

The value of museum and other uncollated data in reconstructing the decline of the chequered skipper butterfly *Carterocephalus palaemon* (Pallas, 1771)

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Abstract

The chequered skipper butterfly *Carterocephalus palaemon* (Pallas, 1771) was declared extinct in England in 1976 after suffering a precipitous decline in range and abundance during the 20th Century. By searching and collating museum and other records, we show how a deeper understanding of this decline can be achieved, thus furthering conservation objectives. A preexisting Butterflies for the New Millennium (BNM) database of United Kingdom butterfly species records, created by Butterfly Conservation in conjunction with the Biological Records Centre (BRC), contained 266 historic *C. palaemon* records from England. United Kingdom (UK) museums and natural history societies were contacted for specimen data, and these sources added 2175 new records to the BNM. Owners of private specimen collections were also contacted, and these collections accounted for a further 465 records. Specimens originating from UK museums, other institutions, and private collections represent 2640 (71%) of total new records. Other sources, such as personal accounts held in museums, published and unpublished texts produced an additional 894 records. A further 437 records from museums, private collections, and other sources were considered partial and omitted from the data due to limited or misleading date and/or locality information. In summary, data from UK museums and other sources has infilled English *C. palaemon* distribution prior to 1976, offering further insight into potential environmental and anthropogenic drivers of decline at key sites. The quality and quantity of data obtained using the method outlined in this study suggests similar work could be carried out for other extinct or declining butterfly species to improve our knowledge of habitat requirements and historical distribution via modelling, identify causes of decline, and provide valuable information for potential reintroductions.

Keywords

Chequered skipper, *Carterocephalus palaemon*, butterfly, ecology, conservation, museum, collections, natural history

Introduction

In order to reconstruct the historic decline of a butterfly species, long-term data must be collected to understand the extent to which various environmental and anthropogenic drivers may have affected its abundance and distribution. Although there is a growing body of literature on the value of museum specimens for conservation of many different species (e.g. ; Roy, *et al.*, 1994; Shaffer, *et al.*, 1997; McCarthy, 1998; Krupnick and Kress, 2005; Nakahama, 2021), museums have been underutilised as sources of information for declining or extinct butterflies such as the English chequered skipper *Carterocephalus palaemon* (Pallas, 1771) (Dockerty and Cook, 2020; Nakahama, 2021).

Figure 1. Male C. palaemon in Rockingham Forest, May 19th 2019. © David James.

C. palaemon (Figure 1) was declared extinct in England in 1976 after experiencing a precipitous decline in the 20th Century, caused by factors such as coppice abandonment, agricultural intensification, and coniferisation (Collier, 1986; Warren, 1990; Ravenscroft, 1995; Moore, 2004). Despite being a prominent case of an insect going nationally extinct, the decline of *C. palaemon* in England is not well documented despite studies by Collier (1966, 1984), Farrell (1973), Ravenscroft (1995), and Moore (2004) due to a paucity of hard data. In order to understand how a restricted, but once locally abundant butterfly could be lost, a research collaboration between the University of Northampton and Butterfly Conservation to complement the reintroduction of *C. palaemon* to Rockingham Forest, England, was established to collect historic *C. palaemon* date and locality information from museum and private collections, personal accounts, and other sources of uncollated data.

Methods

Data collection

Messages requesting historic English *C. palaemon* records from institutions and private collectors were published on social media and circulated to Natural Sciences Collection Association (NatSCA) JiscMail discussion list (natsca@jiscmail.com) subscribers (Jisc, 2021). *C. palaemon* specimens listed for sale were located on an e-commerce website (eBay, 2021), and their sellers contacted via private message to request data from any further specimens in their possession. Requests were also made on a blog post, during a presentation to the general public (Wildman, 2020; 2021a), and on social media (Wildman, 2021b). Every attempt has been made to verify the authenticity and source of records and eliminate duplicates. Time and locality data from specimen labels were interpreted as records of sightings. For textual accounts, where abundance of *C. palaemon* at a specific locality in a given year was unable to be precisely quantified (e.g. John Keith Bates' June 5th 1949 diary entry states that 'quite a number of chequered skippers' were at Wakerley Wood [Bates c. 1945-1950]), a single record was included to indicate presence to avoid overestimation. Consequently, historical abundance at many sites has been underestimated (see Farrell, 1973).

Data from museums and private collections were provided in the form of photographs, spreadsheets, and scans of record cards. Label data was transcribed from photographs and record card scans remotely by J.P. Wildman, by museum staff on-site, or, in the case of a substantial private collection in Wiltshire, volunteers acting under instruction. Museums were emailed to inquire whether they held *C. palaemon* specimens. Data was sourced from private, unpublished sources (e.g. J.C. Dale c. 1810-1830; Bates c. 1945-1950), published sources (e.g. Ryland *et al.*, 1902; Macqueen, 1969; Archer-Lock, 1982; Duddington and Johnson, 1983), local researchers (e.g. Adrian Russell), and hobbyist butterfly collectors as well as museums. Data was obtained from 40 UK institutions (including museums, collections centres, natural history societies, universities, and trusts) and one United States (US) museum for this project (see Appendix I). Where collected museum or other uncollated data duplicated records already present in the BNM database, they were omitted from this study.

Dataset creation

A database was created in Microsoft Excel and all records meeting quality control standards were added. Every record was assigned a unique identification number to avoid confusion with other records and duplication. Columns were given the following headings and completed for each record: decade, , date (dd/mm/yyyy), county of origin, vice county number, nearest known locality, OS grid reference, type and source of record (MS = museum specimen, PS = private specimen, UP = unpublished text, PU = published text, BNM = existing data), present location of data, recorder name, collector name, reference (if from a textual source), museum collection name, and notes. Northamptonshire and Cambridgeshire localities were assigned 6-figure OS grid references (10-figure for small sites) based on Northamptonshire Site Register (James, *pers. comms.*) and Bird Club Gazeteer (Cambridgeshire Bird Club, 2021) lists respectively.

Butterflies for the New Millennium (BNM) – a butterfly recording scheme organised by Butterfly Conservation and the Biological Records Centre (BRC) in the United Kingdom (UK), and the Dublin Naturalists' Field Club in the Republic of Ireland – was developed in 1995-99 to assess the status of all native species for *The Millennium Atlas of Butterflies in Britain and Ireland* (Asher *et al.*, 2001). Historical records dating back to the 17th Century and records collated by the BRC for a previous atlas (Heath *et al.*, 1984) were incorporated. Since 1995, it has operated as the UK recording scheme for distributional 'casual' records and now holds over 14 million records (Butterfly Conservation, 2021). The data has been used in over 50 scientific research papers (e.g. Warren *et al.*, 2001; Thomas *et al.*, 2004; Suggitt *et al.*, 2018), and as part of a longstanding series of 'State of Butterflies' reports (Fox *et al.*, 2007; 2011; 2015). Grid references for localities elsewhere in England were generated using the UK Grid Reference Finder website in cases where records lacked existing geographic coordinates. Additional columns were later added to the database to account for changes in sites names, records being assigned to localities in different counties, and grid reference irregularities versus raw data. These were: corrected county, corrected vice county, corrected locality, and corrected grid reference.

Data classification

Lynne Farrell's Joint Committee for the Conservation of British Insects (JCCBI) report on the status of *C. palaemon* in England (Farrell, 1973) was classified as a published text for the purpose of this analysis to differentiate it from personal accounts such as diaries. Even though the report is not the public domain, it was nonetheless printed and circulated amongst JCCBI member organisations after its completion in September 1973. Diaries (e.g. Bates [c. 1945-1950]; Tozer [c. 1937-1970]) held in museums were classified as unpublished texts, the same as privately-owned notebooks (e.g. Fuller, *pers. comms.*; Russell, *pers. comms.*).

Criteria for inclusion and exclusion

Records were considered to have met quality control standards and accepted as complete if they contained date and locality information (e.g. a place name), and originated in England. Naming variations (e.g. checkered skipper, *Papilio paniscus* (Fabricius, 1775)) were also permitted. Records were not accepted if a label's place name could not be confidently matched to a specific locality (e.g. 'Morris Links'). Specimens vaguely labelled with settlements (e.g. 'Corby') were assigned to best-candidate woodland in close proximity using georeferenced historical OS maps (National Library of Scotland, 2021) if the site met the following criteria: a) was >10.9ha in size (equal to the smallest known historically occupied site in England, Barrowden Fox Covert), b) possessed internal ride structure, and c) was not coniferous. If clear and obvious provenance of a specimen could not be established, its locality was not changed. Original label wording was often left unchanged to limit the impact of speculation and personal bias on the dataset and outputs.

Ambiguous specimen labelling was a common practice historically, and often a consequence of the commercial interests of professional dealers outweighing interest in accuracy (Green, *pers. comms.*). Solitary records from outside the accepted geographic range of the species (Rockingham Forest and

Lincolnshire) were accepted to illustrate the stated locality of all records, but must be treated with some caution (Blathwayt, 1925; Turner, 1955; Mendel and Piotrowski, 1986; Fuller, *pers. comms.*), as eggs and larvae collected from well-known colonies may have been labelled with their breeding and/or release location instead (Green, *pers. comms.*). This may account for isolated records from Kent, Somerset, Buckinghamshire, and West Sussex. Several collectors were resident in these vice-counties around the time records exist: Edgar James Hare (1884-1969) in London and latterly, Kent, William Holland Ballett Fletcher (1852-1941) in West Sussex, Archdale Palmer Wickham (1835-1935) in Somerset, and Cyril Humphrey Cripps (mid-20th Century) in Buckinghamshire. Wild caught and bred specimens could also be purchased from commercial dealers, particularly in the late 1800s-early 1900s (Allan, 1943; Salmon, *et al.*, 2000; Fuller, *pers. comms.*). Such records could be interpreted as hoaxes, cases of misidentification, or unsanctioned releases following captive breeding/rearing or translocation. Partial records were omitted from the data.

Data visualisation

For the purpose of this article, plots and tables were created in Microsoft Excel, and the dataset subsequently exported to Quantum Geographic Information System (QGIS) (QGIS Development Team, 2021) as a csv file for distribution mapping. The Field Studies Council (FSC) Biological Records Tool (TomBio Tools, 2021) was used to translate EPSG:4326 – WGS 84 CRS to British EPSG:227700 – OSGB 1936 / British National Grid CRS and the data plotted as circular points on a Watsonian Vice County Boundary NBN Shapefile using 2km tetrads.

Results

Museums and natural history society specimens that met quality control standards provided 2175 new English *C. palaemon* records. Specimens in private collections accounted for a further 465 new records. Specimens originating from museums, other institutions, and private collections represent 2640 (71%) of total records. Other sources, such as personal accounts held in museums, published and unpublished texts produced an additional 893 records. A further 437 records from museums, private collections, and other sources did not meet quality control standards and were omitted from the data due to limited or misleading date and/or locality information. Incomplete records that did not meet quality control standards have been retained for future reference, as it is possible the provenance of some specimens could eventually be determined by cross-referencing available data with information from other sources.

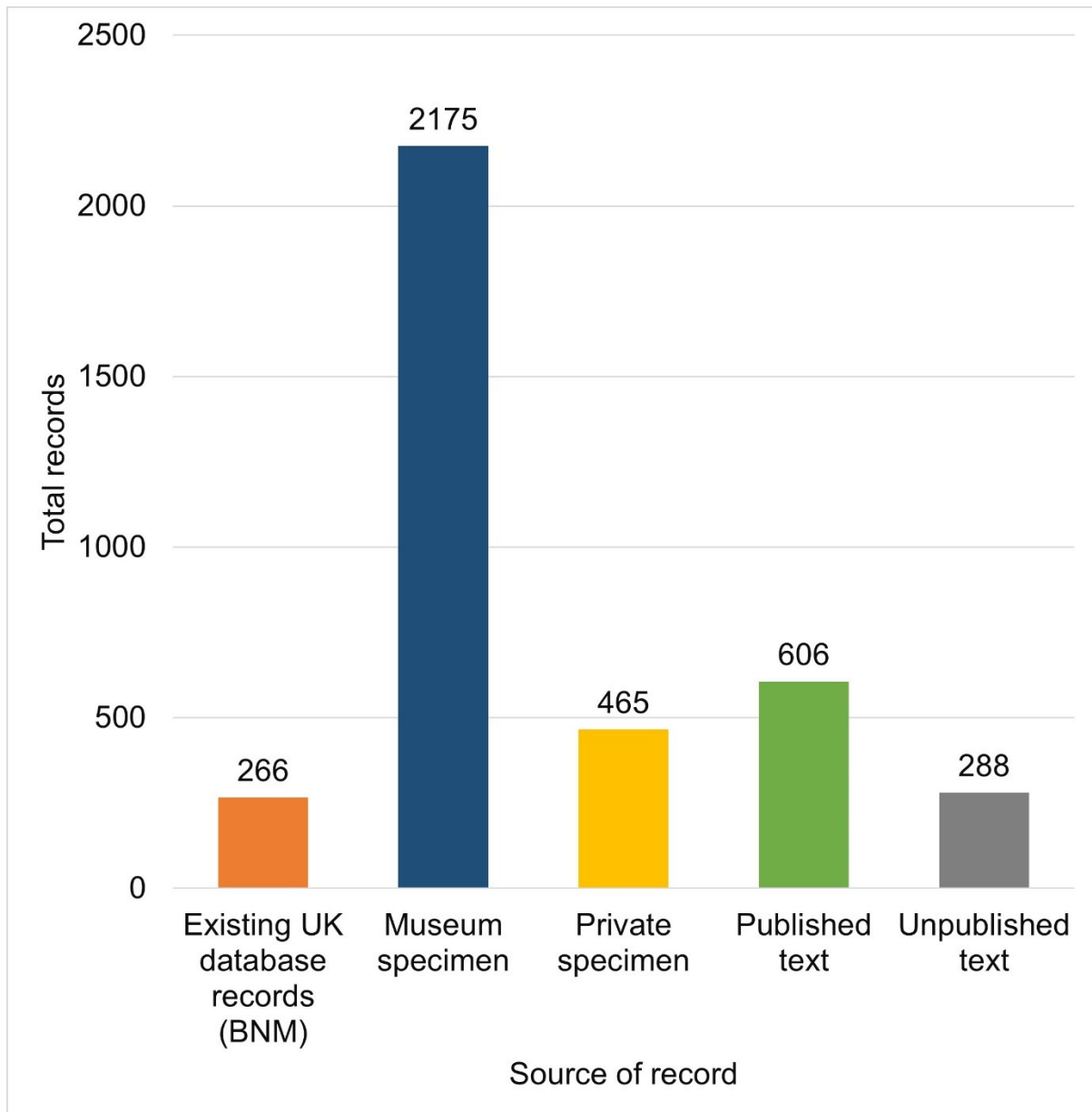


Figure 2. Total English *C. palaemon* records by data source.

The existing BNM database contained 266 records. 3533 records were added through this project (a 1328% increase in known records) (Figure 2). UK museum data was principally dated between 1880-1959 (2112 records), with 1940-1949 being the most abundant decade (949 records). Only 39 museum records were dated between 1826 (the oldest specimen) and 1879. The most recent museum specimen was from Monks Wood, Huntingdonshire, collected on the 25th May 1965. Only 24 museum specimens were dated between 1960 and 1976, whereas 285 records belonging to the same time period were obtained from published and unpublished texts (e.g. Collier, 1966; Macqueen, 1969; Farrell, 1973; Fuller, *pers. comms.*) (Figure 3).

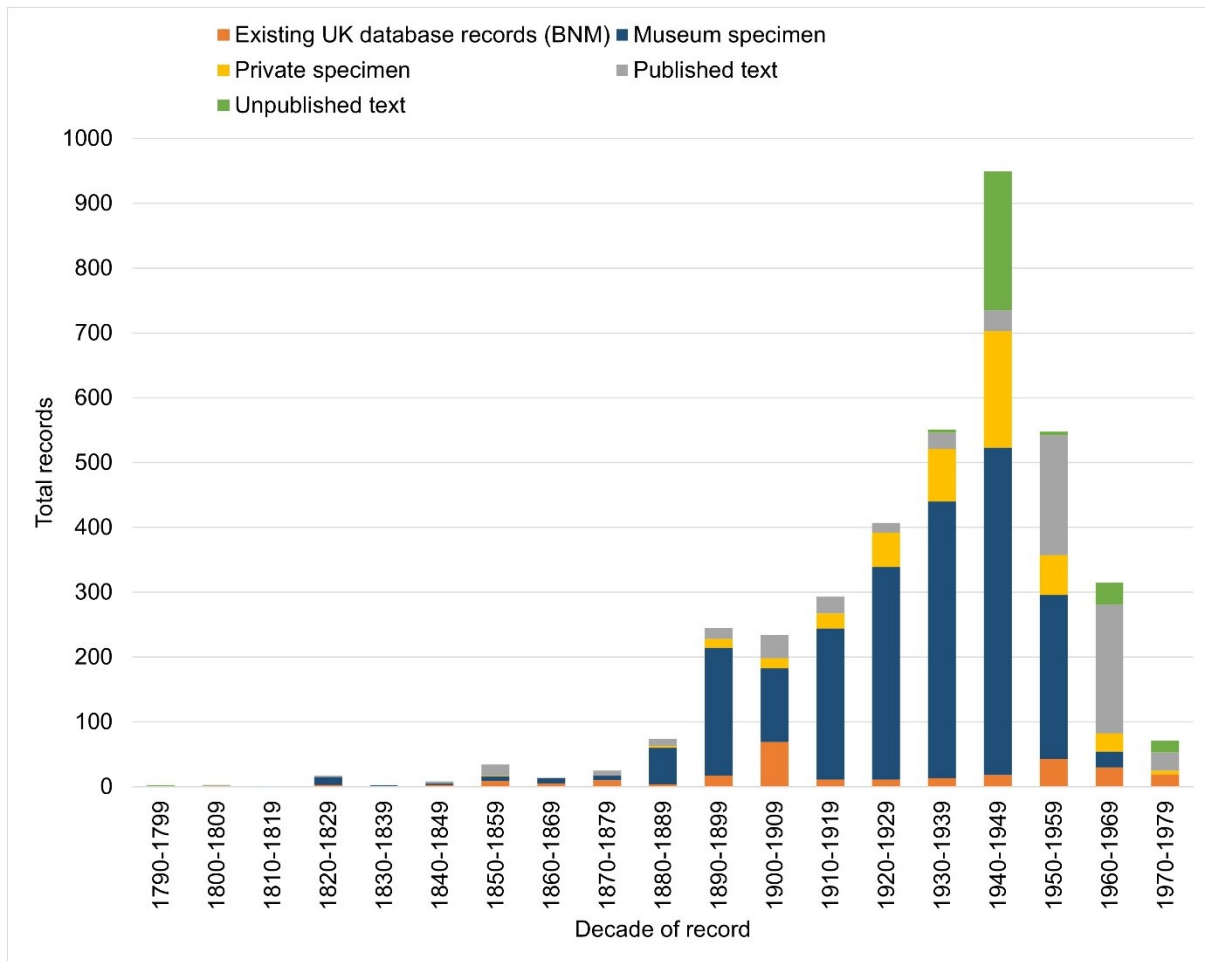


Figure 3. Total English records by decade from all data sources.

A total of 803 UK museums and natural history society specimens were from Cambridgeshire (748) and Huntingdonshire (55) (62% of total records from the vice-counties combined), 250 (65%) from South Lincolnshire, and 924 (58%) from Northamptonshire. In total, 1977 museum specimens belong to these four Watsonian vice-counties. The Natural History Museum, London (NHM) donated the largest number of complete records (681), alongside 92 incomplete records (Figure 4). Magdalene College, Cambridge has 229 records, 213 of which were from Fermyn Woods in Northamptonshire. Peterborough Museum & Art Gallery, Bristol City Museum & Art Gallery, Brighton Museum & Art Gallery, Oxford University Museum of Natural History, and the University Museum of Zoology, Cambridge provided >100 specimens each. Lancashire and Cheshire Entomological Society data (21 records) is held by National Museums Liverpool. Both Wisbech & Fenland Museum (60 records) and Magdalene College, Cambridge data was supplied by the University Museum of Zoology, Cambridge (Figure 4). Nonetheless, institutions were separated to acknowledge the exact source of all records.

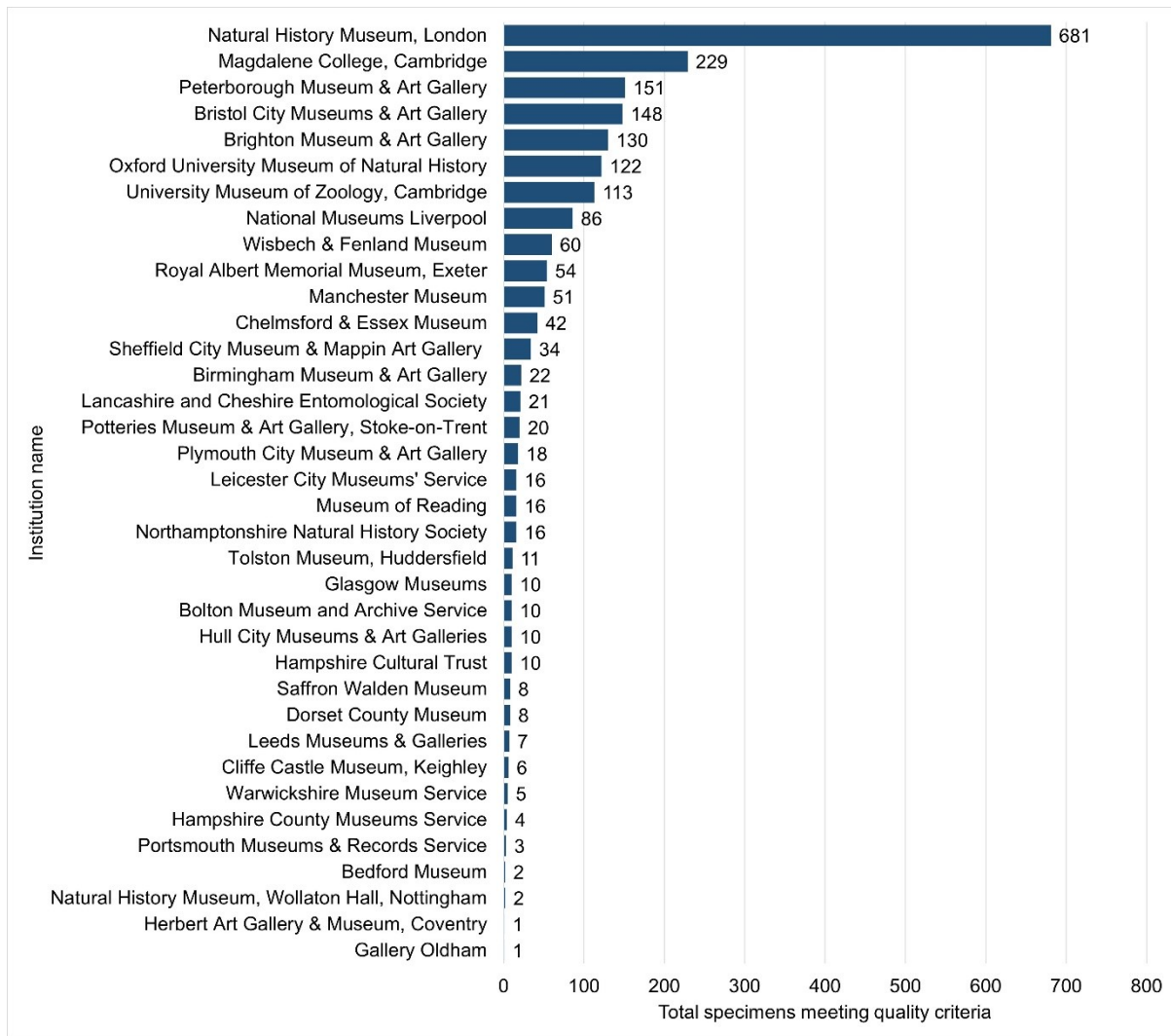


Figure 4. Total English specimens from institutions meeting quality control standards.

Only one specimen held in a private collection originated from a Rutland site, whereas 39 were from museum collections. Similarly, only 17 South Lincolnshire specimens were held in private collections, compared to 250 in museums. Records originating from Kent, Devon, Dorset, Hampshire, Leicestershire (distinct from Rutland, the location of the Luffenham Heath sub-landscape near Barrowden and Wakerley Woods), Norfolk, and Oxfordshire were obtained from museums, but these vice-counties were not represented in any private collections. Specimen data from Derbyshire and Worcestershire (3 records total) were the only vice-counties represented by private collections not known to be present in any museum collections. BNM data is dwarfed by new data at all major English sites. New data also confirmed the importance of the Rockingham Forest and Lincolnshire Limewoods landscapes by infilling known distribution (Figure 5).

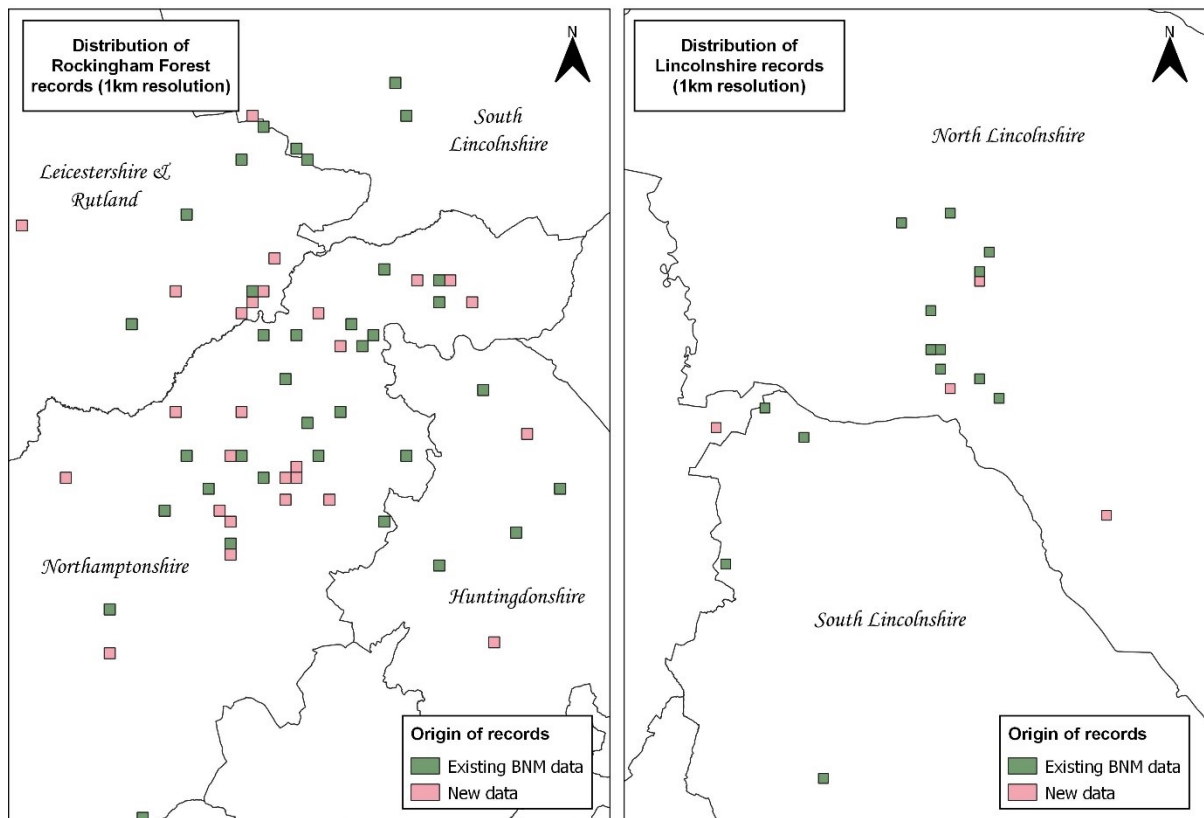


Figure 5. *C. palaemon* distribution in Rockingham Forest and Lincolnshire, 1798-1976.

Data from museum specimens pushed back the first date of known records at 9 of the 20 most populous English sites (Figure 6) with both existing and new museum data. In the case of Great Fen (under which Holme and Woodwalton Fen records were merged), the earliest dated museum specimen attributed to Holme Fen was 1851, whereas the earliest existing database record attributed to Woodwalton Fen was 1950, thus accounting for the 99 year difference in earliest dates of known occupation between the two data sources. The vice-counties of Derbyshire and Kent, and 31 English localities with >1 record (10 with >5 records) were not represented in existing BNM data.

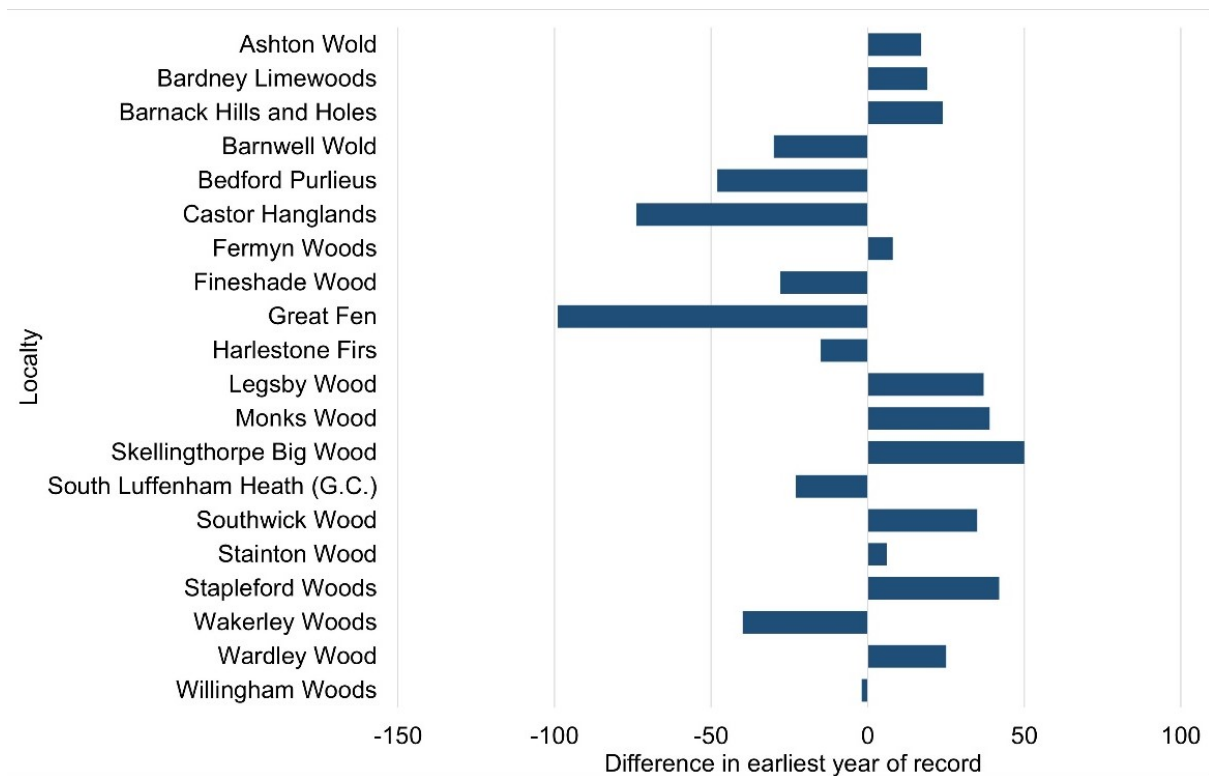


Figure 6. Difference in earliest year of record at most abundant English localities: museum specimens versus existing UK database records (BNM).

Only two museum specimens meeting quality control standards are dated later than 1964 (both 1965): one is housed at the NHM (BMNH(E): 1381012), and the other at the Royal Albert Memorial Museum, Exeter (RAMM). The NHM specimen, labelled 'G A. M' from Collyweston Great Wood and Eastern Hornstocks, is one of only two museum specimens known to originate from the site. The RAMM specimen (EXEMS: 74/2015/213) was captured at Monks Wood in Huntingdonshire. Three newer specimens (dated 1967-69) did not meet quality control standards as their provenance could not be determined and were therefore excluded from this study. One of a total 14 1964 museum specimens is labelled 'Wigsley Wood' – a Nottinghamshire site 4.47km west-southwest of Skellingthorpe Big Wood in South Lincolnshire. The specimen (BMNH(E)1363871), collected by 'A. Palmer' and housed at the NHM is both the only Wigsley Wood specimen and post-1939 record with definitive Nottinghamshire provenance known to exist (a single 1960 private specimen is vaguely labelled 'Nottingham'). J.C. Dale manuscripts at the Oxford University Museum of Natural History push the earliest English record of *C. palaemon* back 5 years to 1798 (at Clapham Park Woods in Bedfordshire) compared to BNM data (at Gamlingay Wood in Cambridgeshire in 1803).

Cyril Humphrey Cripps and 'S.W.' Humphrey collected a combined total of 283 *C. palaemon* at Fermyn Woods between 1942-1944. Magdalene College donated 213 records (all C.H. Cripps) from the site, whilst a single private Wiltshire collection included 70 Humphrey specimens. Sidney H. Kershaw is cited as the collector of 13 additional specimens belonging to the same collection. A total of 41 specimens dated 1940 are unlabelled but considered to have 'almost certainly' been captured by Kershaw because of the way they are characteristically 'badly set' (Clarke, *pers. comms.*). Cripps,

Humphrey, and Kershaw's specimens (including unlabelled attributions) accounted for 77% of all records from Fermyn Woods (437). Overall, 136 new Fermyn records were from the private Wiltshire collection, and 268 from museum collections, emphasising the historical significance of the woodland complex in respect to the wider Rockingham Forest landscape. Existing BNM data contained only 10 records attributed to Fermyn.

Cripps, who had an interest in 'rarer' butterflies (St John's College obituaries, 2000), visited Fermyn Woods on May 24th 1942, likely at the emergence peak, and captured 122 *C. palaemon*. On the following day, May 25th, Humphrey collected 33 specimens. Cripps returned to Fermyn in 1943 and collected 55, however there are no 1943 specimens attributed to Humphrey in the Wiltshires collection. On May 24th 1944, Humphrey took 31 *C. palaemon*, whilst Cripps collected 26 four days later on May 28th. Cripps and Humphrey subsequently took a total of 21 *C. palaemon* from Fermyn between 1947-1953. It is not known whether the men were aware of each other, but collectors of the time were considered 'very competitive' (Green, *pers. comms*). Only 10 more recent Fermyn records are known to exist, dated between 1956 and 1964. 312 specimens were collected from Fermyn across 4 flight periods (1940, 1942, 1943, 1944). However, only one specimen – held at the NHM and labelled 'Laudimer' – is dated 1941 (BMNH(E)1365098).

Figure 7. Page from J.K. Bates' diary at Leicestershire County Council Museum Collections in Barrow. © Adrian Russell.

John Keith Bates' diary describes how he, Don Tozer, and Arthur L. Goodson (then of Tring Museum) collected 120 of 150 *C. palaemon* they saw at Wakerley Woods on May 25th 1947 (Figure 7). Bates' accounts are corroborated by the presence of 'A.L. Goodson' and 'D. Tozer' Wakerley Woods specimens from 1947 at the NHM, Glasgow Museums, National Museums Liverpool, and RAMM. However, they collectively number only 27 (23%) of the 120 *C. palaemon* known to have been taken from Wakerley by the trio in 1947.

Discussion

That only 23% of Bates, Tozer, and Goodson's 1947 Wakerley Woods specimens have been located suggests new data from UK museums, private collections, personal accounts, and other sources represents only a fraction of all uncollated data that exists or ever existed. George Sellars' 1972 photograph at Addah Wood, for example, is the only evidence that *C. palaemon* colonised the Rutland site. The original 35mm slide is held in a private collection (Russell, *pers. comms.*) (Figure 8).

Figure 8. Scan of 35mm slide of male C. palaemon photographed at Addah Wood, Rutland, June 1972 by George Sellars. © Adrian Russell and Jamie Wildman.

It is quite possible that a significant percentage of uncollated data – especially those in private hands – has been lost or destroyed, given biological specimens are fragile and vulnerable to pest damage. Bates' diaries make it clear that he collected extensively, yet his collection at Leicester Museum consists of just six drawers and three *C. palaemon* specimens (Figure 9). Tozer's Coleoptera collection and 1937-1970 diaries were also donated to Leicester Museum, but his Lepidoptera collection was sold at auction to a non-entomologist and is now feared lost, as are his 1956-1961 diary entries (Russell, *pers. comms.*). Pratt's collection, containing 319 complete *C. palaemon* specimens, has been placed in storage since label transcription took place.

Figure 9. A drawer from J.K. Bates' collection at Leicester County Council Museum Collections in Barrow. © Adrian Russell.

There is no evidence of mass collecting having taken place at Fermyn Woods after 1944 and Wakerley Woods after 1947, despite *C. palaemon* being described as 'common' and 'fairly plentiful' at Wakerley as late as 1957 (Farrell, 1973). While *C. palaemon* populations remained healthy at key sites, it is unlikely collectors would have been motivated to search for other localities where the butterfly was abundant, as 'only limited availability would have driven a search for new sites' (Clarke, *pers. comms.*). However, in 1948 – the year after Bates, Tozer, and Goodson collected 120 *C. palaemon* at Wakerley – Tozer comments in a May 16th diary entry that there are 'very few Paniscus about & apparently they are quite scarce, but other butterflies abundant.' *C. palaemon* is again described by Tozer as 'scarce' at the site in 1949 (Tozer c. 1937-1970). Bates, however, notes 'quite a number of chequered skippers – not so many as usual at this time of year in other years' in an entry dated June 5th, 1949 (Bates c. 1945-1950). 23 *C. palaemon* were caught in 1950 (Farrell, 1973), however none of these specimens have been located during the course of this study. Numbers are only described as 'fair' at Fermyn in

1950 (Farrell, 1973), and only 19 records originate from the complex following this date, compared to 48 from Wakerley.⁸⁴ textual records from Castor Hanglands (1961-1963), 48 from Luffenham Heath (1968), and 'between 30 and 40' from Skellingthorpe (1953) (Farrell, 1973; Duddington and Johnson, 1983) shows that healthy colonies were documented where present in the 1950s and 1960s. *C. palaemon* was thought to have been lost from Fermyn by 1961 according to Farrell's JCCBI report (1973), however two 1964 records have since come to light in the BNM database and a published text (Izzard, 2018). The last Wakerley record, however, remains 1961 (BNM).

This is not to suggest collecting is a principal cause of extinction at either Fermyn and Wakerley. Rather, it is an example of a novel, anthropogenic pressure evidenced through museum data that, when combined with major drivers such as coniferisation and coppice abandonment (Moore, 2004; Peterken 1976; Peterken and Harding, 1974; Orchard, *pers. comms.*), may have marginally accelerated decline at both sites. Mark-release-recapture (MRR) studies (e.g. Thomas, 1983; Warren, 1983; Bourn and Thomas, 1993) have shown populations are much higher than casual observations demonstrate, and that collecting is unlikely to drive butterfly species to extinction on sites unless population size has already become very small due to other pressures. Brereton (1997), for example, determined it was possible to remove up to 50% of a population present on one day by MRR when numbers were low (<50 individuals). However, even with intensive sampling, only 5% of a total population could be removed per day. He concedes, however, that the effect of collecting was likely to be slightly underestimated by the MRR programme. The quantity of museum and private specimen data presented in this study merely demonstrates how plentiful *C. palaemon* once was where found, and how unfathomable scenes of '12 in the net at one time' (as was the case at Legsby and Lynwode Woods in 1890) (Farrell, 1973) are in the present day.

Figure 10. Lancashire and Cheshire Entomological Society record card, featuring 1945 Luffenham Heath specimen data. © World Museum, Liverpool.

The 'large colony' stated to be present at Luffenham Heath golf course in 1968 in Macqueen (1969) and Farrell (1973) indicates a minimum 9-year occupation (1968-1976) of the Rutland site. Compared to existing BNM data, known occupation has now been lengthened to 45 years (1932-1976). Earliest known occupation was initially increased to 32 years (1945-1976) after National Museums Liverpool provided a scanned Lancashire and Cheshire Entomological Society collection record card featuring the wording 'Luffenham Heath G.C., Rutland - (12) - 09.05.1945' (Figure 10). These 12 specimens indicate that the Luffenham Heath area was colonised whilst still continuous heathland known as South Luffenham Heath and Barrowden Leys, 'an expanse of heath grassland and scrub, stretching northeastwards from Barrowden towards Ketton [...] ploughed over by 1950' (Messenger, 1971). Construction of the golf course began in 1909 and finished in 1911. The 1945 specimens also add credibility to 1942-1946 Tozer diary entries, which mention a 'small wood near Barrowden' at which *C. palaemon* was present 'in hundreds' (Tozer c. 1937-1970). The diaries were found at Leicestershire County Council Museum Collections, Barrow (Russell, *pers. comms.*). The 'small wood' was subsequently determined to be Coppice Leys, situated 213m south of Luffenham Heath golf course.

An entry dated May 23rd, 1947 in Bates' diary, also at Barrow, states he saw '2 Chequered Skippers flying together (gambolling flight) over the road between Coppice Leys & the Spinney – Courtship?' Bates c. 1945-1950. The 'Spinney' in question was subsequently identified as Culligalane Spinney. An image of a 1932 Luffenham Heath specimen labelled with the collector 'Mason, A.G.L.' was later found on an archived eBay listing (Russell, *pers. comms.*). Rather than being an isolated site at which *C. palaemon* merely hung on at in its final years, the broad time span of occupation and quantity of Luffenham Heath records – comparable to key localities in Rockingham Forest – suggest the site may have driven the metapopulation dynamics of its sub-landscape for several decades, if not longer. Agricultural intensification and insufficient woodland management (Messenger, 1971) is believed to have confined *C. palaemon* to Luffenham Heath by the 1950s. As the earliest known record from the site is dated 1932 – 21 years after construction of the golf course was completed – it is not known whether development of the heathland for recreational purposes had any impact on population health.

A general decline in records beginning in the late 1950s is not considered an artefact of reduced collecting, as the number of specimens from 1956 (134) exceeds the highest total from any year in the 1920s or 1930s. The introduction of collecting restrictions at East Midlands National Nature Reserves (NNRs) from 1964 (Collier, 1986) and increasing scarcity of *C. palaemon* in the 1960s is jointly responsible for lower numbers of more recent specimens. Although few conclusions can be drawn regarding *C. palaemon*'s status after the mid-1960s using specimens alone, museum data has lengthened the known historical occupation of key sites compared to existing BNM data, including Luffenham Heath (the last locality in England at which *C. palaemon* was sighted), Wakerley Woods, Castor Hanglands, Bedford Purlieus, and Fineshade Wood. Importantly, a significant quantity of new data is concentrated around the mid-20th Century – the time when *C. palaemon*'s decline in England is believed to have begun (Collier, 1986; Ravenscroft, 1992).

Although most records belong to Rockingham Forest, Rutland, and Lincolnshire, museum data spanning over a century (1829-1938) from the south coast hints at a third concentration of colonies stretching across Devon, Dorset, Somerset, West Sussex, Buckinghamshire, and Kent. It is plausible that *C. palaemon* once occupied the Weald, given it featured the largest area of woodland in Medieval England (Rackham, 2000). Several historic texts indicate Devon, Hampshire, and Dorset occupation (e.g. J.C. Dale c. 1810-1830; Morris, 1853; Westwood, 1854; Newman, 1869;), as do thirteen museum specimens meeting quality control standards dated 1886-1938. It is possible that southern colonies were waning even before the advent of butterfly collecting and recording.

C. palaemon was anecdotally regarded as 'very common' and 'in no danger of extinction' as late as 1961 by Pilcher (1961), and 'incomparably more numerous than it was [30 years ago]' at one site in 1957 by Lane and Rothschild (1957). No effort to systematically evaluate the butterfly's status nationwide occurred until Farrell's 1973 JCCBI report, after which the extinction of *C. palaemon* was inevitable. Little mention of a decline in numbers were published prior to *C. palaemon*'s extinction, although Pilcher accepts that the species 'no longer enjoys its former abundance' at Castor Hanglands in 1961 (Pilcher, 1961), Collier (1966) still considers the butterfly to be 'common' there between 1961-65, however.

Conclusion

A majority of *C. palaemon* records provided by museum collections meet quality control standards for inclusion in this study. Anonymous specimens, and those with labels considered incomplete that offer little in the way of new, reliable data are in the minority. Many museums are in the process of digitally cataloguing their butterfly collections to ensure specimens are preserved for future generations to access (Figure 11).

Figure 11. Digitally photographed C. palaemon specimen housed at the University Museum of Zoology, Cambridge. © University of Cambridge.

The large increase in *C. palaemon* records has been made possible thanks to the digitisation of museum collection data in the 21st century, and better connectivity between researchers seeking historical data and museums thanks to email distribution lists and social media. Museum data has confirmed the historic range of *C. palaemon* and infilled distribution between 1798-1976 in the species' known Rockingham Forest and Lincolnshire strongholds (Farrell, 1973; Collier, 1986; Ravenscroft, 1995; Moore, 2004), significantly increased record abundance, and lengthened known time periods of occupation at key sites. The significant contribution museums have made to this study in the form of both specimens and textual archives has allowed us to draw much stronger conclusions about the species' possible rapid extinction in England, and confirmed the roles of anthropogenic and environmental drivers of decline, such as clearfelling of medieval broadleaf woodland, coppice abandonment, high forest conversion, conifer afforestation, habitat fragmentation, and colony isolation, which, although predominately based on circumstantial evidence, are generally accepted (e.g. Farrell, 1973; Lamb, 1974; Peterken and Harding, 1974; Peterken, 1976; Collier, 1978, 1986; Ravenscroft, 1992; Moore, 2004).

This study has focused on documenting the process of collection and collation of new data and presented initial findings. The enhanced dataset will now be used to look in more detail at the relative significance of factors possibly contributing to extinction, not just at landscape-scale, but per site. It will lead to improved knowledge of habitat requirements and generate valuable information for potential future butterfly reintroductions across the Rockingham Forest network, as well as other conservation work such as habitat management. The quantity and quality of uncollated *C. palaemon* data obtained from museum collections and archives demonstrates the vast potential of this source of information for studies of other extinct, threatened, or declining UK butterfly species to improve our knowledge of their historical distribution via modelling, identify drivers of decline and candidate sites for potential reintroductions. Museums should therefore be considered the foremost point of contact for researchers seeking to obtain historic spatiotemporal data for other UK butterfly species that are similarly poorly understood. The method outlined in this study offers a novel approach to accessing data held by museums and other sources of uncollated data that is not available in an easy-to-access form. However, significant time and energy must be invested in order to build a dataset of records comparable to the one we have built for the English *C. palaemon*, given the number of institutions, individual collaborators, sources, and types of raw data that were involved in its creation.

Appendix I – Museums and Natural History Societies

Bedford Museum: <https://www.thehigginsbedford.org.uk/>
Birmingham Museum & Art Gallery: <https://www.birminghammuseums.org.uk/bmag>
Bolton Museum and Archive Service: <https://www.boltonlams.co.uk/>
Brighton Museum & Art Gallery: <https://brightonmuseums.org.uk/brighton/>
Bristol City Museum & Art Gallery: <https://www.bristolmuseums.org.uk/>
Chelmsford and Essex Museum: <https://www.chelmsford.gov.uk/museums/>
Cliffe Castle Museum: <https://www.bradfordmuseums.org/>
Herbert Art Gallery & Museum: <https://www.theherbert.org/>
Dorset County Museum: <https://www.dorsetmuseum.org/>
Gallery Oldham: <https://galleryoldham.org.uk/>
Glasgow Museums: <https://glasgowlife.org.uk/>
Hampshire Cultural Trust & County Museums Service: <https://www.hampshireculture.org.uk/>
Hull City Museums and Art Galleries: <https://www.hcandl.co.uk/museums-and-galleries/>
Leeds Museums & Galleries: <https://museumsandgalleries.leeds.gov.uk/>
Leicester City Museums' Service: <https://www.leicestermuseums.org/>

Manchester Museum: <https://www.museum.manchester.ac.uk/>
Museum of Reading: <https://www.readingmuseum.org.uk/>
National Museums Liverpool: <https://www.liverpoolmuseums.org.uk/>
Natural History Museum, London: <https://www.nhm.ac.uk/>
Natural History Museum, Wollaton Hall, Nottingham: <https://wollatonhall.org.uk/hall-and-museum/natural-history-museum/>
Northamptonshire Natural History Society: <https://www.nnhs.info/>
Oxford University Museum of Natural History: <https://www.oumnh.ox.ac.uk/>
Perth Museum & Art Gallery: <https://www.culturepk.org.uk/museums-and-galleries/perth-museum-and-art-gallery/>
Peterborough Museum & Art Gallery: <https://cityculturepeterborough.org.uk/museum-art-gallery/>
Plymouth City Museum & Art Gallery: <https://www.theboxplymouth.com/>
Portsmouth Museums & Records Service: <https://portsmouthmuseums.co.uk/>
Potteries Museum & Art Gallery, Stoke-on-Trent: <https://www.stokemuseums.org.uk/pmag/>
Royal Albert Memorial Museum, Exeter: <https://rammuseum.org.uk/>
Saffron Walden Museum: <https://www.saffronwaldenmuseum.org/>
Sheffield City Museum & Mappin Art Gallery: <https://www.museums-sheffield.org.uk/>
Tolston Memorial Museum <https://www.kirklees.gov.uk/beta/museums-and-galleries/tolson-museum.aspx>
University Museum of Zoology, Cambridge <https://www.museum.zoo.cam.ac.uk/>
Warwickshire Museum Service <https://heritage.warwickshire.gov.uk/museum>
Wisbech & Fenland Museum <https://www.wisbechmuseum.org.uk/>
Yale Peabody Museum <https://peabody.yale.edu/>

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Specimens used in this study are held at the following institutions: Bedford Museum (BEDFM), Birmingham Museum & Art Gallery (BIRMG), Bolton Museum and Archive Service (BOLMG), Brighton Museum & Art Gallery (BTNRP), Bristol City Museum & Art Gallery (BRSMG), Chelmsford and Essex Museum (CHMER), Cliffe Castle Museum (BRFMS), Herbert Art Gallery & Museum (COVGM), Dorset County Museum (DORCM), Gallery Oldham (OLDMS), Glasgow Museums (GLAMG), Hampshire County Museums Service (HMCMS), Hampshire Cultural Trust (HMHCT), Hull City Museums and Art Galleries (KINCM), Leeds Museums & Galleries (LEEDM), Leicester City Museums' Service (LEICT), Manchester Museum (MANCH), Museum of Reading (REDMG), National Museums Liverpool (LIVCM), Natural History Museum, London (NHMUK), Natural History Museum, Wollaton Hall, Nottingham (NOTNH), Oxford University Museum of Natural History (OUMNH), Perth Museum & Art Gallery (PERGM), Peterborough Museum & Art Gallery (PETMG), Plymouth City Museum & Art Gallery (PLYMG), Portsmouth Museums & Records Service (PORMG), Potteries Museum & Art Gallery, Stoke-on-Trent (STKMG), Royal Albert Memorial Museum (EXEMS), Saffron Walden Museum (SAFWM), Sheffield City Museum & Mappin Art Gallery (SHEFM), Tolston Memorial Museum (KLMUS), University Museum of Zoology, Cambridge (CAMZM), Warwickshire Museum Service (WARMS), Wisbech & Fenland Museum (WISFM), and Yale Peabody Museum (YPM).

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