Bottom Trawl Surveys In The Bulgarian Black Sea Area, Spring 2017

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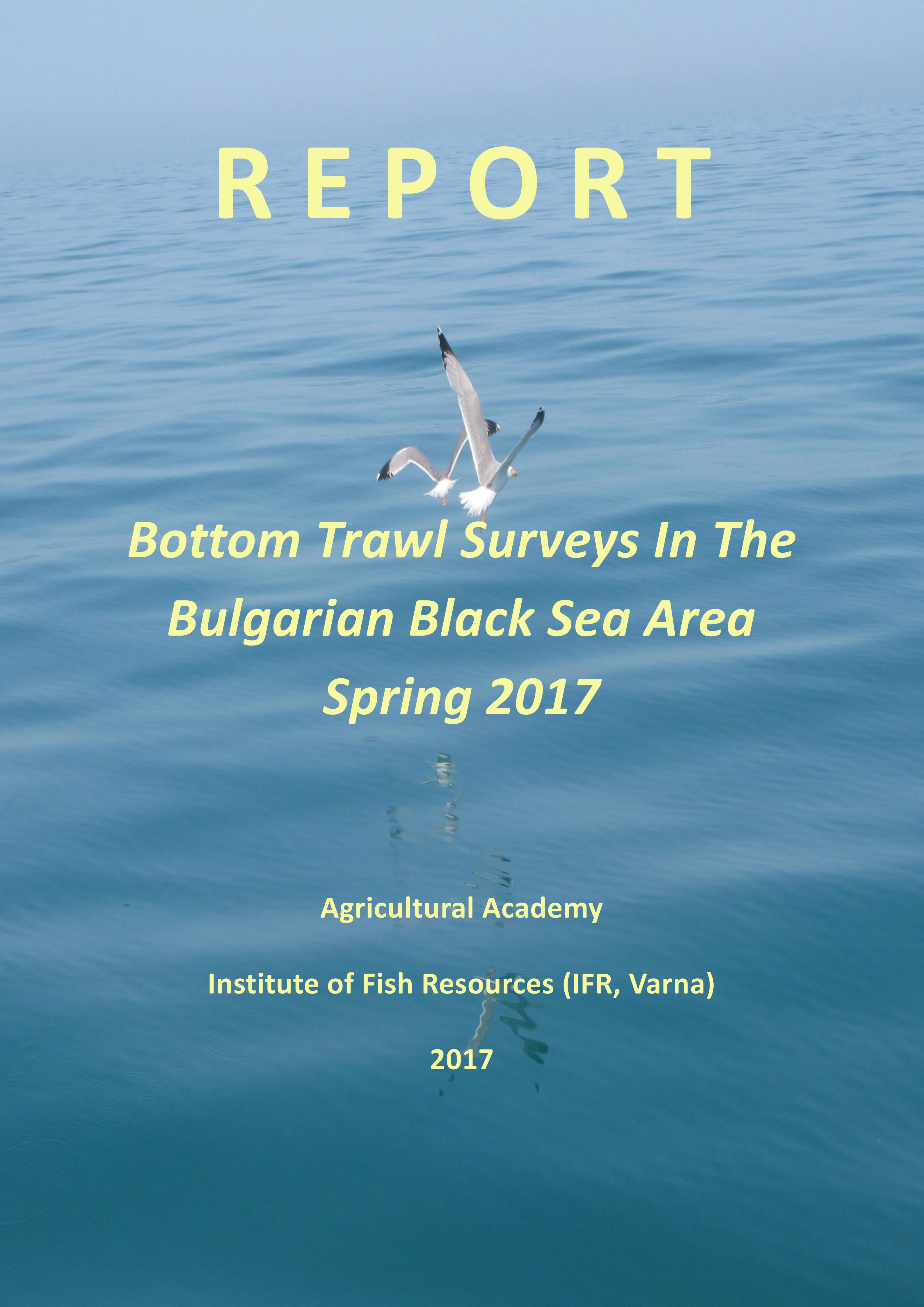

R E P O R T

Bottom Trawl Surveys In The Bulgarian Black Sea Area Spring 2017

Agricultural Academy

Institute of Fish Resources (IFR, Varna)

2017

ЕВРОПЕЙСКИ СЪЮЗ
ЕВРОПЕЙСКИ ФОНД ЗА
МОРСКО ДЕЛО И РИБАРСТВО

МИНИСТЕРСТВО НА ЗЕМЕДЕЛИЕТО, ХРАНИТЕ И ГОРИТЕ

ПРОГРАМА ЗА
МОРСКО ДЕЛО И
РИБАРСТВО

The present study was conducted by a team of specialists from the Institute of Fishery Resources (IFR) – Varna, Agricultural Academy, under contract № D-39/23.05.2017 with the National Agency for Fisheries and Aquaculture (NAFA) - Burgas, for turbot stock assessment in the Bulgarian Black Sea waters during the spring period of 2017.
The study was conducted owing to the financial support of the European Commission in compliance with Council Regulation No. 199/2008 and Commission Decision 2010/93/EU, aimed to help the member states for creating a common frame for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.
The study was performed in the period 24 - 31 May 2017 in the Bulgarian Black Sea waters on board of the "EGEO 3" fishing vessel.

The scientific research was carried out by IRR-Varna:

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Проектно предложение № BG14MFOP001-3.003-0001, „Събиране, управление и използване на данни за целите на научния анализ и изпълнението на Общата политика в областта на рибарството за периода 2017-2019 г.", финансирано от Програмата за морско дело и рибарство, съфинансирано от Европейския съюз чрез Европейския фонд за морско дело и рибарство

BOTTOM TRAWL SUREVY FOR TURBOT STOCK ASSESSMENT IN BULGARIAN BLACK SEA SECTOR DURING SPRING SEASON OF 2017

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LIST OF FIGURES IN THE TEXT

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1. Results from the National Bottom Trawl Surveys in May 2017

During 24-30 May**,** within the frames of the National Programme for Fisheries Data Collection, the research team from IFR - Varna conducted demersal trawl survey with the fishing ship "EGEO 3" in the Bulgarian Black Sea waters - between Durankulak and Ahtopol, within the 100-meter isobath.

This report is based on the data collected through the survey, which are indicative of the distribution and values of the relative biomass and abundance of the reference species *Scophthalmus maximus*. The analyses include an estimation of the biomass indexes and density of the reference species by depth strata, and a study of size/age and sex structure of the stock.

This document contains a series of tables and figures that show the relative biomass distribution, as well as size/age and sex structure analysis of the reference species.

The trawl surveys in V/2017 included the following activities:

- Bottom trawl sampling;
- Qualitative and quantitative analysis of the catches, identification of biological diversity, biometric measurements;
- Collection of otoliths for turbot age determination;
- Sampling and analysis of stomach contents for identification of quantity and composition of the consumed food.

1.1. Fishing vessel and fishing gear

The trawl surveys were conducted on board the fishing ship "EGEO 3" (picture 1) with the following parameters:

- Fishing vessel - TAKA;
- Fishing vessel length -17.23 m;
- Maximum width - 5 m;
- The fishing vessel year of built - 2013;
- Engine power - 320 kW;
- Maximum tonnage - 33.6 t;

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- Net tonnage - 7 t;
- Speed - 9 Nd;
- Crew - 3 people;
- Research team - 3 people.

Picture 1. *Fishing ship*

During the studies, a fishing bottom trawl 22/27-34 was applied (picture 2), with following functional and technical parameters:

- Trawl vertical opening – 2 m;
- Horizontal opening between the otter boards – 9 m;
- Effective part of wing spread – 13 m;
- Trawling speed – 2.2 - 2.6 Nd;
- Trawling duration – 60 min.

Picture 2. *Bottom trawl 22 / 27-34.*

2. Material and methods

The target species was turbot - *Scophthalmus maximus* and the by-catch species - the spiny dogfish (*Squalus acanthias)* and the thornback ray (*Raja clavata*) were also analysed.

The methodology and techniques, used for collection, verification, processing, and data analysis and for complete turbot stock assessment were following the generally applied methodology in the Bulgarian Black Sea zone.

The field data were collected by standard techniques - bottom trawl that remained constant through the surveys. The GPS system of the ship was connected to NAFA satellite system for monitoring of the fishing vessels (VMS) and the ship location was strictly controlled during the trawling.

2.1 Information collected through the bottom trawling

- Depth - measured with the echo-sounder;
- GPS coordinates of the trawling - starting and end points;
- Trawling duration;
- Abundance of fish species in the trawl;
- Weight of the total catch in the trawl;
- Absolute and standard length; weight of collected specimens;
- Collection of otoliths for age determination;
- Sex identification;
- By-catch species composition;
- Turbot stomachs for stomach content analysis;

For turbot biomass calculations, data for catch per unit effort (CPUE) (kg/h) and catch per unit area (CPUA) (kg/km^2) were used.

The results are presented in the form of maps and tables that include data for:

- Catch per unit effort (kg/trawl)
- Catch per unit area (t/km^2);
- Abundance index (individual/km^2);
- Limits of variation of catches pet unit area;
- Total biomass (t.) and abundance (ind).

2.2. Sampling scheme

To establish the abundance and biomass of the reference species *S. maximus* off the Bulgarian Black Sea coast, a standard methodology for stratified sampling (Gulland, 1966; Sparre, Venema, 1998; Sabatella, Franquesa, 2004) was applied. The zones, where trawling was performed, are presented in Figure 1.

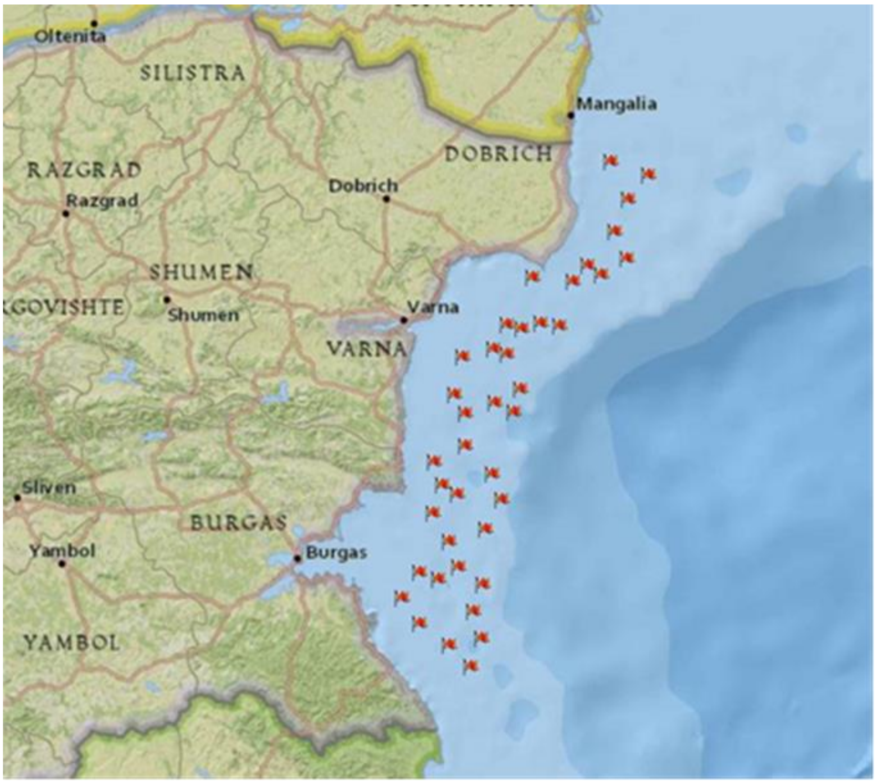

Fig.1. Map of the surveyed sectors, V/2017

The surveyed region was divided into four strata, depending on the depth – Stratum 1 (15 - 35 m), Stratum 2 (35 - 50 m), Stratum 3 (50 - 75 m) and Stratum 4 (75 - 100 m). For assessment of turbot abundance and biomass, the surveyed territory was divided into 143 squares, each of them with sides 5 x 5 Nm, area 25 Nm2 (or 85.8569 m2). The sampling was carried out at 40 randomly chosen fields (rectangles), situated at depth between 15-100 m. Each rectangle is with sides 5'Lat × 5'Long, while the total area is 62.58 km2 (measured by GIS). Each field was marked with letters and digits for better distinction. The seabed area covered during a single haul represents a basic measurement unit, considered representative, as turbots do not aggregate in dense assemblages (Martino, Karapetkova, 1957). The duration of each hauls was 60 min. at trawling speed of 2.4 knots.

On the ship board, the absolute and standard length, as well as the individual weight of each specimen were measured in order to determine the size and weight structure of the turbot stock and to estimate the share of specimens with length below the allowable fishing length in the catches.

2.3. Laboratory analysis

After collecting the samples on shipboard, the age, maturity of the reproductive system and stomach content composition were determined in laboratory.

The turbot age was established by otoliths reading under binocular microscope.

To identify the food composition, a total of 55 stomachs were collected in spring 2017. The stomach content analysis included identification of the taxonomic composition and total number of food components, weight and frequency of occurrence of each food component. The index of relative importance (IRI) was used to determine the significance of each food component in the trophic spectrum (Pinkas et.al., 1971):

$$IRI = (C_N + C_W) * F,$$

C_N - percentage share of the food item *i* in total number; C_W - percentage share of the food item *i* in the total weight; F – frequency of occurrence.

IRI expressed as a percentage was calculated by the equation (Cortes, 1997):

$$\%IRI_i = \frac{100 * IRI_i}{\sum_i^n IRI_i}$$

n – total number of the taxonomic categories at a given taxonomic level.

2.4. Statistical methods

Swept areas method

To determine the relative biomass of the reference species *S. maximus*, the “swept area method” was applied. According to this method, trawl sweeps a well-defined path, the area of which is the length of the path times the width of the trawl, called the "swept area" or the "effective path swept", thus the swept area can be estimated from equation:

$$a = D*hr*X2, \; D = V*t$$

V - is the velocity of the trawl over the ground when trawling, t - the time spent trawling, hr - the length of the head-rope. X2 is that fraction of the head-rope length, hr, which is equal to the width of the path swept by the trawl, the "wing spread", hr*X2, D- distance covered.

To calculate turbot biomass, the catch per unit area(CPUA) was used:

$$\frac{C_{w/t}}{a/t} = \frac{Cw}{a} kg/km^2$$

Cw/t – catch in units of weight per trawling hour, a/t – area swept per trawling hour.

The biomass for each stratum was obtained from equation:

$$B = \left(\overline{C_{w/a}}\right) * A$$

$\overline{C_{w/a}}$ - mean catch per unit of area for all trawl sweeps in the stratum, A – stratum area.

The variance of biomass estimated for each stratum is:

$$VAR(B) = A^2 * \frac{1}{n} * \frac{1}{n-1} * \sum_{i=1}^{n} \left[Ca(i) - \overline{Ca}\right]^2$$

The total area of the surveyed region is equal to the sum of the areas of every stratum:

A = A1+A2+A3

The mean catch for the entire survey area was obtained from equation:

$$\overline{Ca}(A) = \frac{Ca1 * A1 + Ca2 * A2 + Ca3 * A3}{A}$$

Ca1- catch per unit area in stratum 1; A1 – stratum 1 area, etc.; A – total water area.

The total biomass in the survey area is estimated by equation:

$$B = \overline{Ca}(A) * A$$

$\overline{Ca}(A)$- mean weighted catch for the entire surveyed water area, A – total area surveyed.

Maximum sustainable yield

Gulland's formula for virgin stock is:

*MSY = 0.5*M*Bv*

M – coefficient of natural mortality, Bv- biomass of virgin stock.

A generalized version of Gulland was proposed by Cadima (in Troadec, 1971) for exploited fish stocks for which only limited data are available for stock assessment:

$$MSY = 0.5 * Z * \overline{B}$$

$\overline{B}$ - mean annual biomass, Z – total mortality.

Because Z = F + M and Y = F * $\overline{B}$, Cadima suggested that in the absence of data for Z, the equation can be rewritten:

$$MSY = 0.5 * (y + M * \overline{B})$$

y – total catch in one year, $\overline{B}$ - mean biomass in the same year.

<u>TAC - total allowable catch, Prediction models</u>

<u>Beverton and Holt yield per recruit model</u> **<u>(1957):</u>**

$$Y/R = F*\exp[-M*(Tc-Tr)]*W_{\infty} * \left[\frac{1}{Z} - \frac{3S}{Z+K} + \frac{3S^2}{Z+2K} - \frac{S^3}{Z+3K}\right]$$

S = exp [-K (Tc – t_0)], K = von Bertalanffy growth parameter, t0 = von Bertalanffy growth parameter, Tc = age at first capture, Tr = age at recruitment, W□□ = asymptotic body weight, F = fishing mortality, M = natural mortality, Z = F + M, total mortality.

To evaluate the exploitation ratio, the formulae of ***<u>Pauly (1983)</u>*** was used: E = F / Z; E - exploitation ratio, F - fishing mortality, Z - total mortality;

<u>Jones' Length-Based Cohort Analysis</u> **<u>(1981)</u>**

Jones' length-based cohort analysis:

$$\exp\left(\frac{M}{2} * \Delta t\right) = \exp\left[\frac{M}{2} * \frac{1}{K} * \ln\left(\frac{L\infty - L1}{L\infty - L2}\right)\right] = \exp\left[\ln\left(\frac{L\infty - L1}{L\infty - L2}\right)^{M/2K}\right] = \left[\frac{L\infty - L1}{L\infty - L2}\right]^{M/2K}$$

<u>Age and growth</u>

For the estimation of turbot growth rate, the von Bertalanffy growth function (1938) was applied, (according to Sparre, Venema, 1998):

$$L_t = L_{\infty}\left\{1 - \exp\left[-k\left(t - t_0\right)\right]\right\}$$

$$W_t = W_{\infty}\left\{1 - \exp\left[-k\left(t - t_0\right)\right]\right\}^n$$

L_t, W_t are the length or weight of the fish at age **t** years; L∞, W∞ - asymptotic length or weight; k – curvature parameter; t_o - the initial condition parameter.

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The length – weight relationship is obtained by the following equation:

$$W_t = qL_t^n$$

q-constant in length-weight relationship; n - constant in length-weight relationship.

Natural mortality (M)

Pauly's empirical formula (1979, 1980) was applied:

$$\log M = -0.0066 - 0.279 * \log L_\infty + 0.6543 * \log k + 0.4634 * \log T^\circ C$$

$$\log M = -0.2107 - 0.0824 * \log W_\infty + 0.6757 * \log k + 0.4687 * \log T^\circ C$$

L∞, W∞ and k – parameters in von Bertalanffy's equation; TºC - the annual average temperature of the seawater in the horizons of habitation and reproduction of the species.

***Method of Richter si Efanov* (1976)**

$$M = \frac{1.521}{(t_{mat.50\%})^{0.720}} - 0.155$$

t_{mat} – age at first maturation.

3.Results

3.1. Population number and biomass

During the demersal trawl survey in V/2017 the following activities were carried out:

- 40 hauls with a bottom trawl, with duration of 60 minutes for each trawl at depths between 15.0 m and 100.0 m, covering entirely the continental shelf of the Bulgarian Black Sea zone, between Durankulak and Ahtopol.

- for each haul, a qualitative and quantitative analysis of the catch was accomplished, including biometric measurements of 83 turbot specimens and 1 individual spiny dogfish (Picture 3 and 4).

Picture 3. *Bottom trawling yield*

Picture 4. *Conducting biometric measurements and sampling for study of the stomach contents*

During the survey was established: constant presence of *Scophthalmus maximus* in almost all bottom trawls at a depth between 50 -75 m and 75-100 m, with yield - at least 1-4 individuals per haul, mixed with specimens of whiting (*Merlangius merlangus euxinus*) (Picture 5).

Picture 5 *Yield of turbot (S. maximus) and associated species Merlangius merlangus (whiting), Raja clavata (thornback ray), Platichthys flesus (European flounder) and dogfish (Squalus acanthias).*

During the research, one female specimen of dogfish (*Sq. acanthias*) was captured and measured - 140 cm length and 12.8 kg weight.

The basic part of the catch consisted of a mixture of species: whiting (*Merlangius merlangus euxinus*), red mullet (*Mullus barbatus ponticus*) and thornback ray (*Raja clavata* - over 14 individuals). The associated species were identified as black mussel (*Mytilus galloprovincialis*), common jellyfish (*Aurelia aurita*), black scorpionfish (*Scopaena porcus*), flounder (*Platichthys flesus luscus*), goby fish (*Neogobius melanostomus*), sprat (*Sprattus sprattus*) and prawn (*Crangon crangon*).

It should be noted, that in almost all sectors where the bottom trawling was conducted (including the coastal area), significant amount of marine litter was established (drums, boxes and various metal parts, trees, plastic bags, plastic bottles, gillnets for turbot, etc.) (Picture 6).

Picture 6 *Marine debris identified during the bottom trawl in May 2017.*

<u>Comments on the biomass of *Scophthalmus maximus* in the Bulgarian waters by strata</u>

Trawling at a depth of up to 30 m cover only three stations, and due to their small number, they were grouped together with the stations preformed up to 50 m, thus the statistical analysis was conducted for the stratum 15 - 50 m.

The biomass of the three shallow stations (at a depth < 30 m) reached respectively 19.025 kg/km^2, 51.54 kg/km^2 and 0 kg/km^2, with abundance - 34 ind/km^2, 17 ind/km^2 and 0 ind/km^2. At these stations, the highest yield was found off the Cape Kaliakra, while in front of the Shkorpilovtsi area the turbot specimens were not established.

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The information about the yields by stratum is given below:

Stratum 15 - 50 m

The relative turbot biomass varied between 0 and 153.755 kg/km^2, 64.511 kg/km^2 on average (Table 1, Fig. 2). The abundance indices varied between 0 and 69 individuals/km^2, on average - 30 ind/km^2 (Table 2).

Stratum 50 -75 m

This stratum contained the highest number of individuals. The abundance indices varied between 0 and 86 ind/km^2, with average value of 40 ind/km^2 (Table 2, Fig. 2 and 4). The relative turbot biomass varied between 0 and 193.88 kg/km^2, 88.086 kg/km^2 on average (Table 1, Fig. 2 and 3).

Stratum 75 - 100 m

In this stratum, the relative biomass was slightly higher than stratum 50-75 and varied from 36.147 to 195.783 kg/km^2, on average 88.678 kg/km^2 (Table 1, Fig. 2 and 4), with average abundance - 39 ind/km^2 (Table 2).

Table 1

Turbot biomass by strata, May, 2017

15 - 50 м		50 – 75 м		75-100 м	
No. station	t/км^2	No. station	t/км^2	No. station	t/км^2
1	0	3	0.06468	13	0.05241
2	0.11795	5	0.08907	14	0.07869
4	0.12262	6	0.13127	15	0.19578
8	0.0339	7	0.09011	16	0.03615
9	0.04151	12	0.05777	17	0.1503
10	0	19	0	18	0.07178
11	0.15376	22	0.06987	23	0.23435
20	0.0588	26	0.06572	24	0.03269
21	0	27	0.19388	29	0.02888
25	0.1413	28	0.15099	30	0.03165
33	0.05154	31	0	34	0.06278
36	0.14148	32	0.04116		
37	0.08475	35	0.19059		
38	0.02508				
39	0.040471				

40	0.019025				
Total	**1.032183**	**Total**	**1.145121**	**Total**	**0.975454**
Average	**0.064511**	**Average**	**0.088086**	**Average**	**0.088677**
Variance	0.002985		0.003962		0.005158
Standard deviation	0.054639		0.062946		0.071821
Relative standard deviation	0.846969		0.714591		0.809911
Standard error	0.01366		0.017458		0.02394

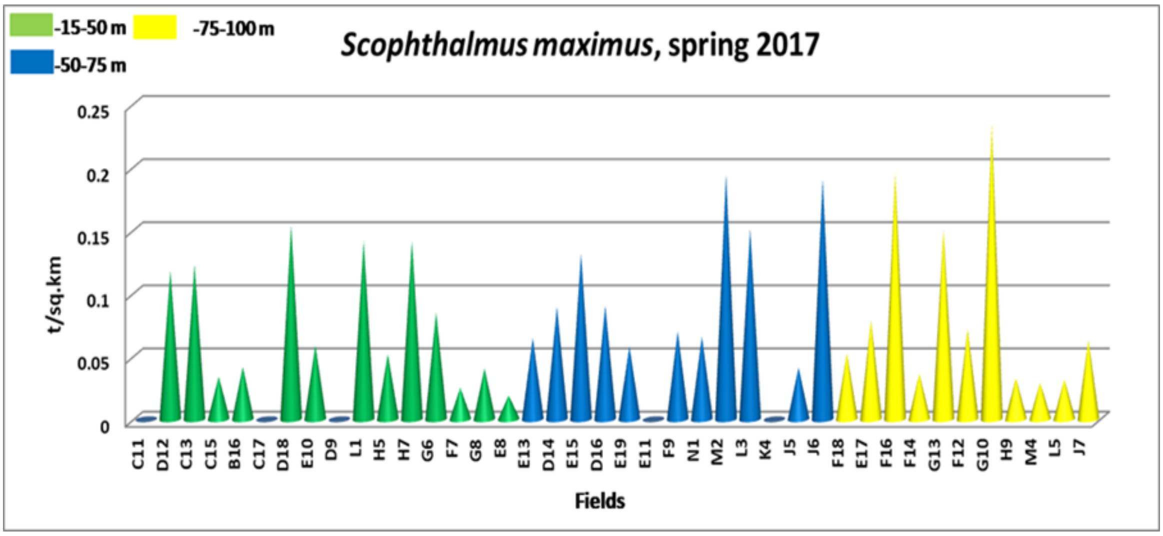

Fig.2 Relative biomass (t/km2) of S. maximus by strata off the Black Sea coast, May 2017.

Table 2 shows the distribution of turbot abundance in May 2017.

Table 2

Current abundance of *S. maximus* by strata in May 2017

15 - 50 м		***50 – 75 м***		***75-100 м***	
No. station	***No. Ind./km2***	***No. station***	***No. Ind./km2***	***No. station***	***No. Ind./km2***
1	0	3	17	13	17
2	69	5	35	14	35
4	52	6	52	15	52
8	17	7	35	16	17

9	35	12	17	17	52
10	0	19	0	18	52
11	52	22	35	23	104
20	35	26	52	24	17
21	0	27	86	29	17
25	52	28	86	30	17
33	17	31	0	34	52
36	52	32	17	13	17
37	35	35	86		
38	17				
39	17				
40	35				
Total	**484**	**Total**	**519**	**Total**	**432**
Average	**30**	**Average**	**40**	**Average**	**39**
Variance	14.2		22.3		16.7
Standard deviation	3.8		4.7		4.1
Relative standard deviation	0.1		0.1		0.1
Standard error	0.2		0.2		0.2

3.2. Catch per unit effort (CPUE)

Catches from a total of 40 trawls were distributed as follows:

- 5 hauls (12.5% of total no. hauls), catch 0 kg.;
- 21 hauls (52.5% of total no. hauls), catch 0.1 – 4.99 kg per haul;
- 10 hauls (25% of total no. hauls), catch 5.0 – 9.99 kg per haul;
- 4 hauls (10% of total no. hauls), catch 10.0 – 14.99 kg per haul;

Stratum < 30 m; 3 hauls:

- 1 haul, catch 0 kg per haul;
- 2 hauls, catch 0 – 4.99 kg per haul;

Stratum 31 – 50 m; 9 hauls:

- 2 hauls, catch - 0 kg per haul;
- 5 hauls, catch - 0.1 - 4.99 kg per haul;
- 2 hauls, catch - 5.0 - 9.99 kg per haul;

Stratum 50 – 75 m; 17 hauls:

- 2 hauls, catch - 0 kg per haul;
- 6 hauls, catch 0.1 – 4.99 kg per haul;
- 7 hauls catch 5.0 – 9.99 kg per haul;
- 2 hauls, catch 10.0 – 14.99 kg per haul;

Stratum 75 – 100 m; 11 hauls:

- 8 hauls, catch 0.1 – 4.99 kg per haul;
- 1 haul, catch 5.0 – 9.99 kg per haul;
- 2 hauls, catch 10.0 – 14.99 kg per haul;

The CPUE distribution in May 2017 is shown in Table 3 and Fig. 4.

Table 3

The sampling stations, coordinates and CPUE (kg/trawl) in May 2017

№	Field	Starting coordinates		Depth (m)	Speed (Nm)	Trawling time (min)	Catch turbot	
		φ	λ				№	Kg
1	C11	42°47'700"	27°59'643"	32.7-34.3	2.4	60	**0**	**0**
2	D12	42°43'642"	28°01'536"	40.2-45	2.4	60	**4**	**6.82**
3	E13	42°38'353"	28°07'621"	66.4-55	2.4	60	**1**	**3.74**
4	C13	42°38'813"	27°59'572"	41-43.3	2.4	60	**3**	**7.09**
5	D14	42°33'382"	28°02'639"	55.2-58	2.4	60	**2**	**5.15**
6	E15	42°28'966"	28°05'504"	66.5-67.1	2.4	60	**3**	**7.59**
7	D16	42°24'570"	28°03'673"	61.3-49.8	2.4	60	**2**	**5.21**
8	C15	42°26'207"	27°58'993"	46.7-38.8	2.4	60	**1**	**1.96**
9	B16	42°23'147"	27°53'166"	36.8-38.5	2.4	60	**2**	**2.4**
10	C17	42°19'147"	27°55'762"	36.5-38.8	2.4	60	**0**	**0**
11	D18	42°14'481"	28°00'979"	48.5-52.4	2.4	60	**3**	**8.89**
12	E19	42°09'484"	28°05'986"	57.2-65.0	2.4	60	**1**	**3.34**
13	F18	42°11'689"	28°10'678"	74.5-80.2	2.4	60	**1**	**3.03**
14	E17	42°16'765"	28°09'886"	77.6-75.6	2.4	60	**2**	**4.55**
15	F16	42°21'879"	28°10'794"	81.8-82.6	2.4	60	**3**	**11.32**
16	F14	42°31'339"	28°12'010"	82.5-83.1	2.4	60	**1**	**2.09**
17	G13	42°36'857"	28°15'715"	89-88.6	2.4	60	**3**	**8.69**
18	F12	42°41'347"	28°15'026"	85.7-80	2.4	60	**3**	**4.15**

19	E11	42°46'726"	28°09'174"	60-48	2.4	60	**0**	**0**
20	E10	42°52'689"	28°08'307"	42-36	2.4	60	**2**	**3.4**
21	D9	42°55'938"	28°05'115"	31-28.7	2.4	60	**0**	**0**
22	F9	42°58'102"	28°12'892"	48-61.4	2.4	60	**2**	**4.04**
23	G10	42°54'438"	28°16'196"	71.2-81	2.4	60	**6**	**13.55**
24	H9	42°56'506"	28°20'740"	80-76	2.4	60	**1**	**1.89**
25	L1	43°37'103"	28°41'448"	49.5-51.7	2.4	60	**3**	**8.17**
26	N1	43°38'951"	28°51'151"	56.8-65	2.4	60	**3**	**3.8**
27	M2	43°34'411"	28°49'318"	62.7-65.3	2.4	60	**5**	**11.21**
28	L3	43°29'138"	28°43'299"	64.3-65	2.4	60	**5**	**8.73**
29	M4	43°24'302"	28°46'749"	75.7-78	2.4	60	**1**	**1.67**
30	L5	43°17'102"	28°41'355"	80.5-74.6	2.4	60	**1**	**1.83**
31	K4	43°21'635"	28°40'109"	69.7-63.5	2.4	60	**0**	**0**
32	J5	43°19'767"	28°35'004"	59.2-60.6	2.4	60	**1**	**2.38**
33	H5	43°16'775"	28°23'531"	30-19.2	2.4	60	**1**	**2.98**
34	J7	43°09'639"	28°33'095"	83-74.1	2.4	60	**3**	**3.63**
35	J6	43°10'863"	28°28'634"	64.3-56	2.4	60	**5**	**11.02**
36	H7	43°09'870"	28°23'680"	51-41.7	2.4	60	**3**	**8.18**
37	G6	43°10'573"	28°19'737"	37.9-30.9	2.4	60	**2**	**4.9**
38	F7	43°07'828"	28°13'862"	37.9-30.9	2.4	60	**1**	**1.45**
39	G8	43°03'635"	28°19'460"	53.7-41	2.4	60	**1**	**2.34**
40	E8	43°04'372"	28°09'465"	28.4-24	2.4	60	**2**	**1.1**

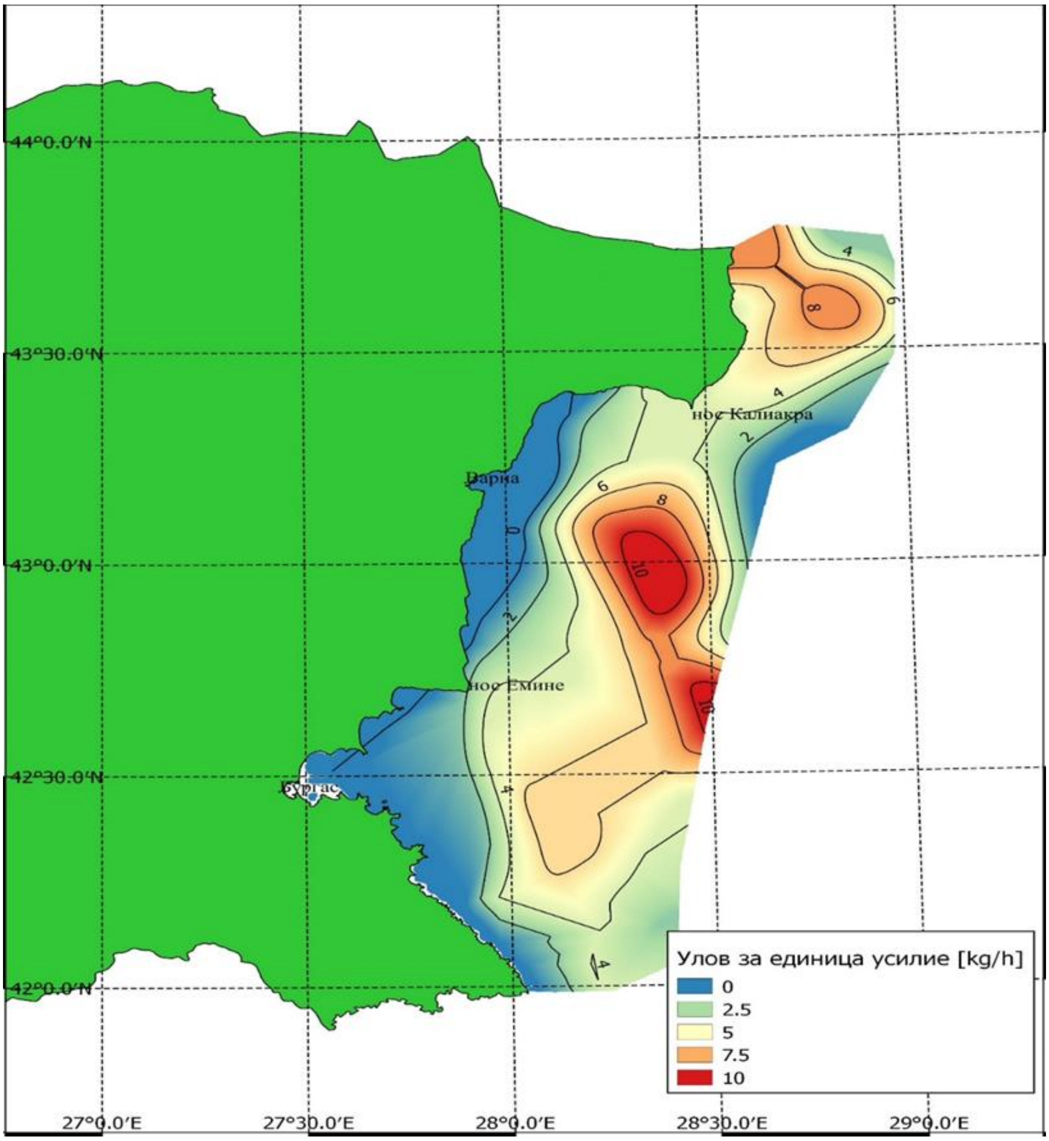

Fig.3 *Distribution of catch per unit effort (CPUE)*

3.3. Catch per unit area (CPUA)

The turbot abundance and biomass per unit area are presented at Table 4 and Fig 2 and 4.

High relative biomass, between 0.15 - 0.23 t/km^2 was established in four sectors of the Bulgarian Black Sea zone:

- in north direction - between Shabla and Kamen bryg at a depth of 62-65 m;

- along the central part of the coast, in front of the Byala (st. G10) at depths of 72 - 81 m and Varna (st. J6) at a depth of 56 – 65 m.
- in south direction, off the cape Emine (st. C13, F14, depth of 41-43, 82-83 m) and Sozopol (st. F16 - 82 m) (Fig.2 and 4).

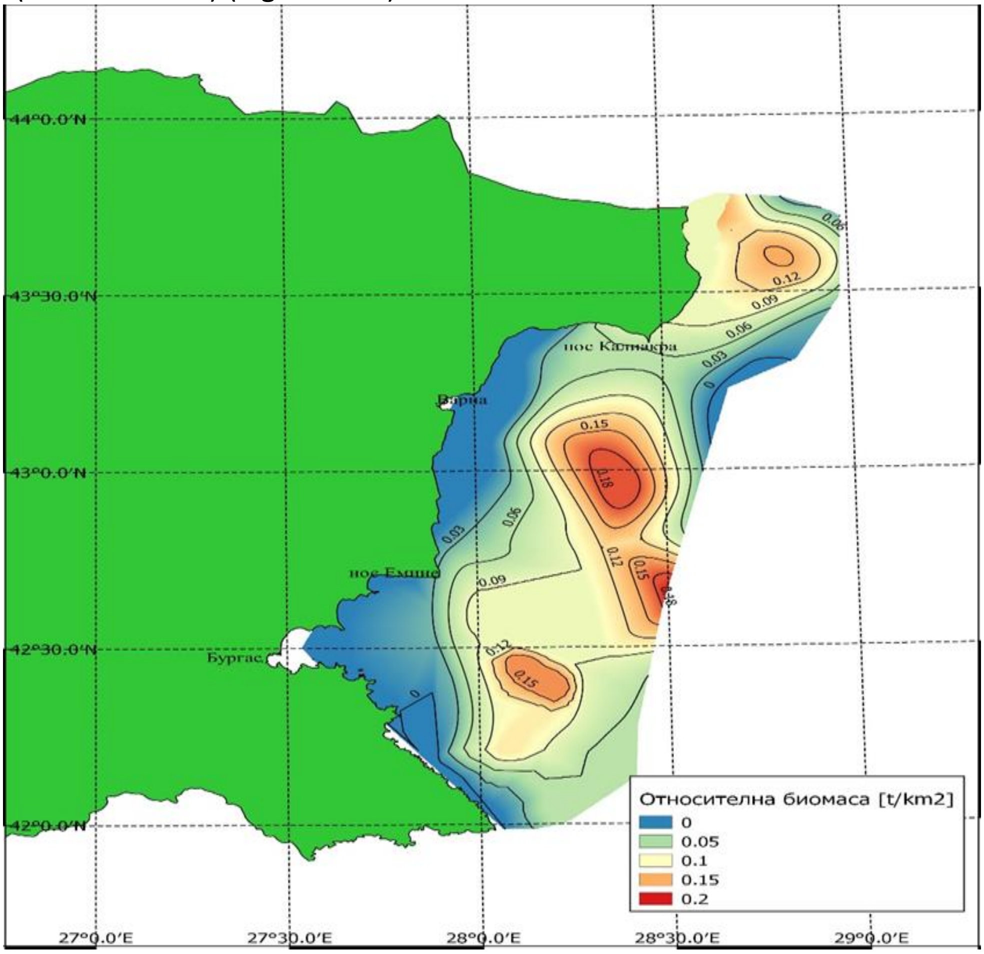

Fig.4 Distribution of the relative biomass (t/km^2) of S. maximus in May 2017.

Table 4

Turbot abundance and biomass observed in the Bulgarian waters in May 2017

No. Station	Field	No. ind./km^2	t/km^2
1	C11	0	0
2	D12	69	0.117954

3	**E13**	17	0.064684
4	**C13**	52	0.122624
5	**D14**	35	0.089071
6	**E15**	52	0.131271
7	**D16**	35	0.090108
8	**C15**	17	0.033899
9	**B16**	35	0.041509
10	**C17**	0	0
11	**D18**	52	0.153755
12	**E19**	17	0.057766
13	**F18**	17	0.052405
14	**E17**	35	0.078694
15	**F16**	52	0.195783
16	**F14**	17	0.036147
17	**G13**	52	0.150296
18	**F12**	52	0.071775
19	**E11**	0	0
20	**E10**	35	0.058804
21	**D9**	0	0
22	**F9**	35	0.069873
23	**G10**	104	0.234351
24	**H9**	17	0.032688
25	**L1**	52	0.141303
26	**N1**	52	0.065722
27	**M2**	86	0.19388
28	**L3**	86	0.150988
29	**M4**	17	0.028883
30	**L5**	17	0.03165
31	**K4**	0	0
32	**J5**	17	0.041163
33	**H5**	17	0.05154
34	**J7**	52	0.062782
35	**J6**	86	0.190594
36	**H7**	52	0.141475
37	**G6**	35	0.084747
38	**F7**	17	0.025078
39	**G8**	17	0.040471

40	**E8**	35	0.019025
Total		1072.308	1435.509
	Average	35.89	0.0788
	Total in the Bulgarian area	**415 963 Ind.**	**913.57 tonnes**

	№ ind./км²	*t/км²*
Variance	**680.8974**	**0.00383**
Standard deviation	**26.09401**	**0.061887**
Relative standard deviation	**0.727101**	**0.785181**
Standard error	**4.125825**	**0.009785**

The calculated current turbot biomass in the Bulgarian Black Sea waters amounted to **913.57** tons (Table 4). The turbot abundance in the surveyed area amounted to **415 963** individuals (Table 4).

3.4. Size structure

The information about the size structure of turbot population in the Bulgarian Black Sea waters in May 2017 is based on biometric measurements - absolute and standard length and individual weight of 83 fish specimens.

The absolute length of the measured individuals varied between 24.00 and 65.00 cm, and their weight - between 260 and 5400 g. The total catch of turbot was 182.290 kg. Out of the total number of 83 individuals, four were of size < 30 cm (4.82%), 8 were of sizes between 30 - 40 cm (9.64%), 32 individuals - between 40-50 cm (38.55%), 35 - in the range between 51-60 cm (42.17%) and 4 individuals - between 61-73 cm (4.82%) (Fig. 5).

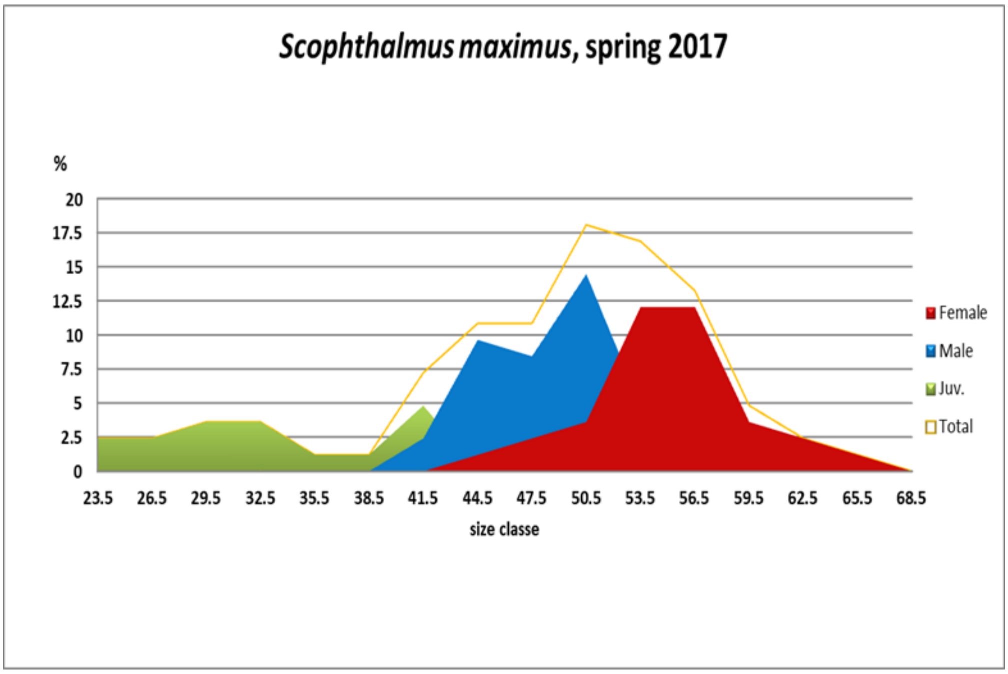

Fig.5 *Length structure of S. maximus.*

Sexually mature individuals dominated in the total catch - 80.72 % /67 specimens/, while juveniles formed 19.28 % (16 specimens). With a percent share of 42.17% /35 specimens/, the males dominated over the females - 38.55 % /32 specimens/.

The size structure was analysed in compliance with the national regulations, setting out the minimum permissible length of the individuals for fishing purpose. The individuals with absolute length under 45 cm are marked as undersized, and those with length > 45 cm - as standard.

Fig. 6 shows the total turbot abundance (ind/km^2) and the distribution of the ratio between the undersized individuals and those of standard length.

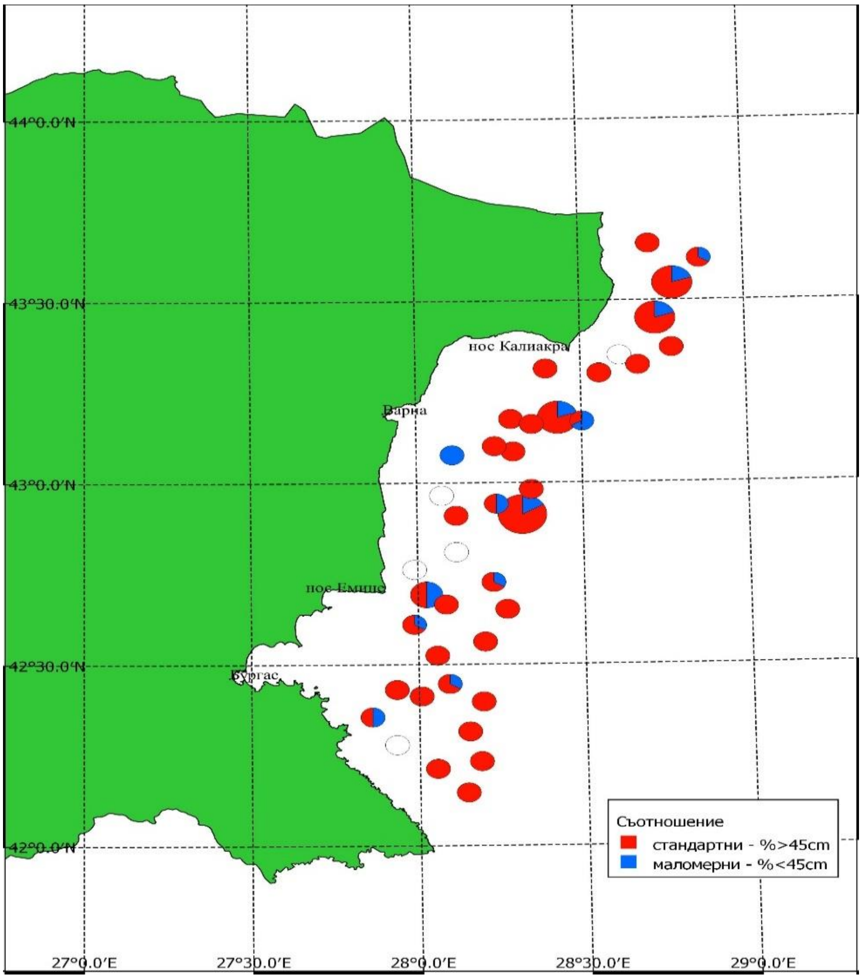

Fig. 6 *Distribution of the S. maximus abundance (ind/km^2) and ratio between the undersized individuals and those with standard length.*

The relative turbot biomass by mean size classes is presented in Fig.7 and show high biomass of two groups - 53.5 cm - 56.5 cm.

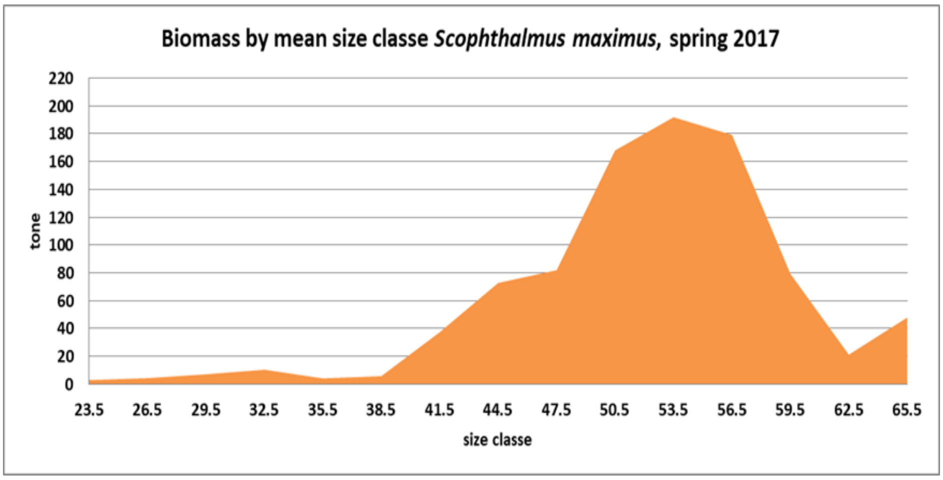

Fig.7 *Biomass by mean size classes of S. maximus.*

3.5. Age structure

The turbot age composition was determined based on an analysis of 67 pairs of otoliths. The age structure included 1 - to 8 - years classes, with domination of the 4 (24.10 %) and 5 (31.33 %) - years (55.43 % in total), followed by 6 - year class - 16.87 % (Fig. 8). In the spring season of 2017, the share of the replenishment of 1 and 2 - year classes reached 13.25 %. Although having small frequency of occurrence, specimens from 7 - to 8 - years classes were registered in the yield. It should be noted, that during the spring of 2016, the share of 1 - and 2 - year classes attained 25.77 %, while in spring of 2017 the percent share of juveniles was almost half of the above value.

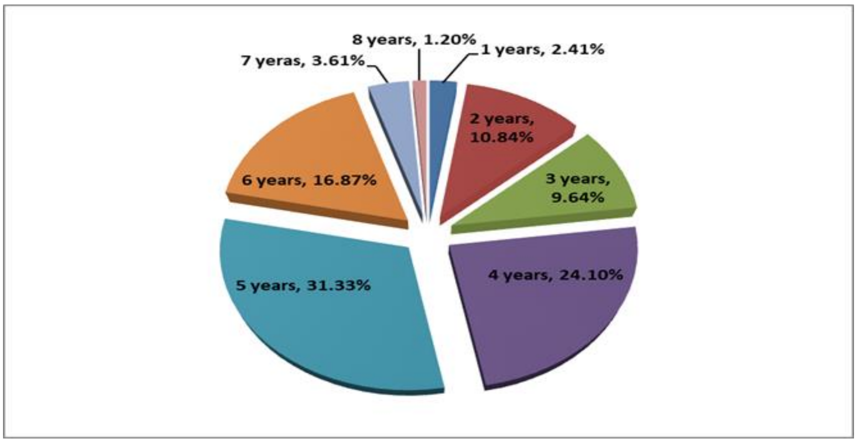

Fig.8 *Age structure of turbot in May 2017.*

The distribution of the age composition of *S. maximus* in the surveyed area is shown in Fig.9.

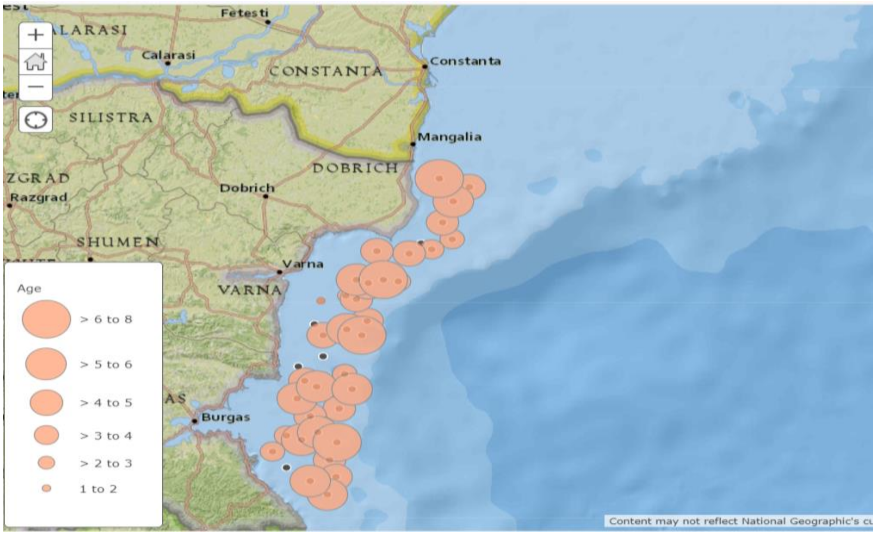

Fig. 9 *Spatial distribution and age structure of S. maximus in May 2017.*

3.6. Biological parameters of *S. maximus*

To identify the turbot growth rate in the Bulgarian Black Sea waters in spring 2017, the data about the average length and weight by age groups for the two sexes were combined.

The calculated values of the parameters in von Bertalanffy's and L-W equation are as follows:

a = 0.0242
b = 2.925
q = -1.617
L_∞ = 68.42
k = 0.366
to = - 0.35

The turbot length-weight relationship, based on the spring survey data is shown in Fig.10.

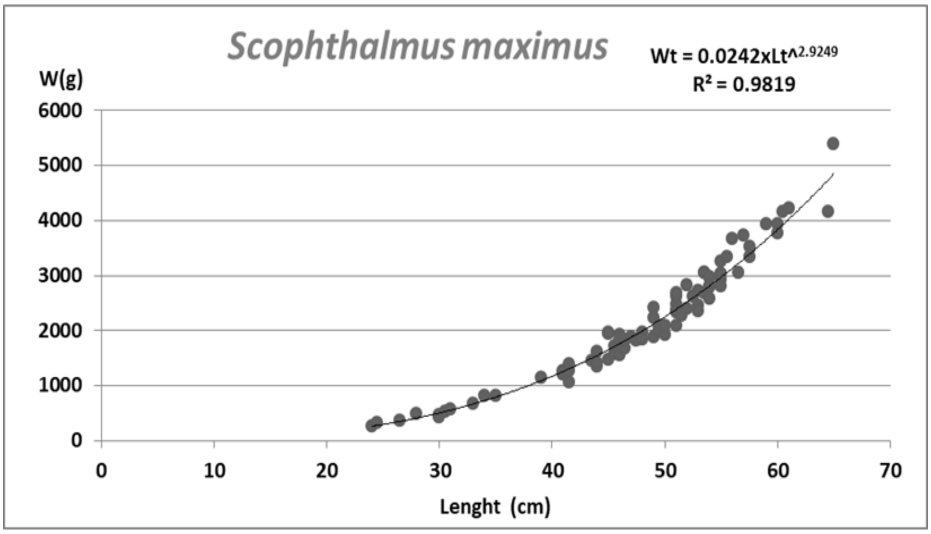

Fig.10 *S. maximus*: Length-weight relationships in May 2017.

Fulton's condition factor (K)

This factor is calculated from the relationship between the weight of a fish and its length, with the intention of describing the "condition" of that individual.

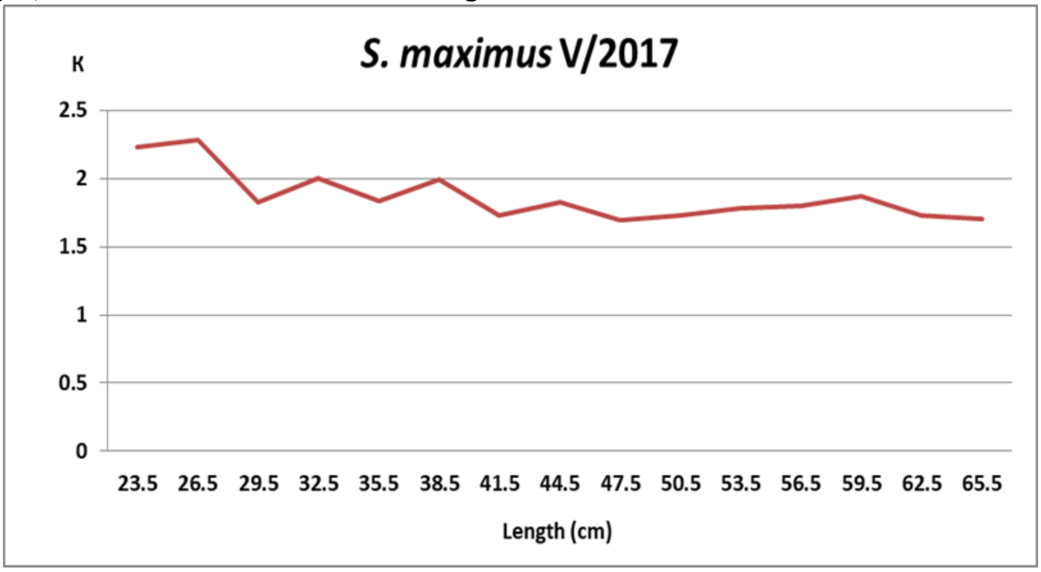

Fig. 11 Relationship between the turbot length and Fulton' coefficient.

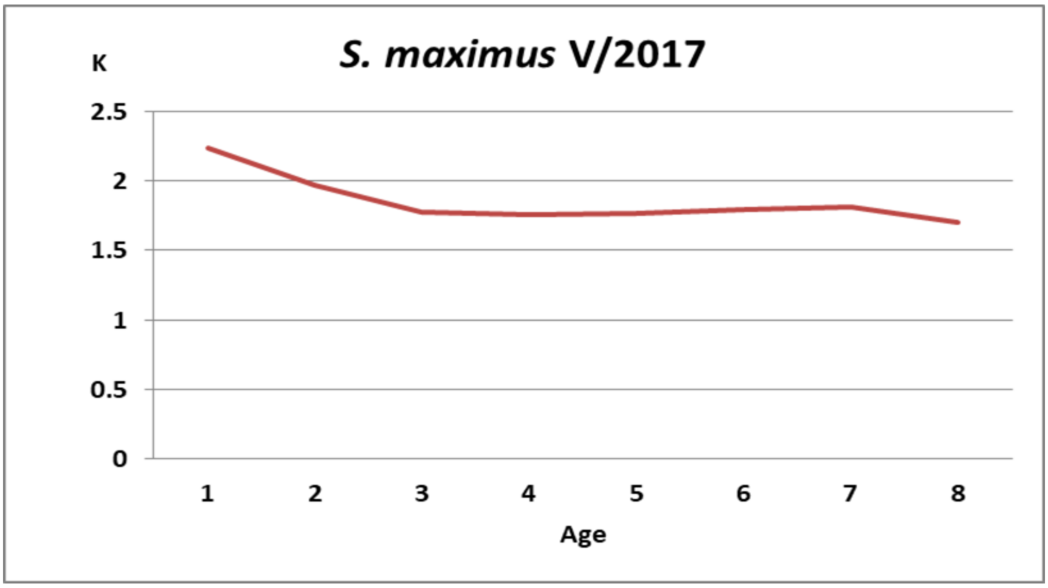

Fig. 12 Relationship between turbot age and coefficient of Fulton.

The collected data show a decrease of Fulton coefficient with the increase on size and age of turbot (Fig. 11 and 12).

The coefficient of natural mortality (M) was calculated according to Pauly's formula (1980), describing the natural mortality as a function of k, L∞, W∞ and water temperature at the bottom layer.

$L\infty = Lt\ max/0.95$

$k = 1/(t2-t1)*\ln(L\infty-L1)/(L\infty-L2)$

$\log(-t0) = -0.3922 - 0.2752*\log L\infty - 1.038*\log k$

$\ln M=-0.0152-0.279\ln L\infty+0.6543\ln k+0.463\ln t0$

Taking into account, that the water temperature was 11 °C during the study, the coefficient of natural mortality (M) for both sexes was equal to 0.29.

3.7. Sex structure

Sex ratio

The results of the turbot sex structure analysis in spring 2017 are shown in Fig.13. The total share of sexually immature individuals comprised 19.28 % of the total yield, the female individuals formed 38.55 %, and the share of males was 42.17 %.

From a total of 40 fields, studied off the Bulgarian coast in May 2017, female specimens were not identified in 19 fields, in 17 fields - males were not estimated, and in 1 field - only young forms were found, while adult specimens were absent (Fig.13).

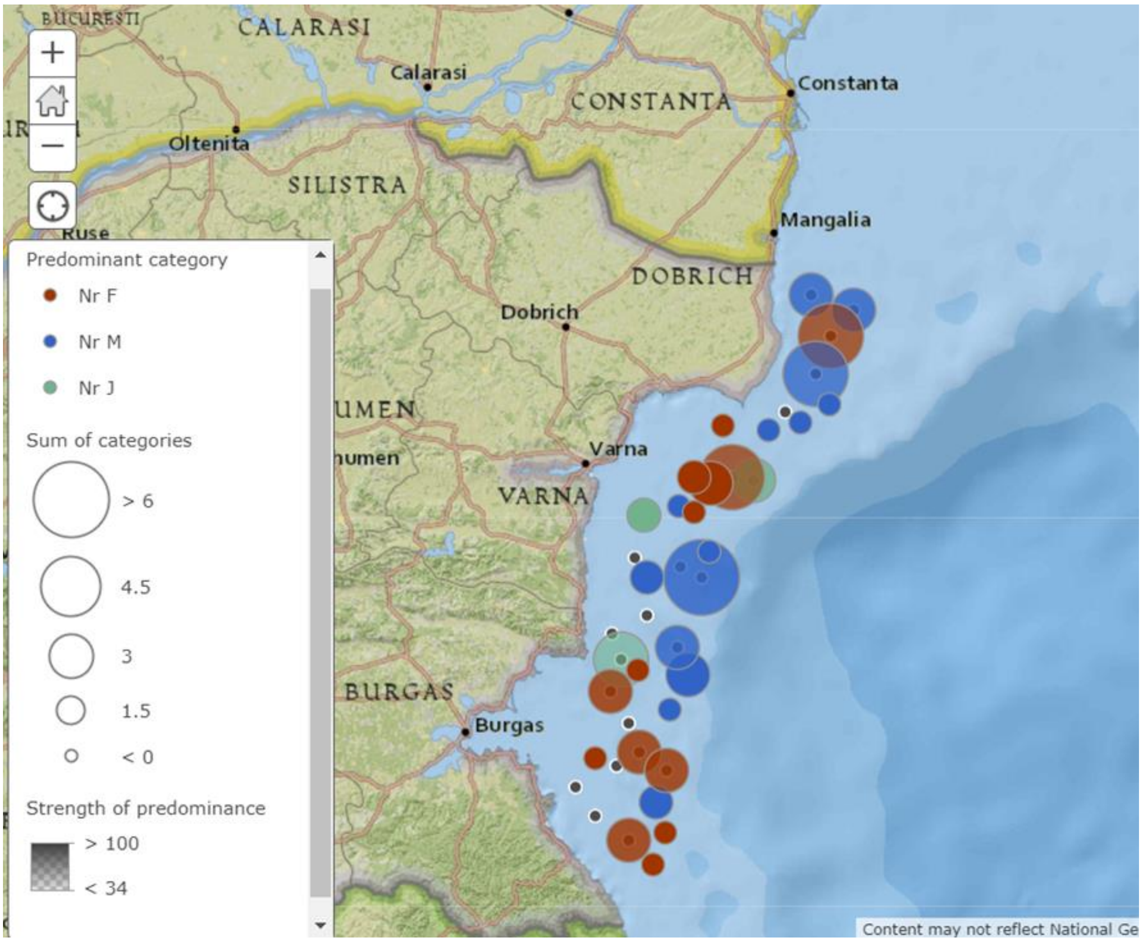

Fig.13 *Sex structure of S. maximus in May 2017: distribution by stations*.

According to the percentage distribution of turbot by sex, the male specimens were mainly found in sectors with a depth of 77 to 88 m, whereas the females were observed from 20 to 80 m depth. The juveniles were concentrated in the section Varna and Byala (20 - 40 m and 74 m) and between Cape Emine - Primorsko they show limited presence.

The females were established mainly in the regions - Shabla, Varna, Cape Emine - Sozopol and Ahtopol, by high concentration of males - in the region of Shabla - Cape Kaliakra, Varna - Byala, and Cape Emine - Primorsko.

The average weight of females was 3100.63 g, with average absolute length TL - 54.73 cm and standard length SL - 41.74 cm. The maximum weight of females reached 5400 g, besides the minimum weight was 1960 g.

Females from the length classes - 52-55 cm and 55 - 58 cm have formed the maximal shares - 31.25 % according to the length distribution analysis (Fig.14). Thus, the females with length 52-57 cm comprised a total of 62.50 % of all studied females. For the length classes over 61 cm (up to 65.5 cm), all studied specimens were only females, comprising 9.38 % of the total abundance. The results demonstrate sexual dimorphism with regard to the body length and superior number of large size classes of females (Fig.14 and 15).

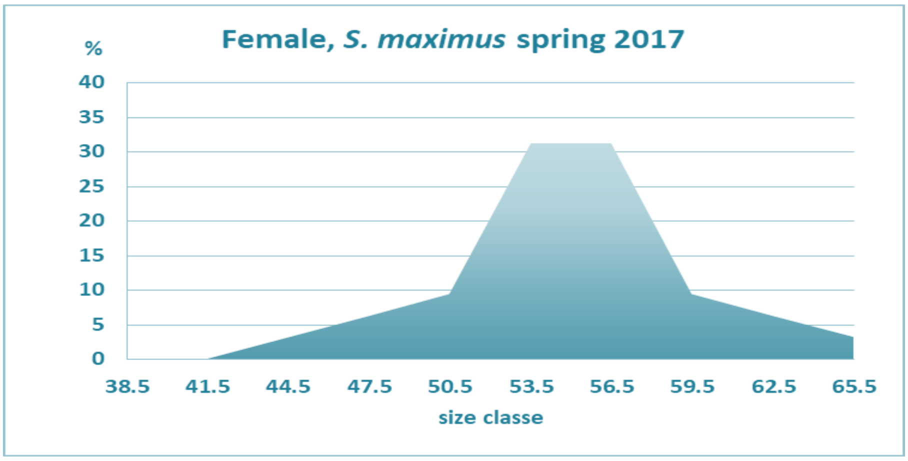

Fig.14 *Female specimens: Percentage distribution by length classes.*

For males (Fig.15), the most significant proportion of total abundance - 77.14 % belonged to the length class 43-52 cm, followed by size classes 52-55 cm - 11.43 %.

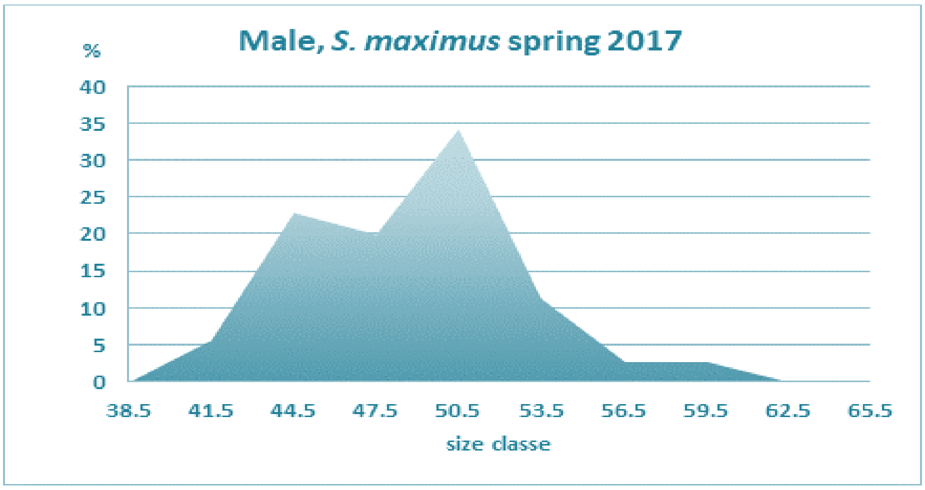

Fig.15 *Male specimens: Percentage distribution by length classes.*

3.8. Food composition

For estimation of the turbot diet composition, a total of 55 stomachs were collected and investigated during spring of 2017. The fish stomachs were preserved in a concentrated formaldehyde solution. The food spectrum analysis included species identification and measurements of quantitative parameters - frequency of occurrence, and percent composition by abundance and biomass.

In May 2017, food components were estimated only in 13 % of the investigated specimens, while 87 % of the specimens were with empty stomachs. In spring 2017 (**Table 5**), the turbot was mainly fed on whiting *(Merlangius merlangus)* - IRI = 2500.

The comparison of the data with those from the previous year (spring, 2016) shows similar results: *Pisces* were dominating group in the turbot food spectrum, by the highest presence of whiting - IRI = 2161,45.

The summary of the results in 2014-2017 period, shows that during the intensive breeding season in spring the turbot feeding was limited and mostly whiting could be identified in the food spectrum of the feeding individuals (Fig. 16).

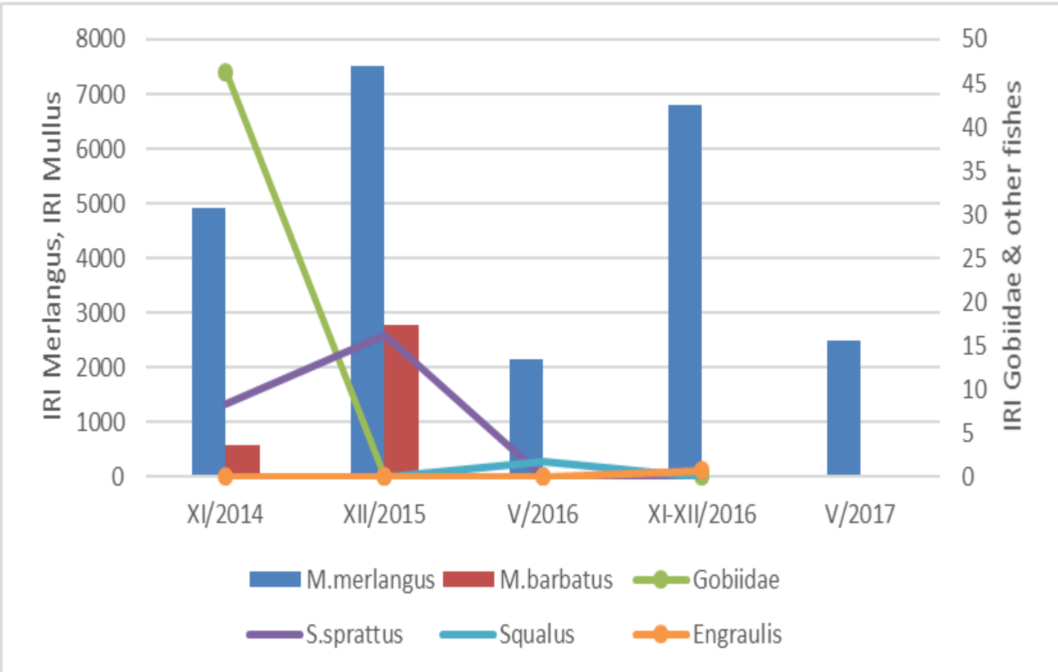

Fig 16 IRI of the fish species during the studied period.

Table 5

Surveyed area, length, weight of specimens, and weight of stomachs (full, empty), stomach contents and index of fullness.

Area	L (cm)	W (kg)	st/full	st/empty	st.cont (g)	ISF
C13/2	53.5	3.0500	26.0836	0	0	
C13/3	56.0	3.6700	21.3840	0	0	
C15/1	45.0	1.9600	15.0715	0	0	
D12/3	48.0	1.9700	17.4982	0	0	
D12/4	52.0	2.8200	28.5419	0	0	
D14/1	49.0	2.4200	23.6018	0	0	
D14/2	53.0	2.7300	19.0827	0	0	
D16/1	45.0	1.9500	15.4520	0	0	
D16/2	55.0	3.2600	48.8921	28.4103	20.4818	0.871482
D16/3	51.0	2.4900	17.0265	0	0	
D18/1	53.5	3.0500	16.9236	0	0	
D18/2	51.0	2.4900	17.1779	0	0	
D18/3	57.5	3.3500	31.2705	0	0	
E10/1	45.0	1.4700	9.1377	0	0	
E10/2	50.0	1.9300	11.2944	0	0	
E13/1	57.0	3.7400	52.6675	30.0888	22.5787	0.804513
E15/2	61.0	4.2200	35.4140	0	0	
E15/3	56.5	3.0500	22.2183	0	0	
E17/1	53.0	2.4500	19.0141	0	0	
E17/2	49.5	2.1000	15.0155	0	0	
E19/1	55.5	3.3400	29.6167	0	0	
F7/1	43.5	1.4500	12.6564	0	0	
F9/2	54.0	2.7800	21.5206	0	0	
F12/2	44.0	1.3600	8.6796	0	0	
F12/3	45.5	1.7200	15.4345	0	0	
F14/1	51.0	2.0900	18.5408	0	0	
F16/1	49.5	1.9900	13.0066	0	0	
F16/2	65.0	5.4000	35.4221	33.2651	2.1570	0.61602
F16/3	60.0	3.9300	18.8142	0	0	
F18/1	55.0	3.0300	33.3359	25.5925	7.7434	0.844637
G6/1	50.0	2.0900	51.6489	16.5412	35.1077	0.791445
G8/1	51.0	2.3400	16.7980	0	0	
G10/2	51.5	2.2800	12.0456	0	0	
G10/4	55.0	2.9400	26.7137	0	0	
G13/1	53.5	2.6800	19.0830	0	0	
G13/2	49.0	2.2300	13.3522	0	0	

G13/3	60.0	3.7800	18.2706	0	0	
H5/1	54.0	2.9800	19.6061	0	0	
H7/1	52.5	2.6200	19.4341	0	0	
H9/1	49.0	1.8900	14.1482	0	0	
I5/1	51.0	2.3800	43.5062	18.3580	25.1482	0.771345
I6/2	46.0	1.8400	27.9206	0	0	
I6/3	64.5	4.1600	9.2566	0	0	
L1/1	51.0	2.6200	18.2666	0	0	
L1/2	41.5	1.3900	6.1168	0	0	
L1/3	60.5	4.1600	33.4310	0	0	
L2/4	55.0	2.8000	17.6335	0	0	
L2/5	51.0	2.6900	18.1492	0	0	
L5/1	46.5	1.8300	10.9831	0	0	
M2/2	44.0	1.6100	9.6644	0	0	
M2/3	57.5	3.5300	26.7811	0	0	
M2/4	47.0	1.8900	29.0218	14.2552	14.7666	0.754243
M4/1	46.5	1.6700	10.9688	0	0	
N1/2	46.0	1.5600	6.7886	0	0	
N1/3	49.5	1.9800	9.8862	0	0	

3.9. Associated species

In the period November 2014 - May 2017, a total of 63 specimens of spiny dogfish and 82 specimens of thornback ray were captured, and the both species have formed minimal shares as bycatch during the spring seasons, when only 1-2 specimens of *Squalus acanthias* and 1-8 specimens of *Raja clavata* were established during the whole trawl surveys (Fig. 17). During the other seasons, the quantities of *Squalus acanthias* ranged from -2-18 specimens and those of *Raja clavata* between -3-20 specimens.

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Проектно предложение № BG14MFOP001-3.003-0001, „Събиране, управление и използване на данни за целите на научния анализ и изпълнението на Общата политика в областта на рибарството за периода 2017-2019 г.“, финансирано от Програмата за морско дело и рибарство, съфинансирана от Европейския съюз чрез Европейския фонд за морско дело и рибарство

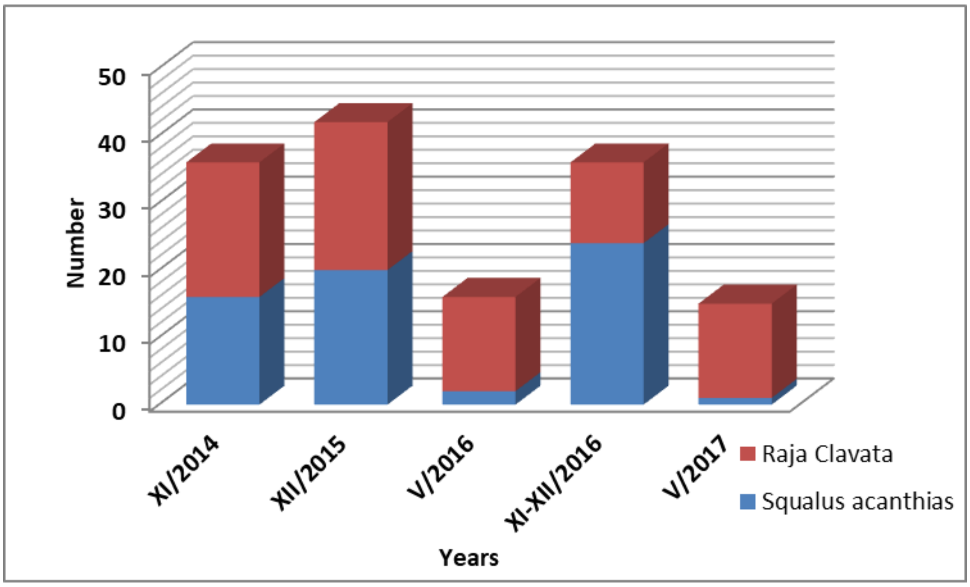

***Fig. 17**. Fluctuations of the species Squalus acanthias and Raja clavata - by seasons and years of research.*

The sex structure of the main associated species is presented in Fig. 18 and 19.

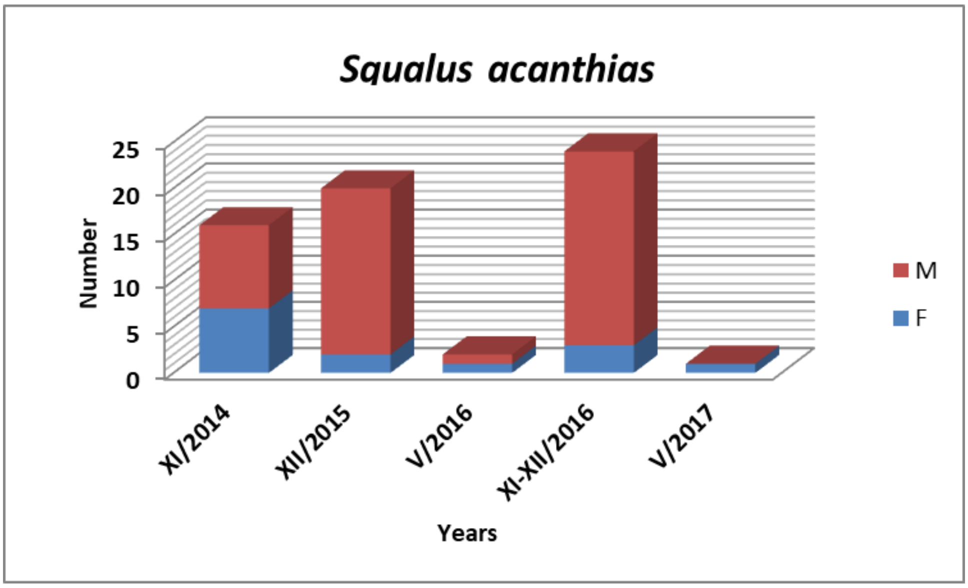

***Fig.18.** Sexual composition of Squalus acanthias - by seasons and years of research.*

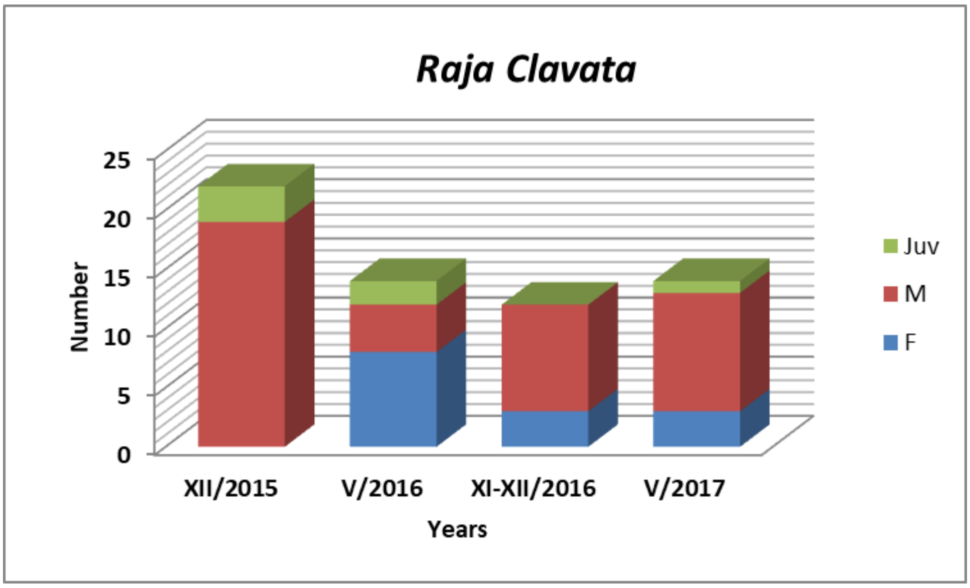

Fig. 19. *Sexual composition of Raja clavata - in seasons and years of research.*

The maximal number of associated species - 42 specimens was registered in December 2015, while the bycatch attained minimal levels during the spring season of 2017 - only 15 individuals.

4. Forecasts and opportunities for exploitation

The estimation of maximum sustainable yield (MSY) was realised using Gulland's formula:

$$MSY = 0.5*M*Bv$$

The coefficient of natural mortality (M) is calculated by Pauly's empirical formula (1979, 1980), thus at constant value of M = 0.2, the MSY is calculated at 91.36 t.

TAC (Total Allowable Catch)

The Beverton and Holt yield per recruit model (Y/R model, 1957) is used for calculations of the maximum sustainable yield and total allowable catch. In order to calculate the yield per recruit, the following parameters are applied: $W\infty$, к, M, t_0, t_r, while the model allows inputs of various F and Tc parameters and assessment of their effects on the yield per recruit. It should be mentioned, that the both parameters - F and Tc can be controlled by fishery managers, because F is proportional to effort and Tc is a function of gear selectivity.

The calculations show that Y/P increase at F_{MSY} = 0.25 (Fig. 20), thus the value of fishing mortality should not exceed 0.25, aiming at maximal sustainable yield of adult specimens.

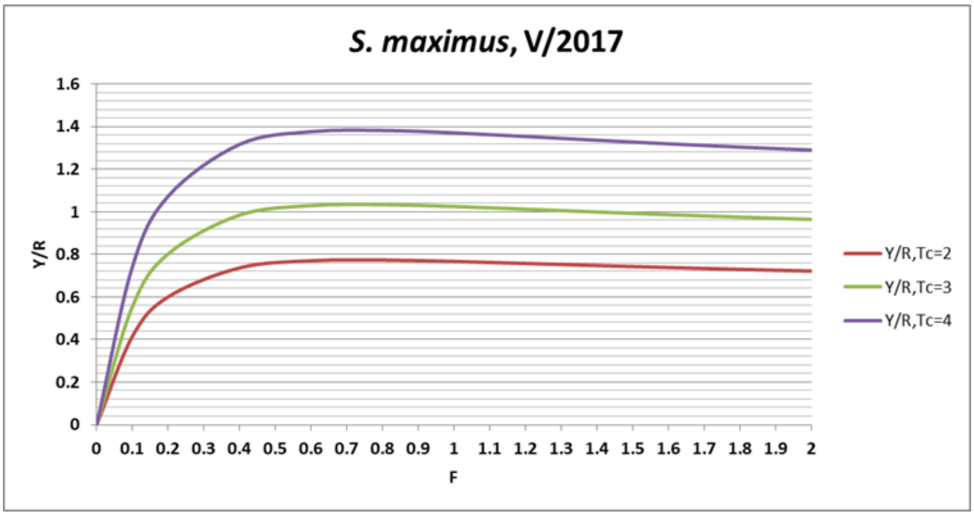

Fig.20 Yield per recruit curves with different ages of first capture (T_c) - 2,3,4

Stock exploitation (E) varies according to the intensity of fishing activities (Avşar, 1998). Based on the exploitation data, if E < 0.5, the population is considered as under-exploited, E = 0.5 gives an optimal level of exploitation, and E > 0.5 is an evidence of overexploitation of the stock. The calculated value reached E= 0.64 and indicated overexploited turbot stock.

According to the Jones method (1981), based on a linear - cohort analysis, the sustainable yield should not exceed 184.29 tons, including specimens with length < 45 cm, that formed 19.28 % of the total catch, i.e. after recalculations and taking into account the catches of specimens with standard length L > 45 cm, the sustainable yield should in Bulgarian waters not exceed 148 tons.

The strategy of dynamic MSY model does not consider yearly variations in recruitment and should be combined with other analytical models, including linear or age virtual population analysis. Therefore, the so-called "ad hoc" special approaches could be applied, such as TAC implementation as a part of MSY - up to 2/3 of MSY (Raykov, 2011). Using the "ad hoc" method, it could be assumed, that the total allowable catch of turbot (specimens with L > 45 cm) in the Bulgarian Black Sea area shouldn't exceed 48-50 tons.

<u>Observed other particular problems</u>

During the expedition in May 2017, the dominant wind directions were East, Southeast, Southwest and Northeast. The sea state was characterised by Beaufort 2-3º in the coastal zone, and Beaufort 3-4º in the open sea. The conditions in the field were normal for conducting the research activities for turbot stock assessment in the Bulgarian Black Sea waters.

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Проектно предложение № BG14MFOP001-3.003-0001, „Събиране, управление и използване на данни за целите на научния анализ и изпълнението на Общата политика в областта на рибарството за периода 2017-2019 г.“, финансирано от Програмата за морско дело и рибарство, съфинансирана от Европейския съюз чрез Европейския фонд за морско дело и рибарство

5. Conclusions and recommendations

In accordance with the collected information and obtained results from the trawl survey in May 2017, the following conclusions and recommendations can be made:

- The turbot biomass in the Bulgarian Black Sea waters was assessed at **913.57** tons. The turbot abundance in the surveyed area was estimated as **415 963** individuals.

- The recommended MSY (maximum sustainable yield) for Bulgaria should not exceed **91**t., it is assumed that the total allowable catch (TAC) of turbot in the Bulgarian Black Sea waters could comprise 48-**50** tons as a relatively acceptable quantity.

- The size structure of the turbot population in the Bulgarian Black Sea zone included length classes from **24** cm to **65** cm, with weight between 260 g and 5400 g. The average turbot weight was estimated as 2196 g. In the turbot length structure, the undersized individuals, with length < 45 cm, formed 19.28 % from the total number, while those of standard length made up 80.72 %.

- The age composition of the population included age classes from 1+ to 8+- years of age, with domination of the **4 (24.10 %) and 5 (31.33 %)** – year classes.

- The established ratio between female, male and sexually immature individuals in the yield was **38.55%: 42.17%: 19.28%.**

- In spring, the intensive turbot reproduction was accompanied by limited feeding, thus only in 13 % of the investigated fish specimens were identified food components in the stomach content. By feeding specimens, the main component of the diet was whiting (*Merlangus merlangus*) **with IRI - 2500**.

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