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CH. ANASTASIADOU, A. KOUKOURAS, M. MAVIDIS, N. CHARTOSIA, MD. MOSTAKIM, M. CHRISTODOULOU, CH. ASLANOGLOU

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CH. ANASTASIADOU, A. KOUKOURAS, M. MAVIDIS, N. CHARTOSIA, MD. MOSTAKIM, M. CHRISTODOULOU & CH. ASLANOGLOU

Department of Zoology, School of Biology,
Aristoteleio University of Thessaloniki,
541 24 Thessaloniki, Greece

e-mail: akoukour@bio.auth.gr

Abstract

In order to elucidate the distinction of Atyaephyra desmarestii subspecies (A. d. desmarestii, A. d. orientalis, A. d. stankoi and A. d. mesopotamica) and investigate their geographical distribution in Greece, the main morphological features and somatometric ratios were studied in numerous specimens collected from a dense station network of Greek fresh waters. Specimens from Belgium, Portugal, Albania and Turkey were also examined. Atyaephyra desmarestii was found in western and northern Greece while it was absent in eastern Greece, the Aegean and the Ionian islands. The comparison of the obtained data with those of the literature revealed a clearly overlapping variability of the main key morphological features among the four subspecies. The results of this study indicate that the current A. desmarestii subspecies are not valid on the basis of the used key features. There is only one very variable species with many ecophenotypes.

Keywords: Decapoda; *Atyaephyra*; Morphological variation; Distribution.

Introduction

The monotypic genus *Atyaephyra* de Brito Capello, 1867 includes the species *Atyaephyra desmarestii* (Millet, 1831) which extends its distribution in the fresh waters of Europe, North Africa and the Middle East up to Iran. A detailed revision of this genus synonyms and etymology has been given by HOLTHUIS (1993). BOUVIER (1913) was the first who distinguished the western (European and North African) from the eastern (Asian) populations as different variations (*occidentalis* and *orientalis* respectively). HOLTHUIS (1961) distinguished two subspecies under the names *A. desmarestii desmarestii* and *A. desmarestii orientalis*, giving a detailed description of *A. desmarestii orientalis* from Turkey. KARAMAN (1972) described the third subspecies from Doirani Lake (F.Y.R.O.M.), *A. desmarestii stankoi*, while AL-ADHUB (1987) described the fourth subspecies from Iraq, *A. desmarestii mesopotamica*.

In any case, the status and the geographical distribution of *Atyaephyra desmarestii* subspecies seem to be uncertain. HOLTHUIS (1961) has recorded considerable morphological variations in *A. d. orientalis* populations from different areas of Turkey. KINZELBACH & KOSTER (1985) noticed the necessity for a more comprehensive study of *Atyaephyra* populations, particularly from the Balkan region. Finally, GORGIN (1996), studying two *A. d. mesopotamica* populations from Iran, questioned the validity of this subspecies concluding: '... more studies should be undertaken to establish the validity of these three subspecies'.

The present study aims at determining the variability range of the key characters used to distinguish *A. desmarestii* subspecies, in order to check the subspecies validity, which could result in the knowledge of the geographical distribution of this species.

Materials and Methods

Atyaephyra desmarestii individuals were collected with a hand net from a dense station network, covering all the Greek fresh waters (Fig. 1). Furthermore, a significant number of individuals from Belgium, Portugal, Albania and Turkey were examined. The Turkish specimens belong to the type-material of *A. d. orientalis* (HOLTHUIS, 1961) and were borrowed from the Nationaal Natuurhistorisch

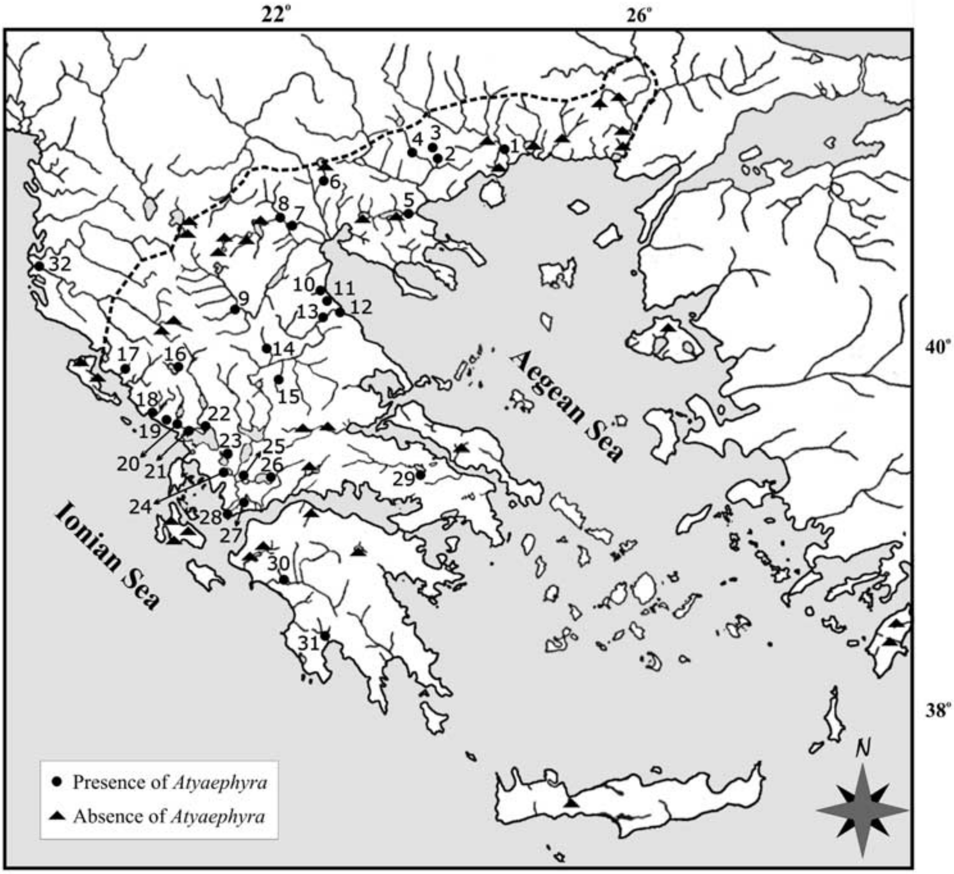

Fig. 1: Map indicating the sampling stations of Greek and Albanian fresh waters.

Museum of Leiden. The data on all material studied are given in Table 1.

In all specimens, approximately 80 morphological features and somatometric ratios were studied. Data were processed with the SPSS software package in an IBM compatible computer, for each station separately. For every studied feature the most frequent values (bulk) that are appearing in more than 70% of the population individuals and the variability range of the feature were calculated.

The review of the relevant literature indicated that 14 features are used as key characters to distinguish *A. desmarestii* subspecies. The variability of these features was estimated among populations from different geographical areas and compared with the relevant literature data (Table 2). Greece was divided into three areas and the most variable populations in each area were selected and grouped (northern Greece, stations 3, 5, 8; central Greece, stations 9, 17, 26; southern Greece, station 30). The data analysis allowed the distinction of the constant features from those overlapping among the populations and the evaluation of their validity as key characters.

Results

In Greece, *Atyaephyra desmarestii* was found in the western and northern part of the mainland (Fig. 1), in lakes and rivers with rich riparian vegetation and a constant water flow of low velocity. On the contrary, this species was not found in the Aegean and Ionian islands.

In all populations studied, the female maximum post-orbital carapace length was longer than that of the males (Table 1).

From Table 2 it is obvious that most of the studied features (e.g. the rostral formula and the number of median setose spines on telson) are variable, overlapping among the populations, while the other features (e.g. the endopod shape of male first pleopod) are not variable. The same patterns are followed concerning the examined material from Turkey (not included in Table 2).

Discussion

The only previous records of *Atyaephyra desmarestii* from Greece were those from the area north of Thessaloniki (BOUVIER, 1913), Koronia Lake (HOLTHUIS, 1961) and Vegoritida Lake (KOUKOURAS, 1973). The collected material revealed that *A. desmarestii* extends its geographical distribution only in the fresh waters of western and northern Greece. This pattern of distribution seems to be the reflection of the mean annual rainfall values in each area. In eastern Greece, where rainfall is low, rivers periodically drain (especially during summer) prohibiting the presence of this shrimp. The deviation of the western Greece rivers, through dams, to the Yliki Lake (station 29) can justify the presence of *A. desmarestii* in this station, which is located in eastern Greece. On the other hand, in Corfu, Crete and Rodos Islands, where permanent inland waters exist, *Atyaephyra* is replaced by *Palaemonetes* species as fact that could be explained by the paleogeography of these areas (PRETZMANN, 1987).

The larger female body size has been previously observed in *A. desmarestii* subspecies (BOUVIER, 1913; HOLTHUIS, 1961; AL-ADHUB, 1987) and is characteristic of this species' populations.

Based on the descriptions of *A. desmarestii* subspecies, *A. d. desmarestii* has a straight and high rostrum (HOLTHUIS, 1961; ZARIQUIEY ÁLVAREZ, 1968), *A. d. stankoi* (KARAMAN, 1972) has a straight and shallow rostrum, *A. d. orientalis* has a shallow rostrum bending upwards (HOLTHUIS, 1961) and *A. d. mesopotamica* has a shallow rostrum bending downwards (AL-ADHUB, 1987). However, this feature is variable. DE BRITO CAPELLO (1867: pl.1, Fig.1) figured *A. d. desmarestii* (under the name *A. rosiana*) from Portugal having a shallow rostrum, while KINZELBACH

Table 1
Data of *Atyaephyra* material studied. (N.I.: number of individuals, CL_{max}: maximum post-orbital carapace length).

Station	Location	Date	♂♂		♀♀	
	Greece		**N.I.**	**CL_{max} (mm)**	**N.I. (ovig.)**	**CL_{max} (mm)**
1	Nestos River, Kirnos, Xanthi	30/ix/2002	26	5.0	19 (1)	8.0
2	Kephalari Stream, Drama	4/iv/2001	17	5.0	13 (7)	7.0
3	Agia Varvara spring, Drama	4/iv/2001	16	5.5	14 (10)	7.0
4	Mylopotamos spring, Drama	4/iv/2001	-	-	22 (19)	9.0
5	Richios River, Thessaloniki	22/x/1997	11	6.0	19 (1)	8.0
6	Axios River, Kilkis	12/xi/1998	8	5.0	7	6.0
7	Kariotissa River, Pella	18/x/2001	13	5.0	17	5.5
8	Edesseos River, Pella	19/x/2001	7	5.5	14	7.0
9	Litheos River, Trikala	14/xi/2001	9	6.0	21	7.0
10	Gritsas River, Pieria	15/xi/2001	7	5.0	5	7.0
11	Litochoro marshes, Pieria	15/xi/2001	2	4.5	3	6.5
12	Pinios River, Stomio, Larisa	15/xi/2001	10	5.0	8 (1)	7.0
13	Pinios River, Agia Paraskevi, Larisa	25/x/2001	3	5.0	2	7.0
14	Enipeas River Karditsa	14/xi/2001	3	5.0	17	8.0
15	Stream near Karditsa city	14/xi/2001	1	4.0	3	5.5
16	Lake Pamvotida, Ioannina	24/x/2001	5	5.5	-	-
17	Thiamis River, Sagiada, Thesprotia	27/x/2001	8	5.0	32	8.0
18	Acherontas River, Preveza	27/x/2001	11	5.0	36 (23)	7.4
19	Ziros Lake, Arta	28/x/2001	13	5.5	21	7.0
20	Louros River, Flabouro, Preveza	28/x/2001	16	6.0	13	8.0
21	Louros River, estuary, Preveza	28/x/2001	3	5.5	7	8.0
22	Arachthos River, Arta	28/x/2001	4	4.5	4	7.0
23	Amvrakia Lake., Aetoloakarnania	23/xi/2001	1	4.0	-	-
24	Ozeros Lake, Aetoloakarnania	22/xi/2001	7	4.5	28	6.5
25	Lysimachia Lake, Aetoloakarnania	22/xi/2001	2	4.0	16	7.0
26	Trichonida Lake, Aetoloakarnania	22/xi/2001	3	5.0	27	6.2
27	Stream near Aetoliko, Aetoloakarnania	4/v/2002	3	5.0	25 (9)	7.0
28	Acheloos River, Aetoloakarnania	22/xi/2001	3	4.0	2	4.5
29	Yliki Lake, Biotia	10/viii/2000	-	-	20	5.0
30	Alphios River, Achaia, Peloponnisos	24/ix/2001	15	5.5	33	6.0
31	Pamisos River, Achaia, Peloponnisos	26/ix/2001	4	4.6	3	6.5
Other material						
32	Aoos River, Avlona, Albania	24/v/2001	22	6.0	17	7.0
33	Sao Barnabe River, Algarve, Portugal	23/vii/1988	17	5.5	13 (8)	7.0
34	Ombret, Belgium	3/vii/1979	23	5.5	27 (3)	8.0
35	Bileybi, SW of Antalya, Turkey	18/vi/1959	6	4.5	9 (9)	6.0

& KOSTER (1985) and GORGIN (1996) observed individuals of *A. d. orientalis* and *A. d. mesopotamica*, respectively, with a straight rostrum. In our material, the three different rostral shapes appeared even in the same population (station 26). Furthermore, in all populations (Table 2), specimens with high and shallow rostrum co-existed. So, the rostral shape and height cannot be used as key characters. Similarly, the rostral dentition that may vary a lot even in the same population (Table 2), is overlapping among the four subspecies and thus is not suitable as a key character.

The variability of the rostral height, even though it has no systematic value, appears to have a geographical gradation, with a high rostrum dominating in NW Europe populations (ZARIQUIEY ÁLVAREZ, 1968; HOLTHUIS, 1961), while the southern European and Asian populations have mainly shallow rostra. The relation between rostral variability and the geographic latitude was also observed in *Palaemonetes varians* (LEACH, 1814) populations (DE GRAVE, 1999). This geographical gradation of rostral height possibly confused KARAMAN (1972) who described *A. d. stankoi* based mainly on rostral differences to distinguish it from the other subspecies. Thus, *A. d. stankoi* should be considered a junior synonym of *A. d. desmarestii*.

The pterygostomian angle bears a tooth only in some specimens from southern and central Greece (Table 2). Similarly, the posterolateral angle of the fifth abdominal somite can be more or less acute appearing round or pointed even in the same population (Table 2). Therefore, both characters have no taxonomic value.

The number of spines on the dactylus of the third pereiopod, the number of spinules on the dactylus of the fifth pereiopod and the number of median setose spines on the telson, as well as the number of spines on the appendix masculina of the male second pleopod vary widely among the studied populations (Table 2). These features are overlapping among *A. desmarestii* subspecies and have also no taxonomic value.

BOUVIER (1913) noticed the triangular shape of the posterior male thoracic sternite on some specimens from Greece and France. Our data confirms this (Table 2). According to the same author, the position of setae on the posterior male thoracic sternite is different between the eastern and western populations distinguishing *A. d. desmarestii* from *A. d. orientalis*. This feature should not be considered as valid, since in the examined *A. d. orientalis* material there are setae all over the posterior male thoracic sternite as in *A. d. desmarestii*.

The distinction between *A. d. desmarestii*, *A. d. orientalis* and *A. d. mesopotamica* is based mainly on features of the endopod of the male first pleopod (BOUVIER, 1925; AL-ADHUB, 1987). From Table 2, it is obvious that the number of setae on the outer margin, and the number of spines on the inner margin, varies in our material and overlaps with the literature data. BOUVIER (1913, 1925) considered the endopod shape as the strongest key character even though he noted that the male sex characters might alter as a result of particular local conditions. Furthermore, HOLTHUIS (1961), referring to a studied male from Koronia Lake (Greece), stated: '...the endopod is heavier and more distinctly curved than in the typical western form, forming more or less a transition to the shape of the edopod of the eastern form'. Eventually, GORGIN (1996) questioned the validity of *A. d. mesopotamica* based on the variability of this character. In our European specimens the endopod is slightly curved, similar to that figured by BOUVIER (1913: 68, Fig. 2 G, I, J) for *A. d. desmarestii*. On the contrary, in the studied Turkish population of *A. d. orientalis* it is strongly curved, but in a few individuals it is less curved, similar to European specimens. Thus even this character is variable and for this reason is not valuable for the distinction of *A. desmarestii* subspecies.

Table 2

The most frequent values and their range (in parenthesis) of *Atyaephyra desmaresti*i subspecies key features, in the studied populations from selected areas, in comparison with the literature data.

(CL_{max}: maximum post-orbital carapace length; L/H: Length / Height ratio; rostral formula – literature: dorsal teeth / ventral teeth; rostral formula – studied populations: post-orbital teeth | orbital tooth | pre-orbital dorsal teeth / ventral teeth)

Rostrum		Subspecies	Literature	Sex	Belgium 23 ♂♂, CL_{max}= 5.5 27 ♀♀, CL_{max}= 8.0	Portugal 17 ♂♂, CL_{max}= 5.5 13 ♀♀, CL_{max}= 7.0	Albania 22 ♂♂, CL_{max}= 6.0 17 ♀♀, CL_{max}= 7.0	S. Greece 23 ♂♂, CL_{max}= 5.5 27 ♀♀, CL_{max}= 8.0	Central Greece 20 ♂♂, CL_{max}= 6.0 80 ♀♀, CL_{max}= 8.0	N. Greece 34 ♂♂, CL_{max}= 6.0 47 ♀♀, CL_{max}= 9.0
Rostrum	Shape	*A.d.d.*	Straight		Straight	Straight	Straight	Straight or Bends upwards	Straight or Bends upwards or Bends downwards	Straight or Bends downwards
		A.d.o.	Bends upwards							
		A.d.s.	Straight							
		A.d.m.	Bends downwards							
	L/H	*A.d.d.*	High	♂	4-5 (3.7-7)	5-13.3 (5-21)	8-8.3 (4-9)	8-10 (4.8-10)	7-12 (4-15)	5-15 (4.4-15)
		A.d.o.	Shallow							
		A.d.s.	Shallow	♀	3.3-5 (3-7)	4.6-6.3 (4-7.8)	5-7.1 (5-8)	5-8 (4.4-15)	5-12 (4-16.7)	5-16 (5-16.7)
		A.d.m.	Shallow							
	Rostral formula	*A.d.d.*	24-33 (21-36) / 2-10	♂	1-2 (1-3) | 1 (0-1) | 19-23 (17-25) / 5-8 (4-8)	0-1 (0-2) | 1(0-1) | 24-31 (15-38) / 4-7 (1-7)	1-2 (0-2) | 1 (0-1) | 20-24 (16-30) / 4-6 (3-8)	2-3 (1-3) | 1 (0-1) | 18-23 (12-24) / 4-7 (3-8)	0 (0-2) | 1 (0-1) | 18-22 (14-24) / 4-8 (2-8)	0-1 (0-2) | 0-1 | 14-21 (13-27) / 0-3 (0-5)
		A.d.o.	19-20 (12-27) / 2-10							
		A.d.s.	18-20 (13-26) / 3 (1-6)	♀	2-3 (1-4) | 0-1 | 19-24 (17-25) / 7-10 (5-10)	2 (1-3) | 1 | 26-28 (16-31) / 4-5 (1-6)	1-2 (0-3) | 1 (0-1) | 21-23 (14-24) / 4-6 (3-8)	1-2 (1-3) | 1 (0-1) | 21-24 (20-33) / 5-6 (4-8)	0-1 (0-4) | 1 (0-1) | 18-22 (16-25) / 4-8 (2-10)	0-2 (0-3) | 0-1 | 14-22 (10-25) / 0-3 (0-5)
		A.d.m.	19-21 (16-23) / 4 (3-6)							

Table 2 (Continued)

	Literature			Belgium 23 ♂♂, CL_{max}= 5.5 27 ♀♀, CL_{max}= 8.0	Portugal 17 ♂♂, CL_{max}= 5.5 13 ♀♀, CL_{max}= 7.0	Albania 22 ♂♂, CL_{max}= 6.0 17 ♀♀, CL_{max}= 7.0	S. Greece 23 ♂♂, CL_{max}= 5.5 27 ♀♀, CL_{max}= 8.0	Central Greece 20 ♂♂, CL_{max}= 6.0 80 ♀♀, CL_{max}= 8.0	N. Greece 34 ♂♂, CL_{max}= 6.0 47 ♀♀, CL_{max}= 9.0
Pterygostomian tooth on carapace	*A.d.d.*	Present		Absent	Absent	Absent	Present or Absent	Present or Absent	Absent
	A.d.o.	Present or Absent							
	A.d.s.	?							
	A.d.m.	Present or Absent							
5th abdominal somite shape	*A.d.d.*	Pointed		Pointed	Pointed	Pointed	Pointed or Round	Pointed	Pointed or Round
	A.d.o.	Pointed							
	A.d.s.	Round							
	A.d.m.	Pointed or Round							
Number of spines on P3 dactylus	*A.d.d.*	8	♂	5-7 (4-7)	6-7 (5-8)	6-7 (5-7)	6-7 (6-8)	6-7 (6-8)	6-8 (4-8)
	A.d.o.	5-6							
	A.d.s.	?	♀	5-7 (4-8)	6-8 (5-8)	5-6 (5-7)	6-8 (6-9)	6-9 (5-9)	6-8 (3-8)
	A.d.m.	7-10							
Number of spinules on P5 dactylus	*A.d.d.*	35	♂	26-30 (11-32)	26-34 (21-40)	26-33 (24-35)	27-33 (25-34)	28-36 (25-41)	29-35 (20-39)
	A.d.o.	40							
	A.d.s.	?	♀	26-38 (21-39)	28-35 (22-37)	23-32 (15-36)	28-34 (23-35)	30-40 (23-44)	30-40 (27-47)
	A.d.m.	50							
Number of median setose spines on telson	*A.d.d.*	Usually 6	♂	7-8 (3-9)	4-6 (2-7)	7-8 (5-9)	4-5	4-6 (2-8)	4-8 (2-10)
	A.d.o.	4-6							
	A.d.s.	?	♀	7-10 (4-11)	5-6 (3-8)	6-7 (5-8)	4-5 (2-6)	4-6 (2-8)	4-9 (3-11)
	A.d.m.	4							

Table 2 (Continued)

Character			Literature	Belgium 23 ♂♂, CL_{max} = 5.5 27 ♀♀, CL_{max} = 8.0	Portugal 17 ♂♂, CL_{max} = 5.5 13 ♀♀, CL_{max} = 7.0	Albania 22 ♂♂, CL_{max} = 6.0 17 ♀♀, CL_{max} = 7.0	S. Greece 23 ♂♂, CL_{max} = 5.5 27 ♀♀, CL_{max} = 8.0	Central Greece 20 ♂♂, CL_{max} = 6.0 80 ♀♀, CL_{max} = 8.0	N. Greece 34 ♂♂, CL_{max} = 6.0 47 ♀♀, CL_{max} = 9.0
Male posterior thoracic sternite	Shape	*A.d.d.*	Styliform or Triangular	Styliform	Styliform	Styliform	Styliform or Triangular	Styliform or Triangular	Styliform
		A.d.o.	Styliform						
		A.d.s.	?						
		A.d.m.	?						
	Setae	*A.d.d.*	All over	All over	All over	All over	All over	All over	All over
		A.d.o.	Only on base						
		A.d.s.	?						
		A.d.m.	?						
Endopod of 1st male pleopod	Shape	*A.d.d.*	Rectilinear or Slightly curved	Slightly curved	Slightly curved	Slightly curved	Slightly curved	Slightly curved	Slightly curved
		A.d.o.	Curved						
		A.d.s.	Rectilinear						
		A.d.m.	Curved						
	Number of setae in outer margin	*A.d.d.*	numerous	10-16 (7-21)	10-14 (9-17)	10-13 (9-16)	6-10 (6-12)	7-11 (6-14)	6-13 (4-18)
		A.d.o.	3-5						
		A.d.s.	numerous						
		A.d.m.	4-5						
	Number of spines in inner margin	*A.d.d.*	12-20	15-23 (11-28)	14-18	13-15 (7-17)	9-14 (8-14)	8-10 (7-14)	12-19 (9-21)
		A.d.o.	20-30						
		A.d.s.	?						
		A.d.m.	15-20						
Number of spines on appendix masculina of 2nd male pleopod		*A.d.d.*	15-18	12-24 (10-24)	18-23 (7-28)	18-23 (10-23)	17-24 (13-30)	21-27 (15-30)	16-30 (14-35)
		A.d.o	Much more than A. d. d.						
		A.d.s.	Much more than A. d. d.						
		A.d.m.	?						

Based on the results of this study, it is certain that the key characters currently used to separate *A. desmarestii* subspecies are invalid. It seems that there is only one very variable species with many ecophenotypes. Nevertheless, taking into account the wide distribution of this species and the isolation degree of its populations, it is very likely that the detailed examination of other morphological features will reveal real differences among the different populations of this species.

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