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Original Article

Variation in the shell form of the swan mussel, *Anodonta cygnea* (Linea, 1876) in response to water current

Fateh Moëzzi[1], Hadi Poorbagher*[1], Amir Ghadermazi[2], Fatemeh Parvizi[3], Saleh Benam[2]

[1]Department of Fisheries, Faculty of Natural Resources, University of Tehran, Karaj, Iran.
[2]Department of Fisheries, Faculty of Fisheries and Environmental Sciences, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.
[3]Department of Fisheries, University of Hormozgan, Bandar abbas, Iran.

Abstract: A biometric study was conducted on the populations of swan mussel, *Anodonta cygnea*, belonged to water bodies with different water current velocity (high current: HC; low current: LC). The shell length, width, height, weight and age of the collected mussels were measured. The two groups had different age-classes distributions. The HC mussels had larger mean and maximal values of the biometric parameters. A high and medium correlation coefficient (width-length, height-length, and weight-length) were found in the HC and LC mussels, respectively. The weight-length relationships showed negative allometric pattern (HC: weight=$3.6121x^{0.8561}$; LC: weight= $3.1362x^{0.8508}$). The 1-2 years old mussels had the highest rates of increase in length, width and height in both groups. Based on the results, water current velocity influences biometric features and population structure of *A. cygnea*.

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Introduction

Swan mussel, *Anodonta cygnea*, is a member of the family Unionidae, having a wide distribution in the world (Pourang et al., 2004). This species inhabits shallow and eutrophic waters and also slow-flowing streams. Swan mussel lives in water bodies with depths ranging from 0.2 m to several meters (Rosinska et al., 2008). This species is sensitive to inappropriate environmental conditions (Moezzi et al., 2013), therefore, it is a bioindicator of unpolluted waters with well-oxygenated bed (Zajac, 2004). Swan mussel is an endemic species of northern Iran, *i.e.* the Caspian Sea basin (Parvaneh, 1994; Pourang, 1996).

Morphometric studies of mollusks provide useful information about their growth rates (Alunno-Bruscia et al., 2001) to assess their habitats (Devescovi, 2009). The size of the valves in bivalve molluscs is an index representing the trophic state of their environment (Azzopardi et al., 2013). In addition, the shell size, *per se*, and its correlation with other biometric para-meters can be appropriate indices for monitoring their population dynamics in natural and deteriorated environments (Deidun et al., 2014; Bayne and Newell, 1983; Palmer, 1990). Growth in bivalves is mainly estimated using the shell dimensions or volume (Hibbert, 1977; Rodhouse et al., 1984; Bailey and Green, 1988; Ross and Lima, 1994; Rueda and Urban, 1998; Ravera and Sproocati, 1997; Deval, 2001; Mutvei and Westermark, 2001). Using allometric equations in bivalves, shell dimension may be used to calculate biomass (Hibbert, 1977; Ross and Lima, 1994; Thorarinsdottir and Jahanesson, 1996; Ravera and Sprocati, 1997; Deval, 2001). Reproductive conditions (Rueda and Urban, 1998), population density (Seed, 1968), physical and biological characteristics of habitat (Thorarinsdottir and Jahannesson, 1996) are among the factors that affect the growth of bivalves and allometric relationships between the shell size and weight.

As yet, biometric and morphometric characteristics of the Iranian populations of *A. cygnea* in different habitats have not been investigated. The present study

*Corresponding author: Hadi Poorbagher
E-mail address: poorbagher@ut.ac.ir
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thus aimed to investigate biometric characteristics (shell length, width, height, weight and their relationships plus age structure) of the populations of swan mussel collected from different flowing water bodies.

Materials and Methods

Study area: A total of 277 individuals of *A. cygnea* were collected from two fast- and slow-flowing water streams (1.5-2 m s^{-1} and < 0.1 m s^{-1}, being named as HC and LC hereafter, respectively) from the Semeskandeh, Mazandaran Province, northern Iran in the autumn 2013 (Fig. 1). Water characteristics were nearly similar in all sampling locations (Table 1), except current velocity, where it was 1.5-2 m s^{-1} at HC environment, which was a water channel, but the LC sampling place was a lentic water habitat with no considerable water current. During the sampling, specimens were collected from the area of 1 m^2 using a quadrat with three replicates. 124 and 153 specimens were collected from HC and LC locations, respectively. Collected mussels were placed in fiberglass tanks and transferred to the laboratory for biometric measurements (Tenjing Sing et al., 2013).

Measurements: Length (L), width (W), and height (H) of shells were measured to the nearest 1 mm using slide calipers. The total weight was measured to the nearest of 0.01 g. The age was determined by counting the annual rings on the shell surface.

Statistical analysis: Measurements results were determined statistically as arithmetical mean, maximum, minimum, variation range, variance, and standard deviation. Width-length and height-length relationships was established using linear equation, Y=aX+b, where a: slope (relative growth rates of the variables), b: intercept (initial growth coefficient), and Y: is width (mm) or height (mm) (Tenjing Sing et al., 2013). The bivalve weight-length relationships was derived by applying the equation $Y=aX^b$ (Tenjing Sing et al., 2013). Relationships between length, width, height, and weight with age were also examined for the two groups of the specimens. All statistical analyses were performed using Microsoft Office Excel (ver. 2013).

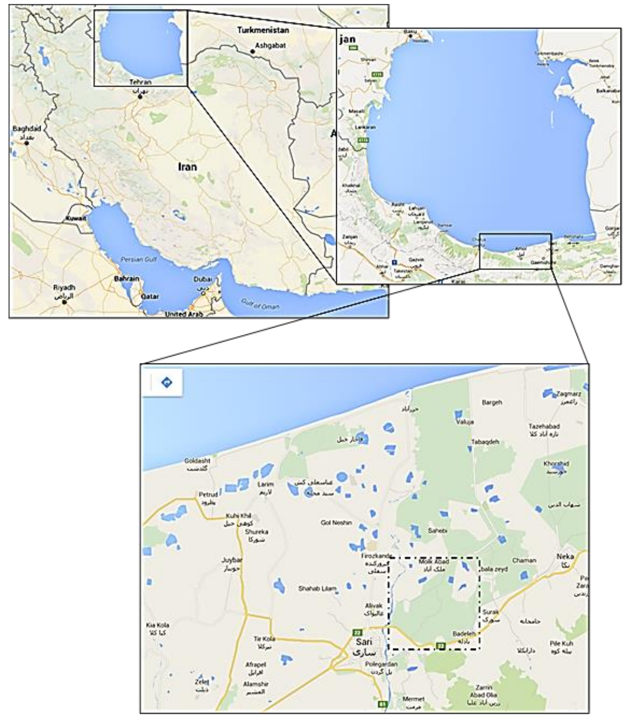

Figure 1. Sampling region at Semes-kandeh, Mazandaran Province, North of the Iran.

Results

Density of bivalves per unit of area in studied sites were 31.2 and 24.8 (individual/m^2) in HC and LC places, respectively. Age of mussels in HC or flow-through water channel ranged from 1 to 6 years, but in LC from 2 to 5 years. Mussels with age 4 years old was dominate specimens in both populations (Fig. 2). Table 2 presents the mean length, width, height and weight of swan mussels based on age groups in the studied sampling places. The mean values of the studied parameters in age groups of 2 and 3 years in

Table 1. Water characteristics at sampling points (HC: high current; LC: low current).

	T (°C)	pH	DO (mg/l)	Sampling depth	Transparency (SD depth(m))
HC	9±3	7.3±0.4	12.7±3.4	0.6±0.3	0.3
LC	12±2	6.9±0.3	9.2±2.1	0.75±0.2	1.5

Table 2. Mean values of length, width, height and weight in different age groups of swan mussel populations collected in studied water bodies.

	Age	N	Length (mm)	Width (mm)	Height (mm)	Weight (g)
HC	1	8	46.75	16.625	25.25	110.6175
	2	7	69.43	25.29	41.14	135.32
	3	15	97.33	32.00	49.67	169.58
	4	46	122.96	48.20	63.14	214.53
	5	33	132.30	51.00	65.41	252.15
	6	15	136.73	53.60	67.27	276.21
LC	2	6	85.83	26.17	38.67	126.69
	3	39	103.62	34.67	49.36	163.03
	4	74	108.93	38.19	51.85	172.47
	5	34	118.56	42.59	57.35	178.41

Table 3. Mean, minimum (min), maximum (max), variation range, variance (var.), and standard deviation (SD) for length, width, height, weight and age of swan mussel specimens collected from water bodies.

		n	mean	min	max	variation	var.	SD.
HC	Length	124	116.07	36	152	116	649.15	25.47
	Width		44.30	12	61	49	128.92	11.35
	Height		58.92	21	72	51	145.73	12.07
	Weight		212.96	92.43	300.35	207.92	2868.744	53.56
	Age		4.08	1	6	5	1.68	1.298
LC	Length	153	108.81	76	126	50	75.70	8.70
	Width		37.79	24	52	28	29.03	5.38
	Height		51.92	34	67	33	50.30	7.09
	Weight		169.58	113.65	194	80.35	176.89	13.30
	Age		3.88	2	5	3	0.62	0.791

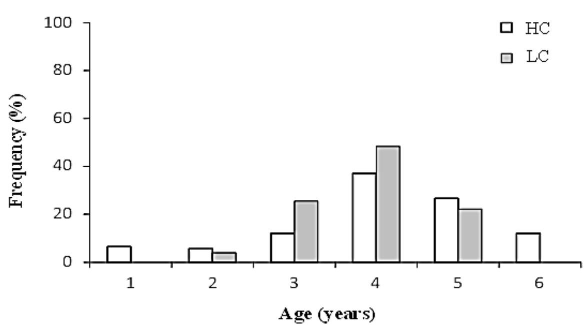

Figure 2. Frequency (%) of mussel individuals at different age groups collected from studied water bodies.

HC population were lower than those of LC, but in higher age classes, the values of these parameters were higher in the HC population compared with the LC population. The mean values of length, width, height, weight and age of mussels were higher in the HC group (Table 3). The highest and lowest measured values of the parameters were observed in the HC group. Range of all studied parameters were higher in the HC group compared to the LC group (Table 2).

Bivariate relationships between width, height, and weight with length of mussels are presented in Figure 3. Linear and positive relationships were found for all bivariate plots. Strong correlations were observed for mussels belongs to the HC group, but correlations between the measured parameters of LC mussel population specimens indicated medium strength. The scatter plot of the weight against the length showed negative allometric pattern for both populations (b_{HC} =0.8561; b_{LC}=0.8508). Figure 4 shows the relationship between Length, width, and height with age for mussels of both populations. Correlations of length, width, and height with age of mussels were strong in the HC population, but in the LC mussels, these relationships has showed moderate correlation for all parameters.

Discussion

There was no specimen with the age older than 6 years old. The 4-year mussels were the dominant age-class

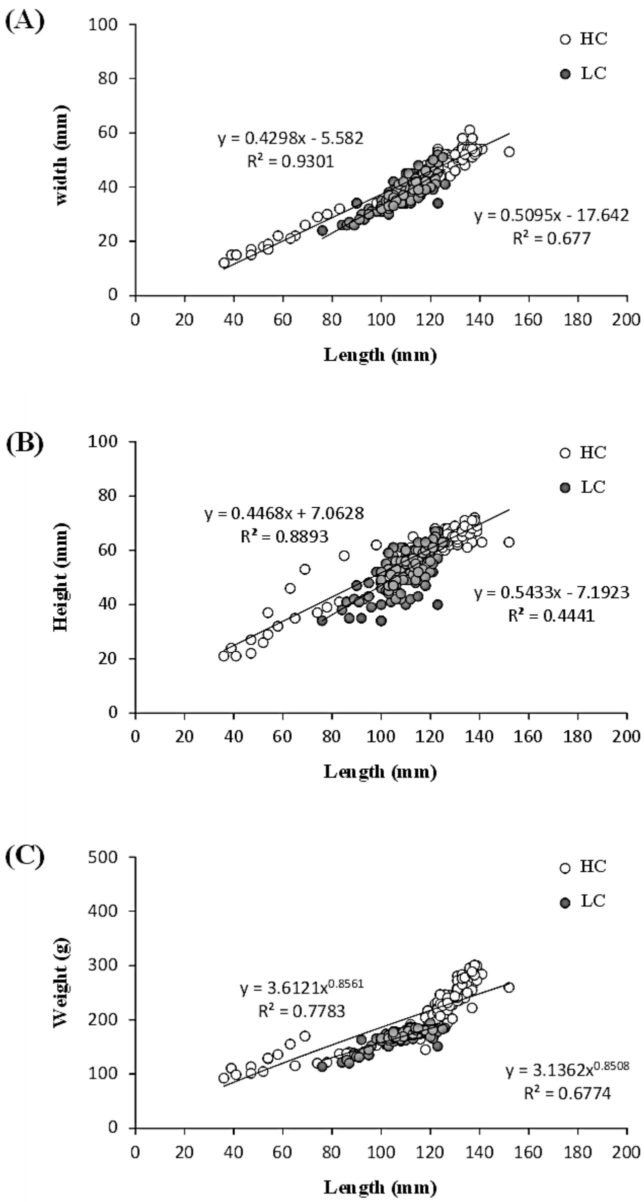

Figure 3. Scatter plots of width-length (A), height-length (B), and weight-length (C) relationships of *Anodonta cygnea* specimens collected from studied water bodies.

at both studied groups. similarly, the maximum observed age of this species in Iranian waters in prior studies was 4 years (Parvaneh et al., 1998; Pourang et al., 2004), whereas specimens with 15 years old have been reported in European waters (Ravera and Sprocati, 1997). In the LC group, there were no specimen belonged to 1 and 6 years age-classes, but in the HC group, the specimens were in 1 to 6 years age-classes. The lack of mussels in some of year classes may be due to rigorous population fluctuations (Rosinska et al., 2008), that may stem from different factors such as environmental pollution, decrease in number of fish, which are the host of the parasitic larvae of this mussel, and temporal water quality changes in these waters (Zajac, 2002).

The maximal mean values of the length, width, height and weight of mussels were belonged to the HC group and also, the maximal values of these parameters were found in that group (length: 152 mm; width: 61 mm; height: 72 mm). The maximal length reported for swan mussel is 200 mm (Wirebellose, 2001). Higher variation in measured biometric parameters in the HC mussels compared to LC mussels may be attributed to dynamic water system in the HC sampling places and higher quality and quantity of nutrient sources in this water body (Azzopardi et al., 2013). Also, population density is reported as an important factor that can affect growth and shell morphometry through either food regulation, physical interface or their interaction (Alunno-Bruscia et al., 2001).

The relationships between width, height, and weight with length showed significant correlations, but these correlations were high and at a medium rate in the HC and LC mussels, respectively. The lower correlation coefficients for the LC mussels maybe is a result of smaller age and size range of these mussels in this water body due to their population fluctuations (Zajac, 2004). Increase in length is happened with linear increase in width and height of mussels in both mussel groups. Linear positive relationships between width-length and height-length of the bivalve's shell are reported previously in different studies on bivalves (Alunno-Bruscia et al., 2001).

The weight-length relationship of mussels in the present study showed negative allometric pattern, where b values were lower than unity for both groups. Weight-length relationships have been isometric in most of the studied species (Müller and Patzner, 1996; Tenjing Singh et al., 2013), but positive and negative allometric patterns have also been reported for different species and within a species in different conditions (Park and Oh, 2002). The mean b values for

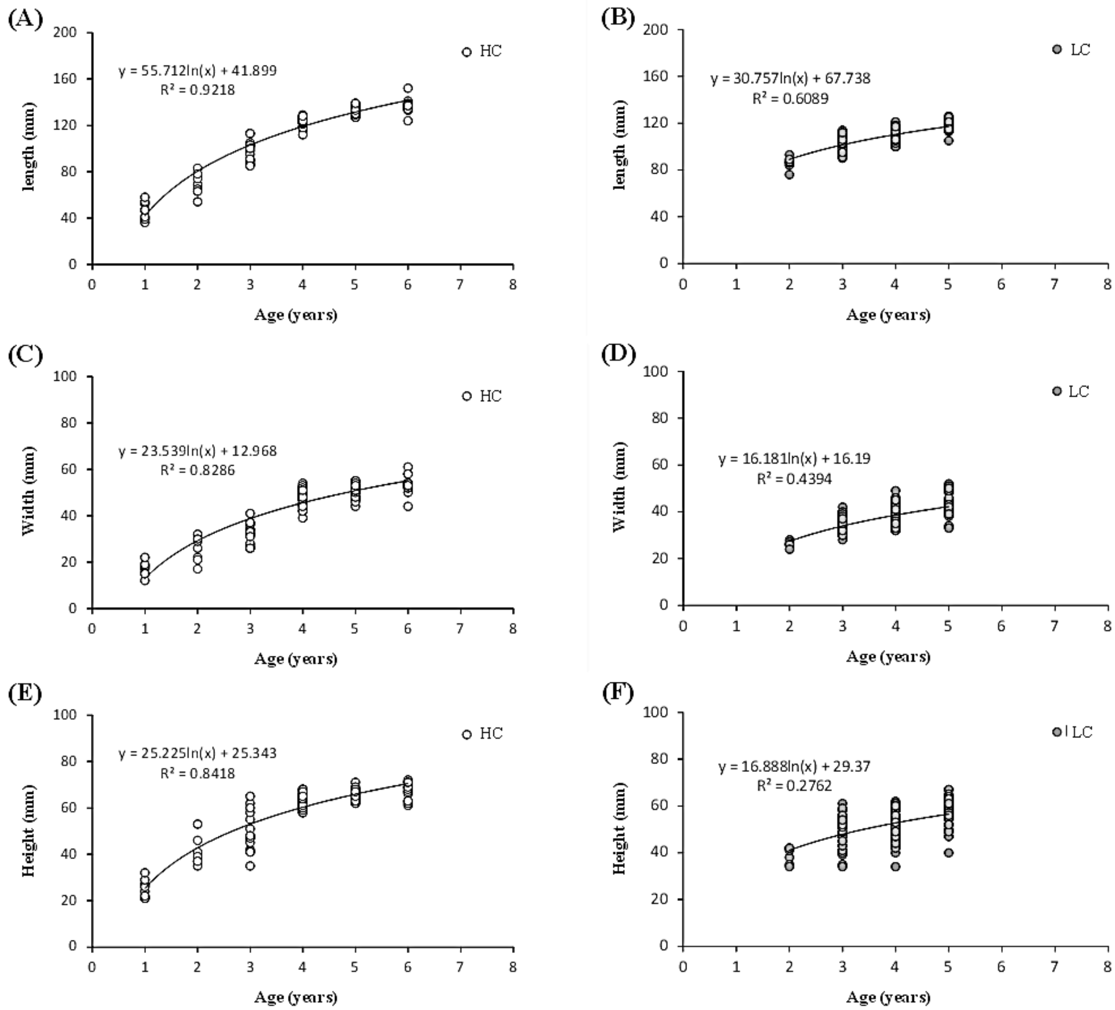

Figure 4. Plot of length (A and B), width (C and D), and height (E and F) at age of *Anodonta cygnea* individuals collected from studied water bodies.

swan mussel populations were between 2 and 4 (Tesch, 1971), but in present study, b values were lower than those values. Changes in b value can be due to different reasons, such as different growth and maturity levels, sex, geographical and local conditions, diseases, environmental pollution and parasitic infections (Tesch, 1971).

The length, width and height were increased along with increase in age, and the highest increases of these parameters were occurred during 1-2 years oldness. R^2 values of biometric parameters at age relationships were high for HC mussels. Shell growth increases with increase in age and bivalve species with thinner shells have faster growth than species with thicker shells (Harmon and Joy, 1990). Maximal growth rate of *A. cygnea* occurs in the second year of the life (Zajac, 2002) and sexual maturity happens in ages of 2-3 years (Rosinska et al., 2008). These changes in growth rate with increase in age is a result of higher energy consumption for gamete production rather than body growth in multiple species after sexual maturity (Zajac, 2004). Generally, in bivalve populations, larger bivalves have higher ages than smaller ones, but it can be observed that mussels with similar size belong to different age-classes (Ravera et al., 2007). Such a situation was observed in the present study in both groups and may be attributed to better habitat conditions (i.e., higher nutrient levels in water) during the period with highest density at the second year of bivalve's life (Rosinska et al., 2008).

Based on the results, it can be concluded that different investigated mussel populations in different environments in terms of their water current, has different biometric and population structures, which probably can be due to environmental fluctuations in the water body with no significant water current. Despite of mentioned differences, both populations have similar characteristics that could not be affected by such factors.

Acknowledgments

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چکیده فارسی

تغییرات در فرم صدف دوکفه‌ای *Anodonta cygnea* (Linea, 1876) در پاسخ به جریان آب

فاتح معزی[1]، هادی پورباقر[1*]، امیر قادرمزی[2]، فاطمه پرویزی[3]، صالح بنام[2]

[1]گروه شیلات، دانشکده منابع طبیعی، دانشگاه تهران، کرج، ایران.
[2]گروه شیلات، دانشکده شیلات و محیط زیست، دانشگاه علوم کشاورزی و منابع طبیعی گرگان، گرگان، ایران.
[3]گروه شیلات، دانشگاه هرمزگان، بندرعباس، ایران.

چکیده:
مطالعه بیومتریک بر روی جوامعی از صدف آنودونت (*Anodonta cygnea*) انجام شد که به دو محیط با سرعت جریان متفاوت متعلق بودند (گروه موجود در سرعت بالا با نام HC و گروه واقع در سرعت پایین با نام LC). طول، عرض و ارتفاع کفه، همچنین وزن و سن صدف‌ها اندازه‌گیری شدند. توزیع رده سنی صدف‌های این دو گروه با هم تفاوت داشتند. صدف‌های HC مقادیر میانگین و حداکثر بالاتری در پارامترهای اندازه‌گیری شده داشتند. ضرایب همبستگی بالا و متوسطی بین وزن- طول، ارتفاع-طول و وزن طول برای صدف‌های HC و LC به‌دست آمد. روابط وزن-طول الگوی آلومتریک منفی را نشان داد (در صدف‌های HC: $3.6121x^{0.8561}$=وزن در صدف‌های LC: $3.1362x^{0.8508}$=وزن). صدف‌های ۱ و ۲ ساله دارای بالاترین نرخ افزایش طول، پهنا و ارتفاع را در هر دو گروه داشتند. بر مبنای نتایج، سرعت جریان آب بر ویژگی‌های بیومتریک و ساختار جمعیتی صدف *A. cygnea* تاثیر می‌گذارد.

کلمات کلیدی: *Anodonta cygnea*، بیومتری، ساختار جمعیت، شرایط آب.