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The degree of similarity of the body form of species within the family Glossiphoniidae

Aleksander Bielecki, Joanna Kalinowska and Adam Jawniak

With 2 figures and 1 table

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This paper is the first to present the similarity of morphotypes of the 12 species belonging to the family Glossiphoniidae, based on a mathematical model of a body form and phenetic analysis.

1 Introduction

Systemic mathematical modelling was first used by Raup (1966, 1967, Raup & al. 1973), who described in this way spirally coiled shells of fossil and extant invertebrates. The same method is applied by Epshtein (1984, 1987, 1989) and Bielecki & Epstein (1994, 1995), the subject of modelling being the body form of leeches. The body form was selected for the following reasons.
1. It is a significant ectosomatic character
2. In some taxa within the class of leeches it is of phylogenetic significance
3. It describes the limits of space within which topographical changes of internal organs take place
4. The body form in leeches can be formalized easily.

2 Material and methods

12 leech species belonging to the family Glossiphoniidae were included in the study (Tab. 1). Altogether we investigated 800 individual leeches, caught at various sites in Poland. The leeches were anaesthetised in 10 % ethyl alcohol, their mucus was washed off and they were preserved in 50 % alcohol and kept in 75 % alcohol. Based on the parameters of the body form model in leeches proposed by Epshtein (1989), Bielecki has produced his own, modified and supplemented computer model of leech body form (Bielecki 1993, 1994, 1997, 2001, Bielecki & Epshtein 1994, 1995).

The model presents the leech body on a plane as two ellipses (suckers) and trapeziums situated between them (anterior body part - two trapeziums; posterior body part four trapeziums). Besides, transverse sections through the anterior body part and posterior body part are considered as two ellipses. The width of the first trapezium (d_2) was determined at the place of the male sexual meatus, d_3 (the width of the second trapezium) was measured at half the distance between: d_2 and d_4. Subsequent values of d_5 and d_6 were determined at half the distance between d_4 and d_7.

The following corrections were made for the body form of the species belonging to the family Glossiphoniidae. The cross-section in the anterior body part was measured at the widest part - d_3, whereas the cross-section in the posterior body part corresponds to the trapezium base – d_4.

The model is constructed according to the following parameters:

- (1-4) Parameters describing the form of the anterior sucker: C_1 = horizontal diameter; C^1_1 = vertical diameter; R_1 = length of anterior part of sucker; M_1 = length of posterior part of sucker.
- (5-12) Parameters describing the form of anterior body part: d_1 = width at sucker junction; d_2 = width at outline narrowing; d_3 = width at border with posterior body part; D_1 = largest width of posterior body part; N_1 = largest height of anterior body part; S_1 = height of first trapezium; S_2 = height of second trapezium; $L_1 = (S_1 + S_2)$ = length of anterior body part.
- (13-25) Parameters describing the form of posterior body part: width at places of outline distortion (bases of consecutive trapeziums); d_4 = base of first trapezium; d_5 = base of second trapezium; d_6 = base of third trapezium; d_7 = base of fourth trapezium (width at sucker junction); D_2 = largest width of posterior body part; N_2 = largest height of posterior body part; $L_2 = (S_3 + S_4 + S_5 + S_6)$ = length of posterior body part (height of consecutive trapeziums); S_3 = height of first trapezium; S_4 = height of scond trapezium; S_5 = height of third trapezium; S_6 = height of fourth trapezium; K_1 = distance from d_3 to D_2; K_2 = distance from D_2 to d_7.
- (26-29) Parameters describing the form of posterior sucker: C^1_2 = horizontal diameter; C_2 = vertical diameter; M_2 = length of anterior part of sucker; R_2 = length of posterior part of sucker.

The 19 body proportion indices (invariants) are:

- 1. Index describing L/D_2 = relative body length.
- Indices describing anterior sucker: 2. C^1_1/d_1 = ratio of horizontal diameter of sucker to anterior body part width at sucker junction; 3. C^1_1/D_1 = ratio of horizontal diameter of sucker to greatest width of anterior; 4. R_1/M_1 = ratio of dorsal part of sucker to its ventral part; 5. C^1_1/C_1 = ratio of horizontal diameter of sucker to its vertical diameter.
- Indices describing anterior body part: 6. L_1/D_1 = ratio of anterior body part length to its greatest width; 7. D_1/N_1 = ratio of greatest anterior body part width to its greatest height; 8. S_1/S_2 = index describing position of greatest width of anterior body part.
- Indices describing posterior body part: 9. L_2/D_2 = ratio of urosome length to its greatest breadth; 10. D_2/N_2 = ratio of greatest posterior body part width to its greatest height; 11. K_1/K_2 = ratio describing position of greatest width of posterior body part.
- Indices describing posterior sucker: 12. C^1_2/d_7 = ratio of horizontal diameter of sucker to urosome width at sucker junction; 13. C^1_2/D_2 = ratio of horizontal diameter of sucker to greatest body height; 14. R_2/M_2 = ratio of dorsal part of sucker to its ventral part; 15. C^1_2/C_2 = ratio of horizontal diameter of sucker to its vertical diameter.
- Indices describing relations between posterior body part and anterior body part: 16. L_2/L_1 = ratio of urosome length to anterior body part length; 17 D_2/D_1 = ratio of greatest width of urosome to greatest width of anterior body part; 18. N_2/N_1 = ratio of greatest height of posterior body part to greatest height of t anterior body part.
- Index describing proportions of suckers: 19. C^1_2/C^1_1 = ratio of horizontal diameter of posterior sucker to horizontal diameter of anterior sucker.

The body shape and size are illustrated in figure 1. The data concerning the average dimensionless values (19 indices), which describe the body form of the specific species are presented in table 1.

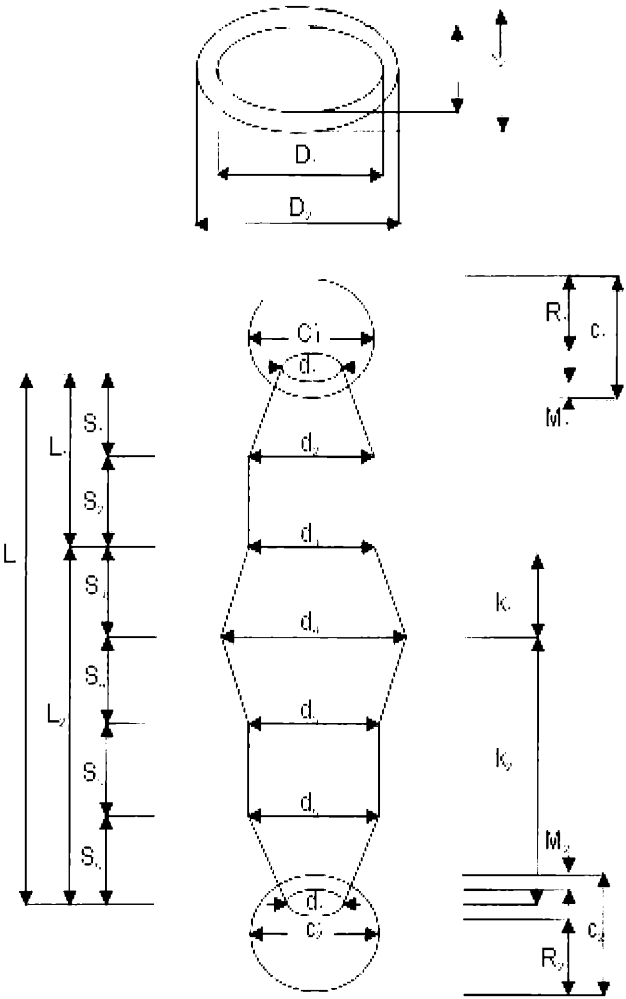

Fig. 1: Model of leech body form (Bielecki 1993, 1994, 1997, Bielecki & Epshtein 1993, 1994, 1995)

Tab. 1: Mean values of 19 body proportion indices in 12 species of Glossiphoniidae; explanations in the text

	L/ D_2	C^1_1/ D	C^1_1/ d	R_1/ M_1	C^1_1/ C	L_1/ D_1	D_1/ N_1	S_1/ S	L_2/ D_2	D_2/ N_2	K_1/ K_2	C^1_2/ d	C^1_2/ D	R_2/ M_2	C^1_2/ C	L_2/ L_1	D_2/ D_1	N_2/ N_1	C^1_2/ C^1
Placobdella costata (Fr. Müller, 1846)	2,0	3,5	0,3	0,5	1,1	0,9	2,2	1,0	1,2	1,9	0,6	2,7	0,3	1,8	1,1	1,7	1,3	1,5	1,4
Theromyzon tessulatum (O.F. Müller, 1774)	5,1	4,1	0,3	0,1	1,4	0,6	2,1	0,7	1,3	2,5	0,6	1,1	0,1	2,0	1,0	2,1	1.0	1,4	0,5
Alboglossiphonia heteroclita (Lukin. 1976)	2,4	1,0	0,1	1,0	0,8	0,9	2,5	0,8	1,5	1,8	2,7	0,3	0,3	0,3	1,0	1,9	1,1	1,5	2,8
Hemiclepsis marginata (O. F. Müller, 1774)	1,1	6,0	0,5	0,5	1,5	0,5	1,6	1,0	0,7	1,0	1,8	2,6	0,5	2,2	1,4	1,6	1,0	1,9	1,0
Batracobdelloides moogi (Nesemann & Csanyi, 1995)	3,0	2,5	0,3	1,6	1,2	1,1	2,8	1,5	1,4	1,8	0,3	2,3	0,2	1,2	0,8	1,6	1,1	1,3	1,7
Boreobdella verrucata (Fr. Müller, 1844)	0,3	2,6	0,2	1,0	2,2	0,5	0,8	1,1	0,7	1,2	2,5	2,0	0,5	2,0	2,0	1,5	1,1	1,2	1,2
Helobdella stagnalis (Linnaeus,1758)	3,2	1,0	0,3	1,0	2,0	1,8	1,3	4,3	1,6	1,2	2,0	1,9	0,6	1,3	1,1	1,0	1,2	1,2	1,9
Batracobdella paludosa (Carena, 1824)	1,8	7,6	0,4	0,4	1,5	1,0	2,3	2,0	1,3	1,3	0,2	2,8	1,1	1,7	2,1	1,6	1,5	1,5	1,4
Glossiphonia complanata (Linnaeus,1758)	1,5	0,3	0,1	1,0	1,1	1,2	4,4	0,8	0,9	4,3	1,9	0,5	0,3	1,5	1,2	1,6	1,2	1,1	2,2
Alboglossiphonia papillosa (Carena, 1820)	1,8	1,0	0,1	1,0	0,8	0,5	5,6	0,7	2,9	5,5	2,3	1,5	3,7	1,0	1,0	2,9	1,2	1,2	3,0
Alboglossiphonia hyalina (O.F Müller, 1774)	2,2	1,3	0,1	1,0	0,8	0,8	4,8	0,8	1,5	4,1	3,9	1,0	5,5	1,0	2,0	2,3	1,2	1,3	1,5
Glossiphonia concolor (Apathy, 1883))	3,1	4,5	0,5	0,8	1,1	1,6	4,0	2,6	2,5	2,0	0,6	2,1	0,3	1,0	0,9	2,2	1,3	1,7	2,1

3 Results

The joining or tree clustering algorithm was chosen to interpret the similarity of body form of the 12 species of Glossiphoniidae. When selecting distance measures, city-block (Manhattan) distance was chosen, which minimises the effect of more distant objects (morphotypes). Of amalgamation or linkage rules, Ward's method was used, since it tends to yield small clusters and with such a low number of species gives a high resolution. The procedure made it possible to divide the species morphotypes in 2 polytypic clusters (Fig. 2):

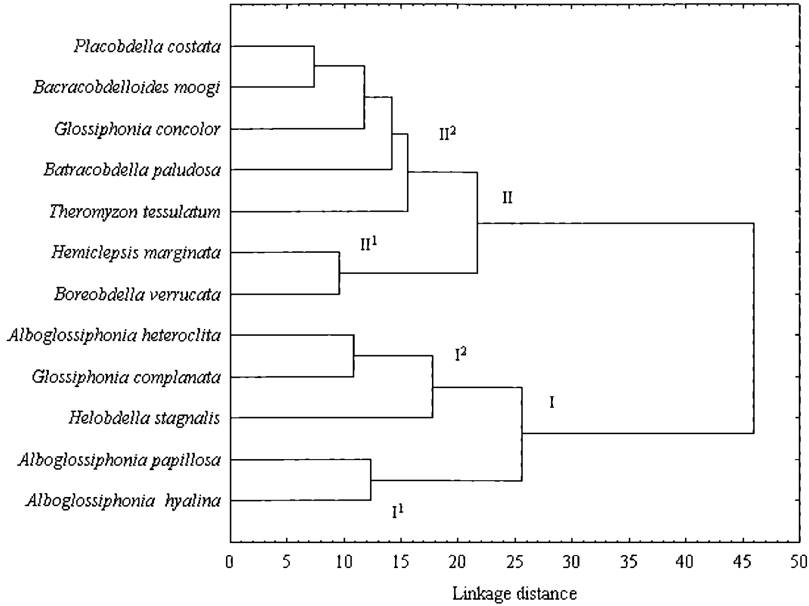

Fig. 2: Tree diagram for 12 species of Glossiphoniidae based on mean value of 19 body proportion indices. Ward's method, Manhattan distances

I- cluster including the species of very similar body form: *Albiglossiphonia hyalina*, *A. papillosa*, *Helobdella stagnalis*, *Glossiphonia complanata* and *A. heteroclita*.
I^1 sub-clusters: *A. hyalina* and *A. papillosa* which are very similar to each other
I^2 sub-clusters: *H. stagnalis*, *G. complanata* and *A. heteroclita* have most similar body form.

II- another polytypic cluster comprising the remaining species: *Boreobdella verrucata*, *Hemiclepsis marginata*, *Theromyzon tessulatum*, *Batracobdella paludosa*, *G. concolor*, *Batracobdelloides moogi*, *Placobdella costata*. The cluster has two large sub-clusters: II^1 including 2 and II^2 5 species.
II^1 sub-clusters: *B. verrucata* and *H. marginata*
II^2 sub-clusters comprising the following species characterised by similar body form: *T. tessulatum*, *B. paludosa*, *G. concolor*, *B. moogi* and *P. costata*, the latter having the most similar body form.

4 Discussion

The morphometric examination of the 12 Glossiphonidae species, based on a mathematical model, shows that the scope of their logistic capabilities is completed if the following conditions, concerning the cross-sections in the anterior and posterior body parts, are met:

$D_2/D_1 = 1$ and $D_2/N_2 = 1$; $D_2/D_1 = 1$ and $D_2/N_2 > 1$; $D_2/D_1 > 1$ and $D_2/D_1 > 1$

Most species realise the space determined by the condition ($D_2/D_1 > 1$ and $D_2/N_2 > 1$), e.g.: *P. costata*, *B. verrucata*, *B. moogi*, *B. paludosa*, *G. concolor*, *A. hyalina*, *A. papillosa*, *G. complanata*, *A. heteroclita*, *H. stagnalis*. However, for *H. marginata* the body form is conditioned by the invariant ($D_2/D_1 = 1$ and $D_2/N_2 = 1$); and *T. tessulatum* ($D_2/D_1 = 1$ and $D_2/N_2 > 1$).

The body of leeches is similar to a cylinder, a leaf, a tape or a "retort" (Bielecki & Epshtein 1994, 1995). The cross section of the anterior and posterior part of the body is similar to a more or less flattened ellipsis. It has a small sucker, which makes it possible for them to enter the host body cavities (e.g. Mollusca); thanks to their flattened body, leeches can adhere to the substrate with the whole body area. Satiated leeches change their body form from flat, leaf-like, to a form similar to that of an ear of corn (*T. tessulatum*). For some of them, such as young *H. marginata*, or *T. tessulatum*, the body form is similar to that of the Erpobdellidae or Piscicolidae, which may result from a particular survival strategy.

This study into the body form of Glossiphoniidae, which was carried out for the first time, shows that it is not a sufficient taxonomic feature within a genus. This may be linked to its ability to adapt to various habitats, including that of a host (a model is used to investigate interactions between the leech body form and habitat and host). However, the body form of the Glossiphoniidae, related to that of the Piscicolidae, functions well in these families' infrastructure and manifests significant differences.

The following species have a transitory body form between the Piscicolidae and Glossiphoniidae: *Baicalobdella cottidarum* and *B. torquata*. However, for *H. marginata*, the body form is close to that of *Piscicola geometra*.

It was shown by means of the cluster analysis that one sub-cluster and two sub-sub-clusters include the species which belong to two sub-genera, e.g. *G. complanata* and *A. heteroclita*, *B. verrucata* and *H. marginata*, or *P. costata* and *B. moogi*. The species were found close to each other in the same cluster, despite the differences resulting from the relative body length. The subcluster comprises *B. veruucata* and *H. marginata*. The first sub-sub-cluster includes *G* *complanata* and *A. heteroclita*, and the second sub-sub-cluster includes *B. moogi* and *P. costata*.

Interestingly, for the two species *B. moogi* and *B. paludosa*, which were not distinguished until recently, the morphological body forms are not very similar. (Bielecki & al. 2000, Nesemann & Csányi 1995).

However, significantly similar body forms were determined for the species within the same genus, *A. papillosa* and *A. hyalina*. Many researchers have treated them as two forms of a nominative species *A. heteroclita* (Pawlowski 1936, Lukin 1976, Grosser & al. 2001).

Further research into the body forms of the Erpobdellidae, Hirudinidae, Piscicolidae and Acanthobdellida, based on a mathematical model as well as phenetic and cladistic analysis, may provide an explanation for the many differences and similarities in leeches.

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Address of the corresponding author: Prof. Dr. Aleksander Bielecki, Warmia and Mazuri University, Department of Zoology, Pl-10-967 Olsztyn - Kortowo, Oczapowskiego Street 5,
alekb@moskit.uwm.edu.pl

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Autor(en)/Author(s): Bielecki Aleksander, Kalinowska Joanna, Jawniak Adam

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