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Original Article

Population structure and shell dimension of the invasive veined whelk (*Rapana venosa*)

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Abstract
The veined whelk (*Rapana venosa*) is a widely known invasive species in the Black Sea. This species exerts negative impacts on the Black Sea ecosystem including destruction of bivalve, mussel and oyster populations. This study aimed to examine population structure using the length-frequency distribution and shell dimensions of *R. venosa*, collected from the Black Sea. A total of 506 specimens were collected from the Trabzon Coast and classified into 6 age groups using the Bhattacharya method. The Von-Bertalanffy growth parameters were calculated as L_∞ = 10.29 cm, k = 0.09, t_0 = 1.25 yr^{-1}. The mortality and exploitation rates were estimated as total mortality Z = 0.51 yr^{-1}, fishing mortality F = 0.31 yr^{-1}, annual mortality M = 0.20 yr^{-1} and exploitation rate E = 0.60 yr^{-1}. This study will help understanding the growth of *R. venosa* and its management.

Keywords: Age; Black Sea; mortality rate; *Rapana venosa*; shell

1 | INTRODUCTION

The veined whelk (*Rapana venosa* Valenciennes, 1846), a large predatory gastropod of the family Muricidae, originated from the Sea of Japan and first occurred in the Black Sea (Novorossiysk Bay) in 1946 (Drapkin 1953; Zaitsev and Ozturk 2001). Generally, the Black sea current system (cyclonic gyres) is directed anticlockwise. In the consecutive years, it spread across the Aegean, Adriatic and Mediterranean Seas (Kinppovich 1932; Drapkin 1953; Chukhchin 1984; Zolotarev 1996; IECS 2004). The veined whelk survives in 12 – 32 ppt salinity and 1 – 30°C temperature (Bondarev 2013). This species has a long life span, high fertility and high adaption capability to adverse environmental conditions such as water pollution and hypoxia. It usually lives in rocky, sandy bottoms down to 30 m depth and feeds on oysters, mussels and other bivalves (Grishin and Zolotarev 1988). The shell-length can reach about 18 cm which is usually grey to reddish-brown in colour. *Rapana venosa* can be used as a controlling agent for colonization or introduction of any unwanted species (Bondarev 2014). Furthermore, the veined whelk is used as an indicator of environmental pollution and can reflect conditions of benthic habitats (Bondarev 2010). However, *R. venosa* is also responsible for the sharp decline in the oyster (*Ostrea edulis*) and mussel (*Mytilus galloprovincialis*) populations in the Black Sea (Comp *et al.* 1976; Chukhchin 1984; Culloty and Mulcahy 2007; Kasapoglu *et al.* 2011) (Figure 1).

As a successful invader, the veined whelk is also commercially important for all Black Sea countries. These species have been mostly caught by dredge and diving on the Turkish Black Sea coast. It is not consumed locally within the country but exported outside Turkey (Gunduz Hosgor and Suzuki Him 2018). Women are primarily employed in the processing factories while men are involved in fishing in the sea (Suzuki Him and Gunduz Hosgor

2016). However, population parameters for this species is still understudied which are important for the sustainable management of the species. Therefore, the status of the stock, population properties and shell dimensions of the veined whelk were examined in this study to better understand the Black Sea ecosystem health.

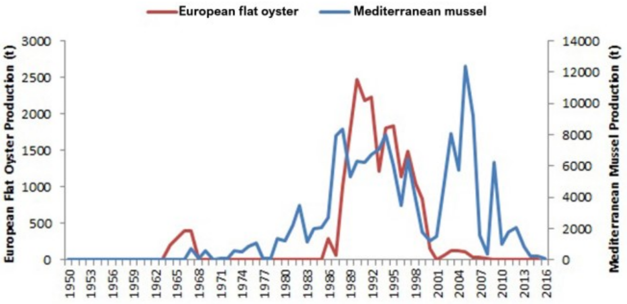

FIGURE 1 The production of European flat oyster and Mediterranean mussel in the Black Sea (source: FAO 2019).

2 | METHODOLOGY

In this study, 506 specimens of *R. venosa* were obtained from Trabzon station (40°57′52′′N – 39°52′30′′E, 40°57′34′′N – 39°52′21′′E in Havaalanı station, 40°55′48′′N – 40°10′17′′E, 40°55′13′′N – 40°10′24′′E in Camburnu station) between September 2010 and May 2011. The samplings were done with DENAR-I research vessel and experimental bottom trawl (40 mm mesh at the cod-end). The towing speed was maintained at 4 knots for 30 minutes. Ten tows were performed and veined whelk specimens were caught as bycatch. The length, width and height of the shell were measured with digital callipers, to the nearest 0.01 mm (Figure 2).

FIGURE 2 Measurement details for *Rapana venosa*.

The body and shell weight were recorded using standard balance, to the nearest 0.01 g. The length-weight relationship (LWR) was estimated by $W = aL^b$ where a and b are constant while W and L refer to the weight of shell and length respectively (Ricker 1975). Age estimation, the Von-Bertalanffy growth parameters, exploitation rate and mortality rates of the species were determined through the Bhattacharya method (FISAT II 2000). The descriptive statistics for male and female individuals were performed in Microsoft Excel (version 2007).

3 | RESULTS

Lengths of *R. venosa* were ranged between 2.2 and 9.8 cm for all samples, 2.3 and 9.8 cm for females and 2.2 and 9.1 cm for males. Whereas, the weight varied from 1.78 – 201.33 g, 1.75 – 201.33 g and 1.78 –158.90 g for combined sexes, females and males respectively. The LWRs were calculated as $TW = 0.199\ SL^{2.9529}$ for all samples, $TW = 0.1964\ SL^{2.9527}$ for female and $TW = 0.1988\ SL^{2.9568}$ for males (Figure 3). Samples were composed of 51% females (n = 260) and 49% males (n = 246; Figure 4).

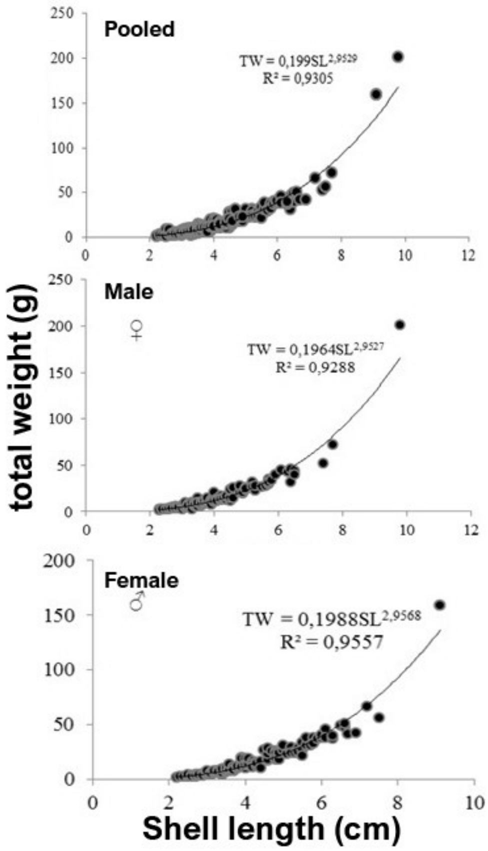

FIGURE 3 Length-weight relationships of *Rapana venosa*.

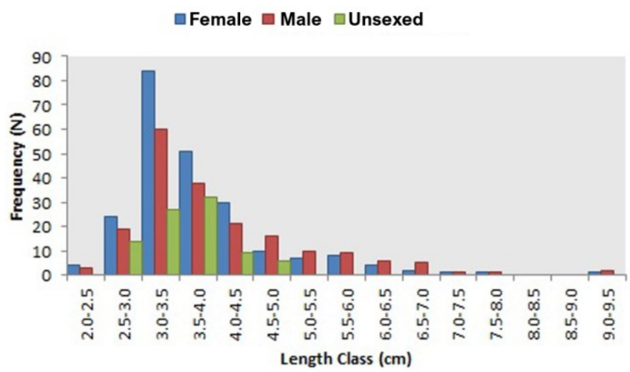

FIGURE 4 Length frequency distribution of *Rapana venosa* specimens (n = 506).

All morphometric parameters of veined whelk were calculated separately for sexes and also for pooled (Table 1). The age of the sample specimens varied between 1 and 6 years. The age groups was dominated by 2 years old (55.62%) followed by 1 year old (15.58%), 3 years old (12.50%), 4 years old (10.51%), 6 years old (3.26%) and 5 years old (2.54%; Figure 5).

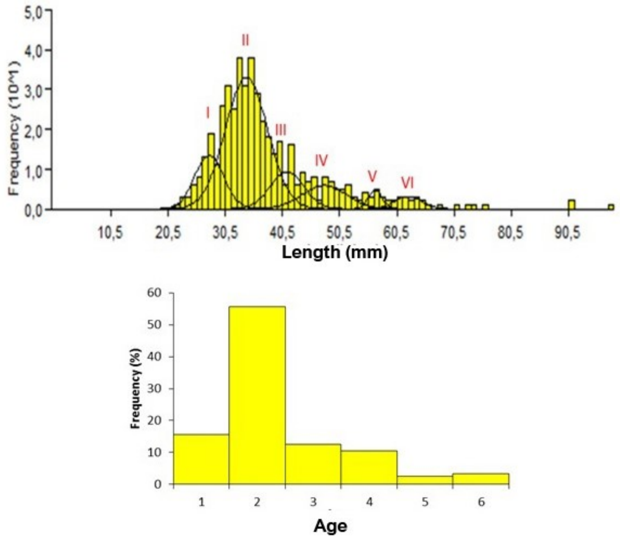

FIGURE 5 Age groups of *Rapana venosa*, determined through Bhattacharya method.

Mean condition factor was estimated 19.08 ± 0.18 for pooled, 18.80 ± 0.24 for female and 19.04 ± 0.26 for male individuals. The von Bertalanffy growth equation $L_t = 10.29\ (1 - e^{-0.09\ (t + 1.25)})$ and $W_t = 169.84\ (1 - e^{-0.09\ (t + 1.25)\ 2.86}$ for pooled data and calculated age-length and age-weight equations are shown in Figure 6.

Instantaneous total mortality rate (*Z*) of veined whelk was calculated as 0.51 year^{-1} whereas the natural mortality rate (*M*) was 0.20 year^{-1} and fishing mortality rate (*F*) was 0.31 year^{-1}. The exploitation rate was calculated as 0.60 year^{-1} (Figure 7).

The highest relationship was detected between the total weight and shell length for male specimens (R^2 = 0.95), while less strong relationship was observed between body weight and shell width for female (R^2 = 0.77). Most of the relationships represented allometric growths of *R. venosa* (Table 2).

4 | DISCUSSION

The length of the *R. venosa* from the Chesapeake Bay was reported 10.27 cm (Harding and Mann 1999) while it varied from 3 – 6 cm for the Black Sea population (Saglam 2004; Sahin *et al.* 2005; Saglam *et al.* 2015; this study). Interestingly the length of the veined whelk has been reported to be getting smaller in recent times. The same is also true for the weight of this species. However, small size may be associated with sampling period, catching method and increased competition for food in the eastern Black Sea's demersal habitat. Age varied between 1 and 6 years. Study by Surer (2013) has showed similar results which could be due to similarity in age determination method between studies.

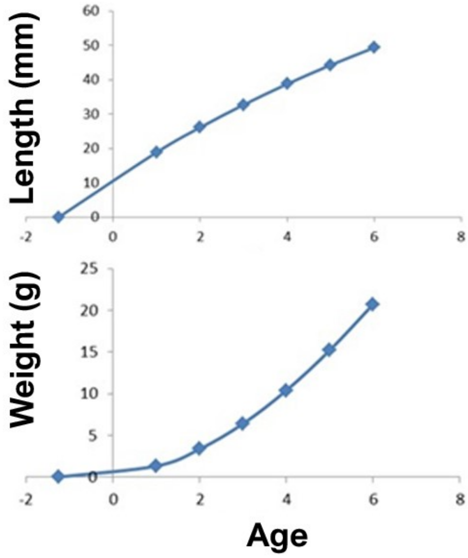

FIGURE 6 Age-length and age-weight equations of the *Rapana venosa*.

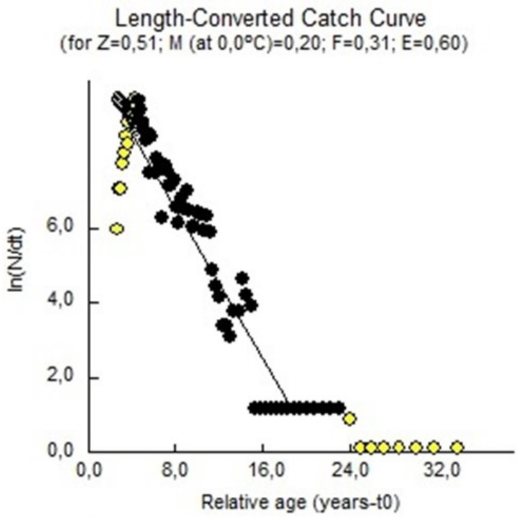

FIGURE 7 The Length-converted catch curve in *Rapana venosa*, based on pooled samples.

The age estimation of the gastropoda, especially *R. venosa*, is challenging but very important for the understanding of growth rates and population structure for effective management. The age estimation of *R. venosa* may involve many techniques including examination of external spawning line on the shell and spawning marks in the cutting shell edge (Chukhchin 1961 and 1970), shell size-frequency analysis, operculum, statoliths and chemical analysis (Hollyman *et al.* 2018). However, these methods are not practical for the routine age determination except the length-frequency analysis. Interestingly, lower growth constant (*K*) values have been reported in recent times. Saglam *et al.* (2015) and Sahin *et al.* (2005) reported similar *K* and t_0 values, but smaller values were observed in the present study. The mortality rate was found to be decreasing. Lower exploitation rate was reported earlier, 0.32 year^{-1} (Sahin *et al.* 2005) and 0.40 year^{-1} (Saglam *et al.* 2015) while it was 0.60 year^{-1} in this study (Table 3).

TABLE 1 Morphometric parameters of veined whelk *Rapana venosa* (mean ± SE).

Parameter	Pooled	Female	Male	Range
Shell length (cm)	3.8±0.05	3.7±0.07	4.0±0.08	2.2–9.8
Total weight (g)	13.0±0.75	12.3±1.14	15.9±1.44	1.8–201.3
Muscle weight (g)	4.0±0.33	3.3±0.19	5.0±0.68	0.4–59.9
Shell width (cm)	3.3±0.19	3.2±0.22	3.8±0.47	1.5–7.4
Shell weight (g)	9.8±0.66	7.8±0.54	12.2±1.30	0.3–99.0

TABLE 2 Relationships between shell measurements and weights of veined whelk.

Parameters	Sex	*a*	*b*	R^2	SE(*b*)	*t*-test	CI 95% of *b*	Growth type
$TW = aSL^b$	F	0.1964	2.9527	0.9288	0.576	68.127	2.864-3.007	Isometric
	M	0.1988	2.9568	0.9557	0.055	57.512	2.923-3.035	Isometric
$TW = aSW_i^b$	F	0.8586	2.4890	0.8877	0.051	44.869	2.311-2.514	Allometric (-)
	M	0.9503	2.4681	0.8830	0.054	41.542	2.316-2.527	Allometric (-)
$BW = a+bSW_i$	F	-5.6634	3.3613	0.7727	0.159	21.104	3.046-3.676	Allometric (+)
	M	-6.6497	3.8276	0.8467	0.146	26.174	3.538-4.117	Allometric (+)
$BW = aSL^b$	F	0.1458	2.3594	0.8356	0.045	55.917	2.294-2.448	Allometric (-)
	M	0.1042	2.5841	0.9435	0.049	54.922	2.425-2.621	Allometric (-)
$SW = aSL^b$	F	0.1101	3.0974	0.8530	0.041	67.931	2.985-3.102	Isometric
	M	0.1247	3.0224	0.9315	0.061	51.769	3.011-3.049	Allometric (+)

TABLE 3 Comparison of the parameters of *Rapana venosa* with previous studies.

Parameter	Duzgunes *et al.* (1992)	Harding and Mann (1999)	Saglam 2004	Sahin *et al.* (2005)	Erik (2011)	Surer (2013)	Saglam *et al.* (2015)	This study
Length	6.22	10.27–14.90	5.29±0.23	5.71±0.43	6.49±0.23	6.20±0.67	5.68±0.36	3.802±0.05
Width	4.54		3.66±0.31		4.93±0.19	4.65±0.53		3.33±0.19
Weight	47.22		27.72±0.40	38.65±1.92	46.1±0.51	57.07±2.36	45.67±0.89	13.03±0.75
Area	Trabzon	Chesapeake Bay	Trabzon	Rize	Sinop	Eastern Black Sea	Samsun	Trabzon
Catch method	Dredge		In tanks	Pot	Pot	Beam trawl	Beam trawl	Bottom trawl
Age				0-5		1-7	0-6	1-6
R	0.96			0.99	0.98	0.97	0.92	0.97
a	0.0005		0.00009	0.00009	0.0002	0.0003	0.0006	0.199
b	2.7716		3.145	3.158	2.877	2.912	2.719	2.952
L_∞				10.39			11.24	10.29
K				0.35			0.31	0.09
t_0				-0.31			–0.486	–1.25
Z				0.96			0.96	0.51
M				0.78			0.57	0.2
F				0.36			0.39	0.31
E				0.32			0.4	0.6

a and *b*, regression constants; *E*, exploitation rate; *F*, fishing mortality; *K*, growth constant; L_∞, asymptotic length; *M*, annual mortality; *R*, correlation coefficient; t_0, the theoretical age when the length equals to zero; *Z*, total mortality.

The increasing production trend can increase demand for the species and this may help developing the Turkish fishing fleets. The price of *R. venosa* is affected by the number of vessels involved in fishing. However, *R. venosa* production gained momentum at the end of the 1990s (Figure 9).

The fishermen sold it at approximately $0.3 for each kg of veined whelk to the processing factories. The factory owners gained $2.7 million from this species' meat trade in 2017 (TSI 2018). In addition, shell and operculum are being exported to Japan, Korea, China, Thailand, the USA, France, etc. (Saglam *et al.* 2008).

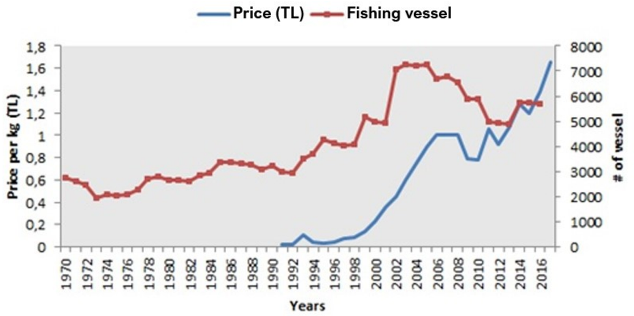

FIGURE 8 The number of the fishing fleet of Turkey for *Rapana venosa* harvest and its price (1 TL = 0.12 USD).

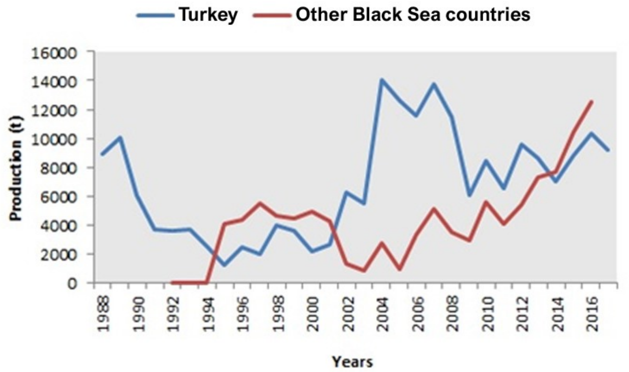

FIGURE 9 Landing data for *Rapana venosa* for the Black Sea (source: FAO 2019).

As an invasive species, the veined whelk adversely affected the Black Sea benthic ecosystem. The impacts include diminishing biodiversity in the habitat, competition for space and food with native species and disrupting the food web (Janssen *et al.* 2014). However, these impacts can be expected when an invasive population established in a new habitat, reported in many studies (e.g. Galib 2020; Galib *et al.* 2021). However, the veined whelk processing plants should be acknowledged for creating fishery for this species which has also created employment opportunities for the local people. This scenario is also common in many countries, especially in developing ones, where non-native species consist an important part of fisheries production and economy (e.g. Galib and Mohsin 2011; Mohsin *et al.* 2012; Galib *et al.* 2013). There are several research projects on this species to monitor and employ effective management strategy in the Black Sea, currently being implemented by Turkish Ministry of Agriculture and Forestry, FAO-GFCM and universities which may be helpful for the sustainable management of the species. Consequently, *R. venosa* spread all over the Black Sea coast, and may need to treat it as a native species at the end of this century.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available on request from the corresponding author.

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