REPORT

Bottom Trawl Surveys In The Bulgarian Black Sea Area

Autumn-Winter 2021

Agricultural Academy

Institute of Fish Resources (IFR, Varna)

2022

ЕВРОПЕЙСКИ СЪЮЗ
ЕВРОПЕЙСКИ ФОНД ЗА
МОРСКО ДЕЛО И РИБАРСТВО

МИНИСТЕРСТВО НА ЗЕМЕДЕЛИЕТО, ХРАНИТЕ И ГОРИТЕ

ПРОГРАМА ЗА
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The present study was conducted by a team of specialists from the Institute of Fishery Resources (IFR) – Varna, Agricultural Academy, under contract № /D-195/10.12.2019 with the Executive Agency for Fisheries and Aquaculture (EAFA) - Burgas, for turbot stock assessment in the Bulgarian Black Sea waters during the autumn season of 2021.
The study was conducted owing to the financial support of the European Commission in compliance with Council Regulation (EU) 2017/1004 of the European Parliament and of the Council 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008 (recast).
The study was performed in the period 05 - 30 December 2021 in the Bulgarian Black Sea waters on board of the “EGEO 2” fishing vessel.

The scientific research was carried out by IFR-Varna:

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Petrova E., Stoykov S., Mihneva V., Valchev S.,Georgiev K., Angelov G., Penchev Ph., Tserkova F., 2022. Bottom trawl surveys in the Bulgarian Black Sea Area, Autumn-Winter 2021, Report under Contract with the Executive Agency Fisheries and Aquacultures, Program for Data collection for fisheries in 2022, p.59.

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BOTTOM TRAWL SURVEY FOR TURBOT STOCK ASSESMENT IN BULGARIAN BLACK SEA SECTOR DURING DECEMBER OF 2021

1. Results from the National Bottom Trawl Surveys in December 2021

During 05 - 30 December 2021, within the frames of the National Programme for Fisheries Data Collection, the research team from IFR - Varna has conducted a demersal trawl survey on the fishing ship "EGEO2" in the Bulgarian Black Sea waters - between Durankulak and Ahtopol, within the 100-meter isobaths.

The filed survey has included the following main 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.

Through the filed survey and laboratory analysis, a dataset has been prepared, allowing assessment of the relative biomass and abundance of the reference species *Scophthalmus maximus* in Bulgarian Black Sea waters. The current report is focused on the estimation of turbot biomass indexes and density by depth strata and includes study on length/weight, age and sex structure of the turbot population.

This document contains a series of tables and figures that represent the distribution of relative abundance and analysis of turbot population - size/age and sex structure, estimation of the L-W relationship, calculations of growth rate and biological parameters, based on *Von Bertalanffy* equations and examination of turbot diet composition

1.1. Fishing vessel and fishing gear

The trawl surveys were conducted on board the fishing ship "EGEO 2" (picture 1) with the following parameters:

- Fishing vessel length -19.5 m;
- Maximum width – 5.9 m;
- The fishing vessel year of built - 2005;
- Engine power – 353.04 kW;
- Maximum tonnage – 38.24t;
- Net tonnage – 11.43 t;
- Speed – 9.5 Nd;
- Crew - 3 people;
- Research team - 3 people.

Picture 1. *Fishing ship and trawling.*

During the studies, a fishing bottom trawl 32/27-34 was applied (picture 2), with following functional and technical parameters:

- Trawl vertical opening - 2 m;
- Effective part of Headrope - 13 m;
- Effective part of Footrope - 15 m;
- Trawling speed - 2.2 - 2.6 Nd;
- Trawling duration - 60 min.
- Mesh size – 200 mm.

Picture 2. *Bottom trawl 32 / 27-34.*

2. Material and methods

The target species of the demersal survey was turbot (*Scophthalmus maximus*), and the by-catch species - the spiny dogfish (*Squalus acanthias),* the thornback ray (*Raja clavata*) and the European flounder (*Platichthys flesus*) were also measured and analysed.

The methodology and techniques, used for data collection, verification, processing and 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 EAFA 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:

- Survey area (km2);
- Catch per unit effort (kg/trawl)
- Catch per unit area (t/km^2);
- Abundance index (individual/km^2);
- Limits of variation of CPUA;
- Total biomass (t.);
- 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.

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 Nm^2 (or 85.8569 m^2). 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 km^2 (measured by GIS). Each field was marked with letters and digits for better distinction.

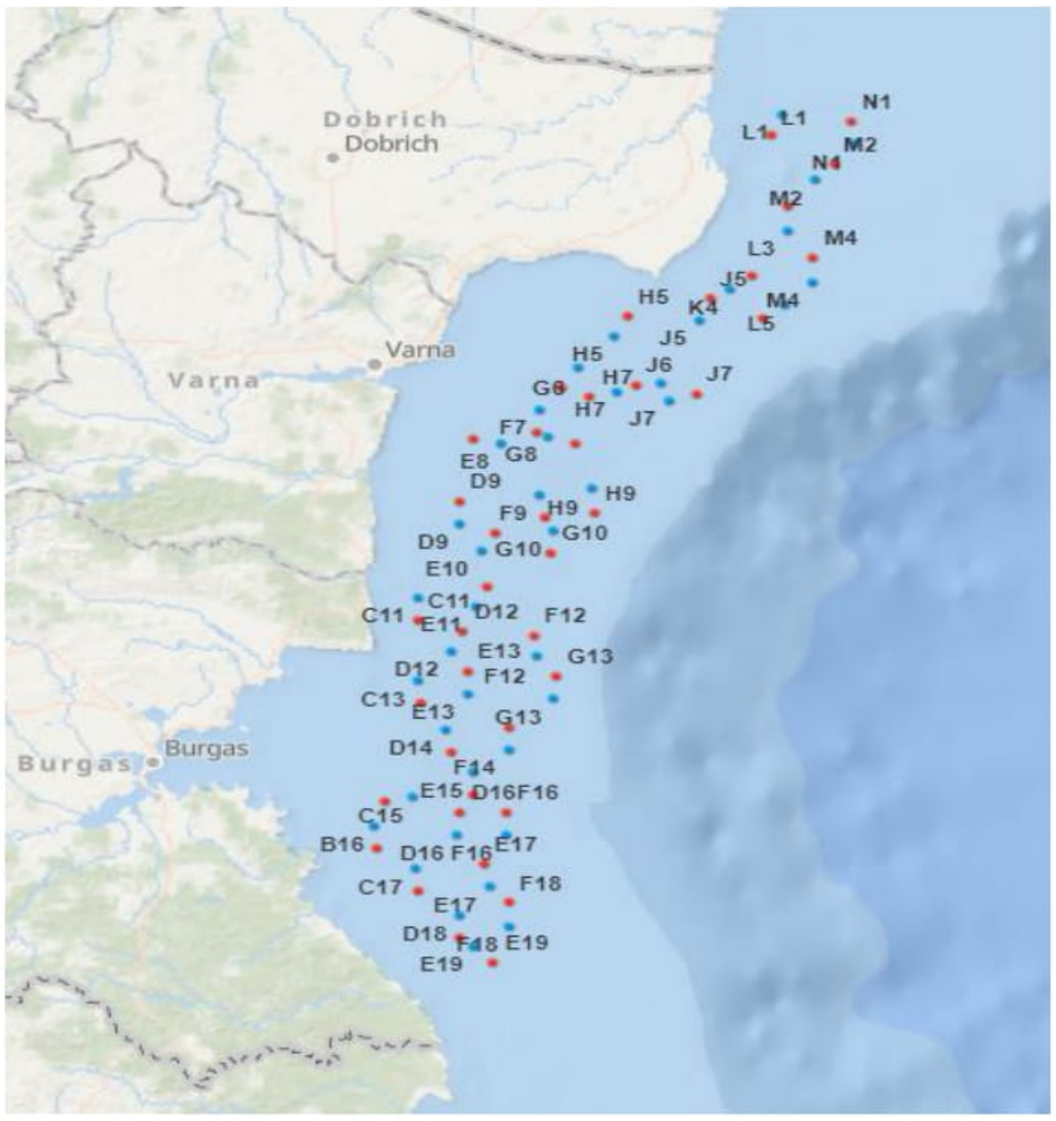

Fig. 1 ***Map of the surveyed sectors, XII/2021.***

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 analyses

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 83 stomachs were collected in autumn-winter 2021. 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.

<u>CPUE (Catch per unit effort)</u> - is calculated by dividing the trawl catch by the fishing hours (kilograms/hour):

CPUE = yield/effort

<u>Maximum sustainable yield</u>

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.

TAC - total allowable catch, Prediction models

***Beverton and Holt yield per recruit model* (1957):**

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

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 ***Pauly (1983)*** was used: E = F / Z; E - exploitation ratio, F - fishing mortality, Z - total mortality;

***Jones' Length-Based Cohort Analysis* (1981)**

Jones' length-based cohort analysis:

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

Age and growth

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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.

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:

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

$$\log \mathrm{M} = -0.2107 - 0.0824 * \log \mathrm{W}_\infty + 0.6757 * \log \mathrm{k} + 0.4687 * \log \mathrm{T^\circ C}$$

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.

Stock exploitation (E)

is determined by Pauly (1983): E = F/Z,
where Z - total mortality, and F - fishing mortality.

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3. Results

3.1. Population number and biomass

During the demersal trawl survey in XII 2021, the following activities were carried out:

- 40 hauls with a bottom trawl, with duration of 60 minutes, at depths between 15 m and 100 m, covering entirely the continental shelf of the Bulgarian Black Sea zone, between Durankulak and Ahtopol (Picture 3).

- for each haul, a qualitative and quantitative analysis of the catch was accomplished, including biometric measurements of 253 turbot specimens, 53 ind. spiny dogfish, 81 specimens of European flounder and 149 specimens of thornback ray (*Raja clavata*) (Picture 4 and 5).

Picture 3. *Bottom trawling yield*

Picture 4. *Yield of turbot (Scophthalmus maximus) and bycatch species Merlangius merlangus (whiting), Platichthys flesus (European flounder), Raja clavata (thornback ray),* spiny dogfish *(Squalus acanthias) and common stingray (Dasyatis pastinaca).*

Constant presence of *S. maximus* was established in almost all bottom trawls at a depth 15-50 m with yield - at least 3-10 individuals per haul (where catch ≠ 0). At depths of 50-75 m, the average catch of turbot was comparable to 15-50 m, while at a depth of 75-100 m, the average registered catch decreased. At seven fields, a high yield was obtained, with ranges between 18.68 to 40.99 kg/trawl.

Fifty-three specimens of dogfish (*Sq. acanthias*) were captured during the survey, with size and weight that varied from – 45cm (0.350kg) to 149cm (16.60kg). The main bycatch species included whiting (*Merlangius merlangus euxinus*), European flounder (*Platichthys flesus luscus* – 81 ind.) and thornback ray (*Raja clavata*). Other bycatch species were black

scorpionfish (*Scopaena porcus*), black mussel (*Mytilus galloprovincialis*), Knout goby (*Mesogobius batrachocephalus*), greater weever (*Trachinus draco*), red mullet (*Mullus barbatus*) and Clupeiformes.

Picture 5. *Conducting biometric measurements and sampling for study of the stomach contents.*

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

Trawling at a depth of up to 30 m covered 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 - 103.25 kg/km^2, 168.28 kg/km^2 and 228.82 kg/km^2, with abundance - 35 ind/km^2, 277 ind/km^2 and 346 ind/km^2. At these stations, the highest yield was found off the under c. Kaliakra and in front of the Shkorpilovtsi, (Table 1, Figures 2).

The average value of the relative turbot biomass varied within a narrow range of 15-50 and 50-75 m, and the highest biomass was detected in the stratum 15-50 m - 0.709 t/km^2, while the highest average abundance was found again in the same stratum - 225 ind/km^2 (Table 1, Fig 2 and 3).

The information about the yields by stratum is given below:

Stratum 15 - 50 m

The relative turbot biomass varied between 10.7 and 708.9 kg/km^2, 223.34 kg/km^2 on average (Table 1, Fig. 2). The abundance indices varied between 35 and 346 individuals/km^2, on average -156 ind/km^2 (Table 2).

Stratum 50 -75 m

The relative turbot biomass fluctuated between 0 and 507.27 kg/km^2, 225.92 kg/km^2 on average (Table 1, Fig. 2 and 3). The abundance indices varied between 0 and 208 ind/km^2, with average value of 101 ind/km^2 (Table 2, Fig. 2 and 4).

Stratum 75 - 100 m

In this stratum, the average relative biomass 79.57 kg/km^2 (varied from 0 to 357.84 kg/km2), (Table 1, Fig. 2 and 4), with average abundance - 52 ind/km^2 (Table 2).

Table 1

Turbot biomass by strata, December 2021

15 - 50 m		50 – 75 m		75-100 m	
No. station	**t/км^2**	**No. station**	**t/км^2**	**No. station**	**t/км^2**
1	0.168	**6**	0.351	**14**	0.147
4	0.229	**17**	0.331	**25**	0.116
40	0.103	**30**	0.046	**36**	0.011
3	0.218	**39**	0.215	**12**	0.144

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2	0.089	**23**	0.507	**13**	0.358
9	0.022	**33**	0.405	**15**	0.000
19	0.251	**16**	0.323	**27**	0.000
20	0.061	**26**	0.000	**10**	0.000
5	0.181	**35**	0.161	**37**	0.098
29	0.205	**21**	0.121	**31**	0.000
24	0.011	**34**	0.033	**11**	0.000
18	0.164	**22**	0.273		
8	0.443	**38**	0.171		
28	0.154				
32	0.709				
7	0.567				
Total	3.57	**Total**	2.94	**Total**	0.88
Average	0.22	**Average**	0.23	**Average**	0.08
Variance	0.04		0.02		0.01
Standard deviation	0.19		0.14		0.11
Relative standard deviation	0.84		0.61		1.34
Standard error	0.05		0.04		0.03

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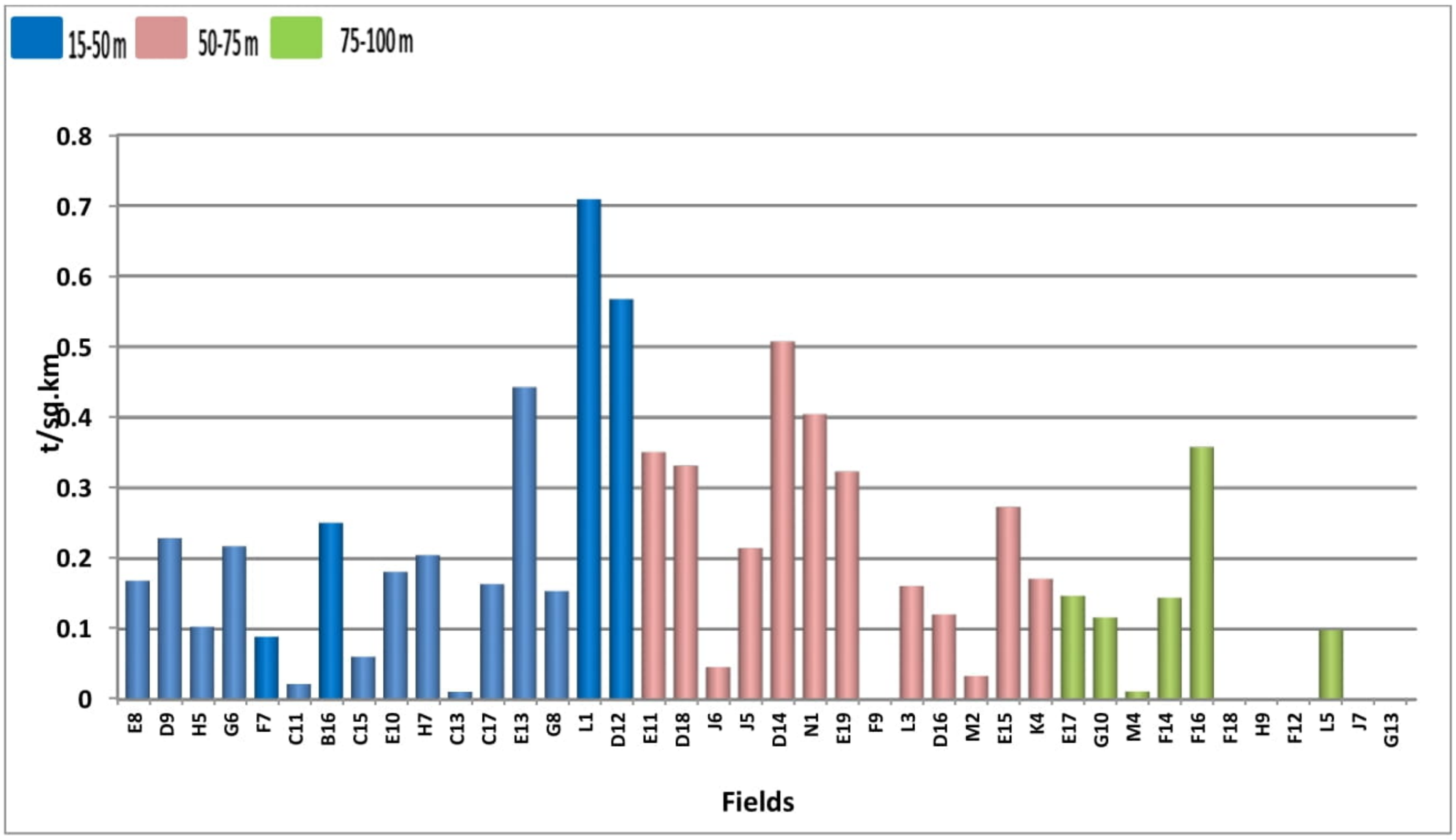

Fig. 2 ***Relative biomass (t/km^2) of S. maximus by strata off the Bulgarian Black Sea coast, XII 2021.***

Table 2 represents detailed data about turbot abundance by strata in December 2021.

Table 2

Abundance of *S. maximus* by strata December 2021.

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	277	**6**	208	**14**	173
4	346	**17**	121	**25**	17
40	35	**30**	17	**36**	17
3	69	**39**	104	**12**	138

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2	69	**23**	190	**13**	173
9	104	**33**	242	**15**	0
19	242	**16**	121	**27**	0
20	52	**26**	0	**10**	0
5	156	**35**	86	**37**	52
29	86	**21**	69	**31**	0
24	35	**34**	17	**11**	0
18	69	**22**	86		
8	311	**38**	52		
28	69				
32	225				
7	346				
Total	2491	**Total**	1314	**Total**	571
Average	156	**Average**	101	**Average**	52
Variance	80.71		51.82		92.24
Standard deviation	8.98		7.20		9.60
Relative standard deviation	0.06		0.07		0.19
Standard error	0.18		0.20		0.40

3.2. Catch per unit effort (CPUE)

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

- 6 hauls (15% of total no. hauls), catch 0 kg;
- 6 hauls (15 %), catch 0.1 – 4.99 kg per haul;
- 12 hauls (30 %), catch 5.0 – 9.99 kg per haul;
- 6 hauls (15 %), catch 10.0 – 15.0 kg per haul;
- 10 hauls (25 %), catch 15.0 – 40.99 kg per haul;

Stratum < 30 m; 3 hauls:

- 3 hauls, catch 5.0 - 15 kg per haul;

Stratum 31 – 50 m; 13 hauls:

- 3 hauls, catch - 0.1 - 4.99 kg per haul;
- 3 hauls, catch - 5.0 – 10.0 kg per haul;
- 4 hauls, catch - 10.0 - 15.00 kg per haul;
- 3 hauls, catch - 15.0-40.99 kg per haul;

Stratum 50 – 75 m; 13 hauls:

- 1 hauls, catch 0 kg per haul;
- 2 hauls, catch 0.1 - 4.99 kg per haul;
- 3 hauls, catch 5.0 - 9.99 kg per haul;
- 7 hauls, catch 10.0 - 29.33 kg per haul;

Stratum 75 – 100 m; 11 hauls:

- 5 hauls, catch 0 kg per haul;
- 5 haul, catch 0.1 - 4.99 kg per haul;
- 1 hauls, catch 10.0 - 20.69kg per haul;

The CPUE distribution in December 2021 is shown in Table 3 and Fig. 3.

Table 3

The sampling stations, coordinates and CPUE (kg/trawl) in December 2021

№	Field	Starting coordinates		Depth (m)	Speed (Nm)	Trawling time (min)	Catch turbot	
		ϕ	λ				№	Kg
1	E8	4304.775	2806.244	24	2.4	60	16	9.73
2	F7	4305.5	2813.843	34	2.4	60	4	5.15
3	G6	4310.42	2816.66	31.5	2.4	60	4	12.58
4	D9	4258.092	2804.481	28	2.4	60	20	13.23
5	E10	4254.71	2808.88	40.5	2.4	60	9	10.47
6	E11	4248.91	2807.84	52	2.4	60	12	20.29
7	D12	4244.08	2804.9	50	2.4	60	20	32.79

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8	E13	4239.555	2805.496	47	2.4	60	18	25.6
9	C11	4245.12	2759.49	34.7	2.4	60	6	1.27
10	F12	4243.58	2813.4	81	2.4	60	0	0
11	G13	4239.247	2816	90	2.4	60	0	0
12	F14	4233.57	2810.5	78	2.4	60	8	8.35
13	F16	4224.42	2810.05	79	2.4	60	10	20.69
14	E17	4218.72	2807.5	71	2.4	60	10	8.51
15	F18	4214.48	2810.5	80	2.4	60	0	0
16	E19	4207.96	2808.62	63	2.4	60	7	18.68
17	D18	4210.8	2804.5	57	2.4	60	7	19.16
18	C17	4215.823	2759.587	46	2.4	60	4	9.47
19	B16	4220.44	2754.66	37	2.4	60	14	14.5
20	C15	4225.623	2755.78	39.5	2.4	60	3	3.5
21	D16	4224.355	2804.57	65	2.4	60	4	6.97
22	E15	4226.31	2806.18	68	2.4	60	5	15.8
23	D14	4230.87	2803.51	60	2.4	60	11	29.33
24	C13	4236.238	2759.86	44	2.4	60	2	0.62
25	G10	4252.488	2815.52	75.5	2.4	60	1	6.73
26	F9	4256.255	2814.719	63	2.4	60	0	0
27	H9	4256.916	2820.63	80.5	2.4	60	0	0
28	G8	4304.173	2818.266	49	2.4	60	4	8.9
29	H7	4309.32	2820.155	42	2.4	60	5	11.84
30	J6	4310.49	2825.47	58	2.4	60	1	2.65
31	J7	4309.66	2832.78	84	2.4	60	0	0
32	L1	4337.26	2841.65	49.5	2.4	60	13	40.99
33	N1	4338.895	2851.282	61	2.4	60	14	23.39
34	M2	4334.345	2849.26	65	2.4	60	1	1.93
35	L3	4329.64	2843.66	63	2.4	60	5	9.3
36	M4	4324.135	2846.753	77	2.4	60	1	0.64
37	L5	4317.68	2840.886	82	2.4	60	3	5.69
38	K4	4322.417	2839.584	70.5	2.4	60	3	9.9
39	J5	4319.88	2834.4	58	2.4	60	6	12.41
40	H5	4318	2824.6	28	2.4	60	2	5.97

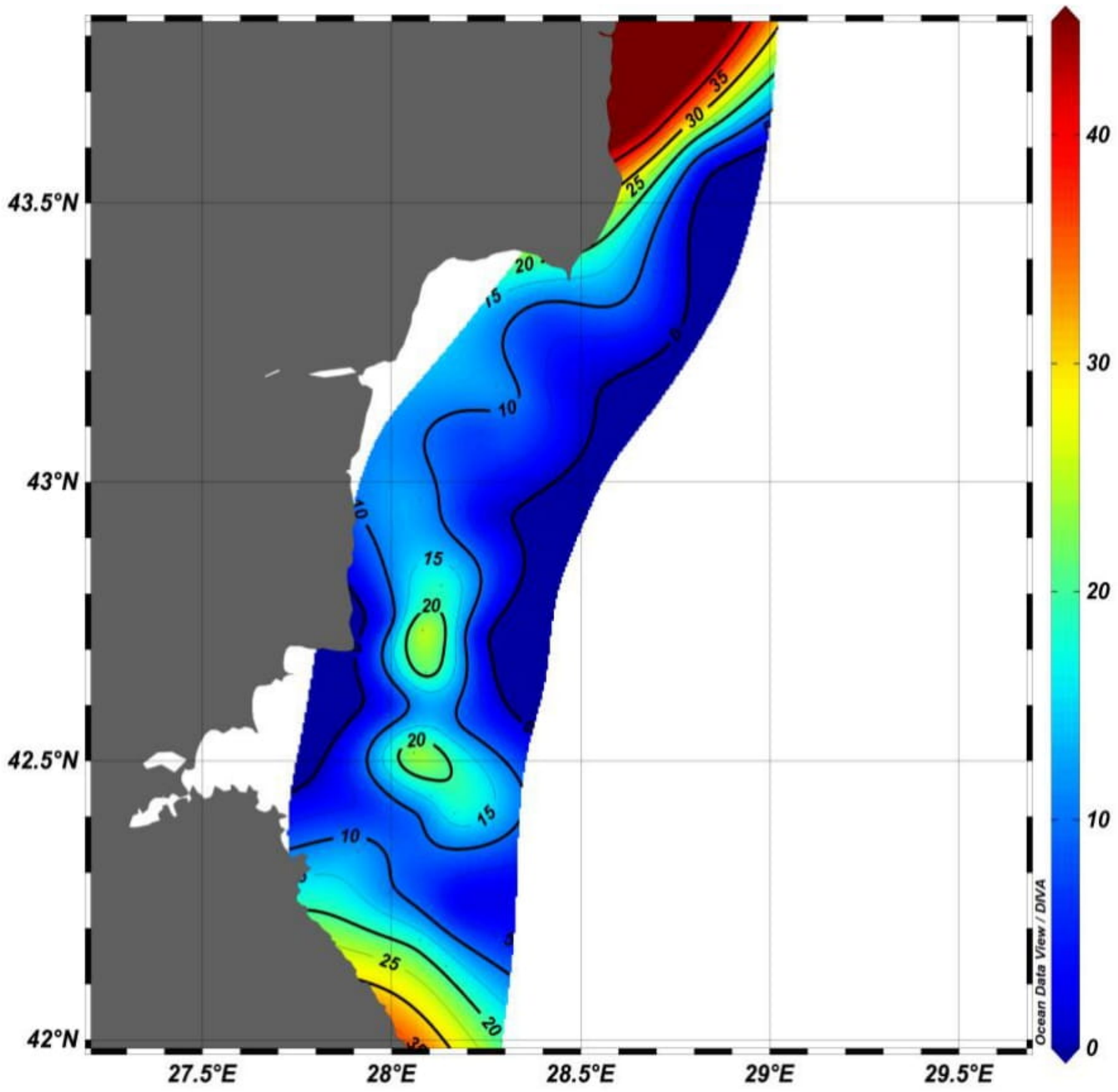

Fig. 3 ***Distribution of catch per unit effort (CPUE, kg/h).***

3.3. Catch per unit area (CPUA)

The turbot abundance and biomass per unit area are presented at Table 4 and Fig 2, 4 and 5 and the distribution of the relative biomass (t/km2) of *S. maximus* in December 2021 is presented at Fig.4.

High relative biomass, between 0.33 - 0.71 t/km^2 was established in three sectors of the Bulgarian Black Sea zone:

- in north direction - in front of Durankulak (st. L1), at a depth of 49-51 m;
- in front of c. Emine and Burgas Bay with a depth of 52-60 m (st. D12 and D14);

- in south direction, in front of Ahtopol (st. E19 and D18, 58-63 m), (Fig.2 and 4);

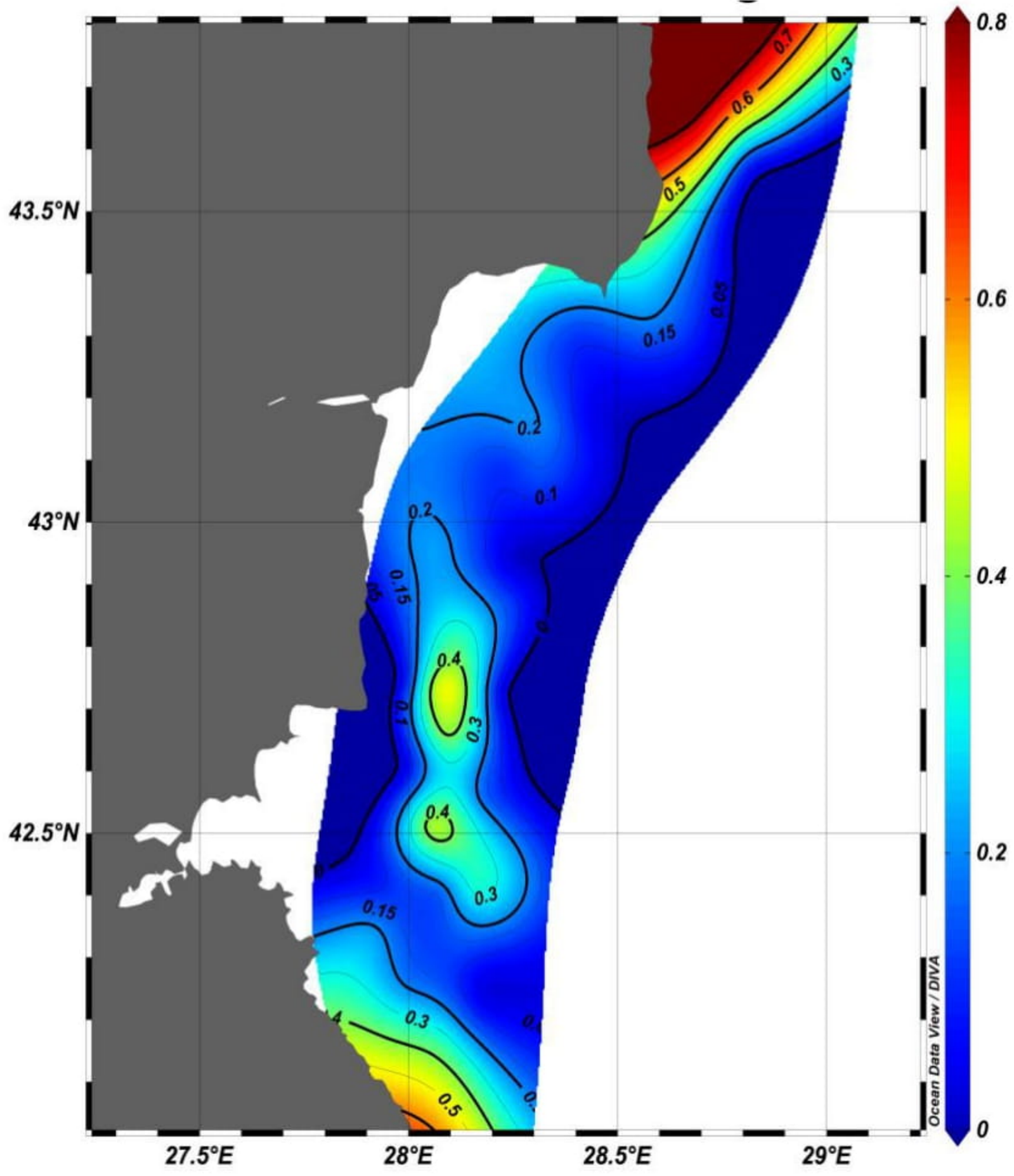

Fig. 4 Distribution of the relative biomass (t/km^2) of S. maximus in December, 2021.

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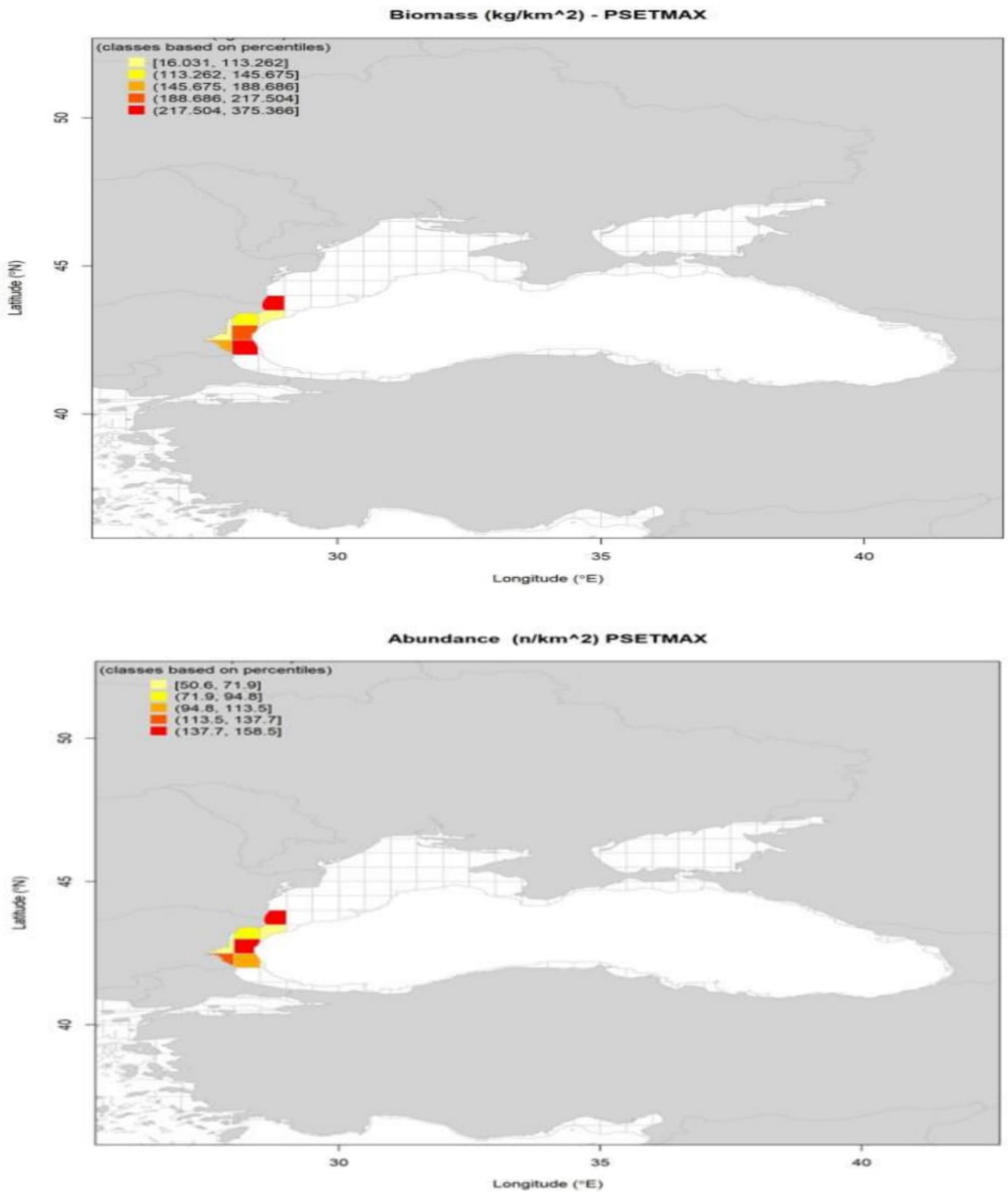

Fig. 5. ***Distribution of the relative biomass (kg / km2) and abundance (n / km2) of S. maximus in December, 2021 by R 4.1.2 (x86-64bit), (BioIndex v. 3.2).***

Table 4

Turbot abundance and biomass observed in the Bulgarian waters in December 2021

No. Station	*Field*	*No. ind./km²*	*t/км²*
1	E8	277	0.168
2	F7	69	0.089
3	G6	69	0.218
4	D9	346	0.229
5	E10	156	0.181
6	E11	208	0.351
7	D12	346	0.567
8	E13	311	0.443
9	C11	104	0.022
10	F12	0	0.000
11	G13	0	0.000
12	F14	138	0.144
13	F16	173	0.358
14	E17	173	0.147
15	F18	0	0.000
16	E19	121	0.323
17	D18	121	0.331
18	C17	69	0.164
19	B16	242	0.251
20	C15	52	0.061
21	D16	69	0.121
22	E15	86	0.273
23	D14	190	0.507
24	C13	35	0.011
25	G10	17	0.116
26	F9	0	0.000
27	H9	0	0.000

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28	G8	69	0.154
29	H7	86	0.205
30	J6	17	0.046
31	J7	0	0.000
32	L1	225	0.709
33	N1	242	0.405
34	M2	17	0.033
35	L3	86	0.161
36	M4	17	0.011
37	L5	52	0.098
38	K4	52	0.171
39	J5	104	0.215
40	H5	35	0.103
Total		4375.708	7.386
	Average	109.39	0.185
	Total in the Bulgarian area	1,267.936 Ind.	2140.105 tonnes

	№ ind./км²	*t/км²*
Variance	22316.4	0.06
Standard deviation	149.4	0.25
Relative standard deviation	1.4	1.37
Standard error	23.6	0.04

The calculated turbot biomass in the Bulgarian Black Sea waters amounted to **2140.105 tons**, by abundance – **1,267.936 individuals** (Table 4).

3.4. Size structure

The information about the size structure of turbot population was based on biometric

measurements of 253 turbot specimens, and included data on the absolute and standard length, and individual weight (pic.4).

The absolute length of the measured individuals varied between 18 and 73 cm, by weight - between 140 and 7150 g. The total turbot catches reached 427.03 kg. The distribution of the length classes was as follows: ninety-five individuals were of size classes between 18-29.5 cm (37.55 %), 55 individuals - between 30-45 cm (21.74%), 90 ind. - in the range between 45.5-60 cm (35.57%) and 13 ind. - 61-73 cm (5.14%) (Fig. 6).

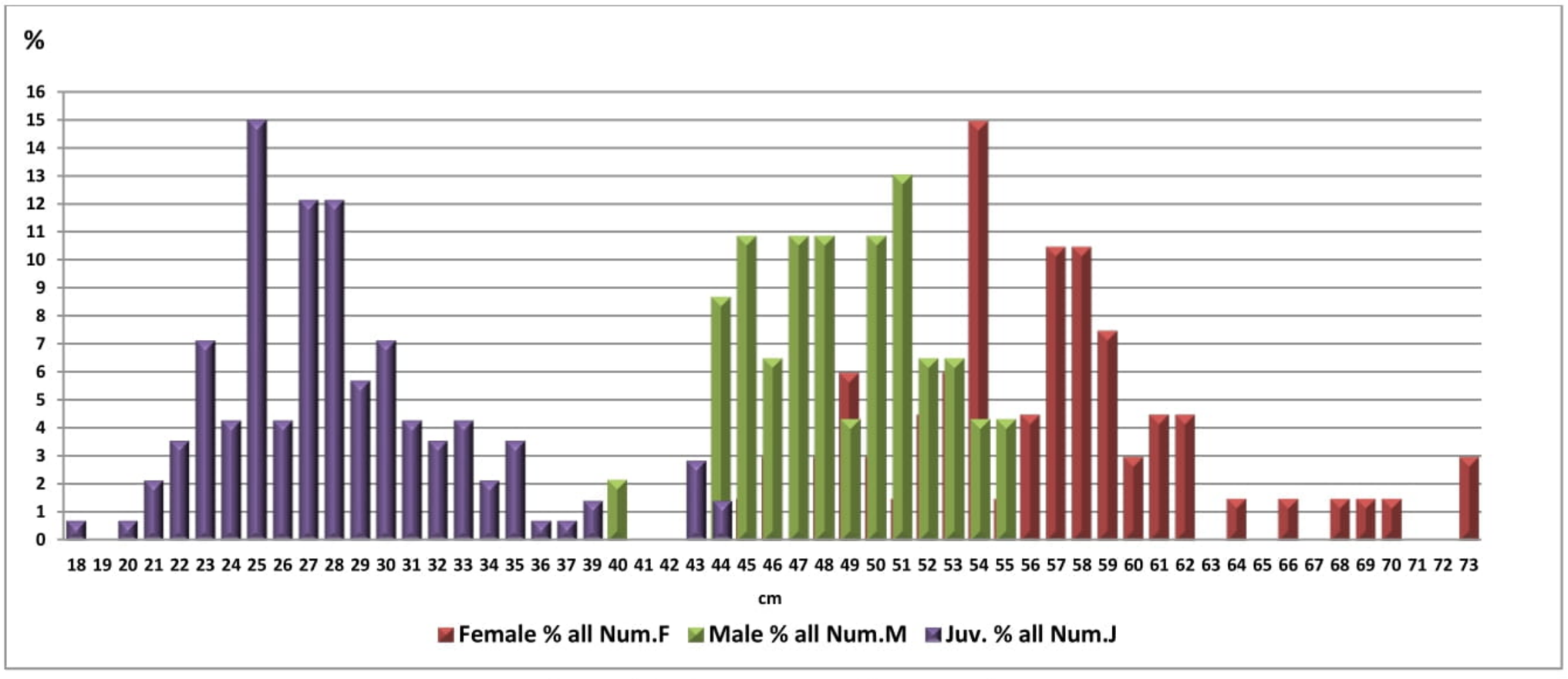

Fig. 6 ***Length structure of S. maximus.***

The young specimens predominated in the total catch - 55.34% /140 individuals/, as adult individuals were as follows: females were 26.5% /67 specimens/, and males specimens - 18.2% /46 individuals/.

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

Fig. 7 shows the total turbot abundance (ind/km^2) and the distribution of the ratio between the undersized individuals and those of standard length.

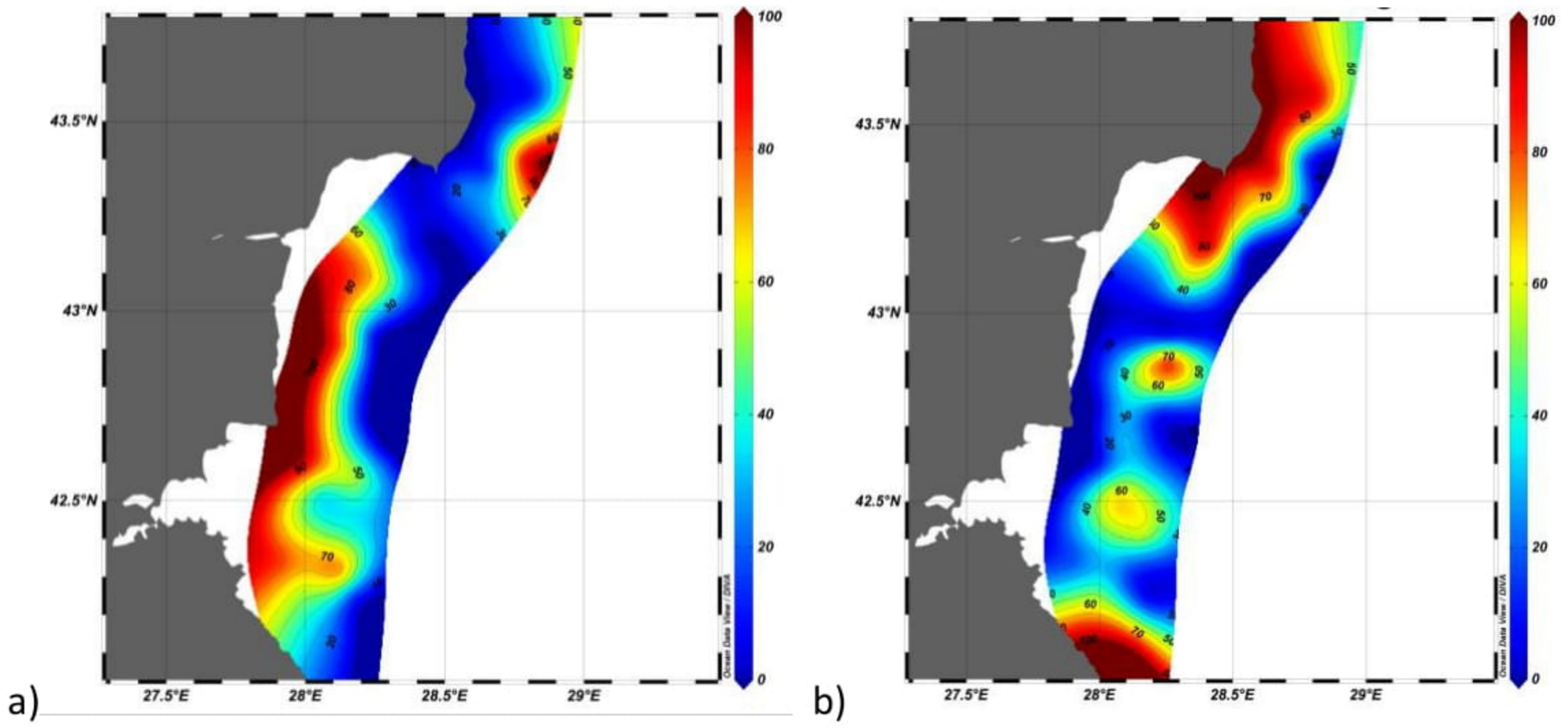

Fig. 7 ***Distribution of the S. maximus abundance (ind/km^2) and ratio between the a) undersized individuals and those with b) standard length.***

The relative turbot biomass by size classes is given in Fig. 8, presenting high biomass for size classes 45-54 cm and 57-62 cm.

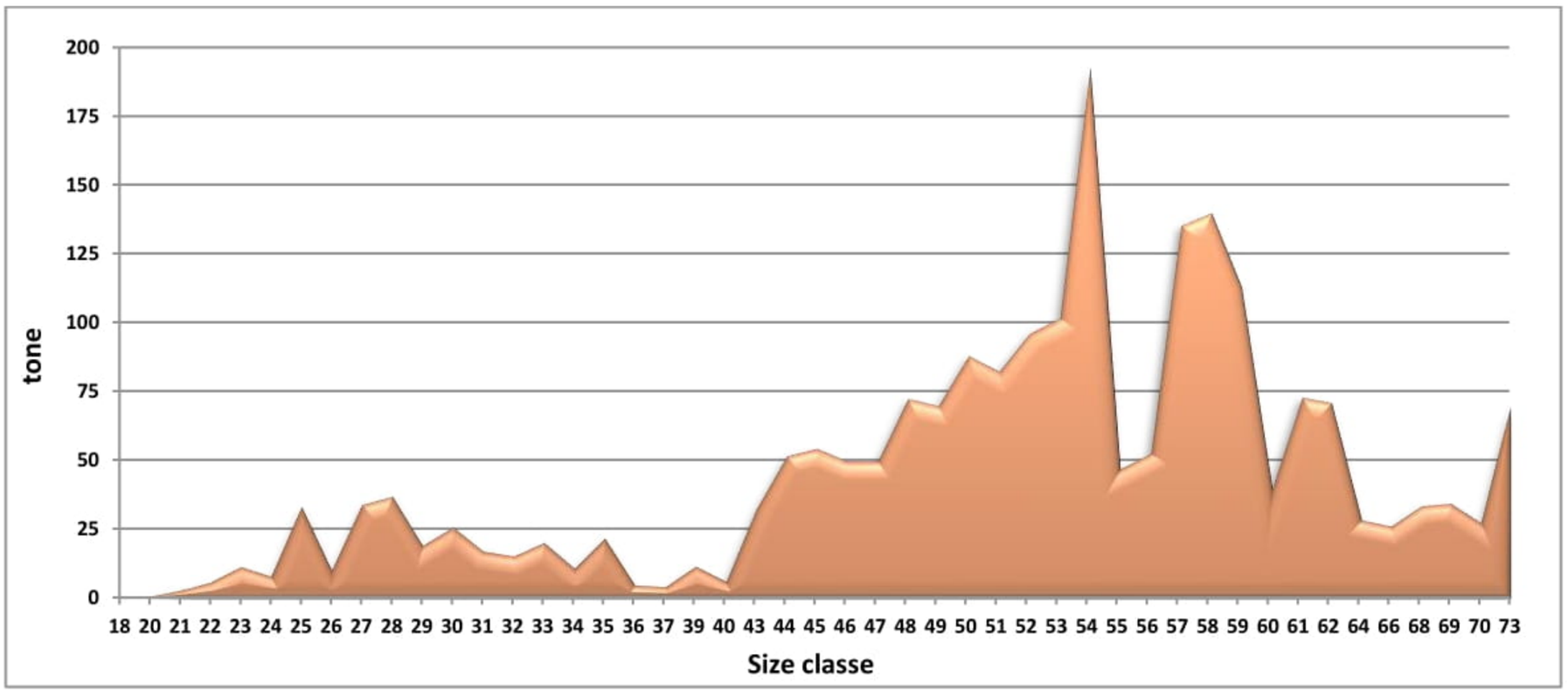

Fig. 8 ***Biomass by mean size classes of S. maximus.***

3.5. Age structure

The turbot age composition was determined through analysis of 108 pairs of otoliths. The age structure included 1 - to 11 - years classes, with domination of the 2 (52.57%), 4 (12.65%) and 5 (16.60%) - years (81.82% in total), followed by 6 - year class – 7.51% (Fig. 9).

During the winter season of 2021 the tendency of predominance of young specimens is preserved and their percentage value is respectively 55.34% of the total number of measured specimens. The young specimens' predominance was observed also in 2020, with a percentage share of 64.44% (in spring) and 41.71% (in autumn) of the total number of collected specimens. We have noted an increasing tendency of the share of young specimens since December 2019, when the juveniles made up 50.79% of the total number of collected specimens.

Although having small frequency of occurrence, specimens from 7- to 11 - years classes were registered in the yield.

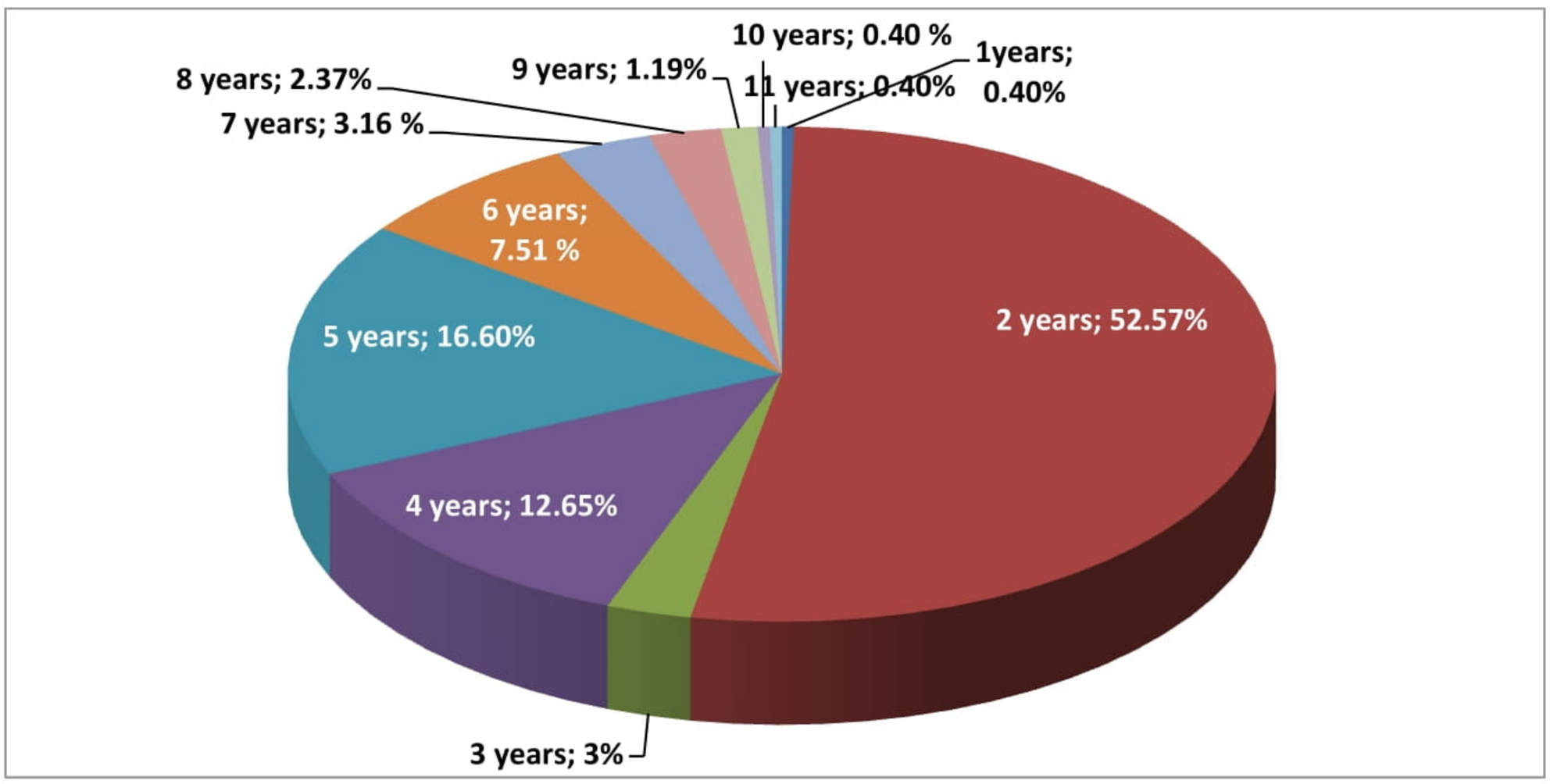

Fig. 9 ***Age structure of turbot in December 2021.***

The distribution of the age composition of *S. maximus* in the surveyed area is shown in Fig.10.

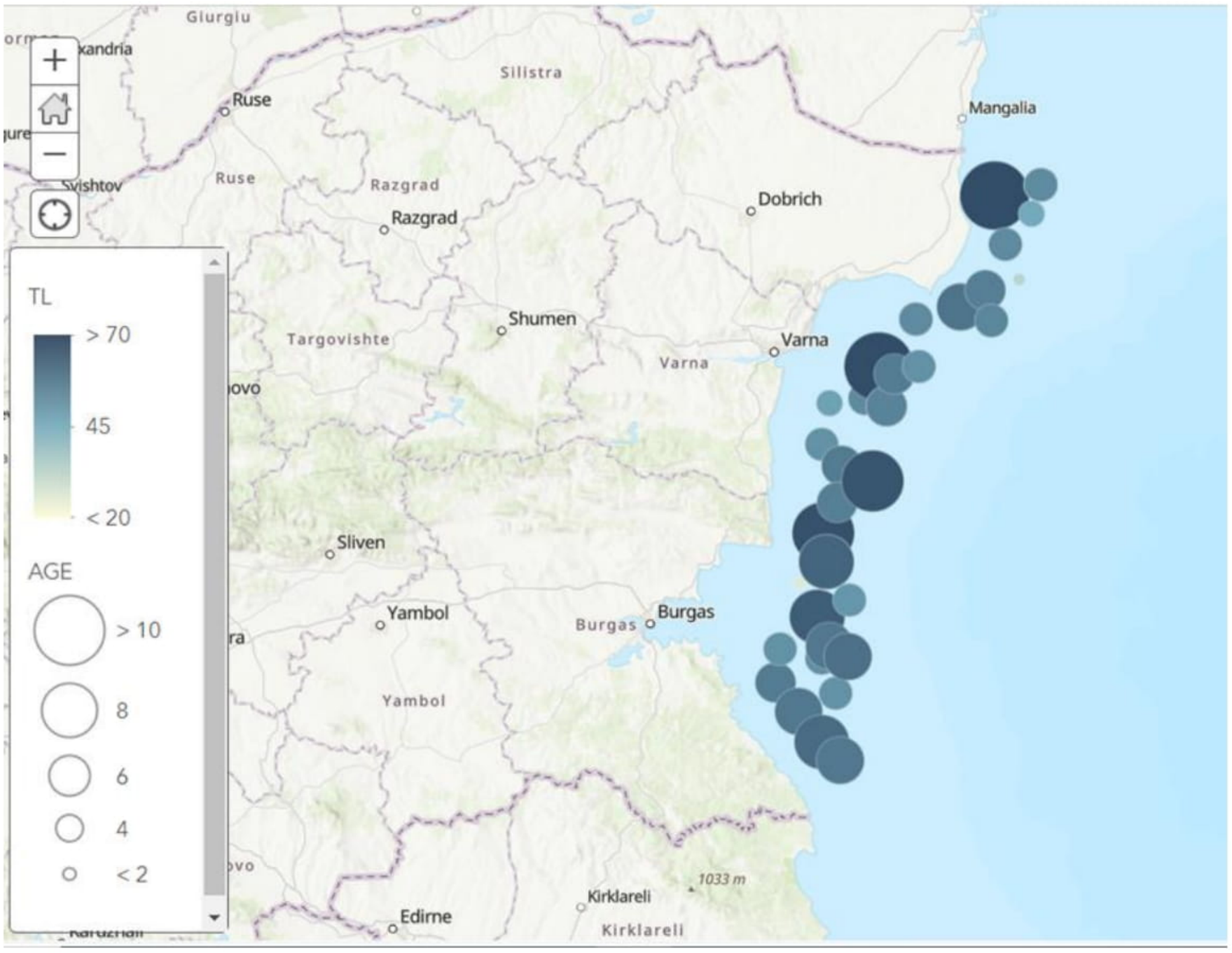

Fig. 10 ***Spatial distribution and age structure of S. maximus in December 2021.***

3.6. Biological parameters of *S. maximus*

To estimate the turbot growth rate, the data about the absolute lengths 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 were as follows: a = 0.0175, b = 3.03, q = -1.756, $L\infty$ = 76.84, k = 0.273, to = -0.48.

The turbot length-weight relationship, based on the autumn survey data is shown in Fig.11.

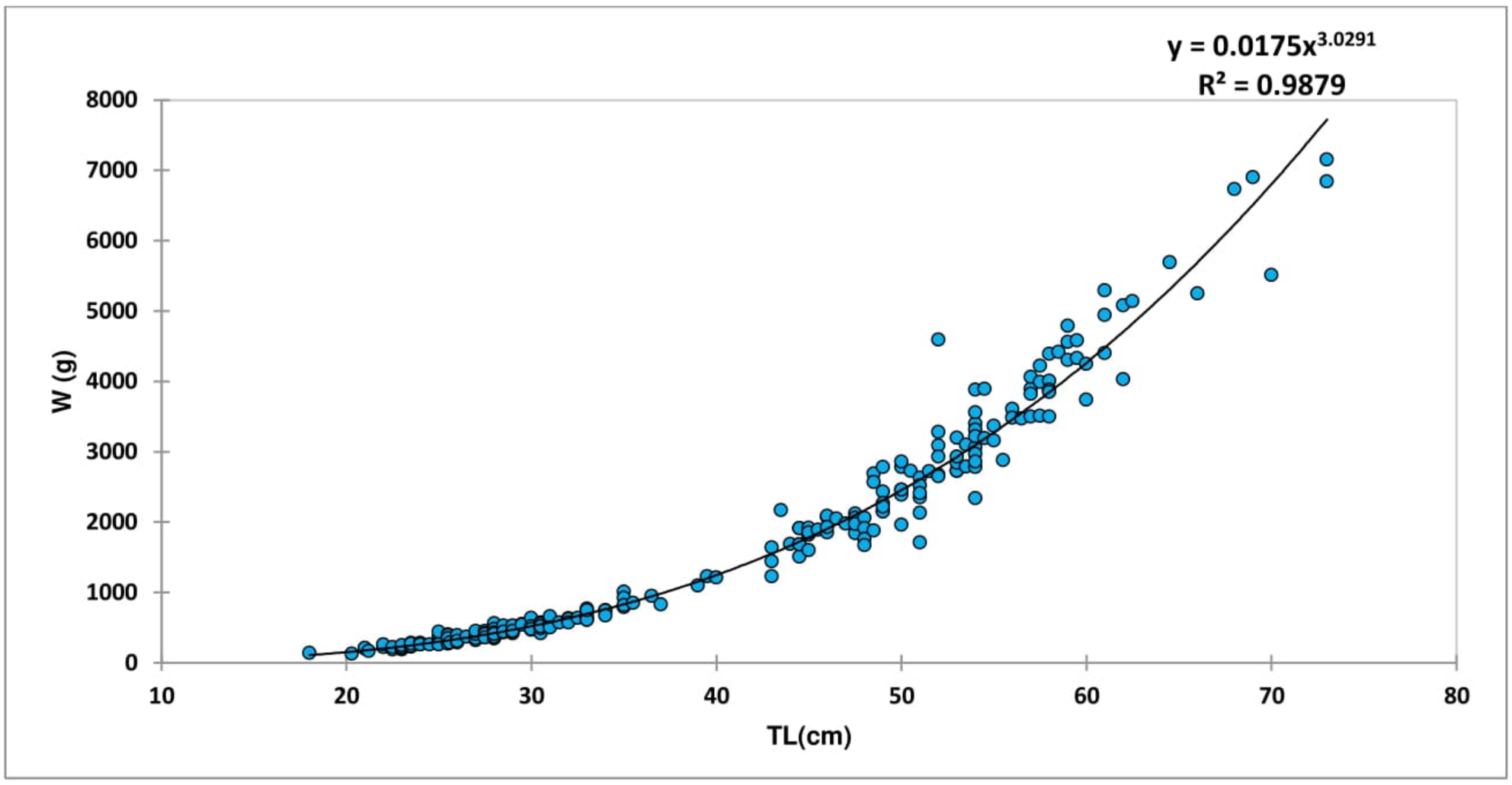

Fig. 11 ***S. maximus: Length-weight relationships in December 2021.***

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.

$L_\infty = L_{t\ max}/0.95$

$k = 1/(t_2-t_1) * \ln(L_\infty-L_1)/(L_\infty-L_2)$

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

$\ln M = -0.0152 - 0.279 \ln L_\infty + 0.6543 \ln k + 0.463 \ln t_0$

Considering, that the water temperature was 8-10 °C during the study, the coefficient of natural mortality (M) for both sexes was equal to 0.31.

Fulton's condition factor (K)

This factor is used as a proxy for the "physiological condition" of individuals. The collected data show that the Fulton coefficient varies in small limits with changes in size and age of turbot (Fig. 12).

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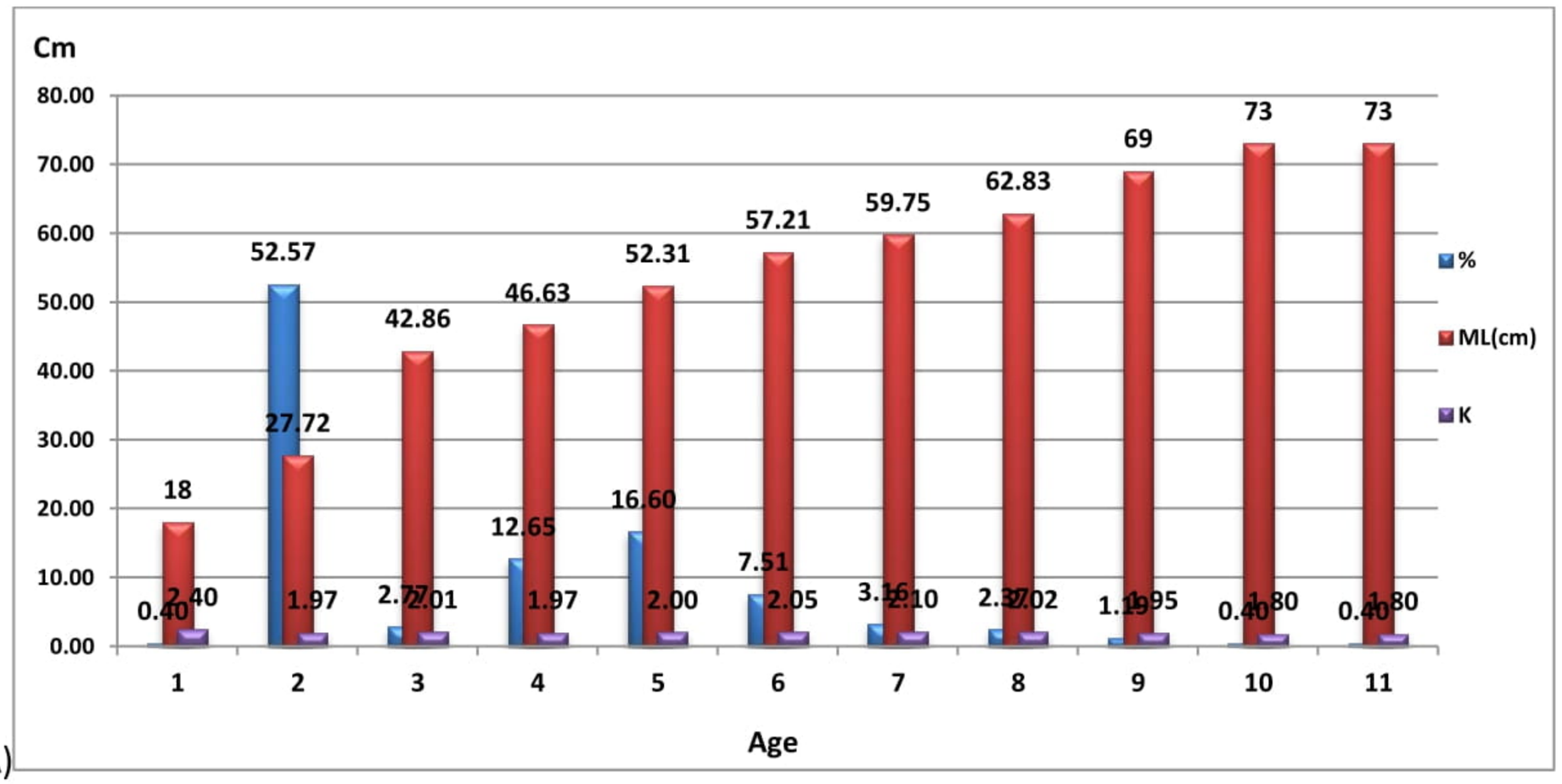
A)



B)

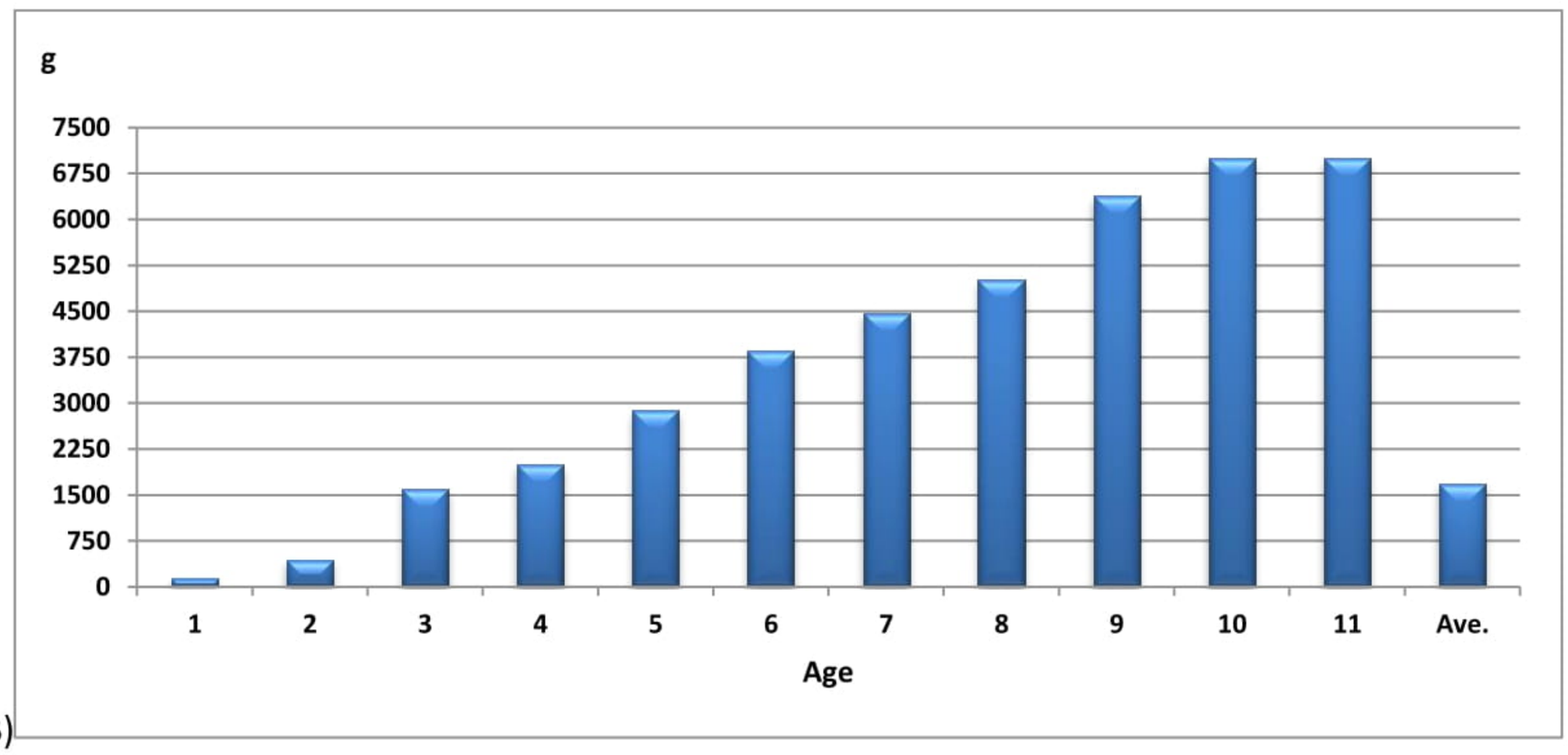


Fig. 12 ***Percentage distribution and relation between the average length and coefficient of Fulton by age groups (A) and an average weight (g) of turbot by age groups (B)***

3.7. Sex structure

Sex ratio

The results of the turbot sex structure analysis in autumn 2021 are shown in Fig.13. The total share of sexually immature individuals formed 55.34% of the total catch, females form 26.5% and males - 18.2%.

From a total of 40 fields, studied off the Bulgarian coast in December, 2021, female specimens were not identified in 15 fields, in 19 fields - males were not estimated, and in 3 fields - only young forms were found, while adult specimens were absent (Fig.13).

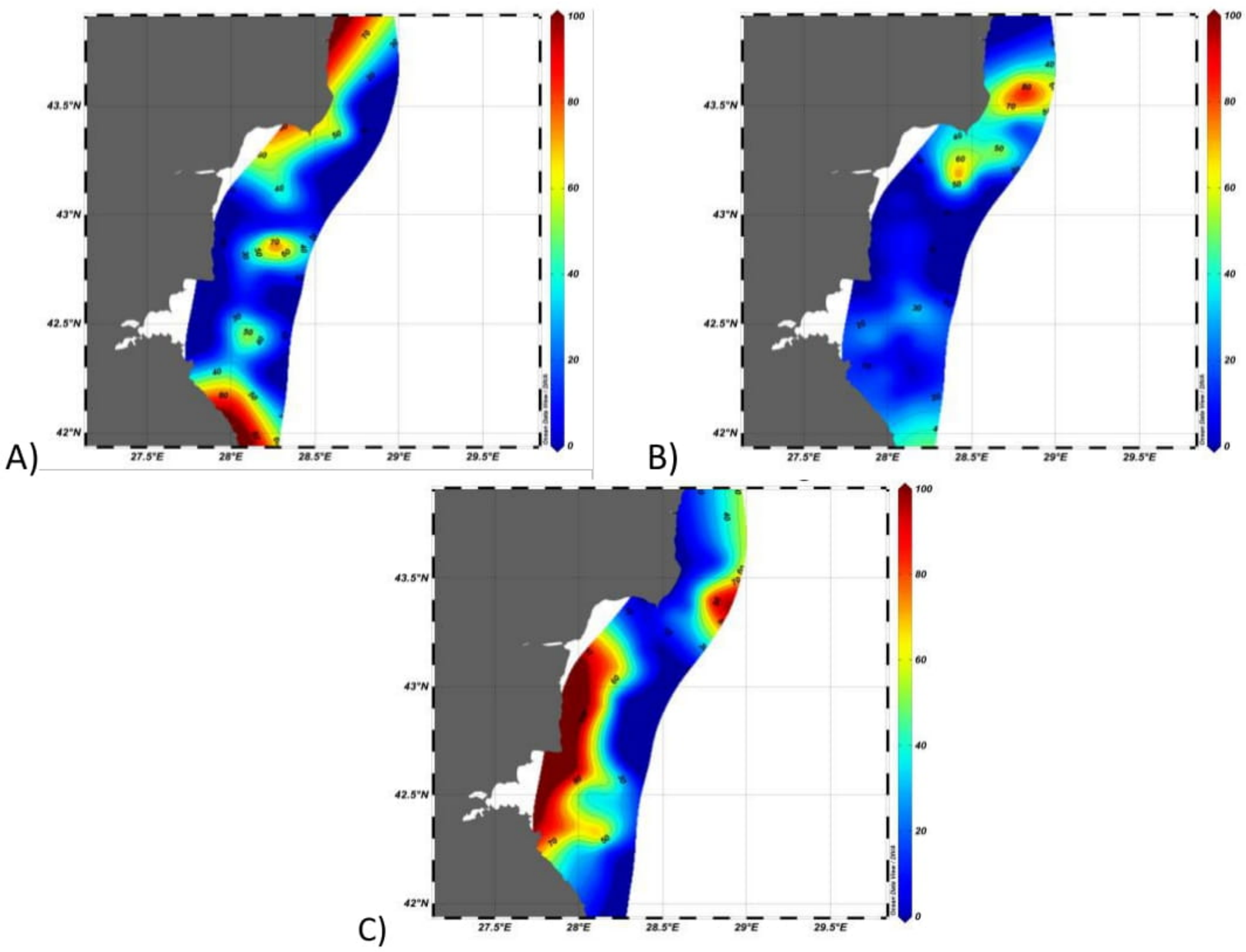


Fig.13 ***Sex structure of S. maximus in December, 2021 A) female, B) male and C) juvenile specimens.***

Male specimens were found over the depths of 63 to 67 m., and female specimens were widespread observed from 28 to 79 m deep. The juveniles were concentrated in front of Shabla-Kavarna (40-79 m) and between Varna - Sozopol (31-72 m).

The females were established mainly in the regions of Durankulak - Varna, Byala – c. Emine and Sozopol - Ahtopol, while high concentrations of males were detected in the region of Krapets – Shabla, and in front of Varna. Low abundance of males was found in the southern direction, in front of Sozopol – Ahtopol.

The average weight of females was 3,828.657 g, with an average length TL = 56.57 cm and standard length SL = 44.69 cm. The maximal weight of females reached 7150 g, besides the minimum weight was 1920 g. The average absolute length TL (cm) of juveniles is 28.49 cm, and in males it is 48.75 cm (Tab. 5).

Table 5

Descriptive statistics, variable - average absolute body length TL (cm) by sex

Descriptive statistics (Quantitative data):			
	F	**M**	**J**
Nbr. of observations	67	46	140
Minimum	45	40	18
Maximum	73	55.5	44.5
1st Quartile	53	46	25
Median	57	48.75	27.75
3rd Quartile	59.25	51	30.63
Mean	56.57	48.86	28.49
Variance (n-1)	36.16	11.70	25.48
Standard deviation (n-1)	6.01	3.42	5.05

Among females, the dominant classes were of 54 to 59 cm, and these size groups have formed 49.25% of all studied females (Fig. 14).

For the length classes over > 56 cm (up to 73 cm), all specimens were only females, comprising 14.63 % of the total abundance.

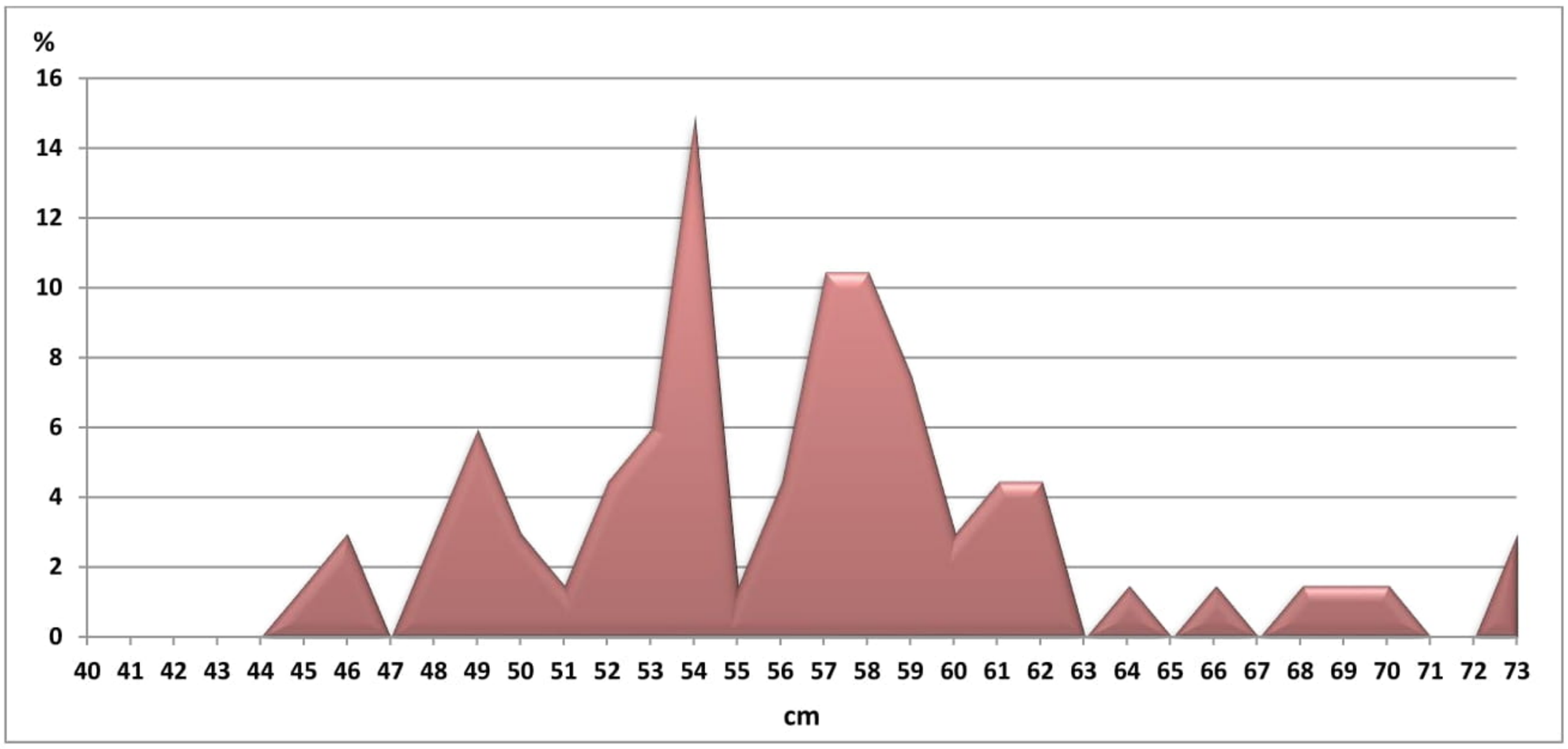


Fig.14 ***Females' specimens: Percentage distribution by length classes.***

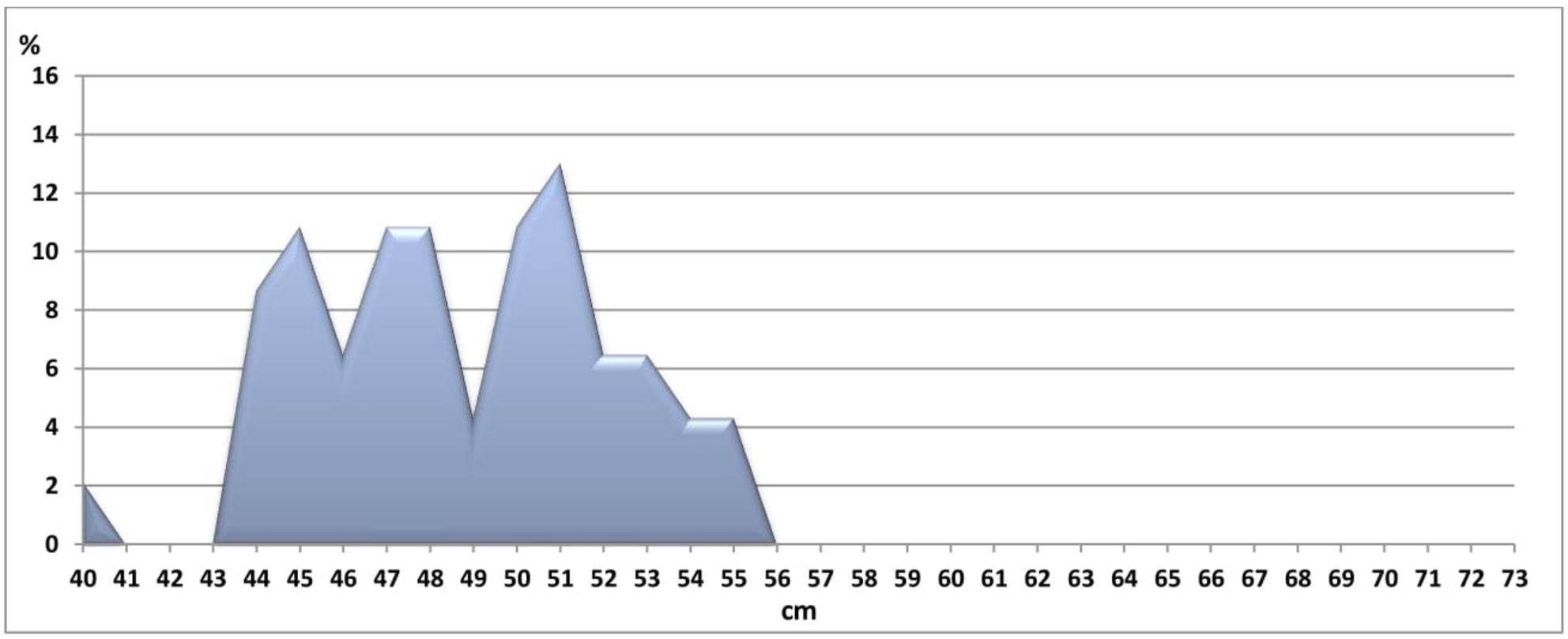


Fig.15 ***Male specimens: Percentage distribution by length classes.***

For males (Fig.15), the most significant proportion of total abundance – 63.04 % belonged to the length class 44 - 50 cm.

The results demonstrate sexual dimorphism regarding the body length, with high presence of large size classes of females (Fig. 14 and 15).

3.8. Fecundity

In May 2021, fecundity of 30 females was determined. The average body weight was **3.31** kg, average total body length – **53.55** cm, and the average age - 6 years (Fig.16).

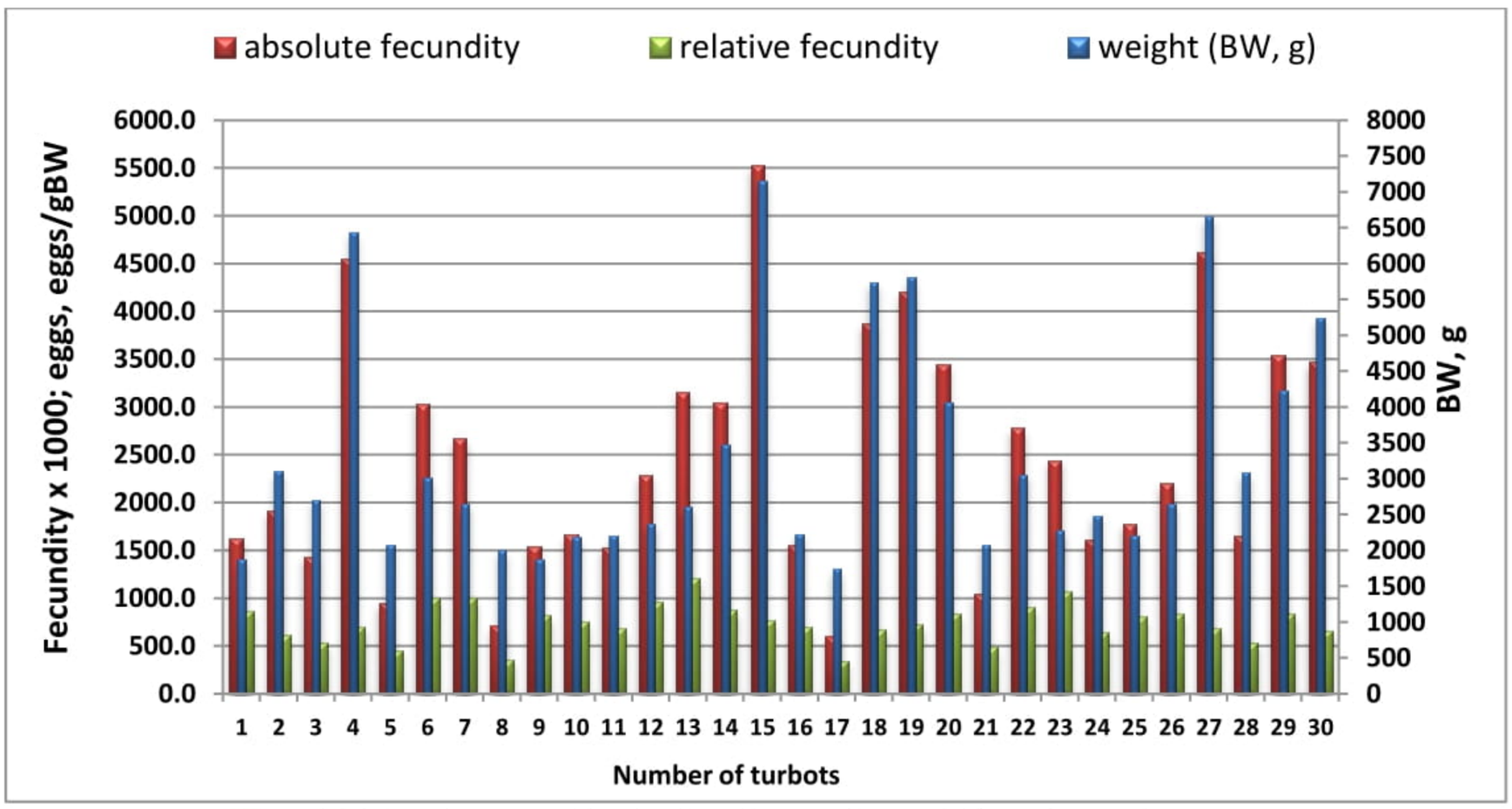


Fig. 16 ***Absolute and relative fecundity of female turbots, May 2021.***

The absolute fertility for the month of May 2021 is 2,487,522.1 caviar grains, and the relative fertility is 749 920.4 caviar grains (Tab. 6).

Table 6

Values for absolute and relative fecundity of **turbot, XII, 2021.**

Indicator	**Average values**
Number of female fish	30
Full body length, TL (cm)	53.55
Body weight, BW (g)	3 310
Absolute fecundity (x10^3), eggs/ individual	2 487 522.1
Relative fecundity (x10^3), eggs /kg BW	749 920.4
Age, year	6

The established fertility of 2,487,522.1 caviar grains/individual is close to that of Aydin et al. 2019, which establishes an absolute fertility of 2,400,000 caviar grains/individual. In their study on the reproductive biology of turbot, Aydin & Sahin, 2011 found an absolute fertility of 2,329,000 caviar grains/individual during the spawning season, which is on average 158,522 caviar grains/individual lower than found in the present study.

Fig. 17 shows the relationship between absolute fertility and total body length, with fertility increasing with increasing body length.

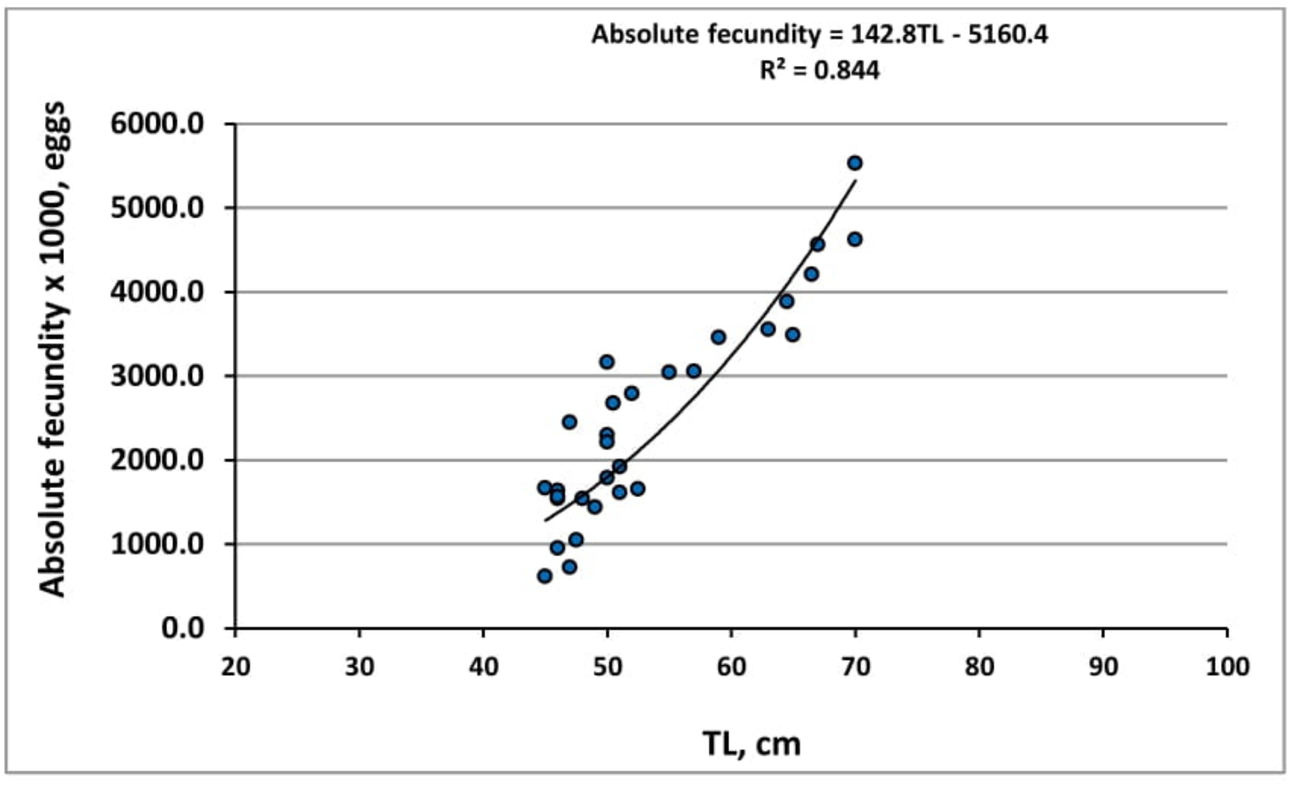


Fig. 17 ***Correlation between absolute fecundity and total length of female turbots, May 2021***

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During the spawning season of turbot in 2019, fertility over 2,200,000 caviar grains/individual was estimated, which is similar to that found in the present study.

Fig. 18 shows the relationship between absolute fertility and weight of females.

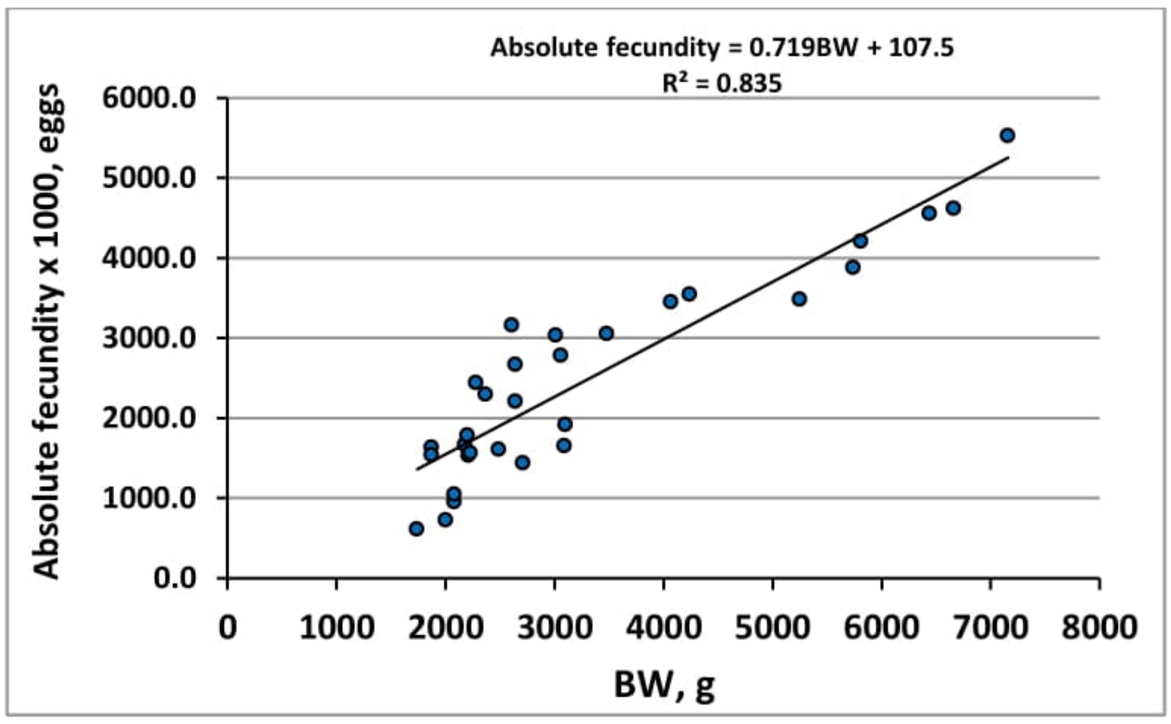

Fig. 18 ***Correlation between absolute fecundity and body weight of female fish, May 2021.***

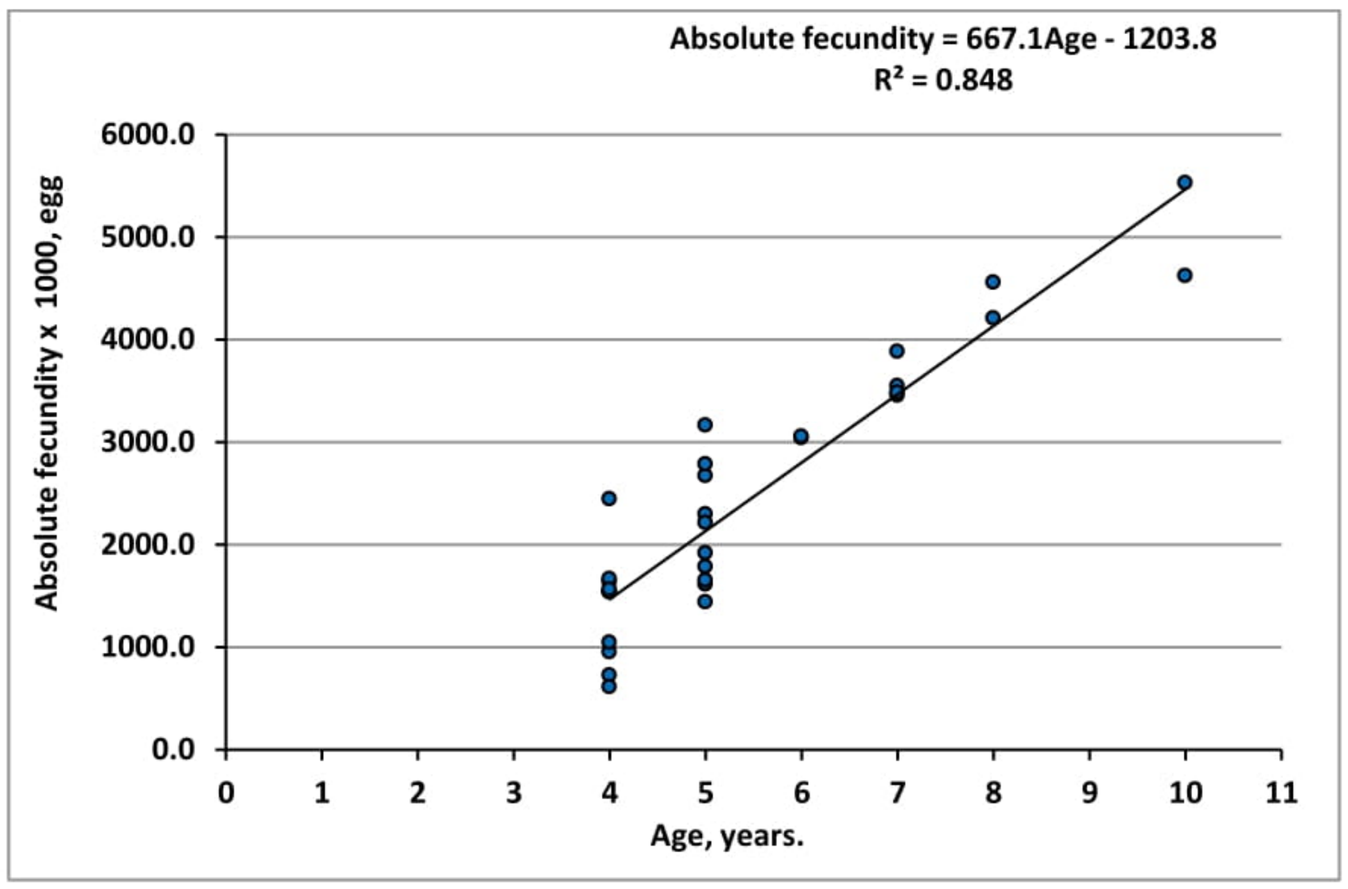

Fig. 19 ***Correlation between absolute fecundity and age of female, May 2021***

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The relation was positive with increasing body weight and absolute fertility increases.

The correlation between absolute fertility and the age of female fish in May 2021 is presented in Fig.19.

3.9. Accompanying species

During the trawl survey, as bycatch were collected 53 specimens of spiny dogfish (*Squalus acanthias*), 149 specimens thornback ray (*Raja clavata*) and 81 individuals of European flounder (*Platichthys flesus*) (Table 7).

Table 7

Data on species composition and biological characteristics of the bycatch species

Bycatch species	N	Size (cm)			Weight (kg)		
		Min.	Max.	Ave.	Min.	Max.	Ave.
Squalus acanthias	53	45	149	114	0.350	16.600	8.124
Raja clavata	149	32	92	66	0.200	6.490	2.245
Platichthys flesus luscus	81	14	38	22	0.030	0.820	0.140

Maps, showing the location of stations with above mentioned bycatch species is presented in Fig. 20. The species *Squalus acanthias* was mainly observed in the north region of Duranculak - Shabla (50-67m) and in front of Ahtopol (63-58 m). Large number of *Pl. flesus* was gathered also in north direction Durankulak to c. Kaliakra, at a depth of 61-65 m and to the south from c. Emine to Primorsko.

Thornback ray were observed in the area below the c. Kaliakra from 79 m to 82 m.

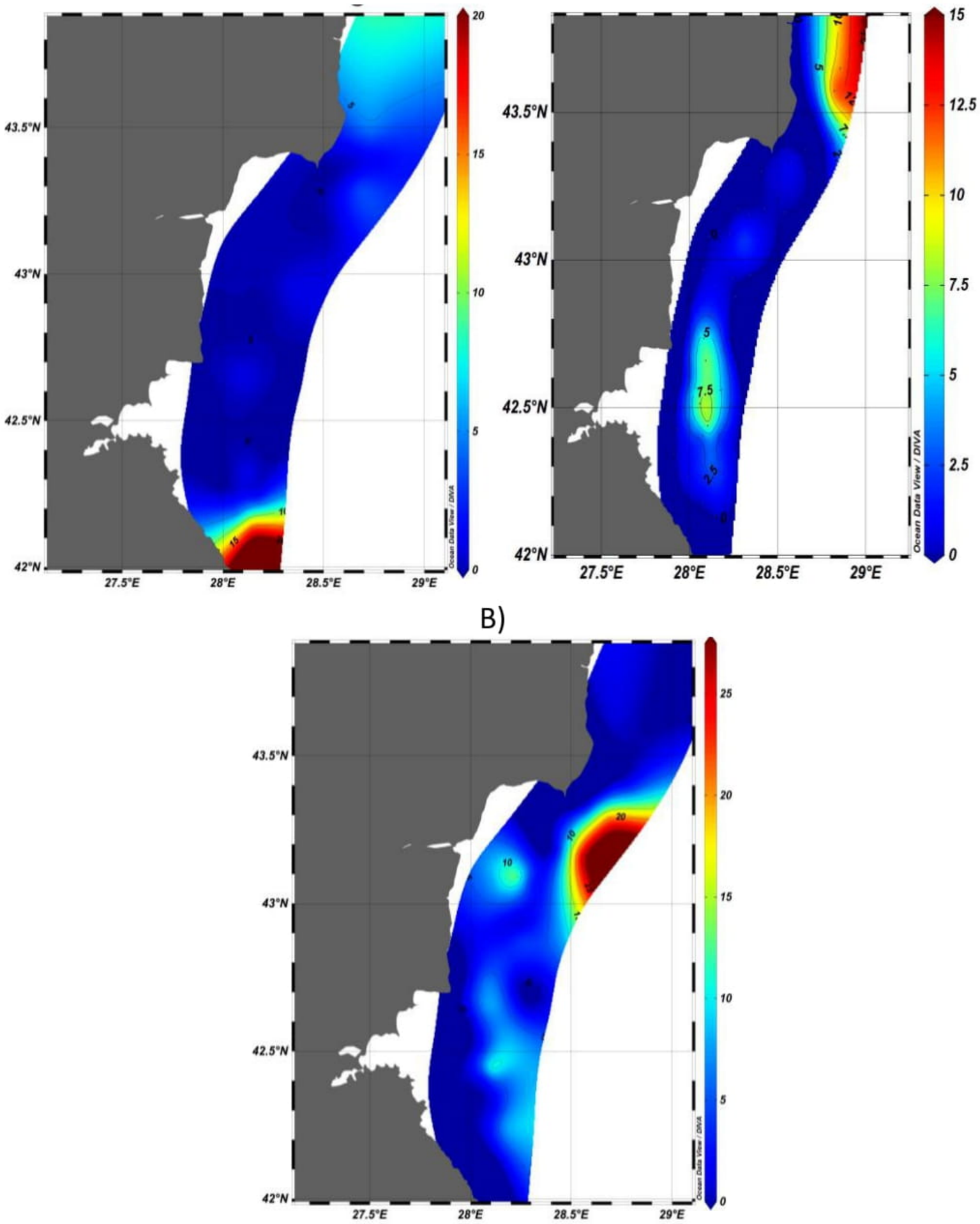

***Fig. 20** Location of stations with bycatch from A) spiny dogfish (S. acanthias), B) flounder (Pl. flesus), and C) thornback ray (R. clavata).*

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4.0. Food spectrum of *S. maximus*

During the winter season of 2021, a total of 83 stomachs were gathered to determine the dietary spectrum of turbot. The food components were found in 55 % of the examined specimens and 45 % were with empty stomachs. Full description of the collected data and some statistical parameters are given in the table 8 and 9:

Table 8

Survey area, length and weight of specimens, stomach contents and index of stomach fullness (ISF).

Trawl	L	W (gr)	ST/full/	ST/em	ST/cont	ISF
B16/13	52	4590	109,27	50,79	58,48	1,274074
B16/14	58,5	4420	144,93	33,75	111,18	2,515385
C15/3	52	2930	37,36	25,61	11,75	0,401024
C17/2	44,5	1910	22,62	18,55	4,07	0,213089
C17/3	59,5	4330	63,42	49,91	13,51	0,312009
C17/4	54	2970	24,63	20,82	3,81	0,128283
D9/20	52	3280	152,59	53,1	99,49	3,033232
D12/14	57	3890	29,17	29,17	0	0
D12/15	53	2730	27,67	27,67	0	0
D12/16	45	1920	15,55	15,55	0	0
D12/17	57,5	3990	29,45	29,45	0	0
D12/18	69	6900	54,66	54,66	0	0
D12/19	62,5	5140	100	52,91	47,09	0,916148

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D12/20	50	2780	27,88	20,76	7,12	0,256115
D16/3	49	2430	29,96	19,41	10,55	0,434156
D16/4	53	3200	41,4	34,13	7,27	0,227188
D18/3	46,5	2050	70,43	20,21	50,22	2,449756
D18/4	55	3370	22,21	22,21	0	0
D18/5	62	5080	87,89	38,57	49,32	0,970866
D18/6	57	4060	33,02	30,33	2,69	0,066256
D18/7	54,5	3890	85,61	49,5	36,11	0,928278
E8/15	40	1210	95,42	43,2	52,22	4,315702
E10/8	50	2460	60,98	23,44	37,54	1,526016
E10/9	58	4010	112,71	43,92	68,79	1,715461
E11/7	47	1980	16,46	16,46	0	0
E11/8	53,5	3100	39,34	39,34	0	0
E11/9	54	3310	26,19	26,19	0	0
E11/10	53	2730	48,84	36,52	12,32	0,451282
E11/11	54,5	3190	27,64	27,64	0	0
E11/12	57	3500	29,56	29,56	0	0
E13/12	50	1960	13,5	13,5	0	0
E13/13	56	3610	44,06	38,37	5,69	0,157618

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E13/14	46	2070	22,96	16,89	6,07	0,293237
E13/15	45	1600	19,99	14,1	5,89	0,368125
E13/16	53,5	2790	20,86	20,86	0	0
E13/17	62	4030	33,91	33,91	0	0
E13/18	64,5	5690	67,27	56,22	11,05	0,1942
E15/3	58	3870	40,52	40,52	0	0
E15/4	59	4300	70,48	41,03	29,45	0,684884
E17/10	52	3090	21,54	21,54	0	0
E19/1	44,5	1510	43,86	18,23	25,63	1,697351
E19/3	46	2090	25,7	14,81	10,89	0,521053
E19/4	59	4560	148,39	80,02	68,37	1,499342
E19/5	48,5	2570	37,2	23,13	14,07	0,547471
E19/6	59,5	4580	48,3	31,96	16,34	0,356769
E19/7	51	2520	20,88	18,72	2,16	0,085714
F7/4	54	3400	104	49,34	54,66	1,607647
F14/4	46	1850	12,28	12,28	0	0
F14/5	51	2630	25,89	22,99	2,9	0,110266
F14/6	48	2060	15,09	15,09	0	0
F16/5	45	1330	12,97	12,97	0	0

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F16/6	50	2860	36,01	23,98	12,03	0,420629
F16/7	57,5	3510	34,1	34,1	0	0
F16/8	52	2670	37,52	22,55	14,97	0,560674
F16/9	54	3060	20,68	20,68	0	0
F16/10	61	5290	33,66	33,66	0	0
G6/3	61	4400	32,77	32,77	0	0
G6/4	73	7150	49,06	49,06	0	0
G8/3	56,5	3470	23,54	20,94	2,6	0,074928
G8/4	56	3480	23,41	23,41	0	0
H7/2	44,5	1910	29,42	17,29	12,13	0,635079
H7/3	50	3500	41,15	40,15	1	0,028571
H7/4	54	2880	27,13	27,13	0	0
H7/5	47,5	2060	23,48	18,63	4,85	0,235437
J6/1	52	2650	50,44	26,85	23,59	0,890189
K4/1	57,5	4220	87,92	51,05	36,87	0,873697
K4/2	50	2460	16,36	16,36	0	0
L1/2	51	2300	20,97	20,97	0	0
L1/3	51,5	2720	71,18	28,78	42,4	1,558824
L1/4	49	2460	81,46	32,75	48,71	1,980081

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L1/5	47,5	1340	19	19	0	0
L1/6	58	3880	35,56	35,56	0	0
L1/7	54	2780	22,01	22,01	0	0
L1/8	60	4250	85,41	53,81	31,6	0,743529
L3/2	45	1850	25,84	17,89	7,95	0,42973
L3/3	54	2860	20,35	20,35	0	0
L5/2	49	2220	32,36	20,49	11,87	0,534685
L5/3	55	3160	26,06	26,06	0	0
M2/1	46	1930	28,28	21,09	7,19	0,372539
N1/7	45	1820	21,6	15,71	5,89	0,323626
N1/8	49	2150	21,72	21,72	0	0
N1/9	53	2840	22,26	22,26	0	0
N1/11	49	2270	13,1	13,1	0	0

Table 9

General statistical data for the measured parameters in stomach content analysis.

	L	W (kg)	ST/full/	ST/cont/g	ISF
Mean	53.03	3.13	43.74	14.46	0.48
Standard Error	0.65	0.13	3.53	2.55	0.09
Median	53.00	2.88	29.96	3.81	0.13

Mode	54.00	2.46	#N/A	0.00	0.00
Standard Deviation	5.92	1.17	32.18	23.25	0.79
Sample Variance	35.10	1.37	1035.56	540.50	0.62
Kurtosis	0.80	1.51	2.59	4.71	7.49
Skewness	0.58	1.01	1.72	2.13	2.51
Range	33.00	5.94	140.31	111.18	4.32
Minimum	40.00	1.21	12.28	0.00	0.00
Maximum	73.00	7.15	152.59	111.18	4.32
Sum	4401.50	259.86	3630.32	1200.35	39.92
Count	83.00	83.00	83.00	83.00	83.00

The average stomach fullness index reached 0.48 % BW ± 0.09 SE (Table 9). The analysis of the spatial distribution of the stomach fullness index (Fig.21) indicated higher values in the central part along the Bulgarian Black Sea coast.

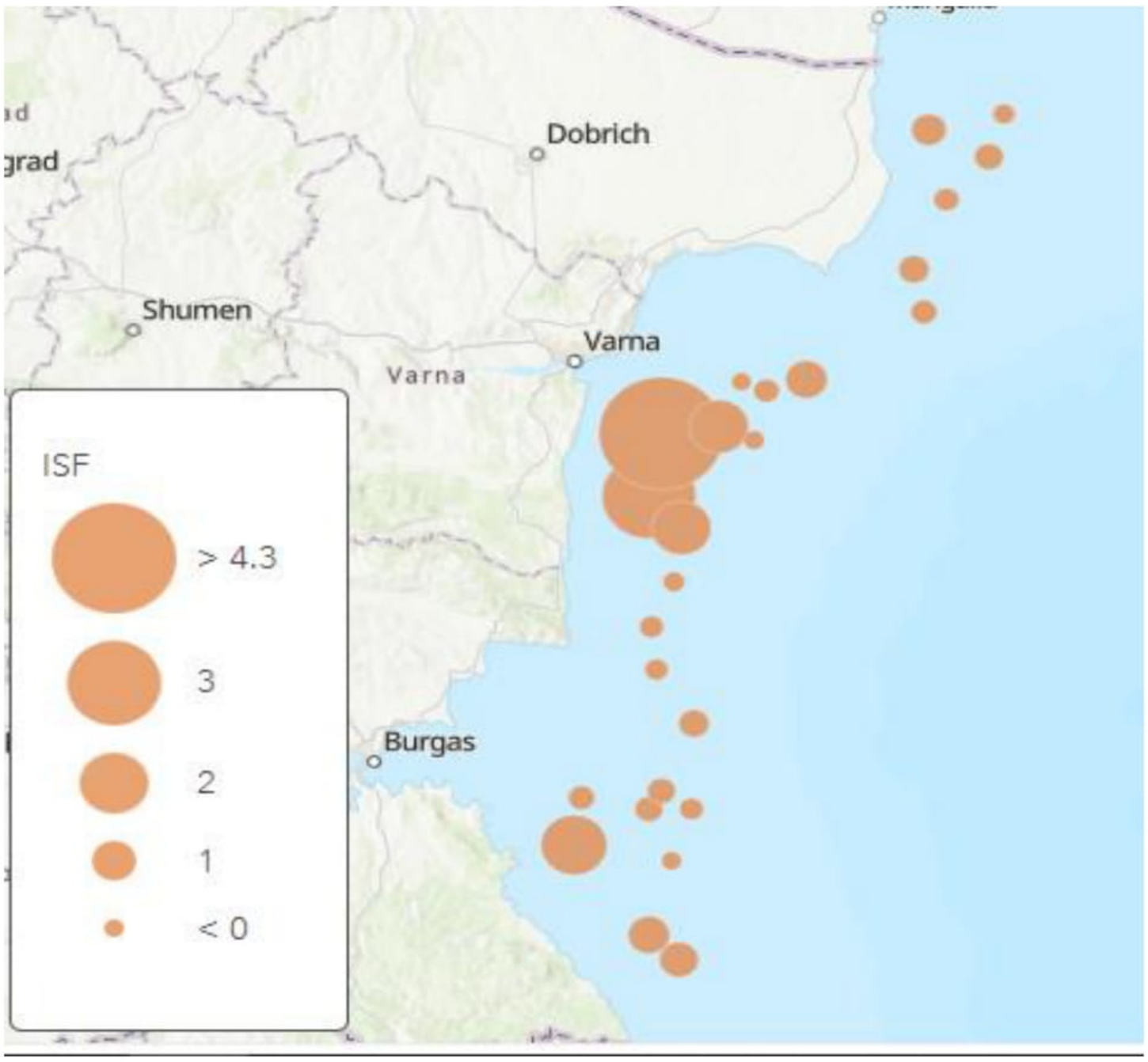

Fig. 21 ***Spatial distribution of ISF (% BW) during the winter season of 2021***

The qualitative composition of the turbot food included completely fish (*Pisces*) (Table 10).

Table 10

Diet spectrum of turbot in the winter season of 2021. (Data for feeding individuals).

Species	CN	CW	F	IRI	IRI %
Pisces					
Merlangius merlangus	23,26	23,10	30,43	1157,79	21,34
Engraulis	27,77	25,65	30,43	1742,22	32,11

encrasicolus					
Gobiidae sp.	3,82	5,40	6,52	15,67	0,29
Trachurus mediteraneus	2,34	2,73	8,70	19,82	0,37
Mullus barbatus	2,08	2,13	2,17	16,10	0,30
Sprattus sprattus	2,60	2,17	4,35	5,53	0,10
Food remains	38,12	38,82	65,22	2468,39	45,50

During the winter season of 2021, the food spectrum of turbot is formed entirely of fish, total value IRI = 2957.13 (54.5%) with main species *Engraulis encrasicolus*, IRI = 1742.22 (32.11%) and *Merlangius merlangus*, IRI = 1157.79 (21.34% IRI). High index was also found for the food remains, which cannot be identified to species level, IRI = 2468.39 (45.50%) (Fig. 22).

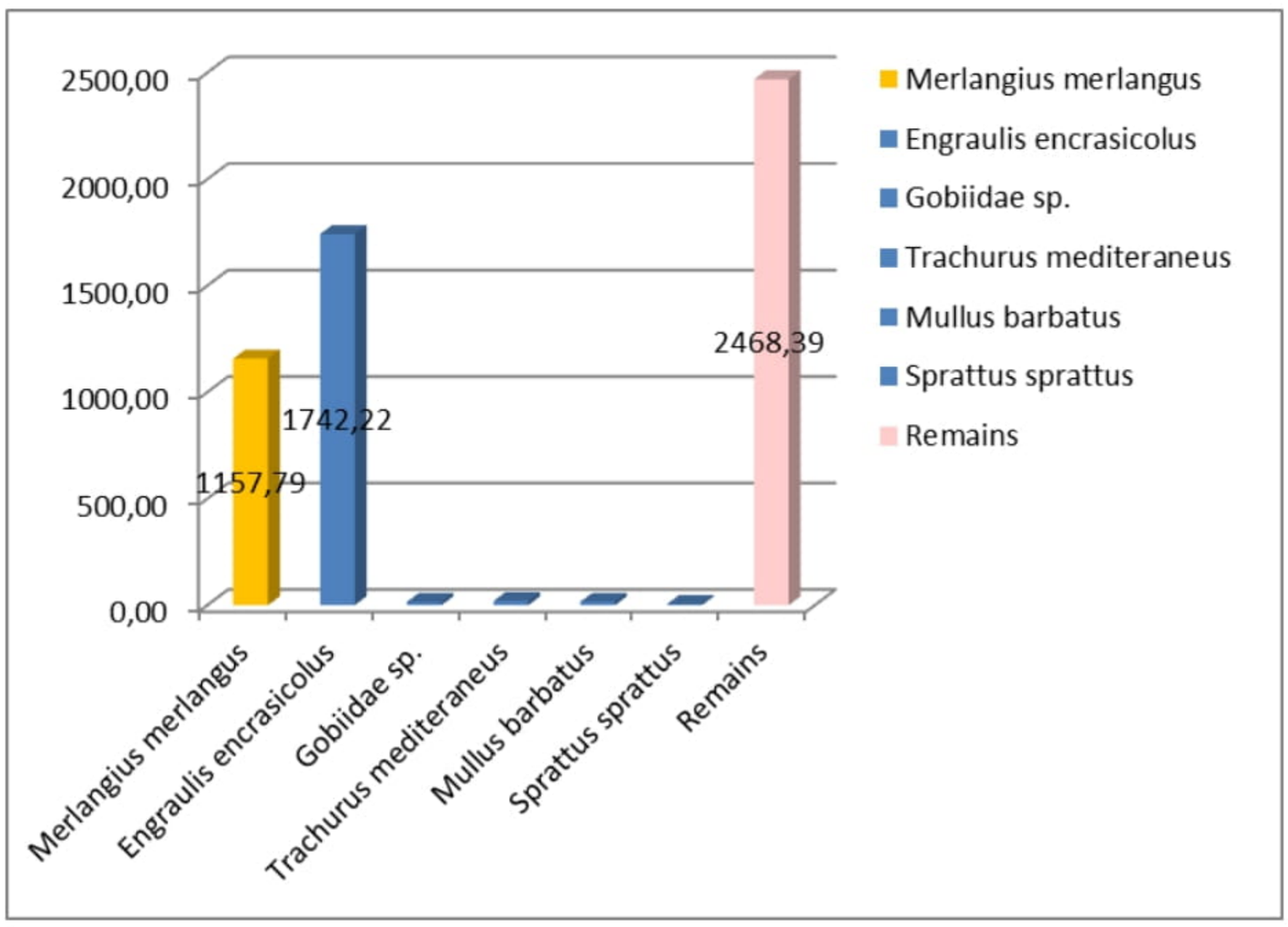

Fig. 22 IRI values of different species in turbot food in winter 2021

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According to IRI (% IRI), the percentage of individual species is distributed as follows: 21 % whiting and 32 % anchovy, a small percentage distributed among other fish species, and 45 % food remains (Fig. 23).

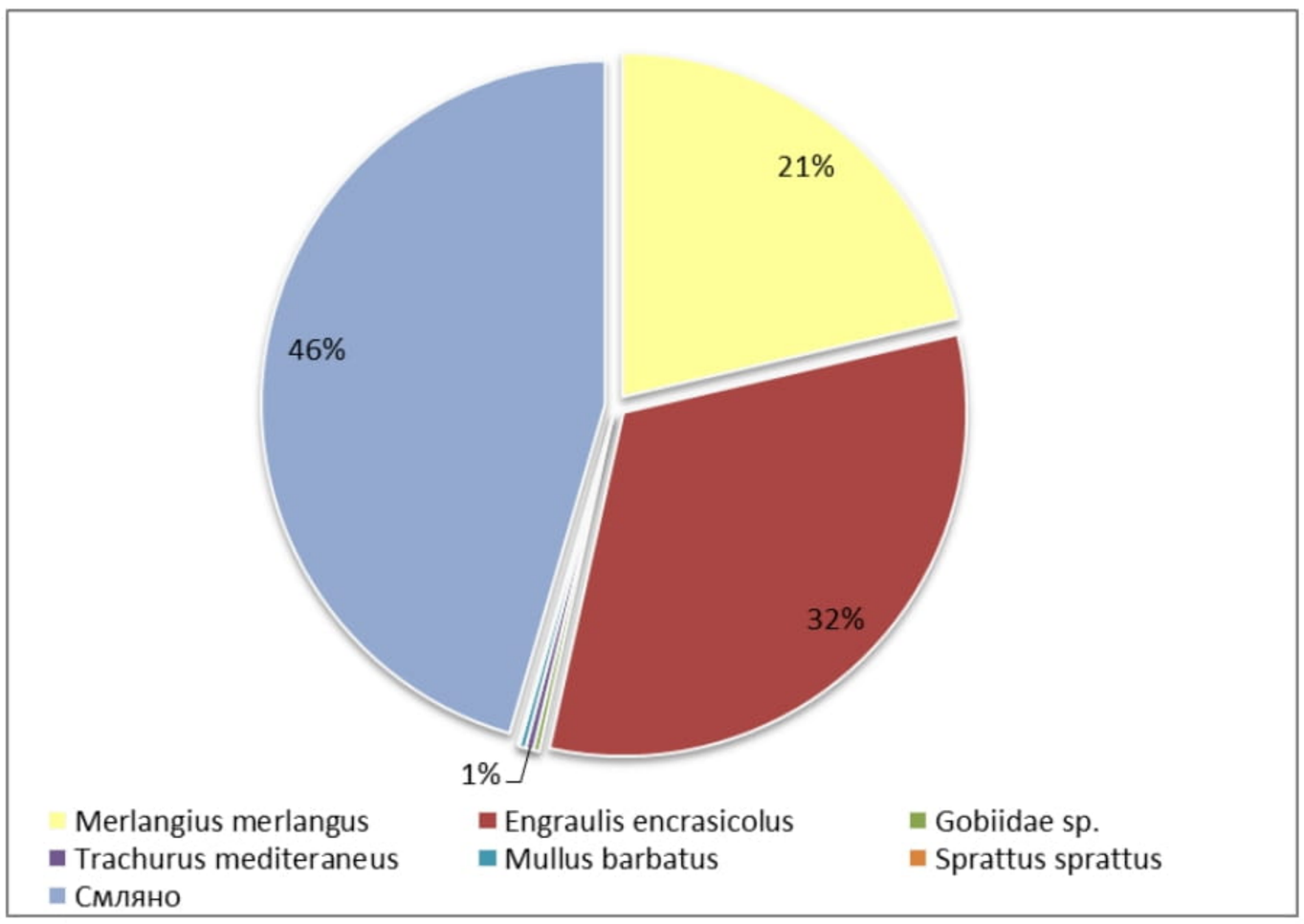

Fig. 23 ***Percentages by species (%, IRI) in the turbot food spectrum in winter 2021.***

5. Forecasts and opportunities for exploitation

The estimation of **maximum sustainable yield (MSY)** is based on the Gulland formula (1971): MSY = 0.5 * M * Bv, and the natural mortality coefficient (M) is calculated using the Pauly's empirical formula (1979, 1980). At a value of M = 0.2, the quantity of MSY by the Gulland method amounts to **214 t** for the autumn season of 2021.

The stock exploitation (E) is determined by the formula E = F/Z (Pauly, 1983) and varies according to the intensity of fishing activities (Avşar, 1998), so that the population is under-exploited at E <0.5, while E = 0.5 gives an optimal level of exploitation, and E > 0.5 indicates over-exploitation. The calculated value of E = 0.6 (for the two studied seasons of 2021) is an indication of a high exploitation of the turbot stock.

The calculated values of the parameters in *von Bertalanffy's* and L-W equation (Fig.24) **for both surveys in 2021 (spring and autumn)** were as follows: a = 0.022, b = 2.96, q = -1.65, $L\infty$ = 76.84, k = 0.28, to = -0.47.

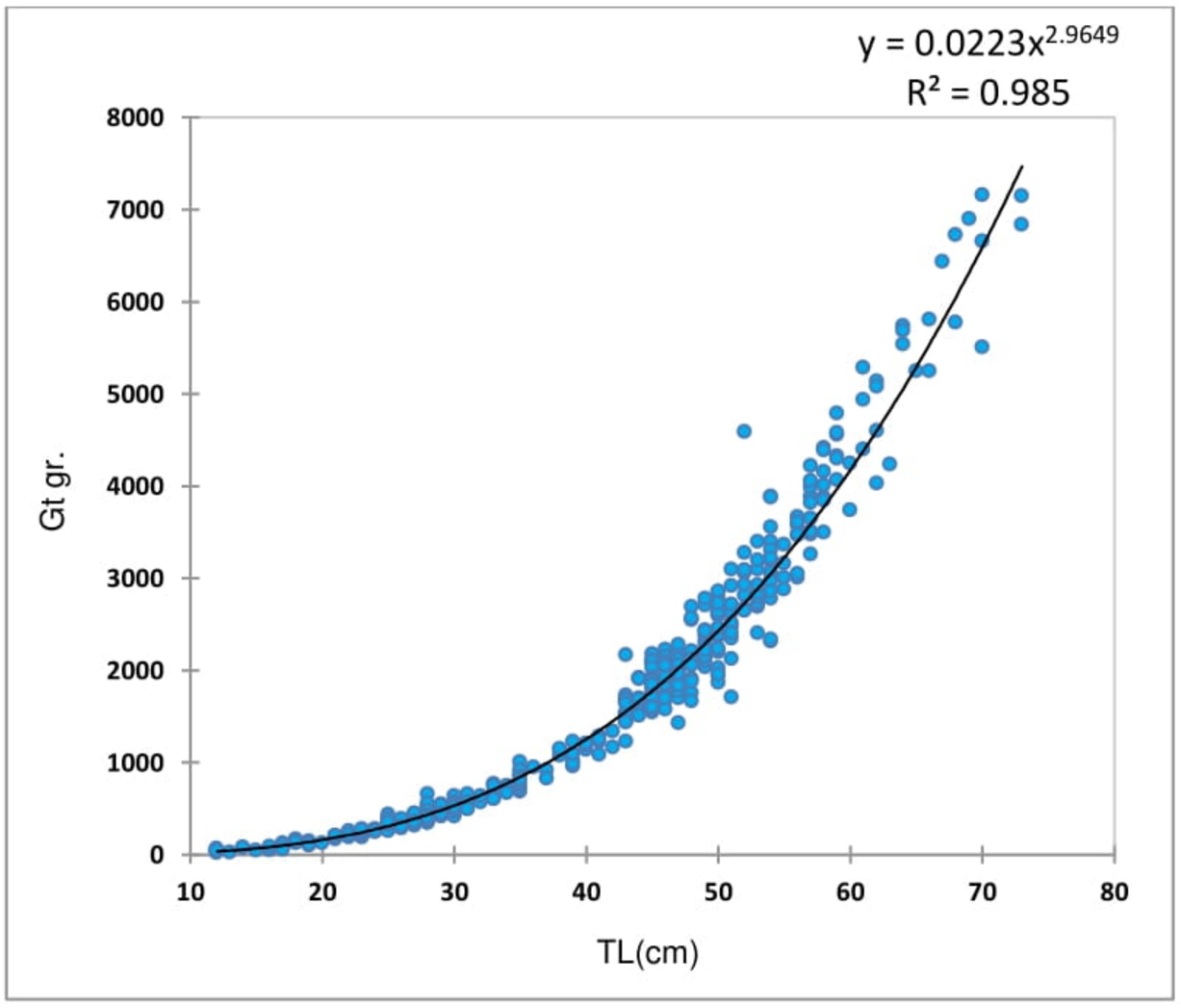

Fig. 24 S. maximus: Length-weight relationships in 2021 г.

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. To calculate the yield per recruit, the following parameters are applied: W_∞, к, M, t_0, t_r, while the model allows inputs of various F and T_c parameters and assessment of their effects on the yield per recruit. It should be mentioned, that both parameters - F and T_c can be controlled by fishery management, because F is proportional to effort and T_c is a function of gear selectivity. The calculations show that Y/P increase at F = 0.2 (Fig. 25), thus the value of fishing mortality should not exceed 0.2, aiming at a maximal sustainable yield of adult specimens.

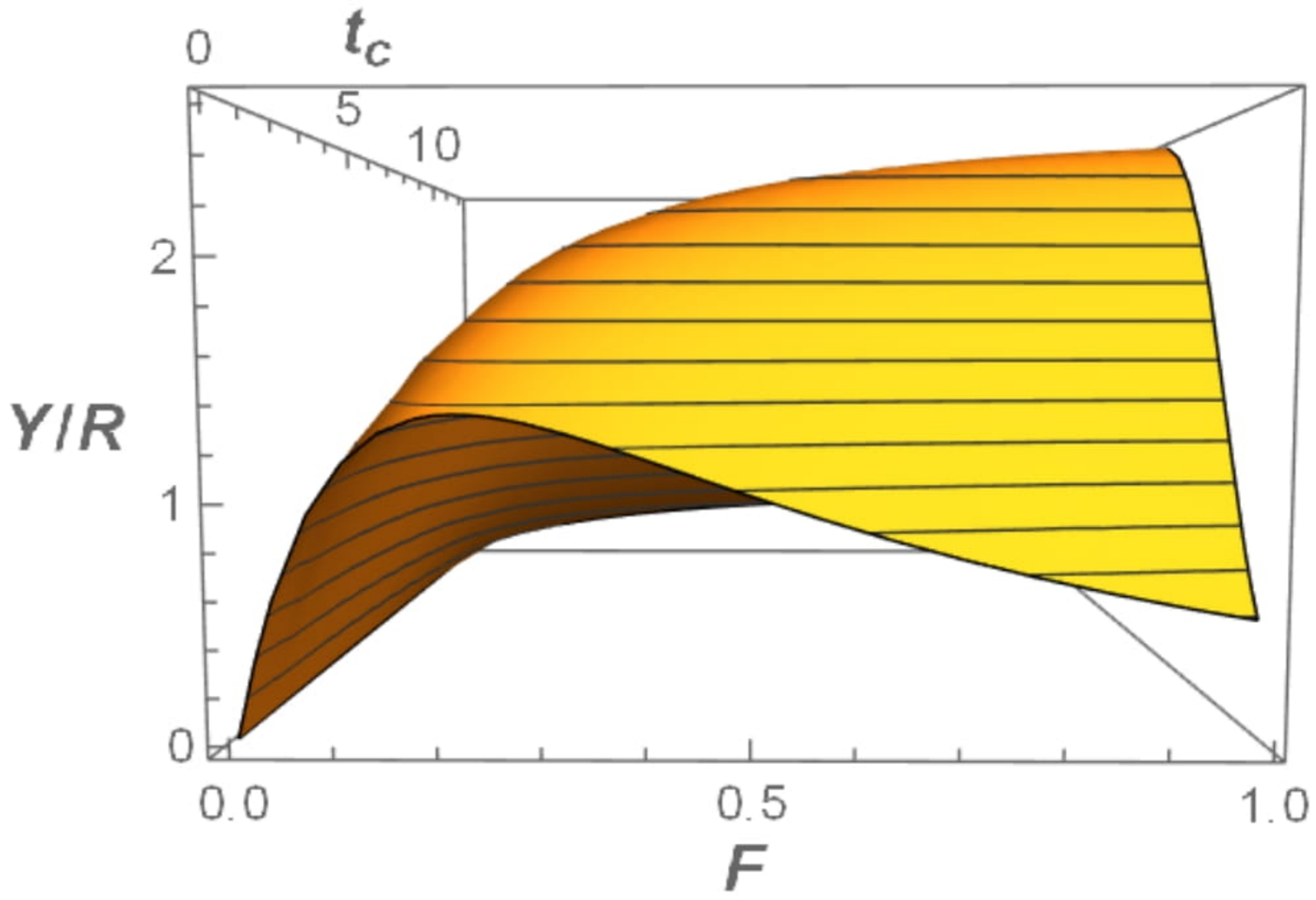

Fig. 25 ***Yield per recruit curves with different ages of first capture (T_c) - 2,3,4.***

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 is assumed that the total allowable catch of turbot can reach **107** tons in the Bulgarian Black Sea, calculated on the basis of data from the autumn season of 2021, but it should be noted that the percentage distribution of sexually mature specimens (L > 45 cm) was 44.7% for the autumn season of 2021 and after recalculations based on this percentage, the total allowable catch should not exceed **65** tons.

Observed other particular problems

During the expedition activity, the dominant wind direction was - Northwest, West, and North by force between 1-2º BF - along the coast and 2-4º BF - at sea.

In the autumn-winter season of 2021, the conditions in the field were normal for conducting the research activities for turbot stock assessment in the Bulgarian Black Sea waters.

6. Conclusions and recommendations

By the collected information and obtained results from the trawl survey in December 2021, the following conclusions and recommendations can be made:

- The **turbot biomass** in the Bulgarian Black Sea waters was assessed at **2,140.105 tons** and the **turbot abundance** was estimated at **1,267.936 individuals**.
- The recommended **MSY (maximum sustainable yield)** for Bulgaria should not exceed **107 t.,** and it is assumed that the total allowable catch (TAC) of turbot in the Bulgarian Black Sea waters could comprise **65 tons** as a relatively acceptable quantity.
- **The size structure** of the turbot population in the Bulgarian Black Sea zone included length classes from **18 cm to 73 cm**, with a weight between **140 g and 7150 g**. The average turbot weight was estimated as **1,687.87** g. In the turbot length structure, the undersized individuals, with length < 45 cm, formed 55.34% from the total number, while those of standard length made up 44.7%.
- **The age composition** of the population included age classes from **1 to 11- years** of age, with the domination of the 2 (52.57%), 4 (12.65%) and 5 (16.60 %) year classes (81.82% total), followed by 6 - year specimens – 7.51%.
- The **established ratio between female, male and sexually immature** individuals in the yield were **26.5%:18.2%:55.34%.**
- Of the studied 83 turbot specimens, food components were found in 55 %, and empty stomachs were found in 45 %. The average stomach fullness index (SFI) was 0.48 % BW ± 0.09. The analysis of the spatial distribution of the SFI indicated high values in the central part along the Bulgarian Black Sea coast. The turbot food spectrum was formed mainly by fish, Engraulis encrasicolus, IRI = 1742,22 (32.11 %) and Merlangius

merlangus, IRI = 1157,79 (21,34 % IRI), and we found a high proportion of the unidentified food remains (IRI = 2468.39, 45.50%).

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