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Three size classes of wing-spread and dwarf forms of the Orange Tip *Anthocharis cardamines* (Lepidoptera: Pieridae) and other butterflies

Drei Größenklassen der Flügelspannweite und Zwergformen des Aurorafalters *Anthocharis cardamines* (Lepidoptera: Pieridae) und anderer Schmetterlinge

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Abstract

Three size classes of wing-spread have been registered in the following butterflies (Lepidoptera) (in alphabetical order of Latin names): the Small Tortoiseshell *Aglais urticae* LINNAEUS 1758 (Nymphalidae), the male of the Orange Tip *Anthocharis cardamines* LINNAEUS 1758 (Pieridae), the Pale Clouded Yellow *Colias hyale* LINNAEUS 1758 (Pieridae), the Peacock Butterfly *Inachis io* LINNAEUS 1758 (Nymphalidae), the Swallowtail *Papilio machaon* LINNAEUS 1758 (Papilionidae), the Green-veined White *Pieris napi* LINNAEUS 1758 (Pieridae), the Small White *Pieris rapae* LINNAEUS 1758 (Pieridae), the Red Admiral *Vanessa atalanta* LINNAEUS 1758 (Nymphalidae), and the Painted Lady *Vanessa cardui* LINNAEUS 1758 (Nymphalidae). The three size classes of wing-spread of the aforementioned butterflies include large, medium large and small individuals, and some of the small individuals are occasionally developed as extraordinary dwarf forms. In comparison with the three size classes of wing-spread of the aforementioned butterflies, also observations of the following butterflies have been evaluated (in alphabetical order of Latin names): the Ringlet *Aphantopus hyperantus* LINNAEUS 1758 (Satyridae), the Black-veined White *Aporia crataegi* LINNAEUS 1758 (Pieridae), the Silver-washed Fritillary *Argynnis paphia* LINNAEUS 1758 (Nymphalidae), the Clouded Yellow *Colias croceus* FOURCROY 1785 (Pieridae), the Plain Tiger *Danaus chrysippus* LINNAEUS 1758 and the Milkweed Butterfly *Danaus plexippus* LINNAEUS 1758 (Danaidae), the Brimstone *Gonepteryx rhamni* LINNAEUS 1758 (Pieridae), the Scarce Copper *Heodes virgaureae* LINNAEUS 1758 (Lycaenidae), the Queen of Spain Fritillary *Issoria lathonia* LINNAEUS 1758 (Nymphalidae), the Wall Brown *Lasiommata megera* LINNAEUS 1767 (Satyridae), the Wood White *Leptidea sinapis* LINNAEUS 1758 (Pieridae), the Small Copper *Lycaena phlaeas* LINNAEUS 1761 (Lycaenidae), the Marbled White *Melanargia galathea* LINNAEUS 1758 (Satyridae), the Large Tortoiseshell *Nymphalis polychloros* LINNAEUS 1758 (Nymphalidae), the Speckled

Wood *Pararge aegeria* LINNAEUS 1758 (Satyridae), the Large White *Pieris brassicae* LINNAEUS 1758 (Pieridae), the Comma Butterfly *Polygonia c-album* LINNAEUS 1758 (Nymphalidae), and the Common Blue *Polyommatus icarus* ROTTEMBURG 1775 (Lycaenidae). The wing-spread of the smallest dwarf forms of the nine investigated butterfly species reaches only about 62 – 75 % of the wing-spread of the largest individuals at the investigated localities. The subordinate to accessory occurrence of small individuals of the nine investigated butterfly species with the only rare establishment of extraordinary dwarf forms testifies to the only occasional development of serious environmental stress which stimulates sometimes the premature pupation of the larvae of the butterflies prior to the achievement of their average or maximum size. The environmental factors triggering the subordinate to accessory premature pupation of the larvae of the butterflies prior to the achievement of their average or maximum size which leads to the development of extraordinary dwarf forms of the butterflies are probably predominantly cold and wet weather periods of longer duration than the usually short phases of cool and moist weather separating longer periods of warm and dry weather during spring and summer. Extended periods of cold and wet weather instead of only short phases of cool and moist weather between longer periods of warm and dry weather during spring and summer prevent some larvae of the butterflies from sufficient feeding which results in retardation of their growth and thus stimulates also premature pupation at the end of the larval stage of the cycle of metamorphosis of the butterflies.

Zusammenfassung

Drei Größenklassen der Flügelspannweite wurden bei folgenden Schmetterlingen (Lepidoptera) festgestellt (in alphabetischer Reihenfolge der lateinischen Namen): Kleiner Fuchs *Aglais urticae* LINNAEUS 1758 (Nymphalidae), Männchen des Aurorafalters *Anthocharis cardamines* LINNAEUS 1758 (Pieridae), Gemeiner Heufalter *Colias hyale* LINNAEUS 1758 (Pieridae), Tagpfauenauge *Inachis io* LINNAEUS 1758 (Nymphalidae), Schwalbenschwanz *Papilio machaon* LINNAEUS 1758 (Papilionidae), Rapsweißling *Pieris napi* LINNAEUS 1758 (Pieridae), Kleiner Kohlweißling *Pieris rapae* LINNAEUS 1758 (Pieridae), Admiral *Vanessa atalanta* LINNAEUS 1758 (Nymphalidae), und Distelfalter *Vanessa cardui* LINNAEUS 1758 (Nymphalidae). Die drei Größenklassen der Flügelspannweite der vorgenannten Schmetterlinge umfassen große, mittelgroße und kleine Individuen, und einige der kleinen Exemplare sind manchmal als außergewöhnliche Zwergformen entwickelt. Zum Vergleich mit den drei Größenklassen der Flügelspannweite der vorgenannten Schmetterlinge wurden auch Beobachtungen der folgenden Schmetterlinge ausgewertet (in alphabetischer Reihenfolge der lateinischen Namen): Brauner Waldvogel *Aphantopus hyperantus* LINNAEUS 1758 (Satyridae), Baumweißling *Aporia crataegi* LINNAEUS 1758 (Pieridae), Kaisermantel *Argynnis paphia* LINNAEUS 1758 (Nymphalidae), Postillon-Heufalter *Colias croceus* FOURCROY 1785 (Pieridae), Monarchfalter *Danaus chrysippus* LINNAEUS 1758 und *Danaus plexippus* LINNAEUS 1758 (Danaidae), Zitronenfalter *Gonepteryx rhamni* LINNAEUS 1758 (Pieridae), Dukatenfalter *Heodes virgaureae* LINNAEUS 1758 (Lycaenidae), Kleiner Perlmutterfalter *Issoria lathonia* LINNAEUS 1758 (Nymphalidae), Mauerfuchs *Lasiommata megera* LINNAEUS 1767 (Satyridae), Senfweißling *Leptidea sinapis* LINNAEUS 1758 (Pieridae), Kleiner Feuerfalter *Lycaena phlaeas* LINNAEUS 1761 (Lycaenidae), Schachbrett *Melanargia galathea* LINNAEUS 1758 (Satyridae), Großer Fuchs *Nymphalis polychloros* LINNAEUS 1758

(Nymphalidae), Waldbrettspiel *Pararge aegeria* LINNAEUS 1758 (Satyridae), Großer Kohlweißling *Pieris brassicae* LINNAEUS 1758 (Pieridae), C-Falter *Polygonia c-album* LINNAEUS 1758 (Nymphalidae), und Hauhechelbläuling *Polyommatus icarus* ROTTEMBURG 1775 (Lycaenidae). Die Flügelspannweite der kleinsten Zwergformen der neun untersuchten Schmetterlingsarten erreicht nur etwa 62 – 75 % der Flügelspannweite der größten Individuen an den untersuchten Standorten. Das untergeordnete bis akzessorische Auftreten von kleinen Individuen der neun untersuchten Schmetterlingsarten mit der lediglich seltenen Entwicklung von außergewöhnlichen Zwergformen spiegelt die nur gelegentliche Ausbildung von schwerwiegendem Umweltstress wider, welcher manchmal die prämature Verpuppung der Larven der Schmetterlinge vor dem Erreichen ihrer durchschnittlichen oder maximalen Größe stimuliert. Die Umweltfaktoren, welche die untergeordnete bis akzessorische prämature Verpuppung der Larven der Schmetterlinge vor dem Erreichen ihrer durchschnittlichen oder maximalen Größe auslösen, welche zu der Entwicklung von außergewöhnlichen Zwergformen der Schmetterlinge führt, sind wahrscheinlich vor allem Perioden kalten und nassen Wetters mit längerer Dauer als die normalerweise kurzen Phasen kühlen und feuchten Wetters, welche längere Perioden warmen und trockenen Wetters in Frühling und Sommer voneinander trennen. Ausgedehnte Perioden kalten und nassen Wetters anstelle von lediglich kurzen Phasen kühlen und feuchten Wetters in Frühling und Sommer hindern einige Larven der Schmetterlinge an der ausreichenden Nahrungsaufnahme, welche in verzögertem Wachstum resultiert und damit auch die prämature Verpuppung am Ende des Larvalstadiums des Metamorphosezyklus der Schmetterlinge bewirkt.

Résumé

Trois catégories de grandeur d´envergure ont été enregistrées en les papillons (Lepidoptera) suivants (en ordre alphabétique des noms latins): la Petite Tortue *Aglais urticae* LINNAEUS 1758 (Nymphalidae), le mâle de l´Aurore *Anthocharis cardamines* LINNAEUS 1758 (Pieridae), le Soufre *Colias hyale* LINNAEUS 1758 (Pieridae), le Paon de Jour *Inachis io* LINNAEUS 1758 (Nymphalidae), le Grand Porte-queue *Papilio machaon* LINNAEUS 1758 (Papilionidae), le Piéride du Navet *Pieris napi* LINNAEUS 1758 (Pieridae), le Petit Blanc du Chou *Pieris rapae* LINNAEUS 1758 (Pieridae), le Vulcain *Vanessa atalanta* LINNAEUS 1758 (Nymphalidae), et la Belle Dame *Vanessa cardui* LINNAEUS 1758 (Nymphalidae). Les trois catégories de grandeur d´envergure des papillons susmentionnés comportent des individus grands, moyen grands et petits, et quelques des individus petits sont parfois développés comme des formes naines extraordinaires. Pour la comparaison avec les trois catégories de grandeur d´envergure des papillons susmentionnés, aussi des observations des papillons suivants ont été utilisées (en ordre alphabétique des noms latins): le Tristan *Aphantopus hyperantus* LINNAEUS 1758 (Satyridae), le Gazé *Aporia crataegi* LINNAEUS 1758 (Pieridae), le Tabac d´Espagne *Argynnis paphia* LINNAEUS 1758 (Nymphalidae), le Souci *Colias croceus* FOURCROY 1785 (Pieridae), les Monarques *Danaus chrysippus* LINNAEUS 1758 et *Danaus plexippus* LINNAEUS 1758 (Danaidae), le Citron *Gonepteryx rhamni* LINNAEUS 1758 (Pieridae), l´Argus Satiné *Heodes virgaureae* LINNAEUS 1758 (Lycaenidae), le Petit Nacré *Issoria lathonia* LINNAEUS 1758 (Nymphalidae), le Satyre *Lasiommata megera* LINNAEUS 1767 (Satyridae), le Piéride de la Moutarde *Leptidea sinapis* LINNAEUS 1758 (Pieridae), le Bronzé *Lycaena phlaeas* LINNAEUS 1761 (Lycaenidae), le Demi-Deuil *Melanargia galathea* LINNAEUS 1758 (Satyridae), la Grande Tortue *Nymphalis polychloros*

LINNAEUS 1758 (Nymphalidae), le Tircis *Pararge aegeria* LINNAEUS 1758 (Satyridae), le Piéride du Chou *Pieris brassicae* LINNAEUS 1758 (Pieridae), le Robert le Diable *Polygonia c-album* LINNAEUS 1758 (Nymphalidae), et l´Argus Azuré *Polyommatus icarus* ROTTEMBURG 1775 (Lycaenidae). L´envergure des formes naines les plus petits des neuf espèces de papillons examinés atteint seulement à peu près 62 – 75 % de l´envergure des individus les plus grands aux localités examinées. La présence subordonnée à accessoire des individus petits des neuf espèces de papillons examinés avec le développement seulement rare des formes naines extraordinaires montre la formation seulement occasionnelle de stress du milieu sérieux qui stimule parfois la pupation prématurée des larves des papillons avant avoir arrivées à leur grandeur moyenne ou maximale. Les facteurs de milieu qui déclenchent la pupation prématurée subordonnée à accessoire des larves des papillons avant avoir arrivées à leur grandeur moyenne ou maximale qui guide au développement des formes naines extraordinaires des papillons sont probablement prépondérant des périodes de temps froides et humides de duration plus longues que les phases courtes de temps fraîches et humides qui normalement séparent les périodes plus longues de temps chaudes et sèches en printemps et en été. Des périodes de temps froides et humides étendues au lieu des phases seulement courtes de temps fraîches et humides entre des périodes plus longues de temps chaudes et sèches en printemps et en été empêchent quelques larves des papillons de la nourriture suffisante qui guide à la croissance retardée et de cette manière déclenchent aussi la pupation prématurée au fin du stade larval du cycle de métamorphose des papillons.

Key Words

Anthocharis cardamines, Orange tip, size classes, dwarf forms, nanism, premature pupation, environmental stress, phaenology, Upper Rhine valley, Heidelberg, Mannheim, Germany, Palaearctic region.

1 Introduction

The Orange Tip *Anthocharis cardamines* LINNAEUS 1758 (Lepidoptera: Pieridae; Fig. 1) is one of the first butterflies which appear in early spring with a newly developed vernal generation of individuals that have freshly emerged from the pupae in the first period of dry and warm weather with temperatures of up to 20 – 25 degrees Centigrade in the current year, whereas many other butterflies showing up in early spring represent in fact the automnal generation of the preceding year, with the adults having hibernated after having already emerged from the pupae in the autumn of the previous year. During my occasional entomological observations between 1964 and 2006, I have always been particularly attracted by the appearance of the Orange Tip *Anthocharis cardamines* in early spring. The flight of the male of the Orange Tip *Anthocharis cardamines* is especially fascinating due to the pronounced orange shining of its fore wings in bright sunlight which makes it easily recognizable among various white butterflies flying across meadows or along forest margins even over larger distances.

In 1981, I have observed an unusually small male of the Orange Tip *Anthocharis cardamines* during the successive flight of numerous males across a mixed meadow with various flowers of different colour at the margin of a forest near Müsch in the eastern part of

the Eifel. The examination of this extraordinarily small male of the Orange Tip *Anthocharis cardamines* has revealed that its wing-spread has been only about 28 – 30 mm in contrast to the standard wing-spread of about 40 – 45 mm. The observation of this outstandingly tiny male of the Orange Tip *Anthocharis cardamines* has stimulated my interest in the analysis of the occurrence of dwarf forms of butterflies, and I have since then paid special attention to the appearance of unusually small individuals of butterflies particularly during my regular entomological observations in the region around Heidelberg and Mannheim in 2007 and 2008. During the course of the years, I have collected several examples of extraordinary dwarf forms of a suite of common butterflies.

The compilation of my book on population dynamics, ecology and conservation of the stag beetle *Lucanus cervus* LINNAEUS 1758 (Coleoptera: Lucanidae) (MADER 2009a) which has also a wide variability of size with the development of three distinct size classes including pronounced dwarf forms has been the reason for the comparative assessment of my observations of the variability of size of the Orange Tip *Anthocharis cardamines* and other butterflies. The evaluation of my records has revealed that three separate size classes with establishment of accentuated nanism can also be distinguished in a suite of common butterflies. The results of my observations of the development of three distinct size classes including the appearance of extraordinary dwarf forms of the Orange Tip *Anthocharis cardamines* and other butterflies are summarized in this paper. Other results of my long-term entomological observations comprising the correlation of the swarm phases of the stag beetle *Lucanus cervus* and other beetles as well as the occurrence of peak numbers of individuals of the Orange Tip *Anthocharis cardamines* and other butterflies with the new moon and the full moon phases of the lunar cycle are published separately (MADER 2009c).

2 Materials and methods

The remarks on materials and methods comprise the listing of the investigated butterflies and the investigated localities as well as comments on data collection and evaluation. Outlines of geography and geology, forest distribution, and temperatures and wind of the study area around Heidelberg and Mannheim in the southwestern part of Germany are contained in MADER (2009b) and are not repeated here. An outline of the succession of five longer periods of warm and dry weather which have been interrupted and separated by shorter phases of cool and wet weather in 2008 is included in MADER (2009c).

2.1 Investigated butterflies

The investigated butterflies (Lepidoptera) include (in alphabetical order of Latin names): the Small Tortoiseshell *Aglais urticae* LINNAEUS 1758 (Nymphalidae; Fig. 10), the male of the Orange Tip *Anthocharis cardamines* LINNAEUS 1758 (Pieridae; Fig. 1), the Pale Clouded Yellow *Colias hyale* LINNAEUS 1758 (Pieridae), the Peacock Butterfly *Inachis io* LINNAEUS 1758 (Nymphalidae; Fig. 11), the Swallowtail *Papilio machaon* LINNAEUS 1758 (Papilionidae; Fig. 5), the Green-veined White *Pieris napi* LINNAEUS 1758 (Pieridae; Fig. 3), the Small White *Pieris rapae* LINNAEUS 1758 (Pieridae), the Red Admiral *Vanessa atalanta* LINNAEUS 1758 (Nymphalidae; Fig. 12), and the Painted Lady *Vanessa cardui* LINNAEUS 1758 (Nymphalidae; Fig. 13).

In comparison with the aforementioned butterflies, also observations of the following butterflies have been evaluated (in alphabetical order of Latin names): the Ringlet *Aphantopus hyperantus* LINNAEUS 1758 (Satyridae), the Black-veined White *Aporia crataegi* LINNAEUS 1758 (Pieridae), the Silver-washed Fritillary *Argynnis paphia* LINNAEUS 1758 (Nymphalidae; Fig. 9), the Clouded Yellow *Colias croceus* FOURCROY 1785 (Pieridae), the Plain Tiger *Danaus chrysippus* LINNAEUS 1758 and the Milkweed Butterfly *Danaus plexippus* LINNAEUS 1758 (Danaidae), the Brimstone *Gonepteryx rhamni* LINNAEUS 1758 (Pieridae; Fig. 2), the Scarce Copper *Heodes virgaureae* LINNAEUS 1758 (Lycaenidae; Fig. 16), the Queen of Spain Fritillary *Issoria lathonia* LINNAEUS 1758 (Nymphalidae), the Wall Brown *Lasiommata megera* LINNAEUS 1767 (Satyridae; Fig. 8), the Wood White *Leptidea sinapis* LINNAEUS 1758 (Pieridae; Fig. 4), the Small Copper *Lycaena phlaeas* LINNAEUS 1761 (Lycaenidae), the Marbled White *Melanargia galathea* LINNAEUS 1758 (Satyridae; Fig. 6), the Large Tortoiseshell *Nymphalis polychloros* LINNAEUS 1758 (Nymphalidae), the Speckled Wood *Pararge aegeria* LINNAEUS 1758 (Satyridae; Fig. 7), the Large White *Pieris brassicae* LINNAEUS 1758 (Pieridae), the Comma Butterfly *Polygonia c-album* LINNAEUS 1758 (Nymphalidae; Fig. 14), and the Common Blue *Polyommatus icarus* ROTTEMBURG 1775 (Lycaenidae; Fig. 15). The English and French names of the aforementioned butterflies have been taken from HIGGINS & RILEY (1971).

2.2 Investigated localities

The various butterflies have predominantly been observed at the following localities which are listed in alphabetical order (the distances from Heidelberg have been measured from the Theodor-Heuss-bridge across the river Neckar between Heidelberg-Altstadt and Heidelberg-Neuenheim): Nußloch (abt. 9 km south of Heidelberg), Rot (abt. 16 km south of Heidelberg), St. Leon (abt. 17 km southsouthwest of Heidelberg), Tairnbach (abt. 17 km southsoutheast of Heidelberg), and Walldorf (abt. 12 km south of Heidelberg). These localities are situated in the middle part of the Upper Rhine valley plain in the region around Heidelberg and Mannheim west of the marginal highlands of Odenwald and Kraichgau in the east. Geology, geography, forest distribution and temperatures of the region around Heidelberg and Mannheim are summarized in MADER (2009b).

The localities Nußloch and Tairnbach are particularly suitable sites for the analysis of the population dynamics of the Orange Tip *Anthocharis cardamines*, because they include westwards-oriented forest margins which border meadows and gardens. During the flight season, the males of the Orange Tip *Anthocharis cardamines* use to fly along the forest margins at the localities Nußloch and Tairnbach in both northwards and southwards direction, thus permitting easy counting of the number of males by daily walking along the forest margins for a distance of abt. 0.5 – 1 km in the early afternoon and recording the quantity of encountered males. At the locality Nußloch, the males of the Orange Tip *Anthocharis cardamines* are particularly active in flying to and fro along the margin of the forest during the period of blossom of the wild garlic which constitutes extensive carpets within the forest.

The various butterflies have subordinately also been observed at the following localities (in

alphabetical order): Hannover-Linden, Mülheim-Kärlich, Müsch, Rodgau-Jügesheim and Wildbad. The locality Hannover-Linden is situated at the western margin of the city of Hannover in the Leine valley in the southern part of the Northern German plain north of the highlands of Weserbergland, Solling and Harz as well as their northern foothills and outposts. The locality Mülheim-Kärlich is situated about 7 km northwest of Koblenz in the Neuwied Basin of the Middle Rhine valley between the highlands of the Eifel in the west and the Westerwald in the east. The locality Müsch is situated about 7 km westnorthwest of Adenau in the Ahr valley in the eastern part of the Eifel. The locality Rodgau-Jügesheim is situated about 18 km southeast of the city centre of Frankfurt am Main in the Frankfurt Basin of the Main valley between the highlands of the Taunus in the north and the Odenwald in the south. The locality Wildbad is situated about 20 km southsouthwest of Pforzheim in the Enz valley in the northern part of the Black Forest.

2.3 Data collection and evaluation

The various butterflies have predominantly been registered during my regular entomological observations at the localities Nußloch, Rot, St. Leon, Tairnbach and Walldorf in the region around Heidelberg and Mannheim from early spring to late autumn in 2007 and 2008. The various butterflies have subordinately also been recorded during my occasional entomological observations at the locality Mülheim-Kärlich between 1964 and 1972, at the locality Wildbad between 1968 and 1972, at the locality Walldorf between 1972 and 1979 as well as between 1989 and 2006, at various localities in the Eifel between Mechernich in the north and Trier in the south between 1975 and 1985, at the locality Hannover-Linden between 1979 and 1986, at the locality Müsch between 1980 and 1983, and at the locality Rodgau-Jügesheim between 1986 and 1989.

The wing-spread of the various butterflies has been measured from the upper left tip to the upper right tip of the fore wings in the position of horizontal inner or lower boundaries of the fore wings.

3 Results

The three size classes of the nine investigated butterfly species are described and compared with other butterfly species as follows.

3.1 The male of the Orange Tip *Anthocharis cardamines*

The three size classes of the male of the Orange Tip *Anthocharis cardamines* (Fig. 1) include large individuals with a wing-spread of about 42 – 45 mm, medium large individuals with a wing-spread of about 37 – 40 mm, and small individuals with a wing-spread of about 28 – 32 mm. The smallest dwarf forms of the male of the Orange Tip *Anthocharis cardamines* are only a little larger than the largest individuals of the Small Copper *Lycaena phlaeas*, and are even still smaller than the largest individuals of the Common Blue *Polyommatus icarus* and the Scarce Copper *Heodes virgaureae* as well as the smallest individuals of the Wood White *Leptidea sinapis*. The smallest dwarf forms of

the male of the Orange Tip *Anthocharis cardamines* (about 28 mm wing-spread) reach only about 62 % of the wing-spread of the largest males (about 45 mm wing-spread) at the investigated localities. The largest males of the Orange Tip *Anthocharis cardamines* reach the size of the smallest individuals of the Brimstone *Gonepteryx rhamni* and the Red Admiral *Vanessa atalanta* as well as of the average individuals of the Marbled White *Melanargia galathea,* the Clouded Yellow *Colias croceus,* the Small White *Pieris rapae* and the Green-veined White *Pieris napi.*

3.2 The Small White *Pieris rapae* and the Green-veined White *Pieris napi*

The three size classes of the Small White *Pieris rapae* and the Green-veined White *Pieris napi* (Fig. 3) include large individuals with a wing-spread of about 47 – 50 mm, medium large individuals with a wing-spread of about 40 – 45 mm, and small individuals with a wing-spread of about 32 – 35 mm. The smallest dwarf forms of the Small White *Pieris rapae* and the Green-veined White *Pieris napi* are only a little larger than the largest individuals of the Small Copper *Lycaena phlaeas*, the Common Blue *Polyommatus icarus* and the Scarce Copper *Heodes virgaureae,* and are even still smaller than the smallest individuals of the Marbled White *Melanargia galathea*, the Wall Brown *Lasiommata megera*, the Speckled Wood *Pararge aegeria* and the Ringlet *Aphantopus hyperantus*. The smallest dwarf forms of the Small White *Pieris rapae* and the Green-veined White *Pieris napi* (about 32 mm wing-spread) reach only about 64 % of the wing-spread of the largest individuals (about 50 mm wing-spread) at the investigated localities. The largest individuals of the Small White *Pieris rapae* and the Green-veined White *Pieris napi* are only a little smaller than the smallest individuals of the Large White *Pieris brassicae* and the Large Tortoiseshell *Nymphalis polychloros*, and reach the size of the average individuals of the Brimstone *Gonepteryx rhamni* and the Painted Lady *Vanessa cardui,* of the largest individuals of the Pale Clouded Yellow *Colias hyale*, and of the smallest individuals of the Red Admiral *Vanessa atalanta*.

3.3 The Pale Clouded Yellow *Colias hyale*

The three size classes of the Pale Clouded Yellow *Colias hyale* include large individuals with a wing-spread of about 47 – 50 mm, medium large individuals with a wing-spread of about 42 – 45 mm, and small individuals with a wing-spread of about 36 – 40 mm. The smallest dwarf forms of the Pale Clouded Yellow *Colias hyale* are only a little larger than the smallest individuals of the Wood White *Leptidea sinapis*, and are even still smaller than the average individuals of the Marbled White *Melanargia galathea* and the Queen of Spain Fritillary *Issoria lathonia*. The smallest dwarf forms of the Pale Clouded Yellow *Colias hyale* reach only the size of the smallest individuals of the Small Tortoiseshell *Aglais urticae*, the Painted Lady *Vanessa cardui* and the Peacock Butterfly *Inachis io* as well as of the average individuals of the male of the Orange Tip *Anthocharis cardamines*. The smallest dwarf forms of the Pale Clouded Yellow *Colias hyale* (about 36 mm wing-spread) reach only about 72 % of the wing-spread of the largest individuals (about 50 mm wing-spread) at the investigated localities. The largest individuals of the Pale Clouded Yellow *Colias hyale* are only a little smaller than the smallest individuals of the Large White *Pieris brassicae* and the Large Tortoiseshell *Nymphalis polychloros*, and reach the size of the average

individuals of the Brimstone *Gonepteryx rhamni* and the Painted Lady *Vanessa cardui*; of the largest individuals of the Small White *Pieris rapae,* the Green-veined White *Pieris napi* and the Small Tortoiseshell *Aglais urticae;* and of the smallest individuals of the Red Admiral *Vanessa atalanta*.

3.4 The Swallowtail *Papilio machaon*

The three size classes of the Swallowtail *Papilio machaon* (Fig. 5) include large individuals with a wing-spread of about 75 – 80 mm, medium large individuals with a wing-spread of about 65 – 70 mm, and small individuals with a wing-spread of about 55 – 60 mm. The smallest dwarf forms of the Swallowtail *Papilio machaon* are even still smaller than the largest individuals of the Large White *Pieris brassicae,* the Black-veined White *Aporia crataegi*, the Red Admiral *Vanessa atalanta*, the Peacock Butterfly *Inachis io* and the Silver-washed Fritillary *Argynnis paphia*, and are only a little larger than the average individuals of the Brimstone *Gonepteryx rhamni* and the Large Tortoiseshell *Nymphalis polychloros* as well as of the largest individuals of the Painted Lady *Vanessa cardui*. The smallest dwarf forms of the Swallowtail *Papilio machaon* (about 55 mm wing-spread) reach only about 69 % of the wing-spread of the largest individuals (about 80 mm wing-spread) at the investigated localities. The largest individuals of the Swallowtail *Papilio machaon* reach or exceed the size of the largest individuals of the Plain Tiger *Danaus chrysippus* and the Milkweed Butterfly *Danaus plexippus*.

3.5 The Red Admiral *Vanessa atalanta*

The three size classes of the Red Admiral *Vanessa atalanta* (Fig. 12) include large individuals with a wing-spread of about 57 – 60 mm, medium large individuals with a wing-spread of about 50 – 55 mm, and small individuals with a wing-spread of about 45 – 48 mm. The smallest dwarf forms of the Red Admiral *Vanessa atalanta* are only a little larger than the largest individuals of the Wall Brown *Lasiommata megera*, the Speckled Wood *Pararge aegeria* and the Ringlet *Aphantopus hyperantus,* and are even still smaller than the largest individuals of the Comma Butterfly *Polygonia c-album* and the average individuals of the Brimstone *Gonepteryx rhamni*. The smallest dwarf forms of the Red Admiral *Vanessa atalanta* reach only the size of the largest individuals of the male of the Orange Tip *Anthocharis cardamines*, the Small White *Pieris rapae,* the Green-veined White *Pieris napi,* the Pale Clouded Yellow *Colias hyale* and the Small Tortoiseshell *Aglais urticae*. The smallest dwarf forms of the Red Admiral *Vanessa atalanta* (about 45 mm wing-spread) reach only about 75 % of the wing-spread of the largest individuals (about 60 mm wing-spread) at the investigated localities. The largest individuals of the Red Admiral *Vanessa atalanta* are even still a bit larger than the smallest individuals of the Swallowtail *Papilio machaon* and reach the size of the largest individuals of the Peacock Butterfly *Inachis io*, the Large White *Pieris brassicae,* the Black-veined White *Aporia crataegi* and the Silver-washed Fritillary *Argynnis paphia.*

3.6 The Painted Lady *Vanessa cardui*

The three size classes of the Painted Lady *Vanessa cardui* (Fig. 13) include large

individuals with a wing-spread of about 52 – 55 mm, medium large individuals with a wing-spread of about 45 – 50 mm, and small individuals with a wing-spread of about 38 – 40 mm. The smallest dwarf forms of the Painted Lady *Vanessa cardui* reach only the size of the smallest individuals of the Marbled White *Melanargia galathea*, the Wall Brown *Lasiommata megera*, the Speckled Wood *Pararge aegeria* and the Ringlet *Aphantopus hyperantus,* and are even still smaller than the average individuals of the Comma Butterfly *Polygonia c-album* and the Clouded Yellow *Colias croceus*. The smallest dwarf forms of the Painted Lady *Vanessa cardui* reach only the size of the average individuals of the male of the Orange Tip *Anthocharis cardamines* and are even still smaller than the average individuals of the Queen of Spain Fritillary *Issoria lathonia*. The smallest dwarf forms of the Painted Lady *Vanessa cardui* reach only the size of the smallest individuals of the Peacock Butterfly *Inachis io*, the Small Tortoiseshell *Aglais urticae* and the Pale Clouded Yellow *Colias hyale* as well as of the average individuals of the male of the Orange Tip *Anthocharis cardamines*. The smallest dwarf forms of the Painted Lady *Vanessa cardui* (about 38 mm wing-spread) reach only about 69 % of the wing-spread of the largest individuals (about 55 mm wing-spread) at the investigated localities. The largest individuals of the Painted Lady *Vanessa cardui* reach the size of the largest individuals of the Large Tortoiseshell *Nymphalis polychloros,* of the smallest individuals of the Swallowtail *Papilio machaon,* and of the average individuals of the Red Admiral *Vanessa atalanta* and the Peacock Butterfly *Inachis io*.

3.7 The Peacock Butterfly *Inachis io*

The three size classes of the Peacock Butterfly *Inachis io* (Fig. 11) include large individuals with a wing-spread of about 57 – 60 mm, medium large individuals with a wing-spread of about 48 – 55 mm, and small individuals with a wing-spread of about 38 – 42 mm. The smallest dwarf forms of the Peacock Butterfly *Inachis io* reach only the size of the smallest individuals of the Marbled White *Melanargia galathea*, the Wall Brown *Lasiommata megera*, the Speckled Wood *Pararge aegeria* and the Ringlet *Aphantopus hyperantus,* and are even still smaller than the average individuals of the Comma Butterfly *Polygonia c-album* and the Clouded Yellow *Colias croceus*. The smallest dwarf forms of the Peacock Butterfly *Inachis io* reach only the size of the average individuals of the Wood White *Leptidea sinapis* and the male of the Orange Tip *Anthocharis cardamines* and are even still smaller than the average individuals of the Queen of Spain Fritillary *Issoria lathonia*. The smallest dwarf forms of the Peacock Butterfly *Inachis io* reach only the size of the smallest individuals of the Small Tortoiseshell *Aglais urticae*, the Painted Lady *Vanessa cardui* and the Pale Clouded Yellow *Colias hyale*. The smallest dwarf forms of the Peacock Butterfly *Inachis io* (about 38 mm wing-spread) reach only about 63 % of the wing-spread of the largest individuals (about 60 mm wing-spread) at the investigated localities. The largest individuals of the Peacock Butterfly *Inachis io* are even still a bit larger than the smallest individuals of the Swallowtail *Papilio machaon* and reach the size of the largest individuals of the Red Admiral *Vanessa atalanta,* the Large White *Pieris brassicae,* the Black-veined White *Aporia crataegi* and the Silver-washed Fritillary *Argynnis paphia.* FRIESE (1979) has figured a series with three size classes of the Peacock Butterfly *Inachis io*, and the dwarf form which is contained therein is still considerably smaller than the smallest individuals that I have observed.

3.8 The Small Tortoiseshell *Aglais urticae*

The three size classes of the Small Tortoiseshell *Aglais urticae* (Fig. 10) include large individuals with a wing-spread of about 47 – 50 mm, medium large individuals with a wing-spread of about 42 – 45 mm, and small individuals with a wing-spread of about 35 – 40 mm. The smallest dwarf forms of the Small Tortoiseshell *Aglais urticae* are only a little larger than the smallest individuals of the Wood White *Leptidea sinapis* and reach only the size of the average individuals of the male of the Orange Tip *Anthocharis cardamines* as well as of the smallest individuals of the Pale Clouded Yellow *Colias hyale*, the Painted Lady *Vanessa cardui* and the Peacock Butterfly *Inachis io.* The smallest dwarf forms of the Small Tortoiseshell *Aglais urticae* are still smaller than the smallest individuals of the Marbled White *Melanargia galathea*, the Wall Brown *Lasiommata megera*, the Speckled Wood *Pararge aegeria* and the Ringlet *Aphantopus hyperantus*. The smallest dwarf forms of the Small Tortoiseshell *Aglais urticae* (about 35 mm wing-spread) reach only about 70 % of the wing-spread of the largest individuals (about 50 mm wing-spread) at the investigated localities. The largest individuals of the Small Tortoiseshell *Aglais urticae* are only a little smaller than the smallest individuals of the Large Tortoiseshell *Nymphalis polychloros* and the Large White *Pieris brassicae*, and reach the size of the average individuals of the Brimstone *Gonepteryx rhamni* and the Painted Lady *Vanessa cardui*; of the largest individuals of the Small White *Pieris rapae*, the Green-veined White *Pieris napi* and the Pale Clouded Yellow *Colias hyale*; and of the smallest individuals of the Red Admiral *Vanessa atalanta*.

3.9 The Marbled White *Melanargia galathea*

KÖSTLER (1986) has described a dwarf form of the Marbled White *Melanargia galathea* (Fig. 6) with a wing-spread of 31 mm in contrast to the wing-spread of about 40 mm of average individuals and about 45 mm of large individuals. The dwarf form of the Marbled White *Melanargia galathea* (31 mm wing-spread) which has been reported by KÖSTLER (1986) reaches only about 69 % of the wing-spread of the largest individuals (about 45 mm wing-spread). The dwarf form of the Marbled White *Melanargia galathea* that has been observed by KÖSTLER (1986) reaches only the size of the smallest males of the Orange Tip *Anthocharis cardamines* which I have noted during my long-term entomological observations.

4 Discussion

The long-term observations of various butterflies including the Small Tortoiseshell *Aglais urticae,* the male of the Orange Tip *Anthocharis cardamines,* the Pale Clouded Yellow *Colias hyale,* the Peacock Butterfly *Inachis io,* the Swallowtail *Papilio machaon,* the Green-veined White *Pieris napi,* the Small White *Pieris rapae,* the Red Admiral *Vanessa atalanta,* and the Painted Lady *Vanessa cardui* have revealed that apart from medium large and large individuals, occasionally also small individuals are developed which comprise sometimes even extraordinary dwarf forms. The wing-spread of the smallest dwarf forms of the nine investigated butterfly species reaches only about 62 – 75 % of the wing-spread of the largest individuals at the investigated localities. The subordinate to accessory occurrence of small

individuals of the nine investigated butterfly species with the only rare establishment of extraordinary dwarf forms testifies to the only occasional development of serious environmental stress which stimulates sometimes the premature pupation of the larvae of the butterflies prior to the achievement of their average or maximum size.

The environmental factors triggering the subordinate to accessory premature pupation of the larvae of the butterflies prior to the achievement of their average or maximum size which leads to the development of extraordinary dwarf forms of the butterflies are probably predominantly cold and wet weather periods of longer duration than the usually short phases of cool and moist weather separating longer periods of warm and dry weather during spring and summer. Extended periods of cold and wet weather instead of only short phases of cool and moist weather between longer periods of warm and dry weather during spring and summer prevent some larvae of the butterflies from sufficient feeding which results in retardation of their growth and thus stimulates also premature pupation at the end of the larval stage of the cycle of metamorphosis of the butterflies. The long-term observations of the nine investigated butterfly species has revealed that some of the usually short phases of cool and moist weather separating longer periods of warm and dry weather during spring and summer have in various years been extended to cold and wet weather periods of longer duration which have affected different butterfly species with a staggered succession of the larval stages and the pupation intervals of the group in the course of the year.

The most important of the short phases of cool and moist weather between longer periods of warm and dry weather during spring and summer in the southern and western parts of Germany are the May cold (Ice Saints), the June cold (sheep cold), the July cold and the August cold (MADER 2009a, 2009c), with each of these short phases of cool and moist weather having been once or several times extended to cold and wet weather periods of longer duration in the time of my long-term observations from 1964 to 2008. The phases of cool and moist weather of the May cold (Ice Saints), the June cold (sheep cold), the July cold and the August cold comprise normally only three to seven days and represent thus pronounced short breaks separating a suite of successive periods of warm and dry weather of longer duration, whereas in extraordinary constellations, these accentuated interruptions of longer periods of warm and dry weather can extend up to two to three weeks. The prolongation of the usually short phases of cool and moist weather of only three to seven days duration to extended periods of cold and wet weather of up to two to three weeks duration has serious impact on the evolution of the larvae of the butterflies, with the exceptionally long persistence of cold and wet conditions instead of warm and dry conditions preventing some larvae of the butterflies from sufficient feeding which results in retardation of their growth and thus stimulates also premature pupation at the end of the larval stage of the cycle of metamorphosis of the butterflies.

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Figures 1 – 16: Examples of butterflies mentioned in the text. **1**: The Orange Tip *Anthocharis cardamines* LINNAEUS 1758 (Pieridae) male (left) and female (right). **2**: The Brimstone *Gonepteryx rhamni* LINNAEUS 1758 (Pieridae) male. **3**: The Green-veined White *Pieris napi* LINNAEUS 1758 (Pieridae) female. **4**: The Wood White *Leptidea sinapis* LINNAEUS 1758 (Pieridae). **5**: The Swallowtail *Papilio machaon* LINNAEUS 1758 (Papilionidae). **6**: The Marbled White *Melanargia galathea* LINNAEUS 1758 (Satyridae). **7**: The Speckled Wood *Pararge aegeria* LINNAEUS 1758 (Satyridae). **8**: The Wall Brown *Lasiommata megera* LINNAEUS 1767 (Satyridae). **9**: The Silver-washed Fritillary *Argynnis paphia* LINNAEUS 1758 (Nymphalidae) male. **10**: The Small Tortoiseshell *Aglais urticae* LINNAEUS 1758 (Nymphalidae). **11**: The Peacock Butterfly *Inachis io* LINNAEUS 1758 (Nymphalidae). **12**: The Red Admiral *Vanessa atalanta* LINNAEUS 1758 (Nymphalidae). **13**: The Painted Lady *Vanessa cardui* LINNAEUS 1758 (Nymphalidae). **14**: The Comma Butterfly *Polygonia c-album* LINNAEUS 1758 (Nymphalidae). **15**: The Common Blue *Polyommatus icarus* ROTTEMBURG 1775 (Lycaenidae). **16**: The Scarce Copper *Heodes virgaureae* LINNAEUS 1758 (Lycaenidae). Figs. **6** and **16**: Photos supplied by FRANZ VETTER (Nürnberg), all other figures: Photos supplies by Dr. KLAUS VON DER DUNK (Hemhofen).