Exploring shell shape disparity in viviparid gastropods (Gastropoda: Viviparidae) using geometric morphometrics

Kristie Hansen[1,2], Bert Van Bocxlaer[1], and Ellen Strong[1]

[1] National Museum of Natural History of the Smithsonian Institution; [2] University of Wisconsin - Whitewater

Introduction

The family Viviparidae has a nearly worldwide distribution (with exception of Antarctica and South America), and encompasses 125-150 species of freshwater gastropods, many of which are of conservation concern. Despite the conservation issue, complete revisions of diversity in the family have not been performed and little is known about the morphological variability in viviparids (but see Annandale, 1924)[3].

We used semilandmark morphometrics to explore shape variation of viviparid shells[4]. The shells of most taxa show mainly variation in the height of the apex, the inflatedness of the whorls and the shape of the aperture. However, some taxa display shell ornaments such as spines and ribs. Shell sculpture is uncommon in viviparids, but every continent has some ornamented taxa. Examples are the North American genus *Tulotoma*, and the Asian genus *Taia* (see fig. 1)[3]. -

Here we present a preliminary quantitative analysis of the disparity in shell morphology for the family Viviparidae. We explore whether marked morphological differences exist in the viviparid fauna of different continents (North America, Asia and Europe), and whether the method used allows separation of ornamented and unornamented shells.

Specimens

Most specimens are part of the Invertebrate Zoology collections of the National Museum of Natural History. Additionally, we incorporated specimens from the Danish Bilharziasis Laboratory of Copenhagen University. All specimens were well-preserved adults to avoid the inclusion of allometric growth variation.

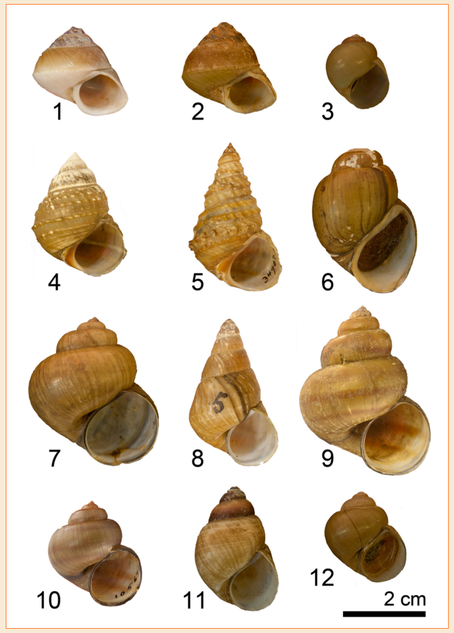


Figure 1. Variation in shell morphology of viviparid gastropods. **1** & **2**. *Trochotaia trochoides*; **3**. *Mekongia sphaericula*; **4** & **5**. *Taia shanensis*; **6**. *Campeloma ponderosa*; **7**. *Lecythoconcha lecythis*; **8**. *Sinotaia boettgeri,* perhaps conspecific with *S. quadrata*; **9** & **10**. *Viviparus contectus*; **11** & **12.** *Mekongia swainsoni*.

Methods

1. Digital photography of gastropods in standard apertural view.
2. Image processing in Adobe Photoshop.
3. Building a .TPS file in tpsDig2[5].
4. Digitization of shell morphology by use of 12 landmarks and four open semilandmark curves (fig. 2).
5. Landmark and curve data were imported in the Integrated Morphometric Package (IMP)[6].
6. Specimens were aligned in IMP Coordgen6h using landmarks one and two as the baseline (fig. 3).
7. Semilandmark alignment in IMP Semiland6.
8. Principal Component Analysis (PCA) in PAST[7].

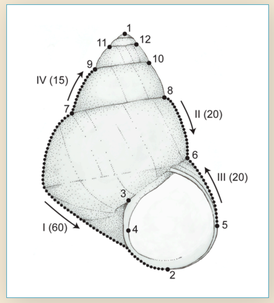


Figure 2. Landmark and semi-landmark positioning used in analysis.

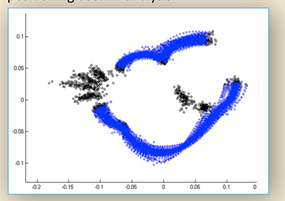
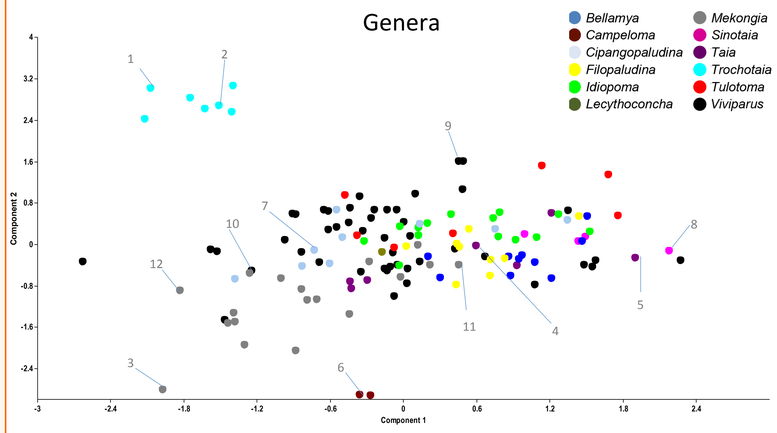


Figure 3. Specimen alignment via Procrustes superimpositioning. Landmarks are in black; semilandmarks in blue.

Morphospace occupation



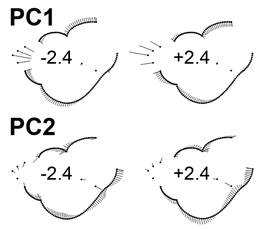
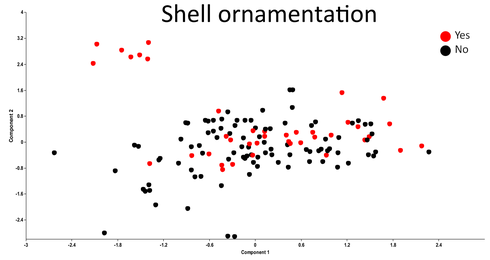


Figure 4. PCA scatter plot of the analyzed specimens. Principal component (PC) 1 explains 42.9% of the variance in the dataset, PC2 23.8%. The plot shows that most included species (31 of 33) and genera (10 of 12) cluster in a central, elongate area, with the major axis of variation almost parallel to PC1. Insets (above) show that PC1 accounts primarily for variation in spiral height and the apical angle. PC 2 accounts mainly for variation in body whorl inflation and in the size and shape of the aperture.



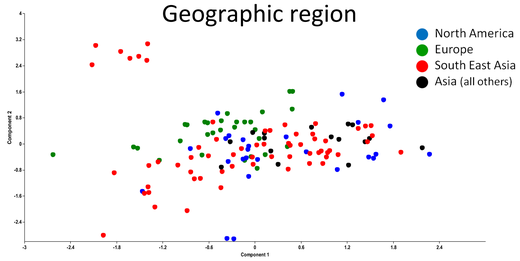


Figure 5. The morphospace occupation plot and the insets in fig. 4 illustrate that no major separation is created between specimens with and those without ornamentation on the first and the second principal components. Further explorations up to PC6 did not find such separation either.

Figure 6. PCA morphospace occupation in relation to geographic origin. The plot shows that viviparids of the different continents overlap in a 'central region' of the morphospace, but also that some areas in this space are occupied only by taxa of one certain continent. Differences in morphospace occupation are most pronounced for North America and Asia.

Conclusions

1. The semilandmark approach we used was most effective for exploring differences in overall shell shape, such as the height of the spire (= top whorls of the shell) and the inflation of the whorls.
2. The method did not capture differences in ornamentation well. Perhaps ratios of traditional caliper measurements can be used in future studies to incorporate this signal better.
3. Some of the viviparids of North America, Asia and Europe occupy the same region in morphospace and, hence, share very similar shell morphologies.
4. A small number of taxa have drastically different morphologies (e.g., *Trochotaia* and *Campeloma*), and these different morphologies appear to be restricted to the viviparid fauna of a single continent. Perhaps these morphologies evolved independently once continents separated.
5. Asian viviparids appear to display a higher degree of disparity in shell morphology although our sampling is uneven. Quantitative measures and additional sampling will need to confirm this.

Future work

James Di Loreto, Smithsonian

1) Enhanced sampling (both of specimens per taxon and taxonomic diversity) will allow us to better investigate the relationships between taxonomic delimitation and morphological disparity better.
2) Explore statistical significance of differences between morphospace clusters.
3) Explore methods that better capture differences in shell ornament.

Acknowledgements

This work was funded by the National Science Foundation and performed during a Natural History Research Experience (NHRE) Internship. We thank the NHRE coordinators Dr. Elizabeth Cottrell, Dr. Gene Hunt, and Virginia Power. We also thank the Flanders Research Foundation for funding to collect data at Copenhagen University.

References

[1] Strong, E. E., O. Gargominy, W. F. Ponder, and P. Bouchet. 2008. Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. Hydrobiologia 595:149–166.

[2] Johnson, P.D., A. E. Bogan, K. M. Brown, N. M. Burkhead, J. R. Codeiro, J. T. Garner, P. D. Hartfield, D. A.W. Lepitzki, G. L. Mackie, E. Pip, T. A. Tarpley, J. S. Tiemann, N. V. Whelan, E. E. Strong. 2013. Conservation Status of Freshwater Gastropods of Canada and the United States. Fisheries 38:246-282.

[3] Annadale, N. 1924. The Evolution of the Shell-Sculpure in Fresh-water Snails of the Family Viviparidae. Proceedings of Royal Society of London 95:60-76

[4] Adams, D. C., F. J. Rohlf, D.E. Slice. 2004. Geometric Morphometrics: Ten Years of Progress Following the 'Revolution'. Italian Journal of Zoology 71:5-16.

[5] Rohlf, F. J. 2006. TPS software series. State University of New York, Stony Brook, NY. URL: http://life.bio.sunysb.edu/morph

[6] Sheets HD (2003) IMP-Integrated Morphometrics Package. Canisius College, Buffalo, NY. URL: http://www3.canisius.edu/~sheets/morphsoft.html

[7] Hammer, Ø. 2009. PAST. University of Oslo, Oslo, Norway. URL: http://folk.uio.no/ohammer/past/