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Morphotypes: Morphological plasticity in *Paphia malabarica* (Chemnitz) (Mollusca: Bivalvia) of a deep estuary, Ashtamudi estuary

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Abstract- Morphometric analysis of shell shape and size seems a priori to be a realistic alternative for inter-group discrimination. Analysis of external shell trait measurements of Venerid clam *Paphia malabarica* of Ashtamudi estuary, a deep estuary unveiled morphological plasticity in the population. The clam population in the barmouth of estuary was found to be morphologically varied from the clam population of upper reaches. The morphotypes displayed variation from 11% to 38% in external shell traits. The phenotypic plasticity can be explained by ecophenotypic variation along a depth gradient with uneven shell thickness and shorter form in deeper part of the estuary near barmouth where wave action and tidal currents were higher and with longer and deeper shells in shallow upper reaches of estuary. Ecological changes in the habitat affect the distribution and abundance of clams in the estuary. Habitat heterogeneity for long period increase genetic variations.

Index Terms- *Paphia malabarica*, phenotypic plasticity, morphotypes, ecophenotypes, shell traits.

I. Introduction

Amongst marine taxa, molluscs have achieved notable evolutionary divergence over the Phanerozoic and acquired a unique variety of morphologies (Sepkoski 1981; Russell-Hunter 1983; Runnegar and Pojeta 1985). External skeleton, the bivalve shell, bound intimately to the growth and development, soft-anatomy and functional morphology of the entire organism. Conchological anatomy form a valid repository of homologous and synapomorphic characters, as well as ontogenetic and functional information. Morphometry deals with variation in the form (size and shape) of organisms. The morphometrics can quantify a trait of evolutionary significance, and deduce something of their ontogeny or evolutionary relationships by detecting changes in the shape of organisms. Morphometrics allow comparisons to describe complex shapes in an austere fashion, and permits numerical comparison between different forms. Most bivalves are ideal subjects for studying the relationship between body form and ecology. Their shape and growth are directly controlled by habitat specific factors due to the sedentary life of these animals.

Shell shape in bivalves is a key morphological characteristic that reflects both phylogenetic history and life habits (Stanley 1970; Crampton and Maxwell 2000). Morphometric techniques have been used to discriminate species on the basis of shell variation (Anderson 1996; Marko and Jackson 2001; Anderson and Roopnarine 2005; Kosnik *et al*. 2006) and to examine patterns of shell development (Roopnarine 2001; Tang and Pantel 2005). Several studies on the bivalve shells have proved that it was very useful in defining specific shape features that might distinguish species or intraspecific variations among different population along a wide geographical range (Dommergues *et al.* 2003; Palmer *et al*. 2004; Rufino *et al*. 2006; Krapivka *et al*. 2007; Costa *et al*. 2008; Marquez *et al*. 2011). Such variability is likely to reflect changing eco-physiological requirements and constraints with body size, alongside genetic and environmental influences on shell morphology (Boulding and Hay 1993; Boulding and van Alstyne, 1993; Hollandar *et al*. 2006; Bondarev 2013). Sandra *et al.* (2011) analysed the ecophenotypic plasticity as a response to different environmental condition in Venerid clam *Tawera gayi*.

Studying growth and establishing allometric relationships yield valuable information for managing fishery resources and understanding environmental changes. The analysis of shape profiles in bivalves can underpin the geographically based studies of morphological variation that occur in individuals of different population. Moreover the allometric relationship allows comparison of life history and morphology between species or between populations of a species from different regions.

II. Materials and Methods

Random samples of bivalve clam, *Paphia malabarica* were collected from the clam beds of the deep estuary, Ashtamudi estuary for a period of two years. The clams collected were transported to the laboratory and kept in aerated habitat water for twenty four hours for defecation. The clams of the estuary were grouped in to two sets, set I constituted the clams collected from the upper reaches of the estuary and that of the barmouth was designated as set II. About hundred clams from each set were sacrificed for biometric measurements. The shell length, shell width, shell thickness and inflation of the shells were noted using digital vernier callipers. T-test was carried out to analyse the mean difference between the shell traits observed in *P. malabarica* morphotypes. Statistical analysis was carried out using SPSS (version 20.0).

III. Result

Intra-species variation in the external shell morphometry: Observations on the external shell morphometry of *P.malabarica* revealed variations in external shell traits (Figure 1a and 1b). The clams collected from the station near the barmouth of the estuary (Type II) was found to be always smaller than the clams collected from the upper reaches of the estuary (Type I). They always exhibited improper shell formation and shells with uneven thickness and with slightly bean shaped ventral outline (Figure 1 b).

Figure 1 Shells of *P. malabarica* morphotypes in the estuary (a) morphotype I (b) morphotype II. Scale bar = 10mm

The analysis of the external shell trait data revealed significant differences between the mean values of shell length ($t=10.947$, $p< 0.001$), shell height ($t= 10.285$, $p< 0.001$) and thickness of the shell ($t=21.821$, $P< 0.001$). The difference in the mean values of inflation was not significant. Variations from 11% to 38% were obtained between each external shell trait recorded (Table 1). The statistical analysis of shell traits confirmed the phenotypic plasticity among the *Paphia* population.

IV. Discussion

As molluscan size varies both intra- and inter-specifically, the relative investment in the shell and non shell parts can change ontogenetically and within/between species. Such variability is likely to reflect changing eco-physiological requirements and constraints with body size, alongside genetic and environmental influences on shell morphology. Shell length and shell height are commonly used parameters to study growth kinetics of bivalves (Zainudin and Tsuchiya 2007). It would be unlikely that significantly different shell shapes in some species is genetically determined and therefore environmental factors would be likely to cause different morphologies resulting from phenotypic plasticity. Morphological variation is related to differences in depth, but not to horizontal distance (Olabarria and Thurston 2004). The dimensional relationships are modified by the environmental conditions such as salinity, current velocity, wave action, depth under which the organism lives (Seed 1968; Hickman 1979; Jones 1979) and overcrowding results in the assumption of a variety of crooked forms (Rao and Nayar 1956).
Differences found among the shell traits of *P.malabarica* population could also be explained as the outcome of the phenotypic plasticity of the population subjected to different environmental conditions. This might be the reason for the shape derangements noted in the *Paphia* population near barmouth where the population density was very high when compared to the density of the *Paphia* population in other sites. Several researchers have opined that density affect the growth rates in bivalves (Sutherland 1970; Creese and Underwood,1982; Claereboudt 1999). In the present study also the population density of the site near the barmouth was found to be higher than that of the remaining sites. It is known that in several bivalve species the height and width of shell increase during growth in order to counter involuntary dislodgement by turbulence and currents (Eagar 1978; Hinch and Bailey 1988).

V. Conclusion

The external shell trait analysis revealed the phenotypic plasticity in *P.malabarica*. The *P.malabarica* population near the barmouth of the estuary showed marked external shell trait differences. They are found to be smaller than the clams collected from other sites. Thus two morphotypes (Type I and Type II) were located in the estuary. Besides over-crowding, the environmental factors such as salinity, current velocity, wave action and depth of the site might be causing the variations in the shell traits. This might be due to the environmental characters of the estuary that modify the dimensional characters in the organisms such as sediment nutrient characters and depth.

References

[1] Anderson, L.C. (1996) Neogene paleontology in the northern Dominican Republic 16. The family Corbulidae (Mollusca: Bivalvia). Bulletins of American Paleontology, 110, 5-34.

[2] Anderson, L.C. & Roopnarine, P.D. (2005) Role of constraint and selection in the morphologic evolution of Caryocorbula (Mollusca: Corbulidae) from the Carribbean Neogene. Paleontologia Electronica, 8:2, 1-18.

[3] Bondarev. (2013) Ecomorphological Analyses of Marine Mollusks' Shell Thickness of Rapana venosa (VALENCIENNES, 1846) (Gastropoda: Muricidae), International Journal of Marine Science,3:45, 368-388

[4] Boulding, E. G. & Hay, T. K. (1993) Quantitative genetics of shell form of an intertidal snail: constraints on short-term response to selection. Evolution, 47,576-592.

[5] Boulding, E. G. & Van Alstyne, K. L. (1993) Mechanisms of differential survival and growth of two species of Littorina on wave-exposed and on protected shores. Journal of Experimental Marine Biology and Ecology, 169, 139-166.

[6] Claereboudt, M.(1999) Fertilization success in spatially distributed population of benthic free- spawners: a simulation model. Ecological Modelling, 121, 221–233.

[7] Costa, C., Aguzzi, J., Menesatti, F., Antonucci, F., Rimatori, V. & Mattoccia, M. (2008). Shape analysis of different population of clams in relation to their geographical structure. Journal of Zoology, 276,71–80.

[8] Crampton, J.S. & Maxwell, P.A. (2000) Size: all its shaped up to be? Evolution of shape through the lifespan of Cenozoic bivalve Spissatella (Crassitellidae). In: The evolutionary biology of the bivalvia, Harper, E.M., Taylor, J.D., and Crame, J.A. (Eds.). London: Geological Society, 177, 399–423.

[9] Creese, R.G. & Underwood, A.J. (1982) Analysis of inter- and intra-specific competition amongst intertidal limpets with different methods of feeding. Oecologia, 53, 337–346.

[10] Dommergues, E., Dommergues, J.L., Magniez, F., Neige, P. & Verrecchia, E.P. (2003) Geometric measurements analysis versus Fourier series analysis for shape characterization using gastropod shell (Trivia) as an example. Mathematical Geology, 35, 887–894.

[11] Eagar, R.M.C. (1978) Shape and function of the shell: a comparison of some living and fossil bivalve mussels. Biological Review, 53,169–210.

[12] Hickman, R.W. (1979) Allometry and growth of the green-lipped mussel Perna canaliculus in New Zealand. Marine Biology, 51,311–327.

[13] Hinch, S.G. & Bailey, R.C. (1988) Within- and among-lake variation in shell morphology of the freshwater clam Elliptio complanata (Bivalvia: Unionidae) from south central Ontario Lakes. Hydrobiologia, 157, 27–32.

[14] Hollander, J., Collyer, M. L., Adams, D. C. & Johannesson, K. (2006) Phenotypic plasticity in two marine snails: constraints superseding life history. The Authors Journal Compilation, 19,1861-1872.

[15] Jones, C. C. (1979) Anatomy of Chione cancellata and some other chionines (Bivalvia, Veneridae). Malacologia, 19:1, 157-199.

[16] Kosnik, M., Jablonski, D., Lockwood, R. & Novack-Gottshall, P. (2006) Quantifying molluscan body size in evolutionary and ecological analysis: maximizing the return on data-collection efforts. Palaios, 21, 588–597.

[17] Krapivka, S., Toro, J. E., Alcapán, A. C., Astorga, M., Presa, P., Pérez, M. & Guiñez, R. (2007) Shell-shape variation along the latitudinal range of the Chilean blue mussel Mytilus chilensis (Hupe, 1854). Aquaculture and Research, 38, 1770–1777.

[18] Marko, P. & Jackson, J.B.C. (2001) Patterns of morphological diversity among and within arcid bivalve species pairs separated by the Isthmus of Panama. Journal of Paleontology, 75, 590-606.

[19] Márquez, F. & Vander Molen, S. (2011) Intraspecific shell-shape variation in the razor clam, Ensis macha along the Patagonian coast. Journal of Molluscan Studies, 77, 123–128.

[20] Olabarria, C.& Thurston, M.H. (2004) Patterns of morphological variation of the deep-sea gastropod Troschelia berniciensis (King, 1846) (Buccinidae) from the North Eastern Atlantic Ocean. Journal of Molluscan Studies, 70, 59-66.

[21] Palmer, M., Pons, G.X. & Linde, M. (2004) Discriminating between geographical groups of a Mediterranean commercial clam [Chamelea gallina (L.): Veneridae] by shape analysis. Fishery Research, 67, 93–98.

[22] Rao, K.V. & Nayar, K.N. (1956) Rate of Growth in Spat and Yearlings of the Indian Backwater Oyster Ostrea madrasensis (Preston). Indian Journal of Fisheries,3,31-260.

[23] Roopnarine, P.D. (2001) Testing the hypothesis of heterochrony in morphometric data; lessons from a bivalve mollusc. In: Beyond Heterochrony: The Evolution of Development. Zelditch, M.L. (Ed.). John Wiley and Sons, 271-303.

[24] Rufino, M.M., Gaspar, M.B., Pereira, A.M. & Vasconcelos, P. (2006) Use of shape to distinguish Chamelea gallina and Chamelea striatula (Bivalvia: Veneridae): linear and geometric morphometric methods. Journal of Morphology, 267, 1433–1440.

[25] Runnegar, B.& Pojeta, J. (1985) Origin and diversification of the Mollusca. In: The mollusca: evolution, Trueman, E. R.and Clarke, M. R. (Eds.). London: Academic Press,1-57.

[26] Russell-Hunter, W. D. (1983) Overview: planetary distribution of and ecological constraints upon the Mollusca. In: The mollusca: ecology, Trueman, E. R., and Clarke, M. R. (Eds.). London: Academic Press,1-27. I

[27] Sandra, G., Marquez, F., Cardenas, J. &Zubimendi, M.A. (2011) Shell variability in Tawera gayi (Veneridae) from southern South America: a morphometric approach based on contour analysis. Journal of Marine Biological Association of the United Kingdom., 91:4,815-822.

[28] Seed, R. (1968) Factors Influencing Shell Shape in the Mussel Mytilus Edulis. Journal of the Marine Biological Association of the United Kingdom, 48, 561-584.

[29] Sepkoski, J. J. (1981) A factor analytic description of the Phanerozoic marine fossil record. Paleobiology, 7, 36-53.

[30] Stanley, S. M. (1970) Relation of shell form to life habits of the Bivalvia. Memoirs Geological Society of America, 125,1-296.

[31] Sutherland, J.P. (1970) Dynamics of high and low population of the limpet "Acmea Scabra" (Gould). Ecological Monogram, 40,169-188.

[32] Tang, C. & Pantel, J.H. (2005) Combining morphometric and paleoecological analysis: examining small-scale dynamics in species-level and community-level evolution. Palaeontologia Electronica, 8, 1-33.

[33] Zainudin, M. & Tsuchiya, M. (2007) Growth of bivalves used on allometric relationship and a time series of length-frequency data. Journal of Sustainablity Science and Management, 2, 1-1.

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Table 1 t-test showing the mean difference between the shell traits observed in *P.malabarica* morphotypes.

Shell traits	Morphotype	Mean	SD	Mean Difference	t - value	Df	p - value
Length	Type I	31.8	2.08	3.457	10.947*	198	< 0.001
	Type II	28.3	2.37				
Height	Type I	23.3	1.82	2.605	10.285*	198	< 0.001
	Type II	20.7	1.77				
Thickness	Type I	1.5	0.22	0.921	21.821*	198	< 0.001
	Type II	2.4	0.36				
Inflation	Type I	14.8	2.09	0.462	1.856	198	Not significant
	Type II	14.3	1.34				