Geographical distribution of *Aegla schmitti* Hobbs III, 1979 (Decapoda Anomura Aeglidae) and morphometric variations in male populations from Paraná State, Brazil

André Trevisan and Setuko Masunari

(AT, SM) Department of Zoology, Institute of Biological Sciences, Federal University of Paraná. Centro Politécnico, Jardim das Américas, Caixa Postal 19020, 81531-980, Curitiba, Paraná, Brazil.
(AT) E-mail: andretrevisan@ufpr.br.

Abstract

Geographical distribution of the freshwater anomuran *Aegla schmitti* and the morphometric variation among populations from different streams of Paraná State that are separated by Serra do Mar mountains were studied. The study was based on specimens deposited at Museum of Natural History of Capão da Imbuia (MHNCI) and on the literature. For morphometric analyses, the following dimensions were obtained from adult male specimens: cephalothorax length, rostrum length, rostrum base width, frontal width, cephalic area length, pre-cervical width, carapace maximum width, longest chelar propodus length, widest chelar propodus width, telson length and its maximum width. Principal Components Analysis (PCA) and Discriminant Function Analysis (DFA) were used to discriminate morphometric differences among populations. Fourteen new records were obtained for *A. schmitti* in Paraná State, and its occurrence limits were extended to the municipality of Matinhos (to East), but remained to Ponta Grossa (to West), to Iporanga (to North) and Canoinhas (to South). PCA analysis formed four main groups, two of them including specimens from Matinhos River and Guaricana Hydroelectric Dam (rivers east of Serra do Mar mountains), a central one composed of populations from Mato Grande, Piraquara and Iraí River B (downstream) (rivers west of Serra do Mar mountains) and the last one formed by animals from Iraí River A (upland stream) (rivers west of Serra do Mar mountains). The results suggest that reproductive isolation of the populations, which are submitted to diverse abiotic variables, can be provoking morphometric alterations at least in males of *A. schmitti.*

Key words: Aeglidae, intraspecific variations, Paraná State, Brazil.

Introduction

The unique freshwater anomuran genus *Aegla* Leach, 1820 has over 60 species whose distribution is limited to the Neotropical Region of South America, from south of Minas Gerais State in Brazil to southern Chile (Bond-Buckup *et al.,* 2008; Santos *et al.,* 2009).

Taxonomic studies of these crabs have been initiated approximately sixty years ago with Schmitt (1942) who described fifteen new species and their geographical distribution. Later, Argentinean species have been recorded (Ringuelet, 1949; Lopretto, 1978a, 1978b, 1979, 1980a, 1980b) and six new species were described from Rio Grande do Sul State from Brazilian waters (Buckup and Rossi, 1979). These authors described the geographical distribution of the genus and the occurrence of sympatric species. Bond-Buckup (1994) carried out an extensive revision of the family Aeglidae, including identification keys, diagnoses, measures, geographical distribution and description of 20 new species.

More recently, the natural history, population dynamics and evolution of aeglids have been studies by several authors (Bahamonde and Lopez, 1961; Lopez, 1965; Rodrigues and Hebling, 1978; Bueno and Bond-Buckup, 2000; Swiech-Ayoub

Nauplius

and Masunari, 2001a, b; Noro and Buckup, 2002; Pérez-Losada *et al.,* 2004; Colpo *et al.,* 2005; Gonçalves *et al.,* 2006; Teodósio and Masunari, 2009).

Morphometric research in aeglids is usually related to the relative growth, in which some dimensions especially those of secondary sexual characters grow faster than others (Colpo *et al.,* 2005; Viau *et al.,* 2006 and Bueno and Shimizu, 2008; 2009). These authors showed that species can initiate a differential growth of the chelae in the males, and of the abdomen in the females when passing from juvenile to adult stage, in a pattern described by Hartnoll (1974; 1978; 1982).

Intraspecific variations in body dimension were only studied in *Aegla uruguayana* Schmitt, 1942 from Uruguay: the cephalothorax lengths of three different populations were analyzed, but no significant differences were found (Vaz-Ferreira *et al.,* 1945). However, these variations are well known in some groups of crustaceans such as caridean and penaeid shrimps that can also be related to sexual dimorphism (Kapiris and Thessalou-Legaki, 2001; Tzeng *et al.,* 2001; Tzeng, 2004; Anastasiadou *et al.,* 2004; Anastasiadou and Leonardos, 2008; Anastasiadou *et al.,* 2009). On the other hand, sexual dimorphism in aeglids is well known (Bueno *et al.,* 2000; Colpo *et al.,* 2005; Viau *et al.,* 2006; Bueno and Shimizu, 2009).

There are seven species of *Aegla* recorded for Paraná State (Bond-Buckup and Buckup, 1994; Bond-Buckup, 2003) and the biology of these species are poorly known in Paraná area since the studies are limited to the population structure of *Aegla castro* Schmitt, 1942 (Swiech-Ayoub and Masunari, 2001a, b) and *Aegla schmitti* Hobbs III, 1979 (Teodósio and Masunari, 2009). According to Bond-Buckup (1994), *A. schmitti* is the most common and largely distributed aeglid species in this area; its geographical distribution is limited from Iporanga city, São Paulo State (northern limit) to the municipality of Canoinhas, Santa Catarina State (southern limit) and from Guaratuba city (eastern limit) to Ponta Grossa city (western limit).

Based on the deposited lots of aeglids in the Museum of Natural History of the Capão da Imbuia (MHNCI) and a literature review (Bond-Buckup and Buckup, 1994; Bond-Buckup, 2003) the present work aims to update the geographical distribution of this species in Paraná State. Additionally, it is proposed to explore morphological variations within male populations coming from streams and rivers located on both sides of Serra do Mar mountains which is an important geographical barrier in Paraná State.

Material and Methods

Geographical distribution

The geographical distribution of *A. schmitti* was obtained from the literature and was updated based on the deposited specimens in MHNCI, Curitiba city. The specimens were identified with the aid of identification keys and diagnoses from Bond-Buckup (1994, 2003) and a distribution map was elaborated using the program ArcView GIS 3.2.

Whenever geographical coordinates of the collection site were not available, data from a specialized internet site (Species link) that show geographical coordinates of deposited specimens in scientific collections were used. If missing record of the exact collection stream occurred only the municipality name and coordinate were used as the reference point.

Examined material [municipality, river, collection date (collector), number of males (m), females (f), ovigerous female (fov) or juvenile (juv), (lot)]: *Quatro Barras,* Taquari River, 04-09.x.1987 (Cury, M.R. and Wosiacki, W.B.) 2 f, 3 m, (371); Iraí River, 13.ix.1991 (Grandó, E.T.), 2 f, 4 m, (454); Iraí River, xi.1998 (Abilhôa, V. and Moura Leite, J.C.), 32 m, (484); *Araucária,* Guajuvira River, 08.iii.1992 (Wosiacki, W.B.), 2 m, (452); Passaúna River, 23.ix.1966 (Cordeiro, A.M. and Ribeiro, J.C), 1 f, 5 m, (938); Passaúna River, 23.ix.1966 (Cordeiro, A.M. and Ribeiro, J.C.), 1 f, (939); Passaúna River, 23.ix.1966 (Cordeiro, A.M. and Ribeiro, J.C.), 1 m, (947); Passaúna River, 23.ix.1966 (Cordeiro, A.M. and Ribeiro, J.C.), 6 f, 1 fov, 3 m (1128); *Piraquara,* Iraí River, 31.x.1991 (Cordeiro, A.A. and Grandó E.T.), 4 f, 6 m (456); Iraí River, 17.x.1964 (Alexandre, Z.), 1 m, (561); Iraí River, 17.x.1964 (Alexandre, Z.), 1 m, (563); Iraí River, 17.x.1964 (Alexandre, Z.), 1 m, (567); Iraí River, 17.x.1964 (Alexandre, Z.), 1 fov, (568); Iraí River, 17.x.1964 (Alexandre, Z.), 1 f, (573); Iraí River, 17.x.1964 (Alexandre, Z.), 1 f, (574); Iraí River, 17.x.1964 (Alexandre, Z.), 1 m, (575); Mato Grande River, no date (no collector), 1 m, (671); Iraí River, 25.xi.1998 (Abilhôa, V.), 16 m, (814); Mato Grande River, 21.

vi.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (836); Mato Grande River, 21.vi.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (838); Mato Grande River, 21.vi.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (839); Iraí River, 11.viii.1967 (Alexandre, Z.), 1 fov, (1073); Iraí River, 27.vii.1967 (Alexandre, Z.), 1 m, (1075); Iraí River, 11.viii.1967 (Alexandre, Z.), 1 m, (1079); Iraí River, 11. viii.1967 (Alexandre, Z.), 1 m, (1084); Iraí River, 27.vii.1967 (Alexandre, Z.), 1 m, (1109); Iraí River, 27.vii.1967 (Alexandre, Z.), 1 m, (1121); Iraí River, 25.xi.1998 (Abilhôa, V.), 13 m, (1122); Iraí River, 27.vii.1967 (Alexandre, Z.), 1 m, (1124); Iraí River, 27.vii.1967 (Alexandre, Z.), 1 m, (1126); Iraí River, 27.vii.1967 (Alexandre, Z.), 1 f, (1131); Piraquara River, 21.viii.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (1210); Iraí River, v.1979 (Nogueira, M.H.), 2 f, 2 m, (1259); Mato Grande River, 21.vi.1983 (Dambrós, A. and Ribeiro, J.C.), 6 m, (1722); Mato Grande River, 14.iv.1983 (Dambrós, A. and Ribeiro, J.C.), 5 f, 10 m, (1737); Mato Grande River, 14.iv.1983 (Dambrós, A. and Ribeiro, J.C.), 3 f, 10 m, (1738); Mato Grande River, 14.iv.1983 (Ribeiro, J.C.), 1 m, (1739); Mato Grande River, 14. iv.1983 (Ribeiro, J.C.), 1 m, (1740); Mato Grande River, 14.iv.1983 (Ribeiro, J.C.), 1 m, (1741); Mato Grande River, 14.iv.1983 (Ribeiro, J.C.), 1 m, (1742); Mato Grande River, 14.iv.1983 (Dambrós, A. and Ribeiro, J.C.), 2 f, (1743); Mato Grande River, 14.iv.1983 (Dambrós, A. and Ribeiro, J.C.), 1 f, (1744); Mato Grande River, 14.iv.1983 (Dambrós, A. and Ribeiro, J.C.), 1 f, (1745); Piraquara River, 25.viii.1983 (Dambrós, A. and Ribeiro, J.C.), 32 m, (1773); Piraquara River, 25.viii.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (1801); Piraquara River, 25.viii.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (1802); Piraquara River, 25.viii.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (1803); Piraquara River, 25. viii.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (1804); Piraquara River, 25.viii.1983 (Dambrós, A. and Ribeiro, J.C.), 1 f, (1805); Piraquara River, 25.viii.1983 (Dambrós, A. and Ribeiro, J.C.), 1 f, (1806); São José dos Pinhais, Miringuava River, 01.vii.1997 (Lopes, O.L.; Santos, C.S. and Sasaoka, S.K.), 2 f, 1 m, (463); Miringuava River, 01.viii.1997 (Lopes, O.L.; Santos, C.S. and Sasaoka, S.K.), 1 f, 2 m, (465); Miringuava River, 01.ix.1997 (Lopes, O.L.; Santos, C.S. and Sasaoka, S.K.), 2 f, (468); Miringuava River, 01.x.1997 (Lopes, O.L.; Santos, C.S. and Sasaoka, S.K.), 1 f, (469); Miringuava River, 01.xii.1997 (Lopes, O.L.; Santos, C.S. and Sasaoka, S.K.), 1juv, (470); Miringuava River, 01.vi.1998 (Torres, J.D. and Lopes, O.L.), 1 m, (480); Miringuava River, 30.ix.1998 (Torres, J.D. and Lopes, O.L.), 1 f, 2 m, (481); Guaricana Dam, 17.vii.1988 (Wosiacki, W.B.), 1 m, (512); Miringuava River, 18. vii.2001 (Abrilhôa, V.), 1 f, 10 m, (801); Miringuava River, 18.vii.2001 (Abrilhôa, V.), 1 f, (804); Miringuava River, 18.vii.2001 (Abrilhôa, V.), 4 f, 4 m, (806); Guaricana Creek, 27.ii.1985 (Dambrós, A. and Ribeiro, J.C.), 1 m, (808); Guaricana Creek, 26.ii.1985 (Ribeiro, J.C.), 1 m, (832); Guaricana Creek, 26.ii.1985 (Ribeiro, J.C.), 1 m, (833); Miringuava River, 04.x.2001 (Abrilhôa, V.), 1 m, (860); Guaricana Dam, 27.ii.1985 (Dambrós, A. and Ribeiro, J.C.), 2 f, 1 m, (1119); Guaricana Creek, 26.ii.1985 (Dambrós, A. and Ribeiro, J.C.), 10 m, (1317); Miringuava River, 26.x.1983 (Dambrós, A. and Ribeiro, J.C.), 1 f, 1 m, (1684); Miringuava River, 26.x.1983 (Dambrós, A. and Ribeiro, J.C.), 1 f, 1 m, (1685); Miringuava River, 26.x.1983 (Dambrós, A. and Ribeiro, J.C.), 1 m, (1686); Miringuava River, 26.x.1983 (Dambrós, A. and Ribeiro, J.C.), 2 m, (1687); Miringuava River, 26.x.1983 (Dambrós, A. and Ribeiro, J.C.), 2 m, (1688); Miringuava River, 26.x.1983 (Dambrós, A. and Ribeiro, J.C.), 2 m, (1689); Guaricana Creek, 01.x.1985 (Carneiro, A. and Ribeiro, J.C.), 3 f, 1 m, (1849); Curitiba, Passaúna River, 06.iii.1963 (Nogueira, M.H.), 1 m, (487), no name, 18.xi.1972 (Nogueira, M.H.), 1 f, 1 m, (525); Passaúna River, 17. vii.1991 (Vivikamanda, Vital and Vital), 1 m, (858); Pinhais, Iraí River, 17.x.1964 (Alexandre, Z.), 1 m, (505); Iraí River, 17.x.1964 (Alexandre, Z.), 1 m, (511); Iguaçu River, 01.v.1967 (Alexandre, Z.), 1 m, (514); Iraí River, 17.x.1964 (Alexandre, Z.), 7 m, (570); Iraí River, 27.vii.1967 (Alexandre, Z.), 3 f, 20 m, (693); Iraí River, 27. vi.1967 (Alexandre, Z.), 1 m, (696); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (789); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (790); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (791); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (792); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (793); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (794); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (795); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (796); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (797); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (798); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (799); Iraí River, v.1973 (Nogueira, M.H.), 1 m, (800); Iguaçu River, 13.ix.1966 (Alexandre, Z. and Nogueira, M.H.), 1 f, (978); Iguaçu River, 13.ix.1966 (Alexandre, Z. and Nogueira, M.H.), 2 f, 10 m, (979); Iguaçu River, 13.ix.1966 (Alexandre, Z. and Nogueira, M.H.), 6 f, 6 m, (980); Iguaçu River, 13.ix.1966 (Alexandre, Z. and Nogueira, M.H.), 1 fov, (1002); Iguaçu River, 13.ix.1966 (Alexandre, Z. and Nogueira, M.H.), 1 f, (1003); Iraí River, 11.viii.1967 (Alexandre, Z.), 7 m, (1072); Iguaçu River, 01.v.1967 (Alexandre, Z.), 3 m, (1085); Iguaçu River, 01.v.1967 (Alexandre, Z.), 3 m, (1086); Iraí River, 11.viii.1967 (Alexandre, Z.), 1 m, (1130); Iguaçu River, 01.v.1967 (Alexandre, Z.), 1 m, (1132); Iraí River, v.1968 (Alexandre, Z.), 2 m, (1165); Iraí River, viii.1970 (Alexandre, Z.), 1 m, (1212); Iguaçu River, 24.xii.1965 (Lange, R.B.), 4 f, 4 m, (1220); Iguaçu River, 24.xi.1965 (Lange, R.B.), 7 f, 2 m, (1701); Iraí River, vii.1970 (Alexandre, Z.), 1 m, (1716); Guaratuba, Guaricana Dam, 24-28.iii.1986 (Ribeiro, J.C.), 1 m, (515); Guaricana Dam, 27.ii.1985 (Dambrós, A. and Ribeiro, J.C.), 1 m, (808); Guaricana Dam, 26.ii.1985 (Malkovski, S.R.), 1 m, (2004); Mandirituba, Maurício River, 10.xi.1972 (Nogueira, M.H.), 4 m, (518); Almirante Tamandaré, Barigui River, 01.xi.1978 (Nogueira, M.H.), 2 m, (526); Tanguá River, 02.xii.1987 (Santos, V.), 1 f, (527); Matinhos, Matinhos River, 25.vii.1964 (Lange, R.B), 4 m, (604); Matinhos River, 26.vii.1964 (Lange, R. B), 15 m, (611); Matinhos River, 4-5.ix.1964 (Lange, R.B), 2 m, (746); Tunas do Paraná, Bomsucesso River, 16.iv.2003 (Abe, L.M., Lara, A., Macedo, L.F. and Schroeder, A.), 2 m, (807); Colombo, Capivari River, 01.xii.1972 (Nogueira, M.H.), 3 m, (1207); Capivari River, 01.xii.1972 (Nogueira, M H.), 4 m, (1853); Capivari River, 01.xii.1972 (Nogueira, M.H.), 5 m, (1854); Tijucas do Sul, Várzea River, 23.vii.1983 (Prado, A.M. and Ribeiro, J.C.), 1 m, (1291); Agudos do Sul, Várzea River, 23.vii.1983 (Prado, A.M. and Ribeiro, J.C.), 2 m, (1299); Campina Grande do Sul, Graciosa Highway, 23-29.v.1987 (Cury, M.R. and Wosiacke, W.B.), 1 m, (1666); Graciosa Highway, 23-29.v.1987 (Cury, M.R. and Wosiacke, W.B.), 1 m, (1667); Graciosa Highway, 23-29.v.1987 (Cury, M.R. and Wosiacke, W.B.), 1 m, (1668), Rio Branco do Sul, Tanguanica River, 11.ii.1987 (Segalla, M.V.), 1 m, (1236); Tanguanica River, 11.ii.1987 (Segalla, M.V.), 1 f, (1237), Tanguanica River, 11.ii.1987 (Segalla, M.V.), 1 m, (1238); Tanguanica River, 11.ii.1987 (Segalla, M.V.), 1 m, (1240).

Morphometric variation in adult males

Voucher specimens of *A. schmitti* coming from localities geographically separated by Serra do Mar mountains were analyzed: two localities east of Serra do Mar mountains – Matinhos River (municipality of Matinhos) and Guaricana Hydroelectric Dam (Guaratuba) – and four localities west of these mountains – two in Piraquara municipal district (Mato Grande River and Piraquara River) and two sites in Iraí River A and B (municipalities of Quatro Barras and Pinhais, respectively), these last ones located in Iguaçu River Basin. These samples were selected because the number of specimens was sufficient for the study of morphometric variability at a population level.

The following dimensions were obtained, exclusively, from adult males: cephalothorax length (CL – from tip of the rostrum to the posterior margin of carapace), rostrum length (RL – from the tip of the rostrum to the posterior margin of orbital sinus), rostrum base width (RW – distance between the two internal margins of the orbital cavity), frontal width (FW – distance between the two anterolateral spines of the carapace), length of cephalic area (CRL – from the posterior margin of orbital sinus to the posterior cervical groove), pre-cervical region width (CW – carapace width by the third hepatic lobes), carapace maximum width (MCW), longest length of chelae propodus (QL), widest width of chelar propodus (QW), telson length (TL – measured along the middle line) and telson maximum width (TW) (Fig. 1).

All the measurement values were $\log_{10}$ transformed to verify the normality assumption. To remove the effect of CL (*X*) variation on characteristic length (*Y*), the allometric equation $Y = aX^b$ was used (Tzeng, 2004). The measures were standardized according to the formula $Yi^* = Yi(X/Xi)^b$, where: Yi* = is the standardized measurement length of the specimen *I;* Yi = measure of the length/width of the specimen *i;* Xi = the measurement of cephalothoracic length of *i*th specimen; X = the mean value of CL's of the examined specimens and b = exponent of the allometric equation $Y = aX^b$. ANOVA test was used to compare the dimension measures of various populations coming from different localities (Zar, 1996).

Principal Components Analysis (PCA) and Discriminant Function Analysis (DFA) were used to identify morphometric differences among the populations. Both analyses are quite useful for the evaluation of variations within species (Thorpe, 1980). The first was used to verify the morphometric differences among the populations and to determine the contribution of each dimension in the total variance (Kovach, 1999; Anastasiadou *et al.,* 2009). On the other hand, the DFA was used to detect the functions capable of performing maximum discrimination between two categories, and also to identify which dimensions have the strongest power of discrimination among the groups within the set of analyzed dimensions (Ayres *et al.,* 2007; Souza *et al.,* 2009). All variables with values of F > 0 were considered for the discrimination of groups. The results were graphically plotted for the visual detection of the formed groups.

Results

Geographical distribution of Aegla schmitti

A total of 441 specimens of *A. schmitti* were examined, from which, 356 (80.73%) were males, 80 (18.14%) females, 4 (0.90%) ovigerous females and 1 (0.23%) juvenile. Fourteen new occurrences for the species were recorded for rivers from the municipalities of Araucaria, Pinhais, Matinhos, Tunas do Paraná, and Agudos do Sul, and from new localities of the municipalities with former records in Curitiba, Guaratuba, São José dos Pinhais and Tijucas do Sul.

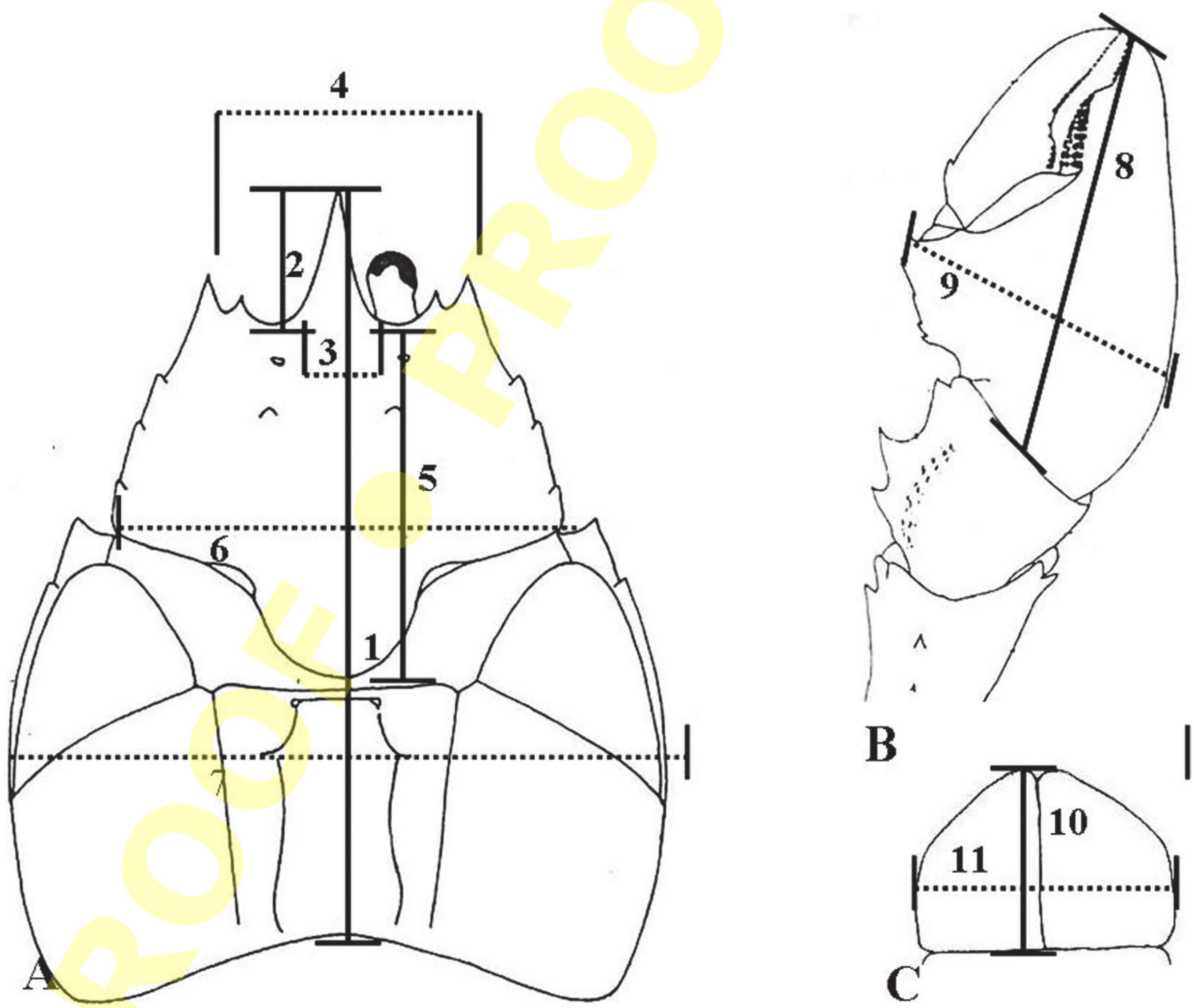

Figure 1. *Aegla schmitti.* Body dimensions measured for morphometric variation in different populations. 1 = cephalothorax length, 2 = rostrum length, 3 = rostrum base width, 4 = frontal width, 5 = length of cephalic area, 6 = pre-cervical region width, 7 = carapace maximum width, 8 = longest chelar propodus length, 9 = widest chelar propodus width, 10 = telson length and 11 = telson maximum width.

With this revision the geographical distribution of the species was extended to Matinhos River Basin to the East, but the remaining limits were maintained in Ponta Grossa city as the westernmost limit, and in north-south direction, from Iporanga city, São Paulo State (northern limit) to the municipality of Canoinhas, Santa Catarina State (southern limit) according to Bond-Buckup (1994) (Fig. 2).

Morphometric variation in adult males

The morphometric measurements were carried out in 134 males of *A. schmitti:* 20 from Matinhos River, 18 from Mato Grande River, 29 from Piraquara River, 16 from Guaricana Dam, 31 and 20 from Iraí River A and B, respectively (Fig. 2). The average values of all dimensions for each population are also presented in Table I.

The average LC varied from 23.58 mm to 29.09 mm, with significant differences (Anova, $F = 24.09$; $p < 0.01$) between populations from Litorânea Basin (Guaricana Dam and Matinhos River) and those from Iguaçu River Basin: the former are smaller in size. The remaining dimensions (RL, RW, FW, CRL, CW, MCW, QL, QW, TL and TW) also showed statistical differences among populations (Table I).

According to PCA analysis, 99.81% of the data variation was explained by two axes: Axis 1 with 99.12% and Axis 2 with 0.69%. All body di-

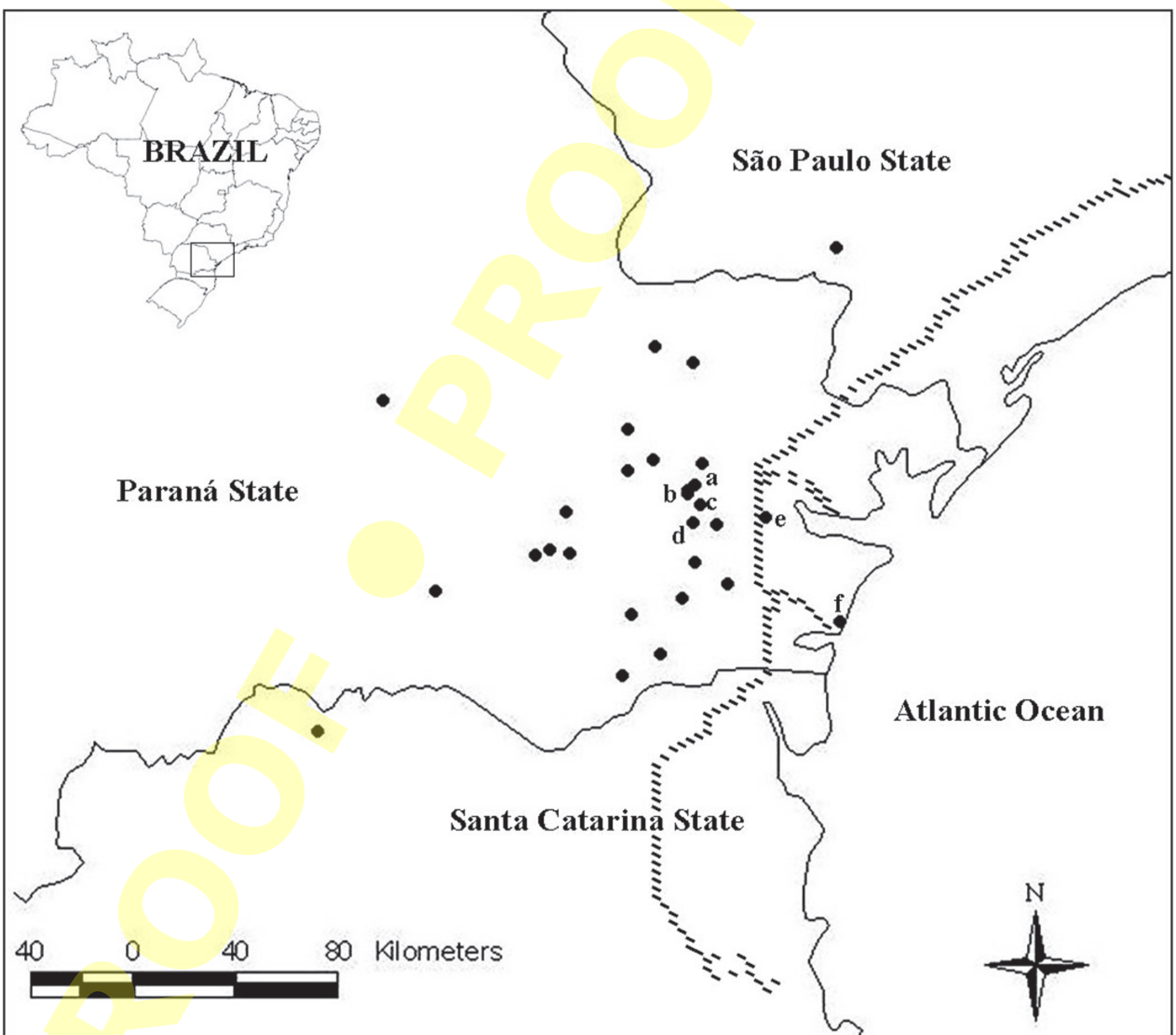

Figure 2. *Aegla schmitti.* Geographical distribution. Dots represent species records and the dashed lines, the summits of Serra do Mar mountains. Populations used for biometric analysis are also indicated: a = Iraí A River, b = Iraí B River, c = Piraquara River, d = Mato Grande River, e = Guaricana Dam and f = Matinhos River.

Table I. *Aegla schmitti.* Mean and standard deviation of the dimensions of adult males coming from different localities. EM = east of, WM = west of, Serra do Mar monuntains. The number of males (N) is also indicated. Same letters indicate statistical similarity among populations. According to ANOVA ($p < 0.05$). CL = cephalothorax length, RL = rostrum length, RW = rostrum base width, FW = frontal width, CRL = length of cephalic area, CW = pre-cervical region width, MCW = carapace maximum width, QL = longest chelar propodus length, QW = widest chelar propodus width, TL = telson length and TW = telson maximum width.

Localities	N	CL	RL	RW	FW	CRL	CW	MCW	QL	QW	TL	TW
Iraí River (A) (EM)	31	29.09 ± 3.86^{c}	5.84 ± 0.30^{d}	4.81 ± 0.30^{e}	8.81 ± 0.56^{ceg}	15.55 ± 0.43^{c}	17.56 ± 0.51^{df}	24.60 ± 1.09^{f}	18.92 ± 2.23^{a}	13.10 ± 1.77^{a}	5.92 ± 0.21^{g}	8.48 ± 0.25^{g}
Iraí River (B) (EM)	20	28.00 ± 3.29^{d}	5.34 ± 0.24^{b}	4.20 ± 0.30^{bdc}	8.51 ± 0.39^{adfg}	13.96 ± 0.34^{a}	16.98 ± 1.62^{cef}	22.65 ± 2.62^{acd}	21.00 ± 4.18^{a}	14.04 ± 2.88^{a}	5.47 ± 0.35^{cef}	7.95 ± 0.25^{cde}
Mato Grande River (EM)	18	27.76 ± 3.16^{a}	5.41 ± 0.40^{b}	4.26 ± 0.31^{cd}	8.61 ± 0.54^{bcd}	14.26 ± 0.54^{bc}	16.58 ± 1.00^{abc}	23.05 ± 1.55^{bc}	20.45 ± 5.75^{a}	13.04 ± 3.70^{a}	5.36 ± 0.41^{ade}	7.94 ± 0.41^{abd}
Piraquara River(EM)	29	28.50 ± 2.28^{b}	5.51 ± 0.38^{b}	4.40 ± 0.44^{c}	8.78 ± 0.48^{bef}	14.51 ± 0.64^{b}	16.99 ± 0.69^{bde}	23.29 ± 1.11^{bd}	21.37 ± 3.56^{a}	13.74 ± 2.50^{a}	5.51 ± 0.25^{df}	7.96 ± 0.37^{be}
Guaricana Dam (WM)	16	23.58 ± 3.12^{e}	3.81 ± 0.27^{c}	3.78 ± 0.28^{a}	7.27 ± 0.31^{h}	12.47 ± 0.39^{d}	14.52 ± 0.88^{g}	19.89 ± 0.88^{e}	18.90 ± 3.15^{a}	13.59 ± 2.85^{a}	5.06 ± 0.26^{b}	7.06 ± 1.00^{f}
Matinhos River (WM)	20	26.46 ± 4.14^{e}	4.77 ± 0.34^{a}	3.94 ± 0.26^{ab}	8.09 ± 0.67^{a}	13.46 ± 0.89^{a}	15.93 ± 0.30^{a}	21.79 ± 0.63^{a}	20.47 ± 3.48^{a}	13.25 ± 2.84^{a}	5.20 ± 0.31^{abc}	7.55 ± 0.25^{ac}

mensions contributed to the variation of the data in the Axis I (except chelae dimensions). The positive values of chelae dimensions, due to the absence of statistical difference among the populations, explain the presence of an isolated group with only those two dimensions in the Axis II (Fig. 3).

Four groups of population were formed with DFA: the first was composed of individuals from Guaricana Dam and the second, from Matinhos River. These two groups belong to localities east of Serra do Mar mountains, Litorânea Basin of Paraná State. In the central area of the graphic, a group composed of populations coming from Rio Iraí B, Mato Grande and Piraquara Rivers is visible; the last group is formed by populations from Rio Iraí A (Fig. 4).

Discussion

The new longitudinal limit established for *A. schmitti* and a significant number of first records observed in the present study indicate that future research will certainly change the current biogeo-

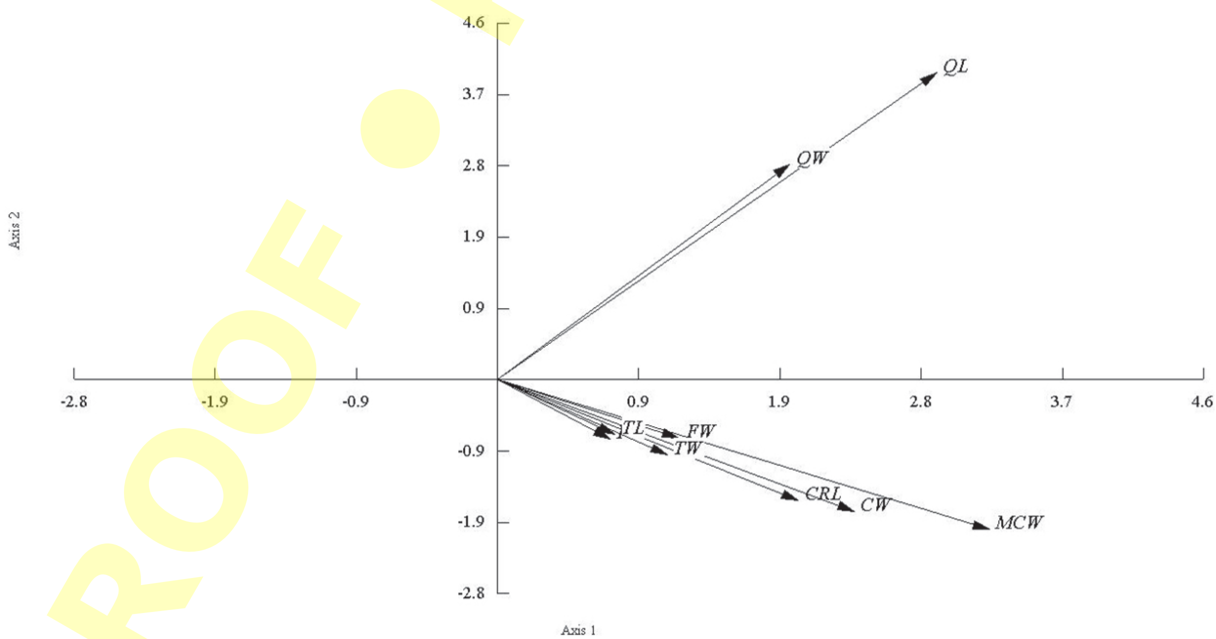

Figure 3. *Aegla schmitti.* Vectors of the variance of the measures for the axes of Principal Components Analysis. RL = rostrum length, RW = rostrum base width, FW = frontal width, CRL = length of cephalic area, CW = pre-cervical region width, MCW = carapace maximum width, QL = longest chelar propodus length, QW = widest chelar propodus width, TL = telson length and TW = telson maximum width.

graphical status of the species. This assumption is based on the existence of vast unexplored areas mainly in Litorânea Basin (east of Serra do Mar mountains) and Ribeira do Iguape River Basin (northwestern). A detailed species survey in those localities can demonstrate a continuous distribution of *A. schmitti* from southern São Paulo State to northern Santa Catarina State, with main area of distribution in Paraná State, on both sides of Serra do Mar mountains.

Additional knowledge that could come from these inventories is a secure diagnosis of the conservation status of *Aegla* species. Pérez-Losada *et al.* (2009), after a revision on the current degree of conservation of the genus *Aegla* based on the distribution and genetic diversity of species in southern South America, concluded that, from a total of 70 analyzed species 43 were considered unthreatened (UN), 18 threatened (CR, VU or EN), two extinct in the wild (EW) and seven did not have available data (DD, NE) for the classification, according to the criteria of the International Union for Conservation of Nature (IUCN).

Furthermore, according to Pérez-Losada *et al.* (2009), Paraná State shows a large number of *Aegla* species threatened with extinction. This information reinforces the urgent necessity to increase the knowledge about systematics and distribution of species, biology, ecology and evolution, in order to establish conservation strategies for the fauna of freshwater ecosystems.

The results of the present study suggest that the Serra do Mar mountains did not represent a barrier for *A. schmitti* distribution along the rivers that drain that area. Perez-Losada *et al.* (2004) presented a biogeographic discussion about *Aegla* based on molecular data and a literature review. In this work they highlighted a discrepancy between the phylogenetic relationships of the group and the current pattern of South America drainage (assuming a Pacific origin for the genus), probably as a result of the changes provoked by Paranan Sea formation (sea transgression of Atlantic Ocean) and the Serra do Mar moutains final uplift in the Late Tertiary.

The current distribution of *A. schmitti* along the rivers of both Iguaçu and Litorânea Basins suggests that Serra do Mar moutains final uplift happened after the species dispersion over the area, and that the isolation of these populations caused subsequent morphometric differentiation, as indicated by biometric data in the present study. This assumption is based on Perez-Losada's (2004) idea that some groups of aeglids speciated about 10.7 ± 1.1 millions of years (my), and therefore clearly after the Serra do Mar moutains final uplift

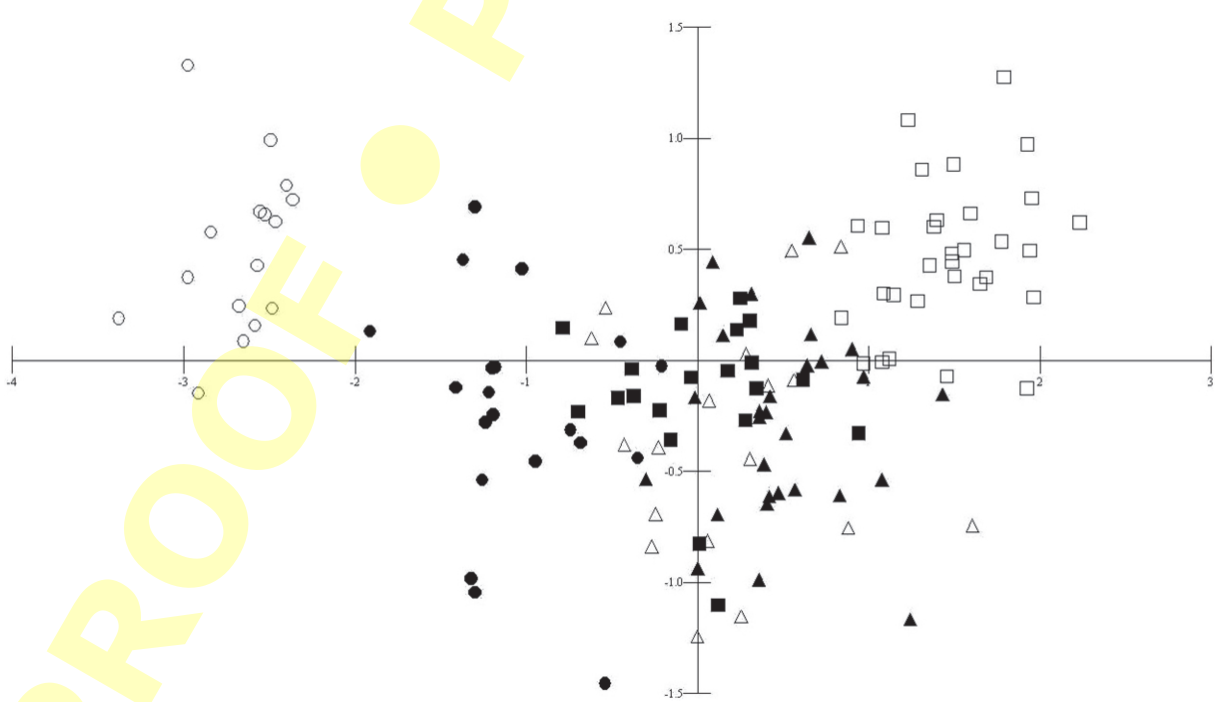

Figure 4. *Aegla schmitti.* Discriminant Function Analysis for the body dimensions. ● = Matinhos River; △ = Mato Grande River; ● = Piraquara River; ● = Guaricana Hydroelectric Dam; ● = Iraí (A) River and ● = Iraí (B) River.

(~ 12 my) and the Paranan Sea regression. However, studies on distribution patterns of other sympatric and non-sympatric aeglid species based on molecular and biogeographic tools is desirable, in order to clarify the biogeographic history of *A. schmitti.*

A comparison between the results of intraspecific variation of the present study and those from the literature is difficult because the only known work of Vaz-Ferreira *et al.* (1945) with *A. uruguayana,* did not show significant differences in size between populations. Distinctly from populations of this species, those of *A. schmitti* obtained from Litorânea Basin (east of Serra do Mar mountains) were smaller (CL) than those from Iguaçu River Basin (west of Serra do Mar mountains) in the present study. Furthermore, the variation in rostrum length (RL) among populations may indicate a probable reproductive isolation, mainly between those located on opposite sides of the Serra do Mar mountains. This assumption is based on the formation of the four groups through DFA.

The results of DFA indicate that in the first discriminant function, all measures support the separation of the groups previously known. In the same way, as observed in PCA, the chelae dimensions do not seem to be responsible for the separation of the observed groups, as they represent the values of the second discriminant function (Table II).

The absence of differences in the chelae size in the examined populations could be associated with the necessity of those animals in having large chelae for feeding and other reproductive activities. This result suggests that, despite the reproductive isolation, this characteristic can be easily disseminated among males of all populations of *A. schmitti,* in a convergent form. This inference is supported by the research of Almerão *et al.* (2010), who mention that males of *A. platensis* use large chelae in agonistic confrontations and when guarding females after fertilization; on the other hand, females of this species employ the chelae only for cleaning the abdominal chamber after the posture. These activities are essential for survival of the populations.

The formation of a fourth group in DFA analysis composed of individuals coming from Iraí River A (Iguaçu River Basin), can be related to the fact that all somatic dimensions of these animals are largest among the populations studied (Table I) For this reason, even after the data standardization, it can generate statistical noise. On the other hand, the sampling method of the deposited animals at the museum was variable (Odete Lopez Lopes, personal communication): in some cases through gill net fishing, another through electro-fishing. In the latter case, sampling is biased towards larger adult males, and certainly this factor influenced the present analysis.

Table II. *Aegla schmitti.* Values obtained from Principal Components Analysis (PCA) for the two axes that explain the major variance in the body dimensions and Discriminant Function Analysis (DFAI and DFAII) responsible for differences among morphometric measures of populations.

Dimensions	PCI	PCII	DFAI	DFAII
Rostrum length	0.123	-0.128	0.799	-0.352
Rostrum base width	0.101	-0.106	0.412	0.636
Frontal width	0.199	-0.127	0.201	-0.071
Length of cephalic region	0.329	-0.261	0.166	-0.202
Pre-cervical region width	0.390	-0.285	0.147	-0.071
Carapace maximum width	0.538	-0.324	0.168	0.114
Longest chelar propodus length	0.480	0.665	-0.057	-0.198
Widest chelar propodus width	0.320	0.467	-0.007	0.269
Telson length	0.129	-0.118	0.269	0.540
Telson maximum width	0.186	-0.163	-0.001	-0.064

The present study presents an initial contribution to the understanding of the differential process of geographic isolation of aeglids, mainly in Paraná State. Additionally, the study opens new perspectives that should be approached such as the analysis of the distribution pattern of genus *Aegla* in the area based on molecular analysis to determine the degree of differentiation of these populations and to know the real role of Serra do Mar mountains as a physical and/or climatic barrier for the current distribution of the family Aeglidae in Paraná State.

Acknowledgements

We thank the National Council for Scientific and Technological Development (CNPq) from the Brazilian Ministry of Science and Technology for the financial support granted to the first author, Dr. Márcia Arzua and M. Sc. Odete Lopes Lopez from Museum of Natural History of Capão da Imbuia for the permission to access deposited aeglid lots. We are also grateful to Prof. Dr. Luís Amilton Foerster from Federal University of Paraná for language revision.

References

Almerão, M.; Bond-Buckup, G. and Mendonça Jr. M de S. 2010. Mating behavior of *Aegla platensis* (Crustacea, Anomura, Aeglidae) under laboratory conditions. Journal of Ethology, 28(1):87-94.

Anastasiadou, C.; Koukouras, A.; Malvidis, M.; Chartosia, N.; Mostakim, M.D.; Christodoulou, M. and Asnalaglou, C.H. 2004. Morphological variation in *Atyephira desmarestii* (Millet, 1831) within and among populations over its geographical range. Mediterranean Marine Science, 5(2):05-13.

Anastasiadou, C. and Leonardos, I.D. 2008. Morphological variation among populations of *Atyaephyra demarestii* (Millet, 1831) (Decapoda: Caridea: Atyidae) from freshwater habitats of north-western Greece. Journal of Crustacean Biology, 28(2):209-233.

Anastasiadou, C.; Liasko, R. and Leonardos, I.D. 2009. Biometric analysis of lacustrine and riverine populations of *Palaemonetes antennarius* (H. Milne Edwards, 1837) (Crustacea, Decapoda, Palaemonidae) from north-western Greece. Limnologica, 39:244-254.

Ayres, M.; Ayres Jr., M.; Ayres, D.M. and Santos, A.A.S. 2007. BioEstat: aplicações estatísticas nas áreas das ciências biomédicas. 4ª ed. 380 p.

Bahamonde, N. and Lopez, M.T. 1961. Estudios biológicos en la población de *Aegla laevis laevis* (Latreille) de el Monte (Crustacea, Decapoda, Anomura). Investigaciones Zoológicas Chilenas, 7:19-58.

Bond-Buckup, G. and Buckup, L. 1994. A família Aeglidae (Crustacea, Decapoda, Anomura). Arquivos de Zoologia, 2:159-346.

Bond-Buckup, G. 2003. A família Aeglidae. p. 21-16. In: G.A.S. Melo (ed), Manual de Identificação dos Crustacea Decapoda de Água Doce do Brasil. Editora Loyola, São Paulo.

Bond-Buckup, G.; Jara, C.G.; Pérez-Losada, M.; Buckup, L. and Crandall, K.A. 2008. Global diversity of crabs (Aeglidae: Anomura: Decapoda) in freshwater. Hydrobiologia, 595:267-273.

Buckup, L. and Rossi, A. 1979. O gênero *Aegla* no Brasil (Crustacea, Decapoda, Anomura, Aeglidae. Revista Brasileira de Biologia, 37(4):879-892.

Bueno, A.A.P. and Bond-Buckup, G. 2000. Dinâmica populacional de *Aegla platensis* Schmitt (Crustacea, Decapoda, Aeglidae). Revista Brasileira de Zoologia, 17(1): 3-49.

Bueno, A.A.P.; Bond-Buckup, G. and Buckup, L. 2000. Crescimento de *Aegla platensis* em ambiente natural (Crustacea, Decapoda, Aeglidae). Revista Brasileira de Zoologia, 17(1):43-49.

Bueno, S.L.S. and Shimizu, R.M. 2008. Reproductive biology and functional maturity in females of *Aegla franca* (Decapoda: Anomura: Aeglidae). Journal of Crustacean Biology, 28(4):652-662.

Bueno, S.L.S. and Shimizu, R.M. 2009. Allometric growth, sexual maturity, and adult male chelae dimorphism in *Aegla franca* (Decapoda: Anomura: Aeglidae). Journal of Crustacean Biology, 29(3):317-328.

Colpo, K.D.; Ribeiro, L.D. and Santos, S. 2005. Population biology of the freshwater Anomura *Aegla longirostri* (Aeglidae) from South Brazilian streams. Journal of Crustacean Biology, 25(3):495-499.

Gonçalves, R.S.; Castiglioni, D.S. and Bond-Buckup, G. 2006. Ecologia populacional de *Aegla franciscana* (Crustacea, Decapoda, Anomura) em São Francisco de Paula, RS, Brasil. Iheringia, Série Zoologia, 96(1):109-114.

Hartnoll, R.G. 1974. Variation in growth patterns between some secondary sexual characters in crabs. Crustaceana, 27:131-136.

Hartnoll, R.G. 1978. The determination of relative growth in Crustacea. Crustaceana, 34:281-293.

Hartnoll, R.G. 1982. Growth. p. 111-196. In: D.E. Bliss (ed), The Biology of Crustacea, Volume 2, Academic Press, New York.

Kapiris, K. and Thessalou-Legaki, M. 2001. Sex related variability of rostrum morphometry of *Aristeus antennatus* (Decapoda: Aristeidae) from the Ionian sea (Eastern Mediterranean, Greece). Hydrobiologia, 449:123-130.

Kovach, W.L. 1999. A Multivariate Statistical Package for Windows, ver 3.1. Kovach Computing Services, Pentraeth, UK.

Lopez, M.T. 1965. Estudios biológicos en *Aelga odebrechtii paulensis,* Schmitt (Crustacea, Decapoda, Anomura). Boletim de Zoologia da Faculdade de Filosofia, Ciências e Letras, 25:301-314.

Lopretto, E.C. 1978a. Estrutua exoesqueletaria y miologia del quinto par de pereiopodos del macho de la familia Aeglidae (Crustacea, Anomura). Limnobios, 1(8):284-198.

Lopretto, E.C. 1978b. Las especies de *Aegla* del centro-oeste Argentino en base a la morfologia comparada del quinto par de pareiopodos (Crustacea, Anomura, Aeglidae). Neotropica, 24(71):57-68.

Lopretto, E.C. 1979. Estúdio comparativo del quinto par de pereiopodos en los representantes de *Aegla* de la Patagonia Argentina (Crustacea, Anomura). Neotropica, 25(73):9-22.

Lopretto, E.C. 1980a. Analisis de las caracteristicas del quinto pereiopodo en las especies de *Aegla* del grupo "platensis" (Crustacea, Anomura, Aeglidae). Physis, 39 Sec. B (96):37-56.

Lopretto, E.C. 1980b. Clave para la determinación de las especies del genero *Aegla* de la Republica Argentina en base al estudio comparativo del quinto par de pereiopodos masculinos (Crustacea, Anomura, Aeglidae). Limnobios, 1(10):431-436.

Noro, C.K. and Buckup, L. 2002. Biologia reprodutiva e ecologia de *Aegla leptodactyla* Buckup and Rossi, 1977 (Crustacea, Anomura, Aeglidae) Revista Brasileira de Zoologia, 19(4):1063-1074.

Pérez-Losada, M.; Bond-Buckup, G.; Jara, C.G. and Crandall, K.A. 2004. Molecular systematics and biogeography of the southern South American freshwater "crabs" *Aegla* (Decapoda: Anomura: Aeglidae) using multiple heuristic tree search approaches. Systematic Biology, 53(5):767-780.

Pérez-Losada, M.; Bond-Buckup, G.; Jara, C.G. and Crandall, K.A. 2009. Conservation assessment of southern South American freshwater ecoregions on the basis of the distribution and genetic diversity of crabs from the genus *Aegla.* Conservation Biology, 23(3):692-702.

Ringuelet, R.A. 1949. Consideraciones sobre las relaciones filogenéticos entre las espécies del gênero *Aegla* Leach. Notas del Museo de La Plata, 14:11-118.

Rodrigues, W. and Hebling, N.J. 1978. Estudos biológicos em *Aegla perobae* Hebling and Rodrigues, 1977 (Decapoda, Anomura). Revista Brasileira de Biologia, 38(2):383-390.

Santos, S.; Bond-Buckup, G.; Pérez-Losada, M.; Bartholomei-Santos, M. and Buckup, L. 2009. *Aegla manuinflata,* a new species of freshwater anomuran (Decapoda: Anomura: Aeglidae) from Brazil, determined by morphological and molecular characters. Zootaxa, 2088:31-40.

Schmitt, W.L. 1942. The species of *Aegla,* endemic South American freshwater crustaceans. Proceedings of the United States National Museum, 91(3132):431-524.

Souza, U.R.; Silva, F.L.; Griffith, J.J.; Lima, J.E.; Quintela, M.C.A. and Costa, E.C.V. 2009. Determinantes de novos contratos de fomento florestal na mesorregião do Vale do Rio Doce, Minas Gerais. Revista Árvore, 33(2):377-386.

Swiech-Ayoub, B.P. and Masunari, S. 2001a. Flutuação temporal e espacial de abundância e composição de tamanho de *Aegla castro* Schmitt (Crustacea, Anomura, Aeglidae) no Buraco do Padre, Ponta Grossa, Paraná, Brasil. Revista Brasileira de Zoologia, 18(3):1003-1017.

Swiech-Ayoub, B.P. and Masunari, S. 2001b. Biologia reprodutiva de *Aegla castro* Schmitt (Crustacea, Anomura, Aeglidae) no Buraco do Padre, Ponta Grossa, Paraná, Brasil. Revista Brasileira de Zoologia, 18(3):1019-1030.

Teodósio, E.A.O. and Masunari, S. 2009. Estrutura populacional de *Aegla schmitti* (Crustacea: Anomura: Aeglidae) nos reservatórios dos Mananciais da Serra, Piraquara, Paraná, Brasil. Zoologia, 26(1):19-24.

Thorpe, R.S. 1980. A comparative study of ordination techniques in numeral taxonomy in relation to racial variation in the ringed snake, *Natrix natrix* (L.). Biological Journal of the Linnaean Society, 13:1-40.

Tzeng, T.D.; Chiu, C.S. and Yeh, S.Y. 2001. Morphometric variations in red-spot prawn (*Metapenaeopsis barbata*) in different geographic waters off Taiwan. Fisheries Research, 53:211-217.

Tzeng, T.D. 2004. Stock identification of sword prawn *Parapenaeopsis hardwichii* in the East China Sea and Taiwan Strait inferred by morphological variation. Fisheries Science, 70:758-764.

Vaz-Ferreira, R.; Gary, R. and Vaz-Ferreira, M. 1945. Notas biométricas sobre los crustáceos decapodos del gênero *Aegla* Leach, I. La variacion de algunas magnitudes em *Aegla uruguayana* Schmitt. Comunicaciones Zoológicas del Museo de Historia Natural de Montevideo, 1(24):1-6.

Viau, V.E.; López Greco, L.S.; Bond-Buckup, G. and Rodríguez, E.M. 2006. Size at onset of sexual maturity in anomuran crab, *Aegla uruguayana* (Aeglidae). Acta Zoologica, 87:253-264.

Zar, J.H. 1996. Biostatistical analysis. New Jersey, Prentice-Hall: 662 p.

Submitted
Accepted