BUTTERFLY AND MOTHS IN L'EMPORDÀ AND THEIR RESPONSE TO GLOBAL CHANGE

Constantí Stefanescu, Tristan Lafranchis
(*Coordinators*)

Universitat de Girona
Càtedra d'Ecosistemes Litorals i Mediterranis

RECERCA I TERRITORI 12

Butterfly and moths in l'Empordà and their response to global change

Recerca i territori Volume 12

Universitat de Girona
Càtedra d'Ecosistemes
Litorals i Mediterranis

can Quintana Museu de la Mediterrània

Parc Natural
del Montgrí, les Illes Medes
i el Baix Ter

NUMBER 12 / SEPTEMBER 2020

Edition

Càtedra d'Ecosistemes Litorals Mediterranis

Parc Natural del Montgrí, les Illes Medes i el Baix Ter

Museu de la Mediterrània

Coordinadors of the volume

Constantí Stefanescu, Tristan Lafranchis

"Recerca i Territori" Collection Coordinator

Xavier Quintana

Graphic design

Mostra Comunicació

Printing

Gràfiques Agustí

ISSN: 2013-5939

Dipòsit legal: GI 896-2020

Printed on recycled paper Cyclus print

With the support of:

Diputació de Girona

Ajuntament de Torroella de Montgrí

Generalitat de Catalunya
Departament de Territori i Sostenibilitat

Fundació Girona
Regió de Coneixement
Universitat de Girona
Diputació de Girona
Ajuntament de Girona
Consell Social de la UdG
Cambra de Comerç

MUSEU DE CIÈNCIES NATURALS DE GRANOLLERS

FUNDACIÓ MASCORT
TORROELLA DE MONTGRÍ

associació del llibre de la festa major

Summary

Foreword

Stopping the loss of biodiversity is one of the most important environmental challenges of this century. According to the Ecological Society of America, biodiversity includes all organisms, species, and populations; the genetic variation among these; and all their complex assemblages of communities and ecosystems. Although more specific definitions of ecological diversity exist, which include other aspects such as the relative abundance of the different species (Magurran, 1988; Margalef, 2002), the term biodiversity basically refers to species richness. Biodiversity and ecological diversity are related to the structure of nature, since species are the components of ecosystems. The relationships among species and between these species and their abiotic environment are the basis of ecosystem functioning (Margalef, 1993), which in turn provides us with ecosystem services (Gamfeldt et al., 2013). This is why a knowledge of biodiversity and its conservation is so important, even from a selfish, human point of view (May, 2011), and several efforts have been made during recent decades to develop biodiversity conservation strategies on a global scale (IPBES, 2018) and on a regional or local scale (Gencat, 2018).

Some estimates put the number of known species at around 1.5 million, but this figure is far from the actual number of existing species, which is estimated to be approximately 8-9 million, with a great variability depending on how these estimations are made (Mora et al., 2011). That is, our current knowledge of the planet's biodiversity is very scarce, barely accounting for 10% of the total number of species inhabiting the Earth. A great effort is still required in order to have an idea of the number of species that exist, and even more so the case in terms of understanding patterns in the biology of these species and how they relate to ecosystems and their ecological functioning. Knowledge of biodiversity is uneven and depends on the organism group (Hawksworth & Kalin-Arroyo, 1995). Among animals, the best-studied groups are the vertebrates, with close to 45,000 species already described, which are likely to represent more than 50% of all living vertebrates. This percentage increases dramatically for mammals and birds, contrasting with our poor knowledge of invertebrates. Insects, for example, is the group with the most species described, over 1 million. However, this number represents a small percentage of the total, since some estimations suggest that more than 80% of all insect species on the planet have yet to be discovered (Stork, 2018). Among Lepidoptera, the order of insects that includes butterflies and moths, which we will discuss in this volume, we have a similar contrast to that found for the total number of species. While there is a good knowledge of butterfly fauna in Catalonia (Vila et al., 2018) and in the Empordà landscapes (Lafranchis, this volume a; Stefanescu, this volume a), knowledge of moth species and their biology is much poorer despite this being a much more diverse group (Lafranchis, this volume b), a possible exception to this being specific moth species regarded as agricultural or forest pests.

The species extinction rate has been estimated at up to 8,700 species per year, although estimations remain highly uncertain (Pearce, 2015). In addition, many species are showing a decline in population. In the case of butterflies in Catalonia, at least 22% of all species are threatened, and more than 65% have decreasing population trends (Vila et al., 2018). The main cause of biodiversity decline is global change, in its broader sense; that is, considering any type of human intervention that affects ecosystems at a global, regional, or local scale. Butterflies and moths respond at these three scales and greater knowledge and monitoring can help us understand how global change can affect species and ecosystems. At a global scale, there are several examples of how global climatic changes in temperature and precipitation regimes cause local uncoupling between the phenology and seasonal cycles of some butterfly species and their nectar sources (Donoso et al., 2016). Climate-driven changes in the frequency and duration of droughts may cause sharp population declines in previously well-established species (Vives-Ingla et al., this volume). At a regional scale, changes in land use, including the abandonment of cultivated fields and their replacement by forest and, more specifically, expansion of the urban surface, has been indicated as one of the leading causes for the decline of butterfly species in Catalonia (Ubach et al, 2020). At a local scale, management actions such as the use of pesticides and the intensive control of vegetation have a strong impact on butterfly populations (Lafranchis, this volume d). At the same time, butterflies respond rapidly to the implementation of management practices aimed at conservation in natural areas (Colom et al., this volume). Therefore, butterflies are valuable indicators of an ecosystem's rapid response to management actions, and are also useful as part of an adaptive management strategy based on an iterative process of simultaneously managing and gaining knowledge about natural resources, whereby managers continuously adapt their decisions to the immediate results from the ecosystem response (Stanley et al., 2005; Williams, 2011). A suitable management strategy should not be limited to protected natural areas. Non-protected open spaces are also important for species conservation in terms of connectivity and dispersal facilities, and certain management decisions can have dramatic consequences for species conservation (Lafranchis, this volume c). Conservation must take into account that populations of species are not isolated, but organized in metacommunities; that is, a set of populations of several species that are linked, to a greater or lesser extent, through their dispersal abilities (Leibold et al., 2004).

This book contains a series of articles related to the biodiversity of butterflies and moths in the Empordà region and how management actions may affect them. The Empordà plain is a strongly humanized landscape, where natural parks and Nature 2000 protected areas alternate with agricultural surfaces that have been exploited for centuries and touristic areas developed during recent decades, resulting in an increase in housing and infrastructure buildings. The result is habitat patches with different levels of human pressure and interconnection, where intensive human use, as well as renaturalization and recovery processes in abandoned areas, have a strong impact on faunal populations. Therefore, some chapters deal with management recommendations to enhance species conservation (Lafranchis, this volume d; Stefanescu, this volume b).

This volume is the sixth of the Recerca i Territori monographs (Recerca i Territori 'Green' series), a collection that includes themes developed by authors who have a long experience in a specific environmental area, and has a two-fold objective: to help disseminate knowledge of the natural heritage and to facilitate the decision-making of those who manage natural spaces. This current volume of the Recerca i Territori collection is the first to deal with a group of fauna, Lepidoptera. The choice of this group of organisms is not accidental, since it is closely related to biodiversity management and conservation and conforms with many of the recurring patterns in biodiversity loss, with species responding at different scales of global change, from global climatic changes to local effects of management practices. Lepidoptera includes butterflies (a relatively well-known fauna), and moths, which are much more diverse, but for which information is still scarce (Lafranchis, this volume e). Moreover, butterflies are often recognizable at species level, thus eliminating the need to capture and kill individuals (particularly interesting for monitoring programs), which is not the case for most invertebrate fauna, with the general exception of dragonflies. Finally, the Empordà region is home to several routes that form part of the Catalan Butterfly Monitoring Scheme (www.catalanbms.org), including the 30-year-old El Cortalet route in Aiguamolls de l'Empordà, which has the oldest ongoing register of invertebrate fauna in Catalonia (Stefanescu, this volume a). All these features make butterflies ideal for understanding patterns in man-induced species decline in the area.

Xavier Quintana
Càtedra d'Ecosistemes Litorals Mediterranis
Universitat de Girona – Ajuntament de Torroella de Montgrí

REFERENCES:

Colom, P., & C. Stefanescu, this volume. Effects of abandonment and restoration in Mediterranean meadows in a butterfly-plant network subject to long-term monitoring.

Donoso, I., C. Stefanescu, A. Martínez-Abraín, & A. Traveset, 2016. Phenological asynchrony in plant–butterfly interactions associated with climate: a community-wide perspective. Oikos 125: 1434–1444.

European Commission, 2020. EU Biodiversity Strategy for 2030. Bringing nature back into our lives. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Document 52020DC0380.

Gamfeldt, L., T. Snäll, R. Bagchi, M. Jonsson, L. Gustafsson, P. Kjellander, M. C. Ruiz-Jaen, M. Fröberg, J. Stendahl, C. D. Philipson, G. Mikusiński, E. Andersson, B. Westerlund, H. Andrén, F. Moberg, J. Moen, & J. Bengtsson, 2013. Higher levels of multiple ecosystem services are found in forests with more tree species. Nature Communications 4:1340.

Generalitat de Catalunya, 2018. Estratègia del Patrimoni Natural i la Biodiversitat de Catalunya 2030. Barcelona.

Hawksworth, D. L., & M. T. Kalin-Arroyo, 1995. Magnitude and distribution of biodiversity. In Heywood, V. H. (ed), Global biodiversity assessment. Cambridge University Press: 107–199.

IPBES. 2018: Rounsevell, M., M. Fischer, A. Torre-Marin Rando & A. Mader (eds.). Regional Assessment Report on Biodiversity and Ecosystem Services for Europe and Central Asia. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.

Lafranchis, T., this volume a. Butterflies of the Montgrí-Baix Ter region

Lafranchis, T., this volume b. Moths of the Montgrí-Baix Ter region

Lafranchis, T., this volume c. The dispersion of Lepidoptera in the Montgrí-Baix Ter region

Lafranchis, T., this volume d. Doing better for butterflies and moths

Lafranchis, T., this volume e. List of Lepidoptera known from Empordà (Catalonia, Spain)

Leibold, M. A., M. Holyoak, N. Mouquet, P. Amarasekare, J. M. Chase, M. F. Hoopes, R. D. Holt, J. B. Shurin, R. Law, D. Tilman, M. Loreau, & A. Gonzalez, 2004. The metacommunity concept: A framework for multi-scale community ecology. Ecology Letters 7: 601–613.

Magurran, A. E., 1988. Ecological diversity and its measurement. Croom Helm Limited, London.

Margalef, R., 1993. Teoría de los Sistemas Ecológicos. Edicions Universitat Barcelona, Barcelona.

Margalef, R., 2002. Diversidad y biodiversidad. In Pineda, F. D., J. M. de Miguel, M. A. Casado, & J. Montalvo (eds), La diversidad biológica de España. Prentice Hall, Madrid: 432.
May, R. M., 2011. Why worry about how many species and their loss?. PLoS Biology 9: 8–9.

Mora, C., D. P. Tittensor, S. Adl, A. G. B. Simpson, & B. Worm, 2011. How many species are there on earth and in the ocean?. PLoS Biology 9: 1–8.

Pearce, F., 2015. Global Extinction Rates: Why Do Estimates Vary So Wildly?. Yale Environment 360 .

Stefanescu, C., this volume a. Three decades of butterfly monitoring at El Cortalet (Aiguamolls de l'Empordà Natural Park)

Stefanescu, C., this volume b. Synthesis: using butterflies as a reference for understanding the impact of climate change and habitat management on biodiversity

Stork, N. E., 2018. How Many Species of Insects and Other Terrestrial Arthropods Are There on Earth?. Annual Review of Entomology 63: 31–45.

Ubach, A., F. Páramo, C. Gutiérrez, & C. Stefanescu, 2020. Vegetation encroachment drives changes in the composition of butterfly assemblages and species loss in Mediterranean ecosystems. Insect Conservation and Diversity. DOI 10.1111/icad.12397

Vila, R., C. Stefanescu, & J. M. Sesma, 2018. Guia de les papalones diürnes de Catalunya. Lynx Edicions. Barcelona.

Vives-Ingla, M., C. Stefanescu, Sala-García, J., & J. Carnicer, this volume. Plastic and phenological variation of host plants mediates local responses of the butterfly *Pieris napi* to drought in the Mediterranean basin.

Butterflies of the Montgrí-Baix Ter region

Tristan Lafranchis

Association Diatheo - Papillons de France et d’Europe
Corresponding author e-mail: lafranchis@yahoo.fr

The results of a 5-year investigation in the Montgrí-Baix Ter region (NE Catalonia) between 2014 and 2019 are presented. Approximately 500 excursions in the field, including many one-hour transects, allowed us to identify 43,000 butterflies belonging to 69 species. In addition to the observation of imagos, early instars were searched for in the field, making possible to obtain a phenological chart for most species and to confirm the use of many larval host plants. Several species have been mapped, but the distribution maps presented here do not pretend to be complete, as they are based only on our personal records. All the information about the biology and ecology was obtained in the Montgrí-Baix Ter region, except in a few cases (for which the precise locations are given). Almost all data were collected within the boundaries of Parc Natural del Montgrí, les Illes Medes i el Baix Ter.

Evolution of habitats and butterfly fauna

The land use history of the Montgrí-Baix Ter area certainly influenced the evolution of the butterfly fauna. In the 14th century, the Montgrí Massif, a royal property, hosted a large flock of transhumant and wintering sheep that spent the summer in the Pyrenees. For several centuries, the hillside had been home, at least seasonally, to several thousand sheep and goats, especially before being cultivated from the 17th century to the 19th century. There were still 4,000 heads in 1882 and 3,700 in 1981 in 14 flocks in the municipalities of Torroella de Montgrí, Ullà, Bellcaire d'Empordà and L'Escala (Roviras Padrós 2001, Serra 2010). Most of the farms, which were successors of the Roman villas built on the lower slopes of the hillside, had a herd (Torró *et al*., 1989). Testimonials and old photographs show that the Montgrí was an area of grazed dry grasslands and rocky slopes with a few woods and fields at the beginning of the 20th century. The typical fauna of dry grasslands on limestone probably found on the Montgrí a suitable environment, but the decline in sheep farming reduced their habitats planted with trees or invaded by scrub. This change in land use also provoked the extinction of several birds who bred on the Montgrí until the 1980s: the black-eared wheatear (*Oenanthe hispanica*), black wheatear (*O. leucura*) and spectacled warbler (*Sylvia conspicillata*). Some dry grassland specialists that were or are still present on the coastal hillsides in Aude (southern France) or in southern Catalonia (*Chazara briseis, Satyrus actaea* or some *Pyrgus*) might have occurred on the Montgrí. In contrast, the reforestation of the hillside at the end of the 19th century (aimed at stopping the movement of a huge sand dune brought to the plateau by the tramontana wind) and the grazing restrictions issued by forest engineers have certainly favored species linked to shrubs and trees, such as *Gonepteryx cleopatra, Leptidea sinapis, Favonius quercus* or *Callophrys rubi*. The present butterfly fauna on the hillside and its valleys is typical of dry mediterranean scrubland (garriga). Particularly widespread is the kermes oak facies, the dominant habitat in the areas burnt in 2004, home of strong populations of both *Satyrium esculi* and *Pyronia bathseba*. *Anthocharis euphenoides* is also widespread and common. *Hipparchia fidia* is largely dominant on stony slopes, being very numerous in mid-summer. *Lasiommata megera* and, at a minor scale, *Lysandra hispana* are common in and around the open pine woodlands.

The lower slopes of the Montgrí have been dedicated to dry crops (olive, almond, vine, cereals) since Roman time. The rather small plots have certainly been good habitats for butterflies for many centuries. The influx and development of tourism at the end of the 20th century brought the construction of housing estates on the southern slope, leaving abandoned olive groves in the unbuilt areas. Here, several emblematic Mediterranean butterflies such as *Zerynthia rumina, Tomares ballus* or *Callophrys avis*, are still found, in small or very small numbers. The houses provide new habitat for some species that can find one of their host plants in the gardens. Despite the immoderate use of pesticides, *Limenitis reducta* (caterpillars on *Lonicera japonica*) and *Pararge aegeria* (caterpillars on various grasses), for example, manage to survive in these areas. These semiurban habitats also help in the expansion of alien species, such as *Cacyreus marshalli*, brought with *Pelargonium* from South Africa.

In the Ter lowland, the strong decline in coastal meadows (old photos show that there were extending to the village of L'Estartit) might have driven the extinction of mesophilic butterflies that are still found in similar habitats in the Aiguamolls natural park. The remaining uncultivated fallow lands with *Tamarix* hedgerows retain thick litter, which reduces floristic and faunistic diversity. It is, however, the main habitat of *Danaus chrysippus*, and the moth fauna is relatively rich. In these meadows, as in the overgrazed grasslands near Sobrestany, several meso-xerophilic and heliophilic species have been found that are scarce or absent on the Montgrí limestone hillside: *Pyrgus malvoides, P. armoricanus* and *Coenonympha pamphilus*. The embankment of the Ter River and the intensification of agriculture to the very edge of streams and ponds has drastically reduced the riparian woodlands and the hedges, preferred habitats of mesophilic species such as *Pieris napi*, *Gonepteryx rhamni* (both definitely more common in the Aiguamolls natural park), *Pyronia tithonus, Inachis io* and *Polygonia c-album*.

Species with less specific requirements due to polyphagous caterpillars are often strongly mobile and can be found more or less regularly throughout the territory of the PNR Montgrí (*Papilio machaon, Pieris rapae, Colias crocea, Lampides boeticus, Vanessa cardui*). Therefore, the distribution of a good number of butterfly species appears to be homogeneous and continuous on a large scale. However, there are striking exceptions that are very local (*Erynnis tages, Callophrys avis, Glaucopsyche alexis*). These species survive in one or two weak populations, that aparently lack any possible connection with the closest other populations in Empordà.

Two limiting climatic variables influence the distribution of butterflies: temperature, which mostly acts in winter, and drought which can be problematic in summer. The distribution maps of two common butterflies (Fig. 1) clearly show the influence of drought. *Pararge aegeria* is nearly absent on the Montgrí hillside, because it is mostly a woodland species that avoids open habitats and dry places. *Lasiommata megera*, on the contrary, prefers sunny and stony or rocky sites. The imagos of this species spend the night hanging to a rock or a stone wall and males exhibit hilltopping behavior, keeping a territory on a high relief: this butterfly prefers rocky habitats. The distribution of these two species in the Montgrí-Baix Ter area reflects their different microclimatic preferences.

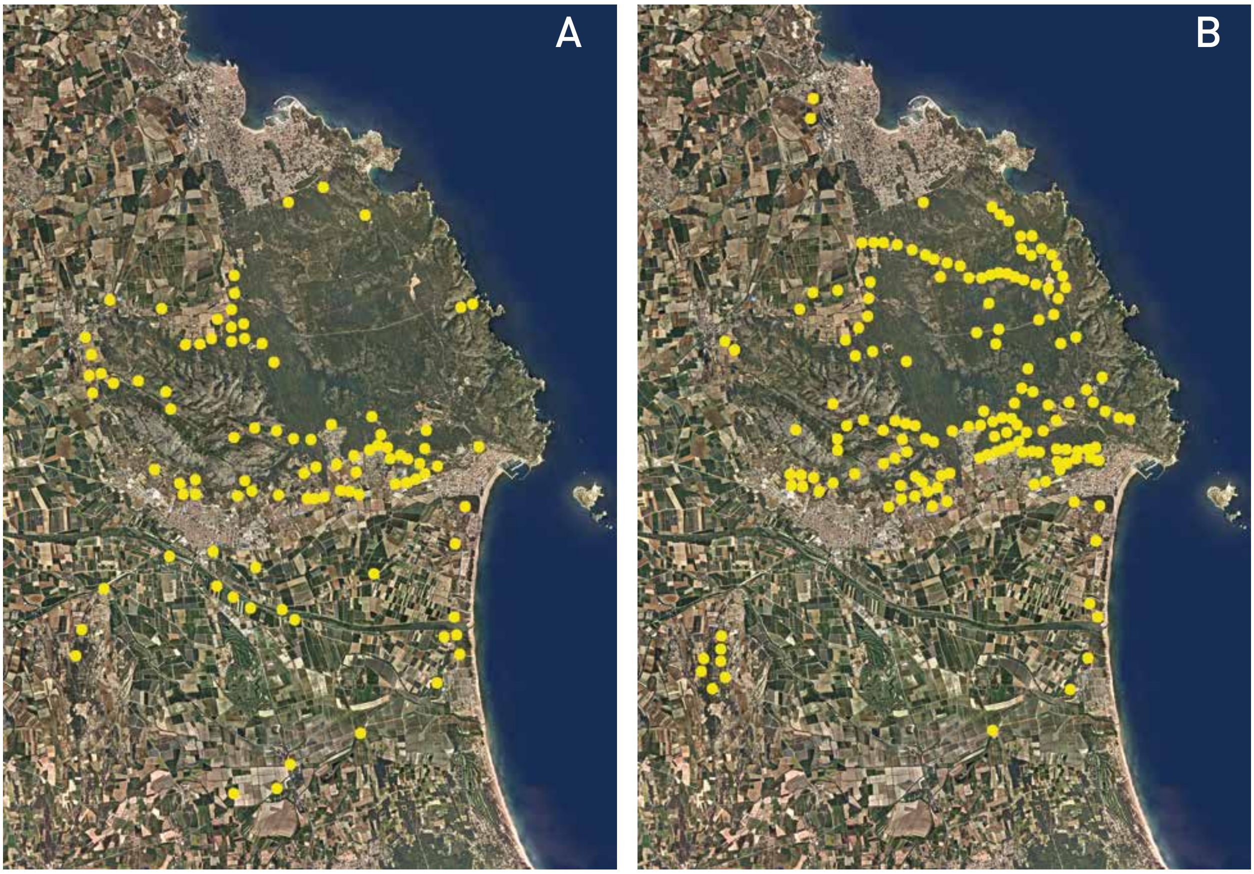


Figure 1. Distribution map of *Pararge aegeria* (A) and *Lasiommata megera* (B) in the Montgrí-Baix Ter.

Commented list

Papilionidae

Iphiclides feisthamelii (Duponchel, 1832)
Males are territorial on high points (hilltopping), females are very mobile, looking first for males and then dispersing their eggs throughout a large range, on shrubs and fruit trees in the family Rosaceae (*Prunus dulcis, P. spinosa* and *Crataegus monogyna* on the Montgrí, *P. armeniaca* at Ampuries). The imagos fly in two broods between mid-March and September; the first individuals of the 2nd brood flying from the 20th of June. A third brood appears in some years and flies until the end of October.

Papilio machaon (Linnaeus, 1758)
Like previous species and often together with it, males spend warm hours on the highest areas of the Montgrí. Eggs and caterpillars are found on *Foeniculum vulgare* (Apiaceae). The exact number of broods per year is difficult to assess. There are three demographic peaks in mid-April, mid-June and at the end

of September. The last instar larvae were found in May, August and October. Even if *P. machaon* appears before *I. feisthamelii* (1 to 5 weeks earlier in 2014-2019), the first generation stock usually increase slowly as meteorological conditions are often not as good in February-early March. *Papilio machaon* normally seems to fly in Empordà in three broods, with the spring brood, which can be abundant, spreading over several months. However, a female butterfly searching for a suitable place to lay eggs on 23.02.2019 indicates the possibility of four generations in years with an early season, such as 2016 or 2019.

Zerynthia rumina (Linnaeus, 1758)

Figure 2. Distribution map of *Zerynthia rumina* on the Montgrí. Yellow dots: imagos, red dot: caterpillars, green dots: sites of *Aristolochia pistolochia*.

A small population, unnoticed for four years in a regularly prospected area, was located in April 2018 on the southeastern slope of the Montgrí, in an open *Pinus halepensis* woodland (Fig. 2). The caterpillars there were on a small population of *Aristolochia pistolochia* (Aristolochiaceae) which was trampled by wild boars in the following winter. No caterpillars were detected in spring 2019, but 3 imagos were seen from slightly eastwards between the 5th of March and the 8th of April. In spring 2020, these *Aristolochia* were very healthy and more abundant than in the previous years, especially in places formerly plowed by wild boars. However, despite a careful search, no eggs, no caterpillars and no signs of presence (eaten leaves or flowers, droppings) were detected. The host plant is too scarce on the Montgrí to maintain a healthy population of this butterfly, which appears to be very threatened. Another birthwort species, *A. rotunda*, feeds caterpillars in less dry habitats along streams at Jafre (an ancient island on the Ter River) and Darnius (on the Ricardell riverside). Repeated searches on the few sites of *A. rotunda* in the Baix Ter, which are very reduced in extension and have only a few plants, did not produce any positive results.

Hesperiidae

Carcharodus alceae (Esper, 1780)

Widespread throughout the territory, its larval host plants colonize various open habitats, especially fallow lands and lane margins. The imagos fly from February to late October, during which there are probably four broods that peak early April, early June, late July and late September-early October, with the last brood being the most abundant. Egg laying and caterpillars were observed on *Althaea officinalis*, *Lavatera maritima* and *Malva sylvestris* (Malvaceae).

Carcharodus baeticus (Rambur, 1839)

Located around decent populations of *Marrubium vulgare* (Lamiaceae), its host plant on the Montgrí, it is able to temporarily colonize less favorable sites (Fig. 3). In March 2014, we found three caterpillars on a single plant of *Marrubium* growing on the edge of a field below the housing of Torre Vella. This solitary plant lived two more years and was then destroyed by plowing. The host plant and butterflies are favored by sheep grazing, and the sustainable presence of *C. baeticus* depends on sheep farming (Lafranchis *et al.,*

Figure 3. Distribution map of *Carcharodus baeticus* on the Montgrí. Yellow dots: imagos, red dots: eggs and larvae.

Figure 4. Distribution map of *Pyrgus malvoides* in the Montgrí-Baix Ter.

2015). The imagos fly in two generations noted on 12th May-20th June and on 1st August-8th October.

Carcharodus lavatherae (Esper, 1783)
Two observations were made in June 2016, both fresh males, at the bottom of Torre Vella and in Vall Petita. This butterfly is known to fly alone or in small numbers, a trait confirmed on the Montgrí.

Spialia sertorius (Hoffmansegg, 1804)
Widespread on the Montgrí, sometimes rather abundant in the fallow lands colonized by *Sanguisorba minor*. Flies in two broods on 12th April-17th June and again on 26th July-10th October, with the first generation being more numerous.

Pyrgus malvoides (Elwes & Edwards, 1897)
Apparently local and scarce. Never found on the hillside, it flies along the Ter River to unused plots in Torroella de Montgrí, on the back dunes at la Fenollera and in meadows near Sobrestany (Fig. 4). Partially bivoltine, the butterflies mostly fly between 29th April and 24th May and some appear again in September.

Pyrgus armoricanus (Oberthür, 1910)
Rather widespread in meadows and mesic fallow lands in the Ter plain and on the foothills (Fig. 5). Bivoltine; the first brood is scarce and therefore difficult to find (observed in May), and the second brood is more abundant and flies between 14th September and 25th October. Egg laying behavior has been observed on *Potentilla reptans* (Rosaceae).

Erynnis tages (Linnaeus, 1758)
A species in strong decline in Catalonia (CBMS, Catalan Butterfly Monitoring

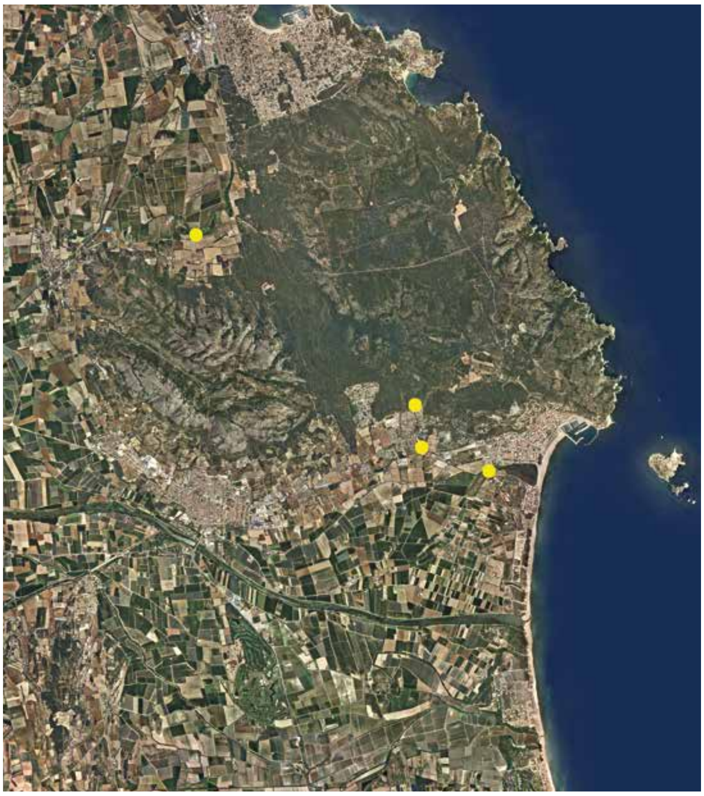


Figure 5. Distribution map of *Pyrgus armoricanus* in the Montgrí-Baix Ter.

Scheme) that is very local on the Montgrí, where it is regularly found in spring (13th April-5th June) on an area less than 5000 m^2 in the upper part of Vall de Santa Caterina. This population is very weak, with only 13 butterflies counted in 8 visits over three years. Almost all of them were males that keep two territories every year, one at each extremity of the site. A female butterfly followed on 16th April 2016 laid an egg on a leaflet of a *Dorycnium pentaphyllum* (Fabaceae) that was very reduced by scrub clearance during the former winter. This behavioral trait has preserved the species from the negative effects of the restoration works. Butterflies in the Gavarres (Pérez De-Gregorio & Rondós 2003) and on the hillsides west of Figueres are at least partially bivoltine, but we do not know if this is the case on the Montgrí.

Thymelicus acteon (Rottemburg, 1775)
Very widespread in sunny grassy places, it flies in a single generation noted between 7th May and 12th July.

Ochlodes sylvanus (Esper, 1777)
Widespread in mesic habitats, it is totally bivoltine in the Montgrí-Baix Ter: on 14th May-22th June and again on 14th August-16th October. Both broods are equally numerous. Early stages were found on Poaceae: egg laying on *Dactylis glomerata* (Empúries) and caterpillar on *Phragmites australis* (Sant Pere Pescador).

Pieridae

Leptidea sinapis (Linnaeus, 1758)
Widespread except in cultivated areas, it flies in three broods that peak in mid-April, mid-June and late September. When summer is especially dry, such as in 2017, the third generation is absent or is too scarce to be detected. Eggs are laid on *Dorycnium hirsutum* and *D. pentaphyllum* (Fabaceae). Both of these plants are largely used by *L. sinapis* in southern Europe, which is not the case for the sister species *L. reali* Reissinger 1989, cited from two sites close to the sea in Empordà: S'Agaro (Lorkovic 1993) and Roses (Vila *et al*., 2018).

Gonepteryx rhamni (Linnaeus, 1758)
Widespread but not common, it is mostly found in woodlands and along the Ter River. The only generation flies between late May and mid-October and again after hibernation from February to May.

Gonepteryx cleopatra (Linnaeus, 1767)
Very widespread, abundant and mobile. Prefers warm open woodlands. The two annual broods peak mid-June and early October and the second one is less numerous. Butterflies may be seen at any time in the year. Hibernated butterflies lay eggs in March and April, sometimes much earlier (26.12.2015) or until May. The imagos from the first lay eggs between June and August. The only known host plant in the Montgrí-Baix Ter is *Rhamnus alaternus* (Rhamnaceae). This plant usually is xerophilic, but it also grows in damp areas in the plains (Aiguamolls of Baix Ter and of Alt Empordà) where it has been followed by *G. cleopatra*. Caterpillars are parasitized by *Hyposoter rhodocerae* (Hymenoptera Ichneumonidae).

Colias crocea (Geoffroy, 1785)
Very widespread in Empordà, it flies continuously on the Montgrí during mild winters, producing at least four broods per year confirmed by observations of the early stages. There are very few imagos in mid-summer and the highest counts are reached in October. Egg laying and caterpillars have been noted on *Astragalus monspessulanus*, *Medicago polymorpha*, *M. sativa, M. truncatula* and *Robinia pseudoacacia* (Fabaceae). A northward migration was recorded on 6.05.2015.

Colias alfacariensis (Ribbe, 1905)
Local in Empordà to dry grasslands on the hillsides, it is not common on the Montgrí. Mostly encountered in Vall Gran de Santa Caterina and Vall Petita, it is occasional elsewhere on the Montgrí. The imagos fly in three broods on 22nd March-18th May, 5th June-2nd July and 23rd August-28th October.

Pieris brassicae (Linnaeus, 1758)
Very widespread and highly mobile, it flies in the Montgrí-Baix Ter between late February and late November, sometimes flying from late January or until mid-December, but always with a gap in mid-winter. Together with the demographic peaks, the recorded mature larvae show that there are three complete broods followed by a weak fourth brood in November. Caterpillars are sometimes found in mid-winter, but the small ones grow very slowly, and many die within their three first instars. However, some manage to survive and continue to grow in winter, as shown by the 4th and 5th instar larvae found at Le Boulou (France) just north of the border with Spain on 20.01.2016. In the Montgrí-Baix Ter region, the first generation is by far the most numerous. Butterflies almost completely disappear between late June and mid-September. Migration towards the north was noted in March and late May. Egg laying and caterpillars were observed on cultivated *Brassica oleracea*, *B. oleracea subsp. robertiana*, *Diplotaxis erucoides*, *Hirschfeldia incana* and *Raphanus raphanistrum subsp. maritimum* (Brassicaceae).

Pieris rapae (Linnaeus, 1758)
Very widespread and common, warm seasons allow him to fly throughout winter. Demographic peaks occur in March and October and butterflies are scarce in summer (annual minimum between mid-July and mid-August). Early stages confirm that there are at least four broods per year. The recorded host plants are *Brassica oleracea, Diplotaxis erucoides, Hirschfeldia incana, Lepidium graminifolium, Lobularia maritima* (Brassicaceae) and *Reseda phyteuma* (Resedaceae).

Pieris mannii (Mayer, 1851)
Widespread and rather common around the Montgrí in and near open woodlands and even very close to the sea. A strong colony (103 imagos were counted in 7 visits in 2016) breeds in a small coastal pine

woodland by the archaeological site of Ampuries. The egg laying dates confirm that there are at least four broods that fly from mid-March to mid-November (from the 5th of February in 2016, until the 1st of December in 2015. The early stages have been found on *Diplotaxis erucoides, D. muralis* and mostly on *Lobularia maritima* (Brassicaceae).

Pieris napi (Linnaeus, 1758)
Widespread but not common except sometimes along the Ter River, it is not especially linked to damp habitats. It was recorded regularly in mesic areas of cultivation (L'Estartit, Bellcaire) and more rarely in pine woodlands on the southern slope of the Montgrí. Butterflies fly in several broods between March (earliest record 14.02.2016) and December. Common around Torroella de Montgrí in approximately 1980 (X. Quintana pers. comm.), this species might have declined after the 2004 fire.

Pontia daplidice (Linnaeus, 1758)
Very widespread, it flies between early February and late December in four or five broods and the autumn brood is the most abundant (annual peak in late September-early October). The imagos hatched and flew throughout winter in 2015-2016 and 2018-2019, and the 2nd brood appeared as early as the 12th of April. Eggs are laid on *Reseda phyteuma* (Resedaceae) and *Diplotaxis erucoides*, caterpillars also feed on *Lepidium graminifolium* (Brassicaceae).

Anthocharis cardamines (Linnaeus, 1758)
Rather local, this butterfly is mostly encountered on and near sites with *Arabis hirsuta*, the main host plant on the Montgri. Egg laying was observed once on *Diplotaxis erucoides* (Brassicaceae). A single brood flies from 12th March to 2nd May.

Anthocharis euphenoides (Staudinger, 1869)
Widespread and common on the Montgrí (Fig. 8 p.64), with a generation recorded from 19th March to 18th May. Eggs and larvae are easy to spot on *Biscutella laevigata* s.l. and *Hirschfeldia incana* (Brassicaceae).

Euchloe crameri (Butler, 1869)
Bivoltine on 26th January-28th April and 15th April-10th June. Both broods are equally numerous. The butterfly is not especially abundant but is very mobile and opportunistic: early stages have been found on *Biscutella laevigata* in garriga, *Bunias erucago* on dry grasslands, *Hirschfeldia incana* in dry fallow lands, *Raphanus raphanistrum* subsp*. maritimus* in the coastal back-dunes, and *Sinapis alba* and *Brassica oleracea* (Brassicaceae) in a garden at Torre Gran.

Nymphalidae

Danaus chrysippus (Linnaeus, 1758)
This irregular migrant was numerous during the autumn in 2014 (until the 2nd of December) everywhere along the coast, with two sightings 2-3 km inland (Torre Gran and along the Ter River) None were seen in 2013, 2015, 2016 and 2017, but there were a few noted at the Aiguamolls natural park in those years. This tropical butterfly visited the Baix Ter region again in 2018 and 2019. Eggs have been found on *Cynanchum acutum* (Asclepiadaceae) growing in hedges near L'Estartit.

Libythea celtis (Laicharting, 1782)
Scarce on the Montgrí, perhaps because nettle-tree (*Celtis australis*) is scattered and uncommon. We observed some imagos in March around a nettle-tree near Torre Ferran.

Charaxes jasius (Linnaeus, 1767)
Scarce on the Montgrí, as its host plant *Arbutus unedo* (a grown caterpillar was located on an isolated tree on 18.03.2016). Butterflies appear occasionally here and there around the Montgrí Massif, including in the centre of villages (Torroella, L'Estartit), mostly in September-October. This species was less scarce in 2013 than in any of the following years.

Lasiommata megera (Linnaeus, 1767)
Very widespread (Fig. 1, p.15), it is definitely the most common butterfly in the Montgrí-Baix Ter. It flew without any interruption between September 2013 and April 2019 (at least), producing four demographic peaks per year in winter, spring, early summer and autumn (Fig. 6). The imagos hatch, pair and lay eggs even in mid-winter. Females lay eggs in dry grasslands, on mesic banks and in gardens on *Brachypodium retusum* and *Piptatherum milliaceum* (Poaceae).

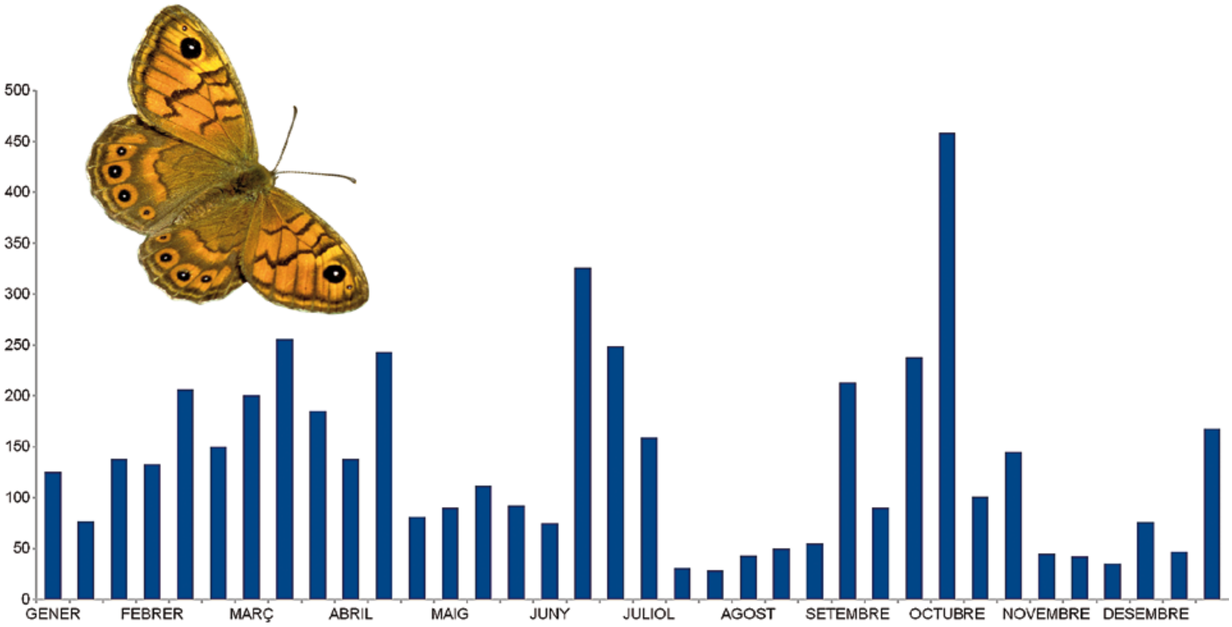


Figure 6. Phenology of *Lasiommata megera* on the Montgrí (number of imagos per 10-day period in 2014-2018).

Lasiommata maera (Linnaeus, 1758)
A scarce species in Empordà. Xavier Quintana caught a single specimen on the Montgrí at the end of the 1970s (Vicens *et al.,* 1987). It is mostly a mountain butterfly in Catalonia: of 53 sites monitored by CBMS, only one is located below 200 m a.s.l. and recent sightings in Empordà were mostly made above 800 m.

Pararge aegeria (Linnaeus, 1758)
Very widespread though it avoids open and dry areas (Fig. 1 p.13). Butterflies fly year-round but are scarcer between mid-July and early September. Demographic peaks occur in February-March, mid-May and early October.

Coenonympha pamphilus (Linnaeus, 1758)

A typical species of meadows and grassy fallow lands, this butterfly is missing or is very scarce on the Montgrí Massif. It is local on the territory of the natural park, with populations in grasslands near Sobrestany, around Ter Vell and near Vall Petita. The imagos fly between late March and mid-November. A pupa found hanging on a bay window in the inner courtyard of a hotel at Ampuries shows that this species can breed on an unsprayed lawn. As for other Satyrinae, the structure of vegetation seems to be more decisive than grass species in the choice of egg laying sites by females.

Maniola jurtina (Linnaeus, 1758)

Widespread but not especially abundant, the single brood flies over an extended period from 10th May to 8th October. Mating occurs in June and egg laying is delayed until September, which is a common feature of this butterfly in southern Europe.

Pyronia cecilia (Vallantin, 1894)

A typical summer butterfly that is widespread and common in various habitats. It flies in a long generation on the wings between early June and mid-September.

Pyronia tithonus (Linnaeus, 1771)

Found in dry fields and in garriga according to Vicens *et al*. (1987), this butterfly was not scarce (X. Quintana, pers. comm.). It is now found only in the vicinity of Sobrestany where it is not very common. It flies in July and August along the hedges in the pastures, from where it sometimes moves to the oak woodland near Torre Ferran (20 imagos were noted in 3 visits, one per year in 2015-2017). This species, the least Mediterranean of the three European *Pyronia*, is probably suffering from the dessication of its habitats.

Pyronia bathseba (Fabricius, 1793)

Very common on the Montgrí, but poorly dispersive. This typical host of Mediterranean scrub flies in a single brood between late April and early July and is very numerous in late May-early June. Sitting in the low vegetation, the female drops an egg to the litter below dense stands of *Brachypodium retusum* (Poaceae - several observations in open pine woodlands in Gavarres).

Melanargia lachesis (Hübner, 1790)

Common in grassy areas, it avoids stony or rocky grounds and is therefore more widespread and abundant in ditches and banks in the Ter plain and on the low foothills. This single-brooded species flies between late May and mid-July.

Melanargia occitanica (Esper, 1793)

The Montgrí maintains a good population of this butterfly, which is in strong decline in Catalonia (Vila *et al*., 2018). Environmental works in Vall de Santa Caterina seem to be favorable for this species as egg laying was observed in 2016 on *Brachypodium phoenicoides* (Poaceae) growing in plots cleared of shrubs in 2015. Forestry works in 2015-2017 thinned the trees, created clearings (which were soon invaded by the host grass) and enlarged the lanes. In spring 2018, imagos were quite numerous and were seen everywhere on the southeastern parts of the Montgrí. Scrub clearing and tree thinning have created new breeding grounds and favored their connectivity. While 10 visits in 2014-2016 produced 60 imagos, we counted 58 in only 5 visits in May 2018. However, the rapid growth of shrubs (especially *Cistus albidus* and *C. monspeliensis*) between

2018 and 2020 in the small newly created clearings is leading back to the initial situation. On 7.05.2016, males had gathered on the top ridge of Muntanya d'Ulla (hill-topping) and no individuals of this species could be found at lower levels. The single brood flies between 24th April and 22nd June, peaking in late May.

Brintesia circe (Fabricius, 1775)

Rather uncommon but mobile and therefore widespread, it has been observed on the Montgrí and occasionally in the villages and in the back dunes and fallow lands by the sea. The flight period spans from 14th June to 4th October, with the imagos aestivating for most of the summer (no observations between 4th July and 11th September).

Hipparchia statilinus (Hufnagel, 1766)

Widespread in various dry habitats, it flies between late July and early October and is the last butterfly to appear during the year on the Montgrí. Egg laying has been observed on *Brachypodium retusum* in an open pine woodland.

Hipparchia fidia (Linnaeus, 1767)

Widespread on the Montgrí, it ventures to the lower slopes but does not leave the hillsides. It prefers stony grounds with sparse vegetation, where it can be very abundant in July, nectaring then mostly on *Eryngium campestre*. The flight period covers the whole summer: mid-June to mid-September.

Hipparchia semele (Linnaeus, 1758)

Very scarce on the Montgrí: 3 imagos were found in 2013-2014, but none were found later. Similar to several other *Hipparchia* species, *H. semele* is used to spending the hot summer in dry woodlands where it remains active. The 2004 fire considerably reduced the extension of woodlands on the Montgrí, which could be a reason for this rarity. However, this butterfly was not mentioned on the Montgrí by Vicens *et al*. (1987) and was probably already scarce in the 1980s. It is still common in the wooded areas in l'Albera.

Issoria lathonia (Linnaeus, 1758)

Scarce, observed in April and again between 25th September and 10th October (7 imagos only).

Argynnis paphia (Linnaeus, 1758)

This butterfly is common in *Quercus suber* woodlands in l'Albera and in *Pinus sylvestris* woodlands in the upper valleys of Empordà. It can be very abundant in hilly areas that retain some moisture in the summer. It seems to visit the Montgrí only occasionally (Lopez 2014) in years of great abundance, which was the case in 2014. The long generation flies in Empordà between early July and late September.

Limenitis reducta Staudinger, 1901

Widespread, it flies in three broods that were noted on 5th April-11th June, 14th June-31st July and 14th August-7th November, with the annual peak in early October. Caterpillars have been found on *Lonicera etrusca* and *L. implexa* in open pine woodlands and on *L. japonica* (Caprifoliaceae) in gardens at Torre Gran.

Vanessa atalanta (Linnaeus, 1758)

Very mobile and very widespread, it flies year-round in the warm areas, probably in three broods, with a short gap in mid-summer. Maximum abundance is reached late October. In winter, males display hill-topping behavior on the ridges when weather is calm, but when it is windy, they keep small territories in the afternoon in sunny and sheltered woodland clearings. Egg laying has been observed, even in mid-winter, on *Parietaria judaica* and *Urtica dioica* (Urticaceae), where caterpillars build characteristic tents made with leaves. Westward migration was recorded in October 2016.

Vanessa cardui (Linnaeus, 1758)
This well-known migrant can be seen everywhere and during any season by the sea. It is most abundant in June. Egg laying and caterpillars have been found on *Malva sylvestris* (Malvaceae) and *Galactites tomentosa* (Asteraceae). The northward spring migration was observed annually between late March and mid-May: on 23-27.03 and 26.04-9.05.2015, 7-12.05.2016, 1-7.05.2017, 9-15.04.2018. These butterflies were especially abundant in 2015 but were scarce in 2014 and 2017.

Aglais io (Linnaeus, 1758)
Widespread in the Montgrí-Baix Ter (Fig. 5 p.59). The imagos fly in late May-early June, in September and again after hibernation between mid-February and mid-April. They are occasionally active for a few days in mid-winter. Caterpillars are sometimes abundant on *Urtica dioica* (Urticaceae). Along the Ter River and at Ter Vell, large caterpillars also eat the leaves of *Humulus lupulus* (Cannabaceae). Despite targeted searches, this species could not be found at any stage between May 2016 and February 2019 (see p.134).

Aglais urticae (Linnaeus, 1758)
This species, which is strongly declining in Catalonia (CBMS), has been found only twice on the northern embankment of the Ter River: a lively caterpillar nest on *Urtica dioica* in May 2015 and a single imago on 19.02.2017. This butterfly is traditionally scarce at low levels in the Mediterranean.

Nymphalis polychloros (Linnaeus, 1758)
Scarce, mostly seen in the Ter plain and on the Montgrí Massif when butterflies leave their hibernation retreats in late February and March.

Polygonia c-album (Linnaeus, 1758)
Widespread but not common. The first brood flies on 7th June-27th July, the second brood on 4th August-7th October and again after hibernation in spring on to April.

Euphydryas aurinia (Rottemburg, 1775)
Reported on the Montgrí by Vicens *et al.* (1987) on the reforested continental sand dune, it was found again in Vall de Santa Caterina during CMBS monitoring in 2014 (López 2014). It is certainly scarce as the monitoring in the following years do not mention it and we could never locate any butterfly or caterpillar of this species.

Melitaea didyma (Esper, 1778)
Reported on the Montgrí by Vicens *et al*. (1987), the specimens kept by Xavier Quintana were collected in the late 1970s on dry grasslands above Torroella (pers. comm.). Not found recently and probably extinct on the Montgrí.

Melitaea phoebe (Denis & Schiffermüller, 1775)
Scattered and scarce (Fig.7), a few butterflies have been seen in May-June and September.

Melitaea deione (Geyer, 1832)
The mention from the Montgrí in Vicens *et al*. (1987) has never been confirmed. This species is found in Gavarres, l'Albera and on the low hillsides west of Figueres, where it flies between April and August.

Lycaenidae

Lycaena phlaeas (Linnaeus, 1758)
Widespread but not especially abundant, it flies between mid-February and late December, probably in four broods, which sometimes start in late January or through autumn to mid-January. The imagos were active continuously during the 2015-2016 winter.

Favonius quercus (Linnaeus, 1758)
Encountered only in the holm oak woodland near Torre Ferrana where it can be abundant. The single brood was noted between 4th July and 12th September.

Tomares ballus (Fabricius, 1787)
Scattered on the foothills and in the valleys of the Montgrí (Fig. 8) where it flies between 12th March and 24th April, it can be seen at the edge of the city of Torroella. Females appear at least one week after the first males. The latter are very territorial and remain on the same spot for several days. The best territories are occupied every year. They are often set in open area with bare ground and small shrubs of *Thymus vulgaris*, the main nectar source for the imagos, which actually hatch when this plant blooms. When a strong northwestern wind (tramontana) blows, they are the only butterflies to maintain some activity: they remain on bare ground in sheltered places and only fly when necessary. Egg laying and caterpillars have often

Figure 7. Distribution map of *Melitaea phoebe* in Montgrí-Baix Ter.

Figure 8. Distribution map of *Tomares ballus* in the Montgrí-Baix Ter. Yellow dots: imagos, red dots: eggs and larvae.

been observed on *Dorycnium hirsutum* in very open habitats (olive groves and dry grasslands) and in open woodlands and clearings. A female also laid eggs on *Medicago truncatula* (Fabaceae) on a mown mesic bank.

Callophrys rubi (Linnaeus, 1758)
Widespread and sometimes very common in places with shrubs (106 counted in one hour on 14th March 2016 near Torre Ferrana) in a single brood between 2nd March and 2nd May. Egg laying and caterpillars were noted on *Cistus albidus* and *C. monspeliensis* (Cistaceae).

Callophrys avis (Chapman, 1909)
A single small population is known on the southern slope of the Montgrí, on the northern edge of the Torre Gran housing (9 imagos in 6 years). These butterflies fly between 12th March and 10th April. Egg laying has been observed on *Coriaria myrtifolia* (Coriariaceae) in an olive grove.

Satyrium esculi (Hübner, 1804)
Very common on the Montgrí hillside, this species is one of the most numerous butterflies. It flies between early May and early July, with the peak in early June. A mention of *S. acaciae* (Fabricius, 1787) from the Montgrí (Vicens *et al.,* 1987) certainly refers to *S. esculi*, which was not cited by the authors because *S. acaciae* is scarce in Empordà and apparently restricted to l'Albera and the upper valleys.

Cacyreus marshalli Butler, 1898
Reported between 13th February and 12th January and thus always with a gap in the coldest part of winter. Eggs and caterpillar on *Pelargonium zonale* (Geraniaceae). A penultimate instar larva was found hibernating in the thick stem of its host plant in a pot kept outside in a south-facing location.

Lampides boeticus (Linnaeus, 1767)
Mobile and widespread, it has been seen mostly between early May and early January. This species is very scarce in early spring and most numerous in autumn. Egg laying and caterpillars were recorded on *Lathyrus latifolius, Medicago sativa* and *Spartium junceum* (Fabaceae).

Leptotes pirithous (Linnaeus, 1767)
Widespread in various habitats. There are at least four broods in warm years (egg laying has been noted in February, May, September and December). As for *L. boeticus*, the annual peak is reached in early October. Egg laying and caterpillars have been observed on *Rosmarinus officinalis* (Lamiaceae), *Medicago sativa, Spartium junceum*, and in gardens on *Sophora japonica* and *Lupinus cf. angustifolius* (Fabaceae). The caterpillars are tended by ants and were found in autumn with *Crematogaster scutellaris* and *Linepithema humile* and more rarely with *Plagiolepis pygmaea* (Hymenoptera Formicidae).

Pseudophilotes panoptes (Hübner, 1813)
Widespread in open dry areas with *Thymus vulgaris*, females lay egg on the flower buds. A single brood flies between early March and late April.

Glaucopsyche alexis (Poda, 1761)
Very scarce in the Montgrí-Baix Ter with a small population discovered in May 2016 in an abandoned

olive grove near Sobrestany (6 imagos in 3 visits during the flight period). The single brood flies between 15th April and 21st May.

Glaucopsyche melanops (Boisduval, 1828)
The single brood is short and has been observed from 5th to 24th April, when the shrublets of *Dorycnium pentaphyllum* start to bloom (flowering time on the Montgrí Massif: 7th April-5th June). Females lay eggs on flower buds, and caterpillars feed on flowers and fruits in May. Males actively patrol above the stands of foodplants looking for freshly emerged females, and they usually do not move far from breeding grounds. The butterfly is more local than its host plant (Fig. 9) with 3-4 breeding areas in valleys that open to the north or the northwest. Monitoring in Vall de Santa Caterina in 2014-2018 shows that intensive scrub clearing since November 2015 in the bottom of the valley first provoked a dispersion of the main population to other areas with untouched host plants. These secondary sites were very reduced and were sometimes mown to the base in the following years, and the number of imagos has decreased over the years. This butterfly cannot survive without flowering host plants, and the shrubs of this species that are mown in January or February do not bloom in the spring.


Figure 9. Distribution map of *Glaucopsyche melanops* on the Montgrí. Yellow dots: imagos, red dots: breeding sites.

Celastrina argiolus (Linnaeus, 1758)
Widespread and rather abundant in shrubby and wooded areas as well as in gardens. There are at least three broods between late January and early October. Egg laying has been noted on *Pistacia lentiscus* buds, *Pistacia x saportae* flower-buds and on the upper stem of *Spartium junceum*.

Plebejus argus (Linnaeus, 1758)
Very scarce on the Montgrí: a single freshly hatched male was found on 19.06.2016 in the open pine woodland on the plateau above Torre Gran. Despite various visits to the site in May and June, no other butterfly could be located. The closest known populations are probably those found in the Aiguamolls natural park.

Aricia agestis (Denis & Schiffermüller, 1775)
Widespread but not common, this species flies in at least three broods between late March (from 25th February in 2019) and early November.

Lysandra hispana (Herrich-Schäffer, 1851)
Widespread on the Montgrí and on the low hillsides of Les Corts (L'Escala), it is not found at all in the lo-

wlands. The imagos fly between mid-April and mid-November in two or three broods. Though a typical Mediterranean species, it is sensitive to severe drought. Very common in 2013-2015, the colonies on the southern side of the Montgrí dramatically decreased later: the summer droughts in 2015 and 2016 reduced the number of host plants. In 2017, the area began to be submitted to scrub clearing and regular mowing to prevent a possible fire from spreading from the woodland to nearby houses. A site of *Hippocrepis comosa subsp. scorpioides* (Fabaceae), where a few larvae tended by the ant *Linepithema humile* were found in March 2014, has completely vanished. This combination of adverse factors has provoked an estimated decrease of 66 %: the number of butterflies per hour during the whole flight time dropped from 6 in 2014 to only 2 in 2016-2018. A closely related species, *Lysandra coridon* (Poda, 1761), has been reported from the Montgrí by Vicens *et al.* (1987), but none of the recent investigations or monitoring transects could confirm its presence. As the butterfly is not known from any other coastal range in Empordà, this mention probably arises from a misidentification with very similar and variable *L. hispana* which is common on the Montgrí.

Lysandra bellargus (Rottemburg, 1775)

There is a small bivoltine population in Vall de Santa Caterina, which has been noted between 3rd May and 5th June, and a unique male was found near Torre Gran in October 2014.

Polyommatus escheri (Hübner, 1823)

Strictly linked to *Astragalus monspessulanus* (Fabaceae), which is the only host plant in most of the European range, this butterfly does not move far from its breeding grounds. The main population lives in the open pine woodlands north of Torre Gran, where the foodplant grows by the hundreds (Fig. 10). A single brood flies on 10th May-4th July.

Polyommatus thersites Cantener, 1834

This species has been recorded once in Vall de Santa Caterina (CBMS). This butterfly is difficult to distinguish from common *P. icarus* (especially from f. *icarinus*) and was never observed by this study. This data requires confirmation.

Polyommatus icarus (Rottemburg, 1775)

Very widespread and particularly abundant in the grazed meadows near Sobrestany and in grassy olive groves, it is scarce in the driest habitats. The imagos fly in three or four broods between late March and mid-November, with numbers increasing in each generation to culminate in early October. Egg laying was observed on *Medicago lupulina, M. minima, M. polymorpha, M. sativa, M. truncatula, Onobrychis caput-galli* and *Trifolium dubium* (Fabaceae).

Figure 10. Distribution map of *Polyommatus escheri* on the Montgrí.

Phenology

To provide references for future studies, we give here for some species the dates of the first sighting in each year. The absolute earliest date is underlined, followed by the number of days between the extreme earliest dates in 2014-2019 (in brackets). Most of these observations were made on the south-facing slope of the Montgrí.

P. machaon: 20.02.2014, 28.02.2015, 30.01.2016, 19.03.2017, 18.02.2018, 14.02.2019 (49 days)
I. feisthamelii: 17.03.2014, 28.03.2015, 12.03.2016, 3.04.2017, 22.03.2018, 24.02.2019 (39 days)
C. alceae: 22.02.2014, 10.03.2015, 5.02.2016, 9.03.2017, 23.02.2018, 16.02.2019 (34)
P. brassicae: 20.02.2014, 24.02.2015, 30.01.2016, 19.02.2017, 23.01.2018, 12.02.2019 (33 days)
E. crameri: 22.02.2014, 10.03.2015, 5.02.2016, 25.02.2018, 26.01.2019 (44 days)
A. cardamines: 17.03.2014,26.03.2015,12.03.2016,19.03.2017,16.03.2018, 12.03.2019 (15 days)
A. euphenoides: 6.04.2014, 12.04.2015, 6.04.2016, 19.03.2017, 5.04.2018 (25 days)
L. sinapis: 17.03.2014, 26.03.2015, 12.03.2016, 19.03.2017, 5.04.2018, 24.02.2019 (41 days)
T. ballus: 17.03.2014, 26.03.2015, 12.03.2016, 15.03.2017, 18.03.2018, 10.03.2019 (17 days)
C. rubi: 17.03.2014, 19.03.2015, 8.02.2016, 9.03.2017, 14.03.2018, 5.03.2019 (40 days)
L. phlaeas: 17.03.2014, 12.03.2015, throughout winter in 2015-2016, 4.04.2017, 18.02.2018, 12.03.2019 (46 days)
C. marshalli: 23.02.2014, 17.04.2015, 13.02.2016, 9.03.2017, 11.03.2018, 3.03.2019 (64 days)
C. argiolus: 12.02.2014, 10.03.2015, 8.01.2016, 16.02.2017, 2.03.2018, 30.01.2019 (62 days)
P. panoptes: 8.03.2014, 26.03.2015, 13.02.2016, 3.04.2017, 22.03.2018, 14.03.2019 (50 days)
P. icarus: 8.04.2014, 30.03.2015, 31.03.2016, 3.04.2017, 9.04.2018, 9.03.2019 (31 days)

Acknowledgements

It is a pleasure for me to thank Xavier Espadaler (Barcelona), who kindly identified the ants attending the Lycaenidae caterpillars; Mark Shaw (Edinburg), who has identified for years the parasitic Hymenoptera hatching from my caterpillars; Xavier Quintana (Torroella de Montgrí), the first lepidopterist in the Montgrí area, who shared information on the butterfly fauna in the 1970s and invited me to publish the results of my observations; Montse Lopez, who participated in useful discussions that allowed to assert the status of several species and Santi Ramos (natural park, L'Estartit), who has provided information and documentation on the natural park during all these years.

References

CBMS (Catalan Butterfly Monitoring Scheme) https://www.catalanbms.org/es/

Lafranchis, T., D. Jutzeler, J.Y. Guillosson, P. Kan & B. Kan, 2015. La vie des papillons. Diatheo, Paris.

López, M., 2014. Memòria del seguiment de papallones diürnes (o Ropalòcers) amb la metodologia del CMBS (Catalan Butterfly Monitoring Scheme) a la Vall de Santa Caterina-Montgrí (temporada 2014). Associació per a la Conservació de l'Entorn i la Recerca, Montcada i Reixac.

Lorkovic, Z., 1993. *Leptidea reali* Reissinger, 1989 (= *lorkovici* Real, 1988), a new European species (Lep. Pieridae). Natura Croatica 2 (1):1-26.

Pérez De-Gregorio, J.J. & M. Rondós, 2003. Fauna lepidopterologica de la serra de les Gavarres (I). Sesión Entomológica ICHN-SCL 13:13-35.

Roviras Padrós, A., 2001. El Montgrí que hem oblidat. L'activitat tradicional al massís del Montgrí. Papers del Montgrí, Torroella de Montgrí n°19.

Serra, J., 2010. Agricultura i ramaderia. In Els masos del Montgrí. Papers del Montgrí, Torroella de Montgrí 31:153-159.

Torró, J., *et al*., 1989. L'activitat agrícola al Montgrí. Papers del Montgrí, Torroella de Montgrí n°8.

Vicens, N., X. Quintana & D. Sunyer, 1987. Anotacions sobre el coneixement dels lepidopters ropalocers del massis del Montgrí. Scientia gerundensis 13:135-141.

Vila, R., C. Stefanescu & J.M. Sesma, 2018. Guia de les papallones diürnes de Catalunya. Lynx Edicions, Barcelona.

Moths of the Montgrí-Baix Ter region

Tristan Lafranchis

Association Diatheo - Papillons de France et d’Europe
Corresponding author e-mail: lafranchis@yahoo.fr

The moth fauna of the Montgrí-Baix Ter was studied for five years (2014-2018) with visits during the day and light trapping at night. Two moth traps connected on the mains were regularly run throughout the night on the balcony of a house in Torre Gran (L'Estartit): one had a 20 W actinic blacklight bulb, and the other had a 125 W mixt bulb. Many visits were made in various areas of the Montgrí-Baix Ter (Fig. 1) during the first hours of the night using one to three 20 W bulbs (actinic and blacklight) on car and motorcycle batteries.

At each occasion, all moths that could not be identified immediately were photographed with a compact macro camera (Panasonic Lumix DMC-TZ35, then Olympus Stylus TG-4), which allowed us to see details on the wings of small Microlepidoptera. Identification was made possible using reference books and some websites. No moths were killed, but the identification of some larger moths was sometimes confirmed through examination of the external genitalia with a lens before freeing the moth. In some cases, identification was not possible below the genus or species group level. More than 87,000 individuals belonging to 888 species have been identified (complete list in annex). Many of the data were collected within the boundaries of Parc Natural del Montgrí, les Illes Medes i el Baix Ter.

Figure 1. Map of moth sampling sites in the Montgrí-Baix Ter in 2014-2018. Yellow dots: occasional visits. Orange dots: several visits in spring, summer and autumn; the large orange dot locates the house in Torre Gran where trapping was conducted regularly over the years.

The phenology of moths in the Montgrí-Baix Ter region

Diversity (total number of species) follows a roughly unimodal curve during the year, with a winter minimum and a summer maximum. There are, however, two poorly marked peaks; the first peak occurs from late May to mid-June and the second, more important peak, occurs in September (Fig. 2A). Abundance (total number of individuals) follows a very bimodal curve, with the first peak in early June and a second much higher peak in September (Fig. 2B). This had already been noticed for the Noctuidae family in Spain (Calle 1982).

Regular trapping showed that the fauna varied in the different seasons (Fig. 3). Geometridae were dominant in spring: *Eupithecia* species first, followed by *Idaea* and *Scopula*. In summer, many Pyralidae and Crambidae were attracted to the light along with numerous small Microlepidoptera (mostly Tineidae, Gelechiidae and Tortricidae), but Noctuidae were very scarce. The latter progressively became more common in autumn, reaching 75% of the content of a trap in November. The winter fauna were mostly composed of Geometridae and medium-size Noctuidae. There were very few micromoths (almost all were Crambidae) and no large moth (Sphingidae, Lasiocampidae, Notodontidae). It appears there is an optimal size for moths activity in winter, probably linked to the ability to reach a muscular temperature that allows the flight without losing much energy. Most of these winter moths have strong furry bodies and only fly when the weather is favorable. In adverse weather, they often stay several days and nights at the same place without moving. In the summer, thermal stress disappears, and the morphological diversity reaches its peak. The same conclusion can be made if we move from a pole to the equator: cold reduces the number of species and the morphological diversity.

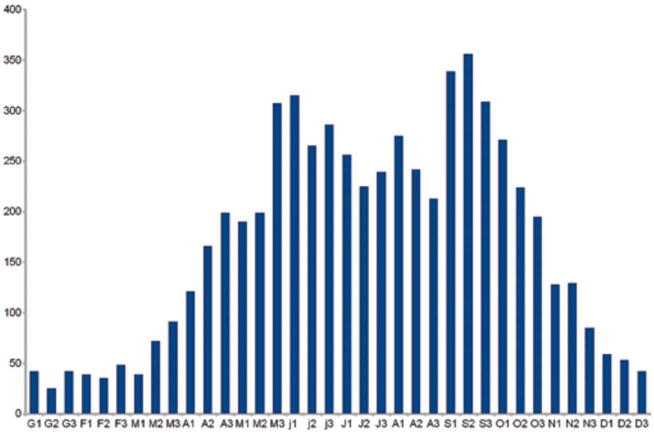


Figure 2A. Annual evolution of the diversity (number of species per 10-day period) of moths, all families mixed.

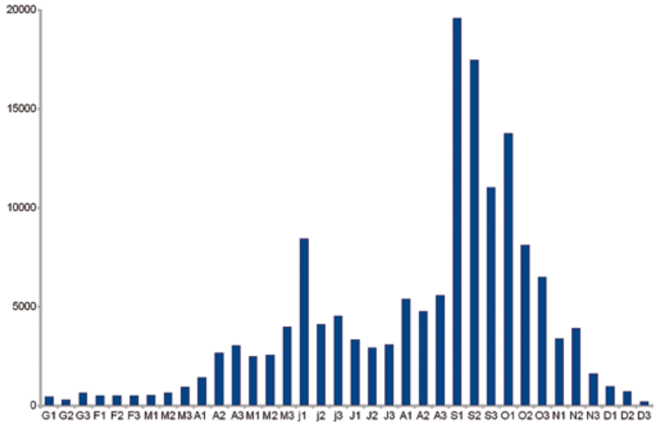


Figure 2B. Annual evolution of the abundance (number of individuals per 10-day period) of moths, all families mixed.

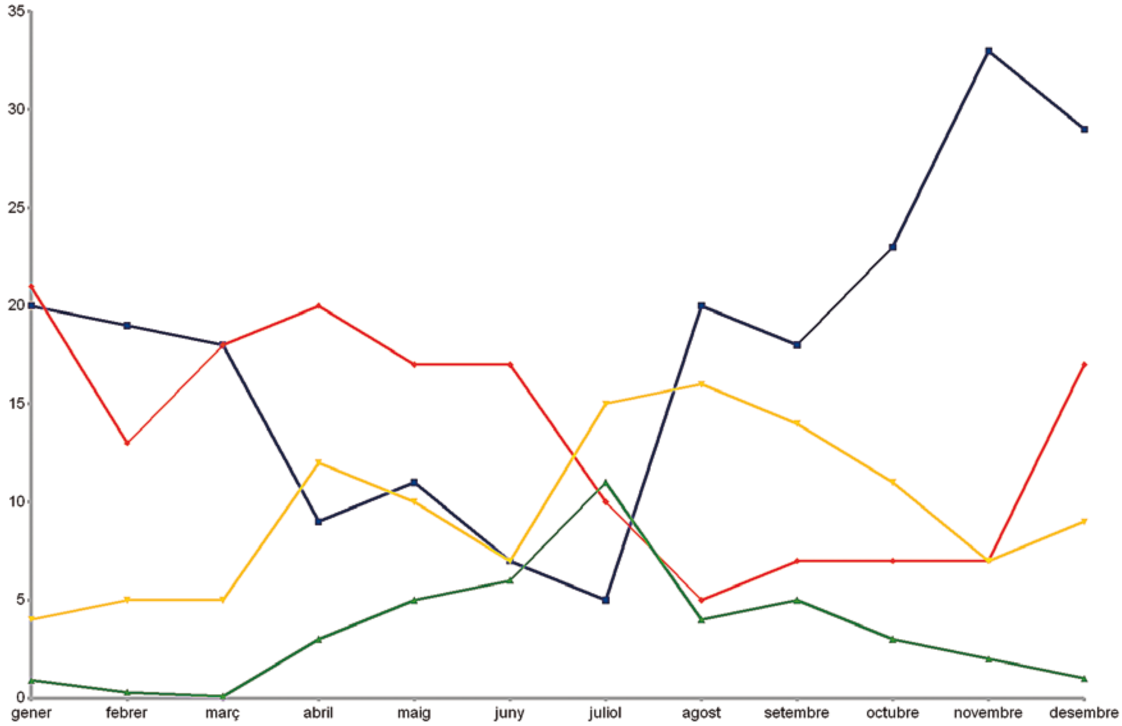


Figure 3. Annual evolution of the relative abundance (total number of imagos divided by the total number of moths) of some families: Geometridae (red), Noctuidae (blue), Pyralidae + Crambidae (yellow) and small Microlepidoptera (green).

Commented list

Phragmataecia castaneae (Hübner, 1790) - Cossidae
A marsh moth linked to stands of reed that is very local in Catalonia. Already known from Aiguamolls de Pals (Dantart & Jubany 2009), it is also found at Ter Vell, where it flies in June.

Hippotion celerio (Linnaeus, 1758) - Sphingidae
An uncommon migrant from Africa, this moth was observed twice at Torre Gran on 24.07 and 9.10.2017; each record was a single fresh imago.

Araeopteron ecphaea (Hampson, 1914) - Erebidae
A widespread moth in Africa that was discovered in Europe in 1990 (Fibiger & Agassiz 2001). It is uncommon in the area: 3 were found at Torre Gran and one was located along the Ter River between late June and late September.

Ophiusa tirhaca (Cramer, 1777) - Erebidae
Scattered in Spain, found singly and sporadically (Calle 1982). Uncommon on the Montgrí in probably two broods in April and September (5 individuals were observed).

Schrankia costaestrigalis (Stephens, 1834) - Erebidae

Scarce in Catalonia, known from Banyoles Lake (Ylla i Ullastre 1997) and in the French Pyrénées-Orientales (Peslier 1999). Equally scarce on the Montgrí: 3 imagos were found at Torre Gran between mid-September and mid-November.

Parascotia nisseni Turati, 1905 - Erebidae

Rather scarce and local on the Iberian Peninsula, with isolated and sporadic captures (Calle 1982). Not so scarce on the Montgrí, where it probably produces two broods on 22nd April-9th June and again on 30th August-6th October (32 individuals).

Zebeeba falsalis (Herrich-Schäffer, 1839) - Erebidae

Described by Calle (1982) as very scarce on the Iberian Peninsula, this moth is not scarce on the Montgrí (as in other coastal areas in Mediterranean Spain) where it flies in two generations on 22nd April-1st June and 3rd September-14th October (123 individuals).

Anthracia ephialtes (Hübner, 1822) - Noctuidae

Very local and scarce on the Iberian Peninsula (Calle 1982), An “enigmatic species” for Marti, who announced its discovery in Catalonia (Pallars Jussà) in 2005. This moth is attracted to light but remains in the shadowed corners, sometimes hiding inside my house. 4 individuals were observed at Torre Gran in August-September (Fig. 4.11).

Atypha pulmonaris (Esper, 1790) - Noctuidae

A single specimen was found in a rocky open scrub above L’Estartit on 12.06.2017 (Fig. 4.12); the moth was not very fresh and could be a vagrant. According to Josep Calle (1982), this species is very scarce in Spain, where it is found in the Pyrenees and Cantabrians. Maurits De Vrieze caught one at Santa Coloma de Farners (Girona) on 8.06.1993 and resumed Calle’s comment (De Vrieze 2003). Bellavista (1993) recorded it from Garrotxa. The known host plants belong to the genera *Pulmonaria and Symphytum* (Boraginaceae) (Ebert 1997, www.lepinet.fr, www.lepiforum.de, www.pyrgus.de). None of them is known to occur in the Montgrí-Baix Ter (Vilar & Quintana 2014) or in nearby wet areas (personal searches). However, *Symphytum tuberosum* is locally found on the plains in Alt Empordà, near Castello d’Empuries and Torroella de Fluvia. In contrast, the two species of *Pulmonaria* found in northern Catalonia (*P. affinis* and *P. longifolia*) occur on the hillsides eastwards to the longitude of La Junquera and do not stretch further towards the sea (www.floracatalana.net). In French Roussillon, Serge Peslier described this moth as uncommon after he caught one in the nature reserve of Mas Larrieu (Peslier 1999). This author wrote “The caterpillar, mentioned on *Pulmonaria*, might have here another host plant yet to be discovered.” This observation reinforces the possibility of a permanent presence near the sea on a known or unknown host plant.

Chilodes maritima (Tauscher, 1806) - Noctuidae

A wetland moth that is scarce in Spain (Calle 1982, Fernandez Vidal 2014); it has been documented from Aiguamolls de l’Empordà (Masó & Valhonrat 1989) and a few other sites in Catalonia. An early specimen was attracted to a light trap at la Gola del Ter on 3.04.2018 in a cold and windy night.

Condica viscosa (Freyer, 1831) - Noctuidae

Widespread in Spain along the Mediterranean coast (Calle, 1982), this moth does not seem to have been re-

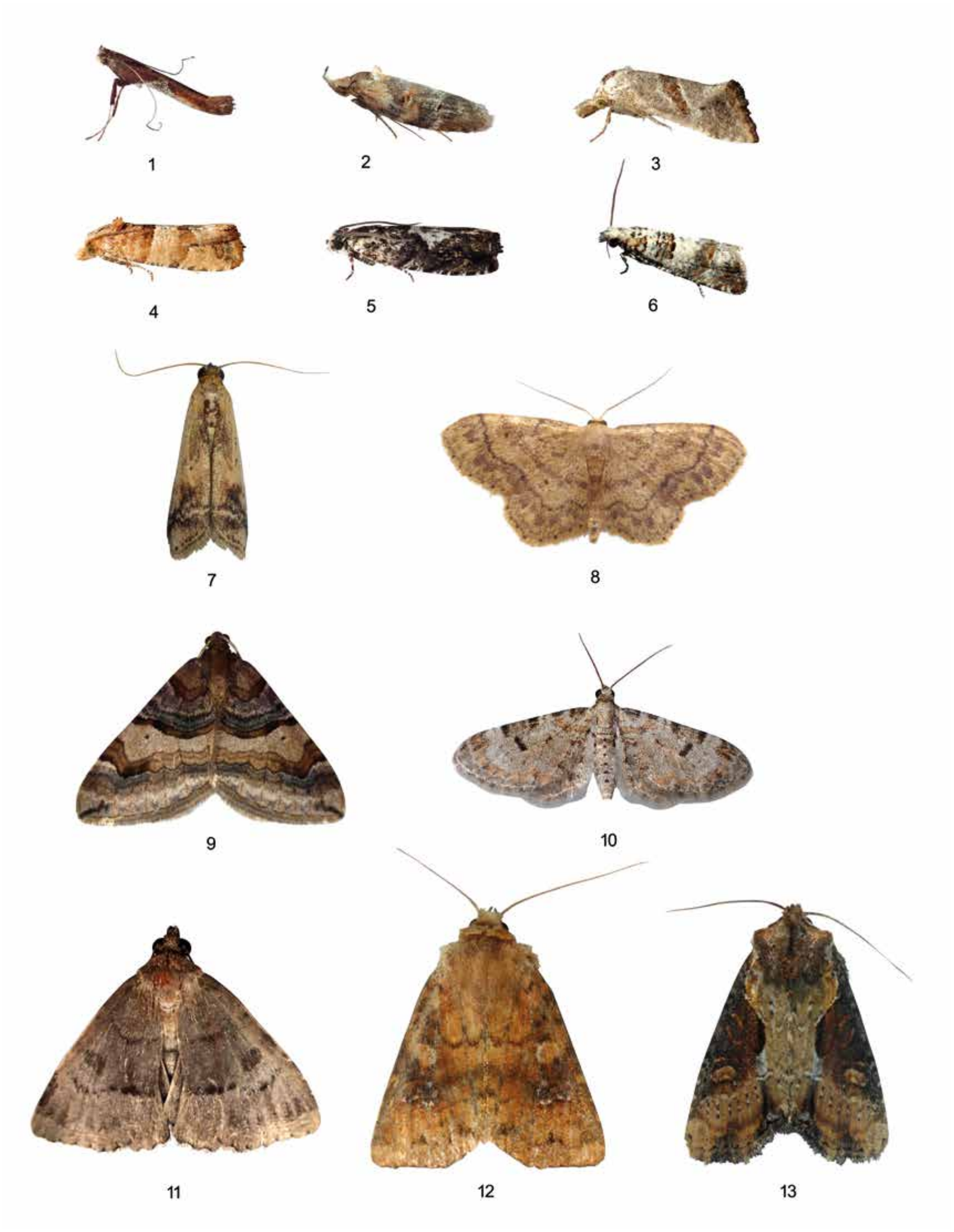


Figure 4. 1. *Caloptilia fidella*. Torre Gran, 23.03.2018. 2. *Anchinia daphnella*. Montgrí, 19.06.2018. 3. *Cochylimorpha halophilana*. Ter Vell, 31.08.2018. 4. *Lobesia indusiana*. Ter Vell, 3.08.2018. 5. *Pammene argyrana*. L'Estartit, 21.04.2018. 6. *Thiodia trochilana*. Torroella de Montgrí, 10.05.2018. 7. *Euzophera osseatella*. Torre Gran, 15.05.2016. 8. *Idaea subsaturata*. Torre Gran, 8.06.2015. 9. *Antilurga alhambrata.* La Pletera, 26.10.2014. 10. *Eupithecia liguriata*. Montgrí, 5.05.2018. 11. *Anthracia ephialtes*. Torre Gran, 9.08.2017. 12. *Atypha pulmonaris*. Montgrí, 12.06.2017. 13. *Lateroligia ophiogramma*. River Ter, 29.05.2017.

corded in Girona Province. A single individual came to a light trap at Torre Gran on 9.11.2014. The Montgrí lies at the northern edge of the range of this moth, which has not been documented in France (www.lepinet.fr.).

Ctenoplusia accentifera (Lefebvre, 1827) - Noctuidae
Always caught singly and sporadically (Calle 1982). Cited from around Barcelona at the end of the 19th century, it does not seem to have been found in Catalonia for a century (Ibarra *et al*., 1983). Four imagos came to the light at Torre Gran between 25th September and 23rd October; one imago was recorded each year. A half-grown caterpillar found in early January 2019 on a potted basil (*Ocimum basilicum* - Lamiaceae) produced an imago in early March.

Cucullia argentea (Hufnagel, 1766) - Noctuidae
A rare moth on the French Mediterranean coast, this species was discovered in Spain in 1984 (Masó i Planas & Pérez De-Gregorio 1985). Rather widespread in northeastern Catalonia, on the coast and inland, it is always scarce (Pibernat & Plana 2011). It is certainly very local and scarce in the Baix Ter area: two last-instar caterpillars were found feeding on *Artemisia vulgaris subsp. glutinosa* (Asteraceae) in the sand dunes at La Pletera on 25.10.2014. Despite several trapping sessions during the flight period in the larval habitat, not a single moth came to the light.

Hadena silenes (Hübner, 1822) - Noctuidae
Uncommon, found along woodland margins on the Montgrí Massif at Coll de les Sorres (pine woodland) and Figueres d’en Quel (young holm oak woodland). Also found in the back dunes at La Pletera. The single brood flies on 19th April-4th May (6 imagos). Also found on a fallow land on sand at Ampuries (L’Escala) and more inland in a rocky woodland above Maçanet de Cabrenys (Alt Empordà).

Lateroligia ophiogramma (Esper, 1794) - Noctuidae
In the Iberian Peninsula, this species is only known from the Pyrenees and the Basque region, where it is very scarce (Calle 1982). It was discovered on the coast of Pyrénées-Orientales at the nature reserve of Mas Larrieu (Peslier 1999). One individual came to the light near the Ter River by Torroella on 29.05.2017 (Fig. 4.13). This moth seems to be scarce but could be resident in wet habitats on the coastal plains.

Mythimna languida (Walker, 1858) - Noctuidae
A subtropical migrant discovered in Spain in 2001 (De Vrieze 2003). Regularly observed on the Montgrí between September and May, with varying abundance over the years: it was very scarce in 2015 and 2016 (respectively 2 and 5 sightings) and more common in 2014, 2017 and 2018 (16-17 imagos each year). This moth has quickly progressed northward in Spain in the first decade of 21st century but appears only occasionally north of the Pyrenees. Empordà lies at the northern edge of its current distribution.

Mythimna straminea (Treitschke, 1825) - Noctuidae
Rather scarce and local in Spain, found in the north-east (Calle 1982). A single specimen came to the light at la Gola del Ter on 10.09.2015.

Leucania zeae (Duponchel, 1827) - Noctuidae
Scarce in Catalonia (Masó & Valhonrat 1989). Five individuals were observed at Torre Gran in May-June and early October.

Phyllophila obliterata (Rambur, 1833) - Noctuidae
Discovered in Spain in 1970, this species is scarce and restricted to the Catalan coast (Calle 1982). It is also known from the Pyrénées-Orientales at Mas Larrieu (Peslier 1999). It is regularly observed at Ter Vell in a single brood between late June and mid-September. In addition, a single moth was found at Torre Gran on 9.08.2014.

Rhizedra lutosa (Hübner, 1803) - Noctuidae
Scarce and very scattered on the Iberian Peninsula (Calle 1982). This moth is mostly found in coastal habitats in the Baix Ter, from where it reaches Torre Gran. The single brood, which is not numerous, flies between 9th September and 17th November (26 specimens). Most of the imagos that came to the light were females.

Spodoptera cilium Guenée, 1862 - Noctuidae
A subtropical migrant that has moved northward in the last decades: this species was not mentioned in Catalonia by Calle (1982), but it is now one of the most abundant moths in Empordà (2300 imagos counted in the Montgrí-Baix Ter). It is still a very scarce migrant to France. This moth flies in several broods between mid-May and early January and is most common in the autumn. It avoids dry areas and is plentiful in gardens and mesic habitats including cultivations.

Spodoptera littoralis (Boisduval, 1833) - Noctuidae
This subtropical migrant only reaches the Montgrí area very occasionally: a single moth came to the light trap at Torre Gran on 4.10.2014. It has also been found a few times further north (mainland France, Great-Britain). The limit of its permanent range probably extends a little south of Catalonia as the moth is considered to be an agricultural pest in Andalusia and in the Valencia Province.

Trachea atriplicis (Linnaeus, 1758) - Noctuidae
Scarce, found in Spain only in the north (Calle 1982). Scarce in our study area, with a single specimen found at Torre Gran on 11.06.2016. Another individual came to the light at Ampuries (L'Escala) on 5.06.2016.

Agrotis vestigialis (Hufnagel, 1766) - Noctuidae
Local in Catalonia, mostly found on sandy coasts (Cervelló *et al*., 2007, Pérez De-Gregorio *et al*., 2008). It seems to be scarce in the Baix Ter: 3 imagos were attracted to light in the dunes at La Pletera on 10.10.2018.

Earias vernana (Fabricius, 1787) - Nolidae
Very local in Catalonia and probably vulnerable (Dantart & Cervello 2008). Two were seen at Torre Gran on 23 and 27.06.2015.

Earias insulana (Boisduval, 1833) - Nolidae
Considered as an occasional migrant in Catalonia (Dantart & Cervello 2008). Our observations (53 individuals), all of which were made between 17th September and 14th November, confirm that it is a migrant with strongly variable abundance over the years.

Eucrostes indigenata (Villers, 1789) - Geometridae
Rather widespread and not scarce in the Montgrí-Baix Ter region (81 imagos) between late May and mid-October. It seems to prefer sandy habitats where it can be quite common in September, often sharing its

sites with *Acroclita subsequana* (Tortricidae) whose caterpillars feed on *Euphorbia segetalis* (Euphorbiaceae).

Idaea blaesii (Lenz & Hausmann, 1992) - Geometridae
Known from Garrotxa (Dantart & Jubany 2011), it is scarce on the Montgrí: 8 imagos were noted between 19th June and 26th September 2018, mostly in late July-early August.

Idaea circuitaria (Hübner, 1819) - Geometridae
A largely widespread moth that is usually distributed among scarce and isolated populations (Hausmann 2004). Scarce on the Montgrí: 4 imagos in dry low scrub in June 2018.

Idaea albarracina (Reisser, 1933) - Geometridae
Endemic to northeastern Spain and the French Pyrénées-Orientales, this moth is rather common. It produces two broods between 28th March and 31st October (305 individuals).

Idaea predotaria (Hartig, 1951) - Geometridae
Very local in Catalonia (Dantart & Jubany 2009). Not scarce on the Montgrí: 96 imagos were found between 16th April and 19th October in at least two broods.

Idaea subsaturata (Guenée, 1858) - Geometridae
Rare and local in the Iberian Peninsula and in southern France (Hausmann 2004), it seems to be scarce on the Montgrí, with only 4 imagos found at Torre Gran (Fig. 4.8) in June and September.

Scopula emutaria (Hübner, 1809) - Geometridae
Populations of this species are often very isolated and are threatened in many areas (Hausmann 2004) but it is abundant at Aiguamolls de l'Empordà (Masó & Valhonrat 1989). It is scarce on the Montgrí: 5 imagos were seen that were probably from two generations in May-June and August-September.

Scopula rufomixtaria (De Graslin, 1863) - Geometridae
Uncommon in various sites along the southern edge of the Montgrí plateau. Bivoltine, flying from mid-April to mid-September (28 specimens, all recorded in 2018).

Antilurga alhambrata (Staudinger, 1859) - Geometridae
Known in Catalonia from Depressió Central and Bages (Dantart *et al*., 2005). Very local in the dunes at La Pletera where it is not scarce in late October-early November (46 individuals, Fig. 4.9), when it is the most common moth at light. The caterpillars obtained from eggs were reared on *Helianthemum apenninum* (Cistaceae), a common plant on these back dunes.

Eupithecia liguriata Millière, 1884 - Geometridae
A very local species in Catalonia (Dantart & Jubany 2005), that is apparently newly recorded in Empordà. The moths were found on a rocky slope with scrub and scattered trees on the southern slope of the Montgrí. Four individuals were noted on 5th and 11th May 2018 (Fig. 4.10).

Monopis laevigella (Denis & Schiffermüller, 1775) - Tineidae
Rarely mentioned on the Iberian Peninsula, it was discovered in Catalonia in 2002 (Requena 2003). Two

moths came to the moth trap at Torre Gran on 17th April and 4th May 2017.

Caloptilia fidella (Reutti, 1853) - Gracillariidae
Two observations at Torre Gran on 23rd March (Fig. 4.1) and 14th November 2018. Discovered in Spain (Lerida) in 2015 (Lastuvka & Lastuvka 2015).

Parahyponomeuta egregiella (Duponchel, 1838) - Yponomeutidae
Two observations on the Montgrí on 30.05.2017 and 25.06.2018. Known in Catalonia from Montsant and Ports (Vallhonrat *et al*., 2010).

Pleurota proteella Staudinger, 1879 - Oecophoridae
Uncommon on the Montgrí: 20 imagos were found between 23rd May and 23rd July. This species was not cited on the Oecophoridae list for Catalonia (Ylla & Macia 2008).

Agonopterix cnicella (Treitschke, 1832) - Elachistidae
A single observation was made near the Mas Reguinell ruins on 9.06.2018. Not cited on the Depressariidae list for Catalonia (Ylla & Macia 2008).

Agonopterix purpurea (Haworth, 1811) - Elachistidae
Scarce on the Montgrí, with three imagos observed in late June, mid-September and early October. This moth was not cited on the Depressariidae list for Catalonia (Ylla & Macia 2008).

Anchinia daphnella (Denis & Schiffermüller, 1775) - Elachistidae
A specimen identified as this species came to the light on a pine woodland edge just north of the Torre Gran housing on 19.06.2018 (Fig. 4.2). Known from Ripollès (Ylla & Macia 2008), this species seems to be linked to shrubs in the genus *Daphne* (Thymelaeaceae) which is only represented on the Montgrí by *D. gnidium*, which grows not far from where the moth was found.

Depressaria halophilella Chrétien, 1908 - Depressariidae
An imago was found at Cala Ferriol, a small cove on the rocky coast of the Montgrí, on 5.06.2018. Also known from Port Bou (Alt Empordà) on *Crithmum maritimum* (Apiaceae) (J. Klimesch leg. www.lepiforum.de), this species was not cited on the Depressariidae list for Catalonia (Ylla & Macia 2008).

Nothris congressariella (Bruand, 1858) - Gelechiidae
A single sighting was made near Torre Ferran on 22.07.2017. This species was not cited from Catalonia by Requena (2009).

Aethes deaurana (Peyerimhoff, 1877) - Tortricidae
A single imago was found at Torre Gran on 4.05.2017. This species was not cited from Catalonia by Ylla *et al.* (2011).

Aethes williana (Brahm, 1791) - Tortricidae
This species, mentioned by Baixeras (1989), lacked any concrete data on the list of Ylla *et al*. (2011). Scarce on the Montgrí Massif and at Ter Vell: 7 imagos were found between 9th April and 2nd October.

Ancylis apicella (Denis & Schiffermüller, 1775) - Tortricidae
Discovered in Catalonia (Cerdanya) in 2008 (Dantart & Jubany 2011). Rather common on the Montgrí, this species was noted between 14th March and 21st October (44 imagos).

Clepsis coriacanus (Rebel, 1894) - Tortricidae
Discovered in Catalonia in Baix Llobregat in 2007 (Dantart & Jubany 2010). Found at Torre Gran and Ter Vell between September and December from 2014 onward. The imagos were observed continuously between December 2018 and March 2019 in an unheated greenhouse on the third floor of a building at L'Estartit, where larvae aggressively fed on the leaves of *Aptenia cordifolia* (Aizoaceae), *Citrus limon* (Rutaceae), *Ficus elastica* (Moraceae), *Mentha sp*. (Lamiaceae), *Rosa sp*. (Rosaceae), *Schefflera sp*. (Araliaceae) and *Schlumbergera sp*. (Cactaceae).

Cochylimorpha halophilana (Christoph, 1872) - Tortricidae
A specimen came to the light in a seasonally damp meadow near Ter Vell on 31.08.2018 (Fig. 4.3). This seems to be the first sighting on the Iberian Peninsula (J. Baixeras *in litt*. January 2019). The closest known populations are found in eastern Provence (southern France). The most commonly cited host plant, *Artemisia caerulescens subsp. gallica* (Asteraceae), grows close to the observation site.

Cochylis molliculana Zeller, 1847 - Tortricidae
Scarce, with only 4 imagos found on the Montgrí Massif and at Ter Vell on 1st-12th August 2018. Already known from Baix Llobregat (Ylla *et al*., 2011).

Eucosma obumbratana (Lienig & Zeller, 1846) - Tortricidae
Known from Baix Llobregat and Ribera d'Ebre (Ylla *et al.,* 2011), a single specimen was found at Ter Vell on 7.06.2016.

Gravitarmata margarotana (Heinemann, 1863) - Tortricidae
This Central European species was discovered in Catalonia (Osona) in 2007 and was new at the time to the Iberian Peninsula (Ylla *et al.,* 2011). It is scarce on the Montgrí: a specimen was found at Figueres d'en Quel on 22.04.2018.

Gynnidimorpha rubricana (Peyerimhoff, 1877) - Tortricidae
A single observation was made on the Montgrí on 22.06.2018. Scarce in Catalonia, this moth has been cited from Anoia (Ylla *et al*., 2011).

Lobesia botrana (Denis & Schiffermüller, 1775) - Tortricidae
Rather common on the Montgrí and at Ter Vell between 22nd April and 14th September (52 imagos). Mentioned only from Osona by Ylla *et al*. (2011).

Lobesia indusiana (Zeller, 1847) - Tortricidae
This species was not cited on the list of Catalonian Tortricidae (Ylla *et al.,* 2011). Two were found in a seasonally damp meadow near Ter Vell on 3rd August (Fig. 4.4) and 11th September 2018.

Grapholita molesta (Busck in Quaintance & Wood, 1916) - Tortricidae

An invasive species mining many cultivated fruits that is now found on five continents (Invasive Species Compendium, https://www.cabi.org/isc/datasheet/29904). A few imagos hatched on 5-13.11.2018 from organic apples originating from Gola del Ter.

Pammene argyrana (Hübner, 1799) - Tortricidae
This species was not cited on the list of Ylla *et al.* (2011). We found a specimen in a wooded scrub west of Torre Ponsa on 21.04.2018 (Fig. 4.5).

Phaneta pauperana (Duponchel, 1843) - Tortricidae
Scarce, with 4 observations in early April on the Montgrí. First found in Catalonia in 2007 (Dantart 2010).

Pelochrista infidana (Hübner, 1824) - Tortricidae
Discovered in Catalonia in 2005 and not often cited from France (Dantart 2010). According to the literature, the caterpillars live in the roots of *Artemisia campestris. A. campestris subsp. glutinosa* is common on the three sites where the moth was found: the back dunes at La Fenollera and La Pletera, and, outside the boundaries of the natural park, at Ampuries (L'Escala). Not common: 20 imagos from a single brood were found on 8th September-10th October.

Thiodia trochilana (Frölich, 1828) - Tortricidae
This moth was not cited from Catalonia by Ylla *et al.,* (2011). Three specimens came to the light in an open pine woodland on the continental sand dune near Mas Julià on 10.05.2018 (Fig. 4.6).

Achroia grisella (Fabricius, 1794) - Pyralidae
Poorly known from Spain, it has been cited from a site in Catalonia in Pla d'Urgell (Pérez De-Gregorio & Requena 2010). This species flies on the Montgrí and at Ter Vell, probably in two annual broods: 23rd May-19th June and 30th September-3rd October (5 imagos).

Euzophera osseatella (Treitschke, 1832) - Pyralidae
Poorly known in Catalonia (Delta del Ebre: Pérez De-Gregorio & Requena 2014), this moth seems to be very scarce on the Montgrí with a single specimen found on 15.05.2016 (Fig. 4.7).

Lamoria anella (Denis & Schiffermüler, 1775) - Pyralidae
Not often mentioned from Catalonia (Baix Llobregat, Cabrerès, Els Ports and Priorat) (Vallhonrat *et al*., 2010), it is largely widespread and common in the Montgrí-Baix Ter region in various habitats. The two broods fly on 13th April-29th June and 31st July-22nd September (274 imagos).

Seeboldia korgosella Ragonot, 1887 - Pyralidae
Still poorly known in Spain and recorded between March and June (Pérez De-Gregorio & Requena Miret 2008), three specimens were found at Gola del Ter and on the Montgrí in September 2017.

Merulempista turturella (Zeller, 1848) - Pyralidae
Known in Catalonia from the Llobregat Delta and Aiguamolls d'Alt Empordà (Pérez De-Gregorio & Requena 2014), this species is not scarce on the Montgrí and in the nearby coastal area between early May and late November (49 observations).

Valdovecaria hispanicella (Herrich-Schäffer, 1855) - Pyralidae
Poorly known in Catalonia, the three specimens mentioned by Pérez De-Gregorio & Requena (2010) were caught in 1906-1943. This species is scarce on the Montgrí Massif, flying in one summer brood between late June and late July (6 imagos).

Hypsopygia incarnatalis (Zeller, 1847) - Pyralidae
Uncommon in Catalonia, known from Anoia, La Selva et Tarragonès (Pérez De-Gregorio & Requena Miret 2008). Two specimens were attracted to the light near Torre Ferran on 22.07.2017.

Agriphila selasella (Hübner, 1813) - Crambidae
First mentioned in Catalonia from PNR Aiguamolls de l'Empordà (Maso & Valhonrat 1989), we documented 5 imagos at Torre Gran and Sobrestany in late September-early October.

Agriphila tersellus (Lederer, 1855) - Crambidae
First mentioned in Catalonia from PNR Aiguamolls de l'Empordà (Maso & Valhonrat 1989), a single individual was found at Torre Gran on 4.09.2016.

_Atralata albofasciali_s (Treitschke, 1829) - Crambidae
A local species that is scarce in the area: a single imago was photographed at Ter Vell on 21.06.2018.

Spoladea recurvalis (Fabricius, 1775) - Crambidae
Discovered in Catalonia in 1997, this attractive species was taken again in Barcelona in 2003 (Pérez De-Gregorio 2004). This subtropical migrant is not scarce on the Montgrí: 45 individuals were observed between late August and late November (30 in the autumn 2018).

Hodebertia testacealis (Fabricius, 1794) - Crambidae
Uncommon in Catalonia, but known from the Llobregat Delta (Dantart & Jubany 2010), this species is scarce at La Pletera and Torre Gran: 9 imagos were found between 10th September and 24th November.

Three uncommon species in Catalonia were found in 2016 at the edge of the Ampuries archaeological site (L'Escala) but were not observed in the Montgrí-Baix Ter: the migrant noctuid *Schinia scutosa* (2 imagos on 8.09), the brachodid *Brachodes funebris* (1 on 5.06) and the tortricid *Cochylimorpha cultana* (1 on 5.06); the latter was cited only from Garrigues by Ylla *et al*. (2011).

Larval host plants identified in the Montgrí-Baix Ter region

and not mentioned in the commented list

Bedellia somnulentella - Bedeliidae: ***Convolvulus althaeoides*** (Convolvulaceae).

Bucculatrix alaternella - Bucculatricidae: ***Rhamnus alaternus*** (Rhamnaceae).

Aspilapteryx tringipennella - Gracillariidae: ***Plantago lanceolata*** (Plantaginaceae).

Dialectica scalariella - Gracillariidae: ***Cynoglossum creticum*** (Boraginaceae).

Agonopterix rutana - Depressariidae: ***Ruta chalepensis*** (Rutaceae).

Emmelina monodactyla - Pterophoridae: ***Convolvulus althaeoides*** (Convolvulaceae).

Cacoecimorpha pronubana - Tortricidae: ***Rhamnus alaternus*** (Rhamnaceae).

Acrobasis romanella - Pyralidae: ***Rhamnus alaternus*** (Rhamnaceae).

Palpita vitrealis - Crambidae: ***Olea europaea*** (Oleaceae).

Uresiphita gilvata - Crambidae: ***Spartium junceum*** (Fabaceae).

Zygaena trifolii - Zygaenidae: ***Dorycnium pentaphyllum subsp. gracile*** (Fabaceae).

Saturnia pavonia - Saturnidae: ***Rubus ulmifolius*** (Rosaceae).

Dendrolimus pini - Lasiocampidae: ***Pinus halepensis, P. pinea*** (Pinaceae).

Malacosoma neustria - Lasiocampidae: ***Crataegus monogyna*** (Rosaceae).

Hyles euphorbiae - Sphingidae: ***Euphorbia characias, E. paralias, E. segetalis*** (Euphorbiaceae).

Hemaris fuciformis - Sphingidae: ***Lonicera etrusca*** (Caprifoliaceae).

Macroglossum stellatarum - Sphingidae: ***Rubia peregrina*** (Rubiaceae).

Phaiogramma etruscaria - Geometridae: ***Rosmarinus officinalis*** (Lamiaceae).

Harpyia milhauseri - Notodontidae: ***Quercus coccifera*** (Fagaceae).

Thaumetopoea pityocampa - Notodontidae: ***Pinus halepensis, P. pinea, P. radiata*** (Pinaceae).

Acronicta rumicis - Noctuidae: ***Pelargonium zonale*** (Geraniaceae).

Aedia leucomelas - Noctuidae: ***Convolvulus althaeoides*** (Convolvulaceae).

Calophasia platyptera - Noctuidae: ***Antirrhinum majus*** (Scrofulariaceae).

Cucullia scrophulariae - Noctuidae: ***Scrophularia auriculata*** (Scrofulariaceae).

Cucullia verbasci - Noctuidae: ***Verbascum sinuatum*** (Scrofulariaceae).

Dryobota labecula - Noctuidae: ***Quercus ilex*** (Fagaceae).

Eremobia ochroleuca - Noctuidae: ***Lolium perenne*** (Poaceae).

Hecatera dysodea - Noctuidae: ***Lactuca virosa*** (Asteraceae).

Helicoverpa armigera - Noctuidae: ***Artemisia caerulescens subsp. gallica, A. vulgaris subsp.***

glutinosa, Cosmos bipinnatus, Dittrichia viscosa, Lactuca sativa (Asteraceae), ***Malva sylvestris*** (Malvaceae), ***Rosmarinus officinalis, Satureja calamintha*** (Lamiaceae).

Heliothis viriplaca - Noctuidae: ***Bituminaria bituminosa*** (Fabaceae).

Pardoxia graellsi - Noctuidae: ***Althaea officinalis, Lavatera maritima, Malva sylvestris*** (Malvaceae).

Phlogophora meticulosa - Noctuidae: ***Vicia faba*** (Fabaceae), ***Rumex sp***. (Polygonaceae).

Synthymia fixa - Noctuidae: ***Bituminaria bituminosa*** (Fabaceae).

Thysanoplusia orichalcea - Noctuidae: ***Cosmos bipinnatus*** (Asteraceae).

Trichoplusia ni - Noctuidae: ***Lactuca sativa*** (Asteraceae).

Acknowledgements

I want to thank my wife Tatiana who cut the pictures from Fig. 4.

References

Baixeras, J., 1990. Situación actual del conocimiento de la familia Tortricidae Latreille, 1803, en Catalunya (Lepidoptera). Sesión Entomológica ICHN-SCL 6 (1989):131-138.

Bellavista, J., 1993. Contribució al coneixement dels Noctuidae de la Garrotxa (Catalunya) (Lepidoptera: Noctuidae). Sesión Entomológica ICHN-SCL 7 (1991):75-82.

Calle, J.A., 1982. Noctuidos españoles. Boletin del Servicio contra Plagas e Inspeccion Fitopatológica, Fuera de Serie n°1.

Cervelló, A., J. Martí & A. Xaus, 2007. Abundància inusual d'Agrotis vestigialis (Hufnagel, 1766) a les platges de la Reserva Natural del Remolar-Filipines (Lepidoptera: Noctuidae). Butlletí de la Societat Catalana de Lepidopterologia 97:55-57.

Dantart, J., 2010. Exapate congelatella (Clerck, 1759), Apotomis capreana (Hübner, [1817]) i Epinotia bilunana (Haworth, [1811]), espècies noves per a la fauna ibèrica, i altres totrícids poc coneguts o no citats de Catalunya (Lepidoptera: Tortricidae). Butlletí de la Societat Catalana de Lepidopterologia 101:71-86.

Dantart, J., T. Mira & P. Passola, 2005. Geomètrids de la col·lecció de Tomàs Mira. Eupithecia graphata (Treitschke, 1828), espècie nova per a la fauna de Catalunya (Lepidoptera: Geometridae). Butlletí de la Societat Catalana de Lepidopterologia 94:47-71.

Dantart, J. & A. Cervello, 2008. Revisió de les espècies del gènere Earias Hübner, [1825], a Catalunya (Lepidoptera: Nolidae). Butlletí de la Societat Catalana de Lepidopterologia 99:17-46.

Dantart, J. & J. Jubany, 2005. Resultats de la nit de les Papallones ("Catalan Moth Nights"): 22 de maig de 2004. Butlletí de la Societat Catalana de Lepidopterologia 95:5-18.

Dantart, J. & J. Jubany, 2009. Resultats de les terceres Nits de les Papallones (Catalan Moth Nights): 27 d'abril a 1 de maig de 2006. Butlletí de la Societat Catalana de Lepidopterologia 100:47-65.

Dantart, J. & J. Jubany, 2010. Resultats de les quartes Nits de les Papallones (Catalan Moth Nights): 11 a 15 d'octubre de 2007. Butlletí de la Societat Catalana de Lepidopterologia 101:19-38.

Dantart, J. & J. Jubany, 2011. Resultats de les cinquenes Nits de les Papallones (Catalan Moth Nights): 24 a 28 de juliol de 2008. Butlletí de la Societat Catalana de Lepidopterologia 102:73-98.

De Vrieze, M., 2003. Contribution to the knowledge of the Noctuidae from Spain. Observations and collecting trips from September 1986 till December 2001 (Lepidoptera: Noctuidae). Phegea 31 (2):61-79.

Ebert, G., 1997. Die Schmetterlinge Baden-Württembergs, Band 6. Ulmer, Stuttgart.

Fernandez Vidal, E.F., 2014. Nuevas citas de Chilodes maritima (Tauscher, 1806) para Galicia (España, N.O. Península Ibérica) (Lepidoptera: Noctuidae). Arquivos Entomoloxicos 12:185-188.

Fibiger, M. & D. Agassiz, 2001. Araeopteron ecphaea, a small noctuid moth in the West Palaearctic (Noctuidae: Acontiinae). Nota lepidopterologica 24 (1/2):29-35.

Hausmann, A., 2004. The Geometrid Moths of Europe, vol. 2. Apollo Books, Stenstrup.

Ibarra, M. de, A. Garcia, J.J. Pérez De-Gregorio & I. Romaña, 1983. Notes sobre els lepidòpters de les comarques gironines X. - les plusies de les nostres comarques (lep. noct. Plusiinae). Revista de Girona 103:147-150.

Lastuvka, A. & Z. Lastuvka, 2015. New records of Lepidoptera from the Iberian Peninsula for 2015 (Insecta: Lepidoptera). SHILAP Revista de Lepidopterología 43 (172):633-644.

Marti, J., 2005. Anthracia ephialtes (Hübner, [1822]), noctuid nou per a la fauna catalana i altres citacions interessants (Lepidoptera: Noctuidae). Butlletí de la Societat Catalana de Lepidopterologia 94:41-45.

Masó, A. & F. Valhonrat, 1989. Els Lepidòpters dels Aiguamolls de l'Empordà. In Sargatal, J. & J. Fèlix, Els Aiguamolls de l'Empordà. Quadern dels Indiketes, Figueres 3:295-305.

Masó i Planas, A. & J.J. Pérez De-Gregorio, 1985. Cucullia argentea Hfn., espècie nova per a la Península Ibèrica (Noctuidae, Cuculliinae). Treballs de la Societat Catalana de Lepidopterologia 7:55-58.

Pérez De-Gregorio, J.J., 2004. Microlepidoptera (Crambidae) nous o interessants per a la fauna catalana i ibèrica (V). Butlletí de la Societat Catalana de Lepidopterologia 92:69-74.

Pérez De-Gregorio, J.J., J. Muñoz Batet & M. Rondos Casa, 2008. Noctuidae nous o interessants per a la fauna catalana i ibèrica, IX (Lepidoptera). Butlletí de la Societat Catalana de Lepidopterologia 99:47-53.

Pérez De-Gregorio, J.J. & E. Requena i Miret, 2008. Microlepidòpters (Pyralidae, Crambidae) nous o interessants per a la fauna catalana i iberobalear (VIII) (Lepidoptera). Sesión Entomológica ICHN-SCL 13-14 (2003-2007):91-106.

Pérez De-Gregorio, J.J. & E. Requena, 2010. Microlepidòpters nous o interessants per a la fauna catalana i iberobalear, X (Lepidoptera: Pyralidae, Crambidae). Butlletí de la Societat Catalana de Lepidopterologia 101:51-59.

Pérez De-Gregorio, J.J. & E. Requena, 2014. Microlepidópteros (Lepidoptera: Pyralidae, Crambidae) nuevos o interesantes para la fauna catalana e ibérica, XII. Heteropterus Revista de Entomología 14(2):125-145.

Peslier, S., 1999. Inventaire des Lépidoptères de la Réserve Naturelle du Mas Larrieu. Travaux 8.

Pibernat, J. & J. Plana, 2011. Nova localitat catalana per a Cucullia argentea (Hufnagel, 1766) (Lepidoptera: Noctuidae, Cuculliinae). A new Catalan record of the Green Silver-spangled Shark, Cucullia argentea (Hufnagel, 1766) (Lepidoptera: Noctuidae, Cuculliinae). Butlletí de la Societat Catalana de Lepidopterologia 102:117-120.

Requena, E., 2003. Tineidae nous per a la comarca de l'Anoia i la Península Ibèrica (Lepidoptera: Tineidae). Butlletí de la Societat Catalana de Lepidopterologia 90:15-19.

Requena, E., 2009. Aproximació a la fauna dels gelèquids de Catalunya i Balears (Lepidoptera: Gelechiidae). Treballs de la Societat Catalana de Lepidopterologia 16:5-77.

Vallhonrat, F., J.J. Perez De-Gregorio & E. Requena, 2010. Addicions a la fauna de lepidopters del Parc Natural de la Serra de Montsant (Priorat), amb noves espècies per a la fauna de Catalunya (Lepidoptera).

Butlletí de la Societat Catalana de Lepidopterologia 101:115-120.

Villar, L., & X. Quintana, 2014. El poblament vegetal i els hàbitats del massís del Montgrí, les illes Medes i la plana del Baix Ter. Recerca i territori, 6.

Ylla i Ullastre, J., 1997. Contribució al coneixement dels heteròcers de l'estany de Banyoles (Insecta: Lepidoptera). Sesión Entomológica ICHN-CSL 9 (1995):5-22.

Ylla, J. & R. Macia, 2008. Contribució al coneixement de la distribució de les families Oecophoridae Bruand, [1851], i Depressariidae Meyrick, 1883, a Catalunya (Lepidoptera). Butlletí de la Societat Catalana de Lepidopterologia 99:5-15.

Ylla, J., E. Requena & R. Macià, 2011. Catàleg actualizat dels tortrícids de Catalunya (Lepidoptera: Tortricidae). Butlletí de la Societat Catalana de Lepidopterologia 102:15-66.

The dispersion of Lepidoptera in the Montgrí-Baix Ter region

Tristan Lafranchis

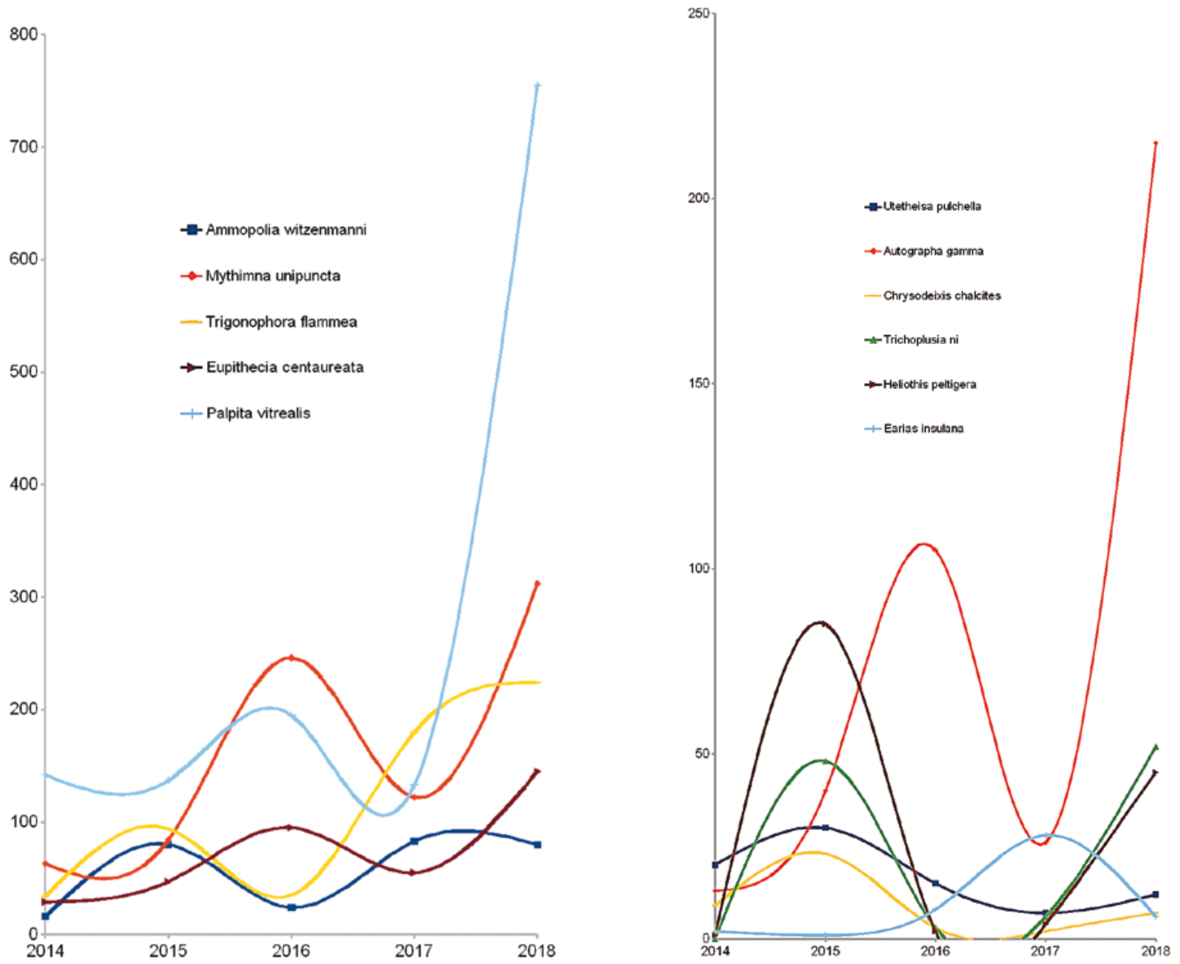
Association Diatheo - Papillons de France et d’Europe
Corresponding author e-mail: lafranchis@yahoo.fr

Population fluctuations

Observed since ancient times, sometimes with fear (remember the seven plagues of Egypt), demographic explosions and mass movements of insects are one of the most dramatic expressions of a general phenomenon that is intimately linked to life: dispersion.

Climatic conditions play a key role in the demography of phytophagous insects, both directly and indirectly, through their host plants. Summer drought is one of the main stressors for flora and fauna in the Mediterranean area and can provoke a strong decline in numbers in the subsequent brood (or broods) when severe. This was the case in 2016 for the autumn brood of *Leptidea sinapis* and *Lysandra hispana*. Their caterpillars feed on the leaves of small legumes that had dried earlier than normal and could not feed their hosts in summer. *Aglais io* was not documented for almost three years. The stands of nettles, its main host plant, suffered considerably during the summer of 2015, completely disappearing from several banks (Cami Vell, field margins in the plain).

In resident species, interannual demographic variation often follows a general pattern that appears strongly correlated with meteorological variables, summer rainfalls and winter temperatures. Moths were definitely more numerous in 2018 than in any of the previous four years: the high temperatures and rather regular rains were very favorable. Most of the resident species showed a marked demographic peak in 2018 (Fig. 1A). Migrant species that come from far away (northwestern Africa, Andalusia) are not so influenced by Catalan meteorology. Their demographic curves show peaks that are dispersed throughout all years (Fig. 1B). For example, 2014 was the only “good year” for *Thysanoplusia orichalcea* on the Montgrí and was also a record year for this subtropical species in Great Britain (www.atropos.info): the migratory influx involved all of Western Europe. In 2015, *Danaus chrysippus, Vanessa cardui, Chrysodeixis chalcites, Helicoverpa armigera* (strong influx in September), *Heliothis peltigera* and *Utetheisa pulchella* came in large numbers: they were 2 to 40 times more numerous than during the second best year between 2014 and 2018. It was also a very good year for the spring migration of birds. The conditions in 2016 were unfavorable for migrations, and none of the migrant species were abundant. In 2017, *Earias insulana* was 7 times more numerous than the average of the four other years. In 2018, *Autographa gamma* (which migrated in April), *Nomophila noctuella* and *Spoladea recurvalis* broke all abundance records. These years of affluence appear to be specific to migrant Lepidoptera even though some years were better (2015) than others (2016).



A

B

Figure 1. Demographic curve of some moths in the Montgrí-Baix Ter. A: Five resident species. B. Six migrant species.

Dispersion in space

Studies on the dispersion of Lepidoptera have increased over the last decades, and the importance of dispersal in gene flow has reinforced this interest (Stevens *et al.,* 2010). Most authors agree on the various factors that control the dispersion of Lepidoptera: sex, species traits, landscape structure, meteorology, density and history of the population (Mattila 2015, Kuussaari *et al.,* 2016). The various individuals in a population do not respond equally to the factors encouraging dispersion; therefore, it is necessary to consider the individual traits revealed by behavioral studies. It is quite unlikely that a butterfly or a moth decides to leave its birthplace to promote gene flow. However, fear, hunger, harassment or pressing reproductive need often chase the insect far from the entomologist. The various factors that contribute to provoking dispersion are essentially induced by major biological constraints: the search for food or shelter (individual survival), the search for a partner or a favorable site for offspring (population survival). The benefits for the species then appear as the consequences of dispersive movements. These gains have certainly contributed to the positive selection of traits favorable to dispersion.

In species that live in isolated populations, imagos do not move much from their breeding grounds, and most of the butterflies in this case are small (Hesperidae, Lycaenidae). This rule seems even more strict in monophagous species: the few imagos of *Callophrys avis* (Lycaenidae) encountered on Montgrí were all found within a 2.5 ha area. This is an extreme case of localization and rarity. *Eupithecia liguriata* (Geometridae) and *Amephana aurita* (Noctuidae) also seem to belong to this category: they are scarce and known from a single site on the Montgrí, but the status of moths is much more difficult to assess, as light trapping of moths is much less efficient than day prospections are for butterflies.

The continuous dispersion of imagos across a wide area is the rule for species leaving in open populations. In the case of butterflies, these are mostly medium-sized to large species with powerful flight abilities (Papilionidae, Pieridae, vanessids). Their caterpillars are polyphagous or feed on widespread plants favored by human activities (ruderal or cultivated plants). These insects do not need to remain in their place of birth; they are comfortable almost anywhere.

Abundance and dispersion

The small *Eublemma ostrina* (Erebidae), though nocturnal, is regularly found during the day, increasing the possibility of contact. Its larvae feed on Asteraceae, which are widespread in the Montgrí-Baix Ter, and the host plant is not a limiting factor for the species. A unique case among the studied moths, it was not seen at all in 2014 and then showed a continuous increase in number between 2015 and 2018 (Fig. 2). Strong dispersion accompanied the population explosion in 2018. It seems very unlikely that this moth appeared on the Montgrí in 2015. The year 2014 corresponds to a demographic gap with numbers that were too low for this species to be detected. Several years were necessary for the population to grow in size and colonize numerous favorable sites.

The case of *Cydalima perspectalis* is particularly interesting as this Far East moth, which was imported to Europe with ornamental boxes, was unknown in Catalonia until 2014 (Bassols & Oliveras 2014), and the first specimen was found at Torre Gran in 2015. The species was scarce until 2017 (2 imagos in 2015, 1 in 2016, 18 in 2017) and then suddenly "exploded" in population in 2018, with 3556 individuals counted. During the first three years of presence records, all observations were made at the same place in Torre Gran (Fig. 3A). In 2018, the moth appeared everywhere including the centre of Torroella de Montgrí, the back dunes at La Pletera and on the Montgrí (Fig. 3B). This crambid has undergone a similar expansion in southern France: hitherto absent from the coast in Aude, it arrived there in 2018 (P. Escudié pers. comm.). In Catalonia, as in Mediterranean France, the moth became very common in the inland valleys (upper valley of the Muga River in Spain, Corbières in France) in 2017 when it was undetectable in previous years: the presence of locally abundant wild boxes allowed it to have a very rapid demographic growth and dispersion.

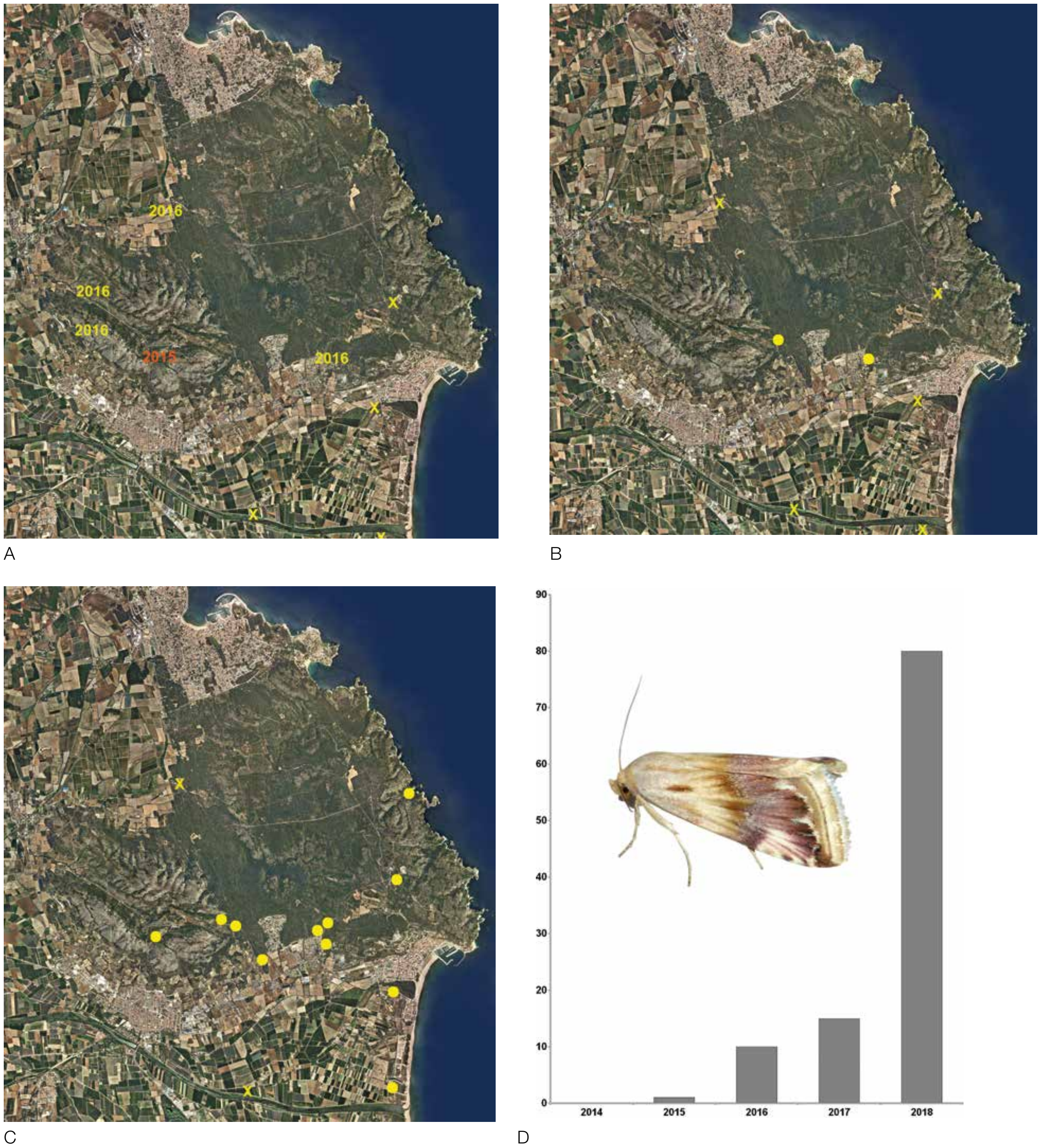


Figure 2. Distribution map of *Eublemma ostrina* in the Montgrí-Baix Ter. A: 2015-2016. B: 2017. C: 2018. Yellow crosses indicate the trapping sites where the species was not found. D: Demographic curve in 2014-2018 with the number of imagos counted each year.

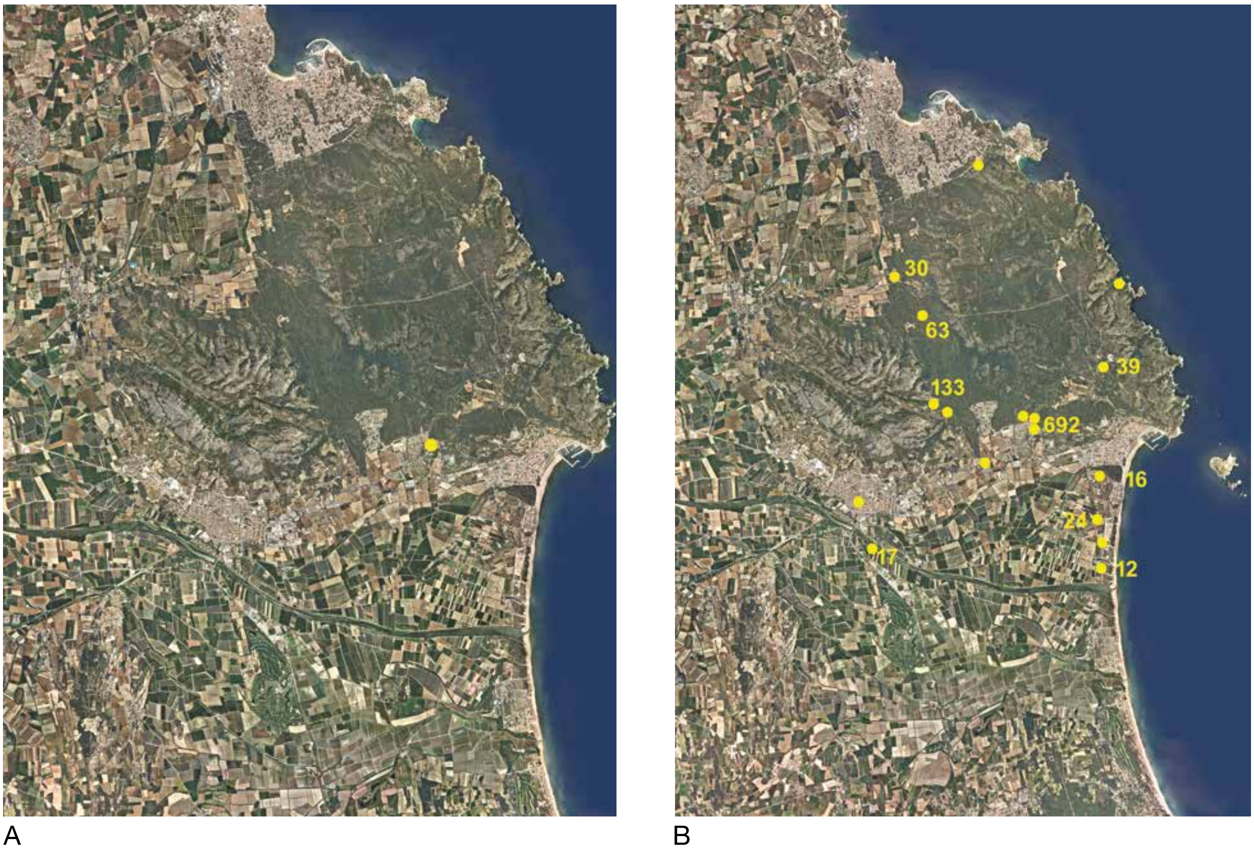


Figure 3. Distribution map of *Cydalima perspectalis* in the Montgrí-Baix Ter. A: in 2015-2017. B: in 2018, with the highest count of moths in a night during the peak of emergence.

Microclimate and dispersion

Poikilothermic animals, such as Lepidoptera, have two ways to warm up: sun bathing for butterflies and very fast wing beats for moths. The insect is able to take off once the thoracic muscles are warm enough. Imaginal flight and dispersion are therefore strongly conditioned by meteorology. This general rule is modulated by a specific trait: the take-off temperature. *Pararge aegeria* is the only European butterfly to fly spontaneously in winter by overcasting mild weather (13 ºC), but *Danaus chrysippus* requires an ambient temperature of at least 21 ºC to fly (Lafranchis *et al*., 2015). This tropical butterfly is not accustomed to low temperatures. In contrast, montane species in the genus *Erebia* begin to fly at temperaturtes between 12 and 15 °C depending on the species (Kleckova *et al*., 2014, own observations). Caterpillars also have a specific temperature range that allows them to be active, feed and grow. Larvae of *Erebia* can feed at 5 °C, a temperature that kills the caterpillars of *D. chrysippus.* This explains why the latter species only appears as a temporary migrant in most of its European range. Even when imagos are powerful and very mobile, their colonization ability is limited by the thermal exigence of their caterpillars.

In winter, imaginal populations of butterflies are usually very weak. The Montgrí area hosts 22 species that are able to fly in mid-winter (December or January), approximately 1/3 of the local butterfly fauna, making it an interesting place to study the effects of climate. Between mid-November and mid-February, heliophilous insects (Lepidoptera, Odonata, Orthoptera, Hymenoptera and Diptera) are looking for warm sites sheltered from the northern wind which often blows at this time of year. This wind lowers temperatures but also keeps the weather clear, and the temperatures then exceed 20°C in sunny and sheltered spots, allowing butterflies to warm up and fly. Microclimatic conditions are the key factor for the winter distribution of day-flying Lepidoptera (butterflies and the hawkmoth *Macroglossum stellatarum*), a fact we could also assert in southern France and southern Greece. Very regular visits to the southern slopes of the Montgrí helped us to locate winter concentration sites (Fig. 4) and allowed us to analyze their ecological features and fauna.

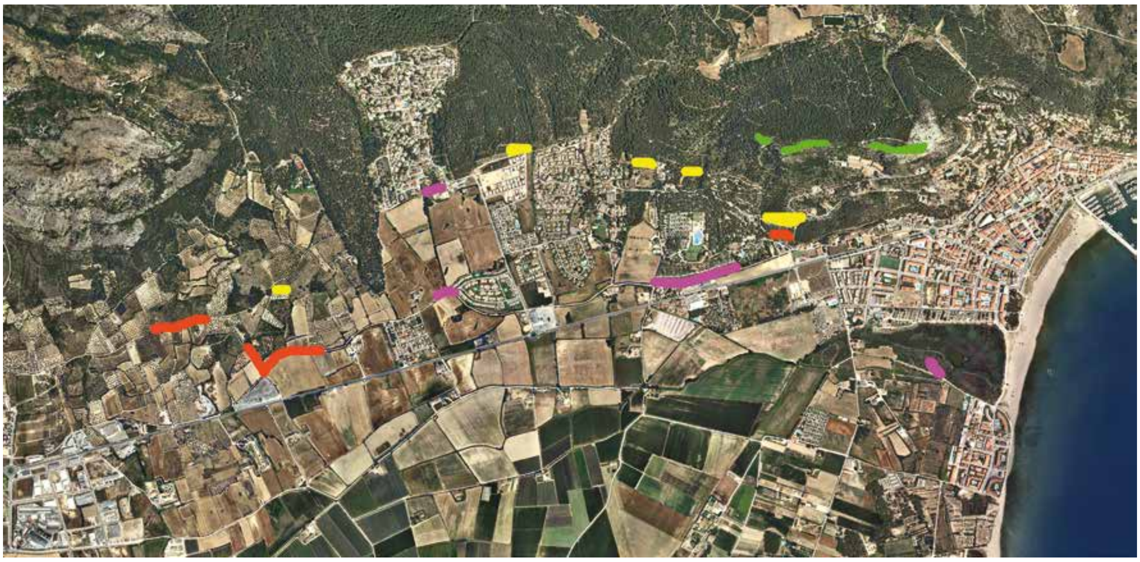


Figure 4. Map of the southeastern part of the Montgrí showing the main winter sites of diurnal Lepidoptera. Yellow: xerothermophilic fauna dominated by *Lasiommata megera* and *Leptotes pirithous*. Red: ruderal fauna dominated by *Pieris rapae* and *Colias crocea*. Pink: main winter sites of *Pararge aegeria*, a woodland species. Green: hill-topping sites occupied in winter by *Vanessa atalanta* and *L. megera.*

The ruderal Pieridae (*Pieris rapae, Pontia daplidice* and *Colias crocea*) are mainly established in the lower part of the foothills between the intensive crops on the plains and the pine woodlands and scrub on the upper part of the slopes. This area is dominated by dry orchards (olive and almond trees) cut by lanes that run in some places along stone walls or hedges that act as windbreakers. Their bottom is home to various winter-flowering plants, such as white *Diplotaxis erucoides* and *Lobularia maritima* (Brassicaceae) and yellow *Calendula arvensis* and *Sonchus tenerrimus* (Asteraceae). Butterflies nectar on the flowers and males patrol along the warmest parts of the lanes, repeatedly following the same limited route. Lycaenidae and Nymphalidae prefer woodland clearings and margins that are warmed by the sun from the morning onwards. If *Lasiommata megera* and *Vanessa atalanta* regularly stay in sites devoid of flowers, *Leptotes pirithous* almost exclusively flies around blooming *Rosmarinus officinalis*, sometimes together with *Lycaena phlaeas* or *Cacyreus marshalli*. To avoid drought, *Pararge aegeria* stays in shaded environments and avoids very sunny places, always remaining in the vicinity of trees. When weather is clear with no wind, males of *V. atalanta* and *L. megera* fly up to occupy a territory on the ridge, especially around the highest spots, where they perform hilltopping and aerial duals with conspecific males, awaiting for a female to fly through.

Flowery sites are not scarce in winter on the southern side of the Montgrí, but only the most sheltered attract butterflies. Diversity and population density are very low in mid-winter; on average 2 species and 6 individuals were counted per hour in good weather. Adverse climatic conditions concentrate butterflies into very limited areas that are favorable to their survival, providing a shelter against climatic aggressions as well as providing nectar sources and often one or more host plants. In addition, their reduced mobility promotes the interaction between sexes that is otherwise made more difficult by low numbers. The winter contraction of the spatial distribution is the adaptive response of butterflies to very precarious survival conditions. This allows several species to have continuous cycles throughout the year, including *P. rapae*, *C. crocea*, *P. aegeria* and *L. megera*. Other candidates for complete winter activity could already operate during particularly mild winters: *P. daplidice* and *L. pirithous* in 2015-2016 and 2018-2019, and *L. phlaeas* in 2015-2016.

All butterflies active in winter belong to common or relatively common species living in open populations. Extreme conditions in mid-winter severely restrict potential habitats and greatly reduce imaginal stock, and winter-active butterflies have adopted the strategy of scarce species. The very mild 2015-2016 winter confirmed that cold is the main factor limiting the abundance and distribution of butterflies in winter: an average of 4 species and 23 individuals were counted per hour in December-January, and the number of frequented sites was definitely higher than in other winters. The same phenomenon was verified in the very early spring 2019, when the number of species and individuals increased regularly in February from 11 to 20 species and from 7 to 25 individuals per hour. Butterflies were seen occupying increasingly more sites and could be seen anywhere in sunny places from the beginning of March onwards.

The search for favorable microclimates may induce seasonal dispersion away from the breeding habitat. Colorful *Aglais io* can be seen everywhere in the Montgrí-Baix Ter in a very diverse range of habitats (Fig. 5). Territorial males have been found in dry scrub on the Montgrí, on rural lanes at Palau Sator and more often on those running along the bottom of the hillside, especially along Cami Vell. Numerous larval nests were found on the nettles growing along the Ter River and in lower numbers at Ter Vell and occasionally on the banks along the cultivated fields in the plains. Breeding sites and imaginal territories are clearly distinct, although they remain within a limited area, an uncommon trait in European butterflies. In autumn, the imagos visit wastelands covered with *Dittrichia viscosa*. At the end of winter and in spring, they are mostly seen around the Montgrí and sometimes on dry scrub on the plateau, in drier sites than on the coastal plain. Free from morning mists, the hillside becomes warm earlier in the day in a season when temperatures are rarely high. Another vanessid, *V. atalanta*, performs similar movements in southwestern France between mesic or damp breeding habitats and drier wintering sites (Lafranchis 2004).

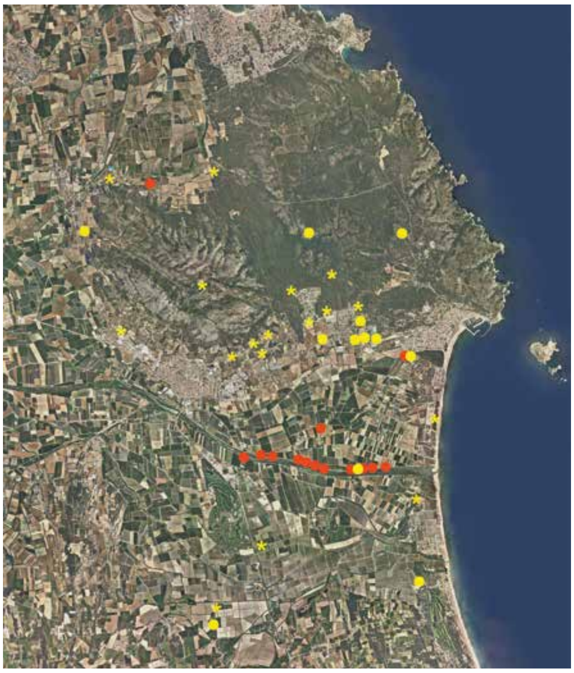


Figure 5. Distribution map of *Aglais io* in the Montgrí-Baix Ter. Red dots: breeding sites. Yellow dots: male territories. Yellow stars: passing butterflies.

Cold is known to be a major stressor for butterflies, but some species are also very sensitive to heat. In the common *Pieris brassicae*, egg size and fertility decrease, and larval growth slows down when the temperature exceeds 33°C (Das *et al*., 2018). This species has developed various adaptative strategies across its very wide range. The studies of Held & Spieth (1999) revealed a summer diapause of pupae in Spain. In southern Greece, imagos spend the summer in wooded gorges at low levels and in dense fir woodlands in the mountains (Lafranchis 2019). They behave exactly as *Callimorpha quadripunctaria* (Erebidae), flying only if disturbed. They do not undergo a true aestivation (such as that of *Nymphalis polychloros*, which does not wake up easily in summer) but a summer inactivity phase. In the Montgrí Baix-Ter, *P. brassicae* imagos are absent in mid-winter (winter diapause at the pupal stage), are very common in spring and disappear almost completely between late June and early September. On 5th June 2015, the temperatures were over 30°C on the plains of Roussillon and Empordà, and *P. brassicae* was plentiful at 1700-1800 m on the slopes of Mont Canigou (Pyrénées-Orientales), where *Erucastrum nasturtiifolium* and other tall Brassicaceae were common. Two years later, on 7th June 2017, just south of the border with France, *P. brassicae* was migrating northwest towards Canigou. The imagos from the hot plains fly to a level where they can find ideal conditions to feed and breed. The same behavior has been recorded on the oriental edge of the range: *P. brassicae* from the plains in North India leave to spend summer in the Himalayas (Kunte & Soman 2020). In Catalonia, as in Asia, their offspring come down to the plains in early September after the first autumn rainfalls, which induces the germination of winter-flowering wild Brassicaceae and invites people to plant in their gardens various kinds of cabbage, which is much appreciated by caterpillars.

Food and dispersion

A. Importance of nectar sources

Most butterflies feed on flower nectar at the imaginal stage. When the weather is sunny, they visit flowers several times per day. The flowering state influences the abundance and precise distribution of butterflies. At the end of March 2019, after two months of clear, sunny and windy weather, the vegetation on the Montgrí began to suffer from drought. Two transects starting from the same point on different routes with equal butterfly richness were conducted on 24 and 25 March during identical weather conditions. The first route, which was very poor in flowers, produced 10 species and 33 individuals, and the second route, which was quite rich in flowers, produced 11 species and 61 individuals.

At the end of summer, flowers are scarce on the Montgrí, and butterflies are also scarce. When *Dittrichia viscosa*, (Asteraceae) begins to bloom, everything changes. Stimulated by the return of rain, numerous butterflies of the second or third broods hatch and gather in the wastelands colonized by *Dittrichia*. It is then possible to count up to 16 species nectaring on the same plot, providing an opportunity for photographers (Fig. 6). This plant plays a very important role in the good health of butterfly populations in the Mediterranean area (Spain, France, Greece) and feeds most migrant Lepidoptera.

Active throughout the year, *Colias crocea* follows flowering in different habitats. The imagos spend the winter on the southern foothills of the Montgrí, where both sexes nectar on yellow Asteraceae (*Calendula* *arvensis, Crepis sancta* and *Reichardia picroides*) and females lay eggs on the seedlings of annual *Medicago* (Fabaceae) plants. In spring and summer, when the lucerne fields are blooming, the flowers provide nectar to the butterflies, and the leaves feed the caterpillars. Hundreds of *C. crocea* then gather on the plains. In autumn, they join other butterflies at the banquet offered by multiflowered *Dittrichia viscosa*.

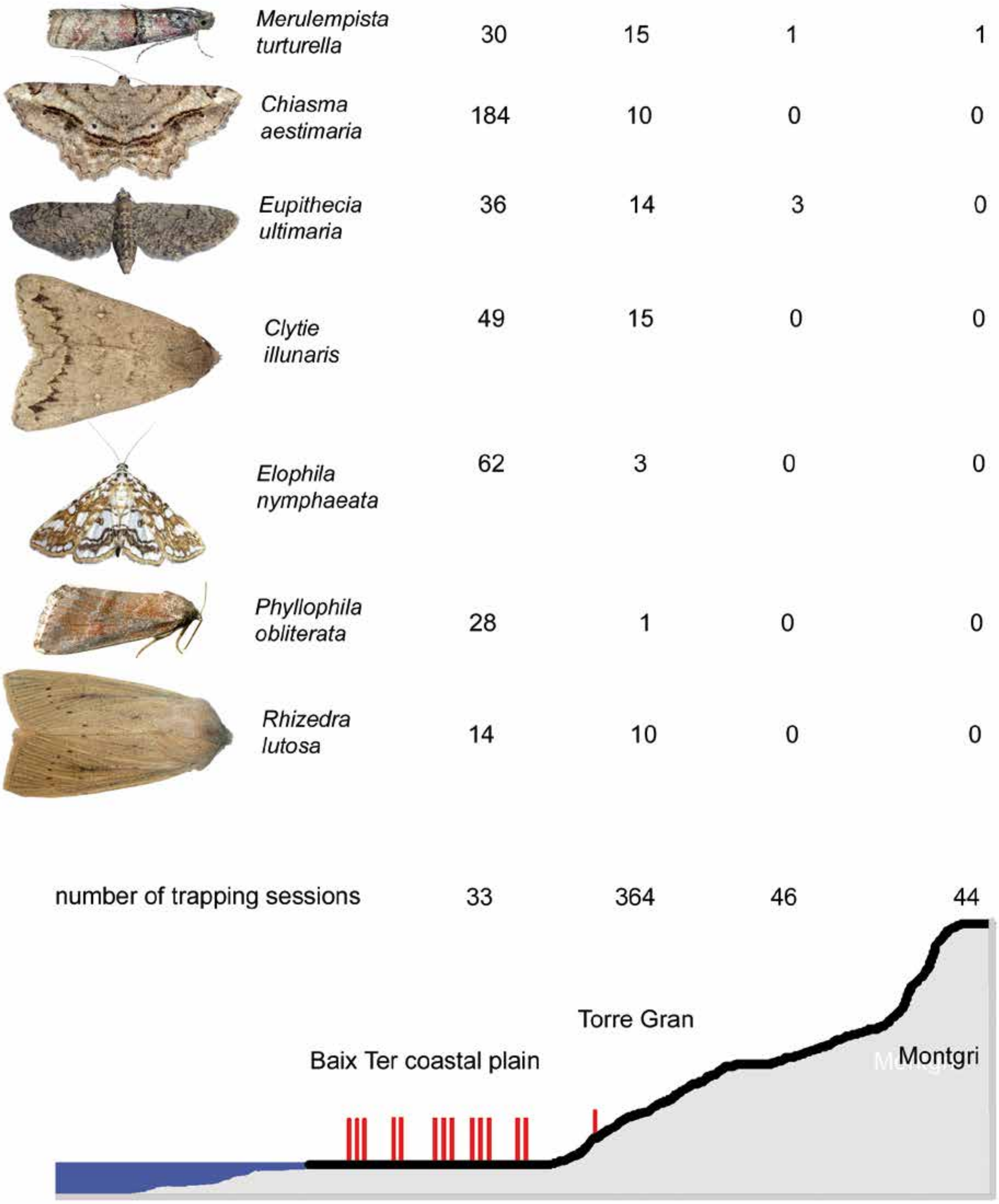
Figure 6. *Danaus chrysippus* and *Vanessa cardui* nectaring on *Dittrichia viscosa* near Ter Vell on 20.10.2014.

B. Host plants and dispersion

Several species of monophagous or oligophagous Lycaenidae show good dispersion capabilities even when the populations are low. As in many butterfly species, females often abandon their birthplace after having laid a large portion of their eggs. An unknown proportion of females definitively leave home and disperse their last eggs on the host-plants encountered in the area they visit. This behavior acts as life insurance for the species in the event of a sudden change in the site of origin. All 3 imagos of *Pseudophilotes panoptes* observed in gardens several hundred meters from a wild population of *Thymus vulgaris* were females. Most imagos of *Glaucopsyche melanops* and *Polyommatus escheri* that were found away from breeding grounds were also females. *Glaucopsyche alexis* is very scarce in the natural park, with a single population near Sobrestany. However, a freshly emerged male appeared on 15th April 2018 in the open pine woodland on the Montgrí plateau above Torre Gran: the only butterfly in 5 years. A fresh isolated male of *Glaucopsyche melanops* was noted on 9th April 2015 around a few shrublets of its host-plant near Torre Gran, more than 3 km away from the nearest permanent population. Another example is a male *Lysandra bellargus* found freshly hatched on 7th October 2014 near Torre Gran and again at the very same place but worn 12 days later. The closest breeding site is located in Vall de Santa Caterina, 7 km away. The list of unique sightings also includes a fresh male of *Plebejus argus* on 19th June 2016 in the very same place as the lonely *G. alexis*. However, we have no idea of the origin of this butterfly, which has never been found in the Montgrí-Baix Ter. In all the mentioned cases, the host plant grew where these individuals were noted. They were the offspring of vagrant females that had laid a few eggs there. However, none of these dispersion events led to the establishment of a new colony of the butterfly. Colonization is not an easy task.

Moths intimately linked to tamarisk (*Tamarix spp*.) offer a good opportunity to compare dispersion ability among several moth species. This low tree was planted in hedges in the coastal area of the Baix Ter plain, extending 1 km inland at below 5 m a.s.l. Few tamarisks are found in the gardens of the houses built along the southern slope of the Montgrí. A single individual was detected in the lower part of the Torre Gran housing estate and none were found above. This tree could host a temporary reproduction of any of these moths but certainly not a resident population. Four sites that were regularly trapped and set along an altitudinal gradient were compared. The first one was Ter Vell, where tamarisk are plentiful; the second was located in the upper part of Torre Gran at 30 m a.s.l. and 600 m (as the crow flies) from the plain; the third lies slightly further up the slope at 50 m a.s.l. and 1 km from the plain, and the last one is on the Montgrí plateau at 120 m a.s.l. and located 1.5 km from the tamarisk stands. Seven species of moths strictly linked to tamarisk were identified in the Montgrí-Baix Ter, 3 of which have been found exclusively on the coastal plain: *Ornativalva pseudotamariciella*, *Parapodia sinaica* (Gelechiidae) and *Agdistis tamaricis* (Pterophoridae). These 3 microlepidoptera are the smallest species. The others, *Merulempista turturella* (Pyralidae), *Chiasmia aestimaria*, *Eupithecia ultimaria* (Geometridae) and *Clytie illunaris* (Erebidae) disperse relatively frequently towards the Montgrí (Fig. 7), but only *M. turturella* has been found in dry habitats on the plateau. It is also the most commonly encountered far from its natural habitat. Hygrophilic moths appear to be on average less dispersive than tamarisk parasites: only *Elophila nymphaeata* (Crambidae), *Phyllophila obliterata* and *Rhizedra lutosa* (Noctuidae) occasionally reach Torre Gran. The same conclusion applies to the lepidopteran fauna of dry scrub and woodlands as only *Watsonalla uncinula* (Drepanidae) has been found at Ter Vell.

The western Mediterranean *Carcharodus baeticus* has at least two permanent populations in the natural park (Fig. 3 p.17); the largest is near Sobrestany and the smaller one is at Torre Ponsa, and both are on pastures that are heavily grazed by sheep. The species breeds where females can find the host plant *Marrubium vulgare*. This xerophilic and nitrophilic labiate is rather widespread on the Montgrí and along the bottom of the hillsides. Three caterpillars found on a single plant of *Marrubium* growing along the edge of a cultivated field below Torre Vella confirmed that temporary reproduction may occur anywhere the host plant is found. An opportunist butterfly, *C. baeticus* takes its chance when its host plant appears in an uncultivated field (Torre Ferrana) or on the margin of a plowed field (below Torre Vella). In these two cases, breeding was only temporary, as the *Marrubium* were destroyed by plowing two years later. As we observed several times in southern France and Catalonia, the few eggs laid by a female on an isolated host plant were often completely destroyed at the larval stage by an undescribed parasitic Hymenoptera of the genus *Cotesia* (Mark Shaw *in litt.*). The strong impact of parasitoids only leaves a chance of survival for populations that live in sites where the host plant is numerous, allowing females to spread their eggs rather than concentrating them. The strong colony of *C. baeticus* found at Sobrestany deserves special attention because it is a reservoir for possible extensions to a larger territory.



Merulempista turturella	30	15	1	1
Chiasma aestimaria	184	10	0	0
Eupithecia ultimaria	36	14	3	0
Clytie illunaris	49	15	0	0
Elophila nymphaeata	62	3	0	0
Phyllophila obliterata	28	1	0	0
Rhizedra lutosa	14	10	0	0
number of trapping sessions	33	364	46	44

Figure 7. Dispersion towards the Montgrí Massif of moths feeding on tamarisk (4 upper species) and 3 wetland species (below). For each species, the total number of imagos counted in 2014-2018 at 4 sites along an altitudinal transect with the number of trapping sessions realized at each site is given. Red bars: tamarisks.

Issoria lathonia is an uncommon butterfly on the Montgrí, but it can be abundant in summer on the hillsides and mountains in northern Catalonia (122 were counted in an hour on 26th August 2014 on Rocacorba above Banyoles). As elsewhere around the Mediterranean (Provence, southern Greece), this butterfly visits coastal areas early in spring and again in autumn, when it can lay eggs on green *Viola* and insure the growth of its caterpillars. *Viola* species at low altitudes dry up in late spring or early summer, and butterflies fly to mountain meadows, where they find abundant nectar sources and other Viola species are still green and able to feed caterpillars (Lafranchis *et al.,* 2015).

Biological traits and dispersion

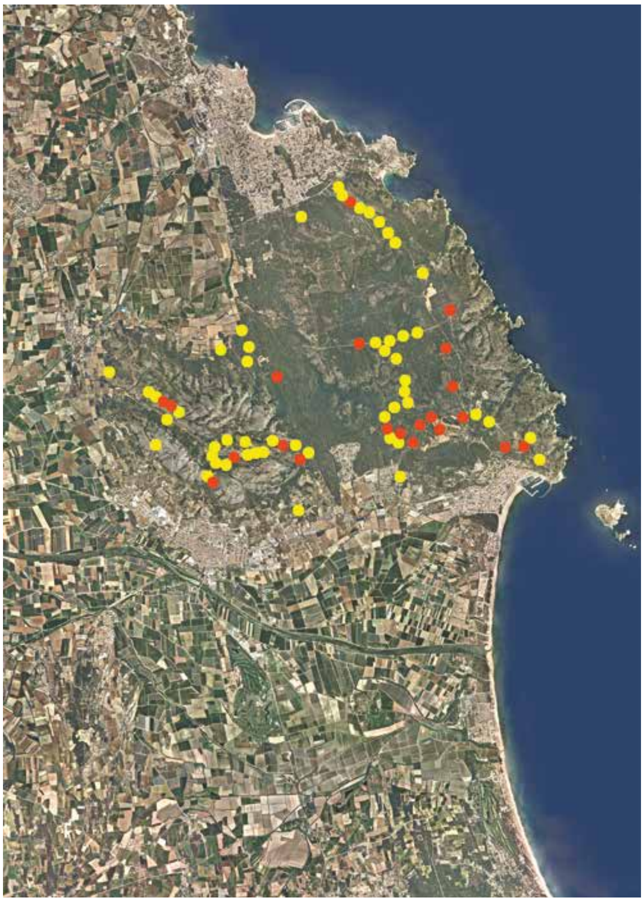


Figure 8. Distribution map of *Anthocharis euphenoides* on the Montgrí Massif. Red dots: caterpillars. Yellow dots: butterflies.

Biological peculiarities can also affect dispersion. In *Anthocharis euphenoides,* the first males hatch one to two weeks before the first females. This biological trait associated with male patrolling behavior causes them to move away from hatching grounds. Once the absence of females is verified, they wander elsewhere in search of other possible breeding sites to look for a partner, following paths and lanes all over the hillside. An early male was seen in Torre Gran housings on 19th March 2017, 700 m away from the nearest breeding place. However, dispersion remains limited to the hillside, and the Montgrí population is isolated from others in Empordà because the cultivated plains are too extensive to cross. The map of breeding sites (Fig. 8) and the field observations on behavior show that females are also dispersive and are able to locate isolated host plants growing amidst scrub. Although this butterfly is strongly linked to *Biscutella laevigata* s.l. on the Montgrí as in most of its range, the females regularly lay there on *Hirschfeldia incana*, a ruderal Brassicaceae very favored by forestry and agricultural works. The abundance of this latter plant in 2017-2018 certainly helped in the species dispersion, with the secondary host plants serving as relays for females in search of *Biscutella*. The possible shift from a specialized host plant (*Biscutella*) to a ruderal one (*Hirschfeldia*) indicates than gene flow between populations from limestone hillsides could be promoted by a network of fallow lands in the cultivated plains.

How butterflies came to the Montgrí-Baix Ter

The present locations of the various ecological ranges of fauna in very different habitats allows us to imagine how the Lepidoptera colonized the Montgrí-Baix Ter. The less demanding species, which are often mobile and sometimes migratory, encountered no obstacles during their postglacial movements. Many of them can still fly across ecological and administrative boundaries. Human activities favor some of them: *P. rapae* and *P. daplidice* both take advantage of disturbed ground where their host plants (several pioneer annual Brassicaceae) germinate without competition. Several pyralids, which produce caterpillars that feed on stored food, are regularly found in houses, where they also benefit from heating in winter; these species include *Aglossa pinguinalis*, *Ephestia spp*., *Plodia interpunctella* and *Pyralis farinalis*. Lucerne fields provide a considerable amount of food for some caterpillars, sometimes producing large numbers of imagos (*Colias crocea, Chiasmia clathrata*). Pine plantations on the plains and on the Montgrí, and the Cupressaceae hedges, which enclose gardens, maintain and offer new habitats to a good number of moths restricted to conifers, such as *Dendrolimus pini*, *Thaumetopoea pityocampa, Bryonycta pineti, Panolis flammea, Adalbertia castiliaria, Bupalus pinaria, Piniphila bifasciana, Pseudococcyx turionella* and four species of *Rhyacionia* whose caterpillars mine pine buds. Pushed northwards by global warming, several subtropical species from Africa recently reached Catalonia after having progressively moved along the Spanish Mediterranean coast: *Danaus chrysippus, Araeopteron ecphaea, Mythimna languida, Spodoptera cilium, Clepsis coriacanus* and *Spoladea recurvalis*. Some of them are not yet fully established.

The banks of the Ter River and the coastal wetlands are the only avalaible habitats for various Central European species that are used to cooler climate and are therefore more hygrophilic in the Mediterranean lowlands, such as *Deilephila elpenor, Clostera curtula, C. pigra, Thyatira batis, Hypena proboscidalis*, *Cucullia scrophulariae, Lateroligia ophiogramma, Hemithea aestivaria, Perizoma flavofasciata, Sesia apiformis, Pterophorus pentadactyla, Tebenna micalis* and *Pandemis dumetana*. These moths certainly accompanied their host plants along the river down to the sea. True wetland moths followed the coast with the aid of the almost continuous presence of lagoons and marshes between the Rhône delta and Empordà: *Phragmataecia castaneae, Macrochilo cribrumalis, Archanara dissoluta, Globia sparganii, Lenisa geminipuncta* and *Chilodes maritima*. Unfavorable soil conditions on the Montgrí Massif and the growing hold of man on the plains have limited and reduced their dispersion. The *Artemisia* steppe fauna took the same route, coming from the northeast and reaching Catalonia without going further south, such as *Cucullia argentea, Phyllophila obliterata, Cochylimorpha halophilana* or *Pelochrista infidana*.

The Montgrí hillside hosts a rich range of xerothermophilic species of western Mediterranean origin that find suitable conditions on limestone. The first clearings and the arrival of sheep at an unknown time certainly favored the plants and insects of dry open habitats. Transhumance, which was well documented between the Montgrí and the Pyrenees during the historical period, required the presence of pastures along the route, and insects took this opportunity to reach new lands. *Melanargia russiae*, a typical butterfly of extensive grasslands on limestone, had been caught in France in various locations far away from any permanent population in the first half of 20th century (Delmas *et al*., 2006) when extensive sheep farming was still the main human activity on the poor lands throughout southern France. Rémi Gaillard (1959) mentioned *M. russiae* in the Gard, saying ”stray individuals having followed the great draye of Languedoc”, which is the transhumance route that runs through Garrigues and Cévennes. Modern cultivation on the Baix Ter plains has transformed the Montgrí Massif into an island for dry grassland insects. The closest populations are found on the hilly areas (Gavarres to the south, Cap Creus and the garrigas de Figueres to the north) that are 15 to 20 km away, making any contact difficult. Although Central European species can still use the Ter valley to move upwards or downwards according to climatic and ecological changes, western Mediterranean species appear to be trapped on the Montgrí. The very weak populations of some of them (*Zerynthia rumina, Callophrys avis, Euphydryas aurinia beckeri*) show that the hillside now offers them only limited suitable areas: these butterflies are relicts from a time, probably not long ago, when the Montgrí was more favorable to Mediterranean fauna.

Another group of Lepidoptera has appeared in the Montgrí-Baix Ter since the end of 20th century without any kind of respect for the laws of biogeography: the invasive species brought by man and his increasingly efficient means of transport. There is, for the moment, a single invasive butterfly (*Cacyreus marshalli*, brought from South Africa) but already several moths that are often agricultural pests: *Catayia insularum* from the Canary Islands; *Tuta absoluta* and *Lantanophaga pusillidactylus* from Latin America; and *Grapholita molesta, Cydalima perspectalis* and *Diplopseustis perieresalis* from the Far East, which have accompanied the Coleoptera, Diptera and Heteroptera coming from all over the world.

References

Bassols i Isamat, E. & J. Oliveras Giralt, 2014. *Cydalima perspectalis* (Walker, 1859), una nova espècie invasora a Catalunya (Lepidoptera: Pyraloidea, Crambidae, Spilomelinae). Butlletí de la Societat Catalana de Lepidopterologia 105:71-78.

Das, P., R.C. Mishra, D. Chauhan, V. Kumar, & P. Bahuguna, 2018. Response of Different Temperatures on Biology of Cabbage Butterfly, *Pieris brassicae* (L.), Lepidoptera: Pieridae on Broccoli Leaves in Laboratory. International Journal of Pure & Applied Bioscience 6(2): 1244-1251.

Delmas, S., J. Maechler & J.M. Sibert, 2006. Lepidoptera: Rhopalocera (Hesperioidea et Papilionidea). Catalogue permanent de l'entomofaune française, Union de l'Entomologie Française.

Gaillard, R., 1959. Grypocères et Rhopalocères du Gard. Alexanor 1 (3):81-86.

Held, C. & H.R. Spieth, 1999. First evidence of pupal summer diapause in *Pieris brassicae* L.: the evolution of local adaptedness. Journal of Insect Physiology 45 (6):587-598.

Kleckova, I., M. Konvicka & J. Klecka, 2014. Thermoregulation and microhabitat use in mountain butterflies of the genus *Erebia*: Importance of fine-scale habitat heterogeneity. Journal of Thermal Biology 41:50-58.

Kunte, K. & A. Soman, 2020. *Pieris brassicae* (Linnaeus, 1758) – Large Cabbage White. In Kunte, K., S. Sondhi & P. Roy (Chief Editors). Butterflies of India, v. 2.74. Indian Foundation for Butterflies.

Kuussaari, M., S. Rytteri, R.K. Heikkinen, J. Heliola & P. von Bagh, 2016. Weather explains high annual variation in butterfly dispersal. Proceedings of the Royal Society B 283:20160413.

Lafranchis, T., 2004. Quand les papillons changent d'habitat. Insectes 131:7-8.

Lafranchis, T., 2019. Notes on the biology of some butterflies in Greece (Lepidoptera: Papilionoidea). Entomologist's Gazette 70:113-134.

Lafranchis, T., D., Jutzeler, J.-Y. Guillosson, P. Kan & B. Kan, 2015. La Vie des Papillons. Ecologie, Biologie et Comportement des Rhopalocères de France. Diatheo, Paris.

Mattila, A.L.K, 2015. Thermal biology of flight in a butterfly: genotype, flight metabolism, and environmental conditions. Ecology and Evolution 5 (23):5539-5551.

Stevens, V.M., C. Turlure & M. Baguette, 2010. A meta-analysis of dispersal in butterflies. Biological Reviews 85:625-642.

Three decades of butterfly monitoring at El Cortalet (Aiguamolls de l'Empordà Natural Park)

Constantí Stefanescu [1,2]

[1] Granollers Natural Sciences Museum, Francesc Macià 51, 08402 Granollers, Barcelona, Spain
[2] CREAF, E08193 Bellaterra (Cerdanyola del Vallès), Barcelona, Spain.
Corresponding author e-mail: canliro@gmail.com

Introduction

The Catalan Butterfly Monitoring Scheme (CBMS; www.catalanbms.org) is a project that monitors butterfly populations in Catalonia, the Balearic Islands and Andorra. It is coordinated by the Granollers Natural Sciences Museum and is funded, above all, by the Department de Territori i Sostenibilitat of the Generalitat de Catalunya (Catalan Autonomous Government). Its main aim is to generate precise estimates of butterfly abundances and to relate population fluctuations to certain environmental factors. Although the project was officially launched in 1994, a pilot scheme had already been operating at two sites in the Aiguamolls de l'Empordà Natural Park (PNAE), El Cortalet and La Rubina, since 1988. In 1989, the Cortalet station was continued, while La Rubina was replaced by an itinerary at Vilaüt. After a hiatus in 1990, monitoring was resumed in 1991 at El Cortalet, where it has continued ever since. During this long period of over 30 years, the butterfly communities in PNAE underwent significant changes, some of which are clearly related to habitat management and others most likely to climate warming and drought. In addition, new routes have been established in other parts of the PNAE: Closes del Tec in 1997 (Colom & Stefanescu, this volume), the Mig de Dos Rius reserve in 2002, and during a single year (1996) at Closes de l'Ullal.

The data collected over all these years have been used in a number of scientific papers to explore the ability of the BMS methodology to monitor the impact of global change on biodiversity. For instance, Stefanescu *et al.* (2003) showed that phenological advancement of the butterfly communities at El Cortalet was occurring as a response to increasing temperatures, while Donoso *et al.* (2016) studied possible mismatches between butterflies and their floral resources. The impacts related to the abandonment of active management in the meadows of Closes del Tec and El Cortalet were studied by Stefanescu *et al.* (2006, 2009) and Colom & Stefanescu (this volume), and the conservation value of different habitats in the natural park in relation to their butterfly fauna were analysed by Stefanescu *et al.* (2005). Recently, two papers have been published, analyzing the impact of summer drought on the population dynamics of the green-veined white *Pieris napi*, one of the commonest butterflies in the PNAE (Carnicer *et al*., 2019; Vives-Ingla *et al.*, this volume).

This article provides an overview of 30 years of butterfly monitoring at El Cortalet and of the status of its butterfly communities in relation to the management methods being practiced there.

Methods

Butterfly transect and counts

The BMS methodology consists of visual butterfly counts along a fixed route or transect. Counts are performed once a week by walking at a constant speed, and only butterflies seen at a distance of 5 m to the front and to the sides of the recorder are counted. The itinerary is divided into different sections, each corresponding to a particular habitat. The Cortalet itinerary has 16 sections and a length of 4,296 m (Fig. 1). Counts are carried out in standardized conditions, during the morning and provided the weather is favourable. The data collection period lasts 30 weeks, from the first week in March to the last in September. For weeks with no counts, data are estimated using the arithmetic averages of the nearest weeks. In addition, impacts (natural or anthropogenic) that may affect the habitats and butterflies are recorded.

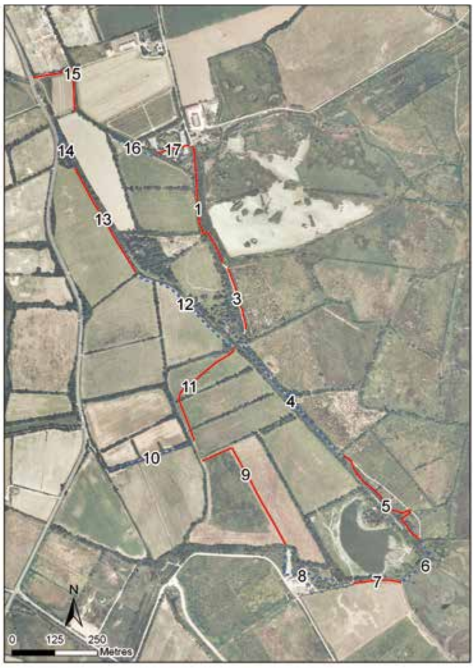


Figure 1. The Cortalet itinerary (CBMS-1), active since 1988, has 16 sections (section 2 disappeared in the early 1990s when the Estany del Cortalet was created) and a total length of 4,296 m.

Vegetation characterization and species habitat preferences

Since 2000, once every six years a characterization of the dominant plant communities (according to the CORINE classification) along the census routes and their coverage in each section has been performed. For the PNAE, characterizations are available for the years 2000, 2006, 2012 and 2018.

To document possible processes of vegetation encroachment (e.g. pasture abandonment) the methodology described in Ubach *et al.* (2020) is followed. Plant communities are classified as either ‘open’ or ‘closed’ on the basis of their structural characteristics. An open community is assigned a value of +1 and a closed community a value of -1. This allows us to calculate a global value for each section in terms of the coverage of the dominant communities, and to quantify processes of closure/opening of habitats based on the characterizations carried out over the years.

This kind of data is essential for calculating two indices used to measure species’ ecological preferences. The TAO index (Ubach *et al.*, 2020) places a species’ preference along a gradient from a closed (forest) to an open (e.g. a meadow) habitat and is expressed as a value between -1 (for a totally forest species) and +1 (for a species totally linked to open environments). The TAO index of each species can be weighted according to their relative abundance to calculate a community-wide value (TAOc), which will reveal changes in community composition over time in terms of the predominance of species from closed or open environments. On the other hand, the Species Specialization Index (SSI) measures the degree to which species use different types of habitats. These categories are based on the vegetation data recorded for the whole CBMS network. This index is calculated using the approach followed by Julliard *et al.* (2006) and ranges from 0 (for an extreme generalist with no habitat preference) to unbounded positive values (although in the CBMS a specialist species only very rarely has an index over 3). As in the previous case, this index can be calculated at community level (SSIc) to investigate how the proportion of generalist and specialist species changes over time, for example in response to habitat degradation or improvement.

Indices of abundance and population trends in species

At the end of each season, an annual index of abundance – the sum of the weekly counts (including estimated data) – is calculated for each species. This annual index allows for comparisons of population fluctuations to be made between successive years.

In this paper, population trends were calculated from simple linear regressions, using log10 (annual index + 1) as the dependent variable and time (years) as the predictor. In order for the analyses to be robust and representative, population trends were only calculated for those species 1) appearing in the counts for a minimum of four consecutive years during the period in which the itinerary was sampled; and 2) those appearing with an annual frequency equal to or greater than 0.5. By applying these restrictive criteria, only species that are regularly recorded in the area and have maintained a population for some time during the sampling period were included.

Indicators of the state of butterfly communities under pressure from global change

To reveal trends in the butterfly communities, two basic descriptive parameters were calculated: population abundance (number of individuals detected annually) and species richness (number of species detected annually). The trends in these two parameters over time were analyzed using simple linear regressions.

These analyses were complemented by an analysis of how population trends relate to four ecological traits that will theoretically influence their demographic responses to phenomena associated with global change. Two traits are related to habitat use and are described above (the TAO and SSI indices), while the other two – the Species Temperature Index (STI) and the Species Precipitation Index (SPI) – relate to the particular climatic niche of the species. The latter two indices measure the mean temperature and precipitation, respectively, that a species experiences throughout its distribution. The distribution corresponds to the UTM 10x10 km grids used in the *Atlas of Iberian Butterflies* (García-Barros *et al.*, 2004), updated with the authors' own data. Climate data are taken from Worldclim with a resolution of 1x1 km (Fick & Hijmans, 2017). Each UTM 10x10 grid square is assigned a temperature or precipitation calculated as the average of the data records for the 100 1x1 km squares it contains.

Linear models were applied in which the response variable is the population trend of the species (the slope of the regression line calculated previously), while the four ecological traits are the predictors.

Results and discussion

The census itinerary

The Cortalet itinerary is located in the PNAE's integral reserve II and starts and ends at the park's information centre (Fig. 1). The first sections (1–8) coincide with the public itinerary to Mas del Matà, from where it returns to the information centre through an area of *closes* (traditionally managed meadows prone to flooding) and fields.

The dominant plant communities include different types of grassland (typically, humid lowland hay meadows, wetland meadows and grasslands dominated by *Polypogon viridis*, *Paspalum distichum* and *Brachypodium phoenicoides*), ruderal communities, hedgerows and riparian woodland (elm and ash) along the drainage irrigation channels.

Over more than 30 years, sections such as 9, 11, 12 and 13 have undergone major transformations and, for example, many hay meadows and pastures were planted with maize and sunflowers in the 1980s. The riparian woodland has also changed in extent, mainly due to the recovery of elms after the massive mortality caused by Dutch elm disease at the beginning of the study period. Overall, there has been a slight encroachment by vegetation, especially along the first half of the route, where the riparian woodland is concentrated (Table 1). Both due to the growth of trees (including some planted ash trees in certain sections of the itinerary) and the recovery of the elms, this part of the route has become shadier. The exception is section 10, where the death of elms in the early 1990s has led to a predominance of grassland and a significant opening up of the vegetation. Taking into account the total length of the sections, the itinerary as a whole closed up by 9.7% in the period 2000–2018.

Table 1. Vegetation closure/opening along sections of the Cortalet itinerary in 2000–2018. Closure is measured as a percentage relative to the initial situation (2000), with negative values corresponding to a gain of 'closed' plant communities (woodland, tall scrub and hedgerows) and positive values to a gain of 'open' communities (grassland and low scrub). After correcting for the length of the different sections, the itinerary as a whole experienced vegetation encroachment of 9.7% in 2000–2018.

Section	Change	Length (m)
1	-20.00	373
3	-54.17	184
4	-25.00	437
5	-30.00	390
6	-37.50	183
7	27.27	139
8	-17.78	264
9	0.00	416
10	20.00	260
11	7.69	358
12	0.00	354
13	0.00	356
14	-35.45	120
15	15.00	236
16	0.00	132
17	-10.00	94

The butterfly communities

In total, 56 species were detected in 27 years of counts (1988–2018; data from 1989–1992 are missing) (Table 2). However, the number of species detected annually is much lower: 32.3 ± 2.76 (mean ± SD). In terms of abundance, a total of 132,475 specimens were counted, with an annual average of 4,906.5 ± 1,056.5. The theoretical species accumulation curve indicates that the butterfly fauna of the Cortalet has been exhaustively sampled and no new species are expected to appear with further recording.

Table 2. Butterfly species detected at El Cortalet in 1988–2018, with the average number of specimens per year, their frequency of annual occurrence and population trend.

Family	Species	Common name	Annual index	Frequency	population trend	
Hesperiidae	*Carcharodus alceae*	Mallow skipper	21,31	1,00	-0,007	stable
Hesperiidae	*Carcharodus baeticus*	Southern marbled skipper	2,41	0,26	-0,036	decline
Hesperiidae	*Pyrgus malvoides*	Southern grizzled skipper	6,69	0,96	0,009	stable
Hesperiidae	*Pyrgus armoricanus*	Oberthür's grizzled skipper	1,17	0,48		
Hesperiidae	*Thymelicus acteon*	Lulworth skipper	15,43	1,00	-0,035	decline
Hesperiidae	*Ochlodes sylvanus*	Large skipper	252,83	1,00	-0,012	decline
Papilionidae	*Iphiclides feisthamelii*	Southern scarce swallowtail	0,15	0,11		
Papilionidae	*Papilio machaon*	Swallowtail	9,70	0,89	0,045	increase
Pieridae	*Leptidea sinapis*	Wood white	0,70	0,26		
Pieridae	*Anthocharis cardamines*	Orange tip	0,28	0,19		
Pieridae	*Euchloe crameri*	Western dappled white	3,44	0,70	-0,044	decline
Pieridae	*Pieris brassicae*	Large white	82,37	1,00	-0,011	stable
Pieridae	*Pieris mannii*	Southern small white	0,31	0,19		
Pieridae	*Pieris rapae*	Small white	583,04	1,00	-0,000	stable
Pieridae	*Pieris napi*	Green-veined white	623,69	1,00	-0,018	decline
Pieridae	*Pontia daplidice*	Bath white	3,94	0,81	-0,013	stable
Pieridae	*Colias crocea*	Clouded yellow	231,57	1,00	0,009	stable
Pieridae	*Colias alfacariensis*	Berger's clouded yellow	0,04	0,04		
Pieridae	*Gonepteryx rhamni*	Brimstone	2,65	0,63	0,015	stable
Pieridae	*Gonepteryx cleopatra*	Cleopatra	6,74	0,81	0,037	increase
Lycaenidae	*Lycaena phlaeas*	Small copper	42,61	1,00	-0,018	decline
Lycaenidae	*Satyrium w-album*	White-letter hairstreak	0,41	0,15		
Lycaenidae	*Lampides boeticus*	Long-tailed blue	12,61	0,96	-0,021	stable
Lycaenidae	*Cacyreus marshalli*	Geranium bronze	0,67	0,07		
Lycaenidae	*Leptotes pirithous*	Lang's short-tailed blue	36,41	1,00	-0,005	stable
Lycaenidae	*Cupido argiades*	Short-tailed blue	1,20	0,15		
Lycaenidae	*Cupido alcetas*	Provençal short-tailed blue	0,31	0,11		
Lycaenidae	*Celastrina argiolus*	Holy blue	69,00	1,00	-0,032	decline
Lycaenidae	*Plebejus argus*	Silver-studded blue	863,56	1,00	0,108	increase
Lycaenidae	*Aricia agestis*	Brown argus	7,44	0,78	0,004	stable
Lycaenidae	*Polyommatus icarus*	Common blue	437,31	1,00	-0,014	decline
Lycaenidae	*Lysandra hispana*	Provence chalk-hill blue	0,04	0,04		
Nymphalidae	*Argynnis paphia*	Silver-washed fritillary	0,07	0,04		
Nymphalidae	*Issoria lathonia*	Queen of Spain fritillary	0,13	0,11		
Nymphalidae	*Vanessa atalanta*	Red admiral	11,09	1,00	-0,012	stable
Nymphalidae	*Vanessa cardui*	Painted lady	70,39	1,00	-0,025	stable
Nymphalidae	*Aglais io*	Peacock	2,54	0,70	-0,005	stable
Nymphalidae	*Aglais urticae*	Small tortoiseshell	0,07	0,07		
Nymphalidae	*Polygonia c-album*	Comma butterfly	22,72	1,00	-0,027	decline
Nymphalidae	*Nymphalis polychloros*	Large tortoiseshell	0,15	0,11		
Nymphalidae	*Melitaea cinxia*	Glanville fritillary	0,11	0,04		
Nymphalidae	*Melitaea phoebe*	Knapweed fritillary	0,50	0,41		
Nymphalidae	*Melitaea didyma*	Spotted fritillary	0,15	0,11		
Nymphalidae	*Limenitis reducta*	Southern white admiral	0,09	0,07		
Nymphalidae	*Charaxes jasius*	Two-tailed pasha	0,06	0,04		
Nymphalidae	*Pararge aegeria*	Speckled wood	714,11	1,00	-0,002	stable
Nymphalidae	*Lasiommata megera*	Wall brown	70,72	1,00	0,032	increase
Nymphalidae	*Coenonympha pamphilus*	Small heath	524,56	1,00	-0,007	stable
Nymphalidae	*Pyronia tithonus*	Gatekeeper	34,50	0,67	-0,105	decline
Nymphalidae	*Pyronia cecilia*	Southern gatekeeper	8,41	0,85	-0,042	decline
Nymphalidae	*Maniola jurtina*	Meadow brown	2,85	0,48		
Nymphalidae	*Melanargia lachesis*	Iberian marbled white	110,69	1,00	-0,039	decline
Nymphalidae	*Hipparchia semele*	Grayling	0,07	0,07		
Nymphalidae	*Hipparchia statilinus*	Tree grayling	0,04	0,04		
Nymphalidae	*Brintesia circe*	Great banded grayling	5,48	0,59	0,059	increase
Nymphalidae	*Danaus chrysippus*	Plain tiger	1,02	0,30		

Despite fluctuations, both species abundance and richness show significant trends throughout the study period, albeit in opposite directions (Fig. 2). The annual number of species has decreased markedly (*P* = 0.001), from an initial value of 38 species to current values of around 30 species. Therefore, during the 30-year study period the community became impoverished by ca. 20% of its species. Conversely, abundances clearly increased (*P* = 0.034) from an initial value of about 4,000 specimens/year to values of 5,000–6,000 specimens/year. In fact, as we discuss later, this increase is almost exclusively due to a single species, the silver-studded blue *Plebejus argus*, which over the past decade has established spectacular populations in certain sections of the itinerary.

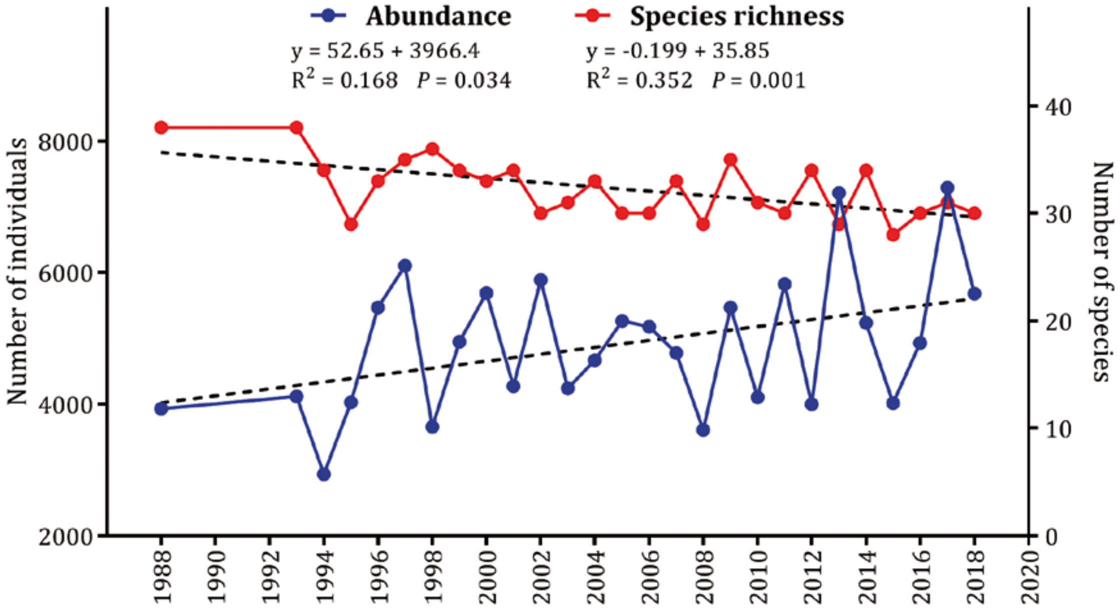


Figure 2. Trends in butterfly abundance and species richness at El Cortalet during the study period. In both cases, there was a significant trend, although in opposite directions.

Population trends were calculated for 32 species, of which 15 (46.9%) remained stable, while 12 (37.5%) declined and just five (15.6%) increased. The predominance of declines in the butterfly community is well illustrated by an average of the population trends of -0.007 (± 0.037), with a negative value indicating a negative slope in the relationship between species abundance and years.

Three species have become locally extinct since 1988: white-letter hairstreak *Satyrium w-album* (1996), southern marbled skipper *Carcharodus baeticus* (2002) and gatekeeper *Pyronia tithonus* (2010). At the same time, no new species have established stable populations, although great banded grayling *Brintesia circe* became extinct in 1994 but re-colonized in 2004, while western dappled white *Euchloe crameri* underwent two extinction and two colonization events during the study period.

The Specialization Index (SSI) appears as the only ecological trait capable of predicting population trends (*P* = 0.0117) (Fig. 3). The negative relationship between the two variables indicates that the most specialized species (with the highest SSI) have declined the most. In fact, the highest SSI values correspond to two of the three extinct species in the area (*S. w-album*: SSI = 2.99; *C. baeticus*: SSI = 2.54), which are not shown in Figure 3 because they do not meet the criteria for calculating their population trends. In any

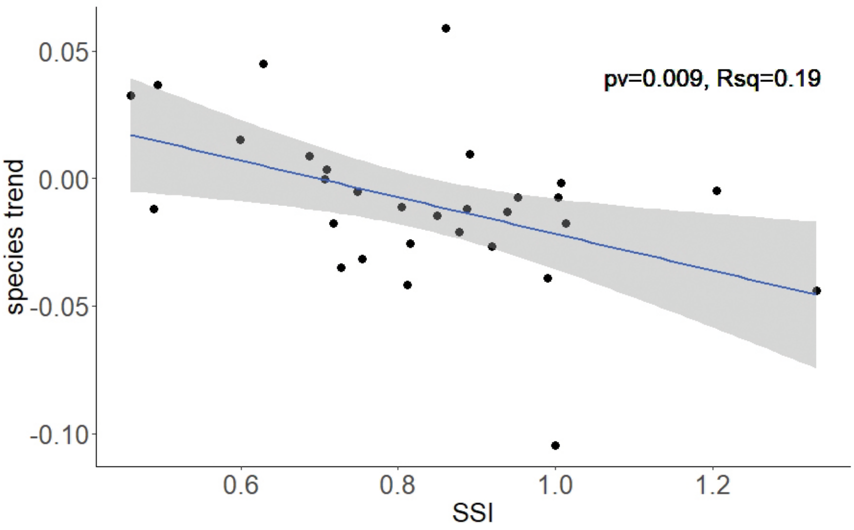


Figure 3. The negative significant relationship between the population trend of species (1988–2018) and their habitat specialization index at El Cortalet.

case, their extinction fully confirms the tendency that the butterfly communities of the PNAE are gradually becoming dominated by generalist species.

Surprisingly and in spite of this, the SSIc index for the whole butterfly community showed the opposite trend, with an increase over the years indicating a progressive domination by habitat specialists (Fig. 4a). However, this apparent contradiction is due solely to the demographic explosion of the silver-studded blue in the past decade, which has one of the highest SSIs and so completely distorts the pattern of the butterfly community. The contribution of this butterfly has increased from <1% of specimens at the start of the monitoring period to about 50% of the total number of butterflies counted in recent years. If the silver-studded blue is excluded from the analyses, the SSIc decreases significantly, confirming the pattern noted in Figure 3.

Of the other community indices analysed, the STIc also showed a significant relationship, with opposite signs depending on whether or not data for the silver-studded blue are included or not (Fig. 4b). If this species is excluded, the STIc increases significantly, indicating a progressive dominance of thermophilous species over time. By contrast, the TAOc and the SPIc do not show any significant relationships.

Habitats and butterflies

The Cortalet itinerary runs through two main habitat types: closed habitats consisting of riparian woodland and hedgerows, and open meadows maintained by pasturing and mowing. To a lesser extent, there are a few sections that are dominated by ruderal plant communities, saltmarsh meadows and *Brachypodium phoenicoides* grassland (Table 3). These latter habitats are associated with very different butterfly communities, which are of different richness and conservation value.

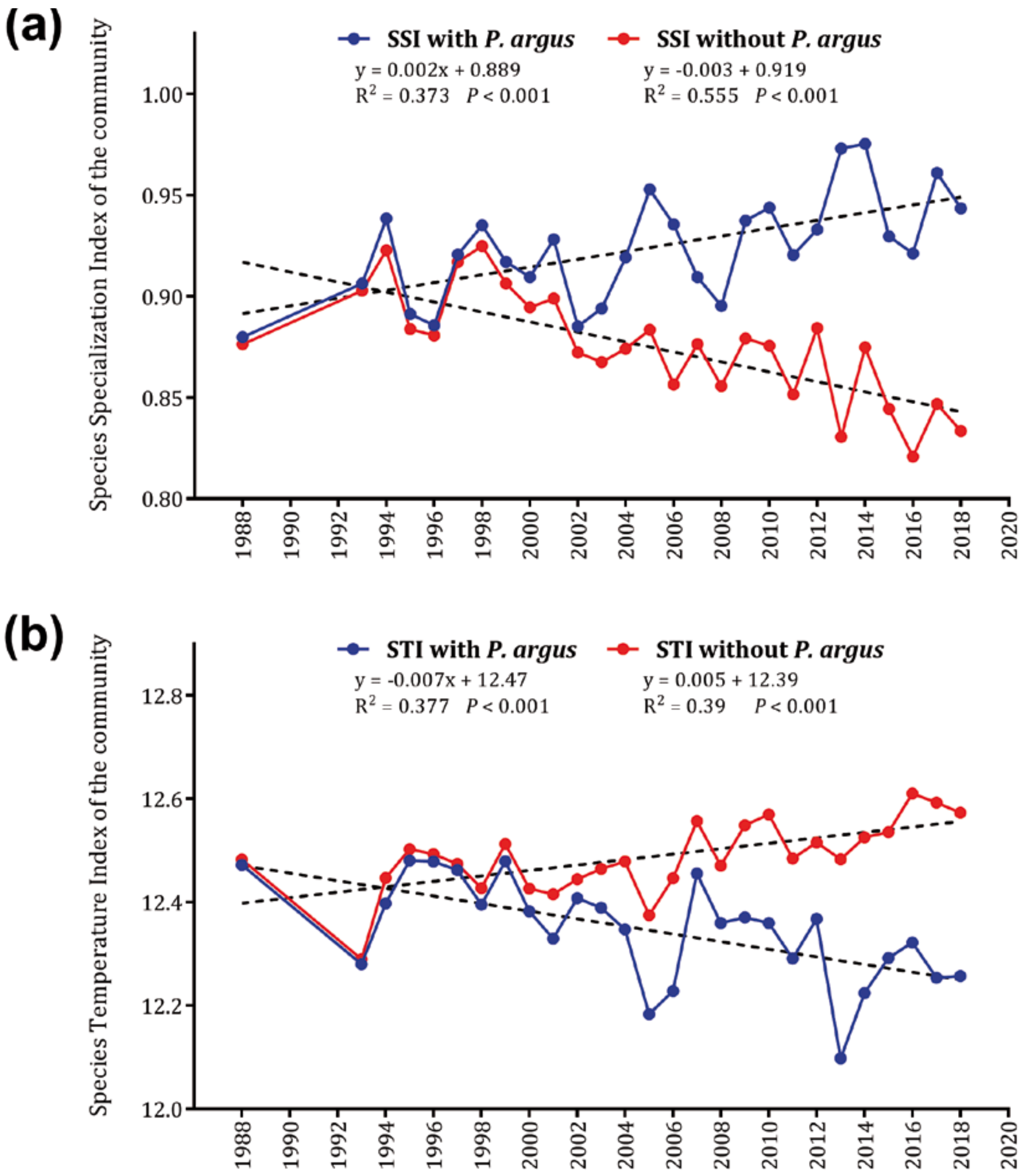


Figure 4. Trends in the species specialization indices (SSIc) and species temperature indices (STIc) at community level. Calculations both include and exclude data for silver-studded blue (*Plebejus argus*). (A) SSIc: with *P. argus*, the SSIc increased significantly (m = 0.002, $P = 0.001$, $R^2 = 0.611$); without *P. argus*, the trend is reversed even more significantly (m = -0.002, $P < 0.001$, $R^2 = 0.745$). (B) STIc: with *P. argus*, the STIc decreased significantly (m = –0.007, $P = 0.001$, $R^2 = 0.614$); without *P. argus*, the trend is reversed even more significantly (m = 0.005, $P < 0.001$, $R^2 = 0.624$).

Grasslands and, more especially, hay meadows, are the most diverse habitats and also harbour the greatest density of butterflies (Table 3). The main exponent of this habitat type are hay meadows with *Gaudinia fragilis*, which dominate in the *closes* in section 11 and have the richest and most abundant butterfly community in the area. Nearby sections 10, 12 and 13 have similar but somewhat poorer communities. Other types of meadows, including the saline meadow in section 5 and the *Brachypodium phoenicoides* grassland in section 8, also figure among the richest habitats at El Cortalet. Nevertheless, the more wooded environments and the sections that are completely dominated by ruderal vegetation (sections 7 and 15) are clearly poorer, both in number of species and in abundances (Table 3).

Table 3. Sections of the itinerary at El Cortalet with the dominant habitat type, and butterfly richness (number of species detected annually) and density (number of specimens counted annually per 100 m). Significant trends in 1988–2018 are shown with the symbols: + *P* <0.1, * *P* <0.05, ** *P* <0.01, *** *P* <0.001.

Section	Habitat	Richness	Trend		ex./100 m	Trend	
1	Riparian woodland	12.5	negative	***	66.3	negative	***
3	Ashes and humid grassland	11.4	negative	***	77.1	negative	***
4	Elms and hedgerows	15.6	negative	***	98.7	negative	***
5	Brachypodium phoenicoides and saline grassland	18.8	negative	**	70.5	negative	***
6	Elms and hedgerows	10.6	negative	***	79.1	stable	
7	Ruderal vegetation	10.4	negative	**	60.8	stable	
8	Brachypodium phoenicoides and reed	17.8	negative	**	140.1	stable	
9	Humid saline grassland	12.2	stable		83.6	stable	
10	Hay meadow	20.2	stable		137.5	stable	
11	Hay meadow	20.7	stable		271.0	positive	***
12	Hay meadow and ruderal vegetation	19.7	stable		104.4	positive	**
13	Hay meadow and ruderal vegetation	20.6	stable		111.1	stable	
14	Riparian woodland	11.7	stable		104.2	negative	*
15	Ruderal vegetation	16.6	stable		76.3	stable	
16	Hay meadow	15.3	stable		78.7	stable	
17	Hay meadow	12.3	stable		68.7	negative	+

A remarkable example: the silver-studded blue *Plebejus argus*

The butterfly fauna of the Cortalet is mainly composed of generalist species, of little interest for conservation at Catalan level. Indeed, the only species out of the 56 that is not classified as of Least Concern (Vila *et al*., 2018) is the southern small white *Pieris mannii*, which is classified as Near Threatened. This butterfly is occasional at El Cortalet, where eight specimens have been detected in 31 years (just one in the past 18 years). Although breeding was recorded on one section of the itinerary (Stefanescu, 1997), no population currently occurs in the area.

Despite this lack of locally rare species, some species in the PNAE are noteworthy for a number of reasons. A case in point is the silver-studded blue, which has become the most abundant species in recent years. This blue is an excellent example of a very sedentary species living typically in metapopulations (populations with clearly defined boundaries that are interconnected by dispersion compensating for local extinction). Its ecology has been well studied as it has served as a model in the development of metapopulation theory (Thomas, 1991; Hanski & Thomas, 1994; Thomas *et al*., 2002). Although it is highly polyphagous, it probably specializes locally on a single host plant, as at El Cortalet where populations depend exclusively on bird's-foot trefoil *Lotus corniculatus*.

This butterfly has an obligatory mutualistic relationship with the ant *Lasius niger*, which strongly conditions the oviposition behaviour of females and the dispersal of both sexes (Jordano & Thomas, 1992; Jordano *et al*., 1992; Seymour *et al.*, 2003). This relationship is based on the secretion of sugars and amino acids by specialized organs in the caterpillar, which are used by the ants in return for protecting the butterfly larvae against predators and parasitoids. The caterpillars feed at night and during the day live inside the *L. niger* nests. Pupation also occurs inside the nests and it is not an uncommon to see new-born adults still surrounded by ants extending their wings near ant nests (Fig. 5).

Although the silver-studded blue is present throughout much of Catalonia, it is always local and rarer than its distribution map suggests (Vila *et al.*, 2018). Most populations live in mountainous areas (max. alt. 2,000 m a.s.l.) but it also locally occurs in the lowlands, sometimes in markedly dry environments (e.g. Cap de Creus). In most of its European distribution it is a univoltine species, with a single generation in late spring or early summer. However, the PNAE populations are unique in Catalonia and the Iberian Peninsula due to their multivoltine phenology. At El Cortalet, for example, it has three well-differentiated emergency peaks, most likely corresponding to three generations (Fig. 6).

After analysing the habitat preferences of the butterflies found on the CBMS itineraries in the PNAE, Stefanescu *et al*. (2006) concluded that the silver-studded blue is one of the species most strongly linked to the typical hay meadows or *closes* in the area. In addition, this species has been repeatedly shown to be very sensitive to habitat modifications. For example, the abandonment of mowing or grazing causes rapid population declines and within only five years it may become locally extinct after having been the dominant species (Stefanescu *et al*., 2006, 2009; Colom & Stefanescu, this volume). On the other hand, it also reacts very quickly to improved conditions and rapid increases in population densities can occur. These remarkable behavioural traits, together with its relative rarity and very local distribution, have led Stefanescu *et al*. (2006) to consider the silver-studded blue to be the best bioindicator in the park's butterfly community of the quality of the *closes*.

Figure 5. A newly emerged silver-studded blue *Plebejus argus*, still attended by *Lasius niger* ants, with which it has an obligatory mutualism in the caterpillar stage. This adult was photographed in section 11 early in the morning, when most emergences occur (photo: Jordi Jubany).

Figure 6. Phenology of the silver-studded blue at El Cortalet, compared to its phenology in the rest of Catalonia. At the PNAE, *P. argus* behaves as a multivoltine species, with a first generation centred on May, a second emergence in July and a third in August–September. Overwintering occurs as an egg at the base or near the host plant, bird's-foot trefoil *Lotus corniculatus*. Source: CBMS.

At El Cortalet, the silver-studded blue is currently largely concentrated in sections 11–13. Nevertheless, the situation has changed radically over the course of the years (Table 4) as in the early 1990s it was very scarce, with just a single population concentrated in a small meadow in front of the Torre del Matà (section 8). This population disappeared when an irrigation channel was opened and the vegetation changed completely but within a few years the species had colonized two nearby *closes* in sections 9 and 11. Although the population in section 9 still persists after over two decades, it has decreased considerably in size as the meadow has become more saline in recent years. Conversely, in section 11 the population has undergone a true demographic explosion and now consists of many thousands of individuals. Moreover, in recent years, it has colonized nearby closes in sections 12 and 13 and established good numbers there. To maintain all these populations, some of whose densities are remarkable, the meadows must be preserved through proper management.

Table 4. Abundance in four different seasons of the silver-studded blue (as a percentage of the annual total) in sections of the itinerary at El Cortalet in which it has been detected. Over the years, the spatial distribution of the main populations has changed dynamically.

Section	**1994**	**2001**	**2010**	**2018**
3	0	0	0	0
4	0	0	0	0
5	2	1	0	1
8	96	1	0	0
9	2	88	18	6
10	0	0	0	9
11	0	10	76	48
12	0	0	5	24
13	0	0	0	11
15	0	0	0	0
16	0	0	0	1
17	0	0	0	0
Butterflies recorded	**50**	**222**	**897**	**2550**

Management of the closes

During these 30 years, certain sections of El Cortalet have undergone important changes that in some cases have had serious effects on butterfly communities. Interestingly, significant decreases in both butterfly richness and abundance have been recorded in sections dominated by riparian woodland, which are also those with the poorest butterfly assemblages. These negative trends are very evident along the first half of the itinerary (sections 1–6, Table 3). By contrast, the butterfly communities in the *closes*, especially along the second part of the itinerary, have remained largely stable or even increased in abundance (e.g. sections 11–12).

It seems highly likely that the impoverishment of the butterfly fauna occupying the riparian woodland is related to a phenomenon of encroachment parallel to tree growth and the recovery from Dutch elm disease (Table 1). The opposite situation (stability or even an increase in abundance) in the sections sampling *closes* is undoubtedly related to correct habitat management. The best examples are provided by section 11, where the coverage of the plant community dominated by *Gaudinia fragilis* has increased from 50% to 90% in the past two decades, and sections 12 and 13, where the very species-poor plant communities in the 2000s (with large extensions of the invasive species *Aster squamatus* and *Conyza* sp.) have been replaced by a much more interesting and mature meadows increasingly resembling the one dominating section 11.

Over the years, mowing and grazing periods in these *closes* have varied greatly, which indicates that there can be some flexibility in how these management tools are used to favour butterfly communities. Both pasturing and mowing are good choices, provided that they are applied with time periods and intensities that are appropriate. If pasturing and trampling are excessive because there are too many animals or continue for too long in the same meadow, invasive plants such as *Aster squamatus* and *Conyza* sp. become dominant and impoverish plant and butterfly communities. Despite a variety of management possibilities, we believe that the best option is to graze in the autumn/winter seasons, then allow for a spring recovery of the meadow, before mowing in early summer. In the years when the highest densities of the silver-studded blue have been recorded, there was no grazing in either spring or summer (e.g. in section 11: 2013, 2016–2018), which possibly allowed for a good development of both the first generation (flying in May) and the second and third summer generations, which emerge in July and August–September. In this way adults emerge when there is good nectar supply and when *Lotus corniculatus* is still very abundant. This situation also favours other butterfly species whose larvae develop mostly in spring. Likewise, these conditions seem also to be good for the populations of *Lasius niger*, which are essential if *P. argus* is to thrive.

Conclusions

In 27 years of butterfly monitoring at El Cortalet (1988 and 1993–2018), 56 species were detected of which just over 30 maintain regular populations, the rest being only occasional. During this period, species richness fell by about 20%, from an initial value of 38 species detected annually to current values of around 30 species. On the other hand, butterfly abundances increased significantly, although this contrasting trend is solely due to the demographic explosion of a single species, the silver-studded blue. Three local extinctions were recorded, in 1996 (white-letter hairstreak), 2002 (southern marbled skipper) and 2010 (gatekeeper). Furthermore, no species that was absent at the onset of the monitoring period established a stable population during these years.

For a total of 32 species it was possible to calculate a population trend: of these, 15 (46.9%) are stable, 12 (37.5%) declined, and only five (15.6%) increased. We explored whether these population trends are related to four ecological traits, two related to habitat preferences and two to species' climate niches. If the silver-studded blue is excluded from the analyses (a species acting as an outlier because of its demographic explosion in the past decade), a highly significant decrease in the degree of habitat specialization is revealed for the butterfly community: greater declines occurred in habitat specialists than in habitat generalists, a phenomenon known as 'faunal homogenization' that has been described elsewhere for butterfly communities and other organisms (Ekroos *et al.*, 2010; Le Viol *et al*., 2012). In line with this trend, the butterfly community in El Cortalet has become increasingly dominated by generalist species, as shown by the significant decrease in a community specialization index over time. Similarly, there were also significant increases in a community species temperature index, which indicates that the butterfly assemblage is becoming more dominated by thermophilous species.

Both faunal homogenization and the gradual dominance of thermophilous species are expected patterns under a scenario of global change. Long-term monitoring in El Cortalet therefore confirms that this type of response is already taking place in this Mediterranean area. The relative greater success of generalist species is interpreted to be a consequence of phenomena such as habitat degradation and fragmentation, which affect species with more strict ecological requirements more severely. It is important to note that the decline in habitat specialists is not necessarily explained only by habitat changes in the studied populations; these species are structured in metapopulations and therefore their dynamics are also affected by landscape-scale phenomena (e.g. at various kilometres around the census route) that also affect other nearby populations.

Nevertheless, monitoring during these three decades has allowed us to document some important changes in the habitats present at El Cortalet. The first half of the route, dominated by woodland, has closed up (estimated at a little under 10% compared to the initial state), probably related to tree growth and elm recovery following the severe incidence of Dutch elm disease in the early 1990s. This closure could explain the mostly negative trends in the butterfly community along the first sections of the itinerary. It should be noted, however, that the butterfly community associated with these environments is much poorer than those associated with the *closes* and the other types of grassland that dominate the second part of the itinerary. The trends observed in these latter habitat types are stable or positive, which is quite remarkable in the context of the decline of butterfly populations in Catalonia as a whole (Melero *et al*., 2016).

Indeed, in El Cortalet there is a set of *closes* (in sections 11–13) whose state greatly improved over the course of the study period. In fact, this area was devoted to intensive agriculture in the late 1980s and early 1990s (maize and sunflower cultivation), and only at the beginning of the monitoring period were these fields converted back into hay meadows. As meadow conditions improved and plant communities became more mature, more interesting butterfly communities were established. The most striking example of this process is the colonization of these *closes* by the silver-studded blue, the butterfly that is considered to be locally the best bioindicator of the quality of the *closes*. Today, there are truly spectacular populations of this butterfly, which was completely absent from these sections of the itinerary at the beginning of the study period.

A review of the actions carried out in these *closes* allows us to identify the best type of management for the butterfly communities that fly there. In our opinion this should consist of grazing during the autumn/winter (by cows or horses), the recovery of the *closes* during spring, and then mowing in early summer. Other options (such as a management based exclusively on mowing or grazing) are also possible but do not lead to such manifest enrichment of the butterfly communities.

Acknowledgements

We wish to thank the staff of the Aiguamolls de l’Empordà Natural Park for their support during these years. Francesc Giró and Jordi Sargatal suggested I start the study in the late 1980s. Marta Miralles, Ferran Páramo, Andreu Ubach and Pau Colom have all helped in different ways. Xavier Espadaler identified the *Lasius niger* ants associated to the silver-studded blue. Michael Lockwood revised the English version. The Butterfly Monitoring Scheme in Catalonia is funded by the Departament de Territori i Sostenibilitat de la Generalitat de Catalunya.

References

Carnicer, J., C. Stefanescu, M. Vives-Ingla, C. López, S. Cortizas, C. Wheat,, R. Vila, J. Llusià, & J. Peñuelas, 2019. Phenotypic biomarkers of climatic impacts on declining insect populations: a key role for decadal drought, thermal buffering and amplification effects and host plant dynamics. Journal of Animal Ecology 88: 376-391.

Colom, P., & C. Stefanescu, this volume. Effects of abandonment and restoration in Mediterranean meadows in a butterfly-plant network subject to long-term monitoring.

Devictor, V., C. van Swaay, T. Brereton, Ll. Brotons, D. Chamberlain, J. Heliölä, S. Herrando, R. Julliard, M. Kuussaari, Å. Lindström, J. Reif , D.B. Roy, O. Schweiger, J. Settele, C. Stefanescu, A. Van Strien, C. Van Turnhout, Z. Vermouzek, M.W. DeVries, I. Wynhoff, & F. Jiguet, 2012. Differences in the climatic debts of birds and butterflies at a continental scale. Nature Climate Change 2: 121-124.

Donoso, I., C. Stefanescu, A. Martínez-Abraín, & A. Traveset, A., 2016. Phenological asynchrony in plant-butterfly interactions associated with climate: a community-wide perspective. Oikos 125: 1434-1444.

Ekroos, J., J. Heliölä, & M. Kuussaari, 2010. Homogenization of lepidopteran communities in intensively cultivated agricultural landscapes. Journal of Applied Ecology 47: 459-467.

Fick, S. E., & R.J. Hijmans, 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37: 4302–4315.

García–Barros, E., M.L. Munguira, J. Martín Cano, H. Romo Benito, P. García Pereira, & E.E. Maravalhas, 2004. Atlas de las mariposas diurnas de la Península 380 Ibérica e islas Baleares (Lepidoptera: Papilionoidea & Hesperioidea). 381 Monografías de la Sociedad Entomológica Aragonesa 11: 1–228.

Hanski, I., & C.D. Thomas, 1994. Metapopulation dynamics and conservation: a spatially explicit model applied to butterflies. Biological Conservation 68: 167-180.

Jordano, D., & C.D. Thomas, 1992. Specificity of an ant-lycaenid interaction. Oecologia 91: 431-438.

Jordano, D., J. Rodríguez, C.D. Thomas, C.D. & J. Fernández-Haeger, 1992. The distribution and density of a lycaenid butterfly in relation to Lasius ants. Oecologia 91: 439-446.

Julliard, R., J. Clavel, V. Devictor, F. Jiguet, F. & D. Couvet, 2006. Spatial segregation of specialists and generalists in bird communities. Ecology Letters 9: 1237–1244.

Le Viol, I., F. Jiguet, Ll. Brotons, S. Herrando, A. Lindström, J.W. Pearce-Higgins, J. Reif, C. Van Turnhout, & V. Devictor, 2012. More and more generalists: two decades of changes in the European avifauna. Biology letters 8: 780-782.

Melero, Y., C. Stefanescu, & J. Pino, 2016. General declines in Mediterranean butterflies over the last two decades are modulated by species traits. Biological Conservation 201: 336-342.

Seymour, A.S., D. Gutiérrez, & D. Jordano, 2003. Dispersal of the lycaenid *Plebejus argus* in response to patches of its mutualistic ant *Lasius niger.* Oikos 103: 162-174.

Stefanescu, C., 1997. *Coronopus squamatus* (Forssk.) Asch. (Cruciferae), una nova planta nutrícia per *Pieris rapae* (L.), *Pieris mannii* May. i *Pieris napi* (L.) (Pieridae) als Aiguamolls de l'Empordà, amb notes addicionals sobre altres recursos tròfics utilitzats a la zona del Cortalet. Butlletí de la Societat Catalana de Lepidopterologia 80: 26-29.

Stefanescu, C., J. Peñuelas, & I. Filella, 2003. Effects of climatic change on the phenology of butterflies in the northwest Mediterranean Basin. Global Change Biology 9: 1494-1506.

Stefanescu, C., J. Peñuelas, & I. Filella, 2005. Butterflies highlight the conservation value of hay meadows highly threatened by land-use changes in a protected Mediterranean area. Biological Conservation 126: 234-246.

Stefanescu, C., J. Peñuelas, & I. Filella, 2006. Les papallones com a bioindicadores dels hàbitats a Catalunya: l'exemple dels prats de dall i les pastures del Parc Natural dels Aiguamolls de l'Empordà. Butlletí de la Institució Catalana d'Història Natural 73: 139-162.

Stefanescu, C., J. Peñuelas, & I. Filella, 2009. Rapid changes in butterfly communities following the abandonment of grasslands: a case study. Insect Diversity and Conservation 2: 261-269.

Ubach, A., F. Páramo, C. Gutiérrez, & C. Stefanescu, 2020. Vegetation encroachment drives changes in the composition of butterfly assemblages and species loss in Mediterranean ecosystems. Insect Conservation and Diversity 13: 151-161.

Thomas, C.D., 1991. Spatial and temporal variability in a butterfly population. Oecologia 87: 577-580.

Thomas, C.D., R.J. Wilson, & O.T. Lewis, 2002. Short-term studies underestimate 30-generation changes in a butterfly metapopulation. Proceedings of the Royal Society of London B 269: 563-569.

Vila, R., C. Stefanescu, & J.M. Sesma, 2018. Guia de les papallones diürnes de Catalunya. Barcelona, Spain: Lynx Edicions.

Vives-Ingla, M., C. Stefanescu, Sala-García, J., & J. Carnicer, this volume. Plastic and phenological variation of host plants mediates local responses of the butterfly *Pieris napi* to drought in the Mediterranean basin.

Effects of abandonment and restoration in Mediterranean meadows in a butterfly-plant network subject to long-term monitoring

Pau Colom *[1]
Constantí Stefanescu [2,3]

[1] Institut Mediterrani d'Estudis Avançats (CSIC-UIB), Global Change Research Group,
Miquel Marqués 21, 07190 Esporles, Illes Balears, Spain
[2] Granollers Natural Sciences Museum, Francesc Macià 51, 08402 Granollers, Barcelona, Spain
[3] CREAF, E08193 Bellaterra (Cerdanyola del Vallès), Catalonia, Spain
* Corresponding author e-mail: pau.colom.montojo@gmail.com

Introduction

Both agricultural intensification and abandonment are recognized as major threats to biodiversity worldwide, above all in industrialized countries (Donald *et al.*, 2001; Briggs *et al.*, 2005; Cramer *et al.*, 2008; Kehoe *et al.*, 2017; Zabel *et al.*, 2019). Paradoxically, many biodiverse systems of high ecological value that are now under threat were originally created by human action as the consequence of traditional agricultural practices (Di Giulio *et al.*, 2001; Tscharntke *et al.*, 2005; Kleijn *et al.*, 2009, 2011; Blondel *et al.*, 2010).

The effects of abandoning traditional management in grasslands has been studied in vascular plants (Meiners *et al.*, 2001; Pruchniewicz, 2017; Uchida *et al.*, 2018) and insects (Erhardt, 1985; Marini *et al.*, 2009; Dover *et al.*, 2011), and in some cases in a combination of these two groups (Steffan-Dewenter & Leschke, 2003; Pöyry *et al.*, 2006; Uchida & Ushimaru, 2015). Butterflies, in particular, have emerged as a model insect group for study due to the rapid response their populations show to environmental changes and the fact that they are easy to monitor (Thomas, 2005).

Various studies carried out in northern and central Europe have found that meadows managed by mowing or grazing maintain a greater diversity of plant species than those that are abandoned or subject to intense management (Poschlod & WallisDeVries, 2002; Pykälä *et al.*, 2005). Disturbance caused by mowing or grazing allows the least competitive species to survive, thereby favouring greater plant co-existence (Zobel *et al.*, 1996). Yet, the literature describes an increase in diversity in butterfly species at the beginning of the succession when meadows are abandoned or management intensity is reduced (Pöyry *et al.*, 2006; Öckinger *et al.*, 2006). Taller but also structurally more diverse vegetation (*i.e.* more diversity of turf heights) initially allows for more diverse insect communities (Kruess & Tscharntke, 2002). However, community responses differ between geographical areas and, for instance, the above-mentioned pattern was not observed in our work area in an earlier work (Stefanescu *et al.*, 2009). This was attributed to the rapid decline and even extinction of various species of Lycaenidae (the most diverse butterfly family in the area) when their primary host plants disappeared at the beginning of the ecological succession.

Nevertheless, it is generally agreed that butterfly species richness decreases as ecological succession advances and shrub vegetation and trees encroach (e.g. Balmer and Erhardt, 2000; Öckinger *et al.*, 2006). In the Mediterranean region, in particular, where most species of butterfly show a strong preference for open habitats, afforestation resulting from the abandonment of traditional agricultural practices (Feranec *et al.*, 2010) has been identified as one of the main factors driving species declines (Herrando *et al.*, 2016; Ubach *et al.*, 2020).

Taken together, these studies have led to a broad consensus that, at least in Europe, a significant loss of biodiversity is resulting from the abandonment of semi-natural meadows. This, in turn, has encouraged work to recover these habitats via the restoration of traditional practices (Pykälä, 2003; Pöyry *et al.*, 2005; Öckinger *et al.*, 2006). However, restoring former management practices does not necessarily lead to an immediate return to the semi-natural state of the habitat prior to the abandonment (Dover *et al.*, 2011). Depending on the time they have been abandoned, it may take a long time for meadows to return to their former states (Rook *et al.*, 2004). Moreover, the effects of the restoration on both plant and butterfly communities will depend on the type and the frequency of the management: some studies suggest that the best results are obtained via grazing rather than mowing (Tälle *et al.*, 2015, 2016), while others advocate an intermediate frequency (Bakker & Berendse, 1999; Watkinson & Ormerod, 2001). In addition, the results obtained will depend on the type of grazing and, for example, some authors report the positive effects on plant and insect species richness of grazing with cows or horses as opposed to grazing with sheep (Carvell, 2002; Öckinger *et al.*, 2006).

This work aims to analyse the long-term (22 years) effects on plant and butterfly communities of both abandonment and restoration in semi-natural grasslands in a protected area in the north-east of the Mediterranean basin. Data were obtained from a system of *closes*, that is, traditionally managed meadows prone to flooding, where some of the effects of abandonment on both butterfly and plant communities have been reported in a previous study (Stefanescu *et al.*, 2009). This kind of grassland has been shown to be the most ecologically diverse and valuable habitat from a conservation point of view in the study area (Stefanescu *et al.*, 2005). In this work, first we compare the ecological trends of communities in abandoned meadows and in meadows in which management has not changed over time, and then proceed to analyze the effects of restoration on meadows under different types of management.

Methods

Study site

The study took place in Closes del Tec, a floodable zone in the Aiguamolls de l'Empordà Natural Park (AENP) in NE Spain (Fig. 1). This area is located at an old mouth of the river Muga, where habitats include arable land, meadows and riparian woodland. Specifically, these *closes* have been designated as habitats of Community Interest (Gesti *et al*., 2003) and consist of traditionally mown and/or grazed meadows separated by lines of deciduous trees running alongside drainage channels. In the study area, a 1.1 km transect was designed and divided into six sections (between 117 and 286 m in length), each in a different meadow separated from the others by ditches or trees.

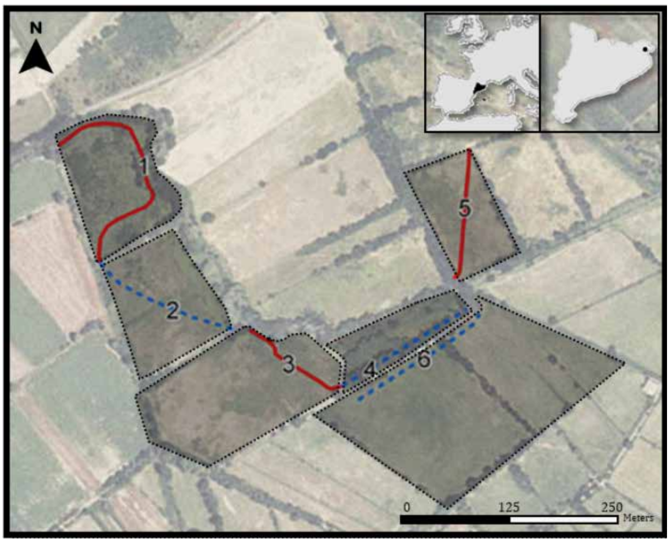


Figure 1. Study area. Transect in Closes de Tec, Aiguamolls de l'Empordà Natural Park, UTM (42.2265, 3.0915).

During the 22 years of butterfly monitoring (1997–2018), these meadows underwent important changes in management practices. In the first two years of the monitoring period, all six meadows were managed traditionally by mowing (sections 1, 2, 5) or by a combination of grazing and mowing (sections 3, 4, 6). As of 1999, sections 1–5 were abandoned (*i.e.* they were no longer grazed or mown), while section 6 continued to be managed as before throughout the whole study period (Fig. 2).

The abandonment of the meadows led to serious changes in the vegetation that had a rapid effect on the butterfly community (Stefanescu *et al*., 2009). However, traditional management practices were restored in 2005 and, uninterruptedly since then, these meadows have once again been managed traditionally. In this second period, section 1 was only grazed, while the other five sections were subject to a combination of grazing and mowing.

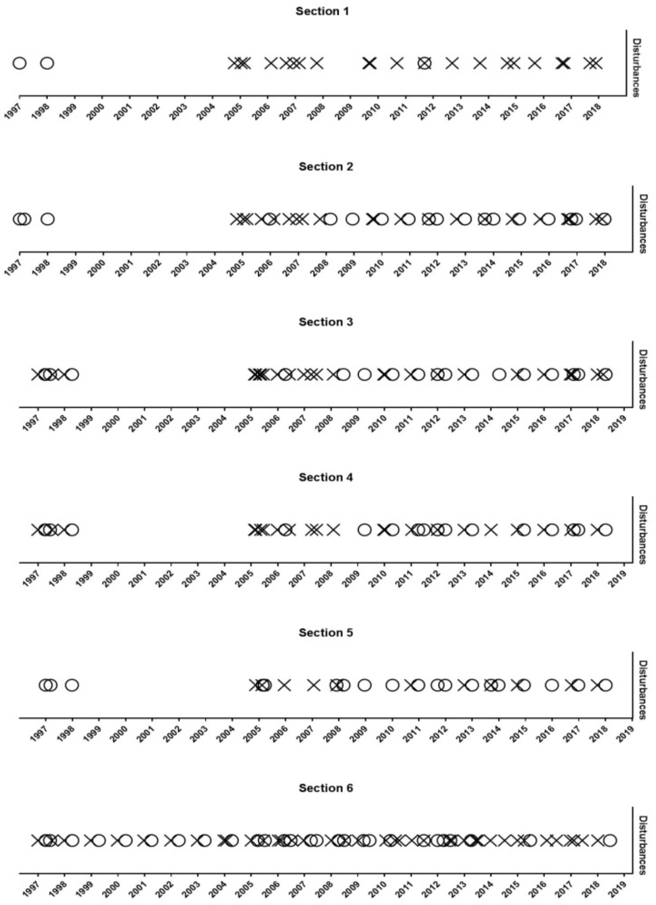


Figure 2. Type of management in the different sections during the study period (1997-2018). Circles indicate episodes of grazing and crosses indicate mowing. As of 1999, sections 1-5 were abandoned while section 6 continued to be managed throughout the study period. Management was restored in 2005 in the abandoned meadows. However, while sections 2–5 combined grazing and mowing, section 1 was managed exclusively by grazing.

Data on butterflies and nectar resources

Since 1997, the butterfly populations in this area have been monitored within the framework of the Catalan Butterfly Monitoring Scheme (<www.catalanbms.org>) using a standardized methodology (Pollard and Yates, 1993) that consists of weekly counts from the first week of March to the last week of September of individual butterflies along a walked transect at distances of 2.5 m on both the sides and 5 m ahead of the recorder. Based on these counts, annual indices of the relative abundances of the detected species were calculated to evaluate population trends during the study period. Abundance values were standardized to 100 m of transect length.

Visits to flowers by butterflies were also recorded during the counts. These records only include butterflies that were actually seen to feed on nectar with their proboscis clearly extended. The abundance and diversity of plants visited by butterflies in each section and year was used as a proxy of the resources that were available for adult butterflies during the season.

The combination of data on butterflies and flowering plants was used to characterize ecological changes over the last 22 years in the study area due to changes in meadow management. Thus, the following eight ecological descriptors were calculated for both sections and years: (1) Butterfly abundance; (2) Butterfly richness; (3) Flower visitor richness (*i.e.* number of butterfly species visiting flowers); (4) Butterfly diversity (calculated using the Shannon-Wiener index); (5) Flower visitor diversity; (6) Flower visits (*i.e.* total number of flower visits); (7) Plant richness (*i.e*. species of flowering plants visited by butterflies); (8) Plant diversity.

Habitat assessment

In 2000, in parallel to the butterfly monitoring, plant communities were characterized for the first time in accordance with the CORINE Land Cover manual. Since then, this characterization has been repeated by the same botanist every six years. He records the changes in flower resources and more general changes in the structure of the plant communities present along the butterfly transect. Over the years vegetation monitoring has provided information regarding which plant communities were dominant in the meadows in the year after the abandonment (2000), in the year after management recovery (2006), and in two subsequent years (2012 and 2018). Moreover, it has proved useful for detecting how habitats have become more open or more overgrown over time, a process known to have serious effects on butterfly communities (Slancarova *et al*., 2016; Ubach *et al*., 2020).

Statistical analyses

Trends over time in the ecological descriptors in the different sections and periods were analysed by linear models. Differences in trends between abandoned (sections 1–5) and managed (section 6) sections during the abandonment period (1999-2004) were analysed using Generalised Linear Models (GLM). Comparisons during the management recovery period (2005-2018) were also made between meadows that were both grazed and mown (sections 2-6) and the meadow that was only grazed (section 1).

Next, we focused on changes in butterfly and plant (*i.e.* flowers visited by butterflies) community structures. For plant composition, however, the analysis did not distinguish between sections due to the limited number of recorded flower-butterfly interactions in some years at section level. Hence, yearly records were pooled for the whole transect. Bray-Curtis dissimilarity indices were used to measure changes in composition between seasons. For the butterfly communities, dissimilarity was calculated for each section and year with respect to the initial first-year community (1997). Temporal trends in dissimilarity values were then calculated using linear models for the different periods of the study, including as a reference value the year previous to the change of management type: (1) abandonment of sections 1-5 (1998–2004); (2) recovery of traditional management in sections 1-5 (2004-2018); (3) the whole study period (1997-2018).

Permanova analysis and NMDS plots were also used to detect differences in species composition between periods and sections. In the case of plants, however, we did not distinguish between sections and we only compared the abandonment and management periods. Simper analysis (Clarke, 1993) was additionally used to identify the species that contributed most to the total dissimilarity between the abandonment and restoration periods.

Finally, we evaluated whether or not butterfly population trends (*i.e.* as measured by changes in the annual indices of relative abundance) could be explained by the ecological traits of the butterfly species themselves during the two periods under study (abandonment and management). The selected ecological traits of the butterflies were: (a) wing length (wing span, from García-Barros *et al*., 2013); (b) mobility according to a categorical index with five classes (0 = forming populations and showing very little dispersal; 1 = closed populations and more frequent dispersal; 2 = closed populations and very frequent dispersal; 3 = open populations and non-directional dispersal; and 4 = open populations and directional migration; see Stefanescu *et al.*, 2005, 2009); (c) overwintering stage (egg, larva, pupa, adult or with no overwintering stage); (d) host-plant specialization (*i.e.* monophagous, oligophagous or polyphagous larvae); (e) voltinism (*i.e.* number of generations per year: univoltine, bivoltine or polivoltine). Life-history data were extracted from García-Barros *et al.* (2013), Vila *et al.* (2018) and personal observations by one of the authors (CS).

Results

Habitat changes related to meadow management

Despite the absence of data on plant communities prior to abandonment, in 2000–2006 important changes in plant communities were observed as a result of the cessation of grazing and mowing. By 2000 (*i.e.* two years after abandonment), Mediterranean grasslands with grasses including *Gaudinia fragilis* and *Brachypodium phoenicoides* were the predominant habitat type along the transect. Other species such as *Euphorbia serrata* and *Galium lucidum*, and typical wetland species such as *Scirpus holoschoenus*, were also abundant. In 2000-2006, however, Mediterranean grassland cover fell by 36±18% in the abandoned sections. Otherwise, in 2006-2012, once the traditional management was restored, this habitat type increased by 24±26% in sections 2-5 where mowing and grazing were combined. By contrast, in section 1, which was only grazed, the Mediterranean grassland continued to decline (12% fall in 2006-2012) until it had completely disappeared by 2018 (Fig. 3). At the same time, the riparian woodland (mainly *Fraxinus angustifolia* and *Ulmus minor*) increased: 2000: 0%; 2006: 10%; 2012: 33.6%; and 2018: 50%. In the other sections, this notable increase in riparian woodland only occurred in section 4, where a stand of *Populus alba* established itself: 2000: 10%; 2006: 40%; 2012: 40%; and 2018: 60%. Furthermore, despite traditional management never having actually

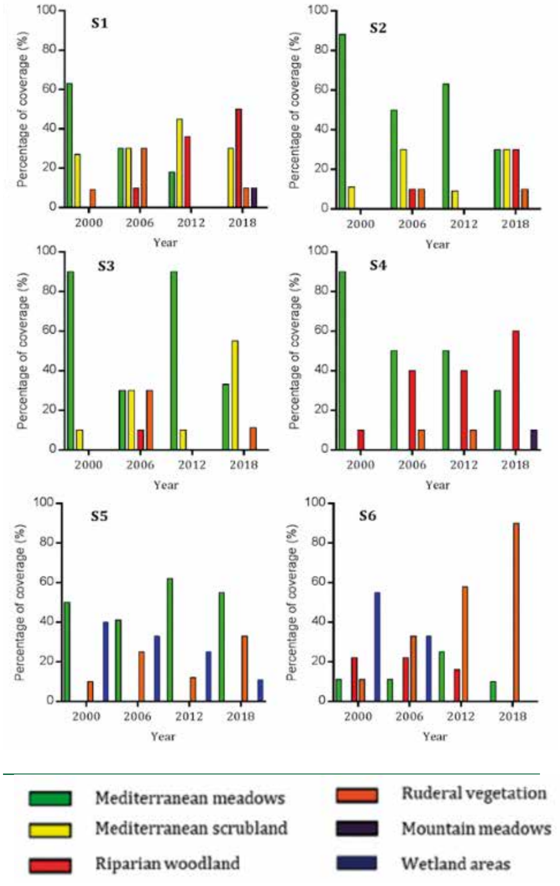


Figure 3. Habitat cover on the different sections in 2000, 2006, 2012 and 2018. Habitat types characterized according to the CORINE Land Cover manual.

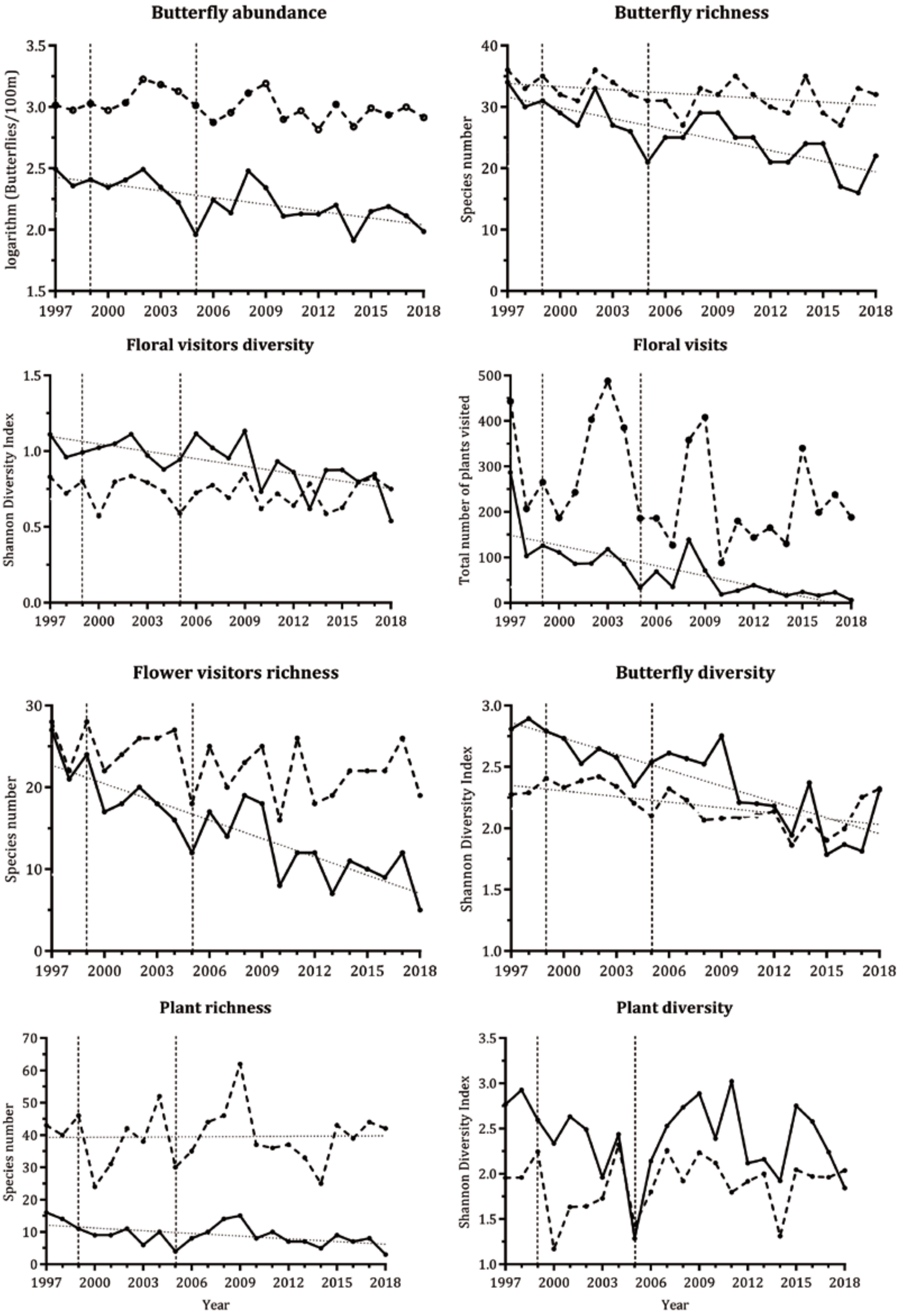


Figure 4. Continuous lines indicate trends for the eight ecological descriptors analysed in section 1. Dotted lines indicate trends for the total of all six sections. Significant trends ($P < 0.05$) are represented by small dotted lines.

ceased in section 6, plant communities there underwent a strong process of ruderalization, probably because of overgrazing by horses: 2000: 11%; 2006: 33.3%; 2012: 58.3%; and 2018: 90% of ruderal habitat type (Fig. 3).

Trends in ecological descriptors

When considering the whole study period, section 1 was the only section that showed significant trends in more than half of the selected ecological descriptors (hereafter EDs) of the communities (Table 1). Specifically, we recorded significant negative trends in seven out of eight EDs, with plant diversity being the only descriptor showing no long-term trends (Fig. 4). On the other hand, negative trends in sections 2–5 were only observed in one ED (butterfly diversity) during the abandonment period. In 2005, after management was restored, in addition to butterfly diversity, negative trends were also observed in other four EDs (butterfly richness, flower visitor richness, flower visitor diversity and flower visits). Moreover, section 6 showed significant negative trends in butterfly richness and diversity when considering the whole period. However, other EDs showed significant trends in this section in the shorter periods of abandonment and restoration of management that affected the other sections. Interestingly, the direction of these trends changed depending on the period in question. Thus, during the abandonment of sections 1–5, four EDs increased their values significantly in section 6, but then decreased significantly once management was restored.

Significant differences between abandoned and managed sections were also detected (Table 1). In all cases, these differences occurred due to simultaneous positive trends in section 6 and negative trends in the abandoned sections (sections 2-5). During the period of management recovery, there were also significant differences between section 1 (only grazed) and sections 2–6 in 6 EDs (grazed and mown). In this period, trends were significantly more negative in section 1.

Changes in butterfly and flowering plant community structures

During the study period as a whole, significant changes in butterfly communities were only observed in sections 1 and 6, and were markedly more linear in section 1 ($R^2 = 0.73$) than in section 6 ($R^2 = 0.18$) (Fig. 5).

During the abandonment period, butterfly communities changed significantly in all sections, irrespectively of whether or not they were managed (Fig. 5, Table 2). However, after management was restored in sections 1–5, section 1 was the only section that continued to increase significantly its dissimilitude value when compared to the control year. By contrast, in the rest of the sections this trend was negative (i.e. butterfly communities became more like the original communities described prior to abandonment) but only significant in section 5. This reflects the fact that the management of section 1, which was only grazed, was different from that of the other sections, which were grazed and mown.

The above results were confirmed by Permanova and NMDS analyses (Fig. 6, Table 3). The importance of abandonment is revealed by significant differences in butterfly communities between periods in all six sections; these differences were especially notable between the abandonment period and the period in which management was restored (Table 3; Fig. 6). Only in section 1 were there significant differences between

Table 1. Temporal trends in all the ecological descriptors in the different analysed periods. The P-values for the Generalised Linear Model comparisons between the trends in the different treatments (abandoned vs managed and grazing vs grazing + mowing) are shown in the GLM * rows.

		Study period (1997–2018)	Abandonment (1998–2004)		Management recovery (2004–2018)	
			Abandoned	Managed	Grazing	Graz. + mown
Butterfly abundance (Number of individuals/100m)	S1	**-7.759** ***P* < 0.001**	-5.85 *P* = 0.528		-4.013 *P* = 0.229	
	S2	-0.322 *P* = 0.906	29.73 *P* = 0.087			-3.944 *P* = 0.382
	S3	-0.689 *P* = 0.753	29.42 *P* = 0.051			-2.424 *P* = 0.459
	S4	**-4.686** ***P* = 0.037**	21.63 *P* = 0.125			-0.209 *P* = 0.923
	S5	1.272 *P* = 0.643	-6.67 *P* = 0.415			3.434 *P* = 0.552
	S6	-3.272 *P* = 0.302		**33.65** ***P* = 0.004**		**-13.88** ***P* = 0.019**
	GLM*		*F* = 3.982; *P* = 0.074		*F* = 1.18 ; *P* = 0.287	
Butterfly richness (Number of butterfly species observed)	S1	**-0.579** ***P* < 0.001**	-0.571 *P* = 0.263		**-0.489** ***P* = 0.022**	
	S2	0.183 *P* = 0.092	0.285 *P* = 0.715			0.111 *P* = 0.539
	S3	0.046 *P* = 0.711	1.643 *P* = 0.074			-0.075 *P* = 0.72
	S4	**-0.327** ***P* = 0.008**	-0.286 *P* = 0.740			0.096 *P* = 0.518
	S5	**-0.208** ***P* = 0.047**	0.285 *P* = 0.363			0.079 *P* = 0.669
	S6	**-0.254** ***P* = 0.031**		0.893 *P* = 0.153		-0.371 *P* = 0.055
	GLM*		*F* = 0.844; *P* = 0.38		***F* = 6.446; *P* = 0.017**	
Flower visitor richness (Number of butterfly species visiting flowers)	S1	**-0.746** ***P* < 0.001**	-0.857 *P* = 0.095		**-0.625** ***P* = 0.005**	
	S2	0.093 *P* = 0.474	1.036 *P* = 0.153			-0.025 *P* = 0.915
	S3	0.14 *P* = 0.294	1.143 *P* = 0.26			0.314 *P* = 0.125
	S4	-0.015 *P* = 0.839	0.464 *P* = 0.248			0.2 *P* = 0.114
	S5	0.016	0.964			0.2

		P = 0.889	P = 0.241			P = 0.342
	S6	-0.071 P = 0.549		**1.643** **P = 0.023**		-0.386 P = 0.051
	GLM*		F = 2.912; P = 0.119		**F = 12.54; P = 0.002**	
Butterfly diversity (Shannon-Wiener diversity of butterflies observed)	S1	**-0.043** **P < 0.001**	**-0.077** **P = 0.004**		**-0.048** **P = 0.003**	
	S2	**0.018** **P = 0.005**	-0.047 P = 0.132			**0.031** **P = 0.021**
	S3	**0.019** **P = 0.008**	0.069 P = 0.126			0.012 P = 0.303
	S4	**-0.021** **P = 0.032**	-0.047 P = 0.294			0.013 0.391
	S5	**-0.034** **P = 0.028**	0.047 P = 0.465			-0.019 P = 0.459
	S6	**-0.031** **P = 0.002**		-0.009 P = 0.616		-0.022 P = 0.244
	GLM*		F = 0.002; P = 0.963		**F = 12.54 ; P = 0.003**	
Flower visitor diversity (Shannon-Wiener index of butterflies visiting flowers)	S1	**-0.016** **P < 0.001**	-0.006 P = 0.659		**-0.022** **P = 0.014**	
	S2	0.001 P = 0.934	0.004 P = 0.862			-0.002 P = 0.676
	S3	0.008 P = 0.136	0.016 P = 0.734			0.012 P = 0.127
	S4	-0.005 P = 0.597	0.007 P = 0.854			0.019 P = 0.238
	S5	-0.001 P = 0.781	0.007 P = 0.775			0.241 P = 0.241
	S6	0.002 P = 0.715		0.031 P = 0.236		0.001 P = 0.923
	GLM*		F = 0.691; P = 0.425		**F = 10.96; P = 0.003**	
Flower visits (Total number of plants visited)	S1	**-7.47** **P < 0.001**	-3.25 P = 0.344		**-4.854** **P = 0.014**	
	S2	-0.016 P = 0.992	20.21 P = 0.109			0.221 P = 0.924
	S3	0.638 P = 0.416	8.786 P = 0.123			1.989 P = 0.076
	S4	0.189	**1.857**			**0.901**

		P = 0.424	***P* = 0.035**			***P* = 0.044**
	S5	0.998 *P* = 0.433	4.714 *P* = 0.356			1.296 *P* = 0.62
	S6	-0.937 *P* = 0.278		**10.39** ***P* = 0.006**		**-3.914** ***P* = 0.015**
	GLM*		*F* = 1.094; *P* = 0.32		***F* = 7.727; *P* = 0.01**	
Plant richness (Number of plant species visited by butterflies)	S1	**-0.028** ***P* = 0.011**	-0.714 *P* = 0.13		-0.278 *P* = 0.16	
	S2	**0.199** ***P* = 0.017**	0.286 *P* = 0.535			0.203 *P* = 0.194
	S3	0.117 *P* = 0.274	0.643 *P* = 0.153			-0.157 *P* = 0.449
	S4	-0.053 *P* = 0.424	0.25 *P* = 0.392			0.05 *P* = 0.701
	S5	0.111 *P* = 0.07	-0.25 *P* = 0.548			**0.304** ***P* = 0.001**
	S6	-0.076 *P* = 0.401		**1.143** ***P* = 0.032**		**-0.425** ***P* = 0.008**
	GLM*		***F* = 5.109; *P* = 0.047**		*F* = 3.203; *P* = 0.085	
Plant diversity (Shannon-Wiener diversity index of plant species visited by butterflies)	S1	-0.014 *P* = 0.307	-0.014 *P* = 0.307		-0.015 *P* = 0.307	
	S2	0.042 *P* = 0.057	0.042 *P* = 0.057			**0.042** ***P* = 0.057**
	S3	0.02 *P* = 0.393	0.02 *P* = 0.393			0.02 *P* = 0.393
	S4	-0.025 *P* = 0.35	0.024 *P* = 0.868			-0.007 *P* = 0.884
	S5	0.027 *P* = 0.123	-0.011 *P* = 0.903			**0.076** ***P* = 0.019**
	S6	-0.019 *P* = 0.297		0.108 *P* = 0.245		**-0.097** ***P* = 0.004**
	GLM*		*F* = 0.853; *P* = 0.301		*F* = 0.0.124; *P* = 0.728	

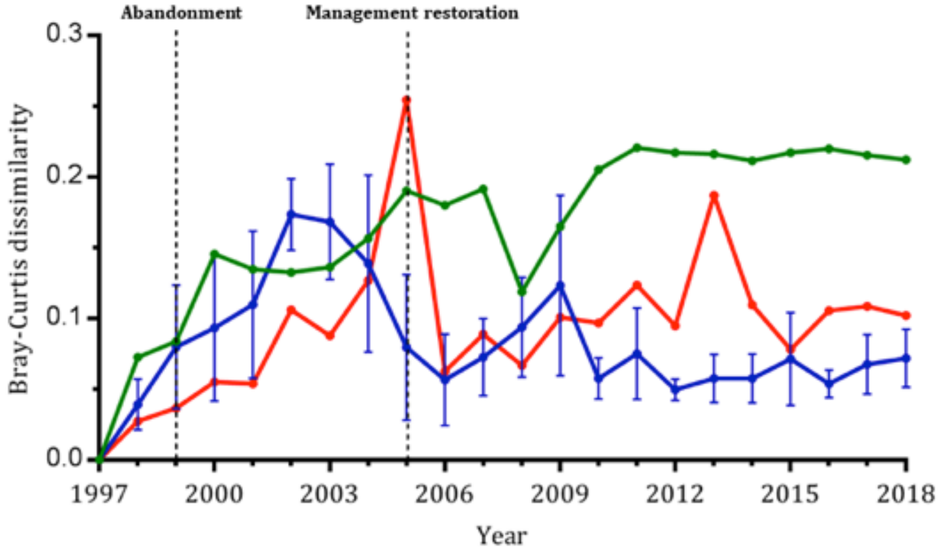


Figure 5. Trends of dissimilarity values with respect to the first year of monitoring (1997) for the butterfly communities. In green: section 1; in blue: sections 2-5 (with standard deviation represented in bars); in red: section 6.

Table 2. Butterfly community dissimilarity trends in the different analysed periods. P-values for the Generalised Linear Model comparisons between the trends in the different treatments (abandoned *vs* managed and grazing *vs* grazing + mowing) are shown in the GLM* row.

	Study period (1997–2018)		Abandonment (1998–2004)		Management recovery (2004–2018)	
			Abandoned	Managed	Grazing	Graz. + mown
Butterfly community dissimilarity trend (Bray-Curtis dissimilarity with respect to 1997)	S1	**0.008** ***P* < 0.001**	**0.012** ***P* = 0.021**		**0.004** ***P* = 0.007**	
	S2	<-0.001 *P* = 0.729	**0.025** ***P* = 0.019**			-0.004 *P* = 0.173
	S3	<-0.001 *P* = 0.836	**0.021** ***P* = 0.016**			-0.002 *P* = 0.145
	S4	-0.002 *P* = 0.152	**0.007** ***P* = 0.31**			<0.001 *P* = 0.916
	S5	-0.002 *P* = 0.268	**0.027** ***P* = 0.011**			**-0.006** ***P* = 0.012**
	S6	**0.003** ***P* = 0.047**		**0.016** ***P* = 0.002**		-0.002 *P* = 0.499
	GLM*		*F* = 0.219; *P* = 0.649		***F* = 15.14 ; *P* < 0.001**	

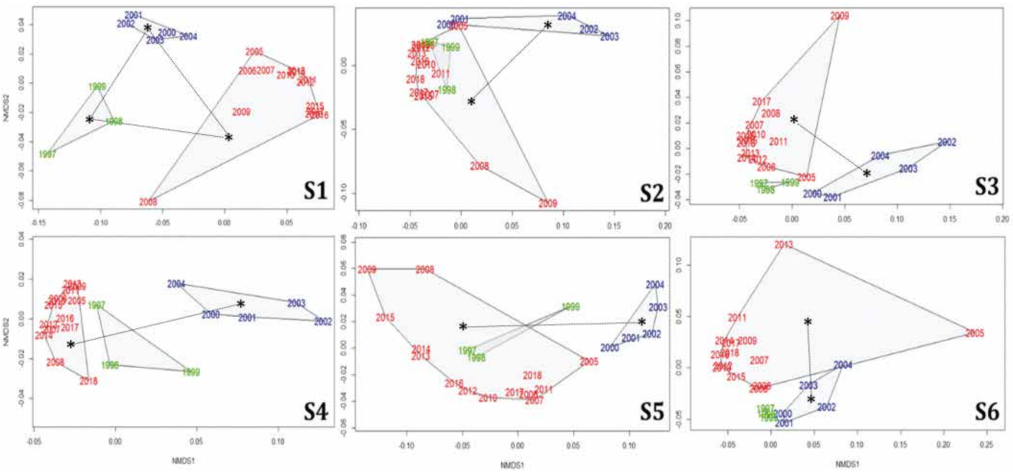


Figure 6. Non-Metric Multidimensional Scaling (NMDS) plots for each section of the transect. Different analysed periods are represented in different colours: green: before abandonment; blue: abandonment period; red: after management was restored. Dotted lines and asterisks represent significant differences (*P* < 0.05 in Permanova analysis) between periods.

all periods (Table 3; Fig. 6). The analyses also revealed significant differences in the composition of the flowering plant communities between the abandonment and management periods at transect level (*P* = 0.009).

Section	Permanova analysis	A vs B	A vs C	B vs C
1	**_P_ < 0.001**	**_P_ = 0.045**	**_P_ = 0.005**	**_P_ < 0.001**
2	**_P_ = 0.009**	*P* = 0.158	*P* = 1	**_P_ = 0.015**
3	**_P_ = 0.001**	*P* = 0.096	*P* = 0.334	**_P_ = 0.001**
4	**_P_ < 0.001**	*P* = 0.164	*P* = 0.052	**_P_ = 0.001**
5	**_P_ = 0.001**	*P* = 0.052	*P* = 1	**_P_ < 0.001**
6	**_P_ = 0.018**	*P* = 0.105	*P* = 0.084	**_P_ = 0.006**

Table 3. Permanova results for the butterfly community between periods: (A): before abandonment*; (B) abandonment; (C) management recovery. * 1999 was included in this period as butterfly communities were still very similar to the initial situation due to the inertia in changes in plant composition in the first year after abandonment (see Figure 6).

The species of butterflies that contributed most to these differences were *Melanargia lachesis*, *Pyronia tithonus*, *P. cecilia*, *Plebejus argus* and *Polyommatus icarus* (Fig. 7). The populations of the first three species (all in the Satyrinae subfamily) increased noticeably during the abandonment period but then rapidly collapsed once grazing and mowing were restored. These increases occurred above all in the abandoned sections but were much more moderate in the non-abandoned section 6. The other two species (*P. argus* and *P. icarus*, both in the Lycaenidae family) showed an almost opposite pattern: when the meadows were abandoned their populations fell severely but increased remarkably in section 6. This was particularly relevant in the case of *P. argus*, whose abundance increased dramatically until it peaked at exceptional levels of 5 butterflies/m in 2005. Once the management was restored in sections 1-5, however, these trends changed dramatically: although their populations in section 6 declined severely, *P. icarus* and *P. argus* numbers returned to their original levels of abundance in sections 1-5.

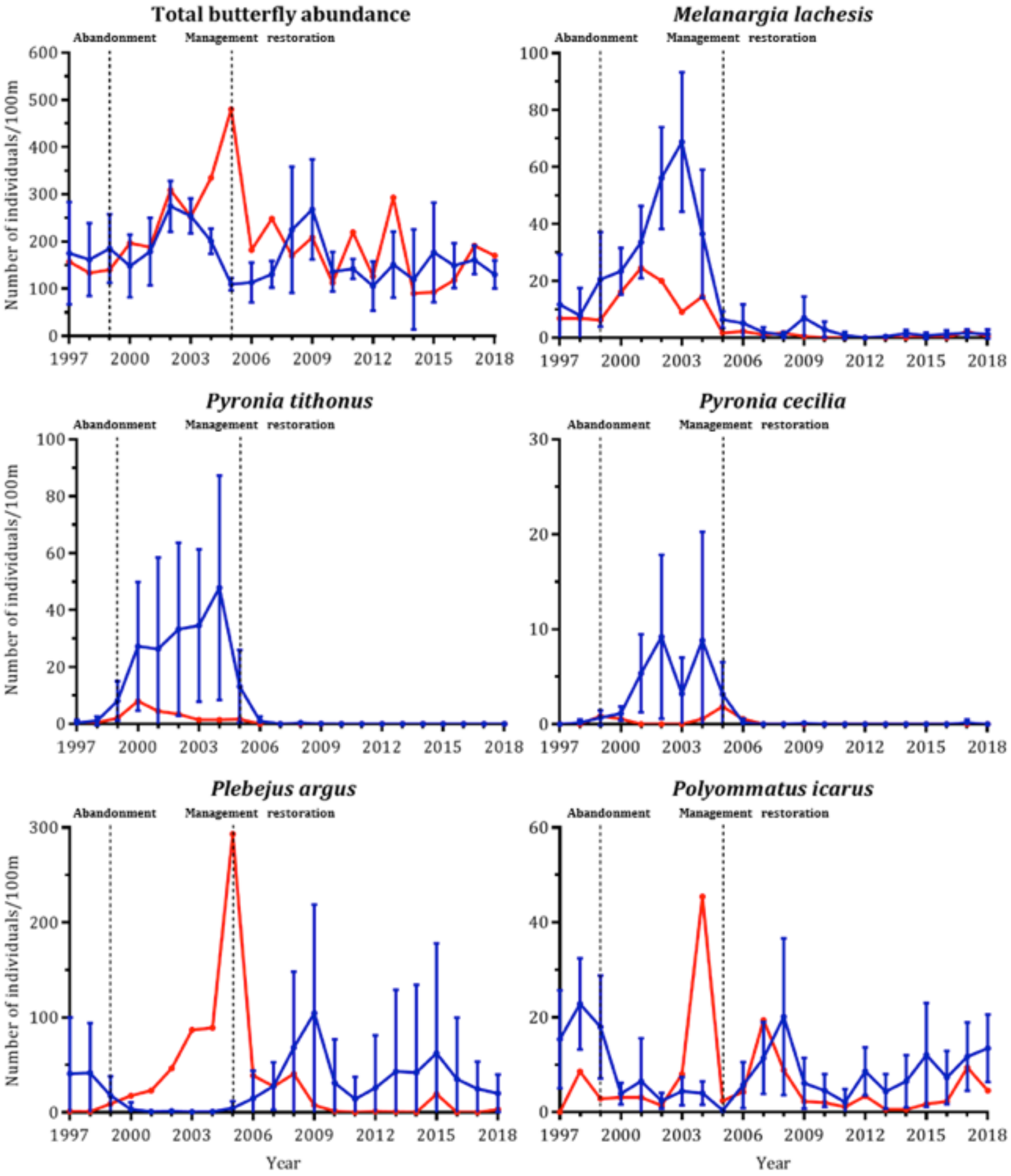


Figure 7. Population trends of the most sensitive butterfly species to management changes according to a Simper analysis. Blue lines show trends of species in abandoned sections (1–5) and red lines trends of species in section 6.

In terms of flowering plants, the species that were most visited by butterflies in the abandonment period were *Cirsium* spp., *Rubus* spp. and *Mentha suavolens*, which dominated the whole of the butterfly-plant interactions recorded during that period (Fig. 8). Once the management was restored, the number of visits to these plants fell dramatically (except for *Rubus* spp., which maintained a large number of visits throughout the whole study period), while the number of visits to *Lotus corniculatus* and several species of *Trifolium*, which had decreased greatly during the abandonment period, increased.

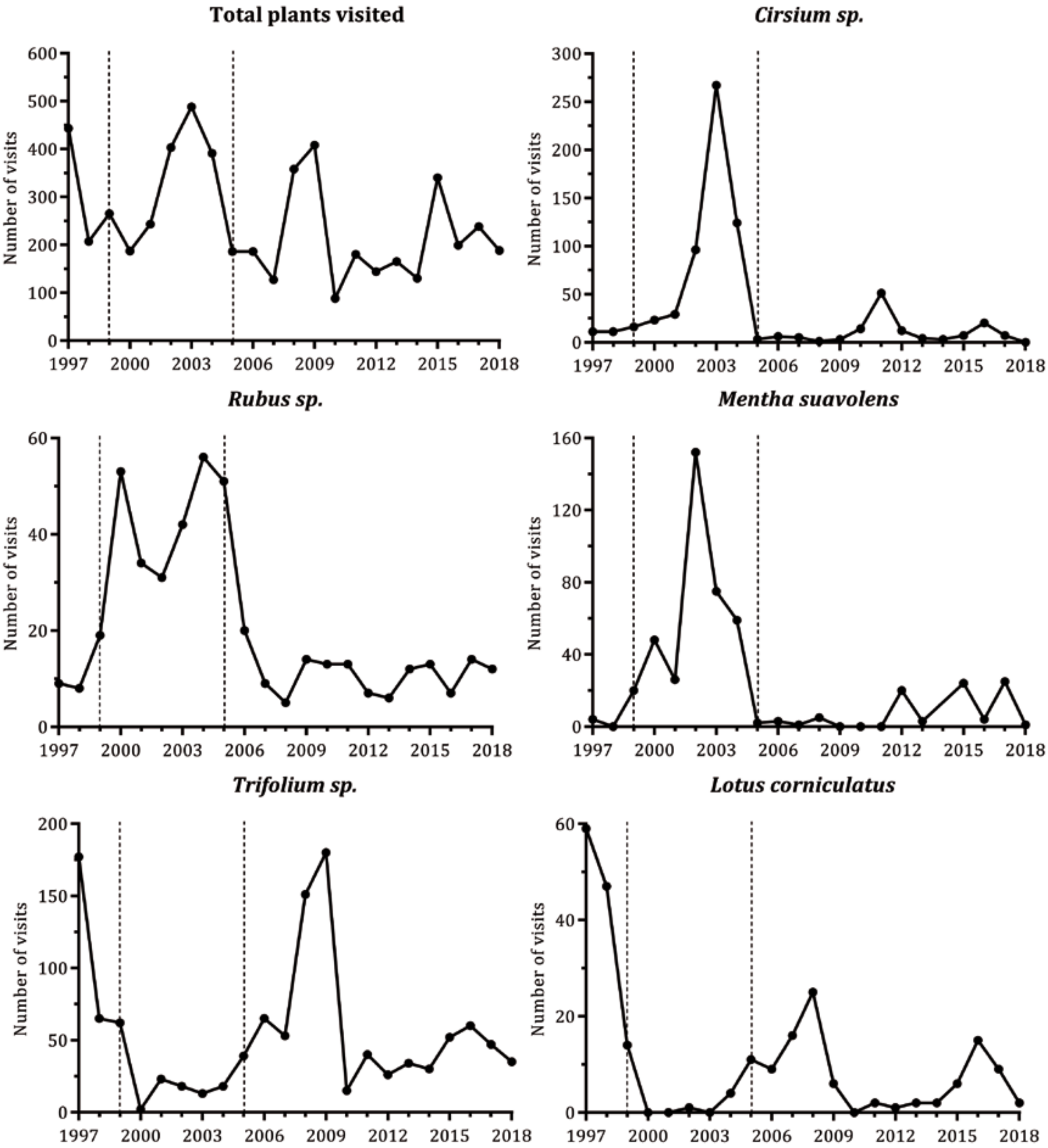


Figure 8. Population trends of the most sensitive plant species to management changes according to a Simper analysis. Trends for the total of the five abandoned sections.

Ecological traits related to changes in butterfly abundance

Voltinism is the only ecological trait that predicts butterfly population trends in the abandoned sections. This trait explained the observed population trends both in the abandonment and the management periods, although with opposite effects (Fig. 9). All univoltine species (*i.e.* one generation per year) experienced positive trends during the abandonment period, which then changed to a negative trend once management was restored. On the other hand, the trends of bivoltine and polivoltine species were fairly variable in both periods. In any case, this analysis suggests that polivoltine species benefit from grazing and mowing since negative trends in their populations fell substantially in the second period (Fig. 9).

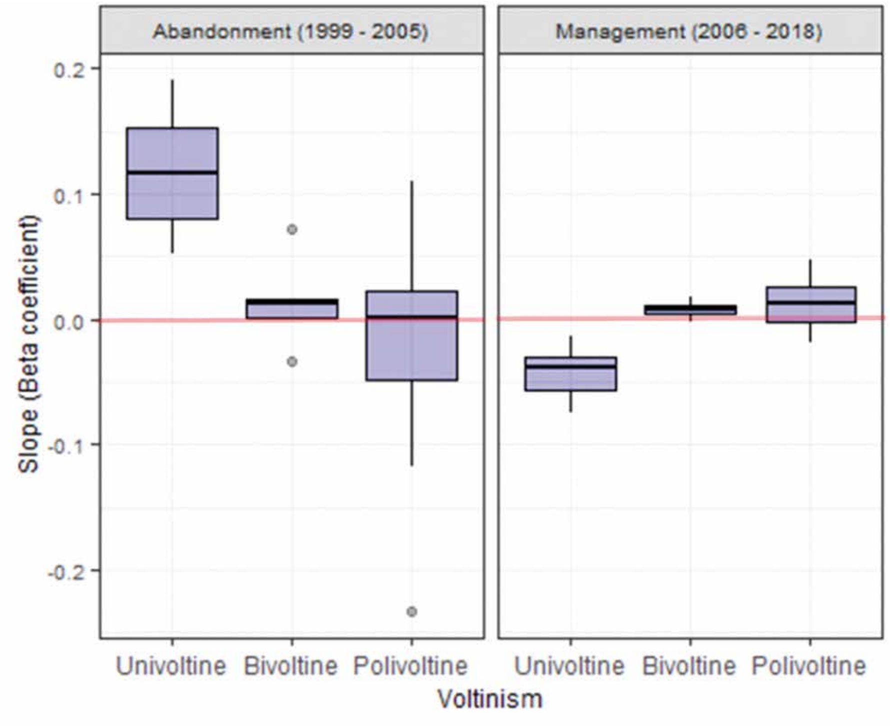


Figure 9. Population trends in the butterfly species in the abandoned sections (1–5) in relation to voltinism (*i.e.* number of generations per year). Population trends of the different species are represented as the slope values of the linear regression models.

Discussion

There is a vast amount of literature showing how rapidly butterfly populations respond to habitat changes of different kinds (*e.g.* Thomas, 1991; Dennis, 2010). Moreover, evidence for such responses has rapidly accumulated over the last decades in many European countries thanks to the establishment of butterfly monitoring schemes and the recognition of butterflies as a good bioindicator group (Thomas, 2005).

In the study area, over two decades of butterfly monitoring was combined with observations of visits to flowers by butterflies and vegetation monitoring to record habitat changes. This extra information is not usually available in butterfly monitoring schemes in such detail and allows us to study how different ecological processes affect interactions between butterfly and plant communities. Here we provide for the first time an analysis of the responses to the abandonment and restoration of grasslands in butterfly and plant communities in the same locality over a period of over 20 years. Moreover, we were able to compare the effects of abandonment using a control meadow that was not abandoned, as well as the effects of restoration under two different types of management.

Our data indicate that plant communities in meadows underwent very rapid and drastic changes soon after the cessation of mowing. Mediterranean meadows, which represented at least 50% of the monitored area at the beginning of the study, were substantially reduced after five years of abandonment, and this had substantial effects on the butterfly assemblages. The study also shows that the coverage of Mediterranean meadows returned to their original levels after traditional management was restored in 2005 in the abandoned meadows, although only when mowing and pasture were combined. On the other hand, pasturing alone proved to be insufficient in one of the original fields, where Mediterranean meadows continued to decline until their complete disappearance by 2018. Thus, in the absence of periodical mowing, the growth of shrubs and trees was not suppressed and woody vegetation progressively came to dominate the community. This suggests that mowing may be necessary here for the conservation of typical Mediterranean meadows, which have been identified as the most valuable habitat for butterflies and, probably, for other pollinators as well in this protected area (Stefanescu *et al*., 2005).

Butterfly community analysis over time confirms that changes in habitats led to rapid modifications in butterfly assemblages. Thus, once the management of sections 1–5 was abandoned, butterfly communities underwent dramatic rearrangements, with a few univoltine grass-feeder species experiencing population explosions and becoming the dominant species. By contrast, the populations of some polivoltine legume-feeders collapsed (see also Stefanescu *et al*., 2009). Interestingly, changes in the populations of these species were also noticed in the sole meadow that remained grazed and mown throughout the whole study. In particular, as sections 1–5 were abandoned, both butterfly abundances and visits to flowering plants substantially increased in section 6. Not only did the univoltine species increase their numbers in the abandoned meadows but – and especially so – numbers of multivoltine species collapsed. Because the habitat remained essentially the same in the managed section during this period, it is clear that population increases of multivoltine species were related to the forced dispersal of populations from nearby deteriorating meadows. This is perfectly exemplified by *Plebejus argus*, whose numbers increased dramatically in section 6 (up to an extraordinary density of 5 individuals/m in 2005) coinciding fully with the collapse of the populations in the abandoned sections. The metapopulation structure of this (Thomas & Harrison, 1992, Lewis *et al.*, 2003) and other butterfly species highlights the fact that population fluctuations are not only related to changes in the habitat where they are recorded but, rather, are affected by a wider range of habitats where they are connected to other subpopulations (Hanski & Thomas, 1994).

Our data also show how a meadow representing a sink habitat for *P. argus* at the beginning of the study became the only stronghold for its vanishing populations amongst the abandoned and deteriorating meadows. Moreover, once the habitat in these meadows improved following management restoration, the single meadow harbouring a population (*i.e.* the former sink) became a source, from which new habitats were re-colonized (Pulliam, 1988). This result highlights the importance of conserving networks of well-connected patches for habitat specialists, as has already been pointed out by much theoretical and empirical work (*e.g.* Hanski, 1999). Moreover, this highly dynamic system allowed for a rapid recovery of collapsing populations once mowing and grazing restarted in the abandoned meadows harbouring the original populations.

Our results also point to the complexity of the management techniques required to reach ideal conditions for plant and butterfly communities, a recurrent theme in butterfly conservation (Settele *et al*., 2009). Thus, the only meadow where management continued throughout the study period deteriorated due to the overgrazing by horses in the second part of the study period (CS, pers. obs.), which ultimately affected butterfly populations. The ruderalization of plant communities had a strong negative effect on flower resources, which led to a decrease in the number of visits and the richness and diversity of the plants visited, as well as in butterfly abundances. The absence of negative trends in butterfly richness and diversity suggests that the loss of available nectar resources led to a reduction in butterfly abundance and not vice versa.

From a more theoretical point of view, our study is interesting as it provides new evidence as to how life-history traits can be used to predict population responses subject to environmental change. Certain previous studies have attempted to explain butterfly population trends in abandoned grasslands by examining the ecological characteristics of the species (Steffan-Dewenter & Tscharntke, 1997; Sanford, 2002, Stefanescu *et al*., 2009, Kithara *et al*., 2000, Slancarova *et al*., 2016) report that species richness declined more in specialists than in generalists along a gradient of increasing disturbance when specialization was measured based on voltinism and host-plant specialization. On the other hand, Pöyry *et al*. (2006) observed that the abandonment of grasslands benefitted generalist herbivores, while low-intensity management was more beneficial to specialists. In our study system, Stefanescu *et al*. (2009) failed to observe differences in host-plant specialization but did detect an increase in seasonal specialization (*i.e*. decrease in voltinism) of the communities in accordance to the r/k species concept (Pianka, 1970). In a habitat with recurrent disturbance (*i.e*. mowing and/or grazing) the species that will dominate the community will be those with high reproductive rates (Brown & Southwood, 1983; Brown, 1985). By contrast, species with longer developmental times and, therefore, with fewer annual generations will benefit from the abandonment of management practices (*i.e*. absence of disturbance). Our results, added to earlier study data from another 10 years of management restoration, confirm that voltinism is indeed the best life-history trait for predicting population trends affected by managing practices in Mediterranean grasslands.

Conclusions

Our study shows that the cessation of management in traditional Mediterranean meadows leads to significant reductions in the cover of typical grasslands, and that this alteration rapidly provokes changes in butterfly assemblages. These changes are of conservation concern, as previous work has identified traditional Mediterranean meadows as the most valuable habitat for butterflies in this protected area (Stefanescu *et al*., 2005). It is important to emphasize that changes in butterfly communities were recorded not only in meadows undergoing such transformations but also in nearby unaltered habitats due to the metapopulation structure of some species (Hanski & Thomas, 1994). A highly dynamic source-sink system ultimately allowed the metapopulation to persist (Keymer *et al*., 2000; Johst *et al*., 2002). Likewise, our data show that management restoration can promote a quick return to the pre-abandonment situation in the butterfly community. However, insufficient management pressure (section 1) or, contrariwise, excessive grazing pressure (section 6) did not allow for proper recovery and led, instead, to a progressive impoverishment in community diversity. Therefore, this work highlights the importance of not only conserving traditional management practices in these semi-natural meadows but also of doing so in a such way that the high diversity of these habitats is preserved.

Acknowledgements

We wish to thank the staff of the Aiguamolls de l'Empordà Natural Park for their support during these years. Thanks too are due to Ferran Páramo and Andreu Ubach for their technical support. The Butterfly Monitoring Scheme in Catalonia is funded by the Departament de Territori i Sostenibilitat de la Generalitat de Catalunya. PC is funded by a PhD fellowship financed by the Govern de les Illes Balears (FPI-CAIB-2018), which is part of the project CGL2017-88122-P and financed by the Spanish Government.

References

Bakker, J. P., & F. Berendse,1999. Constraints in the restoration of ecological diversity in grassland and heathland communities. Trends in Ecology & Evolution 14(2): 63-68.

Balmer, O., & A. Erhardt, 2000. Consequences of succession on extensively grazed grasslands for central European butterfly communities: rethinking conservation practices. Conservation Biology 14(3): 746-757.

Blondel, J., J. Aronson, J. Y. Bodiou, & G. Boeuf, 2010. The Mediterranean region: biological diversity in space and time. Oxford University Press.

Briggs, J. M., A. K. Knapp, J. M. Blair, J.L. Heisler, G. A. Hoch, M. S. Lett & J.K. McCarron, 2005. An ecosystem in transition: causes and consequences of the conversion of mesic grassland to shrubland. BioScience 55(3): 243-254.

Brown, V. K., 1985. Insect herbivores and plant succession. Oikos 44: 17-22.

Brown, V. K., & T. R. E. Southwood, 1983. Trophic diversity, niche breadth and generation times of exopterygote insects in a secondary succession. Oecologia 56(2-3): 220-225.

Carvell, C, 2002. Habitat use and conservation of bumblebees (*Bombus* spp.) under different grassland management regimes. Biological Conservation 103(1): 33-49.

Clarke, K.R, 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18: 117-143.

Cramer, V. A., R.J. Hobbs, & R.J. Standish, 2008. What's new about old fields? Land abandonment and ecosystem assembly. Trends in Ecology & Evolution 23(2): 104-112.

Dennis, R.L.H, 2010. A resource-based habitat view for conservation: Butterflies in the British landscape. Wiley-Blackwell. 406 pp.

Di Giulio, M., P. J. Edwards, & E. Meister, 2001. Enhancing insect diversity in agricultural grasslands: the roles of management and landscape structure. Journal of Applied Ecology 38(2): 310-319.

Donald, P. F., R.E. Green, & M.F. Heath, 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London. Series B: Biological Sciences 268(1462): 25-29.

Dover, J. W., S. Spencer, S. Collins, I. Hadjigeorgiou, & A. Rescia, 2011. Grassland butterflies and low intensity farming in Europe. Journal of Insect Conservation 15(1-2): 129-137.

Erhardt, A. 1985. Diurnal Lepidoptera: sensitive indicators of cultivated and abandoned grassland. Journal of Applied Ecology 22: 849-861.

Feranec, J., G. Jaffrain, T. Soukup, & G. Hazeu, 2010. Determining changes and flows in European landscapes 1990–2000 using CORINE land cover data. Applied Geography 30(1): 19-35.

García-Barros, E., M.L. Munguira, C. Stefanescu, & A. Vives-Moreno, 2013. Lepidoptera: Papilionoidea. Fauna Ibérica, 37. Museo Nacional de Ciencias Naturales-CSIC, Madrid. 1213 pp.

Gesti, J.,G. Mercadal & L. Vilar, 2003. La Biodiversidad de los Prados de Siega de los Aiguamolls de L 'Alt Empordà (Girona). XIX Jornadas de Fitosociología – Congreso de la Federación Internacional de Fitosociología, Biodiversidad y Gestión del Territorio. La Laguna, Tenerife.

Hanski, I., 1999. Habitat connectivity, habitat continuity, and metapopulations in dynamic landscapes. Oikos 87(2): 209-219.

Hanski, I. & C.D. Thomas, 1994. Metapopulation dynamics and conservation: a spatially explicit model applied to butterflies. Biological Conservation 68(2): 167-180.

Herrando, S., L. Brotons, M. Anton, F. Paramo, D. Villero., N. Titeux, J. Quesada & C. Stefanescu, 2016. Assessing impacts of land abandonment on Mediterranean biodiversity using indicators based on bird and butterfly monitoring data. Environmental Conservation 43(1): 69-78.

Johst, K., R. Brandl, & S. Eber, 2002. Metapopulation persistence in dynamic landscapes: the role of dispersal distance. Oikos 98(2): 263-270.

Kehoe, L., A. Romero-Muñoz, E. Polaina, L. Estes, H. Kreft, & T. Kuemmerle, 2017. Biodiversity at risk under future cropland expansion and intensification. Nature Ecology & Evolution 1(8): 1129-1135.

Keymer, J. E., P.A. Marquet, J.X. Velasco-Hernández & S.A. Levin, 2000. Extinction thresholds and metapopulation persistence in dynamic landscapes. The American Naturalist 156(5): 478-494.

Kitahara, M., K. Sei, & K. Fujii, 2000. Patterns in the structure of grassland butterfly communities along a gradient of human disturbance: further analysis based on the generalist/specialist concept. Population Ecology 42(2): 135-144.

Kleijn, D., F. Kohler, A. Báldi, P. Batáry, E.D. Concepción, Y. Clough, M. Diaz, D. Gabriel, A. Holzschuh, E Knop, & A. Kovács, E.J.P. Marshall, T. Tscharntke & J. Verhulst, 2009. On the relationship between farmland biodiversity and land-use intensity in Europe. Proceedings of the Royal Society B: Biological Sciences 276(1658): 903-909.

Kleijn, D., M. Rundlöf, J. Scheper, H.G. Smith, & T. Tscharntke, 2011. Does conservation on farmland contribute to halting the biodiversity decline?. Trends in Ecology & Evolution 26(9): 474-481.

Kruess, A., & T. Tscharntke, 2002. Contrasting responses of plant and insect diversity to variation in grazing intensity. Biological Conservation 106(3): 293-302.

Lewis, O., C. Thomas, J. Hill, M. Brookes, T. P. Crane, Y. Graneau, J. Mallet & O. Rose, 1997. Three ways of assessing metapopulation structure in the butterfly *Plebejus argus*. Ecological Entomology 22(3): 283-293.

Marini, L., P. Fontana, A. Battisti, & K. J. Gaston, 2009. Response of orthopteran diversity to abandonment of semi-natural meadows. Agriculture, Ecosystems & Environment 132(3-4): 232-236.

Meiners, S. J., S. T. Pickett, & M. L. Cadenasso, 2001. Effects of plant invasions on the species richness of abandoned agricultural land. Ecography 24(6): 633-644.

Öckinger, E., A.K. Eriksson, & H.G. Smith, 2006. Effects of grassland abandonment, restoration and management on butterflies and vascular plants. Biological Conservation 133(3): 291-300.

Pianka, E. R. (1970). On r-and K-selection. The American Naturalist 104(940): 592-597

Pollard, E., & T. Yates, 1993 Monitoring Butterflies for Ecology and Conservation. Chapman and Hall, London, UK.

Poschlod, P., & M.F. WallisDeVries, 2002. The historical and socioeconomic perspective of calcareous grasslands—lessons from the distant and recent past. Biological Conservation 104(3): 361-376.

Pöyry, J., S. Lindgren, J. Salminen, & M. Kuussaari, 2005. Responses of butterfly and moth species to restored cattle grazing in semi-natural grasslands. Biological Conservation 122(3): 465-478.

Pöyry, J., M. Luoto, J. Paukkunen, J. Pykälä, K. Raatikainen, & M. Kuussaari, 2006. Different responses of plants and herbivore insects to a gradient of vegetation height: an indicator of the vertebrate grazing intensity and successional age. Oikos 115(3): 401-412.

Pruchniewicz, D., 2017. Abandonment of traditionally managed mesic mountain meadows affects plant species composition and diversity. Basic and Applied Ecology 20: 10-18.

Pulliam, H. R., 1988. Sources, sinks, and population regulation. The American Naturalist 132(5): 652-661.

Pykälä, J., 2003. Effects of restoration with cattle grazing on plant species composition and richness of semi-natural grasslands. Biodiversity & Conservation 12(11): 2211-2226.

Pykälä, J., M. Luoto, R. K. Heikkinen, & T. Kontula, 2005. Plant species richness and persistence of rare plants in abandoned semi-natural grasslands in northern Europe. Basic and Applied Ecology 6(1): 25-33.

Rook, A. J., B. Dumont, J. Isselstein, K. Osoro, M.F. WallisDeVries, G. Parente, & J. Mills, 2004. Matching type of livestock to desired biodiversity outcomes in pastures–a review. Biological Conservation 119(2): 137-150.

Sanford, M. P., 2002. Effects of successional old fields on butterfly richness and abundance in agricultural landscapes. Great Lakes Ent. 35: 193-207.

Settele, J., J. Dover, M. Dolek, & M. Konvicka, 2009. Butterflies of European ecosystems: impact of land use and options for conservation management. Ecology of Butterflies in Europe. Cambridge University Press, Cambridge, 353-370.

Slancarova, J., A. Bartonova, M. Zapletal, M. Kotilinek, Z.F. Fric, N. Micevski, V. Kati, & M. Konvicka, 2016. Life history traits reflect changes in Mediterranean butterfly communities due to forest encroachment. PloS one 11(3).

Stefanescu, C., J. Peñuelas, & I. Filella, 2005. Butterflies highlight the conservation value of hay meadows highly threatened by land-use changes in a protected Mediterranean area. Biological Conservation 126(2): 234-246.

Stefanescu, C., J. Penuelas, & I. Filella, 2009. Rapid changes in butterfly communities following the abandonment of grasslands: a case study. Insect Conservation and Diversity 2(4): 261-269.
Steffan-Dewenter, I. & T.Tscharntke, 1997. Early succession of butterfly and plant communities on set-aside fields. Oecologia 109(2): 294-302.

Steffan-Dewenter, I., & K, Leschke, 2003. Effects of habitat management on vegetation and above-ground nesting bees and wasps of orchard meadows in Central Europe. Biodiversity & Conservation 12(9): 1953-1968.

Tälle, M., H. Fogelfors, L. Westerberg, & P. Milberg, 2015. The conservation benefit of mowing vs grazing for management of species-rich grasslands: a multi-site, multi-year field experiment. Nordic Journal of Botany 33(6): 761-768.

Tälle, M., B. Deák, P. Poschlod, O. Valkó, L. Westerberg, & P. Milberg, 2016. Grazing vs. mowing: A meta-analysis of biodiversity benefits for grassland management. Agriculture, Ecosystems & Environment 222: 200-212.

Thomas, C. D., & S. Harrison, 1992. Spatial dynamics of a patchily distributed butterfly species. Journal of Animal Ecology 61: 437-446.

Thomas, J. A., 1991. Rare species conservation: case studies of European butterflies. In: Spellerberg, I.F., F.B. Goldsmith & M.G. Morris (eds). The scientific management of temperate communities for conservation, pp. 149-197. Blackwell Scientific, Oxford.

Thomas, J. A., 2005. Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. Philosophical Transactions of the Royal Society B: Biological Sciences 360(1454): 339-357.

Tscharntke, T., A.M. Klein, A. Kruess, I. Steffan-Dewenter, & C. Thies, 2005. Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. Ecology Letters 8(8): 857-874.

Ubach, A., F. Páramo, C. Gutiérrez, & C. Stefanescu, 2020. Vegetation encroachment drives changes in the composition of butterfly assemblages and species loss in Mediterranean ecosystems. Insect Conservation and Diversity 13(2): 151-161.

Uchida, K., & A. Ushimaru, 2015. Land abandonment and intensification diminish spatial and temporal β-diversity of grassland plants and herbivorous insects within paddy terraces. Journal of Applied Ecology 52(4): 1033-1043.

Uchida, K., T. F. Koyanagi, T. Matsumura, & A. Koyama, 2018. Patterns of plant diversity loss and species turnover resulting from land abandonment and intensification in semi-natural grasslands. Journal of Environmental Management 218: 622-629.

Vila, R., C. Stefanescu, & J.M. Sesma, 2018. Guia de les papallones diürnes de Catalunya. Barcelona, Spain: Lynx edicions.

Watkinson, A. R., & S. J. Ormerod, 2001. Grasslands, grazing and biodiversity: editors' introduction. Journal of Applied Ecology 38: 233-237.

Zabel, F., R. Delzeit, J. M. Schneider, R. Seppel, W. Mauser, & T. Václavík, 2019. Global impacts of future cropland expansion and intensification on agricultural markets and biodiversity. Nature Communications 10(1): 1-10.

Zobel, M., M. Suurkask, E. Rosén, & M. Pärtel, 1996. The dynamics of species richness in an experimentally restored calcareous grassland. Journal of Vegetation Science 7(2): 203-210.

Plastic and phenological variation of host plants mediates local responses of the butterfly *Pieris napi* to drought in the Mediterranean basin

Maria Vives-Ingla *[1, 2]
Constantí Stefanescu [3, 1]
Javier Sala-Garcia [1]
Jofre Carnicer **[2, 1]

Affiliations
[1] CREAF, E08193 Bellaterra (Cerdanyola del Vallès), Catalonia, Spain
[2] Department de Biologia Evolutiva, Ecologia i Ciències Ambientals, Facultat de Biologia, Institut de Recerca de la Biodiversitat (IRBio), Universitat de Barcelona, 08028 Barcelona, Catalonia, Spain
[3] Granollers Natural Sciences Museum, Francesc Macia 51, 08402 Granollers, Barcelona, Spain

*Corresponding author e-mail: m.vives@creaf.uab.cat

**Corresponding author e-mail: jofre.carnicer@ub.edu

Introduction

Global fingerprints of the effects of climate change on insect populations have already been reported (Boggs, 2016). The responses of insects to these climatic trends are, however, largely variable between species, geographic areas and even between populations of a particular species. Multiple processes that operate at the local scale can shape the climatic exposure and sensitivity of insect populations, modulating therefore their vulnerability to climatic impacts (see Carnicer *et al.*, 2017 for a revision). Among the many mechanisms determining differential exposure to climate there are microclimatic variation produced by the interaction of macroclimatic conditions with biotic and abiotic elements of the environment (Woods *et al*., 2015), and plastic variation in thermoregulatory behavior of insects. For example, Bennett *et al*. (2015) found that interpopulation variability in phenology, oviposition behavior, and the use of host plants and microhabitats in the butterfly *Euphydryas editha* produced a geographic mosaic of populations with different microclimatic and thermal exposures. This represented a case where complex local adaptation of the different populations of *E. editha* conferred them contrasting vulnerability in front of climate change.

Substantial progresses have been made to understand the underlying mechanisms driving the responses of insect populations to climate change. Nonetheless, most of the studies focus on the direct effects of climate on the phenology and the population dynamics of insects, modulated by insect's plasticity and local adaptations (Boggs, 2016; Carnicer *et al*., 2017). Other species that interact with the population of study may also be affected by climate change, however. Considering the additional indirect effects of climate change coming from the responses of insect's interacting species would, therefore, improve our understanding of the climatic impacts on insect populations. Phenological mismatches between insects and their host plants or nectar sources are one of the most common cases of study of the effects of climate change on plant–insect interactions (Singer & Parmesan, 2010; Hindle *et al*., 2015; Donoso *et al*., 2016). To our knowledge, the influence on insect populations of plastic responses to climate change in other plant traits different from phenology, however, have rarely been considered.

Our study assessed the potential role of host-plant plasticity on the mediation of the impacts of summer drought on a declining population of a drought-sensitive butterfly (*Pieris napi*) in the northwestern Mediterranean. A recent study that was partly carried out in Aiguamolls de l'Empordà Natural Park (one of the focus of this monograph) associated the long-term decline of this butterfly population with a decadal trend of increased summer drought (Carnicer *et al*., 2019). The study also identified diverse mechanisms operating at the local-scale modulating the effects of drought on the declining population. Detailed measurements of microclimatic conditions and of a phenotypic biomarker indicative of the thermal conditions during larval development (i.e. adult wing size) showed that the population lacked an effective thermal buffering from vegetation (Carnicer *et al*., 2019). Ecophysiological assays of larval heat tolerance of this population indicated that this thermal exposure was not necessarily lethal, conferring to host-plant quality and availability a crucial role in the butterfly declining trend. Here we describe the phenological cycle of *P. napi* and of its two host plants in the area to assess their phenological match. We also quantify the variation of several host-plant traits crucially affecting plant quality and resource availability. More precisely, we analyze the variability of host-plant traits observed both in the field and in experimental assessments. Our main aim is to evaluate whether host-plant plasticity can effectively modulate the responses of this *P. napi* population to drought.

Methods

Study system

We studied the green-veined white butterfly *Pieris napi* (Fig. 1) and its two main host plants in a protected area (Aiguamolls de l'Empordà Natural Park, Catalonia) at the northeastern Iberian Peninsula. This butterfly is commonly spread across Eurasia, North Africa and North America (Vila *et al*., 2018), though it shows a clear preference for humid habitats. In Catalonia, it is found throughout the country except in its driest areas. The study site, located in a coastal wetland, holds one of the most abundant populations of *P. napi* in Catalonia, despite showing a negative trend. Adults can be detected in this area from late winter to autumn in four–five partially overlapped generations, except in late summer, when abundance is much reduced. Most eggs are individually laid on the leaves of *Lepidium draba* and *Brassica nigra*, although oviposition on other crucifers such as *Coronopus squamatus* has occasionally been observed too (Stefanescu, 1997).

Figure 1. A green-veined white butterfly (*Pieris napi*) nectaring from a crucifer. *P. napi* lays most of their eggs on plants from the Brassicaceae family linked to humid habitats. Photograph: Vlad Dinca.

The heart-podded hoary cress (*Lepidium draba*) is a perennial, rhizomatous herb usually found in ruderal areas and field margins with deep soil. Flowering individuals can be detected from March to June. Plants die back to the root crown after seed development (Jacobs, 2007) and all the aboveground parts completely disappear until new resprouts emerge from subterranean rhizomes in late summer and autumn. Its extensive, multi-branched rhizomes are notably capable of producing many new shoots, which can develop into large monocultural stands (Francis & Warwick, 2008). The black mustard (*Brassica nigra*), in contrast, is a cultivated, annual herb that has been naturalized in humid grasslands. Individuals complete their life cycle in late spring–summer and no new plants can be found until the next growth season. At the study site, both plant species are present in a diversity of habitats, from open fields and wetlands to riparian forests and dense shrublands. The plants selected for oviposition by *P. napi*, however, usually grow in microhabitats presenting an intermediate degree of canopy closure (Vives-Ingla *et al*., 2020), in the margins of paths and irrigation canals protected by the surrounding vegetation (Stefanescu, 1997).

Abundance data of *P. napi*

Weekly abundance of *P. napi* was recorded in El Cortalet from 1993 to 2018, as part of the Catalan Butterfly Monitoring Scheme (CBMS, www.catalanbms.org). The CBMS applies a standardized recording procedure (i.e. Pollard walks) consisting of weekly counts along fixed transects from March to September (30 weeks per year). The recorder counts all individuals of all butterfly species seen within 2.5 m on each side and 5 m in front of the trail (Pollard & Yates, 1993). For the current work, an index of weekly abundance of *P. napi* for each recording day was calculated as the number of butterflies seen divided by the length of the transect (in km). A LOESS analysis against Julian day including the data of all the years was then applied (neighborhood parameter α=0.2) to determine the mean phenology of *P. napi* at the study site. The analyses were conducted with R 3.6.1 (R Core Team, 2019) and were repeated for each year separately to assess phenological variation between years.

The phenological curves were divided into four generational periods: March–April, May–June, July, August–September. Additional abundance indices were then calculated at the annual and generational scales as the sum of weekly abundance indices of each period (i.e. the area under the phenological curve). General linear models were applied on the annual and on the four generational abundances against year to determine their decadal trend. The analyses were also repeated applying a polynomial fit.

Monitoring of host-plant traits and microclimatic conditions

Two local cohorts of *L. draba* (282 individuals) and *B. nigra* (39 individuals) were continuously monitored from March to October of 2017 every two weeks. Each monitoring date a total of 15 individuals of *L. draba* and 6 individuals of *B. nigra* were selected to measure their microclimatic conditions and several phenological, morphological and physiological traits. For each host plant species, the selection included individuals growing in different microhabitats in terms of canopy closure (3 individuals per microhabitat) and ensured that plants were randomly chosen without repetition to avoid pseudoreplication. Replicated foliar measurements were conducted in one apical, one medial and one basal leaf per plant.

Microclimatic measurements included canopy closure, the volumetric water content of the soil and the foliar temperature. The measurement of canopy closure (i.e. “the proportion of the sky hemisphere obscured by vegetation when viewed from a single point", Jennings, 1999) consisted in visually estimating the per cent area occupied by the canopy assigning it to one of the cover classes defined by Daubenmire (1959) (0-5%, 5-25%, 25-50%, 50-75%, 75-95%, and 95-100%) and taking its midpoint. The ocular estimation was conducted in each one of the vertical and the four cardinal directions and the average value was kept. Five microhabitat categories were then defined based on the estimations of canopy closure: closed (C, mean closure of 40% for *B. nigra* and 60% for *L. draba*), semi-closed (SC, 55% for *L. draba*), semi-open (SO, 40% for *L. draba*), open (O, 20% for *B. nigra* and 0% for *L. draba*), and very open (OO, 0% and a very dry soil for *L. draba*). Soil humidity (%) was measured at three points near each plant using a DELTA-T SM150 (Delta-T Devices Ltd, Cambridge, UK) soil-moisture sensor kit. Foliar temperature at its upper surface was measured using a wire K-type thermocouple probe (Omega SC-TT-KI-30-1M, Omega Engineering Ltd, Manchester, UK) attached to a hand-held thermocouple thermometer (Omega HH503, Omega Engineering Ltd, Manchester, UK, and HANNA HI935005N, Hanna Instruments Ltd, Eibar, Spain). Average measurements (at least three records) were kept. The temperatures were measured between 10:00 and 16:00, and the time, wind and radiation conditions were recorded.

Foliar length, width, and chlorophyll content were measured in each monitored plant. Chlorophyll content was estimated as the mean of three measurements from a MINOLTA SPAD-502 (Konica Minolta Sensing, Valencia, Spain) chlorophyll meter. Finally, leaves were severed and immediately weighed (fresh weight, FW) using a Pesola PJS020 Digital Scale (PESOLA Präzisionswaagen AG, Schindellegi, Switzerland) for calculating foliar water content. The leaves were oven-dried in the laboratory at 60 °C for two days to a stable weight (dry weight, DW). The ratio of foliar water content (to DW) was defined as (FW-DW)/DW. An independent phenological census for each microhabitat type was conducted selecting 15 individuals for each plant species. Plants were classified in one of four phenological stages: early vegetative (spring rosettes and young shoots before budding), reproductive (plants with buds, flowers, and/or fruits), senescent, and summer resprout (for *L. draba*). Summer resprouts of *L. draba* can represent a key resource for summer generations of *P. napi*. A census of newly emerging resprouts of *L. draba* was thus conducted since July, when the first shoots grew from resprouting rhizomes. Five 25-cm quadrats were randomly placed in each microhabitat type. The total number of resprouts per unit area was counted (i.e. resprout density), and three resprouts per sampling quadrat were then randomly selected for measuring their heights and counting their total numbers of leaves.

Changes in the daily proportion of individuals at each phenological stage was assessed using LOESS smoothing in each species (neighbourhood parameter α=0.5). We also used LOESS regression between each host-plant variable and Julian day to assess the seasonal progression of plant quality for insect oviposition and hosting. The regression fit was applied separately to each species. The trends for *L. draba* variables were grouped by plant developmental stage (i.e. flowering spring plants vs summer resprouts). Microclimatic and host-plant variables were also modelled against microhabitat type applying an ANOVA followed by a post-hoc Tukey HSD test with the *emmeans* package (Lenth, 2019). The distance between the different monitored microhabitats was short (i.e. less than 10 m for *B. nigra*, and less than 70 m for *L. draba*, except for the more open microhabitats which were 700 m apart from the others), suggesting no strong barriers to gene flow between microhabitats during reproductive and seed dispersal periods. Consequently, host-plant variation between microhabitats was therefore assumed to capture more strongly plastic responses in host-plant development to different microenvironmental conditions (e.g. light, soil humidity and temperature) rather than genetic variation between microhabitats. We evaluated the relative contribution of plant phenological stage and microhabitat (as a partial proxy of host-plant plasticity) on host-plant quality (i.e. foliar chlorophyll and water contents) by applying a two-way ANOVA. Significant interactions between phenology and microhabitat were included in the analyses. Foliar temperatures of host plants ultimately determine the thermal conditions experimented by the eggs and the growing larvae of *P. napi*. To assess the potential role of drought on the thermal conditions of the leaves a general linear model was also fitted on plant foliar temperature against soil humidity, canopy closure and plant height. All the analyses were conducted with R.

Experimental assessment of rain-induced plasticity in host-plant rhizomes

The availability of fresh resprouts of *L. draba* during summer and autumn can be determinant for the performance of *P. napi* late generations (August–October). Knowing the factors driving the resprouting capacity of *L. draba* rhizomes could thus shed some light into the local-scale mechanisms affecting host-plant availability and the population dynamics of *P. napi*. We hypothesized that summer rains could induce plastic development of adventitious buds of *L. draba* rhizomes into green new shoots favoring the recovery of late generations of *P. napi*. To assess this hypothesis, we performed a simple experiment of the plastic resprouting capacity of *L. draba* rhizomes in response to simulated summer rains.

Twenty-four rhizomes were collected at the study site on July 2017 and were divided in three watering treatment groups (8 rhizomes per treatment) simulating three different scenarios of summer rainfall (T-5, T-10, T-75). T-5 simulated a dry July (5 mm/month, corresponding to the first quartile of July rain distribution for 1993–2016), T-10 corresponded to a moderately dry July (10 mm/month, second quartile of the rainfall distribution for this month in meteorological records). Finally, T-75 simulated an extremely wet July (75 mm/month, percentile 90). The length and the width of the rhizomes were measured before the transplant, and the initial adventitious buds they presented were counted. Each rhizome was then planted in a random pot in the laboratory with a standardized soil composition (45% of autoclaved peat, 45% of sand and 10% natural soil inoculum). Air temperature and radiation were continuously recorded using an LCpro+ System radiometer (ADC BioScientific Ltd., Hertfordshire, UK). Pots were watered twice per week and their positions were randomly modified. We recorded the height, the number and the length of the leaves of emerged resprouts. In addition, we measured soil humidity before and after watering, soil temperature and foliar chlorophyll. At the end of the experiment, fully-developed leaf samples were collected in order to measure their water content ((FW-DW)/DW).

Results

Decadal trends and phenology of *P. napi*

The annual surveys of the CBMS completely recorded the first three generations of *P. napi* at the study site (Fig. 2A). The first generation (G1) was usually found between Julian day 60 (early March) and Julian day 120 (late April), the second one (G2) on Julian days 140–180 (May–late June), and the third one (G3) on Ju-

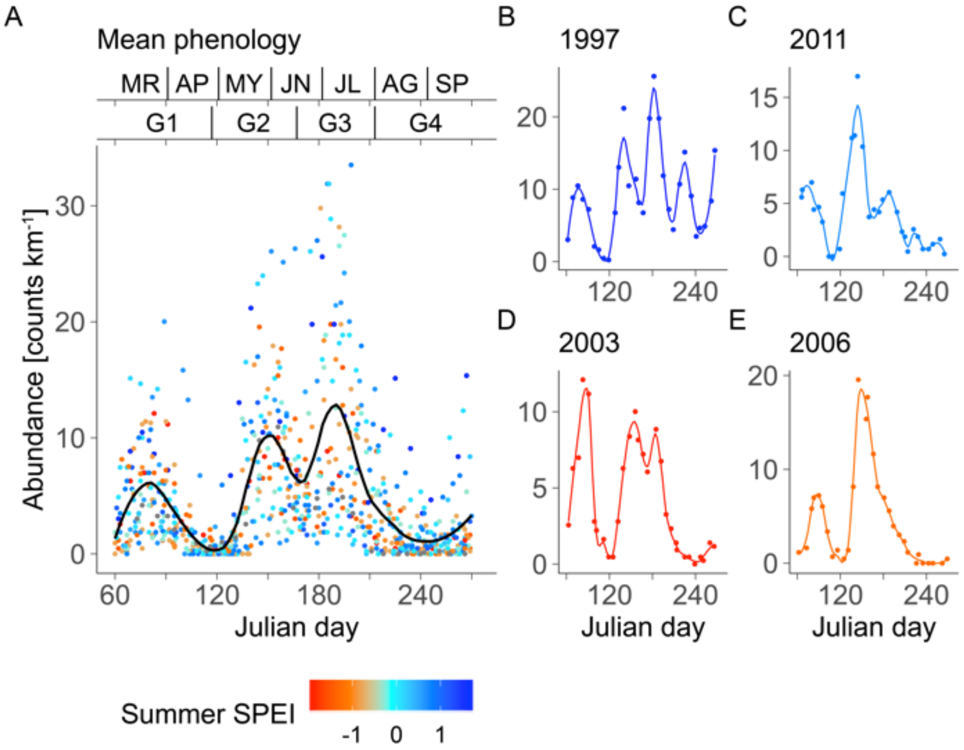


Figure 2. Phenology of flight of Pieris napi in the study site. A: Mean phenological curve (black line) of the period 1993–2018. Each year is colored depending on the value of the SPEI drought index calculated for summer months (June–August) following Beguería & Vicente-Serrano (2017). Low, reddish values correspond to dry summers; while high, blueish values to summers with high rainfall and low temperatures. B, C: phenological curves of the years with two of the wettest summers. D, E: years with two of the driest summers. MR to SP, months from March to September; G1, first generation; G2, second; G3, third; and G4, fourth.

lian days 180–210 (July). During late July and August, the abundance of *P. napi* sharply decreased until late August and September, when the beginning of a fourth generation (G4) was usually detected before the end of the CBMS survey. The phenological curves, however, greatly varied between years (Fig. 2). Adults in flight during late summer could be detected in some years, eventually conforming an August generation (e.g. 1997, Fig. 2B, and 2011, Fig. 2C). These years presented the wettest summers in the study site from 1993–2018 based on the annual SPEI index during June–August (a multi-scalar drought index calculated from data of local rainfall and temperature following Beguería & Vicente-Serrano (2017)). Dry years with low summer SPEI values, in contrast, presented a longer and sharper reduction of butterfly abundance during August (Fig. 2D), even affecting G3 in July (Fig. 2E).

The data gathered by the CBMS during 1993–2018 confirmed a significant decline in annual abundance of the studied butterfly population (Fig. 3A). Significant negative trends at a generational scale could only be detected for summer generations (i.e. G3 and G4) while no significant trend was observed for G1 and G2 (Fig. 3B-E). The results of the polynomial fits were highly similar to the linear models and are thus not included.

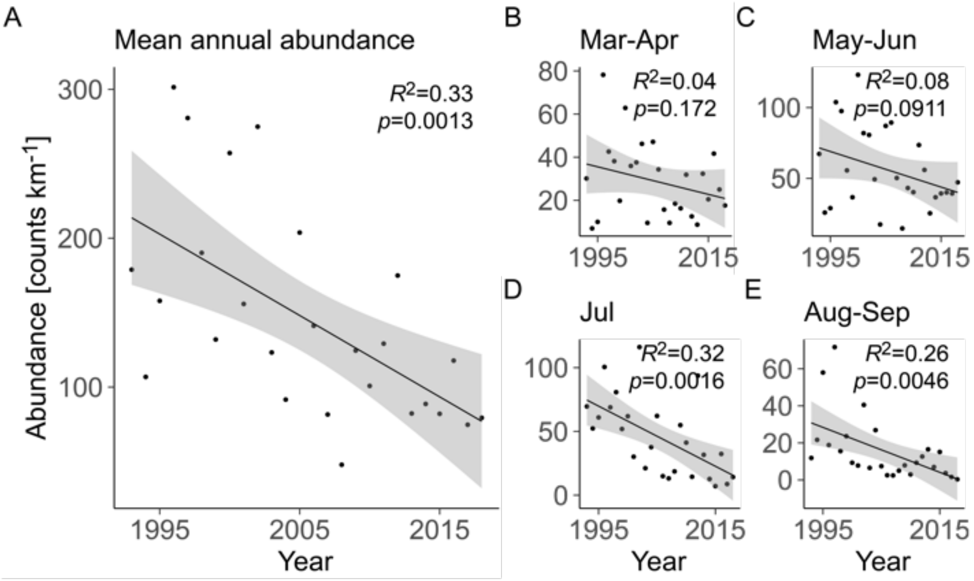


Figure 3. Linear trends of Pieris napi abundance in the study site. A: annual resolution, B: first generation, C: second generation, D: third generation, E: fourth generation.

Phenological and plastic variation of host plants

Butterfly and host-plant phenologies recorded in 2017 were compared to assess their temporal match (Fig. 4). *Brassica nigra* had completely fructified (Fig. 4A) and *L. draba* had already started to senesce (Fig. 4B), during the peak of flight of G2 (around the Julian day 150, Fig. 4C). A parallel decay of foliar chlorophyll and water contents and an increase of foliar temperature were initiated in host plants at this time and maintained during the period of development of eggs and larvae from the G3 (Fig. 4D–F). The emergence of adults of G3 coincided with the senescence of *B. nigra* (Fig. 4A) and the complete absence of aboveground organs of *L. draba* (Fig. 4B). Eggs and larvae of G4, therefore, could uniquely rely on the appearance and availability of fresh, new resprouts of *L. draba*.

Microclimatic conditions (i.e. canopy closure, soil humidity and foliar temperature) significantly varied between the different microhabitats (Fig. 5A-F). Open microhabitats presented higher temperatures (Fig. 5E, F) and drier soils (Fig. 5C, D). Host plants growing in these microhabitats accordingly presented significant differences in foliar traits associated with host-plant quality (Fig. 5G-J). Lower values of foliar water content were measured in open microhabitats (Fig. 5I, J), whereas foliar chlorophyll was inferior in closed microhabitats (Fig. 5G, H). *Lepidium draba* also showed contrasting patterns of summer resprouting between microhabitats (Fig. 6). The microhabitats that were more open presented significantly higher densities of resprouts, with more and longer leaves. Significant differences in microclimatic conditions and host-plant traits between microhabitats were also maintained during the resprouting period. The resprouts of *L. draba* appeared in mid-July, but they remained as short rosettes until September, when they notably grew in plant height, number of leaves and foliar length, coinciding with an increase of rainfall.

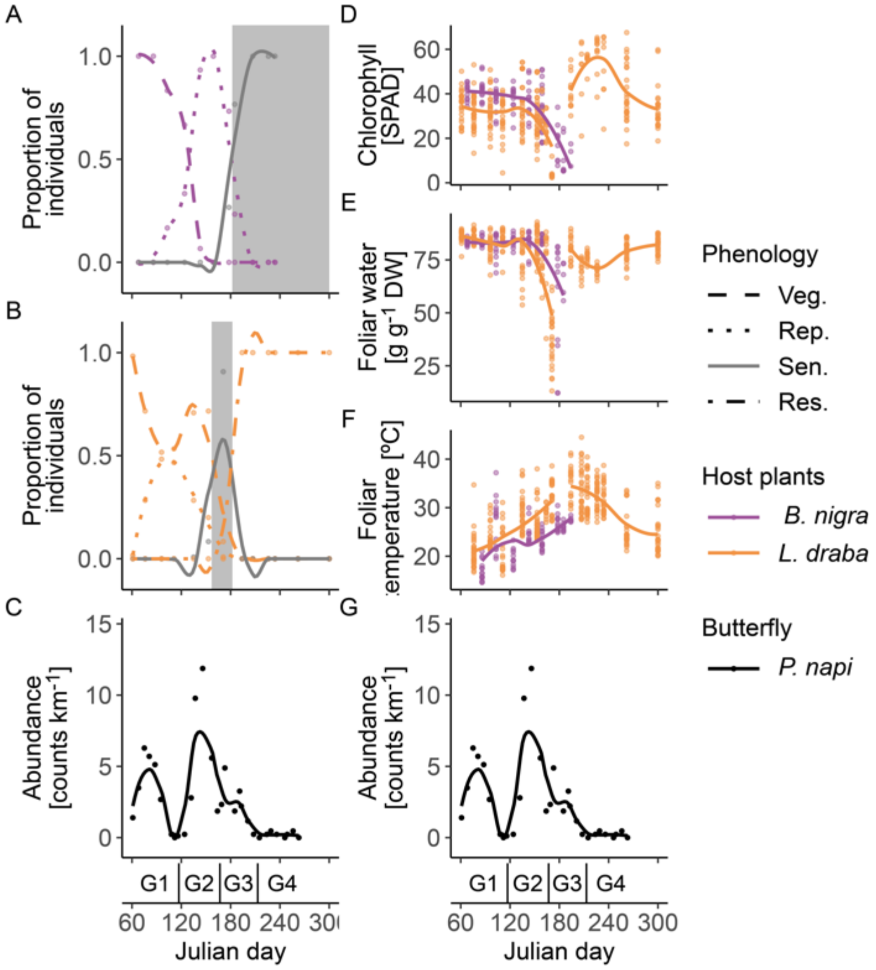


Figure 4. Seasonal progression of the phenology and quality of the host plants and the butterfly recorded in 2017. A: phenology of Brassica nigra. B: phenology of L. draba. C, G: phenology of P. napi. The panel is repeated to facilitate the comparison between the seasonal trends. D, E and F: foliar traits associated with host-plant quality. The gray area indicates the absence of green host plant because of its senescence, corresponding to the period when non-senescent individuals are less than 50% of the total. Veg: vegetative plant, Rep: reproductive, Sen: senescent, Res: summer resprout. G1: first generation, G2: second, G3: third, G4: fourth.

Both the plant phenological stage and the type of microhabitat strongly determined variation in host-plant quality across the whole year, as the results of the two-way ANOVAs indicated (Table 1). A greater relative contribution of phenology on the variation of either the chlorophyll or the water contents was however found in the majority of the analyses comparing the *F* value of both factors and its interaction. Foliar temperature of the two host plants significantly increased with the reduction of soil humidity (Table 2). Canopy closure also negatively influenced foliar temperature of both species while plant height only had significantly negative effects on *L. draba*.

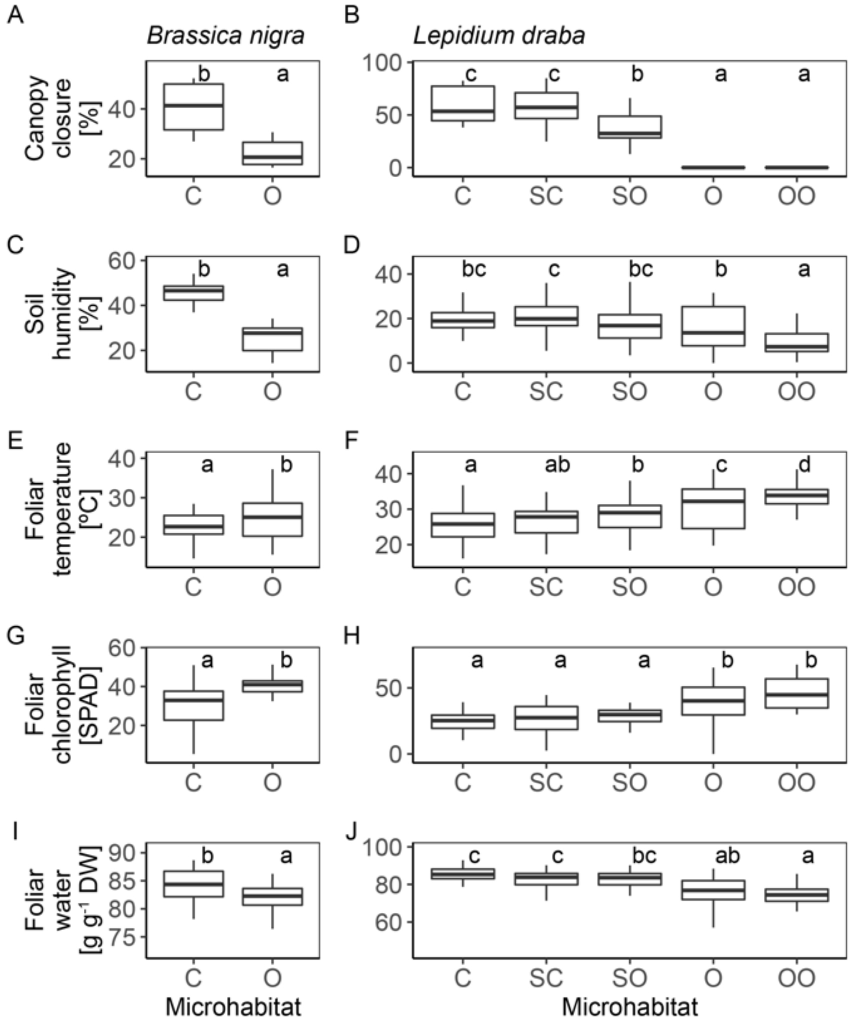


Figure 5. Variation in microclimatic conditions and quality of the two host plants between different microhabitats. Different letters indicate significant differences of the response variable between the microhabitat types in the Tukey HSD test. C, closed microhabitat; SC, semi-closed; SO, semi-open; O, open; and OO, very open.

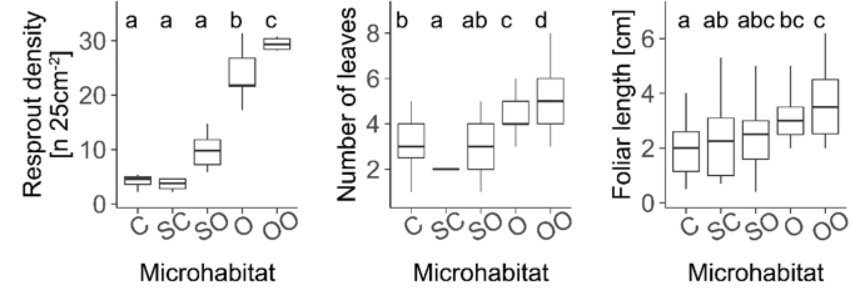


Figure 6. Resprout denstiy (A), number of leaves (B), and foliar length (C) of the summer resprouts of Lepidium draba emerging in different microhabitats. Different letters indicate significant differences of the response variable between the microhabitat types in the Tukey HSD test. C, closed microhabitat; SC, semi-closed microhabitat; SO, semi-open microhabitat; O, open microhabitat; and OO, very open microhabitat.

Table 1. Two-way ANOVAs applied to foliar chlorophyll and water contents for the two host plants during all the monitoring period. R^2, adjusted coefficient of determination of the model; df, degrees of freedom; and SS, sum of squares.

Species	Response	Explanatory	df	SS	*F*	*p*
B. nigra	Chlorophyll (R^2=0,36; p<0,0001)	Microhabitat	1	1947	21,01	<0,0001
		Phenology	2	3866	20,87	<0,0001
		Microhabitat × Phenology	1	26	0,28	0,6002
		Residuals	102	9450		
	Foliar water (R^2=0,67; p<0,0001)	Microhabitat	1	845	14,48	0,0003
		Phenology	2	10435	89,44	<0,0001
		Microhabitat × Phenology	1	3	0,06	0,8117
		Residuals	90	5250		
L. draba	Chlorophyll (R^2=0,71; p<0,0001)	Microhabitat	4	13281	48,06	<0,0001
		Phenology	3	40236	194,16	<0,0001
		Microhabitat × Phenology	9	3612	5,81	0,0001
		Residuals	311	21484		
	Foliar water (R^2=0,77; p<0,0001)	Microhabitat	4	20957	38,98	<0,0001
		Phenology	3	126756	314,39	<0,0001
		Microhabitat × Phenology	9	1723	1,42	0,1766
		Residuals	310	41663		

Table 2. General linear model of foliar temperature for the two host plants during all the monitoring period. R^2, adjusted coefficient of determination of the model.

Species	Response	Explanatory	Estimate	Std. Error	*t*	*p*
B. nigra	Foliar temperature (R^2=0,32; p<0,0001)	Intercept	26,35	1,38	19,1	<0,0001
		Soil humidity	-0,23	0,05	-5,0	<0,0001
		Canopy closure	0,15	0,05	2,9	0,0054
		Height	0,01	0,01	1,3	0,1835
L. draba	Foliar temperature (R^2=0,33; p<0,0001)	Intercept	35,65	0,72	49,5	<0,0001
		Soil humidity	-0,29	0,03	-9,7	<0,0001
		Canopy closure	-0,06	0,01	-5,7	<0,0001
		Height	-0,04	0,01	-4,6	<0,0001

Plastic resprouting of *L. draba* in response to simulated rain

Summer rhizomes of *L. draba* showed significant responses to water treatments (Fig. 7). Higher water availability resulted in earlier resprouting responses (Fig. 7A) and increased resprout height (Fig. 7B). In addition, the interaction between water treatment and time (p<0.0001) in an ANCOVA model predicting resprout height was statistically significant, indicating higher growth rates with increased water availability (Fig. 7B). The initial number of resprouting buds were not differently distributed between treatments (one-way ANOVA p=0.17). Confounding effects of this initial variable could thus be discarded. Different water treatments consistently originated different conditions of soil humidity (ANCOVA test p<0.0001, R^2=0.95).

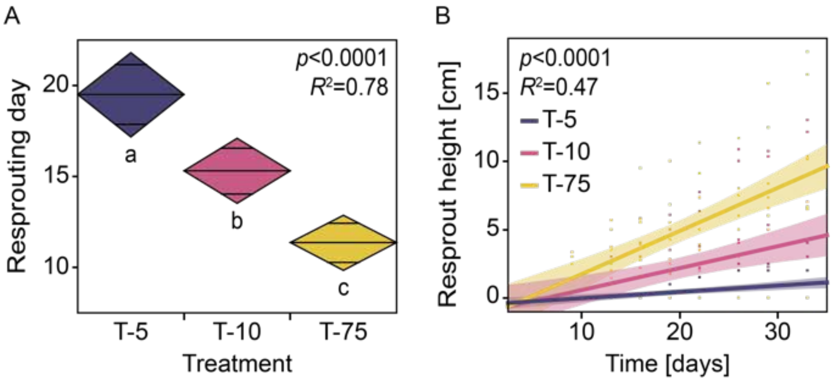


Figure 7. Experimental assessment of the plastic responses of summer rhizomes of Lepidium draba to simulated rains. A: Day of emergence of the resprouts between the three water treatments. Diamond plots indicate the 95% confidence interval for each treatment (vertical span) and the mean (midpoint line). Means that are not labelled by the same letter are significantly different. B: Temporal progression of resprout's height in the three water treatments. Slopes were significantly different (ANCOVA test). Water treatments: 5 L m^{-2} $month^{-1}$ (T-5, purple), 10 L m^{-2} $month^{-1}$ (T-10, pink), 75 L m^{-2} $month^{-1}$ (T-75, yellow).

Discussion

Phenological match between *P. napi* and its two host plants

Here we examined the temporal and spatial variation at the local-scale of the two host plants used by a declining population of the butterfly *P. napi*. Previous studies have associated the decline of the population with summer multidecadal drought (Carnicer *et al*., 2019). Our study confirmed that the negative trend in annual abundance of the population persists (Fig. 3A). At a generational scale, a significant decreasing slope was only detected in the summer generations (i.e. G3 and G4), pointing to summer season as a key period for this population (Fig. 3). The phenological curve of the species in the study site indicated that the abundance of the butterfly is usually reduced in the second half of the summer (Fig. 2A). This reduction was especially sharp in the driest summers of the analyzed period (1993–2018), and could even affect the development of the July generation (G3, Fig. 2D, E). All these results give further support to summer drought as a key driver of the dynamics of the population.

Climate can drive the dynamics of insect populations both directly and indirectly due to its effects on other species that interact with the focal species (Boggs & Inouye, 2012). In our study system, the seasonal decrease in host-plant quality had been suggested to have a synergistic negative role on the mediation of the impacts of summer drought on the declining butterfly (Carnicer *et al*., 2019). Here we assessed how the phenological curves of *P. napi* and of the two host plants match in order to identify the periods when host plants could have limiting and detrimental effects on butterfly performance (Fig. 4). While larvae from G1 and G2 had access to abundant and green host plants, we observed that later, summer generations grew in periods with resource of low quality (G3) or low availability (G4). The larval development of G3 coincided with the senescence of host plants (Fig. 4A-C) and the drastic decay of their foliar chlorophyll and water contents (Fig. 4D, E). Both host plants completely disappeared after senescence until new resprouts of *L. draba* emerged. Summer resprouts, however, did not fully develop until September rains. The development of larvae of G4, hence, was much more limited by host-plant availability than by quality.

The reduction of butterfly abundance in the second half of the summer, after the peak of flight of G3, might be associated with this period of low availability of host plants. Roy & Thomas (2003) found that the seasonal cycle in the availability of host plants was likely representing an annual bottleneck for marginal populations of the Adonis blue butterfly (*Polyommatus bellargus*). We hypothesize that the scarcity of non-senescent host plants during late summer could similarly limit egg-laying opportunities of females of G3 and/or increase the mortality of the derived larvae (G4), resulting in the yearly reduction of butterfly abundance observed in this period (Fig. 2). It should be furtherly examined, however, why this is one of the most abundant populations of Catalonia in spite of their possible annual bottlenecks. Another complementary and nonexclusive hypothesis would be that pupae of summer generations could plastically enter to a dormant state (i.e. estivation or summer diapause) until autumn, avoiding the period of more resource scarcity and climate stress. Although estivation in *P. napi* has never been described before, summer pupal diapause has been detected in Chilean and Spanish populations of the closely-related species *Pieris brassicae* (Benyamini, 1996; Held & Spieth, 1999). Both the lack of resources for oviposition and larval development (Benyamini, 1996) and the need to desynchronize the butterfly life cycle from its specialist parasitoid (Spieth & Schwarzer, 2001; Spieth, 2002) have been suggested as the reasons for these local adaptations. Experimental tests, rather than field observations (Spieth & Schwarzer, 2001), are further required to confirm or reject the estivation hypothesis in our studied population of *P. napi*.

The role of host-plant plasticity in mediating the impacts of drought on a declining population of *P. napi*

Most studies that consider plant–insect interactions in the assessment of climatic impacts on insect populations are conducted from a phenological point of view (i.e. the emerging phenological mismatches as a result of a change in climatic conditions) (see Donoso *et al.*, 2016 for an example at the study site). Plastic responses to climate in other plant traits different from phenology, such as plant growth and foliar traits related to their quality as a food resource, could also exert significant effects, though. Here we monitored several traits related to the availability and quality of host plants to identify the role of host-plant plasticity in mediating the impacts of drought on a declining population of *P. napi*. Foliar chlorophyll and water contents, two host-plant traits usually associated to its quality for herbivorous insects (Scriber & Slansky, 1981), significantly varied between microhabitats (Fig. 5). These results suggest that both foliar traits plastically responded to shifts in microenvironmental conditions. Shifts in host-plant quality, however, were more strongly driven by phenological progression than by microhabitat (Table 1). We also found plastic variation in the resprouting dynamics of *L. draba*, which presented significant differences in resprout density, number of leaves and foliar length between microhabitats (Fig. 6). The resprouts remained, however, as short rosettes until late-summer rains, triggering their growth. In line with these observations, we observed significant differences in the emergence and growth of resprouts between the three watering treatments that simulated three summer rainfall regimes (Fig. 7), fully supporting the hypothesis that the development of *L. draba* resprouts plastically respond to summer rains.

Overall, the results suggest that both the phenological and plastic variation of its main host plants exert an important role in the mediation of local responses of *P. napi* to summer drought. We found that the development of G3 coincided with the decay of quality of host plants, whereas larvae of G4 could be limited by the availability of summer resprouts of *L. draba*. The quality of host plants was most strongly affected by their phenological progression, while the availability and growth of resprouts plastically responded to summer rains. Our results suggest, therefore, that drought impacts on G3 are mainly modulated by the variation in the phenological cycle of host plants. Drier and warmer conditions during late spring and early summer (May–June) could accelerate the phenological progression of host plants, advancing their decay in quality. These climatic conditions could also amplify temperatures at the foliar (Table 2) and microhabitat level, eventually supposing a situation of combined food and thermal stresses for larval development of G3 (Carnicer *et al*., 2019; Vives-Ingla *et al*., 2020). Low quality of food resources can exacerbate the negative impacts of higher thermal conditions on larval growth, as previous experimental studies in *Pieris* butterflies have found (Jones *et al*., 1982; Kingsolver, 2000; Bauerfeind & Fischer, 2013). Drought impacts on G4, in contrast, are more likely mediated by plastic responses of the resprouts of *L. draba*. Drier summers could slow down and postpone the emergence and growth of summer resprouts, affecting therefore the development of the late-summer generation.

Insect responses to climate impacts are shaped by multiple processes occurring at the local scale (Carnicer *et al*., 2017). Most of the studies in this line have described how microclimatic variability and plastic traits or local adaptation of insects can modulate their exposure and vulnerability to climate change. Other local-scale processes, such as host-plant responses to climatic variability, can also mediate climate impacts on insect populations but they have been, however, less studied. Here we reported diverse and co-occurring local-scale processes that involve host-plant responses to drought mediating the impacts of climate on a declining butterfly population. Interestingly, we reported how host-plant plasticity in traits different from phenology (i.e. rain-dependent growth of summer resprouts) can also mediate the indirect effects of climate in insects. The diverse mechanisms suggested here, furthermore, operated in a temporal sequence, affecting different generations. The effects of host plants on G3 would be driven by the impacts of early-summer drought on microclimatic conditions and host-plant phenology and quality, while G4 would be influenced by the plastic responses of *L. draba* to late-summer drought.

Acknowledgements

Francesc Xavier Santaeufemia and the Aiguamolls de l'Empordà Natural Park provided support with permission management, scientific advice and key assistance during fieldwork. We are grateful for the contribution to the field work of (in alphabetical order) Agnieszka Juszczak, Armand Casadó-Tortosa, Carlos López, Joaquim de Gispert, Katarzyna Bartnik, Meritxell Garcia and Sofía Cortizas. This research was supported by the Spanish Ministry of Science and Innovation through a doctoral grant (FPU17/05869) and the Spanish Ministry of Economic Affairs and Digital Transformation (CGL2016-78093-R).

References

Bauerfeind, S. S., & K. Fischer, 2013. Increased temperature reduces herbivore host-plant quality. Global Change Biology 19: 3272–3282.

Beguería, S., & S. M. Vicente-Serrano, 2017. SPEI: Calculation of the Standardised Precipitation-Evapotranspiration Index., https://cran.r-project.org/package=SPEI.

Bennett, N. L., P. M. Severns, C. Parmesan, & M. C. Singer, 2015. Geographic mosaics of phenology, host preference, adult size and microhabitat choice predict butterfly resilience to climate warming. Oikos 124: 41–53.

Benyamini, D., 1996. Pupal summer diapause in Chilean *Pieris brassicae* (Linnaeus, 1758) (Lepidoptera, Pieridae). Nota Lepidopterologica 18: 184–192.

Boggs, C. L., 2016. The fingerprints of global climate change on insect populations. Current Opinion in Insect Science 17: 69–73.

Boggs, C. L., & D. W. Inouye, 2012. A single climate driver has direct and indirect effects on insect population dynamics. Ecology Letters 15: 502–508.

Carnicer, J., C. Stefanescu, M. Vives-Ingla, C. López, S. Cortizas, C. W. Wheat, R. Vila, J. Llusià, & J. Peñuelas, 2019. Phenotypic biomarkers of climatic impacts on declining insect populations: A key role for decadal drought, thermal buffering and amplification effects and host plant dynamics. Journal of Animal Ecology 88: 376–391.

Carnicer, J., C. W. Wheat, M. Vives-Ingla, A. Ubach, C. Domingo-Marimón, S. Nylin, C. Stefanescu, R. Vila, C. Wiklund, & J. Peñuelas, 2017. Evolutionary responses of invertebrates to global climate change: The role of life-history trade-offs and multidecadal climate shifts In Johnson, S. N., & H. Jones (eds), Global Climate Change and Terrestrial Invertebrates. John Wiley & Sons, Ltd, Chichester, UK: 319–348.

Daubenmire, R. F., 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33: 43–64.

Donoso, I., C. Stefanescu, A. Martínez-Abraín, & A. Traveset, 2016. Phenological asynchrony in plant–butterfly interactions associated with climate: a community-wide perspective. Oikos 125: 1434–1444.

Francis, A., & S. I. Warwick, 2008. The biology of Canadian weeds. 3. *Lepidium draba* L., *L. chalepense* L., *L. appelianum* Al-Shehbaz. Canadian Journal of Plant Science 88: 379–401.

Held, C., & H. R. Spieth, 1999. First evidence of pupal summer diapause in *Pieris brassicae* L .: the evolution of local adaptedness. Journal of Insect Physiology 45: 587–598.

Hindle, B. J., C. L. Kerr, S. A. Richards, & S. G. Willis, 2015. Topographical variation reduces phenological mismatch between a butterfly and its nectar source. Journal of Insect Conservation 19: 227–236.

Jacobs, J., 2007. Ecology and Management of Whitetop (*Cardaria draba* (L.) Desv.). U.S. Department of Agriculture, Natural Resources Conservation Service.

Jennings, S., 1999. Assessing forest canopies and understorey illumination: canopy closure, canopy cover and other measures. Forestry 72: 59–74.

Jones, R. E., J. R. Hart, & G. D. Bull, 1982. Temperature, size, and egg production in the cabbage butterfly, *Pieris rapae* L. Australian Journal of Zoology 30: 223–232.

Kingsolver, J. G., 2000. Feeding, Growth, and the Thermal Environment of Cabbage White Caterpillars, *Pieris rapae* L. Physiological and Biochemical Zoology 73: 621–628.

Lenth, R., 2019. emmeans: Estimated Marginal Means, aka Least-Squares Means., https://cran.r-project.org/package=emmeans.

Pollard, E., & T. J. Yates, 1993. Monitoring Butterflies for Ecology and Conservation: The British Butterfly Monitoring Scheme. Chapman & Hall, London.

R Core Team, 2019. R: A Language and Environment for Statistical Computing. Vienna, Austria, https://www.r-project.org/.

Roy, D. B., & J. A. Thomas, 2003. Seasonal variation in the niche, habitat availability and population fluctuations of a bivoltine thermophilous insect near its range margin. Oecologia 134: 439–444.

Scriber, J. M., & F. Slansky, 1981. The Nutritional Ecology of Immature Insects. Annual Review of Entomology Annual Reviews 26: 183–211.

Singer, M. C., & C. Parmesan, 2010. Phenological asynchrony between herbivorous insects and their hosts: Signal of climate change or pre-existing adaptive strategy?. Philosophical Transactions of the Royal Society B: Biological Sciences Royal Society 365: 3161–3176.

Spieth, H. R., 2002. Estivation and hibernation of *Pieris brassicae* (L.) in southern Spain: Synchronization of two complex behavioral patterns. Population Ecology 44: 273-280.

Spieth, H. R., & E. Schwarzer, 2001. Aestivation in *Pieris brassicae* (Lepidoptera: *Pieridae*): Implications for parasitism. European Journal of Entomology 98: 171–176.

Stefanescu, C., 1997. *Coronopus squamatus* (Forssk.) Asch. (Cruciferae), una nova planta nutrícia per *Pieris rapae* (L.), *Pieris mannii* May. i *Pieris napi* (L.) (Pieridae) als Aiguamolls de l'Empordà, amb notes addicionals sobre altres recursos tròfics. Butlletí de la Societat Catalana de Lepidopterologia 80: 26-29.

Vila, R., C. Stefanescu, & J. M. Sesma, 2018. Guia de les papallones diürnes de Catalunya. Lynx Edicions, Bellaterra.

Vives-Ingla, M., J. Sala-Garcia, C. Stefanescu, J. Peñuelas, & J. Carnicer, 2020. Varying thermal exposure, host-plant traits and oviposition behaviour across vegetation ecotones. bioRxiv doi: 10.1101/2020.02.11.944439.

Woods, H. A., M. E. Dillon, & S. Pincebourde, 2015. The roles of microclimatic diversity and of behavior in mediating the responses of ectotherms to climate change. Journal of Thermal Biology 54: 86–97.

Doing better for butterflies and moths

Tristan Lafranchis

Association Diatheo - Papillons de France et d’Europe
Corresponding author e-mail: lafranchis@yahoo.fr

Increasingly fewer butterflies and moths

This observation made for several decades by naturalists from all over Europe and elsewhere in the world is now increasingly popular in the press (Court 2013, Barkham 2017, Altendorf 2019, Soler 2019, Soto 2019, to only cite a few). The very effective monitoring conducted since 1994 by the Catalan Butterfly Monitoring Scheme (CBMS) allows us to estimate the trends of the Catalan populations of many butterflies (Stefanescu *et al.,* 2011). Of the 71 species encountered in the Montgrí-Baix Ter since 2014, 65 were rated by the CBMS: 17 are in decline in Catalonia (4 in 'regressió forta' and 13 in 'regressió moderada'), making up 26% of the total. Two species at least have apparently disappeared from the Montgrí in recent decades, and several other species seem to be on the verge of extinction. The general decline in Lepidoptera in Europe since the middle of 20th century is mostly the result of two factors: changes in habitats (van Swaay *et al.,* 2006) and the use of synthetic pesticides (Muratet & Fontaine 2004, Braak *et al*., 2018). To try to reverse this decline, it is therefore necessary prioritize these two issues. Climate change poses an additional threat with as yet unknown long-term effects that requires measures that are on a scale very different from that of the individual, the municipality or the region. Here, we present a few simple and costless ideas that would reduce the decline in butterflies, moths and other small wildlife. Some have already been implemented locally in Catalonia or in other European countries,

Conserve and create butterfly and moth habitats

Underexploited meadows and grasslands have become rare in Empordà. In natural parks (Montgrí, Cap de Creus), resources are devoted to recreating the open environments favorable to a rich flora and fauna by mechanically or manually clearing scrub and pastures overgrown with shrubs. Alternative habitats, which are complementary to areas cleared for ecological purposes, exist in and around urbanized areas (Fig. 1). Large open spaces remain on the immediate outskirts of built-up areas such as villages and housing estates. They are very regularly mown, sometimes chemically treated and soiled by dog feces. These spaces, however, have great potential for biodiversity. The installation of orchids (*Anacamptis pyramidalis, Ophrys apifera*) and butterflies (some 30 species, with the potential for more) on the wasteland of Torre Gran is proof. The municipalities and the agencies in charge of the management of housing estates could transform these spaces into harbors of nature that are well adapted by their proximity to discovery and to participative sciences without any cost. At Torroella de Montgrí, for example, the lawns along Carrer de Santa Espina could easily be converted into short-turf grasslands with wildflowers and pollinating insects. The mowing of urban lawns and peri-urban wastelands should be limited as much as possible to the summer period. This would allow many plants to grow and mature, and among them, the food plants that are able to feed caterpillars that are safe for human cultivation. The biological community that would settle in these areas would include micropredators and parasitoids, which would benefit the neighboring green spaces and gardens, thus limiting the use of pesticides.

Figure 1. The conservation of flowered areas is essential for the survival of butterflies and other pollinators; parcel covered in *Dittrichia viscosa* near Torroella de Montgrí on 10.10.2015.

Although rather mistreated by repeated mowing or by the spreading of herbicides, road banks and lane margins host rich flora and fauna. A study conducted along Cami Vell, the ancient path connecting Torroella and l'Estartit, detected 262 plant species and 33 butterflies on banks with limited extension (Lafranchis & Oliva i Casas 2018). The very recent history of *Aglais io* in the Montgrí-Baix Ter confirms that human intervention can worsen the impact of natural disasters on butterfly populations. This species was greatly affected by the 2015 drought, which reduced the nettle populations, a nitrophilic and meso-hygrophilic plant that is the only food for young caterpillars. Despite focused searches, no butterflies nor caterpillars were detected between May 2016 and February 2019. Since 2017, the banks of the lane that runs along the northern side of river Ter have been mown more regularly and earlier in the season, bringing a new unfavorable element to the survival of the butterfly. The vegetation is cut to the base several times a year over the entire width of the dike. Herbicide spraying by farmers along the field margins burns the nettles that escaped mowing to death, often during the caterpillar growth period (Fig. 2). In this case, a climatic accident was responsible for the sudden fall of the butterfly population, but human actions were at the same time contrary to its recovery. The main users of this path along the Ter River, where motorized trafic is now prohibited, are walkers and cyclists. It is certainly necessary to mow the lane to allow them to circulate. It is also certainly unnecessary to extend the mowing to the entire dike. Humans and wildlife could cohabitate ; it would be adequate to mow only the path and a strip of 50 cm to 1 m on each side.

Promoted for several decades in various European countries, the development of private gardens for butterflies offers them new resources and can create a network of favorable habitats (Fig. 3). Planting and sowing autochthonous plants in gardens and green spaces is also cheaper: these gardens are well-adapted to the climate, less demanding of water (an increasingly essential resource for human beings), and less sensitive to the often destructive invasive parasites that lead to an increasing use of pesticides. Public parks could easily become seminatural areas for a low cost (with the low maintenance compen-

Figure 2. Grown caterpillars of *Aglais io* on *Urtica dioica* that were sprayed shortly before with chemical weedkiller. Torroella de Montgrí, southern bank of river Ter, 3.05.2015.

Figure 3. A total of 41 butterfly species, 11 of which were recorded as breeding, have been observed in 5 years in this 25 m^2 garden in a housing estate at the bottom of the Montgrí. The former tenant had put the whole garden under plastic sheets covered with a layer of gravel; it took several months for the first seeds to germinate.

sating for the investment), allowing a range of fauna and flora to be established. In 2004, the town hall of Badalona (Barcelona) decided to create a butterfly garden, which was later followed by a few others. Some companies are also starting to adopt the idea: the water management company Sorea has planted native shrubs on 300 m^2 of banks in its treatment plants at Olot and Sant Joan les Fonts (Garrotxa) to help butterflies and biodiversity (La Vanguardia 22.11.2019).

The limits of ecological management

The offices in charge of protected areas should map all the sites deserving special attention (flora, fauna, habitats, cultural heritage) and create a maintenance work schedule (widening of trails, forestry work, etc.) to avoid even temporary destruction of butterfly and moth resources nectar, host-plant, refuges).

Any ecological management intervention should be preceded by a detailed evaluation of the site before work begins, as shown by the following example. Since the end of 2015, the vegetation at the bottom of Vall de Santa Caterina (Parc Natural del Montgrí, les Illes Medes i el Baix Ter) has been regularly cleared of scrub and mown, leaving only scattered young trees (Pinus halepensis and Quercus ilex). The purpose of these environmental works, which are associated with extensive grazing, is to create or keep open grassy habitats to promote the flora and fauna of dry grasslands, which includes the small game preyed upon by the scarce Bonelli's eagle. The populations of various animal and plant species quickly benefited from the works, but not *Glaucopsyche melanops*. The caterpillar of this spring butterfly lives on *Dorycnium pentaphyllum*, a shrublet badly affected by scrub clearing, especially in the only original grassland that once hosted the strongest colony of the butterfly on the Montgrí (Fig. 4). Counts made between 2014 and 2018 showed a decline in their number starting in 2016. In an area where heavy drought is not uncommon, the systematic eradication of bushes poses an additional threat to microfauna. Flowery grasslands are an ideal for naturalists, and the British were the first to use scrub clearing to replace the teeth of the sheep and rabbits that formerly kept open the extended grasslands on limestone hillsides that host many of the British butterflies. However, even under the English climate, radical scrub clearing is now questioned, and some populations of *Lysandra bellargus* have suffered in warm and dry years (Warren & Wigglesworth s.d.).

All major work carried out in protected areas should be closely monitored. Between 2015 and 2018, two small sites of scarce orchids were destroyed by the depositing of materials (cut wood in one case, earth in the other) in the Montgrí natural park. These accidents, such as those resulting from excessive cutting in meadows and along paths, are the consequence of a lack of resources allocated to the administrations in charge of the protected areas. With limited budgets and therefore limited staff, these organizations cannot collect and manage the information necessary to create precise management measures. Similarly, they cannot monitor the works undertaken in the areas under their responsibility.

A B C D

Figure 4. A. Dry grassland with *Dorycnium pentaphyllum* in Vall de Santa Caterina, the main breeding site of *Glaucopsyche melanops* in 2014. B. Top view of the same, at the bottom right, after the clearing works, December 2015. C and D. Same plot in April 2016 (with temporary protective fencing) and in April 2018. The grass cover has not yet returned.

Pesticides or butterflies?

Pesticide use interferes with butterfly survival in several ways (Muratet & Fontaine 2015, Mulé *et al*., 2017, Braak *et al.,* 2018). Insecticides kill them, including so-called specific biological control products, such as the bacterium *Bacillus thuringiensis*, which is now sold to fight against box-tree moth (*Cydalima perspectalis*), an invasive crambid. Herbicides, which are still widely used in Catalonia, impoverish the flora and destroy entire plant communities and their hosts within a few days, including many caterpillars (Fig. 5). Such regular destruction reduces insect populations to low or very low levels, producing an alarming decline in the small birds that feed on them. Recent scientific studies that have confirmed this trend quickly found echoes in the press of Western countries, including that in Spain (Cerillo 2015, Europa Press 2017, Marcos 2019), France (Lebreton 1970, Retien 2019, Rowe-Pirra 2019) and Great Britain (Barkham 2015), to only mention a few. Even if it is always very difficult to prove the harmful effects of a product on an environment governed by multiple factors, many ornithological studies point to the decrease in insect populations as an essential cause of the massive reduction in passerine birds in Europe.

Moving towards the cessation of the use of synthetic pesticides by replacing them with products of natural origin and with integrated pest management strategies should become a priority for citizens as well as for local powers. They have negative effects on all living things, including humans (Koureas *et al*., 2012, Blair *et al*., 2014, Nicolopoulou-Stamati *et al*., 2016), and the damage caused to resources - air, water and soil - as well as to the natural balance is no longer in doubt. Real Decreto 1311/2012 is an interesting tool for limiting the use of pesticides, but it is unfortunately little known and almost never enforced. A growing, albeit still small, number of Catalan municipalities have banned the use of glyphosate and sometimes all pesticides. This development has been made essential by the growing concern of the European population about the health consequences of the use of pesticides.


A

B

Figure 5. A. Ditch treated with weedkillers in the city of Torroella de Montgrí, 25.03.2019. B. Chemical war: spraying of insecticide in an olive grove at the entrance to Vall Petita (Montgrí-Baix Ter natural park), 22.06.2016. Natural parks have no regulatory tools to limit or prohibit the use of pesticides in their territory.

References

Altendorf, D., 2019. Une étude basée sur 81 espèces appuie le déclin alarmant des insectes. SciencePost, 15.07.2019

Barkham, P., 2015. Pesticide may be reason butterfly numbers are falling in UK, says study. The Guardian, 24.11.2015.

Barkham, P., 2017. Flutter bye: where did all the city butterflies go? The Guardian, 22.06.2017.

Blair, A., B. Ritz, C. Wesseling & L.B. Freeman, 2014. Pesticides and human health. Occupational and Environmental Medicine doi:10.1136/oemed-2014-102454

Braak, N., R. Neve, A.K. Jonesa, M. Gibbs & C.J. Breuker, 2018. The effects of insecticides on butterflies – A review. Environmental Pollution 242 (A):507-518.

Cerillo, A., 2015. Un nuevo estudio demuestra que los insecticidas son letales para las aves. La Vanguardia, 19.01.2015.

Court, M., 2013. Dramatique déclin des papillons en Europe. Le Figaro, 24.07.2013.

Europa Press, 3.11.2017. Los plaguicidas más comunes son tóxicos para los pájaros.

Koureas, M., A. Tsakalof, A. Tsatsakis & C. Hadjichristodouloua, 2012. Systematic review of biomonitoring studies to determine the association between exposure to organophosphorus and pyrethroid insecticides and human health outcomes. Toxicology Letters 210:155-168.

Lafranchis, T. & A.M. Oliva i Casas, 2018. El Camí Vell d'anar a l'Estartit, un recorregut per descobrir i revalorar. Llibre de la Festa Major, Torroella de Montgrí, pp. 51-62.

Lebreton, P., 1970. Insecticides et Oiseaux. Bulletin mensuel de la Société linnéenne de Lyon 39 (8):54-60.

Marcos, A., 2019. Los insecticidas amenazan la supervivencia de las aves silvestres. Público, 13.09.2019.

Mulé, R., G. Sabella, L. Robba & B. Manachini, 2017. Systematic Review of the Effects of Chemical Insecticides on Four Common Butterfly Families. Frontiers in Environmental Science 5:32. doi: 10.3389/fenvs.2017.00032

Muratet, A. & B. Fontaine, 2015. Contrasting impacts of pesticides on butterflies and bumblebees in private gardens in France. Biological Conservation 182:148-154.

Nicolopoulou-Stamati, P., S. Maipas, C. Kotampasi, P. Stamatis & L. Hens, 2016. Chemical Pesticides and Human Health: The Urgent Need for a New Concept in Agriculture. Frontiers in Public Health 4:148. doi: 10.3389/fpubh.2016.00148

Retien, P., 2019. Les pesticides, principale cause de la disparition des oiseaux en France. France Culture, 26.09.2019.

Rowe-Pirra, W., 2019. Les insecticides nuisent aussi aux oiseaux. Pour la Science, 5.11.2019.

Soler, A., 2019. «Allà on no hi ha papallones, podem esperar les coses pitjors». Diari de Girona, 25.10.2019.

Soto, E., 2019. ¿Por qué apenos vemos ya mariposas? El Mundo, 25.07.2019.

Stefanescu, C., I. Torre, J. Jubany & F. Paramo, 2011. Recent trends in butterfly populations from north-east Spain and Andorra in the light of habitat and climate change. Journal of Insect Conservation 15:83-93.

van Swaay, C.A.M., M. Warren & G. Loıs, 2006. Biotope use and trends of European butterflies. Journal of Insect Conservation 10:189-209.

Warren, M. & T. Wigglesworth, s.d. Adonis Blue *Polyommatus bellargus* factsheet. Butterfly Conservation, Wareham.

Synthesis: using butterflies as a reference for understanding the impact of climate change and habitat management on biodiversity

Constantí Stefanescu [1,2]

[1] Granollers Natural Sciences Museum, Francesc Macià 51, 08402 Granollers, Barcelona, Spain
[2] CREAF, E08193 Bellaterra (Cerdanyola del Vallès), Barcelona, Spain.
Corresponding author e-mail: canliro@gmail.com

Both El Montgrí and Els Aiguamolls de l'Empordà have been sampled intensively by lepidopterists for many decades and so excellent knowledge of these two area's butterfly fauna now exists. Indeed, it is now possible not only to list most of the species present there but also to summarise their status and recent population trends. The protection of these areas and their current status as natural parks have contributed greatly to this situation since both have given their support to monitoring programmes (e.g. the Catalan Butterfly Monitoring Scheme; www.catalanbms.org) and have attracted the attention of amateur entomologists.

These areas are not particularly diverse and confirm the well-established pattern whereby butterfly diversity in Catalonia peaks at mid-elevation mountain habitats and decreases rapidly towards the coast and the hottest and most arid areas in the south-west (Stefanescu *et al*., 2011). Moreover, few species are truly adapted to wetlands, which means that many of the butterflies found in Els Aiguamolls de l'Empordà are habitat generalists. Even though both natural parks harbour interesting species that need to be protected. For instance, species such as the silver-studded blue (*Plebejus argus*), impressive populations of which fly in the *closes* (the traditionally managed hay meadows in Els Aiguamolls de l'Empordà), deserve a special mention. In terms of size, these populations are only comparable to those found in some areas of the Pyrenees and, in addition, show some particularities including a multivoltine phenology that make them unique in a Catalan context.

In El Montgrí, where very dry Mediterranean habitats are present, specialist butterfly species such as southern small white (*Pieris mannii*), western marbled white (*Melanargia occitanica*), Provence hairstreak (*Tomares ballus*), and Provence chalk-hill blue (*Lysandra hispana*) are widespread and maintain more or less healthy populations (Lafranchis, this volume a).

Systematic monitoring of butterfly populations has provided abundant information on how habitat transformation and other environmental variables affect population trends. In one such case, the butterfly community at El Cortalet has been studied for more than 30 years and provides an unprecedented perspective of its dynamism and fragility. It has become possible, for example, to assess the impact of climatic warming and predict its consequences in the long term. Initial work indicated that butterfly emergence in spring is advancing due to rising temperatures (Stefanescu *et al*., 2003), while subsequent analyses have revealed that drought is a key agent that causes asynchronies between butterflies and their nectar sources (Donoso *et al*., 2016). These two studies show how important long-term monitoring data such as that from El Cortalet is in attempts to understand the effects on climate change on our ecosystems. Another recent example comes from the work by Radchuck *et al.* (2019), who used the butterfly data series from El Cortalet as well as many other sites to demonstrate that phenological advances are adaptive but not sufficient to prevent increasing risks of population extinction.

The negative impact of climate change on the butterfly fauna of Els Aiguamolls has also been analysed at species-level by focusing on one of the most common and representative species in the area, the green-veined white (*Pieris napi*). The study by Carnicer *et al.* (2019) highlights early summer drought as the main reason for the declining trend in lowland populations of *P. napi* (including the one at El Cortalet) due to its interaction with its main host plants. These aspects have been further studied in recent years and some of the main findings are presented here (Vives-Ingla *et al.*, this volume).

Climate change and, more particularly, summer drought, is nowadays one of the biggest threats to the butterfly fauna of El Montgrí. Although data from the recording CBMS site in Montgrí have not yet been formally analysed with this in mind, they have contributed to a general assessment of the Catalan butterfly fauna that indicates that typical species from dry habitats - such as those prevailing in El Montgrí - show the greatest declines owing to the recent extreme summers (Herrando *et al.*, 2019). Moreover, direct observations reported by Lafranchis (this volume b) fully confirm the strong impact of summer drought in El Montgrí on species such as wood white (*Leptidea sinapis*) and the Provence chalk-hill blue, to give just two examples.

However important climate is for explaining butterfly fluctuations and declines, it is also very obvious that up to now habitat loss and transformation has played the most prominent role in explaining butterfly trends in the Empordà plain. Much of this highly fertile area has been converted into agricultural land over the decades, although, crucially, only in the most recent decades has intensive field management transformed farmland into a truly hostile environment for most butterfly species and other insects. Agricultural intensification leads to a homogenization of the landscape with profound negative effects on biodiversity (Donald *et al*., 2001; Benton *et al*., 2003). Common practices in intensive farmland include the widespread use of pesticides (herbicides and insecticides), the systematic reduction and elimination of hedgerows, the extension of monocultures and the use of chemical fertilizers, all of which have proven to be very detrimental to wildlife. Butterflies are no exception and there are plenty of examples that demonstrate the link between these practices and the general declines in butterfly populations recorded the world over (e.g. Feber *et al*., 2007; Pleasants and Oberhauser, 2012; Braak *et al*., 2018).

Agricultural intensification is not the only problem that habitats are facing in our study region. Butterfly data from different transects in Els Aiguamolls de l'Empordà collected over many years identify the *closes* as the most valuable habitat for these insects, and show that certain species are excellent bioindicators of the health status of such *closes* (Stefanescu *et al*., 2005, 2006). However, systematic butterfly monitoring of the *closes* that are nowadays protected has shown that this habitat is highly threatened by two contrasting phenomena: field abandonment and vegetation encroachment, and overgrazing (see Stefanescu *et al*., 2009; Stefanescu, this volume; Colom and Stefanescu, this volume). Proper management of this highly threatened habitat requires a combination of low-pressure grazing in winter and mowing in early summer.

At local level, many simple actions may help butterfly populations, even in populated areas. These actions include setting aside open areas for conservation purposes in villages and housing estates, using native plants in local gardens, avoiding the use of pesticides, and shifting to more beneficial mowing regimes on roadside verges. The article by Lafranchis (this volume c) describes many actions that could benefit butterfly habitats in populated areas, some of which can be undertaken individually by many of us.

We hope that the articles in this volume will increase interest in the butterfly fauna of Els Aiguamolls de l'Empordà and El Montgrí and show that these lovely insects are much more than simple aesthetically pleasing creatures that flutter among flowers in spring and summer. In the past three decades or so, butterflies have taken a leading role in ecological research and biodiversity conservation, and hard science has been developed using butterflies as a study model, in most cases with profound implications for conservation biology (e.g. Hanski, 1999). Likewise, butterfly observation has emerged worldwide as an excellent example of successful citizen science projects and in Europe butterfly monitoring networks in many countries now provide a huge amount of valuable data on biodiversity trends and habitat management.

References

Benton, T.G., J. A. Vickery, & J.D. Wilson, 2003. Farmland biodiversity: is habitat heterogeneity the key? Trends in Ecology and Evolution 18: 182-188.

Braak, N., R. Neve, A.K. Jonesa, M. Gibbs, & C.J. Breuker, 2018. The effects of insecticides on butterflies – A review. Environmental Pollution 242: 507-518.

Colom, P., & C. Stefanescu (this volume). Effects of abandonment and restoration in Mediterranean meadows in a butterfly-plant network subject to long-term monitoring.

Donald, P.F., R.E. Green, R.E., & M.F. Heath, M.F., 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London, Ser. B 268: 25–29.

Donoso, I., C. Stefanescu, A. Martínez-Abraín, & A. Traveset, A., 2016. Phenological asynchrony in plant-butterfly interactions associated with climate: a community-wide perspective. Oikos 125: 1434-1444.

Feber, R.E., P.J. Johnson, L.G. Firbank, A. Hopkins, & D.W. Macdonald, 2007. A comparison of butterfly populations on organically and conventionally mangaed farmland. Journal of Zoology 273: 30-39.

Hanski, I., 1999. Metapopulation ecology. Oxford University Press, Oxford.

Herrando, S., N. Titeux, L. Brotons, M. Anton, A. Ubach, D. Villero, E. García-Barros, M.L. Munguira, C. Godinho, & C. Stefanescu (2019). Contrasting impacts of precipitation on Mediterranean birds and butterflies. Scientific Reports 9: 5680.

Lafranchis, T., this volume a. The Rhopalocera of Montgrí-Baix Ter.

Lafranchis, T., this volume b. The dispersal of butterflies in Montgrí-Baix Ter.

Lafranchis, T., this volume c. Doing better for butterflies.

Pleasants, J. M., & K. S. Oberhauser, 2012. Milkweed loss in agricultural fields because of herbicide use: effect on the monarch butterfly population. Insect Conservation and Diversity 6:135–144.

Radchuk, V., T. Reed, ... & S. Kramer-Schadt, 2019. Adaptive responses of animals to climate change are most likely insufficient. Nature communications, 10:3109.

Stefanescu, C., this volume. Three decades of butterfly monitoring in El Cortalet (Aiguamolls de l'Empordà Natural Park).

Stefanescu, C., J. Carnicer, & J. Peñuelas, 2011. Determinants of species richness in generalist and specialist Mediterranean butterfly: the negative synergistic forces of climate and habitat change. Ecography 34: 353-363.

Stefanescu, C., J. Peñuelas, & I. Filella, 2005. Butterflies highlight the conservation value of hay meadows highly threatened by land-use changes in a protected Mediterranean area. Biological Conservation 126: 234-246.

Stefanescu, C., J. Peñuelas, & I. Filella, 2006. Les papallones com a bioindicadores dels hàbitats a Catalunya: l'exemple dels prats de dall i les pastures del Parc Natural dels Aiguamolls de l'Empordà. Butlletí de la Institució Catalana d'Història Natural 73: 139-162.

Stefanescu, C., J. Peñuelas, & I. Filella, 2009. Rapid changes in butterfly communities following the abandonment of grasslands: a case study. Insect Diversity and Conservation 2: 261-269.

Vives- Ingla, M., C. Stefanescu, Sala-García, J., & J. Carnicer, this volume. Plastic and phenological variation of host plants mediates local responses of the butterfly *Pieris napi* to drought in the Mediterranean basin.

List of Lepidoptera known from Empordà (Catalonia, Spain)

Tristan Lafranchis [1*]
Maxime Pastore [2]
Enric Capalleras
Pascal Escudié
Philippe Geniez

[1] Association Diatheo - Papillons de France et d'Europe
[2] Carrer Puig Esquer, 2. 17780 Garriguella
* Corresponding author e-mail: lafranchis@yahoo.fr

Montgrí-Baix Ter = parc natural del Montgrí, les Illes Medes i el Baix Ter
Aiguamolls = parc natural dels Aiguamolls del Empordà
Albera = L'Albera range between La Junquera and the Mediterranean sea
upper valleys = municipalities of Maçanet de Cabrenys, San Llorenç de la Muga y Albanya

TL, Tristan Lafranchis, MP, Maxime Pastore, EC, Enric Capalleras, PE, Pascal Escudié, PG, Philippe Geniez

Species	**Family**	**Montgrí-Baix Ter**	**Aiguamolls**	**Albera**	**upper valleys**	**other sites**
Acrolepiopsis marcidella	Acrolepiidae				TL	
Acrolepiopsis vesperella	Acrolepiidae	TL			PE	
Adela australis	Adelidae	TL		MP	TL	
Nemophora cupriacella	Adelidae				TL	
Alucita grammodactyla	Alucitidae	TL				
Alucita hexadactyla	Alucitidae	TL			PE	
Alucita palodactyla	Alucitidae	TL				
Apatema impunctella	Autostichidae	TL			PE	
Apatema mediopallidum	Autostichidae	TL				
Oegoconia deauratella	Autostichidae	TL				
Oegoconia novimundi	Autostichidae	TL				
Oegoconia quadripuncta	Autostichidae	TL				
Symmoca oenophila	Autostichidae	TL				
Symmoca orphnella	Autostichidae	TL				
Symmoca signatella	Autostichidae	TL		EC	TL	
Symmocoides oxybiellus	Autostichidae	TL				
Batrachedra parvulipunctella	Batrachedridae	TL				
Bedellia somnulentella	Bedelliidae	TL				
Blastobasis glandulella	Blastobasidae	TL				
Blastobasis magna	Blastobasidae				TL	
Blastobasis phycidella	Blastobasidae	TL			TL	
Blastobasis sardinica	Blastobasidae	TL				
Blastobasis tarda	Blastobasidae	TL				
Brachodes funebris	Brachodidae					Ampuries (TL)
Bucculatrix alaternella	Bucculatricidae	TL				
Bucculatrix albedinella	Bucculatricidae	TL				
Bucculatrix bechsteiniella	Bucculatricidae	TL				
Bucculatrix cf demaryella	Bucculatricidae	TL				
Bucculatrix diffusella	Bucculatricidae	TL				
Bucculatrix maritima	Bucculatricidae	TL				
Bucculatrix regaella	Bucculatricidae	TL				
Paysandisia archon	Castniidae			MP		
Diurnea fagella	Chimabachidae				PE	
Choreutis nemorana	Choreutidae	TL				
Tebenna micalis	Choreutidae	TL				
Coleophora acutiphaga	Coleophoridae		Baldizzone 1986			
Coleophora cf conspicuella	Coleophoridae				TL	
Coleophora halophilella	Coleophoridae	TL				
Coleophora limosipennella	Coleophoridae	TL				
Coleophora millierella	Coleophoridae	TL				
Coleophora salicorniae	Coleophoridae	TL	Baldizzone 1986			
Coleophora salinella	Coleophoridae		Baldizzone 1986			
Coleophora strigosella	Coleophoridae	TL				
Coleophora texanella	Coleophoridae	TL				
Coleophora trifolii	Coleophoridae	TL		TL		

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Anatrachyntis badia	Cosmopterigidae	TL				
Ascalenia vanella	Cosmopterigidae	TL				
Coccidiphila gerasimovi	Cosmopterigidae	TL				
Cosmopterix crassicervicella	Cosmopterigidae	TL				
Cosmopterix lienigella	Cosmopterigidae	TL				
Cosmopterix pararufella	Cosmopterigidae	TL				
Cosmopterix pulchrimella	Cosmopterigidae	TL				
Cosmopterix zieglerella	Cosmopterigidae	TL				
Eteobalea alypella	Cosmopterigidae	TL				
Eteobalea cf beata	Cosmopterigidae	TL				
Pyroderces argyrogrammos	Cosmopterigidae	TL				
Pyroderces wolschrijni	Cosmopterigidae	TL				
Vulcaniella extremella	Cosmopterigidae	TL				
Vulcaniella fiordalisa	Cosmopterigidae	TL				
Vulcaniella pomposella	Cosmopterigidae	TL				
Vulcaniella rosmarinella	Cosmopterigidae	TL				
Cossus cossus	Cossidae	TL	TL, Masó & Valhonrat 1989	MP		
Dyspessa ulula	Cossidae	TL		MP		
Parahypopta caestrum	Cossidae	TL		MP		
Phragmataecia castaneae	Cossidae	TL	Masó & Valhonrat 1989			
Zeuzera pyrina	Cossidae	TL	Masó & Valhonrat 1989	MP		
Acentria ephemerella	Crambidae	Pérez De-Gregorio 2001				
Achyra nudalis	Crambidae	TL	TL	MP		
Acigona cicatricella	Crambidae		Masó & Valhonrat 1989			
Agriphila geniculea	Crambidae	TL	TL, Masó & Valhonrat 1989			
Agriphila inquinatella	Crambidae	TL				
Agriphila latistria	Crambidae		Masó & Valhonrat 1989			
Agriphila selasella	Crambidae	TL	Masó & Valhonrat 1989			
Agriphila tersella	Crambidae	TL	Masó & Valhonrat 1989			
Agriphila tristella	Crambidae				TL	
Anania crocealis	Crambidae	TL				
Anania testacealis	Crambidae	TL	Masó & Valhonrat 1989			
Anania verbascalis	Crambidae	TL				
Ancylolomia disparalis	Crambidae			EC		
Ancylolomia pectinatella	Crambidae			MP		
Antigastra catalaunalis	Crambidae	TL				
Aporodes floralis	Crambidae	TL		EC		
Atraleta albofascialis	Crambidae	TL				
Calamotropha paludella	Crambidae	TL	Masó & Valhonrat 1989			
Cataclysta lemnata	Crambidae	TL				
Catoptria falsella	Crambidae				TL	
Catoptria pinella	Crambidae	TL			TL	
Chilo luteellus	Crambidae	TL				
Chilo phragmitella	Crambidae	TL				
Chilo suppressalis	Crambidae	TL				
Chrysocrambus craterella	Crambidae			EC	TL	
Chrysoteuchia culmella	Crambidae	TL			TL	
Crambus lathoniellus	Crambidae				TL	
Crambus pascuella	Crambidae				TL	
Cydalima perspectalis	Crambidae	TL		MP	TL	
Cynaeda dentalis	Crambidae	TL				
Diasemia reticularis	Crambidae	TL			TL	
Diasemiopsis ramburialis	Crambidae	TL				
Diplopleustis perieresalis	Crambidae	TL				
Dolicharthria aetnaealis	Crambidae	TL			TL	
Dolicharthria bruguieralis	Crambidae	TL				

Species	**Family**	**Montgrí-Baix Ter**	**Aiguamolls**	**Albera**	**upper valleys**	**other sites**
Dolicharthria punctalis	Crambidae	TL				
Donacaula mucronella	Crambidae					Llança (Goater et al. 2005)
Duponchelia fovealis	Crambidae	TL				
Ecpyrrhorrhoe rubiginalis	Crambidae	TL			TL	
Elophila nymphaeata	Crambidae	TL				
Euchromius cambridgei	Crambidae	TL			TL	
Euchromius gozmanyi	Crambidae	TL	Masó & Valhonrat 1989			
Euchromius ocellea	Crambidae	TL	Masó & Valhonrat 1989			
Eudonia angustea	Crambidae	TL			TL	
Eudonia delunella	Crambidae	TL			TL	
Eudonia lacustrata	Crambidae	TL			TL	
Eudonia lineola	Crambidae	TL				
Eudonia mercurella	Crambidae	TL		EC	TL	
Eudonia phaeoleuca	Crambidae				TL	
Evergestis forficalis	Crambidae	TL		EC		
Evergestis frumentalis	Crambidae	TL		TL	TL	
Evergestis isatidalis	Crambidae	TL		EC		
Evergestis limbata	Crambidae				TL	
Heliothela wulfeniana	Crambidae				PE	
Hellula undalis	Crambidae	TL	TL, Masó & Valhonrat 1989			
Hodebertia testalis	Crambidae	TL				
Hydriris ornatalis	Crambidae	TL		MP		
Loxostege sticticalis	Crambidae	TL	TL	TL		
Mecyna asinalis	Crambidae	TL			TL	
Mecyna flavalis	Crambidae	TL	TL			
Metacrambus carectellus	Crambidae	TL				
Metacrambus pallidellus	Crambidae	TL				
Metasia corsicalis	Crambidae	TL				
Metasia cuencalis	Crambidae			EC		
Nascia cilialis	Crambidae		Masó & Valhonrat 1989			
Nomophila noctuella	Crambidae	TL	TL	MP	TL	
Ostrinia nubilalis	Crambidae	TL			TL	
Palpita vitrealis	Crambidae	TL		TL	TL	
Parapoynx stratiotata	Crambidae					Llança (Goater et al. 2005)
Paratalanta hyalinalis	Crambidae				TL	
Paratalanta pandalis	Crambidae				PE	
Pediasia contaminella	Crambidae	TL	Masó & Valhonrat 1989		TL	
Platytes alpinella	Crambidae	TL				
Pleuroptya ruralis	Crambidae	TL			TL	
Pyrausta acontialis	Crambidae	TL				
Pyrausta aurata	Crambidae	TL		EC		
Pyrausta despicata	Crambidae	TL			TL	
Pyrausta purpuralis	Crambidae	TL			TL	
Pyrausta sanguinalis	Crambidae	TL		EC	TL	
Schoenobius forticellus	Crambidae		Masó & Valhonrat 1989			
Schoenobius gigantellus	Crambidae		Masó & Valhonrat 1989			
Scirpophaga praelata	Crambidae		Masó & Valhonrat 1989			
Sclerocona acutella	Crambidae	TL	Masó & Valhonrat 1989			
Scoparia ambigualis	Crambidae			EC		
Scoparia basistrigalis	Crambidae				TL	
Scoparia pyralella	Crambidae				TL	
Sitochroa palealis	Crambidae	TL		EC		
Sitochroa verticalis	Crambidae	TL			TL	
Spoladea recurvalis	Crambidae	TL		EC		
Tegostoma comparalis	Crambidae	TL				
Udea ferrugalis	Crambidae	TL		MP	TL	

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Udea numeralis	Crambidae	TL		TL		
Uresiphita gilvata	Crambidae	TL		MP	TL	
Xanthocrambus delicatellus	Crambidae	TL				
Agonopterix cnicella	Depressariidae	TL				
Agonopterix kaekeritzana	Depressariidae	TL				
Agonopterix purpurea	Depressariidae	TL				
Agonopterix rutana	Depressariidae	TL				
Agonopterix scopariella	Depressariidae	TL				
Agonopterix subpropinquella	Depressariidae	TL				
Agonopterix yeatiana	Depressariidae	TL				
Anchinia daphnella	Depressariidae	TL				
Depressaria adustatella	Depressariidae	TL				
Depressaria albipunctella	Depressariidae	TL				
Depressaria cf douglasella	Depressariidae	TL				
Depressaria depressana	Depressariidae	TL				
Depressaria halophilella	Depressariidae	TL				
Ethmia bipunctella	Depressariidae	TL		EC		
Ethmia terminella	Depressariidae	TL				
Exaeretia lutosella	Depressariidae	TL				
Tubuliferola flavifrontella	Depressariidae					Tamariu (Requena *et al* 2011)
Cilix glaucata	Drepanidae	TL		MP	TL	
Cilix hispanica	Drepanidae	TL		MP		
Drepana curvatula	Drepanidae				TL	
Habrosyne pyritoides	Drepanidae					La Bisbal (Pérez De-Gregorio & Rondos 2003)
Polyploca ridens	Drepanidae			MP		
Tethea ocularis	Drepanidae	TL	MP	MP	TL	
Tethea or	Drepanidae				TL	
Thyatira batis	Drepanidae	TL		MP	TL	
Watsonalla binaria	Drepanidae			MP		
Watsonalla uncinula	Drepanidae	TL		MP	TL	
Elachista argentella	Elachistidae	TL				
Elachista cf biatomella	Elachistidae	TL				
Elachista cf consortella	Elachistidae	TL				
Elachista cf gormella	Elachistidae	TL				
Elachista cf subalbidella	Elachistidae	TL				
Elachista cf utonella	Elachistidae	TL				
Elachista dispunctella	Elachistidae	TL				
Elachista hispanica	Elachistidae	TL				
Elachista maculicerusella	Elachistidae	TL				
Elachista stabilella	Elachistidae	TL				
Elachista subocellea	Elachistidae				TL	
Epermenia aequidentellus	Epermeniidae	TL				
Apaidia mesogona	Erebidae Arctiinae	TL		MP	TL	
Arctia villica	Erebidae Arctiinae	TL	TL	MP, TL	TL	
Coscinia cribraria	Erebidae Arctiinae			MP	TL	
Cybosia mesomella	Erebidae Arctiinae				TL	
Cymbalophora pudica	Erebidae Arctiinae	TL	MP	MP		
Diacrisia sannio	Erebidae Arctiinae					Gavarres (Pérez De-Gregorio & Rondos 2003)
Diaphora mendica	*Erebidae Arctiinae*	*TL*		*MP*		
Dysauxes punctata	Erebidae Arctiinae	TL		MP		
Eilema caniola	Erebidae Arctiinae	TL	Masó & Valhonrat 1989	MP	TL	
Eilema complana	Erebidae Arctiinae	TL		MP	TL	
Eilema depressa	Erebidae Arctiinae	TL		MP	TL	
Eilema griseola	Erebidae Arctiinae			MP		

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Eilema lurideola	Erebidae Arctiinae	TL		EC		
Eilema pseudocomplana	Erebidae Arctiinae			MP		
Eilema sororcula	Erebidae Arctiinae	TL		MP	TL	
Eilema uniola	Erebidae Arctiinae	TL			TL	
Euplagia quadripunctaria	Erebidae Arctiinae			MP	TL	
Hyphoraia testudinaria	Erebidae Arctiinae				TL	
Lithosia quadra	Erebidae Arctiinae	TL		MP	TL	
Miltochrista miniata	Erebidae Arctiinae			MP	TL	
Ocnogyna latreillei	Erebidae Arctiinae					Gavarres (Pérez De-Gregorio & Rondos 2003)
Paidia rica	Erebidae Arctiinae				TL	
Pelosia muscerda	Erebidae Arctiinae	TL				
Pelosia obtusa	Erebidae Arctiinae		Masó & Valhonrat 1989			
Phragmatobia fuliginosa	Erebidae Arctiinae	TL		MP	TL	
Spilosoma lubricipeda	Erebidae Arctiinae	TL	Masó & Valhonrat 1989	MP	TL	
Spilosoma lutea	Erebidae Arctiinae	TL				
Spilosoma urticae	Erebidae Arctiinae		Masó & Valhonrat 1989			
Spiris striata	Erebidae Arctiinae	TL	TL, Masó & Valhonrat 1989	MP	TL	
Utetheisa pulchella	Erebidae Arctiinae	TL		MP		
Watsonarctia deserta	Erebidae Arctiinae				TL	
Laspeyria flexula	Erebidae Aventiinae				TL	
Parascotia nisseni	Erebidae Boletobiinae	TL	Masó & Valhonrat 1989	TL		
Apopestes spectrum	Erebidae Erebinae	TL		EC		
Araeopteron ecphaea	Erebidae Erebinae	TL		Pérez De-Gregorio & Rondos 2005		
Autophila dilucida	Erebidae Erebinae	TL				
Catephia alchymista	Erebidae Erebinae	TL		EC	TL	
Catocala conjuncta	Erebidae Erebinae	TL		MP	TL	
Catocala conversa	Erebidae Erebinae	TL		MP	PE	
Catocala dilecta	Erebidae Erebinae			MP		
Catocala electa	Erebidae Erebinae				TL	
Catocala elocata	Erebidae Erebinae		PG	MP		
Catocala nupta	Erebidae Erebinae	TL		EC		
Catocala nymphaea	Erebidae Erebinae			MP		
Catocala nymphagoga	Erebidae Erebinae	TL		MP	TL	
Catocala optata	Erebidae Erebinae			MP		
Catocala sponsa	Erebidae Erebinae	TL				
Clytie illunaris	Erebidae Erebinae	TL	Masó & Valhonrat 1989	MP		
Dysgonia algira	Erebidae Erebinae	TL		MP	TL	
Euclidia glyphica	Erebidae Erebinae	TL		MP	TL	
Euclidia mi	Erebidae Erebinae				TL	
Grammodes bifasciata	Erebidae Erebinae	TL	TL	MP		
Grammodes stolida	Erebidae Erebinae	TL		MP		
Lygephila craccae	Erebidae Erebinae	TL		EC	TL	
Minucia lunaris	Erebidae Erebinae	TL		EC	TL	
Ophiusa tirhaca	Erebidae Erebinae	TL				
Eublemma candidana	Erebidae Eublemminae			EC		
Eublemma ostrina	Erebidae Eublemminae	TL		MP	TL	
Eublemma parva	Erebidae Eublemminae	TL	Masó & Valhonrat 1989	EC	TL	
Eublemma pulchralis	Erebidae Eublemminae	TL		MP		
Eublemma pura	Erebidae Eublemminae	TL		EC		
Eublemma scitula	Erebidae Eublemminae	TL		MP		
Glossodice polygramma	Erebidae Eublemminae			MP		
Metachrostis velox	Erebidae Eublemminae	TL	TL	MP	TL	
Odice jucunda	Erebidae Eublemminae	TL		MP	TL	
Odice suava	Erebidae Eublemminae			EC		

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Herminia tarsipennalis	Erebidae Herminiinae			MP		
Macrochilo cribrumalis	Erebidae Herminiinae	TL	Masó & Valhonrat 1989			
Nodaria nodosalis	Erebidae Herminiinae	TL		MP	TL	
Paracolax tristalis	Erebidae Herminiinae			MP	TL	
Pechipogo plumigeralis	Erebidae Herminiinae	TL		MP		
Zanclognatha lunalis	Erebidae Herminiinae	TL			TL	
Zanclognatha tarsipennalis	Erebidae Herminiinae					Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Hypena lividalis	Erebidae Hypeninae	TL		MP		
Hypena proboscidalis	Erebidae Hypeninae	TL				
Schrankia costaestrigalis	Erebidae Hypenodinae	TL				
Arctornis l-nigrum	Erebidae Lymantriinae		Masó & Valhonrat 1989			
Callitaera pudibunda	Erebidae Lymantriinae			MP	TL	
Euproctis chrysorrhoea	Erebidae Lymantriinae			MP		
Lymantria dispar	Erebidae Lymantriinae	TL		MP	TL	
Lymantria monacha	Erebidae Lymantriinae	TL		MP	TL	
Ocneria rubea	Erebidae Lymantriinae	TL		MP		
Orgya antiqua	Erebidae Lymantriinae	TL		MP	TL	
Orgyia trigotephras	Erebidae Lymantriinae	TL		MP		
Phytometra sanctiflorentis	Erebidae Phytometrinae					
Phytometra viridaria	Erebidae Phytometrinae				TL	
Raparna conicephala	Erebidae Phytometrinae	TL				
Rivula sericealis	Erebidae Rivulinae				TL	
Zebeeba falsalis	Erebidae Rivulinae	TL				
Scoliopteryx libatrix	Erebidae Scoliopteryginae			MP	TL	
Eriocottis nicolaeella	Eriocottidae	TL				
Eriocottis paradoxella	Eriocottidae			MP		
Eutelia adulatrix	Euteliidae	TL		MP		
Acompsia cinerella	Gelechiidae				TL	
Anarsia leberonella	Gelechiidae	TL				
Anarsia lineatella	Gelechiidae	TL	Requena 2009			
Apodia bifractella	Gelechiidae	TL			TL	
Aproaerema anthyllidela	Gelechiidae	TL				
Aristotelia decurtella	Gelechiidae	TL				
Aristotelia subericinella/billii	Gelechiidae	TL				
Brachmia blandella	Gelechiidae	TL				
Bryotropha senectella	Gelechiidae	TL				
Carpatolechia aenigma	Gelechiidae	TL				
Carpatolechia decorella	Gelechiidae	TL				
Chrysoestia sexguttella	Gelechiidae				TL	
Dichomeris acuminatus	Gelechiidae	TL				
Dichomeris alacella	Gelechiidae	TL				
Dichomeris lamprostoma	Gelechiidae	TL				
Dichomeris limbipunctellus	Gelechiidae	TL				
Ephysteris diminutella	Gelechiidae	TL				
Ephysteris promptella	Gelechiidae	TL				
Epidola barcinonella	Gelechiidae	TL				
Eulamprotes wilkella	Gelechiidae	TL				
Helcystogramma lutatella	Gelechiidae				TL	
Isophrictis kefersteiniellus	Gelechiidae	TL				
Isophrictis lineatellus	Gelechiidae				TL	
Istrianis myricariella	Gelechiidae		Requena 2009			
Ivanoskiella psamathias	Gelechiidae	TL				
Megacraspedus balneariellus	Gelechiidae	TL	Requena 2009			
Megacraspedus imparellus	Gelechiidae	TL				
Mesophleps corsicella	Gelechiidae	TL				

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Mesophleps oxycedrella	Gelechiidae	TL				
Mesophleps silacella	Gelechiidae	TL				
Metzneria artificiella	Gelechiidae	TL				
Metzneria hilarella	Gelechiidae	TL	Requena 2009			
Metzneria neuropterella	Gelechiidae				TL	
Mirificarma mulinella	Gelechiidae	TL				
Nothris congressariella	Gelechiidae	TL				
Nothris verbascella	Gelechiidae	TL				
Ornativalva pseudotamariciella	Gelechiidae	TL				
Palumbina guerinii	Gelechiidae	TL				
Parapodia sinaica	Gelechiidae	TL	Requena 2009			
Pexicopia malvella	Gelechiidae	TL				
Platyedra subcinerea	Gelechiidae	TL		MP		
Pseudotelphusa occidentella	Gelechiidae	TL				
Ptocheuusa inopella	Gelechiidae	TL				
Ptocheuusa paupella	Gelechiidae	TL				
Recurvaria nanella	Gelechiidae				PE	
Scrobipalpa halimionella	Gelechiidae	TL				
Scrobipalpa ocellatella	Gelechiidae	TL				
Scrobipalpa salinella	Gelechiidae	TL				
Scrobipalpa spergulariella	Gelechiidae		Huemer & Karsholt 2010			
Scrobipalpa vasconiella	Gelechiidae	TL				
Stomopterix basalis	Gelechiidae	TL				
Stomopteryx detersella	Gelechiidae	TL				
Syncopacma cf suecicella	Gelechiidae	TL				
Thiotricha subocellea	Gelechiidae	TL				
Tuta absoluta	Gelechiidae	TL				
Abraxas pantaria	Geometridae	TL				
Adactylotis contaminaria	Geometridae	TL				
Adactylotis gesticularia	Geometridae			MP	TL	
Adalberta castillaria	Geometridae	TL		MP	TL	
Agriopis aurantiaria	Geometridae			MP		
Agriopis bajaria	Geometridae	TL				
Agriopis marginaria	Geometridae	TL		MP		
Aleucis distinctata	Geometridae			MP	PE	
Alsophila aceraria	Geometridae			MP		
Alsophila aescularia	Geometridae			MP		
Angerona prunaria	Geometridae				TL	
Anticlea derivata	Geometridae				PE	
Antilurga alhambrata	Geometridae	TL				
Aplasta ononaria	Geometridae	TL		TL		
Aplocera plagiata	Geometridae				TL	
Apocheima hispidaria	Geometridae			MP		
Ascotis selenaria	Geometridae	TL			TL	
Aspitates gilvaria	Geometridae	TL			TL	
Aspitates ochrearia	Geometridae	TL	TL	MP		
Biston betularia	Geometridae			MP	TL	
Biston strataria	Geometridae	TL		MP	PE	
Bupalus pinaria	Geometridae	TL			TL	
Cabera exanthemata	Geometridae			EC		
Cabera pusaria	Geometridae				TL	
Campaea honoraria	Geometridae	TL		MP	TL	
Campaea margaritata	Geometridae			MP	TL	
Camptogramma bilineata	Geometridae	TL		TL	TL	
Casilda consecraria	Geometridae	TL	Masó & Valhonrat 1989			
Cataclysme riguata	Geometridae			EC		

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Cataclysme uniformata	Geometridae	TL		MP	TL	
Catarhoe basochesiata	Geometridae	TL		MP		
Catarhoe cucullata	Geometridae				TL	
Charissa ambiguata	Geometridae			MP		
Charissa mucidaria	Geometridae	TL		EC	TL	
Chemerina caliginearia	Geometridae	TL		MP		
Chesias legatella	Geometridae	TL		MP		
Chesias rufata	Geometridae			EC		
Chiasmia aestimaria	Geometridae	TL	TL, Masó & Valhonrat 1989	MP		
Chiasmia clathrata	Geometridae	TL	TL	MP	TL	
Chlorissa viridata	Geometridae			MP		
Chloroclysta siterata	Geometridae	TL		MP		
Chloroclystis v-ata	Geometridae		MP	MP	TL	
Cidaria fulvata	Geometridae				TL	
Cleora cinctaria	Geometridae	TL		EC		
Coenocalpe millierata	Geometridae	TL		MP		
Colostygia multistrigaria	Geometridae	TL		EC		
Colotois pennaria	Geometridae	TL		MP		
Comibaena bajularia	Geometridae			MP		
Compsoptera opacaria	Geometridae	TL		MP		
Cosmorhoe ocellata	Geometridae				TL	
Costaconvexa polygrammata	Geometridae	TL				
Crocallis dardoinaria	Geometridae	TL				
Crocallis elinguaria	Geometridae			MP		
Crocallis tusciaria	Geometridae			MP		
Cyclophora annularia	Geometridae				TL	
Cyclophora lennigiaria	Geometridae			MP		
Cyclophora linearia	Geometridae			EC		
Cyclophora punctaria	Geometridae			MP		
Cyclophora puppillaria	Geometridae	TL		MP	TL	
Cyclophora ruficillaria	Geometridae	TL			TL	
Cyclophora suppunctaria	Geometridae			EC	TL	
Dyscia penulataria	Geometridae	TL		EC		
Ecleora solieraria	Geometridae			MP		
Ectropis crepuscularia	Geometridae				PE	
Ematurga atomaria	Geometridae	TL	TL		TL	
Ennomos alniaria	Geometridae			MP		
Ennomos fuscantaria	Geometridae		Masó & Valhonrat 1989			
Ennomos quercinaria	Geometridae			EC		
Epirrhoe alternata	Geometridae	TL		MP		
Epirrhoe galiata	Geometridae	TL		MP	TL	
Epirrhoe rivata	Geometridae				TL	
Erannis defoliaria	Geometridae	TL		MP		
Euchloris smaragdaria	Geometridae		Masó & Valhonrat 1989			
Eucrostes indigenata	Geometridae	TL	Masó & Valhonrat 1989	EC		
Eupithecia absinthiata	Geometridae	TL				
Eupithecia alliaria	Geometridae			MP		
Eupithecia assimilata	Geometridae	TL				
Eupithecia centaureata	Geometridae	TL	Masó & Valhonrat 1989	MP	TL	
Eupithecia cocciferata	Geometridae	TL		MP	PE	
Eupithecia distinctaria	Geometridae	TL				
Eupithecia dodoneata	Geometridae	TL		MP	TL	
Eupithecia haworthiata	Geometridae				TL	
Eupithecia icterata	Geometridae			EC		
Eupithecia indigata	Geometridae				PE	
Eupithecia innotata	Geometridae	TL				

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Eupithecia inturbata	Geometridae				TL	
Eupithecia irriguata	Geometridae	TL		MP	TL	
Eupithecia liguriata	Geometridae	TL				
Eupithecia massiliata	Geometridae	TL				
Eupithecia oxycedrata	Geometridae	TL		MP	PE	
Eupithecia pauxillaria	Geometridae	TL				
Eupithecia phoeniceata	Geometridae	TL		MP		
Eupithecia scopariata	Geometridae			TL	TL	
Eupithecia ultimaria	Geometridae	TL	TL, Masó & Valhonrat 1989			
Eupithecia unedonata	Geometridae	TL				
Eupithecia variostrigata	Geometridae	TL				
Eupithecia virgaureata	Geometridae	TL				
Eurranthis plummistraria	Geometridae					Llers (TL)
Gymnoscelis rufifasciata	Geometridae	TL		MP	TL	
Hemithea aestivaria	Geometridae	TL				
Horisme radicaria	Geometridae	TL			?	
Horisme tersata	Geometridae		Masó & Valhonrat 1989			
Horisme vitalbata	Geometridae	TL		MP	TL	
Hypomecis punctinalis	Geometridae			MP	TL	
Hypomecis roboraria	Geometridae			MP	TL	
Idaea albarracina	Geometridae	TL				
Idaea alyssumata	Geometridae	TL	Masó & Valhonrat 1989			
Idaea aversata	Geometridae	TL		MP	TL	
Idaea biselata	Geometridae				TL	
Idaea blaesii	Geometridae	TL				
Idaea calunetaria	Geometridae	TL		MP		
Idaea cervantaria	Geometridae	TL			TL	
Idaea circuitaria	Geometridae	TL		MP		
Idaea contiguaria	Geometridae			MP		
Idaea degeneraria	Geometridae	TL		MP	TL	
Idaea dilutaria	Geometridae				TL	
Idaea dimidiata	Geometridae	TL				
Idaea efflorata	Geometridae	TL		EC		
Idaea elongaria	Geometridae	TL		MP		
Idaea eugeniata	Geometridae	TL		MP	TL	
Idaea filicata	Geometridae	TL		MP	TL	
Idaea fuscovenosa	Geometridae	TL				
Idaea hispanaria	Geometridae					Vall Repos (Dantart & Jubany 2007)
Idaea humiliata	Geometridae				TL	
Idaea incalcarata	Geometridae	TL		MP		
Idaea infirmaria	Geometridae	TL		MP		
Idaea laevigata	Geometridae	TL				
Idaea luteolaria	Geometridae			MP		
Idaea mancipiata	Geometridae		Masó & Valhonrat 1989			
Idaea mediaria	Geometridae	TL				
Idaea moniliata	Geometridae	TL		EC	TL	
Idaea muricata	Geometridae		Masó & Valhonrat 1989			
Idaea mustelata	Geometridae	TL		MP		
Idaea obsoletaria	Geometridae	TL			TL	
Idaea ochrata	Geometridae	TL	TL		TL	
Idaea ostrinaria	Geometridae	TL		MP	TL	
Idaea politaria	Geometridae	TL		MP	TL	
Idaea predotaria	Geometridae	TL			TL	
Idaea rubraria	Geometridae			MP	TL	
Idaea sardoniata	Geometridae			MP		

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Idaea seriata	Geometridae	TL		EC		
Idaea straminata	Geometridae	TL		EC	TL	
Idaea subsaturata	Geometridae	TL			TL	
Idaea subsericeata	Geometridae	TL		MP	TL	
Isturgia famula	Geometridae			EC		
Isturgia limbaria	Geometridae				TL	
Isturgia miniosaria	Geometridae	TL				
Larentia clavaria	Geometridae	TL		MP		
Larentia malvata	Geometridae	TL		MP		
Ligdia adustata	Geometridae			MP	TL	
Lobophora halterata	Geometridae				PE	
Lomaspilis marginata	Geometridae				TL	
Lomographa bimaculata	Geometridae				PE	
Lomographa temerata	Geometridae				TL	
Lycia hirtaria	Geometridae	TL		TL	TL	
Lythria purpuraria	Geometridae	TL	TL	EC	TL	
Lythria sanguinaria	Geometridae				TL	
Macaria alternata	Geometridae				TL	
Macaria brunneata	Geometridae			EC		
Macaria liturata	Geometridae				TL	
Macaria notata	Geometridae			MP		
Melanthia procellata	Geometridae				TL	
Menophra abruptaria	Geometridae	TL		MP	TL	
Menophra japygiaria	Geometridae	TL		MP		
Menophra nycthemeraria	Geometridae				TL	
Microloxia herbaria	Geometridae	TL	Masó & Valhonrat 1989	EC		
Minoa murinata	Geometridae				TL	
Nebula ibericata	Geometridae	TL		EC		
Nychioides notarioi	Geometridae			MP	TL	
Odezia atrata	Geometridae			MP	TL	
Onychora agaritharia	Geometridae	TL		EC		
Opisthograptis luteolata	Geometridae	TL		MP	TL	
Orthonama obstipata	Geometridae	TL		MP	TL	
Pachynemia hippocastanaria	Geometridae	TL		MP	TL	
Pachynemia tibiaria	Geometridae					Cap Creus (MP)
Paradarisa consonaria	Geometridae				PE	
Pasiphila chloerata	Geometridae				TL	
Pasiphila rectangulata	Geometridae				TL	
Pennithera firmata	Geometridae				TL	
Pennithera ulicata	Geometridae	TL		MP		
Peribatodes ilicaria	Geometridae	TL		MP	TL	
Peribatodes perversaria	Geometridae			MP	TL	
Peribatodes rhomboidaria	Geometridae	TL	Masó & Valhonrat 1989	TL	TL	
Peribatodes secundaria	Geometridae	TL			TL	
Peribatodes umbraria	Geometridae	TL		TL	TL	
Perizoma bifasciata	Geometridae	TL				
Perizoma flavofasciata	Geometridae	TL		MP		
Petrophora chlorosata	Geometridae				TL	
Petrophora convergata	Geometridae	TL		MP		
Petrophora narbonea	Geometridae	TL			TL	
Phaiogramma etruscaria	Geometridae	TL		MP	TL	
Phaiogramma faustinata	Geometridae	TL	Masó & Valhonrat 1989			
Phyllometra gracilaria	Geometridae			EC		
Pseudopanthera macularia	Geometridae			MP		
Pseudoterpna coronillaria	Geometridae	TL		MP	TL	
Rhodometra sacraria	Geometridae	TL	TL	MP	TL	

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Rhodostrophia calabra	Geometridae	TL		EC	TL	
Rhodostrophia vibicaria	Geometridae			MP	TL	
Rhoptria asperaria	Geometridae	TL		TL	TL	
Scopula asellaria	Geometridae			EC		
Scopula decorata	Geometridae	TL		MP		
Scopula emutaria	Geometridae	TL	Masó & Valhonrat 1989	MP		
Scopula floslactata	Geometridae				TL	
Scopula imitaria	Geometridae	TL		MP		
Scopula immutata	Geometridae		Masó & Valhonrat 1989			
Scopula incanata	Geometridae			MP		
Scopula luridata	Geometridae			EC		
Scopula marginepunctata	Geometridae	TL		MP	TL	
Scopula minorata	Geometridae	TL	TL, Masó & Valhonrat 1989	MP		
Scopula nigropunctata	Geometridae				TL	
Scopula ornata	Geometridae	TL	TL	EC	TL	
Scopula rubiginata	Geometridae	TL		MP	TL	
Scopula rufomixtaria	Geometridae	TL		EC		
Scopula submutata	Geometridae	TL		MP	TL	
Scotopteryx bipunctaria	Geometridae				TL	
Scotopteryx chenopodiata	Geometridae				TL	
Scotopteryx moeniata	Geometridae				TL	
Scotopteryx mucronata	Geometridae			EC	TL	
Scotopteryx octodurensis	Geometridae				TL	
Scotopteryx peribolata	Geometridae	TL		MP		
Selenia tetralunaria	Geometridae				PE	
Selidosema taeniolaria	Geometridae	TL		MP		
Stegania cararia	Geometridae				TL	
Stegania trimaculata	Geometridae	TL		MP	TL	
Synopsia sociaria	Geometridae	TL		MP		
Tephrina murinaria	Geometridae	TL	TL	MP		
Tephronia codetaria	Geometridae	TL			TL	
Tephronia sepiaria	Geometridae	TL		MP	TL	
Thera cupressata	Geometridae	TL		MP		
Thera obeliscata	Geometridae			MP	TL	
Thera ulicata	Geometridae			MP		
Thetidia smaragdaria	Geometridae				TL	
Timandra comae	Geometridae	TL		MP	TL	
Triphosa dubitata	Geometridae			EC		
Xanthorhoe ferrugata	Geometridae			MP		
Xanthorhoe fluctuata	Geometridae	TL	TL	MP	TL	
Xenochlorodes olympiaria	Geometridae	TL		MP		
Glyphipterix equitella	Glyphipterigidae	TL				
Glyphipterix simpliciella	Glyphipterigidae	TL				
Acrocercops cocciferelum	Gracillariidae	TL				
Aspilapteryx tringipennella	Gracillariidae	TL				
Caloptilia fidella	Gracillariidae	TL				
Caloptilia fribergensis	Gracillariidae	TL				
Calybites phasianipennella	Gracillariidae	TL				
Dialectica scalariella	Gracillariidae	TL				
Euspilapteryx auroguttella	Gracillariidae	TL				
Parectopa ononidis	Gracillariidae	TL				
Parornix sp.	Gracillariidae	TL				
Phyllocnistis cf saligna	Gracillariidae	TL				
Phyllonorycter belotella	Gracillariidae	TL				
Phyllonorycter cerasinella	Gracillariidae	TL				

Species	**Family**	**Montgrí-Baix Ter**	**Aiguamolls**	**Albera**	**upper valleys**	**other sites**
Phyllonorycter endryella	Gracillariidae	TL				
Phyllonorycter insignitella	Gracillariidae	TL				
Phyllonorycter messaniella	Gracillariidae	TL				
Phyllonorycter rebimbasi	Gracillariidae	TL				
Phyllonorycter trifasciella	Gracillariidae	TL				
Triodia sylvina	Hepialidae	TL	Masó & Valhonrat 1989	MP		
Dendrolimus pini	Lasiocampidae	TL		MP	TL	
Gastropacha quercifolia	Lasiocampidae	TL	Masó & Valhonrat 1989	MP	TL	
Lasiocampa quercus	Lasiocampidae	TL	TL	MP		
Lasiocampa trifolii	Lasiocampidae	TL	Masó & Valhonrat 1989	MP		
Macrothylacia rubi	Lasiocampidae			MP		
Malacosoma neustria	Lasiocampidae	TL		MP	TL	
Odonestis pruni	Lasiocampidae					La Bisbal (Pérez De-Gregorio & Rondos 2003)
Phyllodesma kermesifolia	Lasiocampidae			MP	PE	
Phyllodesma suberifolia	Lasiocampidae	TL		MP	TL	
Poecilocampa populi	Lasiocampidae			MP		Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Psilogaster loti	Lasiocampidae					Gavarres (Pérez De-Gregorio & Rondos 2003)
Trichiura castiliana	Lasiocampidae	TL				
Eurodachtha canigella	Lecithoceridae	TL				
Eurodachtha pallicornella	Lecithoceridae	TL		TL	TL	
Lecithocera nigrana	Lecithoceridae	TL		EC		
Odites kollarella	Lecithoceridae	TL				
Apoda limacodes	Limacodidae			MP		
Hoyesia codeti	Limacodidae	TL		MP		
Mompha miscella	Momphidae	TL				
Ectoedemia cf atrifrontella	Nepticulidae	TL				
Ectoedemia cf haraldi	Nepticulidae	TL			TL	
Ectoedemia erythrogenella	Nepticulidae					Port Bou (Nieukerken *et al* 2004)
Stigmella alaternella	Nepticulidae					Port Bou (Nieukerken *et al* 2004)
Stigmella centifoliella	Nepticulidae				Nieukerken et al 2004	
Stigmella eberhardi ?	Nepticulidae	TL				
Stigmella hemargyrella	Nepticulidae				Nieukerken et al 2004	
Stigmella perpygmaeella	Nepticulidae				Nieukerken et al 2004	
Stigmella tityrella	Nepticulidae				Nieukerken et al 2004	
Trifurcula anthyllidella	Nepticulidae					Rosas (Nieukerken et al 2004)
Trifurcula calycotomella	Nepticulidae					Port Bou, Rosas (Nieukerken et al 2004)
Trifurcula rosmarinella	Nepticulidae					Port Bou (Nieukerken et al 2004)
Trifurcula stoechadella	Nepticulidae					Port Bou (Nieukerken et al 2004)
Trifurcula teucriella	Nepticulidae					Port Bou (Nieukerken et al 2004)
Abrostola asclepiadis	Noctuidae				TL	
Abrostola tripartita	Noctuidae					St Feliu de Guixols (Pérez De-Gregorio & Rondos 2003)
Abrostola triplasia	Noctuidae	TL				
Acontia lucida	Noctuidae	TL	TL	MP		
Acontia trabealis	Noctuidae	TL	TL	MP		
Acontia viridisquama	Noctuidae			MP		
Acronicta auricoma	Noctuidae			EC		
Acronicta cuspis	Noctuidae					La Jonquera (Pérez De-Gregorio)
Acronicta euphorbiae	Noctuidae			MP		La Jonquera (Pérez De-Gregorio)
Acronicta ligustri	Noctuidae				TL	
Acronicta psi	Noctuidae			MP		Gavarres (Pérez De-Gregorio & Rondos 2003)

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Acronicta rumicis	Noctuidae	TL	MP		TL	
Acronicta tridens	Noctuidae	TL		MP		
Actinotia hyperici	Noctuidae					Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Aedia leucomelas	Noctuidae	TL		MP		
Aegle vespertinalis	Noctuidae			EC		
Agrochola blidaensis	Noctuidae	TL		MP		
Agrochola circellaris	Noctuidae	TL				
Agrochola haematidea	Noctuidae					Pedralta (Pérez De-Gregorio & Rondos 2003)
Agrochola helvola	Noctuidae	TL		MP		
Agrochola litura	Noctuidae			MP		
Agrochola lota	Noctuidae	TL		MP		
Agrochola lunosa	Noctuidae			MP		
Agrochola lychnidis	Noctuidae	TL		MP		
Agrochola macilenta	Noctuidae			MP		
Agrochola pistacinoides	Noctuidae			MP		
Agrotis bigramma	Noctuidae	TL		MP		
Agrotis catalaunensis	Noctuidae	TL		MP		
Agrotis clavis	Noctuidae	TL		MP		
Agrotis exclamationis	Noctuidae	TL			TL	
Agrotis graslini	Noctuidae		Masó & Valhonrat 1989			
Agrotis ipsilon	Noctuidae	TL	Masó & Valhonrat 1989	MP	TL	
Agrotis puta	Noctuidae	TL		MP		
Agrotis segetum	Noctuidae	TL		EC	TL	
Agrotis trux	Noctuidae	TL	Masó & Valhonrat 1989	MP		
Agrotis vestigialis	Noctuidae	TL	Pérez De-Gregorio et al. 2008			
Allophyes alfaroi	Noctuidae	TL		MP		
Amephana aurita	Noctuidae	TL				
Ammoconia caecimacula	Noctuidae			MP		
Ammopolia witzenmanni	Noctuidae	TL		MP		
Amphipyra livida	Noctuidae			MP		
Amphipyra pyramidea	Noctuidae			MP		
Amphipyra tetra	Noctuidae			MP		
Amphipyra tragopoginis	Noctuidae			MP		
Anarta myrtilli	Noctuidae			MP		Calonge, S Cristina d'Aro (Marti 2005)
Anarta pugnax	Noctuidae	TL		MP	TL	
Anarta sodae	Noctuidae	TL	Masó & Valhonrat 1989			
Anarta trifolii	Noctuidae	TL	Masó & Valhonrat 1989	MP		
Anorthoa munda	Noctuidae			MP		
Anthracia ephialtes	Noctuidae	TL				
Antitype chi	Noctuidae			MP		
Apamea anceps	Noctuidae		Masó & Valhonrat 1989			
Apamea lithoxylea	Noctuidae				TL	
Apamea monoglypha	Noctuidae			EC		
Apamea sublustris	Noctuidae			MP		
Aporophylla australis	Noctuidae	TL		MP		
Aporophylla canescens	Noctuidae	TL				
Aporophylla nigra	Noctuidae	TL		MP		
Archanara dissoluta	Noctuidae	TL	Ylla 1997			
Archanara geminipuncta	Noctuidae					Gavarres (Pérez De-Gregorio & Rondos 2003)
Archanara sparganii	Noctuidae			MP		
Atethmia centrago	Noctuidae	TL	Ylla 1997	MP		
Athetis hospes	Noctuidae	TL		TL		
Atypha pulmonaris	Noctuidae	TL				

Species	**Family**	**Montgrí-Baix Ter**	**Aiguamolls**	**Albera**	**upper valleys**	**other sites**
Autographa gamma	Noctuidae	TL	TL	MP	TL	
Bryonycta pineti	Noctuidae	TL		MP	TL	
Bryophila ravula	Noctuidae			MP		
Bryophila vandalusiae	Noctuidae	TL		MP		
Brythis crini	Noctuidae		Stefanescu & Miralles 1992			
Callopistria juventina	Noctuidae				PE	
Callopistria latreillei	Noctuidae	TL		MP		
Calocasia coryli	Noctuidae			MP		
Calophasia almoravida	Noctuidae		Masó & Valhonrat 1989	MP		
Calophasia opalina	Noctuidae					
Calophasia platyptera	Noctuidae	TL		MP	TL	
Caradrina aspersa	Noctuidae	TL		MP	TL	Alt Emporda (Marti 2005)
Caradrina clavipalpis	Noctuidae	TL	Masó & Valhonrat 1989	MP	TL	
Caradrina flavirena	Noctuidae	TL		MP	TL	
Caradrina fuscicornis	Noctuidae			MP		
Caradrina germainii	Noctuidae	TL				
Caradrina kadenii	Noctuidae	TL		MP		
Caradrina morpheus	Noctuidae		Masó & Valhonrat, 1989			
Caradrina noctivaga	Noctuidae	TL		MP	TL	
Caradrina proxima	Noctuidae	TL		MP	TL	
Caradrina selini	Noctuidae	TL		MP		
Cardepia sociabilis	Noctuidae			MP		
Celaena leucostigma	Noctuidae		Masó & Valhonrat 1989			
Cerastis rubricosa	Noctuidae				PE	
Charanica trigrammica	Noctuidae				TL	
Chilodes maritima	Noctuidae	TL	Masó & Valhonrat 1989	EC		
Chloantha hyperici	Noctuidae	TL		MP	TL	
Chrysodeixis chalcites	Noctuidae	TL		MP		
Cleonymia yvanii	Noctuidae			EC		
Colocasia coryli	Noctuidae				TL	
Condica viscosa	Noctuidae	TL				
Conisania andalusica	Noctuidae	TL				
Conistra alicia	Noctuidae			MP		
Conistra erythrocephala	Noctuidae	TL		MP		
Conistra ligula	Noctuidae			MP		
Conistra rubiginea	Noctuidae			MP	PE	
Conistra rubiginosa	Noctuidae			MP		
Conistra vaccinii	Noctuidae	TL		EC		
Cornutiplusia circumflexa	Noctuidae			EC		
Cosmia diffinis	Noctuidae			MP		
Cosmia trapezina	Noctuidae			MP	TL	
Craniophora ligustri	*Noctuidae*	*TL*		*MP*		
Cryphia algae	Noctuidae	TL		MP		
Cryphia ochsi	Noctuidae	TL		MP		
Cryphia pallida	Noctuidae	TL	Masó & Valhonrat 1989	MP		
Ctenoplusia accentifera	Noctuidae	TL				
Cucullia argentea	Noctuidae	TL				
Cucullia calendulae	Noctuidae	TL		MP		
Cucullia chamomillae	Noctuidae			EC		Gavarres (Pérez De-Gregorio & Rondos 2003)
Cucullia erythrocephala	Noctuidae			MP		
Cucullia santolinae	Noctuidae	TL				
Cucullia scrophulariae	Noctuidae	TL				
Cucullia thapsiphaga	Noctuidae			EC		
Cucullia verbasci	Noctuidae	TL		EC		
Deltote pygarga	Noctuidae				TL	

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Dicyla oo	Noctuidae			MP		
Diloba caeruleocephala	Noctuidae					Palafrugell (Pérez De-Gregorio & Rondos 2003)
Dryobota labecula	Noctuidae	TL		EC		
Dryobotodes eremita	Noctuidae	TL		MP		
Dryobotodes monochroma	Noctuidae	TL		MP		
Dryobotodes roboris	Noctuidae	TL		MP		
Dryobotodes tenebrosa	Noctuidae	TL		MP		
Dypterigia scabriuscula	Noctuidae			MP		
Egira conspicillaris	Noctuidae	TL		MP	PE	
Elaphria venustula	Noctuidae	TL			TL	
Epilecta linogrisea	Noctuidae			MP	TL	
Epimecia ustula	Noctuidae	TL				
Eremobia ochroleuca	Noctuidae	TL				
Eugnorisma glareosa	Noctuidae	TL		MP		
Euplexia lucipara	Noctuidae			MP	TL	
Euxoa cos	Noctuidae					Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Euxoa obelisca	Noctuidae			MP		
Euxoa temera	Noctuidae		Masó & Valhonrat 1989	MP		
Globia sparganii	Noctuidae	TL	Masó & Valhonrat 1989	MP		
Gortyna xanthenes	Noctuidae	TL				
Griposia aprilina	Noctuidae			MP		
Hada plebeja	Noctuidae			MP		
Hadena albimacula	Noctuidae				TL	
Hadena compta	Noctuidae	TL				
Hadena confusa	Noctuidae	TL		TL	TL	
Hadena perplexa	Noctuidae	TL		MP		
Hadena silenes	Noctuidae	TL	Masó & Valhonrat 1989	MP	TL	
Haemerosia renalis	Noctuidae			MP		
Hecatera bicolorata	Noctuidae	TL		MP		
Hecatera dysodea	Noctuidae	TL	Masó & Valhonrat 1989	MP		
Hecatera weissi	Noctuidae		Masó & Valhonrat 1989	MP		
Helicoverpa armigera	Noctuidae	TL	TL	MP	TL	
Heliothis peltigera	Noctuidae	TL		MP	TL	
Heliothis viriplaca	Noctuidae	TL	TL	MP		
Helotropha leucostigma	Noctuidae	TL				
Hoplodrina ambigua	Noctuidae	TL		MP	TL	
Hoplodrina hesperica	Noctuidae					Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Hoplodrina octogenaria	Noctuidae			MP		
Hoplodrina superstes	Noctuidae			MP		
Hydroecia osseola	Noctuidae		Masó & Valhonrat 1989			
Jodia croceago	Noctuidae	TL				
Lacanobia blenna	Noctuidae		Masó & Valhonrat 1989			
Lacanobia oleracea	Noctuidae	TL		MP		
Lacanobia w-latinum	Noctuidae				TL	
Lateroligia ophiogramma	Noctuidae	TL				
Lenisa geminipuncta	Noctuidae	TL	Masó & Valhonrat 1989			
Leucania loreyi	Noctuidae	TL		MP		
Leucania obsoleta	Noctuidae	TL	Masó & Valhonrat 1989			
Leucania pallens	Noctuidae	TL				
Leucania punctosa	Noctuidae			EC		
Leucania putrescens	Noctuidae	TL		MP		
Leucania straminea	Noctuidae	TL	Masó & Valhonrat 1989			
Leucania zeae	Noctuidae	TL	Masó & Valhonrat 1989	MP		
Leucochlaena oditis	Noctuidae			MP		

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Lithophane leautieri	Noctuidae	TL		MP		
Lithophane ornithopus	Noctuidae			MP		
Lithophane semibrunnea	Noctuidae	TL				
Lophoterges millierei	Noctuidae			MP		
Luperina dumerilii	Noctuidae			MP		
Luperina testacea	Noctuidae	TL		MP		
Lycophotia erythrina	Noctuidae	TL				
Macdunnoughia confusa	Noctuidae	TL	TL			
Mamestra brassicae	Noctuidae				TL	
Meganephria bimaculosa	Noctuidae					Alt Emporda (Dantart & Jubany 2010)
Melanchra persicariae	Noctuidae				TL	
Mesapamea secalis/secalella	Noctuidae	TL		EC		
Mesoligia furuncula	Noctuidae	TL			TL	
Metopoceras felicina	Noctuidae	TL	Masó & Valhonrat 1989	MP		
Mniotype adusta	Noctuidae			MP		
Mniotype occidentalis	Noctuidae	TL		MP		
Moma alpium	Noctuidae					Palamos (Pérez De-Gregorio & Rondos 2003)
Mormo maura	Noctuidae			MP		
Mythimna albipuncta	Noctuidae	TL		EC	TL	
Mythimna congrua	Noctuidae	TL	Masó & Valhonrat 1989			
Mythimna ferrago	Noctuidae	TL		MP	TL	
Mythimna l-album	Noctuidae	TL		MP		
Mythimna languida	Noctuidae	TL		MP		
Mythimna littoralis	Noctuidae		Masó & Valhonrat 1989			
Mythimna prominens	Noctuidae					Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Mythimna pudorina	Noctuidae		Masó & Valhonrat 1989			
Mythimna riparia	Noctuidae	TL		MP		
Mythimna sicula	Noctuidae	TL	Masó & Valhonrat 1989	MP	TL	
Mythimna unipuncta	Noctuidae	TL	MP	MP	TL	
Mythimna vitellina	Noctuidae	TL		MP	TL	
Noctua comes	Noctuidae	TL	Masó & Valhonrat 1989	MP	TL	
Noctua fimbriata	Noctuidae	TL		MP	TL	
Noctua interjecta	Noctuidae					Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Noctua janthe	Noctuidae	TL		MP		
Noctua janthina	Noctuidae	TL			TL	
Noctua orbona	Noctuidae	TL				
Noctua pronuba	Noctuidae	TL		MP	TL	
Noctua tirrenica	Noctuidae	TL		MP	TL	
Nonagria typhae	Noctuidae		Masó & Valhonrat 1989			
Nyctobria muralis	Noctuidae	TL	Masó & Valhonrat 1989	MP		
Ochropleura leucogaster	Noctuidae	TL				
Ochropleura plecta	Noctuidae					La Bisbal (Pérez De-Gregorio & Rondos 2003)
Oligia furuncula	Noctuidae		Masó & Valhonrat 1989			
Oligia latruncula	Noctuidae				TL	
Oligia strigilis	Noctuidae			MP		
Oligia versicolor	Noctuidae			MP		
Orthosia cerasi	Noctuidae	TL		MP	PE	
Orthosia cruda	Noctuidae	TL			PE	
Orthosia gothica	Noctuidae	TL		MP	PE	
Orthosia gracilis	Noctuidae	TL				
Orthosia incerta	Noctuidae	TL		MP	PE	
Pachetra sagittigera	Noctuidae				TL	

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Panolis flammea	Noctuidae	TL		MP	PE	
Pardoxia graellsi	Noctuidae	TL	TL	MP	TL	
Peridroma saucia	Noctuidae	TL		MP	TL	
Phlogophora meticulosa	Noctuidae	TL		MP	TL	
Photedes pygmina	Noctuidae		Masó & Valhonrat 1989			
Phylophyla obliterata	Noctuidae	TL				
Plusia festucae	Noctuidae	TL	TL, Masó & Valhonrat 1989			
Polia nebulosa	Noctuidae			EC		
Polymixis argillaceago	Noctuidae	TL		EC		
Polymixis dubia	Noctuidae	TL		MP		
Polymixis flavicincta	Noctuidae	TL		EC		
Polymixis lichenea	Noctuidae			MP		
Polymixis xanthomista	Noctuidae			MP		
Polyphaenis sericata	Noctuidae	TL		MP	TL	
Polyphaenis viridis	Noctuidae			MP		
Pseudenargia ulicis	Noctuidae			MP		
Pseudozarba bipartita	Noctuidae	TL				
Pyrois effusa	Noctuidae	TL				
Raphia hybris	Noctuidae			MP		Jafre (TL)
Recophora canteneri	Noctuidae	TL		MP, TL		
Rhizedra lutosa	Noctuidae	TL	Masó & Valhonrat, 1989			
Rusina ferruginea	Noctuidae			MP	TL	
Schinia scutosa	Noctuidae					Ampuries (TL)
Scotochrosta pulla	Noctuidae			MP		
Sesamia cretica	Noctuidae					Darnius (Bellavista 1988)
Sesamia nonagrioides	Noctuidae	TL	Masó & Valhonrat 1989	MP	TL	
Simyra albovenosa	Noctuidae		Masó & Valhonrat 1989			
Spodoptera cilium	Noctuidae	TL		MP		
Spodoptera exigua	Noctuidae	TL		MP	TL	
Spodoptera littoralis	Noctuidae	TL				
Subacronycta megacephala	Noctuidae	TL				
Synthymia fixa	Noctuidae	TL		MP		
Thalpophila vitalba	Noctuidae	TL		MP		
Thysanoplusia daubei	Noctuidae	TL	Masó & Valhonrat 1989			
Thysanoplusia orichalcea	Noctuidae	TL				
Tiliacea aureago	Noctuidae			MP		
Trachea atriplicis	Noctuidae	TL				
Trichoplusia ni	Noctuidae	TL		MP		
Tridaenia tridens	Noctuidae	TL				
Trigonophora crassicornis	Noctuidae			MP		
Trigonophora flammea	Noctuidae	TL		MP		
Trigonophora jodea	Noctuidae			EC		
Tyta luctuosa	Noctuidae	TL	EC	MP	TL	
Valeria jaspidea	Noctuidae	TL		MP	PE	
Xanthia gilvago	Noctuidae	TL				
Xanthia ruticilla	Noctuidae	TL		MP	PE	
Xestia agathina	Noctuidae	TL		MP		
Xestia c-nigrum	Noctuidae	TL			TL	
Xestia castanea	Noctuidae			MP		
Xestia ditrapezium	Noctuidae			MP		
Xestia triangulum	Noctuidae			MP		
Xestia xanthographa	Noctuidae	TL		MP		
Xylena exsoleta	Noctuidae	TL				
Xylocampa areola	Noctuidae	TL		MP		
Bena bicolorana	Nolidae			MP		
Earias clorana	Nolidae	TL	Dantart & Cervello 2008	MP		

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Earias insulana	Nolidae	TL				
Earias vernana	Nolidae	TL	Dantart & Cervello 2008	MP		
Meganola albula	Nolidae	TL				
Meganola strigula	Nolidae	TL		EC	TL	
Meganola togatulalis	Nolidae	TL		EC		
Nola chlamitulalis	Nolidae	TL		TL		
Nola cicatricalis	Nolidae	TL		MP	TL	
Nola confusalis	Nolidae	TL		MP	PE	
Nola infantula	Nolidae			MP		
Nola squalida	Nolidae		Masó & Valhonrat 1989			
Nola subchlamydula	Nolidae			EC		
Nola thymula	Nolidae	TL				
Nycteola asiatica	Nolidae	TL	Masó & Valhonrat 1989			
Nycteola columbana	Nolidae	TL		MP	TL	
Nycteola revayana	Nolidae	TL		EC	TL	
Nycteola siculana	Nolidae			EC		
Pseudoips prasinana	Nolidae			MP	TL	
Cerura erminea	Notodontidae					Jafre (TL)
Cerura iberica	Notodontidae			MP		
Clostera curtula	Notodontidae	TL				
Clostera pigra	Notodontidae	TL		MP	TL	
Dicranura ulmi	Notodontidae		PG & R, 2003	MP		Gavarres (Pérez De-Gregorio & Rondos 2003)
Drymonia ruficornis	Notodontidae			MP	TL	
Furcula bifida	Notodontidae	TL				
Gluphisia crenata	Notodontidae				TL	
Harpyia milhauseri	Notodontidae	TL		MP	TL	
Neoharpyia verbasci	Notodontidae					Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Notodonta dromedarius	Notodontidae			MP	TL	
Notodonta tritophus	Notodontidae				TL	
Notodonta ziczac	Notodontidae	TL				
Peridea anceps	Notodontidae	TL		MP	TL	
Phalera bucephala	Notodontidae				TL	
Phalera bucephaloides	Notodontidae	TL				
Pheosia tremula	Notodontidae	TL		MP		
Pterostoma palpina	Notodontidae	TL	Masó & Valhonrat 1989	MP	TL	
Ptilodon cucullina	Notodontidae			MP	TL	
Ptilophora plumigera	Notodontidae					La Jonquera (Muñoz et al 2011)
Rhegmatophila alpina	Notodontidae				TL	
Spatalia argentina	Notodontidae					Bell Lloch (Pérez De-Gregorio & Rondos 2003)
Stauropus fagi	Notodontidae			MP	TL	
Thaumetopoea pityocampa	Notodontidae	TL		MP	TL	
Thaumetopoea processionea	Notodontidae			MP		
Alabonia geoffrella	Oecophoridae				TL	
Batia lunaris	Oecophoridae	TL				
Crassa unitella	Oecophoridae				TL	
Dasycera oliviella	Oecophoridae			TL		
Denisia luctuosella	Oecophoridae	TL				
Epicallima bruandella	Oecophoridae	TL				
Epicallima formosella	Oecophoridae	TL				
Esperia sulphurella	Oecophoridae			MP		
Goidanichiana jourdheuillella	Oecophoridae	TL			TL	
Harpella forficella	Oecophoridae				TL	
Pleurota aristella	Oecophoridae	TL		EC	TL	
Pleurota ericella	Oecophoridae	TL		TL		

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Pleurota gallicella	Oecophoridae				TL	
Pleurota honorella	Oecophoridae	TL				
Pleurota planella	Oecophoridae	TL				
Pleurota proteella	Oecophoridae	TL				
Pleurota pungitiella	Oecophoridae				TL	
Opostega salaciella	Opostegidae				TL	
Opostegoides menthinella	Opostegidae	TL				
Pseudopostega chalcopepla	Opostegidae	TL				
Carcina quercana	Peleopodidae	TL		TL		
Plutella xylostella	Plutellidae	TL		MP	TL	
Prays oleae	Praydidae	TL				
Dahlica pinkeri	Psychidae					Port Bou, Colera (Arsncheid & Weidlich 2017)
Epichnopterix plumella	Psychidae				TL	
Eumasia pariatariella	Psychidae	TL				
Penestoglossa dardoinella	Psychidae	TL				
Psyche casta	Psychidae	TL				
Sterrhopterix fusca	Psychidae	TL				
Pterolonche sp.	Pterolonchidae	TL		TL		
Agdistis bennetii	Pterophoridae		Requena 1999			
Agdistis heydeni	Pterophoridae					
Agdistis manicata	Pterophoridae					
Agdistis meridionalis	Pterophoridae		Requena 1999			
Agdistis paralia	Pterophoridae		Requena 1999			
Agdistis tamaricis	Pterophoridae	TL	Requena 1999			
Amblyptilia acanthadactyla	Pterophoridae	TL				
Calyciphora adamas	Pterophoridae	TL				
Calyciphora punctinervis	Pterophoridae	TL				Darnius (Gielis 1996)
Emmelina monodactyla	Pterophoridae	TL			TL	
Lantanophaga pusillidactylus	Pterophoridae	TL				
Marasmarcha fauna	Pterophoridae	TL				
Merrifieldia baliodactylus	Pterophoridae				TL	
Merrifieldia garrigae	Pterophoridae	TL				
Merrifieldia spicidactyla	Pterophoridae	TL				
Merriefieldia tridactyla	Pterophoridae				PE	
Oxyptilus tristis	Pterophoridae	TL				
Platyptilia calodactyla/iberica	Pterophoridae	TL				
Pterophorus pentadactyla	Pterophoridae	TL				
Stangeia siceliota	Pterophoridae	TL				
Stenoptilia aridus ?	Pterophoridae	TL				
Stenoptilodes taprobanes	Pterophoridae	TL				
Wheeleria spilodactylus	Pterophoridae	TL				
Acentropus niveus	Pyralidae	Pérez De-Gregorio 1977				
Achroia grisella	Pyralidae	TL				
Acrobasis advenella	Pyralidae	TL			TL	
Acrobasis bithynella	Pyralidae	TL				
Acrobasis centunculella	Pyralidae	TL			PE	
Acrobasis consociella	Pyralidae				TL	
Acrobasis glaucella	Pyralidae	TL			TL	
Acrobasis legatea	Pyralidae				PE	
Acrobasis marmorea	Pyralidae				TL	
Acrobasis obliqua	Pyralidae	TL		TL	TL	
Acrobasis porphyrella	Pyralidae				TL	
Acrobasis romanella	Pyralidae	TL			TL	
Acrobasis suavella	Pyralidae	TL			TL	
Acroclita subsequana	Pyralidae	TL				

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Aglossa brabanti	Pyralidae	TL				
Aglossa pinguinalis	Pyralidae	TL				
Amphithrix sublineatella	Pyralidae	TL				
Ancylosis cinnamomella	Pyralidae	TL		EC	TL	
Ancylosis oblitella	Pyralidae	TL				
Aphomia cephalonica	Pyralidae	TL				
Aphomia sociella	Pyralidae			EC	TL	
Apomyelois ceratoniae	Pyralidae	TL				
Asalebria florella	Pyralidae	TL				
Assara conicolella	Pyralidae	TL				
Bostra obsoletalis	Pyralidae	TL			TL	
Cadra figulilella	Pyralidae	TL				
Cataya insularum	Pyralidae	TL				
Cryptoblabes gnidiella	Pyralidae	TL				
Delplanqueia cf dilutella	Pyralidae	TL				
Denticera divisella	Pyralidae	TL		EC		
Dioryctria abietella	Pyralidae				TL	
Dioryctria mendacella	Pyralidae	TL			TL	
Dioryctria simplicella	Pyralidae			MP		
Dioryctria sylvestrella	Pyralidae	TL			TL	
Ematheudes punctella	Pyralidae	TL				
Endotricha flammealis	Pyralidae	TL			TL	
Ephestia disparella	Pyralidae	TL				
Ephestia elutella	Pyralidae	TL			TL	
Ephestia welseriella	Pyralidae	TL				
Ephestia woodiella	Pyralidae	TL			TL	
Epischnia asteris	Pyralidae	TL				
Epischnia illotella	Pyralidae	TL				
Epischnia prodromella	Pyralidae	TL				
Etiella zinckenella	Pyralidae	TL		TL		
Euzophera bigella	Pyralidae	TL				
Euzophera osseatella	Pyralidae	TL				
Euzophera pinguis	Pyralidae	TL			TL	
Galleria mellonella	Pyralidae	TL			TL	
Homoeosoma nebulella	Pyralidae	TL				
Homoeosoma sinuella	Pyralidae	TL	TL	TL	TL	
Hypochalcia ahenella	Pyralidae				TL	
Hypotia corticalis	Pyralidae	TL		EC		
Hypotia muscosalis	Pyralidae					Tossa de Mar, La Selva (Perez de Gregorio et al 2008)
Hypsopygia costalis	Pyralidae	TL		EC		
Hypsopygia glaucinalis	Pyralidae	TL				
Hypsopygia incarnatalis	Pyralidae	TL				
Hypsopygia rubidalis	Pyralidae	TL				
Hypsotropa roseostrigella	Pyralidae	TL				
Isauria dilucidella	Pyralidae	TL				
Khorassania compositella	Pyralidae	TL				
Lamoria anella	Pyralidae	TL				
Loryma egregialis	Pyralidae	TL		EC		
Merulempista turturella	Pyralidae	TL				
Metallostichodes nigrocyanella	Pyralidae	TL				
Moitrelia italogallicella	Pyralidae	TL				
Myelois circumvoluta	Pyralidae					Biure (TL)
Nephopterix angustella	Pyralidae	TL				
Nyctegretis ruminella	Pyralidae	TL				
Oncocera semirubella	Pyralidae	TL	TL		TL	

Species	**Family**	**Montgrí-Baix Ter**	**Aiguamolls**	**Albera**	**upper valleys**	**other sites**
Oxybia transversella	Pyralidae	TL		EC	TL	
Pempelia albariella	Pyralidae				TL	
Pempelia ardosiella	Pyralidae	TL				
Pempelia palumbella	Pyralidae	TL			PE	
Phycita roborella	Pyralidae	TL			TL	
Phycitodes albatella	Pyralidae	TL				
Phycitodes cf bentickella	Pyralidae				TL	
Phycitodes inquinatella	Pyralidae	TL			TL	
Pima boisduvaliella	Pyralidae					Ampuries (TL)
Plodia interpunctella	Pyralidae	TL				
Pseudacrobasis tergestella	Pyralidae	TL			TL	
Psorosa dahliella	Pyralidae	TL				
Psorosa mediterranella	Pyralidae	TL				
Pterothrixidia rufella	Pyralidae	TL				
Pyralis farinalis	Pyralidae	TL		MP		
Pyralis regalis	Pyralidae	TL		MP	TL	
Rhodophaea formosa	Pyralidae	TL				
Sciota adelphella	Pyralidae					Jafre (TL)
Sciota hostilis	Pyralidae	TL				
Sciotia rhenella	Pyralidae	TL				
Seeboldia korgosella	Pyralidae	TL				
Selagia spadicella	Pyralidae	TL				
Stemmatophora borgialis	Pyralidae	TL		EC		
Stemmatophora brunnealis	Pyralidae	TL		EC		
Stemmatophora combustalis	Pyralidae	TL		EC		
Stemmatophora syriacalis	Pyralidae	TL				
Stemmatophora vulpecalis	Pyralidae	TL				
Synaphe punctalis	Pyralidae	TL		EC	TL	
Valdovecaria hispanicella	Pyralidae	TL				
_crobasis fallouella	Pyralidae	TL				
Carcharodus alceae	R Hesperiidae	TL	TL	Vila et al. 2018	TL	
Carcharodus baeticus	R Hesperiidae	TL	TL			
Carcharodus flocciferus	R Hesperiidae			Vila et al. 2018	TL	
Carcharodus lavatherae	R Hesperiidae	TL				
Erynnis tages	R Hesperiidae	TL				
Hesperia comma	R Hesperiidae				TL	
Ochlodes sylvanus	R Hesperiidae	TL	TL	Vila et al. 2018	TL	
Prgus alveus	R Hesperiidae			Vila et al. 2018		
Pyrgus armoricanus	R Hesperiidae	TL	TL	Vila et al. 2018	TL	
Pyrgus carthami	R Hesperiidae					La Bisbal 1972 (Pérez De-Gregorio & Rondos 2003)
Pyrgus cirsii	R Hesperiidae				Carbonell & Lockwood 2007	
Pyrgus malvoides	R Hesperiidae	TL	TL	Vila et al. 2018	TL	
Spialia sertorius	R Hesperiidae	TL	TL		TL	
Thymelicus acteon	R Hesperiidae	TL	TL	TL		
Thymelicus lineola	R Hesperiidae				TL	
Thymelicus sylvestris	R Hesperiidae				TL	
Lycaena alciphron	R Lycaenidae			Vila et al. 2018		
Lycaena phlaeas	R Lycaenidae	TL	TL	TL	TL	
Lycaena tityrus	R Lycaenidae				TL	
Tomares ballus	R Lycaenidae	TL				
Aricia agestis	R Lycaenidae	TL	TL	Vila et al. 2018	TL	
Cacyreus marshalli	R Lycaenidae	TL	TL	Vila et al. 2018	TL	
Celastrina argiolus	R Lycaenidae	TL	TL	TL	TL	
Cupido alcetas	R Lycaenidae				TL	

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Cupido argiades	R Lycaenidae			Vila et al. 2018	TL	
Cupido minimus	R Lycaenidae				TL	
Cupido osiris	R Lycaenidae				TL	
Cyaniris semiargus	R Lycaenidae					La Bisbal (coll. Swietek)
Glaucopsyche alexis	R Lycaenidae	TL			TL	
Glaucopsyche melanops	R Lycaenidae	TL			PE	
Lampides boeticus	R Lycaenidae	TL	TL	TL	TL	
Leptotes pirithous	R Lycaenidae	TL	TL	TL	TL	
Lysandra bellargus	R Lycaenidae	TL		TL	TL	
Lysandra coridon	R Lycaenidae					Alt Empordà (Vila et al. 2018)
Lysandra hispana	R Lycaenidae	TL		Vila et al. 2018	TL	
Plebejus argus	R Lycaenidae	TL	TL		TL	
Polyommatus amandus	R Lycaenidae				PE	
Polyommatus damon	R Lycaenidae				Browning et al. 2005	
Polyommatus escheri	R Lycaenidae	TL				
Polyommatus icarus	R Lycaenidae	TL	TL	Vila et al. 2018	TL	
Polyommatus thersites	R Lycaenidae				TL	
Pseudophilotes panoptes	R Lycaenidae	TL		Vila et al. 2018		
Scolitantides orion	R Lycaenidae				Browning et al. 2005	
Callophrys avis	R Lycaenidae	TL		Vila et al. 2018	PE	
Callophrys rubi	R Lycaenidae	TL	TL	TL	TL	
Laeosopis roboris	R Lycaenidae			Vila et al. 2018	TL	
Neozephyrus quercus	R Lycaenidae	TL	TL	Vila et al. 2018	TL	
Satyrium acaciae	R Lycaenidae				TL	
Satyrium esculi	R Lycaenidae	TL		TL	TL	
Satyrium ilicis	R Lycaenidae					Gavarres (Pérez De-Gregorio & Rondos 2003)
Satyrium spini	R Lycaenidae				TL	
Satyrium w-album	R Lycaenidae		Vila et al. 2018		Carbonell & Lockwood 2007	
Thecla betulae	R Lycaenidae				TL	
Aglais io	R Nymphalidae	TL	TL	Vila et al. 2018	TL	
Aglais urticae	R Nymphalidae	TL	PE	Vila et al. 2018	TL	
Apatura ilia	R Nymphalidae			Vila et al. 2018	TL	
Apatura iris	R Nymphalidae				Browning et al. 2005	
Araschnia levana	R Nymphalidae				Vila et al. 2018	
Argynnis adippe	R Nymphalidae				TL	
Argynnis aglaja	R Nymphalidae				TL	
Argynnis pandora	R Nymphalidae			TL	TL	
Argynnis paphia	R Nymphalidae	López 2014	Vila et al. 2018	TL	TL	
Boloria dia	R Nymphalidae				TL	
Boloria euphrosyne	R Nymphalidae				Lockwood & Carbonell 2010	
Boloria selene	R Nymphalidae				Lockwood & Carbonell 2010	
Brenthis daphne	R Nymphalidae				Browning et al. 2005	
Charaxes jasius	R Nymphalidae	TL		Vila et al 2018	TL	
Danaus chrysippus	R Nymphalidae	TL	TL			
Danaus plexippus	R Nymphalidae		Vila et al. 2018			
Euphydryas aurinia	R Nymphalidae	Lopez 2014		TL		
Issoria lathonia	R Nymphalidae	TL	Vila et al. 2018	TL	TL	
Libythea celtis	R Nymphalidae	TL		TL	TL	
Limenitis camilla	R Nymphalidae				TL	
Limenitis reducta	R Nymphalidae	TL		Vila et al. 2018	TL	
Melitaea (athalia) nevadensis	R Nymphalidae			Vila et al. 2018	TL	
Melitaea cinxia	R Nymphalidae			Vila et al. 2018	TL	
Melitaea deione	R Nymphalidae	Vicens et al. 1987		Vila et al. 2018	TL	
Melitaea diamina	R Nymphalidae				Lockwood in litt.	

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Melitaea didyma	R Nymphalidae	Vicens et al. 1987	TL	Vila et al. 2018	TL	
Melitaea parthenoides	R Nymphalidae				TL	
Melitaea phoebe	R Nymphalidae	TL		Vila et al. 2018	TL	
Nymphalis antiopa	R Nymphalidae			TL	TL	
Nymphalis polychloros	R Nymphalidae	TL	Vila et al. 2018	Vila et al. 2018		
Polygonia c-album	R Nymphalidae	TL	TL	Vila et al. 2018	TL	
Vanessa atalanta	R Nymphalidae	TL	TL	TL	TL	
Vanessa cardui	R Nymphalidae	TL	TL	TL	TL	
Aphantopus hyperantus	R Nymphalidae Satyrinae				TL	
Arethusana arethusa	R Nymphalidae Satyrinae				TL	
Brintesia circe	R Nymphalidae Satyrinae	TL	TL	Vila et al. 2018	TL	
Coenonympha arcania	R Nymphalidae Satyrinae				TL	
Coenonympha dorus	R Nymphalidae Satyrinae			Vila et al. 2018		
Coenonympha glycerion	R Nymphalidae Satyrinae				Lockwood in litt.	
Coenonympha pamphilus	R Nymphalidae Satyrinae	TL	TL	Vila et al. 2018	TL	
Erebia meolans	R Nymphalidae Satyrinae				TL	
Erebia neoridas	R Nymphalidae Satyrinae				Vila et al. 2018	
Erebia triaria	R Nymphalidae Satyrinae				Lockwood & Carbonell 2010	
Hipparchia fagi	R Nymphalidae Satyrinae			Vila et al. 2018	TL	
Hipparchia fidia	R Nymphalidae Satyrinae	TL		Vila et al. 2018		
Hipparchia semele	R Nymphalidae Satyrinae	TL		Vila et al. 2018	TL	
Hipparchia statilinus	R Nymphalidae Satyrinae	TL	TL	Vila et al. 2018	TL	
Lasiommata maera	R Nymphalidae Satyrinae	Vicens et al. 1987			TL	
Lasiommata megera	R Nymphalidae Satyrinae	TL	TL	Vila et al. 2018	TL	
Maniola jurtina	R Nymphalidae Satyrinae	TL	TL	TL	TL	
Melanargia lachesis	R Nymphalidae Satyrinae	TL	TL	Vila et al. 2018	TL	
Melanargia occitanica	R Nymphalidae Satyrinae	TL		TL		
Pararge aegeria	R Nymphalidae Satyrinae	TL	TL	TL	TL	
Pyronia bathseba	R Nymphalidae Satyrinae	TL	TL	TL	TL	
Pyronia cecilia	R Nymphalidae Satyrinae	TL	TL	Vila et al. 2018		
Pyronia tithonus	R Nymphalidae Satyrinae	TL	TL	Vila et al. 2018	TL	
Satyrus actaea	R Nymphalidae Satyrinae			Vila et al. 2018	TL	
Iphiclides feisthamelii	R Papilionidae	TL	TL	TL	TL	
Papilio machaon	R Papilionidae	TL	TL	TL	TL	
Zerynthia rumina	R Papilionidae	TL	TL	Vila et al. 2018		
Anthocharis cardamines	R Pieridae	TL	TL	Vila et al. 2018	TL	
Anthocharis euphenoides	R Pieridae	TL				
Aporia crataegi	R Pieridae			TL	TL	
Colias alfacariensis	R Pieridae	TL			TL	
Colias crocea	R Pieridae	TL	TL	TL	TL	
Euchloe crameri	R Pieridae	TL	TL	TL		
Gonepteryx cleopatra	R Pieridae	TL	TL	TL	TL	
Gonepteryx rhamni	R Pieridae	TL	TL	Vila et al. 2018	TL	
Leptidea reali	R Pieridae					Roses (Vila et al. 2018), S'Agaro (Lorkovic 1993)
Leptidea sinapis	R Pieridae	TL	TL	Vila et al. 2018	TL	
Pieris brassicae	R Pieridae	TL	TL	Vila et al. 2018	TL	
Pieris mannii	R Pieridae	TL	TL	Vila et al. 2018	Browning et al. 2005	
Pieris napi	R Pieridae	TL	TL		TL	
Pieris rapae	R Pieridae	TL	TL	TL	TL	
Pontia daplidice	R Pieridae	TL	TL	TL	TL	
Hamearis lucina	R Riodinidae				Vila et al. 2018	
Actias isabellae	Saturnidae				TL	
Saturnia pavonia	Saturnidae	TL		MP		
Saturnia pyri	Saturnidae			MP	PE	
Enolmis cf acanthella	Scythrididae	TL				

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Scythris cf apicalis	Scythrididae	TL				
Scythris limbella	Scythrididae	TL				
Scythris scopolella	Scythrididae	TL				
Bembecia uroceriformis	Sesiidae	TL				
Chamaesphecia sp.	Sesiidae	TL				
Paranthene tabaniformis	Sesiidae	TL				
Pyropteron chrysidiformis	Sesiidae			MP		
Pyropteron meriaeformis	Sesiidae			MP		
Sesia apiformis	Sesiidae	TL				
Synanthedon codeti	Sesiidae	TL				
Synanthedon myopaeformis	Sesiidae			MP		
Acherontia atropos	Sphingidae	TL	Masó & Valhonrat 1989	MP		
Agrius convolvuli	Sphingidae	TL		MP		
Daphnis nerii	Sphingidae					La Bisbal (Pérez De-Gregorio & Rondos 2003)
Deilephila elpenor	Sphingidae	TL	Masó & Valhonrat 1989	EC		
Deilephila porcellus	Sphingidae			MP		
Hemaris fuciformis	Sphingidae	TL			TL	
Hemaris tityus	Sphingidae				TL	
Hippotion celerio	Sphingidae	TL		MP		
Hyles euphorbiae	Sphingidae	TL		MP	TL	
Hyles livornica	Sphingidae	TL		MP		
Laothoe populi	Sphingidae	TL		MP	TL	
Macroglossum stellatarum	Sphingidae	TL	TL	MP	TL	
Marumba quercus	Sphingidae	TL		MP	TL	
Mimas tiliae	Sphingidae	TL		MP	PE	
Proserpinus proserpina	Sphingidae		Pérez De-Gregorio & Rondos 2003	MP		La Bisbal (Pérez De-Gregorio & Rondos 2003)
Smerinthus ocellata	Sphingidae	TL	Masó & Valhonrat 1989	MP		
Sphinx ligustri	Sphingidae			MP	PE	
Sphinx maurorum	Sphingidae	TL	Masó & Valhonrat 1989	MP	TL	
Thyris fenestrella	Thyrididae			MP		
Anomalotinea liguriella	Tineidae	TL				
Ateliotum insulare	Tineidae	TL				
Ateliotum petrinellum	Tineidae	TL				
Elatobia fuliginosella	Tineidae	TL				
Eudarcia glaseri	Tineidae					Cap Creus (Gaedike 2015)
Eudarcia leopoldella	Tineidae	TL				Pals (Gaedike 2015)
Infurcitinea atrifasciella	Tineidae	TL				
Monopis crocicapitella	Tineidae	TL				Port Bou (Requena 2003)
Monopis imella	Tineidae	TL				
Monopis laevigella	Tineidae	TL				
Monopis nigricantella	Tineidae	TL				
Monopis obviella	Tineidae	TL			TL	
Morophaga morella	Tineidae	TL				
Myrmecozela ataxella	Tineidae	TL				
Nemapogon agenjoi	Tineidae	TL				
Nemapogon cf inconditella	Tineidae	TL				
Nemapogon nevadella	Tineidae	TL				
Neurothaumasia ankerella	Tineidae	TL				
Niditinea fuscella	Tineidae	TL				
Stenoptinea cyaneimarmorella	Tineidae	TL				
Tenaga cf nigripunctella	Tineidae	TL				
Tinea basifasciella	Tineidae	TL				
Tinea murariella	Tineidae	TL				
Tinea pellionella	Tineidae	TL				

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Tinea trinotella	Tineidae	TL			PE	
Trichophaga bipartitella	Tineidae	TL				
Trichophaga tapetzella	Tineidae	TL				
Coptotriche angusticolella	Tischeriidae	TL				
Coptotriche marginea	Tischeriidae	TL			TL	
Acleris cristana	Tortricidae				PE	
Acleris literana	Tortricidae			MP		
Acleris loeflingiana	Tortricidae	TL				
Acleris sparsana	Tortricidae			MP		
Acleris variegana	Tortricidae	TL			TL	
Acroclita subsequana	Tortricidae	TL				
Aethes bilbaensis	Tortricidae	TL		TL		
Aethes deaurana	Tortricidae	TL				
Aethes margarotana	Tortricidae	TL				
Aethes williana	Tortricidae	TL				
Agapeta angelana	Tortricidae		Requena et al. 2011			
Agapeta zoegana	Tortricidae				TL	
Ancylis apicella	Tortricidae	TL				
Ancylis badiana	Tortricidae			EC	TL	
Aneuxanthis locupletana	Tortricidae					Palamos, Tamariu (Ylla et al. 2011)
Archips crataegana	Tortricidae					Palamos (Ylla et al 2011)
Archips podana	Tortricidae					Palamos (Ylla et al 2011)
Archips rosana	Tortricidae		Requena et al. 2011			
Archips xylosteana	Tortricidae	TL		MP	TL	
Argyrotaenia ljungiana	Tortricidae				TL	
Bactra bactrana	Tortricidae	TL	Requena et al. 2011			
Bactra lancealana	Tortricidae	TL				
Cacoecimorpha pronubana	Tortricidae	TL		MP	TL	
Clavigesta purdeyi	Tortricidae	TL			TL	
Clavigesta sylvestrana	Tortricidae					Tamariu (Ylla et al 2011)
Clepsis consimilana	Tortricidae	TL		TL	TL	
Clepsis coriacanus	Tortricidae	TL		MP		
Clepsis pallidana	Tortricidae	TL				
Cnephasia cf ecullyana	Tortricidae	TL				
Cnephasia communana	Tortricidae	TL		TL		
Cnephasia pasiusana	Tortricidae	TL				
Cochylimorpha cultana	Tortricidae					Ampuries (TL)
Cochylimorpha decolorella	Tortricidae			EC		
Cochylimorpha halophilana	Tortricidae	TL				
Cochylimorpha meridiana	Tortricidae	TL				
Cochylis molliculana	Tortricidae	TL				
Crocidosema plebejana	Tortricidae	TL		MP		
Cydia amplana	Tortricidae	TL				
Cydia fagiglandana	Tortricidae	TL				
Cydia pomonella	Tortricidae	TL		MP	TL	
Cydia splendana	Tortricidae	TL				
Cydia succedana	Tortricidae		Requena et al. 2011			
Cydia trangulella	Tortricidae					Palamos (Ylla et al 2011)
Ditula angustiorana	Tortricidae	TL				
Endothenia gentianaeana	Tortricidae	TL				
Endothenia marginana	Tortricidae					Palamos (Ylla et al 2011)
Epagoge grotiana	Tortricidae				TL	
Epinotia dalmatana	Tortricidae	TL				
Epinotia festivana	Tortricidae					Palamos (Ylla et al 2011)
Epinotia nisella	Tortricidae	TL			TL	
Epinotia rubiginosana	Tortricidae				TL	

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Epinotia thapsiana	Tortricidae	TL			TL	
Eucosma cana	Tortricidae				TL	
Eucosma cf fulvana	Tortricidae	TL			TL	
Eucosma conformana	Tortricidae	TL				
Eucosma conterminana	Tortricidae	TL				
Eucosma fervidana	Tortricidae	TL				
Eucosma hohenwarthiana	Tortricidae				TL	
Eucosma obumbratana	Tortricidae	TL				
Eudemis profundana	Tortricidae					Tamariu (Ylla et al 2011)
Grapholita funebrana	Tortricidae	TL				
Grapholita molesta	Tortricidae	TL				
Gravitarmata margarotana	Tortricidae	TL				
Gynnidimorpha rubricana	Tortricidae	TL				
Gypsonoma aceriana	Tortricidae	TL				
Hedya nubiferana	Tortricidae			TL	TL	
Hedya pruniana	Tortricidae			TL		
Isotrias rectifasciana	Tortricidae				TL	
Isotrias stramentana	Tortricidae				TL	
Lobesia bicinctana	Tortricidae		Requena et al. 2011			
Lobesia botrana	Tortricidae	TL				
Lobesia indusiana	Tortricidae	TL				
Lobesia cf limoniana	Tortricidae	TL				
Lobesia littoralis	Tortricidae		Masó & Valhonrat 1989			
Lozotaenia cupidinana	Tortricidae		Requena et al. 2011			
Lozotaeniodes cupressana	Tortricidae	TL				
Lozotaeniodes formosana	Tortricidae				TL	
Notocelia cynosbatella	Tortricidae	TL		EC	TL	
Notocelia incarnatana	Tortricidae	TL				
Olethreutes arcuella	Tortricidae				TL	
Oxypteron schawerdai	Tortricidae	TL				
Pammene argyrana	Tortricidae	TL				
Pandemis corylana	Tortricidae				TL	
Pandemis dumetana	Tortricidae	TL	Masó & Valhonrat 1989			
Pandemis heparana	Tortricidae					Jafre (TL)
Paramesia alhamana	Tortricidae	TL				
Paramesia gnomana	Tortricidae					Palamos (Ylla et al 2011)
Pelochrista caecimaculana	Tortricidae		Masó & Valhonrat 1989			
Pelochrista infidana	Tortricidae	TL				
Pelochrista mollitana	Tortricidae					Palamos (Ylla et al 2011)
Periclepsis cinctana	Tortricidae				TL	
Phalonidia albipalpana	Tortricidae	TL	Masó & Valhonrat 1989			
Phalonidia contractana	Tortricidae	TL				
Phaneta pauperana	Tortricidae	TL		MP		
Phteochroa rugosana	Tortricidae	TL		MP		
Phteochroa simoniana	Tortricidae					Tamariu (Ylla et al 2011)
Piniphila bifasciana	Tortricidae	TL			TL	
Pseudargyrotoza conwagana	Tortricidae					
Pseudococcyx tessulatana	Tortricidae	TL		EC		
Pseudococcyx turionella	Tortricidae	TL				
Pseudosciaphila branderiana	Tortricidae				PE	
Rhyacionia buoliana	Tortricidae	TL		MP	TL	
Rhyacionia duplana	Tortricidae				TL	
Rhyacionia maritimana	Tortricidae	TL				
Rhyacionia miniatana	Tortricidae				TL	
Rhyacionia pinicolana	Tortricidae				TL	
Rhyacionia pinivorana	Tortricidae	TL			TL	

Species	Family	Montgrí-Baix Ter	Aiguamolls	Albera	upper valleys	other sites
Selania resedana	Tortricidae	TL				
Sparganothis pilleriana	Tortricidae					Tamariu (Ylla et al 2011)
Thiodia trochilana	Tortricidae	TL				
Tortricoides alternella	Tortricidae	TL			TL	
Tortrix viridana	Tortricidae	TL		MP	TL	
Xerocnephasia rigana	Tortricidae	TL				
Zeiraphera isertana	Tortricidae		Requena et al. 2011			
Cedestis gysseleniella	Yponomeutidae				TL	
Cedestis subfasciella	Yponomeutidae	TL				
Parahyponomeuta egregiella	Yponomeutidae	TL				
Paraswammerdamia albicapitella	Yponomeutidae	TL				
Pseudoswammerdamia combinella	Yponomeutidae	TL				
Yponomeuta evonymella	Yponomeutidae	TL				
Yponomeuta padella	Yponomeutidae	TL				
Yponomeuta sedella	Yponomeutidae				TL	
Zelleria oleastrella	Yponomeutidae	TL				
Ypsolopha divisella	Ypsolophidae	TL				
Ypsolopha mucronella	Ypsolophidae	TL				
Aglaope infausta	Zygaenidae			MP		
Zygaena fausta	Zygaenidae	TL				
Zygaena filipendulae	Zygaenidae				TL	
Zygaena hilaris	Zygaenidae				TL	
Zygaena lavandulae	Zygaenidae	TL			TL	
Zygaena occitanica	Zygaenidae	TL		MP		
Zygaena rhadamanthus	Zygaenidae				TL	
Zygaena romeo	Zygaenidae				TL	
Zygaena sarpedon	Zygaenidae	TL				
Zygaena transalpina	Zygaenidae				TL	
Zygaena trifolii	Zygaenidae	TL	TL			

Acknowledgements

TL wants to thank Pierre-Yves Gourvil (Billère, France) for sending the statement from the Swietek collection, Mike Lockwood (Besalu, Spain) who sent unpublished records from northwest Empordà and Philippe Mothiron (Verneuil-sur-Seine, France) for identifying several Sesiidae and other moths from the Montgrí.

References

Abos, L., 2015. Checklist to the Lepidopters of the Albera (unpublished).

Arnscheid, W.R. & M. Weidlich, 2017. Microlepidoptera of Europe Vol. 8 Psychidae. Brill, Leiden.

Baldizzone, G., 1986. Contributions à la connaissance des Coleophoridae. XLII. Sur quelques Coleophoridae d'Espagne (Seconde partie : Espèces nouvelles pour la Faune espagnole, ou peu connues). Nota lepidopterologica 9 (1-2):2-34.

Bellavista, J., 1993. Contribució al coneixement dels Noctuidae de la Garrotxa (Catalunya) (Lepidoptera: Noctuidae). Sesión Entomológica ICHN-SCL 7 (1991):75-82.

Browning, P., R. Carbonell & M. Lockwood, 2005. Observacions interessants de ropalòcers (Lepidoptera: Hesperioidea, Papilionoidea) a l'EIN de l'Alta Garrotxa. Butlletí de la Societat Catalana de Lepidopterologia 95:37-40.

Carbonell, R. & M. Lockwood, 2007. Observacions interessants de ropalòcers (Lepidoptera: Hesperioidea, Papilionoidea) a l'EIN de l'Alta Garrotxa (II). Butlletí de la Societat Catalana de Lepidopterologia 97:59-62.

Dantart, J. & A. Cervello, 2008. Revisió de les espècies del gènere Earias Hübner, [1825], a Catalunya (Lepidoptera: Nolidae). Butlletí de la Societat Catalana de Lepidopterologia 99:17-46.

Dantart, J. & J. Jubany, 2007. Resultats de les segones Nits de les Papallones (Catalan Moth Nights): 1 a 3 de juliol de 2005. Butlletí de la Societat Catalana de Lepidopterologia 97:9-36.

Dantart, J. & J. Jubany, 2010. Resultats de les quartes Nits de les Papallones (Catalan Moth Nights): 11 a 15 d'octubre de 2007. Butlletí de la Societat Catalana de Lepidopterologia 101:19-38.

Gaedike, R., 2015. Microlepidoptera of Europe Vol. 7 Tineidae I. Brill, Leiden.

Gielis, C., 1996. Microlepidoptera of Europe Vol. 1 Pterophoridae. Apollo Books, Stenstrup.

Goater, B., M. Nuss & W. Speidel, 2005. Microlepidoptera of Europe Vol. 4 Pyraloidea I. Apollo Books, Stenstrup.

Huemer, P. & O. Karsholt, 2010. Microlepidoptera of Europe Vol. 6 Gelechiidae II. Apollo Books, Stenstrup.

Lockwood, M. & R. Carbonell, 2010. Observacions interessants de ropalocèrs (Lepidoptera: Hesperioidea, Papilionoidea) a l'EIN de l'Alta Garrotxa (III). Butlletí de la Societat Catalana de Lepidopterologia 101:95-100.

López, M., 2014. Memòria del seguiment de papallones diürnes (o Ropalòcers) amb la metodologia del CMBS (Catalan Butterfly Monitoring Scheme) a la Vall de Santa Caterina-Montgrí (temporada 2014). Associació per a la Conservació de l'Entorn i la Recerca, Montcada i Reixac.

Lorkovic, Z., 1993. Leptidea reali Reissinger, 1989 (= lorkovici Real, 1988), a new European species (Lepid. Pieridae). Natura Croatica 2 (1):1-26.

Marti, J., 2005. Anthracia ephialtes (Hübner, [1822]), noctuid nou per a la fauna catalana i altres citacions interessants (Lepidoptera: Noctuidae). Butlletí de la Societat Catalana de Lepidopterologia 94:41-45.

Masó, A. & F. Valhonrat, 1989. Els Lepidòpters dels Aiguamolls de l'Empordà In Sargatal, J. & J. Fèlix, Els Aiguamolls de l'Empordà. Quadern dels Indiketes, Figueres 3:295-305.

Maso, A., J.J. Pérez De-Gregorio & F. Vallhonrat i Figueras, 1992. Les lépidoptères des marais d'Empordà (Catalogne). Nota lepidopterologica Suppl. No 3:43-52.

Muñoz, J., L. Abós, J. Pibernat & J. Plana, 2011. Troballa de Ptilophora plumigera ([Denis & Schiffermüller], 1775) (Lepidoptera: Notodontidae) al Pirineu Oriental de l'Alt Empordà. Butlletí de la Societat Catalana de Lepidopterologia 102:107-108.

Nieukerken, E.J. van, A. Lastuvka & Z. Lastuvka, 2004. Annotated catalogue of the Nepticulidae and Opostegidae of the Iberian Peninsula (Lepidoptera: Nepticuloidea). SHILAP Revista de Lepidopterología 32 (127):211-260.

Pérez De-Gregorio, J.J., 1977. Anotaciones a la Lepidopterología gerundense. Revista de Girona 79:151-160.

Pérez De-Gregorio, J.J., 2001. Fauna lepidopterològica de la serra de les Gavarres (segona part). Sesión Entomológica ICHN-SCL XXX:405-410.

Pérez De-Gregorio, J.J., J. Muñoz Batet & M. Rondós Casas, 2008. Noctuidae nous o interessants per a la fauna catalana i ibèrica, IX (Lepidoptera). Butlletí de la Societat Catalana de Lepidopterologia 99:47-53.

Pérez De-Gregorio, J.J. & M. Rondós, 2003 (2005). Fauna lepidopterològica de la serra de les Gavarres (I). Sesión Entomológica ICHN-SCL 13:13-35.

Pérez De-Gregorio, J.J. & M. Rondós i Casas, 2005. Algunes troballes noves o interessants de Noctuidae a Catalunya (Lepidoptera: Noctuidae). Butlletí de la Societat Catalana de Lepidopterologia 94:111-114.

Pérez De-Gregorio, J.J., R. Orozco, R. Sanchis & E. Requena Miret, 2005. Microlepidoptera (Pyralidae, Crambidae) nous o interessants per a la fauna catalana i ibèrica (VI). Butlletí de la Societat Catalana de Lepidopterologia 94:73-79.

Pérez De-Gregorio, J.J. & E. Requena Miret, 2008. Microlepidòpters (Pyralidae, Crambidae) nous o interessants per a la fauna catalana i iberobalear (VIII) (Lepidoptera). Sesión Entomológica ICHN-SCL 13-14 (2003-2007):91-106.

Requena, E., 1999. Noves dades sobre la distribució del gènere Agdistis Hübner, [1825], a Catalunya (Lepidoptera: Pterophoridae). Butlletí de la Societat Catalana de Lepidopterologia 84:9-16.

Requena, E., 2003. Tineidae nous per a la comarca de l'Anoia i la Península Ibèrica (Lepidoptera: Tineidae). Butlletí de la Societat Catalana de Lepidopterologia 90:15-19.

Requena, E., 2009. Aproximació a la fauna dels gelèquids de Catalunya i Balears (Lepidoptera: Gelechiidae). Treballs de la Societat Catalana de Lepidopterologia 16:5-77.

Stefanescu C. & M. Miralles, 1992. Troballa de Brythis crini pancratii Cyrillo, 1787 (Noctuidea: Hadeninae) al Parc Natural dels Aiguamolls de l'Empordà. Butlletí de la Societat Catalana de Lepidopterologia 72:39-41.

Vicens, N., X. Quintana & D. Sunyer, 1987. Anotacions sobre el coneixement dels lepidopters ropalocers del massis del Montgrí. Scientia gerundensis 13:135-141.

Vila, R., C. Stefanescu & J.M. Sesma, 2018. Guia de les papallones diürnes de Catalunya. Lynx Edicions, Barcelona.

Ylla I Ullstre, J., 1997. Contribució al coneixement del Heterocers de l'Estany de Banyoles (Insecta: Lepidoptera). Sesión Entomológica ICHN-SCL 9 (1995):5-22.

Ylla, J., E. Requena & R. Macia, 2011. Catàleg actualizat dels tortricids de Catalunya (Lepidoptera Tortricidae). Butlletí de la Societat Catalana de Lepidopterologia 102:15-66.

can Quintana
Museu de la Mediterrània

Parc Natural
del Montgrí, les Illes Medes
i el Baix Ter

Universitat de Girona
Càtedra d'Ecosistemes
Litorals i Mediterranis

Diputació de Girona

Ajuntament de
Torroella de Montgrí

Generalitat de Catalunya
Departament de Territori
i Sostenibilitat

Fundació Girona
Regió de Coneixement
Universitat de Girona
Diputació de Girona
Ajuntament de Girona
Consell Social de la UdG
Cambra de Comerç

MUSEU
DE CIÈNCIES NATURALS
DE GRANOLLERS