Biology, distribution, and extinction of *Colias myrmidone* (Lepidoptera, Pieridae) in Bavaria and its situation in other European countries

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Abstract: *C. myrmidone*, the Danube Clouded Yellow, one of the most endangered butterfly species in Germany and listed as threatened with extinction, is very likely to be currently extinct. For *C. myrmidone* and several other pontic south-east European species (i.e. of the genus *Cytisus*) the slopes along the river Danube served as an immigration route to Bavaria. The paper describes how a period of decline followed a period of suspected dispersal. In Germany, *C. myrmidone* was last reported in the year 2000 although great efforts were undertaken to find the species in 2001 and 2003. A combination of factors were likely to be responsible for the decline and extinction of *C. myrmidone* in Bavaria and Germany. Firstly, unfavourable grassland management led to a drastic deterioration of habitat quality over the last 10 years. Furthermore, larval habitats like sun-exposed xeric hillsides constantly decreased. Lastly, heavy summer rainfalls and mild, wet winters over more recent years were probably disadvantageous. The present study and recommendations developed were too late to prevent any apparent extinction across Germany.
The aim of this paper is to summarise the conservation biology of *C. myrmidone*, to discuss factors influencing its extinction in Bavaria and to provide insight into its conservation status in other European countries. Conclusions are given regarding the future conservation of the butterfly.

Key words: butterflies, *Colias myrmidone,* conservation, distribution, habitat-use.

Introduction

Colias myrmidone (Esper 1780), the Danube clouded yellow, is one of the most endangered butterfly species in Germany, if not globally. The species is listed as being threatened with extinction in both the Red Data Book of Germany (Pretscher 1998) and in the Red Data Book of Bavaria (Geyer & Bücker 1992). *C. myrmidone* is rapidly declining in neighbouring countries, e.g. the Czech Republic and Slovak Republic, Austria, and Hungary (Beneš et al. 2002, Kudrna & Mayer 1990). In Europe *C. myrmidone* was already classified as "vulnerable" in the 1980's and again recently (Heath 1981, van Swaay & Warren 1999).

Populations of *C. myrmidone* in southern Germany were restricted to Bavaria and at the end of the 20th century, the species completely disappeared from southern Bavaria. Its center ranges around Regensburg have been reduced to a few populations. Prior to 2000 the butterfly occurred north of Regensburg, near to Kallmünz in the Naab valley. Some authors (Weidemann 1989, Kudrna & Mayer 1990) pointed out a serious decrease in population sizes combined with a decline in habitat quality over the past 25 years and they predicted an imminent extinction of the species.

Although conservation efforts started in the late 1980's (Kudrna & Mayer 1990), it is very probable that *C. myrmidone* is now extinct in Bavaria and the species was last seen in the year 2000 (two males, Geyer et. al 2001).

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In this paper we discuss the reasons for this particular extinction and the situation in other countries.

The Biology and Ecology of *Colias myrmidone*

Understanding the distribution and extinction of *C. myrmidone* in Bavaria (Germany) requires knowledge of its biology and ecology. The Western European range of *C. myrmidone* should be referred to as *C. myrmidone myrmidone* (Esper, 1781). Populations found east of Southern Ukraine belong to the distinct subspecies *C. myrmidone ermak* (Grum Grshimailo, 1890). *C. myrmidone* occurs in Central Europe and eastwards in Poland, Hungary, the former Northern Yugoslavia, Bulgaria and across Southern Russia as far as Western Asia. The most western edge of the *C. myrmidone* distribution range is Bavaria, with the northern edge of the range not well-known (Menhofer 1938, Schneider 1936, Settele et al. 1999, Kudrna & Mayer 1990, Weidemann 1989, 1995). Single records from western and eastern Prussia date from the early 20th century (Menhofer 1938, Warnecke 1929). Generally, *C. myrmidone* is very locally distributed.

The butterfly is associated with continental biotopes (Kudrna & Mayer 1990). Suitable habitats at the edge of the western distribution range are calcareous and dolomitic grasslands with a southern slope exposure, primary heath-steppes, open heath-forests, secondary xeric grassland communities of grazed flat slopes, xeric valleys with oligotrophic grassland communities and clearings in pine-forests (Gauckler 1962, Settele et al. 1999, Weidemann 1995). *C. myrmidone* is confined to the occurrence of its host-plants, which, in Bavaria are several and complex. Thus Weidemann (1989, 1995) observed egg-laying on *Cytisus ratisbonensis* in the field, whereas eggs were also laid on *Cytisus nigricans* and *Cytisus purpurascens* in cages (plant nomenclature: Oberdorfer 1990). However, larvae did not feed on these broom species. By contrast, Metschl & Sälzel (1925) noted that females preferred *C. ratisbonensis* to *C. nigricans*, and Kudrna & Mayer (1990) found that larvae fed on both *C. ratisbonensis* and *Cytisus supinus*. There is also a different host-plant use in different geographical regions (Warnecke 1929). Nevertheless, *C. myrmidone* is monophageous on the genus *Cytisus*.

In Bavaria the Danube Clouded Yellow is usually bivoltine, but during long, hot summers a partial third generation may occur (Gauckler 1962, Metschl & Sälzel 1925). Adults of the first generation emerge in late May or in early June and fly until mid to late June. The second generation flies from mid July to early September (Metschl & Sälzel 1925, Kudrna & Mayer 1990, Settele et. al 1999).

Kudrna & Mayer (1990) stated that *C. myrmidone* requires large expanses of biotopes with a characteristic set of resources, i.e. flowery patches, rocks with food-plants, and shelter. Gauckler (1962) and Weidemann (1995) emphasised that eggs are always laid on the upper side of leaves near the top of a sprout. Furthermore only sun-exposed sprouts at microclimatically-favoured, warm sites were chosen for egg-laying. This observation was confirmed by Romstöck-Völkl et. al (1999) who additionally found that oviposition depended on the size and position of food-plant patches. There was a significant accumulation of oviposition on patches with over 30 sprouts present and in patches close to rocks (< 1m distance). A study in the White Carpathians and adjacent sites (Czech Republic and Slovakia) revealed similar results (Geyer et. al. 2001, Dolek et al. in prep.). The Carpathian yellows used *Cytisus austriacus* as a food-plant with eggs laid at the top of young, exposed shoots as well. *C. myrmidone* is clearly largely thermophilous.

Young larvae feed on leaves near the top of a sprout and when resting, they firmly attached themselves to the upper side of the leaves by a small mat of silk (Geyer et. al 2001, Kudrna & Mayer 1990). In the laboratory caterpillars never move far from their resting position during early instars and although adult larvae become increasingly mobile, they remain on the top of the plant (Geyer et. al 2001). In the field, larvae of the first generation pupate on stems near the ground (Metschl & Sälzel 1925, Kudrna & Mayer 1990, Weidemann 1995, Settele et al. 1999), while in the lab pupation never took place near the ground, but at the end of the sprouts (Geyer et al. 2001). Furthermore, information on hibernation is contradictory. Weidemann (1995) stated that third instar larvae hibernate in the litter on the ground. By contrast, Metschl (1923, cited in Gauckler 1962) described that larvae hibernate on the stems of their host-plant.

The Danube Clouded Yellow is a specialized species with regard to microclimatic conditions and

larval food requirements. At the immature stages they are extremely vulnerable since they do not hide.

Distribution and extinction of *C. myrmidone* in Bavaria

C. myrmidone was first found in Bavaria in 1849. Speyer & Speyer (1858) wrote that *C. myrmidone* regularly appeared after 1849 at a well collected location near Regensburg, although it had never been seen before this. A possible hypothesis for this pattern follows: For several pontic southeastern European species (e.g. the plant genus *Cytisus*), slopes of the Danube served as a migration corridor (Gauckler 1962, Gößmann 1962, Weidemann 1995). These species are adapted to dry and hot summers as well as cold winters. Such conditions only occur in the most continental parts of Germany, such as the Regensburg area. In the middle of the 19th Century the "Little Ice Age" ended bringing cold winters and wet summers to Europe for several centuries causing bad harvests and famines (e.g. www.autrocontrol.at/cgi-bin/lexikon.cgi?Kleine_Eiszeit). The wet summers in particular were certainly not very favorable for *C. myrmidone* thus preventing its expansion to Central Europe. At the end of the Little Ice Age and the once again changing climate an expansion to the west became possible.

During the second half of the 1800's, the butterfly's range expanded and many new sites were colonized (or discovered, if the above assumption is incorrect). At the beginning of the 1900's, *C. myrmidone* was known to have two main distribution centers, one in the Munich area and one in the Greater Regensburg area (Fig. 1). Most known

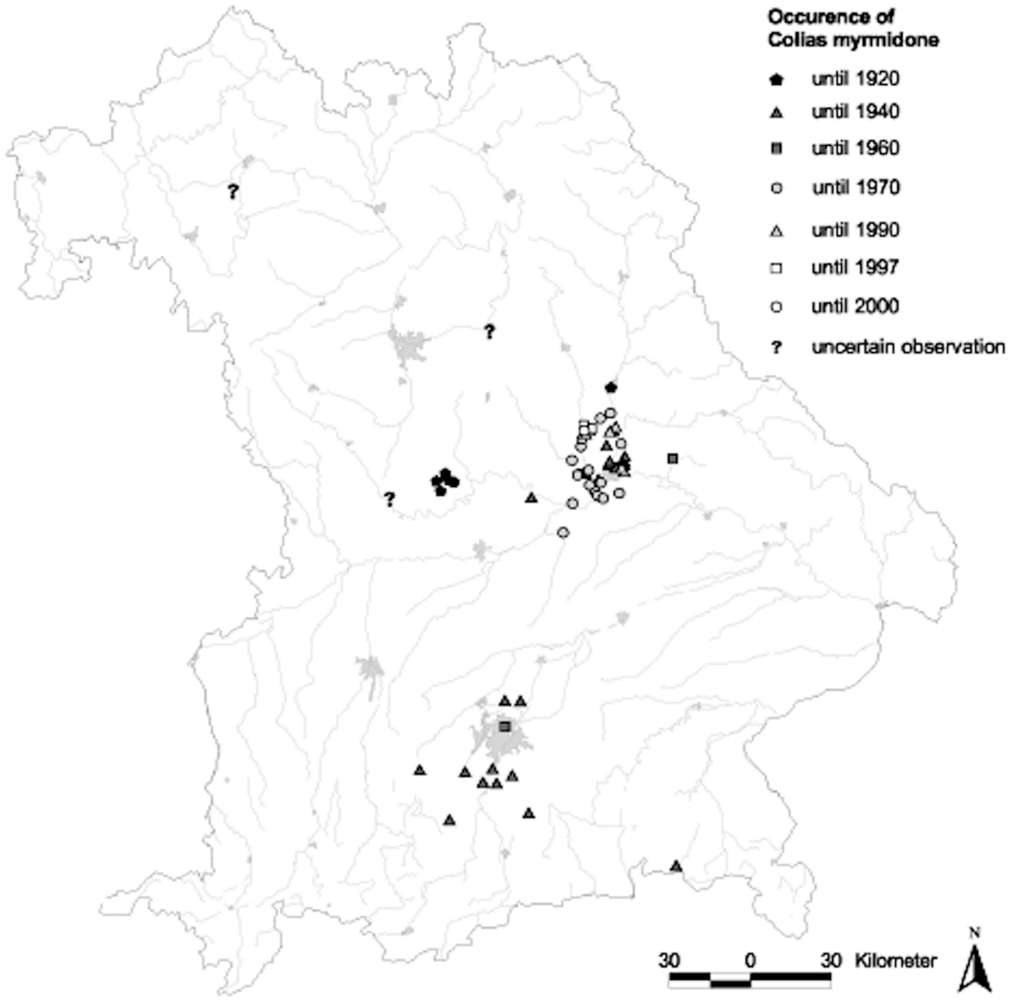

Figure 1: Distribution and decline of *C. myrmidone* in Bavaria. Literature used: Gauckler 1962, Knörzer 1914, 1917, Kraemer 1911, Kudrna & Mayer 1990, Menhofer 1959, Metschl & Sälzel 1925, Osthelder 1925, Romstöck-Völkl & Völkl 1996, Segerer et al. 1987, Warnecke 1929, Weidemann 1989, Wolfsberger 1950.

Munich area colonies were situated close to or south of Munich. *C. myrmidone* was also found across scattered sites in Upper Bavaria (Kudrna & Mayer 1990, Krämer 1911, LfU 2001, Osthelder 1925, Warnecke 1929, Wolfsberger 1950). Both Regensburg and Franconian Jura sites were on the slopes of the rivers Danube, Anlauter (a tributary to the Altmühl), Naab and Regen (Gauckler 1962, Knörzer 1914, 1917, Metschl & Sälzel 1925, Osthelder 1925). The village Emsing, near Eichstätt, was the western-most site of the butterfly (Krämer 1911).

However, *C. myrmidone* became extinct in all areas close to Munich before 1960, with a slower decline in the Jura. Gauckler (1962) enumerated over 20 sites with populations of the species. However, this meant a decline of about 50% from the maximum distribution. Between 1980 and 1989 only five sites near Kallmünz and Regensburg were left (Kudrna & Mayer 1990; Segerer et. al 1987). By 1996 Romstöck-Völkl et al. (1999) mentioned only three remaining sites. During an intensive investigation in 2000 Geyer et al. (2001) only found two males on a hillside near Kallmünz. In both 2001 and 2003 no individuals were found. The species appears to have become extinct in Bavaria since 2001.

Explanations for the extinction of *C. myrmidone* in Bavaria

Metschl & Sälzel noted decreasing numbers of *C. myrmidone* at the sites near Regensburg from about 1925. At that time people kept sheep and goats in stables in the villages and *Cytisus ratisbonensis* was gathered in large amounts as fodder. Osthelder (1925) wrote that populations of butterfly were declining because of increased cultivation of heathland that negatively impacted *C. ratisbonensis*.

By the end of the 1980's both Kudrna & Mayer (1990) and Weidemann (1989) warned of decreasing population sizes of *C. myrmidone* in the remaining colonies near Kallmünz. They attributed the steep decline to a massive deterioration of habitat quality. Weidemann (1989) specifically criticized the lack of grazing. The slopes near Kallmünz had been extensively grazed by sheep for a long period, with grazing being abandoned around 1960 (Kudrna & Mayer 1990). Weidemann (1989) pointed out that the lack of grazing resulted in the spreading of shrubs. Furthermore, increased nutrient (nitrogen) input from air pollution and the surrounding agricultural practices resulted in a selective increase in grass growth (for nitrogen emission by air see e.g. Ellenberg 1985). All of these factors changed the microclimatic conditions especially those close to the ground. This would have prevented females of *C. myrmidone* from detecting suitable host plants for oviposition under the required microclimatic conditions. Moreover, the loss of a mosaic of habitat patches, resulting in a loss of diversity of the required resources was to the butterfly's disadvantage (Kudrna & Mayer 1990, Weidemann 1989). Kudrna & Mayer (1990) showed from mark and recapture studies that recaptures were only made within sites. This was the only mark and recapture study carried out, with the number of marked individuals being so low that the usually small number of individuals assumed to be moving between sites could not be assessed. Consequently, one might reconsider the interpretation that non-suitable, "butterfly-hostile" habitats between sites prevented adults from passing from one site to another. Clearly, the small population size itself makes movements between habitat patches extremely unlikely. Many former nutrient-poor meadows and open pine stands with rich herb-layers disappeared following fertilization, afforestation, or agricultural intensification. Kudrna & Mayer (1990) regarded the small remaining populations as intrinsically threatened, with increasing vulnerability from stochastic variations in the environment and population size.

To improve the habitat quality of suitable slopes, all authors agreed that the appropriate measures should have been taken to remove bushes. Furthermore, grazing, the traditional form of land-use in the Franconian Jura, was generally recognized as the most effective form of management for long-term conservation (Dolek 1994, 1995, Harnischmacher 1988). Kudrna & Mayer (1990) however noted that grazing could imply hidden dangers as sheep feed on *Cytisus* sp. In spite of this insight, sheep grazing was reintroduced as a form of conservation in the 1990's, without being monitored for its effectiveness. Ironically, now all measures are too late.

A combination of factors are likely to have driven the extinction of *C. myrmidone* in Bavaria. 1) There was a constant decrease in suitable habitats as slopes were converted when grazing seized. 2) Unfavourable management practices were introduced on the

remaining grasslands in the 1990's. Some parts of the land lay fallow while other parts were used as fenced pastures with high grazing pressure. 3) Romstöck-Völkl & Völkl (1996) argued the loss of nectar plants due to an increased growth in grasses (annual herbs being suppressed) over large expanses of the sites and even in spite of the reintroduced sheep grazing. 4) There was no integrated management of grazing practice, since the behavior of caterpillars was not considered. Caterpillars feed and rest at the ends of sprouts that sheep feed upon and it is most likely that pupae as well as hibernating larvae remain on the plant, therefore a time period for harmless grazing was lacking (Dolek et al., in prep.). In order to avoid high mortality of *C. myrmidone*, only parts of each site should be grazed per year. Thus, a mosaic of differently grazed areas would be created. This policy would not only reduce the negative side-effects, but is also likely to increase total biodiversity. Unfortunately, grazing continued without a management plan and without sufficient instructions to farmers.

As part of a management plan shrubs were removed in 1993 and 1994 across part of the populated hillsides which anticipated an increase in the population size of *C. myrmidone* with an increase in habitat quality. Unfortunately, the butterfly became locally extinct at this comparably well, but formerly sparsely occupied hillside site. Romstöck-Völkl & Völkl (1996) assumed that this local extinction resulted from unknown ecological factors combined with a reduced population size. In any case, the outcome was not prevented by short-term conservation management.

Finally, high summer precipitation with wet, mild winters over the last few years presumably also contributed to the butterfly's decline. These unsuitable weather conditions are an example of stochastic ecological disasters that Kudrna & Mayer (1990) feared led to the extinction of many small populations in the past. Detailed information on the influence of a wet summer is available for *Parnassius apollo*: Large numbers of caterpillars were counted on a well studied site in the Northern Franconian Jura, but a long rainy period at the beginning of the flight period reduced butterfly numbers to a mere fraction of the expected number (Geyer & Dolek, unpubl. data).

Parnassius apollo went extinct locally in the mid 1990s on the hillsides near Kallmünz. Larvae of Apollo are associated with sunny, warm, rocky places with abundant larval foodplant, *Sedum album* (Geyer & Dolek 1995). *C. myrmidone* requires similar microclimatic conditions for its larval development. It therefore seems likely that the strictly rock-loving *Parnassius apollo* died out first and was followed by *C. myrmidone* which is presumably less restricted to open rocks.

The situation in other European countries

Kudrna & Mayer (1990) reported deteriorating conditions across the former Czechoslovakia. The Danube Clouded Yellow has been extinct in Bohemia since the 1970s. The local extinction of the last Bohemian populations coincided with the extinction from adjacent Austrian localities. Similarly, the butterfly has disappeared from most of its Moravian localities. Its current distribution in the Czech republic is now limited to the White Carpathians (Beneš et al. 2002), whereas in the Slovak Republic the last published finding was in 1950 (Kudrna & Mayer 1990). By contrast, van Swaay & Warren (1999) mentioned recent records in the Slovak Republic in their review of the European status of this species. Geyer et al. (2001) showed that *C. myrmidone* still occurs in the White Carpathians and adjacent areas on both sides of the border between the Czech Republic and the Slovak Republic. Although the meta-population there has higher numbers than in many other countries, there is no doubt of a significant decline. For example, at one site where *C. myrmidone* had a high density in 1999 and 2000 (Kopecek, pers. comm.), no butterfly was detected in 2001. Vegetation cover was laid fallow in the preceding two years, which presumably resulted in changes in habitat quality and the consequent disappearance of *C. myrmidone*. Populated sites appear to require small-scale, diversified land use: patchiness created by small scale grazing and mowing. However, such practices are currently diminishing throughout Central Europe. Without a change in current practices in the near future, this land use practice will be the key threat to the Danube Clouded Yellow and many other plant and animal species dependent on this dynamic habitat type.

For Austria, distribution data are available from an atlas based on the zoogeographical data bank "ZOODAT" (Reichl 1992). Kudrna & Mayer (1990)

cited this resource that reported 11 quadrants inhabited by *C. myrmidone* after 1970, but only 4 quadrants after1980. A 2000 survey revealed 7 more recent reports in ZOODAT. However, none of these occurrences has been confirmed (various informants, pers. comm., Geyer et al. 2001). Yet again, the most frequently cited cause of extinction was the change in habitat, e.g. at a site near Klagenfurt (Kärnten) patchy, mowed meadows were replaced by intensively cultivated meadows and cattle pastures (Dolek et al., unpublished). In the Red Data Book of Lower Austria (Höttinger & Pennerstorfer 1999) it is stated that there are new records (after 1980) from only a few sites (6 quadrants).

In Romania several colonies existed until recently (Mihut, pers. comm.). In the course of a visit in 2001, no individuals of *C. myrmidone* could be found in spite of an intensive search during the emergence time of both generations. Possible reasons for the rapid decline were the warm and humid weather during the previous winter and the extremely long dry period in the following summer (Mihut, pers. comm.). In contrast to the sites in most other western countries, such as Austria, habitat conditions still appear to be suitable.

The population sizes of *C. myrmidone* in Hungary are also in decline. Varga (pers. comm.) described the situation in terms of the most dramatic decline of any butterfly population observed in recent years.

In summary, *C. myrmidone* is decreasing in most parts of its geographical range (see Table 1). Although both proximate and ultimate causes of the declines and extinctions remain unknown, they appear to involve interacting factors as a result of changes in land use practices and changing weather patterns.

CODA

Although *C. myrmidone* would appear to be extinct on the last populated sites near Kallmünz, these hillsides still provide valuable habitat for other highly endangered insect species as butterflies (e.g. *Maculinea rebeli*, *Pseudophilotes baton*), bees (e.g. *Andrena ratisbonensis*) and grasshoppers (e.g. *Calliptamus italicus*). For some species the region is one of their last bastions in Germany. Hence the correct forms of conservation management should be implemented to maintain and improve habitat conditions. With

Table 1: Overview of present distribution and threat of *C. myrmidone* in other European countries.

country	references	region	situation and treath
Europe	van Swaay & Warren (1999)	whole	vulnerable, 20-50% SPEC 2: global distribution concentrated in Europe and considered threatened in Europe
Germany	Geyer et. al (2001), this study	Greater Regensburg area	extinct, changes in land use; declining area, unfavourable weather?
Austria	ZOODAT, Tschinder (pers. comm.)	Kärnten	probably extinct, changes in land use
Austria	ZOODAT, Zöchne (pers. comm.)	Greater Wien and Linz area	probably extinct, changes in land use
Hungary	Varga (pers. comm.)	whole	great decline, uncertain reasons
Czech Republic, Slovak Republic	Kopecek, Vitaz (pers. com.)	White Carpathians	decline, changes in land use
Romania	Mihut (pers. cmm.)	Greater Cluj Napoca area	unknown, no observaion in 2001, unfavourable weather?

such steps the habitat requirements of the Danube Clouded Yellow could be created and under such a scenario, possible existing populations might still occur and survive since it is always difficult to come up with concrete evidence for the extinction of any species. Should an overlooked population have survived, such management would obviously benefit the colony. Finally, reintroduction would be a further option following the restoration of habitat quality (for examples of other butterflies, see Wynhoff 1998).

As outlined above, the overall European situation of *C. myrmidone* is not promising. In most countries relative declines seem well underway and therefore conservation efforts in these places should start immediately. An international co-operation would be particularly useful for the Moravian and Slovakian White Carpathian colonies. The recent inclusion of *C. myrmidone* in the supplement of the FFH directive of the European Union will hopefully encourage immediate conservation efforts for the species.

Acknowledgements

We are grateful to Dr. C. van Swaay (Wageningen, Holland, De Vlinderstichting), Dr. S. Mihut (Cluj Napoca, Romania), Dr. J. Kulfan (Zvolen, Slovak Republic, Institute for forest ecology of SAW), Dr. O. Kudrna (Schweinfurt, Germany), F. Kopecek (Czech Republic), L. Vitaz (Slovak Republic), R. Hentschulek (Austria), Tschinder (Austria) for their support with the international investigation. Dr. C. Ruf, an anonymous referee, and the editor provided useful critical comments and improvements to the manuscript. S. Gwillym improved our English considerably.

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