

## Male trimorphism in *Pelecopsis mengei* (Erigoninae, Linyphiidae, Araneae)

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### Abstract

In males of *Pelecopsis mengei* (Simon, 1884) dimorphism in cephalothorax form was described earlier. I have studied this phenomenon on a large sample of *Pelecopsis mengei* from one locality in the Czech Republic. Unexpectedly, I found a third, hitherto not described morph of this species. Moreover, both previously described morphs were present in the population. No overlay between individual morphs and between females was found. The hypothesis that the form of the cephalothorax is encoded by a single locus with two alleles is analysed. I discuss the relevance of these findings for evolutionary biology and sexual selection in spiders.

**Key words:** sexual selection, trimorphism, cephalic lobe, sulcal sacs

### INTRODUCTION

Spiders of the genus *Pelecopsis* (Linyphiidae, Erigoninae) are known mainly from the Palearctic region and Africa (Platnick 2002). To date 83 species are described in this genus (Platnick 2002). Males of this genus often have a more or less strongly raised cephalic part of the carapace, which forms in most of the species a cephalic lobe. This cephalic lobe is generally broadly rounded over the top and carries the posterior median eyes. On either side, the lobe is delineated by a longitudinal groove, often designated as the postocular sulcus, a shallow elongate-oval impression extending backwards from above the posterior lateral eyes. It is bordered by a very fine edge, and is well defined by having darker pigmentation than the surrounding integument. In its anterior part, often close to the lateral eyes, there is a round or oval orifice leading into a pit, sometimes enlarged to a wide sulcal sac. The internal wall of the sacs is equipped with long hairs directed outwards. These features of male cephalothorax are highly species-specific and fixed within individual *Pelecopsis*

species, although some variability was described in East African species (Holm 1979).

According to our knowledge, some variability in this feature is described only in one European species - *Pelecopsis mengei* (Simon, 1884). For the first time, Holm (1945) noted that the form of the cephalic lobe is rather variable and depicted two males standing on opposite sides of the variability spectrum - one with large cephalic lobe and large sulcal orifice, and a second one with small sulcal orifice and not so arched cephalic lobe. Many other authors who depicted the male cephalothorax of *P. mengei* (see Locket & Millidge 1953; Miller 1966; Miller 1971; Palmgren 1976; Saito & Yasuda 1988) showed only the morph with high cephalic lobe. Interestingly, Wiehle (1960) illustrated the morph with smaller cephalic lobe and noted that the height of this lobe is very variable, it can be 50% higher than on the illustration. Finally, Holm (1979) suggested that the males of *P. mengei* are dimorphic. They occur only in two different morphs with no intermediates - the first one, which is more frequent, with a high cephalic lobe and large

sulcal orifice, and the second with a lower lobe and a much smaller orifice. In the first morph the sulcal sacs are large and touch each other medially inside the cephalothorax, whereas in the second morph the sulcal sacs are smaller, not touching each other. Both morphs were found together by Holm (1979).

This species is not common in Europe and that is why some questions concerning the variability still remain unanswered. In this study, I took the advantage of being able to examine a large population of *P. mengei* occurring in the Krive Jezero National Nature Reserve (South Moravia, Czech Republic). I studied the seasonal dynamics of the species with respect to the occurrence of both morphs. Unexpectedly, I found a third, hitherto undescribed, shape of carapace in the species. Here I describe this third morph and propose a model for diallelic inheritance of the form of cephalothorax in *P. mengei*.

## MATERIAL AND METHODS

Spiders were collected using pitfall trapping from January 1998 to December 2001 in the Krive Jezero National Natural Reserve. The traps were filled with 4% formaldehyde plus detergent and were emptied monthly. The Krive Jezero reserve is a flooded meadow (associations *Cnidion venosi* and *Caricion*

*gracilis*) with some solitary willows and oaks. It is situated in Southern Moravia, map grid number 7166, Czech Republic. Spiders were analysed by using a stereomicroscope Olympus SZX 12. The images were scanned by a CCD camera, and measurements were conducted in MicroImage™, version 4.0 for Windows software.

The effect of season on the occurrence of individual phenotypes was tested by Contingency Tables ( $\chi^2$ ) using the program JMP (SAS Institute Inc. 1995).

## RESULTS

### Seasonal dynamics

During this study, altogether 1959 specimens of *P. mengei* were analyzed. In total, both sexes were represented by nearly the same number of individuals (females:males) = 905:1054, sex ratio = 0.86). Although spider abundances were similar in individual years - 715 individuals in 1998, 405 in 1999, 459 in 2000 and 380 in 2001, the sex ratio varied greatly: 0.55 in 1998, 0.85 in 1999, 1.4 in 2000 and 1.1 in 2001. The reasons for such variations remain unclear but I can hypothesise that increased number of males in 1998 may correspond with catastrophic floods in July 1997 when the Krive Jezero meadow was several weeks under the water. Seasonal dynamics of *P. mengei* is demon-

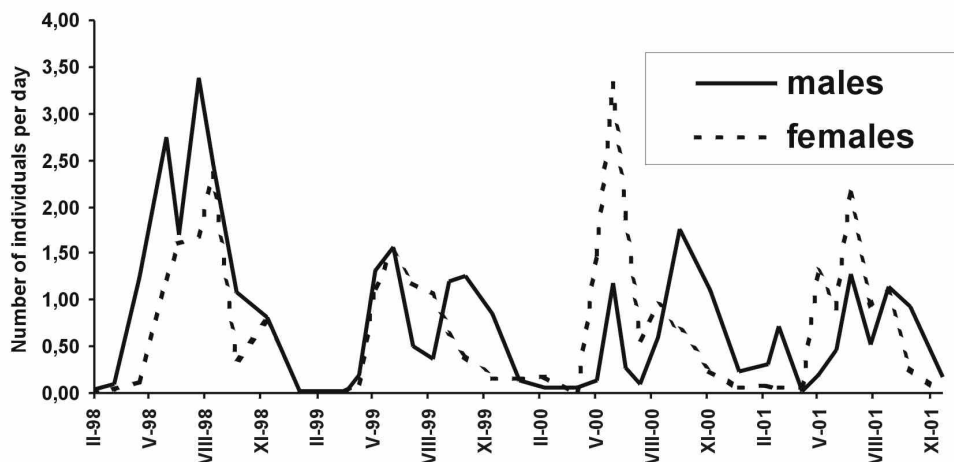


Fig. 1. Seasonal dynamic of *Pelecopsis mengei* during the investigated period.

strated in Fig. 1. Males exhibited two activity peaks (or populations?) during the vegetation season - the first peak of activity corresponded with the activity of females in early summer and the second one, which was of the same or even higher intensity than the first one, appeared in late September and lasted until the end of November. Although the data for females was not so clear they also seemed to have two activity peaks during the season. Based on these data, I suppose that *P. mengei* has a bivoltine life cycle.

### Males of *P. mengei* are trimorphic

In my large material of males of *P. mengei*, I focused on the shape of the cephalothorax. I analyzed 784 males and I found unexpectedly three morphs (Fig. 2). The first morph (N=708) was identical with the morph usually illustrated as *P. mengei* (see Introduction). The basic characters of this morph are a high cephalic lobe and large, almost round sulcal orifices leading to large sulcal sacs (Fig. 2A). The second morph (N=75) had a smaller cephalic lobe with much smaller sulcal orifices and reduced sulcal sacs (Fig. 2B). The third morph (N=1) had only an elevated cephalic part of the cephalothorax, while the cephalic lobe was not developed. The sulcal orifices were present and are round in shape (Fig. 2C). This morph was observed for the first time and has not been described yet. Although small variability in individual morphs existed, the differences among individual shape types were clearly defined and each specimen could be assigned to one of the morphs. Based on these facts, I propose that males of *P. mengei* are trimorphic.

To confirm that all specimens belonged to *P. mengei*, I carefully studied the structure of the male copulatory organs and did not find any noticeable variation. This was also the case for the females, where I did not detect any variation neither in the shape of cephalothoraxes nor in the structure of the epigynes.

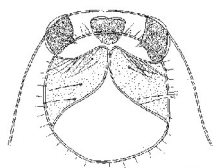
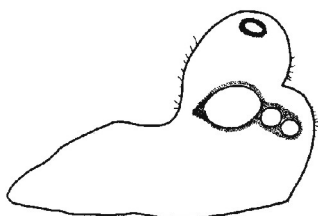
### The ratio between individual morphs is stable

Since the population of *P. mengei* in Krive Jezero has a well defined phenology I wanted to know whether the differences in the abundance of individual morphs existed during the year. That is why I analyzed the ratio of the male morphs in the entire population both during seasons and during both peaks of males' activity. As the new morph without cephalic lobe was represented by only one male, it was not included in this analysis. As shown in Fig. 3, the effects of season and peak were not significant. The percentage of the morph with a median cephalic lobe in the population was rather stable at about 10% both during the vegetation season (max. 11.3% in spring, min. 7.8% in winter) as well as during both peaks of male activity (in early summer peak 10.7%, and in the autumn peak 8.7%). These data strongly support the hypothesis that the male morph ratio is constant during the population cycle of *P. mengei*, and that the individual morphs do not represent seasonal forms.

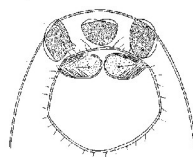
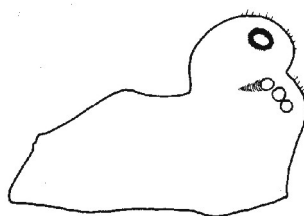
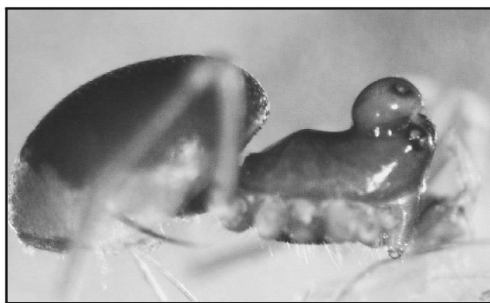
### The male trimorphism may be encoded by a single locus with two alleles

I propose a hypothesis that the form of cephalothorax is encoded by a single locus 'A' with two alleles (*A* and *a*). This hypothesis is based on the facts, that male trimorphism exists in the population and the presence and frequency of individual male morphs in the population do not vary during the annual cycle. According to this hypothesis, males with high cephalic lobe are homozygotes with genotype *AA*, males with medium lobe are heterozygotes with genotype *Aa* and males without cephalic lobe are homozygotes with genotype *aa*. Importantly, locus 'A' is expressed only in males.

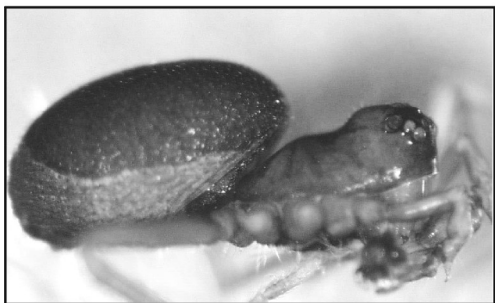
If this hypothesis is right, the frequencies of individual phenotypes can be described by the Hardy-Weinberg rule. The Hardy-Weinberg rule says that in a large, randomly mating population, in the absence of migration, mutation and selection, allele frequencies

**A**

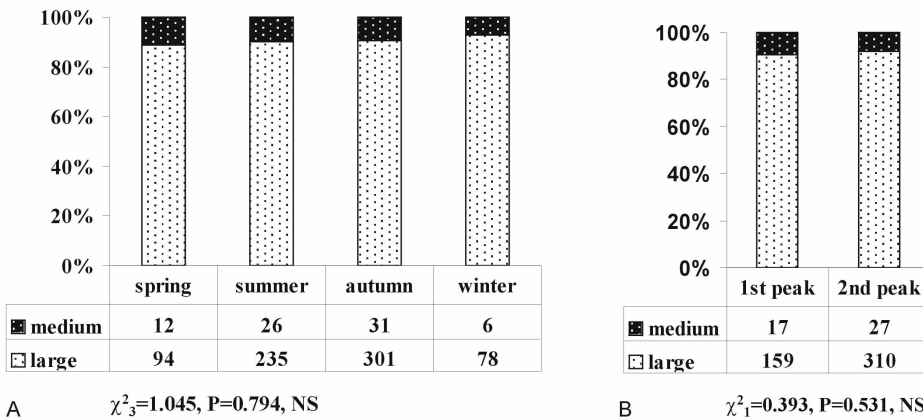
Holm, 1979

**B**

Holm, 1979

**C**

**Fig. 2.** The male morphs of *Pelecopsis mengei*. **(A)** morph with large cephalic lobe and sulcal orifices. **(B)** morph with median cephalic lobe and reduced sulcal orifices. **(C)** morph with no cephalic lobe. A and B is accompanied by drawings of sulcal sacs in dorsal view as illustrated by Holm (1979).



**Fig. 3.** The proportion of individual morphs during the seasons (**A**) and activity peaks (**B**). Number of individuals per morphs and statistical significance between these groups is indicated.

stay the same from generation to generation. Accordingly it follows from the rule that, if the allele frequency of one of the alleles at a locus is  $p$  and that of the other is  $q$  then the frequencies of the two homozygotes and the heterozygote are given by  $p^2$ ,  $q^2$  and  $2pq$ . In my population, I found 708 males with large lobe ( $AA$ ), 75 males with medium lobe ( $Aa$ ), and 1 male with no lobe ( $aa$ ). For our population,  $p$  and  $q$  can be easily determined from the frequencies of homozygotes  $AA$  (0.904) and heterozygotes  $Aa$  (0.095) as  $p=0.95$  and  $q=0.05$ . According to this scheme the expected number of males with no lobe in our sample ( $N=784$ ) is 1.94. It fits well the observed data and supports the above-described hypothesis.

## DISCUSSION

In this study, I analyzed a large population of *P. mengei* in Southern Moravia (Czech Republic). I show that males of *P. mengei* have two peaks of activity during the year - in early summer and in the autumn. Furthermore, I show that males of *P. mengei* appear in three morphologically distinguishable morphs that differ in the shape of cephalothorax. Because the frequency of these morphs was stable during the year, I formulated the hypothesis that the shape of head is encoded by a single locus

with two alleles. The frequencies of individual phenotypes in my population were in good agreement with the Hardy-Weinberg rule, which supports my hypothesis.

Dimorphism in males of *P. mengei* was described previously (Holm 1945; Holm 1979). Importantly, Holm (1979) pointed out that the morph with large lobe is the most frequent. This suggests that the frequencies observed in my population, where this morph had almost 90% dominance, can appear also in other populations. An interesting consequence of this fact is that, if my hypothesis is right, the morph without the cephalic lobe should be very rare everywhere with a dominance at about 0.1%. It is necessary to study also other populations of *P. mengei* to confirm this finding. Importantly, I have found only one animal of the morph without cephalic lobe. For this reason I cannot exclude the possibility that this specimen is aberrant in some way. My ideas thus can gain further support when more individuals of the third morph are found.

Polymorphism within one sex is rare and it is generally related to genetically based alternative mating strategies (Andersson 1994). The presence of two morphs in one population can only be stable if both morphs have the

same average fitness (Gadgil 1972). The male cephalic structure is important for successful mating (Schaible et al. 1986) as was described in many species - e.g. *Baryphyma pratense* (Blackwall, 1861) (see Blest & Taylor 1977), *Hypomma bituberculatum* (Wider, 1834) (see Bristowe 1931) or *Oedothorax gibbosus* (Blackwall, 1841) (see Heineman & Uhl 2000). It was demonstrated in another dimorphic species - *Oedothorax gibbosus* (see Maelfait et al. 1990)- that the morph *gibbosus* with a hairy groove is probably more attractive to females than the morph *tuberosus* without this hairy groove (Vanacker et al. 2001). It is probably due to the role of the groove in gustatorial courtship behaviour, moreover it seems that a hairy groove acts as a nuptial feeding device (Vanacker et al. 2002). As a mechanism compensating for higher attractiveness of the *gibbosus* morph, shorter juvenile development and sex ratio distortion in favour of the female sex in the *tuberosus*-genotypes was suggested (Vanacker et al. 2001). One can imagine a similar scenario also in *P. mengei* - the morph with high cephalic lobe and large sulcal sacs with many hairs inside may be more attractive to females than the morph with reduced sulcal sacs and lower cephalic lobe. Morphs with smaller cephalic lobe may compensate for such a disadvantage in sexual selection e.g. by mechanisms described in the *tuberosus* morph of *Oedothorax gibbosus*. However, this hypothesis is purely speculative and needs to be investigated in laboratory rearing experiments.

In this study, I describe the male trimorphism of *P. mengei*. Unfortunately, some interesting consequences of our findings remain to be tested. Laboratory rearing experiments, as well as histological studies focused on ultrastructure of cephalic lobe are currently in preparation. I hope that our study might also help other arachnologists to study the polymorphism in spiders in the light of evolutionary biology and sexual selection.

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