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EARLY DISPERSION AND COLONY FORMATION OF THE LARGE HEATH BUTTERFLY *COENONYMPHA TULLIA SSP. DAVUS* FOLLOWING A SPECIES REINTRODUCTION ONTO CHAT MOSS, MANCHESTER, UK

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ABSTRACT

Coenonympha tullia ssp. davus (F.), a specialist peatland butterfly characteristic of the northwest of England, is threatened by habitat loss resulting in numerous extirpations. A species reintroduction onto Chat Moss, Manchester, UK took place in May-June 2020. Dispersion during the first two flight seasons of the programme was monitored using GPS combined with distance-bearing estimates, producing fine grain maps of butterfly micro-distribution. The release population formed a colony across a well-defined habitat patch, within 50m of the release point, with gradual dispersion extending the overall range over the course of two flight seasons.

Keywords: Large heath butterfly; *Coenonympha tullia*; species reintroduction; peatland; lowland raised bog; colonial butterfly; dispersion; butterfly tracking; GPS; distance-bearing; movement ecology.

INTRODUCTION

Coenonympha tullia ssp. davus (F.), a specialist butterfly of lowland raised bog in the northwest of England, is the most threatened of the UK large heath butterfly subspecies (Bourn & Warren, 1997) due to habitat destruction, with only 1.3% of lowland raised bog in England remaining in good condition (Maddock, 2008).

C. tullia was first described in Britain on the Manchester Mosslands, most likely in the Chat Moss area (Lewin, 1795:50). Historical accounts of Chat Moss (Defoe, 1724-1727) describe 35 square miles of impenetrable mire, which has now been almost completely drained and converted to farmland, industry, or urban development, resulting in extirpation of the *C. tullia* population. However, there are remaining peatland fragments, forming a network of nature reserves in various stages of a multi-decade process of ecosystem restoration (Osborne *et al.*, 2021).

Detailed habitat assessment on several of these reserves was undertaken (Osborne *et al.*, 2022) prior to the species reintroduction - an area on Astley Moss nature reserve (SSSI) (53.475, -2.457), was deemed the most suitable.

The reintroduction site's micro-topography consists of alternating troughs and ridges, relating to previous peat cutting, visible in the LIDAR (Laser Imaging, Distance And Ranging) elevations in Figure 1. The wet troughs ("Cotton-grass Beds") (Figs 2,3,4 & 6) contain a dense cover of hare's-tail cotton-sedge *Eriophorum vaginatum* tussocks, the larval foodplant (Melling, 1987; Dennis & Eales, 1999), and overwintering habitat niche (Joy & Pullin, 1997; Joy & Pullin, 1999). *Sphagnum* moss hummocks are abundant, with common cotton-sedge *Eriophorum angustifolium* in shallow pools. The inhospitable drier ridges are dominated by purple moor-grass *Molinia caerulea*. Cross-leaved heath *Erica tetralix*, the main adult nectar resource (Dennis & Eales, 1997; Wainwright, 2005), had been introduced into the area over the previous three years in preparation for the *C. tullia* reintroduction and was in various stages of maturity at the time of the reintroduction, many plants not yet flowering, although there were also clumps of established *E. tetralix* with abundant inflorescences.

The Chat Moss *C. tullia* species reintroduction (Weston, 2020; GM Wetlands, accessed 28.xii.2021) was modelled on a previous successful reintroduction conducted by Lancashire Wildlife Trust (LWT) and Chester Zoo in 2013 (BIAZA, 2017). Mature pupae were transported to Astley Moss and kept in a mesh tent enclosure, sited within the release area. The pupae were checked twice daily for emergence, and newly emerged adult butterflies released outside the tent. During the first phase of the programme, approximately 60 *C. tullia* adults were released between 26 May 2020 and 20 June 2020.

It was initially assumed that the released butterflies would randomly disperse across the reserve and effectively disappear until, optimistically, they completed a lifecycle, and a larger number of adults took flight in 2021. However, within a few days it was noted that significant numbers of *C. tullia* were flying over the patch of confluent *E. vaginatum* tussocks and *E. tetralix* surrounding the release tent, with occasional sightings 50-80m distant. A survey protocol was rapidly devised to quantify early butterfly dispersion. The research aims were;

1. To quantify the dispersal range of the reintroduction population.
2. To quantify the extent of any colonial behaviour.

METHOD

A 960m transect (Fig. 1) was devised, in order to walk the tough *Molinia* tussock along the edges of the Cotton-grass Beds – this yielded reasonably even sampling of the survey area. A 180° ark in front of a slowly walking observer was viewed and the position of *C. tullia* sightings accurately determined using GPS (Breed & Severns, 2015; Fernández *et al.*, 2016). Flights paths and rest points were recorded by tracking flights using a Bad Elf BE-GPS-1008 GPS receiver linked to a

GPS recording app on iPhone (Stichling, 2020). Weather permitting, the transect was walked on a daily basis during the warmest part of the afternoon, from 29 May until 20 June 2020.

To avoid damage to the newly released butterflies, they were not netted or marked. A distance of greater than two metres from the subject was maintained because the butterflies appeared to react to observer proximity either by moving away or dropping into the vegetation.

Due to logistical constraints, there was no second release in 2021, giving an ideal opportunity to continue to measure ongoing dispersion during a second flight season. A longer monitoring transect of 2237m was devised (Fig. 3), in order to walk the edges of the Cotton-grass Beds across a wider area of the nature reserve. Butterflies in flight were first noted on 13 June 2021 and the transect walked daily until 30 June 2021. GPS coordinates of sightings were recorded using a Bad Elf Surveyor GPS receiver (providing 1m accuracy and improved battery life) linked to a recording app on iPhone (Imperial College London, 2019). In order to minimize environmental damage, a distance-bearing protocol (Růžičková & Elek, 2021) was used in conjunction with GPS coordinates. Accurate 'position fixes' were combined with position estimates derived from flight distances and directions, when the flight crossed vulnerable or inaccessible areas where it was not possible to track the flight directly. The site had received significant attention from project personnel and visitors during the 2020 flight season, resulting in trampling of the Cotton-grass Beds and the thin covering of *Sphagnum* moss – this necessitated a modification in protocol to strictly protect vulnerable areas of the reserve (a SSSI).

During the 2020 flight season the area immediately adjacent to the release tent contained a large number of sightings. This could have reflected the release of butterflies from the tent immediately before walking the survey transect, rather than butterfly dispersal and subsequent position fixes. Additionally, the configuration of the Cotton-grass Beds resulted in loops of the transect becoming congested in the release tent area, potentially resulting in double counting of butterflies crossing the transect. To control for these issues a rectangular buffer zone surrounding the release tent, measuring 10% of the north-south and east-west extent of the 2020 dispersal range, was defined and these sightings eliminated from subsequent analysis.

The data were collated into a single .csv file, recording latitude/longitude coordinates for the start and end of each flight and rests/breaks in flight ("Flight Points"). Date, 2020/2021 flight season, the day number during each flight season ("Flight Season Day") and the total number of flight days since the first butterfly release ("Total Flight Days") were also recorded.

The data were imported into Quantum GIS mapping software (QGIS) version 3.16.14 (QGIS Development Team, 2020) to generate maps demonstrating the distribution of Flight Points and convex hulls of the dispersal range during the 2020 and 2021 flight seasons. A heatmap was also generated to demonstrate maximum density of Flight Points in relation to the release tent and Cotton-grass Beds - the map was manually adjusted to exclude aggregations of less than five Flight Points.

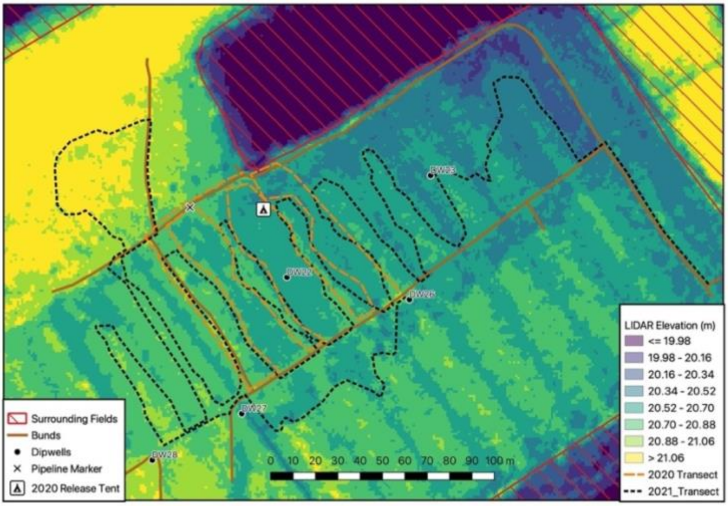

Fig. 1. Site plan of the release area of Astley Moss nature reserve generated in QGIS. The micro-topography (Environment Agency open access 2019 LIDAR data) shows an arrangement of ridges and shallow troughs (18-36 cm height difference) running northwest to southeast across the release area. Low peat dams (bunds) and other points of reference are marked. The 2020 transect was centred on the largest Cotton-grass Bed between the release tent and dip well 22 (dip wells are plastic pipes installed in the peat for water table monitoring) (Fig. 2A). The 2021 transect extended widely into other potentially suitable habitat patches.

Statistical analysis was performed in R version 4.0.4 (R Core Team, 2021) using R Studio version 1.4.1106 (RStudio Team, 2021). The Euclidean distance of Flight Points from the release tent ("Dispersal Distance") was calculated using the 'pointDistance' function in the raster package (Hijmans *et al.*, 2015). The difference between the 2020 and 2021 distributions of Dispersal Distances was tested using the Wilcoxon test. Linear regression models were constructed to test the hypotheses that the Flight Season Day of each flight season predicted Dispersal Distance, and that the Total Flight Days over two flight seasons predicted Dispersal Distance.

Fig. 2. June 2020, (A) Looking northwest along the largest Cotton-grass Bed towards dip well 22 and the release tent. *Eriophorum vaginatum* bog cotton is visible, with *Erica tetralix* inflorescences in the foreground; (B) newly emerged *Coenonympha tullia* adult; (C) *C. tullia* released onto an *Erica tetralix* stem, the butterfly is agile and climbs well amongst ground vegetation; June 2021, (D) A new generation of *C. tullia,* well camouflaged whilst resting on *Molinia caerulea*. ©: A. Osborne.

RESULTS

Eighty-six flights were included in the analysis of 2020 data (Fig. 3) and forty-two flights in the analysis of 2021 data (Fig. 4). Sightings were generally sporadic. However, there were concentrated sightings over the largest Cotton-grass Bed during the first three weeks of the 2020 flight season (when most of the butterflies were being released), and on the first day of the 2021 flight season, when fourteen *C. tullia* were seen flying in the area between the release tent and dip well 22 (Figures 3 and 4).

During both flight seasons, most of the Flight Points occurred in the central section of the transect with few detections peripherally - a hypothetical version of each transect, shortened by 50% and covering the central area of the dispersal range, would have allowed detection of significantly more Flight Points than the peripheral 50% of the transect; 114 out of 123 (93%) 2020 Flight Points (χ^2=52.73, DF=1, p<0.001), and 88 out of 94 (94%) 2021 Flight Points (χ^2=42.04, DF=1, p<0.001). Hence the transects covered sufficient area to reliably detect *C. tullia* presence and define the limits of the dispersal range.

Isolated sightings of *C. tullia* were made, at approximately 200m from the release tent (verbal report Mark Champion, LWT) and 600m (verbal report Mike Longden, LWT).

During both flight seasons a distinct range was established. The 2020 dispersal polygon (Fig. 3) covered an area of 4468m^2, with a maximum Dispersal Distance of 69.8m. The 2021 dispersal polygon (Fig. 4) covered a larger area of 9229m^2, with a maximum Dispersal Distance of 117.6m. The distribution of Dispersal Distances between 2020 and 2021 was significantly different (W=2612, p<0.001).

Linear regression models of Dispersal Distance (Fig. 5) showed that the number of the Flight Season Day during the 2020 season significantly predicted Dispersal Distance (F: 7.35 on 1 and 121 DF, Adj R^2 0.05, p=0.008) and the number of the Flight Season Day during the 2021 season significantly predicted Dispersal Distance (F: 9.44 on 1 and 93 DF, Adj R^2 0.08, p=0.003). Overall, the number of Total Flight Days since first release significantly predicted Dispersal Distance (F: 86.11 on 1 and 216 DF, Adj R^2 0.28, p<0.001).

The heatmap (Fig. 6) showed a ‘home range’ aggregation of Flight Points predominantly coinciding with the largest Cotton-grass Bed.

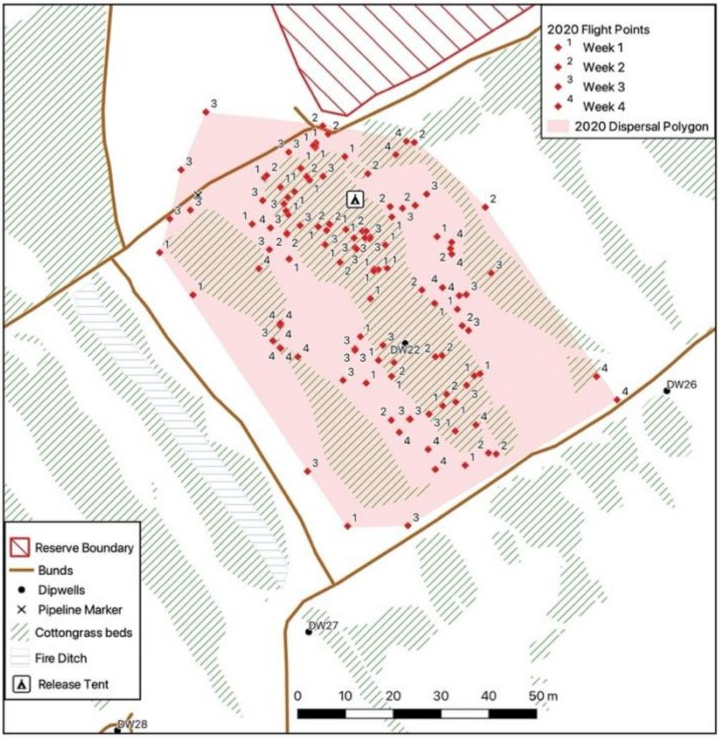

Fig. 3. *Coenonympha tullia* Flight Points during the 2020 flight season. Points are numbered according to the calendar week (Monday – Sunday) of the flight season. Activity is initially concentrated around the release tent and over the largest Cotton-grass Bed (Figure 2A). The range gradually expands, with Flight Points in weeks 3 and 4 more numerous near the edges of the dispersal polygon and less frequent in the central area.

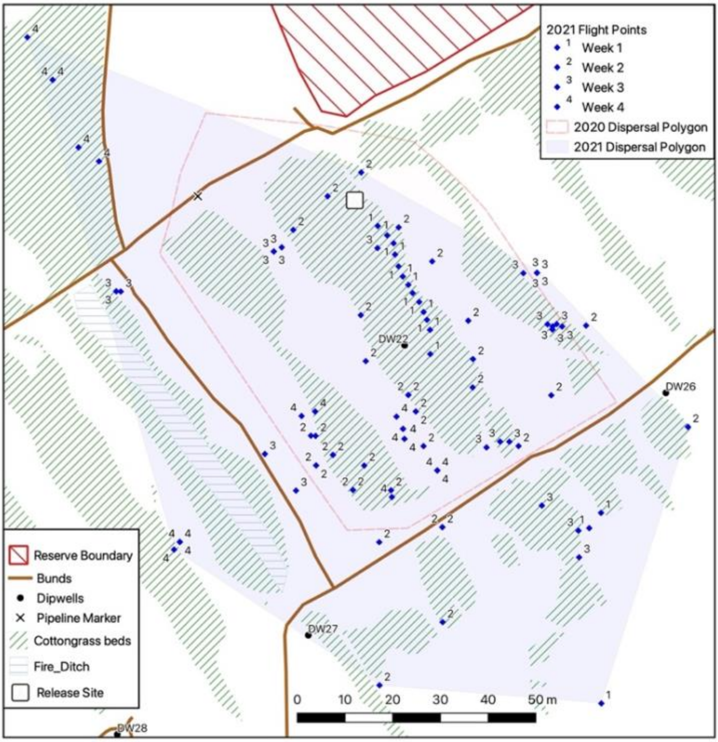

Fig. 4. *Coenonympha tullia* Flight Points during the 2021 flight season. Points are numbered according to calendar week (Monday – Sunday) of the flight season. Initially activity is concentrated between the 2020 release site and dip well 22, over the largest Cotton-grass Bed. The range expands more rapidly than in 2020, with the eventual dispersal polygon and distribution of Dispersal Distances being significantly greater than in 2020.

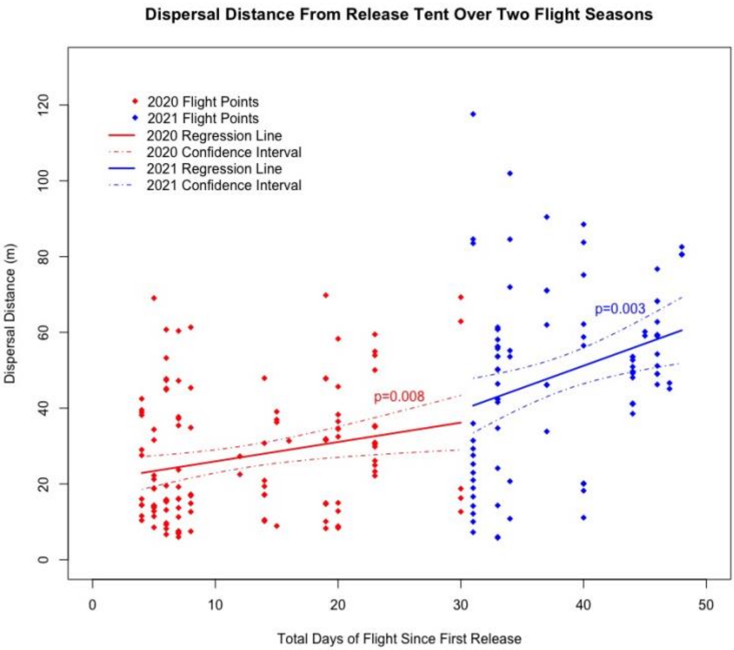

Fig. 5. Plot of *Coenonympha tullia* Dispersal Distance against Total Flight Days since the first release. There is an aggregation of flight points in the first week of the release at Dispersal Distance 5-20 m, when the rate of butterfly emergence and release near the tent is maximal. The linear regression lines demonstrate the significant increases in Dispersal Distance during the 2020 and 2021 flight seasons.

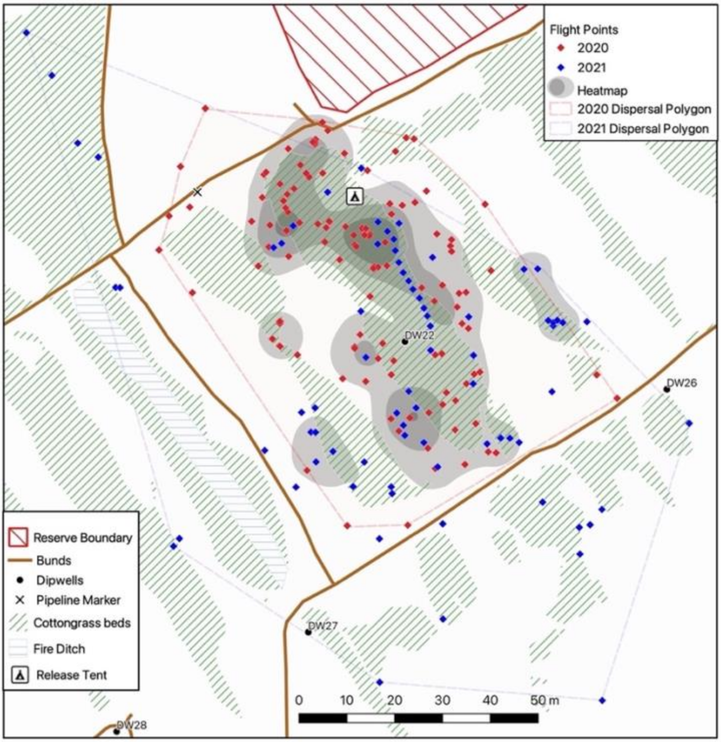

Fig. 6. Heatmap showing aggregations of five or more Flight Points generated from 2020-21 *Coenonympha tullia* Flight Point data. Although there is a gradual, but statistically significant, overall range expansion during the two flight seasons, *C. tullia* activity is concentrated over the largest Cotton-grass Bed, the most abundant patch of suitable habitat within the release area.

DISCUSSION

The observation of numerous *C. tullia* flying on 13 June 2021 (Fig. 2D) confirmed the initial success of the Chat Moss species reintroduction. The 2021 flight season arrived two-three weeks later than anticipated, likely because of a cool spring, and an unusually cold May with an average local temperature anomaly of approximately -2°C (MetOffice, 2021).

Our data show that the *C. tullia* reintroduction population behaved colonially, maintaining a small home range across a patch of optimal habitat, while gradually dispersing and increasing their overall range, which concurs with previous descriptions of *C. tullia* mobility (Wainwright, 2005; Wainwright & Ellis, accessed 29.xii.2021). There were isolated observations of individuals dispersing widely from their home range, across a largely inhospitable landscape, the furthest at 600m, which is comparable with previous observations of *C. tullia*'s dispersal limit (Melling 1984, Wainwright 2005). Similarly changing movement patterns, within and between habitat patches, have been described in other butterfly species (Schultz, 1998; Schtickzelle *et al.*, 2007).

Colonial behaviour is observed in about 80% of butterfly species, notably if there is a specialist larval foodplant and habitat niche (Thomas, 2016), as is the case for *C. tullia.* Beyond the scope of this paper, spatial statistical analysis relating detailed environmental and habitat resource data to the micro-distribution of Flight Points may help to explain *C. tullia* habitat use and the observed pattern of *C. tullia* dispersal and aggregation. Flight Points in the immediate vicinity of the release tent were discounted from the analysis, making it unlikely that the observation of a home range aggregation was purely an artefact of the reintroduction being from a fixed point at the release tent.

The opportunity to undertake this study presented itself unexpectedly, early in the reintroduction programme. The method of data collection was constrained by the delicate nature of the habitat, the importance of protecting the reserve (a SSSI) and the wellbeing of the small reintroduction population. However, a coherent dataset was collated across the two flight seasons, permitting quantitative analysis. In future it would be beneficial to combine capture-mark-recapture data with the current geo-spatial protocol (Wang *et al.*, 2021), as the *C. tullia* population becomes more abundant and widespread across the reserve.

This rare opportunity to observe the colonisation process from a fixed release point improves our understanding of the way in-which *C. tullia* utilises and moves between patches of suitable habitat, informing future restoration efforts (Schultz, 1998) to the benefit of the species, both within Astley Moss SSSI and across other closely related reserves within the Chat Moss area, which have the potential to form a network of metapopulations.

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