Faculty of Science and Technology

How can information on the ecology and monitoring of *Cicindela sylvatica*, in a global context, inform conservation management in Purbeck Heaths NNR?

A dissertation submitted as part of the requirement for the BSc Ecology and Wildlife Conservation

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Abstract

Global biodiversity is declining at unprecedented levels. The primary driver of this loss has been identified as changes in land use which has led to habitat fragmentation. Past studies have found that habitat specialists are more susceptible to habitat fragmentation and therefore face higher extinction risk. Most tiger beetle species (*Cicindelidae*) are characterized by highly narrow habitat specialization. However, geographic ranges of *Cicindelidae* have been shown to vary (i.e., range is wider), due to contributing factors such as dispersal power. Tiger beetles are strongly connected to multiple factors such as climate, weather condition and habitat type. Therefore, species research from within their geographical range could be utilised in localised areas, especially where they are of high conservation concern.

The aim of this study is to systematically review information on *C. sylvatica* regarding life cycle, habitat requirement, distribution, reasons for change in distribution and abundance, survey methods and recommendations for habitat management from across its global distribution and use this to inform species future monitoring plans and conservation management in the Purbeck Heaths NNR in Dorset.

The results of the study identified an abundance of research on the distribution and habitat requirements of *C. sylvatica*, but less so on life cycle, recommendations for habitat management, reasons for change in distribution and abundance and survey methods. Recommendations for conservation management and monitoring are discussed in detail within the paper. Furthermore, nearly every topic was increasingly mentioned within literature over the time frame looked at within the study (pre-1970, 1970-1999 and 2000-2024). This suggests that research on *C. sylvatica* has evolved from primarily focusing on observational field studies to more data-driven scientific studies that are focused on conserving this rare and unique species.

Acknowledgements

I would like to thank my supervisor, Anita Diaz, for her continuous guidance and support throughout this project. I would also like to thank my family, especially my amazing mum and university friends, Christina Bryant, Amy Lovatt and Catherine Stedman, for their continuous encouragement. Throughout not just this project, but my whole three years at university. I will be forever grateful for all of them. I would also like to thank Scotty Dodd for the invaluable advice and access to important resources for my project.

Contents

1. Introduction

Global biodiversity is declining at unprecedented levels. If current trends continue, then further loss of global biodiversity is expected. Experts estimate that ~37% of species may be threatened or driven to extinction by 2100 (Isbell, 2023).

This decline has been principally driven by the overexploitation of resources, climate change, pollution and invasive alien species. However, the most significant threat has been identified as changes in land use (IPBES, 2019). Changes in land use can lead to the deterioration of habitat quality and habitat loss (Hanski, 2011). Habitat loss can negatively impact biodiversity directly by decreasing species abundance, richness and population growth rate (Donovan and Flather, 2002; Rogan and Lacher Jr, 2018).

Past studies have found that habitat specialists are more susceptible to habitat fragmentation and loss than habitat generalists, as generalists are not entirely dependent on the focal habitat (Carrara et al. 2015; Ramiadantsoa et al, 2018). Specialist species are defined by their association with specific habitats or environmental conditions (stenotopic), whereas generalist species have wider tolerances (eurytopic) (Futuyma and Moreno, 1988). In most cases, specialists are more sensitive to environmental changes than generalists (Clavel et al. 2011), meaning that they are generally more susceptible to extinction risk (McKinney, 1997; Biesmeijer et al. 2006). The identification of species and populations at higher extinction risk is crucial for developing suitable conservation measures in regard to current and future environmental change (Colles et al. 2009). In order to develop suitable conservation measures, an understanding of a species ecological characteristics is important to make conservation planning more efficient (Chichorro et al. 2019). Furthermore, species monitoring is essential for conservation management by determining population trends and assessing the effectiveness of measures (Reynolds et al. 2016; Legge et al. 2018).

1.1 Specialist species

Specialist species are often targets of local or regional conservation efforts (Thompson 1994; Julliard et al. 2004; Davison and Fitzpatrick, 2010; Staude et al. 2021; Yan et al. 2022). Studies informing the conservation management of specialists are often localized as species are restricted to smaller geographic ranges (Brown, 1995). Various hypotheses have been proposed in order to explain this restriction in geographic range. MacArthur (1972) noted the relevance of trade-offs in the context of range limits. He suggested that particular adaptations make a species successful within its range but can constrain occurrence outside of this range. Brown’s (1984) resource breadth hypothesis proposed that species with broad ecological niches should have a large geographical range size. Therefore, the opposite can be assumed of species with a restricted geographical range.

For example, many tiger beetle species (*Cicindelidae*) are characterized by highly narrow habitat specialization (Freitag, 1979), with only a minor number of species considered generalists (Jaskuła, 2011; Jaskuła, 2015; Jaskuła et al. 2019). This indicates that tiger beetle species distribution is usually strongly connected with a specific geographical region, type of climate, weather condition and habitat type (Pearson 1988; Pearson and Cassola, 1992; Pearson and Vogler, 2001). For example, *Cephalota deserticoloides* is only found in a few localised sites in south-eastern Iberia, where it is highly specialised in arid saline steppe habitat (Herrera-Russert et al. 2021).

However, geographic range sizes of specialist species can vary, owing to additional factors such as ease of dispersal to suitable habitat and biotic interactions within their environment (Saupe et al. 2015). This variation is evident in tiger beetle species. For example, *Cephalota circumdata circumdata* is a specialist within salt marsh habitat. Despite this specialization, the species has a broad geographic range and is well distributed within the Mediterranean Basin through Europe, parts of Asia and Africa (Cassola, 1970; Lisa et al. 2002). This may be due to the higher availability of salt marsh habitat and suitable climate within the Mediterranean (Davidson, 2018), although factors underlying geographic range variation are still poorly understood (Calosi et al. 2010).

A recent paper by Jaskula et al. (2019), studied *C. circumdata circumdata*, within its range in south-east Europe, and identified that the species strongly prefer soils with higher salinity values and humidity. This research could be utilised in localised areas of the species geographical range, where they are of conservation concern, due to the strong connection between their distribution and habitat type, For example, the species is also found in the Maghreb region (specifically Algeria and Tunisia) where at least 85% of *Cicindelinae* taxa are endangered by human activity (Jaskula, 2015). Understanding the relationship between a species and their habitat can determine what is required for the long-term survival of a species, allowing priorities to be set for conservation management (National Research Council, 1995).

Reviewing global research has shown to benefit species by not only addressing current gaps in knowledge but also by informing their local conservation management (Wilkinson et al. 2023). Therefore, reviewing available global research on tiger beetle species, that have a wider geographical range, may be able to inform their conservation on a local scale. Furthermore, as tiger beetle species have similar life histories, management and research methods that appear to be successful for one species may be applicable to others (Knisley and Gwiazdowski, 2021), especially for those that are less studied. For example, only a few studies have focused on the habitat specialization or preferences of tiger beetle species known from Africa (Guppy et al. 1983; Mawdsley and Sithole, 2008; Mawdsley et al. 2009), even though the continent represents one of the largest number of known tiger beetle species (~546 species) (Pearson and Wiesner, 2023).

1.2 Tiger Beetles

There are over 3000 species of tiger beetles described worldwide (except within the polar regions and some oceanic islands), with *Cicindela* considered the largest genus (Duran et al. 2024). Due to their widespread distribution, tiger beetles are often used as biological indicators to determine biodiversity patterns, both regionally and globally, and are recognized as a significant flagship group for global beetle conservation (Knisley and Hill 1992; Pearson and Cassola 1992). Furthermore, it's argued that tiger beetles make good indicator taxa for biodiversity and conservation studies due to their prominent appearance and association to early successional and threatened habitats (Pearson and Cassola, 1992).

Tiger beetles are important bioindicators as they are sensitive to environmental changes. However, this means that they have a higher risk of extinction. This is predominantly due to their dependency on declining successional habitats (King and Schlossberg, 2014). Therefore, several tiger beetle species are thought to be in decline. For example, in the US, numerous species and subspecies (~15% of taxa) have shown a decrease in population (Pearson et al. 2015). Furthermore, on an international scale, 27 tiger beetle species are currently classed as either Vulnerable, Endangered or Critically Endangered on the IUCN red list (IUCN, 2023). Nevertheless, this number is still very small, in comparison to the number of known tiger beetle species worldwide. This highlights the need for extinction risk assessments to be conducted on more tiger beetle species to determine their conservation status.

A primary cause of decline in tiger beetle species is habitat destruction/fragmentation. This has principally been caused by increased urbanization and agricultural practices. Furthermore, existing habitats have become unsuitable due to the loss of open, bare ground which tiger beetles depend on for foraging and larval development (Knisley et al. 2014). As well as anthropogenic pressures, habitat succession and a lack of natural disturbance are also a threat to many tiger beetle species, especially those that are dependent on open and early successional habitats (Knisley, 2011; Knisley and Gwiazdowski, 2021). Early successional habitats are broadly defined as open habitats that are generally occupied by annual plants, grasses and forb species (herbaceous flowering plants) (Machtinger, 2007). A characteristic of these types of habitat are that they are created by intense or recurring disturbances. If this is not maintained, then succession can occur, wherein the habitat becomes mature forest, and no longer supports the same species (Greenberg et al. 2011).

In regard to habitat preferences, tiger beetle species generally occupy terrestrial, sandy, open habitats wherein both larvae and adults live. However, due to the species narrow habitat specialization, they can be found only in one or in a few very similar types of macrohabitats (Jaskuła et al. 2019). Heathland is an important habitat for certain tiger beetles species in the genus *Cicindela*. Heath tiger beetles (*Cicindela sylvatica*), green tiger beetles (*Cicindela campestris*) and North dune tiger beetles (*Cicindela hybrida*) can all be found on heathland. *C. hybrida* was described as one of the few mobile diurnal predators in pioneer inland drift sand habitat in Europe, which consists of dry heathland and open forest (Nijssen and Siepel, 2010), meaning they often utilise heathland, primarily for hunting small insects but also for shade if required (Dreisig, 1981; Harrold, 2020). *C. campestris* are considered generalist species as they inhabit multiple habitat types. However, they often utilise heathland to hunt prey (Dorset Wildlife Trust, 2023). *C. sylvatica* utilizes areas of dry, compacted bare sand on lowland heath for hunting prey and digging larval burrows (Offer et al. 2003).

1.3 Heathland

Heathlands are characterized by highly specialized species that are often threatened due to their confinement to the habitat (Buchholz et al. 2013; Schirmel and Fartmann, 2014). Heathlands are a 'semi-natural habitat' as their development has occurred as a result of centuries of forest clearances, followed by the use of the land for grazing stock and for the collection of fodder and fuel, with fire often used to prevent regeneration of the forest and to promote the growth of Calluna, the most characteristic vegetation type of heathlands (Gimingham 1972; Webb 1986). In the UK, lowland heath is an important habitat for specialists, including ground nesting bird species such as Nightjars and Dartford Warblers (JNCC, 2020). Heathland also supports all six of the UK's native reptile species. Many scarce and threatened invertebrates are also found on lowland heathland (JNCC, 2020). As well as being a home to highly specialized species, lowland heathland is also a priority for nature conservation in the UK due to its rarity. It has rapidly declined during the last two centuries. It's estimated that only one sixth of the heathland that was present in 1800 remains in England and it's still facing immense pressures today (JNCC, 2020). At present, The Purbecks Heaths NNR in Dorset is the largest area of lowland heath managed as a single nature reserve in England, covering 3,331 hectares (GOV.UK, 2020).

1.4 Purbeck Heaths NNR

The Purbeck Heaths National Nature Reserve (NNR) was first declared in 2020. This incorporates three existing NNRs at Hartland Moor, Stoborough Heath and Studland and Godlingston Heath to form a new 'super' National Nature Reserve. Purbeck Heaths is one of the most biodiverse places in the UK, supporting thousands of species. Over 450 of these are listed as rare, threatened, or protected (National Trust, 2020). This includes *C. sylvatica*, a tiger beetle species that is characteristic of lowland heath habitat (Howorth, 2022).

1.5 Heath tiger beetle

The heath tiger beetle *(Cicindela sylvatica)* is characterized by a broad Palaearctic distribution (Dudko et al. 2010). However, within the UK, they are confined to the South of England with small, isolated populations found in Dorset, Surrey, Hampshire and Sussex. *C. sylvatica* has experienced a dramatic population decline in England over the last few decades and is now classed as 'Nationally scarce'. This is thought to be associated with the fragmentation and degradation of lowland heathland habitat, a trend that's also thought to be impacting the species across their European range (De Vries, 1996). This is why their conservation is so crucial.

1.6 Aims and Objectives

The aim of this study is to systematically review information on the ecology, monitoring & conservation management of *C. sylvatica* from across its global distribution and use this to inform the species future monitoring plans and conservation management in the Purbeck Heaths NNR.

The objectives of the study were:

- To review information on the life cycle, habitat requirement, distribution, reasons for change in distribution and abundance, survey methods and recommendations for habitat management for *C. sylvatica* from across its global distribution
- To identify how this information could inform future monitoring and conservation management for *C. sylvatica* within the Purbeck Heaths NNR

2. Methods

The systematic review literature searches were performed in Google scholar, Web of Science and Scopus databases. Grey literature was found using the databases of main organizations such as 'Natural England' and 'Joint Nature Conservation Committee (JNCC)'. Search terms were focused on the specific topics of interest: life cycle, habitat requirement, distribution, reasons for change in distribution and abundance, survey methods and recommendations for habitat management. A variation of search terms was tested within the databases, until six topics were found that retrieved relevant literature.

Only the scientific name (*C. sylvatica*) of the species was used, rather than the common name (heath tiger beetle or wood tiger beetle) as academic literature tends to use the former. Furthermore, species having more than one common name can cause confusion. For example, *Cicindela hybrida* was referred to as the heath tiger beetle, before being renamed as the 'Northern dune tiger beetle' (Sutton and Browne, 2001). Furthermore, due to the lack of extensive literature on C. sylvatica, techniques such as truncation were used in some instances to widen the search results.

The search terms were: *Cicindela sylvatica,* ecology OR conservation AND *Cicindela sylvatica,* protection OR preservation AND *Cicindela sylvatica,* life cycle* OR life stage* AND *Cicindela sylvatica,* nature reserve* OR national park* AND *Cicindela sylvatica,* monitor* OR survey* AND *Cicindela sylvatica,* distribution OR abundance AND *Cicindela sylvatica,* habitat OR environment AND *Cicindela sylvatica* and programme OR project AND *Cicindela sylvatica* (Table 1).

A test search was also conducted using just ‘*Cicindela’*. However, this retrieved a variety of literature that focused on other species within the genus. Therefore, it was decided that the literature would be too broad to address the aim, so this was not included in the finalised search terms.

The majority of literature within the first Scopus search was identified as irrelevant to *C. sylvatica*. This was partly due to publications mentioning ‘*sylvatica*’ in the context of ‘*Fagus sylvatica’* (European Beech) and ‘*Rana sylvatica’* (Wood frog). As this literature could not be removed by refining the search, the searches were continued by just looking within the title, abstract and key words of literature. This saved time and narrowed down the search, so the results were more relevant.

The use of multiple search terms and the limiting of restrictions such as language, location, or date ensured that the search strategy was comprehensive. Furthermore, the use of various search engines made the review more inclusive as grey literature such as reports, conference papers and dissertations/theses were included as well as peer-reviewed journals. The selection of a set number of search results (i.e., the first 50) reduced bias as literature was not missed or skipped over due to personal preference.

Date	Search engine	Search term	Total no. of literature looked at	No. of literature discarded due to relevance of title and abstract	No. of literature discarded due to relevance of full text	No. of literature discarded due to duplicates	No. of literature discarded due to lack of access	Total no. of literature kept	Filters used
12/10/23	Google scholar	*Cicindela sylvatica*	51	8	5	1	1	36	Included citations
12/10/23	Scopus	*Cicindela sylvatica*	37	22	9	3	0	3	All fields
12/10/23	Web of Science	*Cicindela sylvatica*	8	1	0	6	1	0	All Databases (within topic)
13/10/23	Google scholar	ecology OR conservation AND *Cicindela sylvatica*	50	4	1	38	0	7	Included citations
13/10/13	Scopus	ecology OR conservation AND *Cicindela sylvatica*	1	0	0	1	0	0	Search within Article title, Abstract, Keywords
13/10/23	Web of Science	ecology OR conservation AND *Cicindela sylvatica*	6	0	0	6	0	0	All Databases (within topic)
14/10/23	Google scholar	protection OR preservation AND *Cicindela sylvatica*	50	2	5	35	0	8	Included citations
14/10/23	Scopus	protection OR preservation AND *Cicindela sylvatica*	1	0	0	1	0	0	Search within Article title, Abstract, Keywords
14/10/23	Web of Science	protection OR preservation AND *Cicindela sylvatica*	1	0	0	1	0	0	All Databases (within topic)

16/10/23	Google Scholar	life cycle* OR life stage* AND *Cicindela sylvatica*	50	4	9	31	0	6	Included citations /
16/10/23	Scopus	life cycle* OR life stage* AND *Cicindela sylvatica*	1	0	0	1	0	0	Search within Article title, Abstract, Keywords
16/10/23	Web of Science	life cycle* OR life stage* AND *Cicindela sylvatica*	2	0	0	2	0	0	All Databases (within topic)
21/10/23	Google Scholar	nature reserve* OR national park* AND *Cicindela sylvatica*	50	2	11	29	0	8	Included citations
21/10/23	Scopus	nature reserve* OR national park* AND *Cicindela sylvatica*	0	0	0	0	0	0	Search within Article title, Abstract, Keywords
21/10/23	Web of Science	nature reserve* OR national park* AND *Cicindela sylvatica*	1	0	0	1	0	0	All Databases (within topic)
23/10/23	Google scholar	monitor* OR survey* AND *Cicindela sylvatica*	50	2	12	33	0	3	Included citations /
23/10/23	Scopus	monitor* OR survey* AND *Cicindela sylvatica*	0	0	0	0	0	0	Search within Article title, Abstract, Keywords
23/10/23	Web of Science	monitor* OR survey* AND *Cicindela sylvatica*	0	0	0	0	0	0	All Databases (within topic)
25/10/23	Google scholar	distribution OR abundance AND	50	0	2	47	0	1	Included citations

		Cicindela sylvatica							
25/10/23	Scopus	distribution OR abundance AND *Cicindela sylvatica*	1	0	0	1	0	0	Search within Article title, Abstract, Keywords
25/10/23	Web of Science	distribution OR abundance AND *Cicindela sylvatica*	4	0	0	4	0	0	All Databases (within topic)
27/10/23	Google scholar	habitat OR environment AND *Cicindela sylvatica*	50	0	0	50	0	0	Included citations
27/10/23	Scopus	habitat OR environment AND *Cicindela sylvatica*	4	0	0	4	0	0	Search within Article title, Abstract, Keywords
27/10/23	Web of Science	habitat OR environment AND *Cicindela sylvatica*	5	0	0	5	0	0	All Databases (within topic)
03/11/23	Google scholar	programme OR project AND *Cicindela sylvatica*	50	0	0	48	1	1	Included citations
03/11/23	Scopus	programme OR project AND *Cicindela sylvatica*	0	0	0	0	0	0	Search within Article title, Abstract, Keywords

03/11/23	Web of Science	programme OR project AND *Cicindela sylvatica*	0	0	0	0	0	0	All Databases (within topic)
10/11/23	JNCC	*Cicindela sylvatica*	10	0	6	0	0	4	-
10/11/23	Natural England	*Cicindela sylvatica*	25	0	11	2	0	12	-

Table 1. Table showing the date of each search, along with the search engine and search term used, how many pieces of literature were disposed of and why, how many pieces of literature were kept and any filters that were used when carrying out each search

Hand-searching was utilised, in which further references were identified within the literature. Hand-searching is a recognized tool in the systematic review process that increases the sensitivity of searches and minimizes bias, as further relevant literature can be examined and identified to make the search more comprehensive (Armstrong et al. 2005; Faggion Jr et al. 2016).

Once the records had been narrowed down (Figure 1), the relevance of each individual record was assessed with regard to the six topics of interest (i.e., life cycle, habitat requirement, distribution, reasons for change in distribution and abundance, survey methods and recommendations for habitat management). Topics for each record were marked with a 'Y' (yes) if it was mentioned within the literature and a 'N' (no) if it wasn't.

<u>Statistical tests</u>

Tests used were the independent-samples Kruskal-Wallis test and the independent-samples Mann-Whitney U test. All statistical testing was conducted using SPSS to establish whether there was a significant difference between the age of literature that mentioned the six topics as well as between literature that just mentioned distribution in comparison to those that also mentioned how this distribution had changed over time.

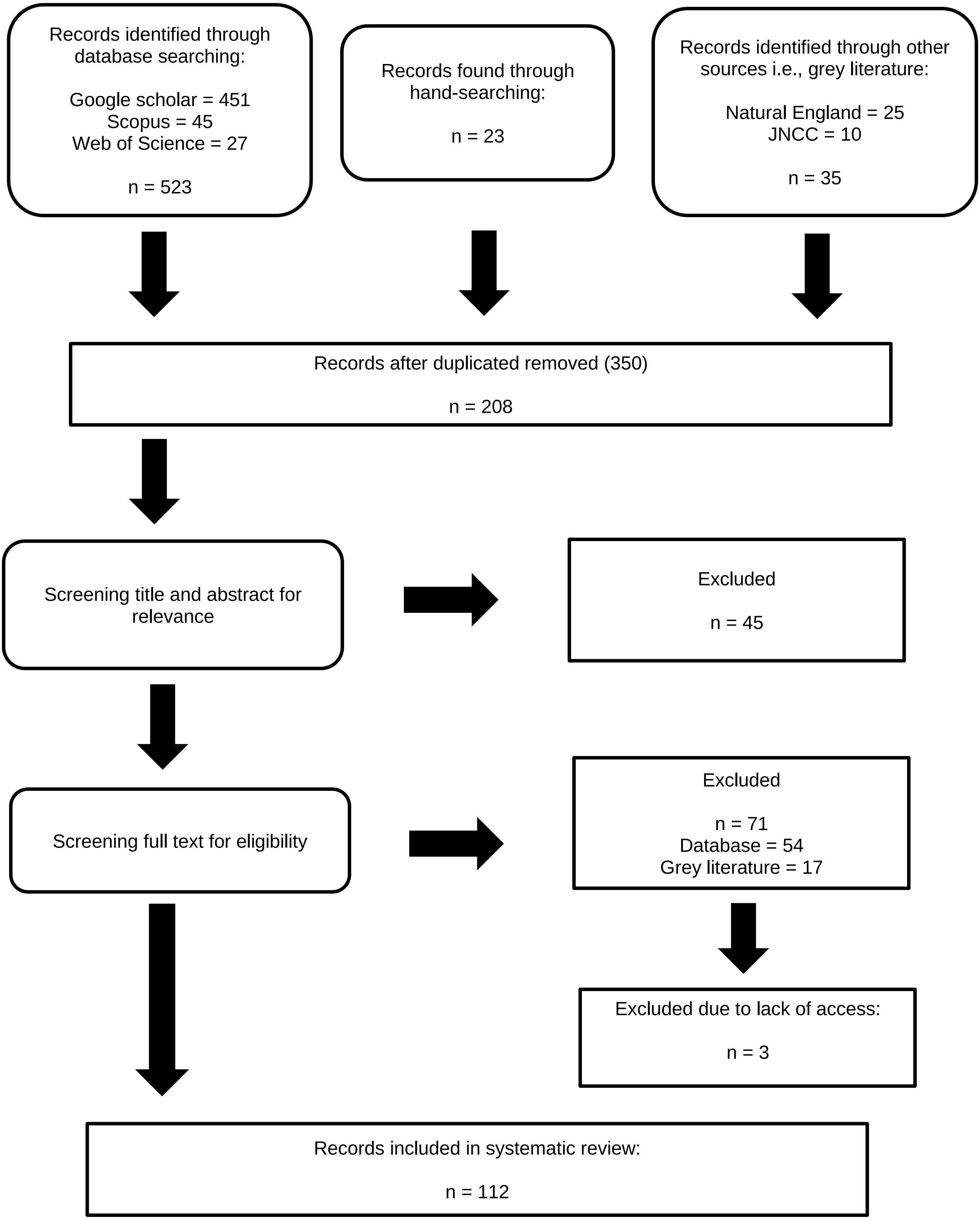

Figure 1. Flow diagram using PRISMA format to outline the systematic review process of excluding literature (Page et al. 2021)

3. Results

The study reviewed 96 pieces of literature which included journal articles, books, and conference papers, as well as 16 pieces of grey literature.

Distribution and habitat requirement were the most mentioned topics, being referred to in over 80 pieces of literature (Figure 2). This was followed by survey methods, reasons for change in distribution and abundance and recommendations for habitat management. Life cycle was the least mentioned topic, being referred to in only 13 pieces of literature.

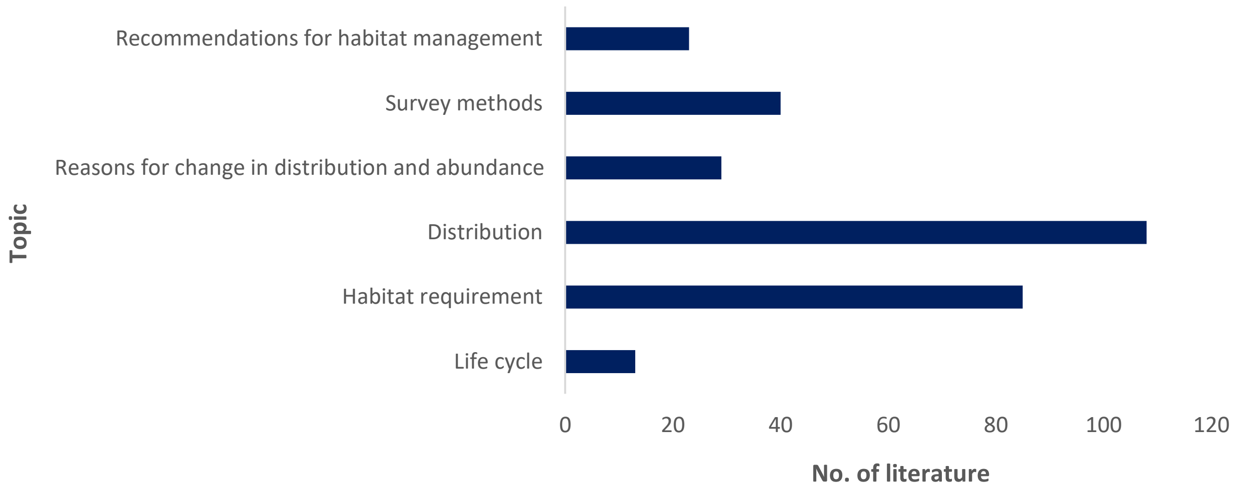

Figure 2. Total number of literature identified within the systematic review that mentioned the six topics of interest (see methods section)

The topic of discussion was examined further to ascertain whether literature also mentioned how distribution had changed over time (Figure 3). 83% of literature just mentioned distribution i.e., referred to a geographical location where C. sylvatica is thought to occur or has occurred. Only 17% of literature described how distribution had changed over time.

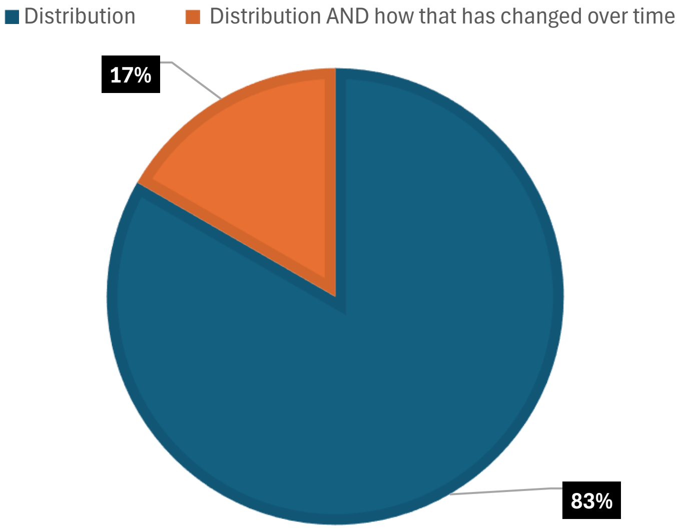

Figure 3. Percentage of literature, identified within the systematic review, that only mentioned distribution against those that also described how distribution had changed over time.

Nearly every topic was increasingly mentioned within literature over the time frame looked at within the study (Figure 4). Recommendations for habitat management had the largest percentage increase of mentions, increasing from 4 mentions within literature published in 1970-1999 to 19 mentions within literature published in 2000-2024. It was the only topic not mentioned in literature pre-1970.

Life cycle had a percentage increase in mentions from literature published pre-1970 to literature published in 1970-1999. However, it was the only topic that did not have an increase of mentions within literature published in 2000-2024.

Distribution and habitat requirement were the most mentioned topics within literature published pre-1970.

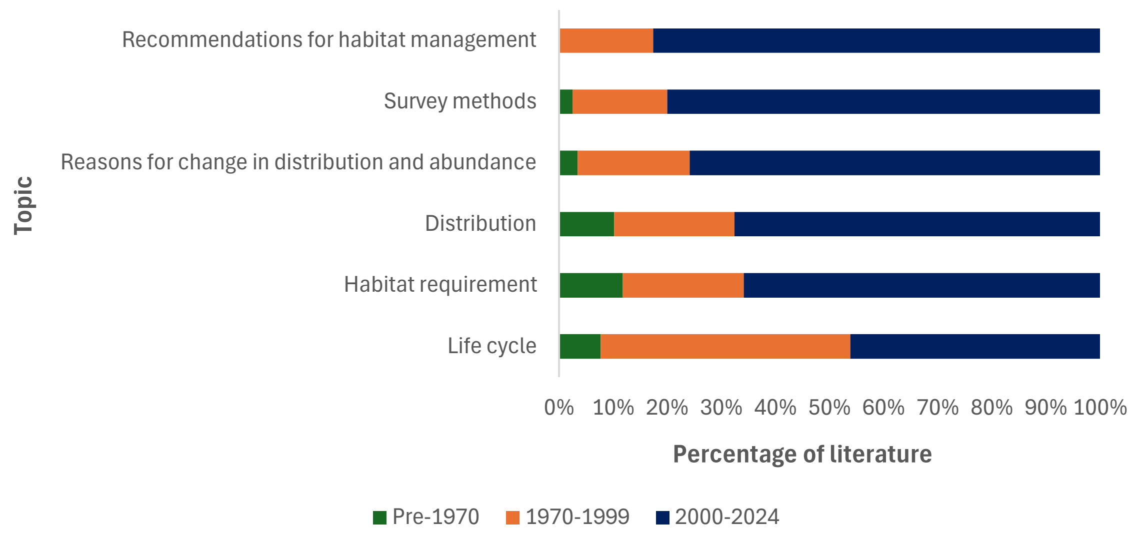

Figure 4. Percentage of literature that mentioned the topics of interest, according to the time period in which they were published (i.e., pre-1970, 1970-1999 or 2000-2024).

The age data was analysed for each of the topics. It was found that the data points were non-normally distributed. Therefore, due to this variance, the non-parametric Kruskal-Wallis test was used. There were no significant differences in the median age of papers between topics (H= 5.292, P=0.381, df = 5, n=298) (Figure 5).

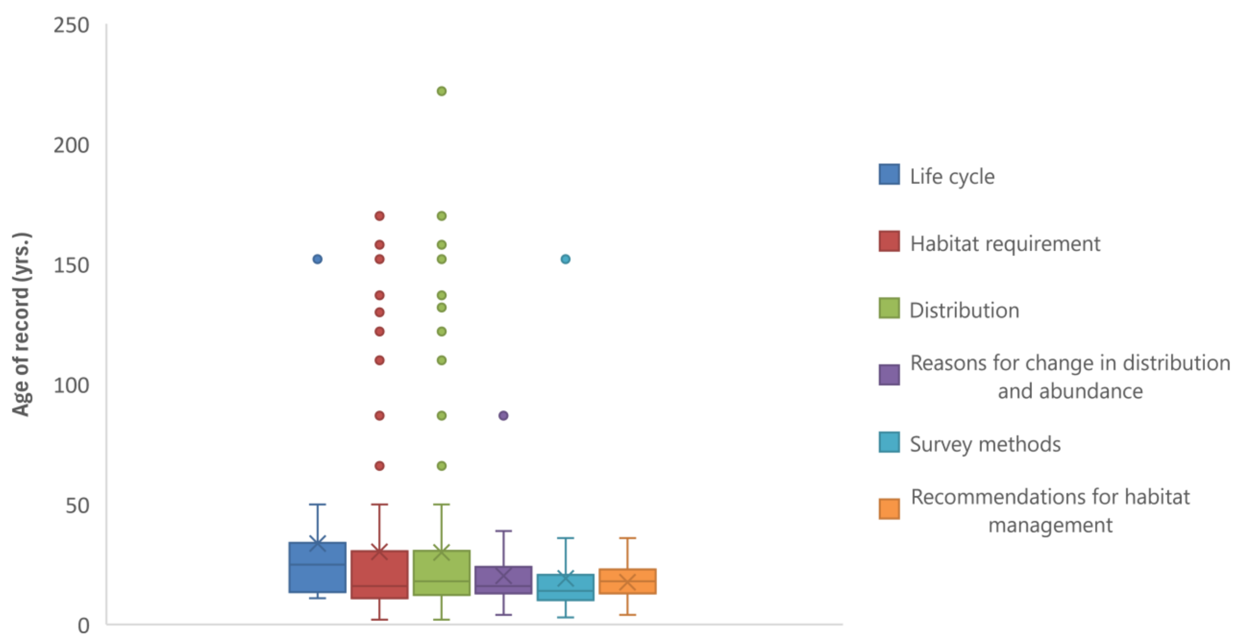

Figure 5. Box plot of data points representing literature from all six topics. There were no significant differences in the median age of papers between topics (H= 5.292, P=0.381, df = 5, n=298)

The age data was also analysed for literature that just mentioned distribution versus those that also mentioned how this had changed over time. The data points were found to be non-normally distributed, so the non-parametric Mann-Whitney U test was used. There were no significant differences in the median age of papers that mentioned distribution AND how this has changed over time compared to those that just mentioned distribution (U= 777, P=0.785, df = 1, n=108) (Figure 6).

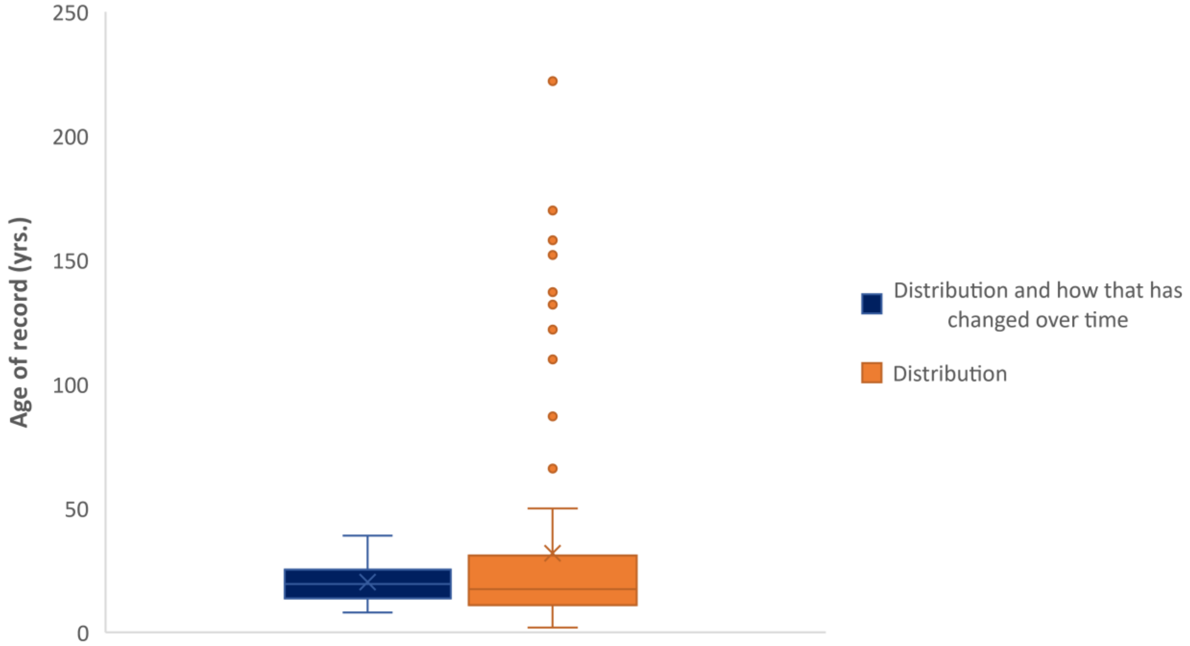

Figure 6. Box plot of data points representing literature that only mentioned distribution against those that also described how distribution had changed over time. There were no significant differences in the median age of papers (U= 777, P=0.785, df = 1, n=108)

The topics of distribution, habitat requirement and survey methods were mentioned within literature from all five geographical subregions. These subregions have been classified and defined by the UN (UN, 2012). A map was created for the results, to pinpoint the sub-regions within which C*. sylvatica* individuals had been identified in the field (Figure 7). The information was taken from literature where it was clear that C. sylvatica individuals had been sighted in the field by the author/s themselves. *C. sylvatica* individuals sighted in the field by researchers other than the author/s were not included to ensure the reliability of sources. Grey literature was also excluded from this analysis to prevent bias, as databases used were of UK origin.

Reasons for change in distribution and abundance were mentioned within literature from four geographical subregions but wasn't mentioned within literature from Central Asia. Recommendations for habitat management were mentioned within literature from three geographical subregions, with it not mentioned within literature from Eastern Europe or Central Asia. The topic of life cycle was only mentioned within literature from two geographical subregions: Southern and Western Europe.

Western and Southern Europe were the only geographical subregions to mention all six topics within their literature. Northern Europe literature mentioned five topics, with distribution and survey methods being the most mentioned. Eastern Europe literature mentioned four topics and Central Asia literature mentioned three.

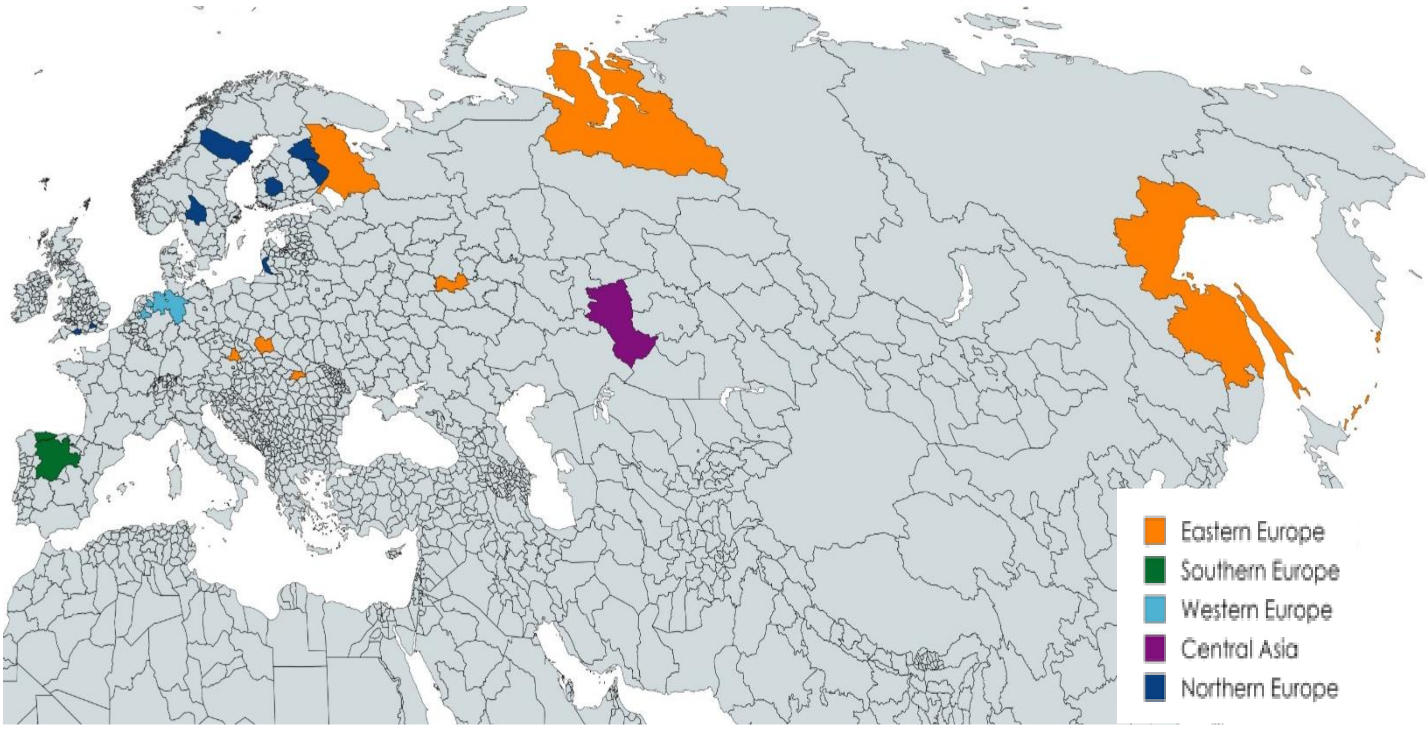

Figure 7. Study areas (shown within relevant sub-regions) within which *C. sylvatica* individuals were collected by the author/s (template from MapChart, 2024)

4. Discussion

4.1 Life cycle

Life cycle was the least mentioned topic within the systematic review. Aspects of the biology of tiger beetles have been well studied historically, including species life history (Shelford 1908; Pearson, 1988). For example, it's been discovered that the majority of tiger beetle species larvae go through the same three successive instars (developmental stages between moults) (Knisley and Pearson, 1984; Burakowski, 1993; Knisley and Schultz, 1997; Pearson and Vogler, 2001; Taboada, 2013). Furthermore, three seasonal patterns (spring, spring and fall, and summer) have been recognized based on when tiger beetle adults are active within the year (Shelford, 1908). This can group species that share similar life history traits.

C. sylvatica shares similar biology and dispersal abilities with *Cicindela campestris.* Furthermore, the pattern of occurrence of *C. sylvatica* adults throughout the year is similar to that of *C. campestris* and *C. hybrida*, suggesting that they have the same developmental cycle (Luff et al. 1993; Taboada, 2013). For example, adults within these species generally occur in spring and summer as after pupation, emerged adults overwinter in the pupal burrow before appearing (Burakowski, 1993; Luff et al. 1993; Luff 1998; Walters, 2013). Therefore, much of the information on the lifecycle of *C. sylvatica* has been informed by previous research on congeneric species. This may explain why life cycle was mentioned less than other topics within the literature, as there is already an abundance of research on the life history of tiger beetles. Furthermore, as the life history of certain tiger beetles species are similar i.e., through observed seasonal patterns, then research on one species can inform that of another. This is further highlighted by the fact that life cycle was also the only topic that didn't have an increase in mentions within literature published from 1970-1999 to 2000-2024.

The life cycle of *C. sylvatica* is generally completed within a 1–3-year period (Lindroth, 1974; Trautner and Geigenmüller, 1987; Pearson 1988; Burakowski, 1993; UKBAP, 1999; Bouwman, 2010; Boyce and Walters 2010; Taboada, 2011; Taboada, 2013; Walters, 2013). However, life cycle length can differ as growth rates and timing of diapause (overwintering stage) can vary within geographic ranges of beetle species (Butterfield, 1996; Butterfield and Coulson, 1997). For example, in North America and Europe, the emergence of adults in northern populations is typically later in the summer than for southern populations (Ashworth, 2001). Furthermore, weather conditions can also influence life cycle. During adverse weather, tiger beetle larvae are able to close their burrows and become inactive (Taboada et al. 2013), therefore increasing the length of a particular life stage. Consequently, patterns of occurrence in *C. sylvatica* adults may differ due to varying influences on their life cycle length. Further study is needed to identify potential factors that may influence this across their geographic range. The results also showed that life cycle was only mentioned within literature from Southern and Western Europe, meaning it was the least represented, geographically, of all of the topics. This further highlights the need for investigation into the life cycle of *C. sylvatica* across their geographic range.

Climate change may also cause life cycles to undergo significant transformations. Increases in temperature, due to global warming, may shift the timing of life cycle events, such as egg-laying, mating and emergence of adults (Parmesan, 2007; Fatah et al. 2023). Studies on insects indicate that warmer winter conditions can reduce the survival and fecundity of diapausing species (Irwin & Lee, 2000; Irwin and Lee, 2003; Vesterlund et al. 2014; Abarca et al. 2019). However, there may be benefits to climate change. For example, increased temperatures in winter can ease constraints on low-temperature tolerances and performance. This can lead to population increases of terrestrial ectotherms (Deutsch et al. 2008; Biella et al. 2021). Long-term research on species is required to determine a common life cycle pattern and its transformation trends (Khomitskiy et al. 2020). Therefore, long-term monitoring should be conducted on *C. sylvatica* to monitor the effects of climate change on life cycle patterns. Furthermore, as a potential bioindicator species, any changes in their life cycle duration may prompt monitoring of local environmental changes (Jaskula, 2020). This would be beneficial for the monitoring of local environmental changes in Purbeck Heaths NNR, especially as one of the primary aims of the reserve is to increase resilience to climate change and other pressures (Bridger, 2023). Monitoring has been previously undertaken within the Purbeck area, but this did not specifically focus on the species life cycle (Schofield and Liley, 2002).

Only 2 out of the 13 pieces of literature that mentioned life cycle related the topic to conservation. Prior studies have been conducted on the life history, developmental effects, and physiology of tiger beetles (Shelford, 1908; Palmer, 1981; Pearson and Knisley, 1985). This research has been utilised in the past to plan captive rearing methods to reintroduce the endangered *Ellipsoptera nevadica lincolniana* and *Ellipsoptera puritana* into suitable sites in the US (Gwiazdowski et al. 2011). However, in regard to *C. sylvatica*, further research is needed. Boyce and Walters (2010) suggested further investigations into their ecology in relation to their life cycle. This includes looking at egg laying sites and larval ecology to inform habitat management and future reintroductions.

The species recovery trust and Sparsholt college have recently set up a reintroduction project for *C. sylvatica*. They plan to run a captive breeding program to breed large numbers of individuals for reintroduction (Carne, 2021). Due to their abundance and similar life history, the program first decided to focus on breeding a pair of *C. campestris* individuals in 2020. The project has seemingly been a success as fourteen *C. campestris* adults emerged in 2023 (Sparsholt College, 2023). The knowledge that has been gained from the project so far, such as ideal egg laying sites and soil choices, can now be used to successfully captive breed *C. sylvatica*. Within the systematic review, there appears to be an 11-year gap without any further investigations into the life cycle of *C. sylvatica*, as the topic was not mentioned in literature after 2013. However, if the research from this project is published, then the insights gained, as originally suggested by Boyce and Walters (2010), could be utilized to reintroduce *C. sylvatica* into suitable sites in Dorset to expand their distribution and strengthen existing populations in the Purbeck Heaths NNR.

4.2 Habitat requirement

Tiger beetles are a group of long-standing fascination with entomologists (Gwiazdowski et al. 2020). Much of the early research on tiger beetles has been conducted through hours of observations and documentation of field notes on the species and their environment (Shelford, 1907; Shelford, 1908; Vaurie, 1950), which might explain why habitat requirement was the most mentioned topic within literature published pre-1970. This continued fascination has generated further research on tiger beetle species (Gough et al. 2019), highlighting their status as a bioindicator and flagship group for conservation due to their narrow habitat preferences (Jaskula, 2011). This may explain why habitat requirement was one of the most mentioned topics within the literature overall. Furthermore, multiple detailed studies from different regions have highlighted the narrow habitat specialization of tiger beetle species (Jaskula, 2011). This may explain why habitat requirement was one of the most geographically represented topics as it was mentioned within literature from all five subregions.

C. sylvatica is generally characterized as a stenotopic species of lowland heathland habitat (hence their common name of heath tiger beetle) (Dawson, 1854; Wood, 1872; Fowler and Donisthorpe, 1887; Hoffman, 1897; Hall, 1914; Lindroth, 1974; Harde, 1984; Lindroth, 1985; Desender et al. 1989; Else, 1993; Vermeulen et al. 1994; Hůrka 1996; Telfer and Eversham, 1996; Bullock and Pakeman, 1997; Luff, 1998; Telfer and Eversham, 2000; Lake et al. 2001; Sutton and Browne, 2001; Boyce, 2004; Vermeulen and Spee, 2005; Cuesta et al. 2006; Webb et al. 2010a; Webb et al. 2010b; Webb et al. 2010c; Lowen et al. 2009; Bouwman, 2010; Boyce and Walters 2010; Eggers et al. 2010; Taboada, 2010; Dodd, 2011; Taboada et al. 2011; Taboada et al. 2012; Morán-Ordóñez et al. 2013; Walters, 2013; Alonso et al. 2018; Brock and Allen, 2022). Localities within lowland heathland habitat of *C. sylvatica* include tracks, firebreaks and bare ground created by military training activities (Boyce and Walters, 2010; Telfer, 2016). *C. sylvatica* is also associated with forest/heathland habitat i.e., within open or thin pine heath forests (Lindroth, 1974; UKBAP, 1999; Sutton and Browne, 2001; Berglind, 2004), and strictly forest habitat within their geographic range (e.g., beech, coniferous (larch), pine forests) (Mandl, 1937; Székessy, 1958; Niemelä et al. 1988; Spanton, 1988; Burakowski, 1993; Den Boer and Van Dijk, 1994; Lafer et al. 1997; Gongalsky et al. 2006; Merkl, 2008; Mordkovich et al. 2008; Dudko et al. 2010; Siepel et al. 2010; Jaskula, 2011; Noordijk, 2011; Venn et al. 2015; Heikkala, 2016; Tsuji et al. 2016; Ruchin et al. 2019; Hägglund et al. 2020; Kanarsky, 2021; Putchkov et al. 2021; Ruchin et al. 2021; Stan and Serafim, 2021; Serafim and Stan, 2022). Other habitat types include young fallow land (Rulyova et al. 2020), isolated mountain massifs (Cassola, 1999), brownfield sites (i.e., old quarries) (Webb et al. 2010b; Webb et al. 2010c), and open seashore habitats (e.g., drift sands, brown dunes, inland sand dunes) (Hengeveld, 1985; Turin and Den Boer, 1988; Ferenca, 2014).

Whilst these habitats vary, they share similar characteristics that have enabled *C. sylvatica* to successfully inhabit them. For example, many of the habitats mentioned are young or early successional (Niemelä et al. 1988; Mordkovich et al. 2008; Siepel et al. 2010; Rulyova et al. 2020), meaning that the environment is open due to recent disturbance. *C. sylvatica* are known to be associated with open, early successional vegetation (Alonso et al. 2018). Bare ground provides a sun-exposed surface for both adults and larvae to attain a higher body temperature to effectively hunt invertebrate prey (Pearson, 1988; Key, 2000; Lake et al. 2001; Schofield and Liley, 2002; Offer et al. 2003; Boyce and Walters, 2010), and creates suitable habitat for larvae to dig their burrows (Pearson, 1988; Schofield and Liley, 2002; Offer et al. 2003; Dunford, 2010). Furthermore, *C. sylvatica* individuals have shown a preference to slopes that face the sun, further indicating that the species prefers warmer areas within the areas that they were found (Schofield and Liley, 2002).

C. sylvatica are described as a psamophile (Kanarsky, 2021), as they prefer sandy substrates (i.e., sand, sandy soils) (Dawson, 1854; Rye, 1866; Wood, 1872; Fowler and Donisthorpe, 1887; Kappel and Kirby, 1892; Furneaux, 1894; Hall, 1914; Mandl, 1937; Lindroth, 1974; Harde, 1984; Lindroth, 1985; Hengeveld, 1985; Falk, 1991; Else, 1993; Den Boer and Van Dijk, 1994; Luff, 1998; UKBAP, 1999; Telfer and Eversham, 2000; Lake et al. 2001; Sutton and Browne, 2001; Schofield and Liley, 2002; Berglind, 2004; Boyce, 2004; Vermeulen and Spee, 2005; Webb et al. 2010a; Webb et al. 2010b; Bouwman, 2010; Boyce & Walters 2010; Taboada 2010; Taboada et al. 2011; Dodd, 2011; Jaskula, 2011; Walters, 2013; Telfer, 2016); Resl, 2021; Brock and Allen, 2022; Serafim and Stan, 2022). Sandy patches warm up quickly in the spring and summer and therefore provide good basking opportunities for invertebrates (McCracken, 2009).

Fires are an ecological process that have shown to be important for species that are dependent on early successional habitat, especially in forested landscapes (Farrell et al. 2017). Ruchin et al. (2019) found that the dynamic density of *C. sylvatica* largely increased after crown fire impact within the forested areas of the Mordovia state nature reserve, in comparison to areas that were unburned or had light surface burns. It's thought that a reduction in vegetation, the thinning of forests and creation of open habitat enabled the species to inhabit these forest ecosystems. Nijssen et al. (2013)

found large numbers of *C. sylvatica* within a burnt area, after the second year of a wildfire in the Netherlands in 2010. The largest part of the burned forest developed into dry heathland, with sparse patches of pine and birch forest, making it a suitable habitat for *C. sylvatica*. Individuals were also identified in young burnt pine forest sites in Western Siberia. The species were found to dominate this area of vegetation within the years of the study (1999-2002), after it underwent a strong fire ten years prior, due to the abundance of open bright-lit bare sand areas (Mordkovich et al. 2008).

Patches of vegetation are also important for tiger beetle species as they can provide protection and shelter to tiger beetle adults from predators and adverse weather (Hori, 1982). *C. sylvatica* is associated with heathland mosaics (Vermeulen and Spee, 2005), and have previously been observed in areas characterized by bare ground in combination with dense vegetation (Taboada et al. 2013). Furthermore, adjacent mature heather is thought to be an important aspect of the species habitat, as adults have often been observed flying into patches of tall heather when disturbed (Boyce and Walters, 2010). Lowland heathland, in favorable condition, should ideally have heath vegetation of varying structure and height (Alonso et al. 2018). *C. sylvatica* have also been observed in forest habitat, which supports a wide range of vegetation. However, the species is generally associated with open clearings, roads, paths and the edges of the forest (Hoffman, 1897; Székessy, 1958; Niemelä et al. 1988; Burakowski, 1993; Den Boer and Van Dijk, 1994; UKBAP, 1999; Sutton and Browne, 2001; Siepel et al. 2010; Noordijk, 2011; Venn et al. 2015; Tsuji et al. 2016). Open habitat insect species have shown to be previously reluctant to enter forests (Vermeulen 1994b; Schmitt et al. 2000; Fried et al. 2005; Samways & Sharratt 2010) as they can act as barriers to suitable habitat (Noordijk et al. 2011). However, edges of forest can be beneficial for heliophilic and xerophilic species, such as *C. sylvatica*, as they are exposed to more sunlight and therefore drier conditions (Venn et al. 2015).

Microhabitat characteristics such as soil, shade, salinity, vegetation cover and moisture are also important when investigating species habitat requirements, as they are deciding factors in tiger beetle oviposition site choice (Shelford 1908; Knisley 1987; Schultz 1989; Hoback et al. 2000; Romey and Knisley 2002; Cornelisse and Hafernik 2009). Soil compaction is an important microhabitat characteristic in determining tiger beetle oviposition site choice (Cornelisse and Hafernik, 2009).

However, knowledge on soil compaction preference for *C. sylvatica* within the literature appears contradictory. Webb et al. (2010a) and Webb et al. (2010b) state that *C. sylvatica* prefers friable (loose) sandy soil, whereas Telfer (2016) states that the species prefers compact sandy soil. A moderate to high level of soil compaction is thought to indicate higher habitat quality for some tiger beetle species (Knisely, 2011), but can be detrimental to others (Cornelisse and Hafernik, 2009). In addition, some species are unaffected by soil compaction, as larvae burrows have been found on both types (Cornelisse et al. 2012). As *C. sylvatica* has association with both types, then they too could be unaffected as a species.

Whilst the general habitat requirements of *C. sylvatica* are known throughout its distribution, further study should be conducted to determine the impacts of microhabitat characteristics such as soil compaction on *C. sylvatica* oviposition site choice. This may also benefit Sparsholt college's reintroduction programme as site conditions can be optimized for future translocations of *C. sylvatica* larvae, including within the Purbeck Heaths NNR. The use of habitat suitability modelling to map suitable habitat within the reserve would be beneficial for both adults and larvae. A similar model was used by Taboada et al. (2013), to look at the relation of the presence/abundance of adults and larvae to abiotic and biotic variables. Web-based remote sensing tools (i.e., Google Earth and Microsoft TerraServer) could be a cost-effective method for a preliminary investigation into suitable habitat (Mawdsley, 2008). However, this method is not suitable for detecting micro-habitats due to their smaller scale. Therefore, field observations may be more accurate.

4.3 Distribution

Distribution was the most mentioned topic, as nearly all of the literature mentioned *C. sylvatica* in combination with a geographic location (i.e., a specific country or region). From the literature, it's known that *C. sylvatica* has a wide geographic range across parts of East, South, West and North Europe and Central Asia, with isolated subspecies in northern Spain and northern Turkey (Cassola, 1999; Serrano, 2003, Serrano et al. 2003; Boyce and Walters, 2010).

Tiger beetles are generally thought to exist within a metapopulation structure (Knisley et al. 2005). This has been observed in *C. sylvatica* in a previous study (Dodd, 2011). During a survey by Dutch Butterfly Conservation of the National Park Drent-Friese

Wold in 2009, individuals of *C. sylvatica* were found for the first time at the heathland Aekingerzand. The population was found at a location with small sand dunes with Calluna vulgaris and open sand (Bouwman, 2010). A further example of this was observed in 2011, when *C. sylvatica* was recorded in the Steppe zone of Ukraine for the first time (Putchkov et al. 2021). Within the species range in England, individuals were also recorded in the Burley area of the New Forest in March 2003 (Brock and Allen, 2022). This was after it was mentioned in a report published in 2004 that no colonies of *C. sylvatica* had been found in the New Forest, despite repeated searches of its historic sites (Boyce, 2004). These findings shows that *C. sylvatica* can be present in very small numbers and can easily be overlooked. This highlights the need for further surveys to be conducted outside of the species known geographic range, as the presence of rare or cryptic species can often be missed (Loehle, 2020). Furthermore, mapping the areas in which species used to inhabit can also be beneficial to identify their historical range (Taylor et al. 2017). For example, historical range data can be utilised for identifying areas to reintroduce species. The mapping of areas wherein C. sylvatica individuals are no longer found in Purbeck Heaths NNR can be utilised in a positive way by identifying these areas as future reintroduction sites (Figure 8).

The topic of discussion was examined further in the results. It was found that 83% of literature just mentioned distribution i.e., referred to a geographical location whereas only 17% of literature described how distribution had changed over time. Distribution data is useful as it could be utilized within a species distribution model for *C. sylvatica,* to predict how current species distributions are likely to change as a response to climate change (Massimino et al. 2017). Although, environmental data is also needed to assess the relationship between environmental conditions and species occurrences. However, species distribution is dynamic, not static. Meaning that it will change with time over multiple spatial scales (Real et al. 2017). Furthermore, this change can be exacerbated by factors such as climate change, which can cause shifts in species distribution patterns, leading to shifts in range and even local extinction (Brown et al. 2016). Therefore, the species may not be found in certain areas that they have been observed in historically.

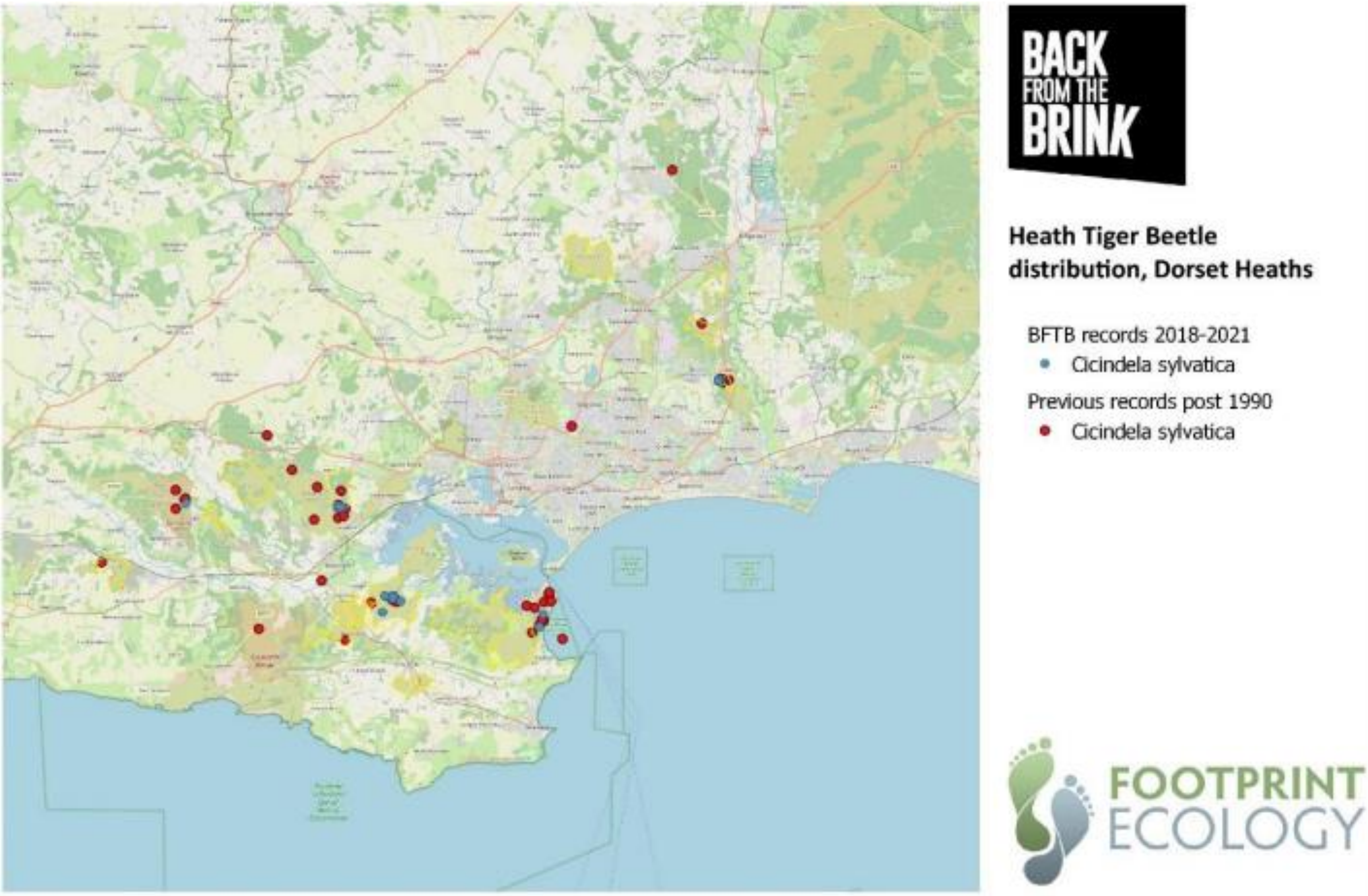

Figure 8. Distribution records for *C. sylvatica* within Dorset heathland. Red dots show previous records post 1990 and blue dots show Back From The Brink records between 2018-2021 (previous records supplied by Dorset Environmental Records Centre) (Howorth, 2022). This map could be utilised in locating suitable reintroduction sites for *C. sylvatica*.

4.4 Reasons for change in distribution and abundance

A rise in global anthropogenically driven environmental changes means that predicting how the distribution and abundance of species will respond to these changes is crucial (Ehrlén and Morris, 2015). As historical records of tiger beetles are extensive in multiple areas, scientists have attempted to distinguish the primary causes of changes in distribution and abundance (i.e., anthropogenic impact on habitat or 'natural' range contractions/expansions associated with climate change) and to document ongoing trends (Pearson and Wiesner, 2023). This may explain why reasons for change in distribution and abundance was increasingly mentioned within literature over the time frame looked at within the study.

Burnt habitat has been shown to increase the abundance of *C. sylvatica* (Cuesta et al.

2006; Gongalsky et al. 2006; Nijssen et al. 2013; Heikkala, 2016; Ruchin et al. 2019; Hägglund et al. 2020). However, *C. sylvatica* was not identified in any alternative plots (i.e., control plots or other treatment types) in any of the studies. Therefore, it's unknown whether fire had an impact on local species distribution. Other treatments that have been shown to increase the abundance of *C. sylvatica* include the long-term nitrogen fertilization of heathland plots (see recommendations for habitat management for further detail). However, as individuals were not captured within the control plots or other treatment types, then it's unknown as to whether this impacted local species distribution (Cuesta et al. 2008)

The rate at which newly available habitat, beyond a species' existing range, is colonized will depend upon dispersal (Travis and Dytham, 2012). *C. sylvatica* is thought to exhibit limited powers of dispersal (Dodd, 2011). However, distance between two populations has been observed over a greater distance, meaning that *C. sylvatica* may be capable of dispersing further (Dodd, 2011). A similar study could be conducted within the Purbeck Heaths NNR to assess the dispersal power of *C. sylvatica* within its range. Further study should also be conducted across the species geographical range to determine the effects of fire on the distribution of *C. sylvatica*, and whether the availability of new suitable habitat is a trigger for longer-range dispersal. Reasons for change in distribution and abundance was mentioned within literature from four geographical subregions but wasn't mentioned within literature from Central Asia. Therefore, this should be a priority study region.

Within Europe, *C. sylvatica* has decreased in abundance across its distribution in the Netherlands and is thought to have disappeared from the Dutch province of Drenthe since 1969. Before 1930, *C. sylvatica* was relatively common in a central part of the Netherlands. This area consisted of vast stretches of blown sand, opening up plentiful habitat for the species. However, during the 1930s, the area was planted with pine trees, after which *C. sylvatica* was only found occasionally and in scattered locations (Hengeveld, 1985). In regard to the disappearance of *C. sylvatica* from Drenthe, it's thought that the primary reason for the species decline was the loss of a large part of its hunting habitat due to the overgrowth of mosses (Vermeulen and Spee, 2005). Furthermore, habitat quality is thought to have decreased throughout the Netherlands during the second half of the 20th century. Air pollution increased acidification and eutrophication of the upper soil layers, replacing *Calluna* and *Erica* with grasses, triggering habitat fragmentation (Den Boer and Van Dijk, 1994; Vermeulen and Spee, 2005; Kotze et al. 2011). This meant that populations became isolated from each other, making recolonization after local extinction difficult.

This isolation may have been exacerbated for *C. sylvatica* due to their metapopulation structure. Hullenzand heath is also very small (less than 4 ha) so the area may not have been able to maintain viable populations (Den Boer and Van Dijk, 1994). It has been debated whether climate change may have had an impact on *C. sylvatica* abundance in the Netherlands. Records have shown that climate did not change significantly when *C. sylvatica* first disappeared from pitfall catches within Drenthe in 1969 (Kotze et al. 2011). Therefore, it's likely that changes in the environment and habitat fragmentation (in the case of Hullenzand and Mantingerveld) was the primary cause of their decline. Despite this decline, *C. sylvatica* has still been found in certain areas of the Netherlands (i.e., Da Haere heathland nature reserve) (Noordijk et al. 2008; Noordijk, 2011). As well as the Netherlands, *C. sylvatica* has also decreased in abundance within areas of Denmark, Belgium and Luxembourg since 1950. Desender et al. (1989) found that carabid species associated with heath vegetation decreased in these areas primarily due to loss of suitable habitat.

Within England, post-1970 records of *C. sylvatica* are very sparse and the species appears to have been lost from formerly known sites. This is thought to be the result of the loss of its heathland habitat to intensive agriculture, forestry or development (De Vries 1996; UKBAP, 1999; Lake et al. 2001; Sutton and Browne, 2001; Boyce, 2004b). For example, *C. sylvatica* was only recorded in Manton Common, Lincolnshire up to 1926, after which most of the common was ploughed for agriculture (Key, 1993). Furthermore, a lack of traditional management (i.e., grazing or burning) has prevented the creation of suitable bare ground habitat and has led to scrub invasion (UKBAP, 1999; Lake et al. 2001; Sutton and Browne, 2001; Boyce, 2004a; Boyce, 2004b; Boyce and Walters, 2010). This lack of bare ground means that populations have become isolated due to separation by land which is unsuitable for their dispersal (Dodd, 2011; Telfer, 2016). This includes major roads, urban areas, conifer plantations and secondary woodland (Telfer, 2016).

Taboada et al. (2011) found that the distribution of *C. sylvatica reiseri* has decreased over time in northern Spain due to similar factors i.e., the loss of heathland habitat and the afforestation and invasion of open heathland by grasses and shrubs due to inappropriate management. However, it is also thought that increasing temperature and drought due to climate change may impact the range restricted populations of *C. sylvatica reiseri.* For example, if Calluna heathlands in the region become extinct then this may force the expansion of the species to higher latitudes. Under climate change, species have been shown to shift their range towards higher latitudes in search of suitable climatic conditions (Stephens et al. 2016).

Various characteristics have been shown to affect species potential to shift their ranges. Species that show a higher dispersal capacity, reproductive rate and degree of ecological generalization are generally more likely to be able to colonize new suitable habitat (Lehikoinen, 2021). *C. sylvatica* has been shown to have a lower dispersal ability, low reproductive rate (due to their lengthy life cycle) and high ecological specialization. Therefore, the species may struggle to colonize new suitable habitat. However, an expansion in the geographic range of *C. sylvatica* has been observed in the past. For example, individuals were identified near the Dzhazator River within the South Eastern Altai, an area in which they are uncharacteristic. The species was thought to have travelled from their position in the Central Altai (an area in which they are characteristic) due to the presence of larch forest (Dudko et al. 2010). *C. sylvatica* was also recorded for the first time in the Steppe zone of Ukraine in 2011, which may indicate a possible expansion of natural distribution (Putchkov et al. 2021).

4.5 Survey methods

60% of studies within the literature captured *C. sylvatica* adults using pitfall traps, including studies wherein *C. sylvatica* was not the target species. It was therefore the most popular method of sampling. Variations of pitfall traps included a ‘widened’ pitfall trap which consisted of two plastic cups with a one-meter iron fence in between. This was utilised so more individuals could be captured (Vermeulen et al.1994). 50% of the pitfall traps used lethal methods to capture and preserve specimens (Den Boer and Van Dijk, 1994; Cuesta et al. 2006; Cuesta et al. 2006; Cuesta et al. 2008; Gongalsky et al. 2006; Noordijk et al. 2008; Purchart et al. 2010; Heikkala, 2016; Ruchin et al. 2019. Preserving agents used included formalin solution, propylene glycol, alcohol and detergent, and a mixture of water, salt and detergent. 27.78% of studies didn’t specify what happened to the specimens after capture (Niemelä et al. 1988; Turin and Den Boer, 1988; Vermeulen et al. 1994; Lafer et al. 1997; Vermeulen and Spee, 2005), and the remaining 22.22% used non-fatal pitfall traps so specimens were released after live capture (Eggers et al. 2010; Dodd, 2011; Taboada et al. 2012; Taboada et al. 2013). Lethal window traps (aka flight intercept traps) were also used (Noordijk, 2011; Hägglund et al. 2020), and water traps (Berglind, 2004). Window traps can be highly effective at capturing large numbers of flying taxa, especially forest beetles (Bouget et al. 2008; Allison and Redak, 2017).

Entomological research, even with a conservation focus, frequently uses lethal methods (Lövei and Ferrante, 2024). However, sampling lethally, on a large scale, can lead to abundance declines, especially in rare taxa (Minteer et al. 2014). Since the arthropod conservation field has grown (Eggleton, 2020), there has been a larger emphasis on the utilization of non-lethal sampling methods (Lövei and Ferrante, 2024). Pitfall traps are a cost-effective method commonly used for surveying ground-dwelling arthropods (Hohbein and Conway, 2018). However, the use of non-fatal pitfall traps have previously produced low capture rates of *Cicindela* (Samu and Sarospatake, 1995; Eggers et al. 2010; Dodd, 2011). This is thought to be because of the species ability to exit the trap using vertical take-off flight (Taboada, 2012). In 2011, Taboada et al. (2012) trialed and tested suitable techniques for the live trapping of tiger beetle species *C. sylvatica* and *C. campestris*. They found that the Inverted_Medium trap design, which consisted of a large plastic cup containing an inverted medium-sized plastic cup, was the most successful alternative sampling technique for capturing adult tiger beetles alive. This trap design was then utilised in a later study (Taboada et al. 2013).

In regard to *C. sylvatica*, other non-lethal methods of sampling included the utilization of entomological nets and visual surveys (transects, point counts, observation). Visual surveys are beneficial as they allow for monitoring with little or no disturbance. However, care needs to be taken to walk at a steady, slow pace on transects, to ensure that disturbance is minimized. This reduces the risk of double counting individuals as beetles are not flushed out and pushed along the transect (Schofield and Liley, 2002). Therefore, point counts are deemed slightly more efficient as there is less chance of reencountering individuals (Schofield and Liley, 2002).

Hand-netting is thought to be the most common technique for capturing tiger beetles (Pearson and Vogler, 2001). It has been a successful surveying method for capturing tiger beetles in the past, with one study capturing 90 tiger beetles via hand netting whereas only 8 were captured within pitfall traps (Dowd et al. 2007). However, the effectiveness of hand netting has also proven to be relatively low, due to the beetle's ability to exit traps using vertical take-off flight (Dodd, 2011), Effectiveness is likely to increase through a greater survey effort and/or a larger number of surveyors, but this funding dependent (Dodd, 2011).

In regard to the other literature, 11 mentioned capturing C. sylvatica individuals but did not specify which survey methods were used. 3 mentioned survey methods, but these weren't specific to C. sylvatica. Methods were also described in regard to sampling larvae. This included the use of quadrats to survey beetle larvae (Taboada et al. 2013). As *C. sylvatica* appear to spend the entirety of their life cycle within the same location, the use of quadrats as a sampling method may be beneficial to map larvae burrows once they have been observed. First, second and third larval instars can be determined by measuring the diameter of burrow openings, as this correlates to the size of the species head and prothorax (Hori 1982; Takeuchi and Hori, 2007; Taboada, 2013).

Additionally, the use of grass stalks was recommended to dig larvae out of their burrows (Wood, 1872). However, the latter is an outdated method as invasive techniques such as this can disrupt the fragile larval habitat (Harvey et al. 2011). This was also the only survey method mentioned in literature published pre-1970. It's thought that the earliest reference to pitfall trapping in the field was made by Hertz (1927). Therefore, it's surprising that the use of this sampling method in regard to C. *sylvatica* was not mentioned before 1970, especially as it was the most dominant method used within the literature. However, its use as a method for sampling a larger community of species only became prominent from the 1970s onward. Authors such as Baars (1979) utilised the technique over a longer period, so the data collected was representative of the actual abundance.

Almost all of the studies conducted were not specifically focused on *C. sylvatica* as a target species so sampling methods used were not specific to the species. However, the data from the literature is useful in knowing which methods may produce higher capture rates of *C. sylvatica*. In regard to the Purbeck Heaths NNR, The Inverted_Medium trap design, designed by Taboada et al. (2012) may be a more successful technique at capturing individuals live. The use of lethal sampling methods should ideally not be used in conjunction with *C. sylvatica* due to its rarity and status in England (Hyman and Parsons, 1992; Key, 2000).

4.6 Recommendations for habitat management

The field of conservation has evolved from primarily focusing on natural history and observational field studies to a more data-driven multidisciplinary field that is focused on applied environmental issues (Anderson et al. 2021). The scientific field of conservation biology emerged in the mid-1980's (Meine, 2010), in response to increasing knowledge of the natural world and expanding human demands. It primarily focuses on protecting and preserving biodiversity by integrating conservation policy with theories from fields such as ecology and taxonomy, which has direct implications for species and habitat management (Gerber, 2010). This change from studying species on an observational basis to utilizing the research for conservation efforts likely underpins why recommendations for habitat management also had the largest percentage increase of mentions within the literature from 1970-1999 to 2000-2024. Furthermore, conservation biology literature has been largely dominated by problem-based studies that aim to understand the main anthropogenic drivers associated with biodiversity and decline. However, the frequency of solution-based studies, those that are designed to propose, evaluate and implement solutions to environmental issues, have shown to be more frequent from 1980 to 2019 (Fonseca et al. 2021). This may explain why the topic wasn't mentioned in literature pre-1970. This further highlights an increase in efforts, over time, to understand how to conserve species, including the management of their habitats. However, it was the second least mentioned topic, most likely because of this recent shift in attitude.

There was a common theme within recommendations for habitat management which was the creation of bare ground, predominantly via traditional methods such as cutting or prescribed burning. Past studies have utilised controlled (also known as prescribed) burning as a habitat management technique, which in turn have increased the abundance of *C. sylvatica.* For example, Cuesta et al. (2006) found that the number of

C. sylvatica reiseri increased after controlled burning within the Calluna heathlands of the Cantabrian mountain range. It's thought that the creation of new, open habitat combined with an increase in prey i.e., springtails (*Collembola*) within the burned plots, contributed to this. Furthermore, a study conducted in Gravberget, Norway found that *C. sylvatica* was the most characteristic species of burned clear-cut plots (completely cleared of trees), as opposed to those that were burned but selectively cut, those burned with uncut standing forest (typical forest of the region), and unburned forest plots (Gongalsky et al. 2006). Restoration burning was also trialed in stands of boreal forest within Sweden in 2012 (Hägglund et al. 2020). *C. sylvatica* individuals were not found within the area before restoration burning was conducted, indicating that the removal of vegetation via burning within these areas benefited the species. Prescribed burning was also conducted within a boreal forest in eastern Finland in 2002. *C. sylvatica* were only present in areas that had been managed by prescribed burning. The study found that overall ground beetles had a good tolerance to disturbance. Therefore, species, such as *C. sylvatica* may benefit from frequent use of prescribed fire, possibly because this maintains open and sunny ground and field layer (Heikkala, 2016).

Cuesta et al. (2008) looked at the effects of nitrogen fertilization on arthropods associated with *Calluna vulgaris* heathlands in north-west Spain. They found *C. sylvatica reiseri* individuals within areas that had been fertilized with nitrogen for a period of 15 months. *C. sylvatica reiseri* had not been observed in the area before the treatment started, raising questions as to how the effects of nitrogen may have explained their appearance. In the case of carabid beetles, an increase in the flowering of *C. vulgaris* may have resulted in greater seed production, indirectly benefiting granivorous species. However, as *C. sylvatica* is a predatory beetle, with no evidence of alternative feeding behaviors (see Jaskula, 2015), it's unlikely that this was reason enough for the observed increase. A more likely explanation may be that nitrogen fertilization resulted in an abundance of prey species such as *Collembola* due to an increase in food quality for herbivores (Sjursen et al. 2005).

The creation of purpose-made 'scrapes' has increased suitable habitat for *C. sylvatica* (Howorth, 2022). Artificial scrapes are created by scraping the ground free of vegetation, creating suitable bare ground habitat. *C. sylvatica* individuals have been recorded on new scrapes at multiple sites (e.g., Slepe Heath, Sopley Heath and Great Ovens) (Howorth, 2022), suggesting that the creation of sandy scrapes has been successful for the species. However, due to a lack of adequate baseline data, it has been difficult to assess whether the scrapes have led to a species recovery at population level. The refreshing of existing scrapes appears to be unsuitable due to the longer life cycle of *C. sylvatica*. Therefore, the creation of replacement scrapes is ongoing within these sites (Howorth, 2022). Cornelisse et al. (2013) recommended that scrape plots be created every two years to maintain bare ground and to ensure usage by female *Cicindela ohlone* as oviposition sites (as the species life cycle is approx. 1-2 years). As the life cycle of *C. sylvatica* can last up to three years, the creation of scrape plots should ideally match this. A regular monitoring programme has also been recommended, to assess its ongoing effectiveness. Furthermore, its implementation into Purbeck Heaths NNR may be less disruptive to the surrounding habitat in comparison to burning or experimental fertilisation treatment.

5. Conclusion

Overall, the distribution and habitat requirements of *C. sylvatica* were the most mentioned topics within the systematic review whereas recommendations for habitat management, reasons for change in distribution and abundance and survey methods weren't mentioned as frequently. This suggests that research on *C. sylvatica* has evolved from primarily focusing on observational field studies to more data-driven scientific studies that are linked to how environmental changes are impacting species conservation. Life cycle was the least mentioned topic for *C. sylvatica*. This is likely to be because *C. sylvatica* is known to share a similar life history to congeneric species, reducing the need for further research. Suggested future monitoring includes use of the Inverted_Medium trap design to survey adults within Purbeck Heaths NNR and the use of less invasive techniques to map larval burrows (i.e., quadrats). Research on larval ecology from the recent captive breeding of *C. campestris* may prove invaluable in the reintroduction of *C. sylvatica* individuals. General habitat requirements of the species are known but further research is needed to assess the impacts of microhabitat characteristics on adults and larvae, especially if reintroductions are to be successful.

6. References

Abarca, M., Larsen, E.A. and Ries, L., 2019. Heatwaves and novel host consumption increase overwinter mortality of an imperiled wetland butterfly. *Frontiers in Ecology and Evolution*, **7**, 193.

Allison, J.D. and Redak, R.A., 2017. The impact of trap type and design features on survey and detection of bark and woodboring beetles and their associates: a review and meta-analysis. *Annual Review of Entomology*, **62**, 127-146.

Alonso, I., Curson, J., Cox, J. and Drewitt, A., 2018. *Appendix E – Lowland Heathlands*. Natural England.

Anderson, S.C., Elsen, P.R., Hughes, B.B., Tonietto, R.K., Bletz, M.C., Gill, D.A., Holgerson, M.A., Kuebbing, S.E., McDonough MacKenzie, C., Meek, M.H. and Veríssimo, D., 2021. Trends in ecology and conservation over eight decades. *Frontiers in Ecology and the Environment*, **19**(5), 274-282.

Armstrong, R., Jackson, N., Doyle, J., Waters, E. and Howes, F., 2005. It's in your hands: the value of handsearching in conducting systematic reviews of public health interventions. *Journal of public health*, **27**(4), 388-391.

Ashworth, A. C., 2001, Chapter 8: Perspectives on Quaternary Beetles and Climate Change. *In (L. C. Gerhard, W. E. Harrison, and B. M. Hanson, eds.), Geological Perspectives of Global Climate Change.* American Association of Petroleum Geologists Studies in Geology #47. 153- 168)

Avgin, S. and Özdikmen, H., 2007. Checklist of the Tiger Beetles of Turkey with a review of distribution and biogeography (Coleoptera: Cicindelidae). *Munis Entomology and Zoology*, **2**(1), 87-102.

Baars, M.A., 1979. Catches in pitfall traps in relation to mean densities of carabid beetles. *Oecologia*, **41**,.25-46.

Barševskis A., Cibuļskis R., Shavrin A., Anichtchenko A., Valainis U., Balalaikins M., Vorobjova I. and Litvinceva J., 2012. Faunistic records of the beetles (Hexapoda: Coleoptera) in Latvia. 4. *Acta Biol. Univ. Daugavp*.,**12**(4), 85-117.

Berglind, S.Å., 2004. Area-Sensitivity of the Sand Lizard and Spider Wasps in Sandy Pine Heath Forests: Umbrella Species for Early Successional Biodiversity Conservation? *Ecological Bulletins*, 189-207.

Biella, P., Ćetković, A., Gogala, A., Neumayer, J., Sárospataki, M., Šima, P. and Smetana, V., 2021. Northwestward range expansion of the bumblebee Bombus haematurus into Central Europe is associated with warmer winters and niche conservatism. *Insect Science*, **28**(3), 861-872.

Biesmeijer, J.C., Roberts, S.P., Reemer, M., Ohlemuller, R., Edwards, M., Peeters, T., Schaffers, A.P., Potts, S.G., Kleukers, R.J.M.C., Thomas, C.D. and Settele, J., 2006. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science*, **313**(5785), 351-354.

Bouget, C., Brustel, H., Brin, A. and Noblecourt, T., 2008. Sampling saproxylic beetles with window flight traps: methodological insights. *Revue D'écologie,* (suppl. n° 10), p-21.

Bouwman, J., 2010. The forest sand ground beetle, *Cicindela sylvatica* (Coleoptera: Carabidae), has been found again in Drenthe after almost 40 years. *Entomological Messages,* **70**(1), 7-9.

Boyce, 2004a. *Scarce Ground Beetle Project: Final Report on work 2000-2004*. Natural England. *ENSRP1255 (Part 1).*

Boyce, 2004b. *Scarce Ground Beetle Project: Final Report on work 2000-2004*. Natural England. *ENSRP1255 (Part 5).*

Boyce, D. and Walters, J. 2010. *A review of the Biodiversity Action Plan Tiger-beetles: Cliff Tiger-beetle Cicindela germanica, Northern Dune Tiger-beetle Cicindela hybrida and Heath Tiger-beetle Cicindela sylvatica.* Peterborough: Buglife.

Bridger, M.A., 2023*. Effectiveness of UK Legislation and Management in Producing*

Nature Conservation Outcomes: A Case Study of the Purbeck Heaths (Doctoral dissertation, Bournemouth University).

Brock, P.D. and Allen, A.J., 2022. An overview of Coleoptera of the New Forest, Hampshire. *The Coleopterist*, **31**(2), 66-91

Brown, C.J., O'Connor, M.I., Poloczanska, E.S., Schoeman, D.S., Buckley, L.B., Burrows, M.T., Duarte, C.M., Halpern, B.S., Pandolfi, J.M., Parmesan, C. and Richardson, A.J., 2016. Ecological and methodological drivers of species' distribution and phenology responses to climate change. *Global change biology***, 22**(4), 1548-1560.

Brown, J.H., 1984. On the relationship between abundance and distribution of species. *The American naturalist*, **124**(2), 255-279.

Brown, J.H., 1995. Macroecology. University of Chicago Press.

Buchholz, S., Hannig, K. and Schirmel, J., 2013. Losing uniqueness–shifts in carabid species composition during dry grassland and heathland succession. *Animal Conservation*, **16**(6), 661-670.

Bullock, J.M. and Pakeman, R.J., 1997. Grazing of lowland heath in England: management methods and their effects on heathland vegetation. *Biological Conservation*, 79(1),.1-13.

Burakowski, B., 1993. Laboratory methods for rearing soil beetles (Coleoptera). *Memorabilia Zoologica*, **46**.

Butterfield, J., 1996. Carabid life-cycle strategies and climate change: a study on an altitude transect. *Ecological entomology*, **21**(1), 9-16.

Butterfield, J.E. and Coulson, J.C., 1997. Terrestrial invertebrates and climate change: physiological and life-cycle adaptations. *In Past and future rapid environmental changes: the spatial and evolutionary responses of terrestrial biota* (401-412). Berlin, Heidelberg: Springer Berlin Heidelberg.

Calosi, P., Bilton, D.T., Spicer, J.I., Votier, S.C. and Atfield, A., 2010. What determines a species' geographical range? Thermal biology and latitudinal range size relationships in European diving beetles (Coleoptera: Dytiscidae). *Journal of Animal Ecology*, **79**(1), 194-204.

Calvo, L., Alonso, I., Fernández, A.J. and De Luis, E., 2005. Short-term study of effects of fertilisation and cutting treatments on the vegetation dynamics of mountain heathlands in Spain. *Plant Ecology*, **179**, 181-191.

Cameron, K., 2010. *Barely manageable: the relationship between bare ground patch size and carabid biodiversity on a heathland* (Doctoral dissertation, Department of Life Sciences, Silwood Park, Imperial College London).

Carne, 2021. *HEATH TIGER BEETLES: Species Status Report 2020*. Species Recovery Trust.

Carrara, E., Arroyo-Rodríguez, V., Vega-Rivera, J.H., Schondube, J.E., de Freitas, S.M. and Fahrig, L., 2015. Impact of landscape composition and configuration on forest specialist and generalist bird species in the fragmented Lacandona rainforest, Mexico. *Biological Conservation*, **184**, 117-126.

Cassola, F. and Jaskuła, R., 2004. Materials to the knowledge of the tiger beetles of Romania (Coleoptera: Cicindelidae). *Polskie Pismo Entomologiczne*, **73**(3),193-214.

Cassola, F., 1970. Ecologia, distribuzione geografica e subspeciazione di Cicindela (Taenidia) circumdata Dej. *Bolletino dell'Associazione Romana di Entomologia*, **25**(3), 59-70.

Cassola, F., 1999. Studies on tiger beetles. CVII. The cicindelid fauna of Anatolia: faunistics and biogeography (Coleoptera, Cicindelidae). *Biogeographia–The Journal of Integrative Biogeography*, **20**(1).

Chichorro, F., Juslén, A. and Cardoso, P., 2019. A review of the relation between species traits and extinction risk. *Biological Conservation*, **237**, 220-229.

Clavel, J., Julliard, R. and Devictor, V., 2011. Worldwide decline of specialist species: toward a global functional homogenization? *Frontiers in Ecology and the Environment*, **9**(4), 222-228.

Colles, A., Liow, L.H. and Prinzing, A., 2009. Are specialists at risk under environmental change? Neoecological, paleoecological and phylogenetic approaches. *Ecology letters*, **12**(8), 849-863.

Convocatoria de ayudas para investigacion postdoctoral, Leuphana Universität

Cornelisse, T.M. and Hafernik, J.E., 2009. Effects of soil characteristics and human disturbance on tiger beetle oviposition. *Ecological Entomology*, **34**(4), 495-503.

Cornelisse, T.M., Vasey, M.C., Holl, K.D. and Letourneau, D.K., 2013. Artificial bare patches increase habitat for the endangered Ohlone tiger beetle (Cicindela ohlone). *Journal of Insect Conservation*, **17**, 17-22.

Cuesta, D., Taboada, A., Calvo, L. and Salgado, J., 2006. A preliminary investigation of ground beetle (Coleoptera: Carabidae) assemblages and vegetation community structure in Calluna vulgaris heathlands in NW Spain. *Entomologica Fennica*, **17**(3), 241-252.

Cuesta, D., Taboada, A., Calvo, L. and Salgado, J.M., 2006. Short-term effects of fire on arthropods in Calluna-heathlands in NW Spain. *Forest Ecology and Management*, **234**(1), S186.

Cuesta, D., Taboada, A., Calvo, L. and Salgado, J.M., 2008. Short-and medium-term effects of experimental nitrogen fertilization on arthropods associated with Calluna vulgaris heathlands in north-west Spain. *Environmental Pollution*, **152**(2), 394-402.

Davidson, N.C., 2018. European tidal saltmarshes. In The wetland book II: Distribution, description, and conservation. *Springer*, 959-972.

Davison, M.A. and Fitzpatrick, J.W., 2010. Role of human-modified habitat in protecting specialist species: A case study in the threatened Florida Scrub-Jay. *Biological Conservation*, **143**(11), 2815-2822.

Dawson, J.F., 1854. *Geodephaga Britannica: A Monograph of the Carnivorous Ground-beetles Indigenous to the British Isles.* J. Van Voorst.

den Boer, P.J. and Van Dijk, T.S., 1994. *Carabid beetles in a changing environment (No. 94-6).* Wageningen Agricultural University.

Desender, K. and Turin, H., 1989. Loss of habitats and changes in the composition of the ground and tiger beetle fauna in four West European countries since 1950 (Coleoptera: Carabidae, Cicindelidae). *Biological Conservation*, **48**(4), 277-294.

Deutsch, C.A., Tewksbury, J.J., Huey, R.B., Sheldon, K.S., Ghalambor, C.K., Haak, D.C. and Martin, P.R., 2008. Impacts of climate warming on terrestrial ectotherms across latitude. *Proceedings of the National Academy of Sciences*, **105**(18),.6668-

6672.

Dodd, S.G., 2011. Population size and dispersal of the Tiger Beetles Cicindela sylvatica Linnaeus, 1758 (Heath Tiger Beetle) and Cicindela campestris Linnaeus, 1758 (Green Tiger Beetle) (Coleoptera: Carabidae: Cicindelinae) within a Surrey heathland mosaic. Master of Science Dissertation. *University of Birmingham*.

Donovan, T.M. and Flather, C.H., 2002. Relationships among North American songbird trends, habitat fragmentation, and landscape occupancy*. Ecological Applications*, **12**(2), 364-374.

Dorset Wildlife Trust, 2023. Green tiger beetle. Dorset Wildlife Trust. Available from: Green tiger beetle | Dorset Wildlife Trust [Accessed 15/04/2024].

Dowd, L., Ballester, A., Singler, C., Metzger, M. and Green, T., 2007. *A Comparison of Efficacies of Pitfall Trapping to Netting of Tiger Beetles*. Brookhaven National Laboratory: United States.

Dreisig, H., 1981. The rate of predation and its temperature dependence in a tiger beetle, Cicindela hybrida. *Oikos*, 196-202.

Dudko, R.Y., Matalin, A.V. and Fedorenko, D.N., 2010. The ground beetle fauna (Coleoptera, Carabidae) of southeastern Altai. *Entomological Review*, **90**, 968-988.

Dunford, 2010. *Species Management Sheet: Heath Tiger Beetle*. Buglife.

Duran, D.P., 2010. *Speciation and diversification in the North American tiger beetles of the Cicindela sylvatica group: Morphological variation and an ecophylogeographic approach.* Vanderbilt University.

Duran, D.P., Laroche, R.A., Roman, S.J., Godwin, W., Herrmann, D.P., Bull, E. and Egan, S.P., 2024. Species delimitation, discovery and conservation in a tiger beetle species complex despite discordant genetic data. *Scientific Reports*, **14**(1), 6617.

Eggers, B., Matern, A., Drees, C., Eggers, J., Haerdtle, W. and Assmann, T., 2010. Value of semi-open corridors for simultaneously connecting open and wooded habitats: a case study with ground beetles. *Conservation Biology*, **24**(1), 256-266.

Eggleton, P., 2020. The state of the world's insects. *Annual Review of Environment and Resources*, **45**, 61-82.

Egorov, L.V., Ruchin, A.B., Semenov, V.B., Semionenkov, O.I. and Semishin, G.B., 2020. Checklist of the Coleoptera of Mordovia State Nature Reserve, Russia. *ZooKeys*, **962**,13.

Ehrlén, J. and Morris, W.F., 2015. Predicting changes in the distribution and abundance of species under environmental change. *Ecology letters*, **18**(3), 303-314.

Else, G.R., 1993. The distribution and habitat requirements of the tiger beetle Cicindela germanica Linnaeus (Coleoptera: Carabidae) in southern Britain. British *Journal of Entomology and Natural History*, **6**(1), 17-21

Faggion Jr, C.M., Wu, Y.C., Tu, Y.K. and Wasiak, J., 2016. Quality of search strategies reported in systematic reviews published in stereotactic radiosurgery. *The British Journal of Radiology*, **89**(1062), 20150878.

Falk, S., 1991. *A review of the scarce and threatened bees, wasps and ants of Great Britain (Vol. 35)*. Peterborough: Nature Conservancy Council.

Farrell, C.E., Wilson, S. and Mitchell, G., 2017. Assessing the relative use of clearcuts, burned stands, and wetlands as breeding habitat for two declining aerial insectivores in the boreal forest. *Forest Ecology and Management*, 386, 62-70.

Fatah, A.M.A., Zalat, S., Elbanna, S.M., Al-Khalaf, A.A. and Nasser, M., 2023. Climate Change and the Dung Beetle: Evaluation of Global Warming Impact on the Distribution of Phyllognathus excavatus (Forster, 1771) through the Mediterranean Region. *Applied Sciences*, **13**(22), 12107.

Ferenca, R., 2014. Beetle (Insecta, Coleoptera) fauna and its distribution in seashore habitats of Lithuania. Doctoral Dissertation, *Vilnius University Nature Research Centre.*

Fonseca, C.R., Paterno, G.B., Guadagnin, D.L., Venticinque, E.M., Overbeck, G.E., Ganade, G., Metzger, J.P., Kollmann, J., Sauer, J., Cardoso, M.Z. and Lopes, P.F., 2021. Conservation biology: four decades of problem-and solution-based research. *Perspectives in Ecology and Conservation*, **19**(2), 121-130.

Fowler, W.W. and Donisthorpe, H.S.J.K., 1887. *The Coleoptera of the British islands: A descriptive account of the families, genera, and species indigenous to Great Britain and Ireland, with notes as to localities, habitats, etc.* (Volume 1) London, L. Reeve &

co

Fowler, W.W. and Donisthorpe, H.S.J.K., 1913. The Coleoptera of the British islands: a descriptive account of the families, genera, and species indigenous to Great Britain and Ireland, with notes as to localities, habitats, etc. (Volume 6) London, L. Reeve & co

Freitag, R., 1979. Reclassification, phylogeny and zoogeography of the Austallian species of Cicindela (Coleoptera: Cicindelidae). *Australian Journal of Zoology Supplementary Series*, **27**(66), 1-99.

Fuller, R., Marshall, M., Eversham, B., Wilkinson, P. and Wright, K., 2016. The increasing importance of monitoring wildlife responses to habitat management. *British Wildlife*, **27**, 175-186.

Furneaux, W.S., 1894. *The out-door world, or Young collector's handbook*. Longmans, Green.

Futuyma, D.J. and Moreno, G., 1988. The evolution of ecological specialization. *Annual review of Ecology and Systematics*, **19**(1), 207-233.

Gerber, L. 2010. Conservation Biology. *Nature Education Knowledge*, **3**(10),14

Gimingham, C.H.,1972. *Ecology of Heathlands*. Chapman & Hall, London.

Gongalsky, K., Midtgaard, F. and Overgaard, H., 2006. Effects of prescribed forest burning on carabid beetles (Coleoptera: Carabidae): a case study in south-eastern Norway. *Entomologica Fennica*, **17**(3), 325-333.

Gough, H.M., Duran, D.P., Kawahara, A.Y. and Toussaint, E.F., 2019. A comprehensive molecular phylogeny of tiger beetles (Coleoptera, Carabidae, Cicindelinae). *Systematic Entomology*, **44**(2), 305-321.

GOV.UK, 2020. *UK's first 'super' National Nature Reserve created on Purbeck Heaths*. GOV.UK.

Greenberg, C.H., Collins, B., Thompson, F.R. and McNab, W.H., 2011. Introduction: What are early successional habitats, why are they important, and how can they be sustained? *Sustaining young forest communities: Ecology and management of early successional habitats in the Central Hardwood Region, USA*, 1-10.

Guppy, M., Guppy, S. and Hebrard, J., 1983. Behaviour of the riverine tiger beetle Lophyridia dongalensis imperatrix: effect of water availability on thermoregulatory strategy. *Entomologia experimentalis et applicata*, **33**(3), 276-282.

Gwiazdowski, R.A., Andersen, J.C., Knisley, C.B., Griffin, B.P. and Elkinton, J.S., 2020. First account of phylogeographic variation, larval characters, and laboratory rearing of the endangered cobblestone tiger beetle Cicindelidia marginipennis, Dejean, 1831 with observations of their natural history. *Insects*, **11**(10), 708.

Gwiazdowski, R.A., Gillespie, S., Weddle, R. and Elkinton, J.S., 2011. Laboratory rearing of common and endangered species of North American tiger beetles (Coleoptera: Carabidae: Cicindelinae). *Annals of the Entomological Society of America*, **104**(3), 534-542.

Hägglund, R., Dynesius, M., Löfroth, T., Olsson, J., Roberge, J.M. and Hjältén, J., 2020. Restoration measures emulating natural disturbances alter beetle assemblages in boreal forest. *Forest ecology and management*, **462**, 117934.

Hall, C.A., 1914. *Common British Beetles* (Vol. 12). A. and C. Black.

Hanski, I., 2011. Habitat loss, the dynamics of biodiversity, and a perspective on conservation. *Ambio*, **40**(3), 248-255.

Harde, W.K., 1984. *A field guide in colour to beetles*. London: Octopus Books.

Harrold, J., 2020*. Northern Dune Tiger Beetle species information guide*. Back From the Brink.

Harvey, D.J., Hawes, C.J., Gange, A.C., Finch, P., Chesmore, D. and Farr, I.A.N., 2011. Development of non-invasive monitoring methods for larvae and adults of the stag beetle, Lucanus cervus. *Insect Conservation and Diversity*, **4**(1), 4-14.

Heikkala, O., 2016. Emulation of natural disturbances and the maintenance of biodiversity in managed boreal forests: the effects of prescribed fire and retention forestry on insect assemblages. *Dissertationes Forestales*, **222**, 1-46.

Hengeveld, R., 1985. Dynamics of Dutch beetle species during the twentieth century (Coleoptera, Carabidae). *Journal of Biogeography*, 389-411.

Herrera-Russert, J., López-López, A., Serrano, J., Cordero-Rivera, A. and Galián, J.,

2021. First population estimates of the vulnerable southeast Iberian endemic tiger beetle Cephalota (Taenidia) deserticoloides. *Insect Conservation and Diversity*, **14**(6), 793-799.

Hertz, M., 1927. Huomioita petokuoriaisten olinpaikoista. *Luonnon Ystävä*, **31**(218-222).

Hoback, W.W., Golick, D.A., Svatos, T.M., Spomer, S.M. and Higley, L.G., 2000. Salinity and shade preferences result in ovipositional differences between sympatric tiger beetle species. *Ecological Entomology*, **25**(2), 180-187.

Hofmann, E., 1897. *The Young Beetle-collector's Handbook*. S. Sonnenschein.

Hohbein, R.R. and Conway, C.J., 2018. Pitfall traps: A review of methods for estimating arthropod abundance. *Wildlife Society Bulletin*, **42**(4), 597-606.

Howorth, 2022. *Back from the Brink – Species summary: Heath Tiger Beetle*. Plantlife.

Hristovski, S., Mihajlova, B. and Guéorguiev, B., 2016. Review of the ground beetles (Coleoptera, Carabidae) from Macedonia in the collection of the Macedonian Museum of Natural History. Anniversary Proceedings (1926 – 2016). *Mac. Mus. Nat. Hist*, 21-51.

Hurka, K., 1996. *Carabidae of the Czech and Slovak republics*. Ing. Vit Kabourek, 565.

Hyvärinen, E., 2006. Green-tree retention and controlled burning in restoration and conservation of beetle diversity in boreal forests. *Dissertationes Forestales*, **21**, 55.

IPBES, 2019. *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat: Bonn, Germany.

Irwin, J.T. and Lee Jr, R.E., 2000. Mild winter temperatures reduce survival and potential fecundity of the goldenrod gall fly, Eurosta solidaginis (Diptera: Tephritidae). *Journal of Insect Physiology*, **46**(5), 655-661.

Irwin, J.T. and Lee, Jr, R.E., 2003. Cold winter microenvironments conserve energy and improve overwintering survival and potential fecundity of the goldenrod gall fly, Eurosta solidaginis. *Oikos*, **100**(1), 71-78.

Isbell, F., Balvanera, P., Mori, A.S., He, J.S., Bullock, J.M., Regmi, G.R., Seabloom, E.W., Ferrier, S., Sala, O.E., Guerrero-Ramírez, N.R. and Tavella, J., 2023. Expert perspectives on global biodiversity loss and its drivers and impacts on people. *Frontiers in Ecology and the Environment*, **21**(2), 94-103.

IUCN, 2023. IUCN Red List. IUCN. Available from: IUCN Red List of Threatened Species [15/04/2024]

Jaskuła, R., 2011. How unique is the tiger beetle fauna (Coleoptera, Cicindelidae) of the Balkan Peninsula? *ZooKeys*, (100), 487.

Jaskuła, R., 2015. The Maghreb–one more important biodiversity hot spot for tiger beetle fauna (Coleoptera, Carabidae, Cicindelinae) in the Mediterranean region. *ZooKeys*, (482), 35.

Jaskula, R., 2015. Unexpected vegetarian feeding behaviour of a predatory tiger beetle *Calomera littoralis nemoralis* (Olivier, 1790) (Coleoptera: Cicindelidae). *Journal of the Entomological Research Society*, **17**(2), 1-6.

Jaskuła, R., Peśić, V. and Pavicević, D., 2005. Remarks on distribution and diversity of the tiger beetle fauna of Montenegro (Coleoptera: Cicindelidae). *Fragmenta Funistica*, **4**(1),15-25.

Jaskuła, R., Płóciennik, M. and Schwerk, A., 2019. From climate zone to microhabitat—environmental factors affecting the coastal distribution of tiger beetles (Coleoptera: Cicindelidae) in the south-eastern European biodiversity hotspot. *PeerJ*, **7**, 6676.

JNCC, 2020. *UK Terrestrial & Freshwater Habitat Types: Lowland Heathland Habitat descriptions.* United Kingdom: JNCC.

Julliard, R., Jiguet, F. and Couvet, D., 2004. Common birds facing global changes: what makes a species at risk? *Global Change Biology*, **10**(1),148-154.

Kanarsky, Y., 2021. *Ground beetles (Coleoptera, Carabidae) of the Pivnichne Podillia National Nature Park (Ukraine). Part I: Cicindelinae, Omophroninae, Nebriinae, Elaphrinae, and Carabinae. GEO&BIO*, **21**,185–195

Kappel, A.W. and Kirby, W.E., 1892. *Beetles, Butterflies, Moths, and Other Insects: A Brief Introduction to Their Collection and Preservation*. Cassell.

Kashevarov, B.N., 2003. Beetles of the Nature Reserve Friendship and their monitoring. *Biodiversity and conservation of boreal nature//The Finnish environment*, **485**, 202-205.

Key, R., 1993. Coleoptera recording in Lincolnshire – vice-counties 53 and 54 – a history and the current position. In *The Coleopterist* (eds Mendel, H), 2, 49-53.

Key, R., 2000. Bare ground and the conservation of invertebrates. *British Wildlife*, **11**(3), 183-191.

Khomitskiy, E., Zamotajlov, A., Beliy, A., Esipenko, L. and Balakhnina, I., 2020. *Revisiting the study of the life cycles of predatory ground beetles (Coleoptera, Carabidae) in the agrolandscape of the foothill zone of Krasnodar Krai.* In BIO Web of Conferences (Vol. **21**, 00009). EDP Sciences.

King, D.I. and Schlossberg, S., 2014. Synthesis of the conservation value of the early-successional stage in forests of eastern North America. *Forest Ecology and Management*, **324**, 186-195.

Knisley, C.B. and Gwiazdowski, R., 2021. Conservation strategies for protecting tiger beetles and their habitats in the United States: Studies with listed species (Coleoptera: Carabidae: Cicindelidae). *Annals of the Entomological Society of America*, **114**(3), 293-301.

Knisley, C.B. and Hill, J.M., 1992. Effects of habitat change from ecological succession and human impact on tiger beetles. *Virginia Journal of Science*, **43**(1), 133-142.

Knisley, C.B. and Pearson, D.L., 1984. Biosystematics of larval tiger beetles of the Sulphur Springs Valley, Arizona. Descriptions of species and a review of larval characters for Cicindela (Coleoptera: Cicindelidae). *Transactions of the American Entomological Society*, 465-551.

Knisley, C.B. and Schultz, T.D., 1997. *The biology of tiger beetles and a guide to the species of the South Atlantic States (No. 5).* McDonald and Woodward Publishing Company.

Knisley, C.B., 1987. Habitats, food resources, and natural enemies of a community of larval Cicindela in southeastern Arizona (Coleoptera: Cicindelidae). *Canadian Journal* *of Zoology*, **65**(5), 1191-1200.

Knisley, C.B., 2011. Anthropogenic disturbances and rare tiger beetle habitats: benefits, risks, and implications for conservation. *Terrestrial Arthropod Reviews*, **4**(1), 41-61.

Knisley, C.B., Hill, J.M. and Scherer, A.M., 2005. Translocation of threatened tiger beetle Cicindela dorsalis dorsalis (Coleoptera: Cicindelidae) to Sandy hook, New Jersey. *Annals of the Entomological Society of America*, **98**(4),552-557.

Knisley, C.B., Kippenhan, M. and Brzoska, D., 2014. Conservation status of United States tiger beetles. *Terrestrial Arthropod Reviews*, **7(**2-4), 93-145.

Koshkin, E.S., Rogatnykh, D.Y. and Bezborodov, V.G., 2016. Ground beetles (Coleoptera: Carabidae) of the Bureinskii State Nature Reserve, Khabarovskii Krai, Russia. *Euroasian Entomological Journal*, **15**(4), 309-318.

Kotze, D.J., Brandmayr, P., Casale, A., Dauffy-Richard, E., Dekoninck, W., Koivula, M.J., Lövei, G.L., Mossakowski, D., Noordijk, J., Paarmann, W. and Pizzolotto, R., 2011. Forty years of carabid beetle research in Europe–from taxonomy, biology, ecology and population studies to bioindication, habitat assessment and conservation. *ZooKeys*, (100), 55.

Kryzhanovskiĭ, O.L., 1995. *A checklist of the ground-beetles of Russia and adjacent lands (Insecta, Coleoptera, Carabidae) (No. 3).* Pensoft publishers.

Lafer, G.S., Nilsson, A. and Kholin, S.K., 1997. Additional records and new synonyms of Cicindelidae and Carabidae (Coleoptera) from the Island of Sakhalin in the Russian Far East. *Entomologica Fennica*, **8**(1), 13-17.

Lake, S., Bullock, J.M. and Hartley, S., 2001. *Impacts of livestock grazing on lowland heathland: English Nature Research Reports*. Natural England. 422.

Legge, S., Robinson, N., Lindenmayer, D., Scheele, B., Southwell, D. and Wintle, B. eds., 2018. *Monitoring threatened species and ecological communities*. CSIRO publishing.

Lehikoinen, A., 2021. Climate and land use changes: repeatability of range and abundance changes in two European countries. *Ornis Fennica*, **98**, 1-15.

Leśniak, A., 1987. Zoogeographical analysis of the Carabidae (Coleoptera) of Poland. *Fragmenta Faunistica*, **30**(17), 297-312.

Lindroth, C.H. 1985., *The Carabidae (Coleoptera) of Fennoscandia and Denmark (Fauna Entomologica Scandinavica).* Leiden: Scandinavian Science Press Ltd.

Lindroth, C.H., 1974. *Handbooks for the identification of British insects. Coleoptera, Carabidae.* Royal Entomological Society of London.

Lisa, T., Gourvés, J., Camard, A. and Coffin, D., 2002. Le cicindele d'Italia. *Association Roussillonnaise d'Entomologie.*

Loehle, C., 2020. Quantifying species' geographic range changes: conceptual and statistical issues. *Ecosphere*, **11**(3), e03070.

Lövei, G.L. and Ferrante, M., 2024. The Use and Prospects of Nonlethal Methods in Entomology. *Annual Review of Entomology*, **69**,183-198.

Lowen, J., Liley, D., Underhill-Day, J. and Whitehouse, A., 2009. *Scientific research into the effects of access on nature conservation: Part 2: access on bicycle and horseback.* Natural England. NECR013.

Luff, M.L. and Duff, A.G., 2002. Checklist of beetles of the British Isles: Carabidae. Available from: The Coleopterist - Checklist of Beetles of the British Isles, Carabidae [13/04/2024]

Luff, M.L. and Larsson, S.G., 1993. *The Carabidae (Coleoptera) Larvae of Fennoscandia and Denmark* (Vol. 27). Brill.

Luff, M.L., 1998. Provisional atlas of the ground beetles (Coleoptera, Carabidae) of Britain. *Biological Records Centre Institute of Terrestrial Ecology.*

Lüneburg.

Machtinger, E., 2007. *Early Successional Habitat Introduction*. NRCS/ WHC Fish and Wildlife Habitat Management Leaflet.

Mandl, K., 1937. Cicindela silvatica L. und ihre Rassen. *Kol. Rdschau*, **23**,136-140.

MapChart, 2024. World Map: Subdivisions. MapChart. Available from: World Map - Subdivisions | MapChart [02/11/2024]

Marsham, T., 1802. *Entomologia britannica: sistens insecta Britanniæ indigena, secundum methodum Linnæanam disposita (Vol. 1).* prostat venalis apud J. White.

Massimino, D., Johnston, A., Gillings, S., Jiguet, F. and Pearce-Higgins, J.W., 2017. Projected reductions in climatic suitability for vulnerable British birds. *Climatic Change*, **145**, 117-130.

Mawdsley, J.R. and Sithole, H., 2008. Dry season ecology of riverine tiger beetles in Kruger National Park, South Africa. *African Journal of Ecology*, **46**(2), 126-131.

Mawdsley, J.R. and Sithole, H., 2009. Natural history of the African riverine tiger beetle Chaetodera regalis (Dejean) (Coleoptera: Cicindelidae). *Journal of Natural History*, **43**(31-32), 1891-1908.

Mawdsley, J.R., 2008. Use of simple remote sensing tools to expedite surveys for rare tiger beetles (Insecta: Coleoptera: Cicindelidae). *Journal of insect conservation*, **12**, 689-693.

McCracken, D.I., 2009. Machair invertebrates: the importance of ‘mosaiciness’. *The Glasgow Naturalist*. **25**, 29-30.

McKinney, M.L., 1997. Extinction vulnerability and selectivity: combining ecological and paleontological views. *Annual review of ecology and systematics*, **28**(1), 495-516.

Meine, C., 2010. Conservation biology: past and present. *Conservation biology for all*, **1**, 7-26.

Merkl, O., 2008. Data to the knowledge on the beetle fauna of Maramureş, Romania (Coleoptera). *Studia Universitatis Vasile Goldis Seria Stiintele Vietii (Life Sciences Series),* **18**, 243-311.

Minteer, B.A., Collins, J.P., Love, K.E. and Puschendorf, R., 2014. Avoiding (re) extinction. *science*, **344**(6181), 260-261.

Morán-Ordóñez, A., Bugter, R., Suárez-Seoane, S., de Luis, E. and Calvo, L., 2013. Temporal changes in socio-ecological systems and their impact on ecosystem services at different governance scales: a case study of heathlands. *Ecosystems*, **16**, 765-782.

Mordkovich, V.G., Berezina, O.G., Lyubechanskii, I.I., Andrievskii, V.S. and

Marchenko, I.I., 2008. Soil arthropoda of post-fire successions in northern taiga of West Siberia. *Contemporary problems of ecology*, **1**, 96-103.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A. and Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature*, **403**(6772), 853-858.

National Research Council, 1995. *The Role of Habitat Conservation and Recovery Planning*. In: Science and the Endangered Species Act. National Academies Press (US).

National Trust, 2020. *UK's first 'super' nature reserve at Purbeck Heaths.* United Kingdom: National Trust. Available from: A 'super' nature reserve at Purbeck Heaths | National Trust [11/03/2024].

Niemelä, Jari, Yrjö Haila, Eero Halme, Tapani Lahti, Timo Pajunen, and Pekka Punttila., 1988. "The distribution of carabid beetles in fragments of old coniferous taiga and adjacent managed forest." In *Annales Zoologici Fennici*, 107-119. Finnish Academy of Sciences, Societas Scientiarum Fennica, Societas pro Fauna et Flora Fennica and Societas Biologica Fennica Vanamo.

Nijssen, M. and Siepel, H., 2010. *The characteristic fauna of inland drift sands. In Inland drift sand landscapes*. KNNV Publishing, 255-278.

Nijssen, M., Smits, J. and Vogels, J., 2013. Opportunities for a N2000 heathland after Wildfire: Effects, recovery and monitoring. *In: North Western dune and lowland heaths – natural processes and management. Abstracts and excursion guide. 13th European Heathland Workshop*, Denmark, 23rd to 28th of June 2013. Department of Geosciences and Natural Resource Management (IGN), Denmark.

Noordijk, J., Schaffers, A. and Sýkora, K.V., 2008. Diversity of ground beetles (Coleoptera: Carabidae) and spiders (Araneae) in roadside verges with grey hair-grass vegetation. *European Journal of Entomology*, **105**(2).

Noordijk, J., Schaffers, A.P., Heijerman, T. and Sýkora, K.V., 2011. Using movement and habitat corridors to improve the connectivity for heathland carabid beetles. *Journal for Nature Conservation*, **19**(5), 276-284.

Noss, R.F., Platt, W.J., Sorrie, B.A., Weakley, A.S., Means, D.B., Costanza, J. and Peet, R.K., 2015. How global biodiversity hotspots may go unrecognized: lessons from the North American Coastal Plain. *Diversity and Distributions*, **21**(2), 236-244.

Novomodnyi, E.V., 2022. Ground beetles (Coleoptera, Carabidae) of Khabarovsky Region in the collection of Grodekov Khabarovsk Regional Museum. *Амурский зоологический журнал*, **14**(4), 570-593.

Offer, D., Edwards, M. and Edgar, P., 2003. *Grazing heathland: a guide to impact assessment for insects and reptiles: English Nature Research Reports.* Natural England. 497.

Page, assessment forJ.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E. and Chou, R., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Bmj*, **372**.

Palmer, M., 1981. Rearing tiger beetles in the laboratory. *CABI*, 1-11.

Parmesan, C., 2007. Influences of species, latitudes and methodologies on estimates of phenological response to global warming. *Global change biology*, **13**(9), 1860-1872.

Pearson, D.L. and Cassola, F., 1992. World-wide species richness patterns of tiger beetles (Coleoptera: Cicindelidae): indicator taxon for biodiversity and conservation studies. *Conservation Biology*, **6**(3), 376-391.

Pearson, D.L. and Knisley, C.B., 1985. Evidence for food as a limiting resource in the life cycle of tiger beetles (Coleoptera: Cicindelidae). *Oikos*, 161-168.

Pearson, D.L. and Vogler, A.P., 2001. *Tiger beetles: the evolution, ecology, and diversity of the cicindelids*. Cornell University Press.

Pearson, D.L. and Wiesner, J., 2023. The use of tiger beetles (Coleoptera: Cicindelidae) in adapting hotspot conservation to global, regional, and local scales. *Journal of Insect Conservation*, **27**(1), 19-48.

Pearson, D.L., 1988. Biology of tiger beetles. *Annual Review of Entomology*, **33**(1), 123-147.

Pearson, D.L., Knisley, C.B., Duran, D.P. and Kazilek, C.J., 2015*. A field guide to the tiger beetles of the United States and Canada: identification, natural history, and distribution of the Cicindelinae.* Oxford University Press.

Purchart, L., Kula, E. and Suchomel, J., 2010. Effects of contaminated mining sites on ground beetles (Coleoptera: Carabidae) in Central Europe. *Community ecology*, **11**(2), 242-249.

Putchkov, A.V., Martynov, A.V., Shyshkina, M.G. and Markina, T.Y., 2021. Rare and protected species of Caraboidea (Coleoptera) of the Steppe zone of Ukraine. *Ecologica Montenegrina*, **48**, 62-70.

Ramiadantsoa, T., Hanski, I. and Ovaskainen, O., 2018. Responses of generalist and specialist species to fragmented landscapes. *Theoretical population biology*, **124**, 31-40.

Real, R., Barbosa, A.M. and Bull, J.W., 2017. Species distributions, quantum theory, and the enhancement of biodiversity measures. Systematic Biology**, 66**(3), 453-462.

Resl, K., Linhart, M. and Láska, R., 2021. Střevlíkovití brouci (Coleoptera: Carabidae) lokality Bzenec-Přívoz*. Acta Carpathica Occidentalis*, **12**.

Reynolds, J.H., Knutson, M.G., Newman, K.B., Silverman, E.D. and Thompson, W.L., 2016. A road map for designing and implementing a biological monitoring program. *Environmental Monitoring and Assessment*, **188**, 1-25.

Rogan, J.E. and Lacher Jr, T.E., 2018*. Impacts of habitat loss and fragmentation on terrestrial biodiversity.* In Reference Module in Earth Systems and Environmental Sciences. Elsevier.

Romey, W.L. and Knisley, C.B., 2002. Microhabitat segregation of two Utah sand dune tiger beetles (Coleoptera: Cicindelidae). *The Southwestern Naturalist*,169-174.

Ruchin, A.B., Alekseev, S.K. and Khapugin, A.A., 2019. Post-fire fauna of carabid beetles (Coleoptera, Carabidae) in forests of the Mordovia State Nature Reserve (Russia). Nature Conservation Research. *Заповедная наука*, **4**(S1),11-20.

Ruchin, A.B., Egorov, L.V., Alekseev, S.K., Semishin, G.B. and Esin, M.N., 2021. Notes on the fauna of beetles (Insecta, Coleoptera) adjacent to the territory of the Mordovia State Nature Reserve. *Амурский зоологический журнал*, **13**(1), 12-35.

Rulyova, M.M., Bobrenko, M.A. and Kabdullina, D.A., 2020. TO THE STUDY OF THE HERPETOBIUM OF MENDYKARA DISTRICT OF KOSTANAY REGION. *Kostanay Regional University*.

Rye, E.C., 1866. *British beetles: an introduction to the study of our indigenous Coleoptera*. Lovell Reeve.

Samu, F. and Sárospataki, M., 1995. Estimation of population sizes and" home ranges" of polyphagous predators in alfalfa using mark-recapture: an exploratory study. *Acta Jutlandica*, **70**, 47-56.

Saupe, E.E., Qiao, H., Hendricks, J.R., Portell, R.W., Hunter, S.J., Soberón, J. and Lieberman, B.S., 2015. Niche breadth and geographic range size as determinants of species survival on geological time scales. *Global Ecology and Biogeography*, **24**(10), 1159-1169.

Schirmel, J. and Fartmann, T., 2014. Coastal heathland succession influences butterfly community composition and threatens endangered butterfly species. *Journal of insect conservation*, **18**, 111-120.

Schofield, A. and Liley, D., 2002. *Heath Tiger Beetles:(Cicindela Sylvatica): a Report of Findings by the RSPB Dorset Heathland Project Into Survey Techniques, Habitat Requirements and Behaviour*. RSPB.

Schultz, T.D., 1989. Habitat preferences and seasonal abundances of eight sympatric species of tiger beetle, genus Cicindela (Coleoptera: Cicindelidae), in Bastrop State Park, Texas. *The Southwestern Naturalist*, 468-477.

Serafim, R. and Stan, M., 2022. On the Palaearctic tiger beetle species (Coleoptera: Cicindelidae) in the collections of “Grigore Antipa” National Museum of Natural History, Bucharest. *Travaux du Muséum National d’Histoire Naturelle “Grigore Antipa”*, **65**(2), 107-126.

Serrano, J., 2003. Catálogo de los Carabidae (Coleoptera) de la Península Ibérica. Monografías S.E.A., 9, Sociedad Entomológica Aragonesa, Zaragoza, 130 pp. *Sociedad Entomológica Aragonesa*.

Serrano, J., Lencina, J.L. and Andújar, A., 2003. Distribution patterns of Iberian Carabidae (Insecta, Coleoptera). *Graellsia*, **59**(2-3), 129-153.

Shelford, V.E., 1907. Preliminary note on the distribution of the tiger beetles (Cicindela) and its relation to plant succession. *The Biological Bulletin*, **14(**1), 9-14.

Shelford, V.E., 1908. *Life-histories and larval habits of the tiger beetles (Cicindelidae)*.

Linnean Society of London.

Shepheard-Walwyn, E. and Bhagwat, S.A., 2018. Maintaining standing stones benefits biodiversity in lowland heathland. *Oryx*, **52**(2), 240-249.

Siepel, H., Riksen, M., Nijssen, M., Sparrius, L. and Fanta, J., 2010. Drift sand landscape development, protection and management. In *Inland drift sand landscapes* (333-352). KNNV Publishing.

Sjursen, H., Michelsen, A. and Jonasson, S., 2005. Effects of long-term soil warming and fertilisation on microarthropod abundances in three sub-arctic ecosystems. *Applied Soil Ecology*, **30**(3), 148-161.

Spanton, T.G., 1988. The Cicindela sylvatica group: geographical variation and classification of the Nearctic taxa, and reconstructed phylogeny and geographical history of the species (Coleoptera: Cicindelidae), *Quaestiones Entomologicae*, **24**, 51-161.

Sparsholt College, 2023. *FIRST GREEN TIGER BEETLES BRED IN CAPTIVITY EMERGE AS ADULTS*. Sparsholt College. Available from: First Green Tiger Beetles Bred in Captivity Emerge as Adults - Sparsholt College Hampshire [02/04/2024]

Stan, M. and Serafim, R., 2021. Tiger beetles of Romania (Coleoptera: Carabidae: Cicindelinae) in the Collections of “Grigore Antipa” National Museum of Natural History, Bucharest. *Travaux du Muséum National d’Histoire Naturelle “Grigore Antipa”*, **64**(2), 69-91.

Staude, I.R., Overbeck, G.E., Fontana, C.S., Bencke, G.A., Silva, T.W.D., Mimet, A. and Pereira, H.M., 2021. Specialist birds replace generalists in grassland remnants as land use change intensifies. *Frontiers in Ecology and Evolution*, **8**, 597542.

Stephens, P.A., Mason, L.R., Green, R.E., Gregory, R.D., Sauer, J.R., Alison, J., Aunins, A., Brotons, L., Butchart, S.H., Campedelli, T. and Chodkiewicz, T., 2016. Consistent response of bird populations to climate change on two continents. *Science*, **352**(6281), 84-87.

Stork, N.E. and Habel, J.C., 2014. Can biodiversity hotspots protect more than tropical forest plants and vertebrates? *Journal of Biogeography*, **41**(3), 421-428.

Sutton, P. G: & Browne, D. E., 2001. British Tiger Beetles. In *Bulletin of the Amateur*

Entomologists' Society by Amateur Entomologists' Society, 60 (435),

sylvatica: habitat suitability, genetic diversity and morphological differentiation.

Székessy, V., 1958. Homokfutrinkák. Cicindelidae. *Faun. Hung*, **34**.

Szél, G., 2006. New ground beetle species in the Hungarian fauna (Coleoptera, Carabidae). *Folia entomologica hungarica*, **67**, 37-54.

Taboada, A. 2010. *Conservation biology of the endangered carabid species Cicindela*

Taboada, A., Pérez-Aguirre, C. and Assmann, T., 2012. A new method for collecting agile tiger beetles by live pitfall trapping. *Entomologia Experimentalis et Applicata*, **145**(1), 82-87.

Taboada, A., Renken, A., Matern, A. and Assmann, T., 2011. Habitat modelling for the conservation of the endangered and endemic heath tiger beetle Cicindela sylvatica rubescens in northern Spain. In: Calvo L. & Suárez-Seoane S. (eds.). 2011. Southern European heathlands-diverse landscapes under global change. Workshop, Symposium and Excursion Guide. 12th European Heathland Workshop, Spain-Portugal, 12th-18th of June 2011. University of León - University of Trás-Os Montes e Alto Douro

Taboada, A., von Wehrden, H. and Assmann, T., 2013. Integrating life stages into ecological niche models: A case study on tiger beetles. *PLoS One*, **8**(7), e70038.

Takeuchi, Y. and Hori, M., 2007. Spatial density-dependent survival and development at different larval stages of the tiger beetle Cicindela japonica (Thunberg). *Population ecology*, **49**(4), 305-316.

Taylor, G., Canessa, S., Clarke, R.H., Ingwersen, D., Armstrong, D.P., Seddon, P.J. and Ewen, J.G., 2017. Is reintroduction biology an effective applied science? *Trends in Ecology & Evolution*, **32**(11), 873-880.

Telfer, M.G. and Eversham, B.C., 1996. Ecology and conservation of heathland Carabidae in eastern England. In *Annales Zoologici Fennici*, 133-138. Finnish Zoological and Botanical Publishing Board.

Telfer, M.G. and Eversham, B.C., 2000. *Species Recovery Programme: Workshop on the ecology and conservation of BAP ground beetles.* Unpublished report to Natural England.

Telfer, M.G., 2005. Carabid conservation within a nature reserve network established for birds. *DIAS report*, 325.

Telfer, M.G., 2016. A review of the beetles of Great Britain: Ground Beetles (Carabidae): Species Status No. 25. *Nat. Engl. Commis. Reports*, (189), 151.

Thomaes, A., Beck, O., Liégeois, S., Struyve, T., Van Hoydonck, G. and Dekoninck, W., 2018. When and where to apply for permits in Belgium when studying insects. *Bulletin de la Société royale belge d'Entomologie*, **154**(3), 273-280.

Thompson, J.N., 1994. *The coevolutionary process*. University of Chicago press.

Trautner, J. and Geigenmüller, K., 1987. *Tiger beetles, ground beetles. Illustrated key to the Cicindelidae and Carabidae of Europe*. TRIOPS Verlag.

Travis, J.M. and Dytham, C., 2012. Dispersal and climate change: a review of theory. *Dispersal ecology and evolution*, 337-348.

Tsuji, K., Hori, M., Phyu, M.H., Liang, H. and Sota, T., 2016. Colorful patterns indicate common ancestry in diverged tiger beetle taxa: Molecular phylogeny, biogeography, and evolution of elytral coloration of the genus Cicindela subgenus Sophiodela and its allies. *Molecular Phylogenetics and Evolution*, **95**, 1-10.

Turin, H. and Den Boer, P.J., 1988. Changes in the distribution of carabid beetles in The Netherlands since 1880. II. Isolation of habitats and long-term time trends in the occurrence of carabid species with different powers of dispersal (Coleoptera, Carabidae). *Biological Conservation*, **44**(3), 179-200.

Turin, H., Haeck, J. and Hengeveld, R., 1977. *Atlas of the carabid beetles of the Netherlands.* North-Holland Publishing Company.

UKBAP, 1999. *Tranche 2 Action Plans: Volume 4 – Invertebrates*. JNCC.

UKBAP, 2007a. *List of UK BAP Priority Terrestrial Invertebrates*. JNCC.

UKBAP, 2007b. Report on the Species and Habitat Review JNCC.

UKBAP, 2008. Common Standards Monitoring Guidance for Terrestrial and Freshwater Invertebrates: JNCC.

UN, 2012. Classification and definition of regions. United Nations Statistics Division.

Vaurie, P., 1950. Notes on the habitats of some North American tiger beetles*. Journal of the New York Entomological Society*, **58**(3), 143-153.

Venn, S., Schulman, H., Törrönen, S., Salla, A., Pajunen, T., Kerppola, S., Paukkunen, J., Nieminen, M., Vilisics, F. and Karjalainen, S., 2015. Helsinki. *Vertebrates and invertebrates of european cities: Selected non-Avian fauna*, 323-377.

Vermeulen, H.J.W., Spee, A.J., Maelfait, J.P. and Butowski, R.O., 1994. Road-size verges as a new habitat for carabid beetles of heathlands. *Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society*, **5**, 101-108.

Vermeulen, R. and Spee, A., 2005. The Mantingerveld: effects of fragmentation and defragmentation followed by carabid beetles. In *European Carabidology 2003 (Proceedings of the 11th European Carabidologists' Meeting).* DIAS Report Plant Production, 114, 379-389.

Vesterlund, S.R., Lilley, T.M., Van Ooik, T. and Sorvari, J., 2014. The effect of overwintering temperature on the body energy reserves and phenoloxidase activity of bumblebee Bombus lucorum queens. *Insectes sociaux*, **61**, 265-272.

Walters, J., 2013. *Identification: British tiger-beetles*. British Wildlife, 328-333.

Webb, J.R., Drewitt, A.L. and Measures, G.H., 2010a. *Managing for species: Integrating the needs of England's priority species into habitat management: Lowland farmland.* Natural England. NERR024.

Webb, J.R., Drewitt, A.L. and Measures, G.H., 2010b. *Managing for species: Integrating the needs of England's priority species into habitat management: Brownfield sites.* Natural England. NERR024.

Webb, J.R., Drewitt, A.L. and Measures, G.H., 2010c*. Managing for species: Integrating the needs of England's priority species into habitat management. Part 2 Annexes*. Natural England. NERR024.

Webb, N. R., 1986. Heathlands. Collins, London.

White, J., Hoskin, R., Liley, D., Sharp, J., Underhill-Day. and Tyldesley, D., 2008. *Nature Conservation Representations to the Secretary of State with regard to the Regional Spatial Strategy Proposed Changes on behalf of Purbeck District Council*.

Unpublished report by Footprint Ecology & David Tyldesley & Associates. Commissioned by Purbeck District Council.

Wilkinson, C.E., Dheer, A., Zett, T., Torrents-Ticó, M., Yarnell, R.W., Bar Ziv, E., Bhandari, S., Jacobson, A. and Dloniak, S.M., 2023. Review of the global research on Hyaenidae and implications for conservation and management. *Mammal Review*.

Wood, J.G., 1872. *Insects at Home: Being a Popular Account of Insects, Their Structure, Habits and Transformations*. Scribner.

Yan, Y., Jarvie, S., Liu, Q. and Zhang, Q., 2022. Effects of fragmentation on grassland plant diversity depend on the habitat specialization of species. *Biological Conservation*, **275**, 109773.

7. Appendices

Publication	Author	Year of publication	Life cycle	Habitat requirement	Distribution	Reasons for change in distribution and abundance	Survey methods	Recommendations for habitat management
Post-fire fauna of carabid beetles (Coleoptera, Carabidae) in forests of the Mordovia State Nature Reserve (Russia)	Ruchin et al.	2019	N	Y	Y	Y	Y	N
Checklist of the Coleoptera of Mordovia State Nature Reserve, Russia	Egorov et al.	2020	N	N	Y	N	N	N
Remarks on distribution and diversity of the tiger beetle fauna of Montenegro (Coleoptera: Cicindelidae)	Jaskuła et al.	2005	N	N	Y	N	N	N
Rare and protected species of Caraboidea (Coleoptera) of the Steppe zone of Ukraine	Putchkov et al.	2021	N	Y	Y	N	Y	N
Integrating Life Stages into Ecological Niche Models: A Case Study on Tiger Beetles	Taboada et al.	2013	Y	Y	Y	Y	Y	Y

THE CICINDELA SYLVATICA GROUP: GEOGRAPHICAL VARIATION AND CLASSIFICATION OF THE NEARCTIC TAXA, AND RECONSTRUCTED PHYLOGENY AND GEOGRAPHICAL HISTORY OF THE SPECIES (COLEOPTERA: CICINDELIDAE)	Spanton	1988	N	Y	Y	N	N	N
How unique is the tiger beetle fauna (Coleoptera, Cicindelidae) of the Balkan Peninsula?	Jaskula	2011	N	Y	Y	N	N	N
FAUNISTIC RECORDS OF THE BEETLES (HEXAPODA: COLEOPTERA) IN LATVIA	Barševskis et al.	2012	N	N	Y	N	Y	N
Short- and medium-term effects of experimental nitrogen fertilization on arthropods associated with Calluna vulgaris	Cuesta et al.	2008	N	Y	Y	Y	Y	N

heathlands in north-west Spain								
Short-term effects of fire on arthropods in Calluna-heathlands in NW Spain	Cuesta et al.	2006	N	Y	Y	Y	Y	Y
The distribution of carabid beetles in fragments of old coniferous taiga and adjacent managed forest	Niemelä et al.	1988	N	Y	Y	N	Y	Y
Dynamics of Dutch beetle species during the twentieth century (Coleoptera, Carabidae)	Hengeveld	1985	N	Y	Y	Y	N	N
Using movement and habitat corridors to improve the connectivity for heathland carabid beetles	Noordijk	2011	N	Y	Y	N	Y	N
CHECK-LIST OF THE TIGER BEETLES OF TURKEY WITH A REVIEW OF DISTRIBUTION AND BIOGEOGRAPHY (COLEOPTERA: CICINDELIDAE)	Avgın and Özdikmen	2007	N	N	Y	N	N	N
Temporal Changes in Socioecological Systems and Their Impact on Ecosystem Services at Different Governance Scales: A Case Study of Heathlands	Morán-Ordóñez et al.	2013	N	Y	N	N	N	N
Diversity of ground beetles	Noordijk et al.	2008	N	Y	Y	Y	Y	Y

(Coleoptera: Carabidae) and spiders (Araneae) in roadside verges with grey hair-grass vegetation								
Road-size verges as a new habitat for carabid beetles of heathlands	Vermeulen et al.	1994	N	Y	Y	N	Y	N
Tiger beetles of Romania (Coleoptera: Carabidae: Cicindelinae) in the Collections of “Grigore Antipa” National Museum of Natural History, Bucharest	Stan and Serafim	2021	N	Y	Y	N	N	N
Studies on tiger beetles. CVII. The cicindelid fauna of Anatolia: faunistics and biogeography (Coleoptera, Cicindelidae)	Cassola	1999	N	Y	Y	Y	N	N
On the Palaearctic tiger beetle species (Coleoptera: Cicindelidae) in the collections of “Grigore Antipa” National Museum of Natural History, Bucharest	Serafim and Stan	2022	N	Y	Y	N	N	N
Ecology and conservation of heathland Carabidae in eastern England	Telfer and Eversham	1996	N	Y	Y	N	Y	N
Colorful patterns indicate common ancestry in diverged tiger beetle taxa: Molecular phylogeny,	Tsuji et al.	2016	N	Y	Y	N	N	N

biogeography, and evolution of elytral coloration of the genus Cicindela subgenus Sophiodela and its allies								
A preliminary investigation of ground beetle (Coleoptera: Carabidae) assemblages and vegetation community structure in Calluna vulgaris heathlands in NW Spain	Cuesta et al.	2006	N	Y	Y	N	Y	Y
Loss of Habitats and Changes in the Composition of the Ground and Tiger Beetle Fauna in four West European Countries since 1950 (Coleoptera: Carabidae, Cicindelidae)	Desender et al.	1989	N	Y	Y	Y	N	N
Ground beetles (Coleoptera, Carabidae) of Khabarovsky Region in the collection of Grodekov Khabarovsk Regional Museum	Novomodnyi	2022	N	Y	Y	N	N	N
The Carabidae (Coleoptera) Larvae of Fennoscandia and Denmark	Luff et al.	1993	Y	N	Y	N	N	N
Beetles of the Nature Reserve Friendship and their monitoring	Kashevarov	2003	N	N	Y	N	Y	N

Value of Semi-Open Corridors for Simultaneously Connecting Open and Wooded Habitats: a Case Study with Ground Beetles	Eggers et al.	2010	N	Y	Y	N	Y	Y
When and where to apply for permits in Belgium when studying insects	Thomaes et al.	2018	N	N	Y	N	N	N
TO THE STUDY OF THE HERPETOBIUM OF MENDYKARA DISTRICT OF KOSTANAY REGION	Rulyova et al.	2020	N	Y	Y	N	Y	N
Ground beetles (Coleoptera: Carabidae) of the Bureinskii State Nature Reserve, Khabarovskii Krai, Russia	Koshkin et al.	2016	N	Y	Y	N	Y	N
Speciation and diversification in the North American tiger beetles of the Cicindela sylvatica group: morphological variation and an ecophylogeographic approach	Duran	2010	N	N	Y	N	N	N
Population size and dispersal of the Tiger Beetles Cicindela sylvatica Linnaeus, 1758 (Heath Tiger Beetle) and Cicindela campestris Linnaeus, 1758 (Green Tiger Beetle)(Coleopter	Dodd	2011	N	Y	Y	Y	Y	Y

a: Carabidae: Cicindelinae) within a Surrey heathland mosaic								
Heath Tiger Beetles (Cicindela sylvatica). A Report of Findings by the RSPB Dorset Heathland Project into Survey Techniques, Habitat Requirements and Behaviour.	Schofield and Liley	2002	N	Y	Y	N	Y	N
The Mantingerveld: effects of fragmentation and defragmentation followed by carabid beetles	Vermeulen and Spee	2005	N	Y	Y	Y	Y	Y
Barely manageable: the relationship between bare ground patch size and carabid biodiversity on a heathland	Cameron	2010	N	Y	Y	Y	Y	Y
A new method for collecting agile tiger beetles by live pitfall trapping	Taboada et al.	2012	N	Y	Y	N	Y	N
Carabid beetles in a changing environment	Den Boer and Van Dijk	1994	N	Y	Y	Y	Y	N
Identification: British tiger-beetles	Walters	2013	Y	Y	Y	N	N	N
Area-sensitivity of the sand lizard and spider wasps in sandy pine heath forests – umbrella species for early successional	Berglind	2004	N	Y	Y	N	Y	N

biodiversity conservation?								
Soil Arthropoda of Post-Fire Successions in Northern Taiga of West Siberia	Mordkovich et al.	2008	N	Y	Y	N	Y	N
Changes in the Distribution of Carabid Beetles in The Netherlands Since 1880. II. Isolation of Habitats and Long-term Time Trends in the Occurrence of Carabid Species with Different Powers of Dispersal (Coleoptera, Carabidae)	Turin and Den Boer	1988	N	Y	Y	N	Y	N
Forty years of carabid beetle research in Europe – from taxonomy, biology, ecology and population studies to bioindication, habitat assessment and conservation	Kotze et al.	2011	N	N	Y	Y	Y	Y
Effects of prescribed forest burning on carabid beetles (Coleoptera: Carabidae): a case study in south-eastern Norway	Gongalsky et al.	2006	N	Y	Y	Y	Y	Y
Carabid conservation within a nature reserve network established for birds	Telfer	2005	N	N	Y	N	N	N
Additional records and new synonyms of	Lafer et al.	1997	N	Y	Y	N	Y	N

Cicindelidae and Carabidae (Coleoptera) from the Island of Sakhalin in the Russian Far East								
Beetles, Butterflies, Moths, and Other Insects: A Brief Introduction to Their Collection and Preservation	Kappel and Kirby	1892	N	Y	Y	N	N	N
Drift sand landscape development, protection and management	Siepel et al.	2010	N	Y	Y	N	N	N
Common British Beetles	Hall	1914	N	Y	Y	N	N	N
Střevlíkovití brouci (Coleoptera: Carabidae) lokality Bzenec-Přívoz.	Resl	2021	N	Y	Y	N	Y	N
Insects at Home: Being a Popular Account of Insects, Their Structure, Habits and Transformations	Wood	1872	Y	Y	Y	N	Y	N
Maintaining standing stones benefits biodiversity in lowland heathland	Shephea rd-Walwyn and Bhagwat	2018	N	Y	N	N	N	N
Notes on the fauna of beetles (Insecta, Coleoptera) adjacent to the territory of the Mordovia State Nature Reserve	Ruchin et al.	2021	N	Y	Y	N	Y	N
Restoration measures emulating natural disturbances alter beetle	Hägglun d et al.	2020	N	Y	Y	Y	Y	Y

assemblages in boreal forest								
The Carabidae - Coleoptera - Of Fennoscandia and Denmark	Lindroth et al.	1985	N	Y	Y	N	N	N
THE INCREASING IMPORTANCE OF MONITORING WILDLIFE RESPONSES TO HABITAT MANAGEMENT	Fuller et al.	2016	N	Y	Y	N	Y	Y
Laboratory methods for rearing soil beetles (Coleoptera)	Burakowski	1993	Y	Y	Y	N	Y	N
The Out-door World, Or, Young Collector's Handbook	Furneaux	1894	N	Y	N	N	N	N
Beetle (Insecta, Coleoptera) fauna and its distribution in seashore habitats of Lithuania	Ferenca	2014	N	Y	Y	N	Y	N
A review of the scarce and threatened bees, wasps and ants of Great Britain	Falk	1991	N	Y	Y	N	N	Y
Ground beetles (Coleoptera, Carabidae) of the Pivnichne Podillia National Nature Park (Ukraine). Part I: Cicindelinae, Omophroninae, Nebriinae, Elaphrinae, and Carabinae	Kanarsky	2021	N	Y	Y	N	N	N
The Coleopterist	Key	1993	N	N	Y	Y	N	N
Review of the ground beetles (Coleoptera, Carabidae) from Macedonia in the	Hristovski et al.	2016	N	N	Y	N	N	N

collection of the Macedonian Museum of Natural History								
Nature Conservation Representations to the Secretary of State with regard to the Regional Spatial Strategy Proposed Changes on behalf of Purbeck District Council	White et al.	2008	N	N	Y	N	N	N
New ground beetle species in the Hungarian fauna (Coleoptera, Carabidae)	Szél	2006	N	N	Y	N	N	N
Helsinki	Venn et al.	2015	N	Y	Y	N	N	N
Green-tree retention and controlled burning in restoration and conservation of beetle diversity in boreal forests	Hyvärinen	2006	N	N	Y	N	Y	N
Zoogeographical analysis of the Carabidae (Coleoptera) of Poland	Leśniak	1987	N	N	Y	N	N	N
Effects of contaminated mining sites on ground beetles (Coleoptera: Carabidae) in Central Europe	Purchart et al.	2010	N	Y	Y	N	Y	N
GRAZING OF LOWLAND HEATH IN ENGLAND: MANAGEMENT METHODS AND THEIR EFFECTS ON HEATHLAND VEGETATION	Bullock and Pakeman	1997	N	Y	N	N	N	Y

Emulation of natural disturbances and the maintenance of biodiversity in managed boreal forests: the effects of prescribed fire and retention forestry on insect assemblages	Heikkala	2016	N	Y	Y	Y	Y	Y
The Ground Beetle Fauna (Coleoptera, Carabidae) of Southeastern Altai	Dudko et al.	2010	N	Y	Y	Y	Y	N
A checklist of the ground-beetles of Russia and adjacent lands (Insecta, Coleoptera, Carabidae)	Kryzhanovskiĭ	1995	N	N	Y	N	N	N

Publication	Author	Year of publication	Life cycle	Habitat requirement	Distribution	Reasons for change in distribution and abundance	Survey methods	Recommendations for habitat management
Tranche 2 Action Plans: Volume 4 – Invertebrates	UKBAP	1999	Y	Y	Y	Y	N	Y
List of UK BAP Priority Terrestrial Invertebrates (2007)	UKBAP	2007	N	N	Y	N	N	N
Common Standards Monitoring Guidance for Terrestrial and Freshwater Invertebrates	UKBAP	2008	N	N	Y	N	N	N
Report on the Species and Habitat Review 2007	UKBAP	2007	N	N	Y	N	N	N

Publication	Author	Year of publication	Life cycle	Habitat requirement	Distribution	Reasons for change in distribution and abundance	Survey methods	Recommendations for habitat management
Scarce Ground Beetle Project: Final Report on work 2000-2004. Natural England. ENSRP1255 (Part 1).	Boyce	2004	N	Y	Y	Y	N	Y
Boyce, 2004. Scarce Ground Beetle Project: Final Report on work 2000-2004. Natural England. ENSRP1255 (Part 5).	Boyce	2004	N	Y	Y	Y	N	Y
Managing for species: Integrating the needs of England's priority species into habitat management: Brownfield sites.	Webb et al.	2010	N	Y	Y	N	N	N
Habitat modelling for the conservation of the endangered and endemic heath tiger beetle Cicindela sylvatica rubescens in northern Spain	Taboada et al.	2011	Y	Y	Y	Y	N	N

A review of the beetles of Great Britain: Ground Beetles (Carabidae): Species Status No.25.	Telfer	2016	N	Y	Y	Y	N	N
Managing for species: Integrating the needs of England's priority species into habitat management. Part 2 Annexes	Webb et al.	2010	N	Y	Y	N	N	N
Appendix E – Lowland Heathlands	Alonso et al.	2018	N	Y	Y	N	N	N
Managing for species: Integrating the needs of England's priority species into habitat management: Lowland farmland	Webb et al.	2010	N	Y	Y	N	N	N
Grazing heathland: a guide to impact assessment for insects and reptiles	Offer et al.	2003	N	Y	Y	N	N	N
Impacts of livestock grazing on lowland heathland	Lake et al.	2001	N	Y	Y	Y	N	Y

Opportunities for a N2000 heathland after Wildfire: Effects, recovery and monitoring. *In: North Western dune and lowland heaths – natural processes and management. Abstracts and excursion guide. 13th European Heathland Workshop*, Denmark, 23rd to 28th of June 2013. Department of Geosciences and Natural Resource Management (IGN), Denmark	Nijssen al.	2013	N	Y	Y	Y	N	Y
Scientific research into the effects of access on nature conservation: Part 2: access on bicycle and horseback	Lowen et al.	2009	N	Y	Y	Y	N	N

Publication	Author	Year of publication	Life cycle	Habitat requirement	Distribution	Reasons for change in distribution and abundance	Survey methods	Recommendations for habitat management
Materials to the knowledge of the tiger beetles of Romania (Coleoptera: Cicindelidae)	Cassola and Jaskula	2004	N	N	Y	N	N	N
Coleoptera Carabidae. Handbooks for the Identification of British Insects.	Lindroth	1974	Y	Y	Y	N	N	N
Atlas of the carabid beetles of the Netherlands.	Turin et al.	1977	N	N	Y	N	N	N
DATA TO THE KNOWLEDGE ON THE BEETLE FAUNA OF MARAMUREŞ, ROMANIA (COLEOPTERA)	Merkl	2008	N	Y	Y	N	N	N
An overview of Coleoptera of the New Forest, Hampshire	Brock and Allen	2022	N	Y	Y	N	N	N

Provisional atlas of the ground beetles (Coleoptera, Carabidae) of Britain.	Luff	1998	Y	Y	Y	N	N	N
British Tiger Beetles. Bulletin of the Amateur Entomologists ' Society	Sutton and Browne	2001	Y	Y	Y	Y	N	Y
Catálogo de los Carabidae (Coleoptera) de la Península Ibérica. Monografias Sociedad Entomóligica Aragonesa 9: 5-130.	Serrano	2003	N	Y	Y	N	N	N
Distribution patterns of Iberian Carabidae (Insecta, Coleoptera). Graellsia 59: 129–153.	Serrano et al.	2003	N	N	Y	N	N	N
Geodephaga Britannica: A monograph of the carnivorous ground beetles indigenous to the British Isles. London:	Dawson	1854	N	Y	Y	N	N	N

Entomologia Britannica, sistens insecta Britanniae indigena, secundum methodum Linnæanam disposita. Tomus 1: Coleoptera. London : J. White	Marsham	1802	N	N	Y	N	N	N
A Review of the Biodiversity Action Plan Tiger-beetles. Buglife report.	Boyce and Walters	2010	Y	Y	Y	Y	N	Y
Checklist of beetles of the British Isles: Carabidae.	Luff and Duff	2002	N	N	Y	N	N	N
Homokfutrinkák= Cicindelidae (Vol. 6, No. 34). Akadémiai Kiadó.	Székessy,	1958	N	Y	Y	N	N	N
Cicindela silvatica L. und ihre Rassen	Mandl	1937	N	Y	Y	Y	N	N
The Coleoptera of the British islands: a descriptive account of the families, genera, and	Fowler and Donisthorpe	1887	N	Y	Y	N	N	N

species indigenous to Great Britain and Ireland, with notes as to localities, habitats, etc.								
The Coleoptera of the British Islands, Vol 6 (supplement). London:Reeve	Fowler and Donisthorpe	1913	N	N	Y	N	N	N
A Field Guide in Colour to Beetles, London: Octopus.	Harde	1984	N	Y	Y	N	N	N
The Young Beetle Collectors Handbook, London: Swan Sonnenshein & Co.	Hofmann	1897	N	Y	Y	N	N	N
The distribution and habitat requirements of the tiger beetle Cicindela germanica Linnaeus (Coleoptera: Carabidae) in southern Britain. British Journal of Entomology and Natural History (United Kingdom)	Else	1993	N	Y	Y	N	N	N

British Beetles: An Introduction to the Study of Our Indigenous Coleoptera	Rye	1866	N	Y	Y	N	N	N
Tiger beetles, ground beetles. Illustrated key to the Cicindelidae and Carabidae of Europe. Triops Verlag.	Trautner and Geigenm üller	1987	Y	N	Y	N	N	N
De boszandloop kever, Cicindela sylvatica (Coleoptera: Carabidae), na bijna 40 jaar weer gevonden in Drenthe	Bouwma n	2010	Y	Y	Y	N	Y	N