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POPULATION STRUCTURE AND GROWTH DYNAMICS OF *Rapana venosa* (Valenciennes, 1846) FROM THE ROMANIAN BLACK SEA COAST

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Abstract

This study presents the population structure, growth dynamics of the species Rapana venosa (Valenciennes, 1846) with the aim of understanding its response to environmental gradients and anthropogenic pressures, particularly fishing. Data were collected during the 2024 summer expedition, in Romanian coastal area. The sampling depth was between 5 - 35 m and the mean bottom water temperature was 10.81°C. The age composition was formed by 3 to 11 years generations. A total of 3345 specimens were examined, with a mean total length of 63.94 mm and mean total weight of 48.07 g. The length-weight relationship (LWR), characterized by the intercept (a) = 0.00013 and the slope (b) = 3.033, confirmed mostly isometric growth, though some cases showed positive allometry. The high coefficient of determination values (r^2) = 0.937 indicate a strong correlation of LWR. The Von Bertalanffy growth model parameters indicate moderate growth potential for the population. Mortality rates, including natural mortality, fishing mortality and total mortality, showed that fishing is the dominant impact factor. High exploitation rates highlighted intense fishing pressure, indicating the need for sustainable management measures.

Key words: *exploitation rate, length-weight relationship, mortality rate, rapa whelk, Von Bertalanffy growth model.*

INTRODUCTION

The rapa whelk is one of the most important invasive species in the Black Sea ecosystem, having a significant impact on the native benthic fauna (Zolotarev, 1996). Since its first report in the Black Sea in 1946 (Drapkin, 1963), this species has rapidly spread, particularly affecting commercial bivalve populations such as *Mytilus galloprovincialis* and *Anadara inaequivalvis* (Zolotarev, 1996; Saglam & Düzgüneș, 2014). However, due to high demand in Asian markets, this species has become one of the most valuable fishery resources in the Black Sea basin (Dağtekin, 2023). According to data from the European Commission (EC, 2025), between 2020-2023, landings of rapa whelk were on average 84.57% of total landings, and the value of landings was on po 53.38% of total landed values. Currently, the intensive exploitation of this species raises concerns regarding stock sustainability and its impact on the benthic ecosystem (Țiganov et al., 2024). Understanding population structure, growth dynamics, and mortality rates is essential for effective fisheries management. To further highlight these effects, numerous studies have investigated the biology and population dynamics of this species in different regions of the Black Sea and not only. Research has been conducted along the Romanian Black Sea coast (Gomoiu, 1972; Teacă et al., 2007; Micu et al., 2008; Abaza et al., 2010; Danilov et al., 2018; Țiganov et al., 2024, 2018), the Bulgarian Black Sea coast (Trayanova, 2016; Petrova et al., 2020), the Turkish Black Sea coast (Şahin et al., 2009; Saglam & Düzgüneş, 2014; Sağlam et al., 2015; Saglam et al., 2015; Gönener & Özsandikçi, 2017; Mutlu et al., 2022; Dağtekin, 2023), the northern Black Sea coast and the Sea of Azov (Bondarev & Revkov, 2018; Stadnichenko & Kurakin, 2022; Bondarev, 2024, 2016, 2015, 2014, 2013), the Russian Black Sea coast (Khoroshutina et al., 2024), the Adriatic Sea (Savini et al., 2004) as well as in the Mediterranean Sea (Occhipinti-Ambrogi et al., 2011) and other region (Xue et. al., 2018; Spotorno-Oliveira et al., 2020; Acosta et al., 2024). The present study aims to analyse the population structure and growth dynamics of rapa whelk in the Romanian waters of the Black Sea, using Von Bertalanffy growth model parameters, length-weight relationships, estimated mortality and exploitation rates. The results obtained will contribute to a better understanding of this species population and support sustainable management efforts.

MATERIALS AND METHODS

The samples were collected during the research survey in June - July 2024 along the Romanian Black Sea coast. A total of 3345 specimens were examined. Sampling was carried out in 51 stations at three depth strata intervals: 5-15 m, 15-25 m, and 25-35 m (Figure 1), ensuring comprehensive coverage of different habitat zones. The collected specimens were measured using callipers, determining their shell length and shell width with a precision of 0,1 cm. For the length distribution analysis, the measurements were grouped into 1 cm length classes (Figure 2). Subsequently, the brut weight and cleaned weight were recorded with a precision of 0.01 g, the cleaned weight representing specimens after complete removal of biofouling and epibionts. Sex determination was performed by morphological examination of the gonads, specifically, each specimen was classified as male or female based on the distinctive coloration of the gonads - males present dark orange gonads while females display yellow gonads (Bondarev, 2015) and age estimation was performed by counting annual growth increments on the shell surface (Hulak et. al., 2022).

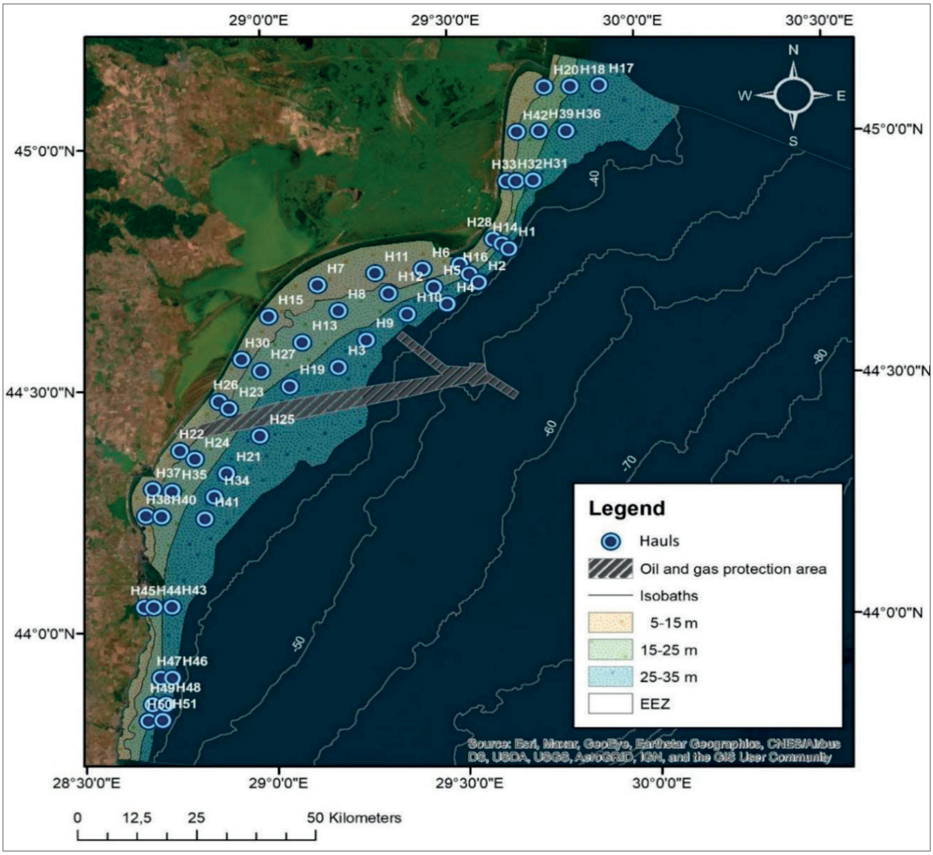

Figure 1. Map of spatial distribution of sampling stations, stratified by depth, along the Romanian Black Sea coast (Dragoș Niculescu, NIMRD "Grigore Antipa")

The depth stratification presented in Table 1 allows for a detailed analysis of the population structure, facilitating the identification of patterns in distribution across different habitat zones.

Table 1. Depth strata, covered area and no. of hauls

Depth strata (m)	Number of hauls	Area (spkm)
5-15	15	1418.01
15-25	15	1662.4
25-35	21	2437.31
TOTAL	**51**	**5517.72**

Subsequently, the variation in the length of the collected specimens (Figure 2) provides a clear representation of their distribution across size classes. This visualization provides insights into growth trends and potential factors affecting size variations among individuals. The estimation of length -weight relationship

Figure 2. Measuring rapa whelk specimens during research survey (original)

(LWRs) was calculated according to the (Ricker, 1975):

$$W = a L^b$$

which can be expressed in its linearized form as:

$$\log W = \log a + b \log L$$

where *W* is the total cleaned weight (g), *L* is the total shell length (cm), *a* is the intercept, and *b* is the slope of the regression. The *b* value was tested by t-test at the significance level of 0.05 to verify if it was significantly different from isometric growth (Beverton & Holt, 1957). The quality of parameters was evaluated using the coefficient of determination (r^2) and 95% confidence intervals (95% CI) (Froese, 2006). The growth parameters were estimated using the von Bertalanffy model, as described by (Beverton & Holt, 1959):

$$Lt = L_\infty (1 - e^{-K (t - t_0)})$$

where L_t is the length at time *t*, L_∞ is the asymptotic length measured in total length, *K* is the VBGF growth constant, and t_0 is the theoretical age at zero length. The parameters of L_∞ and *K* were calculated using the ELEFAN method. The value of t_0 was calculated using the empirical equation proposed by (Pauly, 1980):

$$\log(-t_0) = -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$$

Natural mortality *M* was estimated using the empirical equation developed by (Pauly, 1980):

$$\log M = -0.066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$$

where L_∞ and *K* parameters are the von Bertalanffy equation, and *T* is the mean annual habitat, in °C. Total mortality *Z* was estimated utilizing a catch curves, while fishing mortality *F* was derived from the relationship:

$$Z = F + M$$

To evaluate the impact of fishing pressure on the population, the exploitation rate *E* was calculated according to (Pauly et al., 1984):

$$E = F \times Z^{-1}$$

Statistical analyses were performed using R Studio (Version 2023.06.0+421), JASP (Version 0.18.1), and FiSAT II (Version 1.2.2). R Studio was utilized for data processing, exploratory analysis, and modelling, including applying routines such as ELEFAN pattern analysis, which are essential in fish stock assessment studies. FiSAT II was employed for mortality estimations, JASP facilitated additional statistical tests, including t-tests, ANOVA, and regression analyses, ensuring the robustness and reliability of the obtained results. The combination of these tools allowed for a comprehensive evaluation of the dataset, improving the accuracy of population structure and growth dynamics interpretations.

RESULTS AND DISCUSSIONS

The sex distribution of rapa whelk individuals analysed in this study did not reveal significant differences between depth strata (Table 2). In percentage terms, females were slightly predominant in all three investigated strata, but the differences were not statistically significant (Chi-square test, p = 0.127).

Table 2. Sex distribution by depth strata (no. and %)

	F		M	
Strata	**N**	**%**	**N**	**%**
5-15 m	552	57.08	415	42.92
15-25 m	777	57.90	565	42.10
25-35 m	558	53.86	478	46.14
All strata	1887	56.41	1458	43.59

Note: N - sample size, F - female, M - male

Non-parametric Mann-Whitney U tests, applied for the comparison of F and M pairs in each stratum, indicated values of $p > 0.05$, supporting the hypothesis that there is no significant difference between sexes within each stratum. Also, the Kruskal-Wallis test applied separately for F and M values by depth did not show significant differences between strata (p = 0.368). Thus, the data obtained may reflect a stable population structure, with an F:M ratio close to unity, a characteristic frequently encountered in stable populations of this invasive species.

The length frequency distribution (LFD) of rapa whelk is presented according to sex and sampling depth strata, with cleaned weight highlighted by a heat bar (Figure 3).

Violin plots illustrate the distribution of shell lengths (mm) for both males (M) and females (F) across three depth strata (5-15 m, 15-25 m, and 25-35 m), while box plots indicate the median and quartiles, and individual points are color-coded based on cleaned weight (g). It reveals a clear trend of increasing this species size with depth, suggesting that larger individuals are more frequent in deeper waters. Variability remains relatively constant across depths, though maximum values are slightly higher at greater depths, possibly due to natural selection or resource distribution. Additionally, the similarity in mean values between sexes indicates comparable growth patterns for males and females. The mean LFD values tend to increase with depth, indicating that larger individuals are more frequently found in deeper waters.

Specifically, at depths of 5-15 m, the mean lengths are approximately 62.67 mm for females and 61.15 mm for males. At intermediate depths of 15-25 m, these values slightly increase to around 63.02 mm for females and 63.06 mm for males. At depths of 25-35 m, the mean lengths are noticeably higher, reaching 66.81 mm for females and 66.93 mm for males.

Overall, considering all measurements, the general mean length is 63.94 mm. Similarly, the mean weight also increases with depth for both sexes. . At depths of 5-15 m, the mean weight is 46 g for females and 41.56 g for males. In the 15-25 m stratum, these mean weights increase slightly to 46.29 g for females and 45.77 g for males. At greater depths, between 25-35 m, the mean weight reaches 54.1 g for females and 54.71 g for males.

Considering all measurements, the general mean weight is 48.07 g. The Upeer Whisker values indicate relatively constant variability across depths, but with slightly higher values at greater depths. For example, at 25-35 m, the maximum value reaches 92, compared to 85 at 5-15 m. This may indicate either natural selection for larger individuals at greater depths, or a different distribution of natural resources that favours their growth.

The mean values between sexes are very close between females and males at each depth, suggesting similar growth between the sexes.

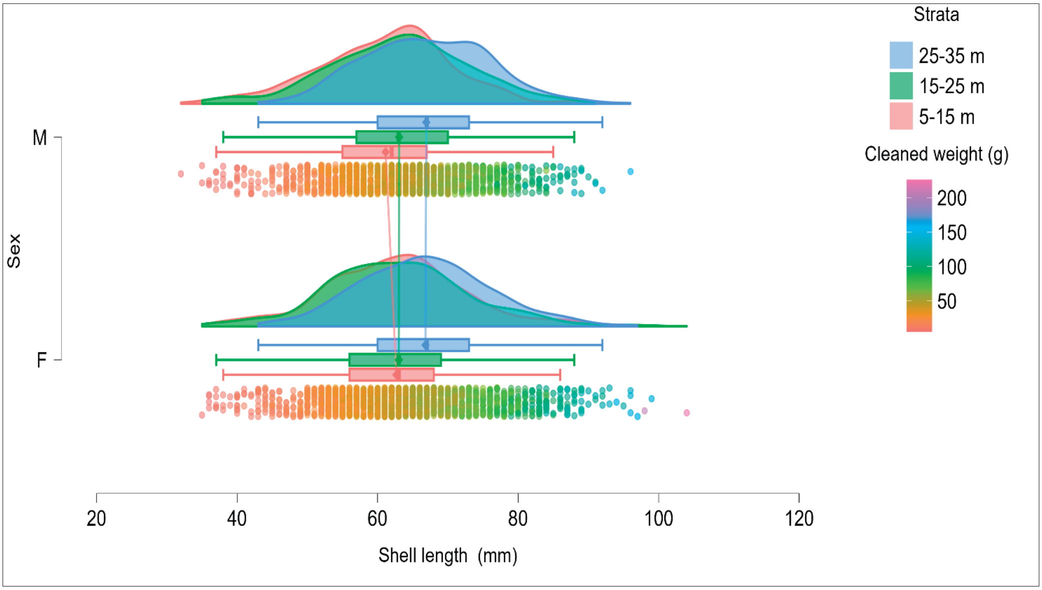

Figure 3. Length frequency distribution (LFD) by sex, depth strata and weight (original)

These observations on variability complement the analysis of mean length and weight across age groups (Figure 4). In the 3-5 year age group, individuals in the 5-15 and 15-25 m strata have smaller mean lengths (43.35 ± 5.12 mm and 42.33 ± 5.12 mm, respectively) compared to those in the 25-35 m stratum (49.11 ± 4.17 mm). As individuals reach the 6-8 year age group, mean lengths become more similar across strata, ranging from (64.64 ± 3.64 to 66.66 ± 2.81 mm). In older individuals 9-11 year, the mean length varies between (78.91 ± 2.59 and 80.58 ± 2.59 mm), with no significant differences among strata. Larger standard errors at younger ages suggest increased variability in the size of juvenile specimens.

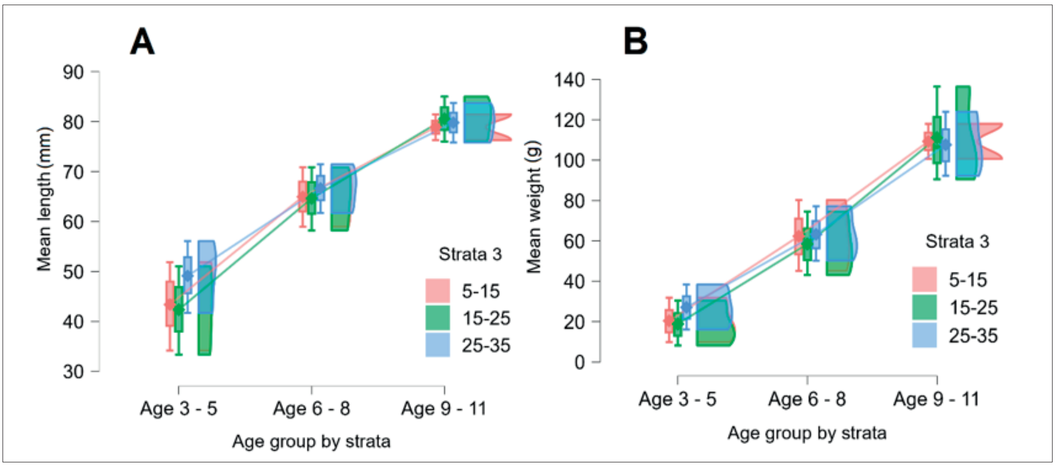

Figure 4. (A) Mean length (mm) and (B) mean weight (g) vs. age group by strata (original)

A similar pattern is observed for weight which increases with age. In the 3-5 year group, individuals in the 25-35 m stratum are heavier (27.05 ± 6.46 g) than those in the 5-15 and 15-25 m strata (ranging from 18.81 ± 6.45 g to 20.39 ± 6.37 g). At 6-8 years, mean weight varies between (58.47 ± 9.05 g and 63.28 ± 7.79 g), with the highest value recorded in the 25-35 m stratum. In the 9-11 year group, mean weight reaches (109.29 ± 8.67 to 111.14 ± 13.44 g) in the 5-15 and 15-25 m strata, but is slightly lower (107.63 ± 9.15 g) in the 25-35 m stratum. Standard errors for weight are generally larger than those for length, indicating greater variability in this parameter. Overall, these data suggest that as individuals grow older, differences among strata become less pronounced, with the 25-35 m stratum displaying higher mean values for both length and weight at younger ages. These findings are relevant for understanding how environmental factors influence the development across different habitats and depth strata. The statistical analysis of the length-weight relationship for rapa whelk (Table 3), conducted across depth strata and segregated by sex, reveals a robust model with very high coefficients of determination (r^2 0.919 and 0.939), indicating that over 91% of the variation in weight is explained by length. For each stratum, the parameters *a* and *b* were estimated, with the values of a (in the order of 10^{-4}) showing slight variations between strata and sexes, while the exponent *b* remains nearly constant around the value of 3 (ranging from 2.963 to 3.093). This suggests an almost isometric growth pattern, where weight increases proportionally to the cube of the length.

Table 3. Length-weight relationships of rapa whelk by depth strata and sex along the Romania Black Sea coast

				95% CI for a				95% CI for b					
Strata	**Sex**	**n**	**a**	**lower**	**upper**	**b**	**$SE_{(b)}$**	**lower**	**upper**	**r^2**	**df**	**P**	**GT**
5-15 m	F	552	0.00013	0.0001	0.00018	3.063	0.035	2.994	3.133	0.932	550	> 0.05	I
15-25 m	F	777	0.00018	0.0001	0.00023	2.981	0.027	2.927	3.034	0.939	775	> 0.05	I
25-35 m	F	558	0.0002	0.0001	0.00026	2.963	0.034	2.896	3.031	0.93	556	> 0.05	I
5-15 m	M	415	0.00011	0.0001	0.00016	3.093	0.039	3.016	3.169	0.939	413	< 0.05	A+
15-25 m	M	565	0.00013	0.0001	0.00017	3.061	0.033	2.997	3.125	0.939	563	> 0.05	I
25-35 m	M	478	0.00016	0.0001	0.00022	3.018	0.041	2.937	3.098	0.919	476	> 0.05	I
5-15 m	C	967	0.00012	0.0001	0.00015	3.081	0.026	3.03	3.133	0.935	965	< 0.05	A+
15-25 m	C	1342	0.00016	0.0001	0.00019	3.014	0.021	2.973	3.056	0.939	1340	> 0.05	I
25-35 m	C	1036	0.00018	0.0001	0.00022	2.987	0.026	2.935	3.039	0.925	1034	> 0.05	I
All strata	F	1887	0.00017	0.00015	0.0002	3.001	0.018	2.966	3.037	0.937	1885	> 0.05	I
All strata	M	1458	0.00012	0.00011	0.00015	3.074	0.021	3.033	3.115	0.938	1456	< 0.05	A+
All strata	C	3345	0.00015	0.00013	0.00017	3.033	0.014	3.006	3.06	0.937	3343	< 0.05	A+

Note: n = sample size, a coefficient (regression intercept), b coefficient (regression slope), their standard errors (SE), 95% confidence intervals (C.I.), the coefficient of determination (r2), degrees of freedom (df), and P value from t-test for isometric growth (H_0: b=3); growth type (GT), I = isometric, A+ = positive allometry; A- = negative allometry.

Sample sizes (n) were substantial, ranging from 415 to 1342 depending on the stratum and sex, and the statistical significance analyses (P) indicate, in most cases, a lack of significant differences between groups (P > 0.05), except in certain instances, such as males in the 5-15 m stratum and in the combined datasets for males and the total sample, where significant values were obtained (P < 0.05, GT = A+).

This detailed analysis underscores the subtle influences of environmental factors and sex differences on the morphometric relationship of this species in the Black Sea.

The robust findings from our statistical analysis on the Romanian Black Sea coast provide a solid baseline for understanding the length–weight relationship of rapa whelk.

To further contextualize these results, the following comparative table presents data from previous studies conducted in various regions of the Black Sea (Table 4), including areas in Turkey, Bulgaria, Ukraine, and Georgia.

This comparison highlights similarities and regional differences in the parameters *a* and *b*, shedding light on how local environmental conditions and sampling methodologies may influence growth patterns in this species.

Table 4. Comparisons with literature on the length-weight relationship for rapa whelk in different areas

Area	Country	Sex	A	b	r^2	Year	Reference
East Black Sea	Turkiye		0.0002	3.058			Şahin et al., 2009
Romania Black Sea coast	Romania		0.0002	2.568	0.83		Micu et. al., 2008
Easter Black Sea	Turkiye	F	0.00006	3.262	0.94	2000	Saglam & Düzgüneş, 2014
Easter Black Sea	Turkiye	M	0.00008	3.195	0.95	2000	Saglam & Düzgüneş, 2014
Trabzon	Turkiye		0.0004	2.826	0.89	2007	Saglam et al., 2015
Samsun	Turkiye		0.0011	2.559	0.85	2007	Saglam et al., 2015
West Black Sea	Turkiye		0.0004	2.824	0.89	2011	Dağtekin, 2023
West Black Sea	Turkiye		0.0001	3.089	0.94	2012	Dağtekin, 2023
Sinop and Samsun	Turkiye		0.005	2.79	0.9	2015	Gönener & Özsandikçi, 2017
Western Black sea - Varna Bay	Bulgaria	F	0.122	3.15	0.94	2016	Trayanova, 2016
Western Black sea - Varna Bay	Bulgaria	M	0.1	3.26	0.88	2016	Trayanova, 2016
Western Black sea - Varna Bay	Bulgaria	C	0.114	3.194	0.92	2016	Trayanova, 2016
SUMAE	Turkiye	C	0.1803	2.9068		2017	GFCM 2023
Bulgaria	Bulgaria	C	0.16	2.99		2017	GFCM 2023
Ukraine	Ukraine	C	0.334	2.7259		2017	GFCM 2023
SUMAE	Turkiye	C	0.1491	3.0854		2018	GFCM 2023
Bulgaria	Bulgaria	C	0.1642	2.99		2018	GFCM 2023
Ukraine	Ukraine	C	0.4304	2.5339		2018	GFCM 2023
SUMAE	Turkiye	C	0.1358	3.1044		2019	GFCM 2023
Bulgaria	Bulgaria	C	0.000078	3.1641		2019	GFCM 2023
Ukraine	Ukraine	C	0.2328	2.8931		2019	GFCM 2023
SUMAE	Turkiye	C	0.187	2.9489		2020	GFCM 2023
Bulgaria	Bulgaria	C	0.000087	3.1249		2020	GFCM 2023
Ukraine	Ukraine	C	0.469	2.568		2020	GFCM 2023
SUMAE	Turkiye	C	0.1787	2.9812		2021	GFCM 2023
Bulgaria	Bulgaria	C	0.0005	2.7265		2021	GFCM 2023
Ukraine	Ukraine	C	0.309	2.756		2021	GFCM 2023
NEA	Georgia	C	0.2517	2.8761		2021	GFCM 2023
SUMAE	Turkiye	C	0.1917	2.9225		2022	GFCM 2023
Bulgaria	Bulgaria	C	0.00024	2.915		2022	GFCM 2023
SUMAE	Turkiye	C	0.1406	3.082		2023	GFCM 2023
IFR	Bulgaria	C	0.00021	2.943		2023	GFCM 2023
NEA	Georgia	C	0.2905	2.8048		2023	GFCM 2023
Romania Black Sea coast	Romania	F	0.00017	3.001	0.937	2024	Present study
Romania Black Sea coast	Romania	M	0.00012	3.074	0.938	2024	Present study
Romania Black Sea coast	Romania	C	0.00015	3.033	0.937	2024	Present study

The results of growth parameter analysis showed that rapa whelk can reach an asymptotic length L_∞ (Figure 5), in the 5-15 m stratum, the asymptotic length L_∞ is 100 mm, the growth coefficient K is 0.373, and the theoretical age at length zero t_0 is -0.498. In the 15-25 m stratum, L_∞ reaches 109.47 mm, K is 0.326, and t_0 is -0.449. In the 25-35 m stratum, L_∞ is 102.11 mm, K is 0.306, and t_0 is -0.411. These parameters indicate a clear trend of decreasing growth rates K with increasing depth, while the maximum achievable length L_∞ varies, peaking at the intermediate depth (15-25 m). The estimated mortality parameters for the analysed depth layers are illustrated by the graphs in Figure 6 describe the relationship between the natural logarithm of the number of individuals per length class (ln(N/dt)) and the estimated relative age (years - t_0), a method commonly used to estimate mortality parameters.

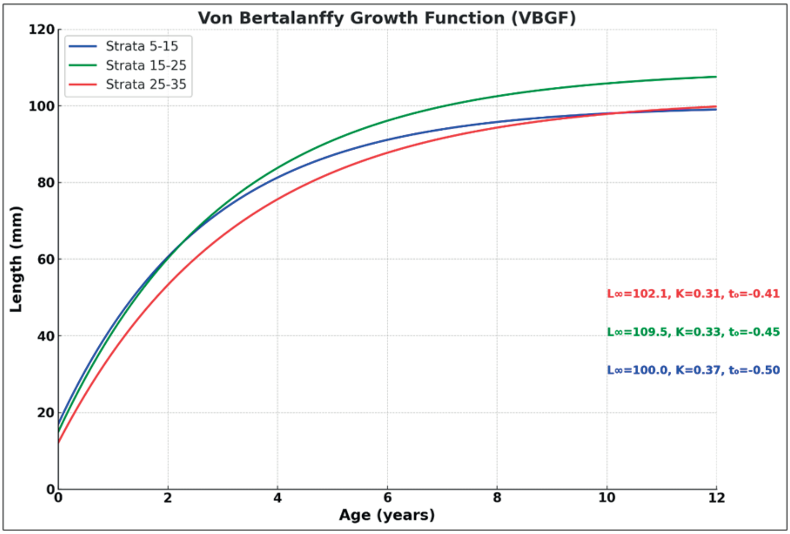

Figure 5. Von Bertalanffy Growth Function (VBGF) by strata (original)

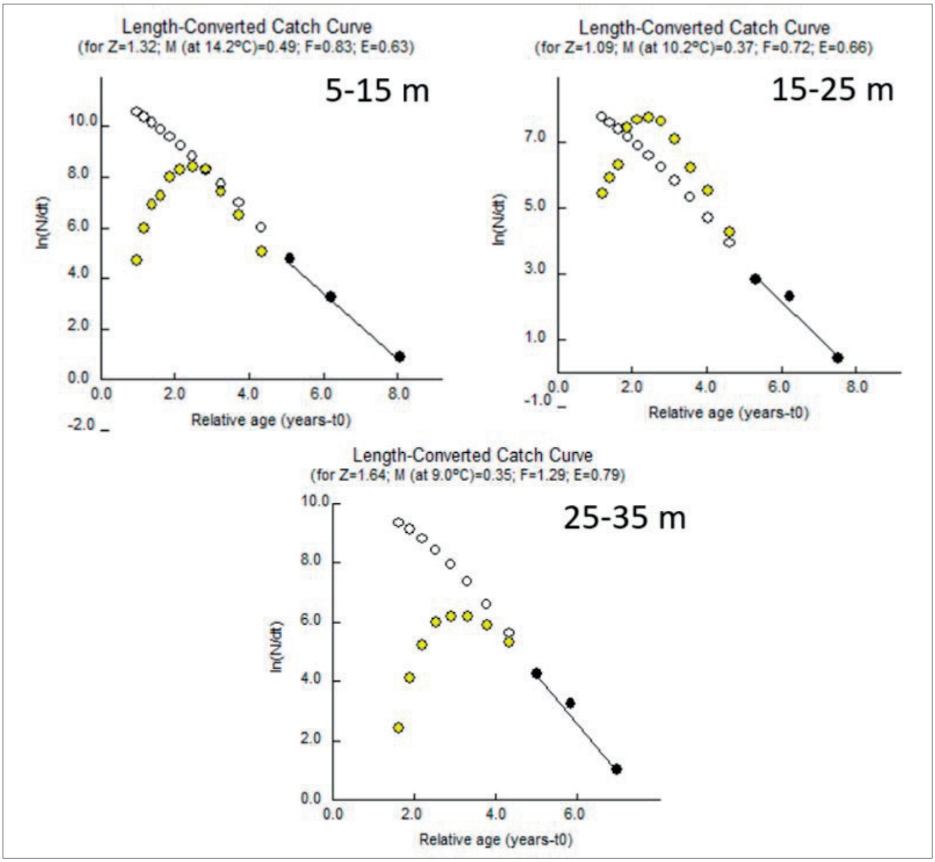

Figure 6. Length-converted catch curve by strata (original)

In the 5-15 m stratum, the natural mortality *M* is 0.49, fishing mortality *F* is 0.83, total mortality *Z* is 1.32, and the exploitation rate *E* is 0.63. In the 15-25 m stratum, the values are $M = 0.37$, $F = 0.72$, $Z = 1.09$, and $E = 0.66$. For the 25-35 m stratum, the values are $M = 0.35$, $F = 1.29$, $Z = 1.64$, $E = 0.79$. Given that the exploitation rates *E* exceed the commonly accepted sustainable threshold 0.50, all analysed strata indicate significant fishing pressure and thus a state of overexploitation. This high exploitation rate reflects an imbalance between the removal rate of this species and the natural capacity of the stock to recover through growth and recruitment.

CONCLUSIONS

The study highlighted the population structure and growth dynamics of rap whelk species. The results showed a stable population structure with a slight predominance of females, but without significant statistical differences between sexes or depth strata. The length-weight relationship analysis indicated an almost isometric growth pattern, with growth values close to the cube of length. The highest growth potential, according to the Von Bertalanffy growth model, was observed at intermediate depths (15-25 m). Mortality rates, including natural mortality, fishing mortality, and total mortality, revealed fishing as the primary impacting factor. The high exploitation rates observed on all depth strata indicate significant fishing pressure, highlighting the need for management measures to ensure the recovery of stocks on the Romanian Black Sea coast.

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REFERENCES

Abaza, V., Dumitrache, C., & Dumitrescu, E. (2010). Structure and distribution of the main molluscs from the Romanian marine areas designated for their growth and exploitation. *Recherches Marines, 39,* 137-152.

Acosta, M. S., Góngora, N., Antuña, D., Correa, P., Chiesa, E., Olivera, E. B., & Muniz, P. (2024). An update of the invasion status of *Rapana venosa* (Mollusca: Gastropoda) in the Río de la Plata estuary. *Marine & Fishery Sciences (MAFIS), 37*(3), 435-448 from https://doi.org/10.47193/mafis.37X2024010109

Beverton, R. J. H., & Holt, S. J. (1957). On the Dynamics of Exploited Fish Populations. *Gt. Britain Fish Invest*., Ser. 2, 19, 1-533.

Beverton, R. J. H., & Holt, S. J. (1959). The lifespan of animals. In O'Conner M. (Ed.), *A review of the lifespans and mortality rates of fish in nature, and their relationship to growth and other physiological characteristics.* Chapter 10, 142-180. Wolstenholme GEW, Ciba Foundation (Colloquia on Ageing); Volume 5; J. and A. Churchill, London, UK, https://doi.org/10.1002/9780470715253.ch10

Bondarev, I. P. (2013). Ecomorphological Analyses of Marine Mollusks' Shell Thickness of Rapana venosa (VALENCIENNES, 1846) (Gastropoda: Muricidae). *International Journal of Marine Science, 3*(45), 368-388, DOI: 10.5376/ijms.2013.03.0045.

Bondarev, I. P. (2014). Dynamics of Rapana venosa (VALENCIENNES, 1846) (Gastropoda: Muricidae) Population in the Black Sea. *International Journal of Marine Science, 4(3),* 42-56.

Bondarev, I. P. (2015). Sexual differentiation and variations sexual characteristics *Rapana venosa* (Valenciennes, 1846). *International Journal of Marine Science, 5(19),* 1-10.

Bondarev I. P. (2016) Structure of Rapana venosa (Gastropoda, Muricidae) population of Sevastopol bays (the Black Sea). *Marine Biological Journal*, 1(3), 14-21.

Bondarev, I. P., & Revkov, N. K. (2018) Consorts of gastropod *Rapana venosa* (Valenciennes, 1846) in the Northern Black Sea. Part III: Mollusca (Gastropoda). *Marine Biological Journal, 3(1),* 23-34.

Bondarev, I. P. (2024). Functional morphology and morphological variability of the operculum of *Rapana venosa* (gastropoda, muricidae). *Marine Biological Journal*, *8(4),* 23-39.

Danilov, C. S., Țiganov, G., Anton, E., Nenciu, M. I., Niţă, V. C., & Cristea V. (2018). *Rapana venosa* - new exploitable resource at the Romanian Black Sea coast. *Scientific Papers. Series D. Animal Science, LXI(2),* 274-279.

Dağtekin, M. (2023). The invasive mollusk Rapana venosa (Mollusca: Neogastropoda: Muricidae) in the mid-southern Black Sea: Distribution, growth, and stock structure. *Acta Ichthyologica et Piscatoria*, 53, 191-199, https://doi.org/10.3897/aiep.53.113745

Drapkin, E. (1963). Effect of Rapana bezoar Linne (Mollusca,Muricidae) on the Black Sea fauna. In *Doklady Akademii Nauk SRR, 151(3),* 700-703.

European Commission (2025). *Fishing fleet capacities*. Accessed (20.01.2025), from https://oceans-and-fisheries.ec.europa.eu/fisheries/rules/fishing-fleet-capacities_en

FiSAT II (Version 1.2.2) [Computer software]. FAO-ICLARM Stock Assessment Tools II, Food and Agriculture Organization of the United Nations (FAO), Rome, 2025, from https://www.fao.org/fishery/en/topic/16072/en

Froese, R. (2006). Cube law, condition factor and weight–length relationships: History, metaanalysis and recommendations. *Journal of Applied Ichthyology, 22(4)*, 241-253, from https://doi.org/10.1111/j.1439-0426.2006.00805.x

General Fisheries Commission for the Mediterranean. (GFCM) (2023). *Validated stock assessment forms (SAFs)*. Accessed (10.01.2025), from https://www.fao.org/gfcm/data/safs/fr/

Gomoiu, M. T. (1972). Some ecologic data on the gastropod *Rapana thomasiana* Crosse along the Romanian Black Sea shore. *Recherches Marines*, *4,* 169-180.

Gönener, S., & Özsandıkçı, U., (2017). Density distribution and some biological properties of veined rapa whelk *Rapana venosa* (Valenciennes, 1846) populations in south central Black Sea. *Cah. Biol. Mar., 59,* 199-206, DOI: 10.21411/CBM.A.8355944F

Hulak, B., Leonchyk, Y., & Chashchyn, O. (2022). The Main Biological Parameters of Rapa Whelk Rapana venosa Population in the North-Western Section of the Black Sea, *Hydrobiological Journal, 58(3)*, 29-45.

JASP (Version 0.18.1) [Computer software]. University of Amsterdam, from https://jasp-stats.org/

Khoroshutina, O., Pierce, G. J., F., & Lishchenko, F., (2024) Statoliths of *Rapana venosa* (Valenciennes, 1846): Microstructure, application for age determination and growth modelling. *Regional Studies in Marine Science, 74*, from https://doi.org/10.1016/j.rsma.2024.103527

Micu, S., Kelemen, B., & Mustata, G. (2008). Current distribution and shell morphotypes of *Rapana venosa* (Valenciennes, 1846) in the Agigea 4 m littoral. *Analele Stiintifice ale Universiatii "Al. I. Cuza" Iasi, s. Biologie animala, 54,* 185-189.

Mutlu, E., Kideys, A., Sahin, F., Erik, G., Aksu, H., Erdem, E., Karayücel, S., & Bat, L. (2022). Population dynamics and ecology of the invasive veined rapa whelk, Rapana venosa in the southern Black Sea. *Estuarine Coastal and Shelf Science, 268,* https://doi.org/10.1016/j.ecss.2022.107807

Occhipinti-Ambrogi, A., Marchini, A., Cantone, G., Castelli A., Chimenz C., Cormaci M., Froglia C., Furnari G., Gambi, M. C., Giaccone G., Giangrande A., Gravili, C., Mastrototaro, F., Mazziotti., C., Relini-O., L., & Piraino S. (2011). Alien species along the Italian coasts: an overview. *Biol. Invasions, 13,* 215–237, https://doi.org/10.1007/s10530-010-9803-y

Pauly, D. (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks, *ICES Journal of Marine Science*, *39(2),* 175–192, https://doi.org/10.1093/icesjms/39.2.175

Pauly, D., Ingles, J., & Neal, R. (1984). Penaeid shrimps: their biology and management. In Gulland, J. A., & Rothschild, B. J. (Eds.), *Application to shrimp stocks of ob¬jective methods for the estimation of growth, mortality and recruit-ment-related parameters from length-frequency data (ELEFAN I and II),* 220-234. Fishing New Books, Farnham, England, from https://hdl.handle.net/20.500.12348/3505

Petrova, P. E., Tserkova F., Mihneva, V., Stoykov, S., Valchev, S., & Penchev, P. (2020). Fish Bycatch Rate by *Rapana venosa* (Valenciennes, 1846) Fishery in the Bulgarian Black Sea Waters, with a Special Emphasis on the Bycatch of Turbot Scophthalmus maximus (L., 1758). *Acta Zoologica Bulgarica, Supplement 15,* 165-172.

R Studio (Version 2023.06.0+421) [Computer software]. Posit Software, PBC, from https://posit.co

Ricker, W. E. (1975). *Computation and interpretation of biological statistics of fish populations.* Ottawa, USA: Bulletin of the Fisheries Research Board of Canada, Bulletin 191.

Sağlam, N. E., Sağlam, C., & Sağlam, Y. D. (2015) Determination of some population parameters of the veined rapa whelk (*Rapana venosa*) in the Central Black Sea. *Journal of the Marine Biological Association of the United Kingdom*, *95(1),* 123-129.

Saglam, H., Kutlu, S., Dağtekin, M., Başçinar, N. S., Şahin, A., Selen, H., & Duzgunes, E. (2015). Population biology of *Rapana venosa* (Valenciennes, 1846) (Gastropoda: Neogastropoda) in the south-eastern Black Sea of Turkey. *Cash. BİOL. Mar., 56,* 363-368.

Saglam, H., & Düzgüneş E. (2014). Biological parameters and feeding behaviour of invasive whelk *Rapana venosa* Valenciennes, 1846 in the south-eastern Black Sea of Turkey. *Journal of coastal life medicine, 2*, 442-446.

Savini, D., Castellazzi, M., Favruzzo, M., & Occhipinti-Ambrogi, A. (2004). The alien mollusc *Rapana venosa* (Valenciennes, 1846; Gastropoda, Muricidae) in the Northern Adriatic Sea: Population structure and shell morphology. *Chemistry and Ecology, 20(sup1)*, 411-424.

Spotorno-Oliveira, P., Lopes, R. P., Larroque, A., Monteiro, D., Dentzien-Dias, P., & de Souza Tamega, F. T. (2020). First detection of the non-indigenous gastropod *Rapana venosa* in the southernmost coast of Brazil. *Continental Shelf Research, 194*, 104047, https://doi.org/10.1016/j.csr.2020.104047

Stadnichenko, S., & Kurakin, A. (2022). Feeding intensity and daily mussel consumption of Rapa whelk (*Rapana venosa*) in the north-western Black Sea. *Oceanological and Hydrobiological Studies, 51(4),* 344-354, https://doi.org/10.26881/oahs-2022.4.04

Şahin, C., Emiral, H., Okumuş, İ., Gözler, A. M., Kalayci, F., & Hacimurtezaoglu, N., (2009). The benthic exotic species of the Black Sea: Blood cockle (*Anadara inaequivalvis*, Bruguiere, 1789: Bivalve) and rapa whelk (*Rapana thomasiana*, Crosse, 1861: Mollusc). *Journal of Animal and Veterinary Advances, 8(2)*, 240-245.

Teacă, A., Begun, T., & Gomoiu, M. T., (2007). The ecological status of the populations of *Rapana venosa* from the Romanian coast of the Black Sea. *Geo-Eco-Marina 14/2008, Supliment 1,* 51-56, http://geoecomar.ro/website/publicatii/supliment2008/6.pdf

Trayanova, A. (2016). Size-weight characteristics, gender structure and density of *Rapana venosa* (Valenciennes, 1846) population in varna bay. *Union of Scientists,* 84-91, https://www.su-varna.org/izdanij/2016/Morski-016/pp_84_91.pdf

Ţiganov, G., Danilov, C. S., Nenciu, M. I., Anton, E., & Năstase, A. (2018). New Equipment and Technologies Used for Rapa Whelk Harvesting at the Romanian Black Sea Coast. In: Finkl, C. & Makowski, C. (Ed.) *Diversity in Coastal Marine Sciences. Coastal Research Library, Springer, 23,* 397-404, https://doi.org/10.1007/978-3-319-57577-3_23

Țiganov, G., Niță, V., Danilov, C. S., Păun, C., Diaconu, D., Grigoraș, D., Nenciu, M., & Galațchi, M. (2024). Status of the Rapa Whelk Agglomerations Along the Romanian Black Sea Coast. *Recherches Marines, 53(1),* 70-82, https://doi.org/10.55268/CM.2023.53.70

Xue, D. X., Graves, J., Carranza, A., Sylantyev S., Snigirov, S., & Liu, J. X. (2018). Successful worldwide invasion of the veined rapa whelk, *Rapana venosa*, despite a dramatic genetic bottleneck. *Biol. Invasions, 20,* 3297–3314.

Zolotarev, V. (1996). The Black Sea Ecosystem Changes Related to the Introduction of New Mollusc Species. *Marine Ecology, 17,* 227-236.