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cynthia

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Cover

Detail of the upperside of Provence Chalk-hill Blue *Polyommatus hispana* (photo: A. Miquel).

Small White *Pieris rapae* on barley spike (photo: J.C. Vicente Arranz).

Editorial

Cynthia celebrates its tenth edition

This edition of *Cynthia*, the annual review of the CBMS network, is the tenth to see the light of day. Over the past 10 years, *Cynthia* has consolidated its position as an attractive, rigorous work that provides a wealth of information – not only for CBMS collaborators, but also for others interested in this wonderful group of insects – regarding progress in the study of the ecology and conservation of butterflies in Catalonia, Andorra and the Balearic Islands. From the outset, we have tried to establish a balance between purely descriptive information relating to the workings of the CBMS and articles with pedagogical content or that discuss advances in the study of Catalan butterflies. Of the more educational content, to date we have published identification sheets for 59 species (almost a third of all butterflies in Catalonia) and articles summarizing knowledge of the ecology of a further 11 species. Data from the CBMS network has been essential in this task of providing new information about these species.

In this tenth edition, we shine the spotlight on the Swallowtail *Papilio machaon*, one of the most spectacular of all our butterflies. This species appears in practically all the CBMS itineraries, even those in the Balearic Islands and in high mountain areas, and as such, it is one of the most familiar of all Catalan butterflies. Nevertheless, we hope that all will learn something new about its biology and ecology from this article and thus be able to view this wonderful species through different eyes. As well, in this edition you will find all the habitual sections that we have maintained over the past 10 years. We would like to thank all of those who have provided us with the photographs and drawings that accompany the texts, an essential part of *Cynthia* and one that guarantees an attractive design that cannot fail to increase interest in the world of the butterflies.

Finally, we are pleased to be able to announce in these difficult times the consolidation of the CBMS project thanks to the signing of a four-year agreement between the Museu de Granollers – Ciències Naturals and the Catalan Government. This agreement will ensure that there will be sufficient funding to continue the efficient running of the CBMS and that all the data collected will be analyzed rigorously in order to extract as much relevant information as possible.

Current situation (2010) of the Butterfly Monitoring Scheme in Catalonia, Andorra and the Balearic Islands

In all, 69 stations provided complete data during the 17th CBMS season. Four new stations were incorporated into the Scheme, while at a further four stations preliminary but regular counts were undertaken. The majority of the stations in the BMSAnd network and on Menorca and Eivissa continued to function. In total, 142,426 butterflies belonging to 164 species were counted in 2010.

During the 2010 season counts at 69 stations provided sufficient data to calculate the annual indexes of the species found (fig. 1). As well, preliminary counts have continued at Llobera (Solsonès, 850 m), Planes de Son (Pallars Sobirà, 1,540 m) – these two stations will form part of the network from 2011 onwards – and Moià (Bages, 700 m), while a new count was begun at Meandre de Castellbell (Bages, 150 m).

The available annual series are shown in figure 2. There are currently 47 stations for which datasets of eight or more years are available. The Cortalet station is the oldest in the network (dataset going back 22 years) and a further five stations have already provided data continuously for 17 years. These figures give some idea of the ability of the CBMS database to detect population trends operating at mid- and long-terms.

New transects

Sils (La Selva, 66 m). This butterfly walk takes place in and around L'Estany de Sils, a lake whose basin has largely been drained, and as such hygrophil communities are well represented (*Magnocaricion* grassland communities and hay meadows). Nevertheless, the itinerary is quite diverse and includes areas of pasture, meadows, scrub and poplar and holm-oak woodland and, as a result, the butterfly community is also fairly diverse despite being located in a lowland area. Counts have revealed the presence of butterflies that are scarce outside of upland areas - Glanville Fritillary *Melitaea cinxia*, Violet Fritillary *Boloria dia* and Black-veined White *Aporia crataegi* – and a remarkable population of Spanish Festoon *Zerynthia rumina* in an area of acid substrate, as well as occasional sightings of Lesser Purple Emperor *Apatura ilia* and Mediterranean Skipper *Gegenes nostrodamus*. Part of the walk passes through land that is managed by a stewardship agreement with the association Acciónatura; counts are carried out by Antoni Mariné, a member of this association.

El Brull (Osona, 832 m). This itinerary was started as a substitute for the Viladrau walk that was outside the limits of the Montseny Natural Park. This new itinerary runs through more Mediterranean habitats, dominated by holm oaks, although there are still plenty of pasture and grassland that ensure that the diversity of butterfly species is very high. Given that the substrate of the itinerary is calcareous, this area holds one of the richest butterfly assemblages in the whole of the Montseny. The Lycaenidae are particularly well represented and include interesting species such as Small Blue *Cupido minimus*, Catalan Furry Blue *Polyommatus fulgens*, Mazarine Blue *P. semiargus*, Chapman's Blue *P. thersites* and Escher's Blue *P. escheri*, as well as many members of the genus *Melitaea* and other species that are scarce in the CBMS network as a whole. The counts are carried out by Arnau Amat.

Vacarisses (Vallès Occidental, 325 m). This walk passes through woodland near the town of Vacarisses that is dominated by scattered holm oaks and pines. Although the butterfly communities are rather poor, there is still a large number of Marsh Fritillaries *Euphydryas aurinia*, and populations of rare species such as Provence Hairstreak *Tomares ballus* and Dingy Skipper *Erynnis tages*. The counts are carried out by José Manuel Sesma.

Sant Feliu de Pallerols (La Garrotxa, 430 m). This new itinerary is situated on a south-facing slope in La Garrotxa Volcanic Zone Natural Park in an area of pasture and holm and downy oak woodland. It is very rich in butterflies as the around 70 species of butterflies counted in the first season testify. Both Lycaenidae and Nymphalidae are abundant, and there are good populations of species that have generally more northerly distributions in Catalonia such as Provençal Short-tailed *Cupido alcetas* and Short-tailed *C. argiades* Blues, Sloe Hairstreak *Satyrium acaciae*, Turquoise *Polyommatus dorylas* and Chalkhill *P. coridon* Blues, Map Butterfly *Araschnia levana* and White Admiral *Limenitis camilla*, although more southerly species such as Provence Hairstreak *Tomares ballus*, Two-tailed Pasha *Charaxes jasius*, Striped Grayling *Hipparchia fidia* and Spanish Gatekepeer *Pyronia bathseba* also appear. The counts are carried out by Beth Cobo.

Compared to 2009, there were four more active stations in 2010 and the total number of active transects now approaches the 70 stations that were walked in 2007 and 2008. In 2010 walks were discontinued at four sites: El Remolar, Olivella, Pessons and Viladrau. The transect at Olivella alternates annually with those of Vallgrassa and Olesa de Bonesvalls, while the station of Viladrau has been replaced by that of El Brull (see above). At both El Remolar and Pessons the walks have been discontinued due to a problem of staffing in these two protected area. The loss of data from Pessons is very unfortunate since this walk was the highest in the whole network and was very representative of alpine environments in Andorra. On the other hand, the stations at Olesa de Bonesvalls, La Granja d'Escarp and L'Aiguabarreig (the latter two in El Segrià) were all reactivated in 2010.

Habitats represented

The main environments and plant communities represented in the 2010 counts are detailed in table 1. The predominance of the Mediterranean environments – above all the various different types of holm oak woodland (54 of itineraries) – continues, although the number of upland montane habitats represented now stands at 13 itineraries (20% of total). Subalpine habitats are still poorly represented, a situation that has been worsened by the loss of the

Pessons (Andorra) itinerary, one of the network's most valuable stations.

Species present

The list of butterflies detected in 2010 and in previous years can be found in table 2. In all, 164 species were detected in 2010, four more than in the previous year and 26.5 more than the average for the period 1994-2009 (fig. 3). Two new species for the CBMS were recorded in 2010: Portuguese Dappled White *Euchloe tagis* (at Granja d'Escarp) and Mountain Argus *Aricia artaxerxes* (at Sant Maurici). Both could have been overlooked in previous years in these and other walks given their resemblance to other commoner species (i.e. Dappled White *Euchloe crameri* and Brown Argus *Aricia agestis*).

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[1] Folch i Guillèn, R., 1981. *La vegetació dels Països Catalans*. Ketres Editora, Barcelona.

[2] Karsholt, O. & Razowski, J., 1996. *The Lepidoptera of Europe. A Distributional Checklist.* Apollo Books, Stenstrup.

Fig. 1. Geographical situation of all the stations that have ever participated in the CBMS network (1994-2010), with their official number and name. Also shown are the generally accepted boundaries of the biogeographical regions present in Catalonia.[1]

Fig. 2. Distribution of the complete annual series available for all the different stations that have participated in the project (1988-2010).

Fig. 3. The number of species detected annually in the CBMS network (1994-2010).

Table 1. Habitats and plant communities represented in the CBMS in 2010, with the number of stations they appear in. Classification of the vegetation zones and plant communities as per reference 1.

Table 2. Butterfly species recorded in the CBMS network over the last 10 years (2001-2010). The number of stations at which a species has been recorded is indicated (out of a possible total of 42 in 2001, 41 in 2002, 46 in 2003, 51 in 2004, 52 in 2005, 64 in 2006, 70 in 2007 and 2008, 66 in 2009 and 69 in 2010). Taxonomy as per reference 2.

Photo 1. The Sils butterfly walk passes through a variety of environments, from Mediterranean scrub to humid hay meadows and riparian woodland (photo). This diversity is reflected in a wide-ranging butterfly community with species such as Spanish Festoon *Zerynthia rumina*, Mediterranean Skipper *Gegenes nostrodamus*, Lesser Purple Emperor *Apatura ilia* and Glanville Fritillary *Melitaea cinxia* (photo: A. Mariné).

Photo 2. Mediterranean Skipper *Gegenes nostrodamus* is a migrant species that has resident populations in the Llobregat delta and nearby areas. Despite being fairly scarce, over the years almost 150 individuals have been detected at 14 stations during the CBMS counts, data that will undoubtedly help to understand this species' migration patterns in Catalonia (photo: P. Luque).

Drawing. Despite being scarce and confined to the Pyrenees, the Purple Emperor *Apatura iris* is undergoing a surprising expansion in Catalonia in the last years. Until recently it was only known from the Vall d'Aran, but new records have located it in different areas of Pallars Sobirà, Andorra, Ripollès, La Garrotxa and Alt Empordà. To date, the only records from the CBMS-BMSAnd network are from Enclar and Gerri de la Sal (drawing: M. Miró).

Seventeenth year of the CBMS
Summary of the 2010 season

After three poor years, 2010 was a somewhat better season for Catalan butterflies as many species made a modest but marked recovery. Annual totals for False Ilex Hairstreak *Satyrium esculi* were the highest since monitoring began and, once again, this hairstreak was the commonest butterfly in the Catalan CBMS network. Counts of Nettle Tree Butterfly *Libythea celtis* were also the highest ever as the positive tendency showed by this species' over the last decade continued. Spring species and the majority of browns were commoner than the year before, possibly as a result of the abundant winter and spring rainfall during the previous two years. On the other hand, it was a poor season for migratory species and others such as Two-tailed Pasha *Charaxes jasius* (whose totals were the lowest since 1994) that are particularly affected by frost and cold winters.

Weather and butterfly counts

In sharp contrast to the exceptionally warm 2009, 2010 was one of the coldest years of the last two decades in Catalonia (see www.meteocat.com). Heavy frosts occurred over much of the country in winter and the number of days with sub-zero temperatures was similar to that of 2005, one of the coldest winters in recent years. Most serious was the heavy snowfall that affected much of central and northeast Catalonia on March 8, right at the beginning of the CBMS season, which was followed by a number of very icey nights. In fact, much of the 2010 season was marked by cold wet weather, although April was dry and warm, July was very hot (above all the first fortnight) and August was more or less average with just a couple of days of intense heat (26 and 27). Although overall 2010 was a fairly wet year, rainfall was quite irregular and some areas had below-average annual figures (e.g. the far west of Catalonia and the *comarques* of Baix Ebre and Montsià), while others such as the northern coastline and the basin of the river Llobregat recorded rainfall figures that were well over annual averages.

In all, an average of 3.2 counts was lost per station in 2010, surprisingly fewer than in 2009 given the generally poor weather condition (fig. 1a). The most critical periods were the second week of March (affected by the exceptional snowfall over much of the northern half of the country), the first fortnight of May (very wet in eastern Catalonia) and the last week in September (when rain swept over much of the country) (fig. 1b).

Changes in abundances: general considerations

Compared to 2009, neither the number of species nor the number of individuals counted changed to any great extent in 2010. In terms of species richness, the average number of species and their standard deviations calculated for the 61 stations that provided comparable data were 47.6 ± 19.7 species per station in 2010, as opposed to 47.1 ± 19.3 in 2009 (Student Test for paired samples, t = 0.71, $P = 0.48$). Average abundances were 2132.8 ± 2073.4 individuals per station in 2010, as opposed to 2212.7 ± 1935.5 in 2009 (t = 0.90, $P = 0.37$). Overall, however, the populations of a number of species did increase slightly in relation to 2009, as is revealed by the species ranking for the season calculated using the annual indices of the 66 commonest species (fig. 2). This graphic shows that to a certain extent Catalan butterfly populations recovered in 2010 after the lowest-ever figures of the three previous years, caused possibly by the extreme drought in 2006–2008. Even so, recent population figures are still clearly lower than those recorded at the beginning of the 1990s (fig. 2).

Changes in abundances: fluctuations in populations

Of the commonest species in 2010, both Nettle-tree Butterfly *Libythea celtis* and False Ilex Hairstreak *Satyrium esculi* reached their highest annual indices since counts began in 1994. The case of the Nettle-tree Butterfly is especially remarkable since this positive trend is merely a continuation of the steady increase in this butterfly's numbers over the past decade that could be related to more frequent favourable winter conditions that ensure greater survival amongst hibernating adults.[2] It is also possible that the increase in the use of the southern nettle tree (*Celtis australis*) as an ornamental plant is favouring the breeding success of this species, ever commoner in Catalonia. The False Ilex Hairstreak is another species that in the previous two years benefitted from the generous late winter and spring rainfall, and for the second consecutive year it was one of the country's commonest butterflies (table 1). These rains also favoured the majority of browns, which were clearly commoner in 2010 than in 2009 (tables 1 and 2). Of note are the highest ever annual figures for Meadow Brown *Maniola jurtina* and the health of the country's populations of Great Banded Grayling *Brintesia circe*, whose numbers have been steadily and significantly increasing since the study period began.

As was to be expected, the season's generally low temperatures gave rise to low numbers of African migrants. The clearest examples are those of Painted Lady *Cynthia cardui* and Plain Tiger *Danaus chrysippus*, which were scarce everywhere and no exceptional migrations such as in the previous year were noted. For example, the Plain Tiger only appeared sporadically in the Ebro delta at the end of the season, despite having been one of the commonest species in 2009. Likewise, Bath White *Pontia daplidice*, Clouded Yellow *Colias crocea*, Large White *Pieris brassicae* and Small White *P. rapae*, as well as the Lycaenidae Lang's Short-tailed Blue *Leptotes pirithous* and Long-tailed Blue *Lampides boeticus,* were all rarer in 2010. The negative tendency in the Long-tailed Blue in Catalonia continued and its 2010 counts were the lowest ever for the species. The combination of a number of factors could have led to this situation: important mortality amongst over-wintering larvae due to the severe frosts, few adults migrants arriving in spring, and poor breeding success of these migrants in what was a cool summer.

The impact of these recent cold winters could also explain the serious drop in numbers of Two-tailed Pasha *Charaxes jasius*, whose annual index in 2010 was the lowest since counts began. This species' larvae do not hibernate fully in winter and as such they are very vulnerable to cold snaps, as has been shown in previous years.[3] On the other hand, low winter temperatures do not seem to have affected species that hibernate as adults (e.g. Camberwell Beauty *Nymphalis antiopa*, Large Tortoiseshell *N. polychloros*, Peacock *Inachis io*, Small Tortoiseshell *Aglais urticae*, Comma *Polygonia c-album*, Brimstone *Gonepteryx rhamni* and Cleopatra *G. cleopatra*), whose counts for 2010 were generally similar to previous years (or even slightly higher).

Finally, an incipient recovery in the populations of most spring species (e.g. Green Hairstreak *Callophrys rubi*, Panoptes Blue *Pseudophilotes panoptes*, Chequered Blue *Scolitantides orion*, Black-eyed Blue *Glaucopsyche melanops*, Spanish Festoon *Zerynthia rumina*, Orange-tip *Anthocharis cardamines* and Moroccan Orange-tip *A. euphenoides*) was noted in 2010, a welcome trend after the serious declines in these species recorded in previous years characterized by prolonged spring droughts.

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[1] Greatorex-Davies, J.N. & Roy, D.B., 2001. *The Butterfly Monitoring Scheme. Report to recorders, 2000*. 76 p. Centre for Ecology and Hydrology, Natural Environment Research Council, Huntingdon.

[2] Stefanescu, C., 2007. "*Libythea celtis*, la papallona del lledoner". *Cynthia*, 6: 19-22.

[3] Stefanescu, C. & Planes, J., 2003. "Com afecta el rigor de l'hivern les poblacions catalanes de *Charaxes jasius*". *Butll. Soc. Cat. Lep.*, 91: 31-48.

Fig. 1. (a) Coverage of the counts at the different CBMS stations, and (b) distribution of the lost counts during the official 30 weeks of the 2010 recording season (1 March–26 September).

Fig. 2. Ranking of the CBMS seasons in terms of the general abundance of the 66 commonest butterflies in the CBMS network. The best year to date was 1995, closely followed by 2002, and the worst 2008. Calculations were carried out using the methodology described in reference 1; annual indexes were calculated with the TRIM programme.

Table 1. Sum of the annual indexes and ranking of the abundance of the 20 commonest species from the 2010 CBMS season compared to the corresponding figures from the 2009 season.

Table 2. Evolution of the annual indexes for the 66 commonest butterflies in the CBMS network (2001–2010), based on an arbitrary value of 1 for 1994. Annual indexes were calculated with the TRIM programme.

Photo. The False Ilex Hairstreak was the most abundant butterfly in Catalonia in 2010. In early summer, huge concentrations of this butterfly on preferred nectar sources were a very common sight (photo: J.M. Sesma).

Drawing 1. The Great Banded Grayling *Brintesia circe* is a large, spectacular butterfly that is found throughout most of Catalonia. Since the beginning of the monitoring project it has tended to increase in numbers, although the reason for this trend is as yet unclear. It is found generally in open grassland and at some sites (e.g. Darnius and Sils) it is highly abundant. Maximum numbers are recorded at the end of spring and at the end of summer; nevertheless, these are not two separate generations since the spring butterflies aestivate in summer and are not detected by the CBMS counts (drawing: M. Miró).

Habitat management and conservation

How will global change affect the diversity of Catalan butterfly communities?

In this article, we analyse the diversity patterns of Catalan butterfly communities. The availability of water seems to be a key factor since aridity has a very powerful negative effect on species richness. The highest densities are found in upland areas where climatic conditions are optimum and landscapes have suffered very little intensification. The increase in temperatures and the loss of open spaces associated with global change could provoke a serious loss in species numbers and, above all, in specialist species (that is, butterflies with specific trophic and habitat requirements and low dispersive ability).

The study of diversity patterns in plants and animals is one of the disciplines that generates most interest in the fields of biogeography and theoretical ecology. An important number of studies have focussed on butterflies due to the existence of precise data regarding their distribution and abundance. It is currently possible to draw general conclusions regarding the main factors that explain observed patterns. Climate appears as the most important factor when analyses are conducted at regional and continental scale, although both habitat diversity and human influence (e.g. landscape degradation) have been identified in some cases as of equal importance.[1-2] At smaller scales, landscape structure plays an important role since the way in which the landscape is managed and the availability of trophic resources for both larvae and adults are also fundamental factors to be taken into account.[3-4]

Patterns of species richness, nevertheless, can be complicated by other sources of variations. For example, in butterflies both geographical region and species ecology are determinant. In the Palaearctic, for example, a latitudinal gradient in the importance of climatic factors exists: whilst temperatures and number of sunshine hours are key at high latitudes, water availability is determinant at lower and hotter latitudes.[5-6] On the other hand, a recent study in Great Britain suggests that climatic variables are more determinant in species that behave as habitat generalists, whilst the richness and distribution of trophic resources for larvae are more important in habitat-specialist species.[7]

These relationships are relevant to conservation biology since they enable us to predict tendencies in butterfly diversity with greater certainty under a scenario of global change. This ability is also relevant at a more general level, given that butterflies can be regarded as an indicator group for many other insect groups for which far less information exists, but which constitute, nevertheless, the most numerical part of terrestrial ecosystems.[8] For a number of different reasons these considerations seem to be particularly important in the case of the Mediterranean area: (1) the Mediterranean represents the limit of distribution for many species that are likely to be seriously affected by climatic change; (2) within a European context the Mediterranean harbours exceptional levels of biodiversity; and (3) very little is known about the biology and distribution of most terrestrial insects (except for butterflies and a few other smaller groups).

In this article we summarize the results of a study exploring these questions that is entirely based on data from the CBMS.[9] Its main aim was to model Catalan butterfly diversity by taking into account simultaneously a large number of factors relating to landscape structure and human impact that operate at different geographical and climatic scales. As well, different ecological groups were considered based on the degree of species specialization.

Methodology

The analysis is based on data obtained between 1994 and 2007 at 82 CBMS stations in Catalonia and two in Andorra. The altitudinal range of the stations (0–1,930 m) is broad enough to have obtained data for a total of 169 species (85% of all Catalan butterfly species). For each station the average annual species-richness (number of species detected annually) was calculated.

The analyses were performed on all species simultaneously and also on different ecological groups of species. First of all, groups were separated according to the degree of food-plant specialization of their larvae (monophagous, oligophagous or polyphagous). Monophagous species were those that only feed on plants belonging to one genus, oligophagous species feed on a variety of plants, but all belonging to the same family, while polyphagous species feed on the plants of a number of different families. Then, the degree of specialization of adult habitat-use was considered and four groups were defined (IEH1 to IEH4, from more to less specialization) based on a specialization index used in previous studies.[10] Finally, species were separated into four categories on the basis of their dispersive abilities: 1 = species that live in metapopulations with little exchange between populations; 2 = species that live in metapopulations with a lot of exchange between populations; 3 = species that live in open populations but with no seasonal migrations; 4 = seasonal migrants. A correspondence analysis was used as the basis for an examination of how these variables are interrelated between Catalan butterflies. The results indicate that there is a clear correspondence between dispersion category 1, monophagous species and habitat specialization classes IEH1 and IEH2. As well, a close correspondence was also found between the classes with lower degrees of specialization (both in terms of trophic resources and habitat use) and greater dispersive ability. Thus, we can talk in broad terms of **specialist butterflies** (monophagous species restricted to few habitats and with poor dispersive ability) and **generalist butterflies** (oligophagous or polyphagous, present in many habitats and with moderate-to-high dispersive abilities)

Ten predictor environmental variables separated into four main groups were used in the analysis:

1) Climatic variables: for each station the average annual temperature, the average annual rainfall and an aridity index was calculated using data from the Catalan Digital Climatic Atlas.

2) Geographical variables: the average longitude and latitude were calculated for each station.

3) Resource variables: within each transect the amount of trophic resources available for larvae and habitat for adults were estimated. The availability of trophic resources was calculated indirectly as the number of plant communities identified during the characterizations of each transect, and the availability of habitat as the percentage of grassland and similar open areas in each itinerary (based on the logic that the majority of European butterfly species [88%] fly in open areas, and that a large percentage [57%] of these species are specialists).[11] The proportion of open areas in each itinerary was calculated using a GIS at two different scales: within 5 m of the transect route and within a buffer zone of 5 km around the central point of the itinerary.

4) Landscape structure and human impact: the landscape structure for each station was characterized using a GIS and 1:25 000 maps of Catalonia based on colour aerial photographs taken in 1993. The percentage of land occupied by woodland, scrub, agricultural land, bare land and built-up areas was calculated in a radius of 5 km around each itinerary. This information was then subjected to a principal components analysis to obtain a single measurement that would place each itinerary along a few easily interpretable landscape axes. Finally, the main axis was used as a gradient of landscape intensification, running from highly humanized areas dominated by agricultural areas and major infrastructures (negative values) to more natural zones where woodland and scrubland predominate (positive values). Given that axis 1 was found to be strongly co-related to aridity and altitude. before the analyses were conducted the residues relating to these variables were extracted in order to work with an independent landscape variable.

The modelling was performed in two stages. First, the bi-variant relationships between species richness and the predictor variables were explored using lineal and quadratic models. Then, different types of multiple regression models were applied using a maximum of four variables simultaneously and correcting for the auto-correlation of the data whenever necessary.

Factors conditioning butterfly species

Butterfly species-richness is clearly related to some of the predictors in the simple models using just two variables (fig. 1): species-richness increases linearly as rainfall increases, while there is a rapid fall in richness as aridity increases. The relationship is quadratic with temperature: species richness increases with temperature within the lowest range of this variable (e.g. in high mountain areas), but beyond a threshold at around 10ºC, increases in temperature have a negative effect on richness. Finally, landscape structure also influences species richness, with fewer species found in the most humanized landscapes.

Multi-variant models that take into account simultaneously a number of different factors explain a large part of the variance (r^2: 0.56-0.71), thereby bestowing this type of model with excellent predictive powers. The combination of these factors mirrors the clear altitudinal gradient in species richness, and predicts a maximum of species in montane areas (fig. 2). At these more moderate altitudes temperature is not a limiting factor and both the degree of aridity and the intensification of habitat change are low, all of which combines to give greater species richness.

When results are analyzed in terms of ecological groups a number of interesting patterns emerge (table 1). Firstly, the general quadratic relationship with temperature is repeated, although with two exceptions: the species with the greatest habitat specialization (group IEH1) and the species with the maximum dispersive capacity (Disp 4) have lineal relationships with temperature, albeit one negative and the other positive. Habitat specialists are very negatively affected by temperature, a fact explained by their dominance in areas of high altitude (fig. 2b), while more mobile species are positively affected by increased temperatures, a relationship that agrees with the fact that these species become scarcer with altitude (fig. 2d).

The remaining predictors also vary depending on whether we are dealing with specialist or generalist species (table 1). For generalists, aridity is very important and always has a negative effect on species richness. The intensification of habitat alteration also has a clear negative effect on this group of butterflies, which is even more marked when the degree of aridity is highest (as is shown by the significant interaction between these two variables). For specialists, aside from the strong relationship with temperature, the importance of habitat availability also emerges. The number of specialists increases as the proportion of grassland and other open areas increases, a factor that does not seem to be important in the case of the generalists.

Interpretation of the results

This study has shown that the richness of butterfly species in Catalonia depends on just a few climatic and landscape-related factors. As was to be expected, it seems that in this Mediterranean region the availability of water is the key factor in determining butterfly species-richness. This coincides with the more general idea that, unlike more central and northern European ecosystems in which temperature is the main limiting factor, the workings of Mediterranean ecosystems are limited above all by drought.

Furthermore, a close relationship has also been found between species richness and the altitudinal gradient. The maximum number of species are found at mid-altitudes (although the exact altitudes varies in terms of the ecological group in question). In particular, two altitudinal ranges have been identified that seem to house the greatest butterfly species richness: 500–700 m and 1,200–1,500 m. These altitudes correspond, respectively, to areas with numerous Mediterranean endemic species and to areas harbouring an abundance of open-area grassland specialists (montane pastures) (fig. 2). The specialization of this latter group of species in particular has been favoured by their isolation in uplands areas acting as post-glacial refugia, a phenomenon that can lead to their eventual differentiation as endemic species.[12] The same phenomenon occurs in other groups of animals and plants, thereby highlighting the exceptional conservationist interest of Mediterranean mountain ranges.[13]

The preservation of the biodiversity of these upland areas is one of the main challenges facing conservationists in light of the global change that heralds important temperature increases and a loss of grassland areas due to changing patterns of land use. A large number of specialist species restricted to mountain areas have developed genetic adaptations to low temperatures, a fact that is quite likely contributing to their disappearance at the lower limit of their ranges where they are subject to much greater thermal stress (this is the case of Black-veined White *Aporia crataegi* in the Sierra de Guadarrama).[14] Likewise, the loss of open areas in uplands due to the abandoning of traditional hill-farming practices has drastic consequences for habitat specialists, as has emerged from a recent analysis of the annual tendencies of a large number of butterfly species.[15] The loss of these open areas not only means a direct loss of habitat, but also a greater fragmentation of the landscape, which has serious negative and well-known consequences for species with poor dispersive ability,[16] which also happen to be the majority of species in upland areas. The combination of these two factors could lead to an unprecedented acceleration in the loss of diversity in these species-rich environments.

Less diverse lowland areas where fewer specialist species fly are not exempt from problems associated with global change. In this case, we are dealing with common generalist species that – their abundance notwithstanding - are also negatively affected by growing aridity combined with greater landscape intensification. Despite these species' greater ecological flexibility, the results of the model predict a loss of common species if these two factors become more extreme in the future. This could mean a fall in species richness even in lowland areas dominated by common species. Similar scenarios are being played out in other countries in which the intensification of the landscape is already severe.[17]

In conclusion, this study reveals that, if we are to mitigate the negative effects of climate change on biodiversity, we must maintain existing open areas in uplands and reduce the growing intensification of the landscape in lowland areas. Furthermore, if changes related to land use also negatively affect diversity, then a synergy of these two factors may occur with disastrous consequences for biodiversity in terrestrial Catalan ecosystems.

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Fig. 1. Relationships between species richness and some of the predictor variables. Each circle represents a CBMS station. See text for more details.

Fig. 2. Species-richness curves along an altitudinal gradient. Patterns are shown for all species combined (a) and for different ecological groups (b-d): IEH1 to IEH4 = species with more to less habitat specialization; Disp 1 to 4 = classes from less to more dispersal ability.

Table 1. Multiple regression models for butterfly species richness. The significant values are: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, **** $P < 0.0001$. See text for more details.

CBMS sites

The CBMS in the Olzinelles valley (Sant Celoni)

In 2006 as part of the presentation by the technical department of the Montnegre i El Corredor Natural Park of the project *Improvement in the hydrological and other natural resources in the Olzinelles valley*, a CBMS walk was set up at Can Valls d'Olzinelles. The aim of this itinerary was to detect whether the proposals made by this project would have any effects on local butterfly populations.

The transect

This transect is walked in the heart of the Olzinelles valley in the western part of the Montnegre massif in the mountains of La Serralada Litoral. The waters of this lush and relatively humid valley drain northwards into the river Tordera. On the shady north-facing slopes stand mixed forests of holm and downy oak, while on the sunnier south-facing slopes the forest consists of a mix of cork oaks and pines. The bottom of the valley is humid and gallery woodland of alders and poplars lines the main watercourses. Other trees here include wild cherry, hazel and the occasional sweet chestnut. Most of the former fields and pastures have been planted with poplars, although in recent years some have been cut down in an attempt to promote a return to arable farming.

The butterfly walk began in 2006 in an area in which the Natural Park planned to implement important habitat changes in many of the walk's sections. The clearing of the first five sections that run along a footpath through mixed woodland was proposed to create a firebreak (i.e. removal of biomass and the creation of vertical and horizontal discontinuities in the forest mass). Sections 6 and 7 in mixed woodland and poplar plantations were to be transformed into crop- and pastureland, respectively. Section 8 runs along a shady path through cork oak and poplar woodland and leads on to section 9, which passes through a former poplar plantation (but with many poplar stumps still present), which by 2006 had become smothered by bushes. Sections 10 and 11 run along roads and tracks, the former through holm oak woodland and the latter marked by a line of poplars and fields. Section 12 consists of a path through a humid poplar plantation, while section 13 passes through a cereal field belonging to the farm of Can Valls.

However, the changes that have taken place between 2006 and 2011 were not as expected: sections 1–6 have been cleared; in 2011 for the first time cereals were cultivated in section 9; and the line of poplars in section 11 were clear cut in 2011.

It is worth remarking that the walk passes by La Pega, one of the best-loved spots in the area around the town of Sant Celoni. Here there are two resin kilns dating back to the ninth and tenth centuries, and L'Alzina de Pega (the Pega holm oak), probably the tallest holm oak in Catalonia (over 35 m tall). As well, the walk passes by a pond, La Bassa de l'Aranyal, which is surrounded by a number of enormous plane trees.

The butterflies

In all, 55 species of butterfly have been recorded at Olzinelles, with an annual average of 37.8 species. In the period 2006–2010, 4,035 butterflies were counted, with annual averages of 807 butterflies and a density of 40.2 butterflies/100 m.

In general, species at home in humid forests predominate and there are well constituted populations of species such as Speckled Wood *Pararge aegeria*, Green-veined White *Pieris napi*, Silver-washed Fritillary *Argynnis paphia*, Holly Blue *Celastrina argiolus*, Orange-tip *Anthocharis cardamines*, Comma *Polygonia c-album*, Brimstone *Gonepteryx rhamni* and White Admiral *Limenitis camilla* (fig. 1). The abundance of False Ilex Hairstreak *Satyrium esculi* can be explained by the predominance of Mediterranean holm oak forests in the area. A number of generalist species linked to ruderal humanized habitats are common (e.g. Small White *Pieris rapae*, Large White *P. brassicae*, Common Blue *Polyommatus icarus* and Small Copper *Lycaena phlaeas*) and these species, as is commented below, have benefitted from the degradation of the open areas of the transect that have been restored.

A number of other, generally rarer species also appear on this butterfly walk: Camberwell Beauty *Nymphalis antiopa*, Large Tortoiseshell *N. polychloros*, Lesser Purple Emperor *Apatura ilia* and Nettle-tree Butterfly *Libythea celtis*. The first three are all tied to the riparian woodland with willows and poplars that thrives in the valley bottom (egg-laying by Lesser Purple Emperor on poplar leaves has been recorded). The presence of many nettle trees explains the existence of a strong population of Nettle-tree Butterflies, and females are often seen in spring laying their eggs on the fresh buds of this tree.

Even rarer species include White-letter Hairstreak *Satyrium w-album*, Brown Hairstreak *Thecla betulae*, Black-veined White *Aporia crataegi* and Geranium Bronze *Cacyreus marshalli*. The first two are possibly commoner than it would seem since as arboreal species they tend to go unnoticed in counts. In both 2006 and 2007 Pearly Heath *Coenonympha arcania* (annual indexes of 6.5 and 7, respectively) was detected; this species is rare in La Serralada Litoral where relict populations hang on in the shadiest valleys. It is possible, though, that this species is extinct in the Olzinelles valley since it has not been recorded there since 2007.

Effects of the work aimed at restoring habitat in the valley

To date, no great changes in butterfly populations attributable to the habitat modifications outlined in the project have been detected on the Olzinelles butterfly walk. The only exception is that of the Speckled Wood *P. aegeria*, a forest species that has declined in number progressively over the years to the extent that currently its populations are at only 20% of their initial levels.

In fact, the conversion of the woodland into open areas did not begin until 2011 and, even then, not in the planned sections of the itinerary, but in nearby spaces. Forest clearance has affected a large part of the itinerary (sections 1–6), although, despite the fact that light now penetrates much more easily to ground level, changes in the vegetation structure have not led to an increase in plant species that might permit an increase in the number of butterfly species present. Only in a few places have a number of aromatic plants (felty germander, marjoram, wild mint) sprung up, which are now visited by a variety of butterflies such as Green-veined and Small White, False Ilex Hairstreak, Small Copper and Meadow Brown. Nevertheless, Lesser Purple Emperors have been observed in these open spaces that have been colonized by poplars.

One of the main difficulties regarding the recuperation of the crop- and pasturelands is the phenomenal ability of ruderal species to occupy not only field margins but the fields themselves. For example, in 2011 section 9 was finally ploughed up and cereals sown. After the harvest in June, the field was abandoned and as a result was invaded by a dense herbaceous layer of different species such as docks (*Rumex* spp.), pokeweed (*Phytolacca americana*) and spiny cocklebur (*Xanthium spinosum*). In the end, all that is achieved is that a forest is turned into a degraded open area, which – in terms of butterflies – only favours the generalist species. At least in the case of Olzinelles it has become obvious that such projects must involve the immediate and specific management – and, potentially, over a protracted period of time – of both forest clearance and weed control in open areas.

Marta Miralles Cassina

Fig. 1. Average abundance (average of the annual indexes during the period 2006–2010) of the 15 the commonest butterflies at the Olzinelles station.

Photo. One of the forestal sections of the transect, after being cleared (photo: Marta Miralles).

Aerial photo. The CBMS transect in the Olzinelles valley, which consists of 13 sections with a total length of 2,005 m; average of 154 m per section (range: 60-241 m).

Review

The African 'Common Blue' *Polyommatus celina*, a new butterfly species for Europe

In a recent article published in *Molecular Ecology*[1] we describe the evolutionary history of one of Europe's commonest butterflies, the Common Blue *Polyommatus icarus*. Recently, it has been found that this species is replaced in North Africa by ***Polyommatus celina***, a very similar species once regarded only as a subspecies of *P. icarus*, and which perhaps should be referred to as the 'African Common Blue'. We used molecular techniques (mitochondrial and genomic DNA analysis) and geometric morphometrics to reconstruct the evolutionary history of this pair of species. Whereas traditional linear morphometrics only measure distances, modern geometric techniques enable us to compare forms and shapes statistically. In particular, we were able to compare the male genitalia and study the patterns on the underside of the wings.

The results were surprising. First of all, we have shown that these two species of blues are not sister species, despite their very similar appearances. In fact, in terms of its evolution *P. icarus* is closer to species such as Eros Blue *Polyommatus eros*. Nevertheless, the 'African' and 'European' Common Blues are very hard to separate in the field: the former has somewhat broader black margins on the upper wings and often has a line of black spots on the rear margin of the hindwing, although examples of *P. icarus* with these characteristics are found. The genitalia of the two species are also very similar and we have only been able to detect minute differences. The only completely reliable way of separating these two species is by DNA sequencing and as such *P. celina* represents a good example of a cryptic species. As a result of new genetic and morphometric techniques, the true extent of the planet's so-called 'cryptic biodiversity', much of which has to date gone unnoticed, is being shown to be much more sizeable than was once thought. This is of great importance if we are to discover just how many species exist and has serious implications for management and conservation.

We have also discovered that *P. celina* has a much broader distribution than was at first thought and in fact flies in continental Europe. The African Common Blue replaces its European counterpart in many areas in southern Iberia, as well as on the Balearic and Canary Islands and on Sardinia and Sicily. It is interesting to note that these two species do not seem to be able to live sympatrically on these islands and that southern Iberia represents a point of contact between these two taxa. One hypothesis that would explain this distribution is that neither species is able to detect the other and that their hybrids are unfertile; thus if one of these blues mates with the other, they will not produce fertile descendents. We have also identified three strongly diverged lineages of *P. celina*: one in North Africa, the Canary Islands and southern Iberia; a second only on Sicily; and a third on the Balearic Islands and Sardinia. The evolutionary history of this species began in North Africa, from where around 800 000 years ago it colonized the Balearic Islands and Sicily. Subsequently, three lineages have evolved independently and only relatively recently have African butterflies colonized Andalusia, and have Balearic butterflies reached Sardinia. Thus, the lineage of *P. celina* on the Balearic Islands is only shared with Sardinia.

The biogeographical history of *P. icarus* is equally complex. Numerous migratory waves originating in central Europe have occurred over the last two million years; nevertheless, the oldest lineages are all but extinct and we have only identified them in the extreme south of this species' distribution in areas in which more recent lineages from the north have not become established. This is the case of the 'European' Common Blues on Crete and a relict population at over 2,000 m on Pico Veleta in the Sierra Nevada, which is currently surrounded by populations of *P. celina*.

Despite their abundance, these two species have rich biogeographic histories, full of changes marked by the colonizations of islands and mountain ranges as climate change provokes northward and then southward movements, during which time one species evicts the other without the two species ever learning to co-exist. Undoubtedly, much still remains to be learnt about the distribution and evolution of these species in what is potentially a very fruitful field of study.

Roger Vila and Vlad Dinca

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Photos. (a) *Polyommatus celina* in Morocco; (b) Mating pair of *Polyommatus celina* in Granada; (c) Mating pair of *Polyommatus icarus* in Romania (photos: V. Dinca).

The butterfly

The Swallowtail, *Papilio machaon*, one of Europe's most spectacular butterflies

One of the commonest and most spectacular of our butterflies is the Swallowtail *P. machaon*. Although it flies in many different habitats, the best place to find it is on hilltops and ridges, where large numbers of males congregate to await the arrival of mating females. Its caterpillars are also extremely eye-catching and easy to spot on their foodplants, which include fennel, wild carrot and rue.

Geographical distribution and situation in the CBMS

The Swallowtail *Papilio machaon* is common in the Palaearctic region, where it is well distributed throughout Europe, Northwest Africa, the Middle East and much of temperate Asia.[1] It is also found in North America, while in the Iberian Peninsula is has been recorded from all the Spanish provinces, Portugal and Andorra, as well as even the smallest of the Balearic islands.[2]

In Catalonia and Andorra its altitudinal range is large and it is regularly observed from sea-level right up to the tops of alpine peaks. It is one of the most widely distributed species in the CBMS network and appears in the counts of almost every transect, including all three Menorcan sites and on Ibiza (fig. 1). Nevertheless, its population densities are distorted by its behaviour as a 'hilltopper': given that male Swallowtails congregate on hilltops and ridges,[3-4] the highest Swallowtail populations in the CBMS network correspond to walks with these type of relief features. This is the case in six out seven transects in which the species appears at densities of over 20 ex/100 m, and the name of some of these six transects is self-explanatory: Turó de Can Tiril, Turó d'en Fumet, Turó de l'Home (*turó* = hill). Other than in a few isolated cases, the highest densities of this species are recorded from coastal sites such as the deltas of the river Ebro and Llobregat, possibly because these areas are staging posts for migrants from southern Iberian or even from North Africa. At the opposite end of the scale, in the high mountain transects individual Swallowtails are only occasionally recorded.

Habitats and food plants

The Swallowtail is an oligophagous species able to use a large number of different food plants belonging to the Umbelliferae and Rutaceae families.[1] Nevertheless, female Swallowtails do have a clear preference for which plants they lay their eggs on, which in general coincides with the preferences of the caterpillars.[5] There is also great variability amongst females: some are strict specialists and only lay on the best food plants, while others are more generalists and accept suboptimum plants.[5] In Catalonia, the species' favourite food plants are wild fennel *Foeniculum vulgare*, wild carrot *Daucus carota* and common rue *Ruta graveolens*. More rarely, eggs and caterpillars have been found on *Peucedanum oreoselinum*, carrot *Pastinaca sativa*, *Seseli montanum*, Pyrenean angelica *Selinum pyrenaeum*, fringed rue *Ruta chalepensis* and even parsley *Petroselinum crispum* growing in gardens.[6]

In terms of habitat, the Swallowtail is one of the most generalist species in Catalonia. It has appeared in all the different habitats represented in the CBMS and according to its habitat specialization index it is one of the 10 most generalist species in the CBMS network. Maximum densities are recorded in the most humanized sites such as groves of tree crops, extensive herbaceous croplands and ruderal areas. It is also one of the butterflies that is most often found in parks and gardens, even in the centre of large cities such as Barcelona.

Natural history and phenology

The Swallowtail is polyvoltine and during the season an indeterminate number of highly overlapping generations appear (possibly as many as four or five depending on the site and the year). The first generation emerges at the end of winter or beginning of spring from pupae that have overwintered, and in lowland areas it is not rare to see the first Swallowtails of the year on the wing during sunny spells at the end of February. Its seasonal dimorphism is marked and butterflies of the first generation are smaller and darker. Subsequently, the summer generations follow on without interruption from the end of spring until mid-autumn.

The biological cycle of the species is completed in around two months, although this will depend on the temperatures at which the immature phases have to develop. The egg is bright yellow, spherical (1.4 mm in diameter), smooth and with no external features. After 1–2 weeks the larva – black with a white saddle – hatches; it is often claimed that this initial colouration mimics bird droppings and thus confuses potential predators.[8] In later stages the larva's characteristic three-part colouration emerges: green background colour, a series of black strips and spots on each segment, and three pairs of orange spots that interrupt the black stripes. Nevertheless, environmental conditions during growth affect the larva's colouring: when the photoperiod is long in hot climates, the green tends to predominate and the black stripes are much narrower, whereas in opposite conditions the larvae are almost black and have sharply defined orange spots (photo d).[9] The pupa is around 30 mm long and attaches itself by means of a silken thread to a stem of its food plant or, more often, of a nearby plant. It is green or brown, the former being commoner in generations that develop without interruption, while the latter is more typical of the generations that overwinter.

Figure 2 shows the flight curves from different areas of the CBMS network. In the Ebro delta, where Swallowtails can appear in any week of the counting season (fig. 2a), there is a clear increase at the beginning of spring, followed by a long summer period when the species is at its most abundance. Numbers vary throughout the year, however, and counts are irregular, with marked oscillations occurring from one week to another due to the arrival of migrants that distort local abundances curves. Even so, despite knowledge of the Swallowtail's migratory and dispersive behaviour,[10-11] much still remains to be discovered about this aspect of this species' biology. For example, we currently know little about the nature of these migratory fluxes in Catalonia and have no idea whether these butterflies originate from areas in southern Iberia and then migrate northwards along the Mediterranean coastline, or whether they originate in North Africa and then cross the Mediterranean Sea.

Figure 2b shows the flight curve for a site in La Serra de Collserola at which hilltopping males are counted. After the first spring generation it is difficult to know whether the abundance of Swallowtails between May and July corresponds to one or possibly more generations that overlap substantially. There is also a clear fall in numbers at the height of summer that could be explained by emigration to areas that do not suffer such a severe summer drought. In fact, flight curves in upland areas over 1,000 m in the mountains of La Serralada Prelitoral and Pyrenees (fig. 3c) are very different and are all but complementary to those at Collserola: few Swallowtails appear until spring is well advanced and maximum numbers are recorded at the height of summer, precisely when the species is rarest in lowland areas. Although more precise data is needed to confirm this supposition, it seems likely that the arrival of the species in upland areas is linked to dispersive movements and its disappearance from areas with marked summer droughts.

The year's final generation flies in lowland areas in September and October and the larvae originating from its eggs do not develop directly into adult butterflies; rather, the pupae overwinter and thus this stage is the longest stage of all, lasting around six months.

Breeding behaviour

A characteristic trait of this species' mating behaviour is known as 'hilltopping', whereby males select hills, ridges or any other prominent relief feature as 'meeting points' for finding females (fig. 3a). They establish territories that they defend from other male Swallowtails or from other species exhibiting similar behaviour (e.g. Scarce Swallowtail *Iphiclides podalirius*). Males pursue each other in long acrobatic flights as one tries to expel another from its territory. This hilltopping behaviour can last for up to six/seven hours, starting at the beginning of the morning and continuing until the beginning of the afternoon.[4] Reconnaissance flights and aerial disputes alternate with periods of perching on prominent vantage points on bushes, plant stems or even on the ground. The marking of butterflies on a hill in El Maresme has shown that a high percentage of males (over 50%) that establish a territory manage to defend it throughout the day.[4] This study has also revealed that only a very small proportion of males (less than 10%) return to the same hill – up to a maximum of around seven days - on consecutive days. As an alternative to hilltopping, males try to mate with females at strategic sites for nectaring such as large buddleia *Buddelia davidii* bushes or fields of alfalfa *Medicago sativa* in flower.[12]

Nonetheless, observations of actual mating are scarce. Males fly closely behind females in an undulating flight and when she stops on a branch or leaf, the male quickly does the same and mating begins. On the three occasions we have been able to record such behaviour in the field the larger female was on top as the male hung head down, sometimes holding on to the vegetation (fig. 3b). When a male mates for the first time or when he has not mated for three days or more, copulation lasts for an hour; however, if he mates on consecutive days the second attempt lasts almost ten times as long.[13] Sexual dimorphism in the Swallowtail implies longer development time for females, as has been reported in related species,[14] and leads to a certain degree of proterandy, whereby males emerge slightly earlier than the females. Thus, the males' first mating attempts in which they invest greater resources (by transferring a larger spermatophore) are likely to take place with virgin females, of greater reproductive value.[13]

Another characteristic of the mating behaviour of the Swallowtail is the males' habit of mudpuddling (photo f). In some sites in the pre-Pyrenees spectacular concentrations of Swallowtails of a dozen or more males occur, mixed in with a number of Scarce Swallowtails. The males extract minerals – above all sodium, lacking in most plants - from the mud, which is accumulated in the spermatophore and then transferred to the females during mating.[15-16] Sodium is a critical element in the production of the eggs and is thus needed by adult females.

Females lay their eggs one-by-one on their chosen food plant (fig. 3c). They have a wonderful ability to localize even the most isolated of these plants, for example, fennel plants growing in urban parks in the cities of Barcelona or Granollers or, remarkably, a plant of common rue growing on the balcony of a fifth-floor flat in the middle of Barcelona (A. Batlle, com. pers.).

Natural enemies

In their first stages the larvae of the Swallowtail are predated by a number of carnivorous invertebrates that include spiders (fig. 4) and Hemiptera (true bugs).[17] A typical defence mechanism used by many swallowtail butterflies against invertebrate predators is the osmeterium, an orange-coloured extensible organ located on the caterpillar's thorax that gives off a pungent smell.[18-19] Rather than the osmeterium, which has no or little effect, the caterpillar's most effective defence against insectivore birds is its aposematic colouration, which warns of its toxic qualities.[20-21] As well, it seems that this colour scheme also provides a certain degree of camouflage at long-distance; thus a combination of crypsis (cryptic colouration) and aposematism reinforces the larvae's defences against predators who locate their prey visually.[22]

In the case of the pupae (which are not rejected by birds)[20] their main defence is their cryptic colouration: they can be green or brown in tune with the background colour of the site in which they have chosen to pupate (photo e). Experiments have shown that this coincidence of coloration and background helps reduce losses to predation and so increases survival rates.[23] Adult Swallowtails, on the other hand, have been seen to be captured in flight on a number of occasions by Bee-eaters *Merops apiaster*.

The Swallowtail is also attacked by a variety of parasitoids, of which the most regular are two specialized species, a tachinid (Diptera) *Buquetia musca* and an ichneumon (Hymenoptera) *Trogus lapidator*, which attack the larvae (although the latter's offspring emerge from the butterfly's pupa), and two generalists, the ichneumon *Pimpla rufipes* and a chalcidid (Hymenoptera) *Pteromalus puparum*, which attack the pupae.[24]

Population trends

Although it rarely occurs in great densities, the Swallowtail is one of the commonest and most widespread of all our butterflies. Population densities are usually low, a factor that theoretically could have led to the development of hilltopping behaviour as an effective mechanism for mate-finding.[25]

Despite its relative abundance, Swallowtail populations in Catalonia declined slightly but significantly in the period 1994–2010 (fig. 5). It is too early to say whether this apparent regression will be confirmed by data from the coming years, or whether these oscillations will even themselves out around the initial value of the data set. Theoretically, the Swallowtail will not be affected that much by the changes that are occurring to habitats – at least compared to other, more sedentary species of butterfly with more precise habitat requirements. Yet, we are still unsure to what degree Catalan Swallowtail populations are reinforced annually by migrants from further south, and how this phenomenon may affect the general dynamics of the species in the country.

In Europe as a whole, the Swallowtail is also a common species and, although population trends in some countries are somewhat negative, in general its populations are regarded as stable.

Constantí Stefanescu

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6 *Pastinaca sativa*: Closes del Tec, Aiguamolls de l'Empordà (C. Stefanescu, pers. obs.); *Petroselinum crispum*: Sant Pere de Vilamajor, Baix Montseny (C. Stefanescu, pers. obs.); *Peucedanum oreoselinum*: Sant Marçal, Montseny (C. Stefanescu, pers. obs.); *Ruta chalepensis*: Cal Tet, Delta del Llobregat i Es Grau, Menorca (M. Lockwood & O. García, pers. obs.); *Selinum pyrenaeum*: Pessons, Andorra (J. Dantart, pers. obs.); *Seseli montanum*: Sant Segimon, Montseny, and a number of other sites in the Pyrenees (J. Dantart & C. Stefanescu, pers. obs.).

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Fig. 1. Relative abundance (expressed as the values of the annual index/100 m) of the Swallowtail *Papilio machaon* in different CBMS sites (1994-2010).

Fig. 2. Phenology of *Papilio machaon* at different CBMS sites. (a) The beach of La Tancada in the Ebro delta in the period 2002–2010 (n = 522 butterflies); (b) On El Turó d'en Fumet in La Serra de Collserola in the period 1996–2010 (n = 525 butterflies); (c) in all CBMS stations located at over 1,000 m; data from the period 1994–2010 for 14 stations in the mountains of La Serralada Prelitoral and the Pyrenees (n = 357 butterflies).

Fig. 3. Prominent relief features are excellent places to see Swallowtails hilltopping. (a) El Turó del Vent is the best place to see this species and the Scarce Swallowtail *Iphiclides podalirius* in Els Aiguamolls de l'Empordà Natural Park; (b) mating pair on El Turó d'Onofre Arnau in El Maresme; (c) Female egg-laying on *Ruta graveolens* (photos: a, C. Stefanescu; b, J. Corbera; c, J. Oliveras).

Fig. 4. A crab spider preying upon a third instar larva on fennel (photo: A. Miquel).

Fig. 5. Population fluctuations in *Papilio machaon* in the stations of the CBMS network in the period 1994–2010 calculated with the programme TRIM. A significant, moderately negative tendency has occurred during this period.

Photos. (a) Two eggs and one first-instar larva on fennel; (b) third-instar larva, and (c) fifth-instar larva; (d) melanic larva in the fifth instar; (e) green and brown overwintering pupae; (f) two males mud-puddling (photos: a and e, J. Jubany; b, J.M. Sesma; c, J.C. Vicente; d, J. Clavell; f, J. Piqué).

Identification

How to separate the species of the genus *Erebia* (3)

As we gain height in the Pyrenees, new species of the genus *Erebia* begin to appear.

Here we look at two pairs of confusing species: Pyrenean Brassy Ringlet *E. rondoui* vs. Common Brassy Ringlet *E. cassioides arvernensis* and Dewy Ringlet *E. pandrose* vs. False Dewy Ringlet *E. sthennyo*, typically found in subalpine and alpine habitats, although the former pair are sometimes reported from lower altitudes.

Of these species, the only two that have been detected in the CBMS-BMSAnd network are *E. rondoui* (once considered to be a subspecies of Sierra Nevada Brassy Ringlet *E. hispania*, an endemic species to the Sierra Nevada) and Common Brassy Ringlet *E. c. arvernensis*, which in theory should not fly together at the same sites. The former flies at 1,600–2,500 m in the eastern Pyrenees (from El Ripollès to La Serra del Cadí), the Pallars and La Vall d'Aran, but seems to be absent from the north of La Cerdanya and Andorra, while the latter flies at 1,800–2,900 m from La Cerdanya to El Pallars, but seems to be absent from La Vall d'Aran. Neither do *E. pandrose* and *E. sthennyo* fly together, although both are found at over 2,000 m. The former is found in El Ripollès, La Cerdanya and Andorra, and the latter in La Vall d'Aran; El Pallars Sobirà represents the frontier between the two species. All four species live in subalpine and alpine pastures and on grassy slopes between screes. All are univoltine. The two dewy ringlets fly earlier, from the second week of June to the beginning of August; *E. rondoui* flies in July and August and *E. c. arvernensis* from July to September. *E. pandrose* and *E. sthennyo* have biennial cycles, and the other two annual cycles. The food plants of *E. sthennyo* are unknown;[1] *E. pandrose* feeds on *Festuca*, *Poa* and *Sesleria*; *E. rondoui* on *Festuca ovina* and *E. c. arvernensis* on *Nardus stricta*.[2]

Jordi Dantart

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Drawings

PYRENEAN BRASSY RINGLET
Upperside (general): dark brown without any obvious metallic reflections (matt appearance)
Underside (general): fore-wing similar, but paler; hind-wing marbled grey with yellowish sheen in both sexes
Marked with line:
Wide, well-defined orange-coloured post-discal band; Two apical eye-spots with large white pupils, joined into a single mark; series of three black eye-spots with orange centres

COMMON BRASSY RINGLET
Upperside (general): very dark brown with characteristic blue-green metallic reflections, above all in males (silky appearance)
Underside (general): fore-wing similar but paler; hind-wing marbled grey. No yellowish sheen in males
Marked with line:
Short, rusty-brown, poorly defined post-discal band Two small apical eye-spots with small white pupils; series of three black eye-spots with rounded rusty-coloured centres

DEWY RINGLET
Upperside (general): reddish brown; fore-wing with rusty-coloured post-discal band and series of blind black eye-spots
Underside (general): fore-wing rusty brown with series of black eye-spots; hind-wing marbled grey with discal band outlined with sinuous transversal lines
Marked with line:
Transversal lines in the cell; post-discal band stands out against background; series of black spots distant from external margin; marbled grey background colour with discal band highlighted in black

FALSE DEWY RINGLET
Upperside (general): rusty brown; fore-wing with post-discal band with blind black eye-spots
Underside (general): fore-wing rusty brown with blind black eye-spots; hind-wing marbled grey; transversal lines less obvious
Marked with line:
Less apparent post-discal band; series of black spots near outer margin; uniform marbled grey background without conspicuous lines

Recent studies[3-4] seem to conclude that the Pyrenean Brassy Ringlet *E. rondoui* is endemic to the Pyrenees and is different from the Sierra Nevada Brassy Ringlet *E. hispania*. On the other hand, it is not as clear that *arvernensis* should be thought of as a good species and so as a matter of prudence we here treat it as a subspecies of *E. cassioides*. These two brassy ringlets tend to be common where they are found and are easy to confuse. *E. rondoui* has a dark brown ground colour without metallic reflections, a broad orange post-discal band, two large apical eye-spots with white pupils that fuse into a single spot, and the underside of the hind-wings grey with a yellowy sheen. To separate Dewy from False Dewy Ringlet the most consistent criterium is the series of black post-discal spots, further from the outer margin in the former than the latter.

Identification

How to separate the species of the genus *Hipparchia* (1)

Two of the commonest butterflies on the wing in Mediterranean environments in mid-summer are Tree *Hipparchia statilinus* and Striped *H. fidia* Graylings, while in more upland areas the Grayling *H. semele* can also be abundant. At first sight, all three are easy to confuse, but there are morphological clues that enable them to be separated relatively quickly.

The Tree Grayling is well-distributed throughout Catalonia from sea-level to the base of the subalpine mountains. It is commonest in areas of the mountains of La Serralada Litoral and pre-Pyrenees, mainly in scrub and open woodland. The Striped Grayling, a butterfly of arid environments with little vegetation cover, also occupies much of Catalonia, but avoids humid woodland in the northern half of the country and the Pyrenees (although it is present in some of the sunnier Pyrenean valleys). The Grayling can become very ab undant to quite high altitudes in open upland areas, above all on and around rocky outcrops, but is only occasionally found in lowland areas. All three are found in the lowest parts of Andorra and have, exceptionally, been recorded in the Balearic islands, although it seems that currently there are no stable populations on these islands.[1] All are univoltine: Tree and Striped Grayling fly from July to September, while the Grayling appears in May-June and flies until September-October, with a peak in August. Males of the three species are territorial. Their larvae feed on grasses belonging to the genera *Arrhenaterum*, *Brachypodium*, *Festuca*, *Koeleria*, *Nardus* and *Stipa* (see ref. 2-3 for more details of the biology).

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Drawings

TREE GRAYLING
Upperside (general): dark brown-grey colouration, with paler areas in the post-discal area in females
Underside (general): uniform grey with at most a dark central line
Marked with line:
Velvety sex-brand; two large eye-spots ringed in yellow in spaces E2 and E5; normally two white eye-spots in spaces E3 and E4; uniform grey sometimes with a dark line separating the discal area

STRIPED GRAYLING
Upperside (general): dark brown, almost grey
Underside (general): contrasting white and black lines on a uniform grey background
Marked with line:
Velvety sex-brand; two large eye-spots ringed in yellow in spaces E2 and E5; two well-marked white eye-spots in spaces E3 and E4; characteristic black zigzag discal and post-discal lines

GRAYLING
Upperside (general): brown, with orange post-discal markings that merge to form a continuous band on the hind-wing
Underside (general): orange tones on fore-wing; grey hind-wing with white patches of varying size
Marked with line:
Velvety sex-brand; large orange areas; irregular dark line marking a sharp angle in the middle of the wing

These three species can be separated from the other Iberian species of the genus *Hipparchia* by the lack of any broad post-discal band on the upper-wing. Of the three, the Grayling is the only with conspicuous orange colouration on the upperside (especially the hind-wing), and also has a large orange patch on the underside of the hind-wing. Striped and Tree Graylings are very similar above, but can be separated by studying the underside: whilst the Tree Grayling is more or less uniform grey (sometimes with a certain white suffusion), Striped Grayling has a black zigzag post-discal stripe and another shorter stripe in the discal area. In general, Striped Grayling prefers drier hotter areas than Tree Grayling, but both species can appear in the same areas. The Grayling is mainly found in upland areas (but is very rare in the mountains of La Serralada Litoral).

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