REPORT

Bottom trawl survey and stock assessment of target species - turbot, spiny dogfish and whiting, and bycatch of thornback ray and other accompanying species of the Bulgarian Black Sea coast during the spring-summer season of 2024.

Agricultural Academy
Institute of Fish Resources (IFR, Varna)

2024

Co-funded by the European Union

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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 № 146/10.03.2023 with the Executive Agency for Fisheries and Aquaculture (EAFA), for turbot stock assessment in the Bulgarian Black Sea waters during the spring-summer period of 2024.

This study was carried out with the financial support of the European Commission in accordance with the Delegated Decision (EU) 2021/1167 of the Commission on April 27, 2021, to approve the multiannual program of the Union for the collection and management of biological, ecological, technical, and socio-economic data in the fisheries and aquaculture sectors from 2022 onwards, and Commission Implementing Decision (EU) 2021/1168 of April 27, 2021, approving the list of mandatory scientific research in the high seas and threshold values under the multiannual Union program for data collection and management in the fisheries and aquaculture sectors from 2022 onwards.

The study was performed in the period 14 - 30 May 2024 in the Bulgarian Black Sea waters on board of the “EGEO 2” fishing vessel.

The reference species in the study were turbot, spiny dogfish, and whiting, and information was collected from the bycatch species.

Scientific research team from IFR Varna

Team leader: Assoc. Prof. Elitsa Petrova - Pavlova, PhD

Participants:

Assoc. Prof. Stoyko Stoykov, PhD

Assoc. Prof. Vesselina Mihneva, PhD

Biologist Stanimir Valchev

Biologist Aysel Hyusein

Assistant Krasimir Georgiev

Chief Assistant, Philip Penchev, PhD

Chief Assistant, Feriha Tserkova, PhD

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BOTTOM TRAWL SUREVY FOR STOCK ASSESSMENT OF REFERENCE BOTTOM SPECIES IN BULGARIAN BLACK SEA SECTOR DURING SPRING-SUMMER SEASON OF 2024

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LIST OF *FIGURES IN THE TEXT*

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BOTTOM TRAWL SURVEY FOR REFERENCE STOCK ASSESSMENT IN BULGARIAN BLACK SEA SECTOR DURING SPRING SUMMER SEASON OF 2024

1. Results from the National Bottom Trawl Surveys in V 2024

During 14 - 30 May 2024**,** under contract number 146/10.03.2023 with the EAFA, in the framework of the National Program for Fisheries Data Collection, the research team from IFR - Varna has conducted a demersal trawl survey with the fishing ship "EGEO 2" in the Bulgarian Black Sea waters. The survey covered the zone between Durankulak and Ahtopol and included an area within 100 m of the shoreline.

The field survey included the following main activities:

- Data on the depth and geographic coordinates of the start and end points of the trawling were collected.
- Bottom trawl sampling;
- Qualitative and quantitative analyses of catches, identification of biological diversity, and biometric measurement
- Collection of otoliths for age determination
- Sampling and analysis of stomach contents were performed to identify the quantity and composition of consumed food.

This report is based on collected field data and laboratory analyses that established the distribution and magnitude of the relative biomass and abundance of the target species. Analyses performed in relation to turbot included the assessment of biomass and abundance of this target species by depth strata and the study of the size, age, and sex structure of the stock. Calculations of linear-weight dependences and parameters in the von Bertalanffy equation and identification of the peculiarities of turbot nutrition. Analyses of *Merlangius merlangus* included the study of the

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size-age and sex structure, calculation of length-weight dependences, and parameters in the von Bertalanffy equation and food spectrum. All applicable biological indicators were determined for all specimens of *S. acanthias* caught. The stock assessment of the target species was based on the application of standard methodology (methodology and software products) used in previous trawl surveys of these species in the Black Sea.

The report contains a series of tables and figures that present the distribution of current biomass and numbers, as well as the size, age, and sex structure of the population of the target species, as well as data on bycatch species in the study area.

1.1. Fishing vessel and fishing gear

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

- Fishing vessel length -19.5 m;
- Maximum width – 5.9 m;
- Fishing vessel year of built in 2005
- Engine power – 367.75 kW;
- Maximum tonnage – 38.24t;
- Net tonnage – 11.43 t;
- Speed – 9.5 Nd;
- Crew - 3 people;
- Research team: Three people.

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Picture 1. *Fishing ship*

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 the headrope - 13 m;
- Effective part of the footrope - 15 m;
- Trawling speed - 2.2 - 2.6 Nd;
- Trawling duration - 60 min.;
- Mesh size - 80/80 mm;

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

2. Material and methods

The reference species of the demersal survey was turbot (*Scophthalmus maximus*), spiny dogfish (*Squalus acanthias*), whiting (*Merlangius merlangus*) and bycatch from the thornback ray (*Raja clavata*) were also measured and analysed.

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

Field data were collected using standard techniques (bottom trawl) and were kept constant throughout the survey. The GPS system of the ship was connected to the EAFA satellite system to monitor fishing vessels (VMS), and the ship location was strictly controlled during trawling.

A standard methodology for data analysis was applied “swept area”, and the obtained results can be reproduced and compared.

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Stratified sampling

By sampling individual "strata" the population was divided into geographic regions to spread the monitoring effort evenly across space. Prior information about variable variations was used to improve the efficiency of the survey in estimating mean values and variance. For this purpose, in stratified sampling (of one species), each sample consisted of 50 fish (large fish) and up to 100 fish (small fish) for reliable statistical analysis.

2.1 Information collected through the bottom trawling

- Depth measured with an echo-sounder;
- GPS coordinates of the starting and end points of trawling;
- Trawling duration;
- Abundance of fish species in trawls;
- Weight of total catch in the trawl;
- Absolute and standard length; weight of collected specimens;
- Collection of otoliths for age determination;
- Sex identification;
- Bycatch species composition;
- Stomachs for stomach content analysis of the reference species;
- Measurement of small turbot specimens;

Individuals with an absolute length below the minimum allowed by the ZRA (< 45 cm) are immediately returned to the sea after the measurements.

For biomass calculations of the reference species, 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 the following data.

- Survey area (km2);

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- Catch per unit effort (kg/trawl)
- Catch per unit area (t/km^2, kg/km^2);
- Abundance index (individual/km^2);
- Limits of variation in the CPUA
- Total biomass in the entire studied area in front of the Bulgarian coast (t.);
- Abundance in the entire studied area in front of the Bulgarian coast (ind);

2.2. Sampling scheme

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

The surveyed region was divided into four strata depending on depth: stratum 1 (15–35 m), stratum 2 (35–50 m), stratum 3 (50–75 m), and stratum 4 (75–100 m). To assess turbot abundance and biomass, the surveyed territory was divided into 143 squares, each with 5 × 5 Nm sides and an area of 25 Nm^2 (or 85.8569 m^2). Sampling was carried out in 40 randomly chosen fields (rectangles), situated at depth between 15-100 m. Each rectangle had sides of 5'Lat × 5'Long, and the total area was 62.58 km^2 (measured by GIS). Each field was marked with letters and digits for better distinction.

The duration of each haul was 60 min. at a trawling speed of 2.5 knots.

On the shipboard, the absolute and standard lengths, as well as the individual weight of each specimen from the reference species, were measured to determine the size and weight structure of the stocks.

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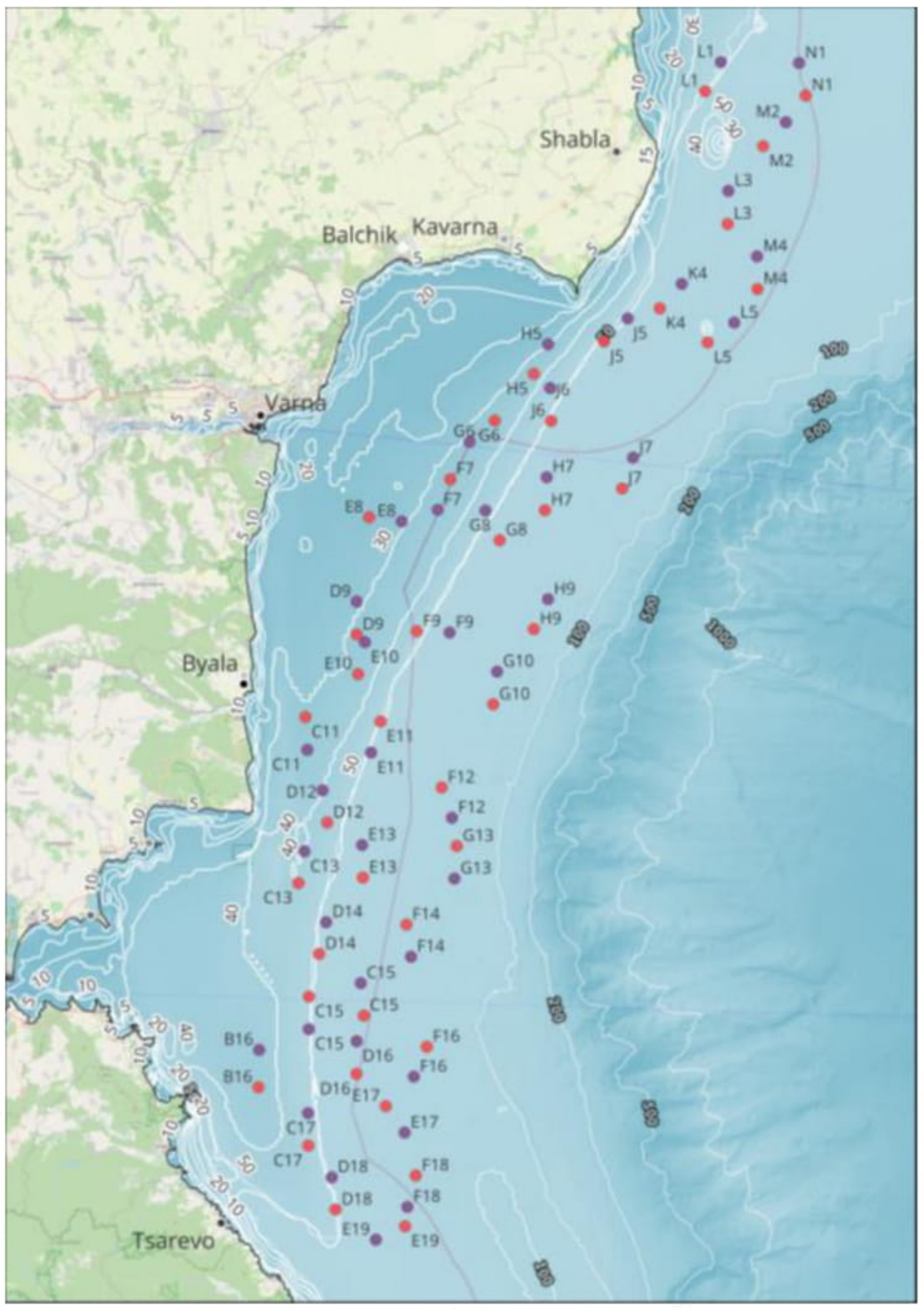

Figure 1 *Map of the surveyed sectors.*

2.3. Laboratory analyses

After collecting samples onboard, the ship, age, degree of sexual maturity, and nutritional spectrum of the target species were determined under laboratory conditions. The ages of the turbot and whiting were determined from otoliths using a binocular microscope. To determine the size-weight structure of the catches, the average, minimum, and maximum lengths and weights of

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individuals of both sexes were calculated, and the percentage distribution by size class (TL, cm) was determined.

During the spring-summer season of 2024, 87 stomachs were analyzed to determine the food spectrum of turbot, and a total of 140 stomachs from additional species - *Squalus acanthias*, *Raja clavata* and *Merlangus merlangus*. Stomach content analysis included the identification of the taxonomic composition and total number of food components, weight, and frequency of occurrence of each food component. Index of stomach fullness (ISF) as a percentage of body mass: (weight of stomach contents/weight of fish body) × 100 (Pinkas et.al., 1971).

IRI, expressed as a percentage, was calculated using the following 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

Index of relative importance (IRI; Pinkas et al., 1971): IRI = (CN + CB) * FO, where CN is the proportion of the taxon (species) of the prey in the food by number, CB is the proportion of the taxon (species) of the prey in the food by biomass, and FO is the frequency of occurrence of the taxon (species).

2.4. Statistical methods

Swept areas method

To determine the relative biomass of the reference species, the swept area method was applied using the BioIndex program : R code to perform bottom trawl data analysis using the MEDITS file format (TA,TB and TC), which enables the calculation of standardized biomass and abundance and length frequency distributions, sex ratio by size class and many other useful results such as: quality checks, trawl positions, period, etc.

(https://data.europa.eu/doi/10.2760/5799,
https://cran.r-project.org/web/packages/MEDITS/MEDITS.pdf)

The swept area is computed according to a simple formula: in the TA file are stored distance covered and net wing opening, so it is only a matter to run sqkm=TAn$wing_opening/10000000*TAn$distance assignment of each haul to one of the five stratification MEDITS depth strata is performed according to the haul mean depth =(TAn$shooting_depth+TAn$hauling_depth)/2.

https://data.europa.eu/doi/10.2760/5799,

Biomass and abundance indices (kg/km^2, n/km^2)

To estimate the mean, variance, standard deviation, and coefficient of variation of the abundance indices in number and weight by square kilometer using stratified random sampling, the following formulations were used (Cochran 1977; Souplet 1996):

Average by strata:

$$\overline{x}_i = \frac{\sum_{j=1}^{n_i} x_{i,j}}{\sum_{j=1}^{n_i} A_{i,j}}$$

xi, j is the weight of individuals caught in the individual hauls of the stratum and Ai, j is the corresponding swept area. Variance was calculated using the following formula:

$$S_{x_i}{}^2 = \frac{1}{n_i - 1} \sum_{j=1}^{n_i} A_{i,j} \left(\frac{x_{i,j}}{A_{i,j}} - \overline{x}_i \right)^2$$

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The abundance index of the main strata (shelf, slope, and total) was computed using the following formula (Souplet, 1996):

$$I = \sum_{i=1}^{N} Wi\,\bar{X}i$$

Wi is the weight of each individual stratum, calculated as the ratio between the area of the stratum and total area of the study area. The variance in this case is given by the following formula:

$$\mathrm{var}(I) = \sum_{i=1}^{N} \frac{W_i^2 S_{x_i}^{\ 2}}{\sum_{j=1}^{n_i} A_{i,j}} (1 - f_i)$$

where fi is the ratio between the swept area and the area of the stratum, that is, the correction factor for finite populations (fpc).

Standard deviation is:

$$\text{s.d.} = \sqrt[2]{Var(I)}$$

and the Coefficient of Variation is.

$$CV\% = (\text{s.d.}/I) * 100$$

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The catch per unit effort (CPUE) was calculated by dividing the trawl catch by the fishing hours (kilograms/h):

$$CPUE = yield/effort$$

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.

TAC - total allowable catch, Prediction models

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

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

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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.

The formulae of ***Pauly (1983)*** were used to evaluate the exploitation ratio: E = F/Z, E = exploitation ratio, F = fishing mortality, and 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

To estimate the turbot growth rate, the von Bertalanffy growth function (1938) was applied according to Sparre and 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 was obtained using the following equation:

$$W_t = qL_t^n$$

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

Fulton's coefficient - K (Nash et al. 2006) is calculated using the measured weight and length of the respective specimens: $K = 100*(W/L^3)$, where: W - weight, L - length.

Natural mortality (M)

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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; T°C - the annual average temperature of the seawater in the horizons of habitation and reproduction of the species.

***Method of Richter & 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.

3. Results

3.1. Population number and biomass

During the demersal trawl survey in V 2024, the following activities were conducted:

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

For each haul, qualitative and quantitative analyses of the catch were performed, including biometric measurements of 169 specimens of turbot, 94 european flounder, 63 thornback ray and 116 spiny dogfish specimens (Pictures 4 and 5);

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Pictures 3. *Bottom trawling yield*

The constant presence of *S. maximus species was found* in almost all bottoms trawls at a depth of 75-100 m., when catching - at least 2-5 specimens of trawls were found (when fishing ≠ 0). At depths of 15 to 50 meters, the average recorded catch is low, and at 50-75 meters, the average catch of turbot is increasing. In the four sectors, the highest catch was obtained, which ranges between 16.5-28.66 kg / trawl.

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Pictures 4. *Catch of turbot (Scophthalmus maximus) and accompanying species - Merlangius merlangus (whiting), Gobiidae, Raja clavata (thornback ray) and spiny dogfish (Squalus acanthias);*

During the study, 116 specimens of the spiny dogfish (*Squalus acanthias*) were caught and measured. Their size ranged from 39 cm (0.210 kg) to 145 cm (14.1 kg) (Photo 4). Additionally, a relatively high number of whiting (*Merlangius merlangus euxinus*) and *Raja clavata* were caught. Other related species included the Gobiidae, scorpion fish (*Scorpaena porcus*), European flounder (*Platichthys flesus*), and red mullet (*Mullus barbatus*).

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Pictures 5. *Performing biometric measurements and collecting samples for research of stomach contents.*

Comments on the biomass of Scophthalmus maximus in the Bulgarian waters by strata

Trawling at a depth of up to 30 m covered only three stations, and because of their small number, they were grouped together with the stations preformed up to 50 m; thus, statistical analysis was conducted for stratum 15–50 m. The biomass of the three shallow stations (at a depth < 30 m) reached respectively - 8 kg/km^2, 24 kg/km^2 и 64 kg/km^2, with abundance - 16 ind/km^2, 17 ind/km^2 and 33 ind/km^2. High catches on small stations depth are realized in front of Balchik and Kavarna (Table 1, Fig. 2).

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The average relative biomass is higher in the stratum at 75-100 - 211 kg/km^2, with an average abundance of 114 ind/km^2. In the 50-75 m stratum, the average relative biomass is lower at 131 kg/km^2, with an average abundance of 70 ind/km^2 (refer to Table 1, Fig. 2, and Fig. 3).

Information on the yields by stratum is provided below.

Stratum 15-50 m

In this stratum, the average relative biomass value ranges from 8-219 kg/km^2, with an average of 79 kg/km^2 (Tab. 1, Figs. 2 and 3). Their abundance varies between 16 and 166 individuals/km^2, with an average – of 49 specimens/km^2 (Tab.2).

Stratum 50 -75 m

The average value of relative biomass per year in this stratum is growing and is 0.00 and 295 kg /km^2, with an average of 131 kg/km^2 (Tab. 1, Figs. 2 and 3). Abundance has values between 0 and 201 ind/km^2, with an average of 70 ind/km^2 (Tab.2).

Stratum 75-100 m

In this stratum, the average value of relative biomass has high values and ranges between-84-470 kg/km^2, with an average of-211 kg/km^2 (Tab. 1, Figs. 2 and 3), and the average cost of abundance is 114 ind./ km^2 (Tabs.2).

Table 1

Relative biomass of turbot (kg/km2) by stratum, May 2024.

15 - 50 м		50 – 75 м		75-100 м	
No. station	kg/км^2	No. station	kg/км^2	No. station	kg/км^2
1	64	32	32	21	84
4	8	10	165	30	147
33	24	26	295	20	84
3	13	8	0	38	470
5	31	17	113	39	272
2	16	28	128	35	321
6	125	27	158	23	138
14	49	40	57	22	176
7	151	12	135		
9	43	11	224		
34	41	36	132		
37	123	31	139		
15	144	18	148		
13	104	29	197		
25	219	19	48		
16	145				
24	44				
Total	1345	Total	1969	Total	1692
Average	79	Average	131	Average	211
Standard error	15		20		47
Median	49		135		161
Standard deviation	62		76		134
Sample variance	3876		5852		17986

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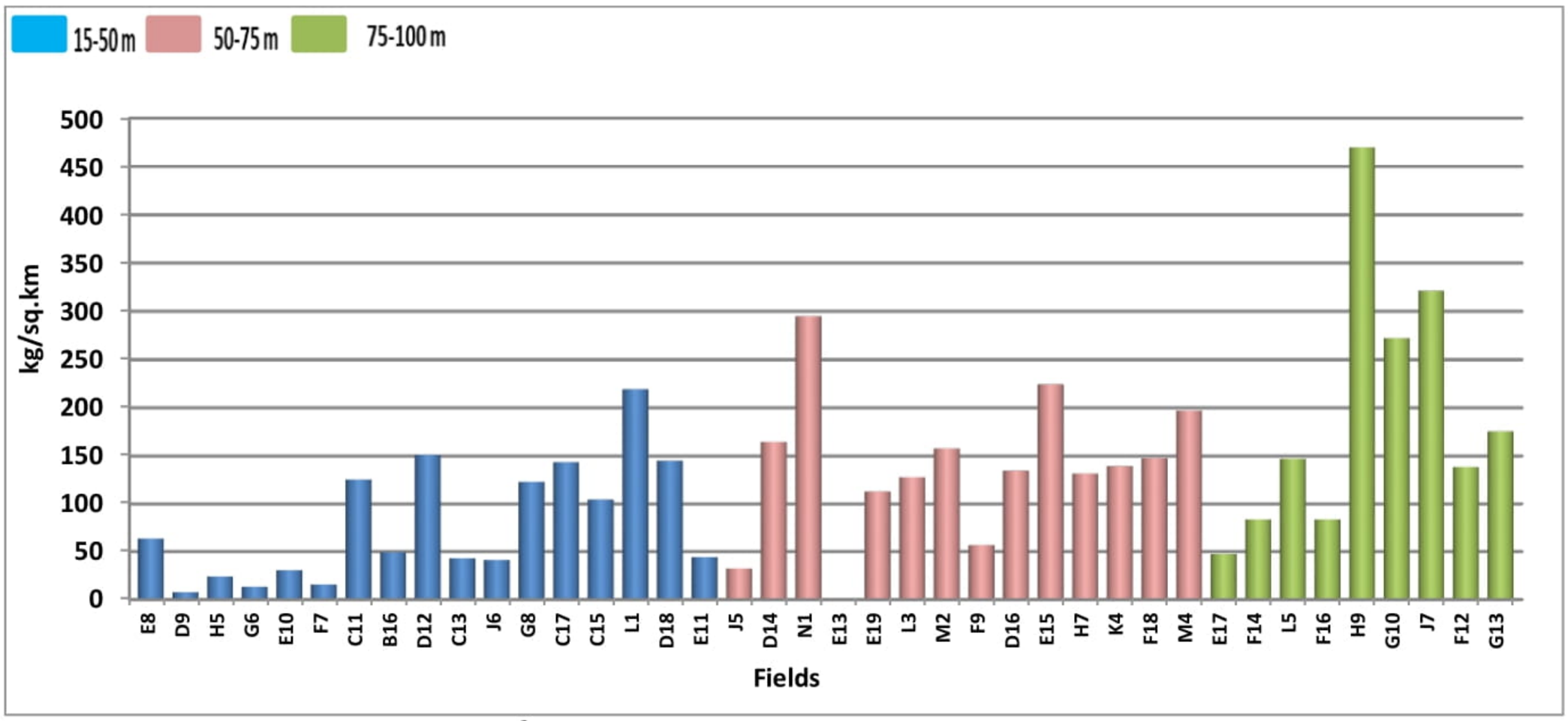

Figure 2 *Relative biomass (kg/km^2) of S. maximus by strata off the Bulgarian Black Sea coast, V 2024*

Table 2 presents detailed data on turbot abundance by strata in May 2024.

Table 2

Abundance of *S. maximus* by stratum in May 2024.

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	33	32	17	21	33
4	16	10	99	30	82
33	17	26	99	20	50
3	17	8	0	38	295
5	17	17	67	39	132
2	16	28	66	35	149
6	115	27	83	23	68
14	72	40	17	22	99
7	166	12	115		
9	50	11	83		
34	33	36	49		

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37	50	31	50		
15	50	18	82		
13	50	29	201		
25	50	19	17		
16	50				
24	33				
Total	834	Total	1044	Total	908
Average	49	Average	70	Average	114
Median	10		13		29
Standard error	50		67		91
Standard deviation	39		50		83
Sample variance	1540		2544		6915

3.2. Catch per unit effort (CPUE)

The catches, from a total of 40 trawls, are distributed as follows:

- 14 trawls (35 %), catch 0-4.99 kg on a trawl;
- 18 trawls (45%), catch 5.0-9.99 kg on a trawl;
- 8 trawls (20%), catch 10.0-28.66 kg on a trawl;

Stratum < 30 m; 3 trawls:

- 3 trawls, catch 0.5-9.99 kg.

Stratum 31-50 m; 14 trawls:

- 7 trawls, catch-0.1-4.99 kg on trawl;
- 6 trawls, catch-5.0-10.0 kg on trawl;
- 1 trawl, catch-10.0-15.0 kg on trawl;

Stratum 50-75 m; 15 trawls:

- 4 trawls, catch 0-4.99 kg on trawl;

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- 8 trawls, catch 5.0-9.99 kg on trawl;
- 3 trawls, catch 10.0-15.99 kg on trawl;

Stratum 75-100 m; 8 trawls:

- 4 trawls, catch 5.0-9.99 kg on trawl;
- 4 trawls, catch 10.0-28.66 kg on trawl;

The data on catch per unit effort (CPUE) during the expedition in V/2024 were presented in Table 3 and Fig.3.

Table 3

The sampling stations, coordinates and CPUE (kg/trawl) in May 2024

№	Field	Starting coordinates		Depth (m)	Speed (Nm)	Trawling time (min)	Catch turbot	
		ϕ	λ				№	Kg
1	E8	4304.31	2809.615	24.5	2.5	60	2	3.84
2	F7	4305.2	2813.38	34.5	2.5	60	1	0.95
3	G6	4310.4	2816.71	33	2.5	60	1	0.81
4	D9	4258.177	2804.91	29	2.5	60	1	0.46
5	E10	4255.065	2805.765	34	2.5	60	1	1.85
6	C11	4246.797	2759.746	34.5	2.5	60	7	7.61
7	D12	4243.68	2801.343	40	2.5	60	10	9.12
8	E13	4239.466	2805.468	56.5	2.5	60	0	0
9	C13	4238.98	2759.435	41	2.5	60	3	2.58
10	D14	4233.514	2801.71	52.5	2.5	60	6	9.94
11	E15	4228.815	2805.333	66	2.5	60	5	13.58
12	D16	4224.323	2804.9	65	2.5	60	7	8.19
13	C15	4225.255	2759.9	48.5	2.5	60	3	6.32
14	B16	4223.646	2754.7	37.5	2.5	60	5	3.44
15	C17	4218.75	2759.81	47.5	2.5	60	3	8.68
16	D18	4213.78	2802.3	51	2.5	60	3	8.77
17	E19	4208.93	2806.91	59	2.5	60	4	6.78
18	F18	4211.48	2810.2	72.5	2.5	60	5	8.98

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19	E17	4217.25	2809.92	78.5	2.5	60	1	2.87
20	F16	4221.58	2810.88	82	2.5	60	3	5.06
21	F14	4230.85	2810.59	79	2.5	60	2	5.03
22	G13	4236.88	2815.13	86.5	2.5	60	6	10.62
23	F12	4241.565	2814.865	86	2.5	60	4	8.2
24	E11	4246.58	2806.41	51.5	2.5	60	2	2.66
25	L1	4339.3	2843	50.5	2.5	60	3	13.22
26	N1	4339.23	2851.18	56	2.5	60	6	17.84
27	M2	4334.74	2849.81	63	2.5	60	5	9.53
28	L3	4329.523	2843.778	62	2.5	60	4	7.72
29	M4	4324.54	2846.78	75	2.5	60	12	11.79
30	L5	4319.5	2844.4	79.5	2.5	60	5	8.95
31	K4	4322.447	2838.915	67.5	2.5	60	3	8.39
32	J5	4319.82	2833.248	52	2.5	60	1	1.95
33	H5	4317.848	2824.924	30	2.5	60	1	1.45
34	J6	4314.5	2825.15	43.5	2.5	60	2	2.48
35	J7	4309.195	2833.81	85	2.5	60	9	19.37
36	H7	4307.689	2824.786	67	2.5	60	3	7.98
37	G8	4305.14	2818.38	46	2.5	60	3	7.42
38	H9	4258.356	2824.92	83	2.5	60	18	28.66
39	G10	4252.8	2819.59	84	2.5	60	8	16.5
40	F9	4255.8	2814.63	63	2.5	60	1	3.44

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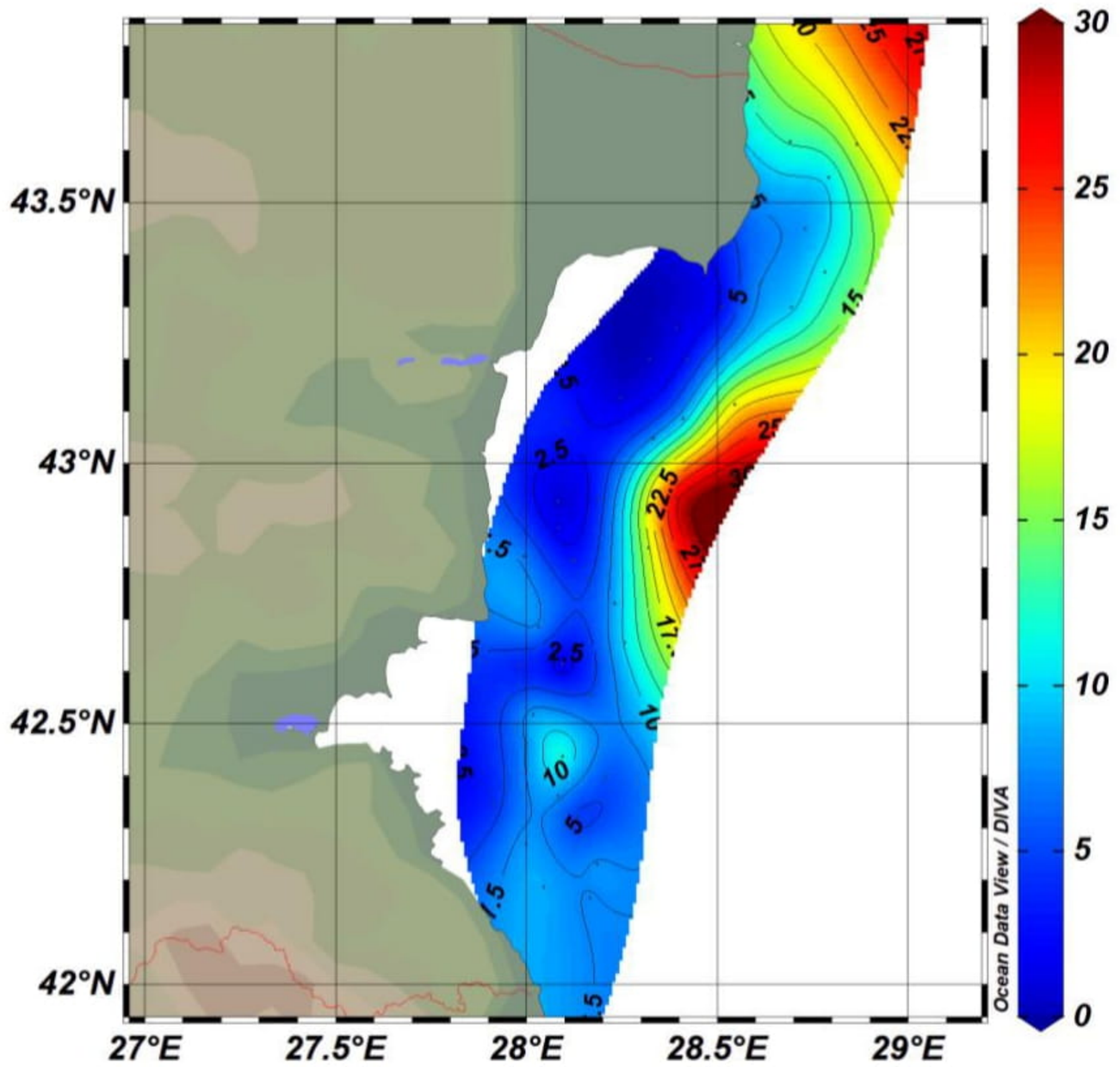

Figure 3 *Distribution of catch per unit effort (CPUE, kg/h).*

3.3. Catch per unit area (CPUA)

The results of processing the data on the abundance and biomass of turbot are presented in Table.4, Fig. 2, Fig. 4 and Fig. 5.

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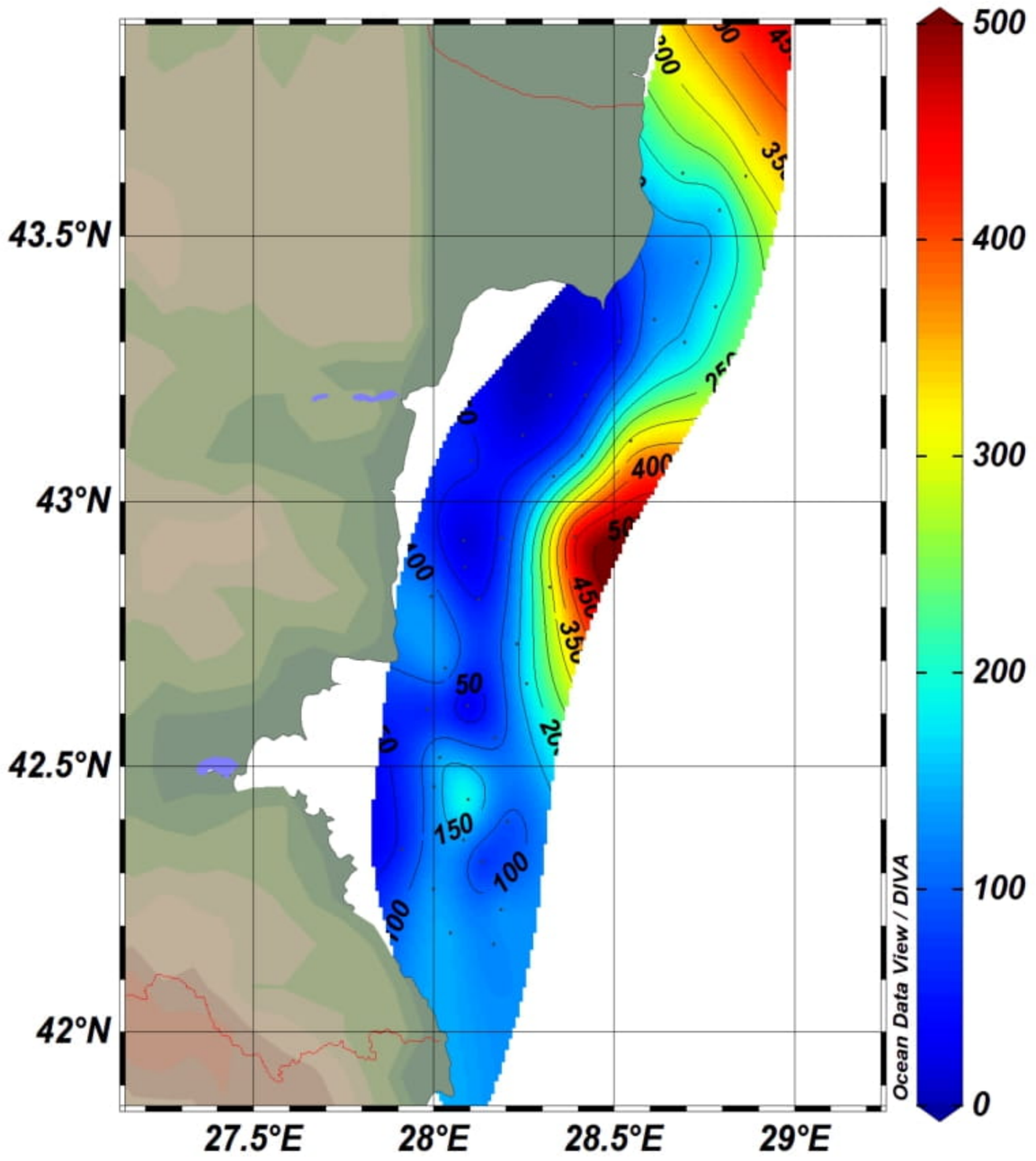

Figure 4 Distribution of the relative biomass (kg/km^2) of S. maximus in May, 2024.

In three fields in the Bulgarian Black Sea area, relatively high biomass levels were recorded, ranging from 295 - 470 kg/km^2. These levels were observed in the north-south direction, before Durankulak-Shabla (f.N1) at a depth of 56 - 63 m, in front of Varna at a depth of 85 - 86 m (f. J7), and at Bqla at a depth of 83 - 85m (H9) (Figs. 2 and 4).

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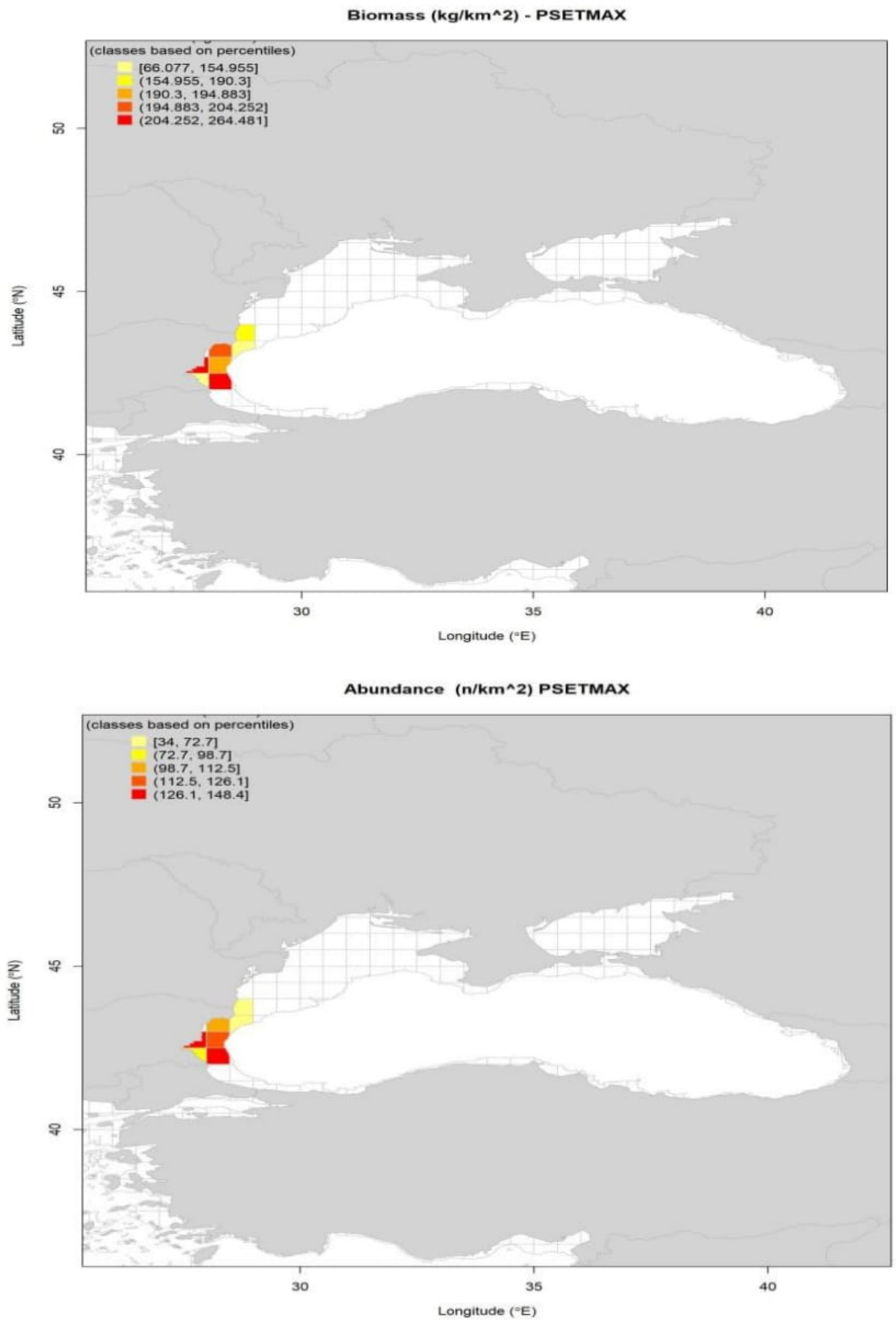

Figure 5 *Distribution of the relative mean biomass (kg / km2) and abundance (n / km2) of S. maximus in May 2024 using BioIndex version 3.3.*

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Table 4

A) Abundance and biomass per fields and B) standard deviations overall for all fields, of turbot in the Bulgarian waters area during May 2024.

A)

No. Station	*Field*	*t/km²*	*No. ind./km²*
1	E8	0.064	33
2	F7	0.016	16
3	G6	0.013	17
4	D9	0.008	16
5	E10	0.031	17
6	C11	0.125	115
7	D12	0.151	166
8	E13	0.000	0
9	C13	0.043	50
10	D14	0.165	99
11	E15	0.224	83
12	D16	0.135	115
13	C15	0.104	50
14	B16	0.049	72
15	C17	0.144	50
16	D18	0.145	50
17	E19	0.113	67
18	F18	0.148	82
19	E17	0.048	17
20	F16	0.084	50
21	F14	0.084	33
22	G13	0.176	99
23	F12	0.138	68
24	E11	0.044	33
25	L1	0.219	50
26	N1	0.295	99
27	M2	0.158	83

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28	L3	0.128	66
29	M4	0.197	201
30	L5	0.147	82
31	K4	0.139	50
32	J5	0.032	17
33	H5	0.024	17
34	J6	0.041	33
35	J7	0.321	149
36	H7	0.132	49
37	G8	0.123	50
38	H9	0.470	295
39	G10	0.272	132
40	F9	0.057	17
Total		**5.0064**	**2786**
Average		**0.1252**	**70**

B)

	t/км²	*№ ind./км²*
Standard error	0.015	9
Median	0.127	50
Standard deviation	0.097	58
Sampling dispersion	0.009	3366

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The turbot biomass in the entire studied area in front of the Bulgarian coast of the Black Sea was estimated at **1506.97** tonnes (Table 4). The abundance in the studied area was estimated at **840.44*10^3** specimens (Table 4).

3.4. Size structure

The information about the size structure of the turbot population was based on biometric measurements of 169 turbot specimens and included data on the absolute and standard length and individual weight (pic.5).

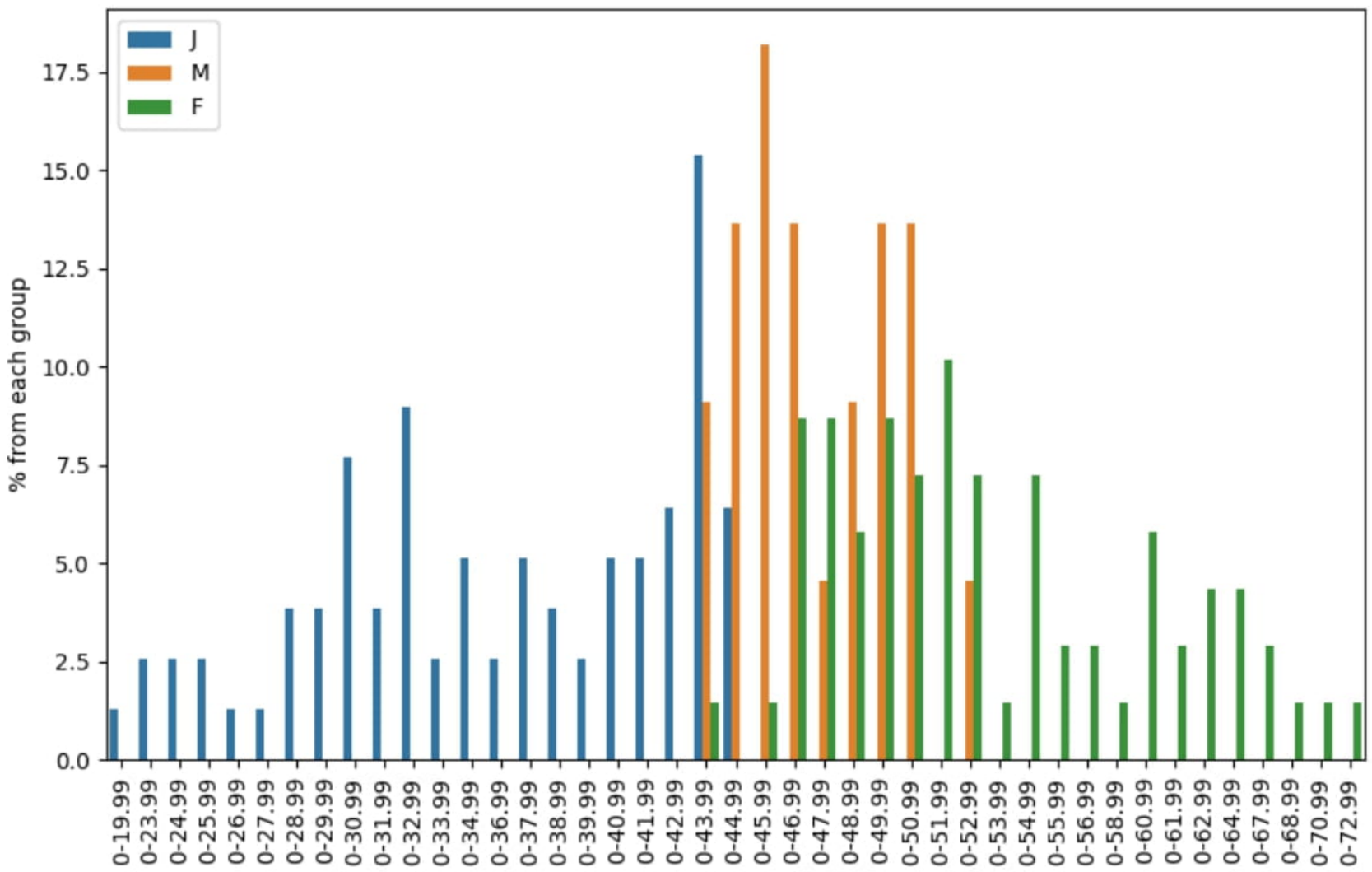

Figure 6 *Length structure of S. maximus caught by sex.*

The total length ranges from 19 to 72 cm, with a weight between 140 and 5970 g. The totals catch on the reaches 303.03 kg. Of the total number - 169, with 48 have sizes between 19.0 and 39.5 cm (28.40%), 36 specimens - between 40.00 and 44.55 cm (21.30%), 36 - in the range between 45 and 49.5 cm (21.30%), and 49 - in the range between 50.0 and 72.0 cm (28.99%).

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Specimens over 45.0 cm predominate in the total catch - 53.85% /91 individuals/, and, those below 45.0 cm are 78 / 46.15%/, female individuals dominate 40.83 % /69 specimens/ over males 13.02 % /22 individuals/.

The size structure was analyzed in compliance with national regulations, setting out the minimum permissible length of individuals for fishing purposes. Thus, individuals with an absolute length < 45 cm were marked as undersized, and those with a length > 45 cm were marked as the standard.

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

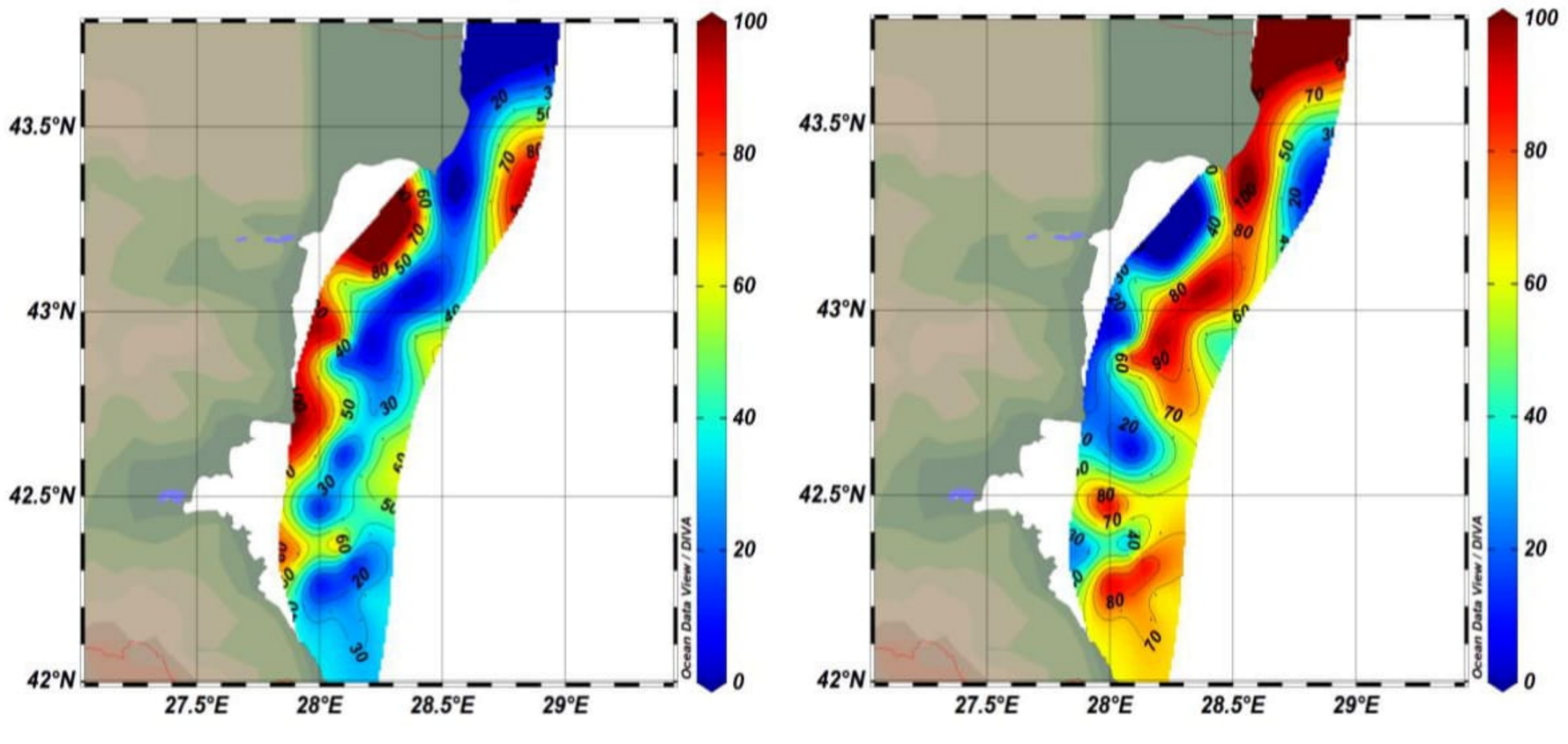

Figure 7 *Percentage distribution of the S. maximus abundance (ind/km^2), a) undersized individuals and b) standard length.*

The relative turbot biomass by size class is shown in Fig. 8, indicating high biomass for two length classes - those 43-44 cm and 46-52 cm.

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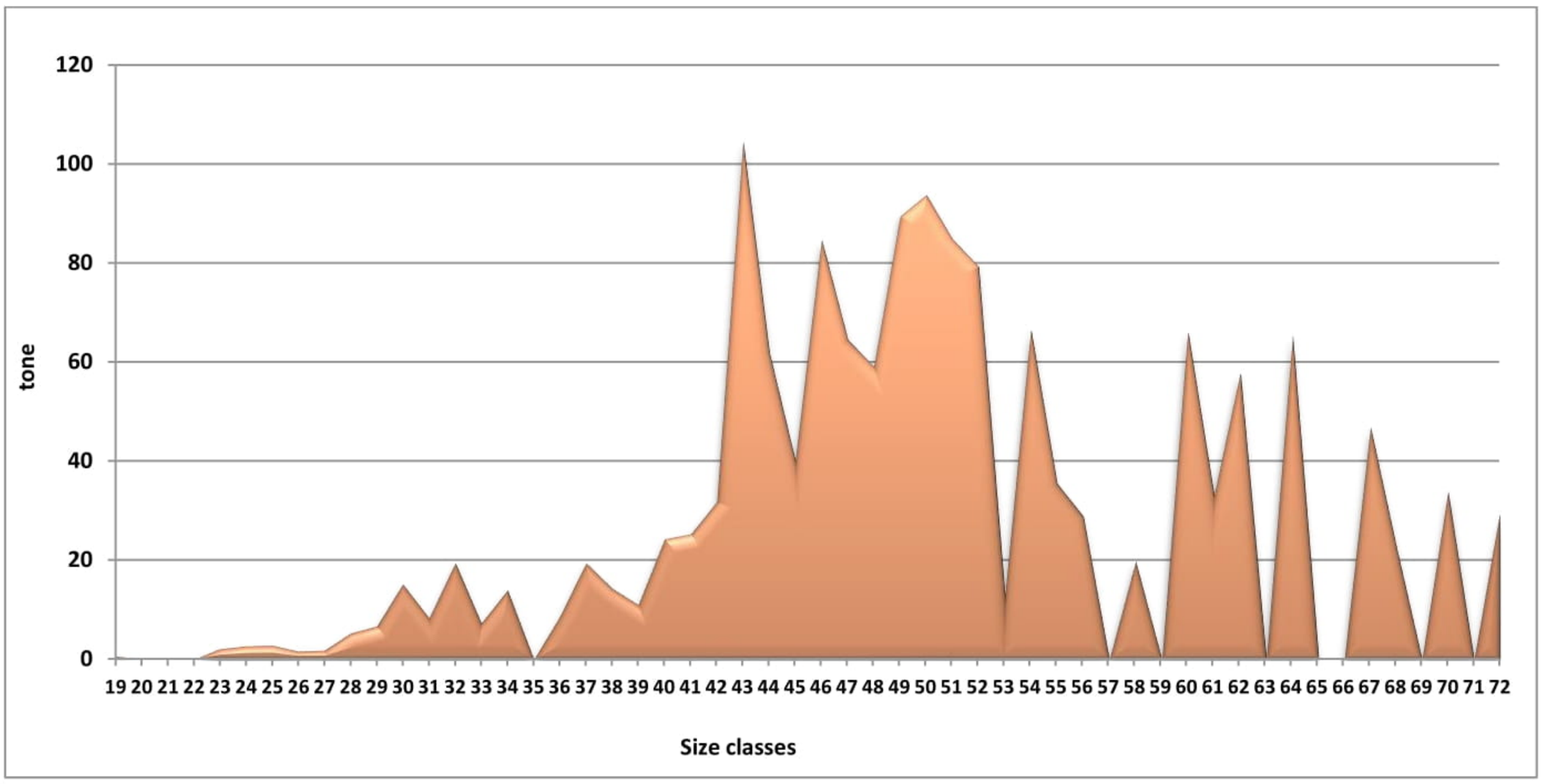

Figure 8 *Biomass by mean size classes of S. maximus.*

3.5. Age structure

The age composition of the turbot was established through the analysis of 91 pairs of otoliths. The age structure of the turbot encompasses specimens ranging from 1 to 10 years old, with a predominance of 2 (27.81%), 3 (19.53%), and 4 (21.89%) year-olds, collectively accounting for 69.23%. This is followed by 5-year-old specimens, which represent 15.98% (fig. 9).

During the spring-summer season of 2024, specimens exceeding 45 cm (53.85%) are more prevalent than those measuring under 45 cm (46.15%).

Specimens aged 8, 9, and 10 years are recorded in the catches.

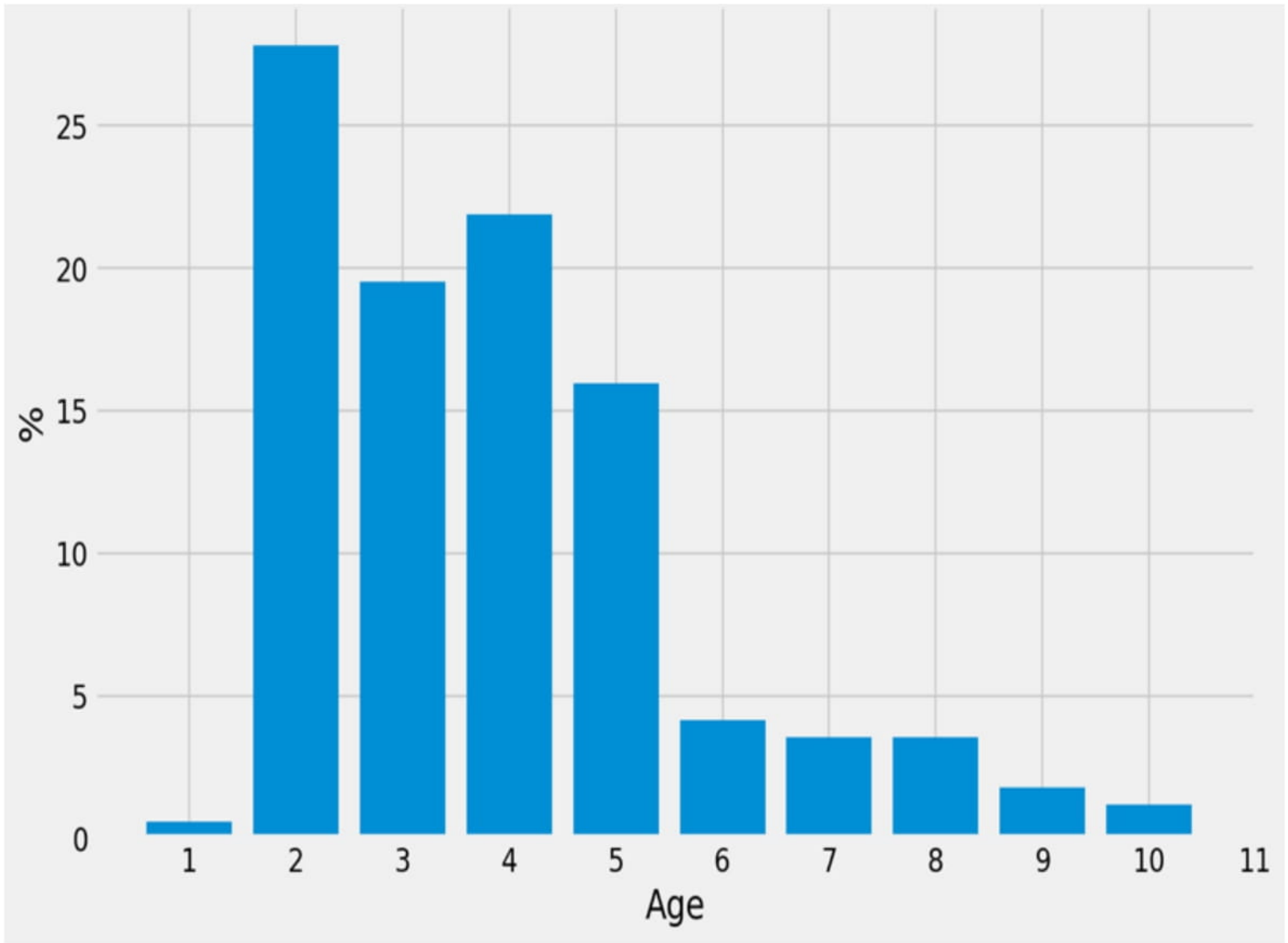

Figure 9 *Age structure of turbot in May, 2024.*

The spatial distribution of *S. maximus* according to the age class in the surveyed area is shown in Fig.10.

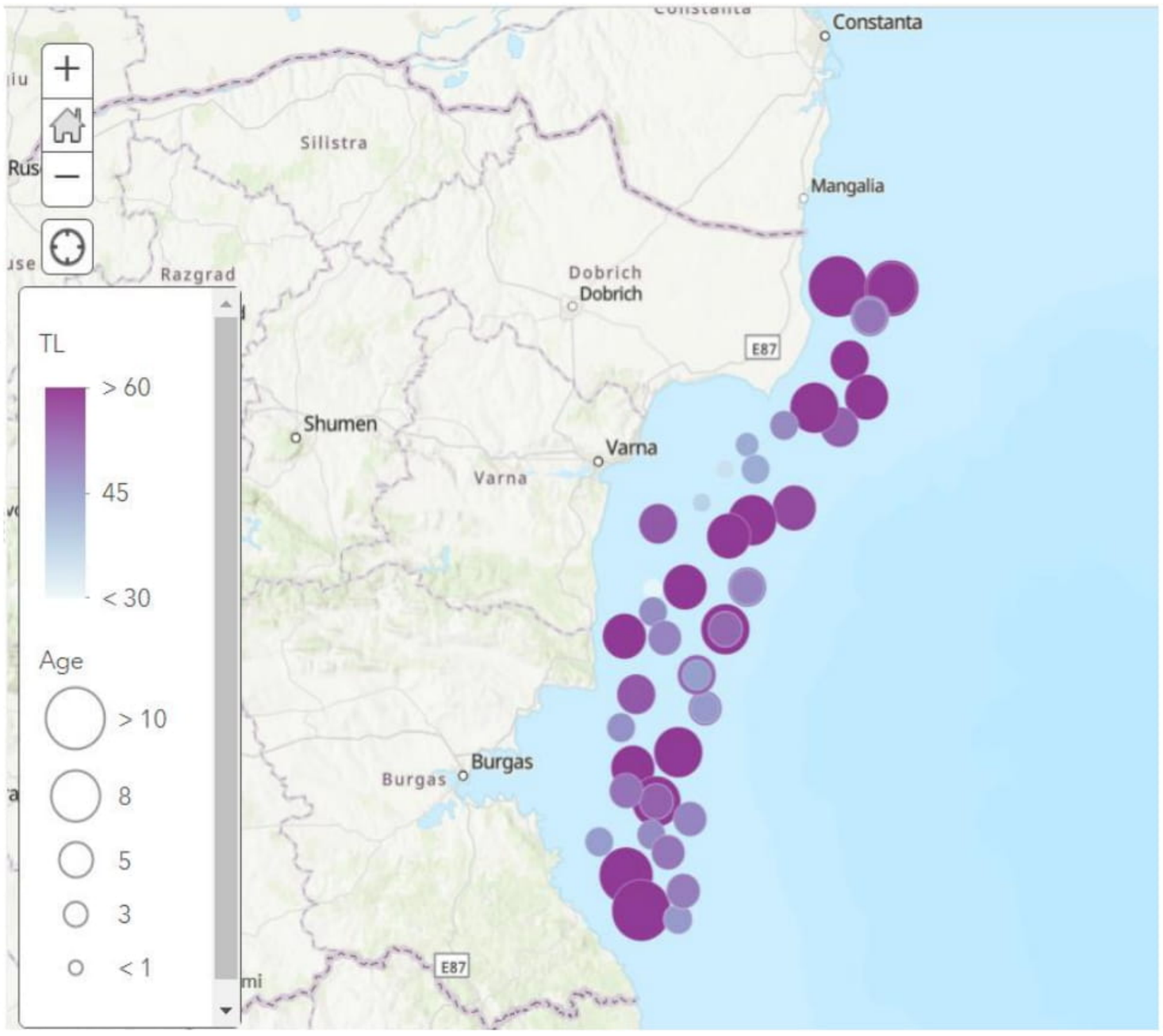

Figure 10 Spatial distribution by ages and lengths of S. maximus.

3.6. Biological parameters of *S. maximus*

To establish the rate of turbot growth in the Bulgarian waters of the Black Sea during the spring-summer season of 2024, data on the absolute lengths and weights of all measured specimens were analyzed. The von Bertalanffy growth equations were derived from the absolute length-at-age data, which included both sexes, undersized individuals, and combined samples. The parameters k, L∞, and t0 were estimated (see Table 5). The values of these parameters in the von Bertalanffy equation were computed as follows:

Table 5

Von Bertalanffy parameters and L-W dependence.

sex	Linf (mm)	k	t0	a	b
F	738.3596	0.2291	-0.4781	0.000153	2.66
M	535.8154	0.5868	0.4588	0.000010827	3.08
C	749.4873	0.2139	-0.6125	0.0239	2.92

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

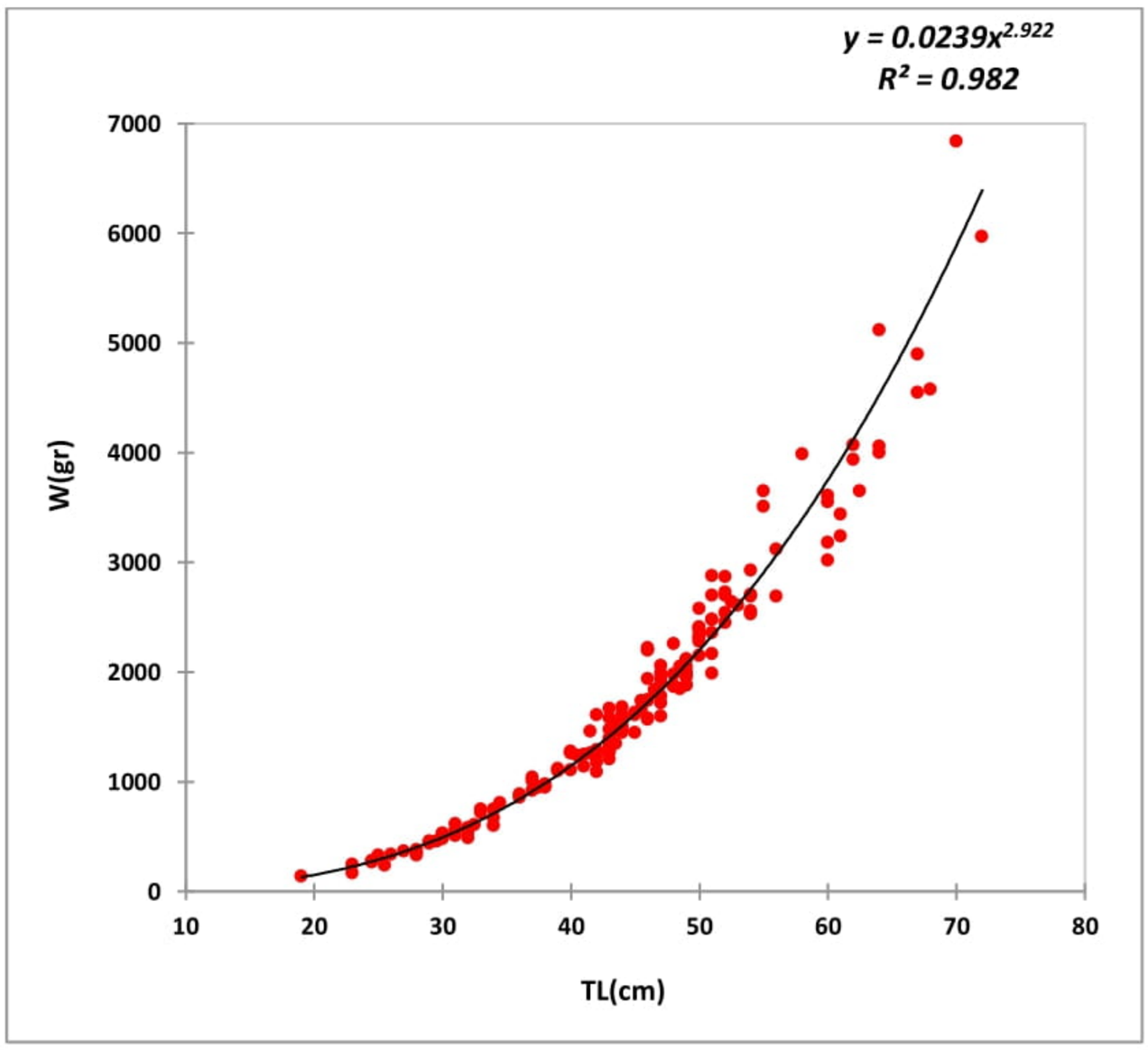

Figure 11 *S. maximus: Length-weight relationships in May, 2024.*

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

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

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

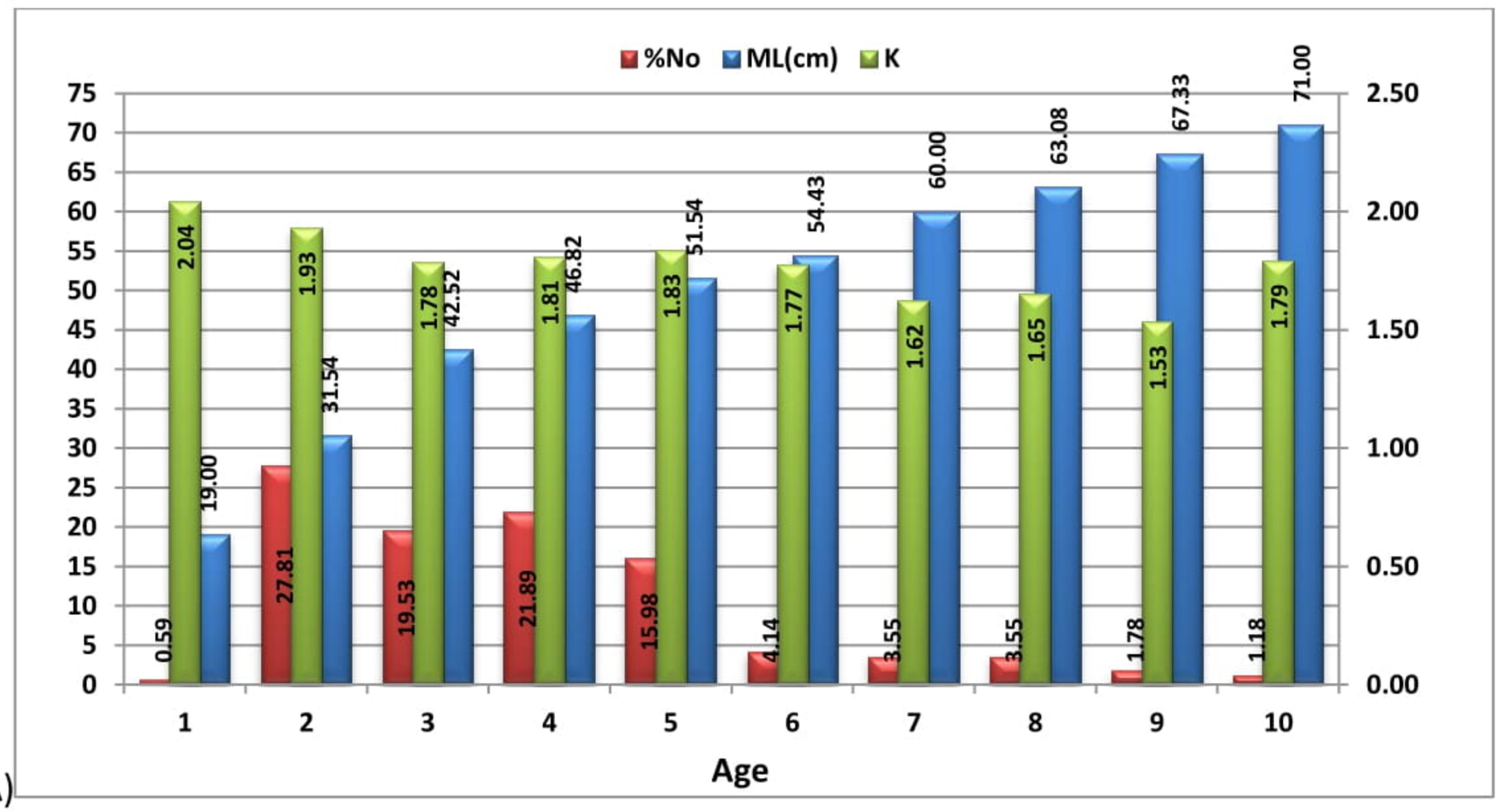
$\log(-t_0) = -0.3922 - 0.2752*\log L_\infty - 1.038*\log k$

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

Considering that water temperature was 8 °C during the study period, the coefficient of natural mortality (M) for both sexes was: 0.37.

Fulton's condition factor (K)

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



A)

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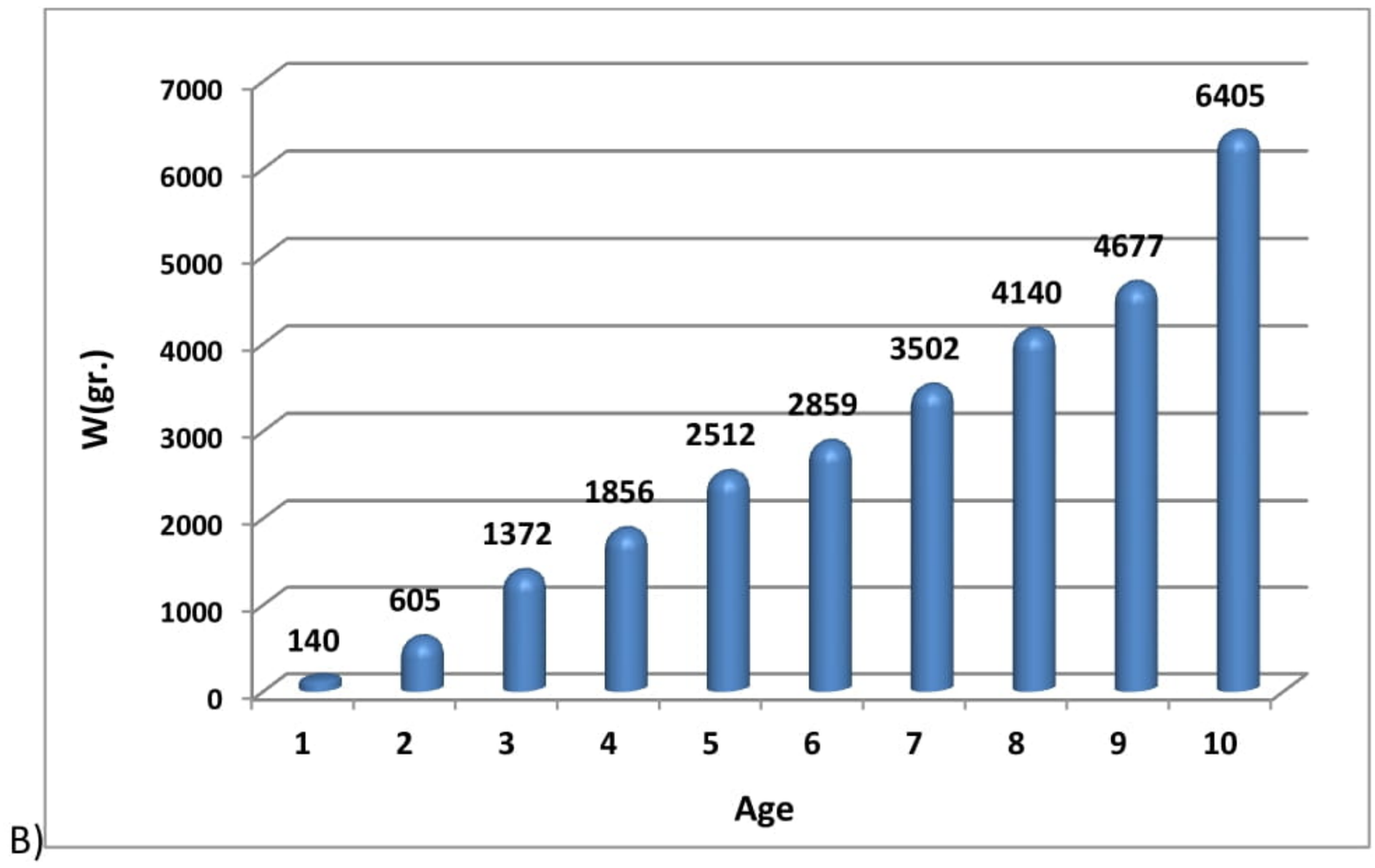

Figure 12 Percentage distribution and relation between the average length (ML) and coefficient of Fulton (K) by age groups (A) and an average weight (g) of turbot by age groups (B).

3.7. Sex structure

Sex ratio

The results of the turbot sex structure analysis of turbot catches in the Bulgarian sector of the Black Sea during the spring-summer season of 2024 reveals that immature individuals constitute for 46.15% of the total catch, while sexually mature individuals represent 53.85%. Females comprise 40.83%, and males constitute 13.02%. The sex ratio of sexually mature individuals is 75.82% females and 24.18% males.

Among the 40 surveyed areas along the Bulgarian coast, no female individuals were detected in 6 areas, no male specimens were identified in 26 areas, and no juvenile specimens were found in 11 areas (Fig. 13).

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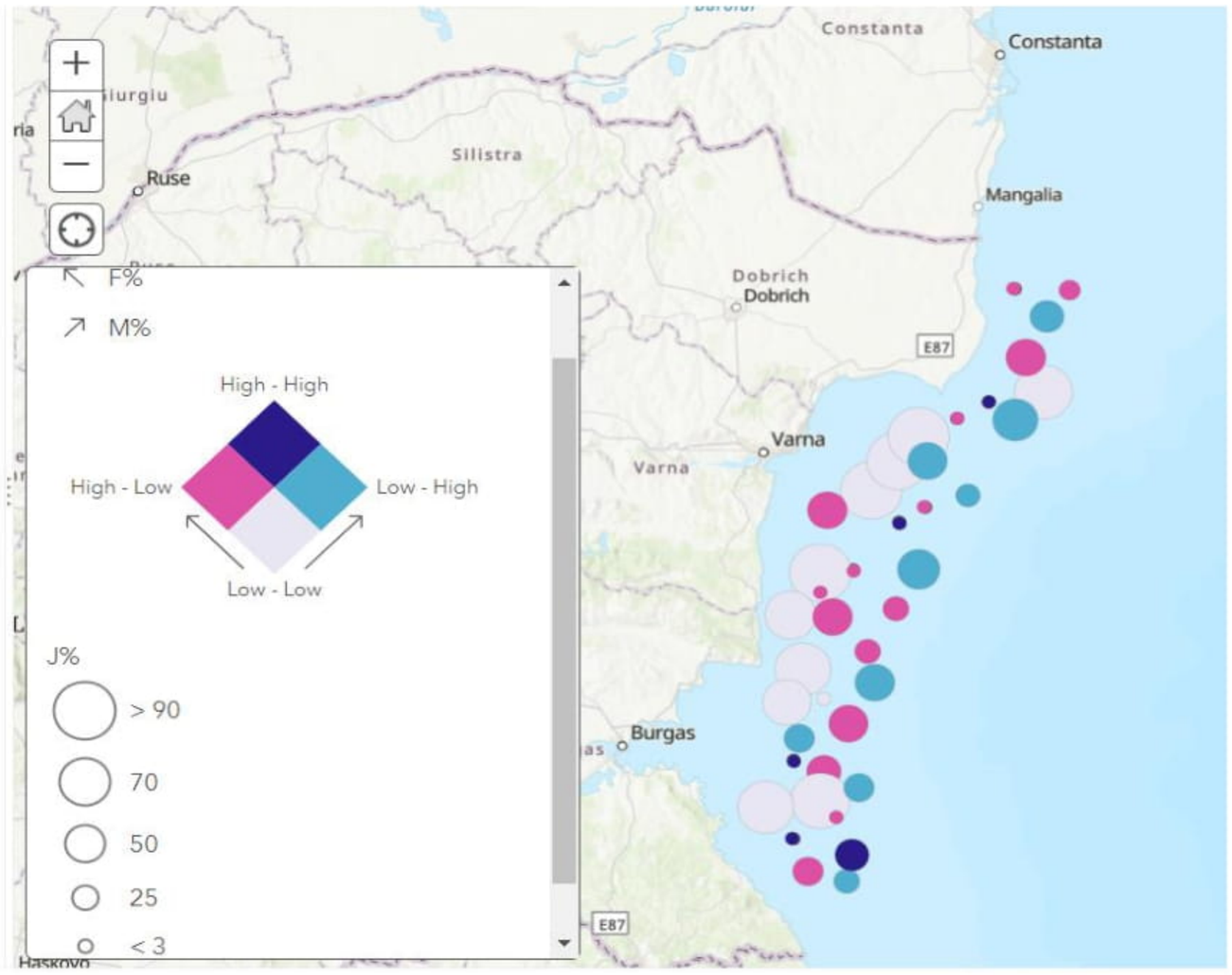

Figure 13. *Sex structure of S. maximus in May 2024: distribution by station (female, male, and juvenile specimens are indicated by purple, blue and grey, dark blue, presence of both sexes, and juveniles).*

Male specimens are mainly found at depths ranging from 45 to 86 meters, while female specimens are observed in significant numbers at depths between 50 and 78 meters. Juvenile individuals are primarily concentrated in the area between Varna and Emine, specifically at depths of 25 to 36 meters.

Female specimens are predominantly located in the regions of Shabla, near Kaliakra-Byala village, and further south near Tsarevo. In contrast, a larger concentration of male specimens has been identified in the Varna area.

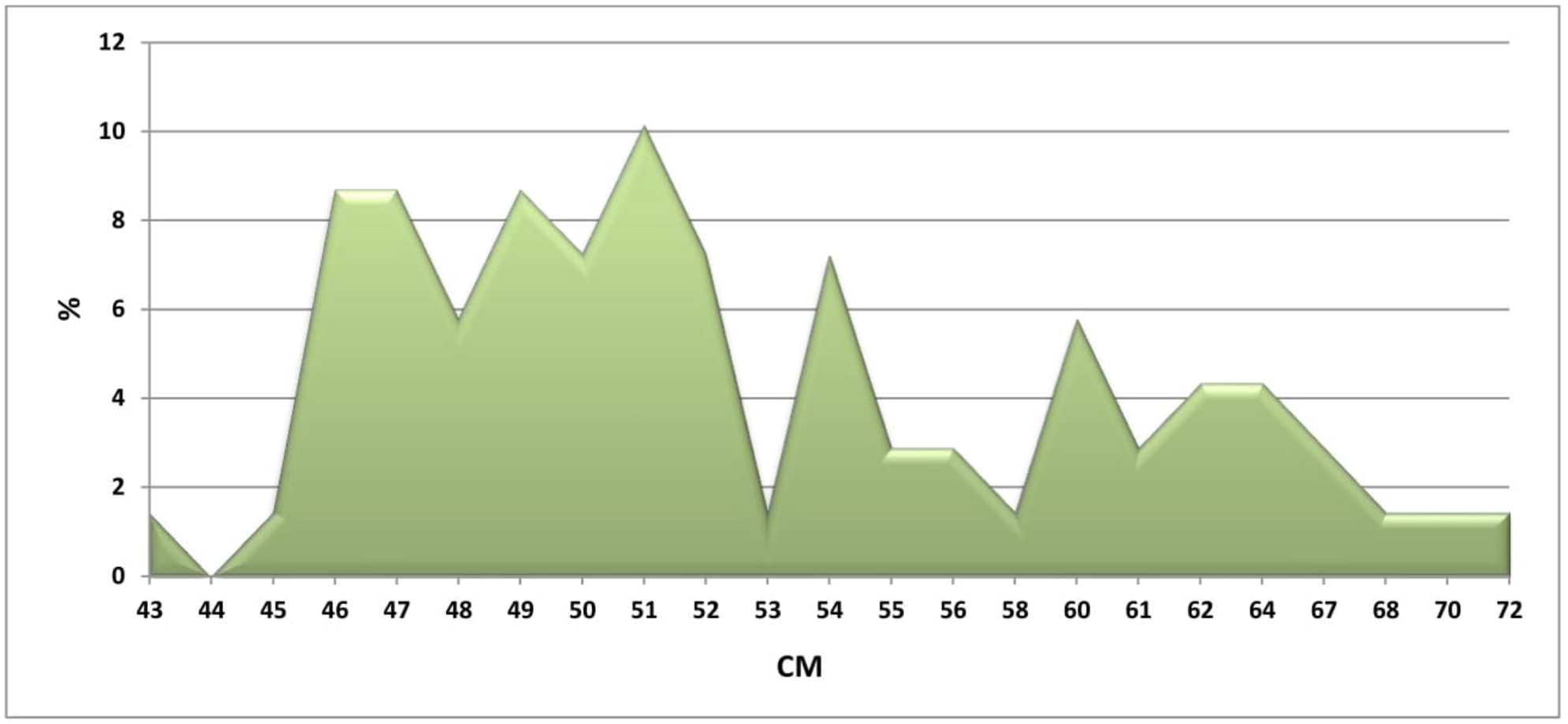

Figure 14 *Female specimens: Percentage distribution by length classes.*

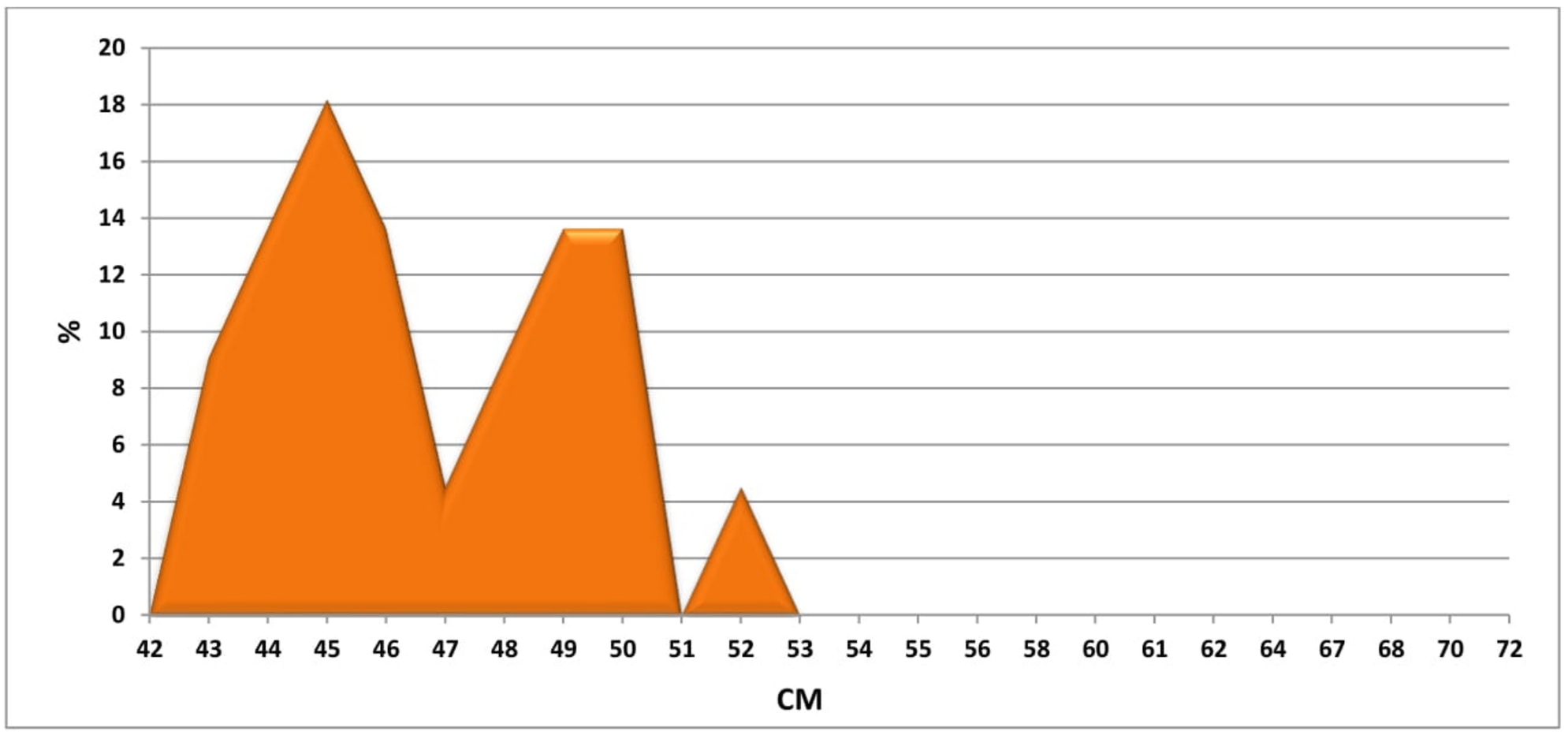

Figure 15 *Male specimens: Percentage distribution by length classes.*

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The distribution by sex and size groups shows that female specimens predominantly fall within the size range of 46 to 52 cm, accounting for 56.52% of the measured female population (Fig. 14). All individuals measuring between 53 cm and 72 cm are female, accounting for 16.56% of the total population.

For male specimens, the largest group-comprising 45.45%-is found in the size category of 44 to 46 cm (Fig. 15).

These findings highlight a clear sexual dimorphism in body size, with females exhibiting larger sizes overall (Figs. 14 and 15).

3.8. Weight structure

The data on the weight distribution of the turbot population in Bulgarian waters of the Black Sea for the year 2024 were collected from an analysis of 169 individuals, with each specimen's weight recorded. The analysis revealed that the majority of specimens had an average weight of 1793.07 g (see Fig. 16).

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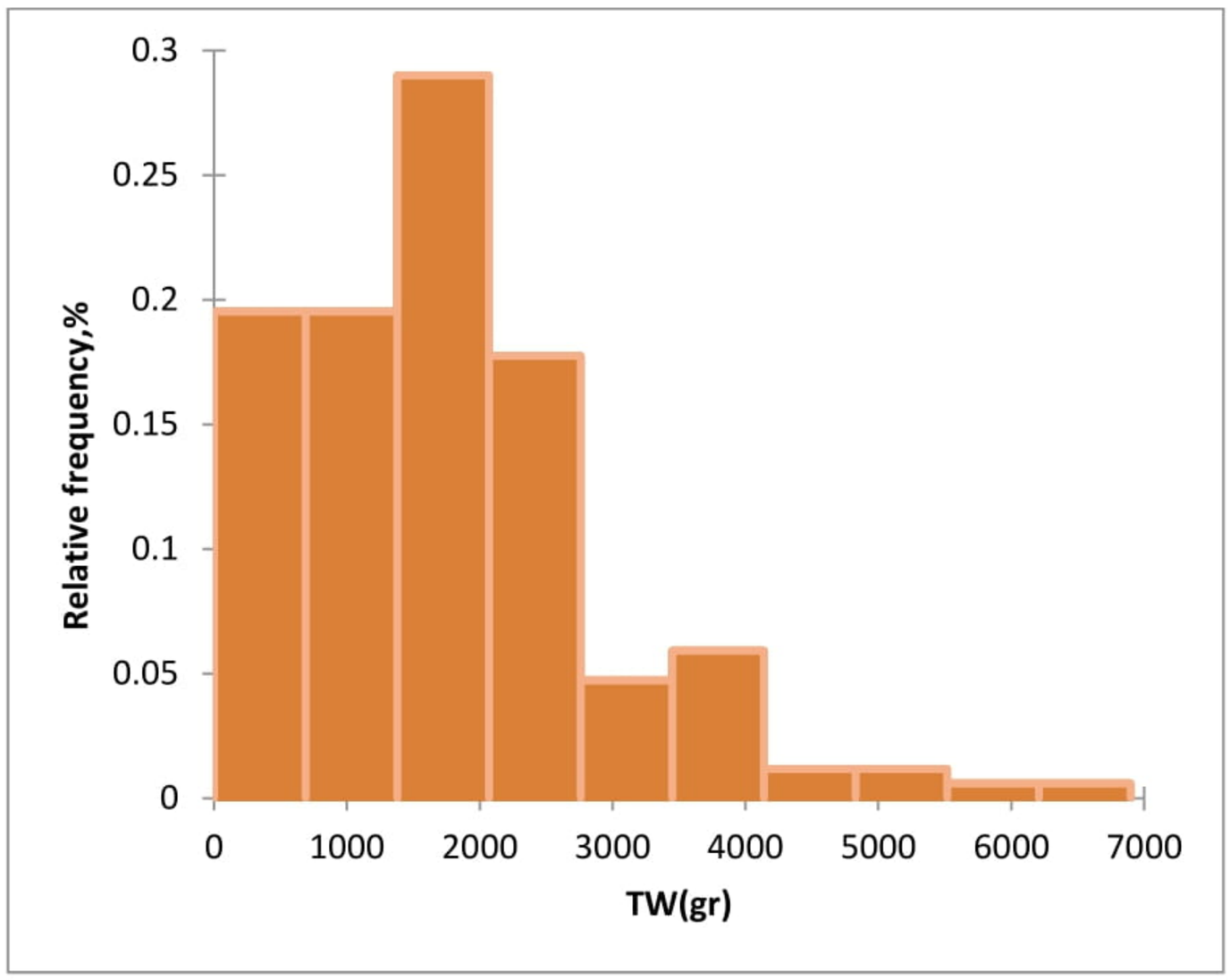

Figure 16 *Weight structure of S. maximus catches.*

Immature specimens weigh between 140.0 and 1670.0 grams, with an average weight of 891.67 grams. Female specimens range from 1350.0 to 6840.0 grams, averaging 2791.59 grams. Male specimens weigh between 1360.0 and 2450.0 grams, with an average weight of 1857.3 grams (see Fig. 17, A, B, and C).

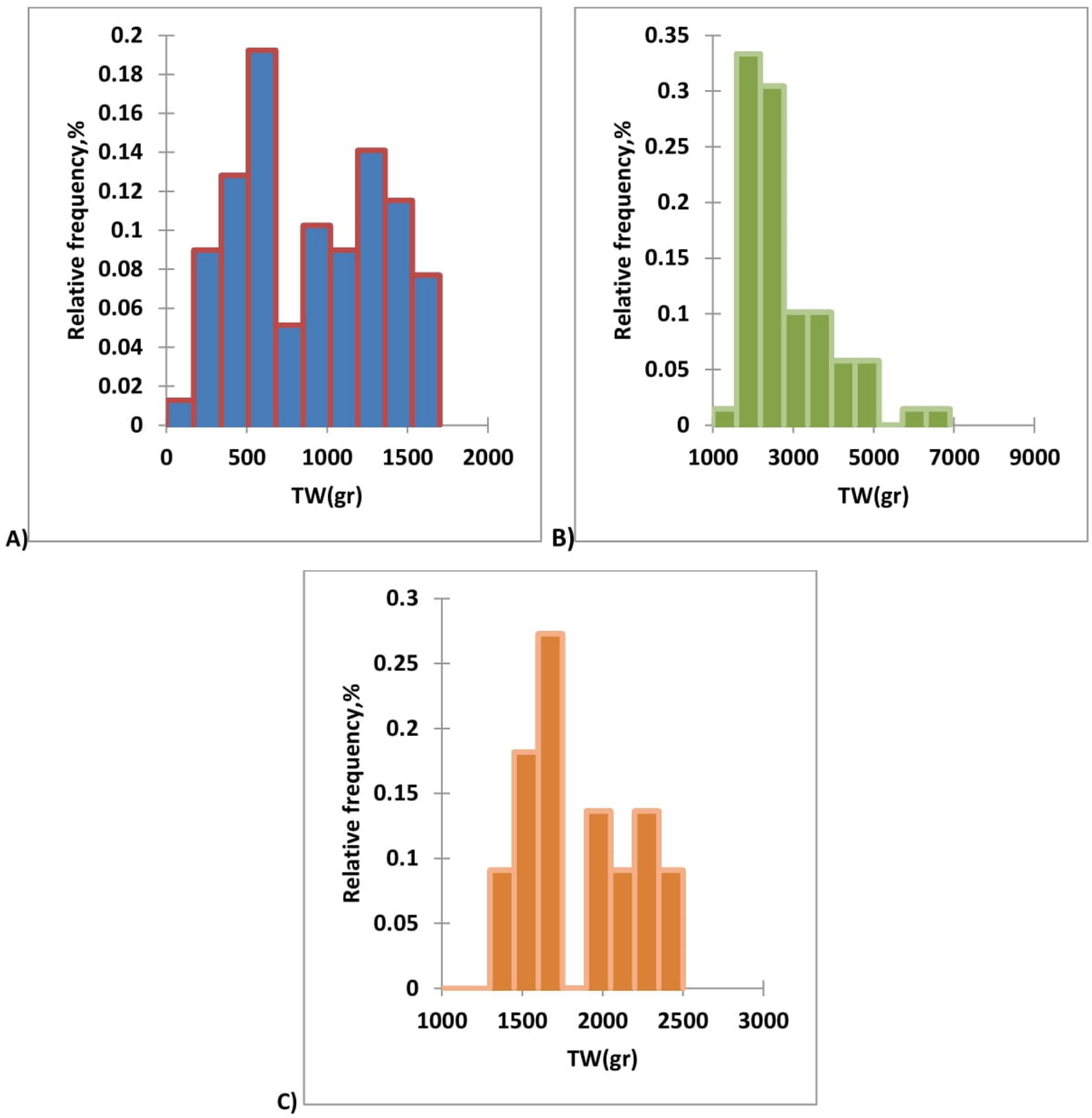

Figure 17 *Weight structure of S. maximus catches by sex: A) immature specimens, B) female and C) male specimens;*

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3.9. Other reference species

During bottom survey in the spring-summer season of 2024, 116 specimens of sharks (Squalus acanthias), 63 specimens of sea foxes (Raja clavata), and 94 specimens of flounder (Platichthys flesus) were collected (Table 6).

Table 6

Data on species composition and biological characteristics of the reference species

Bycatch species	N	Size (cm)			Weight (kg)		
		Min.	Max.	Ave.	Min.	Max.	Ave.
Squalus acanthias	116	39	145	116	0.21	14.1	7.03
Raja clavata	63	31	92	58	0.2	4.37	1.39
Platichthys flesus luscus	94	15	28.5	22	0.07	0.23	0.143
M.merlangus	1300	5.9	23.5	12.08	0.0014	0.093	0.014

Catch per unit effort (CPUE), (kg/trawl) distribution maps of *S. acanthias*, *R. clavata*, *Pl.flesus* and *M.merlangus* are presented in Fig.18.

Specimens of the species *S. acanthias* are primarily observed between n. Kaliakra and n. Emine (25-34 m). Clusters of *Pl. flesus* are located in the northern region of the Bulgarian coast, particularly off Shabla, and in the southern area off Byala, at depths of 51-63 m. Representatives of the species *R. clavata* are noted in front of Varna at depths of 82-86 m. Specimens of the species M. merlangus are prevalent, with a significant concentration observed in the northern region between Durankulak and the Kaliakra River at depths of 55-65 m, and in the southern region from the Emine River to Tsarevo (30-85 m).

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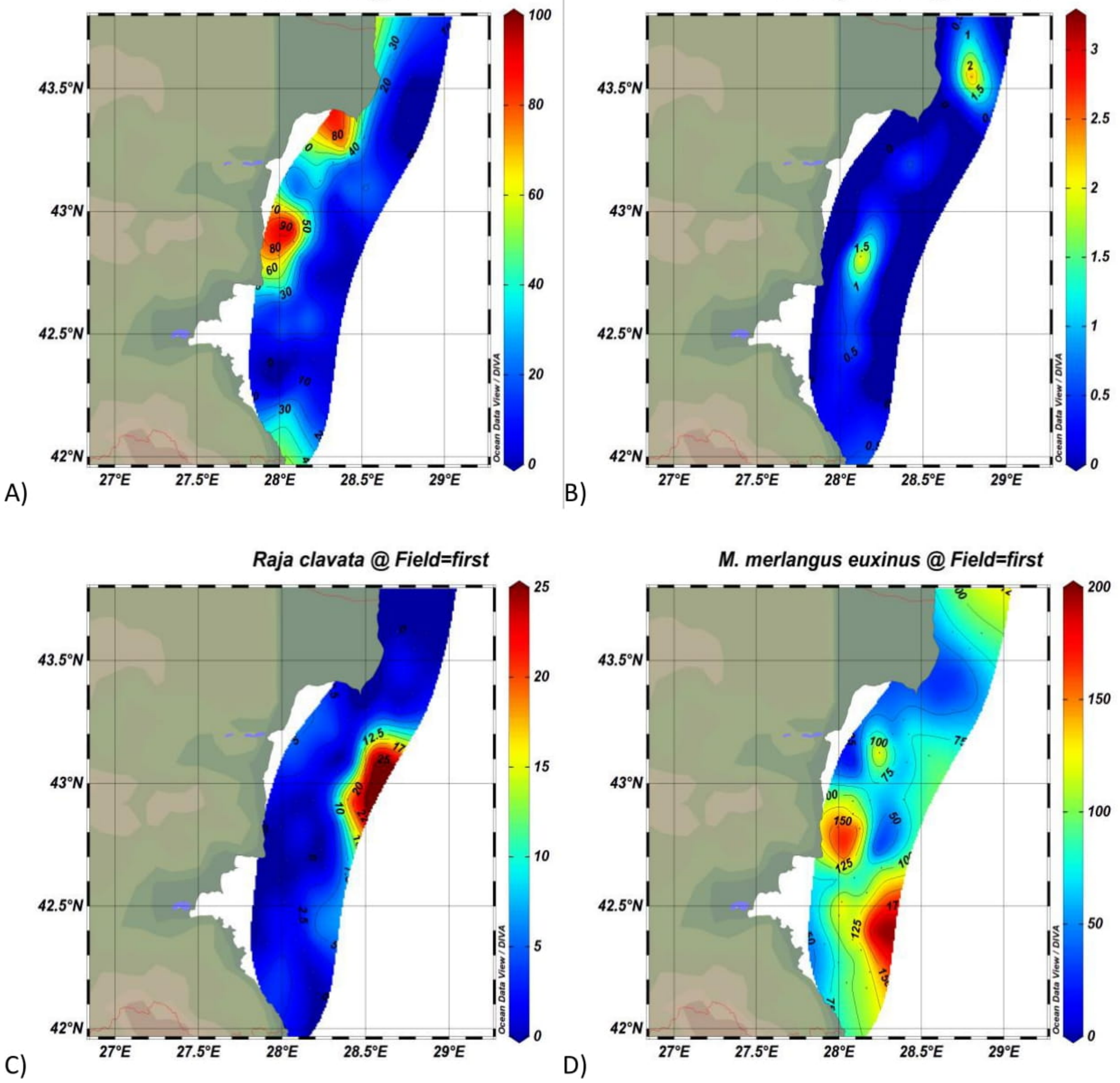

Figure 18 *Location of stations with bycatch from A) spiny dogfish (S. acanthias), B) flounder (Pl. flesus), C) thornback ray (R. clavata) and D) whiting (M. m. euxinus).*

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Catch per unit effort (CPUE) on whiting (*M. merlangus*)

The distribution of the catch per unit effort (CPUE), (kg/h), of the whiting (measurement of 1300 specimens) is presented in Tab.7 and Fig. 18 (D).

Table 7

Results of CPUE (catch per unit effort kg/h) of whiting (*M. merlangus*) by month, May 2024

№	Field	Depth (m)		Catch (Kg/h)
1	E8	24.5	30.5	10
2	F7	34.5	33.5	150
3	G6	33	35.5	40
4	D9	29	31.5	130
5	E10	34	35	100
6	C11	34.5	31.5	160
7	D12	40	43	170
8	E13	56.5	60	70
9	C13	41	42.5	50
10	D14	52.5	51.5	140
11	E15	66	68	100
12	D16	65	63	130
13	C15	48.5	50	120
14	B16	37.5	37.5	60
15	C17	47.5	46.5	80
16	D18	51	48.5	100
17	E19	59	69	110
18	F18	72.5	77	120
19	E17	78.5	72	100
20	F16	82	84	200
21	F14	79	77.8	100
22	G13	86.5	88	110
23	F12	86	85	10
24	E11	51.5	48	170

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25	L1	50.5	51	70
26	N1	56	63	90
27	M2	63	64.5	70
28	L3	62	68	30
29	M4	75	78	40
30	L5	79.5	81	50
31	K4	67.5	64	30
32	J5	52	50.5	50
33	H5	30	36	60
34	J6	43.5	51	80
35	J7	85	86	90
36	H7	67	69.5	60
37	G8	46	63	60
38	H9	83	85	80
39	G10	84	86	40
40	F9	63	47	70

The main biological parameters of *M. merlangus* (measurement of 1300 specimens) are presented in Fig.19, 20, 21 and 22.

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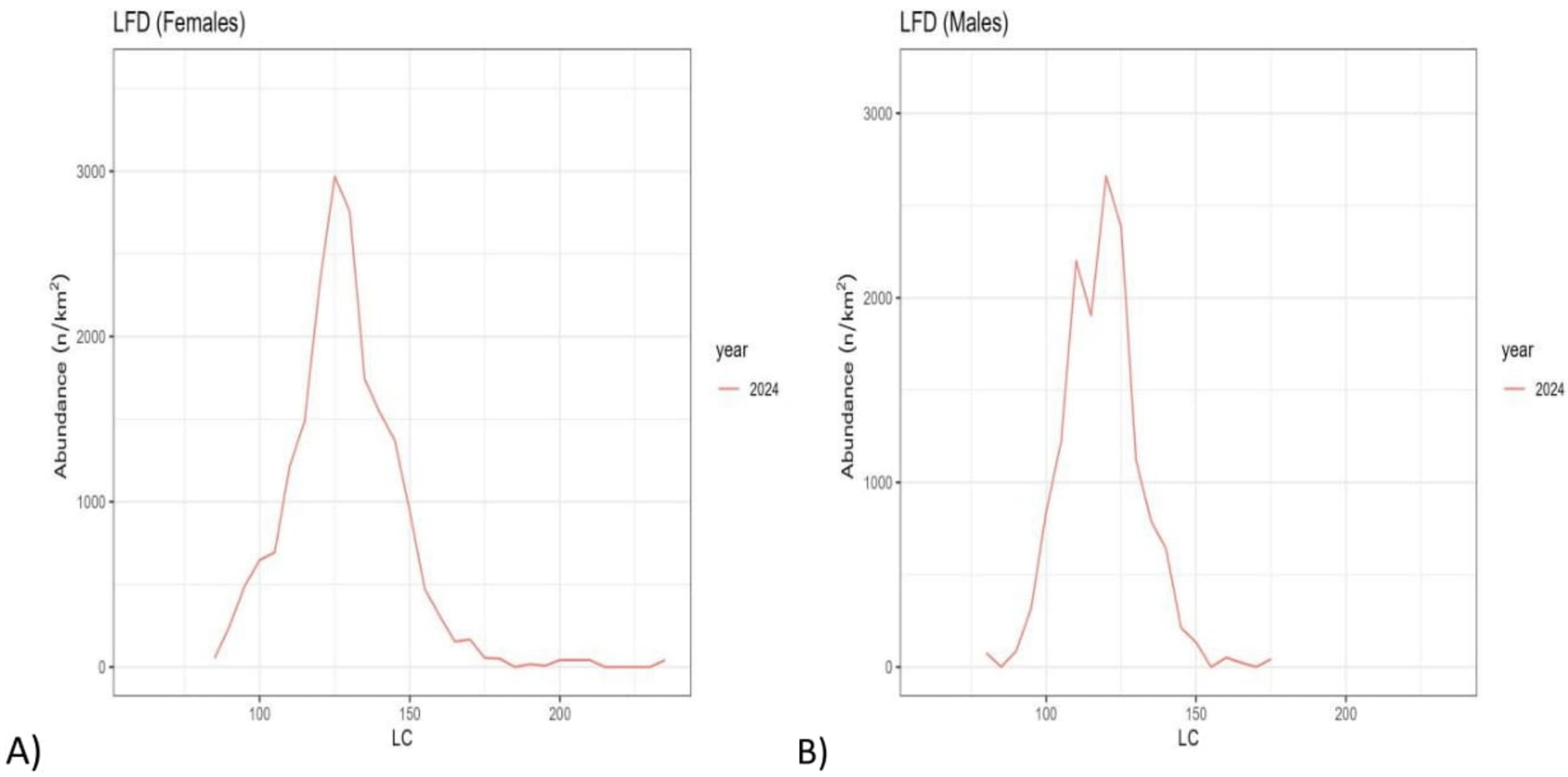

Figure 19 *Length classes (LC, mm) of M.merlangus catch by sex: A) female, B) male.*

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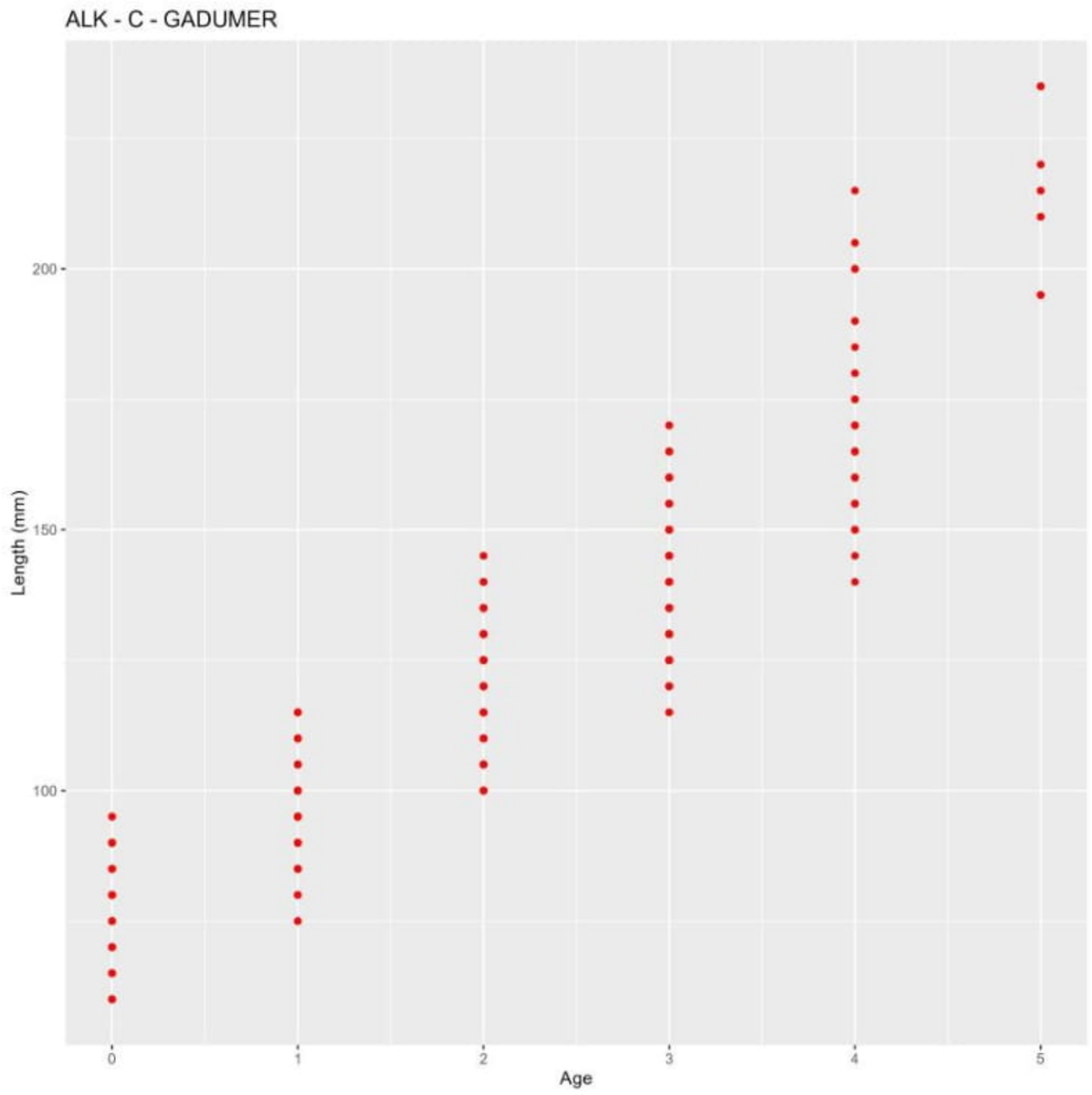
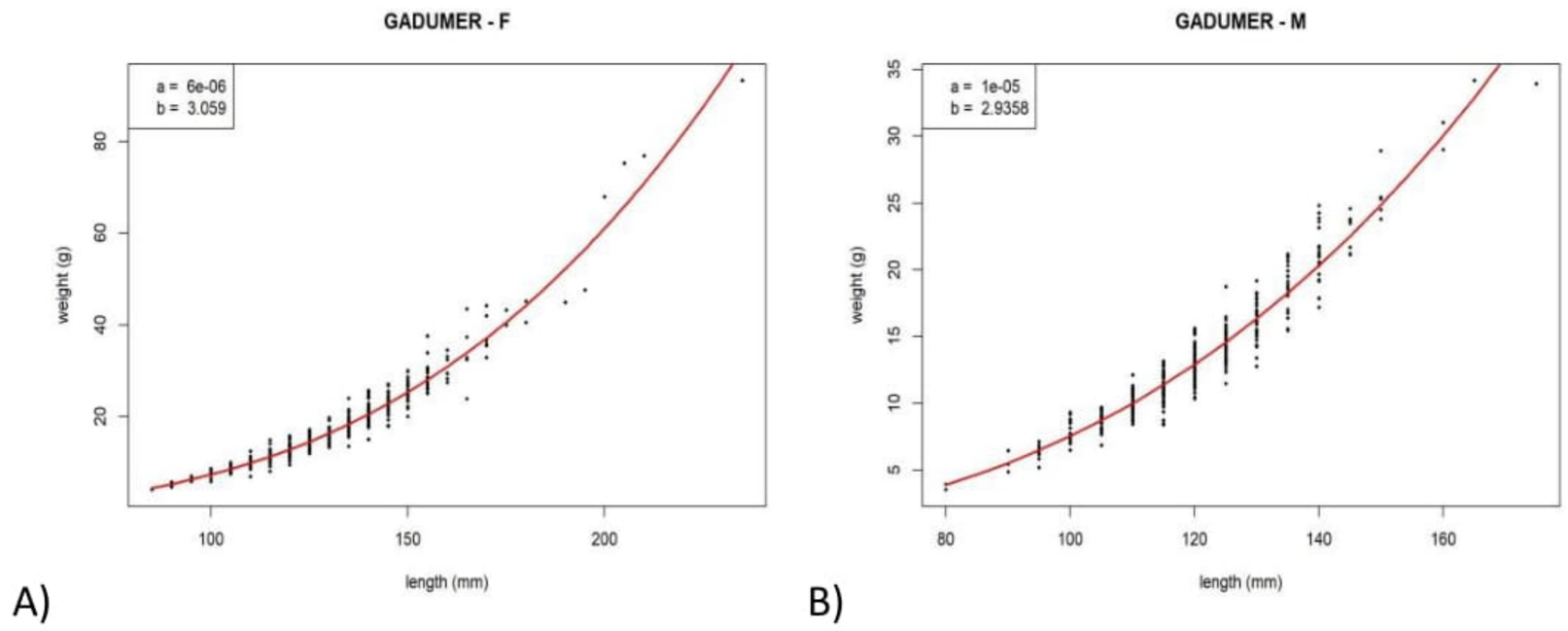


Figure 20 M. merlangus: Age-size relationships.



A) B)

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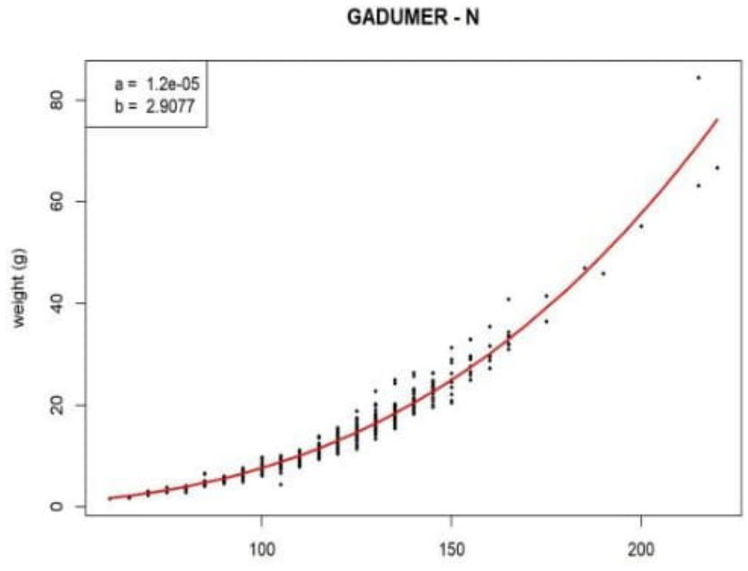
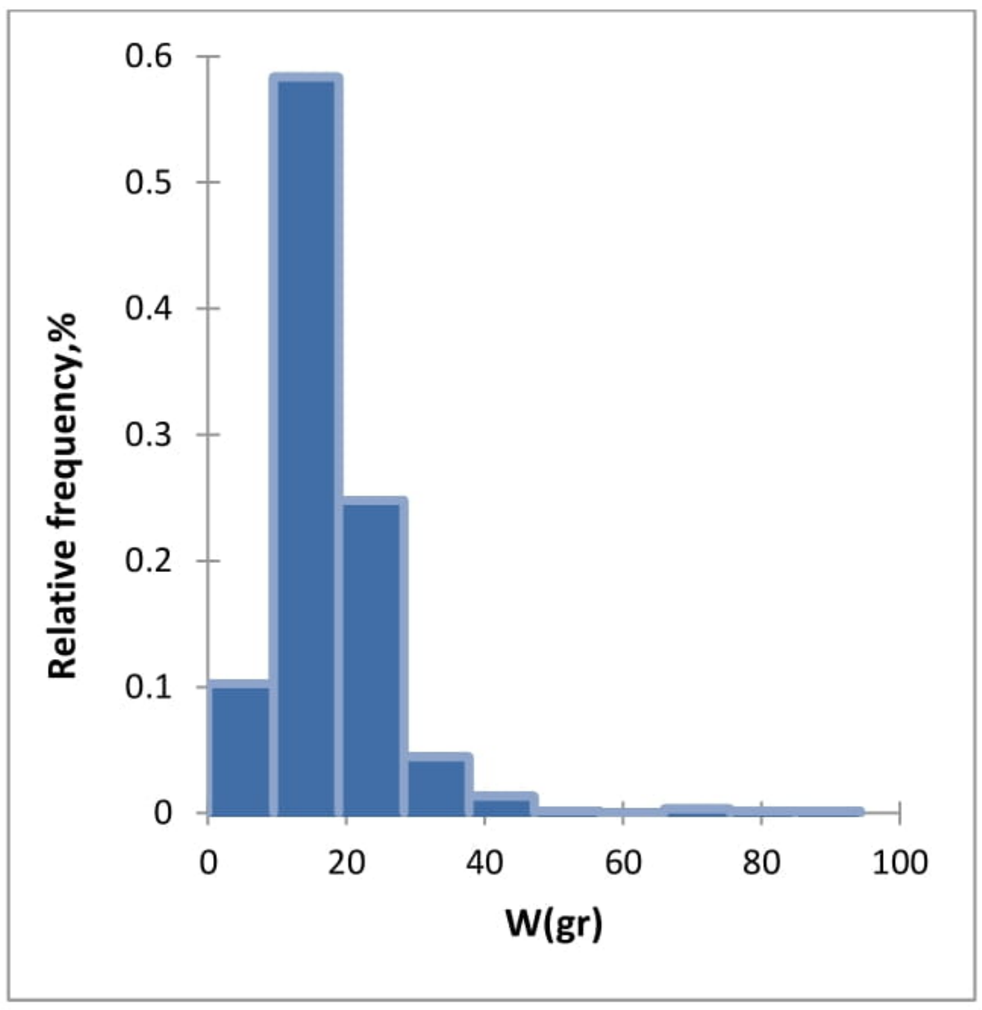
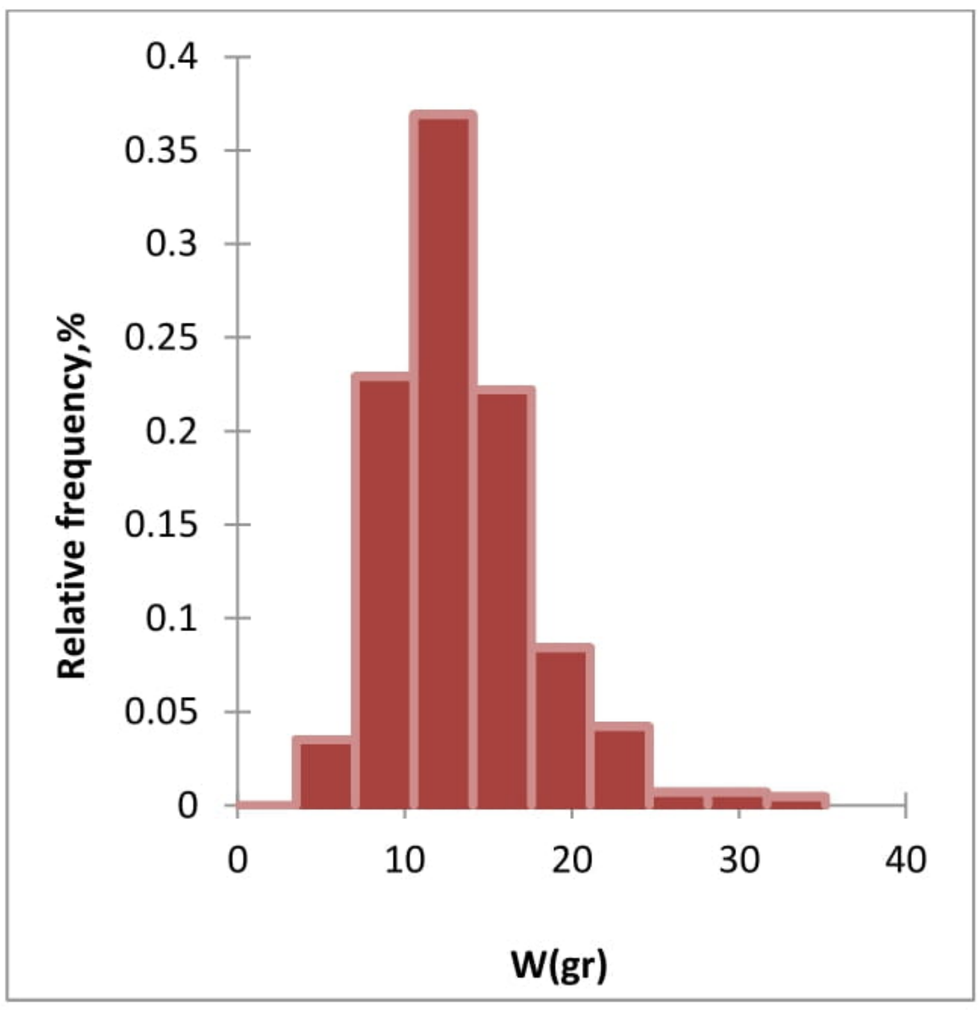


C)

Figure 21 M. merlangus: Length-weight relationships by sex, A) female, B) male and C) indeterminate, May, 2024.



A)



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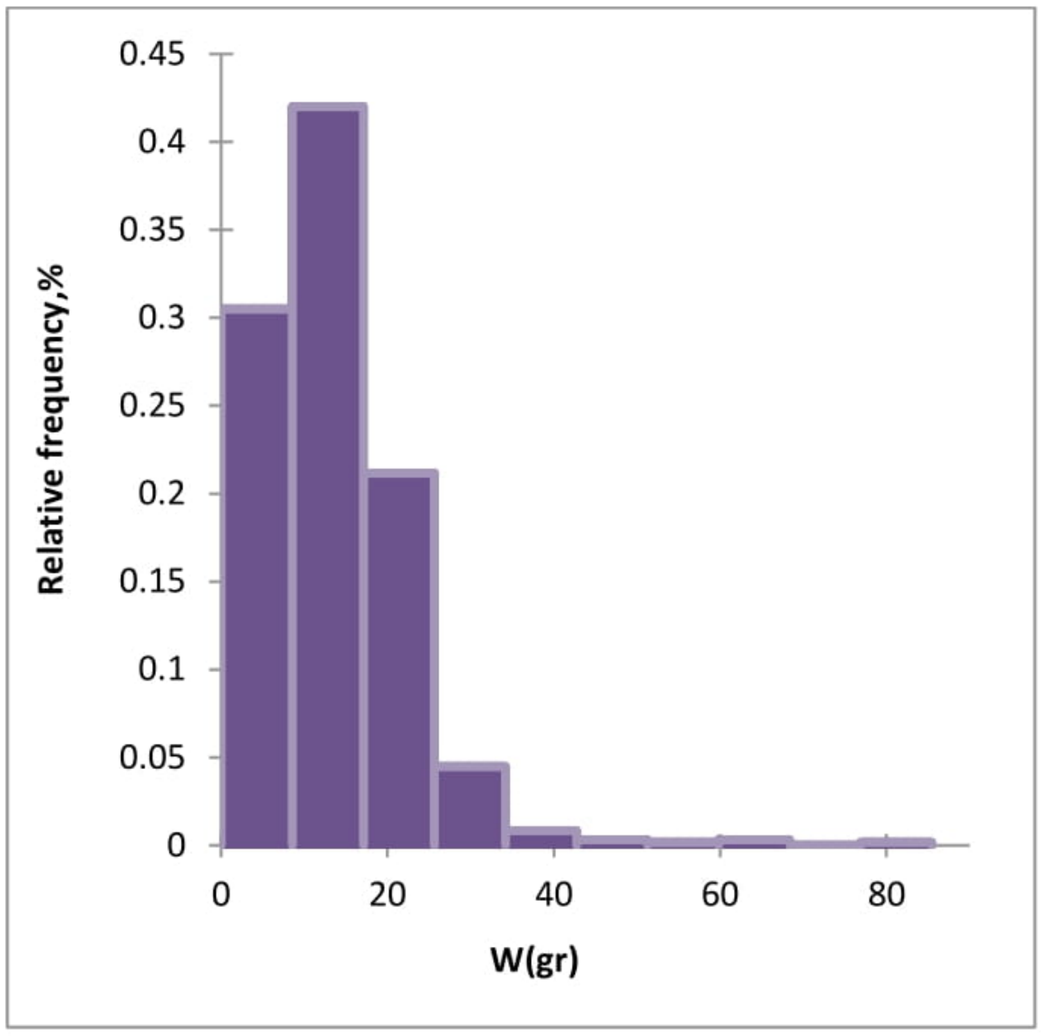

C)

Figure 22 Weight structure of M. merlangus catches by sex: A) female, B) male and C) undetermined specimens;

The GSI index varies on female specimens: 0.17-16.0, with an average – 3.66, while in males the index is lower, and we observe values from 0.17-7.23, and an average – 2.23 (Fig.23). Fecundity was determined between 3.247 and 30.534 (mean: 10.139±6.953) according to 500 gonads examined.

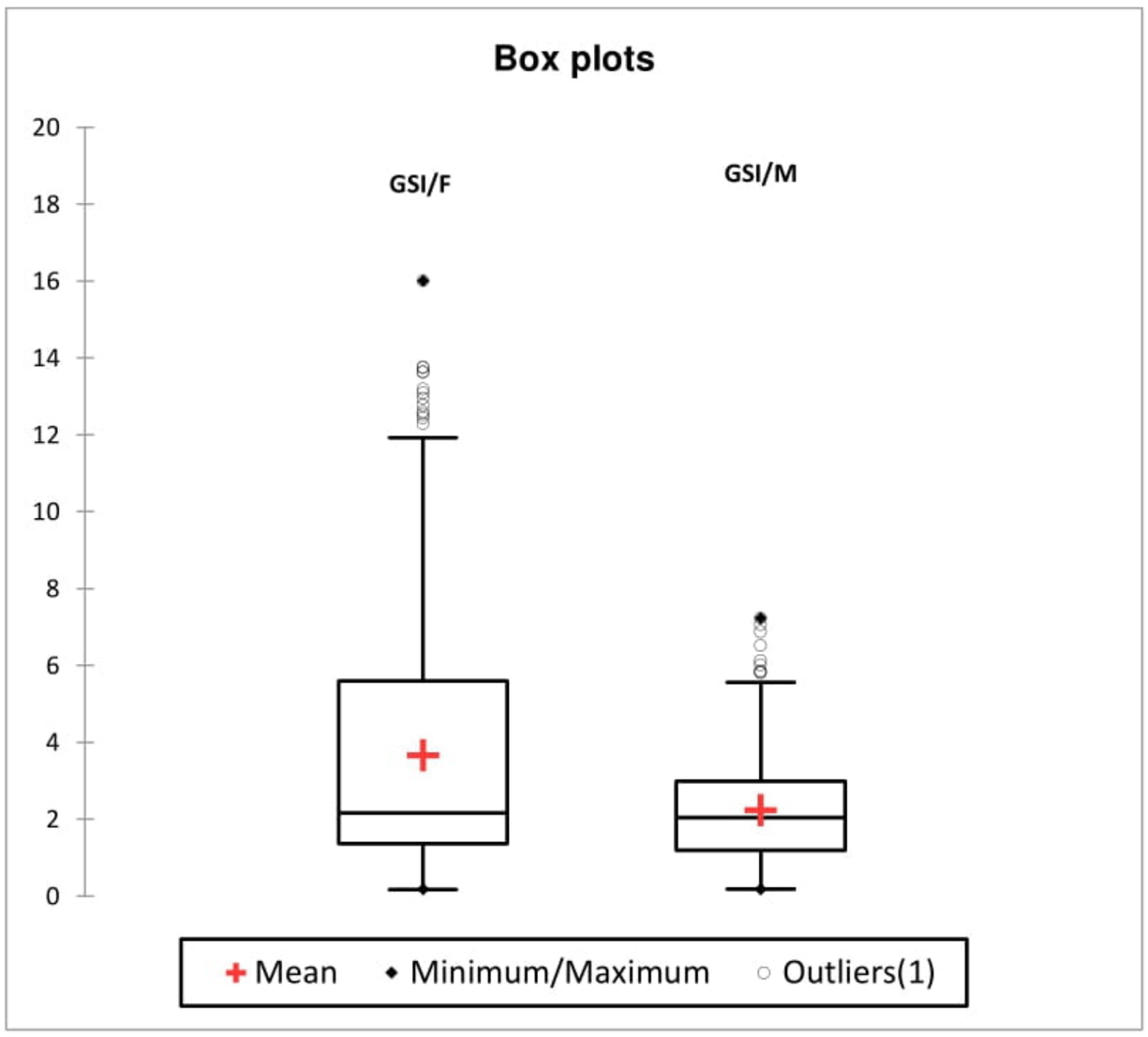

Figure 23 *Gonadosomatic index (GSI) by sex of M. merlangus. Box-plot: the horizontal line is the median; the upper and lower bars show the maximum and minimum range of the data, excluding outliers.*

A high abundance was observed at depth of 45-75 m,(Fig.24). Dominant specimens with sizes of 12.0 cm - 14.0 cm. The established ratio of female, male, and indeterminate individuals is - **46.54 %: 32.92 %: 46.15 %.**

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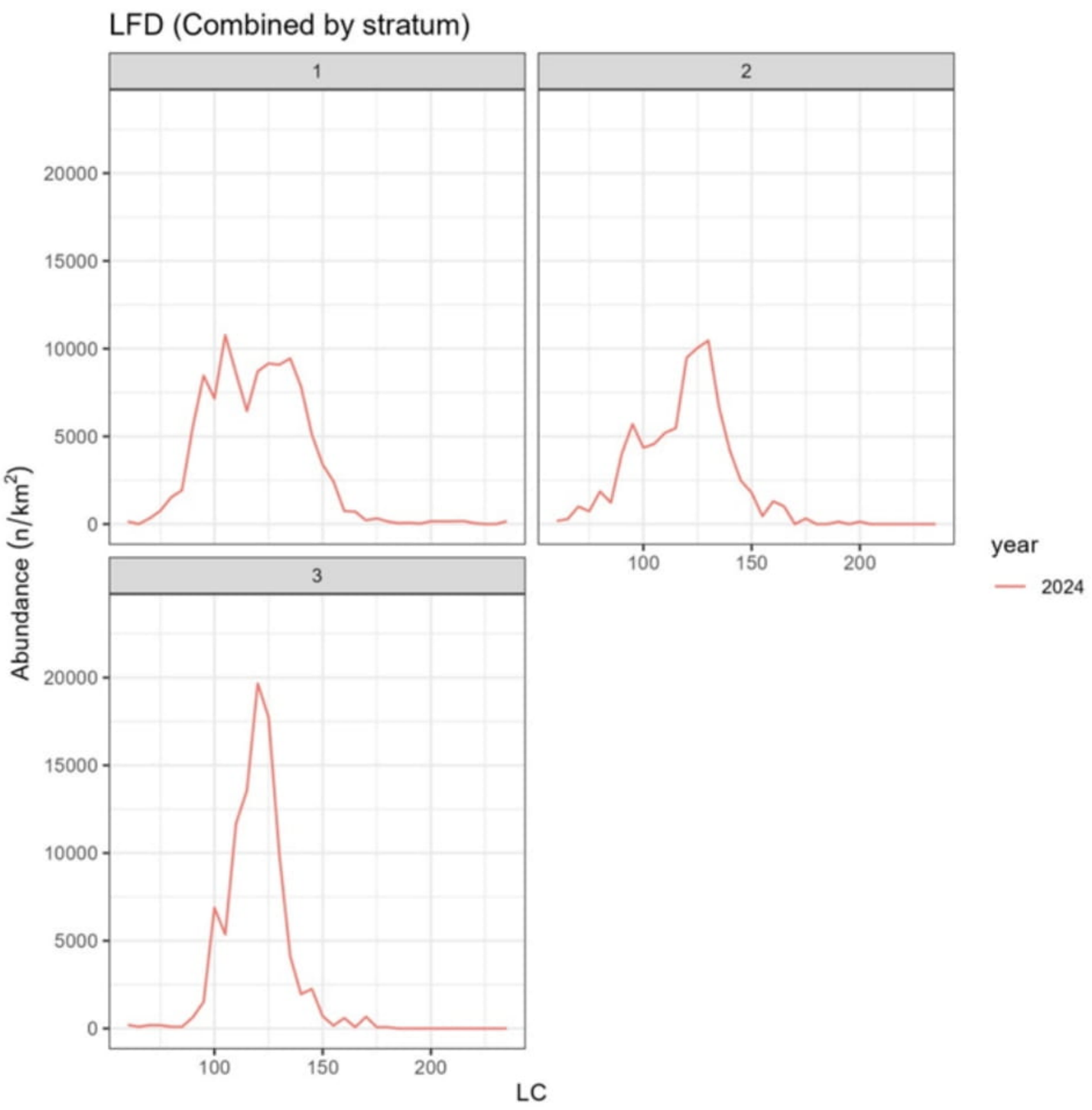

Figure 24 Abundance (n/km2) by length classes (LC,mm) and depth strata (1, 2 and 3) for V 2024;

Mean relative biomass (kg/km2) and abundance (n/km2) distribution on a coordinate grid for whiting is shown in Fig. 25.

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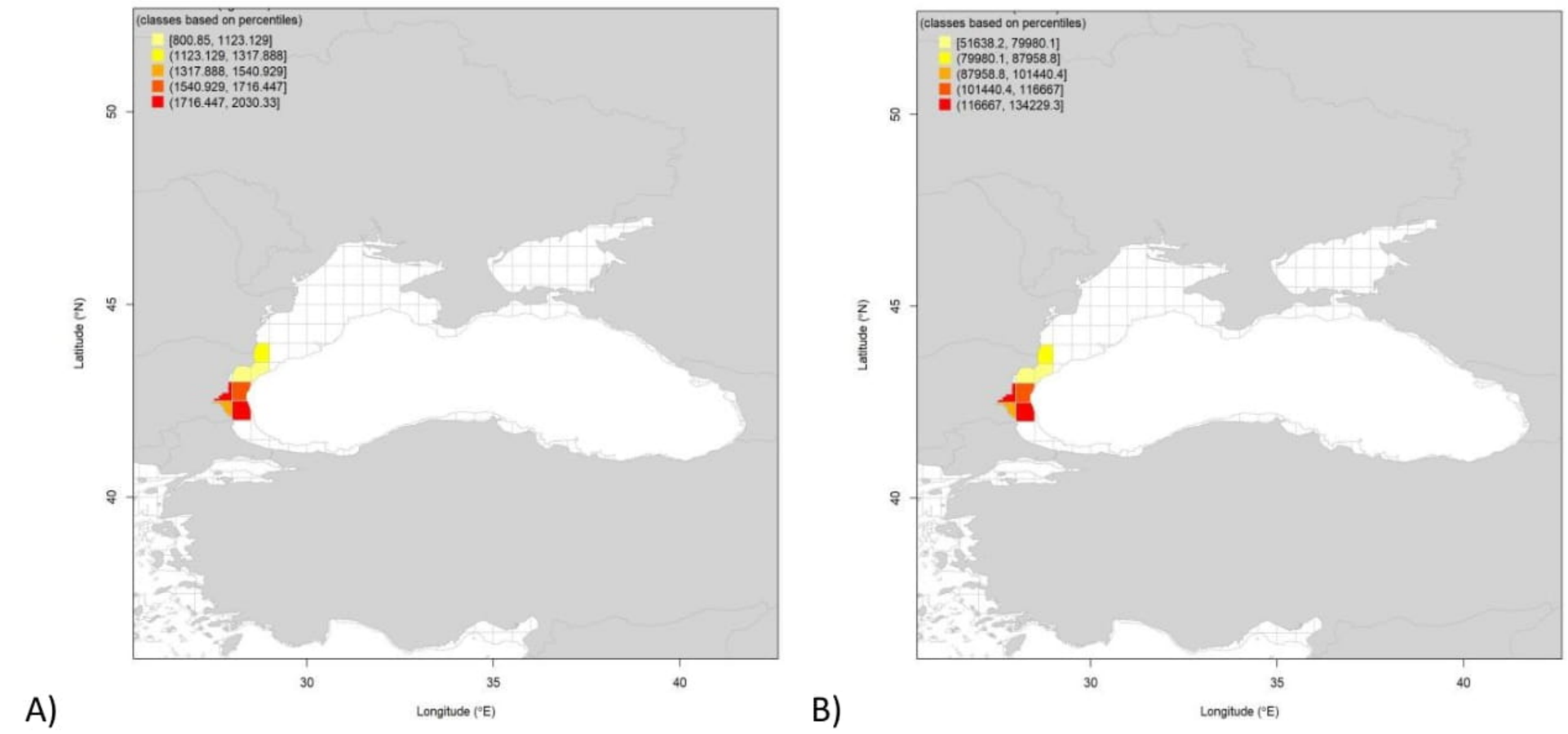

Figure 25 Distribution of mean A) relative biomass (kg /km2) and B) abundance (n/km2) of M. merlangus in May 2024, according to the BioIndex version 3.3;

The whiting biomass in the entire studied area in front of the Bulgarian coast of the Black Sea was estimated at **16680.39** tonnes (Table 4). The abundance in the studied area was estimated at **1172.39*10^{6}** specimens.

Catch per unit effort (CPUE) on dogfish (*Squalus acanthias*)

The distribution of the CPUE (kg/h) of *S. acanthias* is shown in Tab. 8 and Fig.18 (A).

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Table 8

Results from CPUE (kg/h) on dogfish (*S. acanthias*) in May 2024

№	Field	Depth (m)		Catch (Kg/h)
1	E8	24.5	30.5	14.43
2	F7	34.5	33.5	42.97
3	G6	33	35.5	22.87
4	D9	29	31.5	99.71
5	E10	34	35	79.44
6	C11	34.5	31.5	72.63
7	D12	40	43	46.78
8	E13	56.5	60	6.01
9	C13	41	42.5	6.27
10	D14	52.5	51.5	25.06
11	E15	66	68	0
12	D16	65	63	0
13	C15	48.5	50	7.85
14	B16	37.5	37.5	0
15	C17	47.5	46.5	0
16	D18	51	48.5	37.63
17	E19	59	69	17.03
18	F18	72.5	77	12.32
19	E17	78.5	72	12.99
20	F16	82	84	0
21	F14	79	77.8	25.82
22	G13	86.5	88	6.72
23	F12	86	85	0
24	E11	51.5	48	19.12
25	L1	50.5	51	25.6
26	N1	56	63	7.05
27	M2	63	64.5	0
28	L3	62	68	0
29	M4	75	78	0
30	L5	79.5	81	0

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31	K4	67.5	64	7.4
32	J5	52	50.5	26.49
33	H5	30	36	88.04
34	J6	43.5	51	7.11
35	J7	85	86	22.42
36	H7	67	69.5	27.3
37	G8	46	63	0
38	H9	83	85	0
39	G10	84	86	6.6
40	F9	63	47	41.33

The main biological parameters of S. acanthias are presented in Fig.26, 27 and 28. A large part of the captured female specimens with a size between 120-135 cm (Fig. 26, A), and males are smaller, 113-122 cm, (Fig. 26, B). Males predominate in the catch specimens 79.31%, and females are 20.69%.

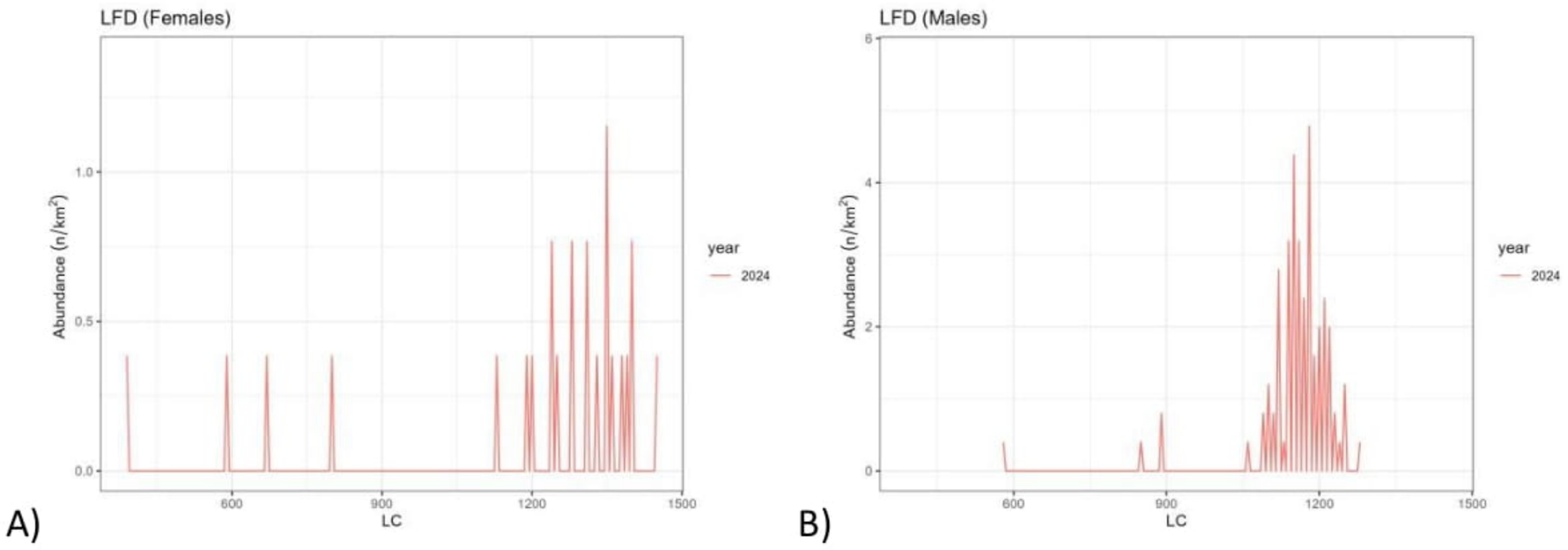

Figure 26 *Abundance (n/km2) and length classes (LC, mm) of S. acanthias catches by sex, A) female and B) male specimens;*

The female specimens captured weighed between 210 and 14100 grams, with an average weight of 9552.5 grams (Fig. 27, A). In contrast, the male specimens weighed less, ranging from 800 to 8530 grams, with an average weight of 6367 grams (Fig. 27, B).

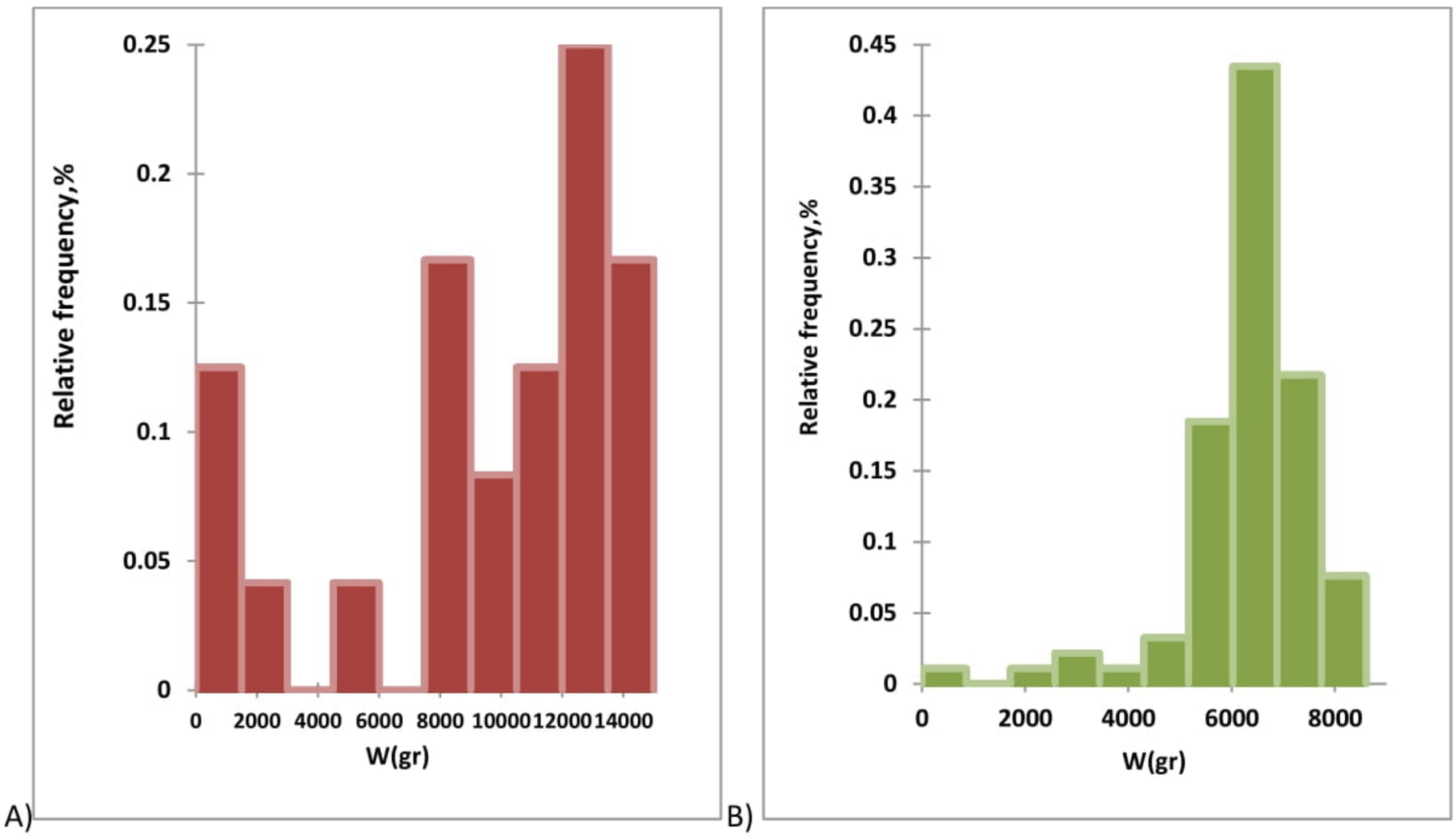

Figure 27 *Weight structure of S. acanthias by sex, A) female and B) male specimens;*

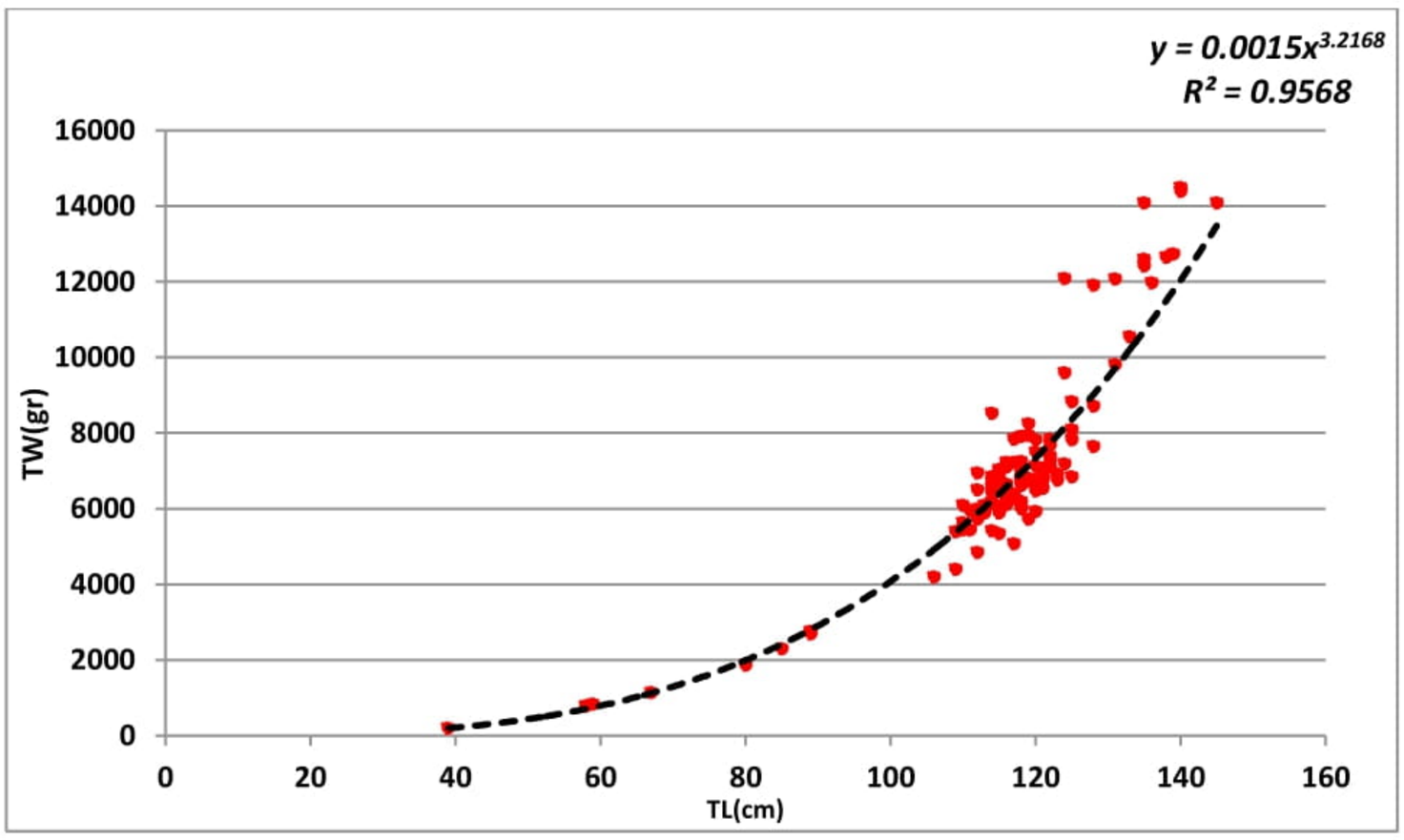

Figure 28 *S. acanthias: Length-weight relationships V, 2024;*

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The most abundant dogfish bycatch was caught at depth of 35-65 m, (Fig. 29).

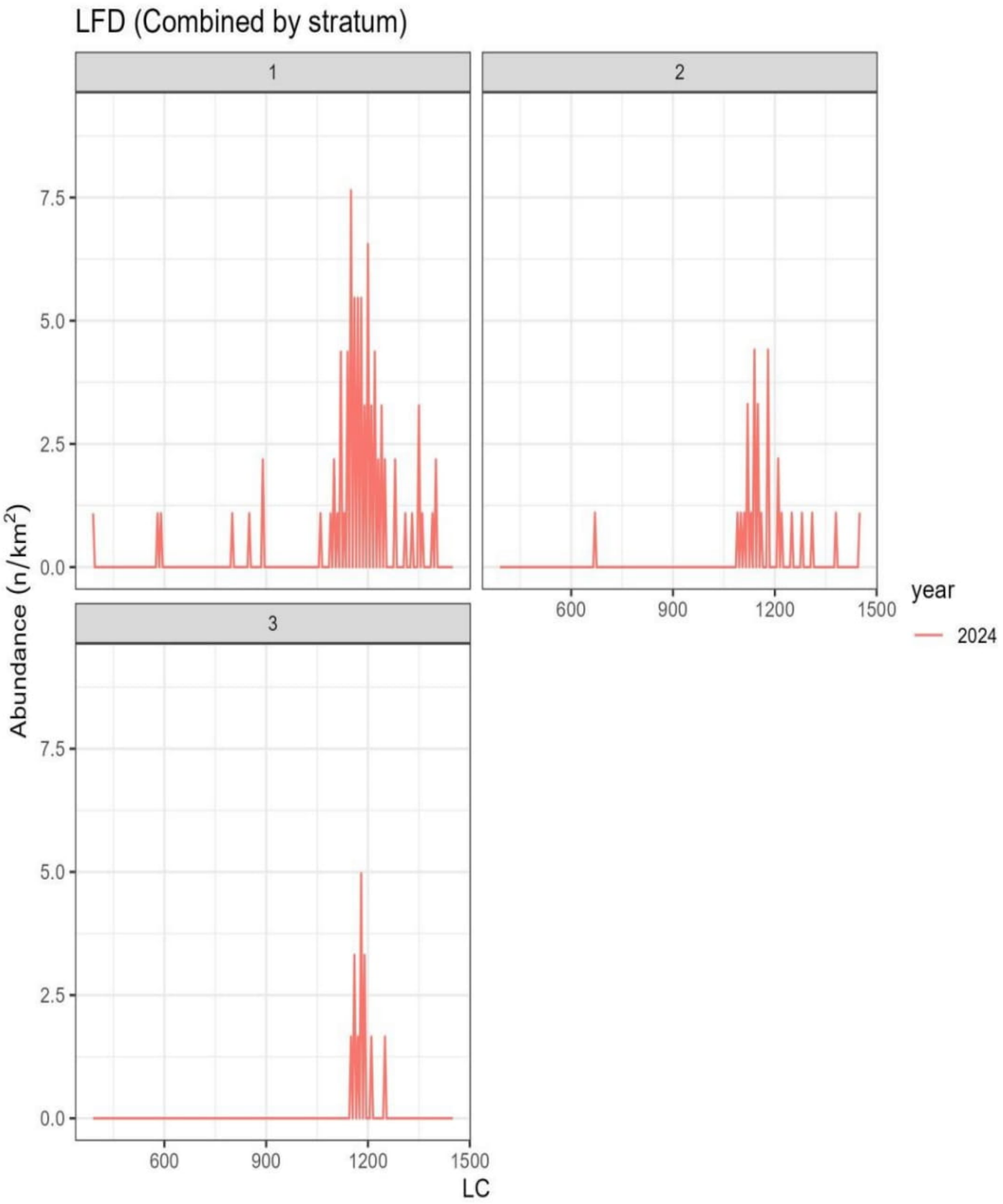

Figure 29 *Abundance (n/km2) by length classes (LC,mm) and depth strata (1, 2 and 3), V 2024;*

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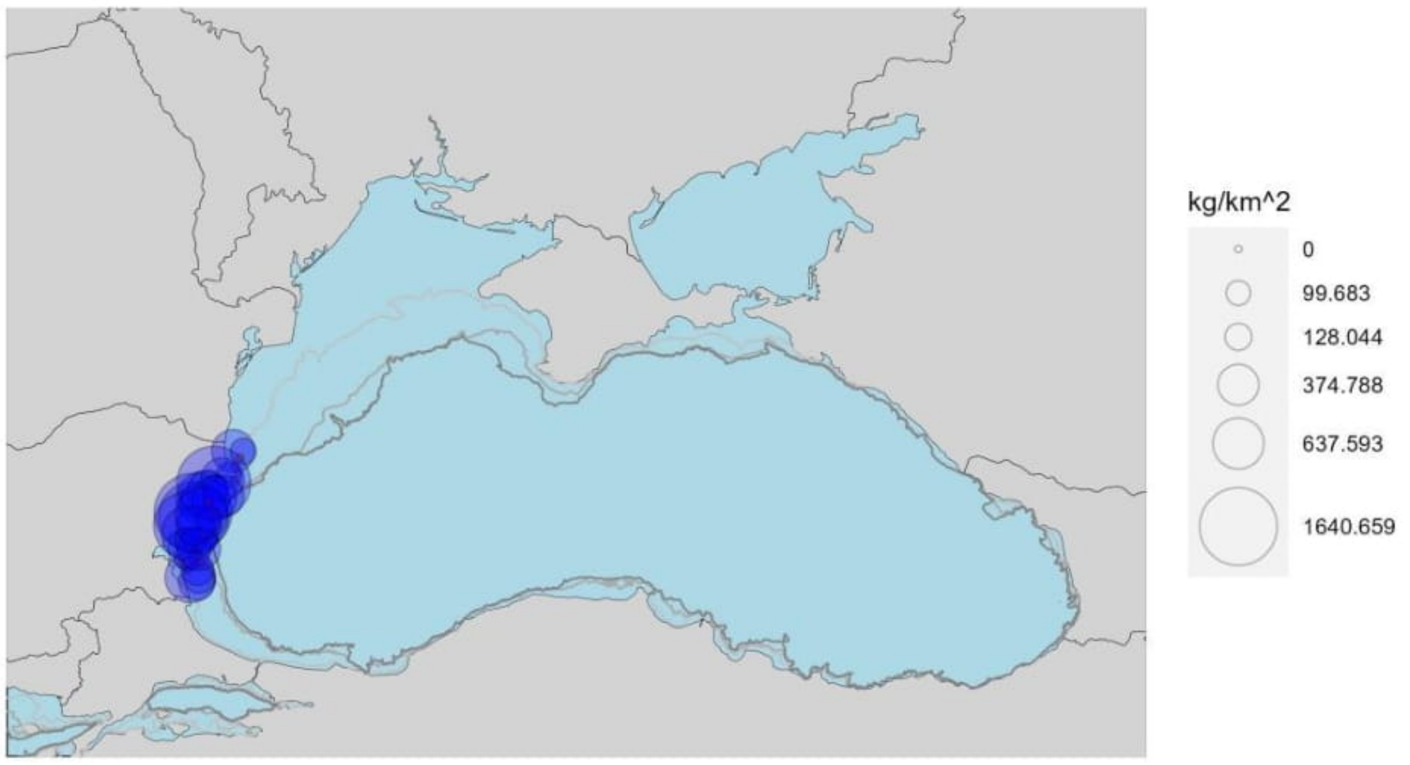

Figure 30 *Distribution of the relative biomass by hauls (kg / km2) of S. acanthias in V 2024 according to BioIndex version 3.3.*

The maximum biomass index of dogfish for V in the Bulgarian water area reaches **1640.66** kg/km^2(Fig. 30).

Estimating the biomass and abundance of a species accurately is challenging due to their highly dispersed distribution, which poses significant challenges. Therefore, estimating biomass based on CPUE may not be accurate. The dogfish biomass in the entire studied area in front of the Bulgarian coast was estimated at **3732.85** tonnes. During the study period, the total abundance in the Bulgarian water area was estimated to be **531.307*10^3** individuals.

Catch per unit effort (CPUE) on thornback ray (*Raja clavata*)

The distribution of the CPUE (kg/h) of *Raja clavata* is shown in Tab. 9, and Fig.18 (C).

Table 9

Results of CPUE (catch per unit effort kg/h) of red fox (R. clavata) by month, May 2024

№	Field	Depth (m)		Catch (Kg/h)
1	E8	24.5	30.5	3.88
2	F7	34.5	33.5	1.58
3	G6	33	35.5	4.93
4	D9	29	31.5	0
5	E10	34	35	0
6	C11	34.5	31.5	0
7	D12	40	43	0
8	E13	56.5	60	0
9	C13	41	42.5	0
10	D14	52.5	51.5	0
11	E15	66	68	0.82
12	D16	65	63	2.02
13	C15	48.5	50	2.81
14	B16	37.5	37.5	0
15	C17	47.5	46.5	3.53
16	D18	51	48.5	3.06
17	E19	59	69	0.2
18	F18	72.5	77	0
19	E17	78.5	72	0
20	F16	82	84	5.95
21	F14	79	77.8	3.64
22	G13	86.5	88	0
23	F12	86	85	0
24	E11	51.5	48	2.24
25	L1	50.5	51	0
26	N1	56	63	0
27	M2	63	64.5	0
28	L3	62	68	2.84
29	M4	75	78	0
30	L5	79.5	81	0
31	K4	67.5	64	1.21
32	J5	52	50.5	0

33	H5	30	36	1.47
34	J6	43.5	51	0
35	J7	85	86	24.9
36	H7	67	69.5	0
37	G8	46	63	0.8
38	H9	83	85	19.95
39	G10	84	86	1.815
40	F9	63	47	0

The main biological parameters of *Raja clavata* are presented in Fig.31, 32 and 33. The caught female specimens are 31-76 cm in size and weigh 200-2630 g (Fig. 31 A and Fig.32 A), and the following values were recorded for males - 43-92 cm and 530-4370 g, (Fig. 31 B and Fig. 32 B). Female specimens predominate in the catch, 61.90 %, and males 38.10%.

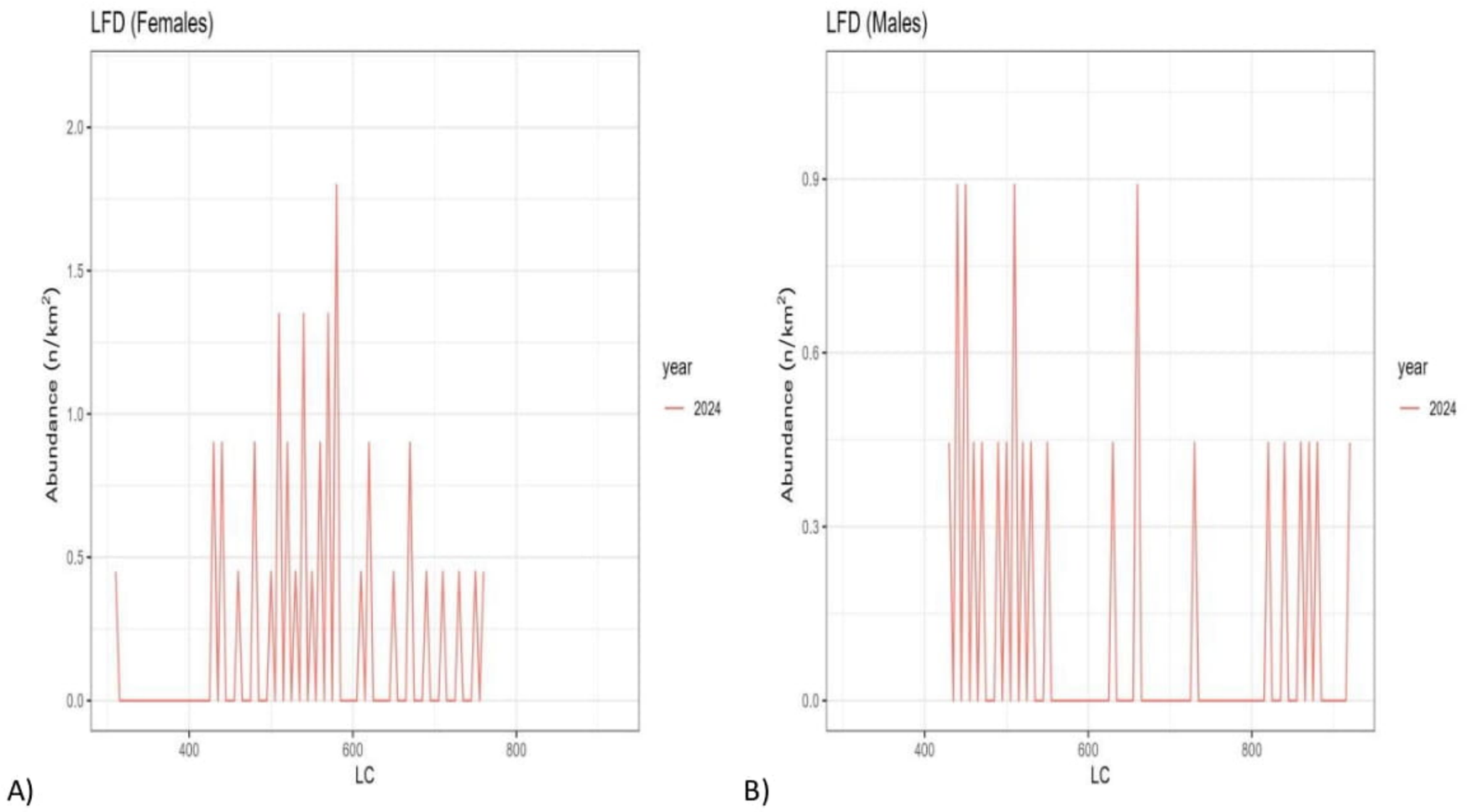

Figure 31 *Abundance (n/km2) and length classes (LC, mm) of Raja clavata by sex, A) female, and B) male specimens;*

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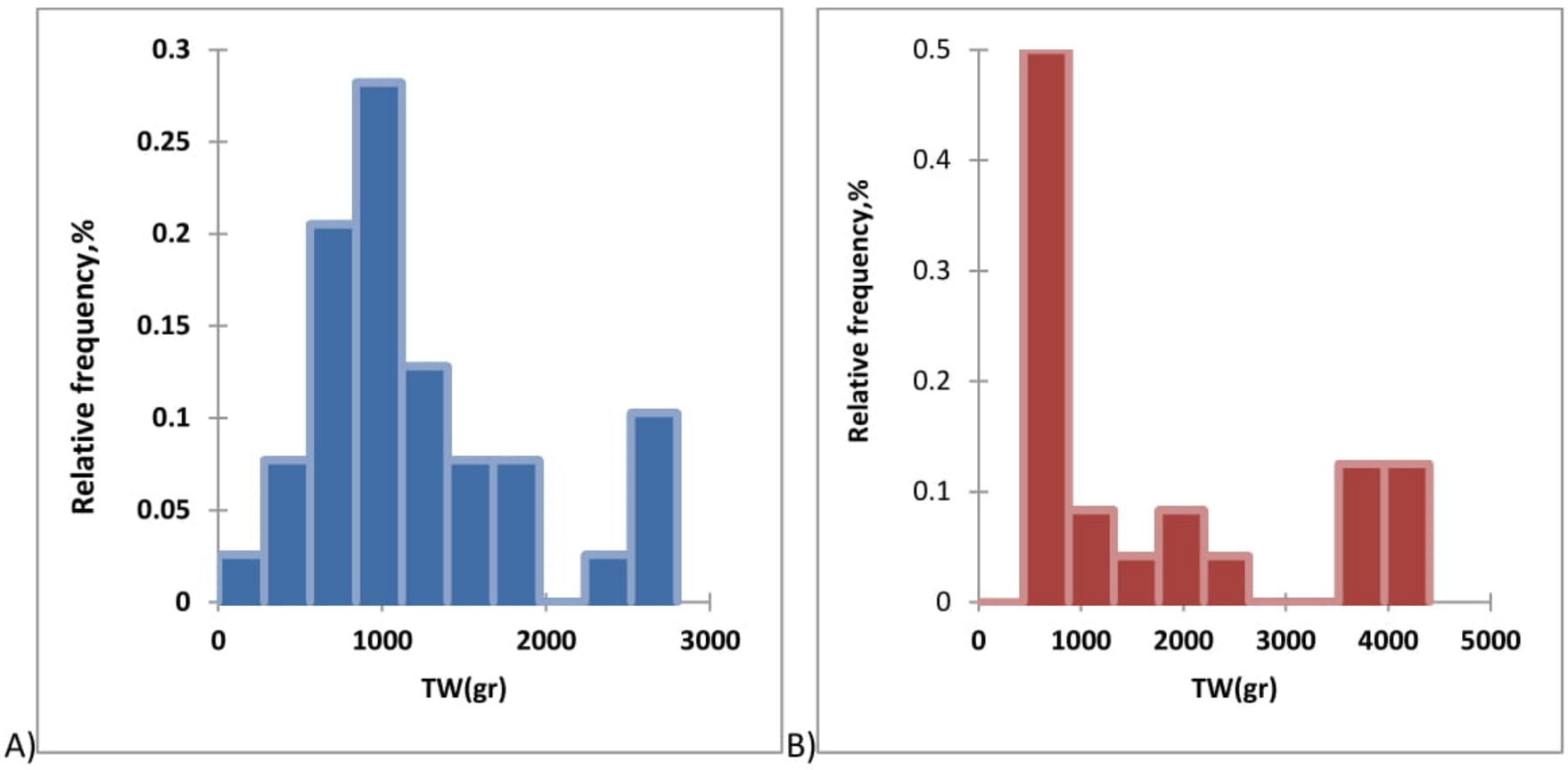

Figure 32 *Weight structure by sex of Raja clavata catches, A) female and B) male specimens;*

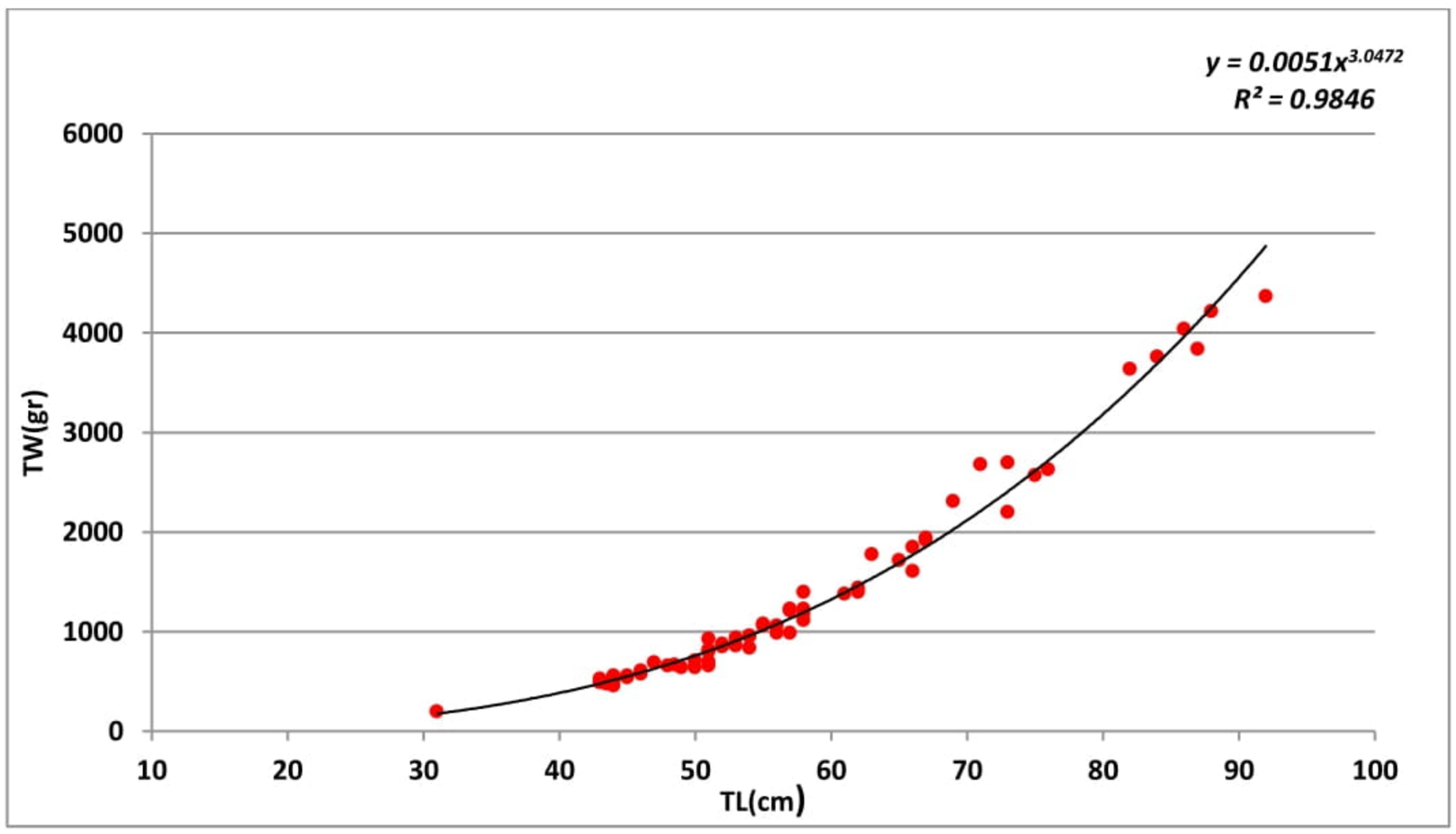

Figure 33 *Raja clavata: Length-weight relationships V, 2024;*

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At a depth of 75-100 m, a high catch of m. fox was recorded, and at this depth catch specimens with lengths between 50 - 65 cm (Fig. 34).

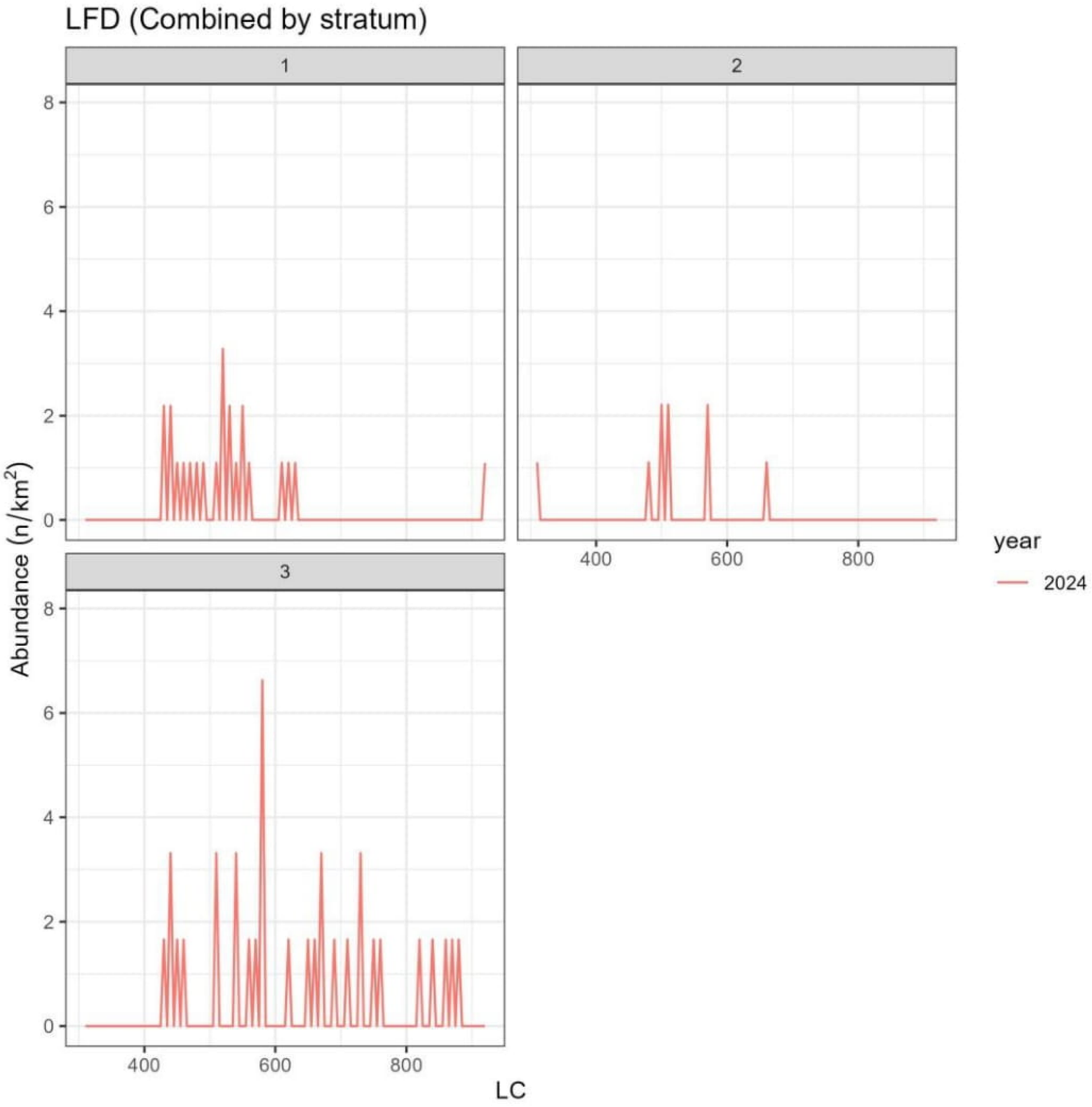

Figure 34 *Abundance (n/km^2) by length classes (LC, mm) and depth strata (1, 2 and 3) for V 2024;*

Mean relative biomass (kg/km2) and abundance (n/km2) distribution on a coordinate grid for thornback ray is shown in Fig. 35.

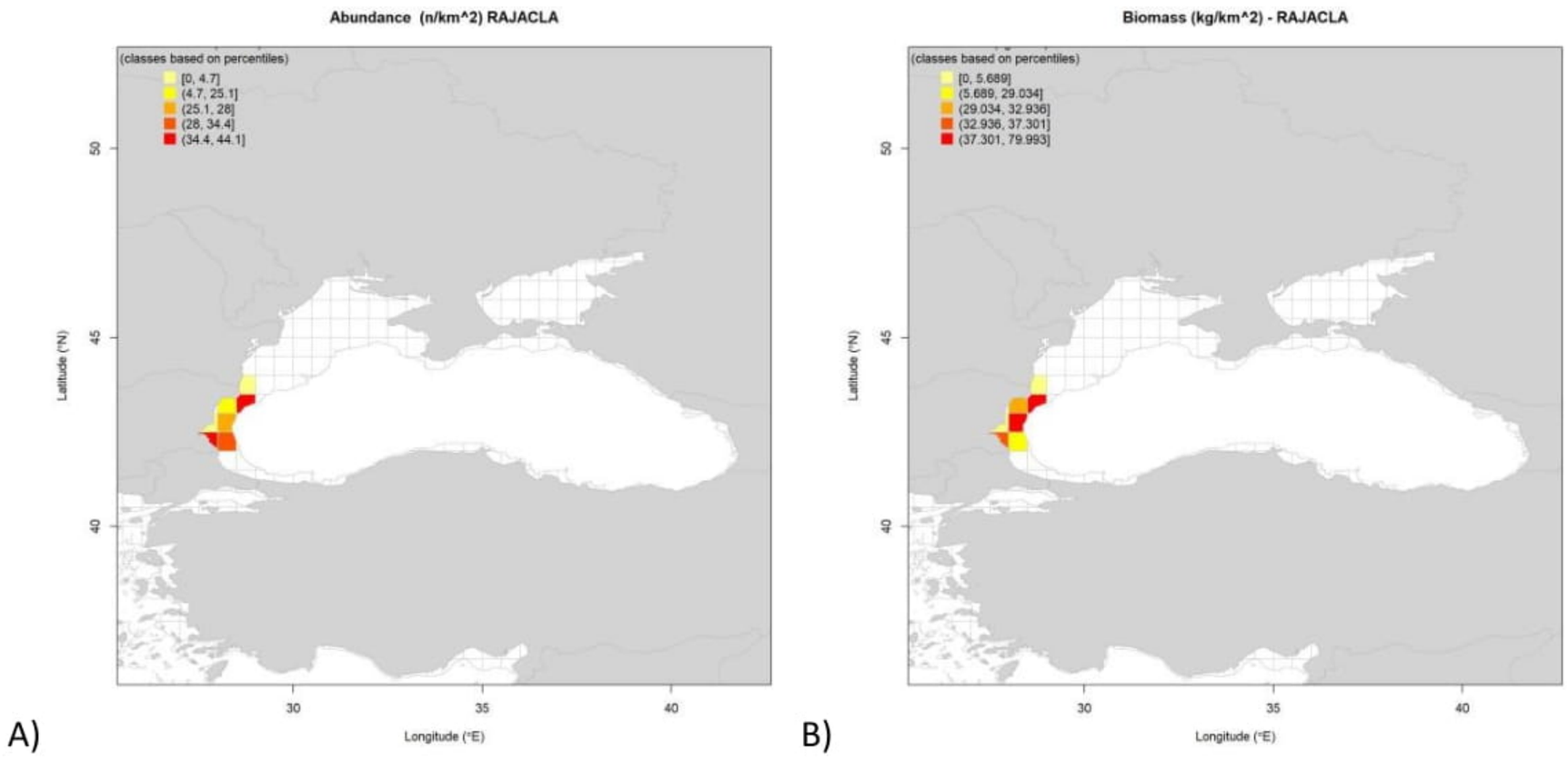

Figure 35 *Distribution of mean A) relative biomass (kg /km2) and B) abundance (n/km2) of Raja clavata in V 2024, according to the BioIndex version 3.3;*

The thornback ray biomass in the entire studied area in front of the Bulgarian coast of the Black Sea was estimated at **475.71** tonnes. The abundance was estimated at **341.94*10^3** specimens.

4. Food spectrum of *S. maximus*

During the summer season of 2024, 87 stomachs were analyzed to determine the diet spectrum of turbot. Nutritional components were found in 41.37% of the examined specimens, while 68.63% were without stomach content, indicating a higher percentage of non-feeding fish during this period. General statistical data for the measured biological parameters are shown in Table 10.

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Table 10

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

	L (cm)	W (gr)	Stomach content (gr)	ISF
Number	36	36	36	36
Sum	1911.50	97880.00	310.55	12.43
Minimum	43.00	1350.00	0.44	0.02
Mean	53.10	2718.89	8.63	0.345
Maximum	68.00	5120.00	30.60	1.14
Std. deviation	7.15	998.27	6.48	0.25
Median	50.50	2510.00	7.25	0.31
Kurtosis	-0.87	-0.53	2.25	1.25
Skewness	0.54	0.65	1.46	1.08
Std. Error	1.19	166.38	1.08	0.04

The mean fullness index of the turbot stomachs reaches 0.345% BW ± 0.04 SE (Table 9). ISF (% BW) values for the summer season of 2024 are shown in Fig. 36.

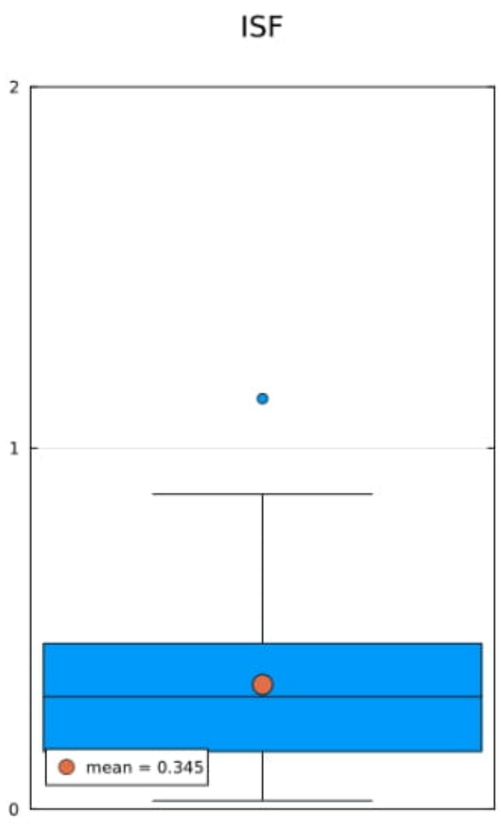

Figure 36 *Box-plot: ISF (% BW) values during the spring-summer of 2024.*

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The spatial distribution of the turbot stomach fullness index (Fig. 37) shows higher values in the northern part of the Bulgarian coast of the Black Sea.

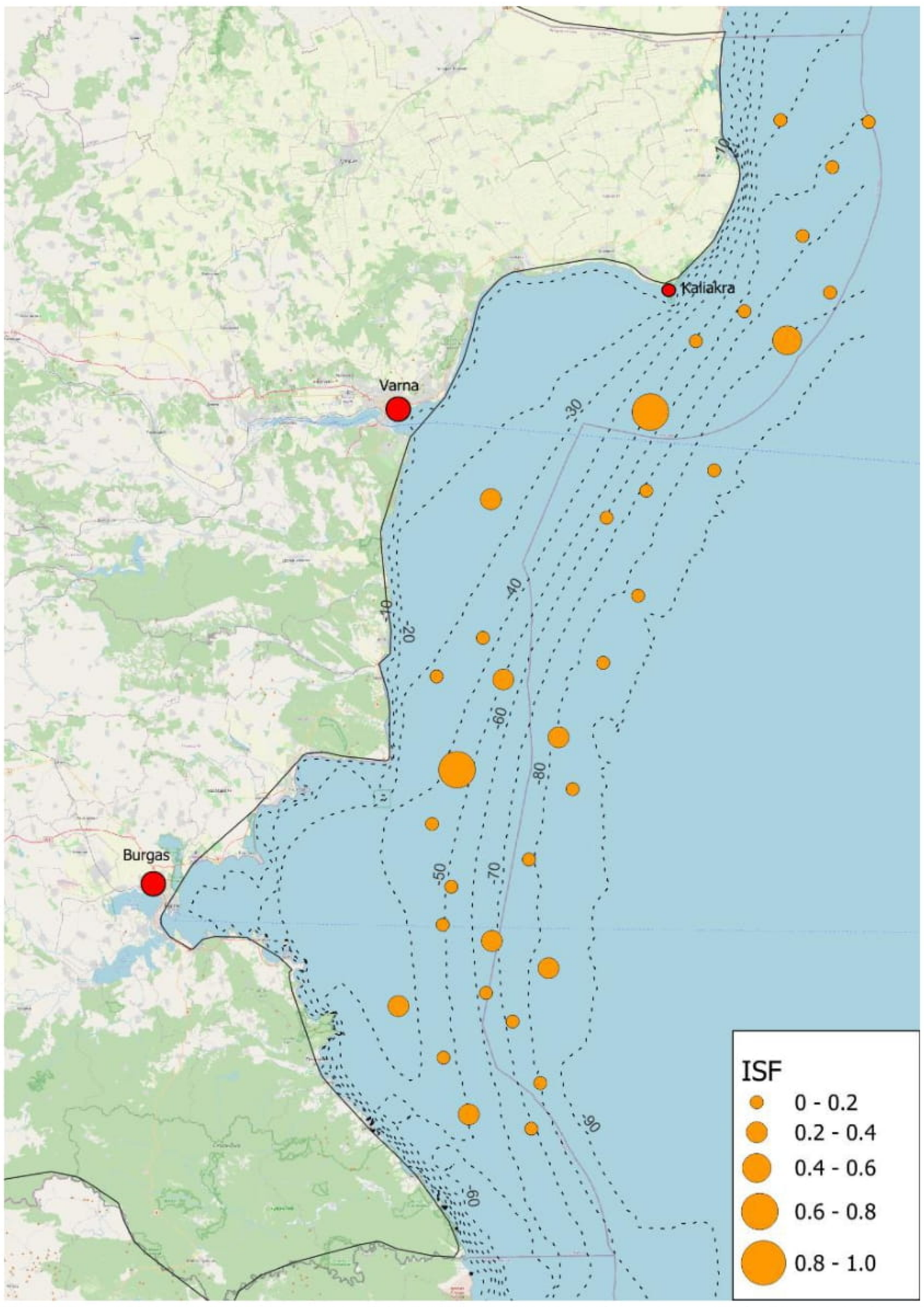

Figure 37 *Spatial distribution of the turbot stomach fullness index (ISF, % BW) during the spring-summer season of 2024.*

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Table 11

Qualitative composition of turbot diet during the study period.

Species	FO	CN	CB	IRI	IRI %
Merlangus merlangus	50.00	34.49	38.14	3631.58	37.77
Sprattus spattus	2.78	2.78	2.78	15.43	0.16
Mullus barbatus	2.78	0.93	2.19	8.66	0.09
Gobiidae sp.	13.89	6.94	6.88	192.06	2.00
Decapoda	27.78	9.79	9.85	545.50	5.67
Liocarcinus vernalis	16.67	2.38	2.33	78.54	0.82
Remains	63.89	42.69	37.82	5144.04	53.50

During the study period, the highest IRI value was for processed content – 5144.04 (53.50%). Three taxonomic groups were identified, with the dominant group being fish IRI=3847.73 (40.02%), followed by crustaceans Crustacea, IRI=624.04 (6.49%). Among the fish group, *Merlangus merlangus* traditionally predominates with the highest IRI=3631.58 (37.77%).

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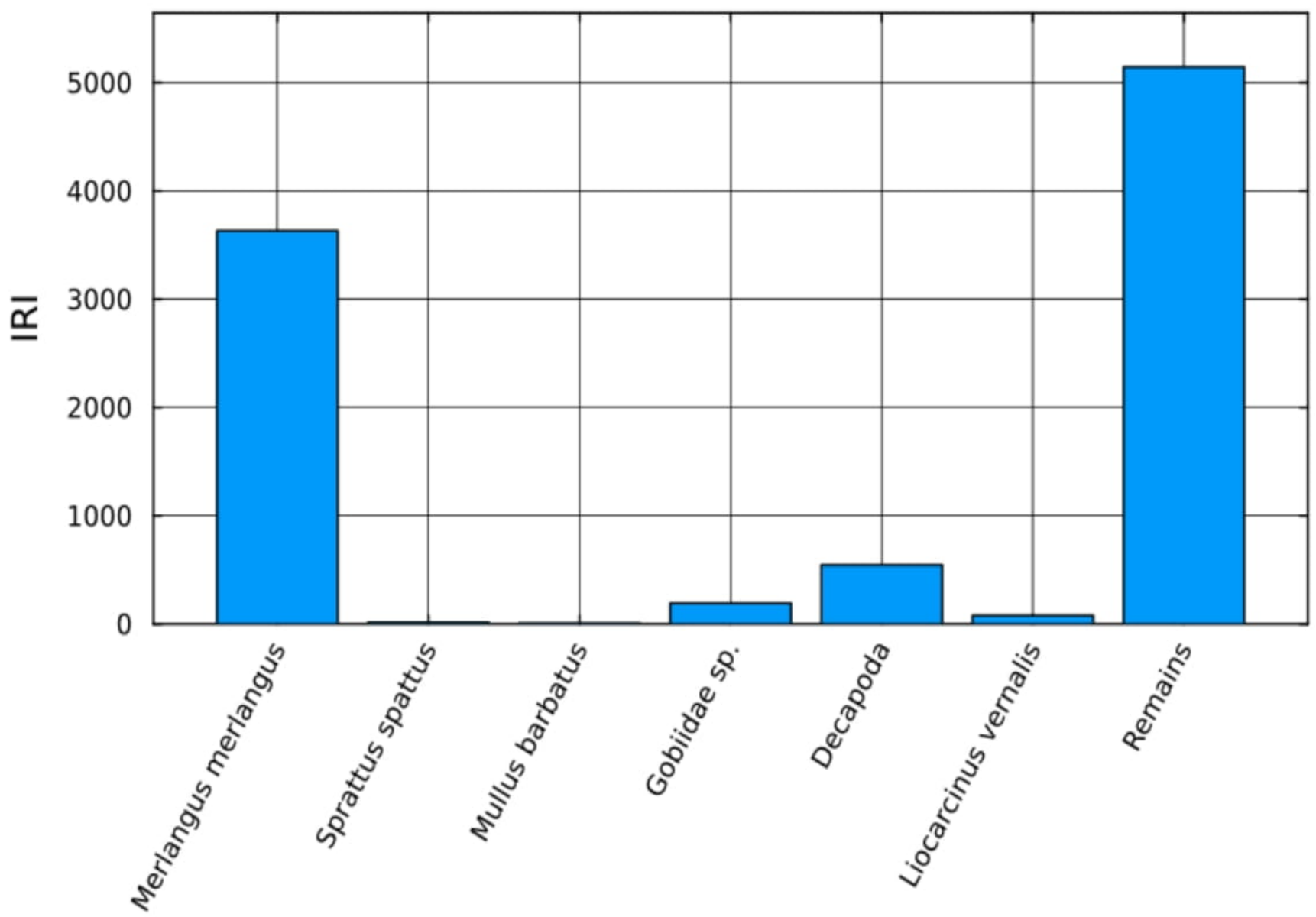

Figure 38 *IRI values by species during the spring- summer season of 2024.*

The percentage distribution of the different taxonomic groups according to % IRI is shown in Fig.39.

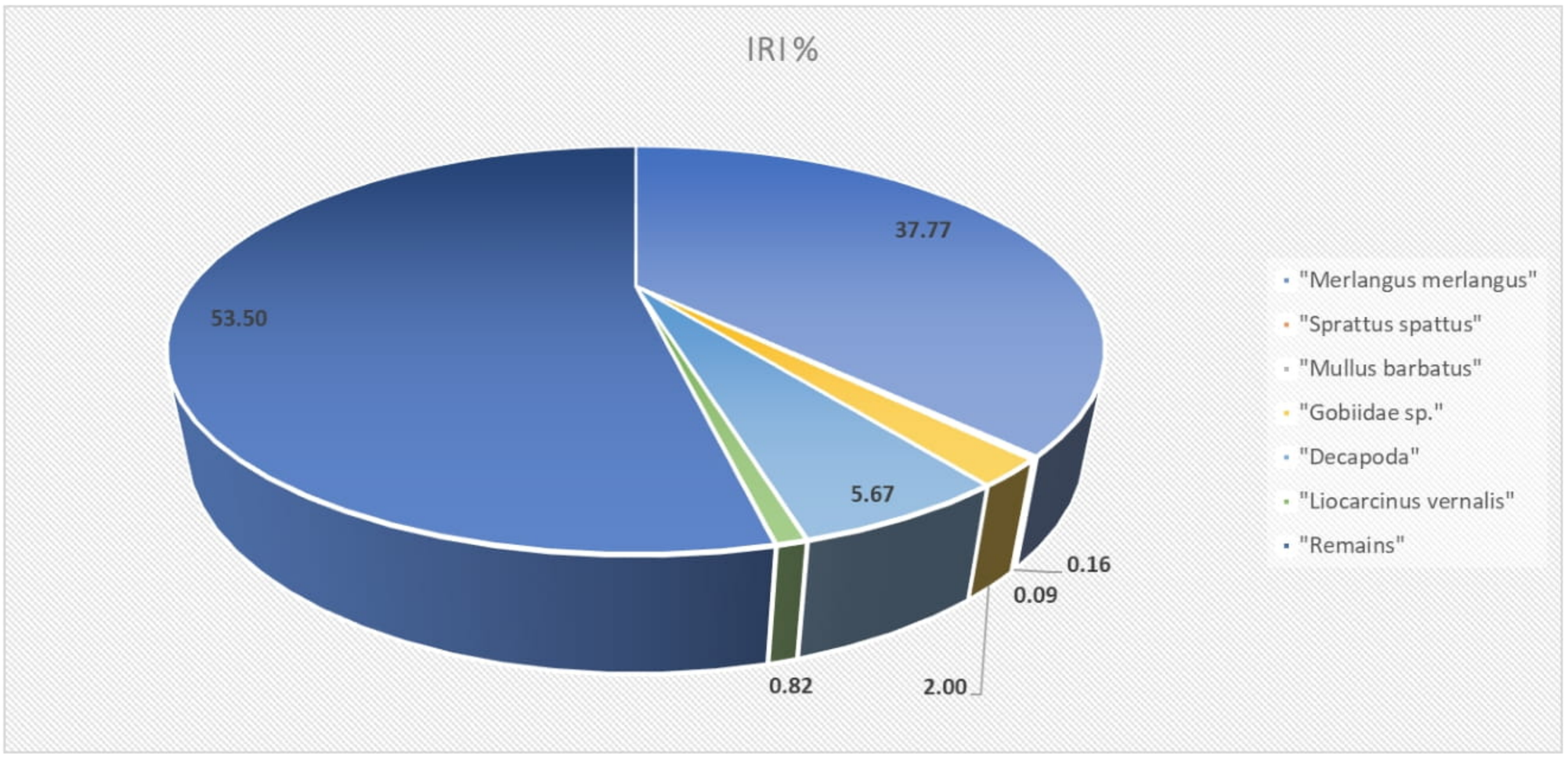

Figure 39 *Percentage shares by groups (% IRI) in the turbot diet spectrum during the spring-summer season of 2024.*

Additional species, diet spectrum

Along with the processed stomachs analyzed for the dietary spectrum of turbot during the spring-summer season of 2024, the dietary spectrum: of *Squalus acanthias*, *Raja clavata*, and *Merlangus merlangus* were also examined.

Piked dogfish (*Squalus acanthias*) - Black Sea shark (Squalus acanthias) - From the 9 stomachs analyzed to determine the diet spectrum, all specimens had stomach content. General statistical data for the measured biological parameters are shown in Table 12.

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Table 12

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

	L	W (gr)	Sum	ISF
Number	9	9	9	9
Sum	1100.00	69940.00	827.21	12.49
Minimum	109.00	5400.00	3.44	0.06
Mean	122.22	7771.11	91.91	1.39
Maximum	138.00	12660.00	262.23	4.36
Std. deviation	9.61	2889.53	83.62	1.49
Median	120.00	6270.00	96.69	0.83
Kurtosis	-0.93	-0.72	-0.12	-0.26
Skewness	0.46	0.97	0.91	1.06
Std. Error	3.20	963.18	27.87	0.50

The mean fullness index of the stomachs reaches 1.39% BW ± 0.50 SE (Table 11).

Thornback ray (*Raja clavata*) - 21 stomachs were analyzed, with stomach content found in 17 of them. General statistical data for the measured biological parameters are shown in Table 13.

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Table 13

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

	L	W (gr)	Sum	ISF
Number	17	17	17	17
Sum	942.50	19150.00	104.87	9.96
Minimum	46.00	610.00	0.11	0.01
Mean	55.44	1126.47	6.17	0.59
Maximum	69.00	2310.00	11.20	1.12
Std. deviation	6.81	497.67	3.27	0.30
Median	54.00	880.00	6.09	0.55
Kurtosis	-0.54	0.09	-0.85	-0.61
Skewness	0.68	1.15	0.05	-0.08
Std. Error	1.65	120.70	0.79	0.07

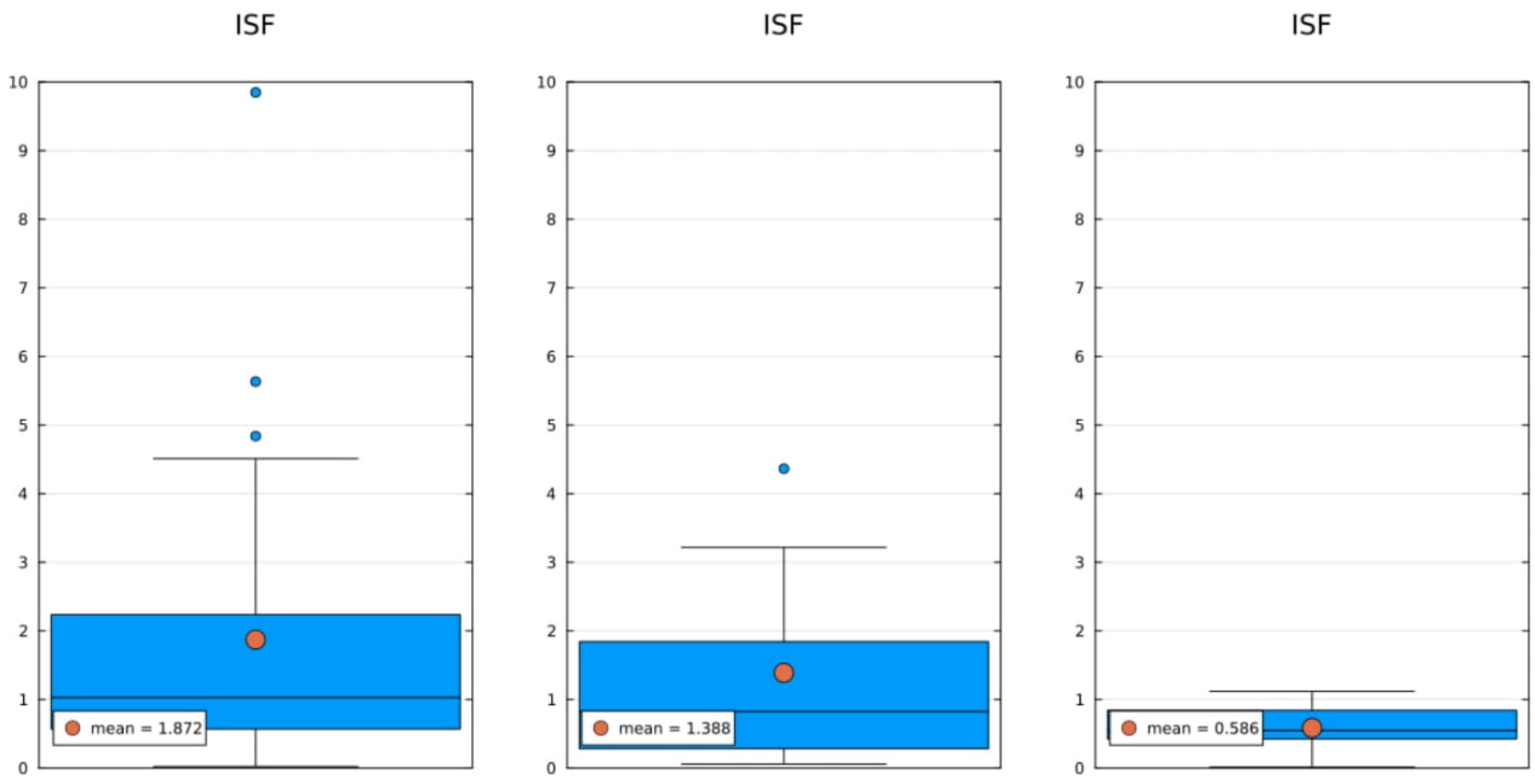
The mean fullness index of the stomachs reaches 0.59% BW ± 0.07 SE (Table 13).

Whiting – (*Merlangus merlangus*) – Whiting (Merlangus merlangus) - From the 110 stomachs analyzed, 52 had stomach content. The mean fullness index of the stomachs reaches 1.59% BW ± 0.57 SE. General statistical data for the measured biological parameters are shown in Table 14.

Table 14

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

	L	W (gr)	Sum	ISF
Number	52	52	52	52
Sum	620.10	524.67	10.94	97.34
Minimum	9.30	4.08	0.00	0.02
Mean	11.93	10.09	0.21	1.87
Maximum	14.40	17.46	1.67	10.10
Std. deviation	1.31	3.21	0.30	2.15
Median	12.10	10.19	0.09	1.03
Kurtosis	-0.73	-0.47	9.88	5.56
Skewness	-0.22	0.22	2.95	2.28
Std. Error	0.18	0.44	0.04	0.30



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a) b) c)

Figure 40 *Box-plot: ISF values for a) Squalus acanthias, b) Raja clavata u c) Merlangus merlangus, spring-summer 2024;*

The quality composition of the food spectrum of *Squalus acanthias, Raja clavata and Merlangus merlangus* is presented in tables 16, 17 и 18.

Table 16

Quality composition of food for *Squalus acanthias*

Видове	FO	CN	CB	IRI	IRI_%
Merlangus merlangus	188.89	38.15	29.99	12870.50	58.06
Mullus barbatus	11.11	2.78	0.63	37.90	0.17
Engraulis encrasicolus	11.11	2.22	0.30	28.06	0.13
Trachurus mediterraneus	11.11	2.78	0.77	39.47	0.18
Gobiidae sp.	11.11	2.78	0.35	34.79	0.16
Dolphin meat	55.56	15.56	41.76	3184.09	14.36
Upogebia pusilla	11.11	2.22	0.27	27.67	0.12
Remains	100.00	33.52	25.92	5943.90	26.82

Table 17

Quality composition of food for *Raja clavata*

Видове	FO	CN	CB	IRI	IRI_%
Merlangus merlangus	5.88	5.88	5.88	69.20	0.67
Sprattus spattus	17.65	4.41	3.59	141.15	1.38
Engraulis encrasicolus	5.88	1.96	1.19	18.53	0.18
Liocarcinus vernalis	23.53	8.82	4.69	317.97	3.10
Decapoda	70.59	53.43	58.14	7875.27	76.77
Remains	35.29	25.49	26.52	1835.53	17.89

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Table 18

Quality composition of food for *Merlangus merlangus*

Species	FO	CN	CB	IRI	IRI_%
Sprattus spattus	7.69	7.69	7.69	118.34	0.76
Crangon crangon	1.92	0.96	1.92	5.55	0.04
Syngnathus typhle	5.77	2.24	1.26	20.21	0.13
Decapoda	1.92	1.92	1.92	7.40	0.05
Remains	88.46	87.18	87.20	15426.00	99.03

The results of the qualitative analysis indicate that the species Squalus acanthias predominantly feeds on fish species, specifically whiting during the study period, which constitute IRI = 12870.50 (58.06%) and Remains IRI = 5943.90 (26.82%). In the diet of Raja clavata, species from two taxonomic groups were recorded - fish with IRI = 228.88 (2.23%) and Decapoda with IRI = 7875.27 (76.77%). For Merlangus merlangus, two taxonomic groups were also observed, respectively fish with IRI = 144.10 (0.93%) and crustaceans from Decapoda - IRI = 7.40 (0.05%). For this species, the processed content has the highest IRI = 15426.00 (99.03%). IRI values for the individual species making up the stomach content for the four species *Squalus acanthias*, *Raja clavata*, and *Merlangus merlangus* during the summer of 2024 are reflected in Figures 41, 42, and 43.

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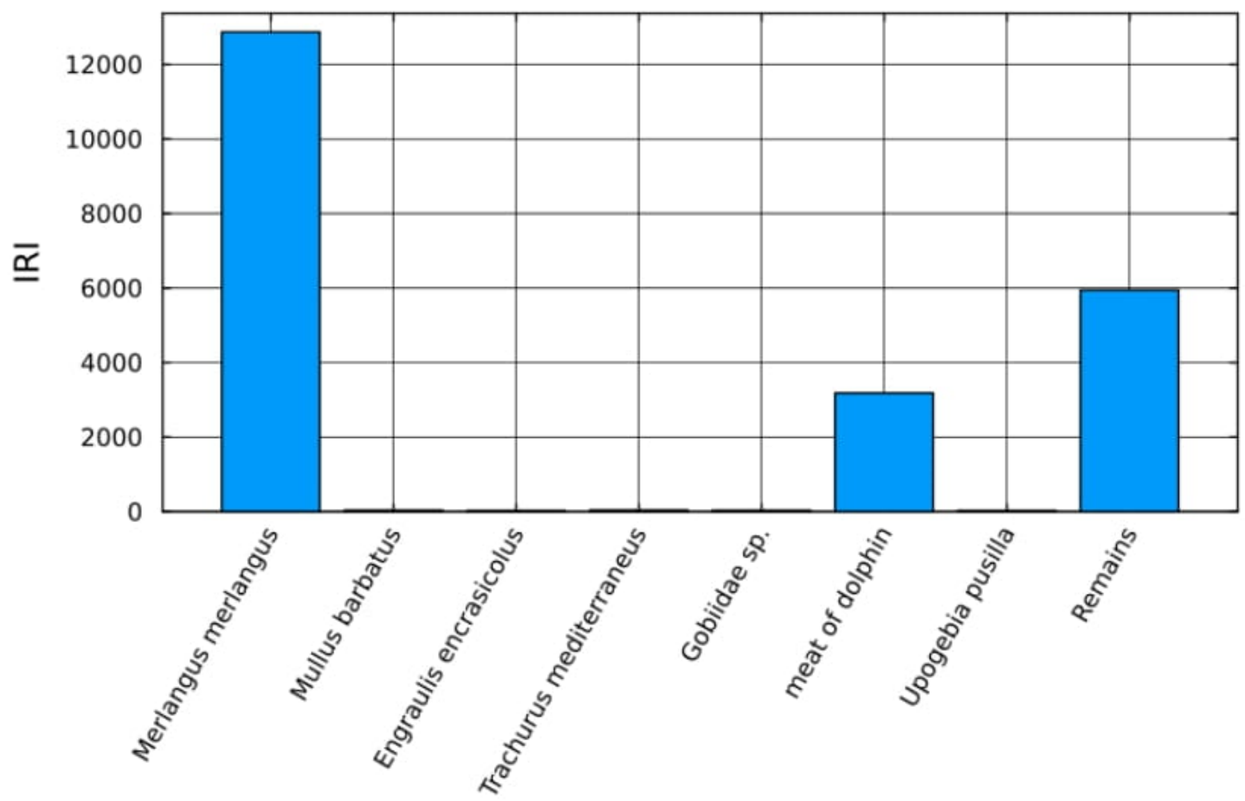

Figure 41 *IRI values by species during the spring-summer season of 2024 - Squalus acanthias;*

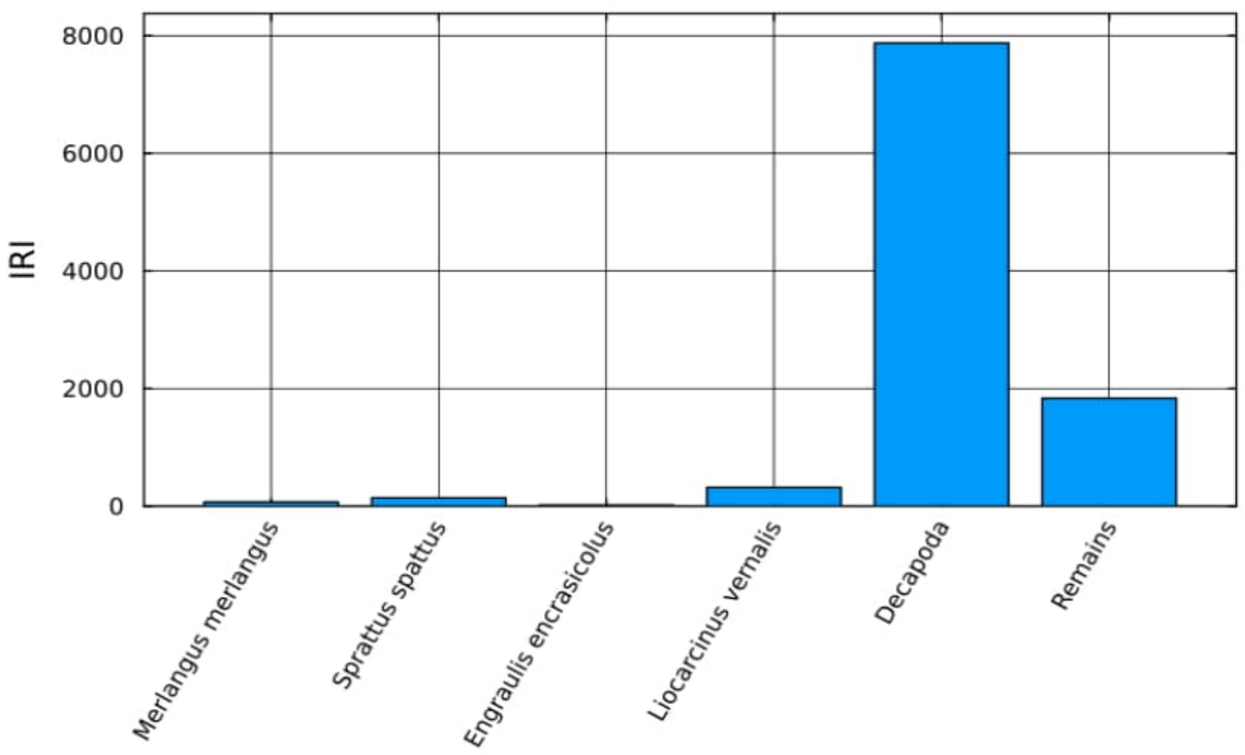

Figure 42 *IRI values by species during the spring-summer season of 2024.- Raja clavata*

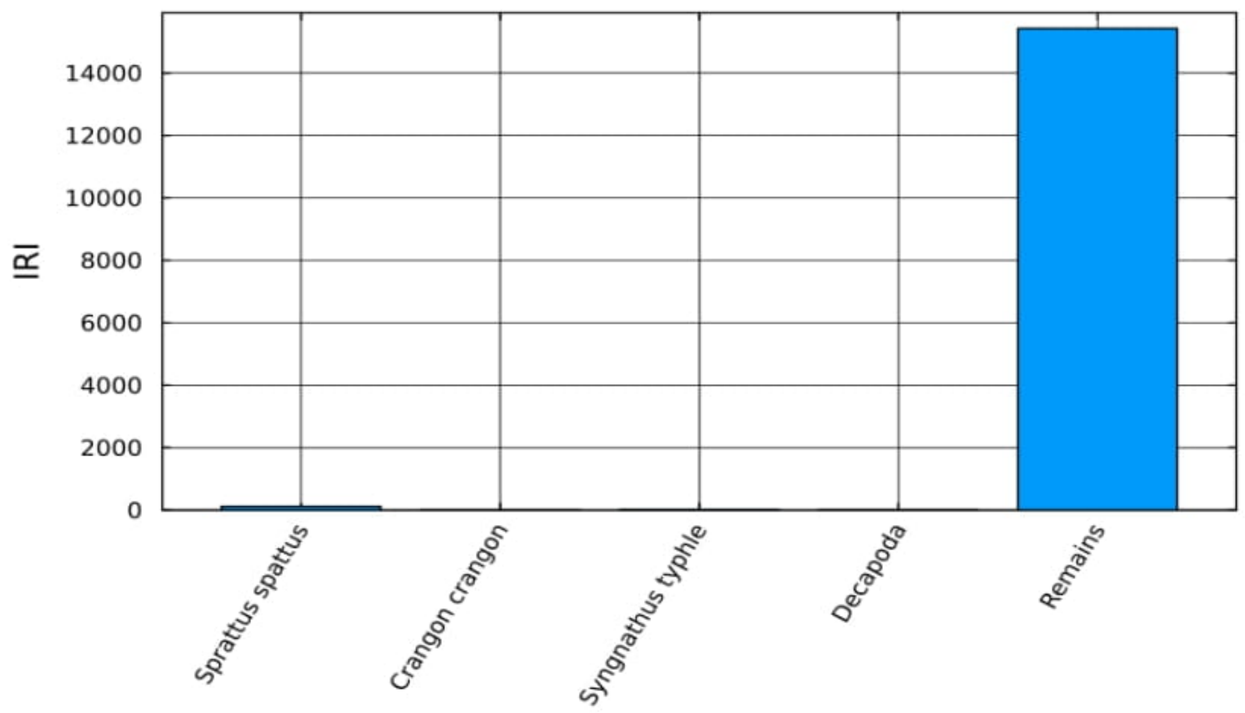

Figure 43 *IRI values by species during the summer season of 2024 - Merlangus merlangus*

5. Fecundity

The fecundity of 56 females was determined in May 2024. The average body weight was **2.84** kg, average total body length - **53.59** cm, and the average age - **6** years (Fig.44).

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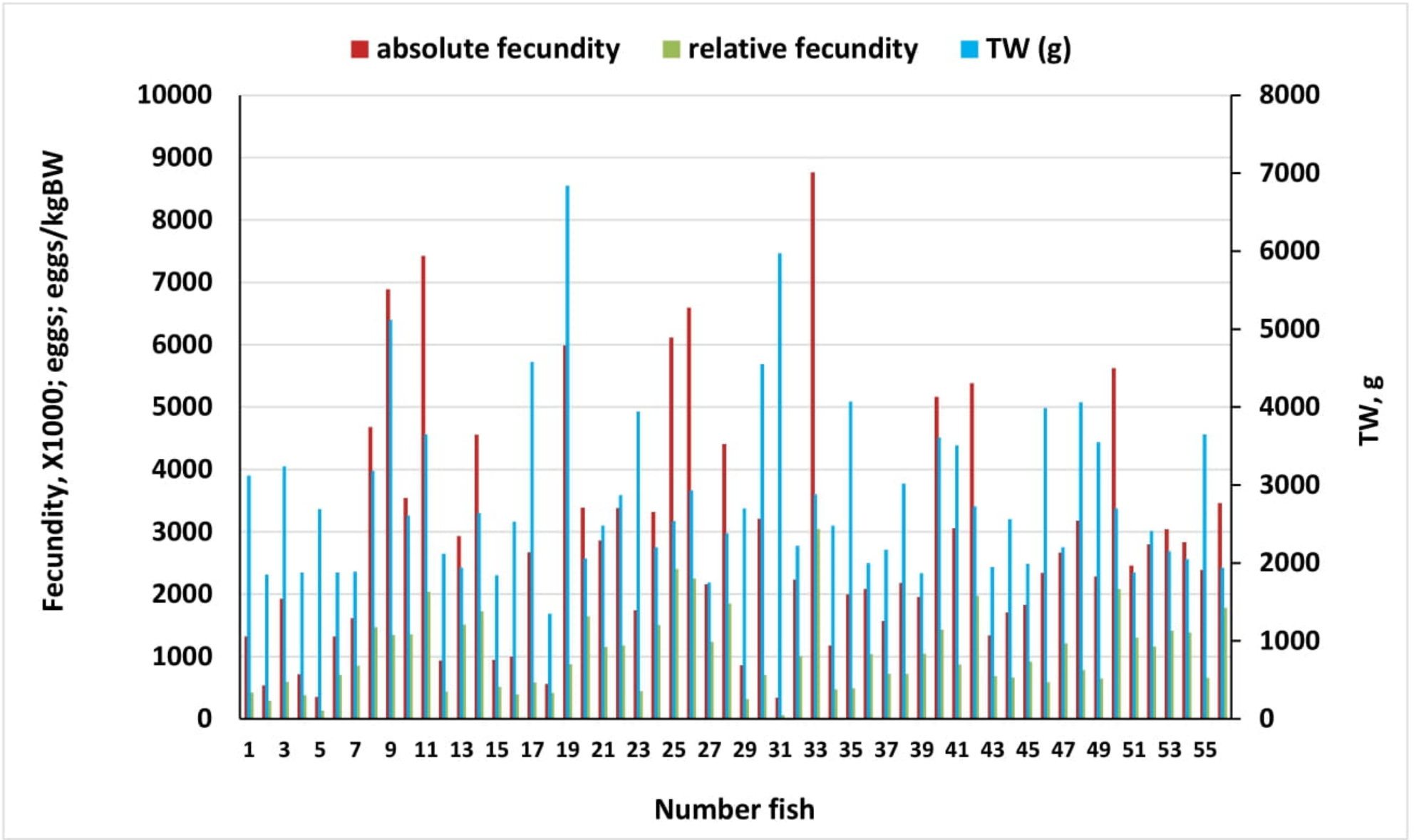

Figure 44 *Absolute and relative fecundity of female turbots, May 2024;*

The absolute fecundity for May 2024 is 2 889 752.4 caviar grains, and the relative fecundity is 1 051 982.8 caviar grains (Tab. 18).

Table 18

Values for absolute and relative fecundity of **turbot V 2024.**

Indicator	Average values
Number of female fish	56
Full body length, TL (cm)	53.59
Body weight, BW (g)	2 839
Absolute fecundity ($x10^3$), eggs/ individual	2 889 752.4
Relative fecundity ($x10^3$), eggs /kg BW	1 051 982.8
Age, year	6

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Absolute fecundity in the current study (2 889 752.4 eggs/individual) exceeded that reported by Aydin & Sahin (2011) by 335 252.4 eggs/individual (2 554 500 eggs/individual) and surpassed the findings of Aydin et al. (2019) by 489 752.4 eggs/individual (2 400 000 eggs/individual). A comparison of the present results with existing literature indicates that the established fecundity of turbot in May is consistent, exhibiting no significant deviations. This consistency can be attributed to the fact that samples from the referenced studies were collected immediately prior to or during the breeding period (May), similar to the methodology employed in the current study.

Current turbot fecundity results are comparable to those determined by IRR, Varna (2 487 522.1 eggs/individual) in 2021, also collected in May during the spawning season.

Weather conditions during the survey

During the expedition activity, the dominant wind directions were West, Northeast and Southeast, exhibiting a force of 1-2 on the Beaufort scale along the coast and 2-3 in the open sea.

In the spring-summer season of 2024, the field conditions were normal for conducting research activities for turbot stock assessment in the Bulgarian Black Sea waters.

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6. Conclusions and recommendations

From the collected information and results obtained from the trawl survey in spring-summer, 2024 the following conclusions and recommendations can be made:

- The turbot biomass in the entire studied area in front of the Bulgarian coast of the Black Sea was estimated at **1506.97** tonnes (Table 4). The abundance in the studied area was estimated at **840.44*10^3** specimens (Table 4).
- The recommended **MSY (maximum sustainable yield)** for Bulgaria will be calculated and incorporated into the autumn-winter report, encompassing data from both trawl surveys conducted in the spring and the autumn-winter season of 2024.
- The size structure of the turbot population, in the Bulgarian Black Sea zone included length classes from **19** cm to **72** cm were observed, with weights varying between **720** g and **5970** g. The average weight of the turbot was estimated at **1793.07** g. Individuals measuring less than 45 cm constituted 46.15% of the total population, while those exceeding 45 cm accounted for 53.85%.
- The age composition of the population included age classes from 1 to 10 years, with a predominant presence of 2-year-olds (27.81%), 3-year-olds (19.53%), and 4-year-olds (21.89%), collectively accounting for 69.23%. This is followed by 5-year-old specimens, which represent 15.98%.
- The established ratio of female, male, and immature individuals in the catch is **40.83%:13.02%:46.15%.**
- The recorded fecundity of turbot in May 2024 is 2 889 752.4 caviar grains per individual. Current turbot fecundity results are nearing those observed in 2021, which recorded 2 487 522 spawn per individual, also sampled in May.
- M. merlangus is widely distributed, with significant concentrations noted in the northern regions, particularly between Durankulak and N. Kaliakra at depths of 55 to 65 meters, and

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in the southern areas from N. Emine to Tsarevo (30-85 meters). The average biomass index (CPUE) for *M. merlangus* is 87.5 kg/h, with peak values recorded off the southern coast, reaching up to 200 kg/h. The catches predominantly consist of size classes measuring 10.5 to 15 cm, with a notable predominance of females.

- The spatial distribution of the target bottom cartilaginous fish species is as follows: *S. acanthias* are primarily observed between Kaliakra and Emine (25-34 m); *Pl. flesus* clusters are located in the northern section of the Bulgarian coast near Shabla and in the southern area near Byala, at depths of 51-63 m. Representatives of *R. clavata* are noted in front of Varna at depths of 82-86 m.
- The whiting biomass in the entire studied water area off the Bulgarian coast of the Black Sea is estimated at **16680.39** tonnes, with an abundance of approximately **1172.39*10^6** million specimens. The calculated biomass of the thornback ray in the same area is **475.71** tonnes, and its abundance is estimated at **341.94*10^3** thousand specimens. Accurate estimation of biomass and abundance for these species is challenging due to their patchy and highly scattered distribution. Consequently, the CPUE biomass estimation method may yield inaccuracies. The current biomass of the dogfish in this water area is estimated at **3732.85** tonnes. For the studied period, the total abundance for the entire area was estimated at **531.30*10^3** individuals.
- In the summer season of 2024, 87 stomachs were analyzed to determine the diet spectrum of turbot and a total of 140 stomachs from additional species - Squalus acanthias, Raja clavata, and Merlangus merlangus. The qualitative composition of the turbot diet shows the presence of three taxonomic groups: fish, Crustacea, and Bivalvia, forming an IRI value of 4471.60 or 46.51%, with the remaining 53.49% being Remains. For the additional three fish species (Squalus acanthias, Raja clavata, Merlangus merlangus), the qualitative composition is mainly formed by two groups - fish and crustaceans.

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