CHAPTER I
MORPHOMETRY

Introduction

Morphometric methods are powerful tools used in the context of sound biological knowledge. They are most frequently used to achieve objectives that are not obtainable at presently by any other means. They allow us to summarise morphological data numerically and graphically, to express and test hypothetical relationship exactly, and with multivariate techniques to examine relationships in many dimensions in a manner not otherwise possible (Daly, 1985).

Morphometrics, i.e., the quantitative description and interpretation of shape and shape variation in biology is a fundamental area of research. Technique of descriptions and comparison of shapes of structures are needed in any systematic study that is based on the morphology of organisms. Measurements of morphological diversity are of interest in ecological and genetic studies. Ways of dealing with shape change are also important for developmental studies and for practical application in the medical sciences (Rohlf, 1990).

Though it is not a coherent discipline, it is practised in partial isolation in various fields of science including Entomology (Daly, 1985). Insects are ideal subjects for morphometric analysis. Although often used for exploration purposes, the most rewarding applications have been where appropriate background knowledge of an insect’s life history, genetic ecology etc., already exists. With an increasing number of techniques available for measurement and analysis, entomologists can use morphometry as a splendid research tool (Daly, 1985).

Morphometry has been interrelated to biochemical, genetic, cytological and ecogeographical information in systematics. For example, morphometry of social bees and wasps (Daly, 1973), asymmetrical relationship between the prey size and the possibility of
the prey capture (Wilson, 1975), positive correlation between the mandible length of the workers of seed eating ants, mandible size and the prey size of the coccinellid beetles (Pearson and Mury, 1979), morphometry and geographic variations in the gall forming aphids (Sokal et al., 1980), length of the wing pad of the fourth instar nymph of delphacid rice pest with the wing length of brachypterous and macropterous adults to understand their population dynamics (Cook and Perfect, 1982), correlation between the wing length of African armyworm to geographical areas of East Africa (Aidley and Lubega, 1979), size differences in the monogeographic races of a coastal dune beetle within the distance up to 500 m from the highest tide (Doyen and Slobodchikoff, 1984), forewings size of Bombus and closely related cuckoo bee Psithyrus and their generic relationship (Plowright and Stephen, 1973), correlation between the morphometry and the dispersal and the distribution of bush fly population in South Australia (Greenham and Hughes, 1971), morphometric asymmetry and developmental instability of extreme phenotypes in honey bees biosystematics (Bruckner, 1976), analysis of races of honey bee population from Europe to Africa (Gadbin et al., 1979), measurements of the wings of species of various genera, families of calyptrate Diptera (Brown, 1979a, b) and the measurements of male genital organ of Psammolestes tertius Lent & Jurberg species (Soares et al., 2001). Within the morphological context, morphometry (Rohlf and Marcus, 1993; Adams et al., 2004) appears as an important taxonomic tool for species discrimination and species variations (Dujardin et al., 1998; Calle et al., 2002; Jaramillo et al., 2002; Monroy et al., 2003; Yurtas et al., 2005; Feliciangeli et al., 2007).}

Delgado and Rubio-Palis (1993) examined the morphometric variation of Anopheles (Nyssorhynchus) nuneztovari Gabaldon and detected variability within Venenzuelan populations. Size variation is more influenced by environmental factors, whereas shape variation has a stronger genetic component (Klingenberg et al., 2004; Dujardin and Slice,
2007). The morphometric analysis (discriminant analysis) of *Anopheles pseudopunctipennis* Theobald (Juri *et al*., 2011) did not reveal a pattern between Bolivian and Argentinean populations based on geographical distances.

Rukmani (1992) expanded the work of Ambrose (1987b) of which she calculated the linear regression coefficients ($r$) of the relative postembryonic development of 27 combinations of parts of 24 species belonging to 13 genera. According to her, these values can be used to identify a particular genus as well as to trace the affinity between different genera of a particular subfamily and to diagnose family Reduviidae from other heteropterous families but it might not be useful to demarcate the subfamilies of Reduviidae. Morphological and biological characteristics of ecotypes and morphs of several species of assassin bugs etc., were studied and correlated (Ambrose, 1999).

Ambrose and Ambrose (2003) studied the linear regression coefficient values ($r$) of postembryonic developmental morphometry as an effective tool in biosystematics of reduviids. The ($r$) values were found useful to identify and understand the affinity of reduviids at subfamily, generic and species levels.

Monroy *et al*. (2003) examined the *Triatoma nitida* Usinger intraspecific variations using morphometry as a tool to compare three populations from different localities, in order to understand its population structure. They also reported that the morphometric analysis of 47 *T. nitida* males from three localities that showed quantitative differences between the populations. Lehmann *et al*. (2005) analysed the morphometry of *Triatoma dimidiata* (Latreille) populations and reported that although wing fluctuating asymmetry was present in all populations, only head characters were necessary to distinguish population level differences. Kwadjo *et al*. (2008) studied the morphometrical changes of eggs of *Rhynocoris*

Ambrose and Ambrose (2009b) analysed 36 morphometric indices belonging to 27 species, 14 genera and 3 subfamilies viz., Harpactorinae, Peiratinae and Reduviinae by direct observation as well as unweighted pair group method using arithmetic mean (UPGMA) incorporating Euclidean Distances, Nei and Li’s Genetic Distance Coefficient and Jaccard's Coefficient which reveals diagnostic intra-as well as intersubfamilial and generic affinities. Moreover, it gives an insight into the placement of genera in the existing divisions (tribes) of subfamilies and their phylogenetic relationship. Further, it clearly suggests two diversified lines of evolution of Peiratinae and Reduviinae from Harpactorinae than the earlier suggested straight line evolution of these two subfamilies from Harpactorinae (Ambrose, 1999). Villacís et al. (2010) studied the variation between the two geographical populations of *Rhodnius ecuadoriensis* Lent and León with wing size and shape. The morphometry of the antennae of *Panstrongylus megistus* Burmeister, *Rhodnius neglectus* Lent, *R. prolixus* Stål and *Triatoma vitticeps* Stål was also studied (Rosa et al., 2010).

Singh (2012) studied generic identity and interspecific differentiation of postembryonic developmental morphometry of four *Rhynocoris* species. The analysis of these species by linear regression coefficient values (r) of postembryonic developmental morphometric suggests its utility as a biosystematics tool at generic and species levels and also the morphometric results confirmed by the dendrogram showed in 100% similarity among the four *Rhynocoris* species.

In the present thesis, an attempt was made to understand whether the linear regression coefficient (r) values of size of various parts of life stages of six species belonging to subfamily Reduviinae viz., *Acanthaspis pedestris* Stål, *A. quinquespinosa* (Fabricius), *A. siva*
Distant, *Empyrocoris annulata* (Distant), *Edocla slateri* Distant and *Velitra sinensis* (Walker) could be used as a tool in their demarcation either at generic or species level. Since reduviids are natural enemies of several insect pests, present study helps their accurate identification for their effective utilization in the Integrated Pest Management.

**Materials and Methods**

The measurement of one body part (a) was compared to that of another (b) from the first nymphal instar to the adult. Thus, six pairs of (I, II, III, IV, V nymphal instars and adult) (a) and (b) values were computed together and the regression coefficient (r) was calculated for a particular part. Equal number of males and females represented the adult measurement. Twenty one such sets of values were computed and the regression coefficient values were analysed to find out biosystematic significance, if any. Affinity was calculated by identifying exact values or relatively closer values (Rukmani, 1992). The analysed sets of values include:

Cluster analysis was made using the software, MultiVariate Statistical Package for Windows, ver. 3.1. A dendrogram was constructed with Unweighted Pair Group Method wing arithmetic mean (UPGMA) and the similarity matrix index was calculated by the percent similarity coefficient (Kovach, 2007).

**Results**

1. **Head Length/Head width (HL/HW)**

   The (r) values are the highest and exactly similar (0.99) among three species belonging to three genera *A. pedestris, E. slateri* and *E. slateri*, lower and unique in *E. annulata* (0.98) and the lowest and exactly similar in *A. quinquespinosa* and *A. siva* (0.97) (Table 1).

2. **Head Length/Prothoracic length (HL/PTL)**

   Though the r values are the lowest and exactly similar in *A. quinquespinosa* and *A. siva* (0.92) it is higher and unique in the rest of the four species: *E. slateri*, (0.99), *A. pedestris* (0.98) *V. sinensis* (0.97) and *E. annulata*, (0.96).

3. **Head length/ Abdominal length (HL/AL)**

   The (r) values are exactly similar in *E. slateri* and *V. sinensis* (0.96). It is the highest in *A. quinquespinosa* (0.99) and lower in *A. siva* (0.92) and the lowest in *A. pedestris* (0.90) and unique among themselves.

4. **Head length/ Diameter of eye (HL/DE)**

   The (r) values are exactly similar (0.98) in three species belonging to two genera viz., *A. quinquespinosa, A. siva* and *E. slateri*. It is the highest in *A. pedestris* (0.99) and lower in *E. annulata* (0.96) and the lowest in *V. sinensis* (0.94) and unique among themselves.
5. Head width/ Width between eyes (HW/WBE)

The (r) values are unique among all the six species: *E. slateri* (0.99) > *A. quinquespinosa* (0.98) > *E. annulata* (0.97) > *A. pedestris* (0.93) > *A. siva* (0.89) > *V. sinensis* (0.84).

6. Head width/ Prothoracic width (HW/PTW)

The (r) values are exactly similar among four species belonging to three genera *A. pedestris*, *A. quinquespinosa*, *E. slateri* and *V. sinensis* (0.96) but it is higher and unique in *E. annulata* (0.98) and much lower and unique in *A. siva* (0.89).

7. Entire Antennal length/ Head length (EAL/HL)

The (r) values are again exactly similar in three species belonging to two genera viz., *A. pedestris*, *A. siva* and *V. sinensis* (0.99) and lower and similar in two species belonging to two genera viz., *E. annulata* and *E. slateri* (0.96) but it is intermediate and unique in *A. quinquespinosa* (0.97).

8. Entire Antennal length/ Prothorax length (EAL/PTL)

The (r) values are exactly similar in two species belonging to two genera viz., *V. sinensis* and *E. slateri* (0.98) but it is slightly higher and unique in *A. quinquespinosa* (0.99) and still lower and unique in the rest of the three species belonging to two genera viz., *A. pedestris* (0.97), *E. annulata* (0.96) and *A. siva* (0.95).

9. Entire Antennal length/Fore tibial length (EAL/FTL)

The (r) values are exactly similar in two species of *Acanthaspis* viz., *A. quinquespinosa* and *A. siva* (0.98) but it is higher and unique in *V. sinensis* (0.99) and lower and unique in the rest of the three species belonging to three genera viz., *A. pedestris* (0.97), *E. annulata* (0.96) and *E. slateri* (0.95).
10. Entire Antennal length/ Abdominal length (EAL/AL)

The (r) values are exactly similar in three species belonging to two genera viz., *A. quinquespinosa*, *A. siva* and *E. annulata* (0.95) but it is higher and unique in the rest of the three species belonging to three genera *E. slateri* (0.98) and *V. sinensis* (0.96) and lesser in *A. pedestris* (0.94).

11. Rostral length/ Head length (RL/HL)

The (r) values are exactly similar in three species of *Acanthaspis* viz., *A. pedestris*, *A. quinquespinosa* and *A. siva* (0.99), slightly lower and unique in two species belong to two genera *E. annulata* and *V. sinensis* (0.98) and still it is slightly lower and unique in *E. slateri* (0.97).

12. Rostral length/ Prothoracic length (RL/ PTL)

The (r) values are unique in all the six species: *A. pedestris* (0.98)>*V. sinensis* (0.97)>*E. annulata* (0.96)>*A. quinquespinosa* (0.92)>*E. slateri* (0.90)>*A. siva* (0.89).

13. Rostral length/ Foretibial length (RL/ FTL)

The (r) values are exactly similar in three species belonging to two genera viz., *A. pedestris*, *A. quinquespinosa* and *V. sinensis* (0.99) and lower and unique in species belonging to three genera viz., *E. annulata* (0.97), *A. siva* (0.95) and *E. slateri* (0.92).

14. Rostral length/ Abdominal length (RL/ AL)

The (r) values are exactly similar in two species of *Acanthaspis* viz., *A. pedestris* and *A. quinquespinosa* (0.98) but it is lower and unique in the rest of the four species belonging to four genera viz., *E. slateri* (0.96), *V. sinensis* (0.95), *A. siva* (0.90) and *E. slateri* (0.89).
15. Prothoracic length/ Prothoracic width (PTL/ PTW)

The (r) values are exactly similar in three species belonging to three genera viz., *A. siva*, *E. annulata* and *E. slateri* (0.99) lower in two species of *Acanthaspis* viz., *A. pedestris* and *A. quinquespinosa* (0.98) and still lower and unique in *V. sinensis* (0.88).

16. Prothoracic length/ Fore tibial length (PTL/ FTL)

The (r) values are exactly similar in two species belonging to two genera viz., *E. annulata* and *V. sinensis* (0.98) and lower and unique in *E. slateri* (0.97) and lowest and similar in three species of *Acanthaspis*: *A. pedestris*, *A. quinquespinosa* and *A. siva* (0.90).

17. Prothoracic length/ Midtibial length (PTL/ MTL)

The (r) values are exactly similar in two species belonging to two genera viz., *A. quinquespinosa* and *E. slateri* (0.99), lower and similar in two species belonging to two genera viz., *E. annulata* and *V. sinensis* (0.98) lower and unique in *A. pedestris* (0.94) and the lowest and unique in *A. siva* (0.86).

18. Prothoracic length/ Hind tibial length (PTL/ HTL)

The (r) value is the highest and unique in *E. slateri* (0.99) lower and exactly similar in two species belonging to two genera viz., *E. annulata* and *V. sinensis* (0.98) and still lower and similar in two species of *Acanthaspis* viz., *A. quinquespinosa* and *A. siva* (0.95) and the lowest and unique in *A. pedestris* (0.94).

19. Prothoracic length/ Abdominal length (PTL/ AL)

The (r) values are exactly similar in two species belonging to two genera: *A. pedestris* and *E. annulata* (0.93) and varies and unique in the remaining four species belonging to three genera viz., *A. siva* (0.99), *A. quinquespinosa* (0.97), *E. slateri* (0.92) and *V. sinensis* (0.90).
20. Prothoracic length/ Abdominal width (PTL/ AW)

The (r) values are the lowest and exactly similar (0.94) in three species of *Acanthaspis* viz., *A. pedestris*, *A. quinquespinosa* and *A. siva*, higher and unique among the rest of the three species belonging to three genera: *E. slateri* (0.99), *E. annulata* (0.96) and *V. sinensis* (0.95).

21. Abdominal length / Abdominal width (AL/AW)

The (r) values are the lowest and exactly similar in three species of *Acanthaspis* viz., *A. quinquespinosa*, *A. siva* and *E. annulata* (0.96), lower in *A. pedestris* (0.97). It is higher and unique in two species belonging to two genera viz., *E. slateri* (0.98) and *V. sinensis* (0.99).

Exactly similar (r) values

1. *A. quinquespinosa* and *A. siva* have 11 similar (r) values, i.e., Head Length/Head width (HL/HW), Head Length/Prothoracic length (HL/PTL), Head length/ Diameter of eye (HL/DE), Entire Antennal length/Foretibial length (EAL/FTL), Entire Antennal length/ Abdominal length (EAL/AL), Rostral length/ Head length (RL/HL), Prothoracic length/ Fore tibial length (PTL/ FTL), Prothoracic length/ Hind tibial length (PTL/ HTL), Prothoracic length/ Abdominal width (PTL/ AW) and Abdominal length / Abdominal width (AL/AW).

2. *A. pedestris*, *A. quinquespinosa* and *A. siva* have three similar (r) values, i.e., Rostral length/ Head length (RL/HL), Prothoracic length/ Fore tibial length (PTL/ FTL), Prothoracic length/ Abdominal width (PTL/ AW). Hence, these values could be considered as generic markers.

3. *A. pedestris* and *A. quinquespinosa* have seven similar (r) values, i.e., Head width/ Prothoracic width (HW/PTW), Rostral length/ Head length (RL/HL), Rostral length/
Foretibial length (RL/FTL), Rostral length/ Abdominal length (RL/AL), Prothoracic length/ Prothoracic width (PTL/PTW), Prothoracic length/ Fore tibial length (PTL/FTL) and Prothoracic length/ Abdominal width (PTL/AW).

4. *E. slateri* and *V. sinensis* have four similar (r) values, i.e., Head Length/Head width (HL/HW), Head length/ Abdominal length (HL/AL), Head width/ Prothoracic width (HW/PTW) and Entire Antennal length/ Prothorax length (EAL/PTL).

5. *A. pedestris* and *A. siva* have four similar (r) values, i.e., Entire Antennal length/ Head length (EAL/HL), Rostral length/ Head length (RL/HL), Prothoracic length/ Fore tibial length (PTL/FTL) and Prothoracic length/ Abdominal width (PTL/AW).

6. *A. pedestris* and *V. sinensis* have four similar (r) values, i.e., Head Length/Head width (HL/HW), Head width/ Prothoracic width (HW/PTW), Entire Antennal length/ Head length (EAL/HL) and Rostral length/ Foretibial length (RL/FTL).

7. *E. annulata* and *V. sinensis* have four similar (r) values, i.e., Rostral length/ Head length (RL/HL), Prothoracic length/ Fore tibial length (PTL/FTL), Prothoracic length/ Midtibial length (PTL/MTL) and Prothoracic length/ Hind tibial length (PTL/HTL).

8. *A. quinquespinosa* and *E. slateri* have three similar (r) values i.e., Head length/ Diameter of eye (HL/DE), Head width/ Prothoracic width (HW/PTW) and Prothoracic length/ Midtibial length (PTL/MTL).

9. *A. siva* and *E. annulata* have three similar (r) values, i.e., Entire Antennal length/ Abdominal length (EAL/AL), Prothoracic length/ Prothoracic width (PTL/PTW) and Abdominal length/ Abdominal width (AL/AW)
10. *E. annulata* and *E. slateri* have three similar (r) values, i.e., Entire Antennal length/Head length (EAL/HL), Entire Antennal length/Prothorax length (EAL/PTL) and Prothoracic length/Prothoracic width (PTL/PTW).

11. *A. quinquespinosa* and *V. sinensis* have two similar (r) values, i.e., Head width/Prothoracic width (HW/PTW) and Rostral length/Foretibial length (RL/FTL).

12. *A. pedestris* and *E. slateri* have two similar (r) values i.e., Head Length/Head width (HL/HW) and Head width/Prothoracic width (HW/PTW).

13. *A. pedestris* and *E. annulata* have one similar (r) value, i.e., Prothoracic length/Abdominal length (PTL/AL).

14. *A. quinquespinosa* and *E. annulata* have one similar (r) value, i.e., Entire Antennal length/Abdominal length (EAL/AL).

15. *A. siva* and *E. slateri* have one similar (r) value, i.e., Prothoracic length/Prothoracic width (PTL/PTW).

16. *A. siva* and *V. sinensis* have one similar (r) value, i.e., Entire Antennal length/Head length (EAL/HL).

**Closer (r) values**

1. *A. pedestris* and *A. quinquespinosa* have four closer (r) values, i.e., Head length/Diameter of eye (HL/DE), Entire Antennal length/Foretibial length (EAL/FTL), Prothoracic length/Hind tibial length (PTL/HTL) and Abdominal length/Abdominal width (AL/AW).

2. *A. pedestris* and *A. siva* have six closer (r) values, i.e., Head length/Diameter of eye (HL/DE), Entire Antennal length/Foretibial length (EAL/FTL), Entire Antennal length/Abdominal length (EAL/AL), Prothoracic length/Prothoracic width (PTL/
PTW), Prothoracic length/ Hind tibial length (PTL/ HTL) and Abdominal length / Abdominal width (AL/AW).

3. *A. pedestris* and *E. annulata* have seven closer (r) values, i.e., Head Length/Head width (HL/HW), Entire Antennal length/ Prothorax length (EAL/PTL), Entire Antennal length/Foretibial length (EAL/FTL), Entire Antennal length/ Abdominal length (EAL/AL), Rostral length/ Head length (RL/HL), Prothoracic length/ Prothoracic width (PTL/ PTW) and Abdominal length / Abdominal width (AL/AW).

4. *E. annulata* and *E. slateri* have seven closer (r) values, i.e., Head Length/Head width (HL/HW), Entire Antennal length/Foretibial length (EAL/FTL), Rostral length/ Head length (RL/HL), Prothoracic length/ Fore tibial length (PTL/ FTL), Prothoracic length/ Midtibial length (PTL/ MTL), Prothoracic length/ Hind tibial length (PTL/ HTL) and Prothoracic length/ Abdominal length (PTL/ AL).

5. *A. quinquespinosa* and *E. annulata* have six closer (r) values, i.e., Head Length/Head width (HL/HW), Head width/ Width between eyes (HW/WBE), Entire Antennal length/ Head length (EAL/HL), Rostral length/ Head length (RL/HL), Prothoracic length/ Prothoracic width (PTL/ PTW) and Prothoracic length/ Midtibial length (PTL/ MTL).

6. *A. pedestris* and *E. slateri* have six closer (r) values, i.e., Head Length/Prothoracic length (HL/PTL), Head length/ Diameter of eye (HL/DE), Entire Antennal length/ Prothorax length (EAL/PTL), Prothoracic length/ Prothoracic width (PTL/ PTW), Prothoracic length/ Abdominal length (PTL/ AL) and Abdominal length / Abdominal width (AL/AW).

7. *A. quinquespinosa* and *V. sinensis* have six closer (r) values, i.e, Entire Antennal length/ Prothorax length (EAL/PTL), Entire Antennal length/Foretibial length
(EAL/FTL), Rostral length/ Head length (RL/HL), Prothoracic length/ Midtibial length (PTL/ MTL) and Prothoracic length/ Abdominal width (PTL/ AW).

8. *E. annulata* and *V. sinensis* have six closer (r) values, i.e., Head Length/Head width (HL/HW), Head Length/Prothoracic length (HL/PTL), Entire Antennal length/ Abdominal length (EAL/AL), Rostral length/ Prothoracic length (RL/ PTL), Rostral length/ Abdominal length (RL/ AL) and Prothoracic length/ Abdominal width (PTL/ AW).

9. *A. pedestris* and *V. sinensis* have five closer (r) values, i.e., Head Length/Prothoracic length (HL/PTL), Entire Antennal length/ Prothorax length (EAL/PTL), Rostral length/ Head length (RL/HL), Rostral length/ Prothoracic length (RL/ PTL) and Prothoracic length/ Abdominal width (PTL/ AW).

10. *A. quinquespinosa* and *E. slateri* have four closer (r) values, i.e., Head width/ Width between eyes (HW/WBE), Entire Antennal length/ Head length (EAL/HL), Entire Antennal length/ Prothorax length (EAL/PTL) and Prothoracic length/ Prothoracic width (PTL/ PTW).

11. *A. siva* and *V. sinensis* have four closer (r) values, i.e., Entire Antennal length/Foretibial length (EAL/FTL), Entire Antennal length/ Abdominal length (EAL/AL), Rostral length/ Head length (RL/HL) and Prothoracic length/ Abdominal width (PTL/ AW).

12. *E. slateri* and *V. sinensis* have four closer (r) values, i.e., Rostral length/ Head length (RL/HL), Prothoracic length/ Fore tibial length (PTL/ FTL), Prothoracic length/ Hind tibial length (PTL/ HTL) and Abdominal length / Abdominal width (AL/AW).
13. *A. siva* and *E. annulata* have three closer (r) values, i.e., Head Length/Head width (HL/HW), Entire Antennal length/Prothorax length (EAL/PTL) and Rostral length/Head length (RL/HL).

14. *A.siva* and *E. slateri* have two closer (r) values, i.e., Rostral length/Prothoracic length (RL/PTL) and Rostral length/Abdominal length (RL/AL).

15. *A. quinquespinosa* and *A. siva* have one closer (r) value, i.e., Prothoracic length/Prothoracic width (PTL/PTW).

**Unique (r) values**

1. **Head Length/Head width (HL/HW)**

   It is unique only in *E. annulata* (0.98).

2. **Head Length/Prothoracic length (HL/PTL)**

   It is unique in four species viz., *E. slateri*, (0.99), *A. pedestris* (0.98), *V. sinensis* (0.97) and *E. annulata*, (0.96) belonging to all the four genera.

3. **Head length/Abdominal length (HL/AL)**

   It is unique in three species of *Acanthaspis*: *A. quinquespinosa* (0.99), *A. pedestris* (0.90) and *A. siva* (0.92).

4. **Head length/Diameter of eye (HL/DE)**

   It is unique in three species belonging to three genera: *A. pedestris* (0.99), *E. annulata* (0.96) and *V. sinensis* (0.94).

5. **Head width/Width between eyes (HW/WBE)**

   It is unique in all the six species belonging to four genera: *A. quinquespinosa* (0.98), *E. annulata* (0.97) and *E. slateri* (0.99), *A. pedestris* (0.93), *A. siva* (0.89) and *V. sinensis* (0.84).
6. Head width/ Prothoracic width (HW/PTW)

   It is unique in two species belonging to two genera: E. annulata (0.98) and A. siva (0.89).

7. Entire Antennal length/ Head length (EAL/HL)

   It is only in A. quinquespinosa (0.97).

8. Entire Antennal length/ Prothorax length (EAL/PTL)

   It is unique in three species of Acanthaspis viz., A. quinquespinosa (0.99), A. pedestris (0.97) and A. siva (0.95) and the lone species of Empyrocoris, E. annulata (0.96) belonging to two genera.

9. Entire Antennal length/ Fore tibial length (EAL/FTL)

   It is unique in four species belonging to three genera: V. sinensis (0.99), A. pedestris (0.97), E. annulata (0.96) and E. slateri (0.95).

10. Entire Antennal length/Abdominal length (EAL/AL)

    It is unique in three species belonging to three genera: E. slateri (0.98), V. sinensis (0.96) and A. pedestris (0.94).

11. Rostral length/ Head length (RL/HL)

    It is unique only in E. slateri (0.97).

12. Rostral length/ Prothoracic length (RL/ PTL)

    It is unique in all the six species belonging to four genera viz., A. pedestris (0.98), V. sinensis (0.97), E. annulata (0.96), A. quinquespinosa (0.92), E. slateri (0.90) and A. siva (0.89).

13. Rostral length/ Foretibial length (RL/ FTL)

    It is unique in three species belonging to three genera: E. annulata (0.97), A. siva (0.95) and E. slateri (0.92).
14. **Rostral length/ Abdominal length (RL/ AL)**

   It is unique in four species belonging to four genera *E. annulata* (0.96), *V. sinensis* (0.95), *A. siva* (0.90) and *E. slateri* (0.89).

15. **Prothoracic length/ Prothoracic width (PTL/ PTW)**

   It is unique only in *V. sinensis* (0.88).

16. **Prothoracic length/ Fore tibial length (PTL/ FTL)**

   It is unique only in *E. slateri* (0.97).

17. **Prothoracic length/ Midtibial length (PTL/ MTL)**

   It is unique in two *Acanthaspis* species viz., *A. pedestris* (0.94) and *A. siva* (0.86).

18. **Prothoracic length/ Hind tibial length (PTL/ HTL)**

   It is unique in two species belonging to two genera: *E. slateri* (0.99) and *A. pedestris* (0.94).

19. **Prothoracic length/ Abdominal length (PTL/ AL)**

   It is unique in four species belonging to three genera viz., *A. siva* (0.99), *A. quinquespinosa* (0.97), *E. slateri* (0.92) and *V. sinensis* (0.90).

20. **Prothoracic length/ Abdominal width (PTL/ AW)**

   It is unique in three species viz., *E. slateri* (0.99), *E. annulata* (0.96) and *V. sinensis* (0.95) belonging to two genera.

21. **Abdominal length / Abdominal width (AL/AW)**

   It is unique in two species viz., *E. slateri* (0.98) and *V. sinensis* (0.99) belonging to two genera.

**UPGMA affinity analysis**

The dendrogram of linear regression coefficient values (r) of postembryonic developmental morphometry was constructed with Unweighted Pair Group Method with
Arithmetic Mean (UPGMA) clustering revealed intergeneric relationships among six species of Reduviinae. The results showed, that among 21 morphometric characters of all the six species, the highest similarity was observed between EAL/HL and EAL/FTL (99.57%) followed by EAL/PTL and AL/AW (99.57%); EAL/AL and PTL/AW (99.56%); HL/HW and RL/HL (99.40%); RL/PTL and RL/AL (99.11%); HW/PTW and PTL/MTL (98.85%) and HL/AL and PTL/FTL (98.40%) (Table 2) (Figure 1).

Discussion

The twenty one morphometric analyses carried out in six species of Reduviinae and observed under exactly similar, closer and unique (r) values reveal inter- and intrageneric and intraspecific characters. The analyses further reveal no subfamily characteristics supported by exactly similar, closer and unique (r) values. This could be attributed to the lesser number of taxa subjected to the analysis.

Intrageneric affinity could be analysed only in *Acanthaspis* since all other three genera are represented by one species each. In this genus intrageneric affinity is revealed by three similar (r) values: RL/HL, PTL/FTL and PTL/AW. Intergeneric affinity is greater between *Edocla* and *Velitra* and *Empyrocoris* and *Velitra, Acanthaspis* and *Velitra* as evidenced by four similar (r) values: HL/HW, HL/AL, HW/PTW, EAL/HL and RL/FTL and RL/HL, PTL/FTL, PTL/MTL and PTL/HTL respectively. The closer (r) value analysis reveal the greater intergeneric affinity between a species of *Acanthaspis* and *Edocla* and *Edocla* and *Empyrocoris* with seven values followed by two species of *Acanthaspis* and *Edocla*, one species of *Acanthaspis* and *Velitra* and *Edocla* and *Velitra* with six values. Thus, the closer values also reveal the differential level of intergeneric affinity between these species. However, varied levels of affinities observed between the three different species of *Acanthaspis* and the other three genera viz., *Edocla, Empyrocoris* and *Velitra* could not be
correlated and subjected into meaningful analysis. This is due to the fact that the genus *Acanthaspis* alone is represented by multispecies and the other three genera are represented by only one species, each. Hence, this analysis should be analysed by incorporating more number of species in each genus and more genera.

Interspecific affinity could be analysed only among the three members of *Acanthaspis*. The two alate species viz., *A. quinquespinosa* and *A. siva* are very closely related than to the micropterous *A. pedestris*. The alate species *A. quinquespinosa* and *A. siva* share a very high affinity with elven exactly similar (r) values: HL/HW, HL/PTL, HL/DE, EAL/FTL, EAL/AL, RL/HL, PTL/FTL, PTL/HTL, PTL/AL and AL/AW. This greater affinity is in much contrast between the two alate species with the micropterous one. For instance the alate *A. quinquespinosa* shares with micropterous *A. pedestris* by seven similar (r) values, and the alate *A. siva* with micropterous *A. pedestris* with four similar (r) values. It is also revealing that *A. pedestris* is closer to *A. quinquespinosa* than to *A. siva*. It is interesting to report here that both *A. pedestris* and *A. quinquespinosa* live in almost microhabitats, i.e., underneath the boulders and in crevices whereas *A. siva* prefers to live under barks. Hence, not only the morphological characters but also the ecological characteristics have the impact on morphometrics. Hence, a multidisciplinary approach of integrating morphometrical, morphological and ecological along with molecular characteristics could lead into a meaningful biosystematic analysis.

The varied levels of interspecific affinity observed between these three species further suggests the genetic variability existing among these species. Such a generic plasticity could be lead not only for species affinity but also leads to speciation.

Intraspecific or species specific (r) values found in *E. slateri* (eleven unique values: (HL/PTL), (HW/WBE), (EAL/FTL), (EAL/AL), (RL/HL), (RL/PTL), (RL/FLTL), (RL/AL),
(PTL/FTL), (PTL/HTL) and (PTL/AL)) followed by *A. pedestris* (ten unique values: (HL/PTL), (HL/AL), (HL/DE), (HW/WBE), (EAL/PTL), (EAL/FTL), (EAL/AL), (RL/PTL), (PTL/MTL) and (PTL/HTL)), *A. siva* (nine unique values: (HL/AL), (HW/WBE), (HW/PTW), (EAL/PTL), (RL/PTL), (RL/FTL), (RL/AL), (PTL/MTL) and (PTL/AL)), *E. annulata* (eight unique values: (HL/HW), (HL/PTL), (HL/DE), (HW/WBE), (HW/PTW), (EAL/PTL), (EAL/FTL) and (RL/FTL)), *V. sinensis* (eight unique values: (HL/PTL), (HL/DE), (HW/WBE), (EAL/FTL), (EAL/AL), (RL/AL), (PTL/PTW) and (PTL/AL)) and *A. quinquiespinosa* (five unique values: (HW/WBE), (EAL/HL), (EAL/PTL), (RL/PTL) and (PTL/AL)) could be considered for species specific markers.

Rukmani (1992) first explored the linear regression coefficient (r) values of postembryonic developmental morphometry of life stages of reduviids as a tool in the multidisciplinary biosystematics. She used 36 morphological characteristics of 27 species belonging to 14 genera and three subfamilies and reported their utility in the multidisciplinary biosystematics. Later Ambrose and Ambrose (2009b) reported 36 morphometric indices belonging to 27 species, 14 genera and 3 subfamilies viz., Harpactorinae, Peiratinae and Reduviinae by direct observation as well as unweighted pair group method using arithmetic mean (UPGMA) incorporating Euclidean distances, Nei and Li’s genetic distance coefficient and Jaccard’s coefficient to understand diagnostic intra- as well as intersubfamilial and generic affinities. George *et al.* (2005) also performed UPGMA cluster analysis of thirty three morphological and biological characteristics of thirty species of reduviids belonging to seventeen genera and three subfamilies and found intra- and intergeneric and interfamilial affinities.

The dendrogram analysis showed the highest affinity between EAL/HL and EAL/FTL (99.57%) followed by EAL/PTL and AL/AW (99.57%); EAL/AL and PTL/AW (99.56%);
HL/HW and RL/HL (99.40%); RL/PTL and RL/AL (99.11%); HW/PTW and PTL/MTL (98.85%) and HL/AL and PTL/FTL (98.40%). The higher similarity values (98.4 to 99.57%) confirmed the intergeneric affinity of all the four genera of subfamily Reduviinae. Singh et al. (2011) analysed the linear regression coefficient values of twenty one morphological characteristics of four *Rhynocoris* species viz., *R. fuscipes*, *R. kumarii*, *R. longifrons* and *R. marginatus* and found interspecific and intraspecific markers.

**Conclusion**

The above said analysis of linear regression coefficient values (r) of postembryonic developmental morphometry suggests its utility as a biosystematics tool at generic and species levels. However, the sample size taken for the present study is highly inadequate. Hence, further studies with more number of species and genera from different subfamilies are imperative to analyze the multidisciplinary facets of biosystematics with postembryonic developmental morphometry as a tool.