The invasion of *Carcharodus alceae, Brenthis daphne* and *Pieris mannii* (Lepidoptera: Hesperiidae, Nymphalidae & Pieridae) into western Belgium through opportunistic data collection

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Abstract. The northward and westward Belgian range expansions of *Carcharodus alceae* (Esper, 1780) (Hesperiidae), *Brenthis daphne* (Denis & Schiffermüller, 1775) (Nymphalidae) and *Pieris mannii* (Mayer, 1851) (Pieridae) are studied, based on a large number of opportunistically collected species occurrences. This information has been filtered to improve the quality of the dataset, and an analysis of this screening is presented. An overview of the range expansion and voltinism for each species is given. Ecological species-specific requirements that potentially influence such expansions are discussed, as well as the westward expansion of all three species.

Samenvatting. De noord- en westwaartse uitbreiding van *Carcharodus alceae* (Esper, 1780) (Hesperiidae), *Brenthis daphne* (Denis & Schiffermüller, 1775) (Nymphalidae) en *Pieris mannii* (Mayer, 1851) (Pieridae) in België worden onderzocht aan de hand van een groot aantal, opportunistisch verzamelde, observaties. Deze data zijn gefilterd om de kwaliteit van de dataset te verhogen en hiervan is een analyse gemaakt. Een overzicht van de soortenuitbreidingen en vliegtijden wordt gegeven. We onderzoeken de soortspecifieke, ecologische verwachtingen die de uitbreidingen kunnen beïnvloeden, met bijzondere aandacht voor de westwaartse expansie van de drie hogervermelde soorten.

Résumé. L'expansion vers le nord et l'ouest de la Belgique de *Carcharodus alceae* (Esper, 1780) (Hesperiidae), *Brenthis daphne* Bergsträsser, 1780 (Nymphalidae) et *Pieris mannii* (Mayer, 1851) (Pieridae) est étudiée sur base d'un grand nombre d'observations, recueillies de manière opportuniste. Les données ont été filtrées pour augmenter la qualité de l'ensemble et une analyse du jeu de données est proposée. Un aperçu des expansions et des temps de vol des espèces est donné. Nous examinons les attentes écologiques spécifiques de chaque espèce qui peuvent influencer ces extensions de l'aire de répartition en portant une attention particulière à l'expansion vers l'ouest des trois espèces.

Key words: Papilionoidea — Range expansion — Phenology — Opportunistic data collection — Belgium.

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Introduction

The distribution range of most butterfly species in Northwest Europe has long since been intensively studied, providing an excellent historical background for studies about distribution dynamics. In the 1900s, dramatic contractions of many species have been well documented. This has been linked to intensive habitat loss and subtle changes in climate, but there were also winners that have benefited from these changes, having expanded their range in a rapidly changing European environment. Range expansions depend on the ability of each species to expand its range into new habitats in fragmented landscapes. These expansions are driven by population growth and the ability to disperse and thrive in new areas. Species in expansion that establish permanent populations should not be confused with seasonal migrants (those usually dependent on northerly spring migration and a southerly autumn migration), i.e. a temporary residence of a species. Researchers often link the recent expansions to anthropogenic climate changes.

The potential expansion of the European butterflies was modelled against climate change by Settele *et al.* (2008) using UTM grid cells of 50×50 km^2. This resulted in a northward shift of the European distribution ranges of many species. Many butterfly species with specific microclimatic requirements can inhabit patches in these large grid areas, and these can affect the overall values/assessments for each grid cell making predictions difficult (Kudrna 2013). Like all modelling studies, the results depend on well-chosen variables to help evaluate a realistic output. More versatile and widespread species that have the ability to survive in a variety of habitats and utilize different larval hostplants make this modelling more difficult, but hostplants are an essential condition in regard to the survival of each species.

In the Balkan peninsula, an unintuitive southward expansion of *Araschnia levana* (Linnaeus, 1758) into Greece has even been documented (Pamperis 2009, 2022) and that does not appear to be a climate-driven expansion. Expansions can also be driven by changes in behaviour and life history as shown (Neu *et al.* 2021) by *Pieris mannii* (Mayer, 1851). Small changes in the gene pool of a species might be the cause of such a changing habitat preference and performance (Holt 2003). Range expansions can be inhibited by interspecific competition (Legault *et al.* 2020) which can influence the rapidity and the geographical limitations of any expansion. Documenting range expansion potentially confirms the relevance of these modelling programs and can influence future studies. Describing such expansions largely depends on the number of observations, and on the accuracy of the recorded data that is uploaded into the database. Online observation platforms (e.g. Waarnemingen.be/Observations.be) or large citizen science projects allow the opportunity for a multitude of participants to gather and upload a large number of opportunistic observations even when it is not the ideal research method with a standardized protocol. The quality of such opportunistic data collection is sensitive to the heterogeneity of the sampling effort, in time and space, and a basic knowledge of species identification is essential and critical.

The recent development of a number of identification tools based on artificial intelligence recognition has added a degree of uncertainty (Mølgaard & Cuvelier 2021) in regard to collating accurate records; this is especially pertinent to those taxa with similar external characteristics. However, Van Eupen *et al.* (2021) acknowledged that the filtering of such opportunistic data can still make a valuable contribution to ecological research. Over several decades, the authors (Cuvelier *et al.* 2007) have studied butterflies in the westernmost province of Belgium and during the course of their surveys have noticed an unexpected expansion of *Limenitis camilla* (Linnaeus, 1764) commencing in 2004. Additionally, recent observations of *P. mannii* and *Carcharodus alceae* (Esper, 1780) in West Flanders initiated a study of the westward expansion of these two species. Coincidentally, the less rapid westwards expansion of *Brenthis daphne* ([Denis & Schiffermüller], 1775) started almost simultaneously with *C. alceae* but at present has not reached the province of West Flanders. The only record of *B. daphne* in western Belgium relates to a single dead specimen that was found on July 20th, 2010, in the enclave of Hainaut in West Flanders (Cuvelier & Spruytte 2011).

Methods

All observations relating to *P. mannii*, *C. alceae* and *B. daphne* were kindly provided by the online nature observation platform, Waarnemingen.be./Observations.be. This data cannot be reproduced without permission. Personal observations regarding the phenology of *P. mannii* and *C. alceae* in the western part of Belgium were recorded by the second author and analysed. Subsequently, the Excel data from this platform was filtered to exclude duplicates and doubtful or erroneous identifications. Regarding the status column, five different levels of validation are provided:

a) approved, based on evidence;
b) approved, based on expert judgement;
c) approved based on knowledge rules – proximity;
d) not evaluable;
e) untreated.

All observations from the two first validation levels were accepted. Observations from the last three levels were analysed and validated or, in some cases, rejected by the authors. Subsequently, non-validated observations were excluded from the study.

A global analysis (Table 1) of the discordance between the provided data and filtered data was made for each species, as well as the judgement regarding the validation process as presented in the Excel spreadsheet from the forum. In preparing the phenograms, all dates were allocated to three-thirds (decades) per month. Filtered data of all the development stages is used to map the annual distribution and to analyse the northerly and westerly expansion of each species. The annual expansions have been analysed as well as the annual spread in northerly and westerly occurrences. Only the filtered data of the adult butterflies were used for the phenological analysis. In some instances, the amount of data was inadequate to provide a meaningful outcome. The flight times of species from West Flanders were compared with those from the provinces of Limburg (both in the Atlantic biogeographical region), Liège, and Luxemburg (situated in the continental biogeographical region). DMAP distribution mapping software was used to create the coverage maps.

Results

1. The database: from the initial observations to the filtered Excel version

Depending on the species (Table 1) there are major differences when comparing the information received with the filtered data. Duplicates of similar observation and identification issues are present at different degrees for the three species.

A summary for the number of rows, the number of specimens, and the ratios per species is given in S1 where more details are available per species.

The filtered data for the three species provides virtually complete geographical coverage for all of Belgium (Table 1) and reveals those areas that are more intensively studied. In Flanders, this is linked to the number of local volunteers, which usually relates to the population density. This creates a heterogeneous observer effect that needs to be taken into account when studying the data for each species. In southern Belgium, the known butterfly hotspots with higher entomological diversity attract twitchers and cause another type of observer effect.

Table 1. Comparison of the filtering to the provided Excel database, according to the levels of validation from the forum. © Cuvelier & Vervaeke.

Levels of validation in the received database	**% filtered/received *C. alceae***		**% filtered/received *B. daphne***		**% filtered/received *P. mannii***	
	rows	specimens	rows	specimens	rows	specimens
approved based on evidence	70%	58%	64%	58%	52%	41%
approved based on expert judgement	100%	100%	na	na	65%	62%
approved based on knowledge rules – proximity	80%	78%	na	na	53%	47%
not evaluable	20%	35%	33%	35%	64%	65%
untreated	31%	49%	69%	64%	72%	43%

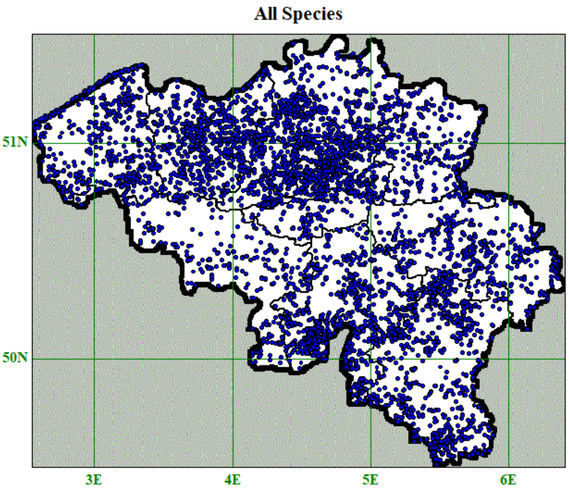


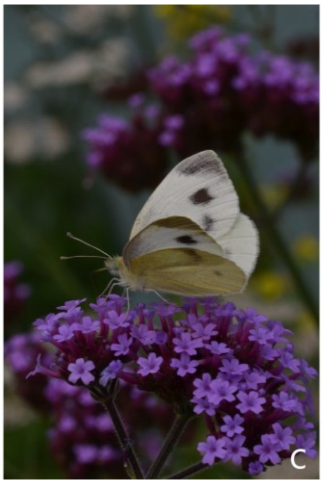
Fig. 1. Map of Belgium depicting the filtered observations of *Carcharodus alceae*, *Brenthis daphne* and *Pieris mannii.* © Cuvelier & Vervaeke.

2. *Carcharodus alceae* (Esper, 1780) / Mallow skipper (Fig. 2d)

The data from the forum included a few observations from 1928, 1933, 2004, and 2005. In regard to the expansion of *C. alceae* in Belgium, continuous annual observations are available from 2007. The distribution map of *C. alceae* (Fig. 3a) shows a different pattern to that of the global distribution map (Fig. 1). The virtual absence of dots in the north-eastern part of Flanders is of note. In the adjacent areas of the Netherlands (Fig. 3b) the situation is identical, confirming that *C. alceae* is, more or less, at the limit of its actual expansion in this part of Flanders. In Wallonia the density of dots is notably lower. Fewer observations resulting from a smaller number of recorders is probably the main reason for this discrepancy and, relating to the intensity of dots in the butterfly hotspots, one can ascertain that the species is no more widespread than in the north of the country. The phenology (Fig. 3c) and chronology of the annual expansion are detailed in S2. In Fig. 3d, the evolution of the northerly and westerly spread is provided. In 2009, *C. alceae* started expanding its range into the northern part of Belgium, and during the following years, a gradual westerly expansion was also witnessed. In 2018 *C. alceae* reached its present distribution boundaries.

3. *Brenthis daphne* (Denis & Schiffermüller, 1775) / Marbled fritillary (Fig. 2a)

The first observations, uploaded in 2008, and subsequent annual observations have been continuous. The map (Fig. 4a) gives the total coverage for all development stages. The species occurs primarily in the provinces of Namur, Liège, and Luxemburg. In western Wallonia and Flanders the intensity of dots is visibly lower. Despite the lower observation intensity in Wallonia, it is clear that at present the strongholds of *B. daphne* are in the more diverse, hilly habitats of Wallonia. The phenology (Fig. 4b) and evolution of the annual expansion are detailed in S3. The northerly and westerly spread of the expansion in Belgium is given for each year (Fig. 4c). In 2009, *B. daphne* started to expand its range in a slow, but continuous, northerly direction, while the western limit of its range barely changed until 2017. In the following years, a slow westerly expansion was documented but the number of observations still remained low. In 2018, *B. daphne* reached the northern Belgian limits. However, the species has not as yet (end of 2022) expanded its range to the western part of the province of Hainaut and West Flanders.



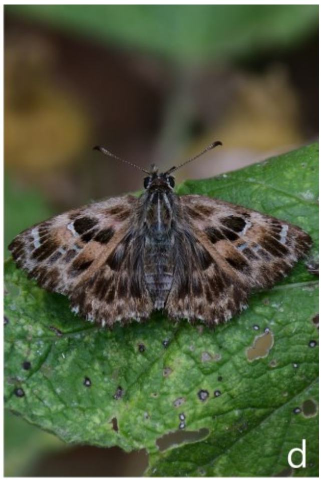
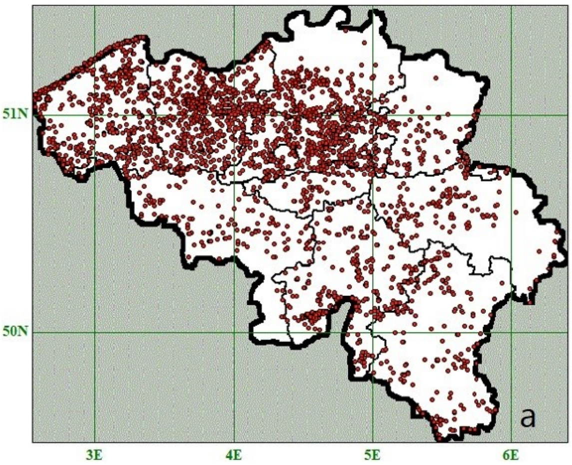


Fig. 2a. *Brenthis daphne*, Börfink Hunsrück-Hochwald National Park (D), 23.vii.2019. © J. Vervaeke.

Fig. 2b. *Pieris mannii* ♂, Gullegem (B), 12.ix.2021. © J. Vervaeke.

Fig. 2c. *Pieris mannii* ♀, Gullegem (B), 12.ix.2021. © J. Vervaeke.

Fig. 2d. *Carcharodus alceae* ♀, Ieper (B) 21.viii.2022. © S. Cuvelier.



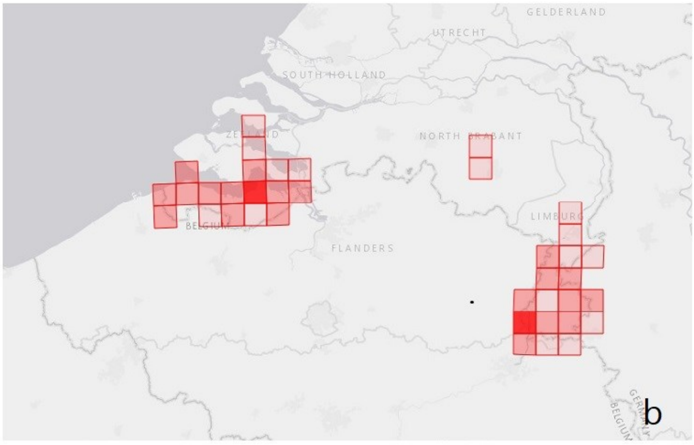


Fig. 3a. Distribution map of *Carcharodus alceae* in Belgium including all filtered observations. © Cuvelier & Vervaeke.

Fig. 3b. Map of the adjacent Dutch distribution of *Carcharodus alceae*. Source: Waarneming.nl.

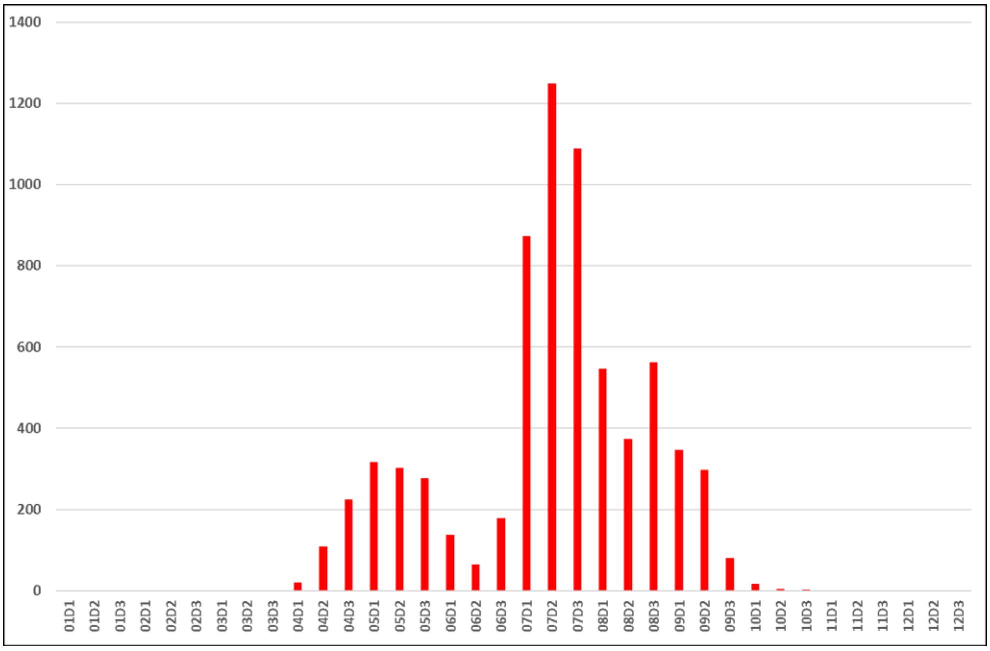


Fig. 3c. Phenogram (2007–2022) of *Carcharodus alceae* imagos.
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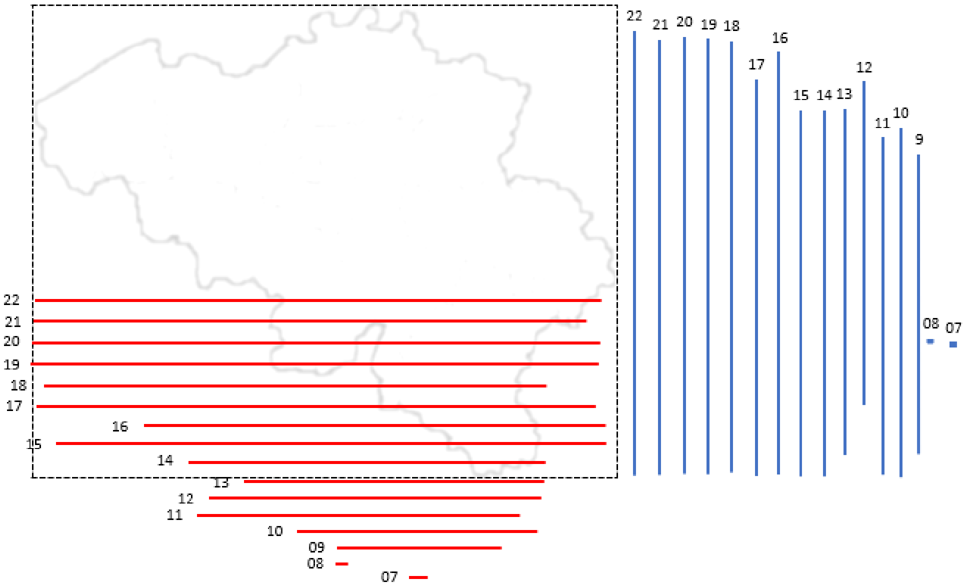

Fig. 3d. Evolution of the annual northerly and westerly spread of *Carcharodus alceae* from 2008–2022.
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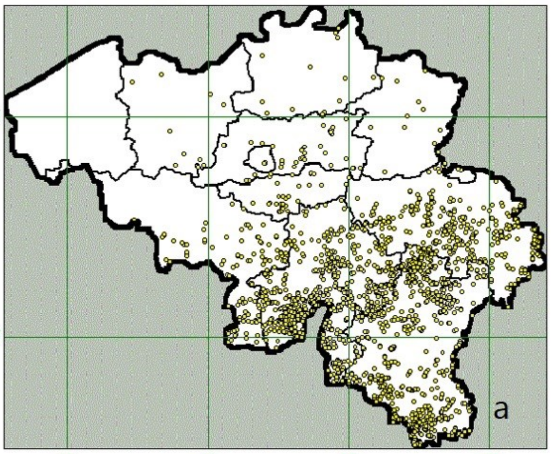


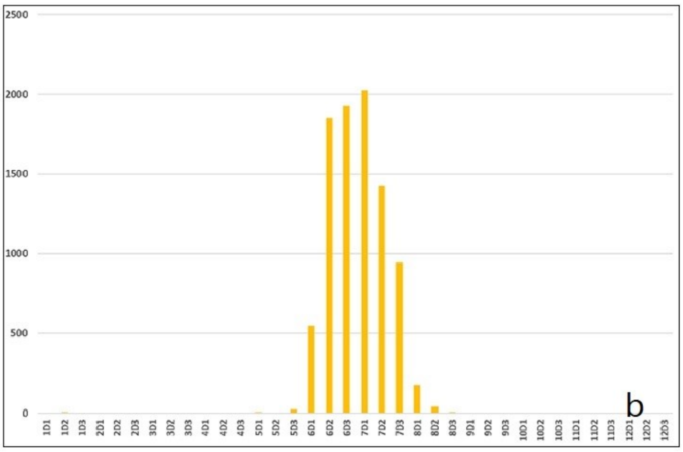


Fig. 4a. Distribution of *Brenthis daphne* in Belgium including all filtered observations. © Cuvelier & Vervaeke.

Fig. 4b. Phenogram (2008–2022) of *Brenthis daphne* imagos. © Cuvelier & Vervaeke.

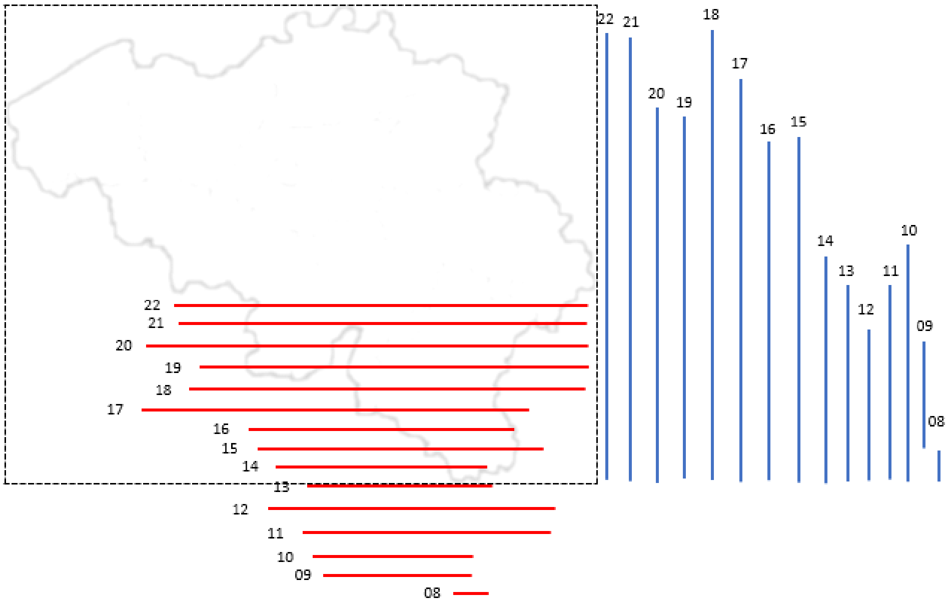
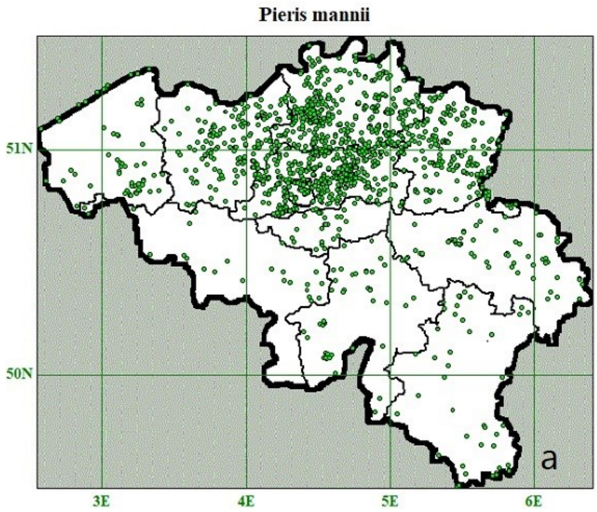


Fig. 4c. Evolution of the annual northerly and westerly spread of *Brenthis daphne* from 2008–2022. © Cuvelier & Vervaeke.

4. *Pieris mannii* (Mayer, 1851) / Southern small white

(Fig. 2b, c)

The first Belgian observations to be uploaded into the forum were made during the summer of 2016. The first specimen was recorded in the province of Luxemburg, and soon after several additional sightings were made in Voeren, an exclave of Flanders. Logically, it appears that *P. mannii* reached Belgium from the East. The Rhine valley has been mentioned as the main route for this northern expansion, and from there *P. mannii* appears to have extended its range in a westerly and easterly direction (Vantieghem 2018). Since 2016, the species has regularly been recorded in Belgium, extending its range westwards, with an extensive shift witnessed as from 2018 (see S4). However, it is interesting to note that the total number of observations made during 2022 fell back to the level witnessed in 2020 (Fig. 5b). Surprisingly, the summer in 2022 was hotter and drier than in 2021, and as *P. mannii* originates from the Mediterranean region (inhabiting warm, dry rocky slopes with scattered bushes), one would assume that this would favour further expansions in the surrogate habitats in Belgium (rock gardens with *Iberis sempervirens* and sites with a warm microclimate where Brassicaceae are available). Fig. 5a shows a different pattern to that of the global distribution map (Fig. 1). The density of observations in Flanders is very evident. The lower density in the western part of Flanders reflects the later westward invasion. The earliest observations in West Flanders were recorded during 2020; however, data suggest that the sparsely populated Polders area is not suitable for the expansion of the species. In Wallonia the density is visibly low, this possibly relates to the lower observer effect and hence observations. Even in the butterfly hotspots in Wallonia the number of recorded sightings is low, suggesting that the species is not common in these areas. Compared to the current status of *C. alceae* and *B. daphne*, it appears that the northern expansion of *P. mannii* is not limited to Belgium. The phenology (Fig. 5c) and evolution of the annual expansion are detailed in S4.



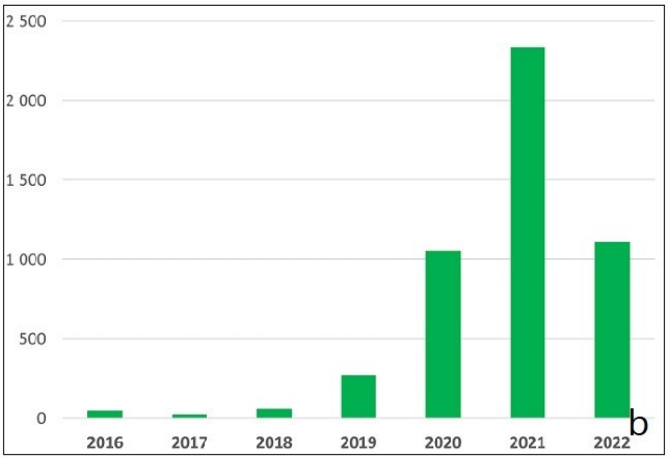


Fig. 5a. Distribution of *Pieris mannii* in Belgium including all filtered observations. © Cuvelier & Vervaeke.

Fig. 5b. *Pieris mannii*, annual number of observations in Belgium including all development stages. © Cuvelier & Vervaeke.

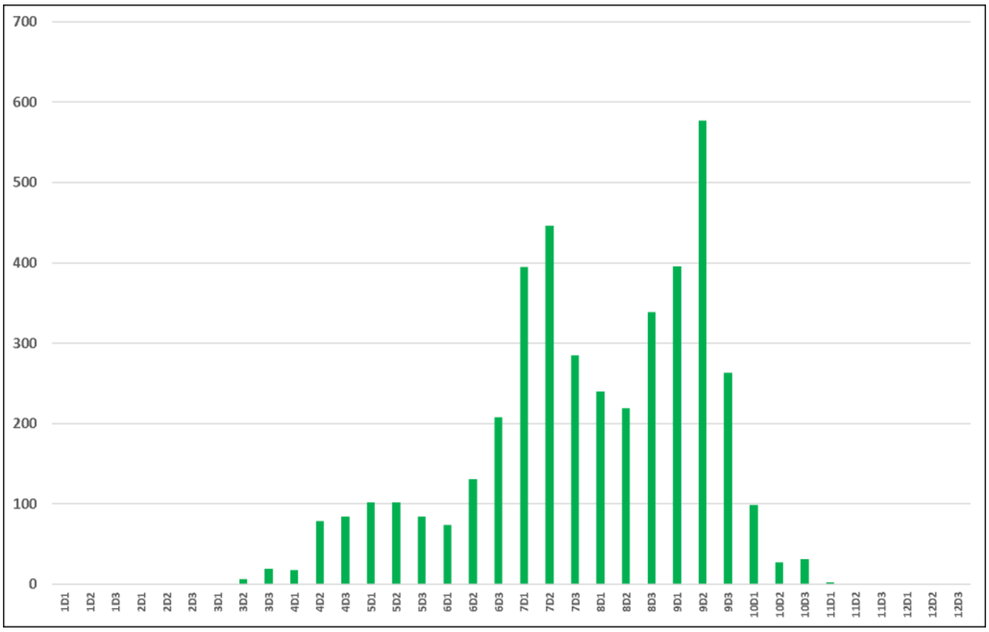


Fig. 5c. Phenogram (2016–2022) of *Pieris mannii* imagos.
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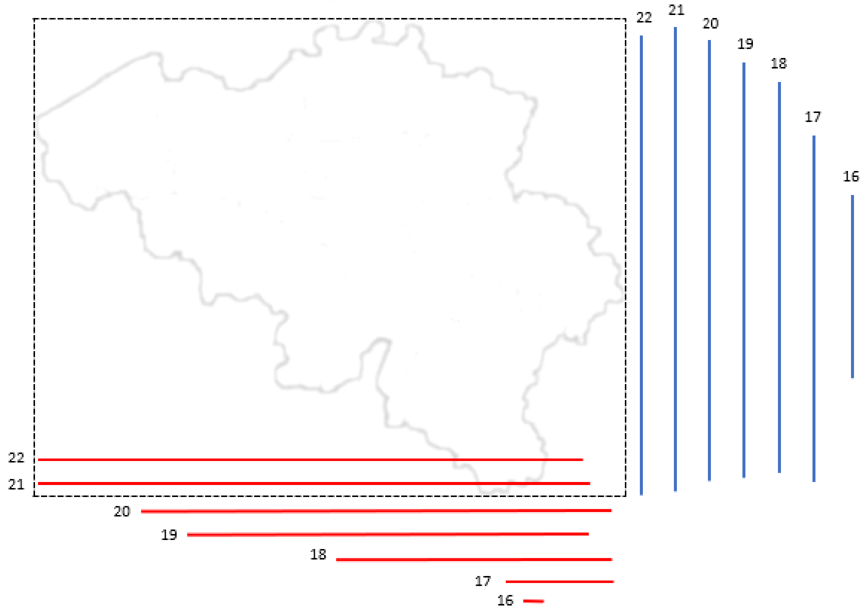

Fig. 5d. Evolution of the annual northerly and westerly spread of *Pieris mannii* from 2016–2022.
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Pieris mannii is on the wing from the second decade of March until the end of October in a succession of broods, approximately one month longer than *C. alceae*, and about five months longer than *B. daphne*. There are three peaks in the phenogram suggesting three annual generations with a large overlap between them. The analysis of the phenograms from separate years (Fig. 9b) confirms this impression. The northerly and westerly spread of the expansion in Belgium is given annually (Fig. 5d). *P. mannii* has gradually increased its range in a northerly and westerly direction, but its western expansion has clearly been more rapid than that witnessed by the other two species. By 2020, *P. mannii* had already reached West-Flanders in Kortrijk, and the first coastal observation, from the area of Knokke, was uploaded onto the forum during the same year. By 2021, the species has advanced its range along most of the Belgian coastline.

Discussion

Filtering data from the online observation forum, to avoid duplicates and misidentifications, was work-intensive, but in so doing provided a large number of accurate observations for the three aforementioned species. As expected, filtering did not influence the heterogeneity of the spatial sampling effort. The intensity of the dots in any given area is dependent on the observer effect, which is obviously greater in the more densely populated areas of Belgium and in the more frequently visited butterfly hotspots. The intensity of the dots in the distribution map of *B. daphne* (Fig. 5a) in the southeast of Wallonia contradicts that of *C. alceae* (Fig. 3a) and *P. mannii* (Fig. 5a) which have their highest number of observations in Flanders. One can assume that this is due to the slower expansion (S4) of *B. daphne*. The disparities regarding the intensity of the dots on the map for *C. alceae* (Fig. 3a), which appears to be virtually absent in northeast Flanders, and for *P. mannii* (Fig. 5a), with lower coverage of dots in the western part of Flanders, are noteworthy.

Pieris mannii only started its westward expansion in 2018 (see S4) reaching West-Flanders, for the first time, in 2020. This disparity regarding the intense concentration of dots might well reflect the timing of the occurrence of the expansion. One should note that the distribution map is an ongoing process, and observations for the western part of Flanders will be added continually. The garden experience by the second author (Fig. 10) supports the hypothesis that predicts the numbers, and spread, of observations in West Flanders will probably mimic the expansion witnessed in other parts of Flanders, except possibly the sparsely populated Polders area in West Flanders. The northern and western limits of the distribution of *C. alceae* (Fig. 3a, S2) have been more or less stable since 2018. We can assume that the intensity of this coverage map is no longer subject to a recent expansion as it is for *P. mannii*. The absence of dots in the north-eastern part of Flanders is not due to a lack in observations. It shows the actual distribution limit of *C. alceae*, and this is confirmed when we compare it to the adjacent distribution area of the species in the Netherlands (Fig. 3b). Additionally, the filtered data can be used to plot the annual northerly (Fig. 6a) and westerly (Fig. 6b) shift of all three species, thus giving a visual representation of the speed of their expansions. *B. daphne* and, to a lesser extent, *C. alceae*, have periods of unpredictable up and down shifts. This is not the case for *P. mannii* which shows a markedly westward shift. Such a visualization is very sensitive but at the same time it depends on a single specimen, a potential outlier.

Comparing the percentual evolution of the annual northerly and westerly expansions of the three species into Belgium (Fig. 3d, Fig. 4c, Fig. 5d) might be a stronger marker for the northward (Fig. 7a) and westward (Fig. 7b) expansion. Additionally, by analysing the annual data, based on the initial observations of all three species, we have a better indicator of the rapid northward and westward expansion of the three species (Fig. 8). At the start of the expansions into Belgium, the northerly shift of all three species was more noticeable, compared to the westerly shift.

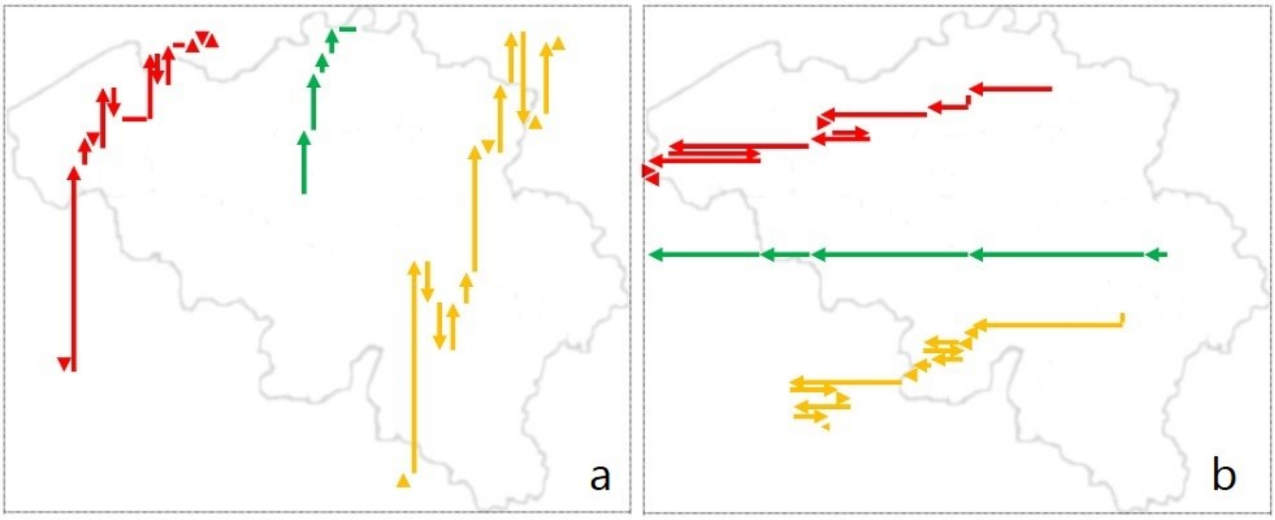
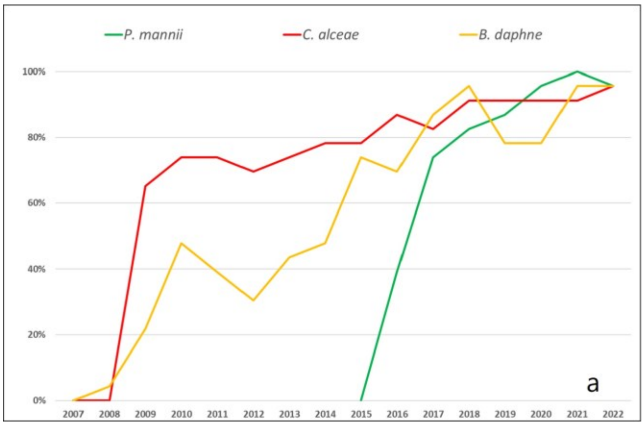


Fig. 6a. Annual northerly shift for the most northern observation. © Cuvelier & Vervaeke.

Fig. 6b. Annual westerly shift for the most western observation. © Cuvelier & Vervaeke.

→ : *Carcharodus alceae*; → : *Pieris mannii*; → : *Brenthis daphne*.



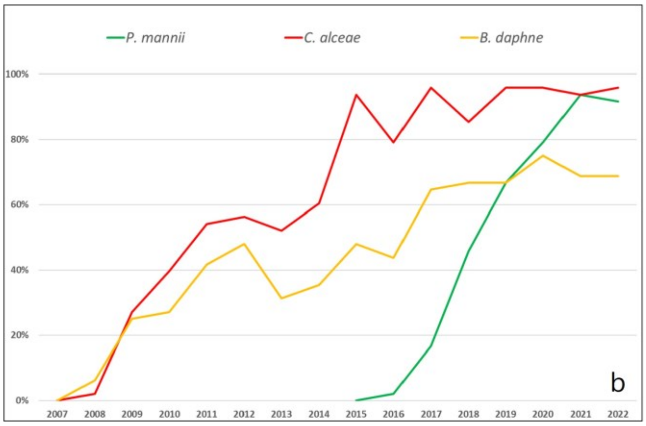


Fig. 7a. Percentual evolution of the annual south-north range expansion of *Carcharodus alceae*, *Brenthis daphne* and *Pieris mannii.* © Cuvelier & Vervaeke.

Fig. 7b. Percentual evolution of the annual east-west range expansion of *Carcharodus alceae*, *Brenthis daphne* and *Pieris mannii.* © Cuvelier & Vervaeke.

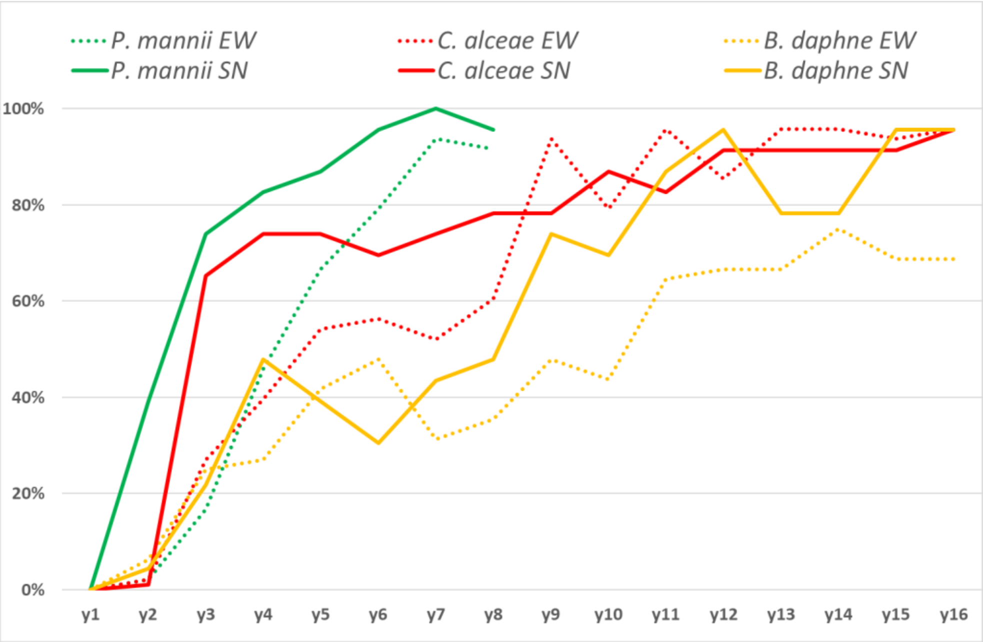


Fig. 8. Percentual evolution of the annual south-north and east-west range expansion of *Carcharodus alceae*, *Brenthis daphne* and *Pieris mannii,* modelled on the year of their first appearance. © Cuvelier & Vervaeke.

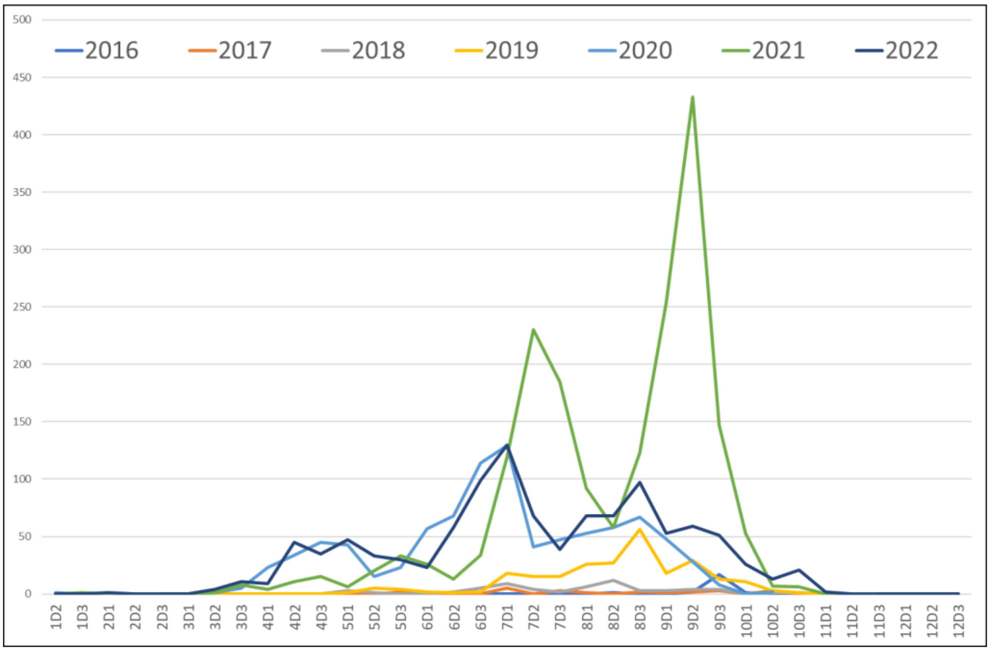


Fig. 9a. Annual phenogram of *Pieris mannii.* © Cuvelier & Vervaeke.

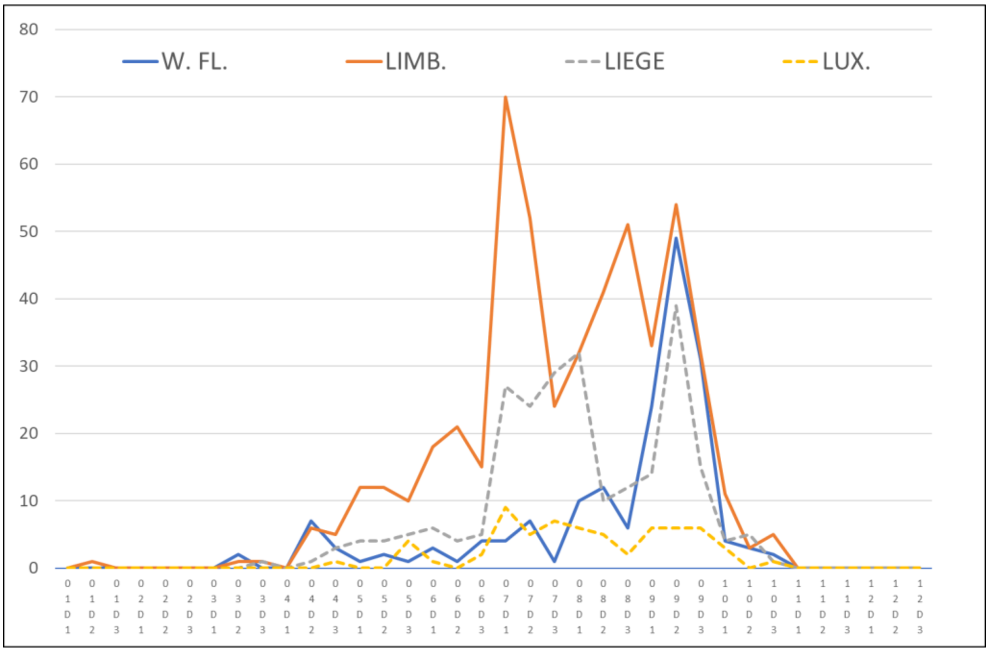


Fig. 9b. Phenogram (2016–2022) of *Pieris mannii* in four Belgian provinces. Full lines: Atlantic biogeographical region, dashed lines: continental biogeographical region. © Cuvelier & Vervaeke.

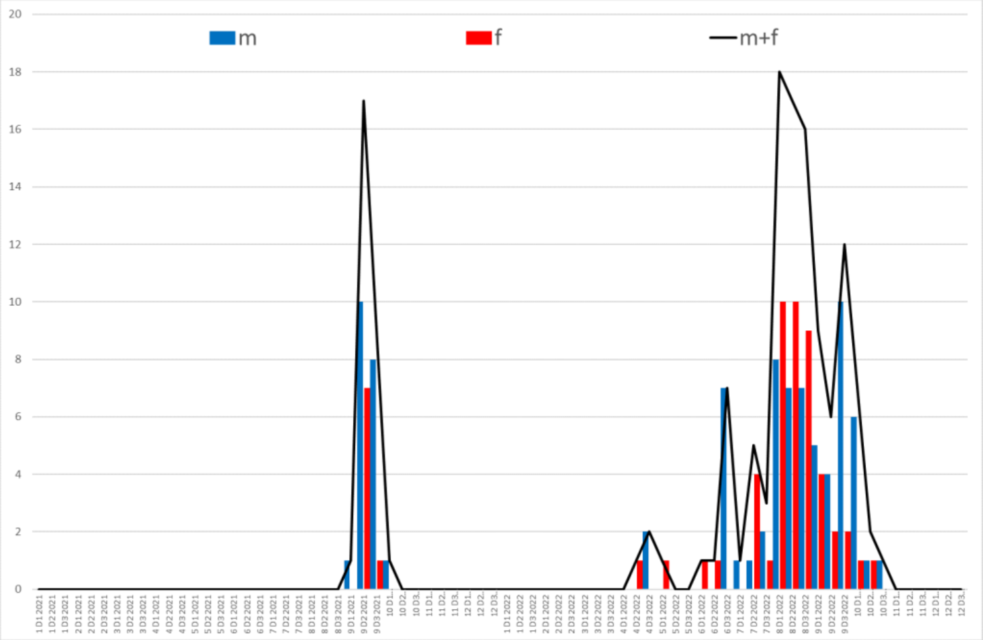


Fig. 10. Phenogram of adult *Pieris mannii* observations (2021–2022) in the garden of Jacques Vervaeke; m: adult males; f: adult females; black line: all imagos. © Cuvelier & Vervaeke)

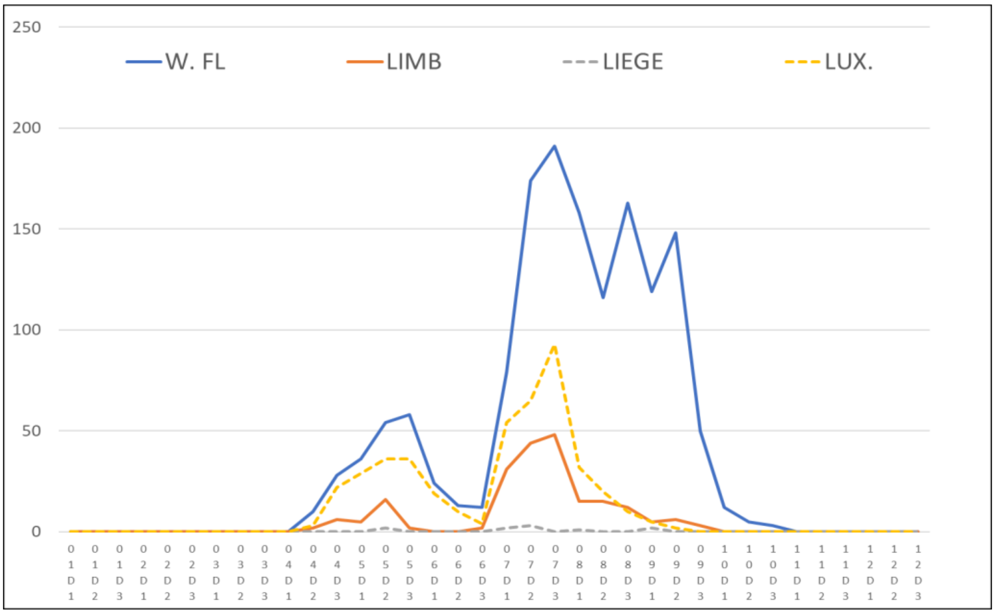


Fig. 11. Phenogram (2007–2022) of *Carcharodus alceae* in four Belgian provinces. Full lines: Atlantic biogeographical region, dashed lines: continental biogeographical region. © Cuvelier & Vervaeke.

Bearing in mind the heterogeneity of the data, *C. alceae*, *B. daphne* and *P. mannii* show different patterns of northerly and westerly expansion. This may be the result of different species-specific variables:

a) hostplant specialization (monophagous-polyphagous);

b) habitat specialization and preferences (specialist to generalist);

c) dispersion ability (low to high);

d) differences in voltinism (number of annual generations).

Referring to the provisional checklist of European butterfly larval foodplants (Clarke 2022), none of the three studied species is monophagous. In increasing order of number of foodplants, *B. daphne* utilises nine foodplants from two genera (*Rubus* and one *Filipendula*); *C. alceae* accepts seventeen foodplants from four genera and *P. mannii* is credited with using twenty-three foodplants from fourteen different genera. The availability and wider distribution of the main food plants have not been studied in depth; they do not appear to be limiting factors regarding the expansion of the three species in Belgium. None of the studied species are habitat specialists, despite having different habitat preferences. Estimating the dispersion ability of each species is difficult without lab work, but being involved in large expansions it appears that all three species are quite capable of continued dispersal. There is a major difference in the phenology of the three species. *B. daphne* has a single generation (Fig. 5b) from early June to early August (7 decades). By contrast, *C. alceae* (Fig. 3c) and *P. mannii* (Fig. 5c) are polyvoltine. The flight time of *C. alceae* stretches from the second decade of April until the end of September (17 decades), compared to *P. mannii* which is on the wing from the end of March till the end of October (22 decades). As voltinism may be an important factor, and because global phenograms are difficult to interpret (Bink & Moenen 2015), more detailed analyses are presented for both *P. mannii* (Figs 9a–b, 10) and *C. alceae* (Fig. 11). By comparing the annual phenograms (Fig. 9a), variations that have occurred in extreme years can be clearly seen, and not in the multiyear phenogram (Fig. 5c). Fig. 9a illustrates the need to show a minimum number of observations to visualize peaks and/or shifts in optimum flight periods when comparing annual flight patterns. In Belgium, the summer of 2021 was one of the wettest since records began in 1833, with 2020 and 2022 being extremely dry, hot, and sunny years. These extreme conditions resulted in a one-decade shift of the July peak emergence and a two-decade shift of the September peak emergence for *P. mannii.*

As Belgium has two different biogeographical regions, analyses of the flight times of *P. mannii* (Fig. 9b) and *C. alceae* (Fig. 11) are presented for two provinces in the Atlantic biogeographical region (West Flanders and Limburg) and for two provinces in the continental biogeographical region (Liège and Luxemburg). There are no conclusive differences in the phenograms for *C. alceae,* and no obvious disparities regarding the voltinism for the two biogeographical regions where *P. mannii* is present. Both graphs (Figs 9b, 11) confirm that below a quantity threshold, the interpretation of phenograms is insignificant.

Additionally, an analysis (Fig. 10) is presented for a single locality in West Flanders, the garden of the second author, from where daily observations of *P. mannii* were recorded. The species was noted for the first time in August 2021, and specimens of both sexes were observed in the second half of September during peak emergence. In April 2022, small numbers of the first generation were recorded, followed by three peaks (further broods/generations), in June, mid-August, and September, with a discernible overlap between these peaks.

For the potentially important variable of voltinism, it appears better to interpret the expansion using the annual number of decades to avoid the pitfall of a number of generations in what is probably an opportunistic overlapping continuum in the summer months until the weather conditions become too bad for a given species. The speed of the expansions of *P. mannii*, *C. alceae* and *B. daphne* correlates well with the annual number of decades in the phenograms. Major factors limiting the protraction, or advancement, of a further northward expansion may depend on future climatic conditions and the sustainability of existing habitats. Limiting factors affecting the continued westward expansion of *B. daphne* may depend on the availability of suitable habitats, and the lack of corridors to expand its range to suitable areas in western Belgium.

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Supplementary material

S1. Analysis of the database before and after filtering.
Zie — http://www.phegea.org/Phegea/Appendices/Phegea51-4_S1.pdf **761 KB**

S2. *Carcharodus alceae* data.
Zie — http://www.phegea.org/Phegea/Appendices/Phegea51-4_S2.pdf **1.253 KB**

S3. *Brenthis daphne* data.
Zie — http://www.phegea.org/Phegea/Appendices/Phegea51-4_S3.pdf **3.174 KB**

S4. *Pieris mannii* data.
Zie — http://www.phegea.org/Phegea/Appendices/Phegea51-4_S4.pdf **2.518 KB**

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