



BIOLOGICAL MONITORING (BIOLOGICAL SAMPLES
COLLECTION) OF THE LANDED RAPANA CATCH BY THE
BULGARIAN FISHING FLEET

Scientific REPORT FOR 2ND QUARTER OF 2018



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This research is carried out by researchers from the Institute of Fish Resources – Varna, Agricultural Academy (AA), within Contract EAFA-Burgas/D-157/16.05.2018 and is focused on the scientific assessment of the quantity and biological parameters of rapana from the landed catch by the Bulgarian fishing fleet in 2018.

This research was done with the financial support from the European Commission in accordance with Regulation №199/2008 of the Council and Decision 2010/93/EC of the Commission, allocated to support member states in the preparation of technical report for the development of a common framework for collection, management and use of data in the Fisheries' sector and to support the scientific consultations about the overall policy in the fisheries' field.

The research is indicative for the 2nd quarter of 2018 and presents the dynamics of the biological parameters of rapana from the landed catch at Rezovo, Varna, Durankulak and Byala, based on the biometric measurements and analysis of 400 individual species.

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Petrova E., Miheva V., Tserkova F., Stoykov S., Valchev S., Penchev Ph., 2018. BIOLOGICAL MONITORING (BIOLOGICAL SAMPLES COLLECTION) OF THE LANDED RAPANA CATCH BY THE BULGARIAN FISHING FLEET FOR 2ND QUARTER 2018, Report unde Contract with Execute Agency for Fisheries and Aquacultures, Program for fishing data collection in 2018, p.45.

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1. INTRODUCTION

The predator snail *Rapana venosa* (*f. Muricidae*) is an invasive species for the Black Sea. The species had been introduced back in the 50s and had successfully adapted to the conditions in the Black and Azov Seas. It feeds with crustacean species and destroys their gatherings.

Turkey starts exploiting rapana back in the 80s and as of now the catch reaches values between 6 and 8 thousand tons. All Black Sea countries perform rapana fishing, while the total catch varies between 10-15 thousand tons. The rapana catch in the Bulgarian territorial waters is around 4 000 t/year for the period 2014 – 2017. This puts the species in second place after the sprat in terms of industrial fishing, however there are years when the rapana is the primary species.

Until 2012 the rapana catch was allowed to be done only by scuba-diving gear. Since 2012 rapana catch with beam trawl has been allowed, regulated by article 35, I.3 from FAA: "industrial and amateur fishing is banned for the objects in article 3, I.1 with the following gears, tools and equipment: I.3 (amended SN, I.59 from 2002) bottom and dredging tools with the exception of beam trawl. During the summer months rapana fishing is still done by scuba divers with small fishing vessels.

Biological monitoring of rapana samples, collected by the landings of the fishing fleet, started in 2018 with quarterly analysis for the calendar year. The monitoring is focused on the dynamics of the landings, weight and gender structure of *R. Venosa* based on the biological samples, by deriving linear-weight ratios and comparison between the different fishing sites.

This report is representative for the 2nd quarter of 2018 and is based on the biometric measurements of 400 individuals *R. venosa*. The document presents detailed data and analysis for the biological parameters of the target species – quantities, linear-weight structure, linear-weight ratios and gender structure for the landings at ports Rezovo, Byala, Varna and Durankulak.

1.1 DATA COLLECTED

This research allowed the collection of the following different types of data:

1. Information on the fishing vessels' activities

- Date of expedition/survey
- Departure port
- Arrival port
- Fishing vessel's name
- Vessel's type
- Vessel's length (m)

2. Used gears

- Depth range of the fishing activities

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3. Basic biological data

- Total weight of target species, landed at port by the relevant fishing vessels
- Total weight of bycatch
- Number of collected individuals for biological sampling
- Total weight of the sample (Total weight – shell weight (TW, g),
- Shell length (Shell length, SL, mm),
- Shell width (mm)
- Shell opening length (Aperture length, AL, mm).

4. Additional biological data

- Gender maturity of collected individuals and relationship between gender, gonado-somatic index (if applicable);
- Gender maturity to shell length, relationship of the genders to shell length and genders to total weight of the individuals.

Results are presented in the form of tables and maps, including data for:

- Target species quantities landed at the ports
- Biological parameters of the rapana – weight, size, linear-weight ratio, gender structure of the samples.

2. MATERIALS AND METHODOLOGY

2.1 SAMPLING SITES

The collection of biological samples (each 400 individuals) was done by using landing sites at four ports – two in the south, and two in the north, in order to assess the differences between the species parameters in the primary fishing sites.

Main ports for sample collection are – Rezovo, Varna, Byala and Durankulak.

The research covered 4 days in the period 01.06 - 30.06.2018 г., and the gathered information is presented in Table 1.

Table 1.

Ports and vessels, which were used for the biological monitoring of landed rapana catch

Date	Fishing vessel's name	No of fishing vessel	Technical specifications	Departure port	Arrival port	Fishing method
18.06.2018	Boat, Elekta	БС 1280	Length - 9 m; Total weight - 4.66 GT; Power 58.84 kW	Rezovo	Rezovo	Scuba
18.06.2018	Tais	ВН 393	Length - 19.4 m; Total weight - 46 GT; Power 378 kW	Varna	Varna	Beam trawl
21.06.2018	Boat, Elekta	ШБ 5939	Length - 3.95 m.; Total weight - 0.48	Durankulak	Durankulak	Scuba

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			GT;			
22.06.2018	Boat, Elekta	БЛ 2947	Length - 7.5 m.; Total weight - 3.68 GT; Power 40.45 kW	Byala	Byala	Scuba

It can be concluded that in the summer months the most common fishing method is scuba diving. The beam trawl was used only around Varna and its technical specifications were: maximal beam length 10 m; max. hight of the appreture 500 mm; sledge and slipper: min. width 200 mm, min. length 500 mm; number of chains - max 5, diatmeter of rings -max. 10 mm; minim. size of net "eye" near to the sack - 40 mm (Order NAFA, 07/08/2013 г.).

2.2 SAMPLE PROCESSING

Random samples to assess the development of *Rapana venosa* in the active fishing season are collected onshore from the landings.

2.3. LABORATORY ANALYSIS

The size, weight and gender structures of the rapana landing is determined by analyzing the size, weight and gender classes of the individuals from different landing (minimum 400 individuals) in the spring-summer period of 2018.

To do this:

- For each individual, basic biometric parameters are measured – total weight of individuals (total weight – shell weight, TW, g), body weight of individuals (body weight – shell weight, BW, g), shell length (shell length, SL, mm), shell width (Wd, mm) and aperture length (aperture length, AL, mm).
- The ratios between all the biometric parameters are calculated
- Gender maturity of the collected individuals is determined and the gender ratio, GSI (if applicable);
- The ratio between the length of the shell and gender is calculated and compared to the total weight of the individuals.

2.4 STATISTICAL METHODS

Morphometric ratios between the different biological parameters – total weight (TW), body weight (BW), shell length (SL), shell width (Wd), aperture length (AL) – are analyzed based on the classical analytical methods. Derived results are further processed by using the least squares method and relevant equations:

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

W – weight; L – size; a, b – constants.

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Natural logarithm (\ln) is used for second way of calculating the parameters a, b of the $L\text{-}W$ ratio:

$$TW(g) = a \cdot SL(mm)^b, \text{ followed by anti-logarithm so } a = \ln q \text{ and } q = \exp^a.$$

XLSTAT software is used to make the linear-weight histograms of the samples from the landed catch, as well as for the data processing. The statistical data about the different classes, presented in the histograms, include – lower and upper limits of the classes, frequency, relative frequency and density.

The accuracy of the software for sample collection is based on the following documents:

- Report of the Workshop on Sampling and Calculation Methodology for Fisheries Data (WKSCMFD) (ICES 2004);
- Report SGPIDS (ICES, 2011a),
- Report of the Study Group on Practical Implementation of Discard Samples (SGPIDS).

3. RESULTS

3.1. BIOMETRIC MEASUREMENTS

3.1.1 LENGTH-WEIGHT RATIOS

3.1.1.1 PORT REZOVO, 18.06.2018

The sample consists of 100 individuals rapana, with a total weight of 14.069 kg from landed 345 kg rapana at Rezovo Port. Rapana was caught by using scuba diving method.

The mean weight of the measured individuals is $140.70 \text{ g} \pm 30.35 \text{ SD}$, average length - $89.59 \text{ mm} \pm 6.62 \text{ SD}$, shell width - $67.29 \text{ mm} \pm 6.20 \text{ SD}$ and aperture length - $54.55 \pm 8.95 \text{ SD}$ (Table 2).

Table 2

Summarized data about biological parameters – total weight of the species in the sample (TW – shell weight, TW, g), shell length (shell length, SL, mm), shell width (Wd, mm) and aperture length (aperture length, AL, mm).

	TW,g	SL, mm	Wd, mm	AL, mm
Mean	140.70	89.59	67.29	54.55
Standard Error	3.03	0.66	0.62	0.90
Median	139.75	90.00	68.00	52.50
Mode	143.50	92.00	68.00	51.00
Standard Deviation	30.35	6.62	6.20	8.95
Sample Variance	921.10	43.88	38.45	80.11
Kurtosis	-0.31	-0.57	-0.23	-0.32
Skewness	0.32	-0.14	-0.02	0.63
Range	137.00	29.00	32.00	40.00
Minimum	78.50	75.00	52.00	39.00
Maximum	215.50	104.00	84.00	79.00
Sum	14069.90	8959.00	6729.00	5455.00
Count	100.00	100.00	100.00	100.00
Confidence Level(95.0%)	6.02	1.31	1.23	1.78

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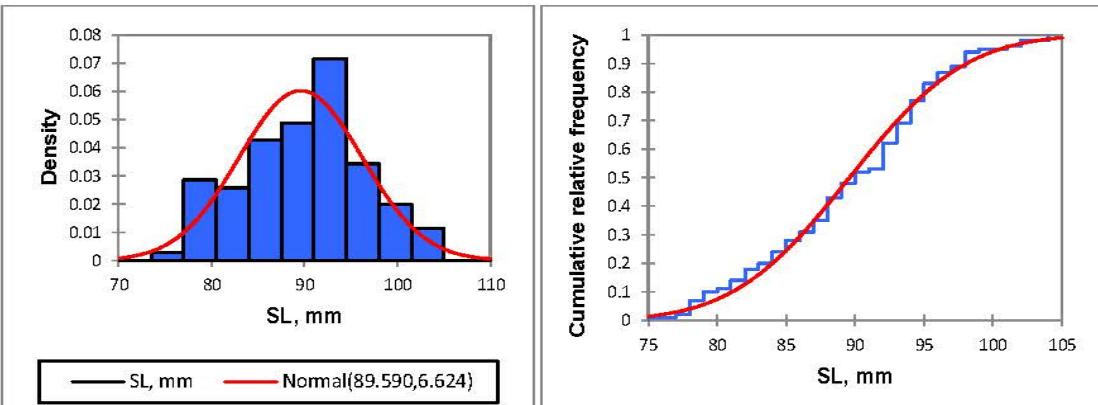


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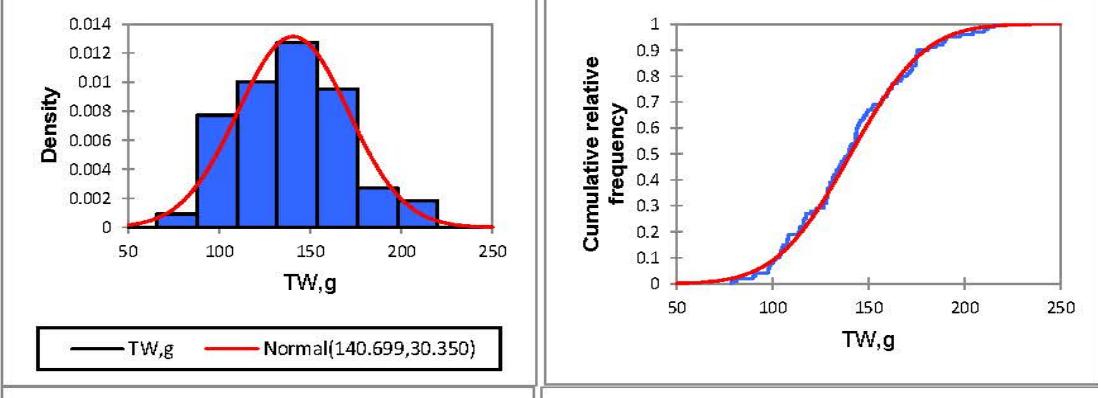


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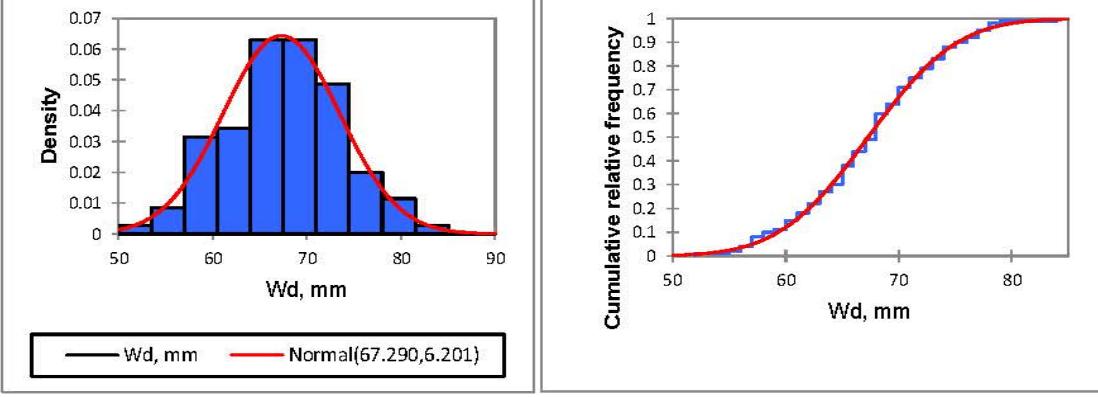
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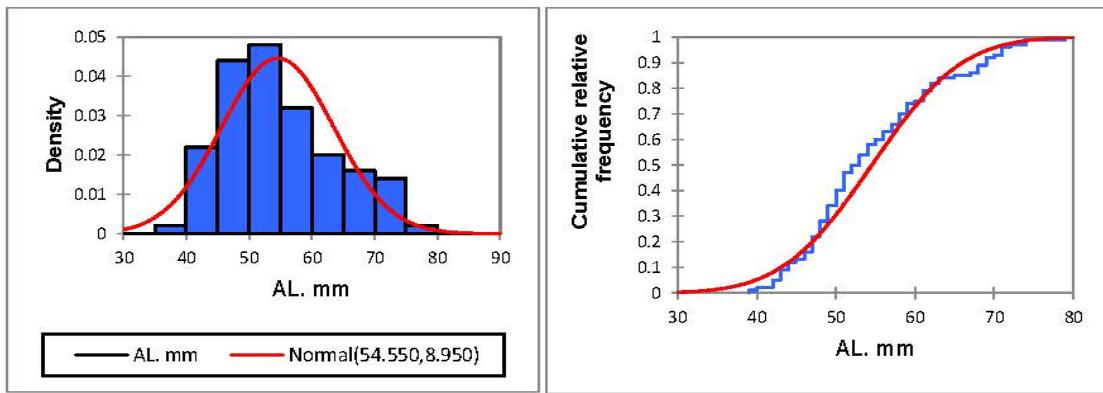
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4.

Figure 1. Distribution of measured parameters: shell length (SL, mm, 1), total weight (TW, g, 2), shell width (Wd, mm, 3), aperture length (AL, mm, 4) by classes and cumulative distribution of the classes in the sample from Rezovo, 18/06/2018

The most common species are within size class - 91 - 94.5 SL mm (25 % from measured species), as well as classes - 87.5 - 91 mm (17 %) and 84 - 87.5 mm (15 %, Fig. 1.1, Table 3.1).

For weight classes (TW, g), the predominant classes are: 132 - 154 g (28 % from all measured individuals), 110 - 132 g (22 %) and 154 - 176 g (21 % from total number of measured individuals (Fig. 1.2, Table 3.2)).

Table 3

Statistical data about the distribution of size classes (mm, 1) and weight (g, 2) of rapana in the sampling from Rezovo Port/18.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	73.5	77	1	0.010	0.003
	77	80.5	10	0.100	0.029
	80.5	84	9	0.090	0.026
	84	87.5	15	0.150	0.043
	87.5	91	17	0.170	0.049
	91	94.5	25	0.250	0.071
	94.5	98	12	0.120	0.034
	98	101.5	7	0.070	0.020
	101.5	105	4	0.040	0.011

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	66	88	2	0.020	0.001
	88	110	17	0.170	0.008
	110	132	22	0.220	0.010

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132	154	28	0.280	0.013
154	176	21	0.210	0.010
176	198	6	0.060	0.003
198	220	4	0.040	0.002

For the parameter “shell width” (Wd, mm), the most common species are (*22 % from all individuals): 64 - 67.5 mm and 67.5 - 71 mm, followed by - 71 - 74.5 mm (17 %, Fig. 1.3).

The parameter “aperture length” (AL, mm) is dominated by classes 50 - 55 mm (24 %) and 45 - 50 mm (22 %, Fig. 1.4).

The following percentage ratios are derived – width (Wd, mm)/ length (SL, mm) of the shells, aperture length (AL, mm)/total length (Wd, mm) of the shell and aperture length (AL, mm)/width (Wd, mm) of the shell.

The mean ratio width (Wd, mm)/length (SL, mm) is $75.15\% \pm 4.92$ SD and AL/SL (%) is $60.97\% \pm 9.47$ SD, while the AL/Wd (%) is $81.05\% \pm 10.54$ SD (Table 4).

Table 4

The percentage ratio between the width and length of the shells (Wd/SL, %), aperture length/ total length of the shell (AL/SL, %) and the aperture length/total width of the shell (AL/Wd, %) for individuals from Rezovo, 18.06.2018

	Wd/SL (%)	AL/SL (%)	AL/Wd (%)
Mean	75.15	60.97	81.05
Standard Error	0.49	0.95	1.05
Median	74.50	58.11	80.00
Mode	75.53	50.00	75.00
Standard Deviation	4.92	9.47	10.54
Sample Variance	24.23	89.70	111.12
Kurtosis	0.67	-0.54	-0.82
Skewness	0.25	0.65	0.16
Range	29.84	39.26	42.38
Minimum	60.64	45.26	61.84
Maximum	90.48	84.52	104.23
Sum	7515.41	6097.18	8105.32
Count	100.00	100.00	100.00
Confidence Level (95.0%)	0.98	1.88	2.09

The following linear-width relationships are derived:

- 1) Weight (TW, g) and linear (SL, mm) size equation: $\text{Log TW (g)} = 0.276 * \log SL (\text{mm}) + 1.3597$, ($R^2=0.65$, $p<0.001$, Fig. 2.1).
- 2) Weight (TW, g) and shell length (Wd, mm): $\text{Log TW (g)} = 0.3491 * \log Wd (\text{mm}) + 1.0797$, ($R^2=0.67$, $p<0.001$, Fig. 2.2)
- 3) Weight (TW, g) and aperture length (AL, mm): $\text{Log TW (g)} = 0.3583 * \log AL (\text{mm}) + 0.9652$, ($R^2=0.24$, $p<0.001$, Fig. 2.3).

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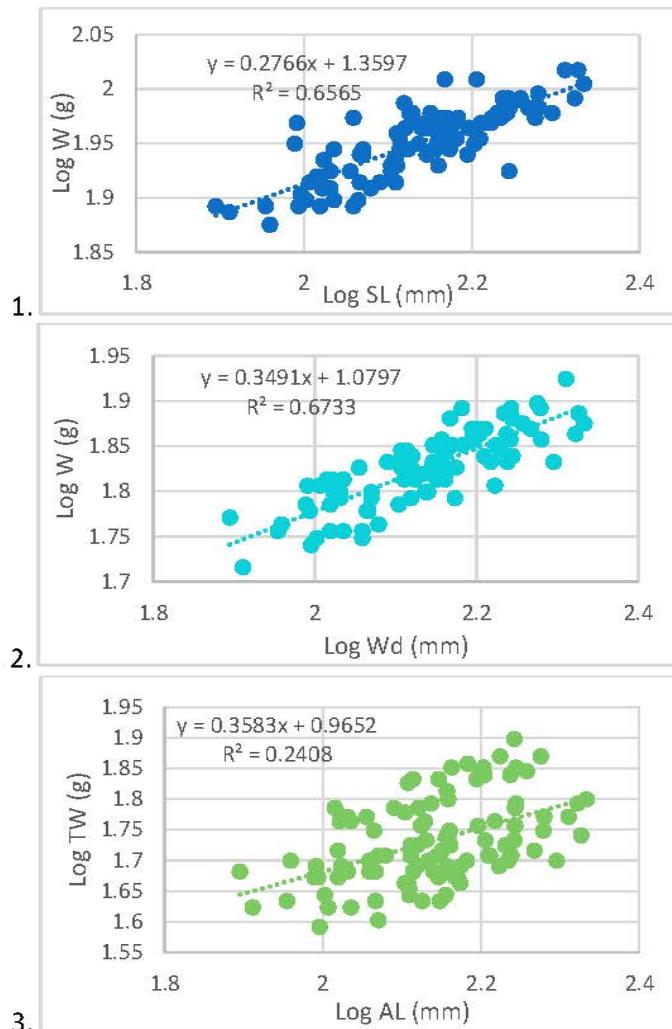


Figure 2. Linear-weight relationship (Log 10) of the measured individuals "rapana, Rezovo, 18.06.2018

Parameters a , b of the linear-weight relationship: $TW(g) = a \cdot SL(mm)^b$ and value of the correlation coefficient R^2 , presented in Table 5.

Table 5

Parameters a , b of L-W relationship: $TW(g) = a \cdot SL(mm)^b$ and value of R^2 .

Equation parameters $W(g) = a \cdot L(mm)^b$	
a	0.00321
b	2.37366
R²	0.65

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3.1.1.2 PORT VARNA, 18.06.2018

A sample with 100 individuals, with a total weight of 4.719 kg (landed weight was 3000 kg), was collected. Fishing vessel "Tais", equipped with beam trawl, was used for fishing.

The average weight of the individuals reaches $47.19 \text{ g} \pm 16.07 \text{ SD}$, at an average length of $64.64 \text{ mm} \pm 7.72 \text{ SD}$, shell width - $48.72 \text{ mm} \pm 5.80 \text{ SD}$ and aperture length $31.15 \pm 4.09 \text{ SD}$ (Table 6).

Table 6

Summarized data about biological parameters – total weight of the individuals in the sample (TW – shell weight, TW, g), shell length (shell length, SL, mm), shell width (Wd, mm) and aperture length (aperture length, AL, mm). (TW – shell weight, TW, g), Varna Port, 18.06.2018

	TW, g	SL, mm	Wd, mm	AL, mm
Mean	47.19	64.64	48.72	31.15
Standard Error (SE)	1.61	0.77	0.58	0.41
Median	43.75	64.00	48.00	31.00
Mode	29.00	62.00	45.00	28.00
Standard Deviation (SD)	16.07	7.72	5.80	4.09
Sample Variance	258.18	59.53	33.60	16.71
Kurtosis	-0.45	-0.41	0.40	-0.17
Skewness	0.53	0.42	0.37	0.49
Range	71.00	32.00	33.00	19.00
Minimum	17.50	52.00	34.00	23.00
Maximum	88.50	84.00	67.00	42.00
Sum	4719.00	6464.00	4872.00	3115.00
Count	100.00	100.00	100.00	100.00

The most abundant individuals (*19 % from measured individuals) are within size classes - 57 - 60.5 mm and 64 - 67.5 mm, followed by individuals in size class 60.5 - 64 mm – 14 % (Fig. 3.1, Table 7.1).

Looking into the weight classes, the predominant one is – $33.85 \div 41.8 \text{ g}$ (23 % from all measured individuals), followed by weight classes $25.9 \div 33.85 \text{ g}$ and $49.75 \div 57.7 \text{ g}$, with a share of - 17% from the total number of measured individuals (Fig. 3.2, Table 7.2).



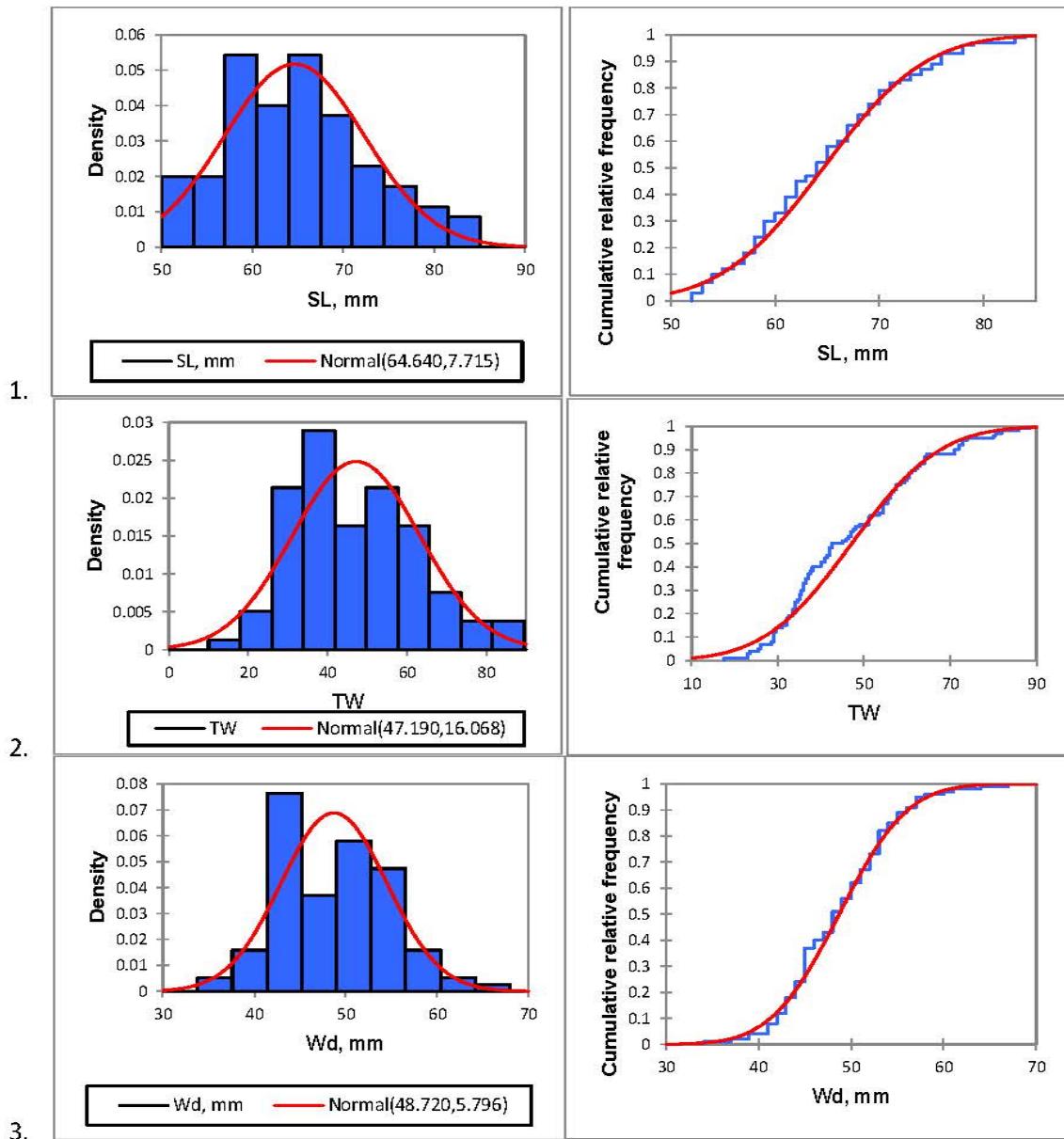
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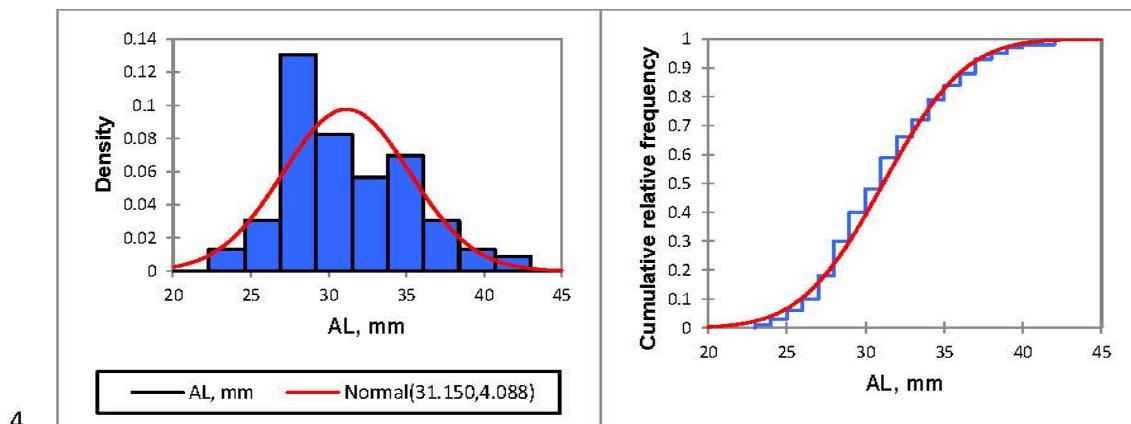


Figure 3. Measured parameters distribution: shell length (SL, mm, 1), total weight (TW, g, 2), shell width (Wd, mm, 3), aperture length (AL, mm, 4) by classes and cumulative distribution of the classes in the sample from Varna Port /18.06.2018.

Table 7

Statistical data about the size (mm, 1) and weight (g, 2) classes of rapana in the sample from Varna Port/18.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	50	53.5	7	0.070	0.020
	53.5	57	7	0.070	0.020
	57	60.5	19	0.190	0.054
	60.5	64	14	0.140	0.040
	64	67.5	19	0.190	0.054
	67.5	71	13	0.130	0.037
	71	74.5	8	0.080	0.023
	74.5	78	6	0.060	0.017
	78	81.5	4	0.040	0.011
	81.5	85	3	0.030	0.009

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	10	17.95	1	0.010	0.001
	17.95	25.9	4	0.040	0.005
	25.9	33.85	17	0.170	0.021
	33.85	41.8	23	0.230	0.029
	41.8	49.75	13	0.130	0.016
	49.75	57.7	17	0.170	0.021
	57.7	65.65	13	0.130	0.016

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65.65	73.6	6	0.060	0.008
73.6	81.55	3	0.030	0.004
81.55	89.5	3	0.030	0.004

The following percentage ratios have been derived - width (Wd, mm)/length (SL, mm) of the shells, aperture length (SL, mm)/total length (Wd, mm) of the shell and aperture length (AL, mm)/width(Wd, mm) of the shell (Table 8).

Table 8

Percentage ratios between the width and length of the shells, aperture length/total width (Varna/18.06.2018)

	Wd/SL (%)	AL/ SL (%)	AL/Wd (%)
Mean	75.51	48.23	64.02
Standard Error	0.47	0.34	0.48
Median	75.35	47.83	63.55
Mode	75.00	50.00	62.22
Standard Deviation	4.68	3.37	4.80
Sample Variance	21.88	11.35	23.08
Kurtosis	1.11	4.77	2.20
Skewness	0.37	1.13	0.79
Range	26.39	23.82	30.39
Minimum	64.15	41.10	53.70
Maximum	90.54	64.91	84.09
Sum	7551.20	4823.38	6402.09
Count	100.00	100.00	100.00

Linear-weight relationships:

- 4) Weight (TW, g) from linear sizes (SL, mm): $\text{Log TW (g)} = 0.315 * \log \text{SL (mm)} + 1.2881$, ($R^2=0.85$, $p<0.001$, Fig. 4.1).
- 5) Between weight (TW, g) and aperture length (Wd, mm): $\text{Log TW (g)} = 0.314 * \log \text{Wd (mm)} + 1.167$, ($R^2=0.84$, $p<0.001$, Fig. 4.2)
- 6) Between weight (TW, g) and aperture length (AL, mm): $\text{Log TW (g)} = 0.3172 * \log \text{AL (mm)} + 0.9668$, ($R^2=0.72$, $p<0.001$, Fig. 4.3).



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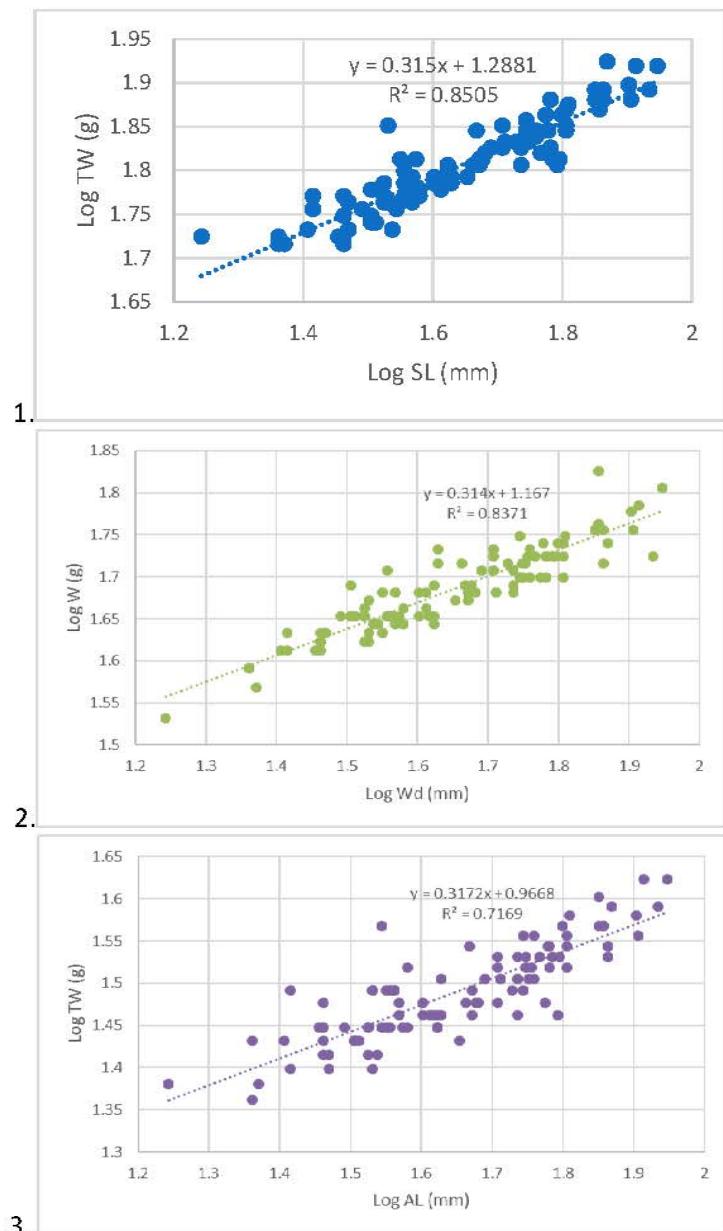


Figure 4. Linear-weight relationships (Log 10) of the measured individuals rapana, Varna, 18.06.2018

Parameters a , b of the linear-weight relationship, given by the equation: $TW(g) = a \cdot SL(mm)^b$ and value of R^2 , presented in Table 9.

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Table 9

Parameters a , b of L-W relationship, given by the equation: $TW(g) = a \cdot SL(mm)^b$ и стойност на R^2 .

Equation parameters $W(g) = a \cdot L(mm)^b$	
a	0.000587
b	2.6998
R^2	0.85

3.1.1.3 PORT DURANKULAK, 21.06.2018

A sample with 100 individuals, with a total weight of 10.036 kg (landed quantity was 430 kg) was collected at Durankulak. Fishing was done with scuba diving.

Summarized statistical data about the biometric measurements is presented in Table 10. The average weight of the measured individuals reaches $100.36 \text{ g} \pm 25.15 \text{ SD}$, at an average length of $81.87 \text{ mm} \pm 6.65 \text{ SD}$, shell width - $63.68 \text{ mm} \pm 5.78 \text{ SD}$ and aperture length $56.91 \pm 8.11 \text{ SD}$.

Table 10

Summarized data about biological parameters – total weight of the individuals in the sample (TW – shell weight, TW, g), shell length (shell length, SL, mm), shell width (Wd, mm) and aperture length (aperture length, AL, mm). (TW – shell weight, TW, g), Durankulak Port, 21.06.2018

	TW, g	SL, mm	Wd, mm	AL, mm
Mean	100.36	81.87	63.68	56.91
Standard Error	2.51	0.67	0.58	0.81
Median	97.00	81.00	63.50	57.00
Mode	104.00	81.00	64.00	61.00
Standard Deviation	25.15	6.65	5.78	8.11
Sample Variance	632.45	44.28	33.45	65.82
Kurtosis	0.83	-0.51	-0.15	-0.28
Skewness	0.81	0.10	0.46	0.12
Range	127.00	29.00	28.00	34.00
Minimum	56.50	68.00	52.00	41.00
Maximum	183.50	97.00	80.00	75.00
Sum	10036.00	8187.00	6368.00	5691.00
Count	100.00	100.00	100.00	100.00
Confidence Level(95.0%)	4.99	1.32	1.15	1.61

The most common size class is $79 \div 82.8 \text{ SL, mm}$ (25 % from measured individuals), while other classes – $75.2 \div 79 \text{ mm}$, $82.5 \div 86.6 \text{ mm}$ and $86.6 \div 90.4 \text{ mm}$ (*16 %, Fig. 5.1, Table 11.1).



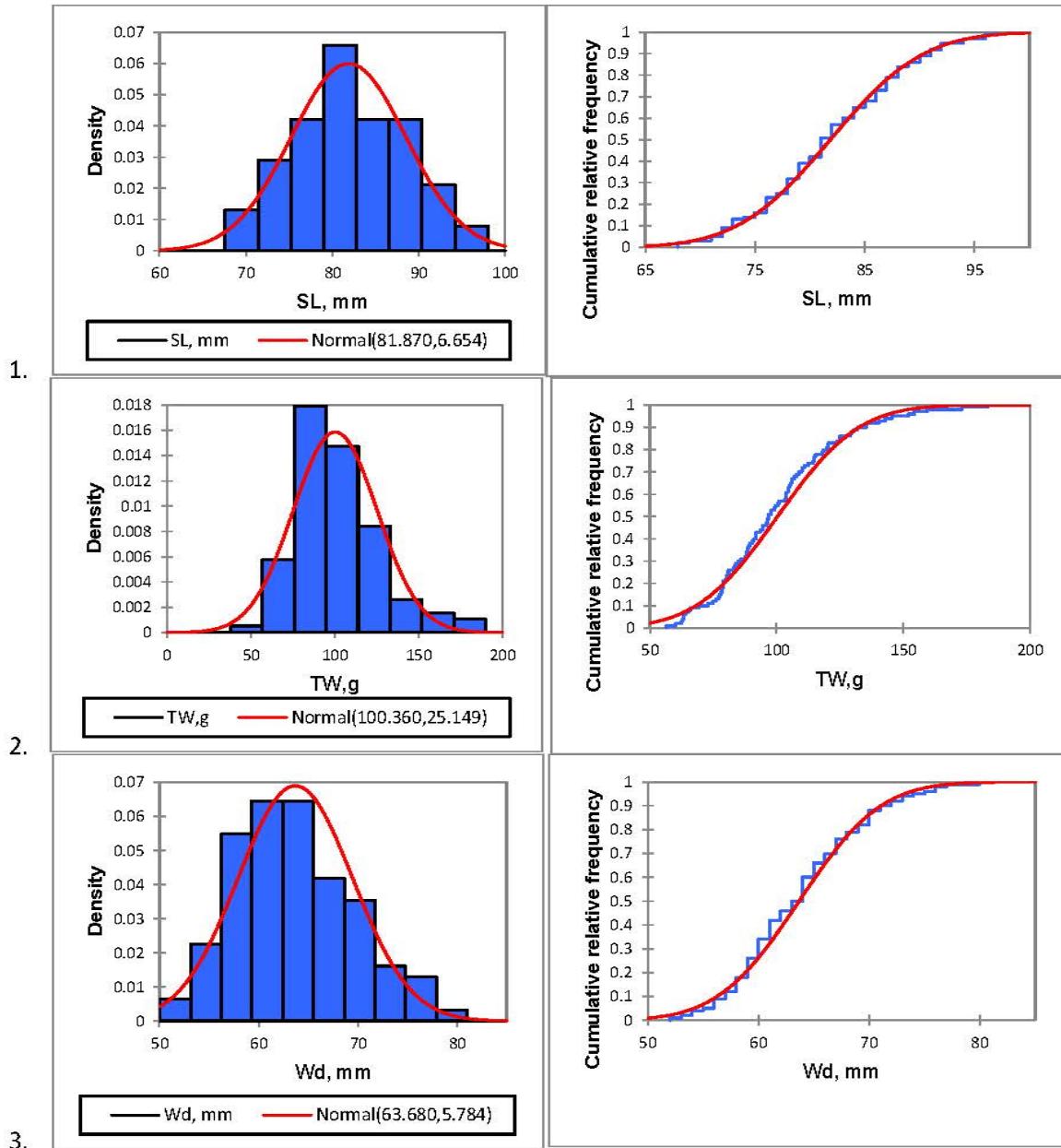
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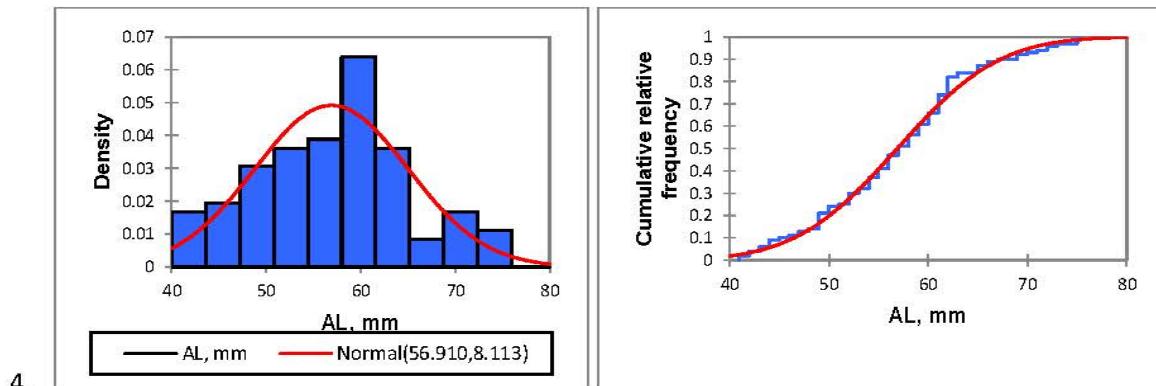


Figure 5. Distribution of measured parameters by classes: shell length (SL, mm, 1), total weight (TW, g, 2), shell width (Wd, mm, 3), aperture length (AL, mm, 4) and cumulative distribution of classes in the sample from Durankulak, 21/06/2018

The predominant classes in the weight (TW, g) structure are: 76 - 95 g (34 % from all measured individuals), 95 - 114 g (28 %) and 114 - 133 g (16 % from the total number of measured individuals (Fig. 5.2, Table 11.2).

Looking at the shell width (Wd, mm) parameter – most common classes (*20 % from measured individuals) are: 59.3 - 62.4 mm and 62.4 - 65.5 mm, followed by class - 56.2 - 59.3 mm (17 %, Fig. 5.3).

For the aperture length (AL, mm), the dominant classes are 58 - 61.6 mm (23 %) and 54.4 - 58 mm (14 %, Fig. 5.4).

Table 11

Statistical data about the size (mm, 1) and weight (g, 2) classes of rapana in the sample from Durankulak Port/21.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	67.6	71.4	5	0.050	0.013
	71.4	75.2	11	0.110	0.029
	75.2	79	16	0.160	0.042
	79	82.8	25	0.250	0.066
	82.8	86.6	16	0.160	0.042
	86.6	90.4	16	0.160	0.042
	90.4	94.2	8	0.080	0.021
	94.2	98	3	0.030	0.008

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	38	57	1	0.010	0.001
	57	76	11	0.110	0.006

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76	95	34	0.340	0.018
95	114	28	0.280	0.015
114	133	16	0.160	0.008
133	152	5	0.050	0.003
152	171	3	0.030	0.002
171	190	2	0.020	0.001

The following percentage ratios have been derived - width (Wd, mm)/length (SL, mm) of the shells, aperture length (SL, mm)/total length (Wd, mm) of the shells and aperture length (AL, mm)/width (Wd, mm) of the shell (Table 12). The mean ration - width (Wd, mm)/length (SL, mm) is 77.80 % \pm 3.54 SD, while AL/SL (%) is 69.34 % \pm 6.46 SD, and for the ratio AL/Wd (%) the derived values is – 89.26% \pm 8.82 SD (Table 12).

Table 12

Percentage ratios between the width and length of the shells, aperture length/total width,
Durankulak, 21.06.2018

	Wd/SL (%)	AL/ SL (%)	AL/Wd (%)
Mean	77.80	69.34	89.26
Standard Error	0.35	0.65	0.88
Median	77.78	70.19	91.18
Mode	75.00	79.12	95.31
Standard Deviation	3.54	6.46	8.82
Sample Variance	12.56	41.79	77.79
Kurtosis	-0.04	-0.83	-0.57
Skewness	0.22	-0.29	-0.26
Range	16.68	25.83	42.01
Minimum	70.33	55.70	70.49
Maximum	87.01	81.52	112.50
Sum	7780.41	6933.76	8925.87
Count	100.00	100.00	100.00
Confidence Level(95.0%)	0.70	1.28	1.75

The following linear-weight relationships have been derived:

- 7) Weight (TW, g) from linear size (SL, mm): $\text{Log TW (g)} = 0.3018 * \log \text{SL (mm)} + 1.3115$, ($R^2=0.82$, $p<0.001$, Fig. 6.1).
- 8) Between weight (TW, g) and shell width (Wd, mm): $\text{Log TW (g)} = 0.3375 * \log \text{Wd (mm)} + 1.1311$, ($R^2=0.84$, $p<0.001$, Fig. 6.2)
- 9) Between weight (TW, g) and aperture length (AL, mm): $\text{Log TW (g)} = 0.4277 * \log \text{AL (mm)} + 0.9002$, ($R^2=0.52$, $p<0.001$, Fig. 6.3).

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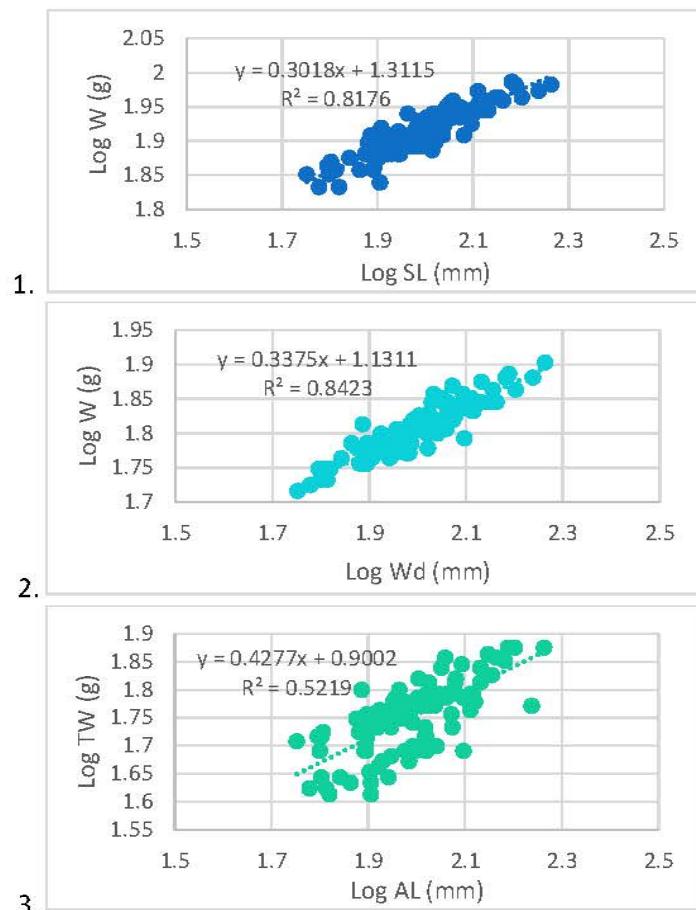


Figure 6. Linear-weight relationship (Log 10) for measured individuals, Durankulak, 21.06.2018

Parameters a , b of the L-W relationship, given by the equation: $TW(g) = a \cdot SL(mm)^b$ and value of R^2 , presented in Table 13.

Table 13
Parameters a , b of L-W relationship, given by the equation: $TW(g) = a \cdot SL(mm)^b$ and value of R^2 .

Equation parameters $TW(g) = a \cdot SL(mm)^b$	
a	0.0006457
b	2.70890
R^2	0.82

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3.1.1.4 BYALA PORT, 22.06.2018

A sample with 100 individuals, with a total weight of 11.583 kg (landed quantity was 300 kg) was collected at Byala. Fishing was done with scuba diving.

Summarized statistical data about the biometric measurements is presented in Table 14. The average weight of the measured individuals reaches $115.83 \text{ g} \pm 29.98 \text{ SD}$, at an average length - $83.48 \text{ mm} \pm 7.08 \text{ SD}$, shell width - $66.71 \text{ mm} \pm 6.68 \text{ SD}$ and aperture length $60.03 \pm 7.21 \text{ SD}$.

Table 14

Summarized data about biological parameters – total weight of the individuals in the sample (TW – shell weight, TW, g), shell length (shell length, SL, mm), shell width (Wd, mm) and aperture length (aperture length, AL, mm). (TW – shell weight, TW, g), Byala Port, 22.06.2018

	TW,g	SL, mm	Wd, mm	AL, mm
Mean	115.83	83.48	66.71	60.03
Standard Error	3.00	0.71	0.67	0.72
Median	114.50	83.00	66.50	60.00
Mode	114.50	81.00	68.00	62.00
Standard Deviation	29.98	7.08	6.68	7.21
Sample Variance	899.07	50.13	44.59	51.99
Kurtosis	-0.36	-0.45	-0.37	-0.20
Skewness	0.35	0.03	0.24	0.30
Range	131.50	33.00	30.00	35.00
Minimum	61.50	68.00	53.00	44.00
Maximum	193.00	101.00	83.00	79.00
Sum	11583.00	8348.00	6671.00	6003.00
Count	100.00	100.00	100.00	100.00
Confidence Level(95.0%)	5.95	1.40	1.33	1.43

Most individuals in the sample are within size class - 81 - 85.2 SL, mm (27 % from measured individuals), as well as classes - 76.8 - 81 mm (18 %) and 85.2 - 89.4 mm (18 %, Fig. 7.1, Table 15.1).

Looking at the weight structure (TW, g), the predominant weight classes are: 80 - 100 g (24 % from all measured individuals), 100 - 120 g (22 %) and 120 - 140 g (20 % from the total number of individuals (Fig. 7.2, Table 15.2).

As for the shell width (Wd, mm) parameter, the most common classes are: 67 - 70.4 mm (23 %) and 63.6 - 67 mm (19 %), followed by class - 56.8 – 60.2 mm (16 % (Fig. 7.3).

The predominant aperture length ((AL, mm) classes are: 60 - 64 mm (23 %) and 56 - 60 mm (19 % (Fig. 7.4).



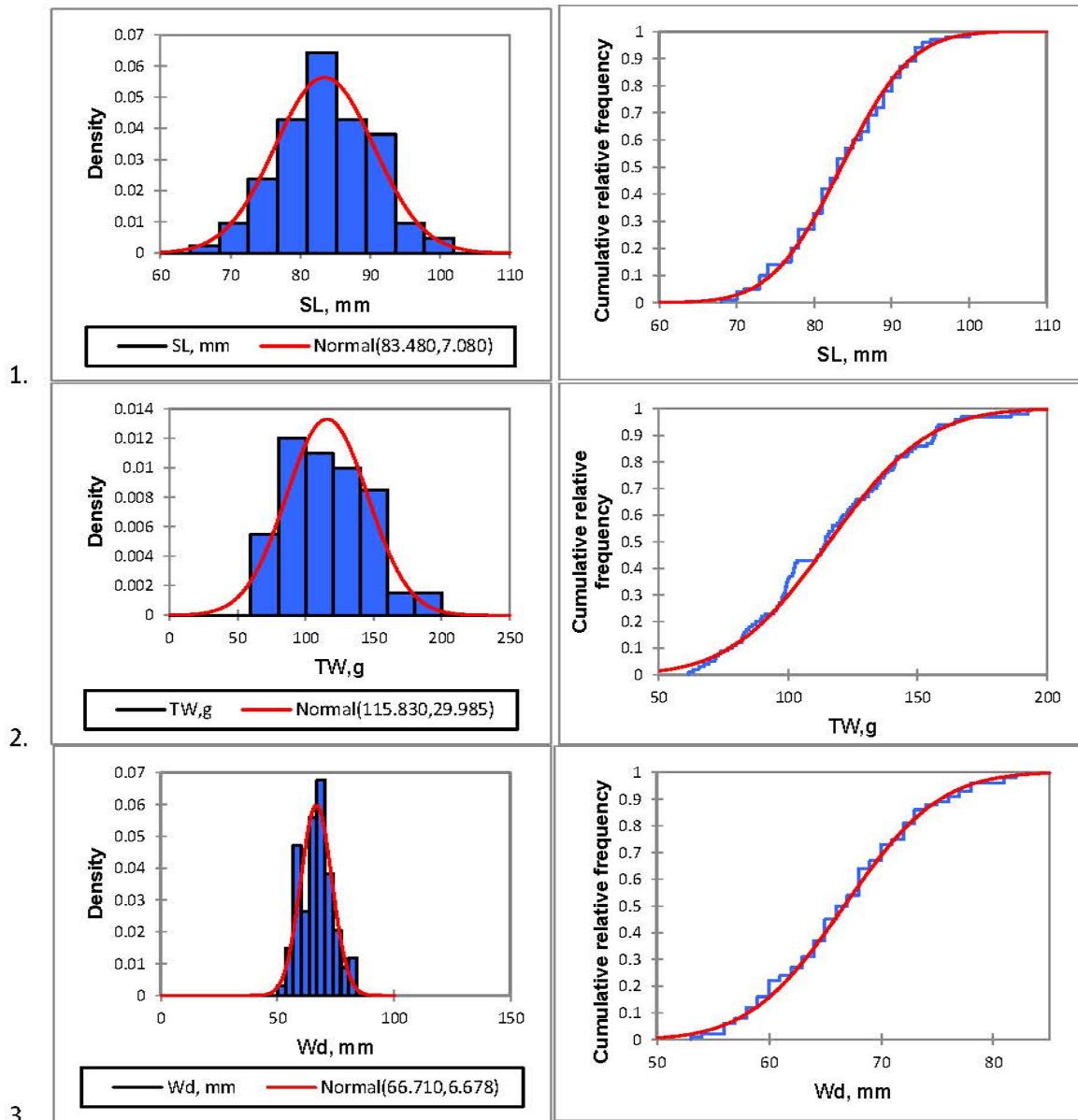
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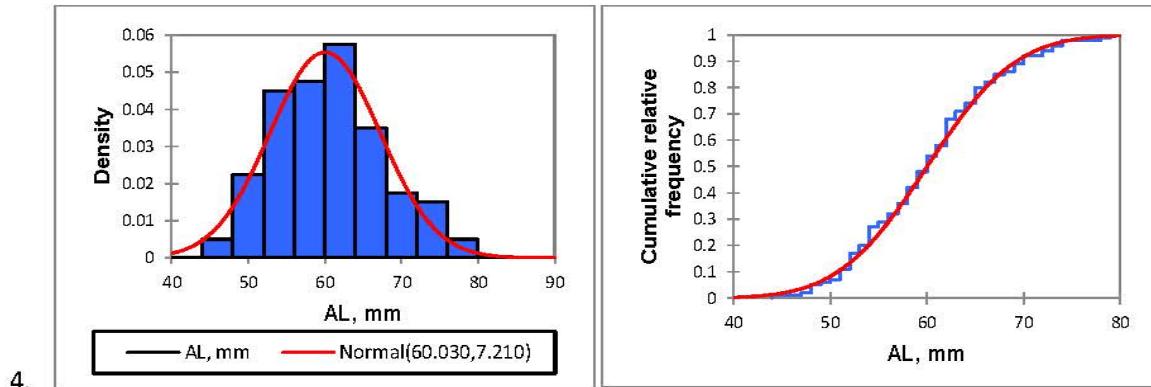


Figure 7. Distribution of the measured parameters by classes: shell length (SL, mm, 1), total weight (TW, g, 2), shell width (Wd, mm, 3), aperture length (AL, mm, 4) and cumulative distribution of the classes in the sample from Byala, 22/06/2018

Table 15

Statistical data about the distribution of size (mm, 1) and weight (g, 2) classes of rapana in the sample from Byala Port Byala Port/22.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	64.2	68.4	1	0.010	0.002
	68.4	72.6	4	0.040	0.010
	72.6	76.8	10	0.100	0.024
	76.8	81	18	0.180	0.043
	81	85.2	27	0.270	0.064
	85.2	89.4	18	0.180	0.043
	89.4	93.6	16	0.160	0.038
	93.6	97.8	4	0.040	0.010
	97.8	102	2	0.020	0.005

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	60	80	11	0.110	0.006
	80	100	24	0.240	0.012
	100	120	22	0.220	0.011
	120	140	20	0.200	0.010
	140	160	17	0.170	0.009
	160	180	3	0.030	0.002
	180	200	3	0.030	0.002

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The following percentage ratios have been derived – width (Wd, mm)/ length (SL, mm) of the shells, length (SL, mm)/total weight (Wd, mm) of the shells and aperture length (AL, mm)/width (Wd, mm) of the shell (Table 16). The mean ration - width (Wd, mm)/length (SL, mm) is 79.89 % \pm 3.81 SD, and AL/SL (%) is 71.90 % \pm 6.01 SD, while the ratio AL/Wd (%) is calculated at 90.02% \pm 6.47 SD (Table 16).

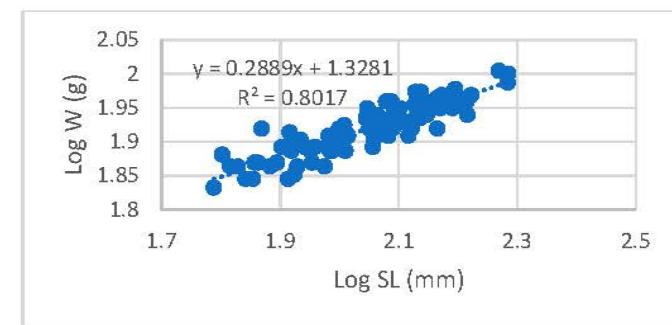
Table 16

Percentage ratios between width and length of shells (Wd/SL, %), aperture length/ total shell length (AL/SL, %) and aperture length/total shell width (AL/Wd, %) of the individuals from Byala, 22.06.2018

	Wd/SL (%)	AL/ SL (%)	AL/Wd (%)
Mean	79.89	71.90	90.02
Standard Error	0.38	0.60	0.65
Median	80.22	70.52	89.39
Mode	80.25	71.23	83.08
Standard Deviation	3.81	6.01	6.47
Sample Variance	14.49	36.17	41.87
Kurtosis	1.11	-0.16	0.81
Skewness	0.09	0.20	0.40
Range	22.24	29.67	36.43
Minimum	68.97	56.04	75.00
Maximum	91.21	85.71	111.43
Sum	7989.30	7190.50	9001.95
Count	100.00	100.00	100.00
Confidence Level(95.0%)	0.76	1.19	1.28

The following linear-weight relationship have been derived:

- 10) Weight (TW, g) relationship on linear size (SL, mm): $\text{Log TW (g)} = 0.2889 * \log \text{SL (mm)} + 1.3281$, ($R^2=0.80$, $p<0.001$, Fig. 8.1)
- 11) Weight (TW, g) and shell length (Wd, mm): $\text{Log TW (g)} = 0.3376 * \log \text{Wd (mm)} + 1.1302$, ($R^2=0.80$, $p<0.001$, Fig. 8.2)
- 12) Weight (TW, g) and aperture length (AL, mm): $\text{Log TW (g)} = 0.341 * \log \text{AL (mm)} + 1.0765$, ($R^2=0.57$, $p<0.001$, Fig. 8.3)



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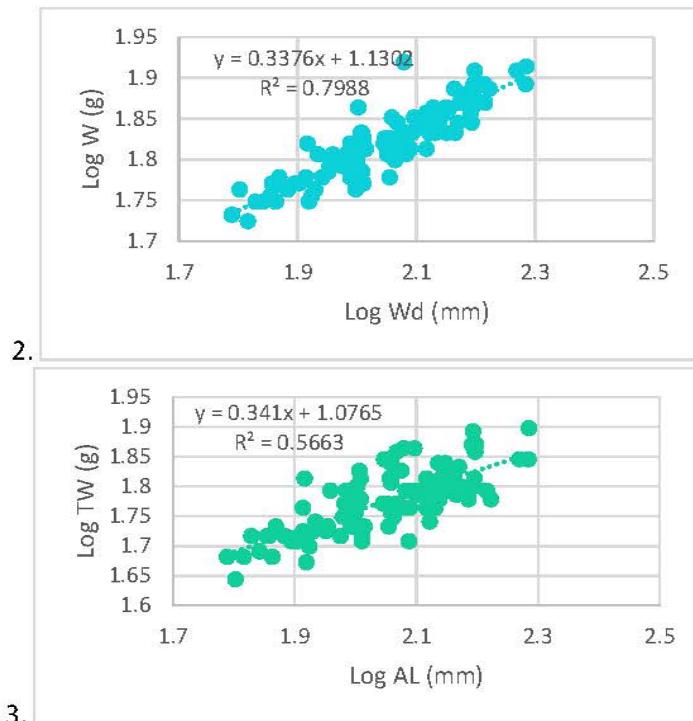


Figure 8. Linear-weight relationship (Log 10) for the analyzed individuals, Byala, 22.06.2018

Parameter a , b of the linear-weight relationship, given by the equation: $TW(g) = a \cdot SL(mm)^b$ and value of R^2 , presented in Table 17.

Table 17

Parameters a , b of L-W relationship, given by the equation:
 $TW(g) = a \cdot SL(mm)^b$ and value of R^2 .

Equation parameters	
$TW(g) = a \cdot SL(mm)^b$	
a	0.000525
b	2.77517
R²	0.80

3.1.1.5. SUMMARIZED DATA

The data for the rapana landings in June 2018 show that the quantities vary between 300 and 1500 kg/day for the four researched ports, depending on the fishing method. The highest landing was observed at Byala Port, while the lowest at Rezovo (Table 18). The quantities, using boats up to 9

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m long and scuba diving, were between 300 and 430 kg/day. Larger fishing vessels (19.4 m long), equipped with beam trawl, could land up to 1500 kg/day. (Table 18).

Table 18

Summarized data for the rapana landings per days and ports from different fishing vessels and fishing methods in June 2018

Date	Port	Weight (kg) of the sample from 100 ind. <i>R. venosa</i>	Total unloaded quantity from the fishing vessel	Fishing vessel's length (m)	Fishing gear used to collect samples
18.06.2018	Rezovo	14.069	345 kg	9 m	Scuba-diving
18.06.2018	Varna	4.719	3000 kg for two fishing days or ~1500 kg/day	19.4 m	Beam trawl
21.06.2018	Durankulak	10.036	430 kg (from two fishing operations)	3.95 m	Scuba-diving
22.06.2018	Byala	11.583	300 kg	7.5 m	Scuba-diving

The dynamics of the biological parameters of the analyzed *R. venosa* individual, show that the maximum average sizes and weights were in Rezovo due to the fishing method (scuba diving and selection of larger species (Fig. 9)). The picture is similar for Byala and Durankulak, also because of the scuba diving method. The sample from Varna showed relatively small average sizes and weights, caused by the beam trawl fishing and the inability for proper selection of the rapana catch (Fig. 9)



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Figure 9. Distribution of the mean values of the biological parameters of *R. venosa* - total weight (TW, g), shell length (SL, mm), shell width (Wd, mm) and aperture length (AL, mm), landings at ports for the 2nd quarter of 2018

The comparison analysis of the derived parameters a and b of the L-W relationship: $TW(g) = a \cdot SL(mm)^b$ shows that *R. venosa* grows allometrically in all samples with coefficient $b \neq 3$ (t-test, $P=0.028$).

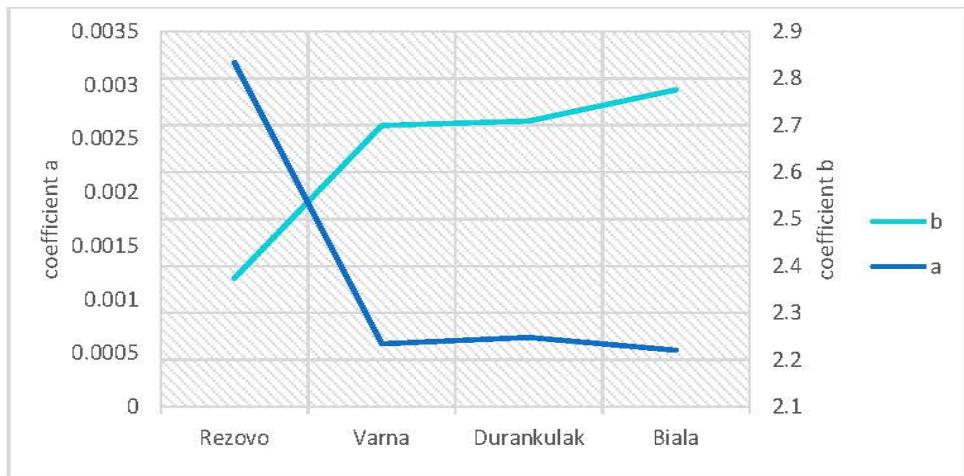


Figure 10. Parameters a , b of the linear-weight relationship in the equation: $TW(g) = a \cdot SL(mm)^b$, derived from the samples from different ports for the 2nd quarter of 2018

When parameter is $b < 3$, it means that there is a negative allometric growth, or in larger individuals the increase in size outpaces the weight growth. The minimum value of $b = 2.373$ was calculated for the Rezovo sample, while for all the rest it is around 2.7 (Fig. 10). Thus, the biological

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parameters of *R. venosa* for the individuals from Rezovo differ significantly from the rest of the samples.

Data about the mean percentage shares of the shell length (Wd/SL, %) of *R. venosa*, aperture length compared to shell length (AL/SL, %) and aperture length/total shell width (AL/Wd, %) for all ports for 2nd quarter of 2018, presented on Fig. 11.

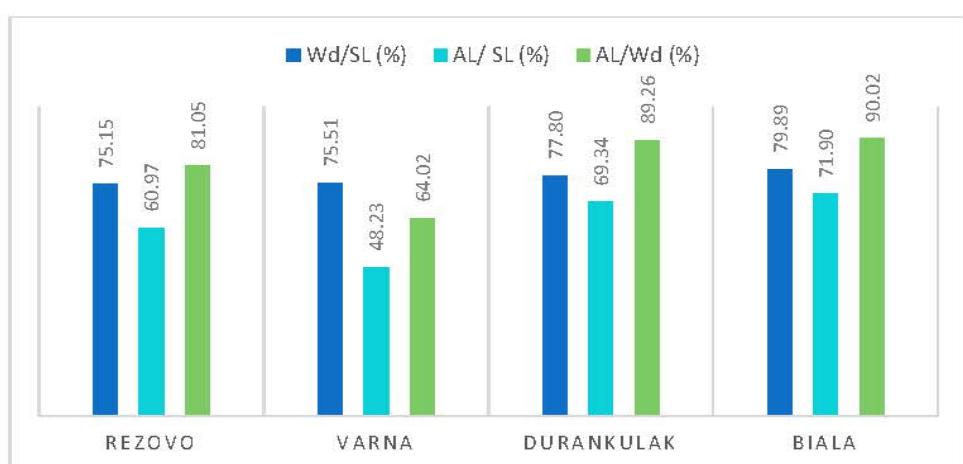


Figure 11. Percentage shares between the width and length of shells (Wd/SL, %) of *R. venosa*, aperture length/ total shell length (AL/SL, %) and aperture length/total shell width (AL/Wd, %) for all ports for the 2nd quarter of 2018

The mean share of Wd/SL for June 2018 is 77.09 % with the least share in the Rezovo sample – 75.15 % and highest at Byala – 79.89% (Fig. 11). Accordingly, the share of AL/SL reaches 62.61%, but has least value in the sample from Varna Port – 48.23 %, while maximum value – 71.90 % is found again in the sample from Byala Port. In respect to the share of AL/Wd (%), the mean value for June 2018 is 81.09 %, with the minimum values in the sample from Varna – 64.02% and maximum – in the sample from Byala Port - 90.02 %.

3.1.2 GENDER STRUCTURE

R. venosa is a dioecious mollusk with distinctive gender characteristics (Picture 1). The species reaches maturity at an age of 2+, while the male and female's gender glands can be distinguished by their color and are located in the upper part of the visceral sac (Chuhchin, 1961 a, b). The mature female individuals have yellow ovaries, in the form of compact tissue with a width of 3 to 6 mm (Chuhchin, 1961a, 1970, 1984). Male individuals have orange gender glands and sex organs with length of 1.9 to 25 mm. *Rapana venosa* species are hermaphrodites (intersex form), so both sex organ (penis) and glands are developed. Both are colored in yellow to slight orange (Mann et al., 2006). The high percentage imposex forms is considered to be a function of the water quality (polluted water).

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Picture 1. Mature male and female individuals *R. venosa* in the sample from Rezovo Port, 18.06.2018

3.1.2.1. REZOVO PORT, 18.06.2018

The ratio between the genders in the analyzed part from the sample is 69.56 % ♀ to 30.43 % ♂, or 2.29: 1. In regard to the shell length (SL, mm), female individuals have an average size of 87.5 mm ± 4.98 SD, while the male are about 4.79 % bigger (Table 19).

Table 19

Summarized statistics of the biological parameters – total weight of the individuals in the sample, shell length (SL, mm) and body weight (TW, g), Rezovo 18.06.2018

	SL, mm		TW, g	
	Females	Males	Females	Males
Mean	87.50	91.79	139.74	155.79
Standard Error	1.24	1.19	6.13	5.73
Median	86.50	92.50	144.25	158.50
Mode	94.00	94.00	128.50	140.00
Standard Deviation	4.98	4.44	24.53	21.46
Sample Variance	24.80	19.72	601.69	460.34
Kurtosis	-1.53	-0.70	-1.34	-1.18
Skewness	0.32	-0.17	-0.14	0.15
Range	14.00	15.00	71.90	63.00
Minimum	81.00	84.00	103.50	127.00
Maximum	95.00	99.00	175.40	190.00
Sum	1400.00	1285.00	2235.90	2181.00
Confidence Level(95.0%)	2.65	2.56	13.07	12.39

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The predominant size classes in the female individuals are 94 - 96 mm, or 28.57 %, as well as size class 82 - 84 mm - 21.43 % (Fig. 12, Table 20.2).

In the male individuals, the most abundant size class is 94 - 96 mm - 28.57 %, followed by 92 - 94 mm - 21.43 %, however there are individuals in size class 98 - 100 mm - 14.29 % (Fig.12, Table 20.1).

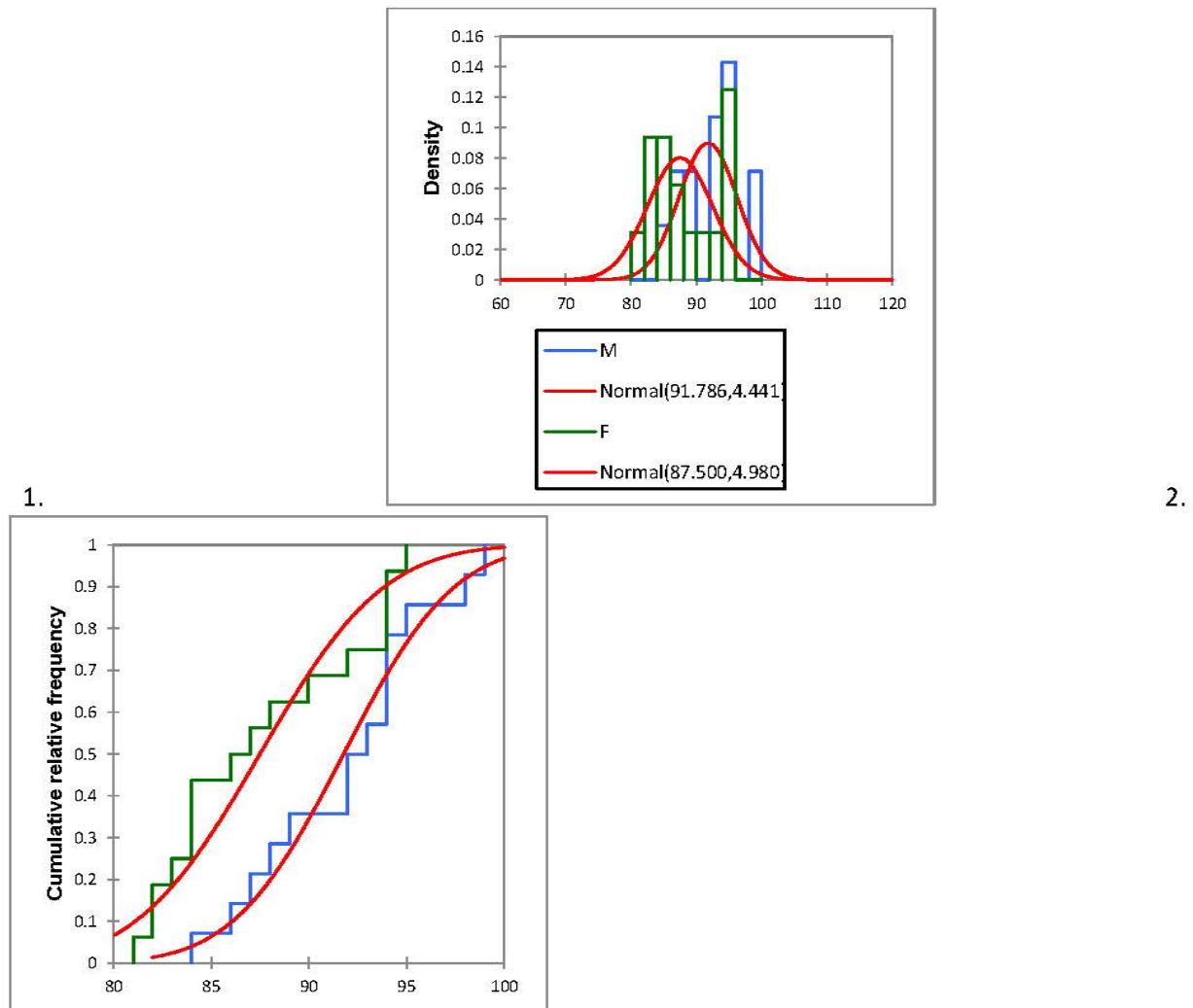


Figure 12. Distribution of the size classes by genders (1) based on shell length (SL, cm) and cumulative distribution of the size classes by genders (2) in the sample from Rezovo, 18/06/2018

Table 20

Statistical data about the distribution of size (mm) classes of rapana by genders (1, male; 2, female) in the sample from Rezovo Port/18.06.2018

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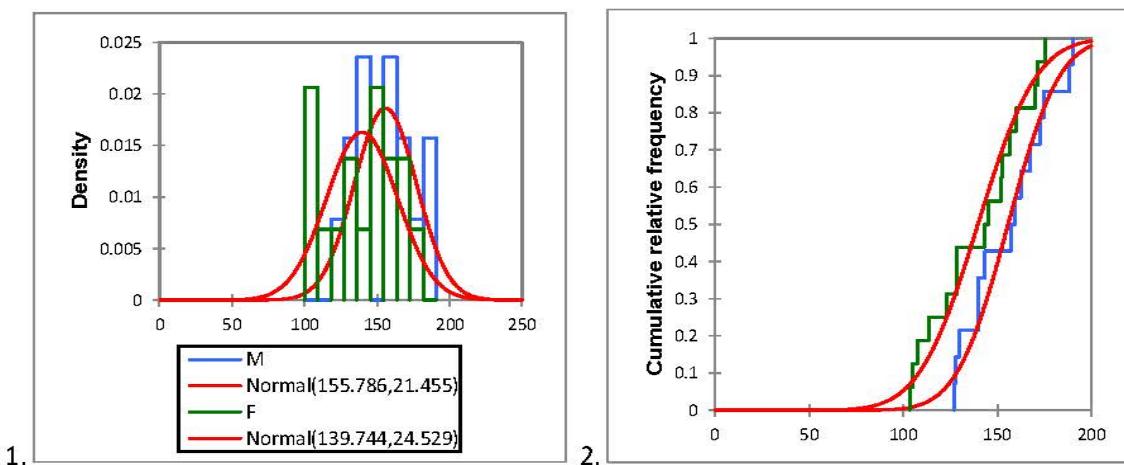
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Lower bound	Upper bound	Frequency	Relative frequency	Density
84	86	1	0.071	0.036
86	88	2	0.143	0.071
88	90	2	0.143	0.071
90	92	0	0.000	0.000
92	94	3	0.214	0.107
94	96	4	0.286	0.143
96	98	0	0.000	0.000
98	100	2	0.143	0.071

Lower bound	Upper bound	Frequency	Relative frequency	Density
80	82	1	0.063	0.031
82	84	3	0.188	0.094
84	86	3	0.188	0.094
86	88	2	0.125	0.063
88	90	1	0.063	0.031
90	92	1	0.063	0.031
92	94	1	0.063	0.031
94	96	4	0.250	0.125

In regard to the body weight (TW, g), the male individuals have an average weight $155.79 \text{ g} \pm 21.46 \text{ SD}$, while the female individuals have an average weight with 10.86 % less (Table 19).

The predominant size classes in male individuals are: 136 - 146 g and 155 - 164 g - *21.43 % (Fig. 13.1, Table 21.1). The female individuals' size classes are: 100 - 109 g и 146 - 155 g - *18.75 % (Fig. 13.2, Table 21.2).





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Figure 13. Distribution of the size classes by gender and body weight (1) (TW, g) and cumulative distribution of the weight classes by gender (2) in the sample from Rezovo, 18/06/2018

Table 21

Statistical data about the distribution of the weight classes (g) of rapana by gender (1, male; 2, female) in the sample from Rezovo Port/18.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	100	109	1	0.071	0.008
	109	118	2	0.143	0.016
	118	127	3	0.214	0.024
	127	136	0	0.000	0.000
	136	146	3	0.214	0.024
	146	155	2	0.143	0.016
	155	164	1	0.071	0.008
	164	173	2	0.143	0.016

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	100	109	3	0.188	0.021
	109	118	1	0.063	0.007
	118	127	1	0.063	0.007
	127	136	2	0.125	0.014
	136	146	1	0.063	0.007
	146	155	3	0.188	0.021
	155	164	2	0.125	0.014
	164	173	2	0.125	0.014
	173	182	1	0.063	0.007

3.1.2.2. VARNA PORT, 18.06.2018 г

The ratio between the genders in the analyzed part of the sample is 46.67 % ♀ to 53.33 % ♂ or 1: 1.14. In respect to the shell size (SL, mm), the female individuals' average size is 64.71 mm ± 8.32 SD, while the males are with 5.32 % bigger (Table 22).

Table 22

Summarized statistics about the biological parameters - total weight of individuals in the sample, shell length (SL, mm) and body weight (TW, g) by gender in the sample from Varna Port, 18.06.2018

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	SL, mm		TW, g	
	Females	Males	Females	Males
Mean	64.71	68.25	47.61	55.00
Standard Error	2.22	2.05	4.07	4.81
Median	65.00	67.50	47.75	54.50
Mode	70.00	76.00	#N/A	73.00
Standard Deviation	8.32	8.19	15.24	19.24
Sample Variance	69.30	67.00	232.39	370.00
Kurtosis	0.75	-1.25	-1.12	-1.14
Skewness	0.70	0.16	0.03	0.09
Range	30.00	26.00	48.50	62.50
Minimum	54.00	57.00	25.50	26.00
Maximum	84.00	83.00	74.00	88.50
Sum	906.00	1092.00	666.50	880.00
Confidence Level(95.0%)	4.81	4.36	8.80	10.25

Three size classes dominate the male individuals, each 18.75 % from all individuals - 57 - 61 mm, 61-64 mm, 75-78 mm (Fig. 14, Table 23.1).

Similar results were derived for the female individuals, three size classes, each forming 21.43 % from the sample - 54 - 57 mm, 64-68 mm, 68-71 mm (Fig. 14, Table 23.2).

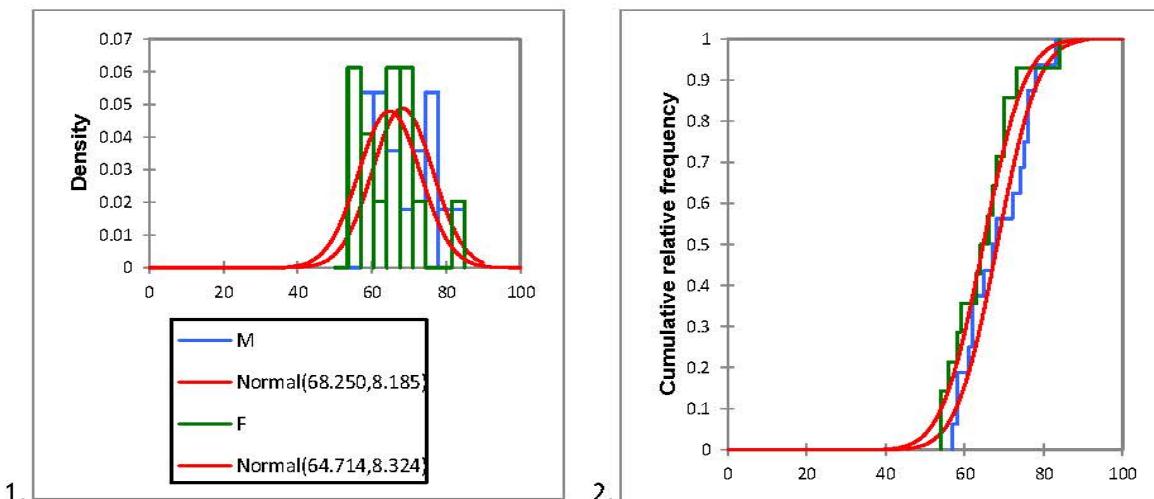


Figure 14. Gender and size classes (1) distribution based on shell length (SL, cm) and cumulative distribution of the size classes by gender (2) in the sample from Varna, 18/06/2018

Table 23

Statistical data about the distribution of size (mm) classes of rapana by gender (1, male; 2, female) in the sample from Varna Port/18.06.2018

1	Lower	Upper	Frequency	Relative	Density

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bound	bound		frequency	
57	61	3	0.188	0.054
61	64	3	0.188	0.054
64	68	2	0.125	0.036
68	71	1	0.063	0.018
71	75	2	0.125	0.036
75	78	3	0.188	0.054
78	82	1	0.063	0.018
82	85	1	0.063	0.018

Lower bound	Upper bound	Frequency	Relative frequency	Density
54	57	3	0.214	0.061
57	61	2	0.143	0.041
61	64	1	0.071	0.020
64	68	3	0.214	0.061
68	71	3	0.214	0.061
71	75	1	0.071	0.020
75	78	0	0.000	0.000
78	82	0	0.000	0.000
82	85	1	0.071	0.020

In respect to the body weight (TW, g), the average weight of male individuals is 55.19 g ± 19.25 SD, while for female individuals it is 14.40 % lower (Table 22).

Regarding the weight classes, the predominant ones in the male individuals are - 69 - 76 g - 18.75 %, followed by weight classes - 27-34 g, 34- 41 g, resulting in 12.5% from all weight classes (Fig. 15, Table 23.1). The female individuals are dominated by weight class -55 - 62 g, with a share of 21.43 % from all weight classes (Fig. 15, Table 23.2).



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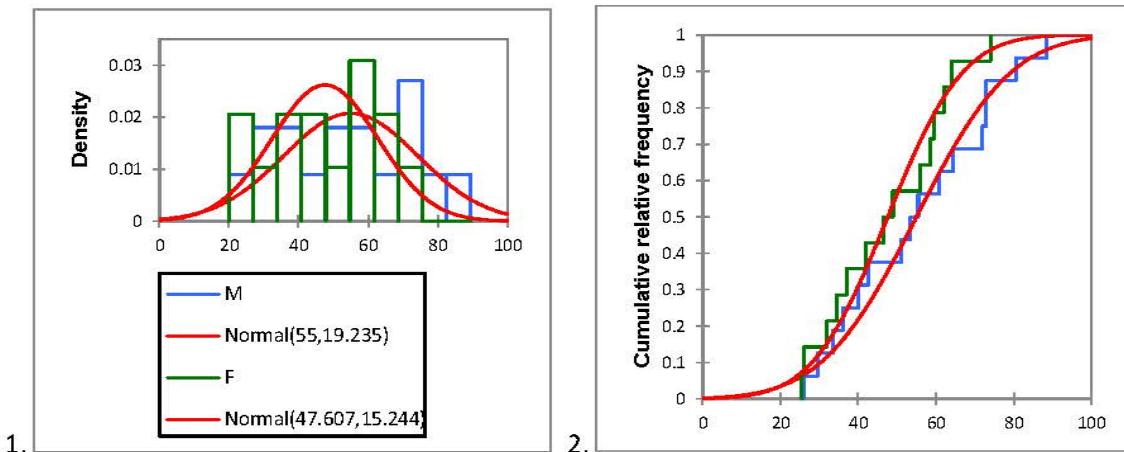


Figure 15. Gender and size classes (1) distribution based on body weight (TW, g) and cumulative distribution of the weight classes by gender (2) in the sample from Varna, 18.06.2018

Table 24

Statistical data about the distribution of weight (g) classes of rapana by gender (1, male; 2, female) in the sample from Varna Port, 18.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	20	27	1	0.063	0.009
	27	34	2	0.125	0.018
	34	41	2	0.125	0.018
	41	48	1	0.063	0.009
	48	55	2	0.125	0.018
	55	62	2	0.125	0.018
	62	69	1	0.063	0.009
	69	76	3	0.188	0.027
	76	83	1	0.063	0.009
	83	90	1	0.063	0.009

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	20	27	2	0.143	0.021
	27	34	1	0.071	0.010
	34	41	2	0.143	0.021
	41	48	2	0.143	0.021
	48	55	1	0.071	0.010
	55	62	3	0.214	0.031

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62	69	2	0.143	0.021
69	76	1	0.071	0.010
76	83	0	0.000	0.000
83	90	0	0.000	0.000

3.1.2.3. DURANKULAK PORT, 21.06.2018 г.

There were imposex individuals in the sample from Durankulak. The ratio between genders in the analyzed part of the sample is 43.33 % ♀ : 46.67 % ♂ : 10 % imposex or - 1:1.08:0.23. In respect to the shell size (SL, mm), the average size of the female individuals is 82.31 mm ± 7.02 SD, while for male individuals it is 5.21 % bigger. Similar to the imposex individuals, the average size of the shell is 1.67 % bigger (Table 25).

Table 25

Summarized statistics of the biological parameters - total weight of the individuals in the sample, shell length (SL, mm) and body weight (TW, g) by gender in the sample from Durankulak Port, 21.06.2018

	SL, mm			TW, g		
	Females	Males	Imposex	Females	Males	Imposex
Mean	82.31	86.71	83.67	107.31	115.86	105.83
Standard Error	1.95	1.78	4.26	8.99	6.95	26.86
Median	81.00	87.50	81.00	105.00	110.75	81.00
Mode	79.00	91.00			92.00	
Standard Deviation	7.02	6.65	7.37	32.40	26.02	46.52
Sample Variance	49.23	44.22	54.33	1049.52	677.17	2164.08
Kurtosis	-0.30	-1.07		1.26	-1.36	
Skewness	0.64	-0.13	1.41	1.00	0.16	1.72
Range	23.00	21.00	14.00	121.00	79.50	82.50
Minimum	73.00	76.00	78.00	62.50	75.00	77.00
Maximum	96.00	97.00	92.00	183.50	154.50	159.50
Sum	1070.00	1214.00	251.00	1395.00	1622.00	317.50
Confidence Level (95.0%)	4.24	3.84	18.31	19.58	15.02	115.56

The predominant size class for the male individuals is 90 - 92 mm - 28.57 (Fig. 16, Table 26.1). The predominant size class for the female individuals is 78 - 81 mm - 38.46 %, (Fig. 16, Table 26.2). The imposex individuals are represented by three size classes - 76 - 78 mm, 78 - 81 mm and 90 - 92 mm (Fig. 16).

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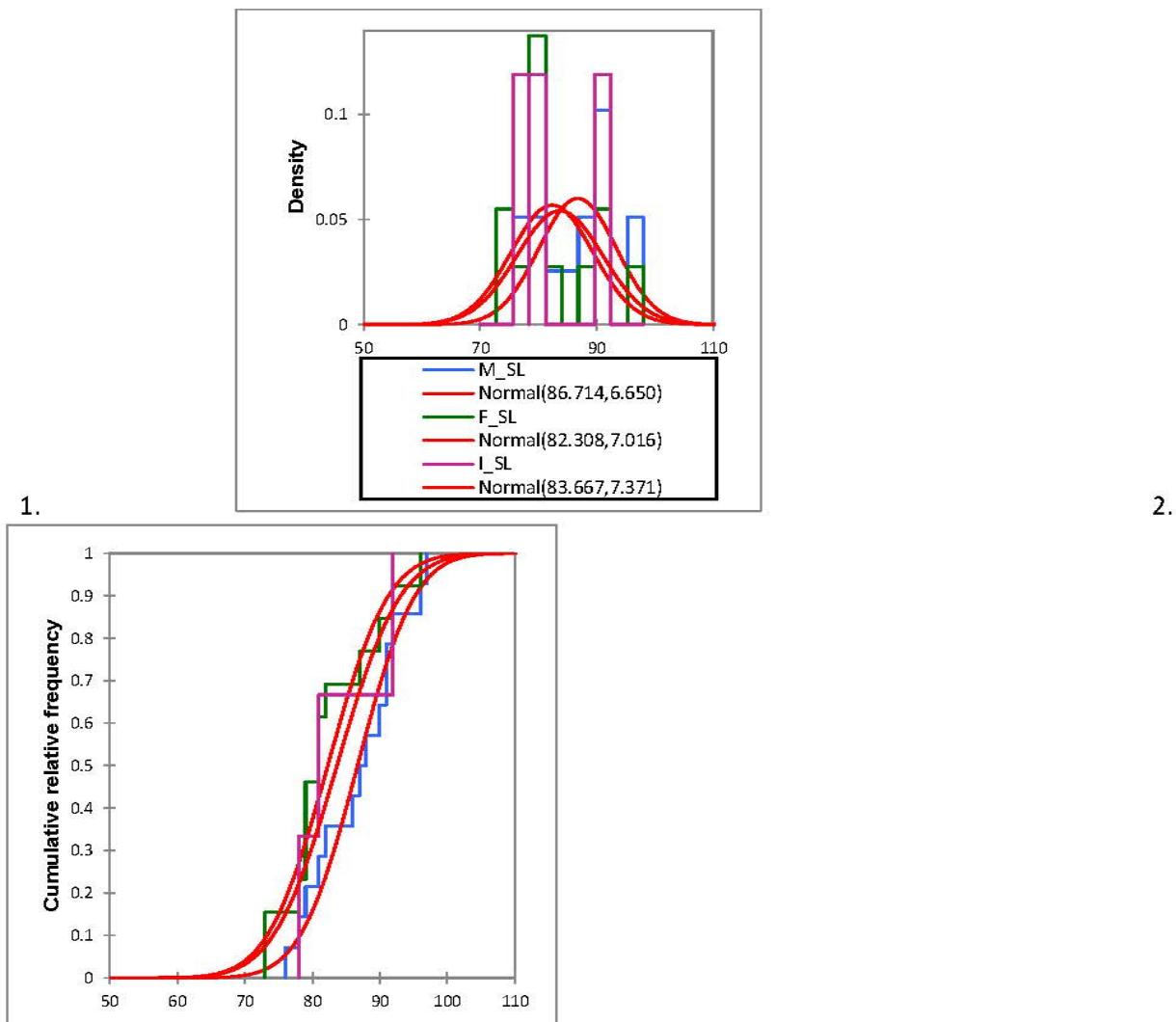


Figure 16. Gender and size classes (1) distribution based on shell length (SL, cm) and cumulative distribution of the size classes (2) in the sample from Durankulak, 21.06.2018

Table 26

Statistical data about the distribution of the size (mm) classes of rapana by gender (1, male; 2, female) in the sample from Durankulak Port, 21.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	76	78	2	0.143	0.051
	78	81	2	0.143	0.051
	81	84	1	0.071	0.026
	84	87	1	0.071	0.026

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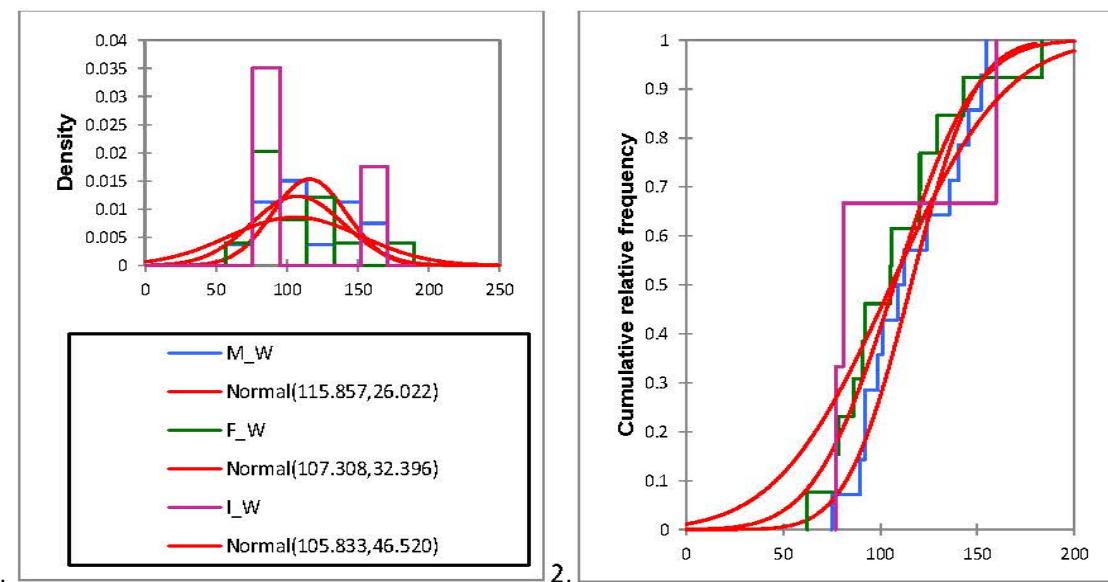
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87	90	2	0.143	0.051
90	92	4	0.286	0.102
95	98	2	0.143	0.051

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	73	76	2	0.154	0.055
	76	78	1	0.077	0.027
	78	81	5	0.385	0.137
	81	84	1	0.077	0.027
	84	87	0	0.000	0.000
	87	90	1	0.077	0.027
	90	92	2	0.154	0.055
	92	95	0	0.000	0.000
	95	98	1	0.077	0.027

In respect to the body weight (TW, g), the average weight of the male individuals is 115.86 g \pm 26.02 SD, for female individuals is with 7.66 % lower, while for the imposex forms it is 9.04% lower (Table 25).

The predominant weight classes for the male individuals are 95 - 114 g - 28.57 %, as well as classes - 76 - 95 g and - 133 - 152 g - *21.43 % (Fig. 17, Table 27.1). The predominant weight classes for the female individuals are 76 - 95 g - 38.46 % and 114 - 133 g - 23.08 % (Fig. 17, Table 27.2). Regarding the imposex forms, the most abundant weight class is 76 - 95 g - 66.67 % (Fig. 17).





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Figure 17. Gender and weight classes (1) distribution based on body weight (TW, g) and cumulative distribution of the weight classes by gender (2) in the sample from Durankulak, 21.06.2018

Table 27

Statistical data about the distribution of weight (g) classes of rapana by gender (1, male; 2, female) in the sample from Durankulak Port, 21.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	57	76	1	0.071	0.004
	76	95	3	0.214	0.011
	95	114	4	0.286	0.015
	114	133	1	0.071	0.004
	133	152	3	0.214	0.011
	152	171	2	0.143	0.008
	171	190	0	0.000	0.000

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	57	76	1	0.077	0.004
	76	95	5	0.385	0.020
	95	114	2	0.154	0.008
	114	133	3	0.231	0.012
	133	152	1	0.077	0.004
	152	171	0	0.000	0.000
	171	190	1	0.077	0.004

3.1.2.4. BYALA PORT, 22.06.2018 г.

The ratio between genders in the sample is 60 % ♂ : 26.67 % ♀ : 13.33 % imosex or 2.25 : 1 : 0.5.

In respect to the shell size (SL, mm), the average length of the female individuals is 80.5 mm ± 6.50 SD, while the males are about 4.52 % bigger in size. In the imosex forms the percentage difference compared to ♀ is 5.73 %, in favor of the imosex individuals (Table 28).

Table 28

Summarized statistics about the biological parameters - total weight of the individuals in the sample, shell length (SL, mm) and body weight (TW, g) by gender in the sample from Byala Port, 22.06.2018

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	SL, mm			TW, g		
	Females	Males	Imposex	Females	Males	Imposex
Mean	80.50	84.22	85.25	110.06	123.50	106.88
Standard Error	2.30	1.84	1.44	8.96	7.36	8.27
Median	81.00	85.00	85.00	101.25	118.50	113.00
Mode	73.00	70.00	85.00			
Standard Deviation	6.50	7.80	2.87	25.33	31.21	16.54
Sample Variance	42.29	60.77	8.25	641.60	974.00	273.56
Kurtosis	1.05	0.03	1.65	0.63	-0.10	3.36
Skewness	0.77	-0.18	0.52	0.85	0.39	-1.79
Range	20.00	30.00	7.00	81.00	121.50	36.50
Minimum	73.00	70.00	82.00	76.50	71.50	82.50
Maximum	93.00	100.00	89.00	157.50	193.00	119.00
Sum	644.00	1516.00	341.00	880.50	2223.00	427.50
Confidence Level (95.0%)	5.44	3.88	4.57	21.18	15.52	26.32

The predominant size class in the male individuals is 89 - 92 mm - 22.22% (Fig. 18, Table 29.1), while in the female individuals two size classes are predominant - 79 - 82 mm (37.5 %), as well as 70 -73 mm - 25 % (Fig. 18, Table 29.2). In the imposex forms, the most common size class is 82-86 mm - 50 % (Fig. 18).

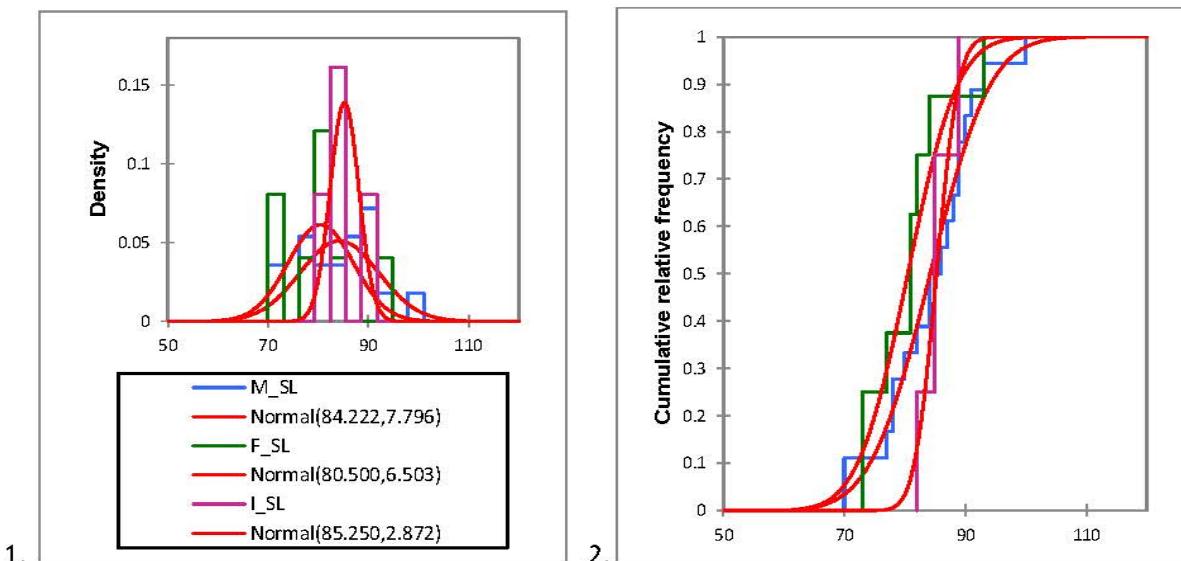


Figure 18. Gender and size class (1) distribution based on shell length (SL, cm) and cumulative distribution of the size classes by gender (2) in the sample from Byala, 22.06.2018

Table 29
Statistical data about the distribution of the size (mm) classes of rapana by gender (1, male; 2, female) in the sample from Byala Port, 22.06.2018

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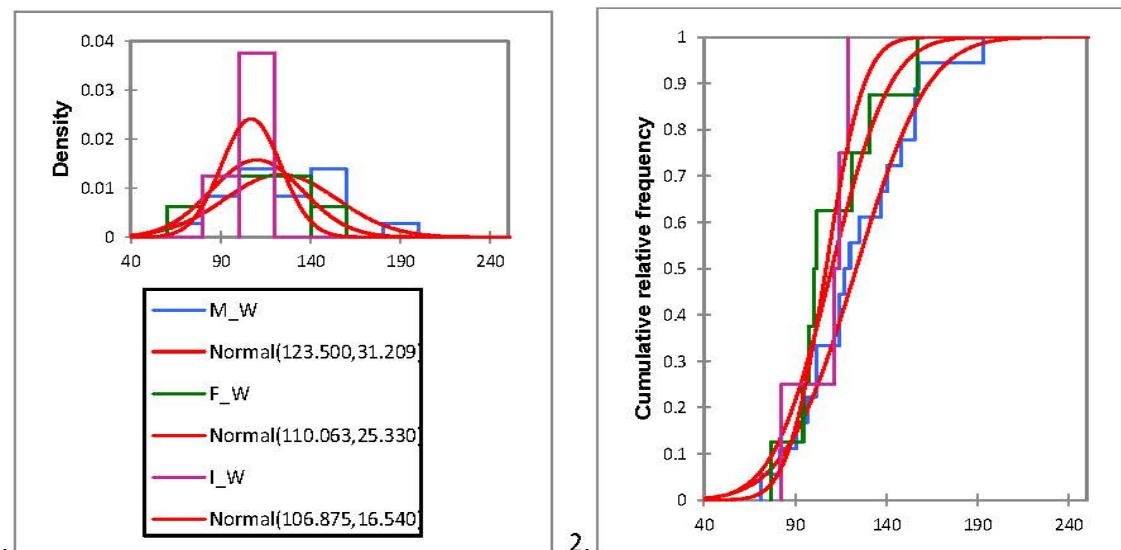
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Lower bound	Upper bound	Frequency	Relative frequency	Density
60	80	1	0.056	0.003
80	100	3	0.167	0.008
100	120	5	0.278	0.014
120	140	3	0.167	0.008
140	160	5	0.278	0.014
160	180	0	0.000	0.000
180	200	1	0.056	0.003

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	60	80	1	0.125	0.006
	80	100	2	0.250	0.013
	100	120	2	0.250	0.013
	120	140	2	0.250	0.013
	140	160	1	0.125	0.006

In respect to body weight (TW, g), the average weight in male individuals is $123.50 \text{ g} \pm 31.21 \text{ SD}$, female individuals have with 11.51 % lower body weight, imposex forms with 14.43 % lower than ♂ (Table 28, Fig. 19).

The predominant weight classes in the male individuals are 100 - 120 g and 140 - 160 g - *27.78 % (Fig. 19, Table 30.1). In the female individuals the predominant weight classes are 80-100 g, 100 - 120 g and 120 - 140 g - *25 % (Fig. 19, Table 30.2). The predominant weight class for the imposex forms is – 100 - 120 g - 75 % (Fig. 19).



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Figure 19. Distribution of the size classes by gender (1) based on weight (TW, g) and cumulative distribution of the weight classes by gender (2) in the sample from Byala, 22.06.2018

Table 30

Statistical data about the distribution of the weight (g) classes of rapana by gender (1, male; 2, female) in the sample from Byala Port, 22.06.2018

1	Lower bound	Upper bound	Frequency	Relative frequency	Density
	100	109	1	0.071	0.008
	109	118	2	0.143	0.016
	118	127	3	0.214	0.024
	127	136	0	0.000	0.000
	136	146	3	0.214	0.024
	146	155	2	0.143	0.016
	155	164	1	0.071	0.008
	164	173	2	0.143	0.016

2	Lower bound	Upper bound	Frequency	Relative frequency	Density
	100	109	3	0.188	0.021
	109	118	1	0.063	0.007
	118	127	1	0.063	0.007
	127	136	2	0.125	0.014
	136	146	1	0.063	0.007
	146	155	3	0.188	0.021
	155	164	2	0.125	0.014
	164	173	2	0.125	0.014
	173	182	1	0.063	0.007

3.1.2.5 SUMMARY OF THE GENDER STRUCTURE

Summarized data about all researched areas, percentage shares of ♀: ♂ : IS forms are 54.89 % ♀: 39.28 % ♂ : 5.83 % IS (Fig. 20). The most abundant imposex forms were observed in Byala - 13.33 % from all analyzed individuals (Fig. 20).

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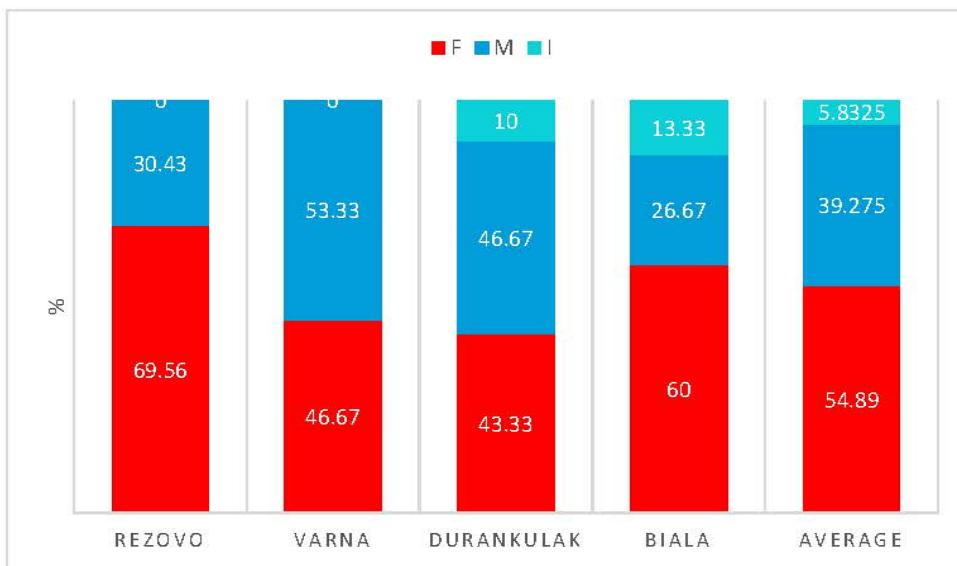


Figure 20. Summarized data about the gender structure of *R. venosa* by ports for 2nd quarter of 2018

Past studies, along the Romanian coastal waters, reveal that the share of imposex forms may reach up to 30% from the ♀ individuals: (F: IS = 3.26:1) (Micu et al., 2009), while data from landings show maximum of 22.22 % from the number of ♀ individuals.

The biggest average sizes were observed in the IS forms - 84.5 mm, followed by ♂ - 79.4 mm, while the smallest average sizes are in the ♀ individuals - 74.5 mm (Fig. 21). The situation with the variations of the size classes by gender and ports is much different – for example in Rezovo (scuba diving) the landings show the biggest average sizes both for male - 91.8 mm, and female individuals – 87.5 mm (Fig. 21). Accordingly, at Varna Port, the landings data show that using beam trawl resulted in only 55 mm average size for the males and 74 mm for the female individuals. The maximum size of 100 mm (male individual) was observed in Byala, while for female individuals 96 mm in Durankulak, where also the IS forms have maximum size – 92 mm (Fig. 21).

The average weight of the male individuals reaches 115.85 g, while for the females it is 105.46 g. There is a clear difference between the ports because of the fishing method – at Rezovo (scuba diving) the average weight of the male individuals is 155.79 g, which is 34 % bigger than the overall average for the period, while for the females it is 32 % bigger - 139.74 g. The opposite trend is observed for Varna Port where the average weight of the male individuals – 68.25 g, which is with 70 % lower than the overall average, while for the females - 64.71 g – or 62 % lower than the average (Fig. 22). Regarding the imposex forms, the average weight for the period is 106.35 g, with a maximum value at Durankulak - 159.50 g. The maximum weight of a female individual was also observed there – 183.50 g, while for a male individual it was observed at Byala Port - 193 g (Fig. 22).



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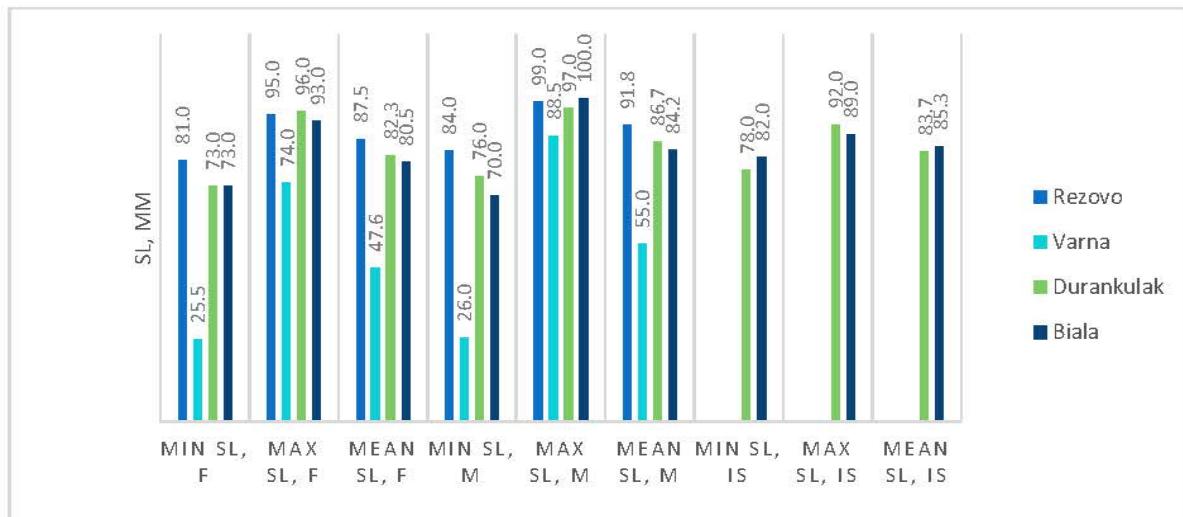


Figure 21. Summarized data about the minimum, maximum and average sizes (SL, mm) by gender *R. venosa* and by ports for 2nd quarter of 2018

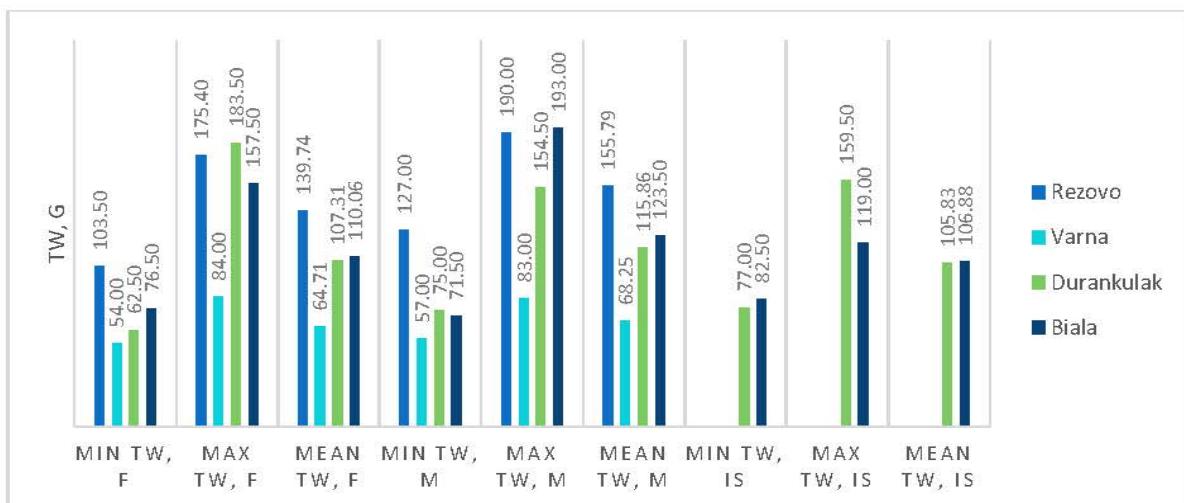


Figure 22. Summarized data about the minimum, maximum and average total weights (TW, g) by gender for *R. venosa* and by ports for 2nd quarter of 2018

It is very hard to derive a common conclusion about the dynamics of the sizes and weights of rapana by gender and ports because of the different fishing methods – beam trawl and scuba diving. Both have their own specifics and most importantly different approach in the selection of the individuals, resulting in different size/weight of rapana.



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4. CONCLUSIONS

- The analysis of the rapana landings in June 2018 were carried out by using 400 individuals from four different ports – Rezovo, Varna, Byala and Durankulak. The main tasks were to assess the differences between the population parameters in the main fishing areas and according to the specific types of fishing.
- The total quantity of the landings for the different ports varied between 300 – 1500 kg/day. By using short fishing boats (up to 9 m long) and scuba divers, the catches were between 300 - 430 kg/day. Longer fishing vessels (19.4 m long), equipped with beam trawl, caught up to 1500 kg/day.
- The maximum average sizes and weights were observed in the samples of *R. venosa* from Rezovo - 89.59 mm SL, 140 g TW, due to the fishing method (scuba diving), allowing the selection of larger individuals. Relatively large average sizes and weights - 81.87 - 83.48 mm SL, 100.36 - 115.83 gTW were observed in catches from Byala and Durankulak, by scuba diving. The smallest average sizes and weights - 64.64 mm SL и тегла - 47.19 g were observed in Varna, where the beam trawl was used for fishing and its technical parameters limit the options for the selection of larger individuals.
- In the 2 quarter of 2018, the mean ratio of Wd/SL reaches 77.09 %, with the smallest share in the sample from Rezovo - 75.15 % and highest in Byala - 79.89%. The ratio of AL/SL reaches an average of 62.61%, with the least share in Varna Port – 48.23 % and maximum in the sample from Byala Port - 71.90 %. In respect to the ratio AL/Wd (%), the average value is 81.09 %, with minimum ratio in Varna Port - 64.02% and maximum - 90.02 % in the sample from Byala Port.
- The comparison analysis of the parameters *a* and *b* of the L-W relationship: $W(g)=a \cdot L(mm)^b$ shows allometric growth of *R. venosa* with a coefficient $b \neq 3$ (*t*-test, $P=0.028$). The parameter $b < 3$ shows a negative allometric growth, which means that in bigger individuals the growth in size outpaces the growth in weight. The coefficient *b* has least value at Rezovo - 2.373, while for the rest of the ports it is about 2.7.
- The average percentage ratio for all ports is ♀: ♂ : IS forms - 54.89 % ♀: 39.28 % ♂ : 5.83 % IS. The most abundant share of imposex forms was observed at Byala - 13.33 % from all analyzed individuals.
- In regard to the dynamics of the mean sizes by gender in the landings, the biggest average size is in the imposex forms – 84.5 mm, followed by ♂ - 79.4 mm, while the least average sizes in the female individuals - 74.5 mm. The average weight of the male individuals reaches 115.85 g, while for females - 105.46 g. There is a clear difference between ports, based on the fishing method – beam trawl or scuba diving, which results in different selectivity of the size/weight of rapana.

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