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SIZE-WEIGHT CHARACTERISTICS, GENDER STRUCTURE AND DENSITY OF *RAPANA VENOSA* (VALENCIENNES, 1846) POPULATION IN VARNA BAY

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РАЗМЕРНО-ТЕГЛОВНИ ХАРАКТЕРИСТИКИ, ПОЛОВА СТРУКТУРА И ПЛЪТНОСТ НА ПОПУЛАЦИЯТА НА *RAPANA VENOSA* (VALENCIENNES, 1846) ВЪВ ВАРНЕНСКИ ЗАЛИВ

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Резюме: *Размерът, теглото, половата принадлежност и плътността на индивидите са важни характеристики, даващи информация за състоянието на популацията на даден вид.*
Изследвани са общо 278 индивида от вида Rapana venosa по отношение на техния размер, тегло и пол през есента на 2015 г. и лятото на 2016 г. Резултатите показват, че средната плътност на популацията на рапаната е 14 инд.м$^{-2}$ като показва по-висока стойност през лятото на 2016 г. в сравнение с есента на 2015 г.. Средните стойности на размерно-тегловните характеристики са както следва: дължина на черупката - 5.89 см, ширина на черупката - 4.50 см, общо тегло - 35.05 гр, тегло на черупката - 20.92 гр и тегло на тялото – 13.93 гр. Женските индивиди на рапаната са по-малки и по-леки от мъжките като разликата е статистически значима (t-test, P <0.05). Честотата на разпределение според дължината на черупката показва, че доминират индивидите от размерен клас 5-6 см като се наблюдава статистически значима разлика в разпределението на мъжките и женските екземпляри. В честотата на разпределение според общото тегло доминират индивидите от размерен клас 20-30 гр, следвани от тези от размерен клас 30-40 гр. Установена е статистически значима разлика между тегловното разпределение на женските и мъжките екземпляри (t-test, P <0.05). Връзката размер-тегло е $W=0.114L^{3.194}$ ($R^2=0.923$), като коефициента на алометрия показва положителен алометричен растеж валиден и за двата пола (b>3). Коефициентът на охраненост по Фултън (K) варира между 2.33 и 9.20 със средна стойнос 6.44. Половата принадлежност на индивидите показва, че процентните дялове на мъжките и женските индивиди са 49.3 % и 50.7 % съответно като съотношението между половете не се различава от статистически очакваното 1:1 ($\chi^2 = 0.058$, P > 0.05).

Ключови думи: *морска биология, бентос, инвазивни видове, Rapana venosa,популационни параметри, размерно-тегловно разпределение, Варненски залив.*

INTRODUCTION

The native worldwide distribution of *Rapana venosa* includes the temperate Sea of Japan, the Yellow Sea, the Bohai Sea, the East China Sea to Taiwan in the south, and Peter the Great Bay off Vladivostok in the north (Mann & Harding, 2003). Currently, there are five known geographic regions containing reproducing populations of *R. venosa* that are distinct from the native (Asian) population (ICES, 2004). These are the Black Sea, the Adriatic and Aegean Seas, Chesapeake Bay in the northwest Atlantic, the Rio de la Plata Estuary in the southwest Atlantic, and the coast of Brittany in France in the northeast Atlantic (ICES, 2004). Limited records have also been made on the Pacific coast of Canada and in Willapa Bay, Washington, USA, where this species is not considered to be established (Mann & Harding, 2003).

Rapana venosa is an invasive species for the Black Sea listed among the 100 of the 'worst invaiders' in the Mediterranean (Streftaris & Zenetos, 2006). It was accidentally introduced into Black Sea in 1946 with the first record in Novorossiysk Bay (Drapkin, 1963). First record along Bulgarian coasts is made by Kaneva-Abadjieva in 1956 in Varna Bay near cape Galata at depth 4-5 m on rocks (Kaneva-Abadjieva, 1958). It has a high ecological fitness as evidenced by its high fecundity, early sexual maturity (Chung *et al.*, 2002; Saglam & Duzgunes, 2007), longevity, fast growth rate (Chukhchin, 1961; Harding & Mann, 1999), broad tolerance to salinity, temperatures, water pollution and oxygen deficiency (Zolotarev, 1996; Mann & Harding, 2003), generalist predator of subtidal mollusks usually feeds on bivalves (Harding & Mann, 1999; Savini *et al.*, 2004), giving it all the characteristics of a successful invader. Its establishment in the Black Sea appeared to be facilitated by the general lack of competition for the food source and a lack of direct predation on Rapana by predators and an abundance of potential prey species (Zolotarev, 1996; ICES, 2004).

Rapana venosa has become established in the Black Sea with significant damage to native benthos (e.g. bivalves; notably *Ostrea edulis, Pecten ponticus* and *Mytilus galloprovincialis*) (Mann & Harding, 2003). It has occupied an empty ecological niche exerting a significant predatory pressure on the indigenous malacofauna. Impact on bivalve populations is variable ranging from rather mild along the Romanian coast, moderate in Bulgarian and Turkish Black Sea, and severe along Russian and Ukrainian coasts where this species has been blamed for local extermination/major decline of a number of bivalves (BSEPR, 2007). Illegal bottom trawling for harvesting of *R. venosa* along the Black Sea shelf has raised ecological concerns with respect to the benthic communities and especially the mussel beds (Knudsen *et al.*, 2010; Ulman *et al.*, 2013).

MATERIAL AND METHODS

The study was carried out in the coastal area of the Western Black Sea - Varna Bay, in the vicinity of Karantinata. Rapana whelks were captured monthly in autumn of 2015 and summer of 2016 by diver who picked up all individuals within a frame with size 1 m^2. A total of 20 frames were sampled. The sediment in the study area was sandy and the depth ranged from 5 to 6.5 m (Table 1).

Table 1. Date and number of frames, coordinates and depth of samples.

Date – frame	Depth (m)	Latitude	Longitude
09.2015 - 1,2,3	5.6	43°10.646’	27°55.749’
10.2015 - 1,2,3	6	43°10.616’	27°55.822’
11.2015 - 1,2,3	6.5	43°10.645’	27°55.944’
06.2016 - 1,2,3,4,5	5.5	43°10.578’	27°55.929’
07.2016 - 1,2,3	5	43°10.591’	27°55.923’
08.2016 - 1,2,3	5	43°10.615’	27°55.900’

In the laboratory shell length and shell width of each specimen were measured with a vernier calliper to the nearest 0.01 mm. Shell length was measured from the apex to the end of the siphonal canal. Total weight, shell weight and shell-free body weight were estimated to the nearest 0.01 g with a balance. A total of 278 specimens have been measured and weighted. The sex of each whelk was identified based on the color of the gonad and the presence/absence of penis.

Two tailed t-test was applied to assess if the differences between the biological parameters were statistically significant.

The length–weight relationships were determined using the equation $W = a L^b$ (Le Cren, 1951; Pauly, 1980; Erkoyuncu, 1995). Relationship between the length and the weight was examined by the simple linear regression analysis. Fulton’s condition factor was calculated by $K=100 (W/L^3)$, where L is the total shell length (cm) and W is the body weight (g) (Le Cren, 1951; Bagenal, 1978; Sparre & Venema, 1992; Erkoyuncu, 1995).

The sex ratio was tested by a $\chi 2$-test. A significance level of 0.05 was considered in all the statistical tests applied in this study.

RESULTS AND DISCUSSION

Morphometric variables of Rapa whelk individuals

The results showed that the mean density of *R. venosa* population was 14 ind.m^{-2} with a minimum of 7 ind.m^{-2} and a maximum of 33 ind.m^{-2}. The mean density was higher in the summer of 2016 (17 ind.m^{-2}) compared to autumn 2015 (10 ind.m^{-2}) and the difference was considered to be statistically significant (t - test, $P < 0.05$).

The mean values of each morphometric variable of females and males, and of all individuals are presented in Table 2.

The length of the shell ranged from 1.74 cm to 7.98 cm. Larger shell length ranges were reported for North Atlantic- USA (10.3-14.9 cm) (Harding &Mann, 1999), for Adriatic Sea (10.1-10.6 cm) (Savini *et al.*, 2004), for Argentina-Uruguay (2.8-12.0 cm) (Giberto *et al.*, 2006) and for Korea (3.88-14.06 cm) (Choi & Ryu, 2009) than the Black Sea specimens (3.5-8.0 cm) (Bondarev, 2014).

The results of the present study were comparable with those estimated by Saglam & Düzgünesh, 2014 in the south-eastern Black Sea (1.4-9.6 cm).

In the Black Sea, there is a significant decrease in average length of captured individuals by time (Daskalov & Rätz, 2011). For example, the mean length recorded in 1986 was 11.0 cm (Ünsal, 1989), in 1991 - 6.7 cm, in 1992 - 6.5 cm (Düzgüneş *et al.*, 1992), in 1999 - 5.4 cm (Emiral, 2003), in 2003 - 4.5 cm (Zengin, 2006) and in 2004 - 4.46 cm (Şahin *et al.*, 2005). In this study the mean length was 5.89 cm (Table 2).

The possible reasons of the decrease in mean length, pointed out by Daskalov and Rätz, 2011 are: (1) the overexploitation of larger length groups due to high demand for market and export; (2) the reduction of natural food sources as a result of intense Rapa whelk predation and consequential poor feeding.

The mean width of the shell was 4.50 cm and varied from 1.09 cm to 6.33 cm. The mean total weight was 35.05 g and ranged from 0.60 g to 91.61 g, the mean weight of the shell was 20.92 g with a range of variation from 0.47 g to 73.46 g, and the mean body weight - 13.93 g with a minimum of 0.12 g and a maximum of 42.48 g (Table 2). The smallest whelk was found in November 2015 – 1.74 cm shell length, 0.60 g total weight and 0.12 g body weight. The largest whelk was registered in July 2016 – 6.33 cm shell length, 82.58 g total weight and 42.48 g body weight.

The mean values of all size-weight characteristics of individuals were higher in the summer of 2016 compared to those established in the autumn of 2015 (Table 3) and the difference was considered to be statistically significant (t –test, $P < 0.05$).

Table 2. Values of morphometric variables of females, male and all individuals (mean±standard deviation, min-max of all individuals).

	Females	**Males**	**All**	**Min-Max**
Shell length (cm)	4.32±0.58	4.68±0.64	5.89±0.73	1.74-7.98
Shell width (cm)	5.69±0.68	6.10±0.73	4.50±0.64	1.09-6.33
Total weight (g)	31.15±10.69	39.07±15.84	35.05±14.03	0.60-91.61
Shell weight (g)	18.90±6.59	22.99±10.11	20.92±8.74	0.47-73.46
Body weight (g)	12.10±4.55	15.82±6.64	13.93±5.98	0.12-42.48

Table 3. Mean values of *R. venosa* size-weight characteristics (mean±standard deviation).

	2015	**2016**
Shell length (cm)	5.77±0.78	5.95±0.70
Shell width (cm)	4.35±0.69	4.57±0.60
Total weight (g)	30.80±14.33	37.05±13.46
Shell weight (g)	19.48±10.04	21.59±7.99
Body weight (g)	11.04±4.87	15.29±5.96

Shell length of females ranged from 1.74 cm to 7.34 cm and total weight from 0.60 g to 63.65 g. Males were larger and heavier – shell length varied between 4.43 cm to 7.98 cm and total weight from 10.85 g to 91.61 g. Female whelks were significantly smaller and lighter than males (t-test, $P< 0.05$).

Length frequency distribution

Length frequency distribution showed that the majority of the population in both sampled years was composed by the individuals of size class 5-6 cm similar to the distribution found by Aydin *et al.*, 2016. In the autumn of 2015 the dominating size class was 5-6 cm (56.2 %) followed by individuals falling into size class 6-7 cm (30.3 %). In the summer of 2016 the length frequency

distribution was analogous but the percentages of size classes 5-6 cm and 6-7 cm were more comparable – 45.5 % and 40.7 % respectively (Figure 1).

The size structure of the sampled population according to the shell length of females and males is presented in the Figure 2. The length frequency distribution differed significantly between females and males (t-test, $P<0.05$). Females with shell length 5-6 cm expressed the highest frequency (61.0 %), while males are dominated by the larger individuals – 6-7 cm (47.4 %).

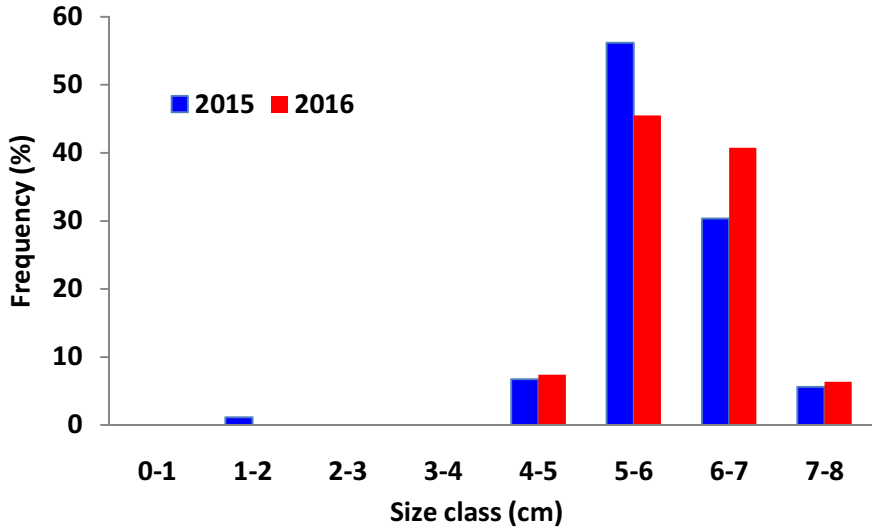

Fig. 1. Length frequency distribution by years.

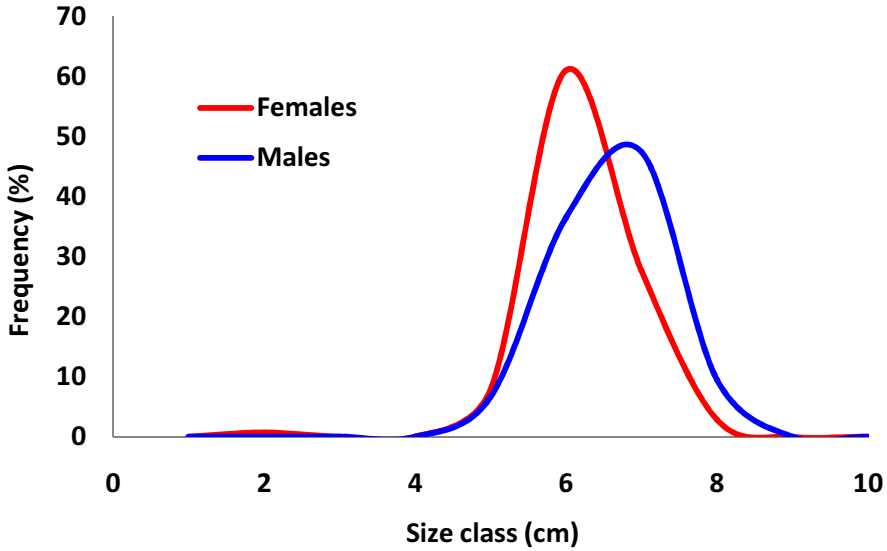

Fig. 2. Length frequency distribution of female and male individuals by years.

Weight frequency distribution

Frequency distribution of individuals according to the weight is given in Figure 3. The distribution showed that in both sampled years individuals of size class 20-30 g dominated with 34.8 % in 2015 and 29.1 % in 2006 in the population structure, followed by those of the size class 30-40 g – 23.6 % in 2015 and 26.5 % in 2016.

The size structure of the sampled population according to the total weight of females and males is presented in the Figure 4. The length frequency distribution differed significantly between females and males (t-test, $P<0.05$). Females were dominated by individuals with total weight between 20 g and 30 g (36.2 %) while males expressed two peaks sharing almost equal percentage shares of size classes 20-30 g and 40-50 g – 25.5 % and 24.1 % respectively (Figure 4).

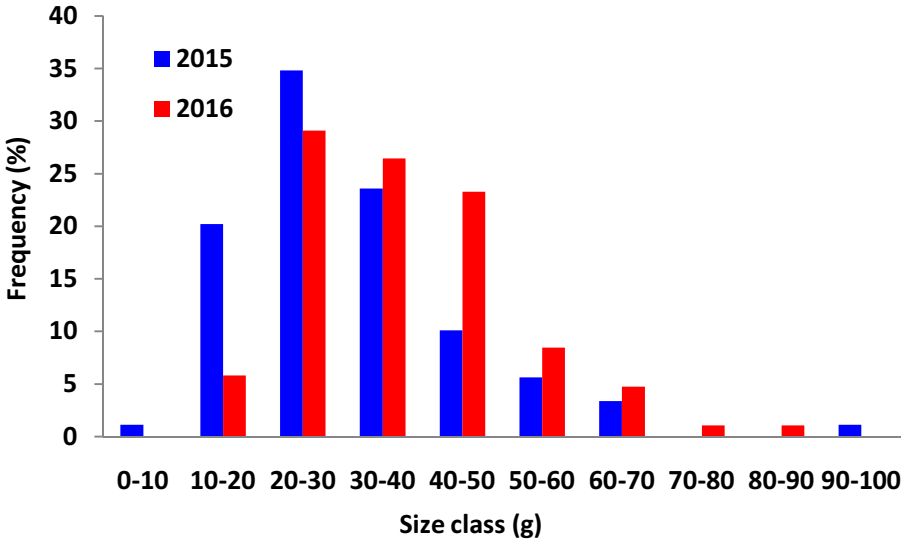

Fig. 3. Weight frequency distribution by years.

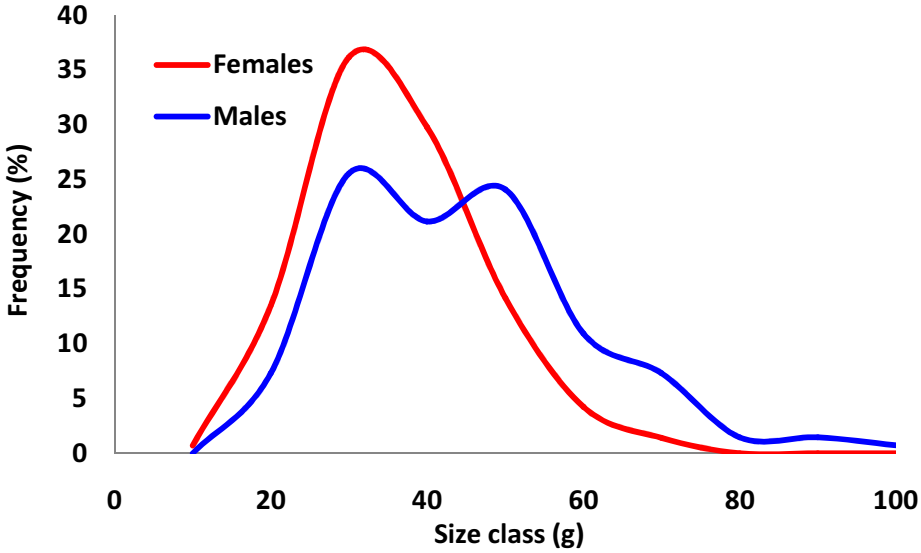

Fig. 4. Weight frequency distribution of female and male individuals by years.

Length - weight relationship

Length-weight relationship was found to be $W=0.114L^{3.194}$ ($R^2=0.923$) for all individuals (Figure 5). The length-weight relationships showed positive allometric growth (b =3.194). A positive allometric relationship was also found in other studies in different areas - Adriatic (b=3.21) (Savini *et al.*, 2004), the Rio de la Plata estuary, Argentina-Uruguay (b=3.39) (Giberto *et al.*, 2006) and the west sea of Korea (b=3.21) (Choi & Ryu, 2009).

Allometric analyses of length – weight relationship showed that the slope (b) was significantly different from 3 (t-test, $P<0.05$) in both females and males, indicating a positive allometric growth pattern for both sexes ($b_{females}=3.155$, Figure 6; $b_{males}=3.267$, Figure 7). The results from the present study are comparable with the values of b estimated by Saglam and Düzgünesh, 2014.

The Fulton's coefficient of condition factor (K) varied between 2.33 and 9.20, and the average K of population was 6.44 ± 1.2 SD.

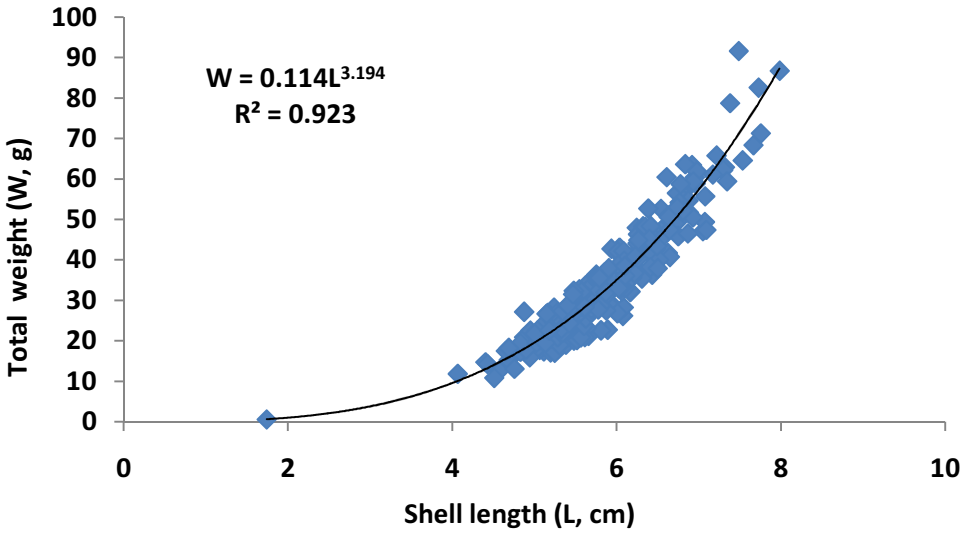

Fig. 5. Shell length (L) - total weight (W) relationship of whelks.

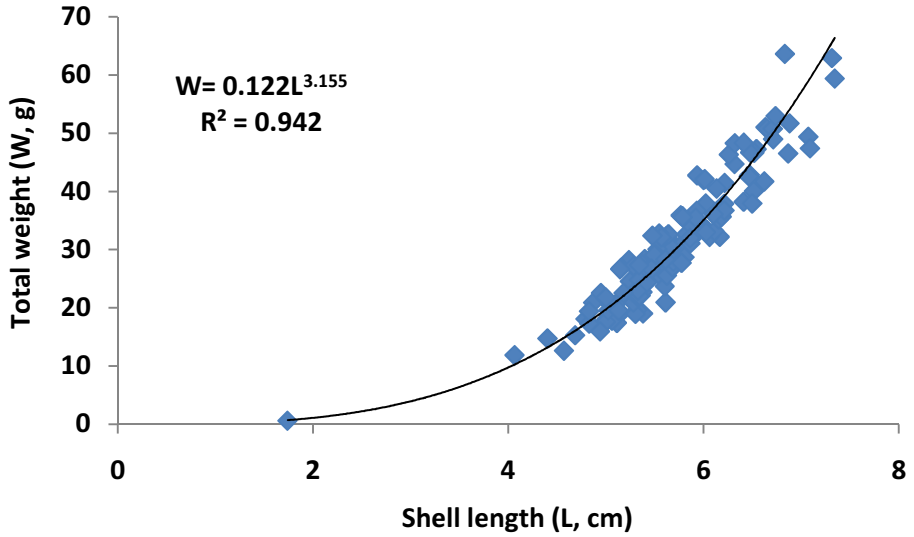

Fig. 6. Shell length (L) - total weight (W) relationship of female whelks.

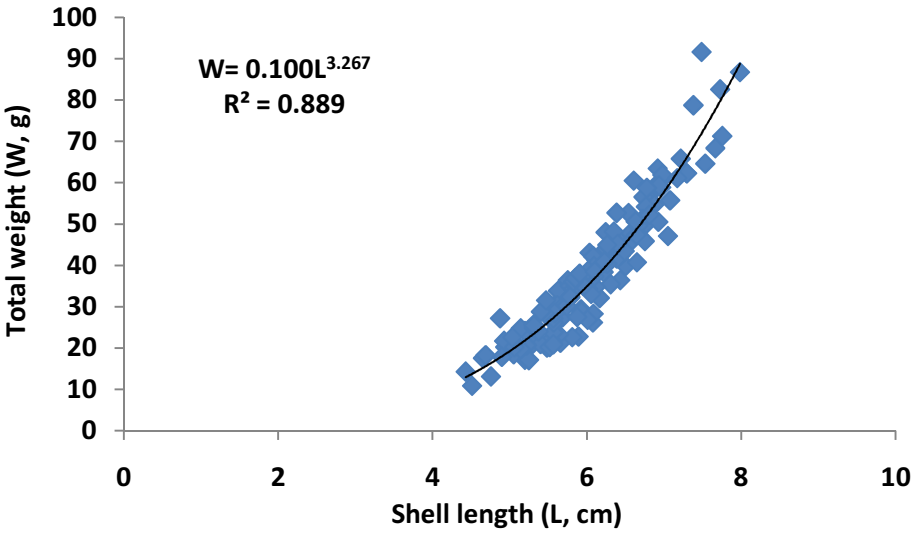

Fig.7. Shell length (L) - total weight (W) relationship of male whelks.

Gender structure

From the 278 specimens of *R. venosa*, 50.7 % were females and 49.3 % were males. The overall sex ratio did not differ statistically from 1:1 ratio ($\chi^2 = 0.058$, $P > 0.05$). The observed seasonal and monthly sex ratio of Rapa whelk population inhabiting sandy sediments of Varna Bay was 1:1 in all cases.

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