Comparison of bivalves of Family Pinnidae from Southern Vietnam: A morphometric approach

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ABSTRACT

Comparison of different morphological characteristics of bivalves is very useful for distinguishing species. Therefore, this study used a morphometric approach to document patterns of phenotypic change through the specimens of family Pinnidae inhabiting the bottom sediments at the coasts of An Thoi Archipelago (south-eastern Gulf of Thailand), in that way excluding intraspecific variations among different populations along a wide geographical range. It was revealed that individuals determined as *Pinna trigonium* separated from specimens of *Pinna nigra* and *Atrina vexillum* at high level, but *P. nigra* and *A. vexillum* were the single species *A. vexillum*, as it is assumed now. Also, it was found that both groups of *P. trigonium* individuals and *A. vexillum* specimens divided into tree subgroups unified the specimens with the similar morphometric parameters: small, medium and large within the populations, though there were no evident divisions into subgroups in the size distributions of the populations. In addition to the interspecific morphological variations, the species also showed significant intraspecific morphological variations even in the same population. Most probable reason for the appearance of the intraspecific morphological variations and division of all specimens into size-specific subgroups in the population is the fact that the growth of Pinnidae bivalves is not isometric.

Key words: *Pinna trigonium*, *Atrina vexillum*, Gulf of Thailand, populations, growth, bivalves, mollusks, shells

INTRODUCTION

The family Pinnidae Leach, 1819 consists of the single genus *Pinna* Linne, 1758, which comprises three subgenera *Atrina* Gray, 1842; *Pinna* Linnaeus, 1758 and *Streptopinna* von Martens, 1880 (OBIS Indo-Pacific Molluscan Database 2006). At the coasts of South Vietnam two Pinnidae species are found. They are *Atrina vexillum* (Born, 1778) (= *Pinna nigra* Dillwyn, 1817; *Pinna nigra* Chemnitz, 1785; *Pinna vexillum* Born, 1778; *Atrina* Okan and Hosgor, 2009) and *Pinna trigonium* Dunker, 1852 (= *Pinna fumata* Reeve, 1858; *Pinna philippinensis* Reeve, 1858). Shells of genus *Pinna* bivalves reach a very large size, up to 120 cm in length for *Pinna nobilis* (Zavodnik *et al*., 1991, cited by Garcia-March *et al*., 2002). Their valves are thick and solid. Shells are inflated and variable in shape from triangular to hatchet-shaped or subglobular. All species have the same mode of life living vertically embedded in the bottom sediments, usually mud or muddy sand (Yonge, 1953; Purchon and Purchon, 1981). *Pinna* bivalves commonly stand point-first in the sea bottom in which they live, anchored by net of byssus threads. They are shallow infaunal suspension feeders (Yonge, 1953).

Little is known about *P. trigonium*. Usually synonymy is referred (Hedley, 1924; Rosewater, 1961; Huber, 2010). Studies about biology and ecology of this species are few (Malakhov *et al*., 1985; Dorofeeva *et al*., 1987). As a rule, bivalves of the genus *Pinna* live vertically embedded in the ground, however, *P. trigonium* was found not only in the ground, but also among the biofouling of the sunken vessel (Silina, 2010).

A. vexillum is a cosmopolitan Indo-Pacific species. It is found from East Africa, including Madagascar, the Red Sea and the Persian Gulf, to eastern Polynesia; north to Japan and Hawaii, and south to Queensland and New Caledonia (Hedley, 1924; Habe, 1968; Morris

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and Purchon, 1981; Abbott and Dance, 1982; Bernard *et al*., 1993; Huber, 2010). Common name of *A. vexillum* is Indo-Pacific pen shell. A shell of *A. vexillum* reaches large size and usually attains 30 cm (max 48 cm) (Poutiers, 1998). This bivalve mollusk is characterized by elongated, wedge-shaped shells (Poutiers, 1998). Its dorsal margin is usually nearly straight, posterior margin is broadly oval to somewhat truncate in outline. Ventral margin is broadly convex posteriorly and concave near the umbones, often strongly lobate in medium-sized and large specimens. Outside of valves it has 10-17 main radial ribs, often bearing scale-like spines, and weaker interstitial riblets. Internal nacreous layer is moderately strong, undivided and occupied the anterior half or 2/3 of valves. Hind margin of posterior adductor scar is slightly protruding beyond the nacreous area. Protrusion of adductor scar is more developed in mature specimens. Colour of the outside surface of the valves varies from dark reddish-brown to nearly black, usually dull. Shell is semitranslucent and reddish purple when it is viewed with transmitted light. Interior colour varies from dark brown to black, iridescent on nacreous area.

Although details of the classification of Pinnidae have recorded (e.g., Hedley, 1924; Yonge, 1953; Bernard *et al*., 1993; Purchon and Purchon, 1981; Abbott and Dance, 1982; Okan and Hosgor, 2009, etc.), there are many discussions concerning *Atrina vexillum*. Originally, it was named *P. vexillum* Born, 1778 and similar specimens as *P. nigra* Dillwyn (1817). Then some researches considered that it is the type species of *Atrina*, and it was recombined as *A. vexillum* (Born, 1778) and *A. nigra* (Okan and Hosgor, 2009). Probably *Pinna* is more modified and *Atrina* the more primitive form (Hedley, 1924). The *Pinna* has an elongated shell with a longitudinal crack filled with a cartilage in the middle of each valve, and *Atrina* has shorter shells without any such crack (Gray, 1842, cited by Hedley, 1924). Additionally Hedley (1924) indicated that the essential *Pinna* characters are the shoulder of the shell towards the apex, which is externally angled and fissured, while that of *Atrina* is rounded and entire. Inside the valve, *Pinna* has a long narrow sinus which extends through the middle of the nacreous tract for the most portion of its length, while the nacreous tract of *Atrina* is not thus cleft. Also, *Atrina* is distinguished from the *Pinna* by the lack of any grooves in the nacreous lining of the shell, and by the central positioning of the adductor scar. However, biogeographical distribution and morphological variations in the *A. vexillum* bivalves are very broad. Therefore, up to now, sometimes, researchers divide the mollusks that look like *A. vexillum* on two groups of *P. nigra* and *A. vexillum*. Now, for *Atrina* Gray, 1842 the type species is *Pinna nigra* Dillwyn, 1817. It is not unique case when Pinnidae species originally described as a *Pinna* was redescribed as *Atrina*, for example, *Atrina affinis* (Sowerby, 1821) (= *Pinna affinis* Sowerby, 1821) (Okan and Hosgor, 2009).

Morphological variations in bivalves are increasingly the focus of diverse ecological studies. Shape in bivalves is a key morphological characteristic that reflects both phylogenetic history and life habits. Comparison of different morphological characteristics of bivalves is very useful for distinguishing species. Therefore, this study used a morphometric approach to document patterns of phenotypic change through the specimens of Pinnidae inhabiting local settlement in the bottom sediments at the coasts of An Thoi Archipelago (south-eastern Gulf of Thailand, South Vietnam), in that way excluding intraspecific variations among different populations along a wide geographical range. Additionally, to answer the following questions: are there intraspecific morphological variations within populations, and is weight and linear growth of *P. trigonium* and *A. vexillum* isometric, the trends of morphometrical changes of specimens of these species during their life were studied.

MATERIALS AND METHODS

Bivalve specimens of genus *Pinna* were sampled at the coasts of An Thoi Archipelago (south-west Vietnam, the south-east Gulf of Thailand (= Siam Bay)), mainly near Hon Vong Island. A depth was 6-7 m. The generic definition was made by Dr. Nam

(Institute of Marine Researches, Nha Trang City, Vietnam). The Pinnidae specimens distinguished as *P. trigonium* were 12 ind., *A. vexillum* were 33 ind. and *P. nigra* were 20 ind.

To study inter- and intraspecific morphological variations of Pinnidae species nine morphometric characteristics were measured on each individual. They were length (L), height (H) and width (D) of mollusk shell, total wet weight of the mollusk (W_{total}), wet weight of posterior adductor muscle (W_{muscle}), wet weight of the rest of the soft tissues ($W_{soft\ tissues}$), weight of the left and right valves, and total shell weight. Besides, such ratios between parameters of mollusk as W_{muscle}/W_{total}, $W_{soft\ tissues}/W_{total}$, $W_{muscle}/W_{soft\ tissues}$, H/L and D/L were calculated for each specimen and used for Cluster analysis.

To study intraspecific morphological variations in each Pinnidae species the trends of morphometrical changes of specimens of these species during their growth were revealed by regression analysis.

RESULTS AND DISCUSSION

1. Interspecific morphological variations

The specimens of *P. trigonium* are distinctly separated off *A. vexillum* individuals, and it was not problem to determine *P. trigonium* in the waters of Vientam. Really, cluster analysis of the bivalve specimens of the genus *Pinna* sampled at the same place revealed that mollusks determined as *P. trigonium* separated from specimens of *P. nigra* and *A. vexillum* at a very high level (Fig. 1). Euclidean distance between these groups was 60-325. However, the specimens of *P. nigra* and *A. vexillum* did not spite up to groups. It allows concluding that *P. nigra* and *A. vexillum* bivalves inhabiting the bottom sediments near the coasts of South Vietnam are the single species, *A. vexillum*, as it is assumed now.

However, each group: (1) of *P. trigonium* individuals and (2) of *A. vexillum* specimens divided into tree subgroups at high level (Fig. 1). Thus, *P. trigonium* group consisted of subgroups: (1) 2, 3, 5, and 6; (2) 4, 7, 8, 10 and 11; and (3) 9 and 12 specimens (see Fig. 1). And *A. vexillum* group consists of subgroups: (1) from *A. vexillum* 1 to *P. nigra* 8; (2) from *A. vexillum* 4 to *P. nigra* 17; and (3) from *A. vexillum* 7 to *A. vexillum* 10 (see Fig. 1). It was found that such subgroups of *A. vexillum* unified the specimens with the similar morphometric parameters: small, medium and large within the population, though there were no evident divisions into subgroups in the size distribution of the population (Fig. 2). The same was revealed for *P. trigonium* specimens. Thus, besides the interspecific morphological variations the species also have significant intraspecific morphological variations even in the same population.

2. Intraspecific morphological variations

At the study population, the total wet weight of *P. trigonium* varied from 262 to 1590 g (559 ± 118 g on the average), wet weight of the soft tissue was 32-132 g (74 ± 10 g) and wet weight of the posterior adductor muscle was 7-25 g (15 ± 2 g) in 1986 (Silina, 2010). The shell length varied from 249 to 377 mm (303 ± 15 mm, Fig. 2), the height of the shell was 121-172 mm (139 ± 5 mm), and the shell width was 33-52 mm (43 ± 2 mm). Tissue wet weight was 8.3-20.0% of total wet weight, that is lower than for *Pinna nobilis* (Garcia-March *et al*., 2007) and the wet weight of the posterior adductor muscle was 1.6-4.6% of total wet weight and 16.8-26.8% of tissue wet weight, that is higher than for *Pinna nobilis* (Garcia-March *et al*., 2007).

The ratio of the weight of soft tissues to shell weight of *P. trigonium* was permanent ($P < 0.001$) during mollusk life (Fig. 3). The ratios of the soft tissues and posterior adductor muscle weights to total weight decreased (df = 1, F = 1.30 and 1.39, P = 0.28 and 0.25, N = 12, regression analysis) under mollusk growth (Fig. 3). It is means that the proportion of soft tissues in total weight declines during mollusk life. The growth of total and posterior adductor muscle weights was not isometric, as the calculated exponents in the equations, which describe changes of these mollusk parameters with increase shell length, were > 3 and < 3, relatively (Table 1). In contrast, the growth of soft tissues and shell was practically isometric, the exponents were about of 3 (Table 1). Besides, the shell height of the *P. trigonium*

Table 1. F … and *Atrina vexillu* …

	R
V …	).820
W …	).794
W_{sc} …	).852
V …	).846
	).791
	).628

W_{total} is w … f the rest of soft tis … cm. R is coefficier …

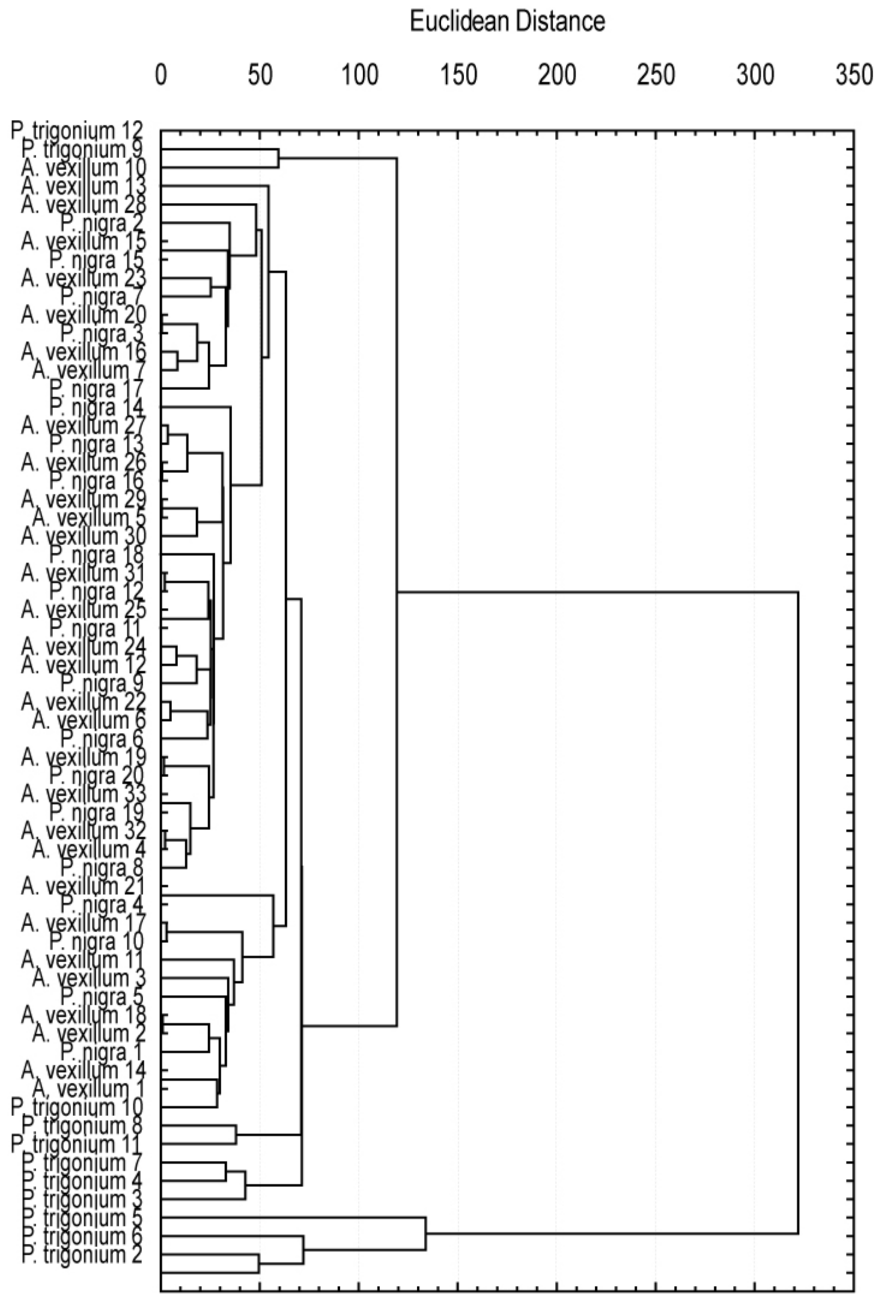

Fig. 1. Tree diagram of clustering analysis of the bivalve specimens of the genus *Pinna* sampled at the south-east Gulf of Thailand.

also did not change isometrically with shell length increase during mollusk life, as the exponent was many less than 1 (Table 1). It means that shell of the *P. trigonium* becomes more prolonged with increase its age. However, the shell convex is proportional to the shell length during all mollusk life, as exponent was practically equal to 1 (Table 1).

At the study population, the total wet weight of *A. vexillum* varied from 82 to 500 g (236 ± 18 g on the average), the wet weight of soft tissues was 15-105 g (41 ± 3 g) and wet weight of the posterior adductor muscle was 5-30 g (13 ± 1 g) (Silina, 2011). The shell

Table 1. Relationships between morhpometric parameters of the pen shells, both *Pinna trigonium* and *Atrina vexillum*, sampled at the coasts of An Thoi Archipelago, south-eastern Gulf of Thailand

Pinna trigonium, N = 12		*Atrina vexillum*, N = 53	
Relation	R	Relation	R
$W_{total} = 0.00275L^{3.563}$	0.907	$W_{total} = 0.160L^{2.560}$	0.820
$W_{muscle} = 0.0017L^{2.6461}$	0.8731	$W_{muscle} = 0.010L^{2.498}$	0.794
$W_{soft\ tissues} = 0.00327L^{2.913}$	0.887	$W_{soft\ tissues} = 0.020L^{2.674}$	0.852
$W_{shell} = 0.00989L^{3.086}$	0.853	$W_{shell} = 0.130L^{2.466}$	0.846
$H = 3.6804L^{0.393}$	0.559	$H = 1.582L^{0.704}$	0.791
$D = 0.1496L^{0.982}$	0.871	$D = 0.698L^{0.614}$	0.628

W_{total} is wet total weight, W_{muscle} is wet weight of posterior adductor muscle, $W_{soft\ tissues}$ is wet weight of the rest of soft tissues (g), and W_{shell} is shell weight, g. L is shell length, H is shell height and D is shell width, cm. R is coefficient of correlation, and N is number of specimens.

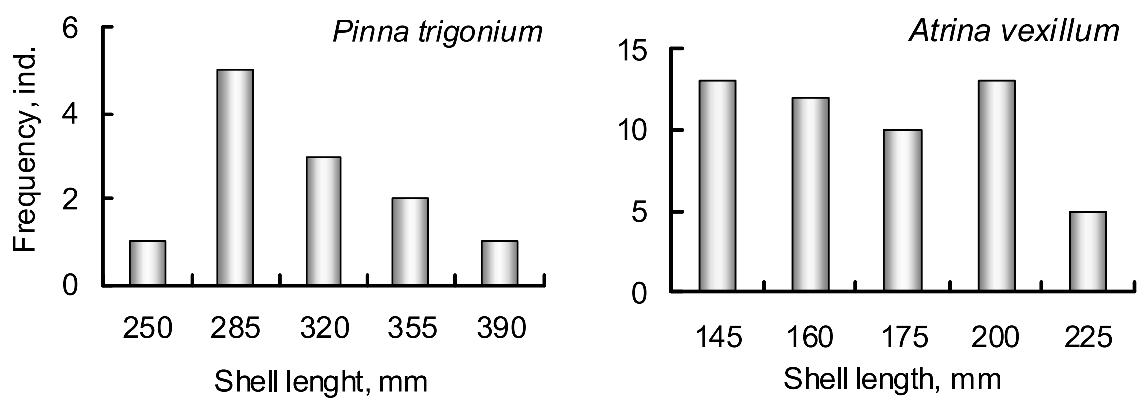

Fig. 2. Size-frequency distributions of the populations of *Pinna trigonium* and *Atrina vexillum* at the south-east Gulf of Thailand.

length varied from 131 to 224 mm (172 ± 5 mm) (Fig. 2), the height of the shell was 85-140 mm (116 ± 3 mm), and shell width was 27-49 mm (40 ± 1 mm). The weight of soft tissues was 10.7-25.0% of total weight, that is lower index than that for *Pinna nobilis* (Garcia-March *et al*., 2007), but higher than for *P. trigonium* (Silina, 2010) and the weight of posterior adductor muscle was 3.1-7.7% of total weight and 19.0-37.0% of the weight of soft tissues, it is higher index than that for *P. nobilis* and *P. trigonium* (Garcia-March *et al*., 2007; Silina, 2010).

In contrast to *P. trigonium*, the ratio of the weight of soft tissues to shell weight was not permanent for *A. vexillum*, it increased (df = 1, F = 2.19, P = 0.14, N = 53, regression analysis) during mollusk growth (Fig. 4). The ratios of both soft tissues and posterior adductor muscle weights to total weight were statistically significantly permanent during mollusk life (Fig. 4). The growth of total weight, and the weights of *A. vexillum* mollusk's parts (soft tissues, posterior adductor muscle and shell) was not isometric with shell length increase, as the exponents were many less than 3 (Table). Classical allometric model had no supported for other Pinnidae species, too (Silina, 2010, 2011; Rabaoui *et al*., 2007). Moreover, the linear parameters of the *A. vexillum* also did not change isometrically during mollusk life, as the exponents were many less than 1 (Table 1). It means that shell of the *A. vexillum* becomes more prolonged and less convex (gibbous) with increase its length.

Thus, though various species of family Pinnidae

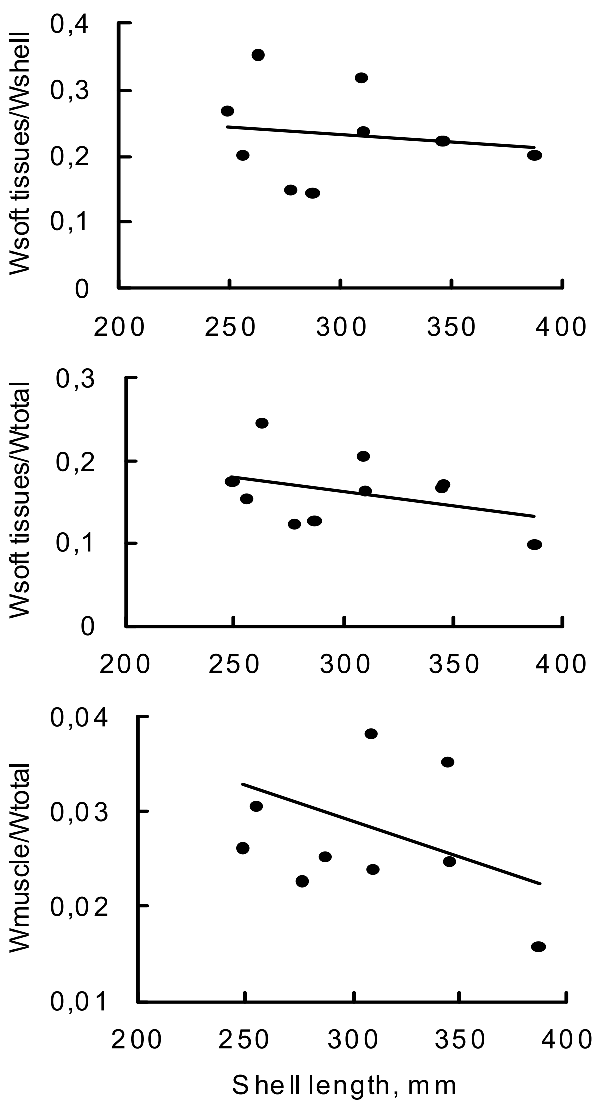

Fig. 3. Trends of ratios between wet weight of soft tissues to shell weight, wet weight of soft tissues to total wet weight, and wet weight of adductor muscle to total wet weight of *Pinna trigonium* with its shell length increase. N = 12.

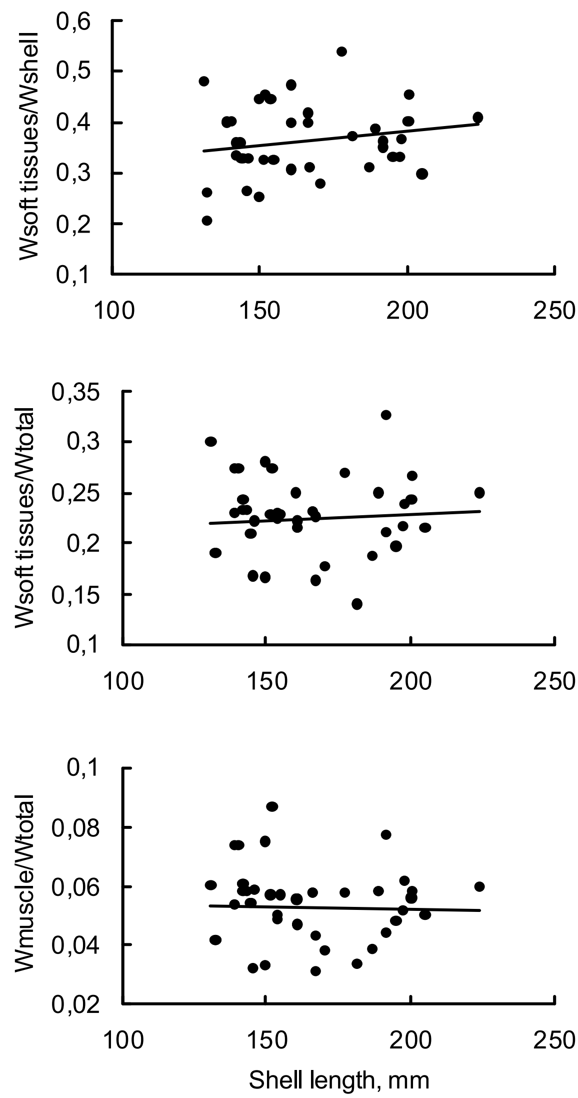

Fig. 4. Trends of ratios between wet weight of soft tissues to shell weight, wet weight of soft tissues to total wet weight, and wet weight of adductor muscle to total wet weight of *Atrina vexillum* with its shell. N = 53.

grow under different rules of changes of ratios between the organs during mollusk life, and the proportions of the organs vary with increase mollusk shell length, the growth of the studied pen shell species is not isometric. It is the most probable reason for the appearance of the intraspecific morphological variations and division of all specimens into size-specific subgroups in the population. Possibly, the revealed disintegration of population on subgroups shows the presence of different stages of mollusk development.

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