

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 autumn-winter season of 2025.

Agricultural Academy
Institute of Fish Resources (IFR, Varna)

2025

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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 № 153/27.03.2025 with the Executive Agency for Fisheries and Aquaculture (EAFA), for turbot stock assessment in the Bulgarian Black Sea waters during the autumn-winter period of 2025.

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 29 November - 19 December 2025 in the Bulgarian Black Sea waters on board 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.

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BOTTOM TRAWL SURVEY FOR STOCK ASSESSMENT OF REFERENCE BOTTOM SPECIES IN BULGARIAN BLACK SEA SECTOR DURING AUTUMN-WINTER SEASON OF 2025

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BOTTOM TRAWL SURVEY FOR REFERENCE STOCK ASSESSMENT IN BULGARIAN BLACK SEA SECTOR DURING AUTUMN-WINTER SUMMER SEASON OF 2025

1. Results from the National Bottom Trawl Surveys in XI-XII 2025

During 29 November – 19 December 2025, under contract number 153/27.03.2025 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 the 100 m isobath.

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. The analyses conducted on turbot included assessment of biomass and density by depth strata, analysis of the stock's size, age and sex structure, calculation of length–weight relationships and von Bertalanffy growth parameters, and analysis of the diet composition of turbot. Analyses of *Merlangius merlangus* included the study of the size-age and sex structure, calculation of length-

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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;
- Gross tonnage – 38.24t;
- Net tonnage – 11.43 t;
- Speed – 9.5 Nd;
- Crew - 3 people;
- Research team: Three people.

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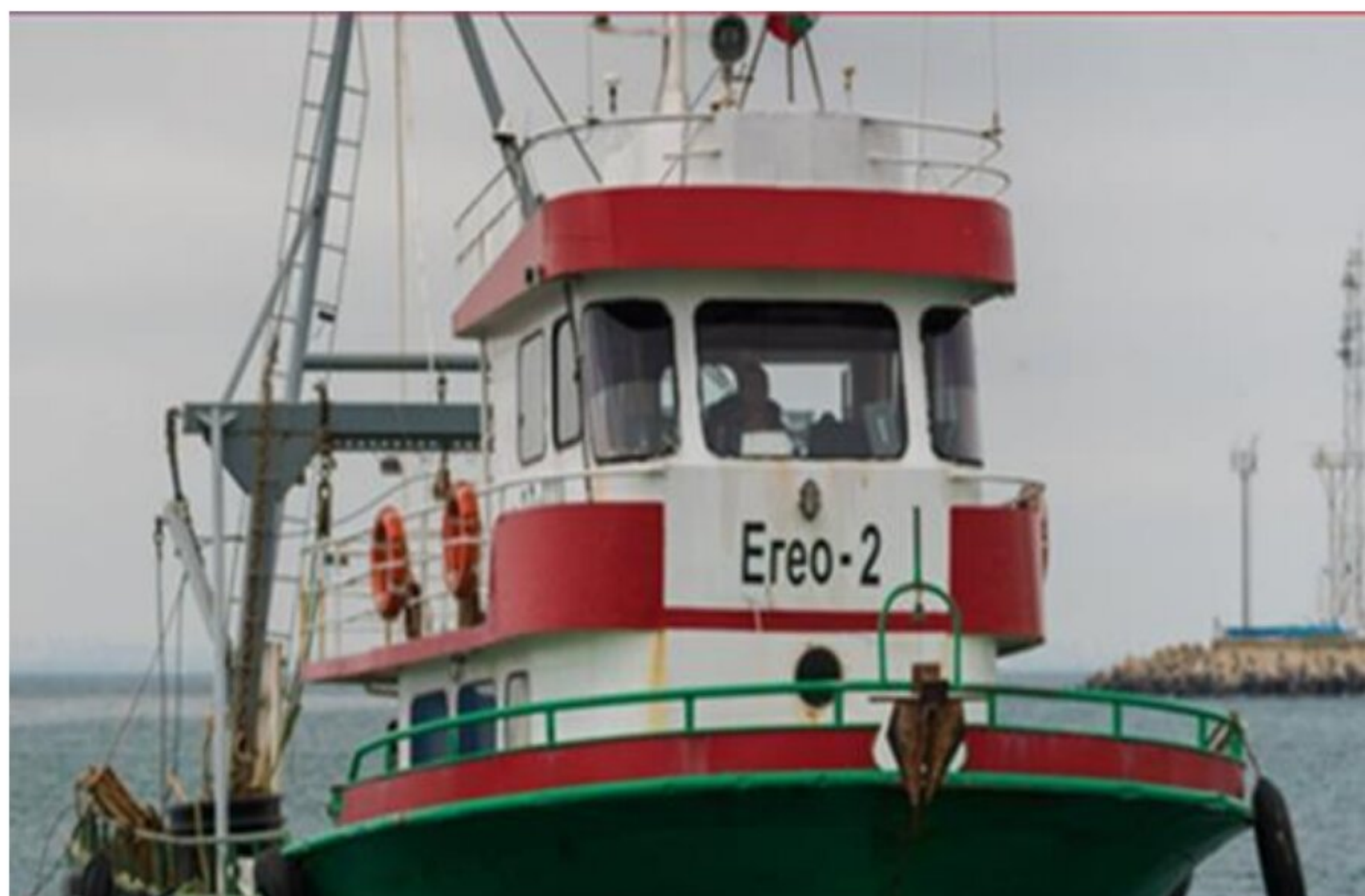
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Picture 1. Fishing ship „EGEO2”.

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.

Stratified sampling

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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/km²) were used.

The results are presented in the form of maps and tables that include the following data.

- Survey area (km²);
- Catch per unit effort (kg/trawl)
- Catch per unit area (t/km², kg/km²);

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- Abundance index (individual/km²);
- 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 Nm² (or 85.85 km²). 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 km² (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 2.4 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 autumn-winter season of 2025, 84 stomachs were analyzed to determine the food spectrum of turbot, and a total of 28 stomachs from additional species - *Squalus acanthias* and *Raja clavata*. 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>,

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<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/km², n/km²)

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:

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

$x_{i,j}$ is the weight of individuals caught in the individual hauls of the stratum and $A_{i,j}$ is the corresponding swept area. Variance was calculated using the following formula:

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

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

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$$I = \sum_{i=1}^N W_i \bar{X}_i$$

W_i 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:

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

where f_i 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:

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

and the Coefficient of Variation is.

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

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

$$\text{CPUE} = \text{yield/effort}$$

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Maximum sustainable yield

Gulland's formula for virgin stock is

$$MSY = 0.5 * M * B_v$$

M – coefficient of natural mortality, B_v- 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:

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

$\bar{B}$ - Mean annual biomass, Z = total mortality.

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

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

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

TAC - total allowable catch, Prediction models

Beverton and Holt yield per recruit model (1957):

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

$S = \exp [-K (T_c - t_0)]$, K = von Bertalanffy growth parameter, t_0 = von Bertalanffy growth parameter, T_c = age at first capture, T_r = 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.

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Jones' Length-Based Cohort Analysis (1981)

Jones' length-based cohort analysis:

$$\exp\left(\frac{M}{2} \Delta t\right) = \exp\left[\frac{M}{2} \cdot \frac{1}{K} \cdot \ln\left(\frac{L_{\infty} - L_1}{L_{\infty} - L_2}\right)\right] = \exp\left[\ln\left(\frac{L_{\infty} - L_1}{L_{\infty} - L_2}\right)^{M/2K}\right] = \left[\frac{L_{\infty} - L_1}{L_{\infty} - L_2}\right]^{M/2K}$$

Age and growth

To estimate the turbot growth rate, the von Bertalanffy growth function (1938) was applied according to Sparre and Venema (1998):

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

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

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_0 - 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: $K = 100 \cdot (W/L^3)$, where: W - weight, L - length.

Natural mortality (M)

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

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

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

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L_{∞} , W_{∞} and k – parameters in von Bertalanffy's equation; $T^{\circ}\text{C}$ - 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, the following activities were conducted:

- 38 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 155 specimens of turbot, 24 european flounder, 284 thornback ray and 18 spiny dogfish specimens (Pictures 4 and 5);

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Pictures 3. Bottom trawling yield

The constant presence of the species *S. maximus* in almost all bottom trawls at a depth of between 50-75 m has been established, when catching - at least 2-5 specimens per trawl (at catch $\neq 0$). At depths - 75-100 m., the average recorded catch is low, and at 15-50 m, the average catch from turbot increases. In seven sectors, the highest catch was obtained, which ranged between 20.7-36.38 kg/trawl.



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Photo 4. Catch of turbot (*Scophthalmus maximus*) and accompanying species - *Merlangius merlangus* (whiting), *Mullus barbatus* (red mullet), *Raja clavata* (thornback ray) and spiny dogfish (*Squalus acanthias*);

During the study, 18 specimens of spiny dogfish (*Squalus acanthias*) were caught and measured, and their size ranged from 60 cm (0.910 kg) to 135 cm (12.4 kg) (photo 4). In addition to turbot catches, relatively high quantities of whiting (*Merlangius merlangus euxinus*) and thornback ray (*Raja clavata*) have been identified. Companion species also include plaice (*Platichthis flesus*) and red mullet (*M. 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 covers three stations and due to their small number, they are grouped together with the stations up to 50 m, and the statistical analysis was carried out on a stratum of 15 - 50 m. The instantaneous biomass of the three stations with a depth of up to 30 m reaches respectively - 148.67 kg/km², 63.48 kg/km² and 69.48 kg/km², with abundance - 63 ind./km², 102 ind./km² and 51 ind./km². High catches at the stations at shallow depth are realized in front of Kavarna and Shkorpilovtsi (Table 1, Fig. 2).

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The average value of the relative biomass of turbot is high in a stratum of 50-75 - 267.8 kg/km² and respectively the average abundance is 107 specimens/km², and in a stratum of 15-50 m, the average relative biomass remains lower - 129.2 kg/km² and the average abundance - 61 specimens/km², (Table 1, Fig. 2 and Fig. 3).

Information on the yields by stratum is provided below.

Stratum 15-50 m

In this stratum, the mean value of the relative biomass varies 7 - 362 kg/km², with an average of 129 kg/km² (Table 1, Figs. 2 and 3). Abundance indices vary between 17 and 154 specimens/km², average - 61 specimens/km² (Tab. 2).

Stratum 50 -75 m

Turbot relative biomass in this stratum is high, ranging from 81 to 620 kg/km² and averaging 268 kg/km² (Tab. 1, Figs. 2 & 3). Abundance ranges from 34 to 204 individuals/km², averaging 107 individuals/km² (Tab. 2).

Stratum 75-100 m

In this stratum, the average value of the relative biomass is between - 0 - 502 kg/km², the average is 95 kg/km² (Tab. 1, Fig. 2 and 3), and the average value of the abundance is 28 specimens/km² (Tab. 2).

Table 1

Relative biomass of turbot (kg/km²) by stratum, November-December 2025.

15 - 50 m		50 – 75 m		75-100 m	
No. station	kg/km ²	No. station	kg/km ²	No. station	kg/km ²
4	148.67	18	94.60	20	60.46
1	63.48	37	168.34	23	502.36
16	69.48	6	322.73	9	110.68
2	272.60	13	402.91	29	84.51
3	82.12	12	107.25	14	0
38	47.40	15	180.32	10	0
33	46.21	7	151.37	21	0
17	45.66	35	321.86	25	0
36	7.68	30	80.89		
32	7.10	27	378.67		
19	206.94	8	215.05		
34	41.52	11	279.76		
22	182.03	24	425.62		
5	354.91	26	619.65		
31	361.89	28	0		
Total	1938	Total	3749	Total	758
Average	129	Average	268	Average	95
Standard error	31		41		60
Median	69		247		30
Standard deviation	120		154		171
Sample variance	14492		23841		29084

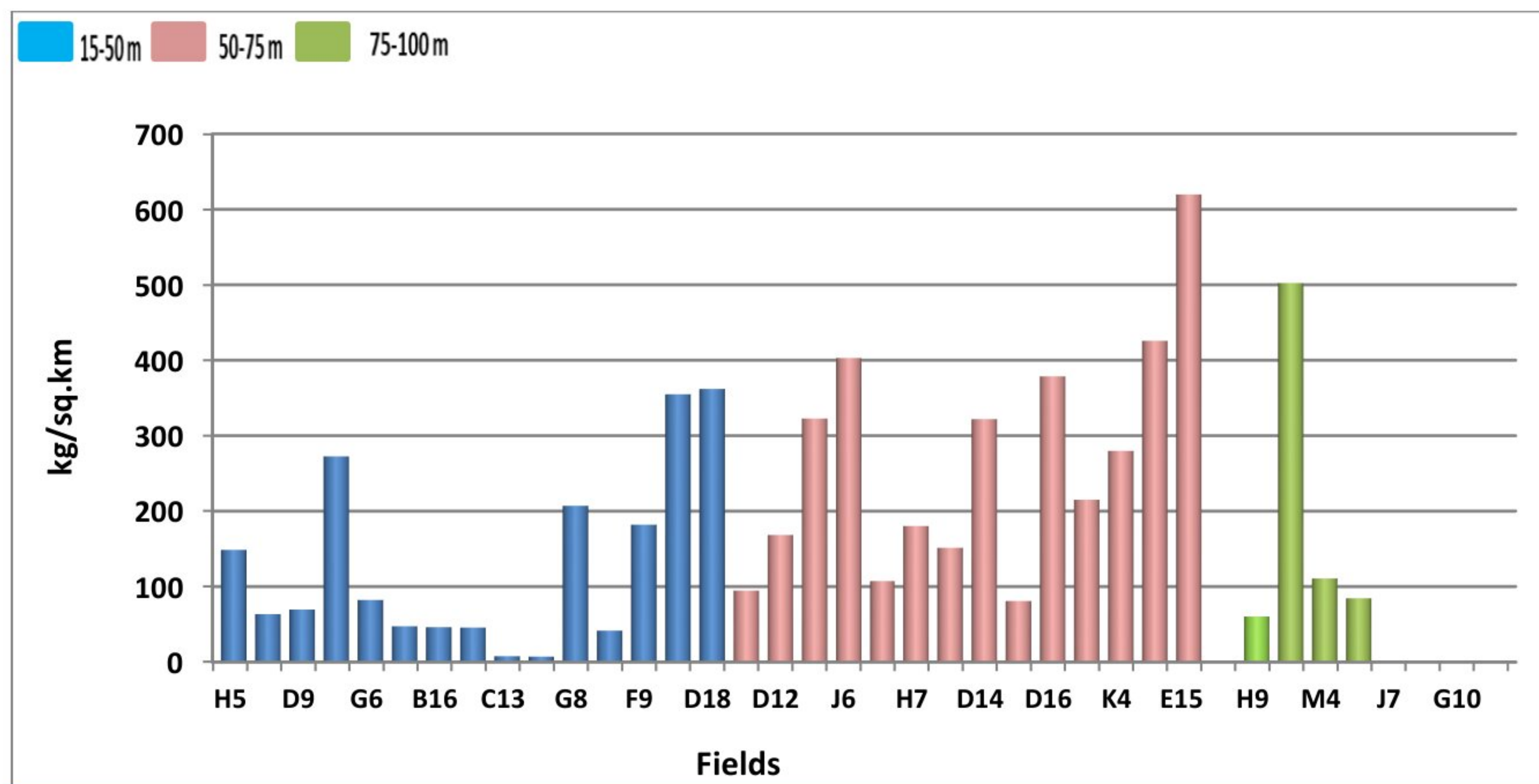


Figure 2 Relative biomass (kg/km²) of *S. maximus* by strata off the Bulgarian Black Sea coast, XI-XII 2025

Table 2 presents detailed data on turbot abundance by strata in November-December 2025.

Table 2

Abundance of *S. maximus* by stratum in November-December 2025.

15 - 50 m		50 – 75 m		75-100 m	
No. station	No. Ind./km2	No. station	No. Ind./km2	No. station	No. Ind./km2
4	63	18	34	20	
1	102	37	85	23	
16	51	6	185	9	
2	85	13	204	29	
3	51	12	34	14	
38	17	15	69	10	
33	68	7	68	21	
17	17	35	102	25	

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36	17	30	34		
32	17	27	137		
19	86	8	69		
34	17	11	120		
22	85	24	154		
5	154	26	204		
31	85	28	0		
Total	916	Total	1499	Total	
Average	61	Average	107	Average	
Median	10		16		
Standard error	63		94		
Standard deviation	40		62		
Sample variance	1616		3786		

3.2. Catch per unit effort (CPUE)

The catches, from a total of 38 trawls, are distributed as follows:

17 trawls (44.74%), catch 0 - 4.99 kg per trawl;

6 trawls (15.79%), catch 5.0 - 9.99 kg. per trawl;

4 trawls (10.53%), catch 10.0 - 15.99 kg per trawl;

11 trawls (28.95%), catch 16.0 - 36.99 kg per trawl;

Sector < 30 m; 5 trawls:

- o 5 trawls, catch 3.0 – 16.99 kg per trawl;

Sector 31 - 50 m; 10 trawls:

- o 6 trawls, catch - 0.1 - 4.99 kg per trawl;

- o 4 trawls, catch - 10.0 - 20.99 kg per trawl;

Sector 50 – 75 m; 15 trawls:

- o 5 trawls, catch 0 - 4.99 kg per trawl;

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- o 5 trawls, catch 5.0 - 15.99 kg per trawl;
- o 5 trawls, catch 16.0 -36.99 kg per trawl;

Sector 75 – 100 m; 8 trawls:

- o 6 trawls, catch 0 - 4.99 kg per trawl;
- o 2 trawls, catch 5.0 - 29.99 kg per trawl;

The data on catch per unit effort (CPUE) during the expedition in XI-XII/2025 were presented in Table 3 and Fig.3.

Table 3

The sampling stations, coordinates and CPUE (kg/trawl) in November-December 2025

№	Field	Starting coordinates		Depth (m)	Speed (Nm)	Trawling time (min)	Catch turbot	
		ϕ	λ				№	Kg
1	E8	4305.08	2805.63	24	2.4	60	6	3.73
2	F7	4306.34	2810.1	27.5	2.4	60	5	16.03
3	G6	4310.59	2815.26	29.5	2.4	60	3	4.85
4	H5	4318.12	2823.56	22	2.4	60	4	9.43
5	L1	4337.18	2841.43	49	2.4	60	9	20.74
6	N1	4339.44	2851.22	56	2.4	60	11	19.22
7	M2	4334.7	2849.84	63	2.4	60	4	8.91
8	L3	4328.48	2843.81	66	2.4	60	4	12.43
9	M4	4324.51	2846.54	75	2.4	60	1	6.5
10	L5	4319.5	2844.04	80	2.4	60	0	0
11	K4	4322.18	2839.53	69	2.4	60	7	16.34
12	J5	4319.2	2834.86	62	2.4	60	2	6.32
13	J6	4314.90	2829.52	57	2.4	60	12	23.65
14	J7	4309.82	2830.46	78	2.4	60	0	0
15	H7	4306.88	2823.58	62	2.4	60	4	10.48
16	D9	4258.38	2803.23	27	2.4	60	3	4.09
17	E10	4255.23	2808.88	40	2.4	60	1	2.68
18	E11	4249.62	2808.16	51	2.4	60	2	5.57
19	G8	4303.21	2817.37	48	2.4	60	5	12.03

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20	H9	4359.91	2820.37	71	2.4	60	1	3.54
21	G10	4254.76	2818.84	80	2.4	60	0	0
22	F9	4258.7	2813.67	48.5	2.4	60	5	10.72
23	F12	4244.60	2810.86	72	2.4	60	9	29.565
24	E13	4239.91	2808.57	69.5	2.4	60	9	24.905
25	G13	4239.60	2816.37	89.5	2.4	60	0	0
26	E15	4229.66	2807.03	70.5	2.4	60	12	36.375
27	D16	4224.39	2805.04	65	2.4	60	8	22.115
28	E17	4219.67	2807.38	70.5	2.4	60	0	0
29	F18	4213.33	2809.49	77.5	2.4	60	2	4.95
30	E19	4207.50	2809.53	64	2.4	60	2	4.78
31	D18	4211.52	2803.17	50.5	2.4	60	5	21.23
32	C17	4215.44	2759.84	46	2.4	60	1	0.415
33	B16	4220.51	2753.98	36.5	2.4	60	4	2.71
34	C15	4226.39	2759.70	48	2.4	60	1	2.45
35	D14	4230.11	2804.51	63	2.4	60	6	18.845
36	C13	4235.17	2759.32	45	2.4	60	1	0.45
37	D12	4240.64	2804.10	52	2.4	60	5	9.9
38	C11	4246.14	2759.44	34	2.4	60	1	2.78

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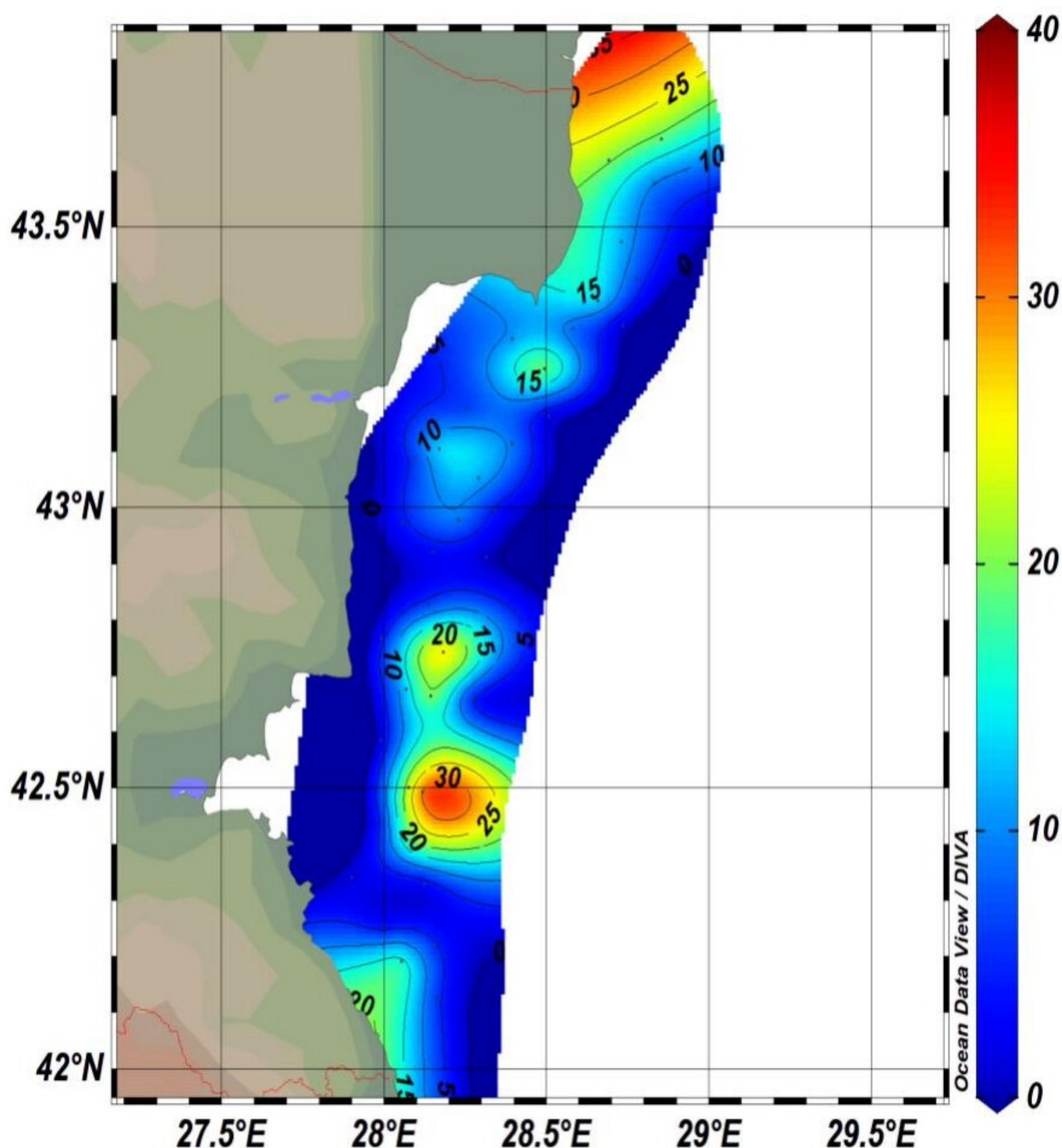


Figure 3 Distribution of catch per unit effort (CPUE, kg/h).

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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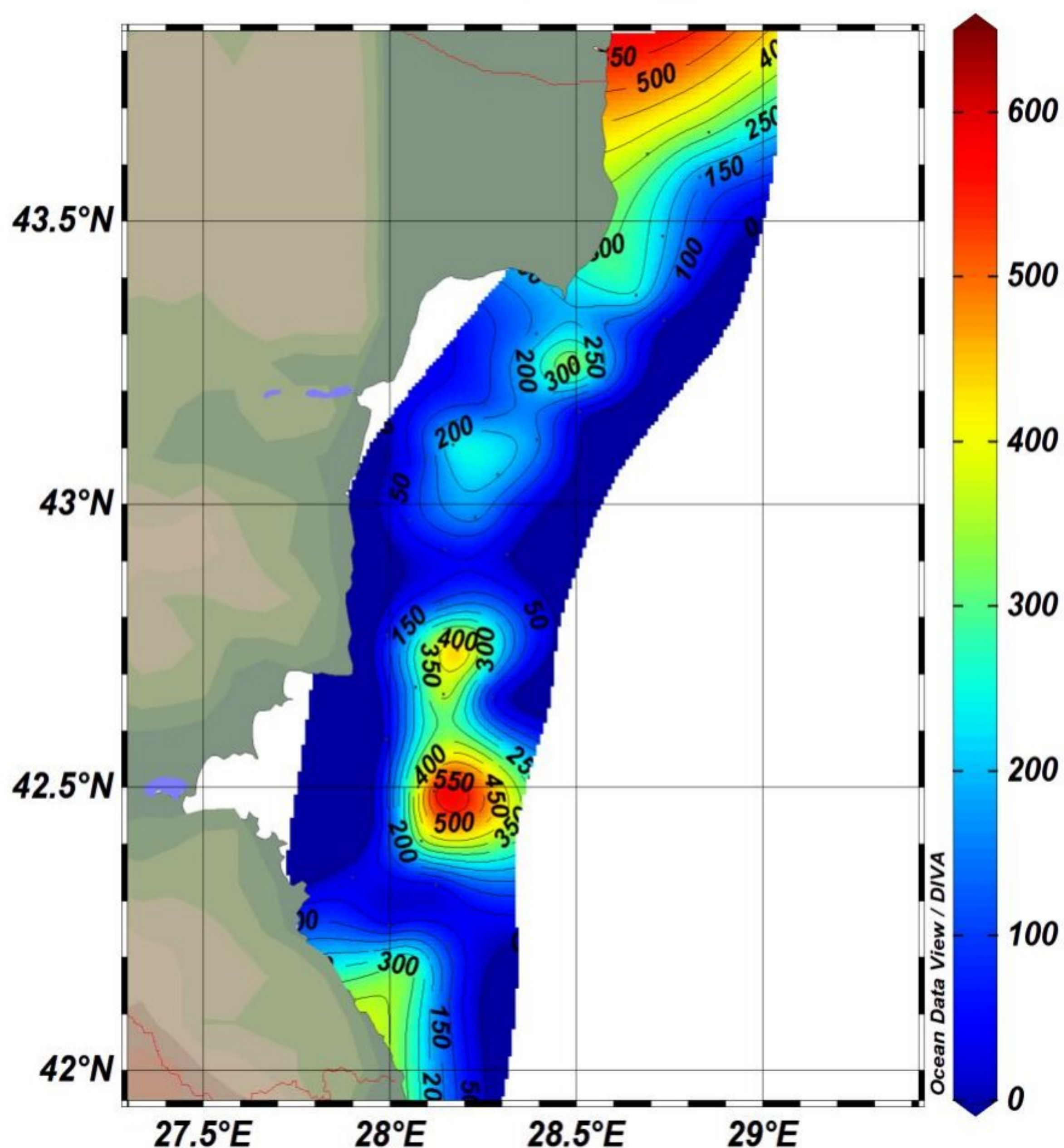


Figure 4 Distribution of the relative biomass (kg/km^2) of *S. maximus* in November-December, 2025.

In seven fields in the Bulgarian Black Sea has been found a relatively high biomass levels were recorded - 355 - 620 kg/km^2 , in the direction from north to south, in front of Durankulak – Kavarna (f. L1) with a depth of 49 - 50 m, in front of Varna at a depth of 57 - 58 m (f. J6), under C. Emine 69 - 74 m (F12, E13), and between Primorsko - Tsarevo (f. E15, D16 и D18) with a depth of 50-69 m (Figs. 2 and 4).



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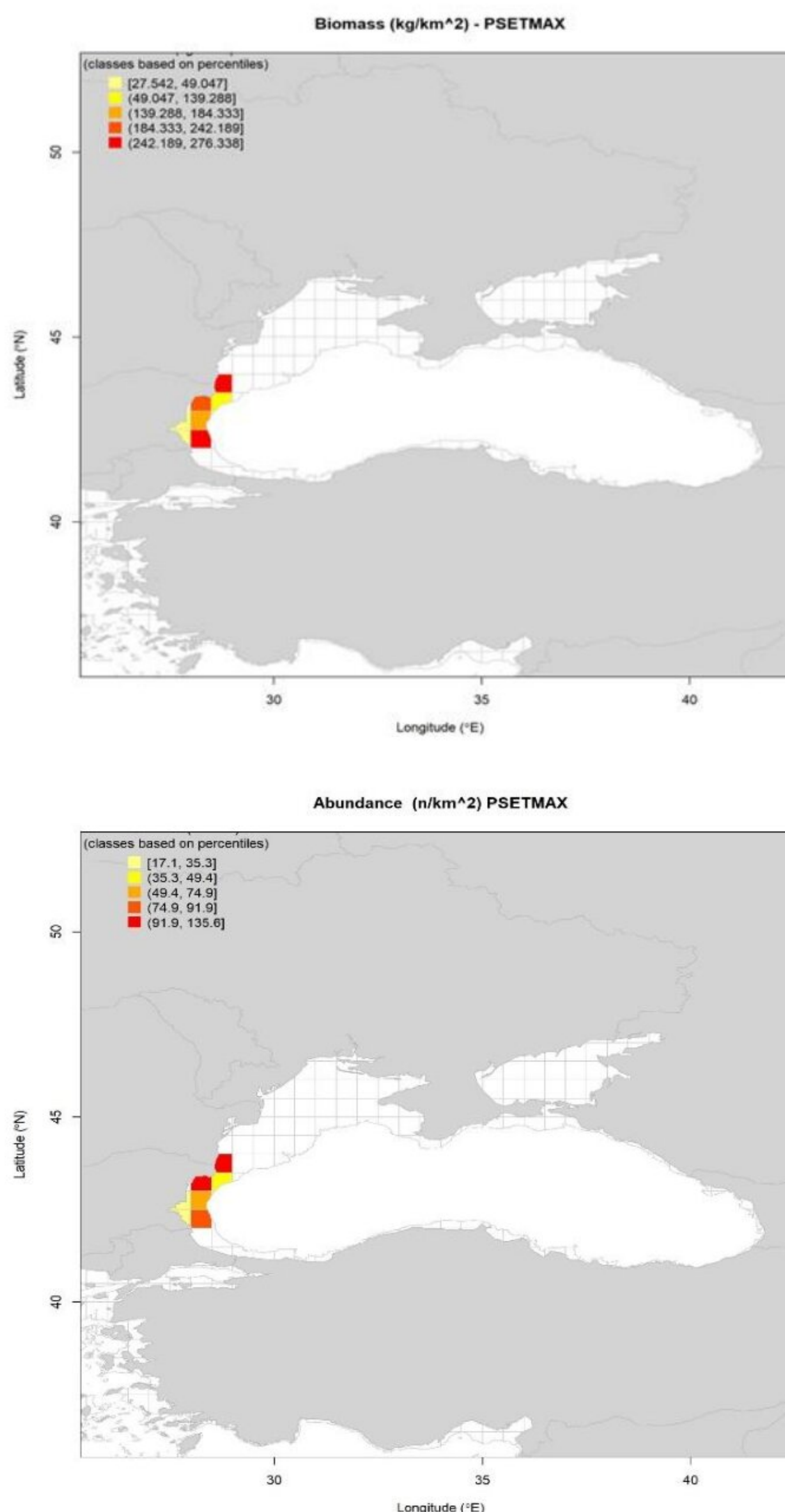


Figure 5 Distribution of the relative mean biomass (kg / km²) and abundance (n / km²) of *S. maximus* in November-December 2025 using BioIndex version 3.3.

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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 November-December 2025.

A)

No. Station	Field	t/km ²	No. ind./km ²
1	E8	0.063	102
2	F7	0.273	85
3	G6	0.082	51
4	H5	0.149	63
5	L1	0.355	154
6	N1	0.323	185
7	M2	0.151	68
8	L3	0.215	69
9	M4	0.111	17
10	L5	0.000	0
11	K4	0.280	120
12	J5	0.107	34
13	J6	0.403	204
14	J7	0.000	0
15	H7	0.180	69
16	D9	0.069	51
17	E10	0.046	17
18	E11	0.095	34
19	G8	0.207	86
20	H9	0.060	17
21	G10	0.000	0
22	F9	0.182	85
23	F12	0.502	153
24	E13	0.426	154
25	G13	0.000	0
26	E15	0.620	204
27	D16	0.379	137

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28	E17	0.000	0
29	F18	0.085	34
30	E19	0.081	34
31	D18	0.362	85
32	C17	0.007	17
33	B16	0.046	68
34	C15	0.042	17
35	D14	0.322	102
36	C13	0.008	17
37	D12	0.168	85
38	C11	0.047	17
Total		6.44	2636
Average		0.170	69

B)

	t/km^2	No ind./km^2
Standard error	0.026	10
Median	0.109	66
Standard deviation	0.16	59
Sampling dispersion	0.03	3529

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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 **1555.95** tonnes (Table 4). The abundance in the studied area was estimated at **636.79*10³** specimens (Table 4).

3.4. Size structure

The information about the size structure of the turbot population was based on biometric measurements of 155 turbot specimens and included data on the absolute and standard length and individual weight (pic.5).

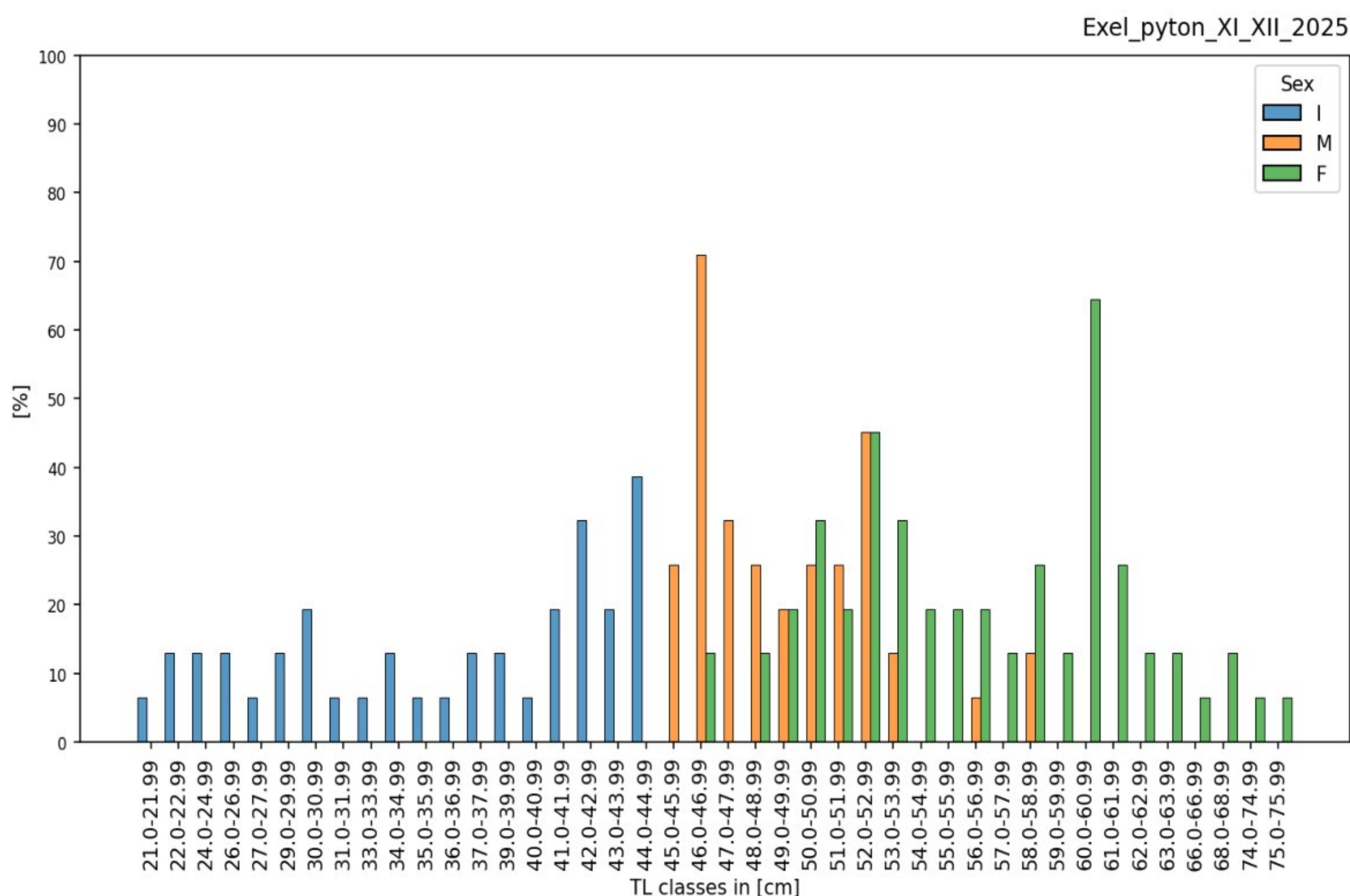


Figure 6 Length structure of *S. maximus* caught by sex.

The total length ranges between 21.5 and 75 cm, with a weight between 160 and 8200 g. The total catch of turbot reaches 378.73 kg. Of the total number of specimens -155, 23 have sizes between 21.5-39 cm (14.84%), 18 specimens - between 40.0-44.5 cm (11.61%), 34 - in the range between 45.0-49.0 cm (21.94%) and 80 - in the range between 50.0-75.0 (51.61%).

Specimens over 45.0 cm predominate in the total catch 73.55% /114 individuals/, and those under 45.0 cm are 41 /26.45%/, females dominate 43.23% /67 specimens/ over males 30.32% /47 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/km²) and the distribution of undersized individuals and those of standard length.

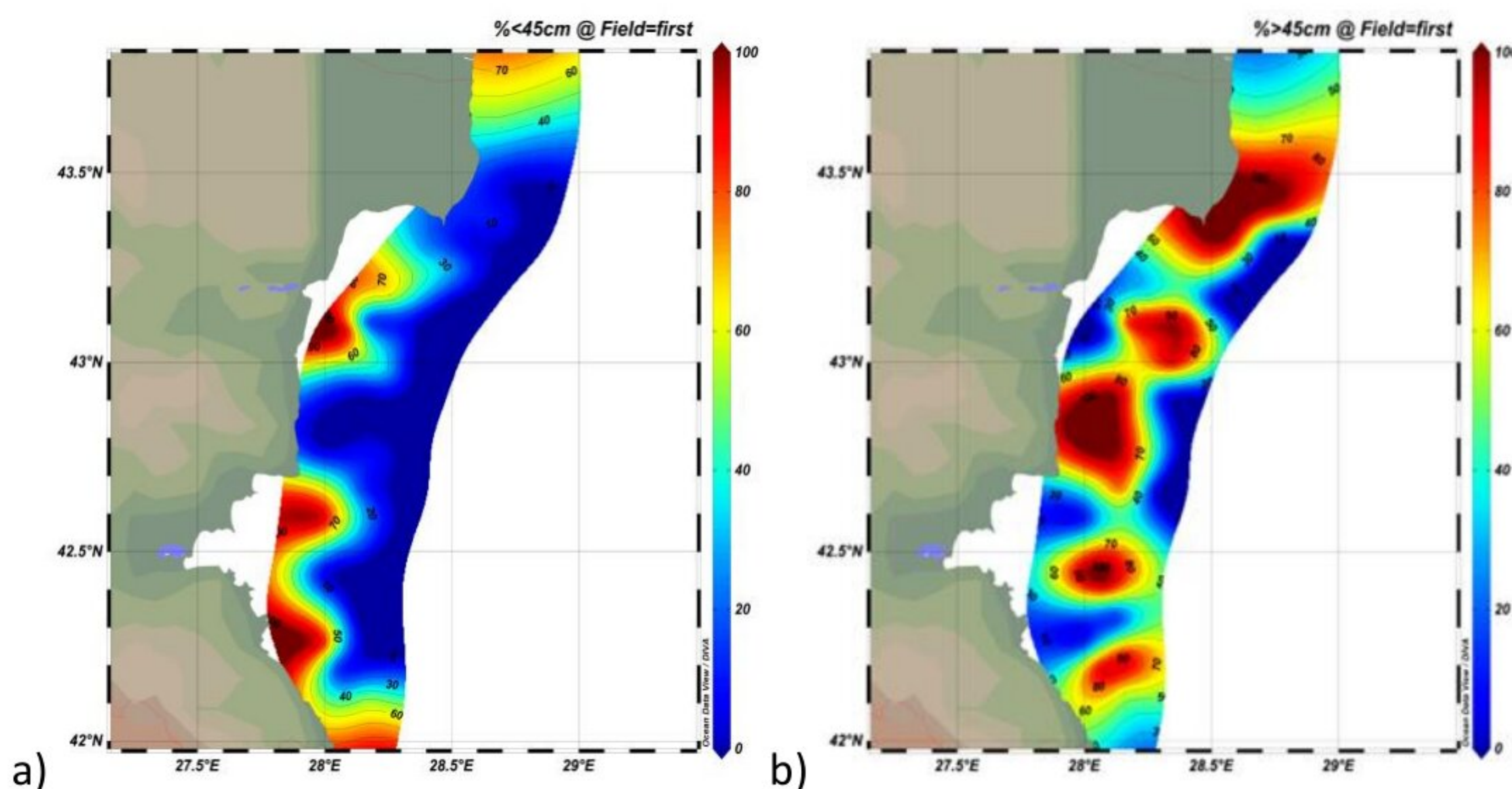


Figure 7 Percentage distribution of the *S. maximus* abundance (ind/km²), a) undersized individuals and b) standard length.

The relative turbot biomass by size class is shown in Fig. 8, indicating high biomass for two length classes - those 50-53 cm and 60-61 cm.

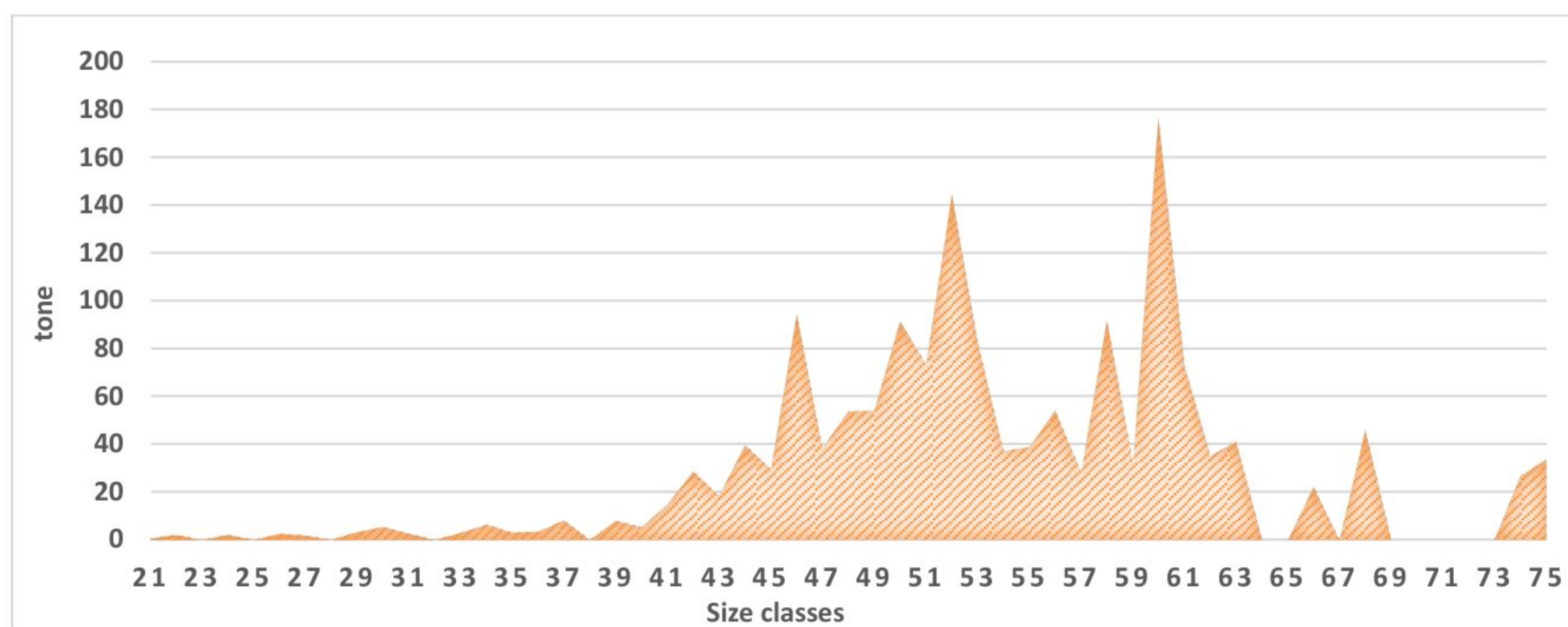


Figure 8 Biomass by mean size classes of *S. maximus*.

3.5. Age structure

The age composition of turbot was determined by analysis of 130 pairs of otoliths. The age structure of turbot includes from 1 to 10 year old specimens, with a dominant role of 2 (16.13%), 3 (22.58%) and 4 (25.81%) - the annual (64.52% total), followed by the 6-year-old specimens - 10.97% (Fig. 9).

During the autumn-winter season of 2025, specimens exceeding 45 cm (73.55%) are more prevalent than those measuring under 45 cm (26.45%).

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



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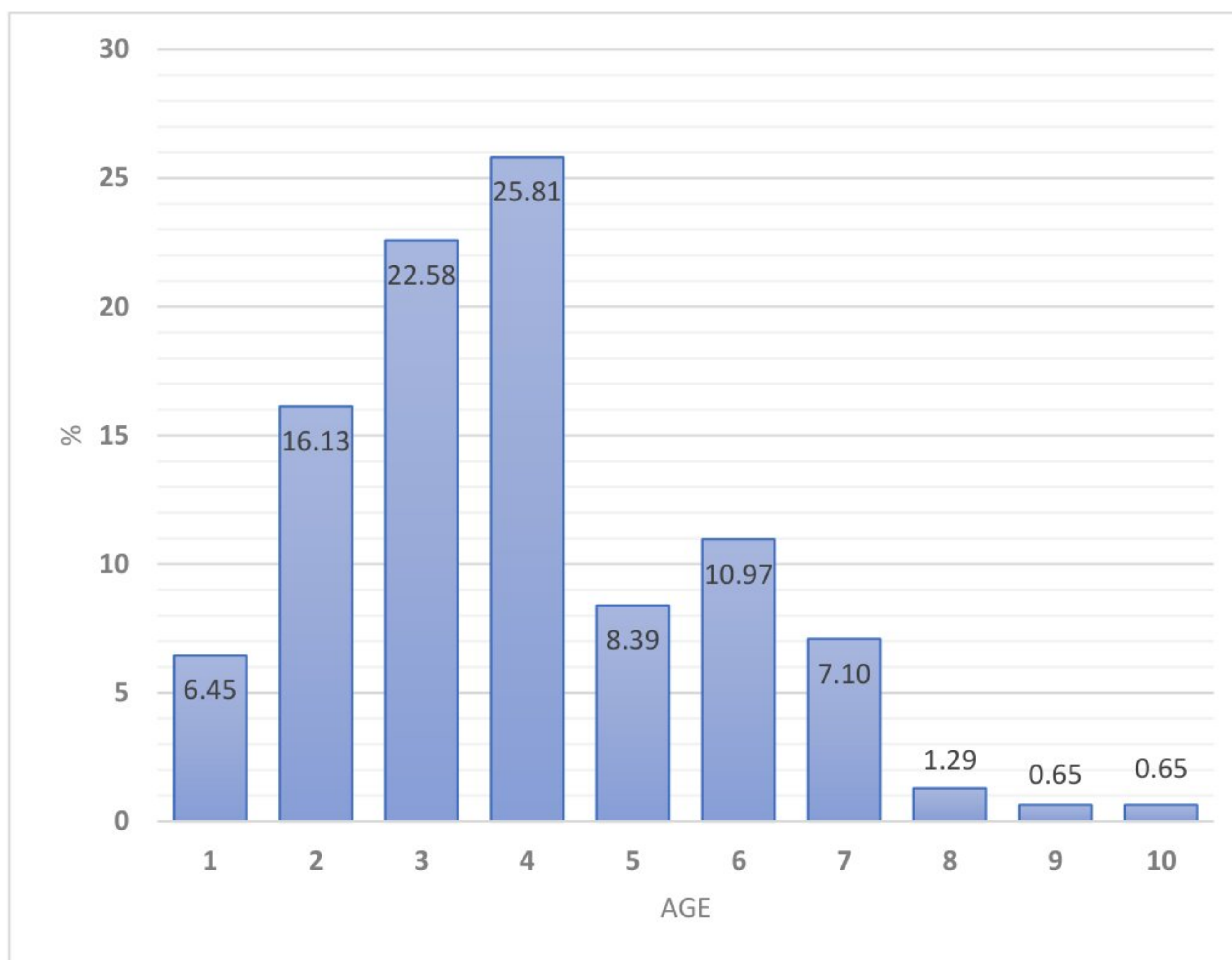


Figure 9 Age structure of turbot in November-December, 2025.

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



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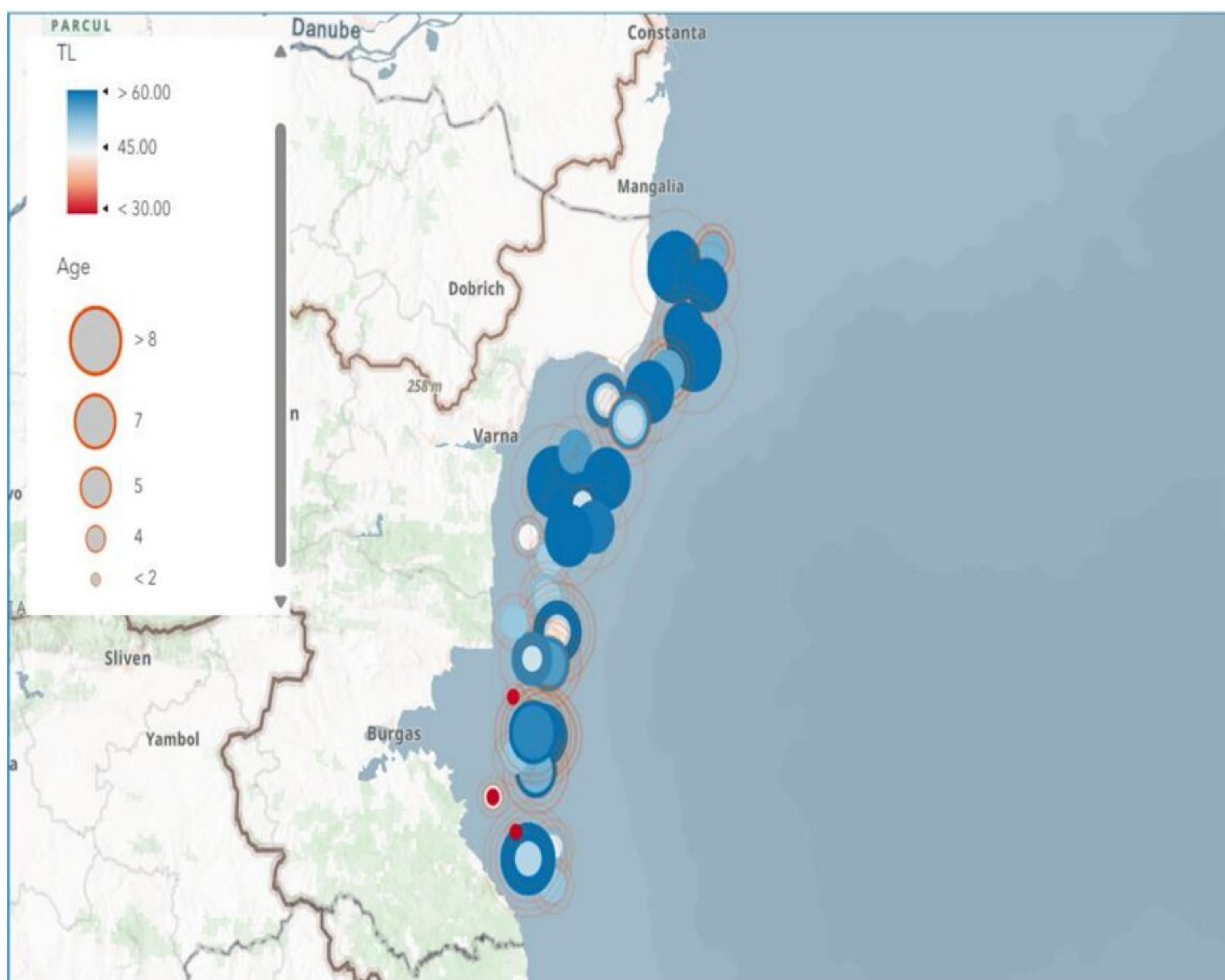


Figure 10 Spatial distribution by ages and lengths of *S. maximus*.

3.6. Biological parameters of *S. maximus*

To establish the rate of turbot growth in the Bulgarian waters of the Black Sea during the autumn-winter season of 2025, 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 t_0 were estimated (see Table 5). The values of these parameters in the von Bertalanffy equation were computed as follows:

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Table 5

Von Bertalanffy parameters and L-W dependence.

sex	Linf (mm)	k	t0	a	b
F	738.8235	0.2429	-0.8431	0.000073	2.79
M	608.5256	0.4387	-0.2117	0.000035	2.89
C	715.5528	0.268	-0.7379	0.016753	3.03

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

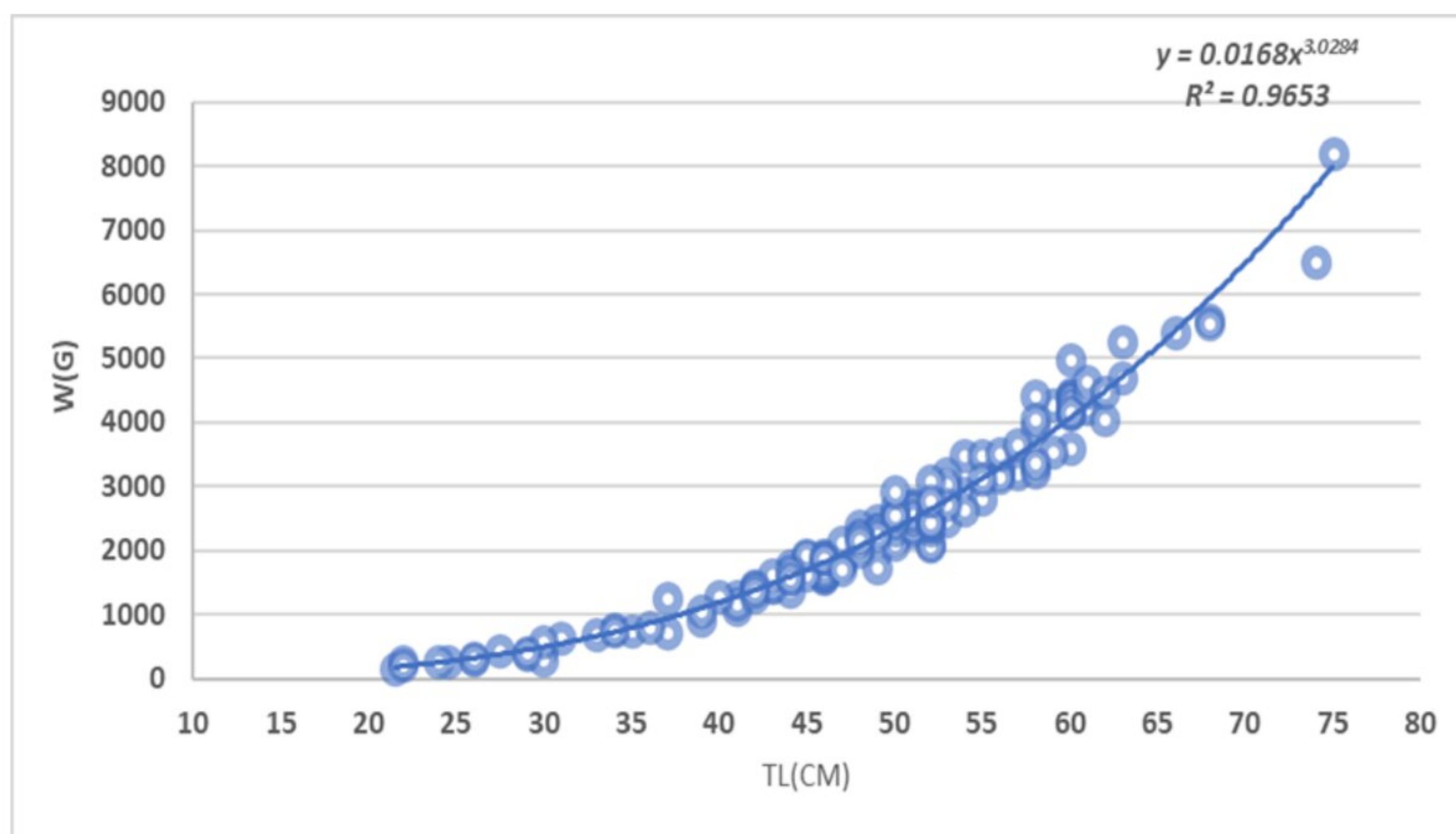


Figure 11 *S. maximus*: Length-weight relationships in November-December, 2025.

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.



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

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

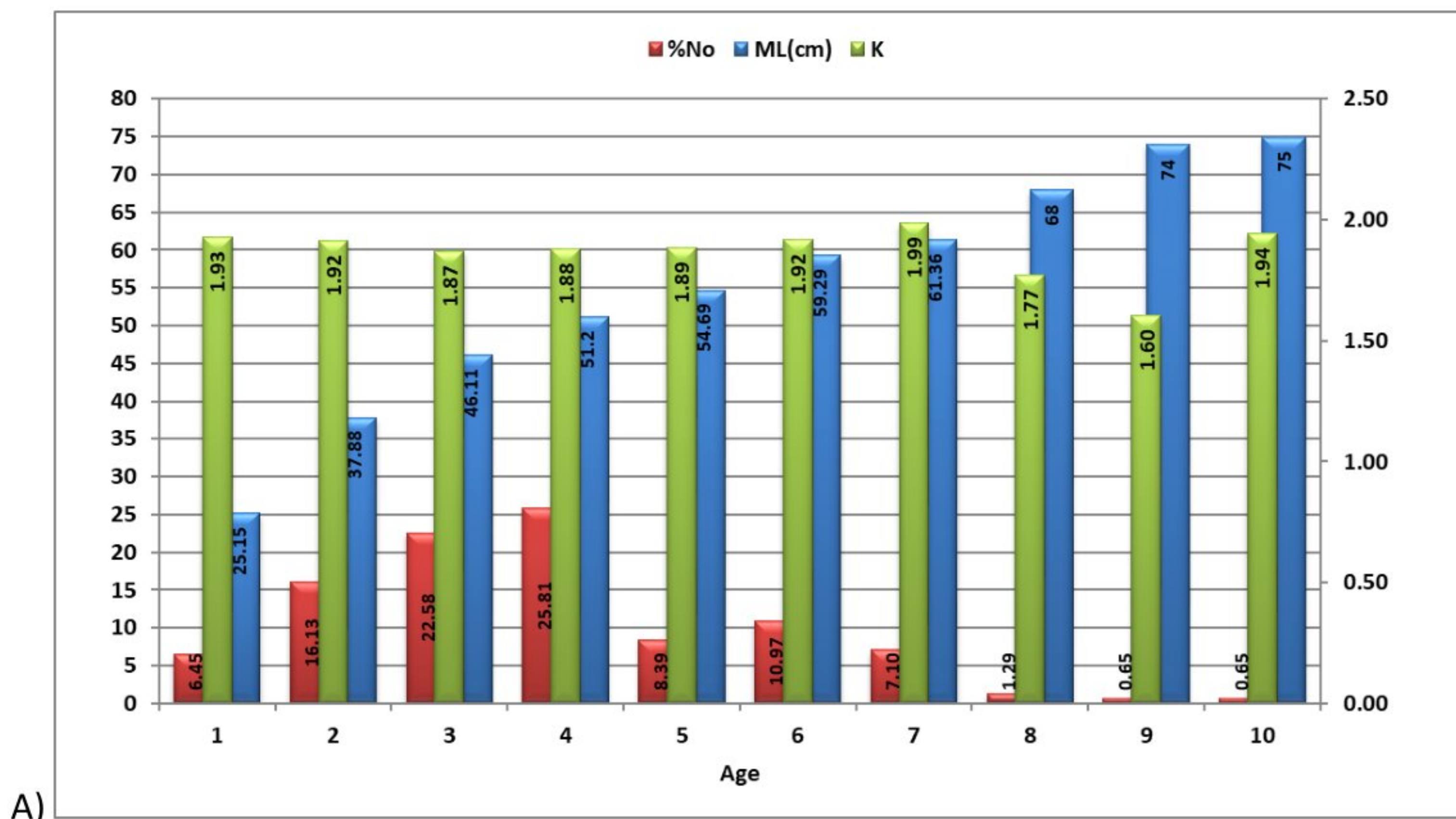
$$\log(-t_0) = -0.3922 - 0.2752 * \log L_{\infty} - 1.038 * \log k$$

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

Considering that water temperature was 8 °C during the study period, the coefficient of natural mortality (M) for both sexes was: 0.29.

Fulton's condition factor (K)

The Fulton condition factor (K), which expresses the relationship between body weight and total length, is widely used as an indicator of fish physiological condition. In the present study, the Fulton condition factor varied within a narrow range, with the highest values recorded in seven-year-old individuals. (Fig. 12).



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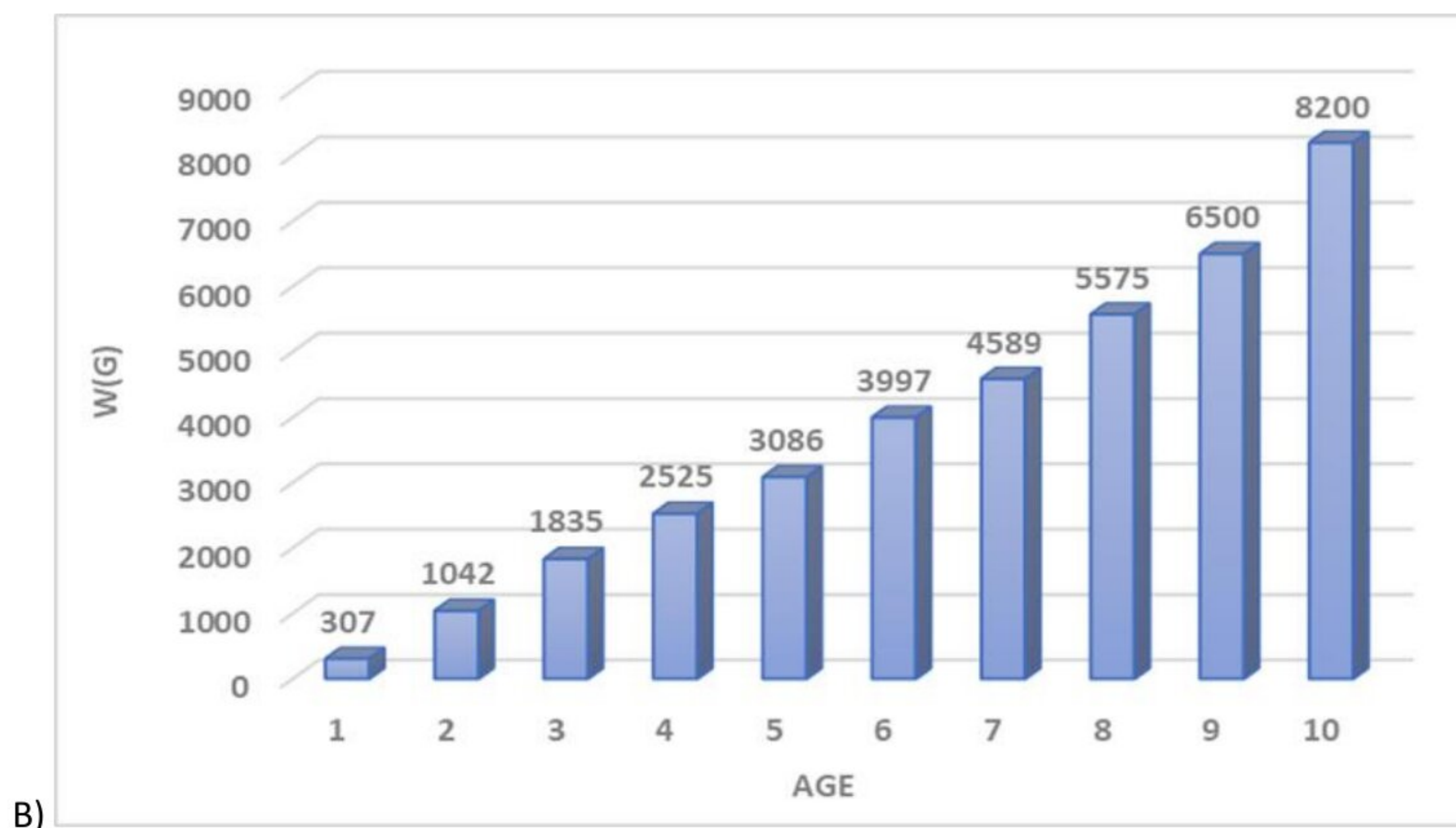


Figure 12 Percentage distribution and relation between the average length (ML) and coefficient of Fulton (K) by age groups (A) and an average weight (g) of turbot by age groups (B).

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 autumn-winter season of 2025 reveals that immature individuals constitute for 26.45 % of the total catch, while sexually mature individuals represent 73.55%. Females comprise 43.23 %, and males constitute 30.32 %. The sex ratio of sexually mature individuals is 58.77 % females and 41.23 % males.

Among the 38 surveyed areas along the Bulgarian coast, no female individuals were detected in 10 areas, no male specimens were identified in 17 areas, and no juvenile specimens were found in 18 areas (Fig. 13).

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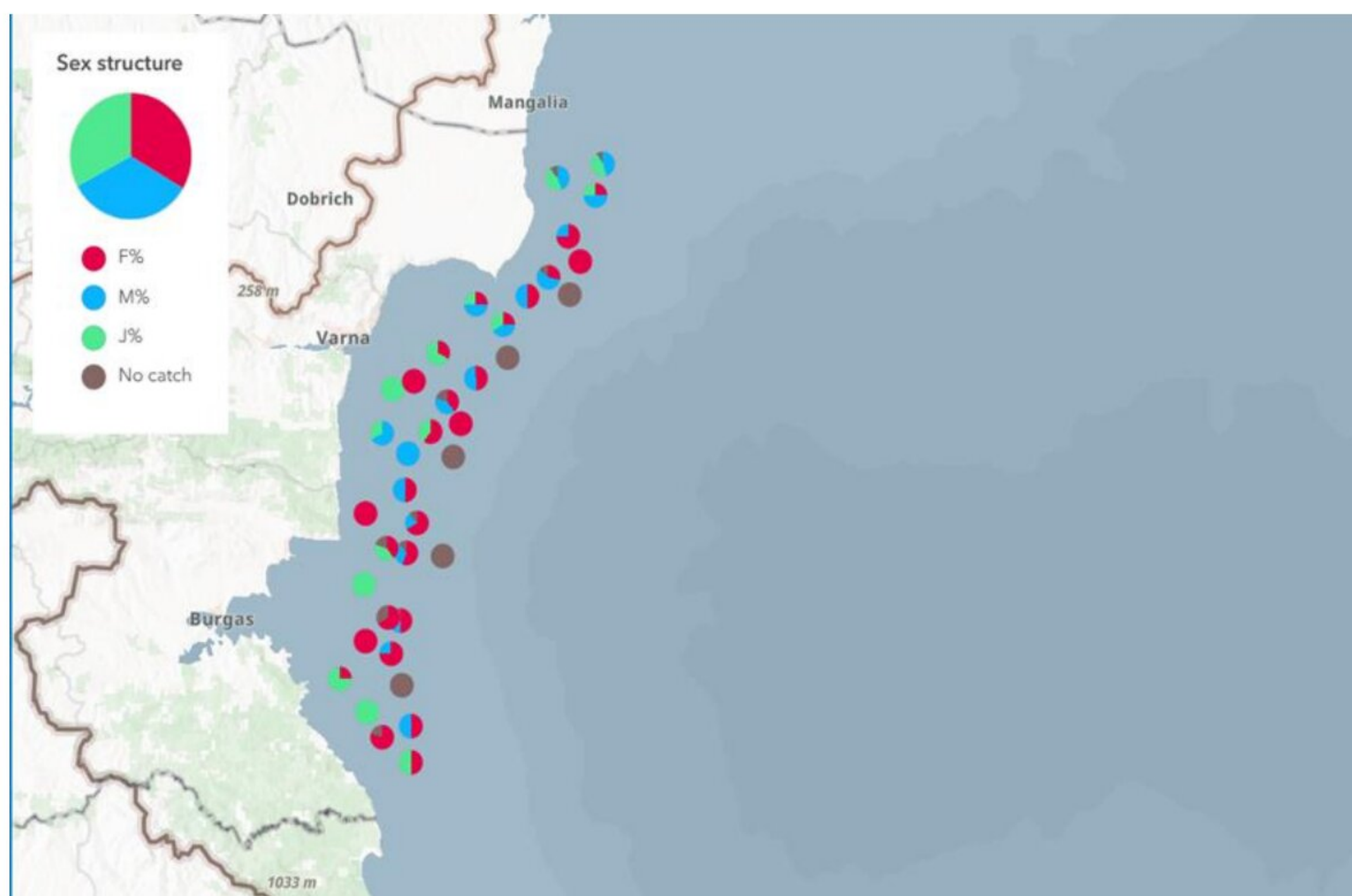


Figure 13. Sex structure of *S. maximus* in November-December 2025: distribution by station (female, male, and juvenile specimens are indicated by red, blue and green, grey- no catch).

Male specimens are mainly found at depths ranging from 30 to 64 meters, while female specimens are observed in significant numbers at depths between 30 to 78 meters. Juvenile individuals are primarily concentrated in the area between C. Emine - Primorsko, specifically at depths of 23 to 45 meters.

Female specimens are predominantly located in the Shabla, C. Emine, and Primorsko regions, while male specimens are more concentrated in C. Kaliakra, Shkorpilovtsy - Bqla.



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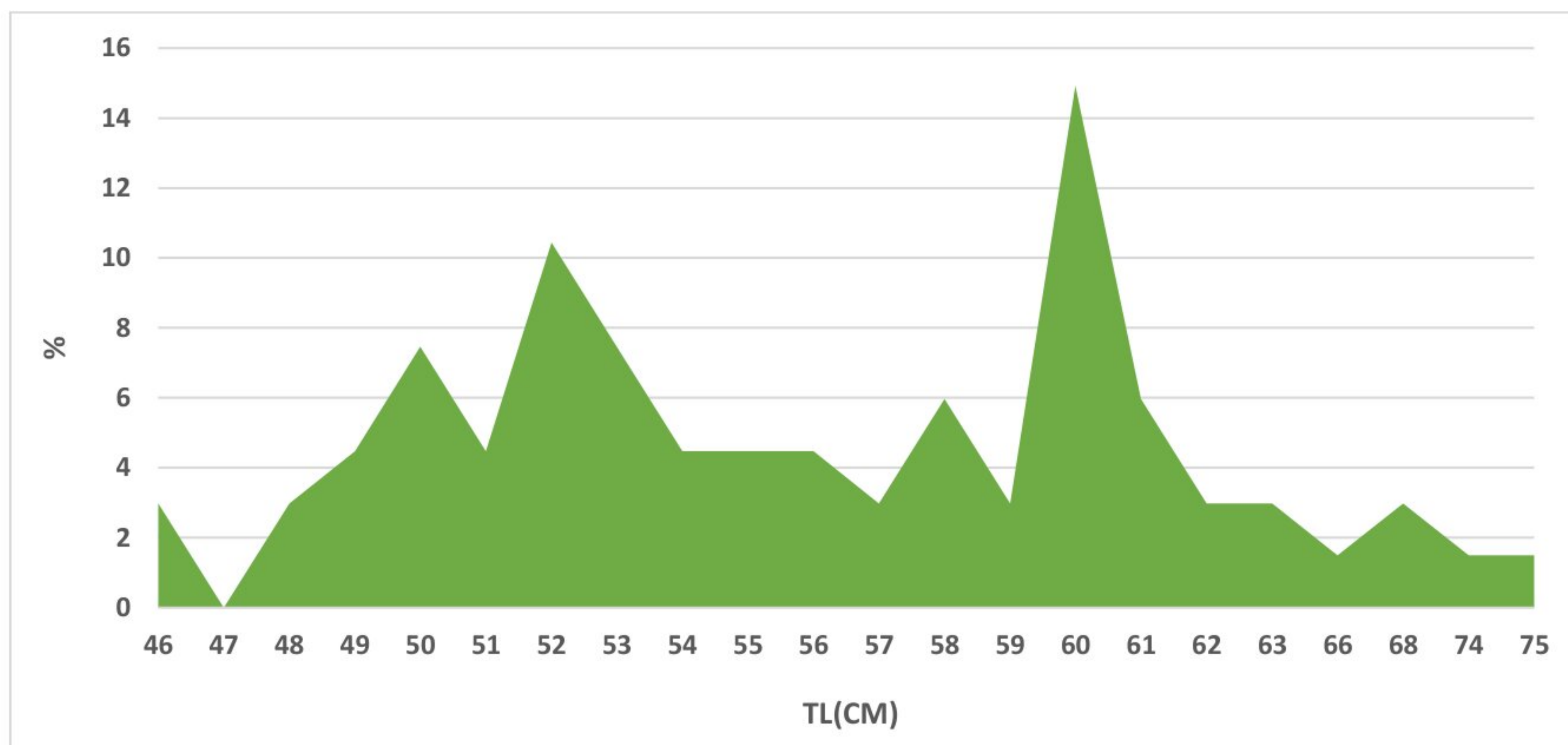


Figure 14 Female specimens: Percentage distribution by length classes.

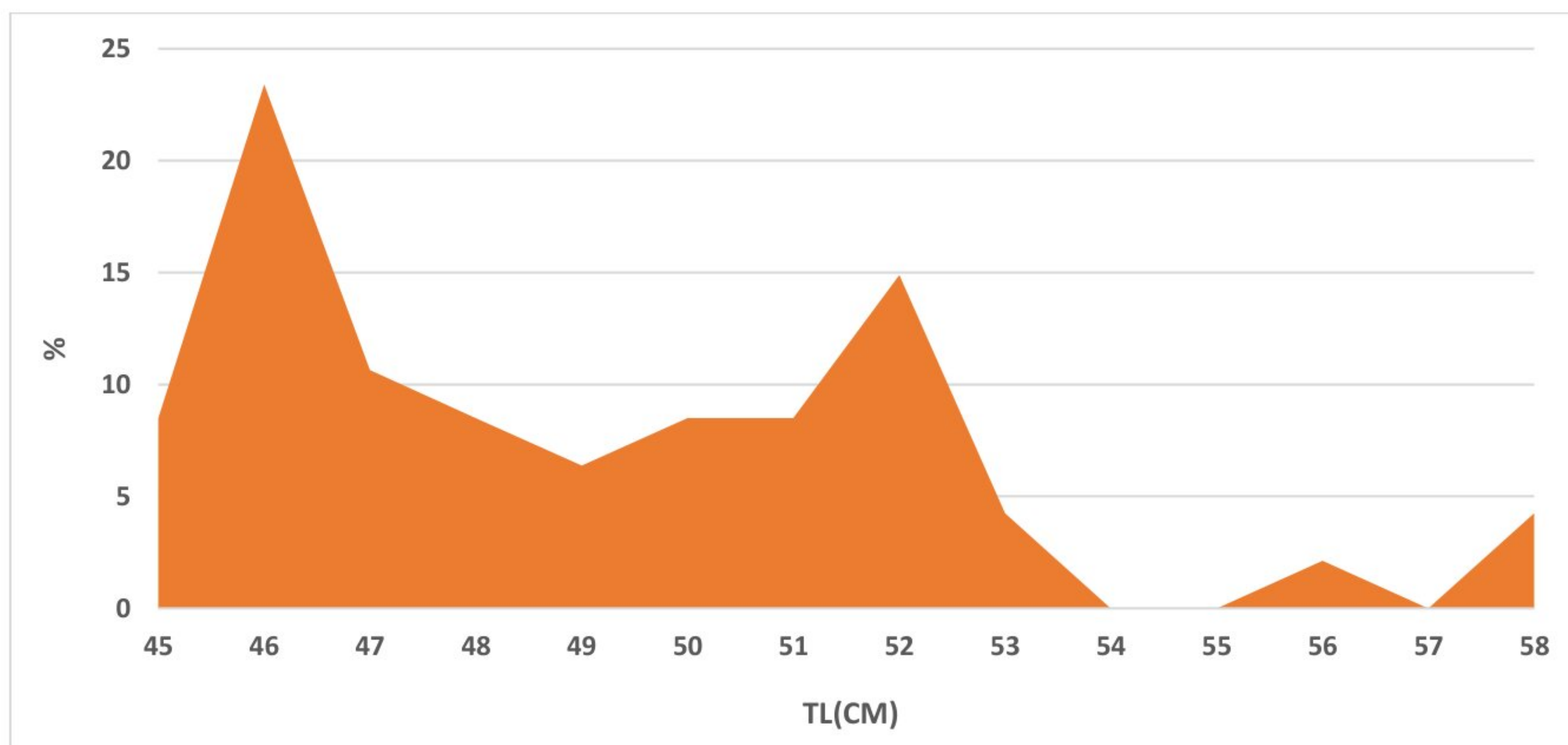


Figure 15 Male specimens: Percentage distribution by length classes.

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The distribution by sex and size groups shows that female specimens predominantly fall within the size range of 52 to 61 cm, accounting for 64.18 % of the measured female population (Fig. 14). All individuals measuring between 58 cm and 75 cm are female, accounting for 37.31 % of the total population.

For male specimens, the largest group-comprising 89.36 %-is found in the size category of 45 to 52 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

Data on the weight distribution of the turbot population in the Bulgarian waters of the Black Sea during November-December 2025 were collected from an analysis of 155 individuals, with each specimen's weight recorded. The analysis revealed that the majority of specimens had an average weight of 2443.42g (Fig. 16).

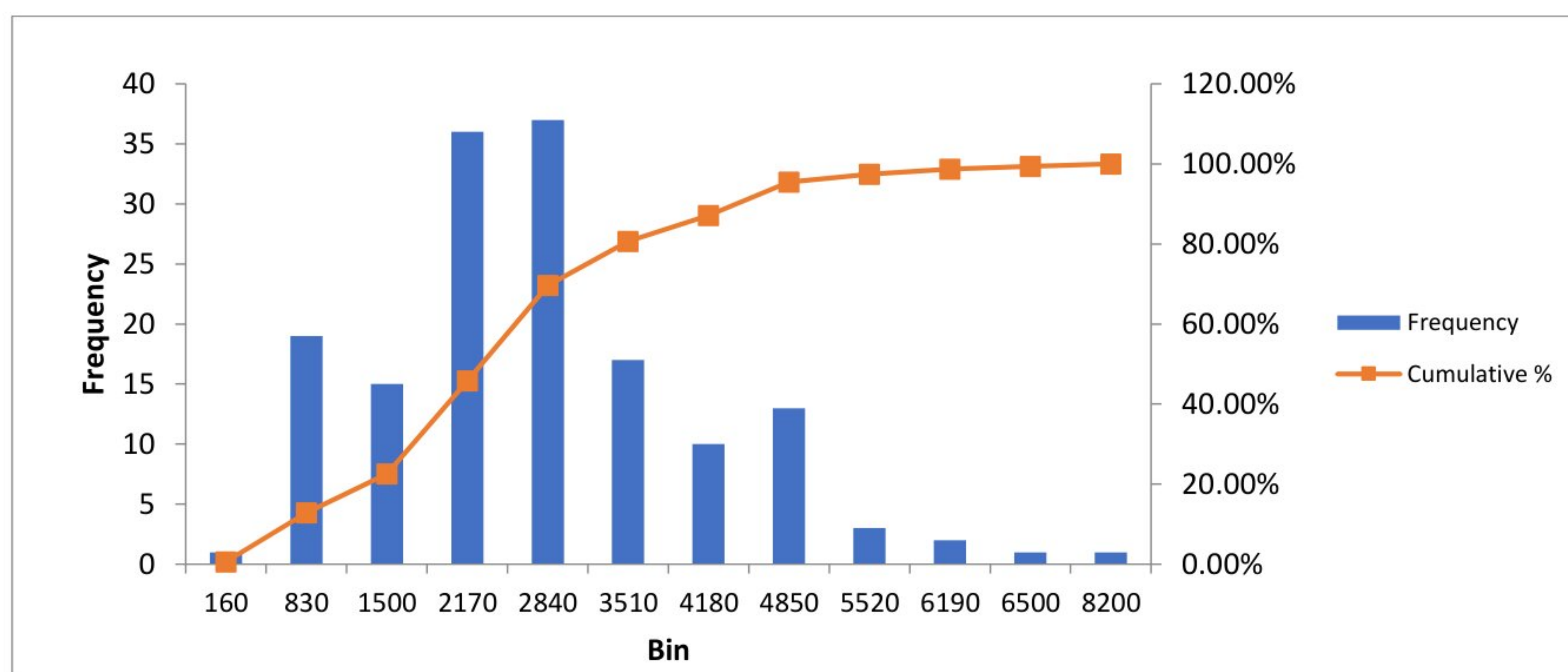
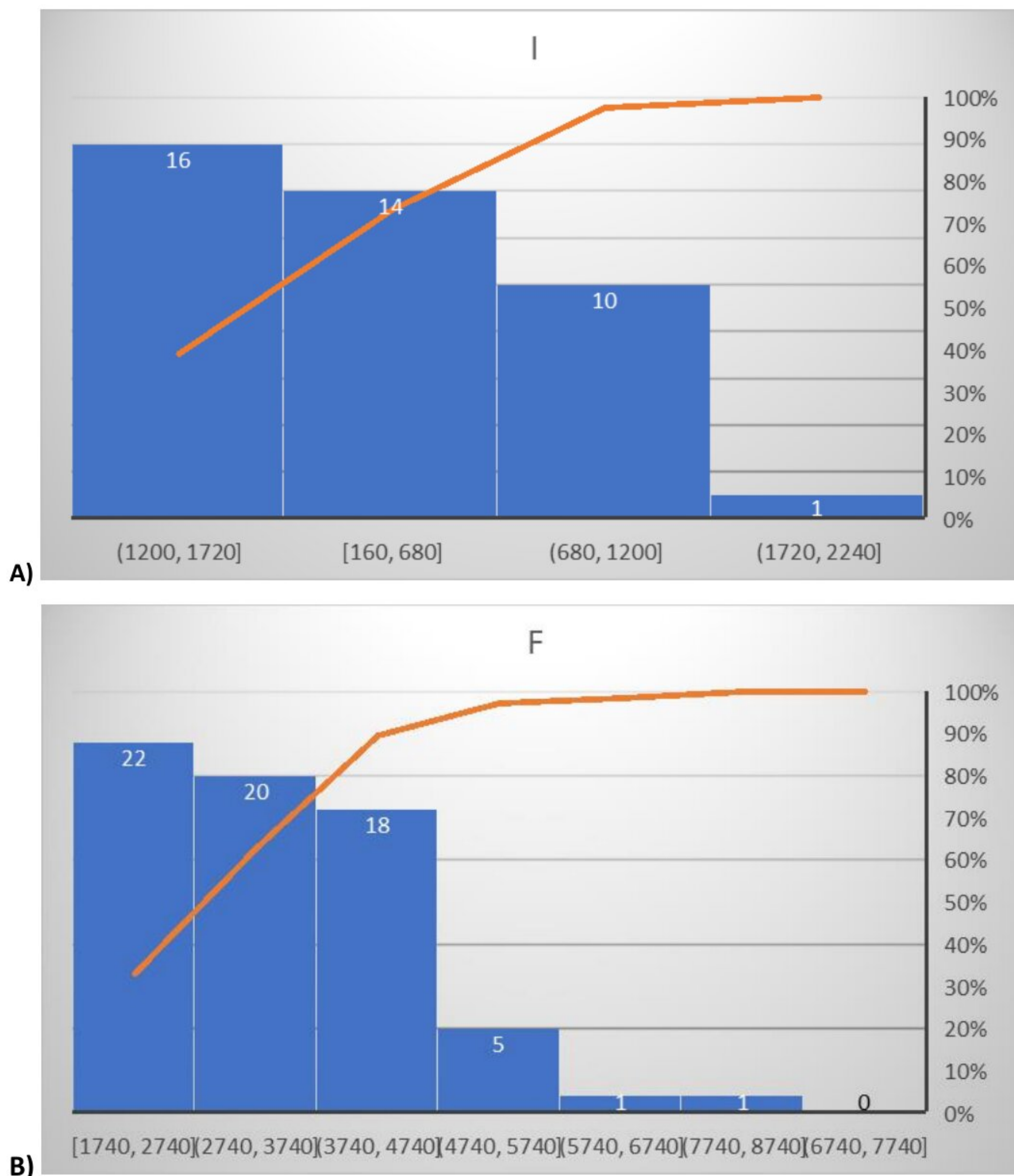


Figure 16 Weight structure of *S. maximus* catches.

Immature specimens weigh between 160.0 and 1580.0g grams, with an average weight of 944.75 grams. Female specimens range from 1840.0 to 8200.0grams, averaging 3535.15 grams. Male specimens weigh between 1920.0 and 3900.0grams, with an average weight of 2194.47 grams (see Fig. 17, A, B, and C).



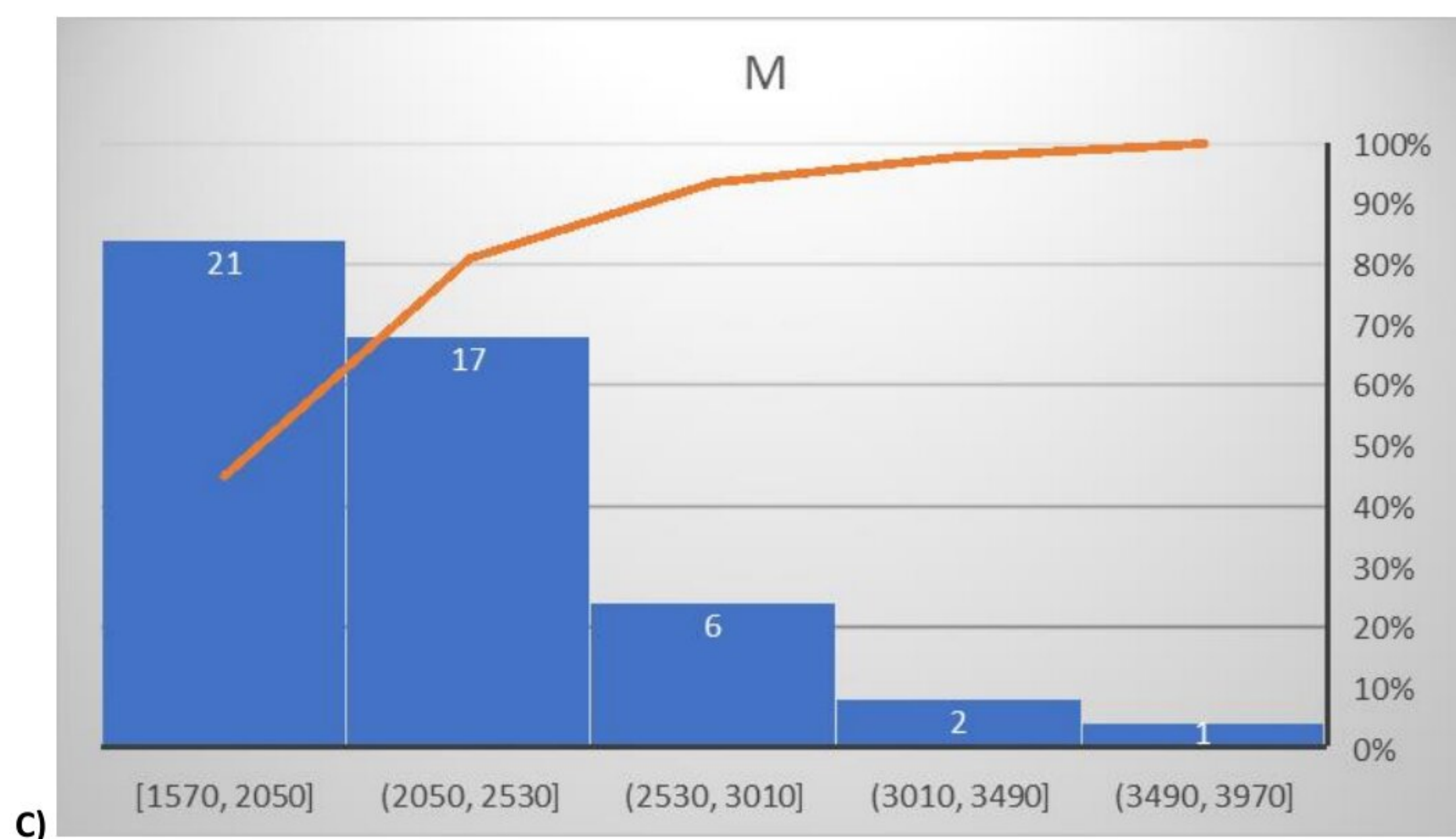


Figure 17 Weight structure of *S. maximus* catches by sex: A) immature specimens, B) female and C) male specimens;

3.9. Other target species and bycatch

During bottom survey in the autumn-winter season of 2025, 18 specimens of spiny dogfish (*Squalus acanthias*), 284 specimens of thornback ray (*Raja clavata*), and 24 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.
<i>Squalus acanthias</i>	18	60	135	110	0.910	12.400	5.822
<i>Raja clavata</i>	284	32	90	65.63	0.155	4.470	1.864
<i>Platichthys flesus luscus</i>	24	16	64	25.2	0.041	1.03	0.216
<i>M. merlangus</i>	1300	7.0	23.2	12.9	0.0023	0.089	0.017

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



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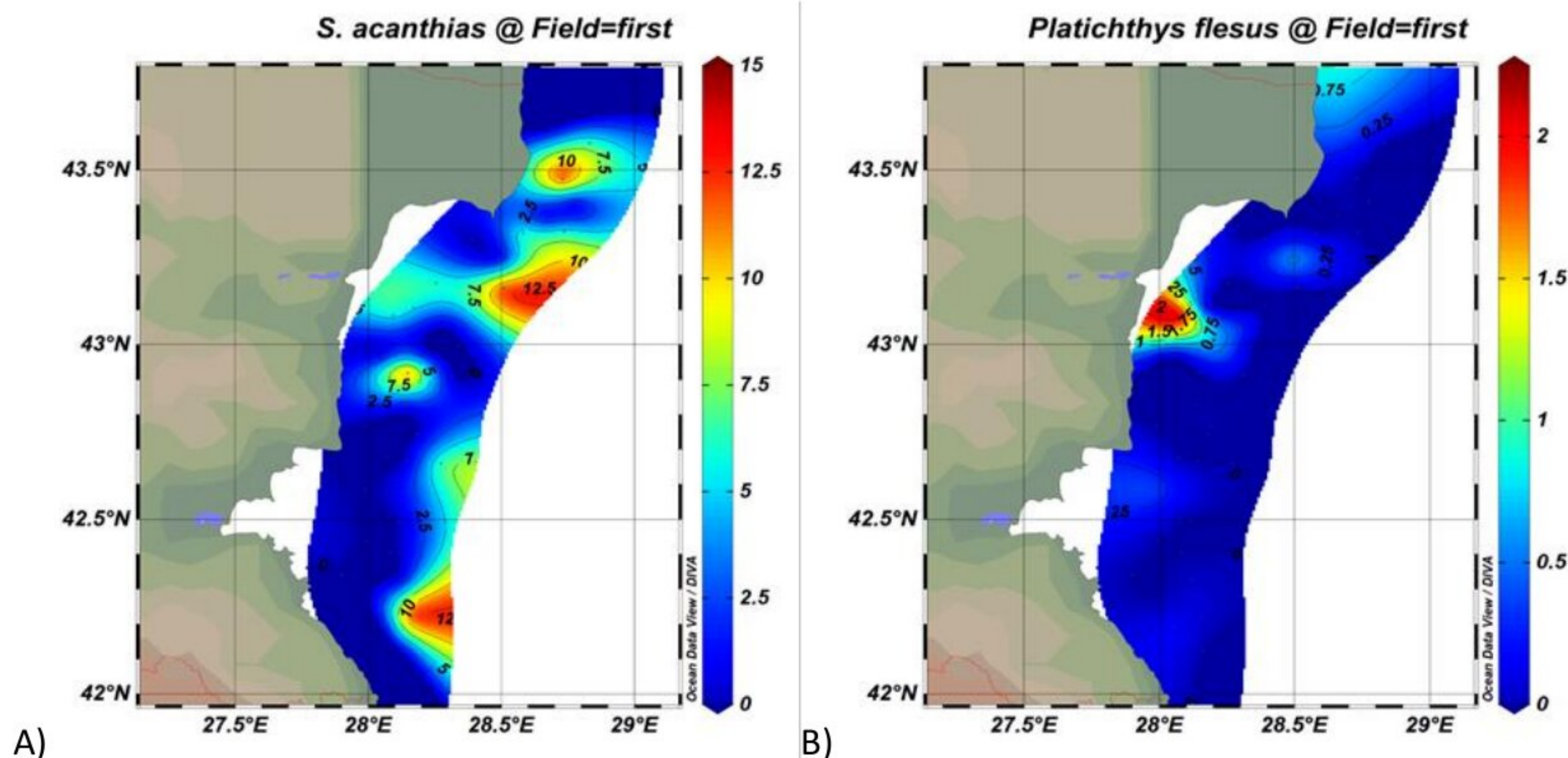


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Specimens of *S. acanthias* are observed between Varna and Byala (30-40 m), where only female specimens have been caught, and in front of the Shabla and Tsarevo (66-88 m) there is an accumulation of males; clusters of *Pl. flesus* occurs in the northern part of the Bulgarian coast in front of the central part of the coast of Varna, at a depth of 24 - 25 m. Representatives of the species *R. clavata* are observed south of Varna at depths of 48 - 50 m in front of Emine-Tsarevo (depth 65 - 69 m). Specimens of the species *M. merlangus*, with a large concentration of the species is observed from north to south Kavarna, Varna and between Emine and Sozopol at a depth of 65 - 78 m.



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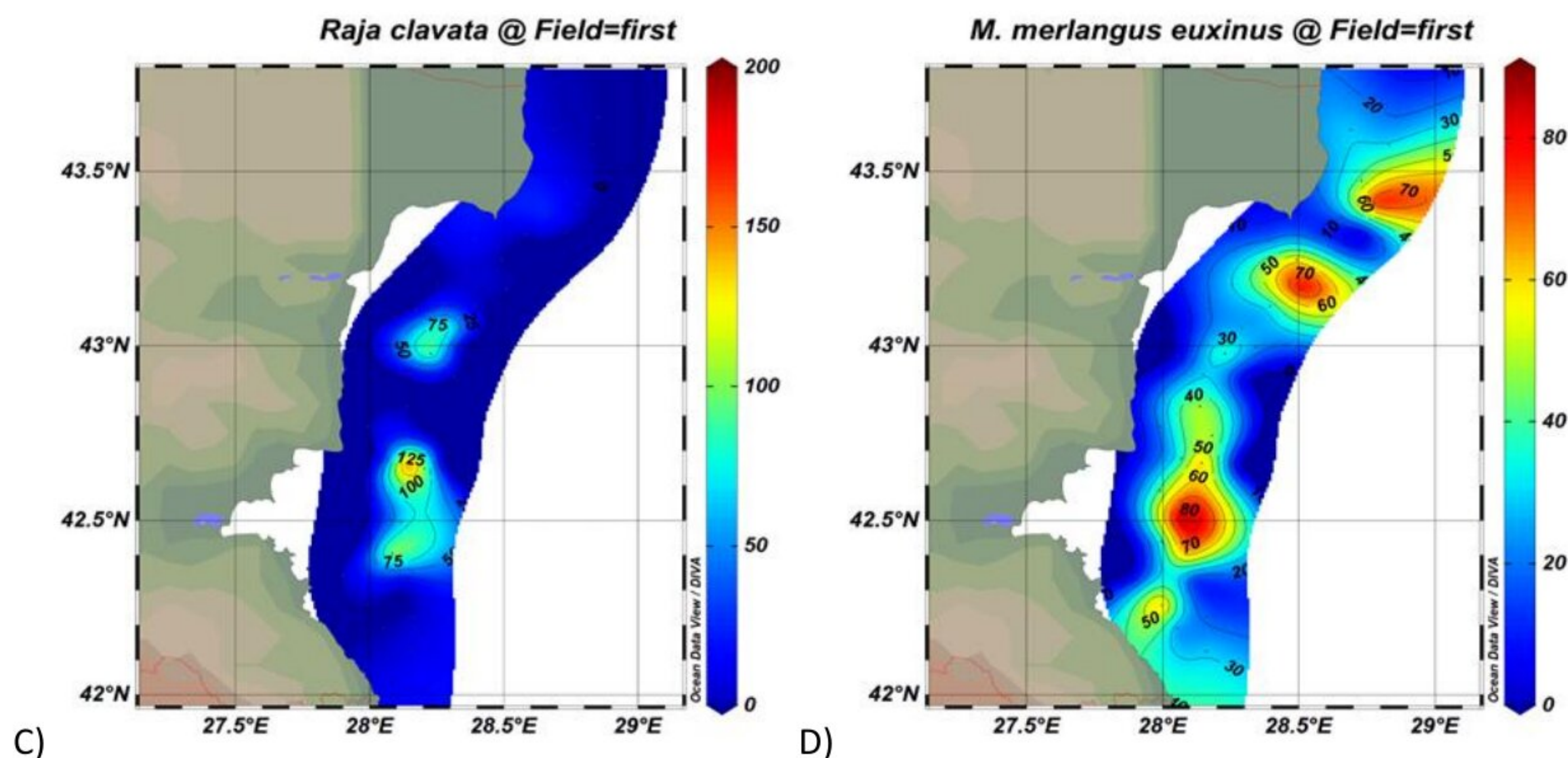


Figure 18 Catch per unit effort kg/h A) spiny dogfish (*S. acanthias*), B) flounder (*Pl. flesus*), C) thornback ray (*R. clavata*) and D) whiting (*M. m. euxinus*).

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, November-December

2025

No	Field	Depth (m)		Catch (Kg/h)
1	E8	24	23	7
2	F7	27.5	27.5	20
3	G6	29.5	28.5	30
4	H5	22	20.5	20
5	L1	49	50	30
6	N1	56	64	20

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7	M2	63	64	30
8	L3	66	69	40
9	M4	75	78	80
10	L5	80	79.5	0
11	K4	69	64	20
12	J5	62	61	12
13	J6	57	58	60
14	J7	78	80	80
15	H7	62	56	30
16	D9	27	31	0.901
17	E10	40	42	30
18	E11	51	57	50
19	G8	48	50	25
20	H9	71	77.5	25
21	G10	80	78	
22	F9	48.5	47	40
23	F12	72	74	50
24	E13	69.5	72	70
25	G13	89.5	88	0.806979
26	E15	70.5	69	80
27	D16	65	64	70
28	E17	70.5	71	6
29	F18	77.5	70	20
30	E19	64	64	30
31	D18	50.5	49	20
32	C17	46	47	70
33	B16	36.5	37	2
34	C15	48	47	30
35	D14	63	62	90
36	C13	45	40.5	40
37	D12	52	50	30
38	C11	34	32	20

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

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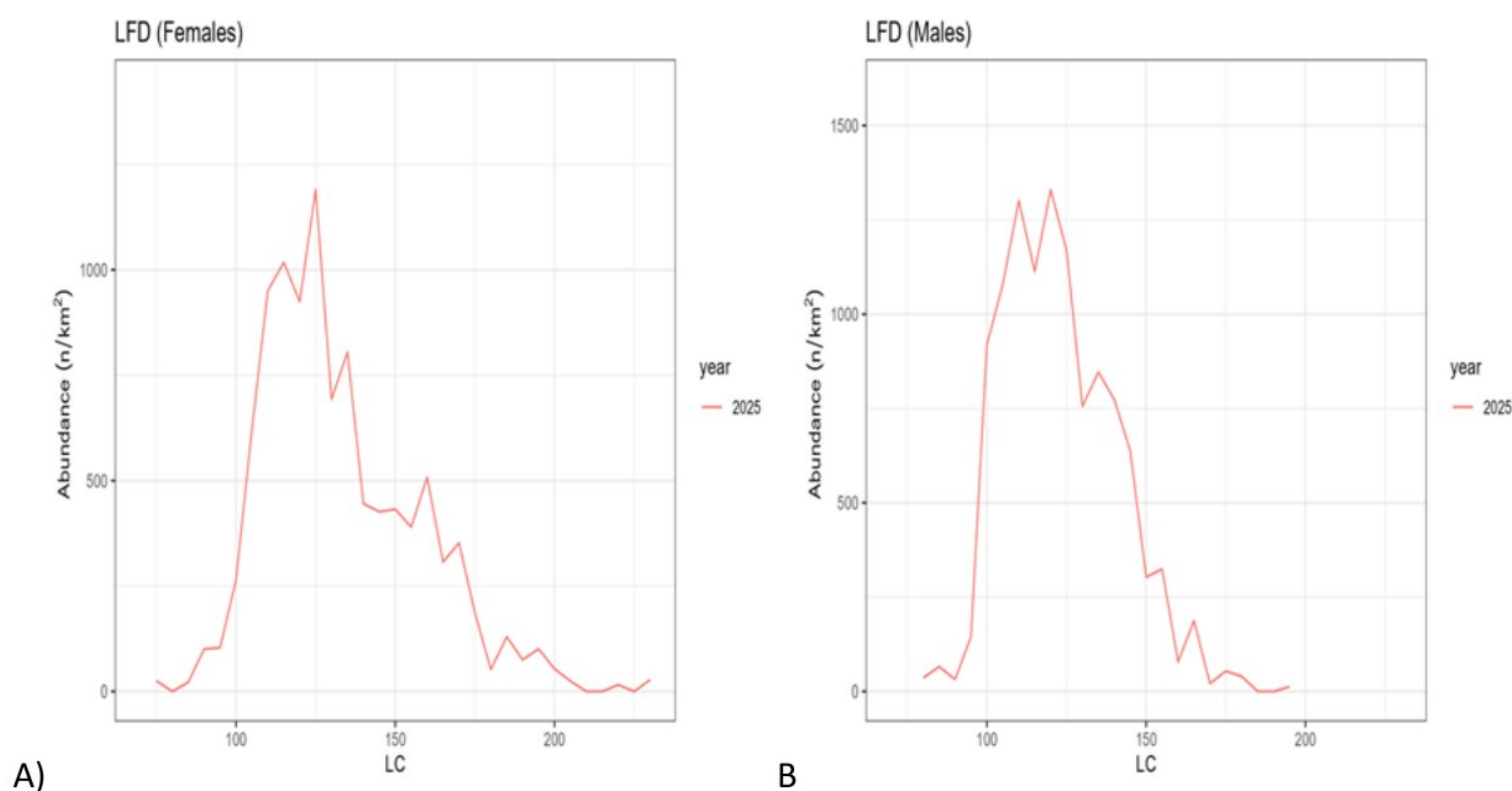


Figure 19 Length classes (LC, mm) of *M. merlangus* catch by sex: A) female, B) male.

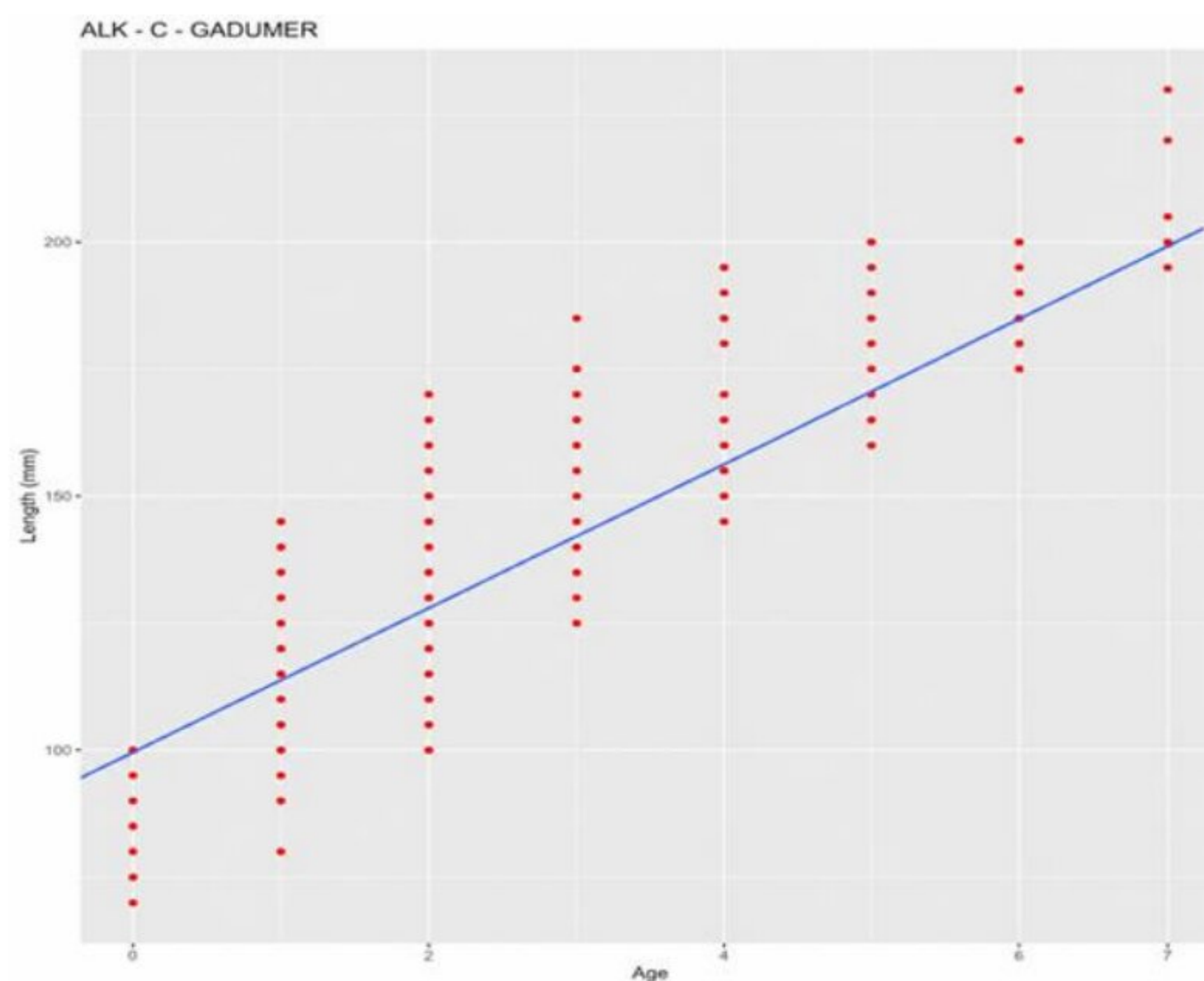


Figure 20 *M. merlangus*: Age-size relationships.

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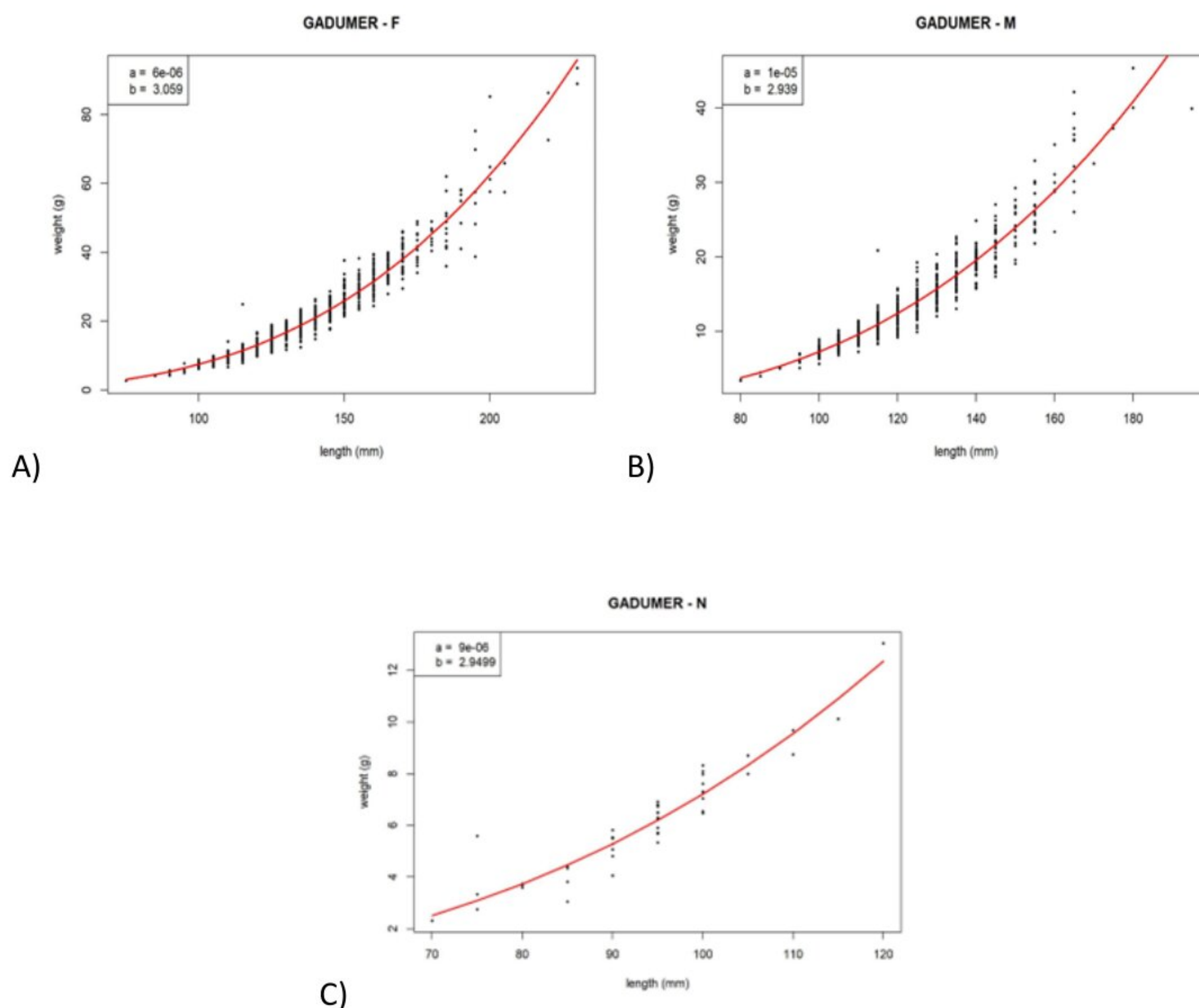


Figure 21 *M. merlangus*: Length-weight relationships by sex, A) female, B) male and C) indeterminate, November-December, 2025.

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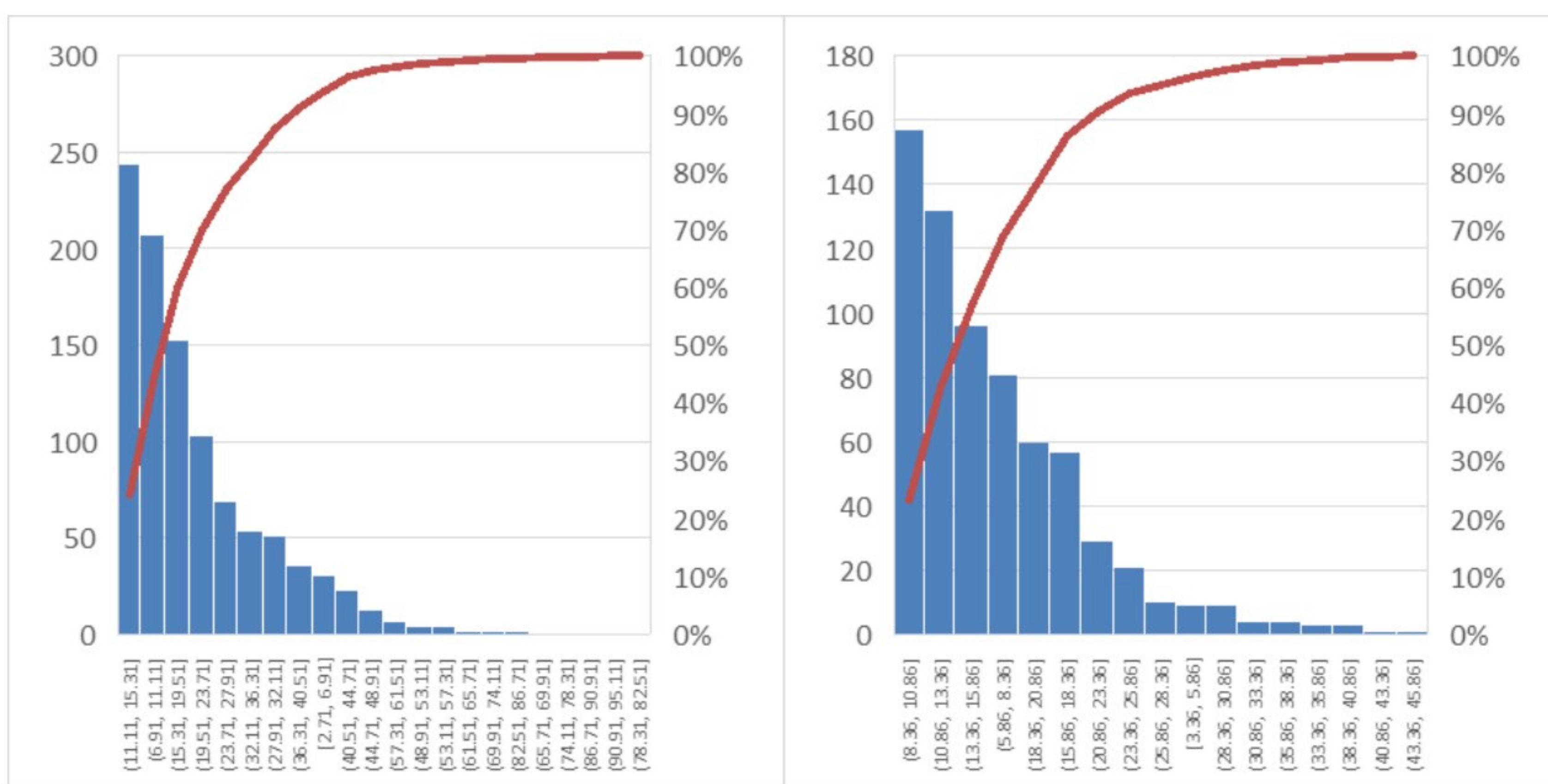
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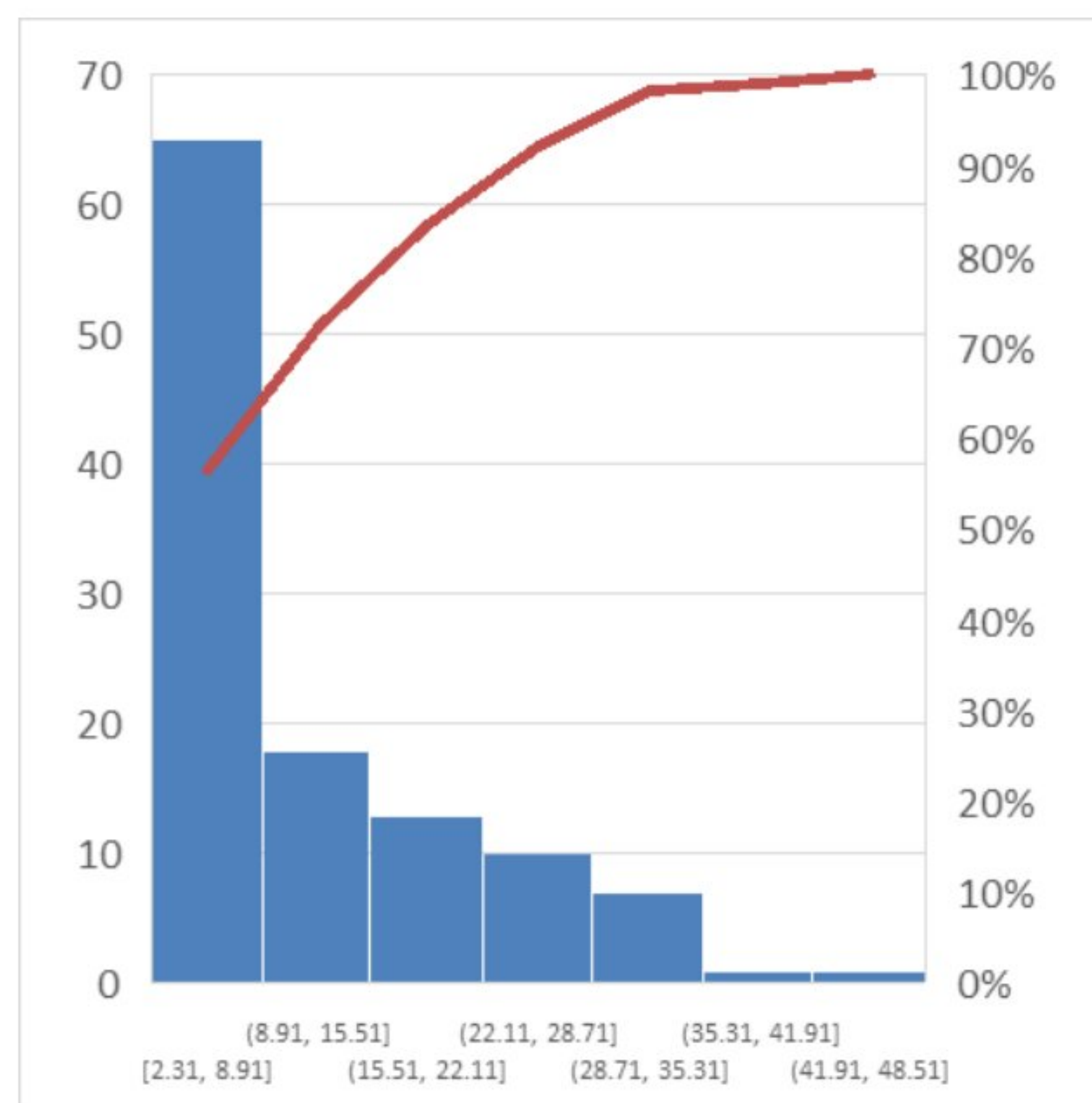


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A)

B)



C)

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

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The GSI index varies in females between 0.44 - 23.92, with an average value of 6.10, while in males the index is lower and we observe values of 0.29- 7.37, an average of 2.94 (Fig.23).

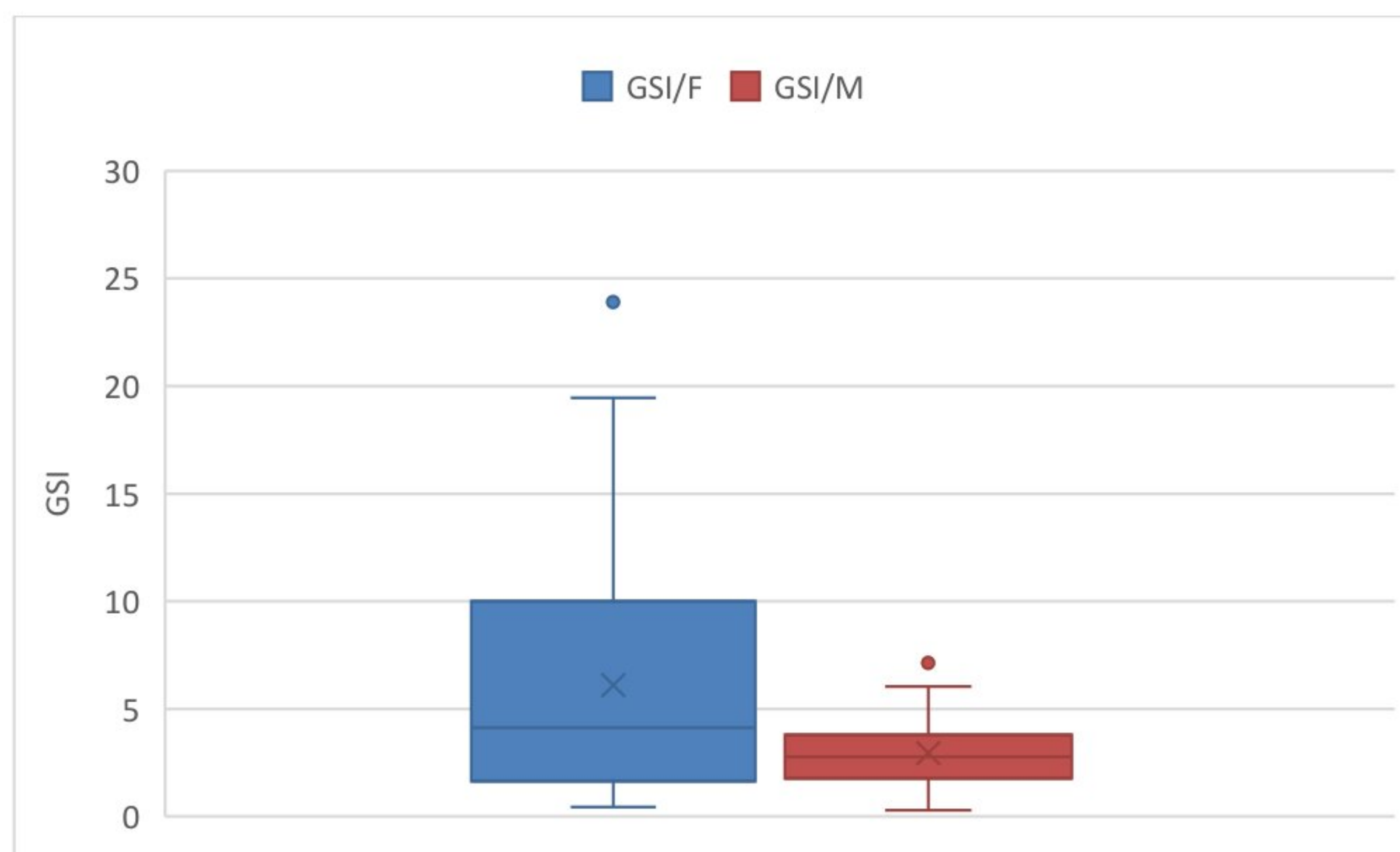


Figure 23 Gonadosomatic index (GSI) by sex of *M. merlangus*.

High abundance is observed at a depth of 45-65 m, (Fig.24). Specimens with a average size of 12.6 cm predominate. The established ratio between female, male and indeterminate sex individuals is - **56.02%:37.59%:6.39%**.



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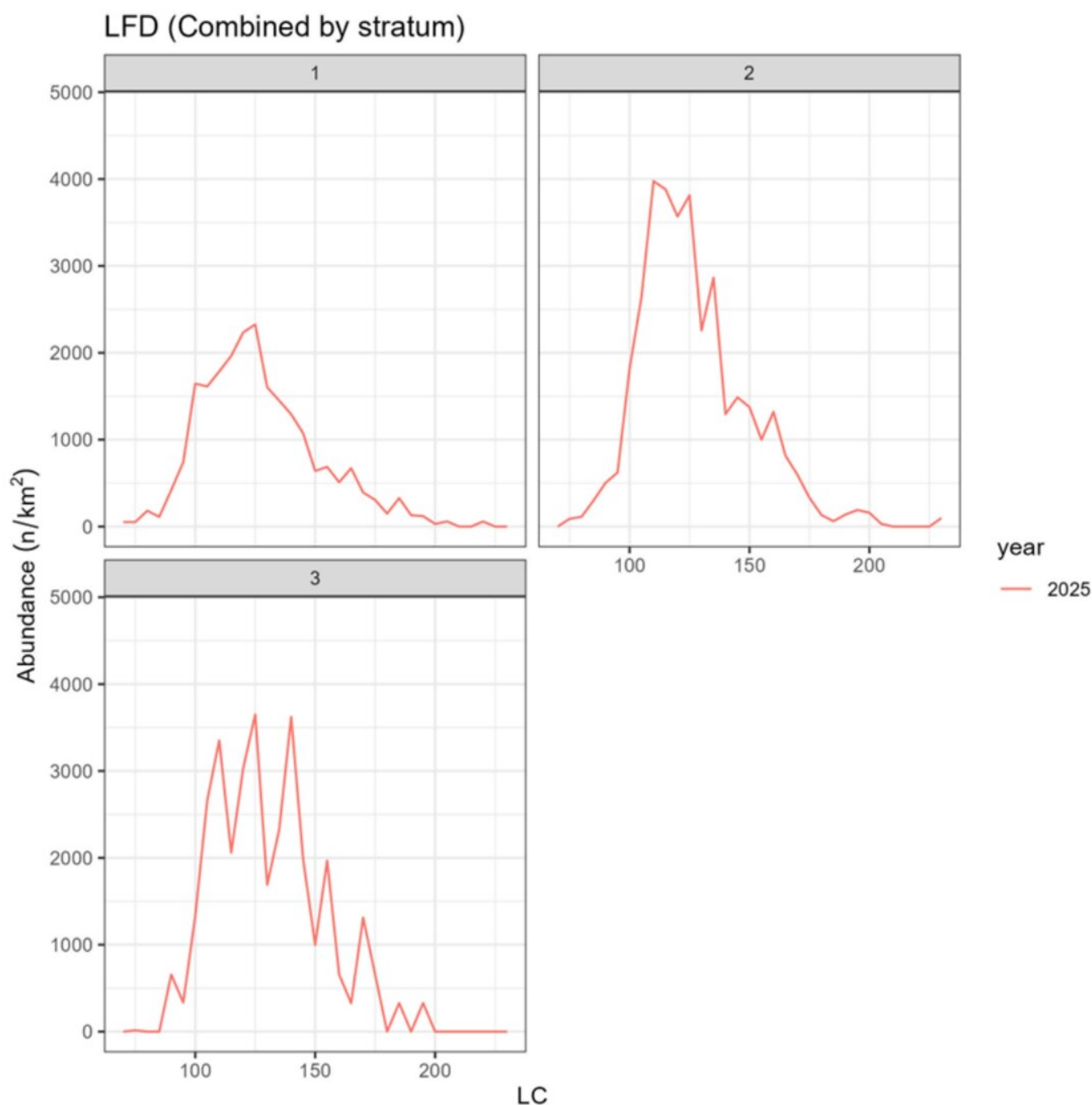


Figure 24 Abundance (n/km^2) by length classes (LC,mm) and depth strata (1, 2 and 3) for XI-XII 2025;

Mean relative biomass (kg/km^2) and abundance (n/km^2) distribution on a coordinate grid for whiting is shown in Fig. 25.

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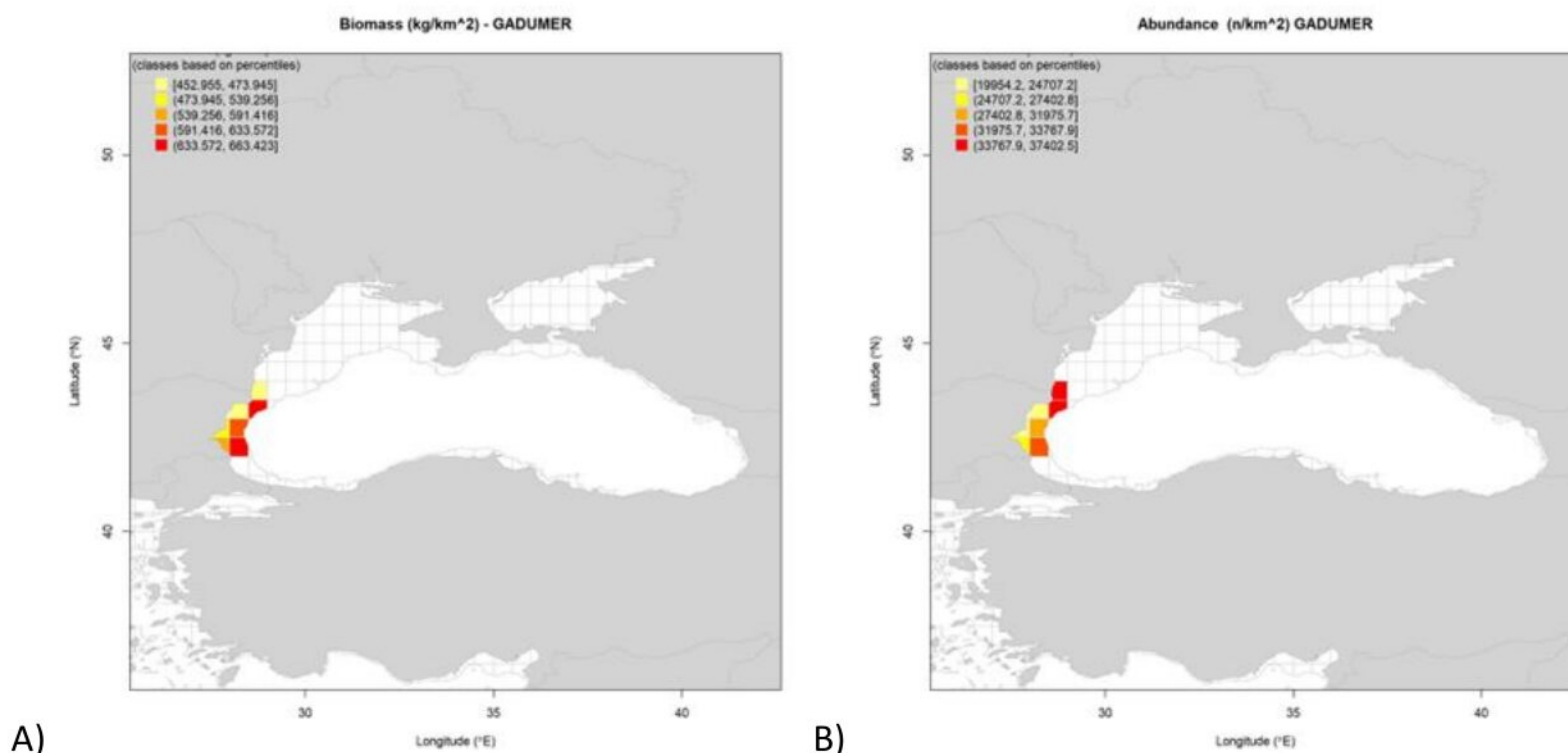


Figure 25 Distribution of mean A) relative biomass (kg /km²) and B) abundance (n/km²) of *M. merlangus* in November-December 2025, according to the BioIndex version 3.3;

The whiting biomass in the entire studied area in front of the Bulgarian coast of the Black Sea was estimated at **6457.16** tonnes (Table 4). The abundance in the studied area was estimated at **376.9*10³** 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).

Table 8

Results from CPUE (kg/h) on dogfish (*S. acanthias*) in November-December 2025

No	Field	Depth (m)		Catch (Kg/h)
1	E8	24	23	5.9
2	F7	27.5	27.5	5.3
3	G6	29.5	28.5	6.26
4	H5	22	20.5	0
5	L1	49	50	0
6	N1	56	64	0
7	M2	63	64	6.53
8	L3	66	69	13.2
9	M4	75	78	0
10	L5	80	79.5	6.48
11	K4	69	64	0
12	J5	62	61	6.91
13	J6	57	58	0
14	J7	78	80	12.49
15	H7	62	56	6.5
16	D9	27	31	0
17	E10	40	42	12.4
18	E11	51	57	0.91
19	G8	48	50	0
20	H9	71	77.5	0
21	G10	80	78	0
22	F9	48.5	47	0
23	F12	72	74	0
24	E13	69.5	72	0
25	G13	89.5	88	6.875
26	E15	70.5	69	0
27	D16	65	64	0
28	E17	70.5	71	0
29	F18	77.5	70	13.215
30	E19	64	64	1.83
31	D18	50.5	49	0
32	C17	46	47	0

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33	B16	36.5	37	0
34	C15	48	47	0
35	D14	63	62	0
36	C13	45	40.5	0
37	D12	52	50	0
38	C11	34	32	0

The main biological parameters of *S. acanthias* are presented in Fig.26, 27 and 28. A large part of the caught females are between 62-135 cm in size (Fig. 26, A), and the males are smaller in size 60-122 cm, (Fig. 26, B). The catch is dominated by males 83% and females by 17%.

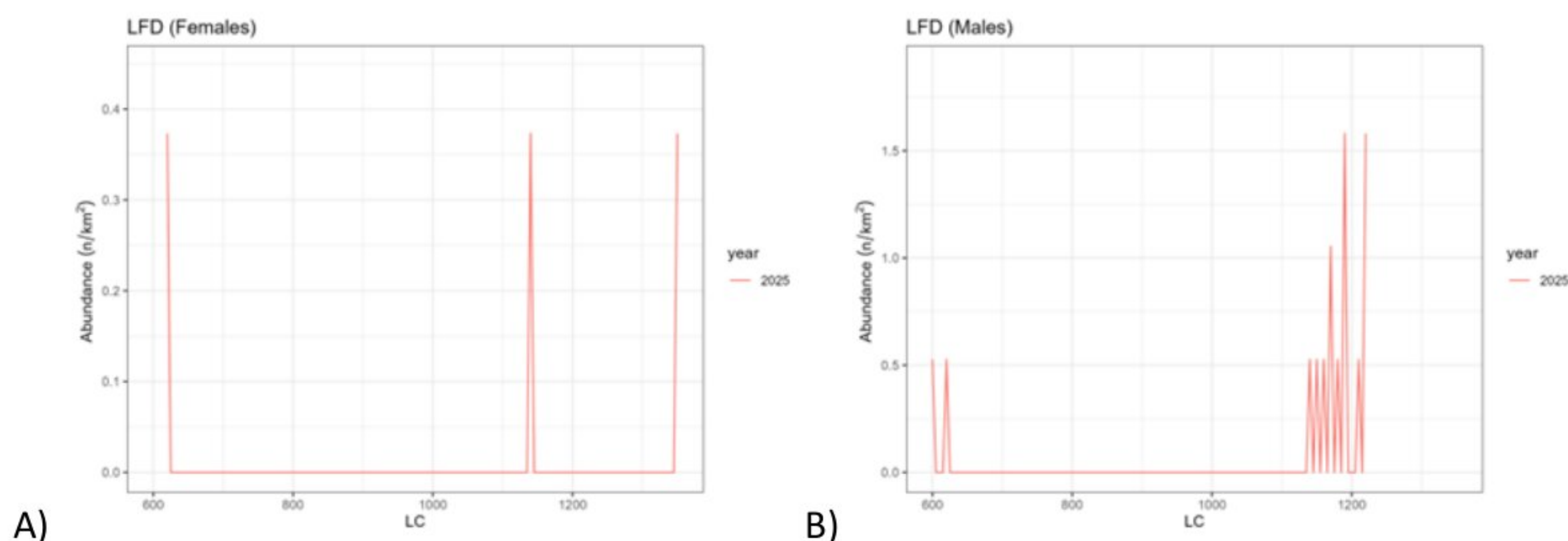


Figure 26 Abundance (n/km^2) and length classes (LC, mm) of *S. acanthias* catches by sex, A) female and B) male specimens;

The female specimens captured weighed between 980 and 12400 grams, with an average weight of 6546.6 grams (Fig. 27, A). In contrast, the male specimens weighed less, ranging from 910 to 7100 grams, with an average weight of 5677.33 grams (Fig. 27, B).

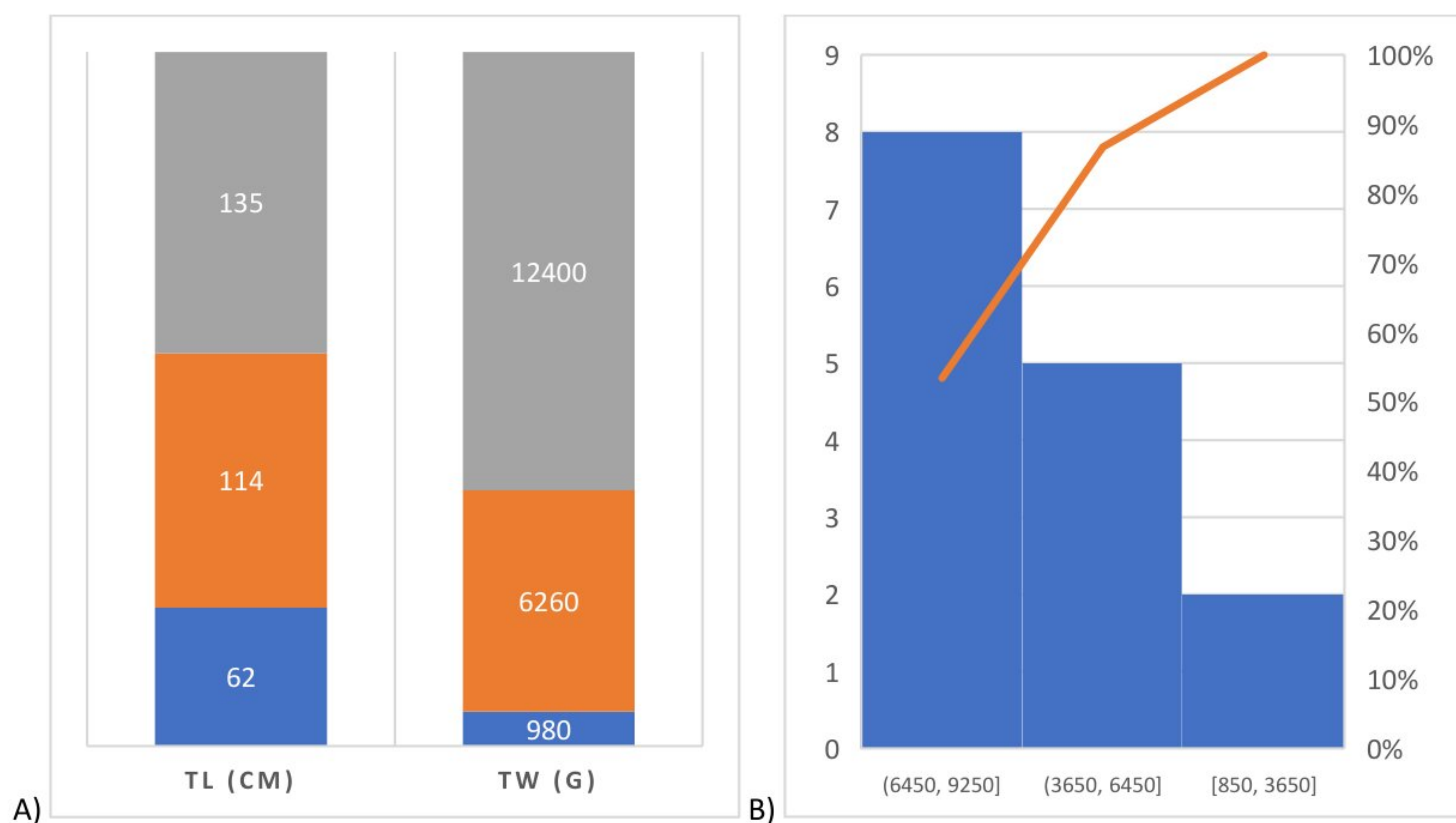


Figure 27 Weight structure of *S. acanthias* by sex, A) female and B) male specimens;

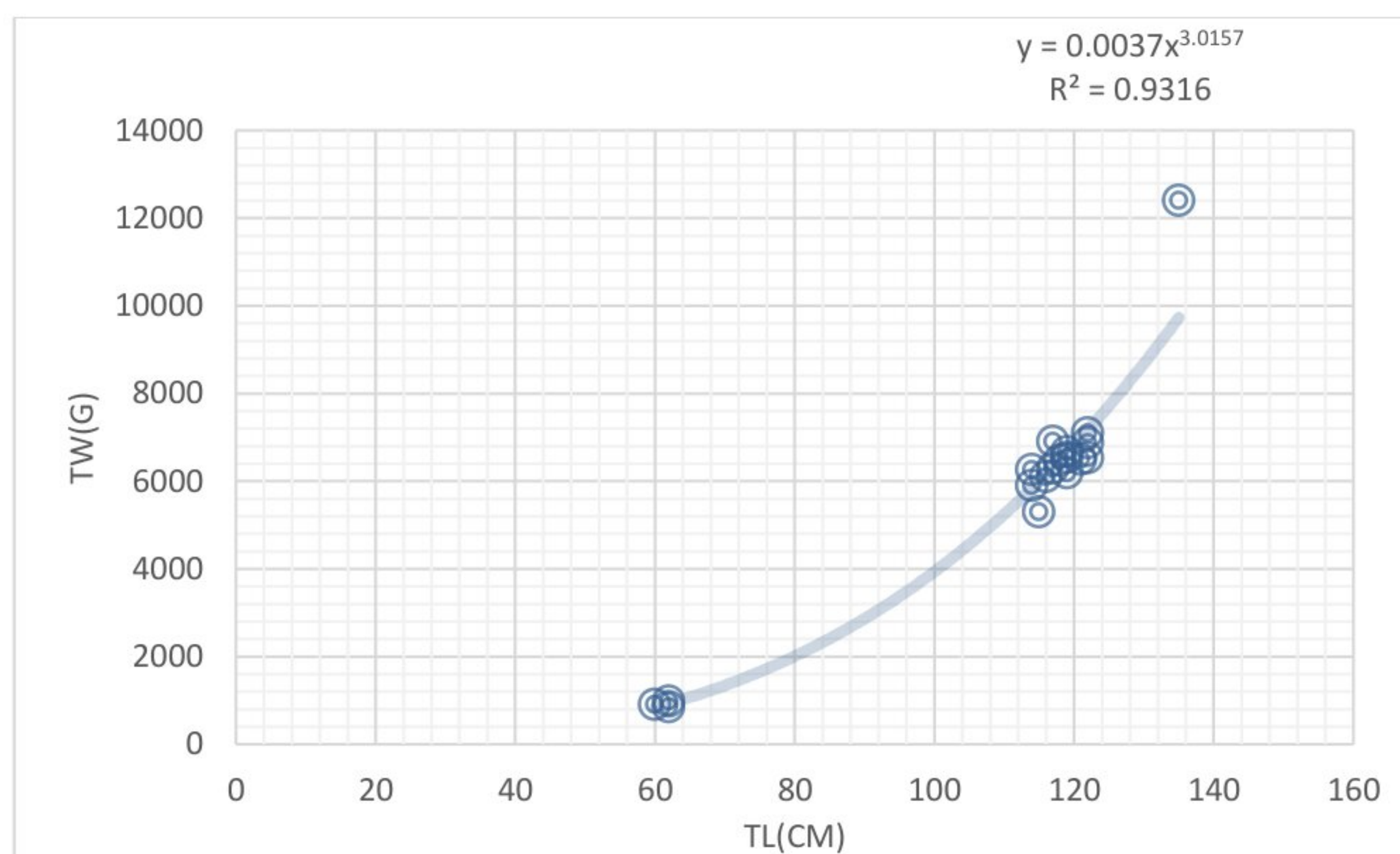


Figure 28 *S. acanthias*: Length-weight relationships XI-XII, 2025;



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The most abundant dogfish bycatch was caught at depth of 60-70 m, (Fig. 29).

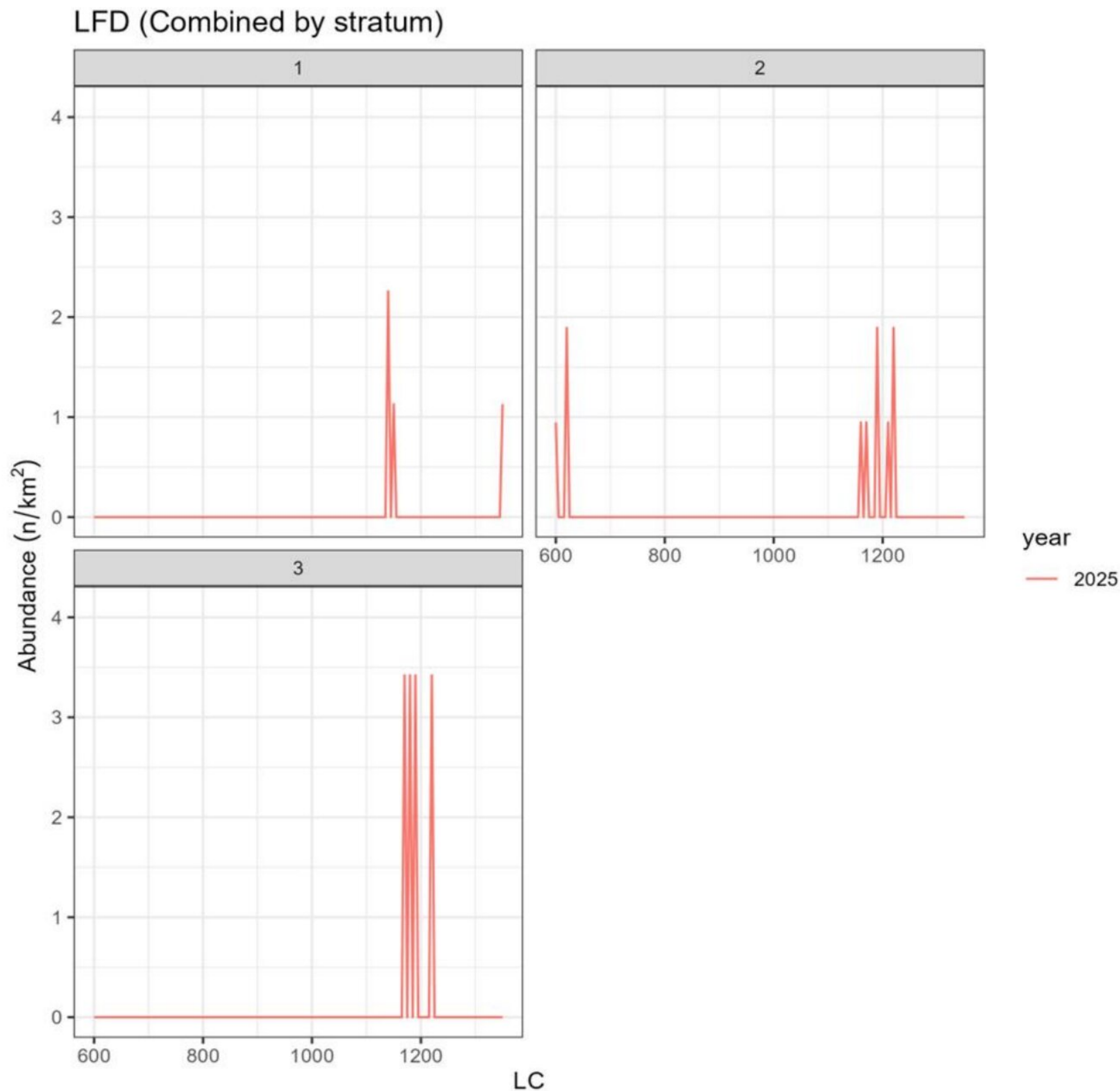


Figure 29 Abundance (n/km^2) by length classes (LC,mm) and depth strata (1, 2 and 3), XI-XII 2025;

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Biomass by haul (kg/km²)

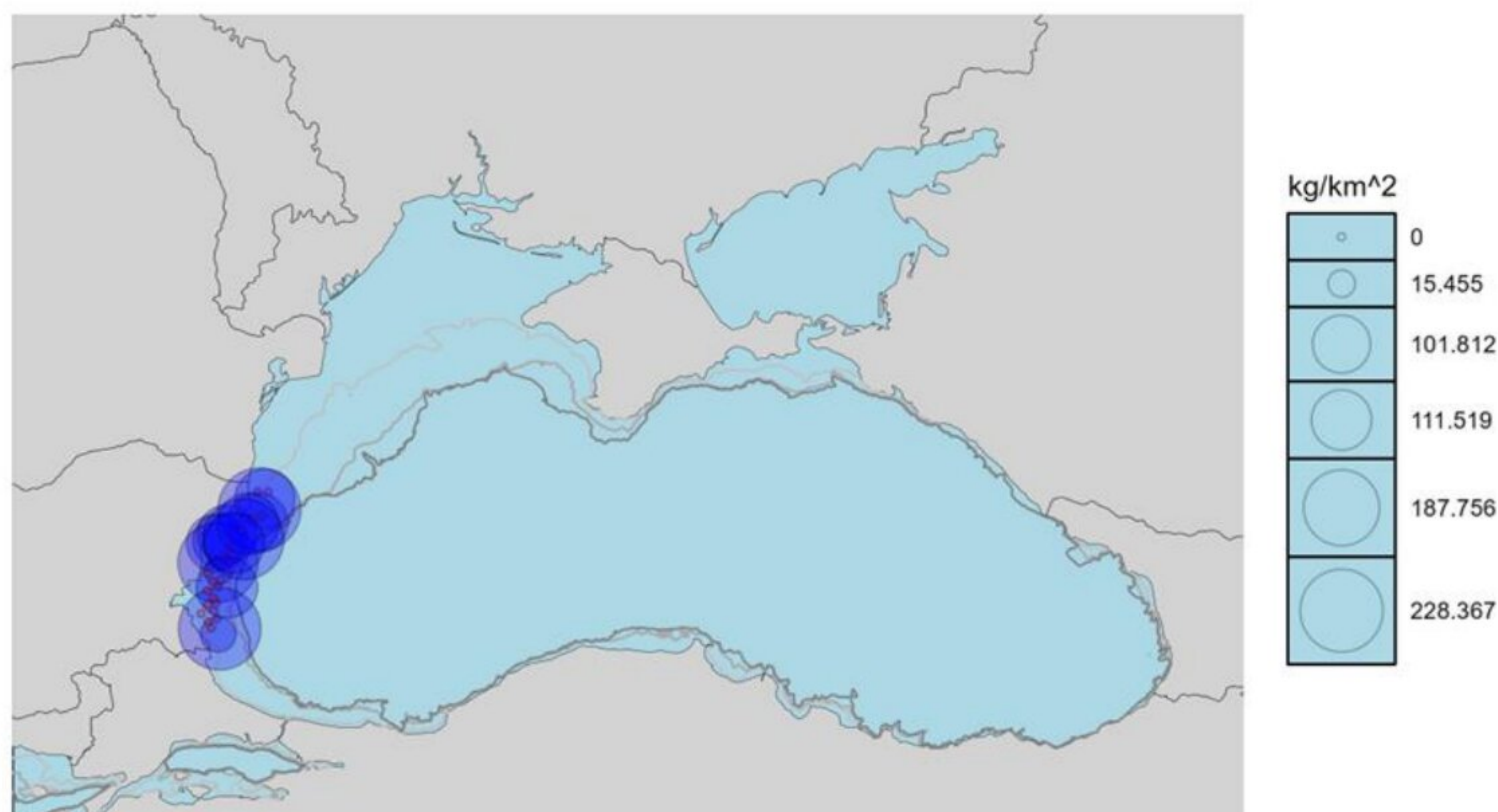


Figure 30 Distribution of the relative biomass by hauls (kg / km²) of *S. acanthias* in XI-XII 2025 according to BioIndex version 3.3.

The maximum biomass index of dogfish for XI-XII in the Bulgarian water area reaches **228 kg/km²**(Fig. 30).

Accurate assessment of biomass and abundance is hampered by the species' patchy and highly dispersed distribution pattern. Therefore, biomass estimates based on CPUE data from November–December may not be sufficiently accurate. The current biomass of spiny dogfish in the entire studied area along the Bulgarian Black Sea coast was estimated at **637.4 tonnes**. During the study period, the abundance in the entire studied area was estimated at **109.5 × 10³** 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).

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Table 9

Results of CPUE (catch per unit effort kg/h) of red fox (*R. clavata*) by month, November-December 2025

No	Field	Depth (m)		Catch (Kg/h)
1	E8	24	23	1.45
2	F7	27.5	27.5	0
3	G6	29.5	28.5	0
4	H5	22	20.5	15.62
5	L1	49	50	3.02
6	N1	56	64	0
7	M2	63	64	0
8	L3	66	69	10.69
9	M4	75	78	6.73
10	L5	80	79.5	0
11	K4	69	64	25.15
12	J5	62	61	0
13	J6	57	58	0
14	J7	78	80	5.08
15	H7	62	56	2.59
16	D9	27	31	9.59
17	E10	40	42	0
18	E11	51	57	2.8
19	G8	48	50	91.37
20	H9	71	77.5	0
21	G10	80	78	0
22	F9	48.5	47	99.01
23	F12	72	74	12.35
24	E13	69.5	72	182.945
25	G13	89.5	88	0
26	E15	70.5	69	66.155
27	D16	65	64	115.85
28	E17	70.5	71	2.135
29	F18	77.5	70	4.945
30	E19	64	64	9.16
31	D18	50.5	49	0.495

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32	C17	46	47	0.155
33	B16	36.5	37	3.68
34	C15	48	47	7.52
35	D14	63	62	36.065
36	C13	45	40.5	1.965
37	D12	52	50	17.355
38	C11	34	32	2.25

The main biological parameters of *Raja clavata* are presented in Fig.31, 32 and 33. The caught female specimens are 32-89 cm in size and weigh 155-4120 g (Fig. 31 A and Fig.32 A), and the following values were recorded for males - 42-90 cm and 390-4470 g, (Fig. 31 B and Fig. 32 B). Female specimens predominate in the catch, 56.89 %, and males 43.11%.

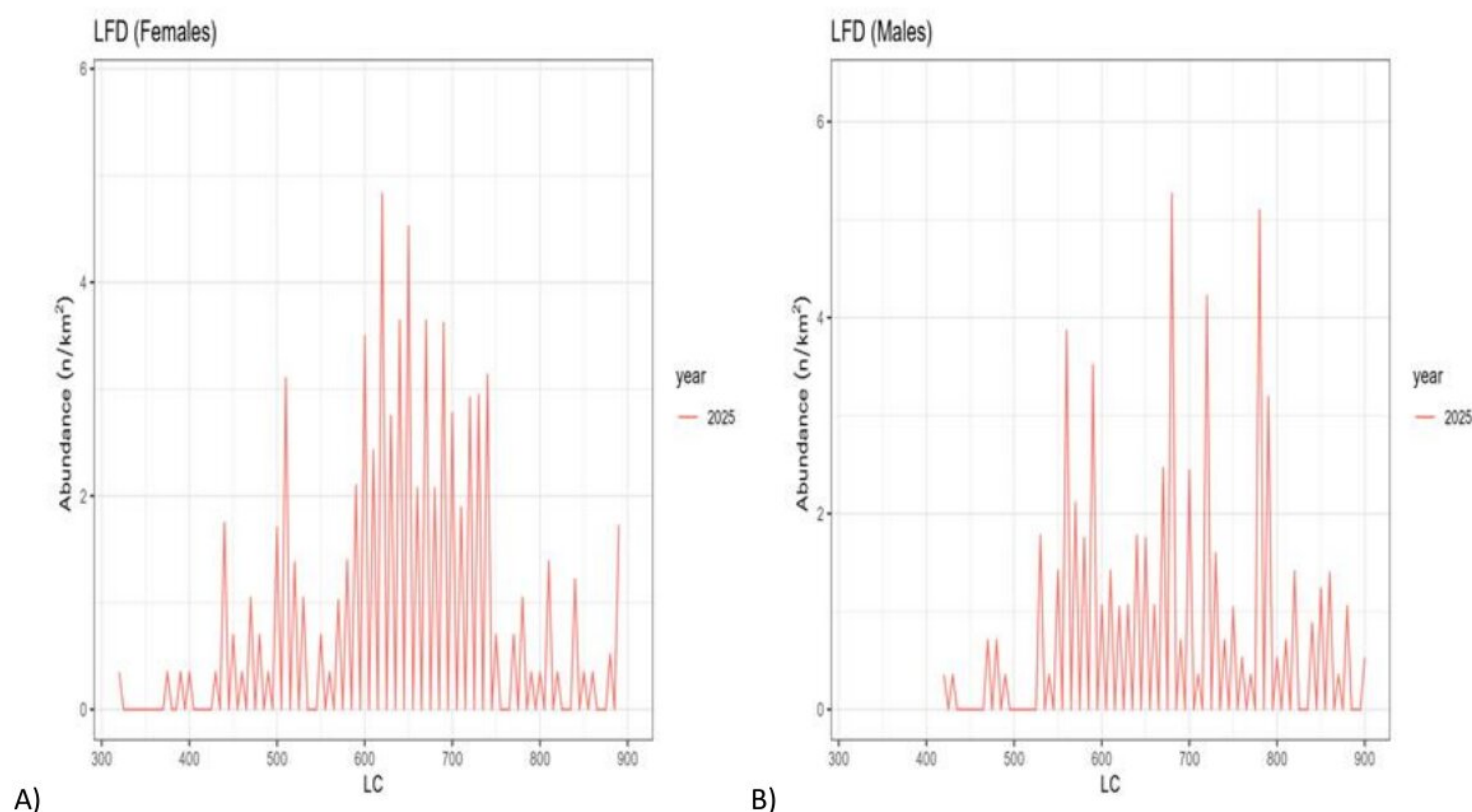


Figure 31 Abundance (n/km²) and length classes (LC, mm) of *Raja clavata* by sex, A) female, and B) male specimens;

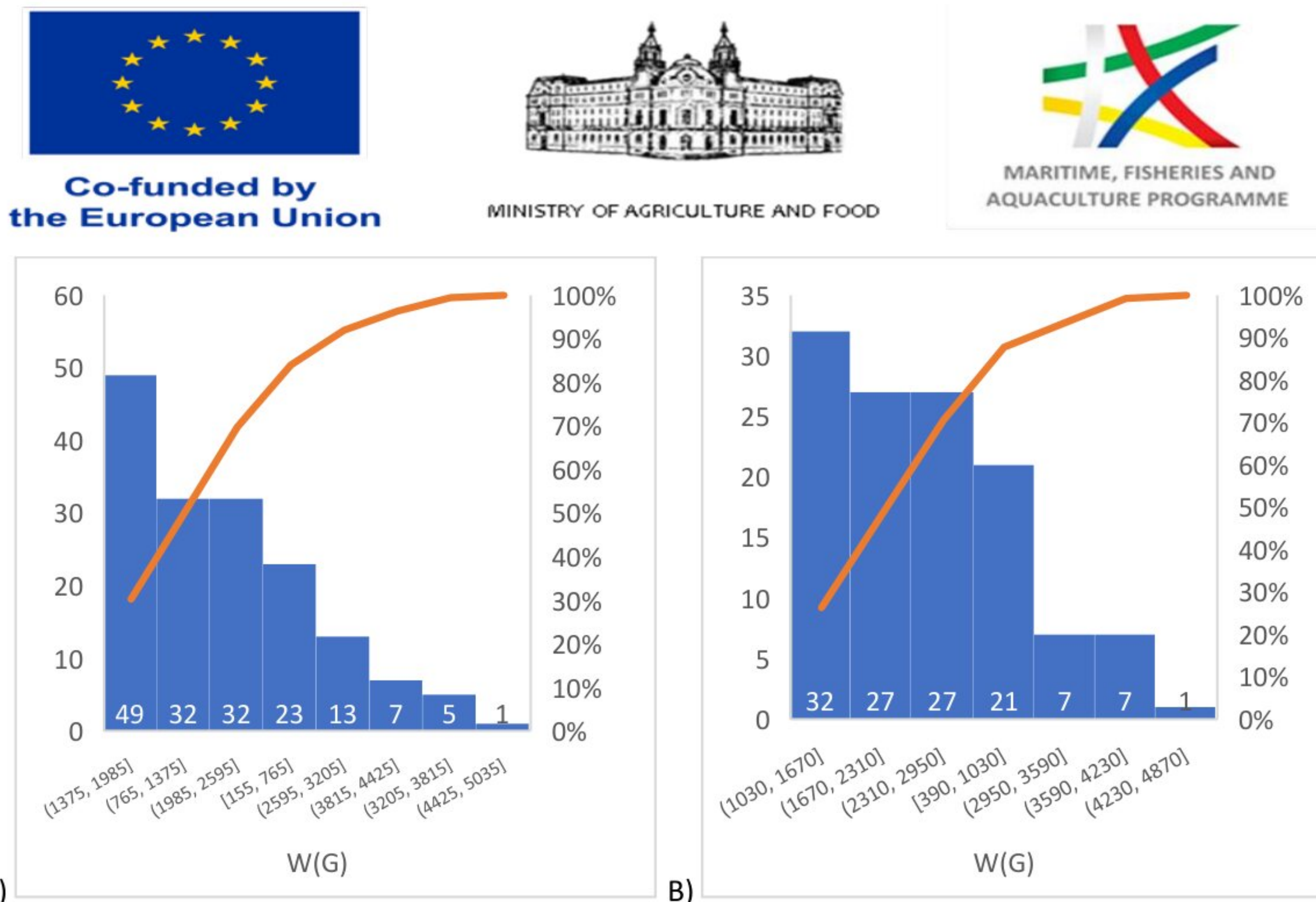


Figure 32 Weight structure by sex of *Raja clavata* catches, A) female and B) male specimens;

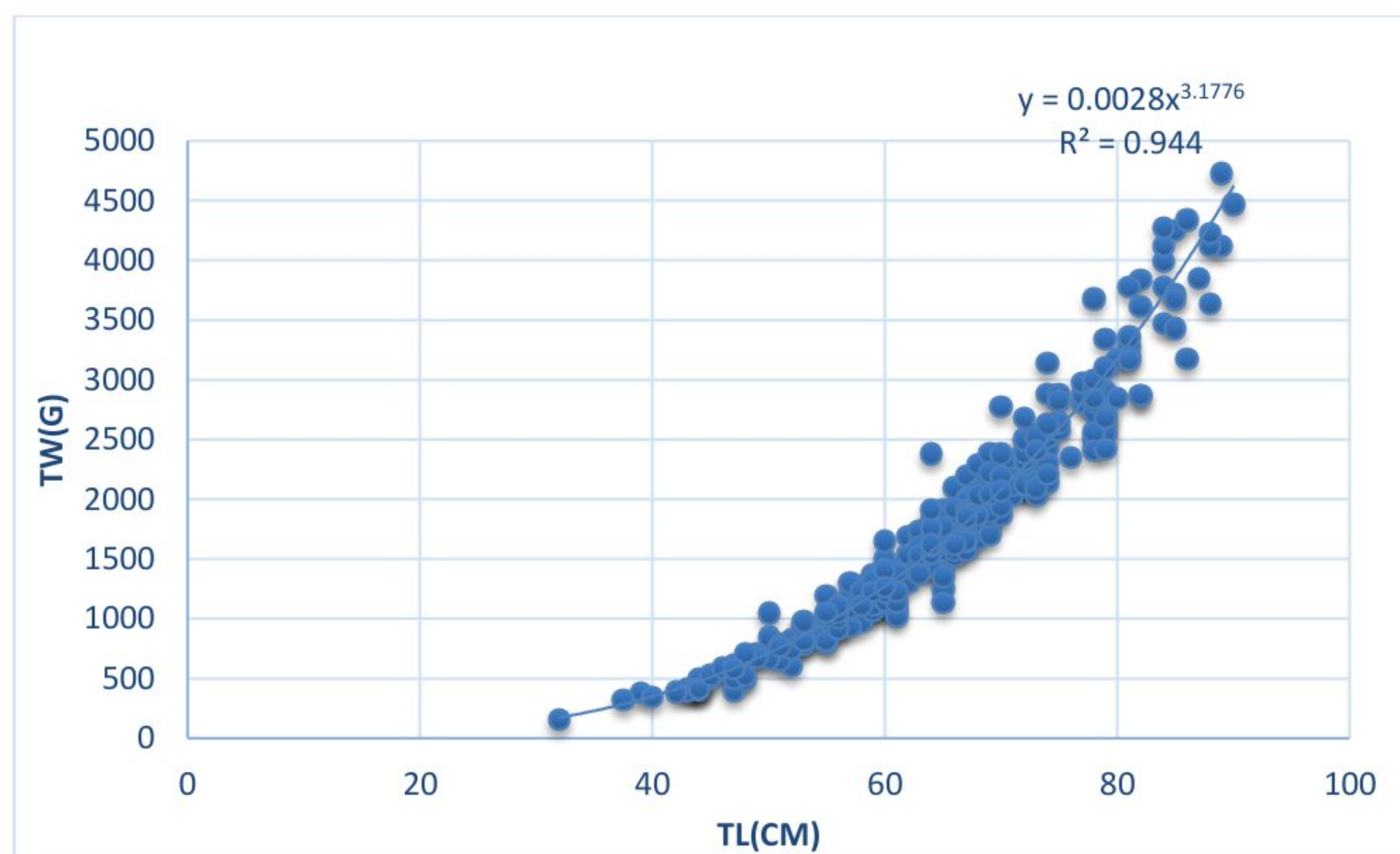


Figure 33 *Raja clavata*: Length-weight relationships XI-XII, 2025;



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At a depth of 50-65 m, a high catch of thornback ray was recorded, and at this depth catch specimens with lengths between 44- 86 cm (Fig. 34).

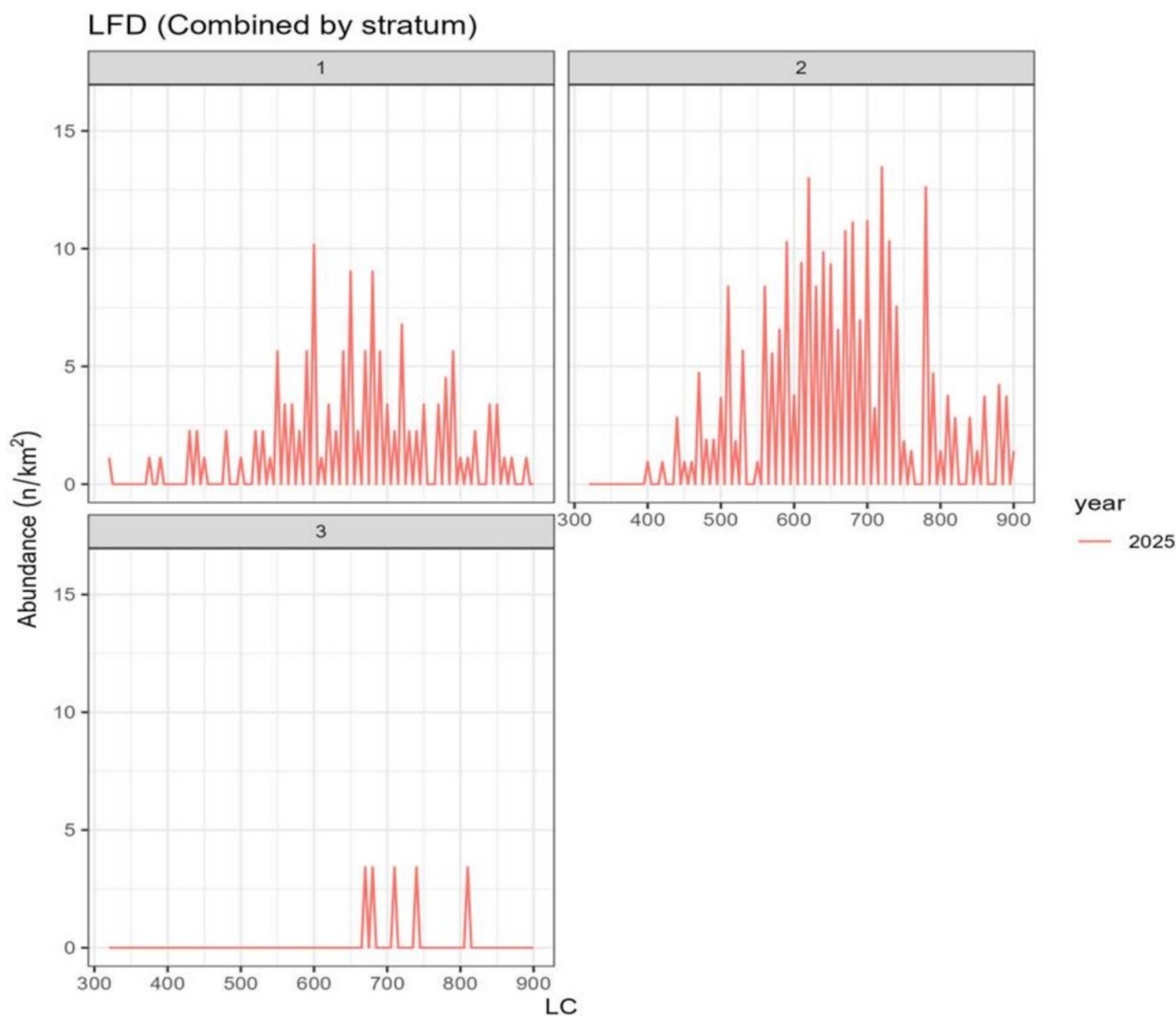


Figure 34 Abundance (n/km^2) by length classes (LC, mm) and depth strata (1, 2 and 3) for XI-XII 2025;

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

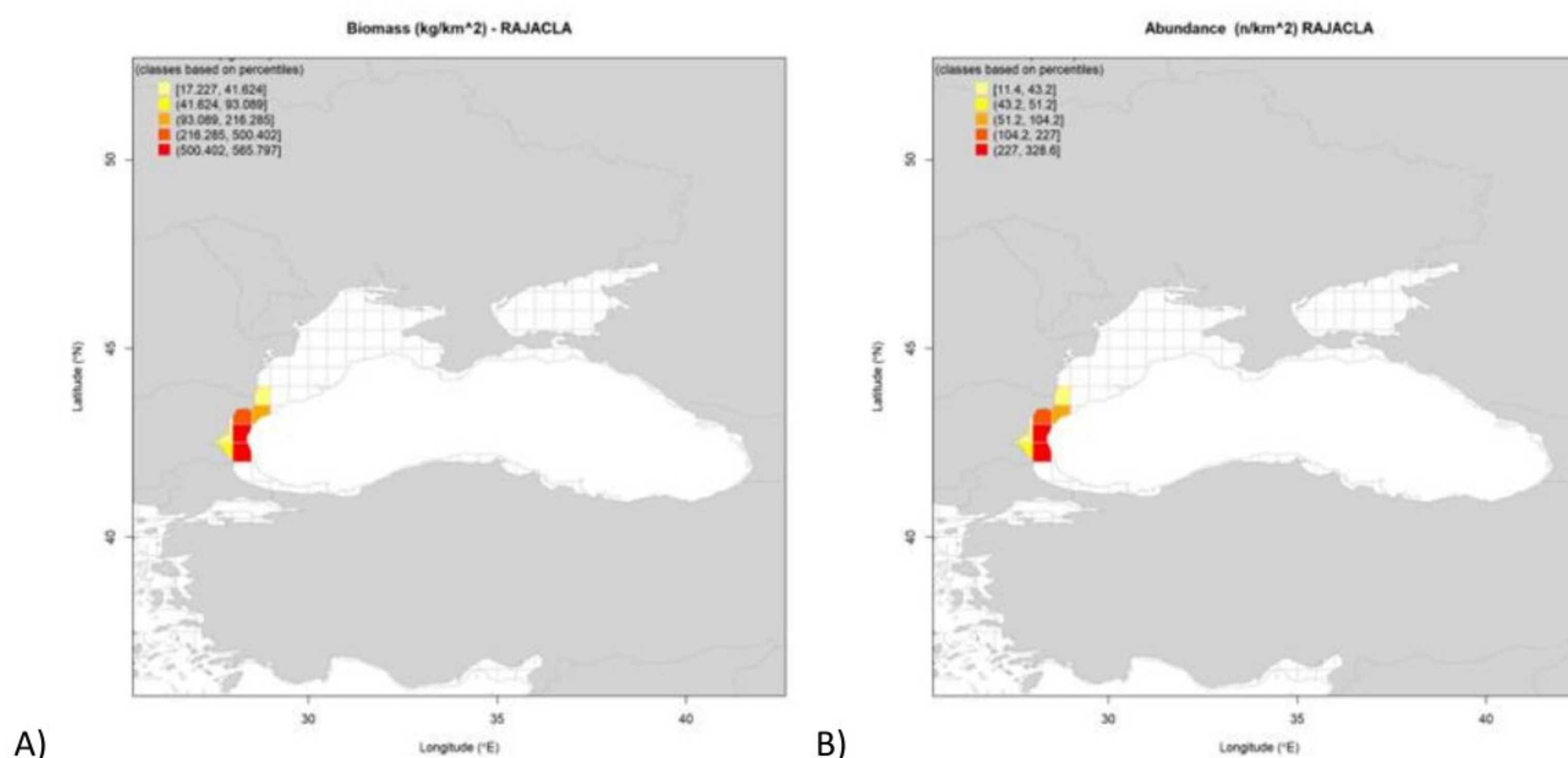


Figure 35 Distribution of mean A) relative biomass (kg /km²) and B) abundance (n/km²) of *Raja clavata* in XI-XII 2025, according to the BioIndex version 3.3;

The thornback ray biomass in the entire studied area in front of the Bulgarian coast of the Black Sea was estimated at **3030.97** tonnes. The abundance was estimated at **1625.29*10³** specimens.

4. Food spectrum of *S. maximus*

During the winter period of 2025, 84 stomachs were analyzed to determine the diet spectrum of turbot. Nutritional components were found in 52 % (46 specimen) of the examined individuals, while 48 % (38 specimens) were without stomach content, which indicates that the feeding fish during the period is even. 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 (g)	Stom. content (gr)	ISF
Number	46	46	46	46
Sum	2444.00	137300.00	1323.50	48.69
Min	46.00	1620.00	1.48	0.04
Mean	53.13	2984.78	28.77	1.06
Max	66.00	5410.00	93.48	3.77
Std. dev	5.63	982.06	26.00	1.02
Median	52.00	2730.00	17.14	0.58
Kurtosis	-1.02	-0.71	0.19	0.73
Skewness	0.39	0.54	1.19	1.35
Std. Err.	0.83	144.80	3.83	0.15

The mean fullness index of the turbot stomachs reaches 1.06 % BW $\pm$ 0.15 SE (Table 10). ISF (% BW) values for the autumn-winter season of 2025 are shown on Fig. 36.

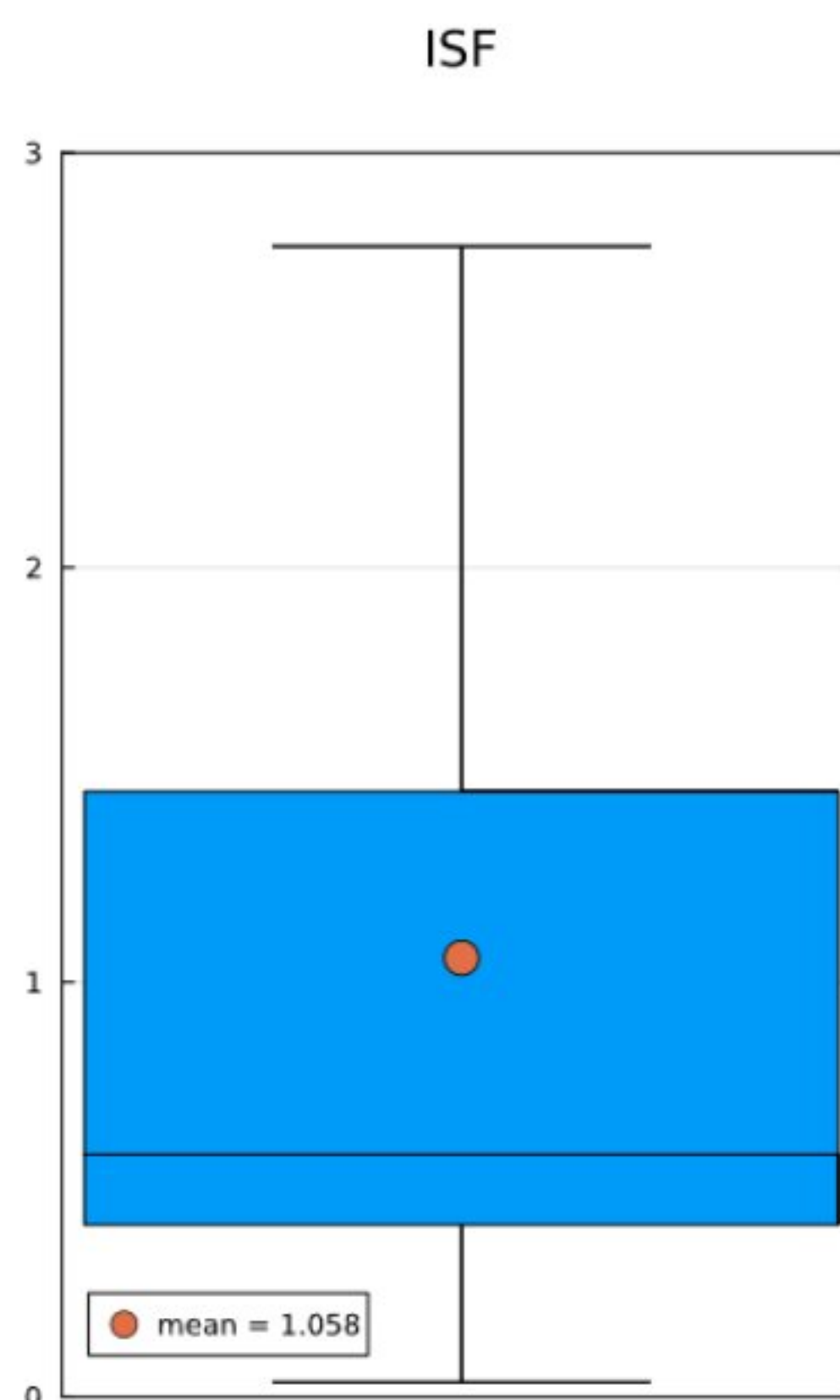


Figure 36 Box-plot: ISF (% BW) values during the autumn-winter of 2025

The spatial distribution of the stomach fullness index of turbot (Fig. 37) indicates higher values in the central and southern sectors of the Bulgarian Black Sea coast.



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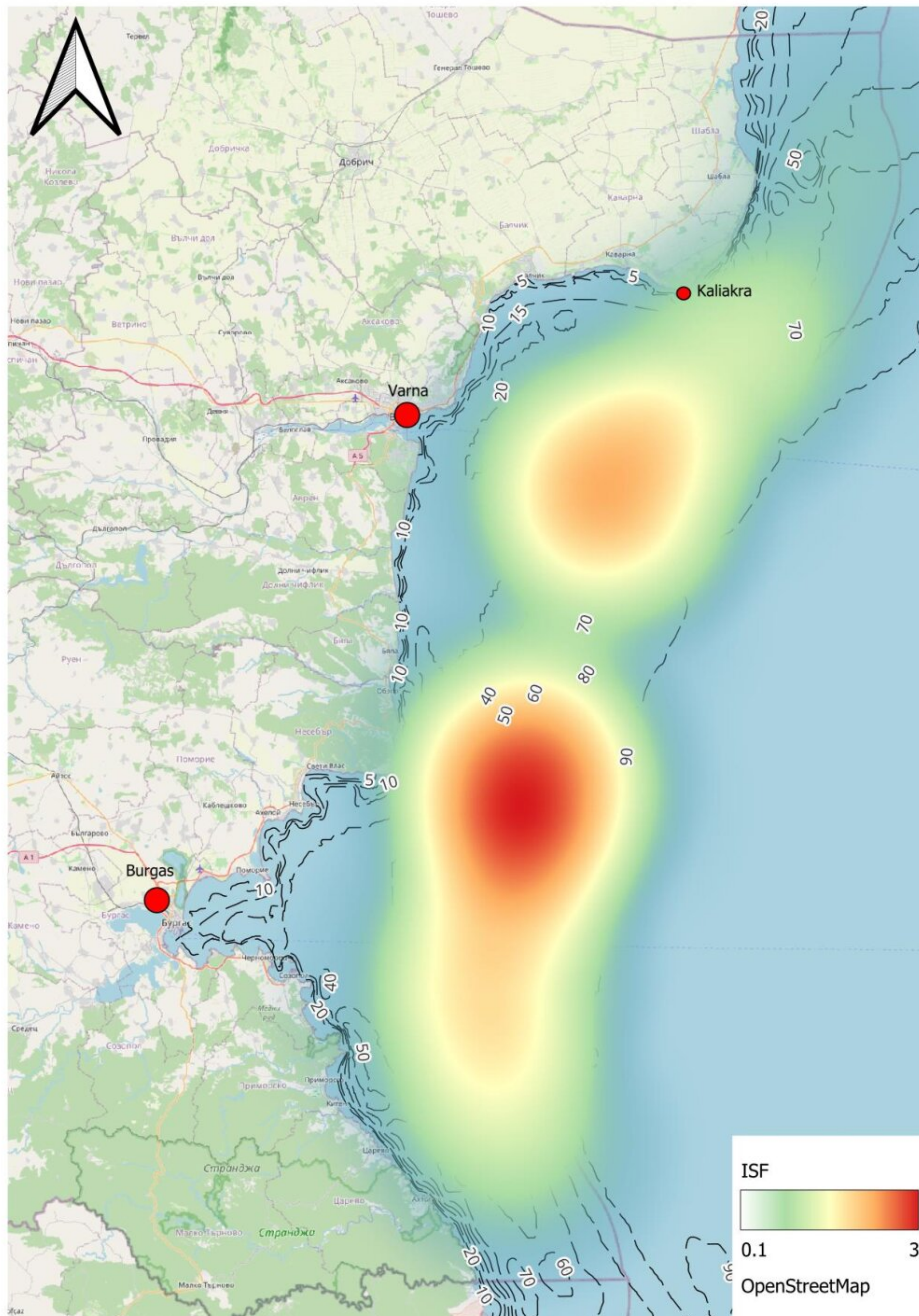


Figure 37 Spatial distribution of the turbot stomach fullness index (ISF, % BW) during the autumn-winter season 2025

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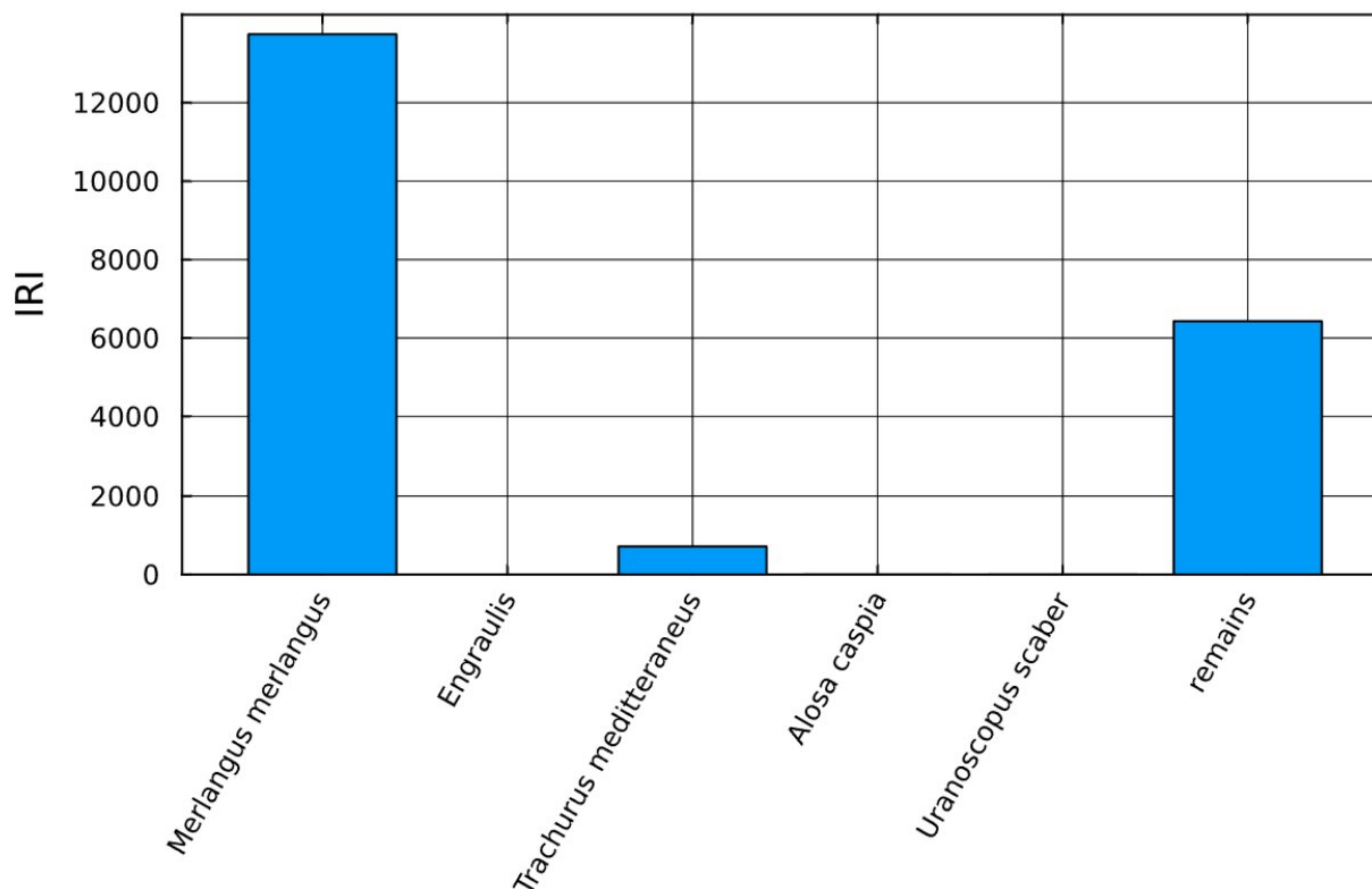


Figure 38 IRI values by species for the autumn-winter season of 2025 – Turbot.

Table 11

Qualitative composition of turbot diet during the study period

Species	FO	CN	CB	IRI	IRI %
"Merlangus merlangus"	136.96	48.80	51.57	13746.70	65.79
"Trachurus mediterraneus "	41.30	8.65	8.66	714.95	3.42
"Alosa caspia"	2.17	0.43	0.74	2.55	0.01

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"Uranoscopus scaber"	2.17	0.31	0.90	2.63	0.01
Remains	80.43	41.80	38.13	6429.33	30.77

During the study period, the highest IRI value was for processed content – 6429.33 (30.77%). Only one major taxonomic group-fish- was identified, dominating the diet with an IRI of 14 466.0 and a relative contribution of 69.23%. Within the fish group, whiting (*Merlangus merlangus*) traditionally prevailed with IRI = 13746.00 (65.79%), followed by *Trachurus mediterraneus* with IRI = 714.95 (3.2 %).

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

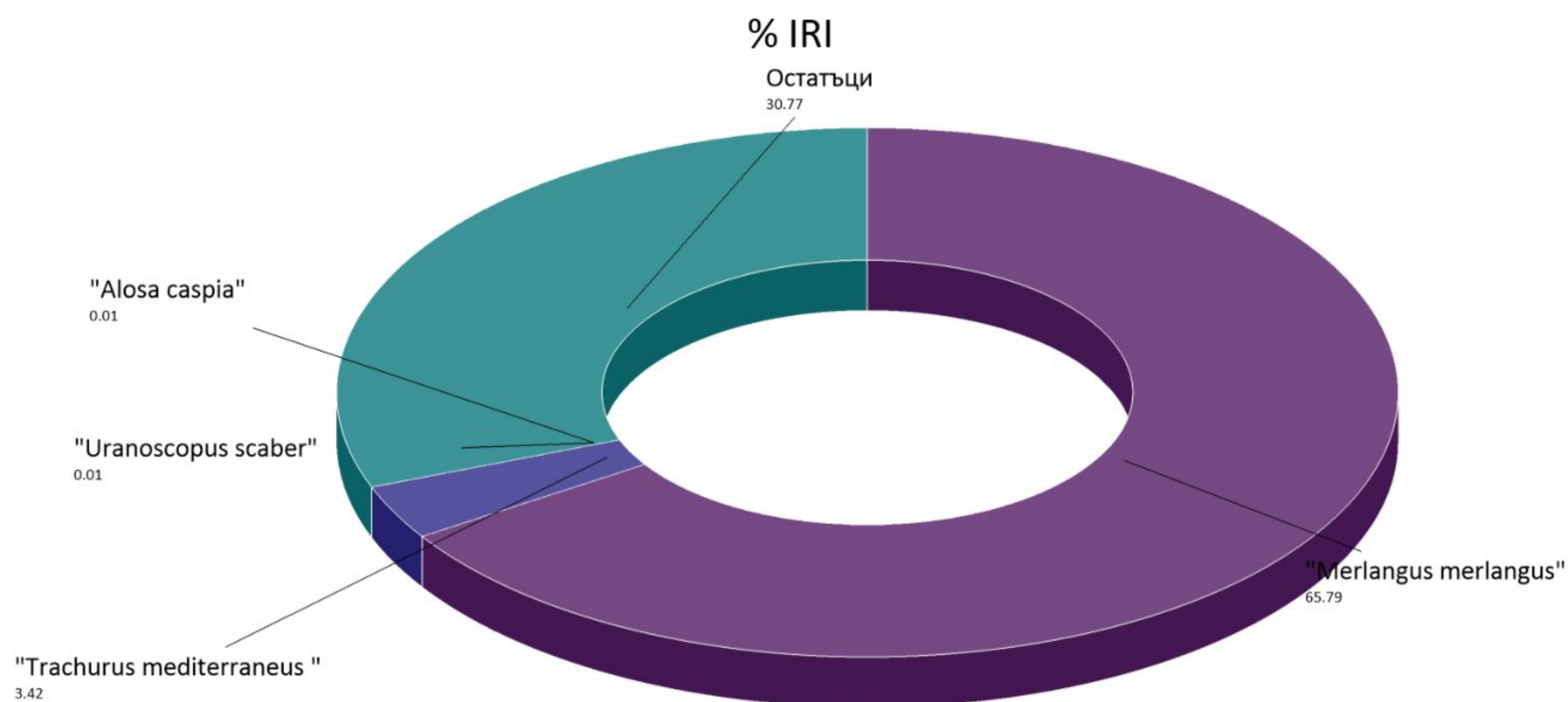


Figure 39 Percentage shares by groups (% IRI) in the turbot diet spectrum during the autumn-winterseason of 2025



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Additional species, diet spectrum

Along with the analyzed turbot stomachs, during the season of 2025 the following fish species were examined to analyze their dietary spectrum: *Squalus acanthias* and *Raja clavate*.

Piked dogfish (*Squalus acanthias*) – Of the 6 stomachs analyzed to determine the diet spectrum, 5 specimens contained stomach contents (83 %). General statistical data for the measured biological parameters are presented in Table 12.

Table 12

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

	L (cm)	W (gr)	Stom. content	ISF
Number	5	5	5	5
Sum	617.00	39020.00	278.29	4.10
Min	119.00	6530.00	14.33	0.14
Mean	123.40	7804.00	55.66	0.82
Max	135.00	12400.00	100.43	1.54
Std. dev	6.66	2573.02	38.96	0.63
Median	122.00	6675.00	60.19	0.90
Kurtosis	0.00	0.24	-1.67	-1.68
Skewness	1.31	1.49	-0.04	-0.06
Std. Err.	2.98	1150.69	17.43	0.28

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The mean value of the ISF (stomach fullness) reaches $0.82 \% \text{ BW} \pm 0.28 \text{ SE}$ (Table 12).

Thornback ray (*Raja clavata*) – A total of 22 stomachs were analyzed, with stomach contents present in 22 specimens (100 %). General statistical data for the measured biological parameters are presented in Table 13.

Table 13

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

	L (cm)	W (gr)	Stom. content	ISF
Number	22	22	22	22
Sum	1602.00	52345.00	496.96	20.68
Min	63.00	1380.00	3.19	0.16
Mean	72.82	2379.32	22.59	0.94
Max	86.00	3360.00	67.79	2.38
Std. dev	6.72	578.46	19.64	0.75
Median	73.00	2400.00	15.53	0.66
Kurtosis	-1.01	-1.04	-0.24	-1.12
Skewness	0.06	-0.10	0.96	0.60
Std. Err.	1.43	123.33	4.19	0.16

The mean value of the ISF (stomach fullness) reaches $0.94\% \text{ BW} \pm 0.16 \text{ SE}$ (Table 13).

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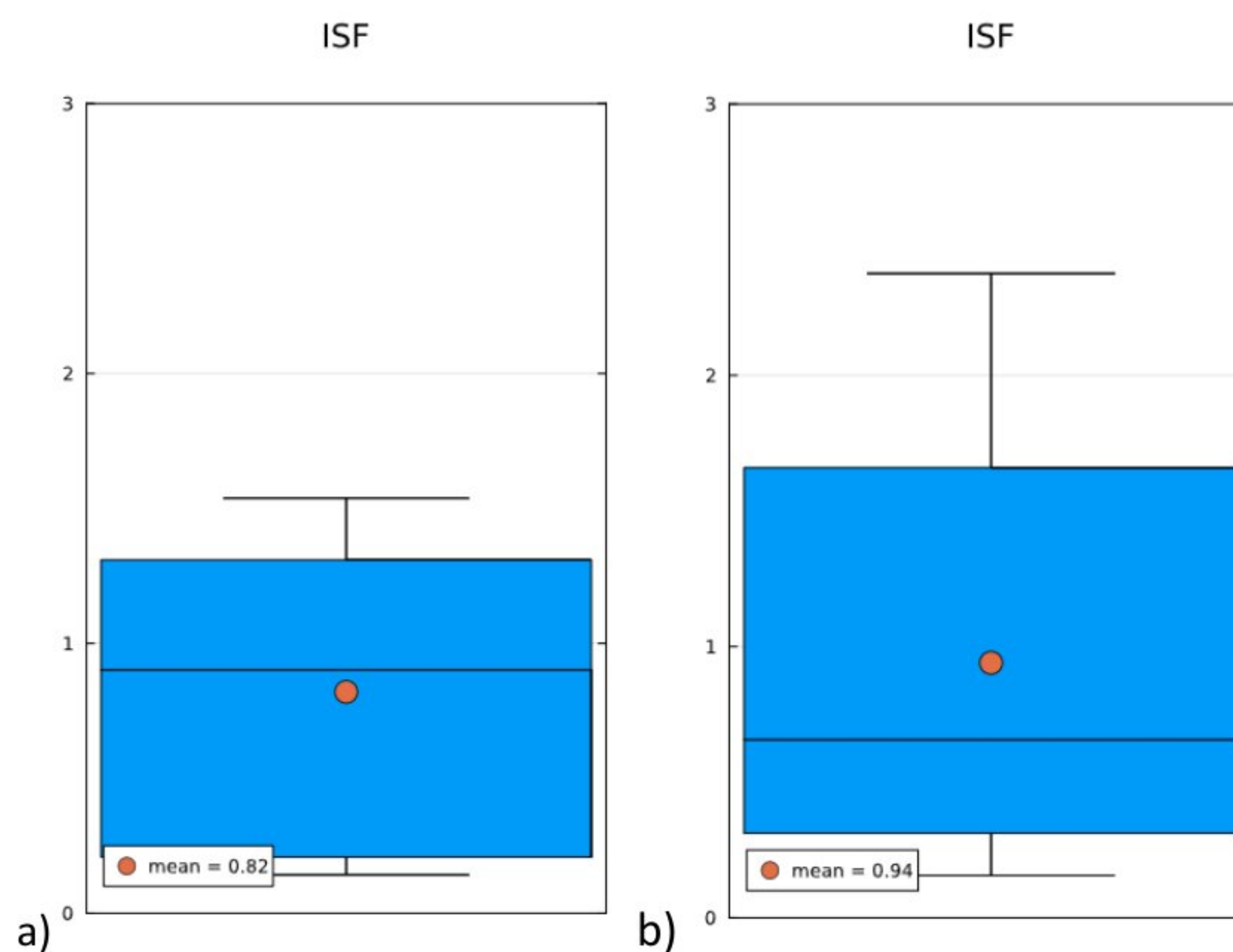


Figure 40 Box-plot: ISF values for a) *Squalus acanthias* and b) *Raja clavata*.

The qualitative composition of the diet of *Squalus acanthias* and *Raja clavata* is presented in Tables 15 and 16.

Table 15

Qualitative composition *Squalus acanthias* diet for the period of research

Species	FO	CN	CB	IRI	IRI %
<i>Merlangus merlangus</i>	120	36	35.26	8551.01	35.41
<i>Sprattus sprattus</i>	180	36.67	20.43	10277.1	42.56
<i>Engraulis encrasicolus</i>	40	6.67	3.58	409.81	1.7
Remains	80	20.67	40.73	4912.1	20.34

Table 16

Qualitative composition of *Raja clavata* diet for the period of research

Species	FO	CN	CB	IRI	IRI %
Merlangus merlangus	81.82	24.17	28.67	4323.21	33.65
Sprattus sprattus	18.18	8.33	10.06	334.47	2.6
Gobiidae	4.55	1.52	1.49	13.67	0.11
Macropipus holsatus	18.18	3.03	0.77	69.15	0.54
Decapoda	50	23.41	24.87	2413.73	18.79
Remains	77.27	39.55	34.13	5693.44	44.32

The qualitative analysis results indicate that the species *Squalus acanthias* feeds mainly on whiting (IRI = 34.41 %) and sprat, which accounts for IRI = 42.56 %. The digested stomach content has a total IRI percentage of 20.34 %. In the diet of *Raja clavata*, species from two taxonomic groups were recorded, fish with IRI = 36.36 % and Decapoda with IRI = 18.79 %. The IRI values of the individual species forming the stomach contents of *Squalus acanthias* and *Raja clavata* during the autumn-winter of 2025 are presented in Figures 40 and 41.

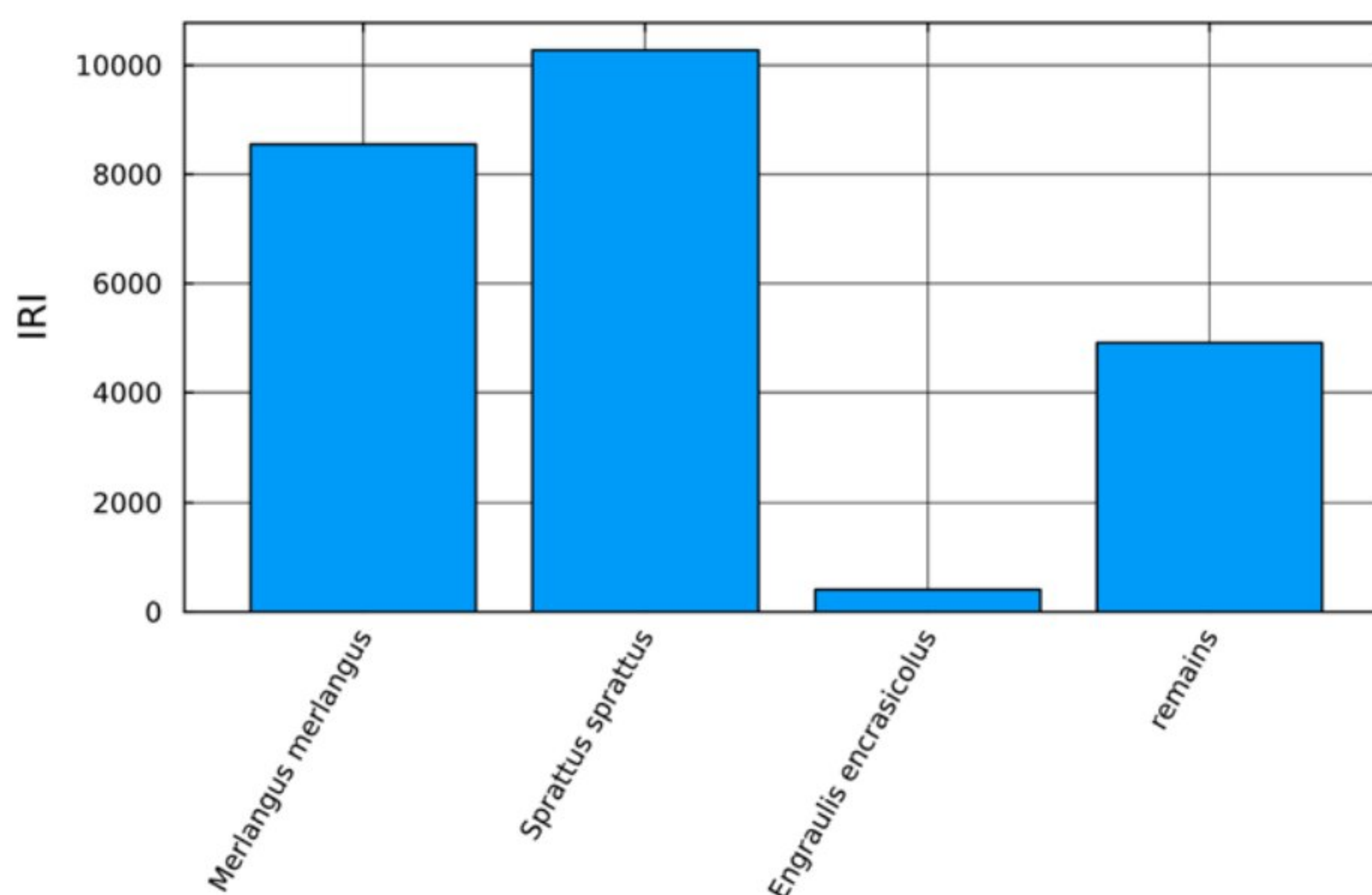


Figure 41 IRI values by species for the autumn-winter season of 2025 - *Squalus acanthias*

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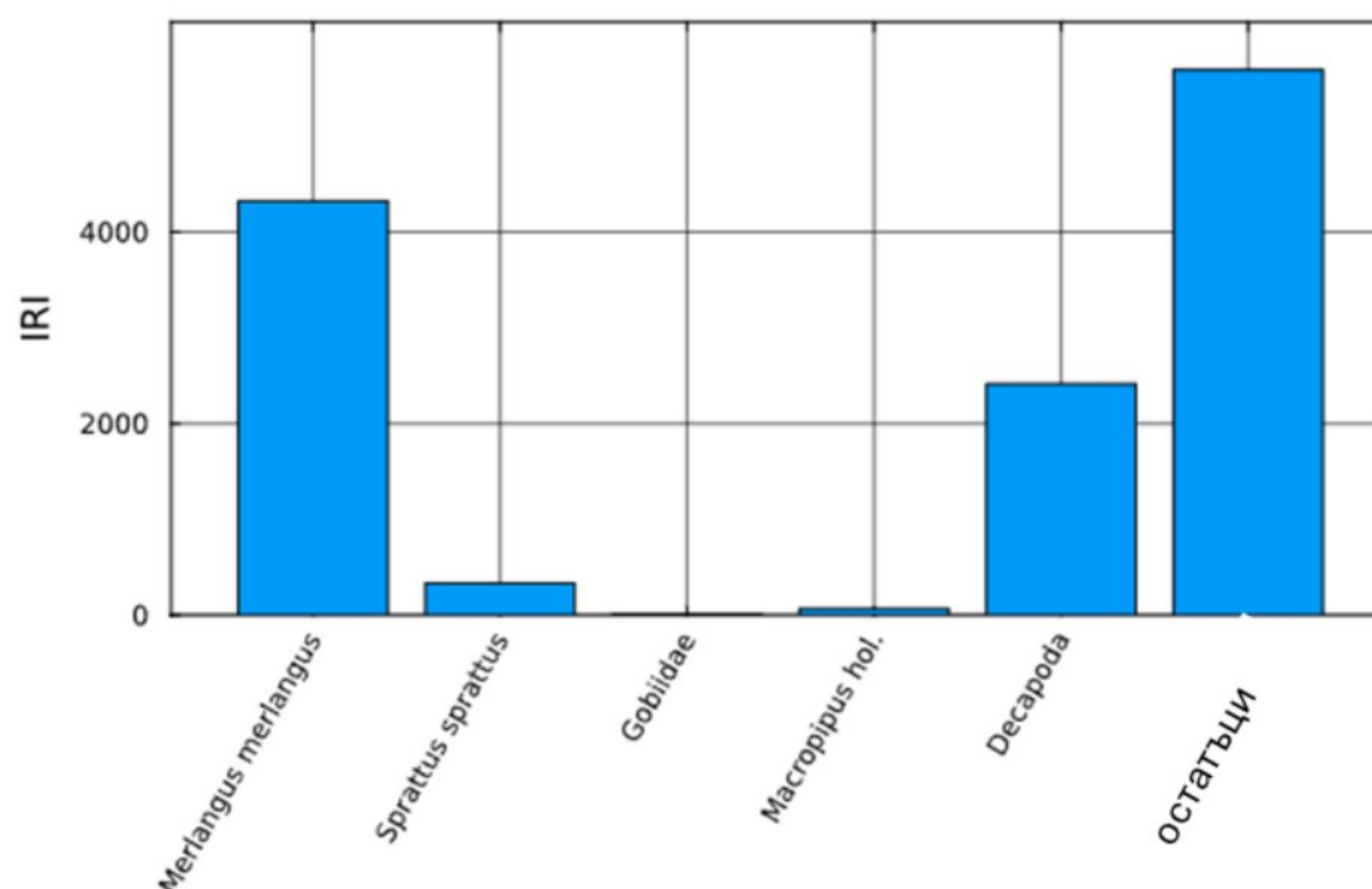


Figure 41 IRI values by species for the autumn-winter season of 2025 – *Raja clavata*;

5. Forecasts and opportunities for exploitation

The determination of MSY (maximum sustainable catch) in the autumn season of 2024 was made according to the formula of Gulland (1971): $MSY = 0.5 \cdot M \cdot B_v$, and the natural mortality rate (M) was calculated according to the formula of Pauly (1979, 1980). With a value of $M = 0.2$, the quantity of MSY according to the Gulland method amounts to **155.59 t** for the autumn-winter season of 2025.

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 the population is under exploited at $E < 0.5$, at $E = 0.5$ it considers an optimal level of exploitation, a $E > 0.5$ indicates over-exploitation

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of the stock. The calculated value of $E = 0.51$ (for the two studied seasons of 2025) is an indication of the optimal level of exploitation of the turbot stock.

The values of the parameters in the von Bertalanffy equation for the two investigated seasons of 2025 were calculated: $a = 0.0000177$, $b = 3.005$, $q = -1.75$, $L_{\infty} = 77.67$, $k = 0.191$, $t_0 = -1.35$ and a linear-weighted dependence for the entire period (Fig. 45).

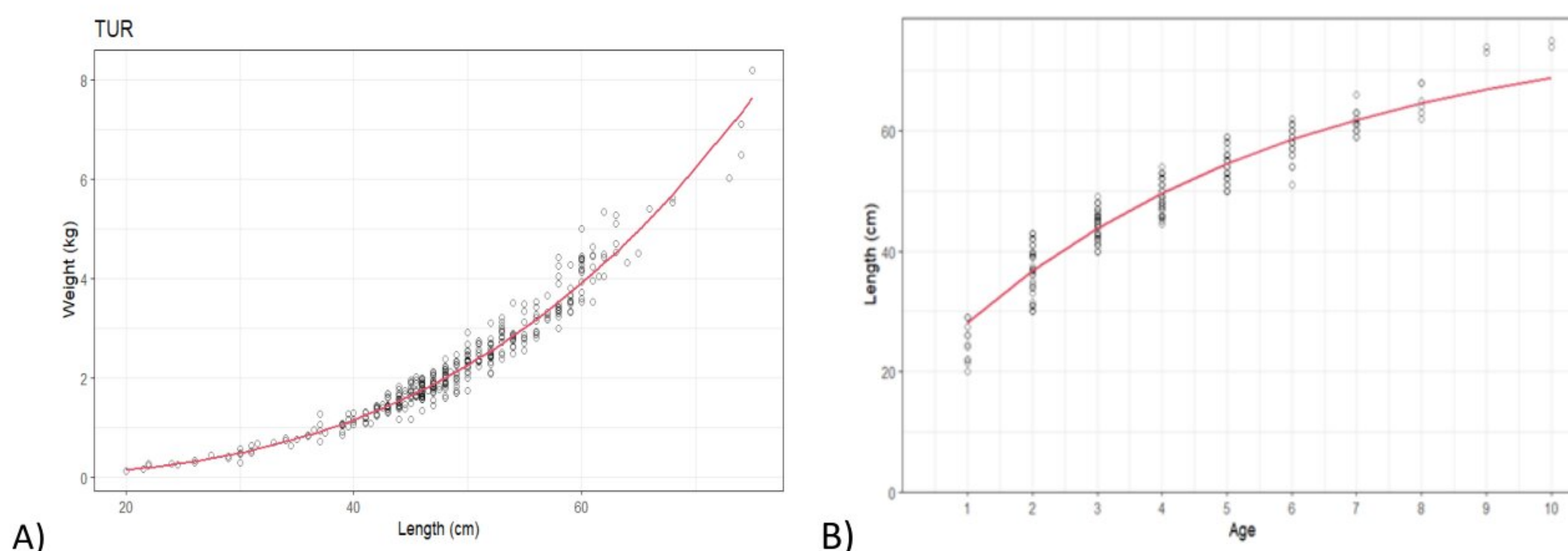


Figure 42 *S. maximus* A) length-weight and B) length-age relationships in 2025;

TAC (Total Allowable Catch)

Beverton & Holt, 1957 - Y/R catch-restocking relationship model is used to calculate total allowable catch. To determine the stock-replenishment relationship, the parameters: W_{∞} , k , M , t_0 , t_r are used, and the model allows to determine Y/R at different input levels of the parameters F - fishing effort and T_c - optimal exploitation age and to assess the effect of their fluctuations. The results are presented in Fig.46, with increasing catch/recruitment values at $F = 0.2$, this is why the fishing mortality value should not exceed 0.2.

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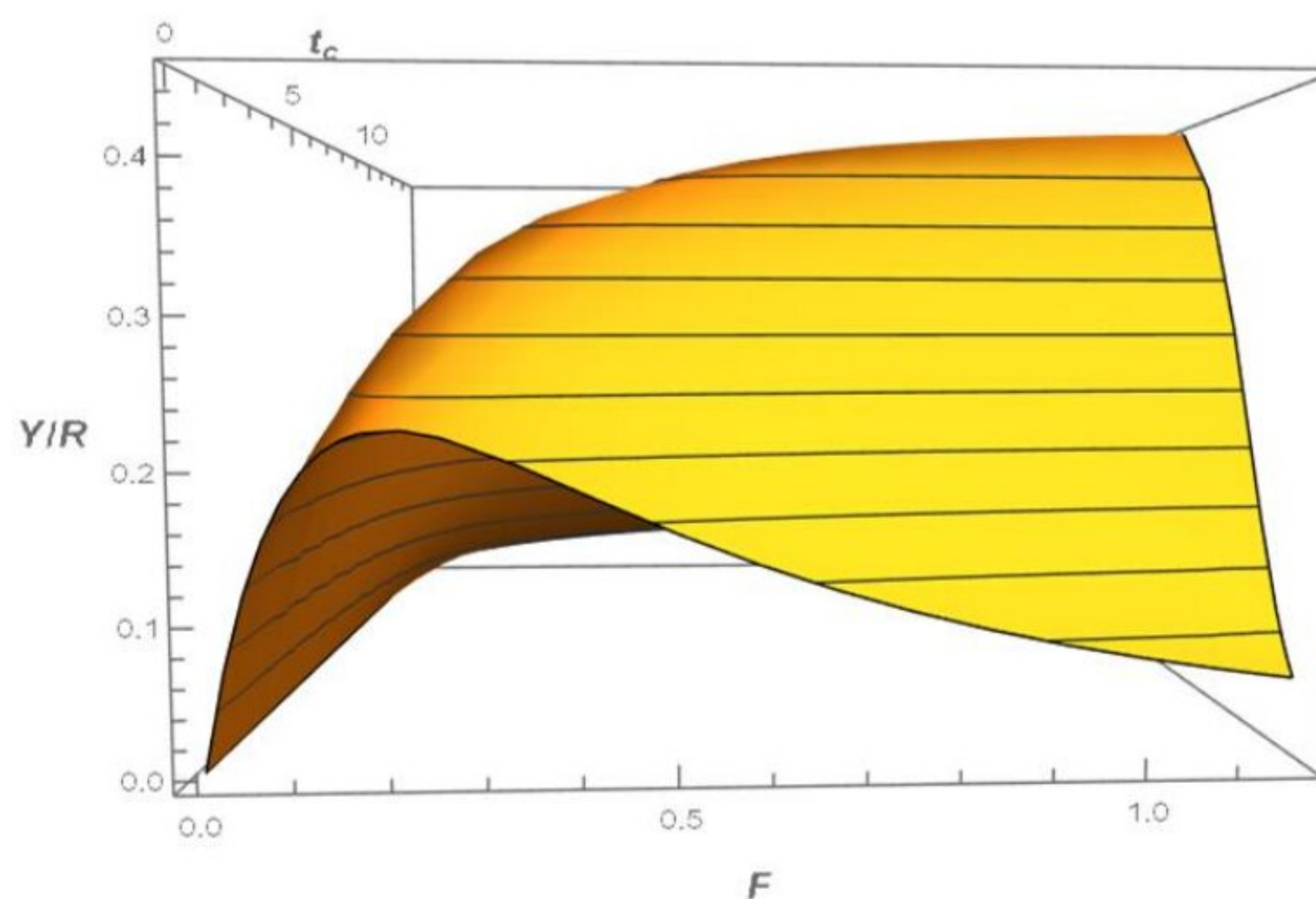


Figure 43 Catch-replenishment dependence as a function of F at three different optimal operational ages;

The dynamic model strategy for MSY does not account for variation in recruitment from year to year, so it should be used with caution in conjunction with other stock assessment analytical models involving linear or age-based virtual population analysis. It is necessary to use the so-called "ad hoc" - special approaches and application of TAC, as part of MSY - up to 2/3 of MSY(Raikov, 2011) or 1/2. When applied this method assumes that the total allowable catch of turbot can reach up to **77.8** tonnes in the Bulgarian waters of the Black Sea, calculated on the basis of data from the autumn season of 2025, but we must note that the percentage distribution of sexually mature specimens is 73.55 % for the winter season of 2025 and after recalculations based on this percentage, the total allowable catch should not exceed **57** tonnes.

Weather conditions during the survey

During the expedition activity, the prevailing wind direction was west, northeast, and southwest, with a force of 1–2 degrees Beaufort along the coast and 2–3 degrees Beaufort in the open sea. In the autumn-winter season of 2025, conditions were normal for conducting a trawl survey to assess turbot stocks in Bulgarian waters of the Black Sea.

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6. Conclusions and recommendations

From the collected information and results obtained from the trawl survey in autumn-winter, 2025 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 **1555.95** tonnes (Table 4). The abundance in the studied area was estimated at **636.79*10³** specimens (Table 4).
- The recommended MSY (maximum sustainable catch) for Bulgaria should not exceed **155.59** tonnes, and the total allowable catch (TAC) can reach up to **57** tonnes as an acceptable amount for the Bulgarian Black Sea water area.
- The size structure of the turbot population, in the Bulgarian Black Sea zone included length classes from **21.5** cm to **75** cm were observed, with weights varying between **160** g and **8200** g. The average weight of the turbot was estimated at **2443.42** g. Individuals measuring less than 45 cm constituted 26.45% of the total population, while those exceeding 45 cm accounted for 73.55%.
- The age composition of the population included age classes from 1 to 10 years, with a predominant presence of 2-year-olds (16.13%), 3-year-olds (22.58%) and 4-year-olds (25.81%), collectively accounting for 64.52%. This is followed by 6-year-old specimens, which represent 10.97%.
- The established ratio of female, male, and immature individuals in the catch is **43.23%: 30.32%: 26.45%**.
- Specimens of the species *M. merlangus*, with a large concentration of the species is observed from north to south Kavarna, Varna and between Emine and Sozopol at a depth of 65 -78 m. The average biomass index (CPUE) of *M. merlangus* is 34.52 kg/h, with the

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highest indicators ahead of the southern coasts (up to 90 kg/h), and catches are dominated by size classes of 10.5 – 13.5 cm, with females dominant.

- Specimens of *S. acanthias* are observed between Varna and Byala (30-40 m), where only female specimens are caught, and in front of Shabla and Tsarevo (66-88 m), there is a concentration of males; *Pl. flesus* is concentrated in the northern part of the Bulgarian coast in front of the central part of the coast of Varna, at a depth of 24 - 25 m. Representatives of the species *R. clavata* are observed south of Varna at depths of 48 - 50 m in front of the Cape Emine-Tsarevo (depth 65 - 69 m).
- The whiting biomass in the entire studied water area off the Bulgarian coast of the Black Sea is estimated at **6457.16** tonnes, with an abundance of approximately **376.9** thousand specimens. The calculated biomass of the thornback ray in the same area is **3030.97** tonnes, and its abundance is estimated at **1625.3 × 10³** individuals. The current biomass of the dogfish in this water area is estimated at **637.4** tonnes. For the studied period, the total abundance for the entire area was estimated at **109.5** thousand individuals. 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 November-December yield inaccuracies.
- In the autumn-winter season of 2025, 84 stomachs were analyzed to determine the diet spectrum of turbot and a total of 28 stomachs from additional species - *Squalus acanthias* and *Raja clavata*. The results of the qualitative analysis show that the species *Squalus acanthias* feeds mainly on whiting (IRI = 34.41 %) and sprat, which accounts for IRI = 42.56 %. The digested stomach content has a total IRI percentage of 20.34 %. In the diet of *Raja clavata*, species from two taxonomic groups were recorded, fish with IRI = 36.36 % and Decapoda with IRI = 18.79 %.

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