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Distribution analysis of monophagous butterflies (Lepidoptera) and their host plants in the western Palaearctic

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Abstract: Döring, E. & Hoffmann, M.H.: Distribution analysis of monophagous butterflies (Lepidoptera) and their host plants in the western Palaearctic. Schlechtendalia **12**: 85–93.

The distribution ranges of monophagous butterflies and their host plants have been studied in western Eurasia and northern Africa. The screening revealed only one really monophagous butterfly (*Colias palaeno* feeding on *Vaccinium uliginosum*) and two nearly monophagous species (*Libythea celtis* mainly feeding on *Celtis australis* and *Charaxes jasius* on *Arbutus unedo*). The ranges of insects and host plants are largely congruent, although sometimes they are slightly divergent due to mapping migratory adults. In several parts of the ranges the butterflies have narrower distribution ranges than their host plants, pointing to other range-limiting factors than the availability of the host plant. This pattern may be explained by climatic factors limiting the insect's range.

Zusammenfassung: Döring, E. & Hoffmann, M.H.: Verbreitungsanalyse monophager Tagfalter (Lepidoptera) und ihrer Futterpflanzen in der westlichen Paläarktis. Schlechtendalia **12**: 85–93.

Die westeurasiatische und nordafrikanische Verbreitung monophager Tagfalter und ihrer Futterpflanzen wird untersucht. Nur eine der untersuchten Arten ist tatsächlich monophag (*Colias palaeno* auf *Vaccinium uliginosum* fressend), zwei weitere Arten (*Libythea celtis* auf *Celtis australis* und *Charaxes jasius* auf *Arbutus unedo*) nutzen an ihrem Arealrand andere nah verwandte Arten als Futterpflanze. Die Verbreitungsgebiete von Pflanze und Schmetterling decken sich meistens sehr gut, weichen sie in einigen Teilen ab, kann das teilweise durch das Wanderungsverhalten der adulten Schmetterlinge erklärt werden. In einigen Fällen besitzt die Pflanze ein weiteres Areal als der Schmetterling, so dass andere Faktoren als die Verfügbarkeit der Nahrungspflanze für die engeren Verbreitungsgrenzen des Falters verantwortlich sein müssen. Diese Arealgrenzen werden klimatisch erklärt.

Introduction

Specialised plant–insect interactions have gained increasing scientific and public interest. Among these interactions, particular interest has been achieved by specialised pollinator-flower interactions, insectivorous plants, insects that force plants to produce galls, and pests that are of great economic importance. Monophagous insects, defined as insects or their larvae that feed only on a single plant species, are comparatively rare, at least in tropical ecosystems (Novotny et al. 2002), and on a regional scale occupy smaller distribution ranges than polyphagous insects (Quinn et al. 1998).

Monophagy of butterflies has frequently received much interest by entomologists but, unfortunately, the area examined rarely comprised the whole distribution range of the species (Jugan 1998). A careful comparison of the distribution ranges may reveal additional hints concerning the true monophagous behaviour of the caterpillars. Three possible patterns from this range comparison may be expected.

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1) Congruence of the distributions of animal and plant.

This pattern would indicate a tight connection between the insect and its food plant and a high probability of a monophagous behaviour. Furthermore, the host plant limits the distribution range of the insect. Range expansion or retraction of the plant may be followed by range expansion or retraction of the insect.

2) The insect occupies a wider distribution range than the plant.

If this pattern does not result from the mapping of migrating adult insects, it would point to a host plant shift in parts of the distribution range. The insect is, thus, not strictly monophagous throughout its range.

3) The insect occupies a smaller distribution range than the plant.

This pattern indicates that other factors than host plant limitation may be responsible for the range limits of these otherwise quite mobile animals. This suggests that climate is a range-limiting factor, because a completely competitive exclusion or a complete predation appears as not highly probable. At the geographical scale of this study, climate is the most important abiotic factor limiting distribution ranges of organisms (WOODWARD 1997).

The aim of this study is to analyse the western Eurasian–north African distribution ranges of monophagous butterflies and their host plants. The following questions will be addressed:

1) How many butterflies are monophagous in the area examined?

2) Can the monophagous behaviour of the butterflies throughout their range be inferred from the distribution maps?

3) Does a smaller distribution range of the insect compared to the host plant correlate with abiotic factors, such as climate, that may be range limiting?

Material and Methods

The monophagous behaviour of the caterpillars has been inferred from the food plant spectra as indicated in various faunistic literature (CARTER 1987; EBERT 1991, 1994; HIGGINS & RILEY 1978; KOCH 1984; PRO NATURA 1991, 1997; SAUER & SCHAIDER 1992a, b; ZAHRADNIK 1998). For many species, there is a reliance on popular scientific literature, but this is acceptable, especially in the family Lepidoptera, because of the many specialised laypersons working in that field.

The distribution maps of the insects have been compiled on the basis of the maps of HIGGINS & RILEY (1978) and SAUER & SCHAIDER (1992a, b) and were supplemented by other data. The distribution ranges of the host plants were obtained from MEUSEL et al. (1965, 1978) and MEUSEL & JÄGER (1992). Some new floristic findings were added. For an extended discussion of the distribution maps see HOFFMANN & WELK (1999). The distribution maps were digitised and processed using the program Arc/Info (ESRI 1992). The climate data were obtained from W. CRAMER (CLIMATE database version 2.1, Potsdam Institute of Climate Impact Research, pers. comm.).

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Results

The food plant spectra as indicated by the literature cited above are sometimes inconsistent. Only one butterfly appears to be monophagous throughout its range, two butterflies make a host shift to closely related plant species:

- *Colias palaeno* L. feeding on *Vaccinium uliginosum* L.
- *Libythea australis* (Laicharting in Fuessly) feeding on *Celtis australis* L. and perhaps *Celtis caucasica* Willd.
- *Charaxes jasius* L. feeding on *Arbutus unedo* L. and *Arbutus andrachne* L.

Other taxa, for example, *Parnassius mnemosyne* L. feeding on several *Corydalis* species and the hawkmoth *Hyles hippophae* Esper feeding on *Hippophae rhamnoides* L. and *Elaeagnus angustifolia* L., revealed not to be strictly monophagous.

The distribution of the plants, at least in the area studied, can be much more finely mapped than the distribution of the animals. One reason may be that in our institute the database for mapping plants was much better than the database for mapping butterflies.

Colias palaeno (Pieridae) and *Vaccinium uliginosum* (Ericaceae) Fig. 1

Colias palaeno prefers open habitats with a high degree of heterogeneity, offering nutrients and shelter throughout the life cycle of the butterfly (EBERT 1991), and the food plant of the caterpillars. The caterpillars pass the winter in the larval stage and pupate in the next spring.

The west Eurasian ranges of animal and host plant show a high degree of congruency. Some incongruence is observed in the Ukraine and the south-eastern part of European Russia. Detailed data on the distribution of the butterfly in that area was not available. The fit between the ranges improve with more fine-scaled data from that area. A remarkable pattern appears at the western boundaries of the distribution ranges where *C. palaeno* has a narrower distribution than *V. uliginosum*. This means that there are more places with host plants available to the insect than are occupied. Because both distribution ranges are well known in that area, this seems not to be a merely accidental pattern. The January isotherme of 0 °C suggests that *C. palaeno* avoids winter-warm areas. This may also be a reason why Scotland is not occupied by the species, although the plant occurs there. Greenland, Iceland and Novaja Zemlya (northern Russia) are not occupied by the butterfly, because of their low summer temperatures (e.g., July temperature below 10 °C).

Libythea celtis (Libytheidae) and *Celtis australis* (Ulmaceae) Fig. 2

Libythea celtis is a migratory butterfly, especially during the hot summer months, in the Mediterranean region. This species has up to three generations anually, one in the winter and one to two in the summer. Whether the adults aestivate or fly for a short period of time remains a controversy (HIGGINS & RILEY 1978, PRO NATURA 1991, SAUER & SCHAIDER 1992a, b). HIGGINS & RILEY (1978) indicate occurrences of the butterfly ranging to Eastern Asia. If this is the case then the species may make a host shift, perhaps to the Middle Asian *Celtis caucasica*.

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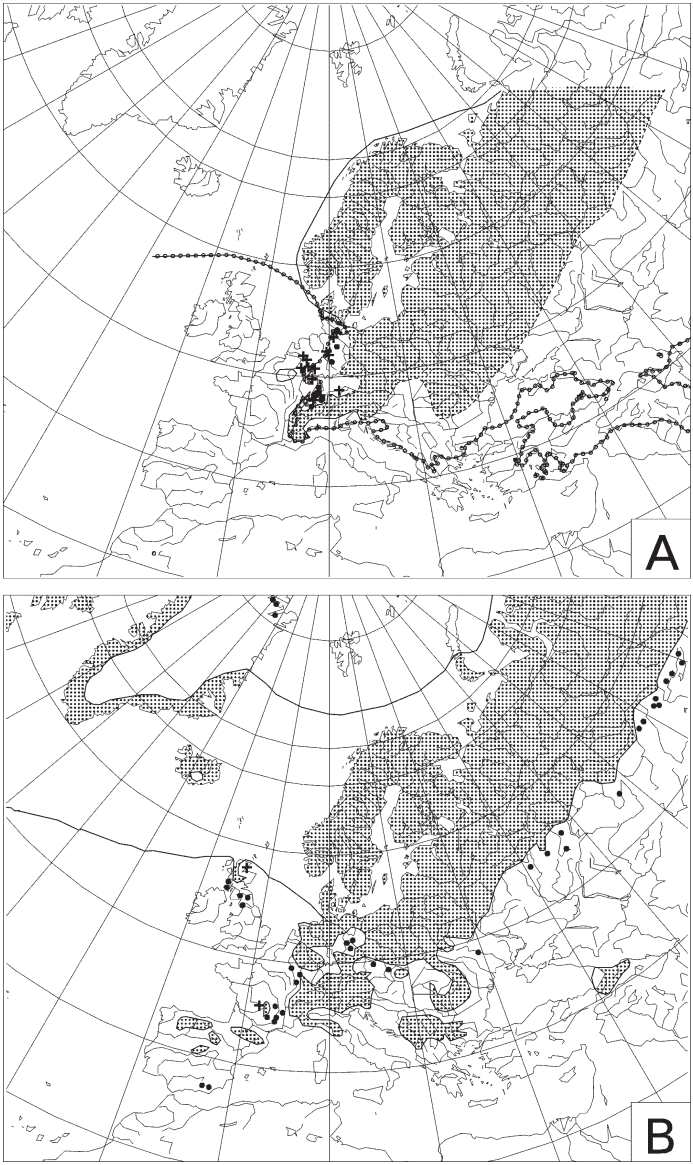

Fig. 1: Distribution ranges of *Colias palaeno* (A) and its host plant *Vaccinium uliginosum* (B). The knotted line in 'A' refers to the 0 °C January isotherme, i.e. all areas north of this line have mean January temperature below 0 °C. Greenland, Iceland and Novaja Zemlya may be not occupied due to low summer temperatures (e.g. July temperature below 10 °C, data not shown). Crosses (+) refer to extinct occurrences; dashed lines indicate insufficiently known distribution boundaries and open circles denote geographically inexact data.

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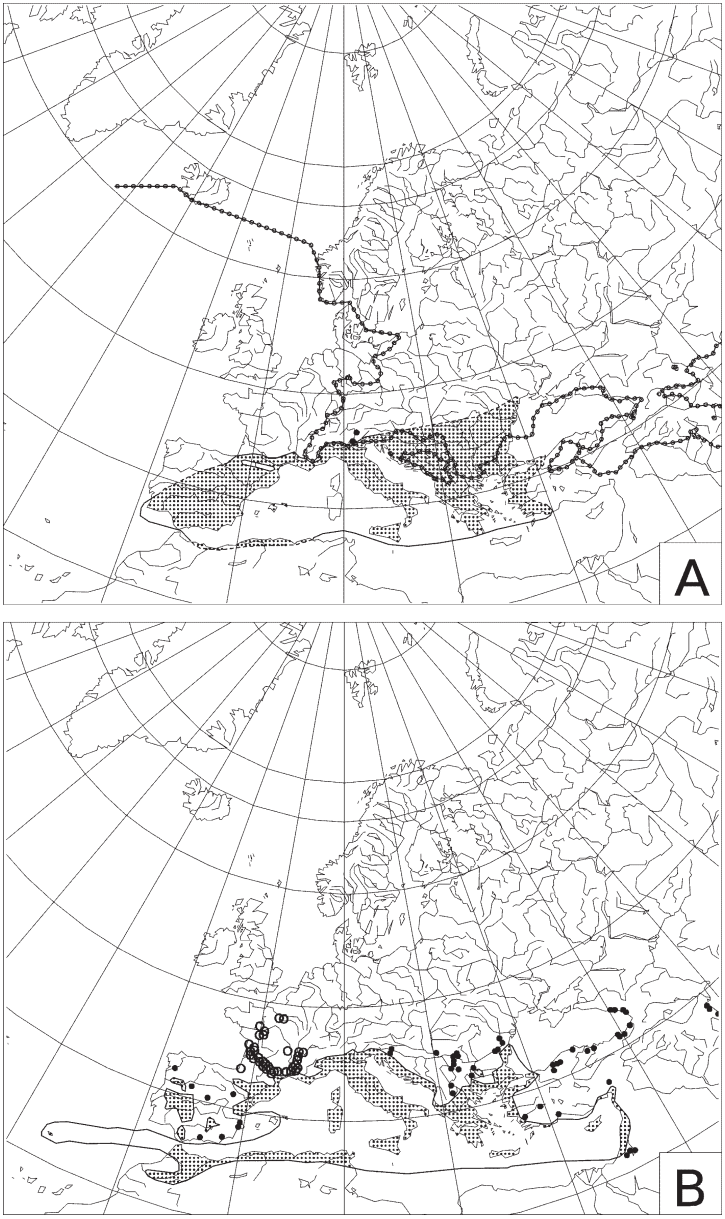

Fig. 2: Distribution ranges of *Libythea celtis* (A) and its host plant *Celtis australis* (B). The knotted line in 'A' refers to the -1 °C January isotherme, i.e. all areas north of this line have a mean January temperature below -1 °C. Small open circles indicate synanthropous occurrences of *C. australis*, dashed lines indicate insufficiently known distribution boundaries.

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The ranges of *L. celtis* and its host plant *Celtis australis* match in the area studied remarkably well. Some incongruence on the Iberian Peninsula and the Balkan Peninsula may be explained by the butterfly's migratory behaviour and the fact that the animals perceived distribution range is based on caught or observed adults. It is quite improbable that the distribution range of the plant is much under-represented in the map. In the southern and south-eastern range, the animal is not as widely distributed as the plant. Range limiting factors are perhaps a very low amount of summer precipitation (e.g., July precipitation < 4 mm) and cold winters (e.g., January temperature < –1 °C). However, this could only be concluded definitively if the range of the caterpillars was differentiated from that of the migratory adults. Furthermore, distribution data of *Libythea* from that area are scarce.

***Charaxes jasius* (Nymphalidae) and *Arbutus unedo* (Ericaceae) Fig. 3**

Charaxes jasius occurs in two generations anually and inhabits light forests and open landscapes. The caterpillars prefer plants at the edge of the forests and need rather warm temperatures for their development (JUGAN 1998). Caterpillars hibernate when the mean daily temperature falls below 11.5–13 °C (ABOS & STEFANESCU 1999).

The distribution ranges are mostly congruent. However, in southern Turkey *C. jasius* appears not to be strictly monophagous anymore because the caterpillars apparently feed there on *A. andrachne*, the species that is more widely distributed in that area than *A. unedo.* The range of the butterfly is smaller than that of the plant in north-western Africa, the Iberian Peninsula and the Apennine Peninsula. On the Apennine Peninsula the distribution of *C. jasius* is very peculiar, because it occurs more or less only in the western half of the peninsula. A climatic interpretation of the distribution range, especially where the animal and plant distribution do not overlap, is difficult. It is easily seen from the range that cold temperatures are avoided throughout the year. On the other hand, the rather warm Atlantic coast of Europe along the northern Iberian Peninsula and France is not occupied. This pattern cannot be explained by single isothermes as in above-mentioned examples. Maybe some thermal threshold values in combination with the amount of precipitation are responsible for the restricted distribution range of *C. jasius*. Similarly, the distribution pattern on the Apennine Peninsula cannot be easily explained climatically.

Discussion

Our survey revealed only one monophagous butterfly in the European fauna and resembles other studies in this observation of the scarcity of monophagous insects (e.g., NOVOTNY et al. 2002). Only one species is monophagous in our strict definition of monophagy, i.e. that the larvae feed only on one plant species. A slight widening of the definition of monophagy (as has sometimes been done in this study) to the genus or maybe family level would result in more butterflies in the list. Maybe a screening of other families of the Lepidoptera, especially those formerly informally named moths, may reveal more monophagous species.

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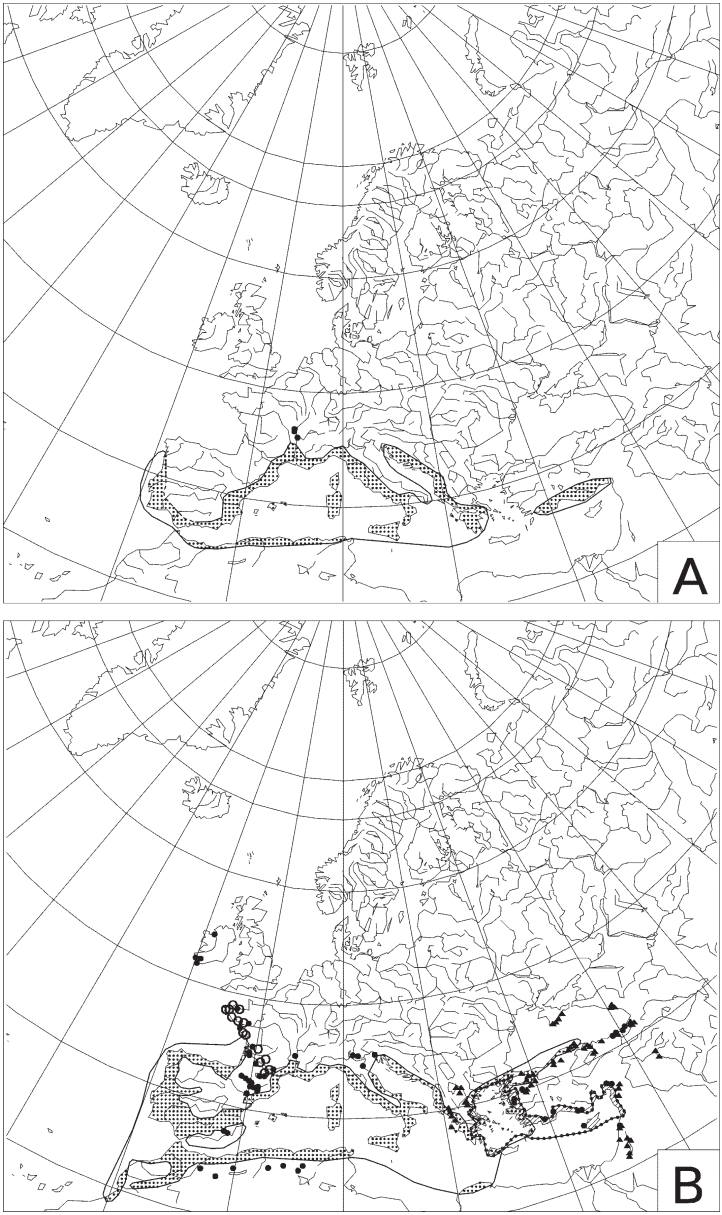

Fig. 3: Distribution ranges of *Charaxes jasius* (A) and its host plants *Arbutus unedo* and *A. andrachne* (B). Small open circles in 'B' refer to synanthropous occurrences of *A. unedo*, the dots refer to single occurrences of the species. The range of *A. andrachne* is indicated as a hashed area surrounded by the knotted line. Single occurrences outside the distribution range are marked with triangles.

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The mapping of plant distribution ranges and putative monophagous insect species has been revealed to be a potentially rapid test of their monophagous behaviour throughout their ranges. However, mapping moths on a large scale might pose severe problems.

Studies in the *Papilio* group (swallowtail butterflies, BOSSART 2003, THOMPSON 1998) show a dynamic behaviour and evolution of oviposition on a range of host plants. It appears that host preference has a genetic basis (BOSSART 2003). Throughout the range of the species, the capacity of an animal to change its host plant range seems to vary (FUNK & BERNAYS 2001). For aphids, these authors conclude that polyphagy is a derived character adaptively evolved in response to the stability of the environment (FUNK & BERNAYS 2001). The rapid evolution of the feeding behaviour may be one reason for the rarity of monophagous insects. A high genetic diversity in monophagous beetles compared with their polyphagous congeners may point in the same direction (VERDYCK & DESENDER 2003).

The relative scarcity of monophagous insects may be explained by the relatively high risk of extinction that may result from dependence on the host plant (NIEMINEN 1996). On the other hand, all plant taxa discussed here were reported from the European Tertiary (MAI 1995): Eocene (*Arbutus* and *Celtis*) and Miocene to Pliocene (*Vaccinium*). Because the butterflies do not have significantly smaller distribution ranges than their host plants, it may be possible that during phases of climatic deterioration both insect and plant may have survived due to migrations in accordance with the climatic conditions. Moreover, in light of the fossil record of plants (MAI 1995), it appears astonishing that only few butterflies are tightly bound to their host plants, because the plants may provide the insects not only food but also with secondary compounds that may repel subsequent insectivorous attacks (HARTMANN & OBER 2000).

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