat potentially suitable, but proved unsuccessful.

Appendix 4. Moth records collected whilst surveying for adult *P. captiuncula* across the Morecambe Bay limestone area.

Taxon	Vernacular	Site	Gridref	VC	Recorder	Date
Anania funebris	White-spotted Sable	Gait Barrows, Silverdale	SD483775	60	Patton, Justine	09/06/2022
Cabera exanthemata	Common Wave	Gait Barrows, Silverdale	SD483775	60	Patton, Justine	09/06/2022
Celypha lacunana	Common Marble	Gait Barrows, Silverdale	SD483775	60	Patton, Justine	09/06/2022
Coleophora fuscocuprella	Hazel Case-bearer	Gait Barrows, Silverdale	SD483775	60	Patton, Justine	09/06/2022
Crambus lathoniellus	Hook-streak Grass-veneer	Gait Barrows, Silverdale	SD483775	60	Patton, Justine	09/06/2022
Micropterix calthella	Plain Gold	Gait Barrows, Silverdale	SD483775	60	Patton, Justine	09/06/2022
Petrophora chlorosata	Brown Silver-line	Gait Barrows, Silverdale	SD483775	60	Patton, Justine	09/06/2022
Pyrausta cingulata	Silver-barred Sable	Gait Barrows, Silverdale	SD483775	60	Patton, Justine	09/06/2022
Chrysoteuchia culmella	Garden Grass-veneer	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Chrysoteuchia culmella	Garden Grass-veneer	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Crambus ericella	Heath Grass-veneer	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022

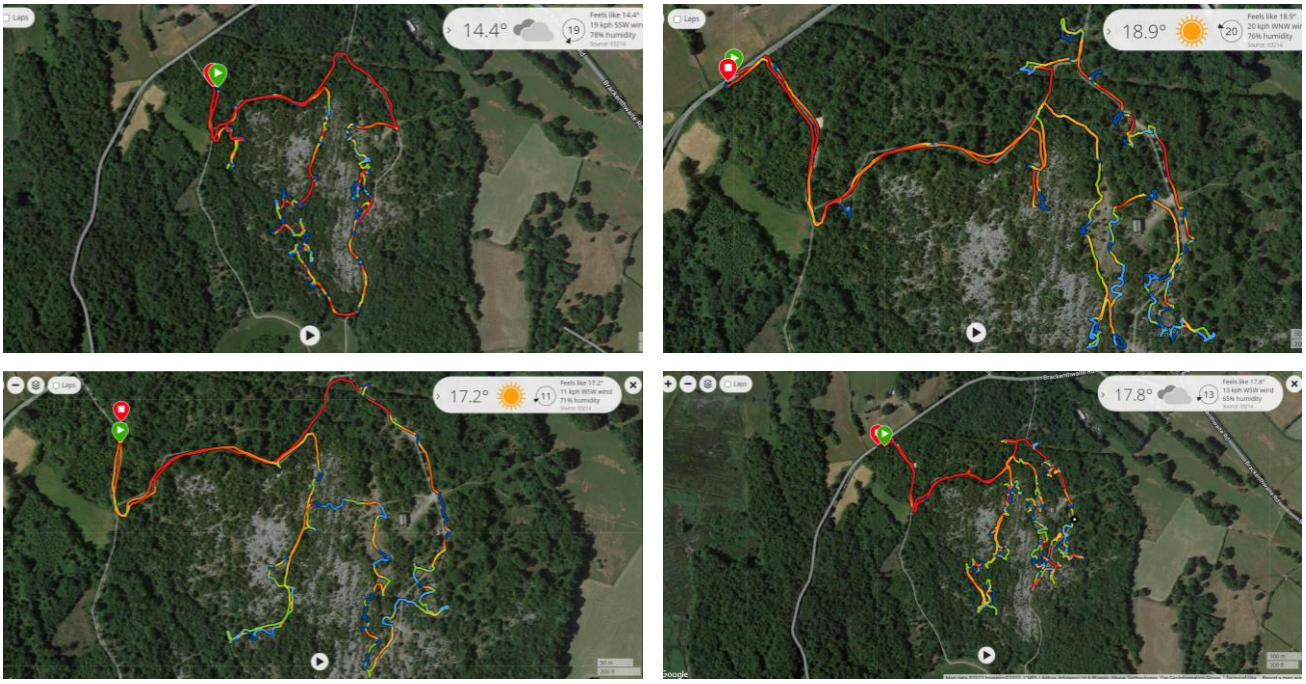
Crambus ericella	Heath Grass-veneer	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Crambus lathoniellus	Hook-streak Grass-veneer	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Crambus lathoniellus	Hook-streak Grass-veneer	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Euclidia mi	Mother Shipton	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Euclidia mi	Mother Shipton	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Tyria jacobaeae	Cinnabar	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Tyria jacobaeae	Cinnabar	Hutton Roof, Crag House Allotment	SD555769	60	Patton, Justine	14/06/2022
Celypha lacunana	Common Marble	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Crambus ericella	Heath Grass-veneer	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Epirrhoe alternata	Common Carpet	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Euclidia mi	Mother Shipton	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Euthrix potatoria	Drinker	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Petrophora chlorosata	Brown Silver-line	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Pyrausta aurata	Small Purple & Gold	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Pyrausta cingulata	Silver-barred Sable	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Tyria jacobaeae	Cinnabar	Hutton Roof, Uberash Plain	SD5578	69	Patton, Justine	14/06/2022
Abrostola triplasia	Dark Spectacle	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Agapeta hamana	Common Yellow Conch	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Agapeta hamana	Common Yellow Conch	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Agapeta hamana	Common Yellow Conch	Gait Barrows, Silverdale	SD4972	60	Patton, Justine	16/06/2022
Agrotis exclamationis	Heart & Dart	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Alcis repandata	Mottled Beauty	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Alcis repandata	Mottled Beauty	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Anania funebris	White-spotted Sable	Gait Barrows, Silverdale	SD4972	60	Patton, Justine	16/06/2022
Apamea epomidion	Clouded Brindle	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Apamea monoglypha	Dark Arches	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Apamea monoglypha	Dark Arches	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Aphomia sociella	Bee Moth	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Aplocera plagiata	Treble-bar	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022

Atolmis rubricollis	Red-necked Footman	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Biston betularia	Peppered Moth	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Calliteara pudibunda	Pale Tussock	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Capua vulgana	Common Twist	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Charanyca trigrammica	Treble Lines	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Chrysoteuchia culmella	Garden Grass-veneer	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Chrysoteuchia culmella	Garden Grass-veneer	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Chrysoteuchia culmella	Garden Grass-veneer	Gait Barrows, Silverdale	SD4972	60	Patton, Justine	16/06/2022
Colostygia pectinataria	Green Carpet	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Crambus lathoniellus	Hook-streak Grass-veneer	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Crambus lathoniellus	Hook-streak Grass-veneer	Gait Barrows, Silverdale	SD4972	60	Patton, Justine	16/06/2022
Craniophora ligustri	Coronet	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Deilephila elpenor	Elephant Hawk-moth	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Ditula angustiorana	Red-barred Tortrix	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Drepana falcataria	Pebble Hook-tip	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Dysstroma truncata	Common Marbled Carpet	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Elachista adscitella	Oblique-barred Dwarf	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Euplexia lucipara	Small Angle Shades	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Hellinsia tephradactyla	Plain Plume	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Herminia grisealis	Small Fan-foot	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Korscheltellus fusconebulosa	Map-winged Swift	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Macaria liturata	Tawny-barred Angle	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Monochroa cytisella	Bracken Neb	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Noctua pronuba	Large Yellow Underwing	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Noctua pronuba	Large Yellow Underwing	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Ochropacha duplaris	Common Lutestring	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Oligia strigilis agg.	Marbled Minor agg.	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Opisthograptis luteolata	Brimstone Moth	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Petrophora chlorosata	Brown Silver-line	Gait Barrows, Silverdale	SD4972	60	Patton, Justine	16/06/2022
Phalera bucephala	Buff-tip	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Pheosia gnoma	Lesser Swallow Prominent	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022

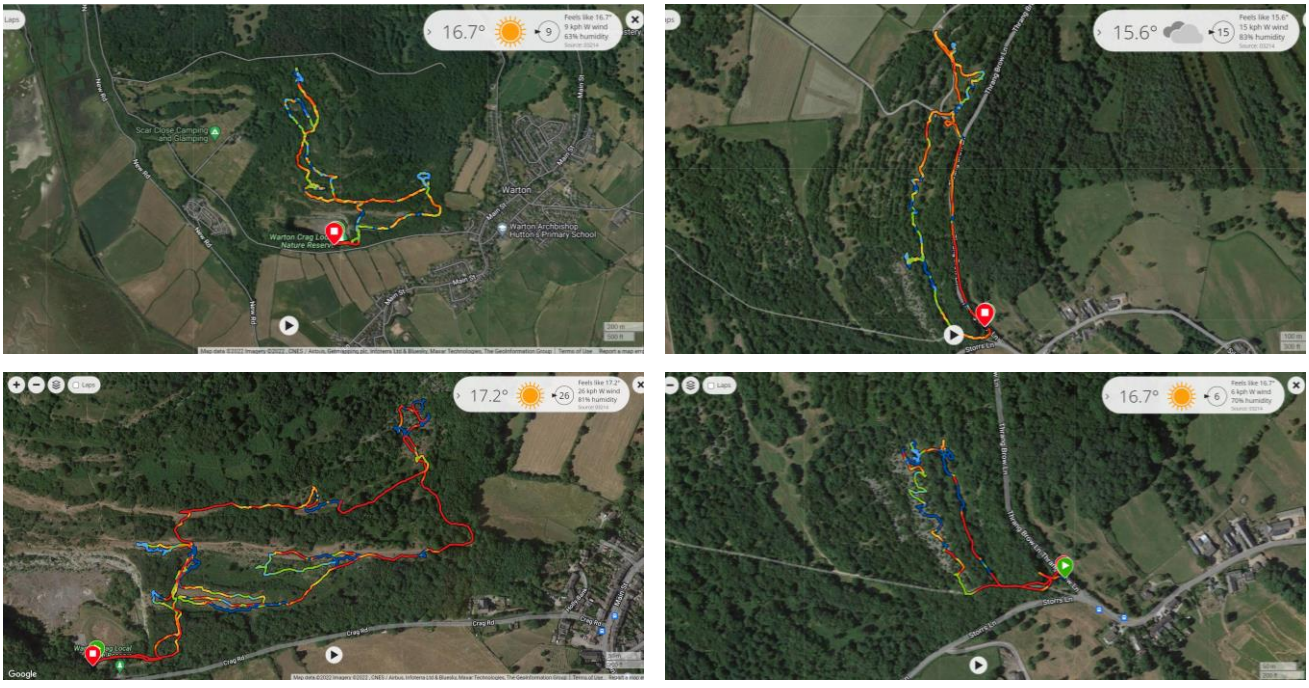
Phycitodes binaevella	Ermine Knot-horn	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Polia nebulosa	Grey Arches	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Pseudoips prasinana	Green Silver-lines	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Rusina ferruginea	Brown Rustic	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Rusina ferruginea	Brown Rustic	Gait Barrows, Silverdale	SD48187748	60	Patton, Justine	16/06/2022
Scoparia subfusca	Large Grey	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Thera britannica	Spruce Carpet	Gait Barrows, Silverdale	SD48297734	60	Patton, Justine	16/06/2022
Scythris fallacella	Bronze Owlet	Warton Crag LNR	SD4972	60	Patton, Justine	17/06/2022
Micropterix aruncella	White-barred Gold	Hutton Roof, Cumbria	SD555774	69	Patton, Justine	20/06/2022
Chrysoteuchia culmella	Garden Grass-veneer	Warton Crag RSPB	SD490726	60	Patton, Justine	20/06/2022
Crambus perlella	Satin Grass-veneer	Warton Crag RSPB	SD490726	60	Patton, Justine	20/06/2022
Eupithecia vulgata	Common Pug	Warton Crag RSPB	SD490726	60	Patton, Justine	20/06/2022
Odezia atrata	Chimney Sweep	Warton Crag RSPB	SD490726	60	Patton, Justine	20/06/2022
Petrophora chlorosata	Brown Silver-line	Warton Crag RSPB	SD490726	60	Patton, Justine	20/06/2022
Scythris fallacella	Bronze Owlet	Warton Crag RSPB	SD490726	60	Patton, Justine	20/06/2022
Tyria jacobaeae	Cinnabar	Warton Crag RSPB	SD490726	60	Patton, Justine	20/06/2022
Chrysoteuchia culmella	Garden Grass-veneer	Heald Brow, Silverdale	SD468741	60	Patton, Justine	21/06/2022
Crambus perlella	Satin Grass-veneer	Heald Brow, Silverdale	SD468741	60	Patton, Justine	21/06/2022
Tyria jacobaeae	Cinnabar	Heald Brow, Silverdale	SD468741	60	Patton, Justine	21/06/2022
Syncopacma taeniolella	Silver-barred Sober	Arnside Knott	SD45477754	69	Patton, Justine	24/06/2022
Catoptria pinella	Pearl-grass Veneer	Thrang End, Yealand	SD49177616	60	Patton, Justine	29/06/2022
Macroglossum stellatarum	Humming-bird Hawk-moth	Thrang End, Yealand	SD49177616	60	Patton, Justine	29/06/2022
Celypha lacunana	Common Marble	Thrang End, Yealand	SD49317664	60	Patton, Justine	08/07/2022
Parornix devoniella	Hazel Slender	Thrang End, Yealand	SD49317664	60	Patton, Justine	08/07/2022
Phyllonorycter coryli	Nut Leaf Blister Moth	Thrang End, Yealand	SD49317664	60	Patton, Justine	08/07/2022
Pyrausta despicata	Straw-barred Pearl	Thrang End, Yealand	SD49317664	60	Patton, Justine	08/07/2022
Celypha lacunana	Common Marble	Ploverlands, Hutton Roof	SD5581	69	Patton, Justine	09/07/2022
Chrysoteuchia culmella	Garden Grass-veneer	Ploverlands, Hutton Roof	SD5579	69	Patton, Justine	09/07/2022
Crambus ericella	Heath Grass-veneer	Ploverlands, Hutton Roof	SD5582	69	Patton, Justine	09/07/2022
Epirrhoe alternata	Common Carpet	Ploverlands, Hutton Roof	SD5583	69	Patton, Justine	09/07/2022
Merrifieldia leucodactyla	Thyme Plume	Ploverlands, Hutton Roof	SD5578	69	Patton, Justine	09/07/2022
Zygaena filipendulae	Six-spot Burnet	Ploverlands, Hutton Roof	SD5580	69	Patton, Justine	09/07/2022

Agriphila straminella	Straw Grass-veneer	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Autographa gamma	Silver Y	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Camptogramma bilineata	Yellow Shell	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Chrysoteuchia culmella	Garden Grass-veneer	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Eupithecia centaureata	Lime-speck Pug	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Noctua pronuba	Large Yellow Underwing	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Pyrausta cingulata	Silver-barred Sable	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Pyrausta despicata	Straw-barred Pearl	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Scoparia pyralella	Meadow Grey	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Scotopteryx luridata	July Belle	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Zelotherses paleana	Timothy Tortrix	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Zygaena filipendulae	Six-spot Burnet	Farleton Knott	SD5480	69	Patton, Justine	11/07/2022
Agriphila straminella	Straw Grass-veneer	Scout Scar, Underbarrow	SD489912	69	Patton, Justine	12/07/2022
Chrysoteuchia culmella	Garden Grass-veneer	Scout Scar, Underbarrow	SD489912	69	Patton, Justine	12/07/2022
Merrifieldia leucodactyla	Thyme Plume	Scout Scar, Underbarrow	SD489912	69	Patton, Justine	12/07/2022
Pyrausta cingulata	Silver-barred Sable	Scout Scar, Underbarrow	SD489912	69	Patton, Justine	12/07/2022
Pyrausta despicata	Straw-barred Pearl	Scout Scar, Underbarrow	SD489912	69	Patton, Justine	12/07/2022
Pyrausta ostrinalis	Scarce Purple & Gold	Scout Scar, Underbarrow	SD489912	69	Patton, Justine	12/07/2022
Agriphila straminella	Straw Grass-veneer	Ploverlands, Hutton Roof	SD55897722	69	Patton, Justine	14/07/2022
Agriphila tristella	Common Grass-veneer	Ploverlands, Hutton Roof	SD55897722	69	Patton, Justine	14/07/2022
Merrifieldia leucodactyla	Thyme Plume	Ploverlands, Hutton Roof	SD55897722	69	Patton, Justine	14/07/2022
Pyrausta cingulata	Silver-barred Sable	Ploverlands, Hutton Roof	SD55897722	69	Patton, Justine	14/07/2022
Acleris aspersana	Ginger Button	Ploverlands, Hutton Roof	SD556773	69	Patton, Justine	17/07/2022
Agriphila straminella	Straw Grass-veneer	Ploverlands, Hutton Roof	SD556773	69	Patton, Justine	17/07/2022
Agriphila straminella	Straw Grass-veneer	Whitbarrow	SD4586	69	Patton, Justine	18/07/2022
Charissa obscurata	Annulet	Whitbarrow	SD4586	69	Patton, Justine	18/07/2022
Chrysoteuchia culmella	Garden Grass-veneer	Whitbarrow	SD4586	69	Patton, Justine	18/07/2022
Hydriomena furcata	July Highflyer	Whitbarrow	SD4586	69	Patton, Justine	18/07/2022
Pyrausta cingulata	Silver-barred Sable	Whitbarrow	SD4586	69	Patton, Justine	18/07/2022
Pyrausta despicata	Straw-barred Pearl	Whitbarrow	SD4586	69	Patton, Justine	18/07/2022
Scoparia ambigualis	Common Grey	Whitbarrow	SD4586	69	Patton, Justine	18/07/2022

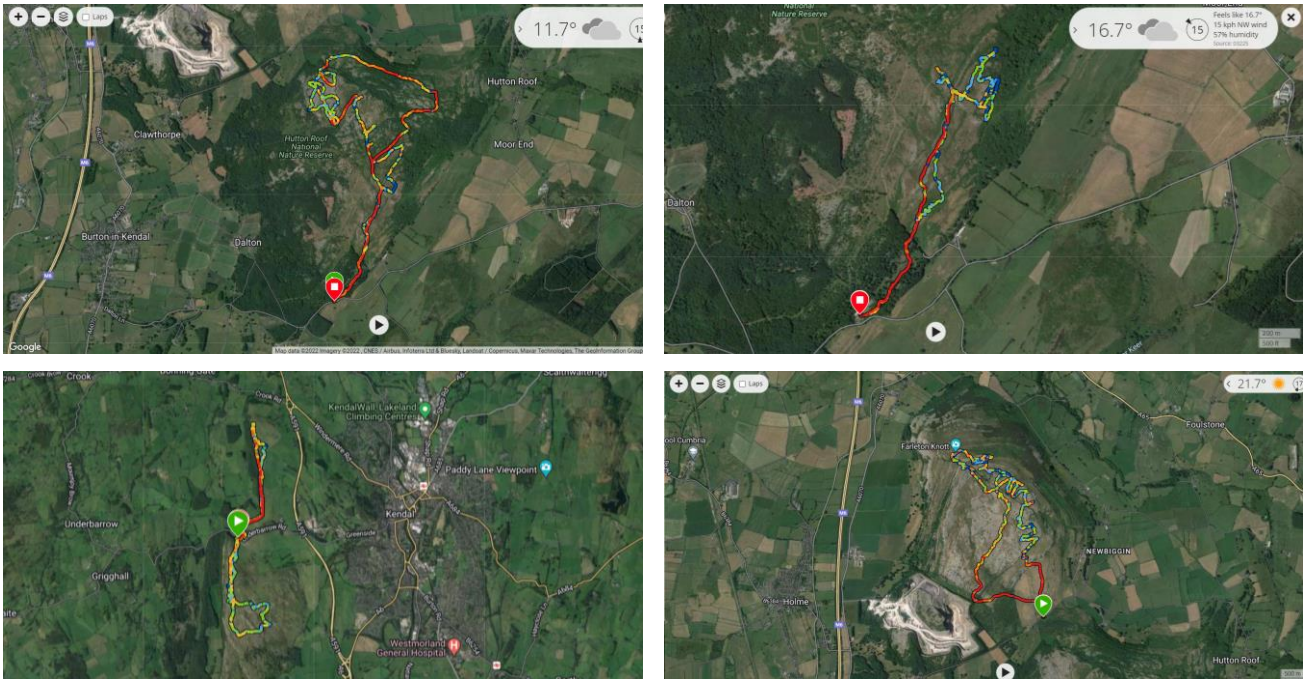
Appendix 5. Adult search walking routes recorded using a Garmin Forerunner 935 © for each of the four visits to Gait Barrows.



Appendix 6. Adult search walking routes recorded using a Garmin Forerunner 935 © for the two visits to Warton Crag (left) and Thrang End (right).



Appendix 7. Adult search walking routes recorded using a Garmin Forerunner 935 © for the two visits to Hutton Roof (top), Farleton Knott (bottom right) and Scout Scar and Cunswick Scar (bottom left).



Appendix 8. Adult search walking routes recorded using a Garmin Forerunner 935 © for the three visits to Arnside Knott and Heald Brow (bottom right).