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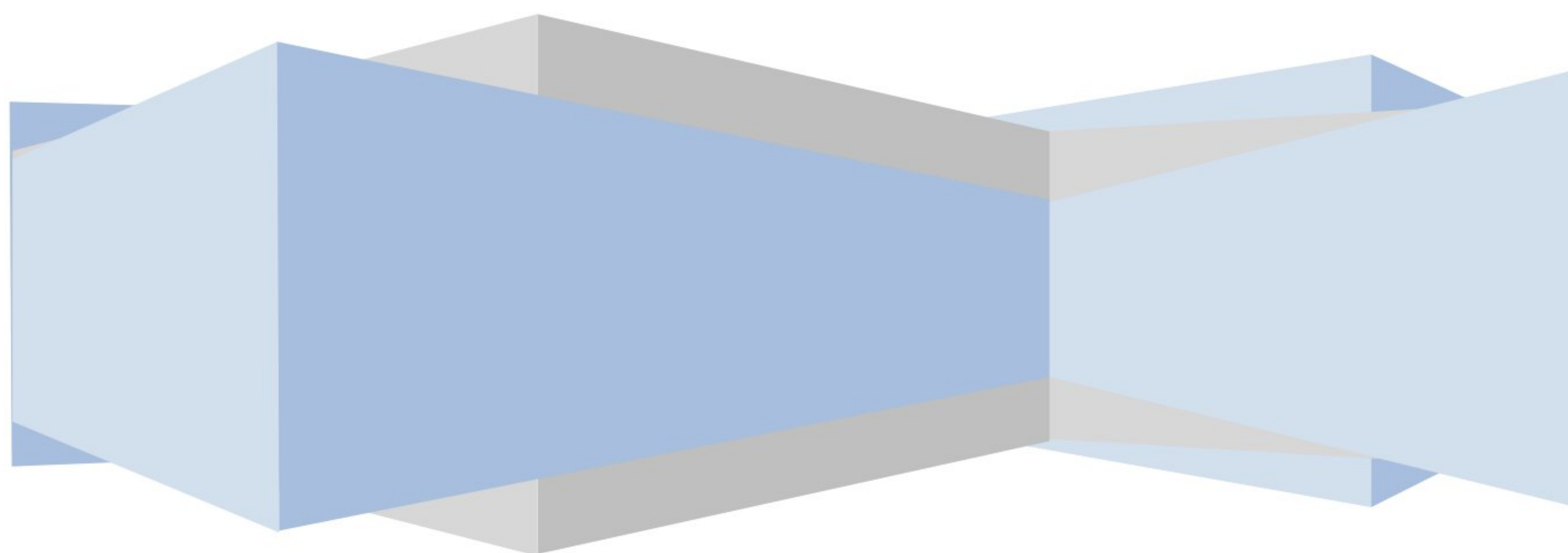
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PELAGIC TRAWL SURVEYS IN THE BULGARIAN MARINE AREA, SEPTEMBER 2025

SCIENTIFIC REPORT



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Project No. BG14MFPR001-1.002-0002 "Collection, management and use of data for the purposes of scientific analysis and implementation of the Common Fisheries Policy for the period 2025-2026", financed by the Maritime, Fisheries and Aquaculture Programme, co-financed by the European Union through the European Fund for maritime, fisheries and aquaculture fund.



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This study was carried out thanks to the financial support of the European Commission under REGULATION (EU) 2017/1004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008 (recast), the National Agency for Fisheries and Aquaculture – Ministry of Agriculture, Bulgaria and Institute of Oceanology – Bulgarian Academy of Sciences, Varna, Bulgaria.

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The survey was carried out in September 2025 in the Bulgarian Black Sea area on board of F/V Lefer in execution of the National Program of Bulgaria for data collection.



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1. Material and Methods

Pelagic trawl survey was accomplished following the National Programs for Data Collection in the Fisheries sector of Bulgaria. The study was conducted in September 2025, in the Bulgarian Black Sea area, enclosed between Durankulak and Ahtopol ($42^{\circ}05'$ and $43^{\circ}45'$ N and $27^{\circ}55'$ and $29^{\circ}55'$ E), with a total length of the coastline of 370 km (Fig. 1.1).

**Locations of Trawling Stations
- First Expedition'2025**

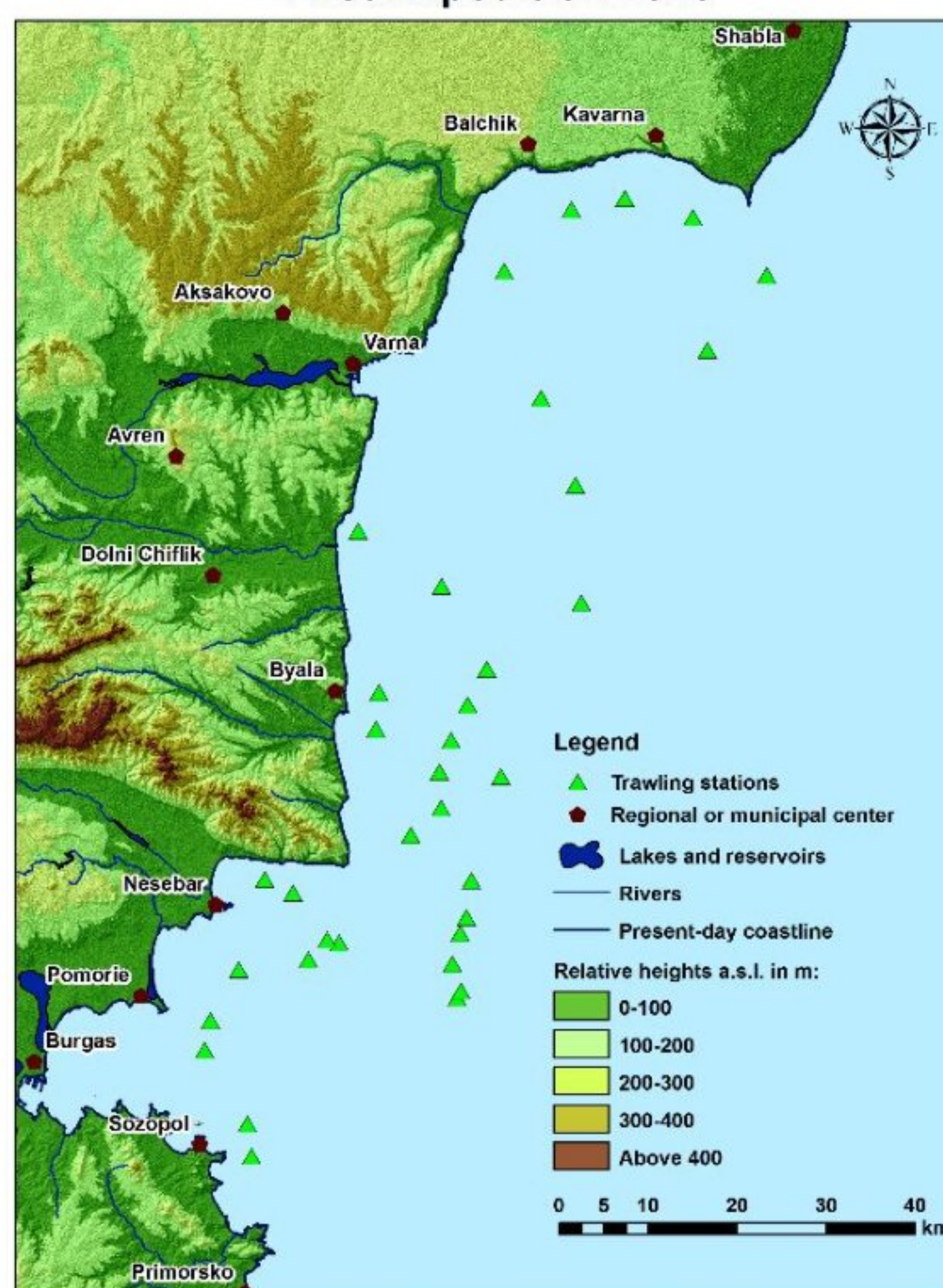


Figure 1.1. Location of the stations in September 2025.

The pelagic trawl survey (OTM) was carried out on board the research vessel “F/V Lefer”. During the survey, a total of 36 trawls were carried out. The trawling was performed during the day with a duration of 30–40 minutes, depending on the hydro-meteorological conditions, at an average speed of 2.7 knots (variation in the range 2.7–2.9).

The size of the pelagic trawl are as follows:

- Pelagic trawl type 50/35 – 74 m;

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- Headrope length – 40 m;
- Horizontal opening – 16 m;
- Vertical opening – 7 m;
- Mesh size – 7×7 mm;
- Effective part of trawl – 27 m;
- Pelagic doors – 3.5 m².

The following types of data were collected:

- Coordinates and duration of each trawl;
- Total catch weight;
- Separation of catches by species;
- Composition of by-catch.

The biological analysis is based on the biomass of the species found during the study. Additionally, an analysis of the distribution and abundance of the other species caught as by-catch is presented.

1.1. Sampling design

In order to determine the abundance of the reference species (*Sprattus sprattus*) in the Bulgarian part of the Black Sea, a standard stratified survey methodology was used (Gulland, 1966). The study area is divided into three subgroups depending on depth: **Stratum 1** (15–30 m), **Stratum 2** (30–50 m), and **Stratum 3** (50–100 m). The research area in Bulgarian waters was further divided into 128 non-overlapping polygons of equal size, located at depths between 15 and 100 m. Sampling was conducted at 36 randomly selected sites using pelagic trawling.

Each field is a rectangle with dimensions 5'' latitude x 5'' longitude and an area of approximately 62.58 km² (measured using GIS), which is large enough to allow trawling for a corresponding duration in the meridional direction. The fields are grouped into larger —referred to as layers— whose geographical and depth boundaries are determined based on the distribution and density of the species observed during the survey. Only one trawl was conducted in each field, lasting between 30 and 40 minutes at a speed of 2.7–2.9 knots (Picture 1.1.1.).

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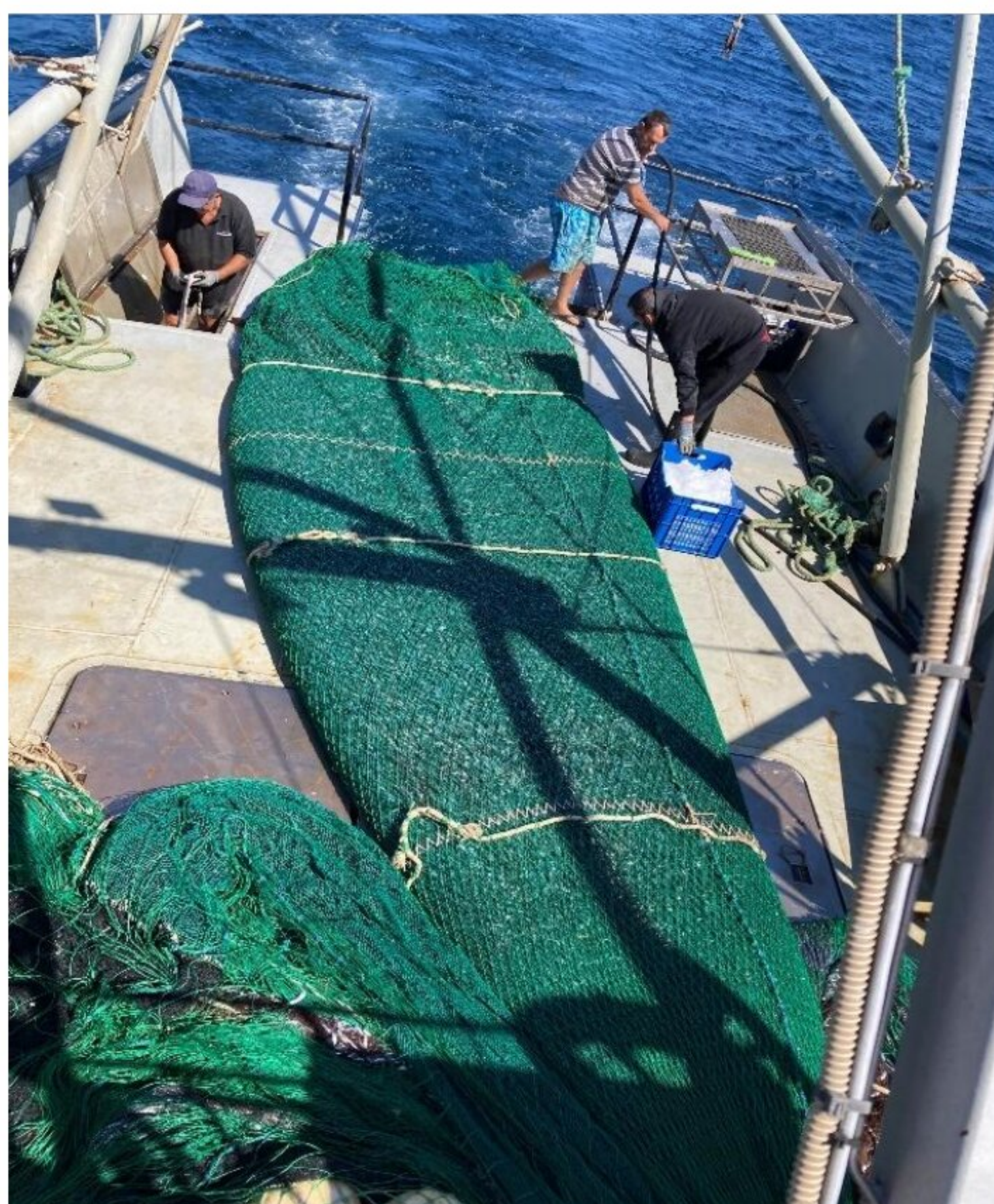
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Picture 1.1.1. Catch in trawl.

1.2. Onboard sample processing

The specimens processed during the survey are presented in Table 1.2.1.

Table 1.2.1. Number of processed individuals

Species	Number
sprat	1500
whiting	1200
red mullet	1200
horse mackerel	1500
anchovy	1500

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The data from each trawl included measurements of the following parameters (Gulland, 1966):

- Depth, measured using the vessel's echo sounder;
- GPS coordinates of start and end haul points;
- Haul duration;
- Abundance of species caught;
- Weight of the total sprat catch;
- Abundance and weight of other species;
- Species composition of the by-catch.

A 4% formaldehyde solution prepared with seawater was used to preserve the stomach contents.

1.3. Laboratory analyses

The processing of the samples collected on board continued under laboratory conditions, focusing on determining the age and nutritional composition of the stomach contents of sprat.

Age was determined based on the analysis of otoliths under a binocular microscope.

The dietary spectrum was assessed by sorting the stomach contents into taxonomic groups, identified to the lowest possible taxonomic level.

1.4. Statistical analyses

Swept area method

This method is based on near-bottom trawling (protrawled area), a widely used direct technique for estimating the instantaneous biomass of benthic organisms (Fig. 1.4.1, 1.4.2).



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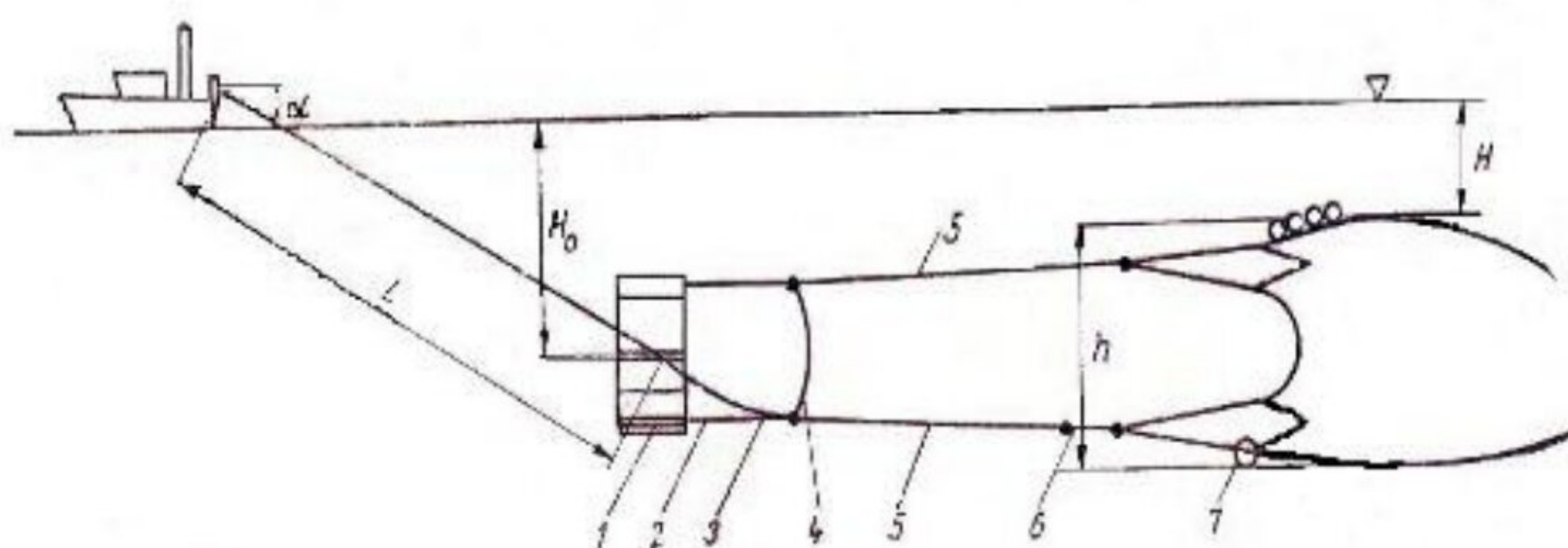


Figure 1.4.1. Scheme of the trawl, used in the Swept area method (according to Grudev et al., 1981) 1 - trawl door; 2 - conjections; 3 - transitional wire; 4 - compensator; 5 - wires; 6 - extension cord; 7- deepener.

In Figure 1.4.2. the scheme of the so-called bathy-pelagic trawl for catching sprat is represented.

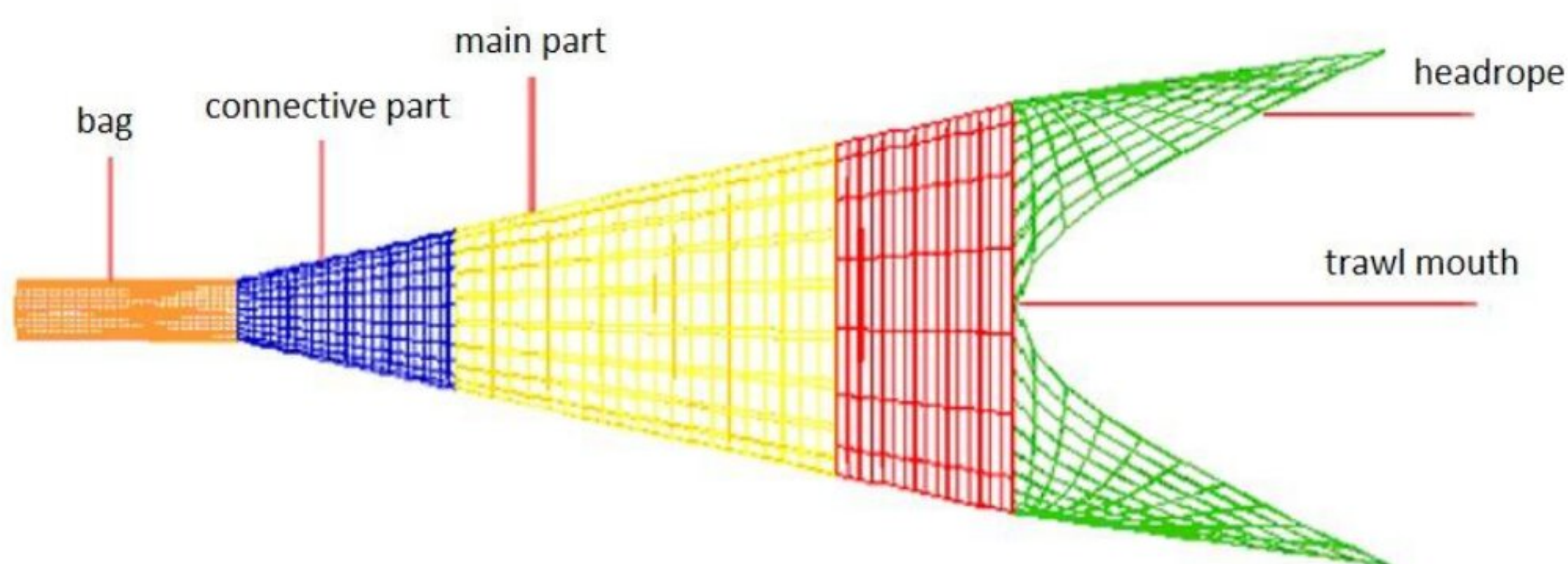


Figure 1.4.2. Scheme of bathy-pelagic trawl for sprat catch.

The main point of the method: the trawl doors are designed to drag along the seafloor for defined distance. Trawling area is calculated as follows:

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$$(1) \begin{aligned} a &= D * h * X2 \\ D &= V * t \end{aligned}$$

(where: a – trawling area, V – trawling velocity, h* X2 – trawl door distance, t – trawling duration (h), D – dragged distance on the seafloor;

$$(2) D = 60 * \sqrt{(Lat_1 - Lat_2)^2 + (Lon_2 - Lon_1) * \cos(0.5 * (Lat_1 + Lat_2))}$$

$$(3) D = \sqrt{VS^2 + CS^2 + 2 * VS * CS * \cos(dirV - dirC)},$$

where, VS is vessel velocity, CS – present velocity (knots), dirV vessel course (degrees), and dirC – present course (degrees).

Stock biomass is calculated using catch per unit area, as a fraction of catch per unit effort from the dragged area:

$$(4) \left(\frac{C_{w/t}}{a/t} \right) = C_{w/a} \text{ kg / sq.km}$$

where: Cw/t – catch per unit effort, a/t – trawling area (km²) per unit time;

Stock biomass of the given species per each stratum could be calculated as follows:

$$(5) B = (\overline{C_{w/a}}) * A$$

where: $\overline{C_{w/a}}$ - mean CPUA for total trawling number in each stratum, A- area of the stratum. The variance of biomass estimate for each stratum is (equation 4):

$$(6) VAR(B) = A^2 * \frac{1}{n} * \frac{1}{n-1} * \sum_{i=1}^n [Ca(i) - \overline{Ca}]^2$$

The total area of the investigated region is equal to the sum of areas of each stratum:

$$A = A1 + A2 + A3$$

Average weighted catch per whole aquatic territory is calculated as follows:

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$$(7) \quad \overline{Ca}(A) = Ca1 * A1 + Ca2 * A2 + Ca3 * A3 / A$$

where: Ca1- catch per unit area in stratum 1, A1 – an area of stratum 1, etc., A- size of total area.

Accordingly, total stock biomass for the whole marine area:

$$(8) \quad B = \overline{Ca}(A) * A$$

where: $\overline{Ca}(A)$ - average weighted catch per whole investigated marine area, A – total investigated marine area.

Estimation of Maximum Sustainable Yield (MSY)

The Gulland's formula for virgin stocks is used:

$$(9) \quad MSY = 0.5 * M * B_v$$

where: M – coefficient of natural mortality; B_v – virgin stock biomass.

A relative yield-per-recruit model with uncertainties:

$$(10) \quad Y' / R = E * U^{M/k} \left\{ 1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)} \right\}$$

where: $U = 1 - (L_c / L_\infty)$

$m = (1 - E) / (M/k) = k/Z$

$E = F/Z$ – exploitation coefficient

Converted catch curve

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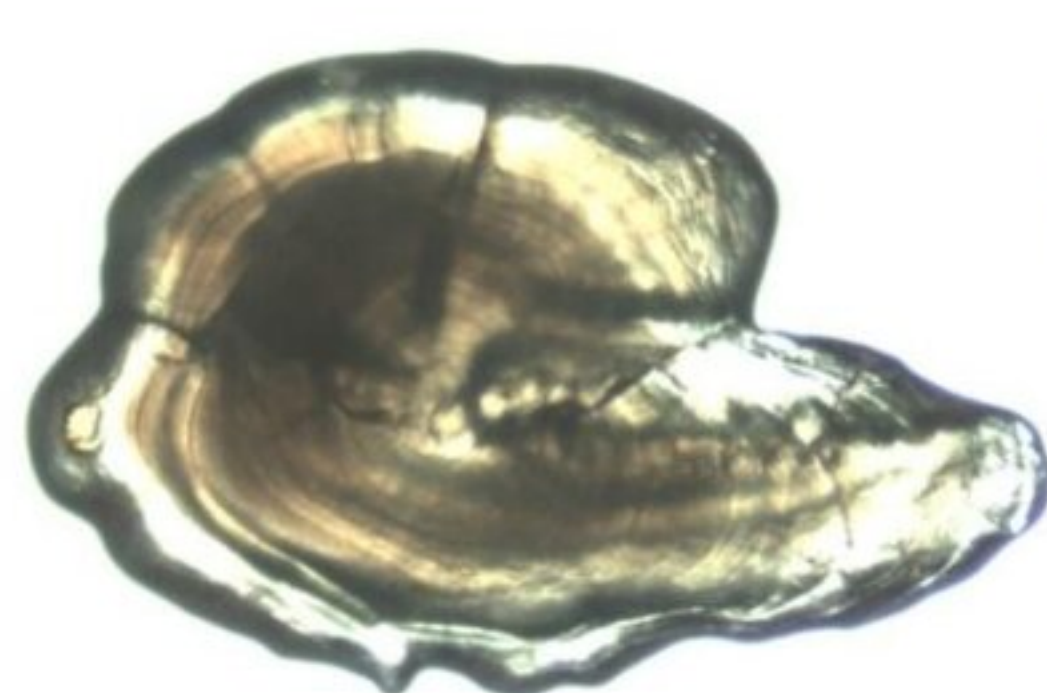


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Several methods are available for estimating total mortality (Z) from length-frequency data. Reliable estimates of Z can be obtained from the mean length of a representative sample or from the slope of a cumulative Jones' plot. A variety of approaches have been developed to analyze length-frequency data, which serve as the functional equivalent of age-structured catch curves. These "length-converted catch curves" are based on assumptions similar to those used in age-structured catch curve analyses.

1.5. Age estimation

Calcified structures (CS) are commonly used to determine age. Aging in fish means the presence of CS visible as opaque and transparent areas. Calcified age-determining structures in fish are various: otoliths (statoliths), dorsal vertebrae, spines, and opercular bones. In some species, so called "sagittae" are used. The most important aspects (difficulties, extraction, storage, method of preparation, criteria for age determination) regarding age analysis are discussed by species. Otoliths play a role in balance, movement, and sound perception. They are most commonly used for age determination, growth and mortality studies. In bony fish, otoliths are the primary CS for age determination and are widely used in ichthyology. On the other hand, when analyzing O_2 isotopes, both species migrations and stock identification are determined. Otoliths serve as balance in space and as hearing organs for fish. Based on the shape and size of the otoliths, the feeding habits of the fish are also determined (Kasapoglu and Duzgunes, 2014). Researchers used reference collections and photographs of otoliths in publications to aid identification (Picture 1.5.1). Otoliths have a characteristic shape that is highly specific but varies greatly among species.



6 cm (0+)



7.5 cm (1+)

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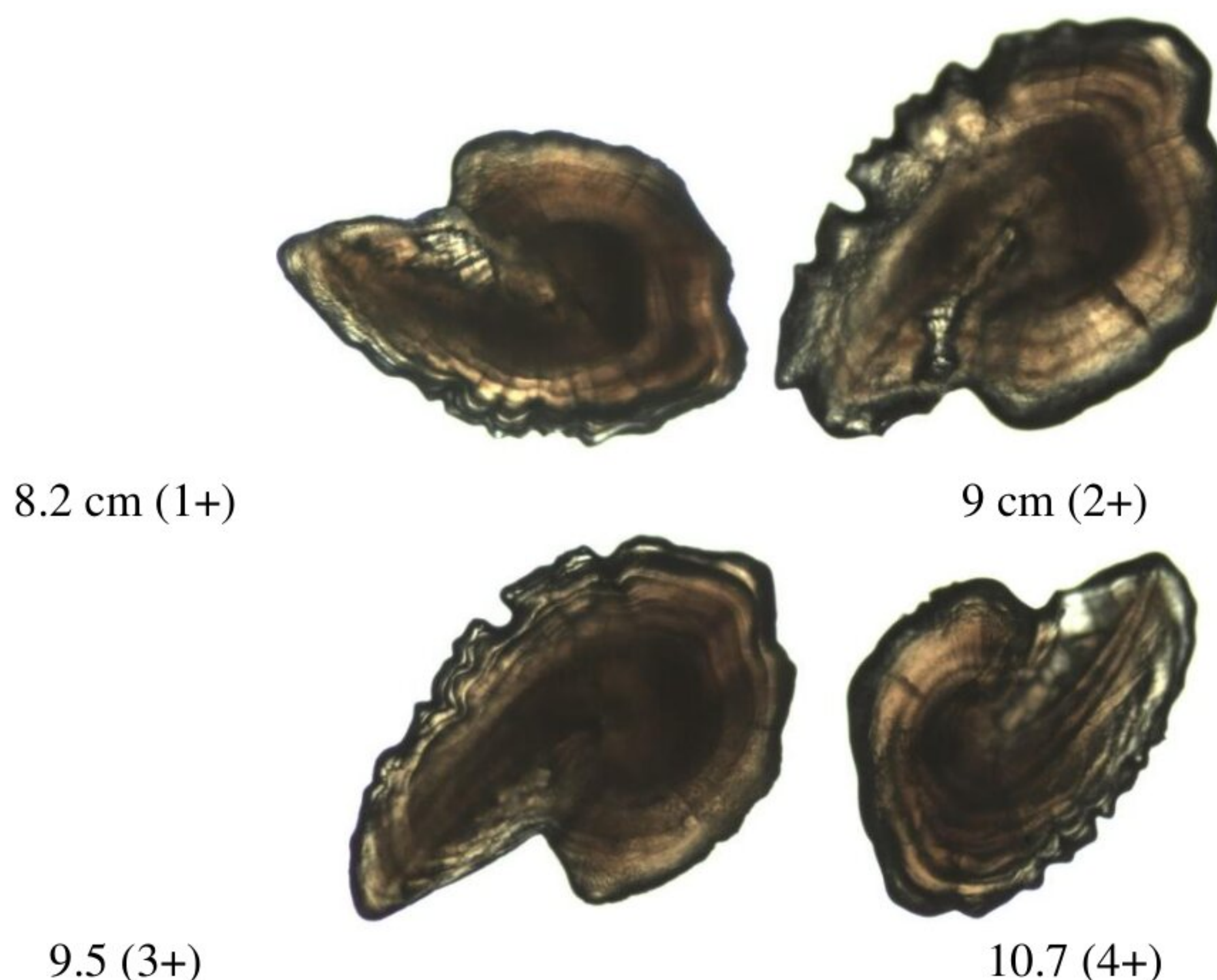
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Picture 1.5.1. Otoliths of sprat.

Otoliths are three types, located on the left and right sides of the head in semi rings: “sagitta” in the sacculus, “lapillus” in the lagenar, and “asteriscus” in the utricular channels. The location, size, and shape of these three types differ by species, the largest is “sagitta” and the smallest is “asteriscus”. So, “sagitta” is the one that is mostly used in age determination of bony fishes. Other reasons for using otoliths to determine age are:

- Their formation in the embryonic phase, which shows all the changes in the life cycle of the fish.
- Their presence in fish which have no scales.
- Achieving better results than those of scale analysis, especially when it comes to older fish.
- No recovery or regeneration.
- Having the same structure in all the individuals of the same species (Jearld, 1983).

On the other hand, their disadvantages are the need to dissect the fish and some problems in age determination due to crystal-like formations by irregular CaCO_3 accumulations on the otoliths.

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1.5.1. Preparation for otolith extraction

It is very important to have a representative sample from which the otoliths will be extracted, and their number depends on the size of the respective species. For smaller species, fewer otoliths are taken. According to availability, 5 specimens from each size group are set aside for age determination. For each fish total length (± 0.1 cm), total weight (± 0.01 g), sex, maturation stage (I-V), and gonad weight (± 0.01 g) are recorded.

Sagittal otoliths of each fish are removed by cutting the head over the eyes after all individual measurements. The fish is then rinsed and placed in 96% ethyl alcohol to remove organic debris and finally stored with a sample number for other operational information.

1.5.2. Preparation of the otoliths for the age determination

Otoliths are placed in small black convex laboratory glasses containing 96% ethyl alcohol for age determination under a binocular stereo microscope with side and top illumination (Polat and Beamish, 1992). The magnification used depends on the size of the otolith, with 4 $\times$ magnification being optimal for sprat.

1.5.3. Age determination and analysis of annual rings

The first step is to identify the location of the center and the first age ring. The observation of consecutive rings, whether continuous or not, is then essential. It is important to determine whether the fish is still growing or has reached the end of its growth period by examining the characteristics of the otolith's outer ring to see if it is opaque or hyaline. After these steps, the otoliths can be read following standardized protocols, which are very important for providing accurate age data, determining realistic population parameters, and reduce abnormal procedures and biases through standardized age reading criteria.

Isometric growth is observed in the sprat's left and right otoliths. These are small, transparent structures (Fig. 1.5.3.1). They feature distinct summer and winter rings, along with a central core. Additionally, spring rings—opaque—and late autumn rings—hyaline—are considered during age determination (Pisil, 2006).



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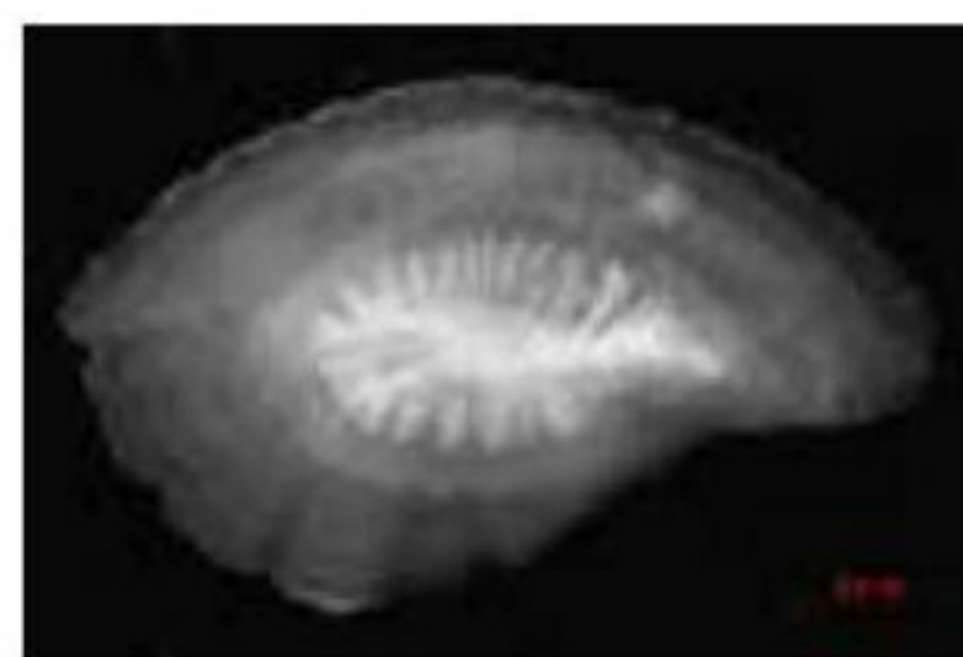
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Sprattus sprattus



Merlangius merlangus



Trachurus mediterraneus



Mullus barbatus

Figure 1.5.3.1. Sprat, whiting, horse mackerel, and red mullet otoliths.

1.5.4. Age reading protocol for sprat

1. The dissected otoliths are rinsed, treated with 96% ethyl alcohol, and stored dry.
2. Age determination is performed by an expert by immersing the entire otolith in 96% ethyl alcohol, then placing it in a convex glass under reflected light against a dark background.
3. Magnification is selected based on the size of the otolith. The aim is to avoid increasing magnification excessively, as this may reveal rings that are not representative for age determination in larger otoliths. A magnification of 4× is optimal for visualizing the hyaline zones in sprat otoliths.
4. Otolith are observed from their distal surface.
5. January 1st of the respective year is considered the hatching date for sprat.

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6. A central point surrounded by hyaline rings forms after the yolk sac and the initiation of free feeding. The next opaque ring is known as "first year growth". This ring retains its circular shape in the postrostrum region. Together with this ring and the next hyaline ring, they form a "V" shape in the rostrum and are accepted as first-year rings.
7. Small, continuous concentric rings near the true hyaline ring as part of the same age mark. These may appear as either very small opaque rings within the hyaline band or as small hyaline rings near the outer edge of an opaque ring.
8. Sprat and some other short-lived species exhibit very rapid growth, particularly in their first years. After the second year, the width of the growth rings narrows significantly, which should be considered when counting rings in older specimens.

The number of small and weak hyaline rings—known as false rings—in the opaque region is generally low, and distinguishing them from true age rings is relatively easy. However, when numerous and indistinguishable, such otoliths should not be used.

1.6. Sex and maturity estimation

1.6.1. Maturity stages

It is very important to use standardized maturity scales for sprat (and all species) to assess sampling strategies and determine the appropriate timing for accurate maturity classification in both sexes. In sprat, the small gonad size and batch spawnings of multiple egg cohorts over an extended period pose significant challenges for standardizing the maturity scale.

According to ICES (2011), standardized sexual maturity scale for sprat includes six stages for both males and females (Fig. 1.6.1.1, Table 1.6.1.1).



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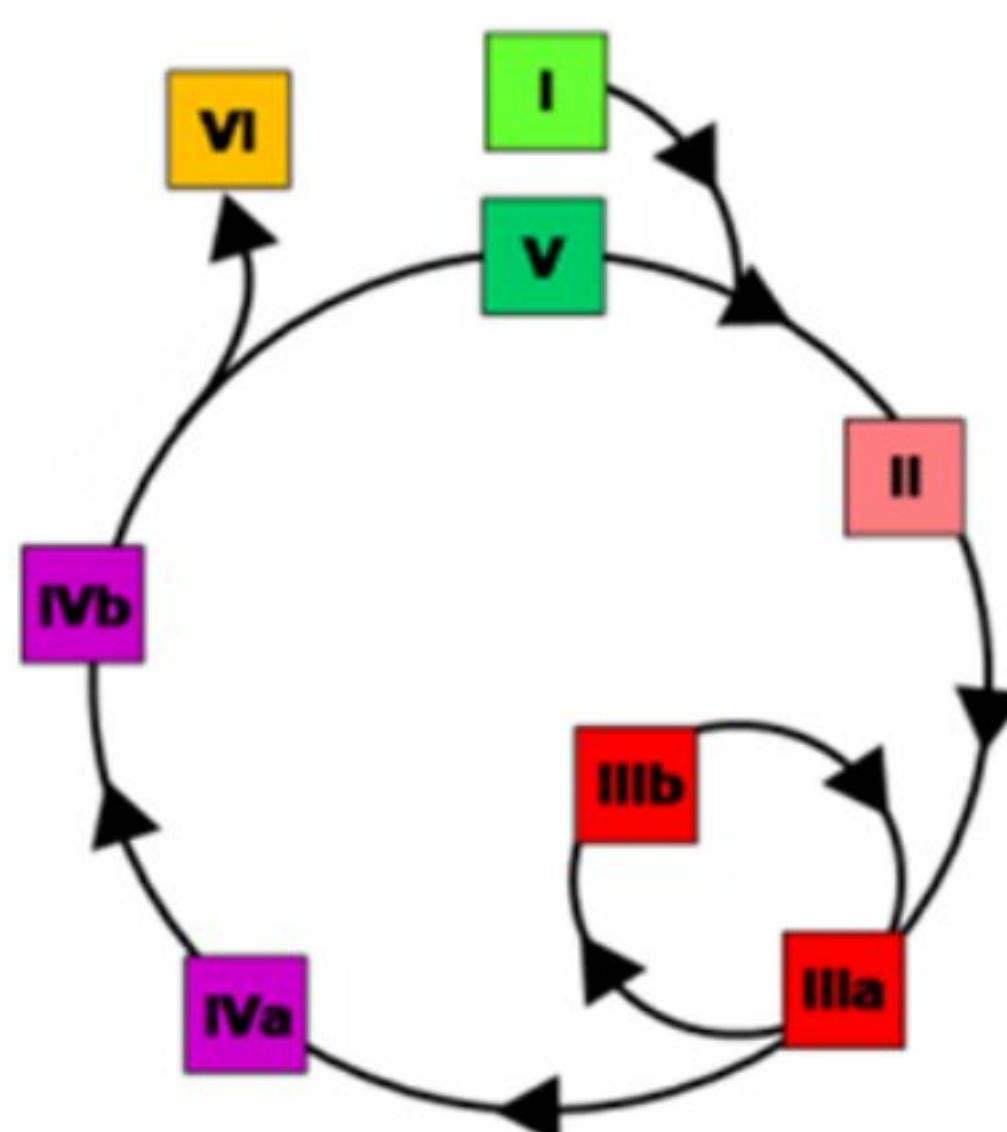


Figure 1.6.1.1. Scale with six maturity stages in sprat (Name of the stages are given in Table 1.6.1.1).

In particular, specimens without visible gland development were grouped into the "Immature" and "Preparation" categories. The spawning stage was subdivided into an inactive spawning stage (maturation and re-maturation, characterized by visible gamete development) and an active spawning stage, indicated by the presence of hydrated eggs. Integrating maturation and re-maturation into the spawning stage allows for more accurate identification of maturing and spawning individuals within the population.

Table 1.6.1.1. Macroscopic and histological characteristics of gonad developmental stages.

Stages	Macroscopic Characteristics	Histological characteristics
<i>FEMALES (OG: Oogonia, PG1: Early previtellogenic oocytes, PG2: Late previtellogenic oocytes, CA: Cortil alveoli oocytes, VT1: Early vitellogenic oocytes, VT2: Mid vitellogenic oocytes, VT3: Late vitellogenic oocytes, HYD: Hydrated oocytes, POF: Postovulatory follicles, SSB: Spawning stock biomass).</i>		
<i>I-Immature</i>	<i>Juvenile: ovaries threadlike and small; transparent to wine red and translucent in color; sex difficult to determine; distinguishable from testes by a more tubular shape; oocytes not visible to the naked eye</i>	<i>OG+/-PGI</i>
<i>II. Preparation</i>	<i>The transition from immature to early maturing; oocytes not visible to the naked eye; ovaries yellow-orange to bright red; ovaries occupy up to half of the abdominal cavity. This stage is not included in SSB.</i>	<i>PG1, PG2, CA</i>
<i>III. Spawning</i> <i>a. Inactive</i>	<i>Maturing and re-maturing: yolked opaque oocytes visible to the naked eye; ovaries change from semi-transparent to opaque yellow-orange or reddish as more oocytes enter the yolk stage; ovaries occupy at least half of the body cavity; re-maturing ovaries may be red to grey-red or purple in</i>	<i>PG1, PG2, CA, VT1, VT2, VT3, +/- POF</i>

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b. Active	color and less firm than an ovary maturing the first batch, few hydrated oocytes may be left Spawning active. Hydrated eggs are visible among yolked opaque oocytes; hydrates oocytes may be running; ovaries fill the body cavity; overall color varies from yellowish to reddish.	PG1, PG2, CA, VT1, VT2, VT3, HYD, POF
IV.a. Cessation	Baggy appearance; bloodshot; grey-red translucent in color; atretic oocytes appear as opaque irregular grains; few residual eggs may remain	PG1, PG2, POF, atretic oocytes, residual HYD
IV.b. Recovery	Ovaries appear firmer and membranes thicker than in sub-stage IV.a; these characteristics together with the slightly larger size distinguish this stage from the virgin stage; ovaries appear empty and there are no residual eggs; transparent to wine red translucent in color	PG1, PG2, atretic VT oocytes
V. Resting	Ovaries appear more tubular and firmer; oocytes not visible to the naked eye; transparent or grey-white to wine red with well-developed blood supply; this stage leads to stage II.	PG1, PG2 +/- atretic oocytes
VI. Abnormal	a) infection; b) intersex - both female and male tissues can be recognized; c) one lobe degenerated; d) stone roe (filled with connective tissue); e) other	Abnormal tissue
MALES (SG: Spermatogonia; PS: Primary spermatocytes; SS: Secondary spermatocytes; ST: Spermatids; SZ: Spermatozoa; SSB: Spawning stock biomass)		
I. Immature	Juvenile: Testes threadlike and small; white-grey to grey-brown; difficult to determine sex, but distinguishable from ovaries by a more lanceolate shape (knife-shaped edge of the distal part of the lobe).	SG, PS
II. Preparation	The transition from immature to mature: Testes easily distinguishable from ovaries by lanceolate shape; sperm development not visible; reddish grey to creamy translucent in color; testes occupy up to 1/2 of the abdominal cavity; this stage is not included in SSB.	SG, PS, SS, potentially few ST
III. Spawning a. Inactive	Maturing and re-maturing: Testes occupy at least half of the body cavity and grow to almost the length of the body cavity; the empty sperm duct may be visible; color varies from reddish light grey, creamy to white; edges may still be translucent at the beginning of the stage, otherwise opaque; re-maturing testes may be irregularly colored with reddish or brownish blotches and grey at the lower edge with partly whitish remains of sperm	SG, PS, SS, ST, SZ
b. Active	Spawning active: testes fill the body cavity; Sperm duct filled and distended throughout the entire length; sperm runs freely or will run from the sperm duct, if transected; color varies from light grey to white..	SG, PS, SS, ST, SZ

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IV.a. Cessation	Baggy appearance (like an empty bag when cut open); bloodshot; grey to reddish-brown translucent in color; residual sperm may be visible in the sperm duct.	SG, PS, atretic SS, ST and SZ
IV.b. Recovery	Testes appear firmer and the testes membrane appears thicker than in stage IVa due to contraction of the testes membrane; these characteristics together with the slightly larger size distinguish this stage from the virgin stage; testes appear empty and no residual sperm is visible in the sperm duct; reddish grey to greyish translucent in color.	SG, PS, potentially SS, atretic SZ
V. Resting	Testes appear firmer, development of a new line of germ cells; grey in color; this stage leads to stage II.	SG, PS, SS
VI. Abnormal	a) infection; b) intersex - both female and male tissues can be recognized; c) one lobe degenerated; d) other.	e.g. oocytes visible among spermatogenic tissues

1.7. Batch fecundity

All fish were measured to the nearest 1 mm in total length (TL) and weighed to the nearest 1 gram. The gonads were examined under a microscope for external characteristics such as hardness and color to determine the stage of maturity. The sex ratio was also calculated in this study as the number of males / the number of females (Simon et al., 2012). Females were identified through macroscopic observation of a mature ovary (Laevastu, 1965). Fecundity rates can vary considerably during the short spawning season—starting low, peaking during peak spawning, and declining again toward the end. Batch fecundity of sprat was determined using the Hydrated Oocyte Method (Hunter et al., 1985). Fat, hydrated females were used. After sampling, their body cavity was opened and preserved in a buffered formalin solution (Hunter et al., 1985). The ovary-free female weight and the ovary weight were recorded. Three tissue samples of approximately 50 mg were taken from different parts of the ovary, and their exact weights were measured. The number of hydrated oocytes in each of the three subsamples was then counted under a binocular microscope. Hydrated oocytes are easily distinguished from other oocyte types by their large size, translucent appearance, and wrinkled surface resulting from formalin preservation. Batch fecundity was estimated based on the average number of hydrated oocytes per unit weight of the three subsamples.

Gonadosomatic Index (GSI) is determined monthly. GSI is calculated as:

$$GSI = \frac{GW}{SW} \times 100$$

where GW is gonads weight and SW is somatic weight (represents the BW without GW).

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For the estimation of sprat growth rate, the von Bertalanffy growth function (1938) is used, (according to Sparre, Venema, 1998):

$$(11) \quad L_t = L_\infty \left\{ 1 - \exp[-k(t - t_0)] \right\}$$

$$(12) \quad W_t = W_\infty \left\{ 1 - \exp[-k(t - t_0)] \right\}^n$$

Where: L_t , W_t are the length and weight of the fish at age t years; L_∞ , W_∞ – asymptotic length and weight, k – curvature parameter, t_0 – the initial condition parameter.

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

$$(13) \quad W_t = qL_t^n$$

where q – condition factor, constant in a length-weight relationship; n – constant in a length-weight relationship.

Coefficient of natural mortality (M), Pauly's empirical formula (1979, 1980) is applied:

$$(14) \quad \log M = -0.0066 - 0.279 * \log L_\infty + 0.6543 * \log k + 0.4634 * \log T^\circ C$$

$$(15) \quad \log M = -0.2107 - 0.0824 \log W_\infty + 0.6757 \log K + 0.4627 \log T^\circ C$$

Where: L_∞ , W_∞ and κ – parameters in von Bertalanffy growth function, $T^\circ C$ – an average annual temperature of the water (environmental parameter of the studied species).

1.8. Maximum Sustainable Catch (MSY)

The maximum sustainable catch was estimated as follow:

$$B_{msy} = 0.5 * B(t)$$

According to FAO (1995), following the precautionary approach:

$$B_{pr} (2/3MSY)$$

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1.9. Planktivorous fish species feeding

The study on the diet of planktivorous fish (sprat and horse mackerel) in the western Black Sea was based on stomach content analysis of 100 sprat specimens and 48 horse mackerel specimens collected between 9 and 19. IX. 2025. During this period, data on the composition and abundance of mesozooplankton in the marine environment were also collected, as this group of organisms forms the primary food base for the fish species studied.

The coordinates of the study area and descriptions of the data are presented in Table 1.9.1.

Table 1.9.1. Study areas in September 2025.

Date	Trawl №	Coordinates		Depth (m)	Temperature (°C)
		Latitude	Longitude		
09.09.2025	T1	43.5894	28.7658	57	16.15
09.09.2025	T3	43.4262	28.9030	78	16.75
10.09.2025	T6	43.3701	28.2944	18	15.91
10.09.2025	T9	43.2154	28.4051	46	16.03
11.09.2025	T10	43.1696	28.1742	20.5	15.55
11.09.2025	T11	43.0810	28.2199	35	15.57
16.09.2025	T16	42.8366	27.9412	27.5	16.17
16.09.2025	T17	42.7870	28.1116	51	15.57
17.09.2025	T19	42.6717	27.8250	22	16.41
17.09.2025	T22	42.6452	28.0621	55	14.53
18.09.2025	T25	42.5137	27.7020	36	15.73
19.09.2025	T27	42.4061	27.7649	40	15.83
19.09.2025	T29	42.1944	28.1280	67	15.12

From the trawl catch, approximately 10/11 live fish specimens were separated and fixed with 10% formaldehyde solution. Under laboratory conditions, the absolute length (TL, with an accuracy of 0.1 cm) and weight (with an accuracy of 0.01 g) of the collected specimens were measured. The stomachs of the studied organisms were weighed using an analytical balance (accuracy, 0.0001 g). The food mass of each fish specimen was calculated as the difference between the weights of full and empty stomachs.

To determine the species composition of the food and the number of food objects, the stomach contents were examined under a microscope. Prey biomass in fish stomachs was calculated by multiplying the number of zooplankton organisms by their individual weights.

The following indices were defined.

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1. Index of stomach fullness (ISF) as a percentage of body mass: (weight of stomach contents/weight of fish body) $\times$ 100
2. Index of relative importance (IRI; Pinkas et al., 1971): $IRI = (N + M) \times FO$, where N is the proportion of the taxon (species) of the prey in the food by number, M 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).

Zooplankton samples were collected from the entire water layer (surface–bottom) with a plankton net with an inlet diameter of $d = 36$ cm and an aperture of $150 \mu\text{m}$ and fixed on board the ship with a 4% formalin-seawater solution (Korshenko & Aleksandrov, 2013). The zooplankton species composition was determined according to the Manuals for the Black and Azov Seas (Mordukhay-Boltovsky et al., 1968) and the quantity in a Bogorov chamber, according to the methodology of Korshenko and Aleksandrov (2013). Cluster analyses method (PRIMER 7.0.17) was used for grouping of data on sprat food composition from different stations and depths.

2. Results

2.1. Species diversity

A total of 26 species were identified during the study, including 18 fish, 2 crustaceans, 2 molluscs, and 3 macrozooplankton species. The most common species in the trawl catches (based on presence/absence) were *Sprattus sprattus* (50.15%), *Merlangius merlangus* (19.22%), *Mullus barbatus* (16.9%) and *Trachurus mediterraneus* (10.4%). Other species, such as *Alosa immaculata*, *Neogobius melanostomus*, *Gobius niger*, *Mesogobius batrachocephalus*, *Zosterisessor ophiocephalus*, *Raja clavata*, *Dasyatis pastinaca*, *Pegusa lascaris*, *Uranoscopus scaber*, *Trachinus draco*, *Scophthalmus maximus*, *Squalus acanthias*, *Acipenser gueldenstaedtii* and *Acipenser stellatus*, had a negligible presence in the catches.

2.2. Horse mackerel (*Trachurus mediterraneus*)

2.2.1. Distribution

Horse mackerel is a migratory species along the Bulgarian coast. It is a carnivorous fish and plays an important role in the food chain, serving as prey for larger predators such as turbot and dolphins. Horse mackerel was significantly represented in the catches in September 2025.

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2.2.2. Horse mackerel biomass by strata

The total area surveyed was 8010.24 km², and the total biomass of horse mackerel was estimated at 3093.2 tonnes (Table 2.2.2.1; Table 2.2.2.2; Fig. 2.2.2.1; Fig. 2.2.2.2). The densest aggregations were observed off the coast of Byala and in Nesebar Bay. The highest biomass was recorded in the 15–30 m depth stratum, with 1057 tonnes, followed by 624 tonnes (30–50 m) and 14 tonnes (50–100 m).

**Biomass (tons) of Horse Mackerel
- First Expedition'2025**

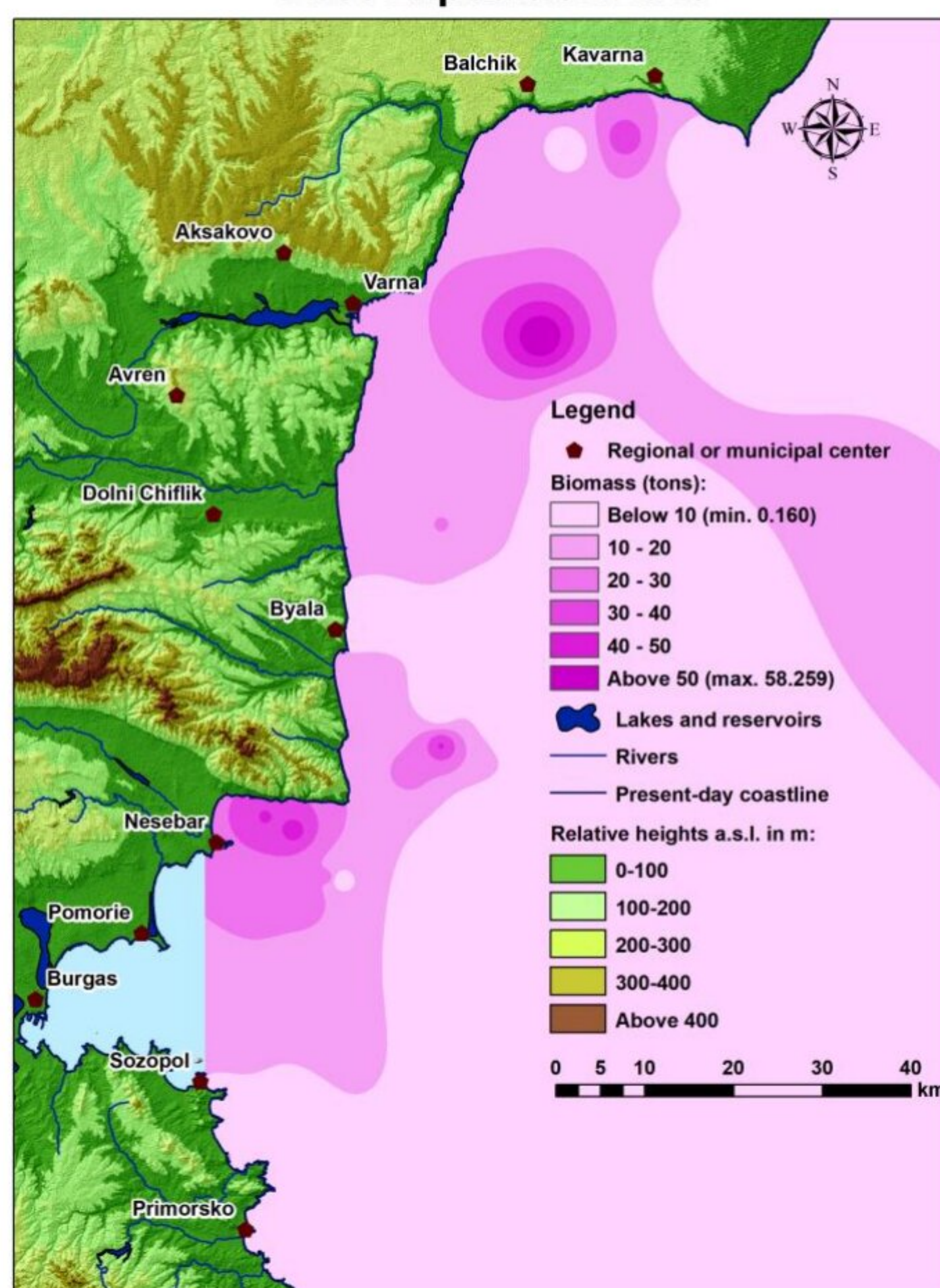


Figure 2.2.2.1. Horse mackerel biomass by strata, September, 2025.

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Table 2.2.2.1. Swept area method for stock survey in September 2025 – average values of catch per unit area (CPUA), biomass (kg), Ax – area and number of fields.

CPUA average	Strata	Biomass (kg)	Ax Surface	Number of stations
512.03	15-30	1057.41	2065.14	33
344.17	30-50	624.61	1814.82	29
3.42	50-100	14.13	4130.28	66
		1696.15	8010.24	128

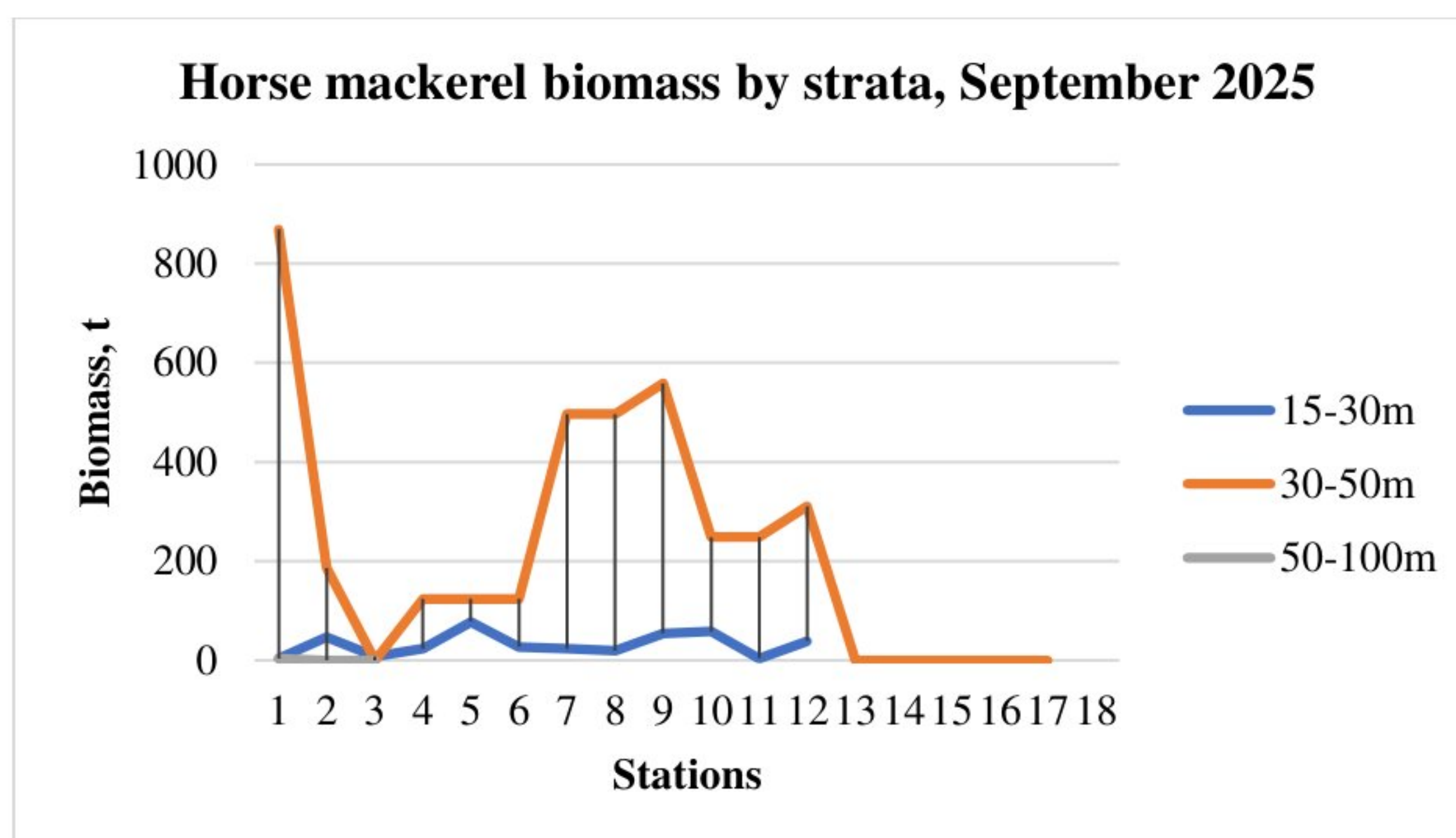


Figure 2.2.2.2. Horse mackerel biomass (kg) by strata in September 2025.

Table 2.2.2.2. Descriptive statistics of horse mackerel CPUA indices (t) in September 2025.

	15-30 m	30-50 m	50-100 m
Average	512.028	222.7002	0.262578
Standard error	108.0733	61.15811	0.262578
Median	403.416	124.128	0
Mode	62.064	0	0
Standard deviation	374.3769	252.1613	0.94674

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Variation	140158.1	63585.34	0.896317
Excess	-0.50395	1.150527	13
Asymmetry	0.553005	1.238271	3.605551
Range	1179.216	868.896	3.41352
Minimum	62.064	0	0
Maximum	1241.28	868.896	3.41352
Amount	6144.336	3785.904	3.41352
Number	12	17	13
Greatest Value (1)	1241.28	868.896	3.41352
Smallest value (1)	62.064	0	0
Confidence level (95.0%)	237.8678	129.6494	0.572109

2.2.3. Catch per unit area (CPUA)

Horse mackerel was recorded at the highest densities in the waters off Byala, Nesebar Bay, Varna, Pomorie and Nesebar (St. Vlas), Kavarna (Fig. 2.2.3.1).

The highest values of CPUA were registered in the 15–30 m depth layer, reaching 1241 kg.km⁻², with an average value of 512 kg.km⁻². In the 30–50 m 124–869 kg.km⁻² and 50–100 m depth layers, the species was recorded with very low values of 3.41 kg.km⁻² (Fig. 2.2.3.1).

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CPUA (kg/km²) of Horse Mackerel - First Expedition'2025

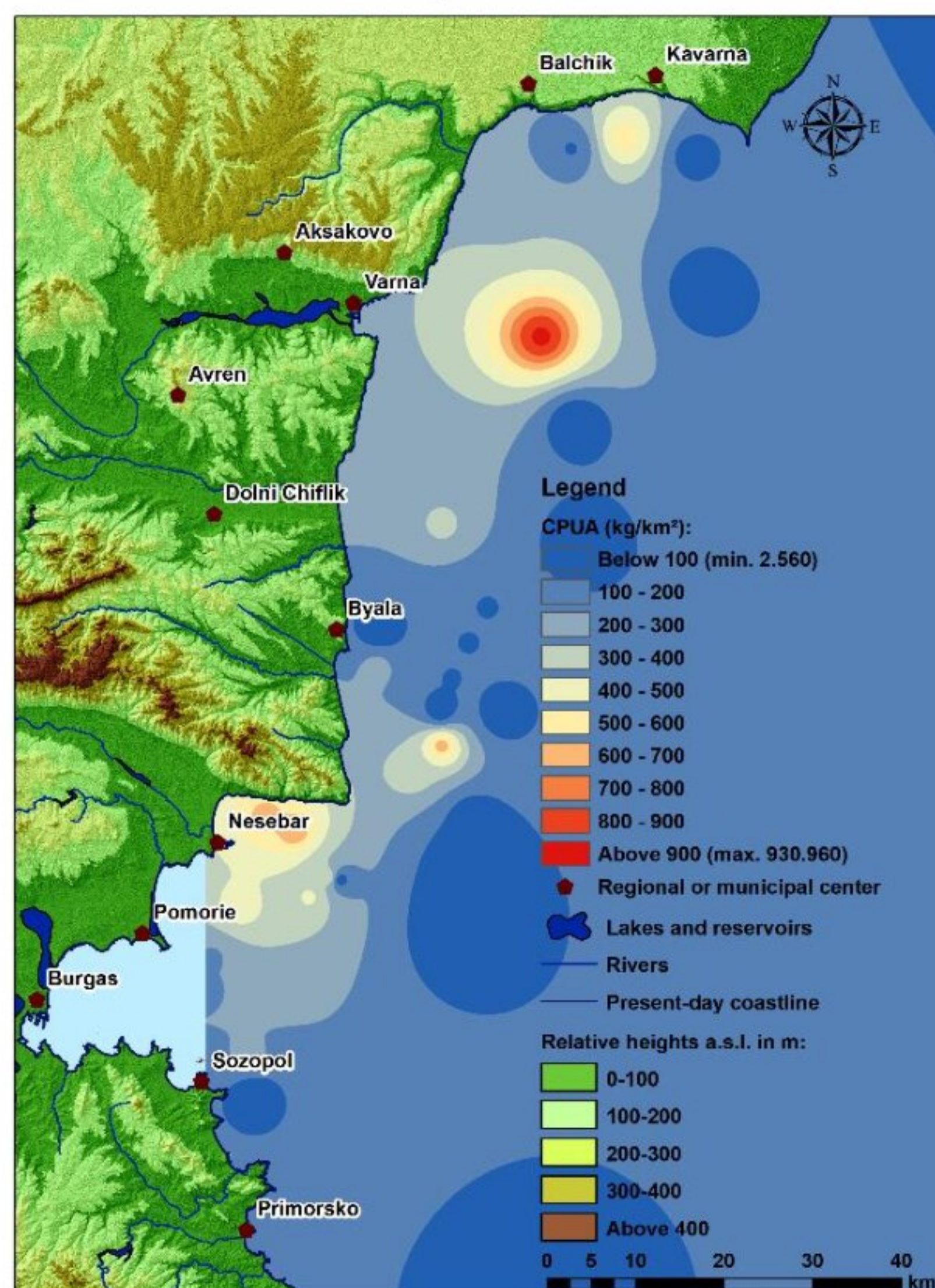


Figure 2.2.3.1. Catch per unit area (CPUA kg.km⁻²), September 2025

2.2.4. Catch per unit effort (CPUE)

The catch per unit effort (CPUE) for the species is presented graphically in Figure 2.2.4.1. The highest CPUE values (kg·h⁻¹) were observed in front of Varna, Obzor, Kavarna, and St. Vlas.

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CPUE (kg/h) of Horse Mackerel - First Expedition'2025

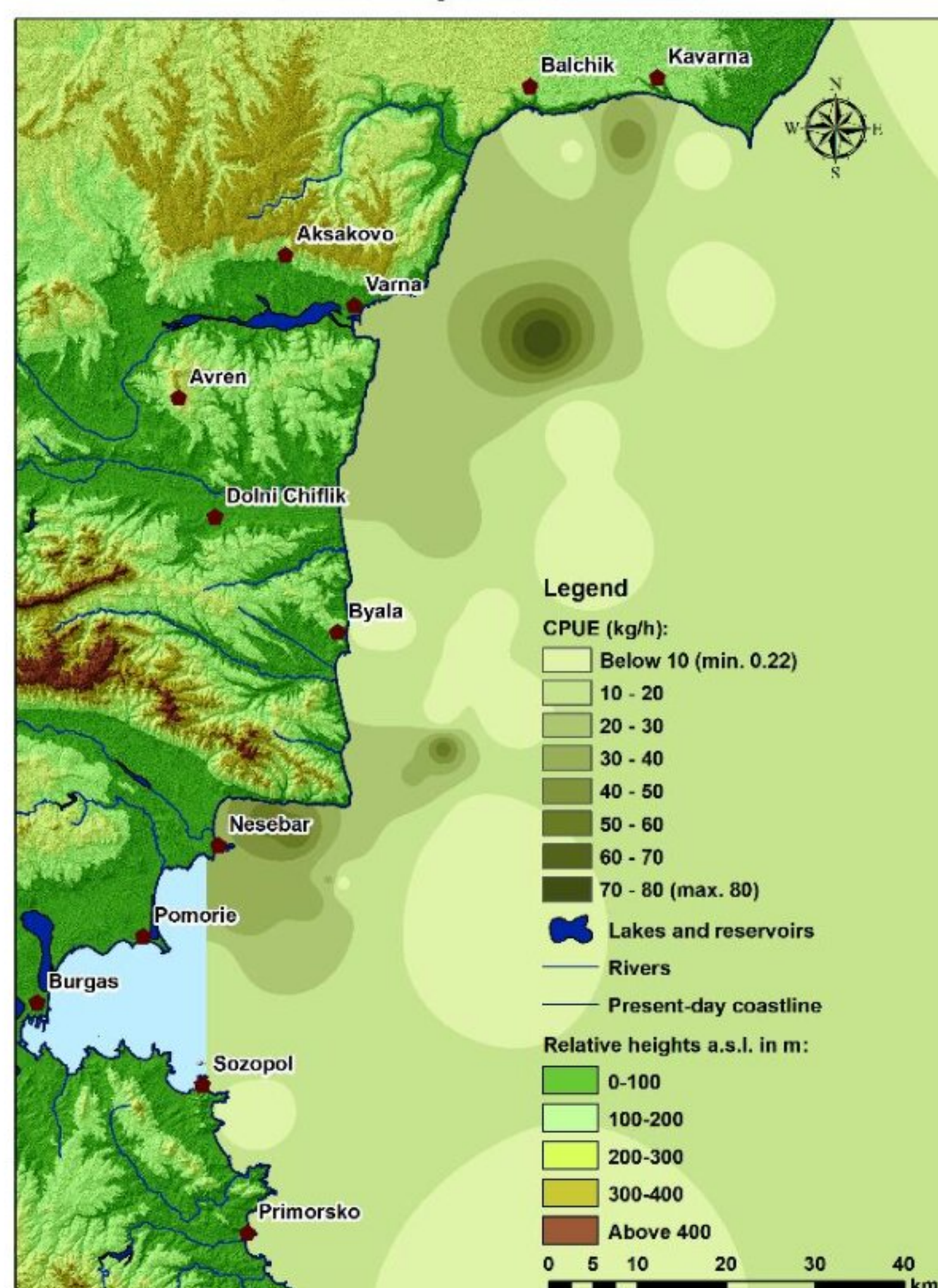


Figure 2.2.4.1. Catch per unit effort (CPUE kg.h⁻¹) for horse mackerel by strata.

2.2.5. Length-weight relationship

The length-weight relationship in horse mackerel is described by the model $W = 0.009 * L^{2.1935}$, allometric growth coefficient >3 , the resulting nonlinear length-weight relationship model has a high degree of determination ($R^2 = 0.94$) (Fig. 2.2.5.1.).

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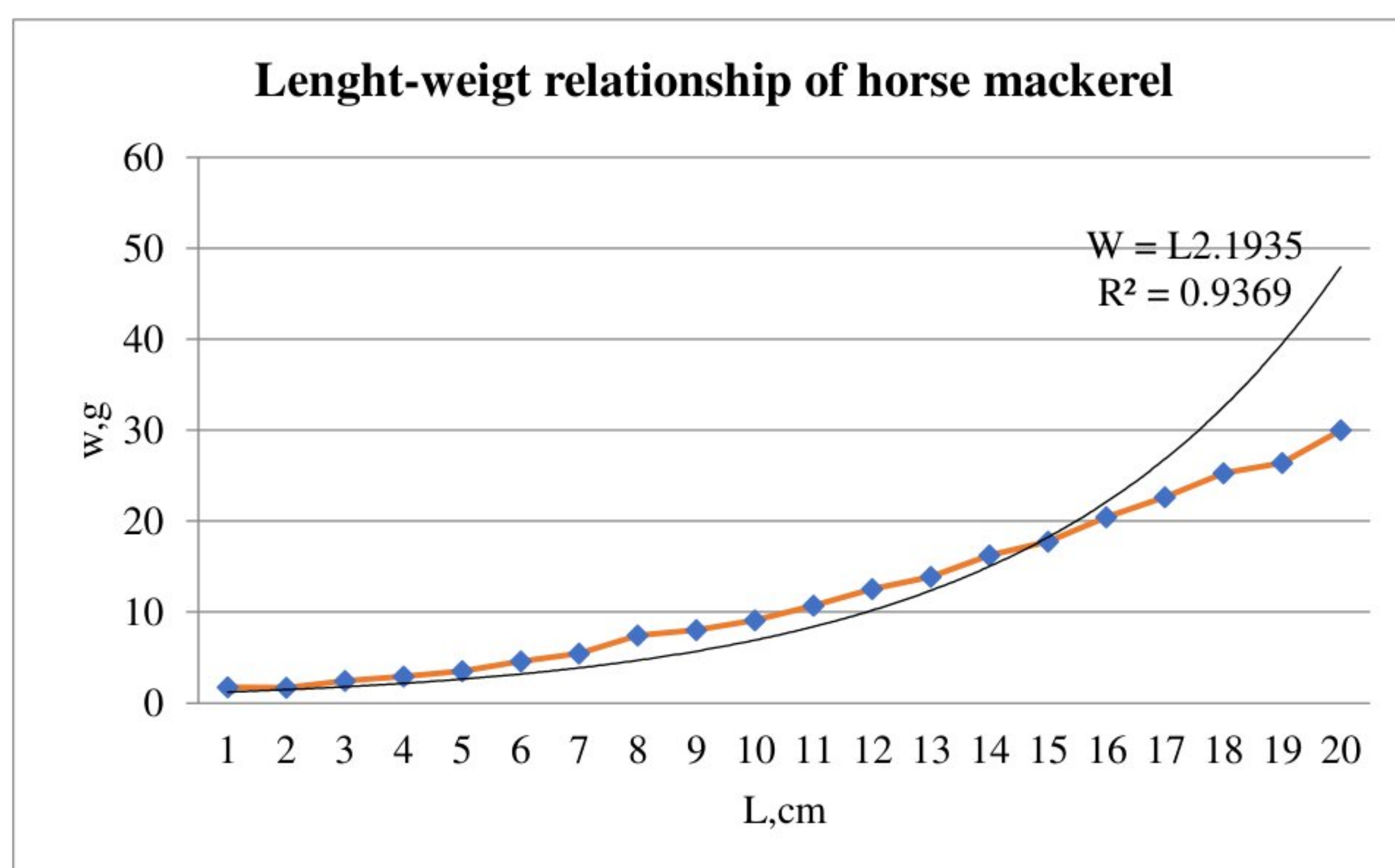


Figure 2.2.5.1. Length-weight relationship of horse mackerel in September 2025.

The size structure of the horse mackerel stock is presented in Figure 2.2.5.2. The length distribution in the horse mackerel samples is normal (gaus), with 2 peaks – bell-shaped, as the most common lengths in the samples were in the range 9-9.5-12.5 -13.5 cm. A peak was observed in the 9 cm size group (1500 ind.) (Фиг. 2.2.5.2).

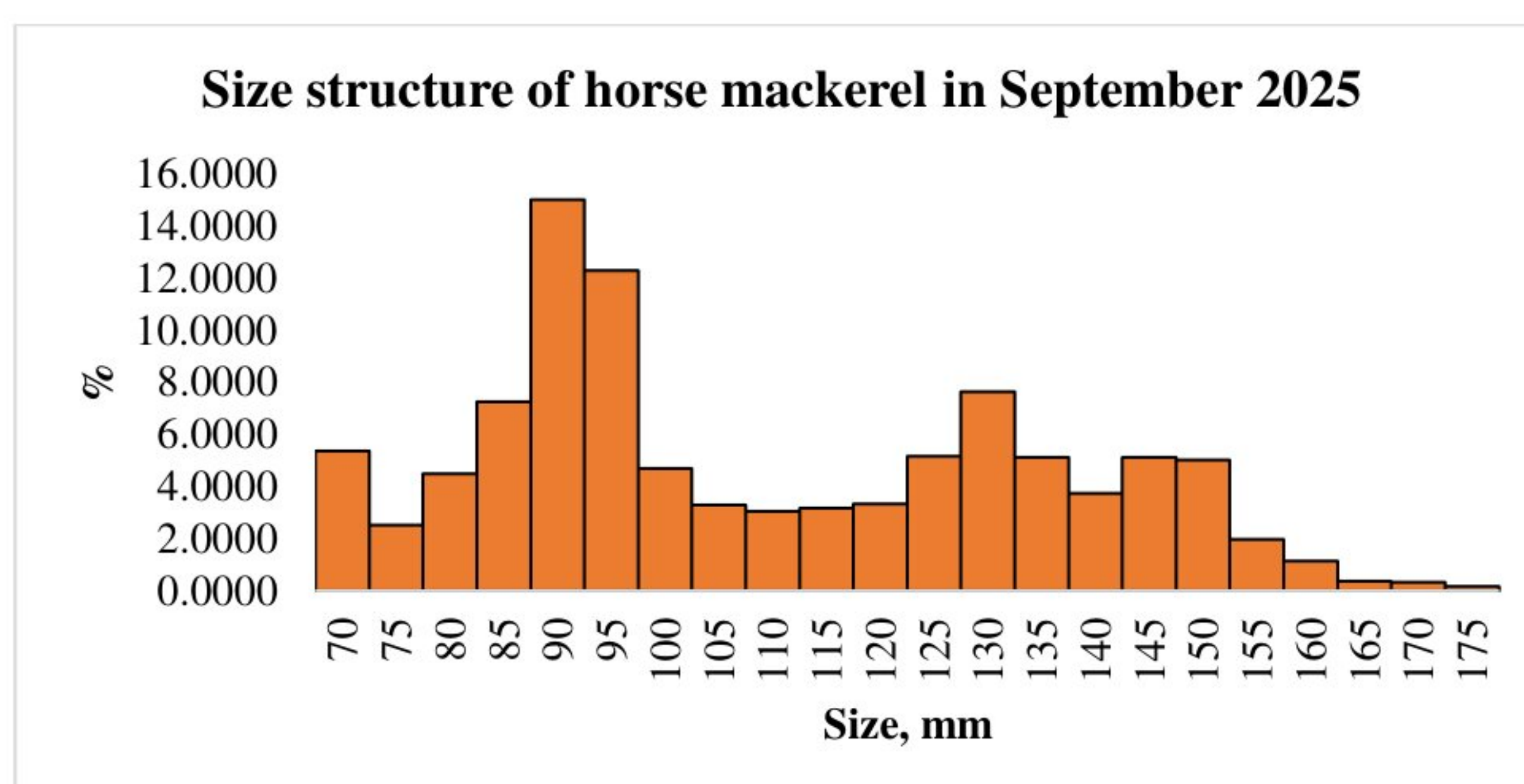


Figure 2.2.5.2. Size structure of horse mackerel in September 2025.

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Average weight varied from 5.66 to 36.1 g (Fig. 2.2.5.3.).

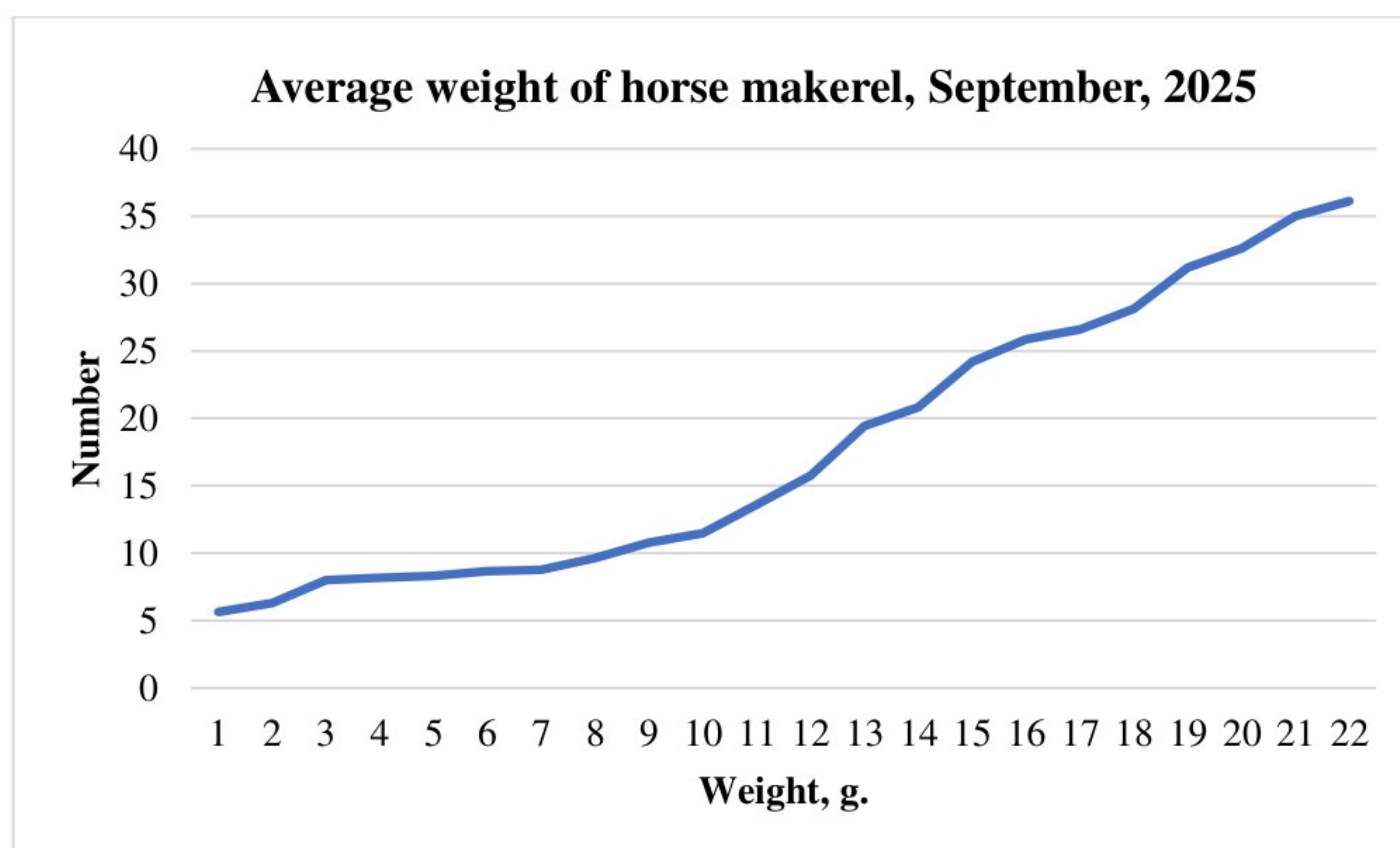


Figure 2.2.5.3. Weight structure of horse mackerel in September 2025.

The dominant age group of horse mackerel during the study period was 2-2+ years (27.27%), followed by age group 1-1+ years (23.11%). The replenishment was represented by 7.55%. The age structure of the horse mackerel varies from 0 to 5+ years, with a significant presence of the 3-3+years age group, comprising 12.99% of the total (Fig. 2.2.5.4.).



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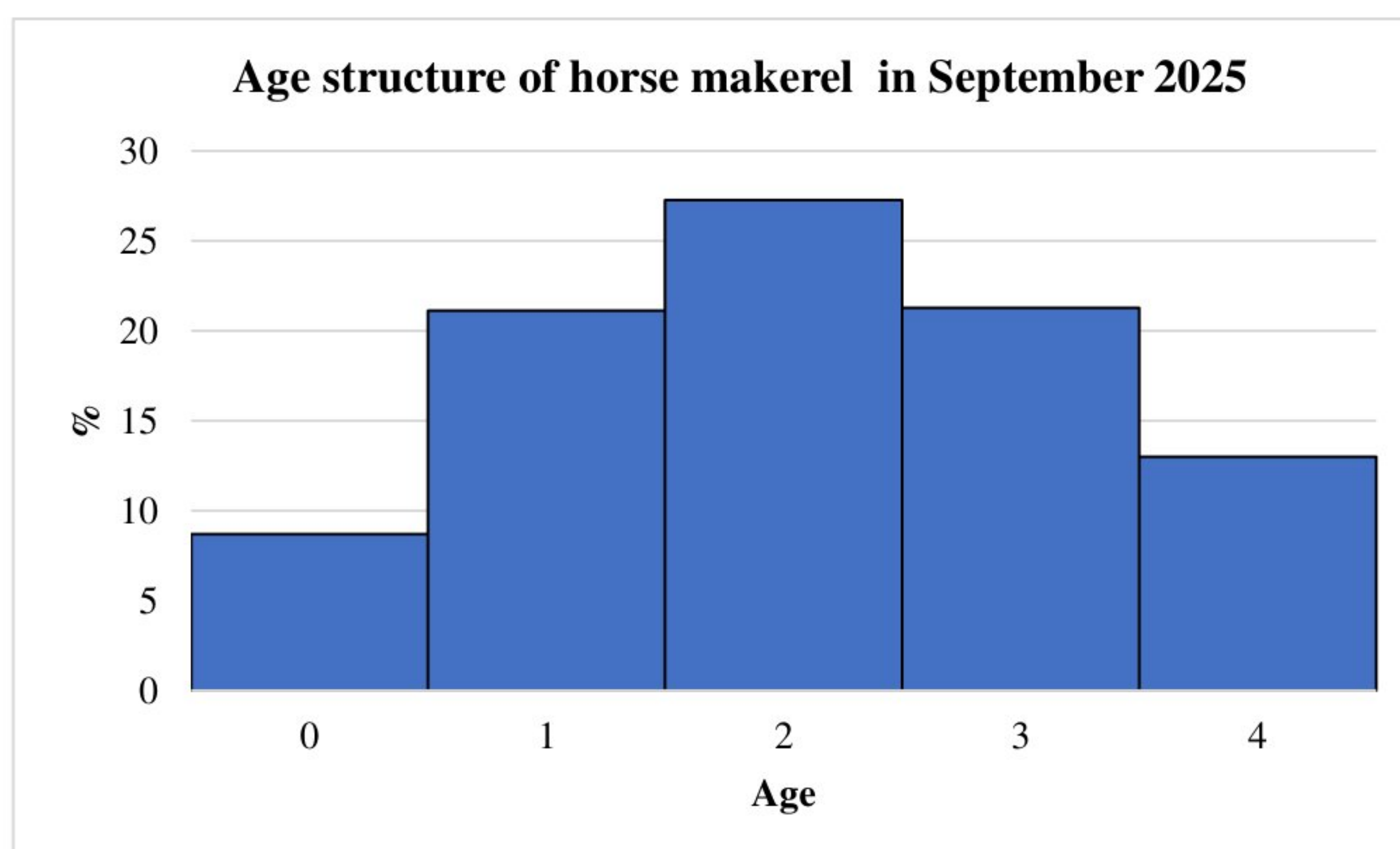


Figure 2.2.5.4. Age structure of horse mackerel in September 2025.

2.2.6. Individual growth

The growth parameters of horse mackerel (1500 ind.), calculated using the von Bertalanffy model, show an asymptotic length of 26.405 cm and higher values of the coefficient determining the rate of reaching the asymptote (Table 2.2.6.1.).

Table 2.2.6.1. Von Bertalanffy Growth Model (VBGF) for horse mackerel.

Species	Asymptotic length	Growth rate	Growth parameter	Growth coefficient	Allometric coefficient
<i>Trachurus mediterraneus</i>	$L_{\infty} = 26.405$	$K = 0.242$	$t_0 = -1.015$	$q = 0.0055$	$n = 2.977$

2.2.7. Abundance and biomass by length and age classes

In September 2025, the 9.0 cm size class had the highest percentage representation in the catches, followed by the 13 cm size class (Fig. 2.2.7.1).

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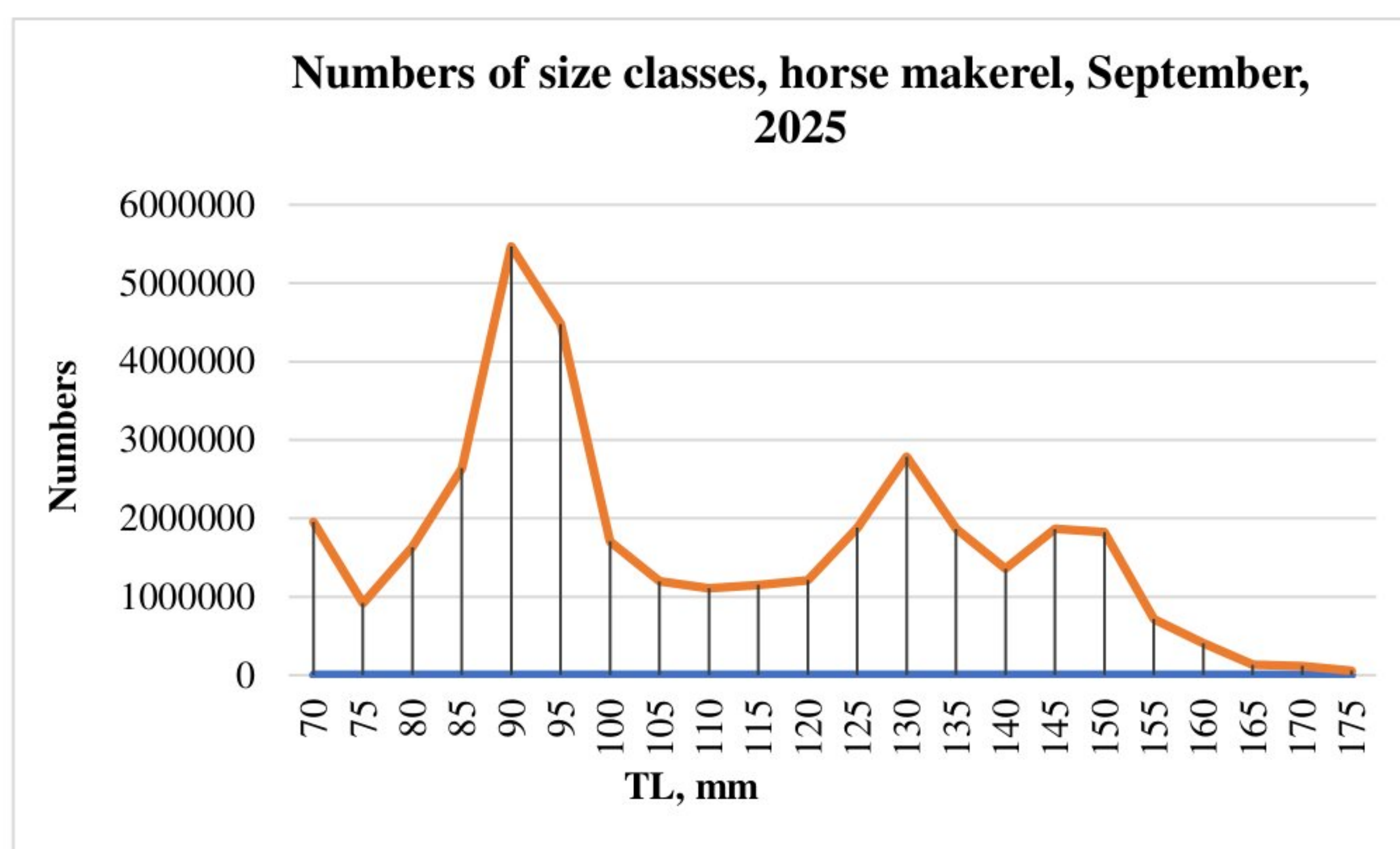


Figure 2.2.7.1. Abundance of horse mackerel by size classes in September 2025.

Analysis of the age structure of the catch showed that age groups 2-2+ and 3-3+ y^{-1} had high abundance indices and dominated the catches (Fig. 2.2.7.2). The age groups recorded in the catches ranged from 0 to 4+ years.



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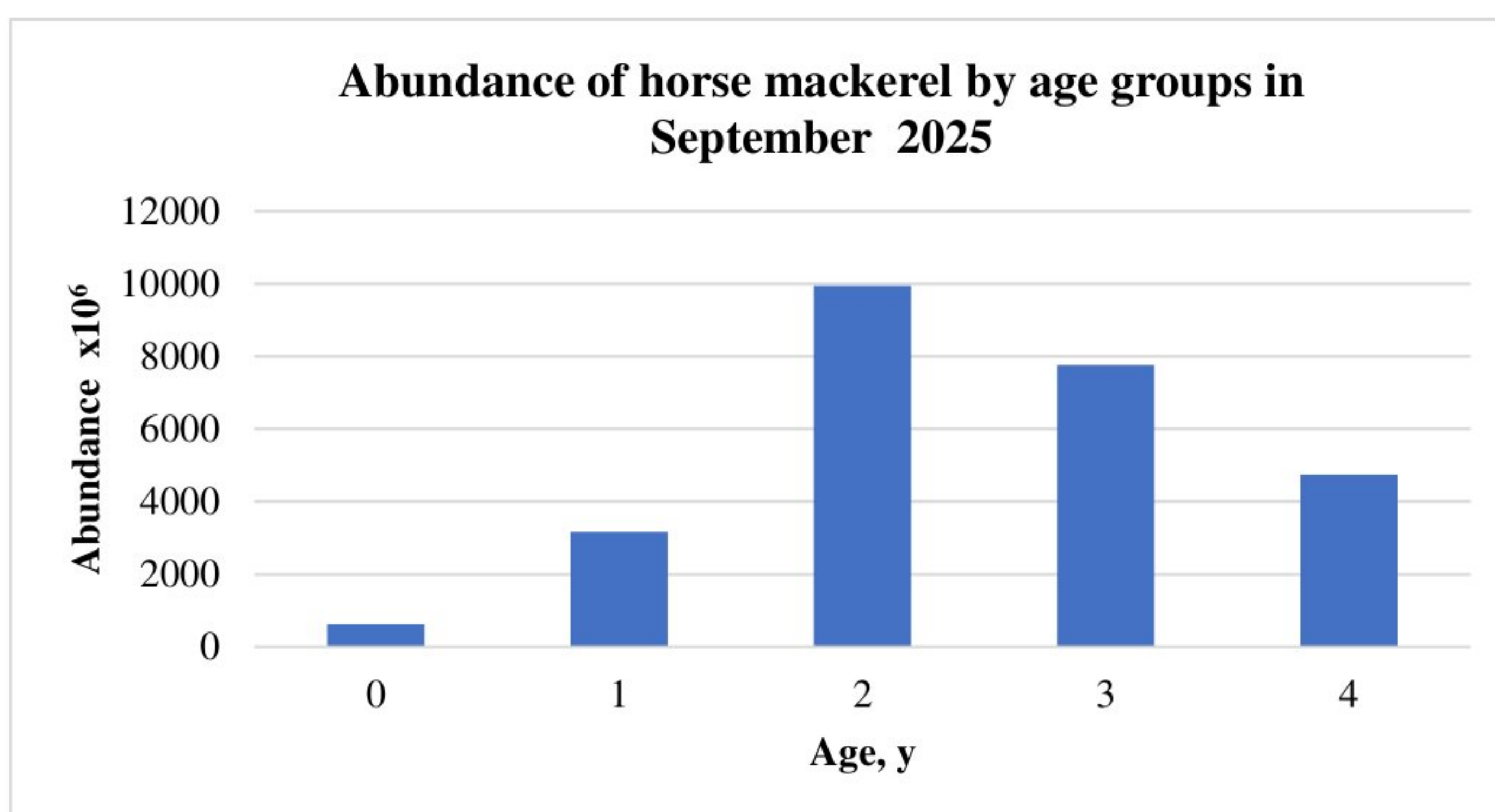


Figure 2.2.7.2. Abundance of horse mackerel by age groups in September 2025.

Biomass, similar to abundance, was dominated by the 90 mm size group, followed by the 95 mm size group (Fig. 2.2.7.3). Figure 2.2.7.4 presents the distribution of biomass by age group. In September 2025, age groups 2-2+ and 3-3+ years, and especially 2-2+ years, had a significantly higher share in the catches compared to other age groups.

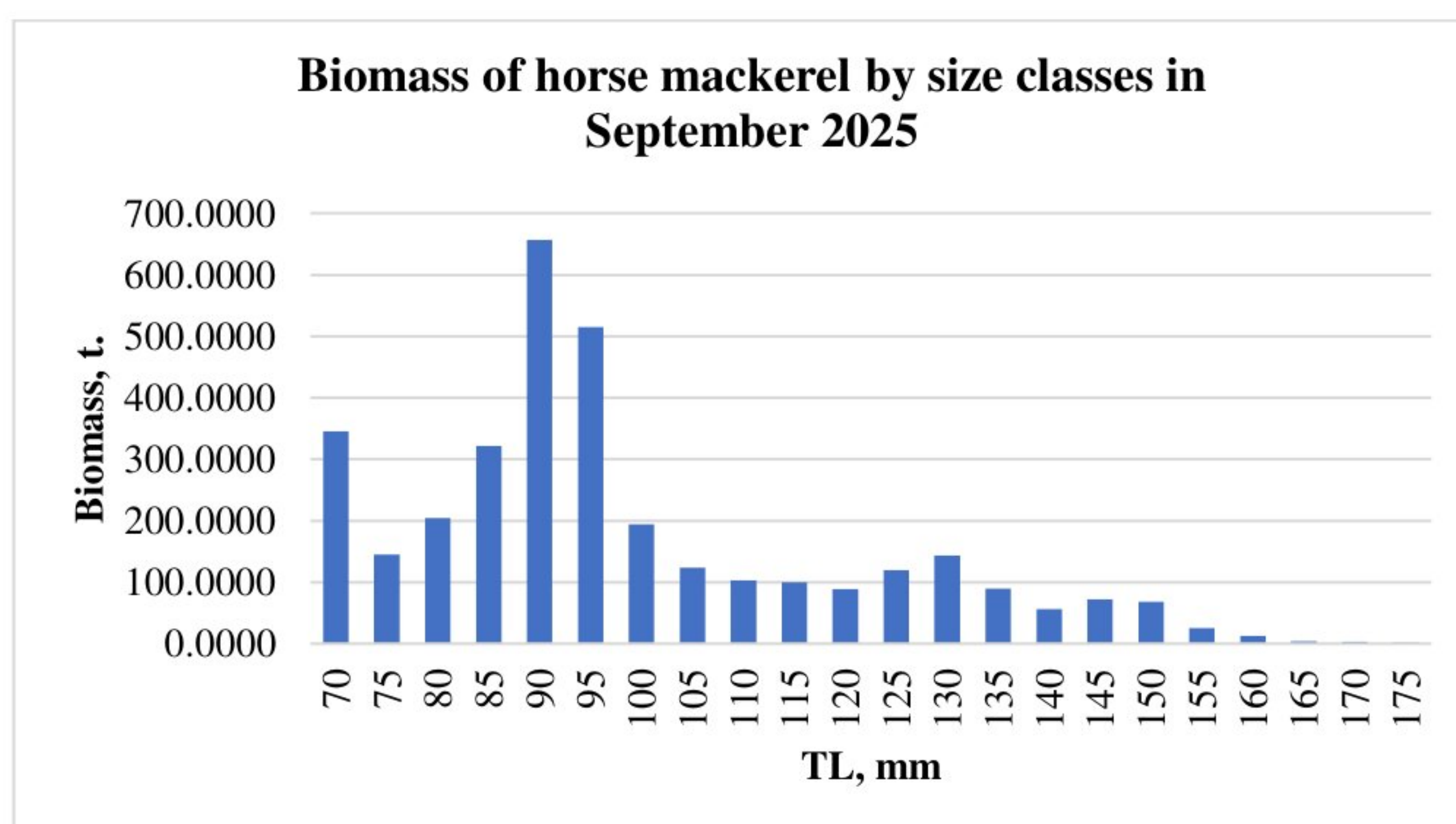


Figure 2.2.7.3. Biomass of horse mackerel by size classes in September 2025.

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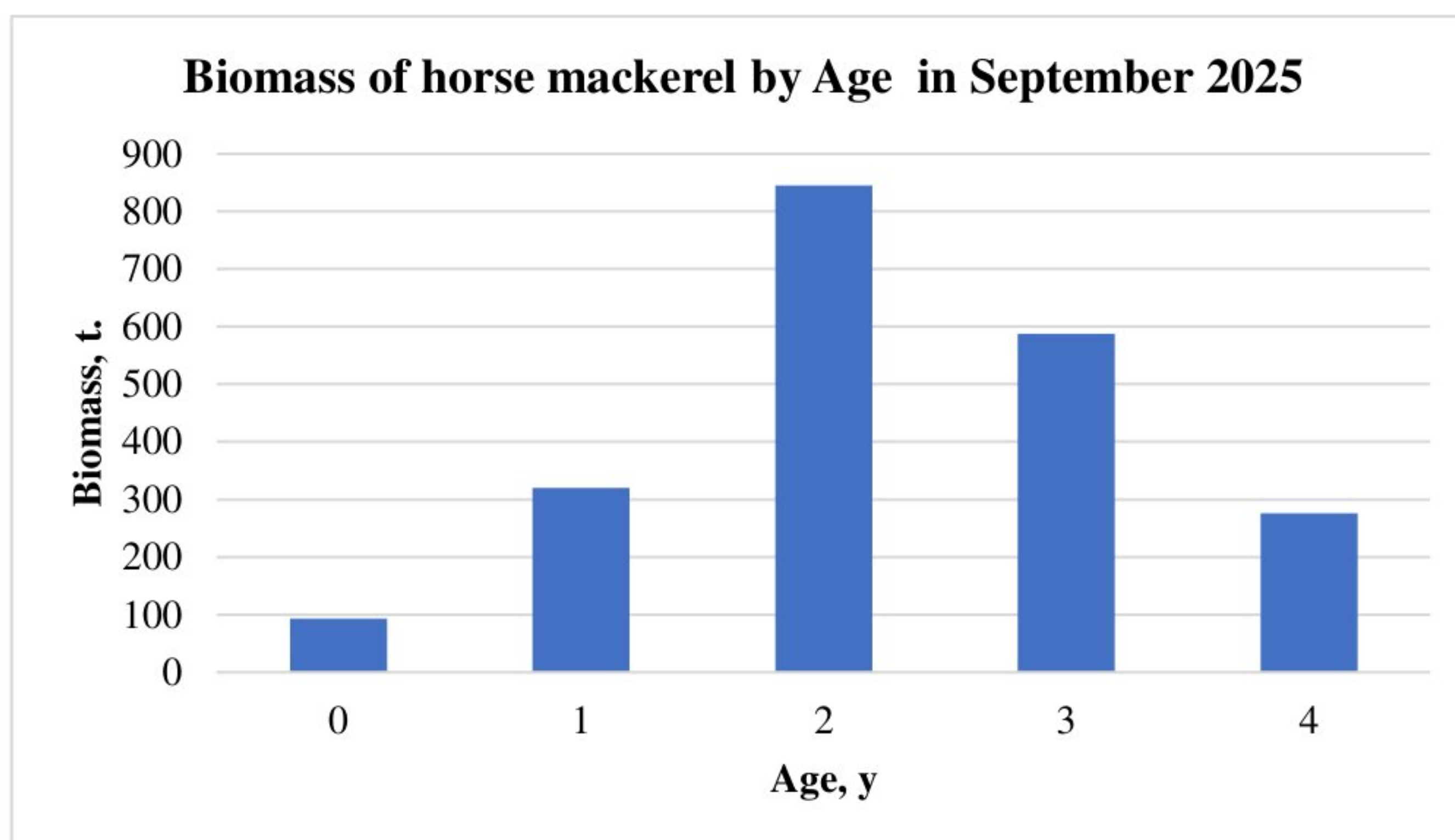


Figure 2.2.7.4. Biomass of horse mackerel by age groups in September 2025.

The sex ratio (250 individuals) of horse mackerel was 49% males and 51% females (Fig. 2.2.7.5).

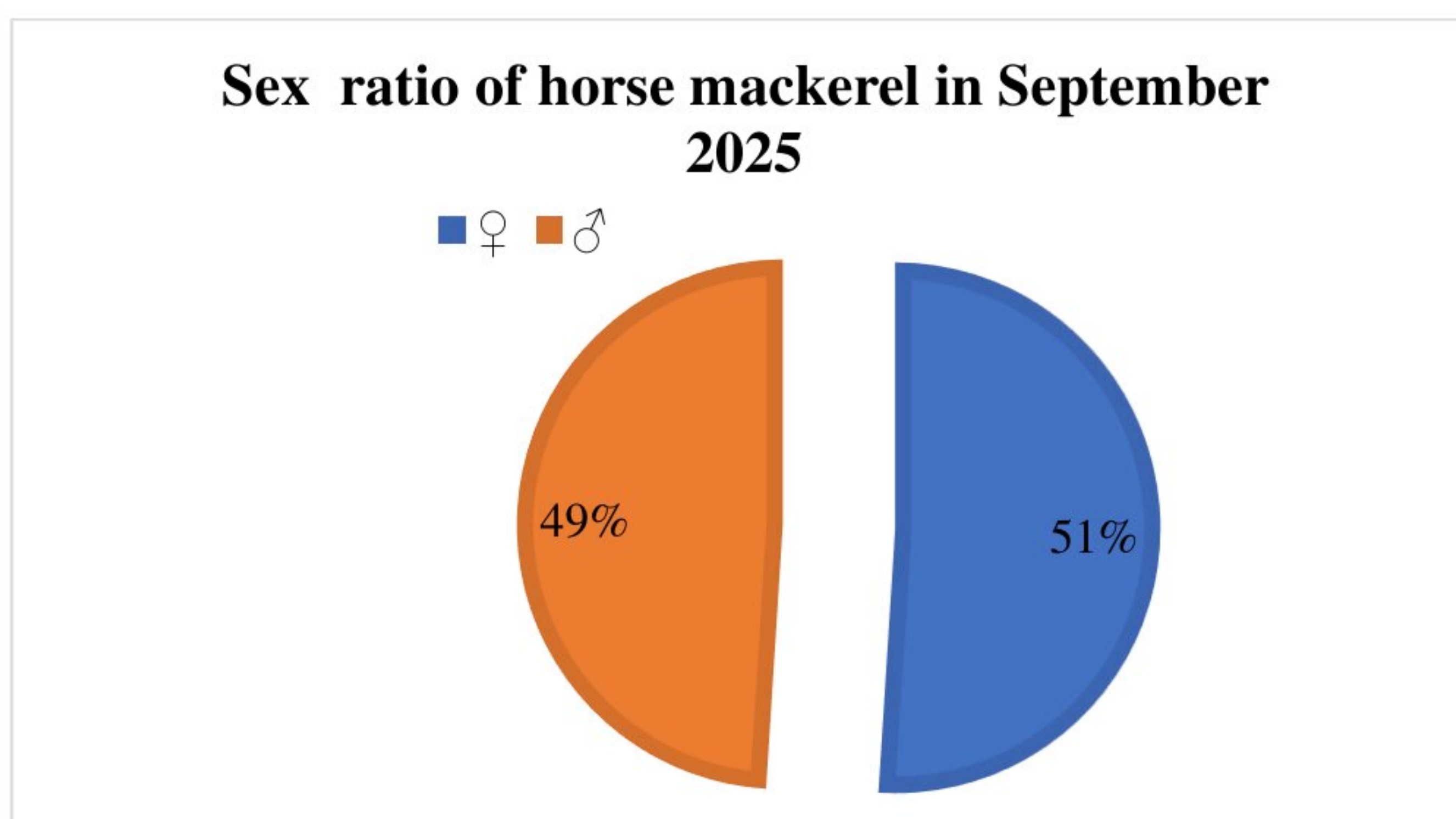


Figure 2.2.7.5. Sex ratio (females – ♀, males – ♂) of horse mackerel, September 2025.

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The sexual maturity of the analyzed species by size classes is presented in Figure 2.2.7.6, and by age groups in Figure 2.2.7.7.

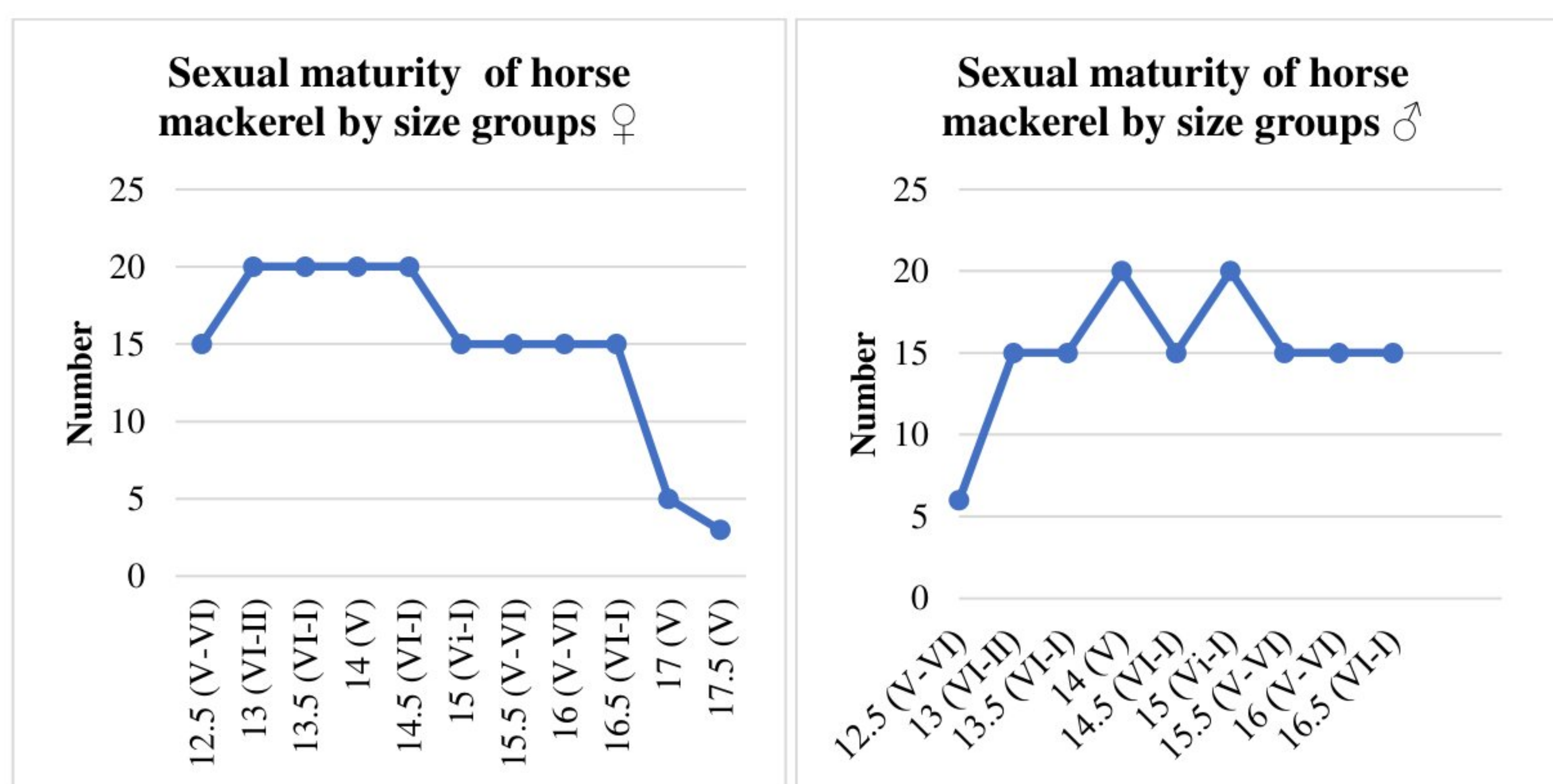


Figure 2.2.7.6. Sexual maturity of horse mackerel by size groups in September 2025.

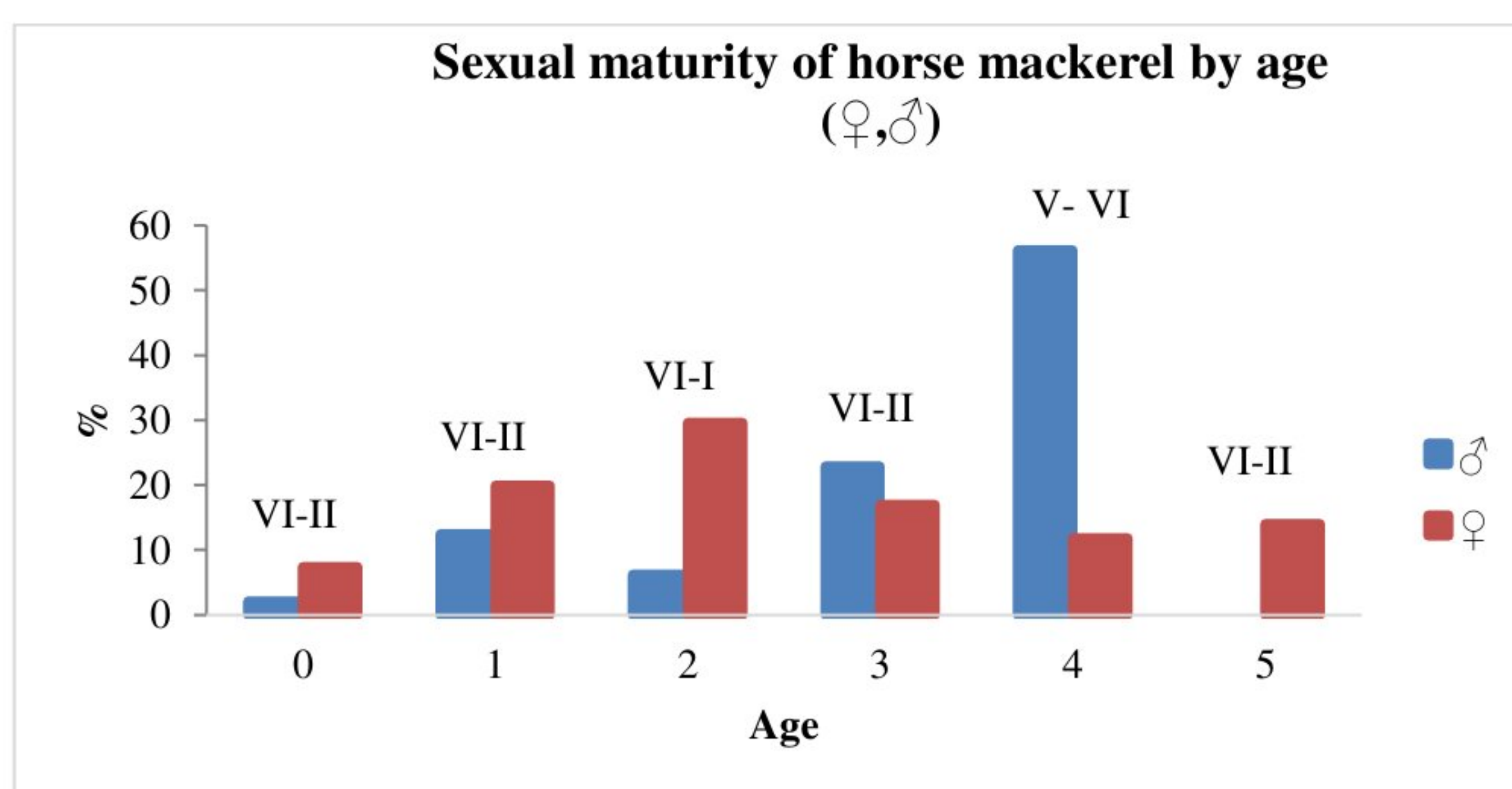


Figure 2.2.7.7. Sexual maturity of horse mackerel by age.

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The gonadosomatic index (GSI, %) of horse mackerel based on 250 individuals measured, is indicative of a later stage of spawning. An R^2 value of 0.328 (Fig. 2.2.7.8) shows a strong correlation between gonad weight and the gonadosomatic index, which indicates mass spawning activity and active sexual maturity of the reproductive organs during the study period.

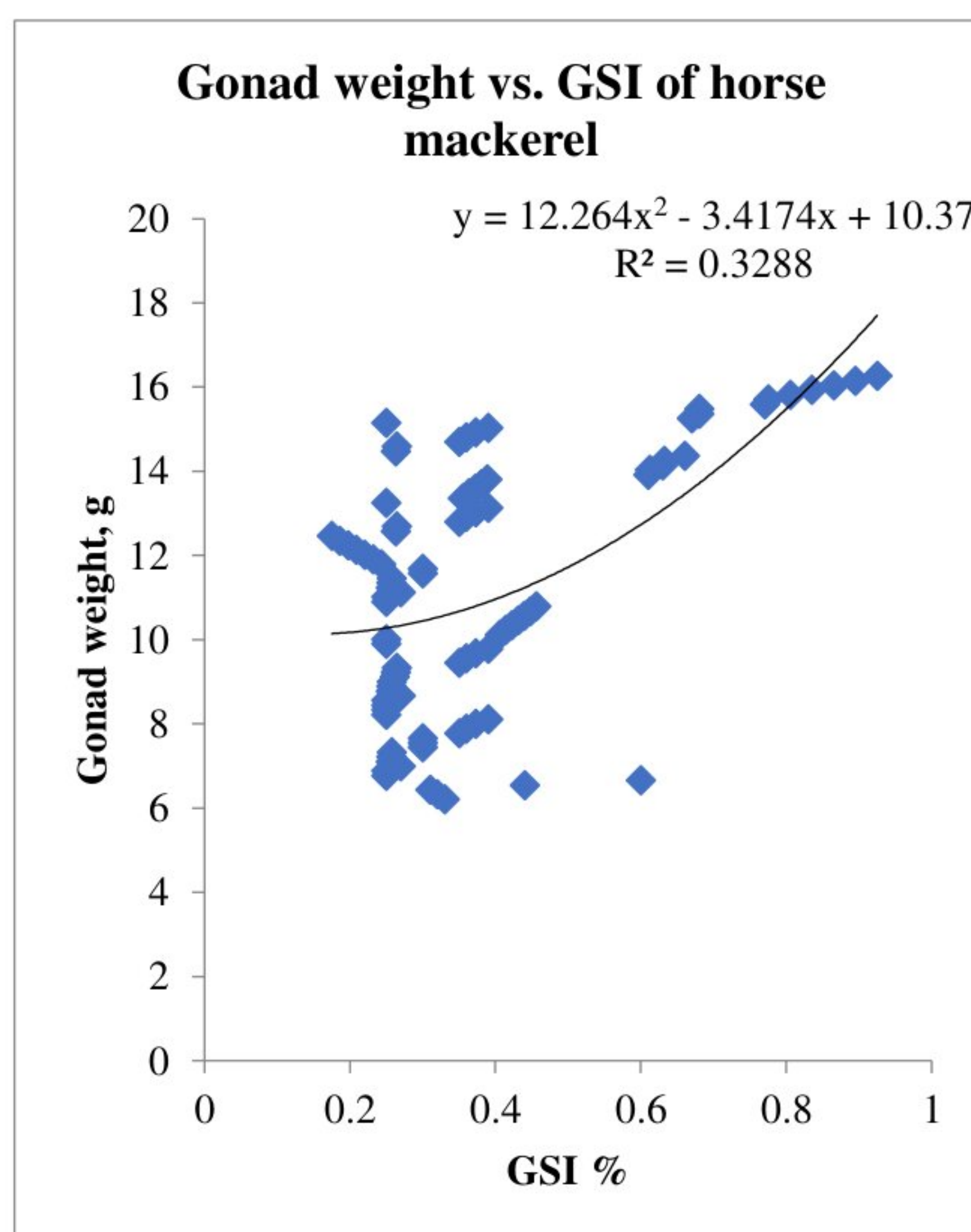


Figure 2.2.7.8. Gonadosomatic index of horse mackerel during the study period (GSI, % vs. Gonad weight).

2.2.8 Absolute and relative fecundity of horse mackerel

Absolute fecundity (measured on 250 ind) at length of 17.5 cm was the highest: 53 222 cavier grains. In terms of relative fecundity, the highest was detected at 13 cm TL individuals: 1235. The mean values of absolute and relative fecundity of the whiting were as follows: 34554,5 and 966,8 (Table 2.2.8.1).

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Table 2.2.8.1. Absolute and relative fecundity of horse mackerel.

Size class	Mean weight (w, g)	Mean length (cm)	absolute fecundity (number of cavier grains)	relative fecundity	No. ♀
10	7.79	9.71	8250±212	1059.05±111	20
10.5	8.93	10.44	8512±118	953.19±95	20
11	11.04	11.25	9835±242	890.85±48	20
11.5	16.53	11.62	11706±355	708.17±51	20
12	18.02	11.99	14800±405	821.31±66	20
12.5	22.06	12.44	28002±1205	1274.71±155	20
13	29.16	13.02	34215±1552	1235.77±168	20
13.5	40.99	13.44	41699±1774	1078.31±112	20
14	42.22	14	46000±1600	1089.53±125	20
14.5	46.01	14.44	46500±1717	1010.65±48	15
15	46.25	15.01	46700±2241	1009.73±61	10
15.5	51.02	15.55	47000±2555	921.2073697	10
16	55.36	16.15	51210±2100	925.0361272	10
16.5	61.5	16.58	52221±1950	849.1219512	10
17	62.33	17.22	53000±1900	850.312851	10
17.5	67.12	17.44	53222±2500	792.9380215	5
Mean			34554.5	966.8	250

2.3. Red mullet (*Mullus barbatus*)

2.3.1. Biomass of red mullet

The total surveyed area was 8010.24 km², and the total biomass of red mullet was 2065.2 tonnes (Table 2.3.1.1). The species was recorded at 16 stations (out of a total of 41). The densest aggregations were observed off Cape Kaliakra and in front of Byala. A biomass peak was recorded in the 15–30 m depth range (164.4859 t) and in the 30–50 m range (1900 t), but missing from catch in strata in 50–100 m stratum (0 t) (Fig. 2.3.1.1; Table 2.3.1.2).

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Table 2.3.1.1. Area-based method for stock assessment in September 2025 – average catch per unit area (CPUA), biomass (kg), A_x – area, and number of fields.

CPUA average	Strata (m)	Biomass (kg)	A_x Surface	Number of stations
79.6488	15-30	164.4859239	2065.14	33
1047.33	30-50	1900.715443	1814.82	29
0	50-100	0	4130.28	66
		2065.201367	8010.24	128

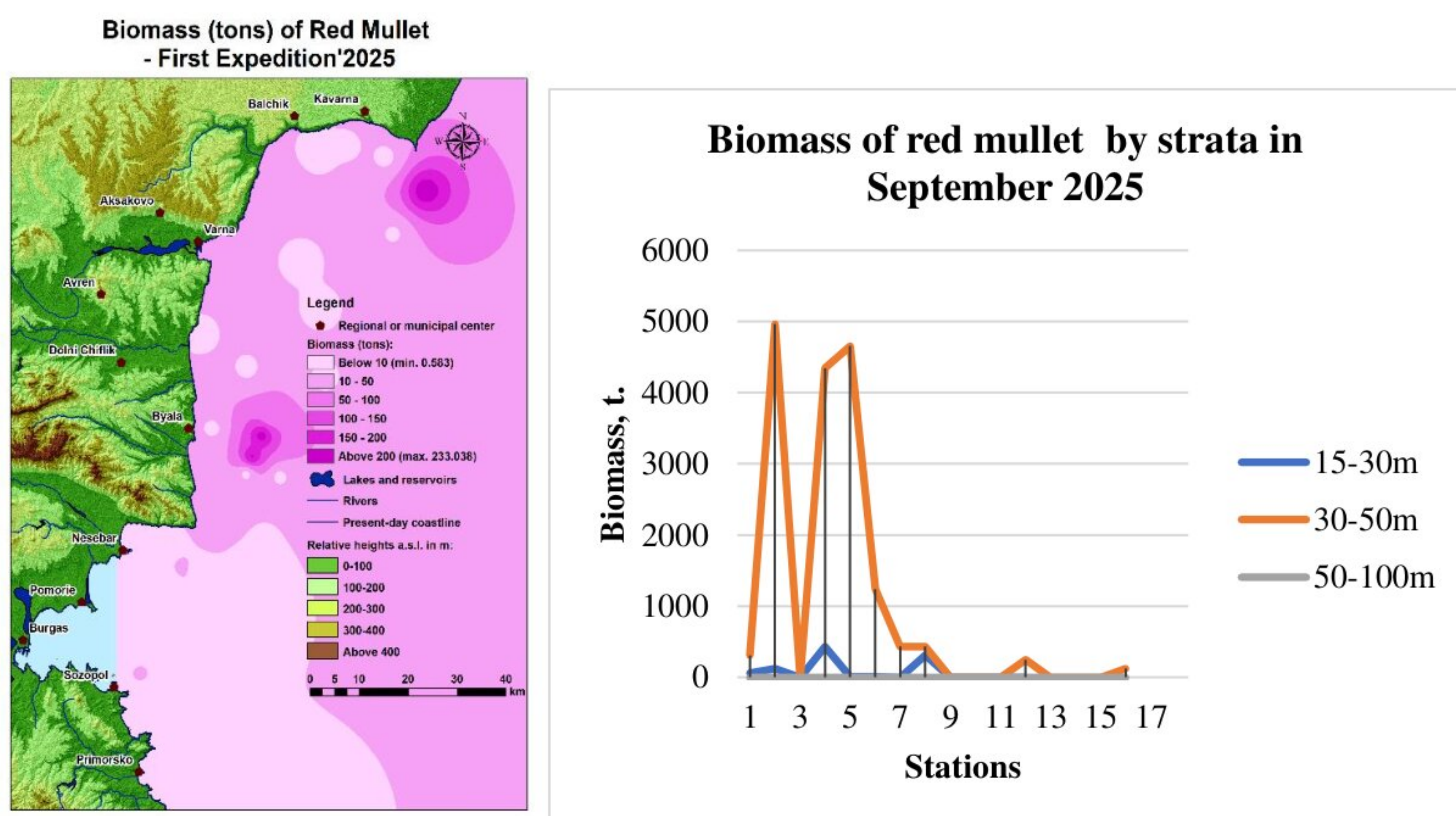


Figure 2.3.1.1. Biomass of red mullet in September 2025.

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Table 2.3.1.2. Descriptive statistics of the CPUA indices (t) of red mullet in September 2025.

	15–30 m	30–50 m	50–100 m
Average	79.6488	1047.33	0
Standard error	38.27065	427.61	0
Median	12.4128	248.256	0
Mode	0	0	0
Standard deviation	137.9868	1763.081	0
Variation	19040.35	3108456	0
Excess	3.285076	1.369081	0
Asymmetry	2.000938	1.715538	0
Range	434.448	4965.12	0
Minimum	0	0	0
Maximum	434.448	4965.12	0
Amount	1035.434	17804.61	0
Number	13	17	0
Greatest Value (1)	434.448	4965.12	0
Smallest value (1)	0	906.4927	0
Confidence level (95.0%)			

2.3.2. Catch per unit area (CPUA kg.km⁻²)

The catch per unit area in the 15–30 m stratum was 80 kg.km⁻² (mean). In the 30–50 m – 1047 kg.km⁻² (средно) and 50–100 m strata, the values was 0 kg.km⁻². The average catch per unit area ranged between 15–310 kg.km⁻² (Fig. 2.3.2.1).

From the analysis of the catch per unit area and the catch per unit area and unit effort (Fig. 2.3.2.1 and Fig. 2.3.2.2.) it is evident that the densest aggregations and numbers are found in a depth zone of 30–50 m (Byala and Kaliakra), followed by a zone of 15–30 m.

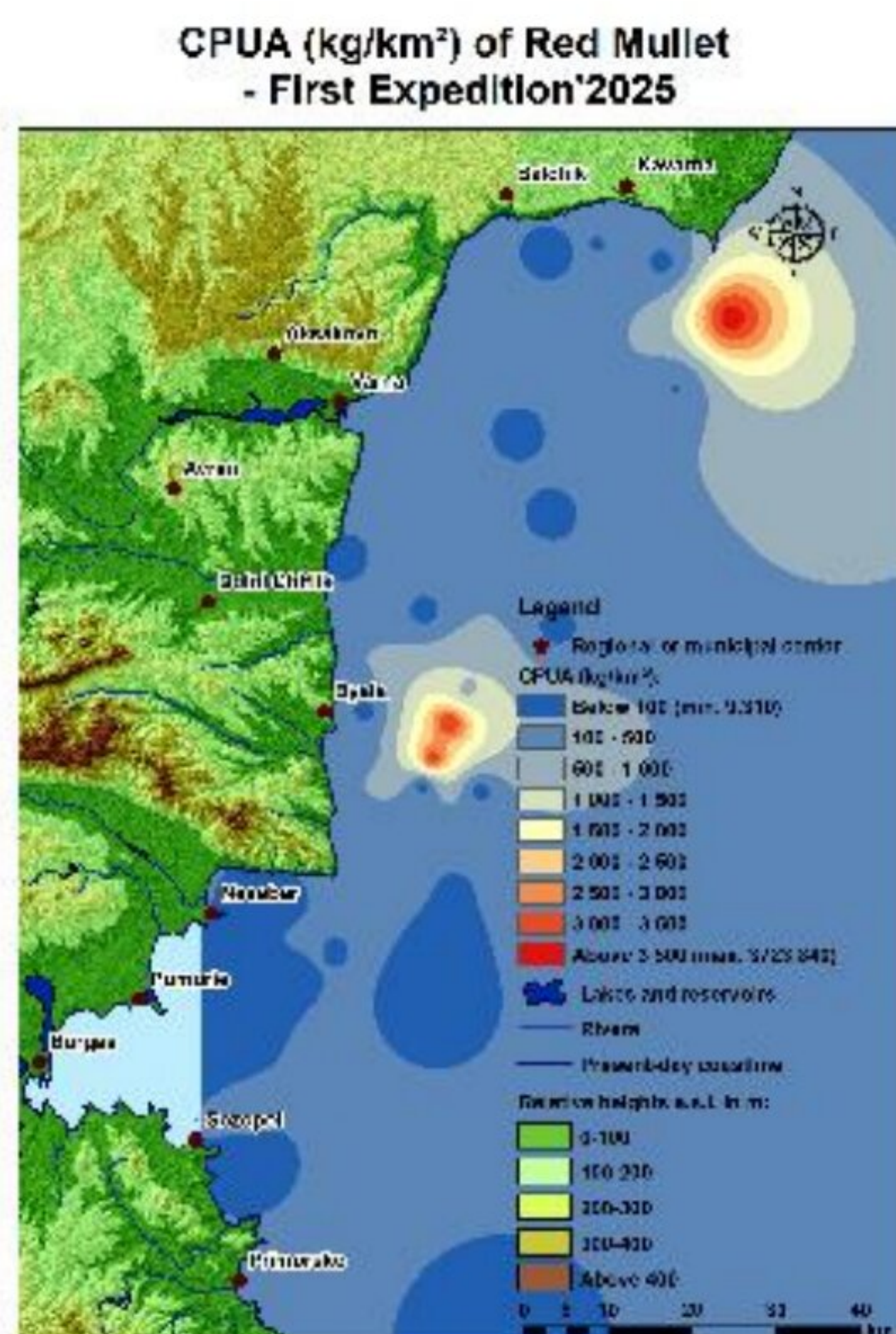


Figure 2.3.2.1. Catch per unit area (CPUA kg.km⁻²) of red mullet in September 2025.



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CPUE (kg/h) of Red Mullet
- First Expedition'2025

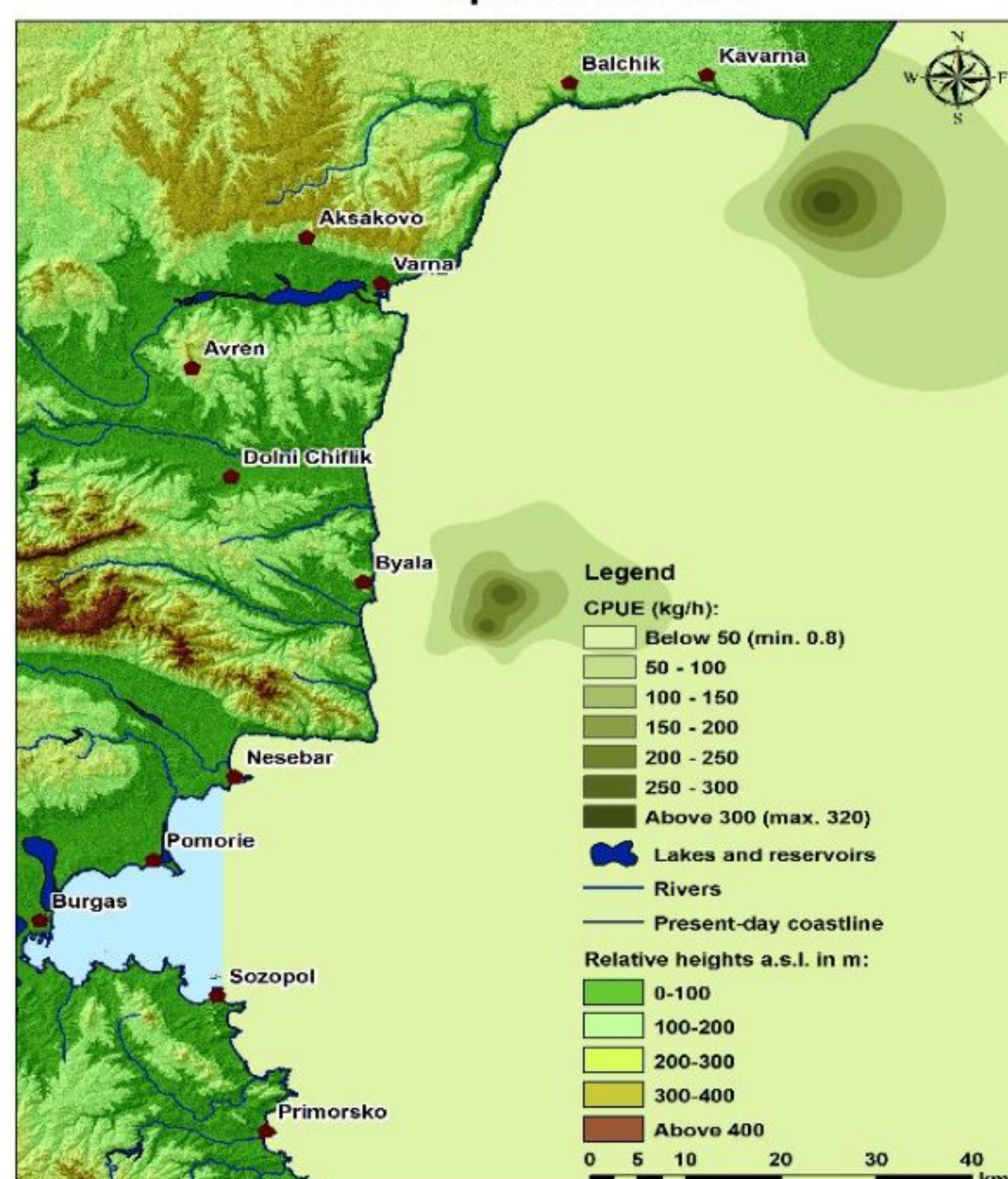


Figure 2.3.2.2. Catch per unit effort (CPUE $\text{kg}\cdot\text{h}^{-1}$) of red mullet in September 2025.

The length-weight (L–W) analysis of red mullet in September 2025 (Fig. 2.3.2.3) shows a very strong correlation between length and weight, with clearly expressed allometric growth ($R^2 = 0.99$) and a high determination coefficient ($n = 3.11$).

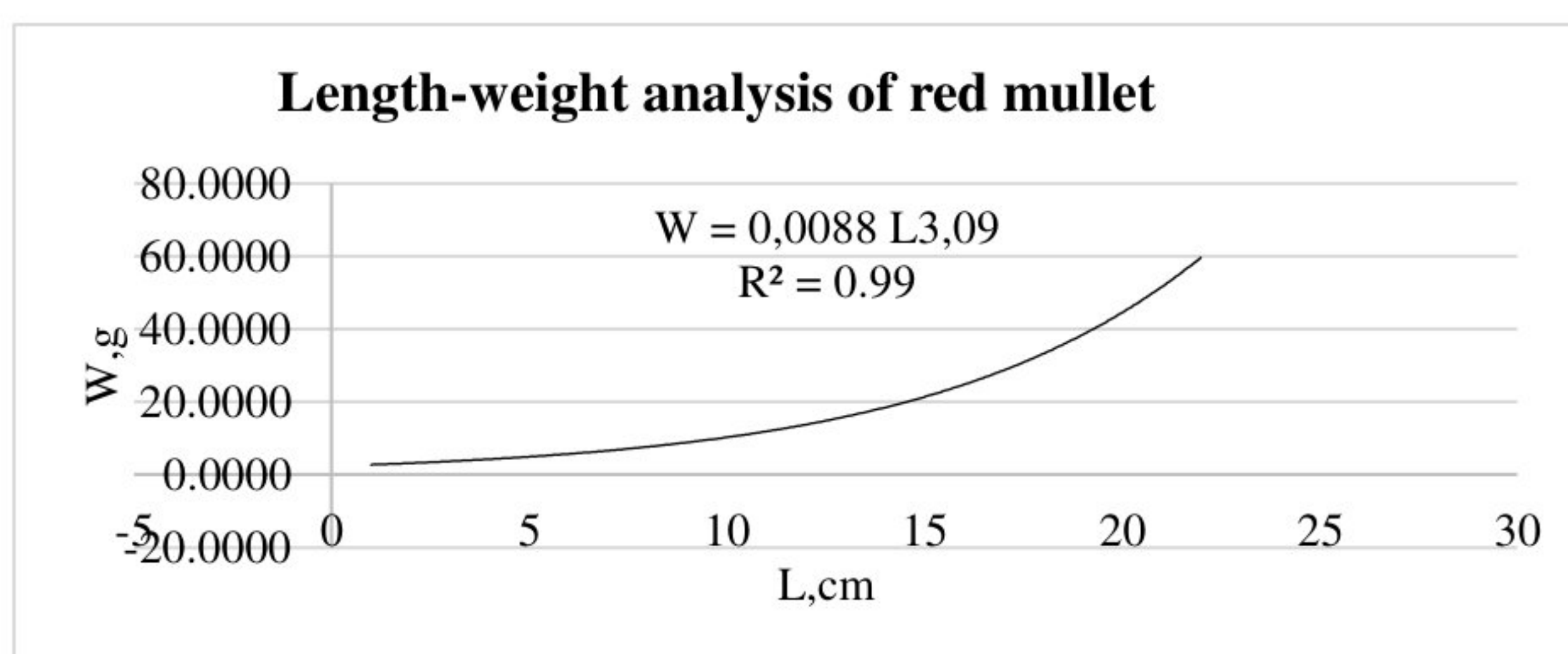


Figure 2.3.2.3. Length-weight analysis of red mullet (L–W) in September 2025.

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The size structure of red mullet (1200 ind.) is presented in Figure 2.3.2.4. During the survey, the dominant size classes in the catch composition were 12 cm and 12.5 cm.

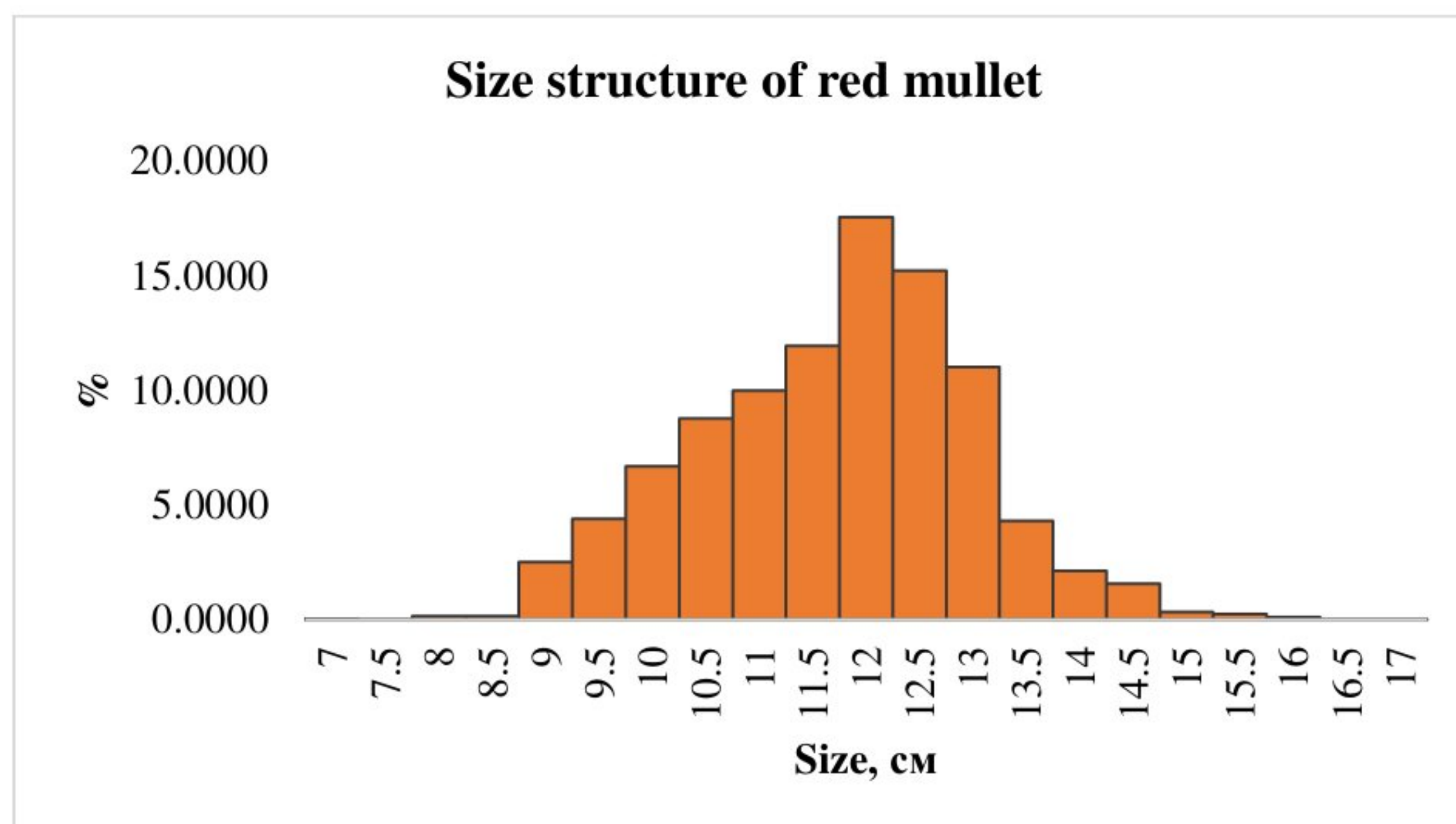


Figure 2.3.2.4. Size structure of red mullet, September 2025.

Age group 2-2+ years was dominant, followed by 3-3+y⁻¹ and 1-1+y⁻¹ (500 ind). The remaining age groups had a negligible presence in the catches during September 2025 (Fig. 2.3.2.5).

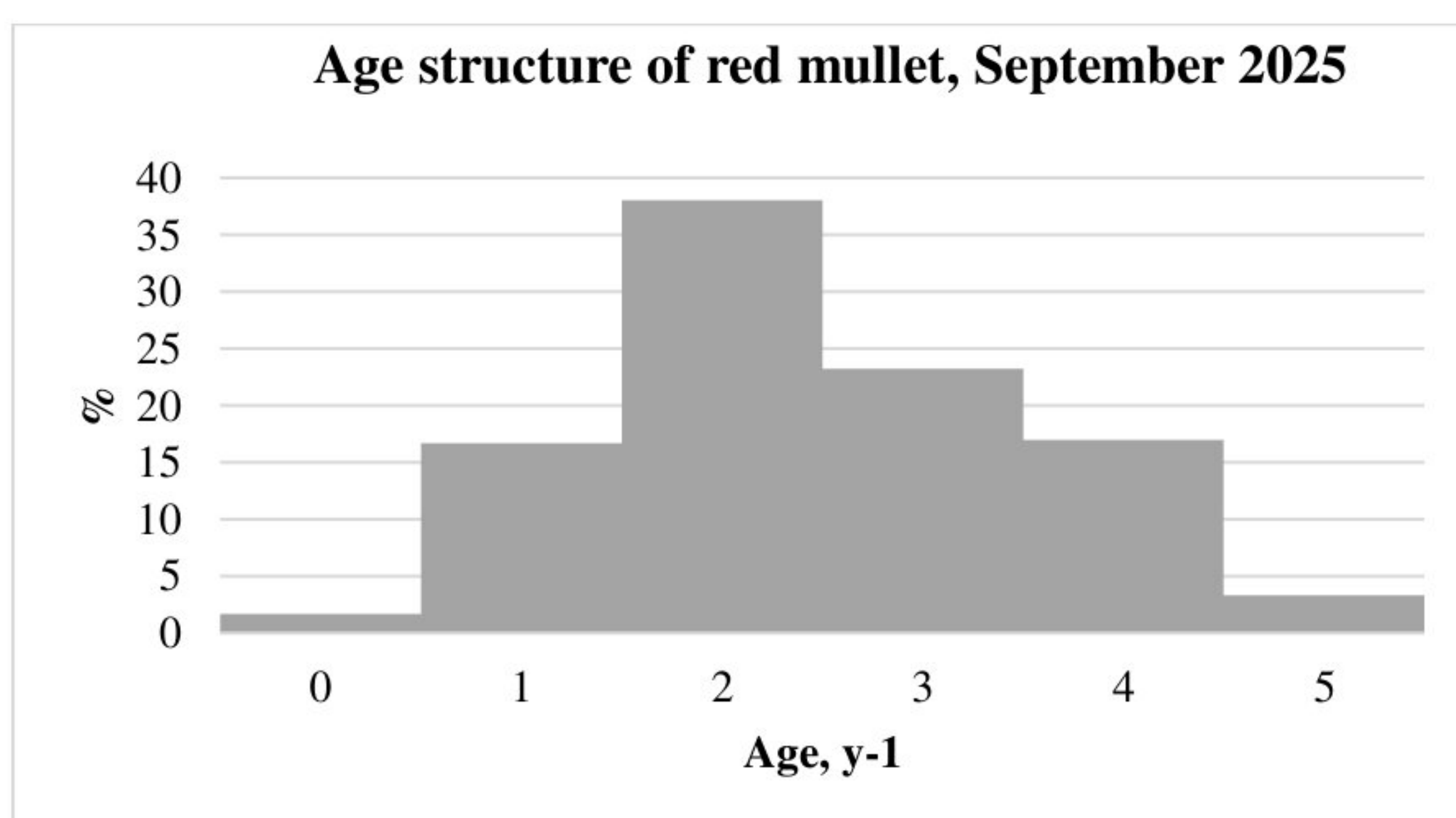


Figure 2.3.2.5. Age structure of red mullet, September 2025.

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The growth parameters (1200 ind.) of red mullet, calculated using the von Bertalanffy model, indicate an asymptotic length of 18.4 cm and higher values of the coefficient that defines the rate of approaching the asymptote (Table 2.3.2.1).

Table 2.3.2.1. Von Bertalanffy growth model (VBGF) for red mullet.

Species	Asymptotic length	Growth rate	Growth parameter	Growth coefficient	Allometric coefficient
<i>M. barbatus</i>	$L_{\infty} = 18.4$	$K = 0.24$	$t_0 = -1.232$	$q = 0.009$	$n = 3.1194$

Somatic growth of red mullet by age did not show any deviations from the norm (Fig. 2.3.2.5).

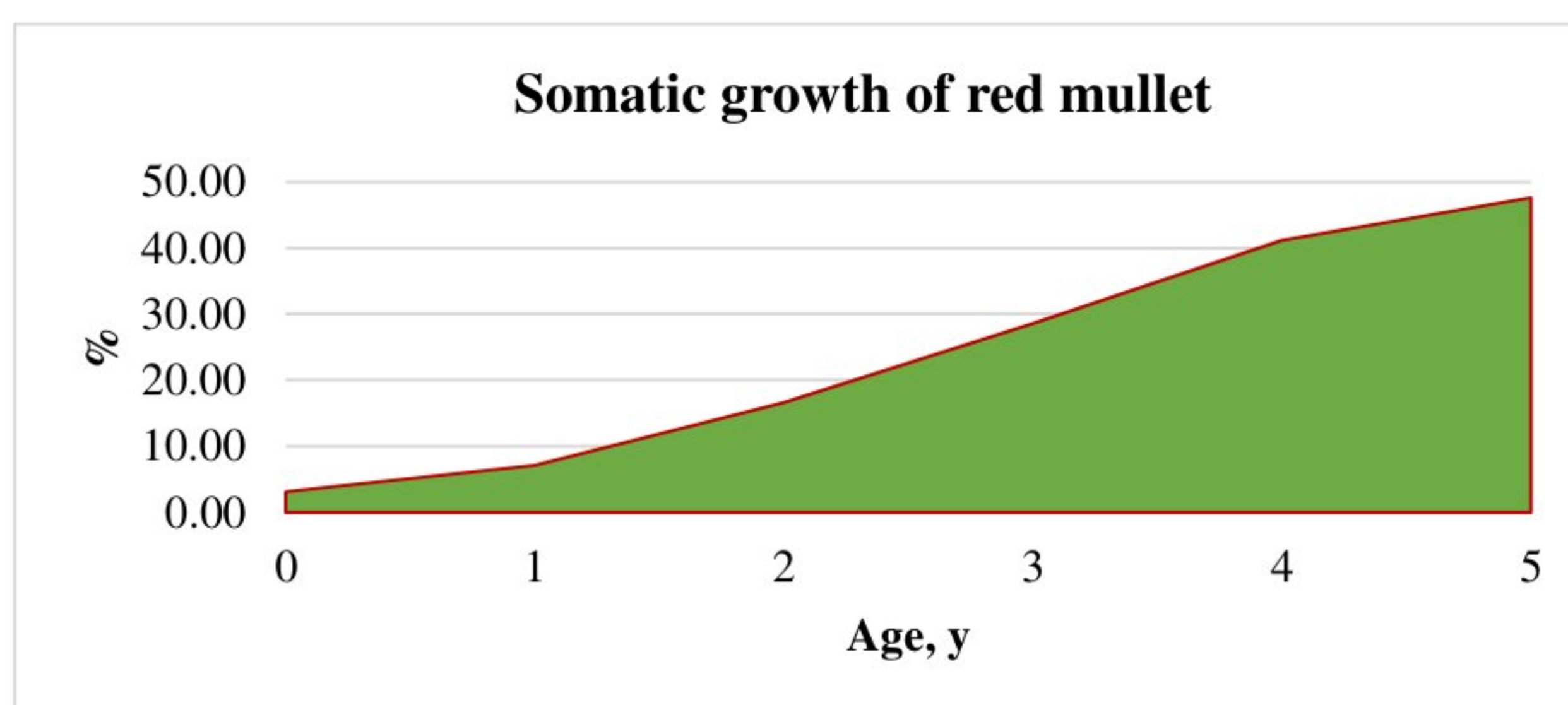


Figure 2.3.2.5. Somatic growth of red mullet by age.

2.3.3. Abundance and biomass by length and age classes

The 11 cm and 13 cm length classes dominated the red mullet catches, while larger length classes were represented by a smaller percentage. In September 2025, the 11 cm length class had the highest percentage representation in the catches, followed by the 13 cm length class (Fig. 2.3.3.1; Fig. 2.3.3.2).



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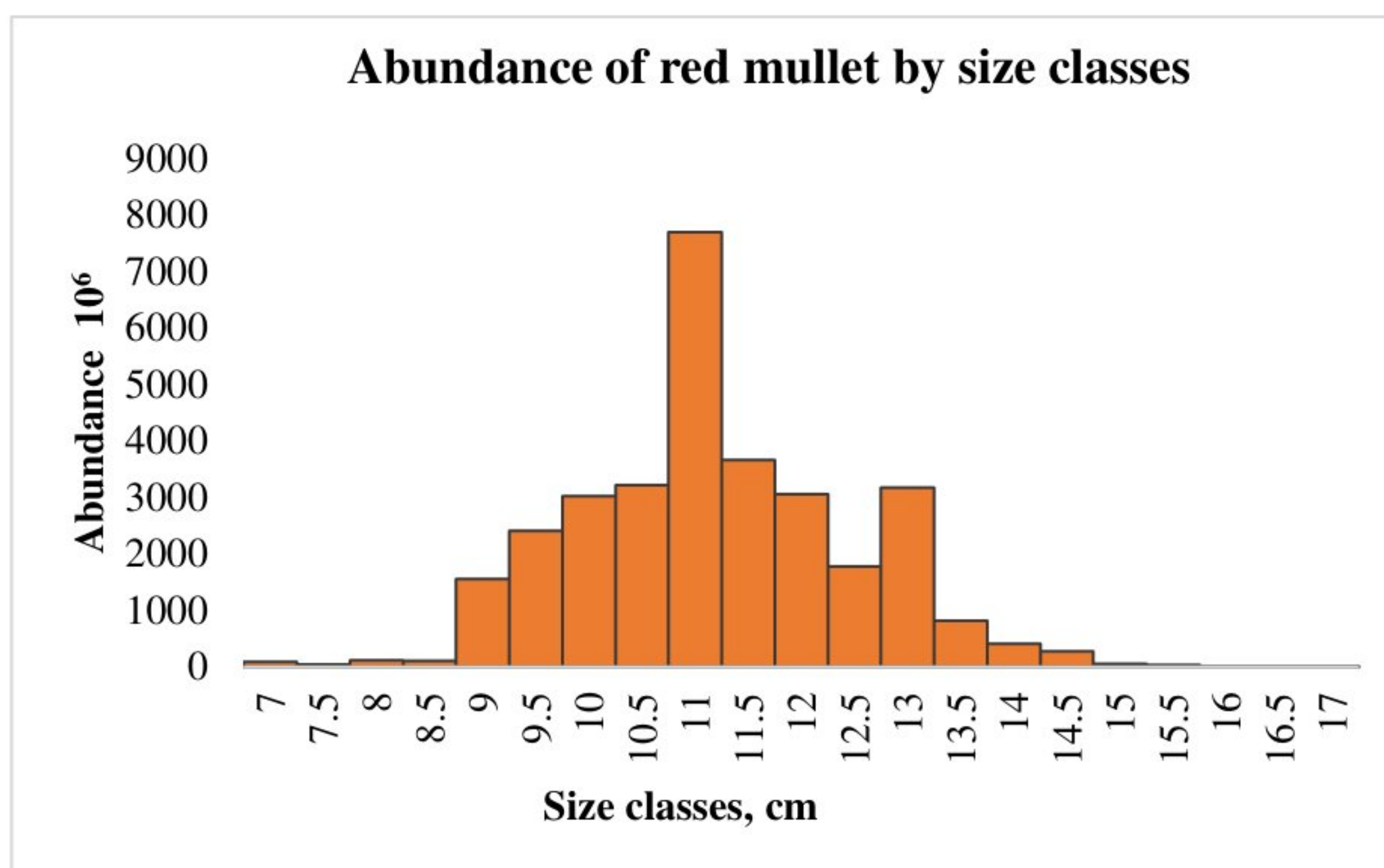


Figure 2.3.3.1. Abundance of red mullet by size classes.

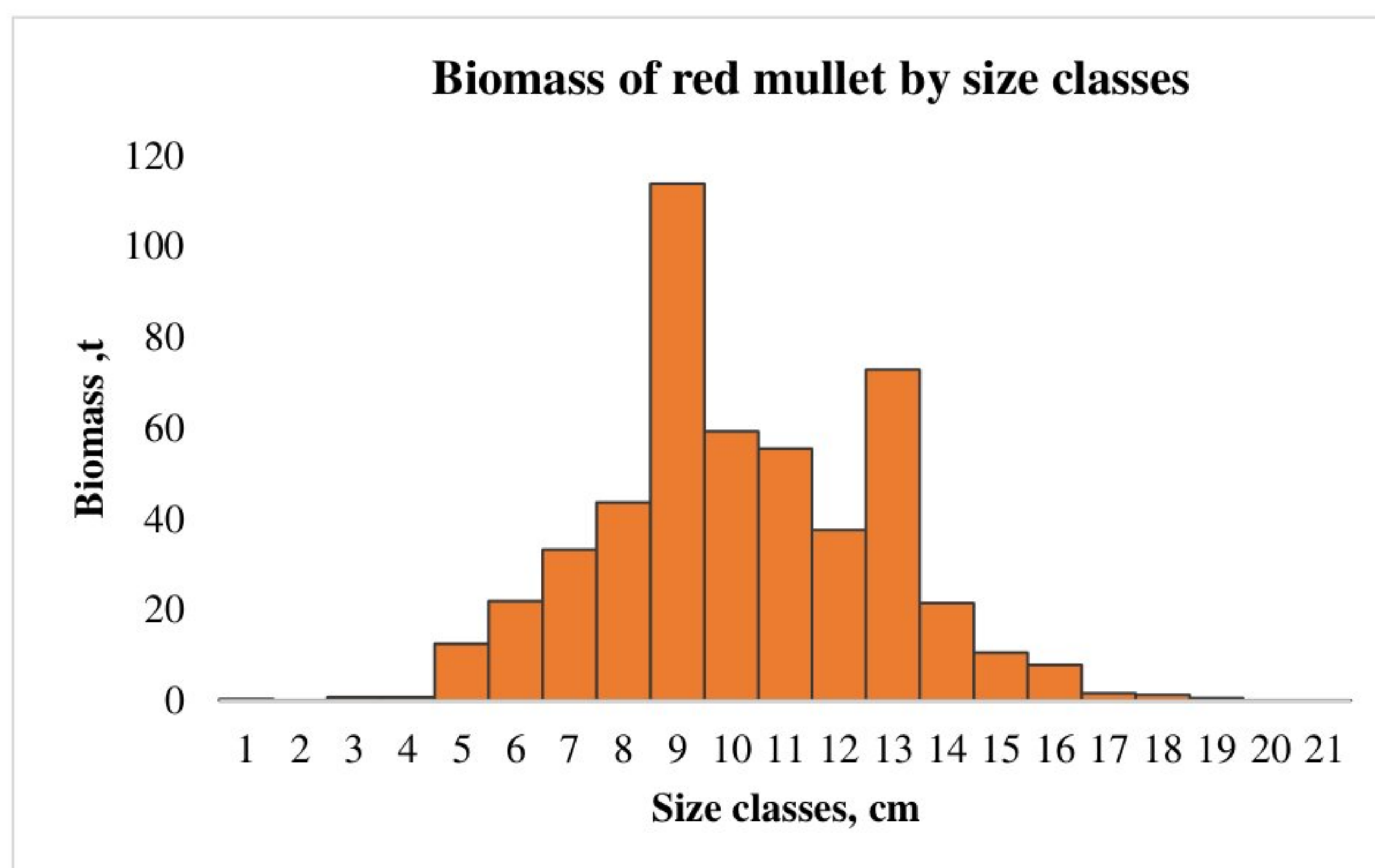


Figure 2.3.3.2. Biomass of red mullet by size classes.

The highest abundance was recorded in the 2–2+ year age group, followed by the 1–1+ year group. Older age groups are in subordinate presence (Fig. 2.3.3.3; Fig. 2.3.3.4).

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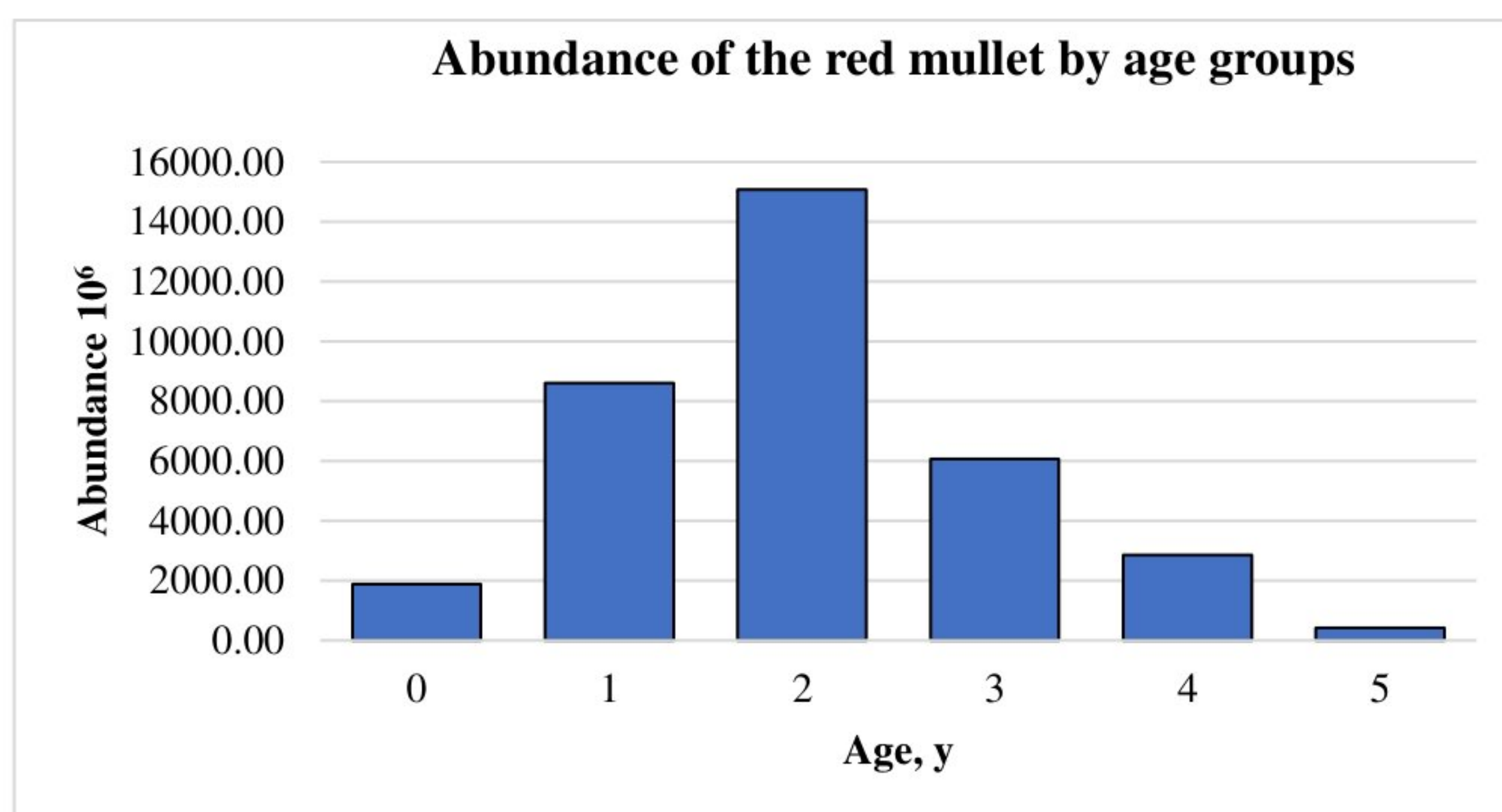


Figure 2.3.3.3. Abundance of the red mullet by age groups.

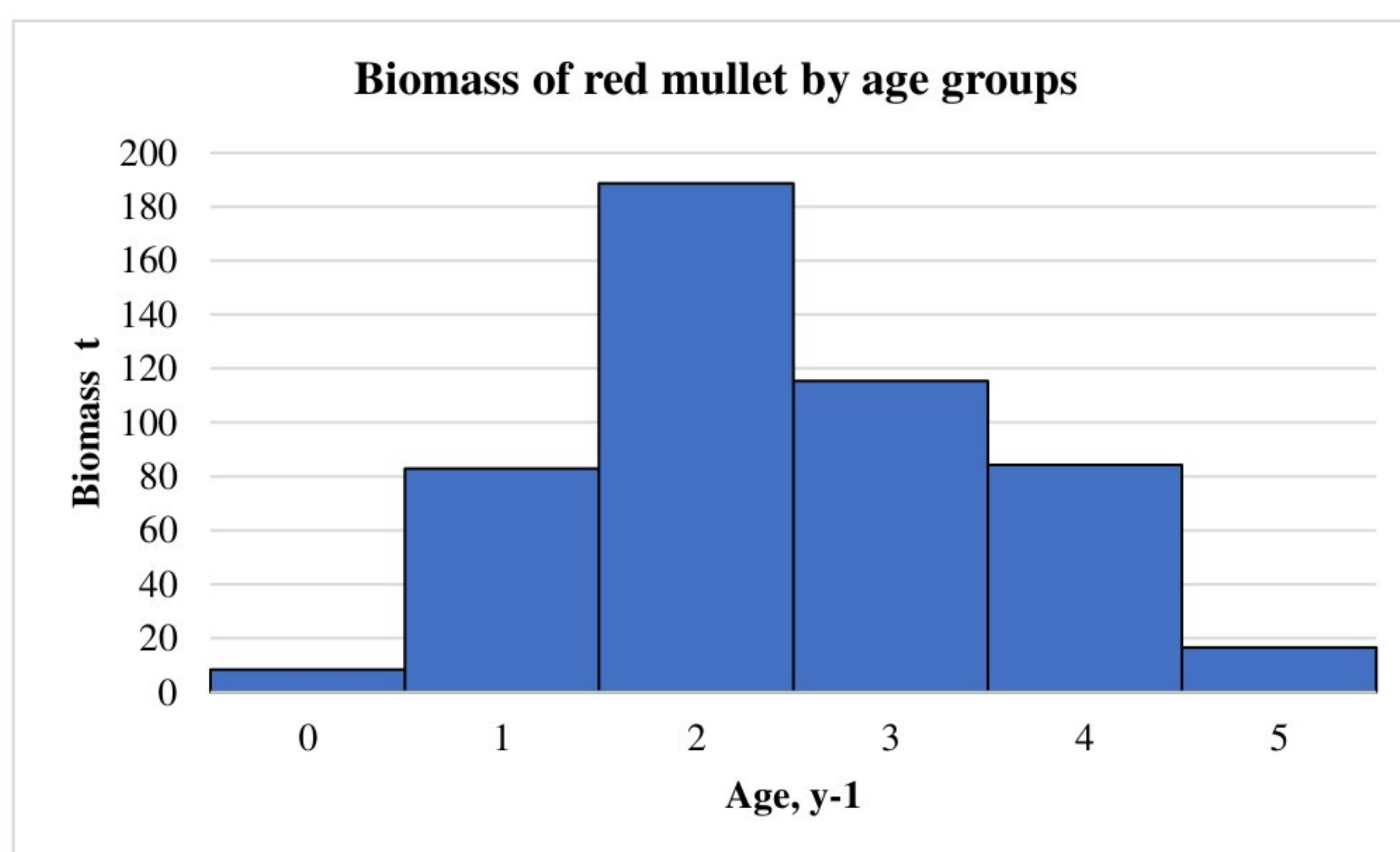


Figure 2.3.3.4. Biomass of red mullet by age groups.

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2.3.4. Sex Ratio and Maturity

The percentage representation of females, males, and sexually immature individuals in red mullet was as follows: 47% females, 45% males, and 8% immature (Fig. 2.3.4.1).

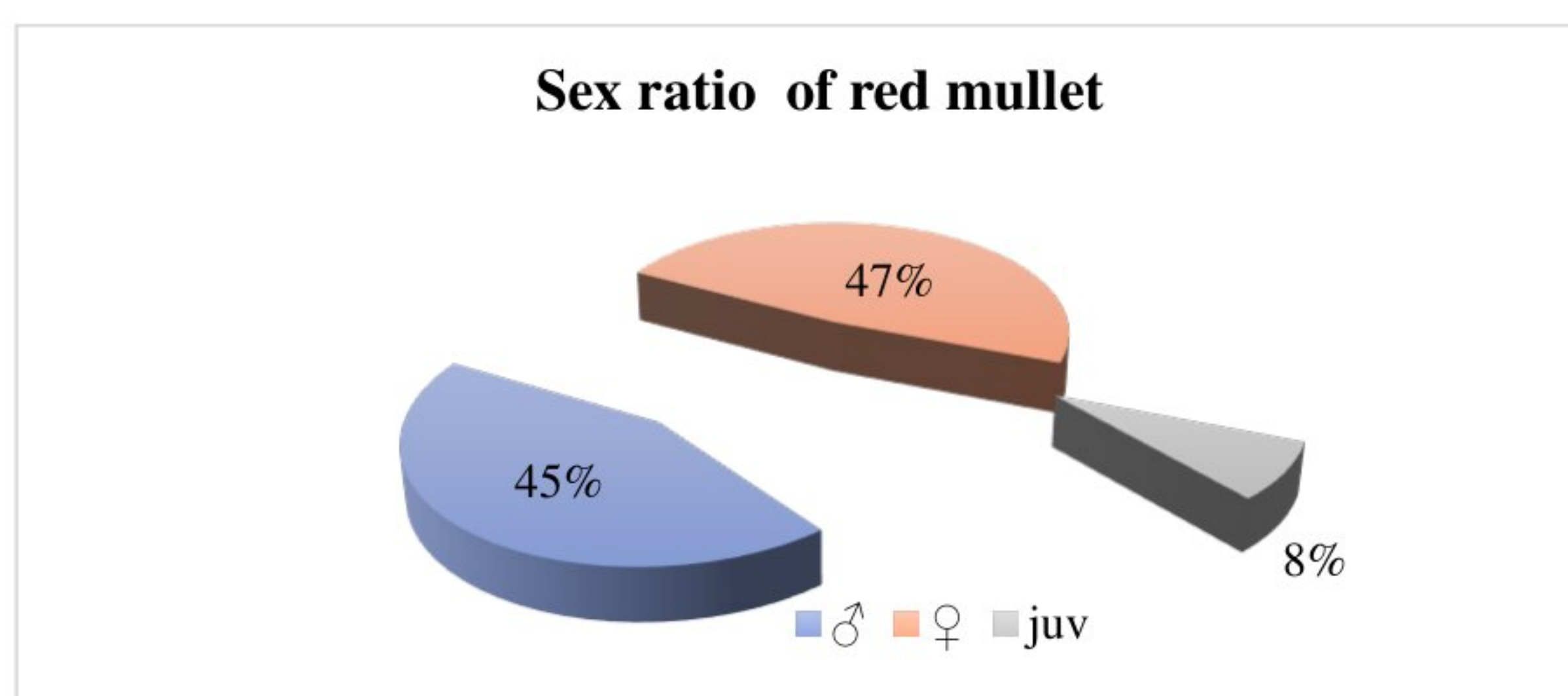


Figure 2.3.4.1. Sex ratio (females – ♀, males – ♂, and juveniles – juv) of red mullet in September 2025.

The sexual maturity of 250 ind. of the analyzed species by length classes is presented in Figure 2.3.4.2, and by age groups in Figure 2.3.4.3.

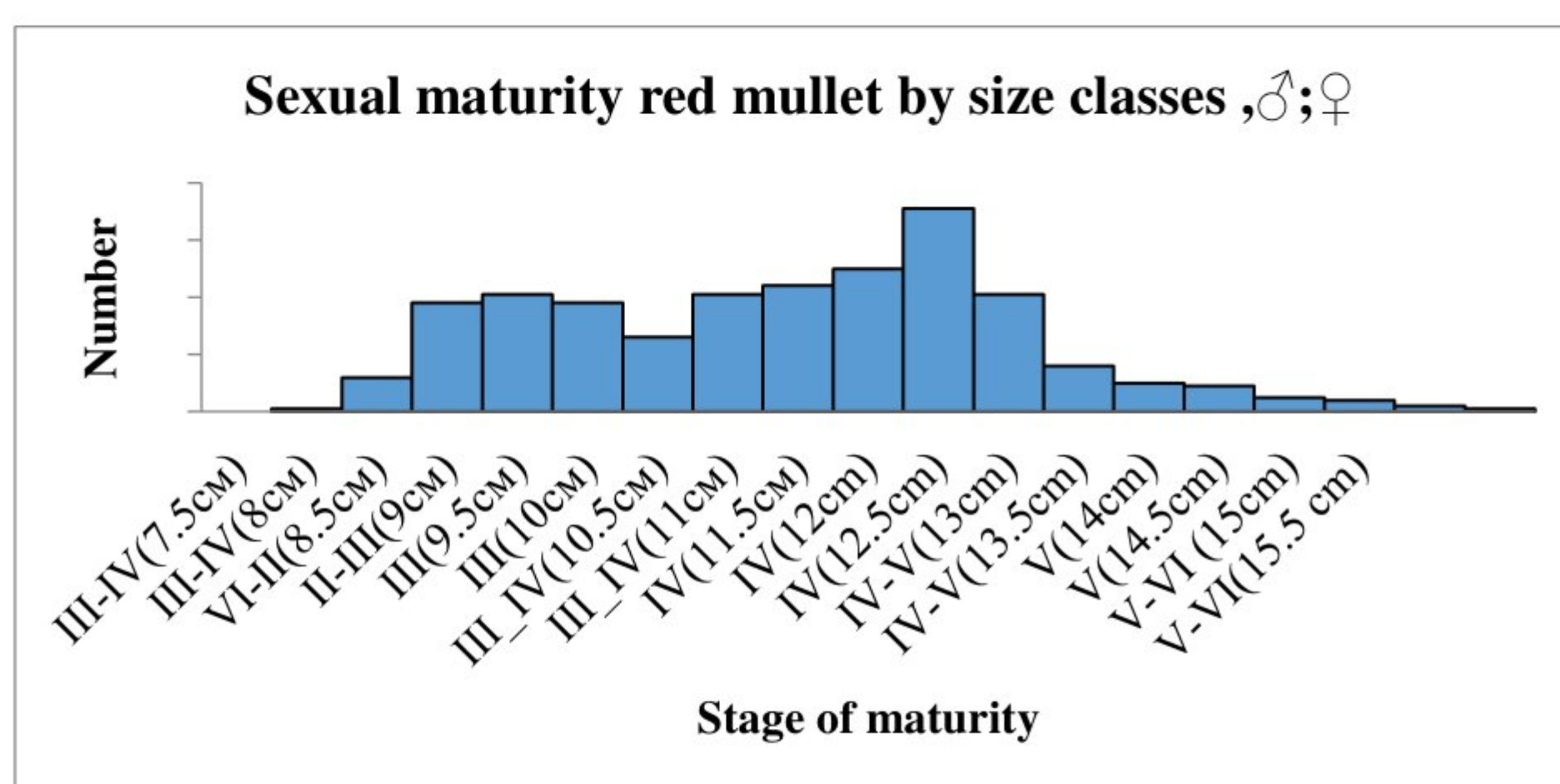


Figure 2.3.4.2. Sexual maturity of the studied species, analysed by size classes (females – ♀ and males – ♂) of red mullet.

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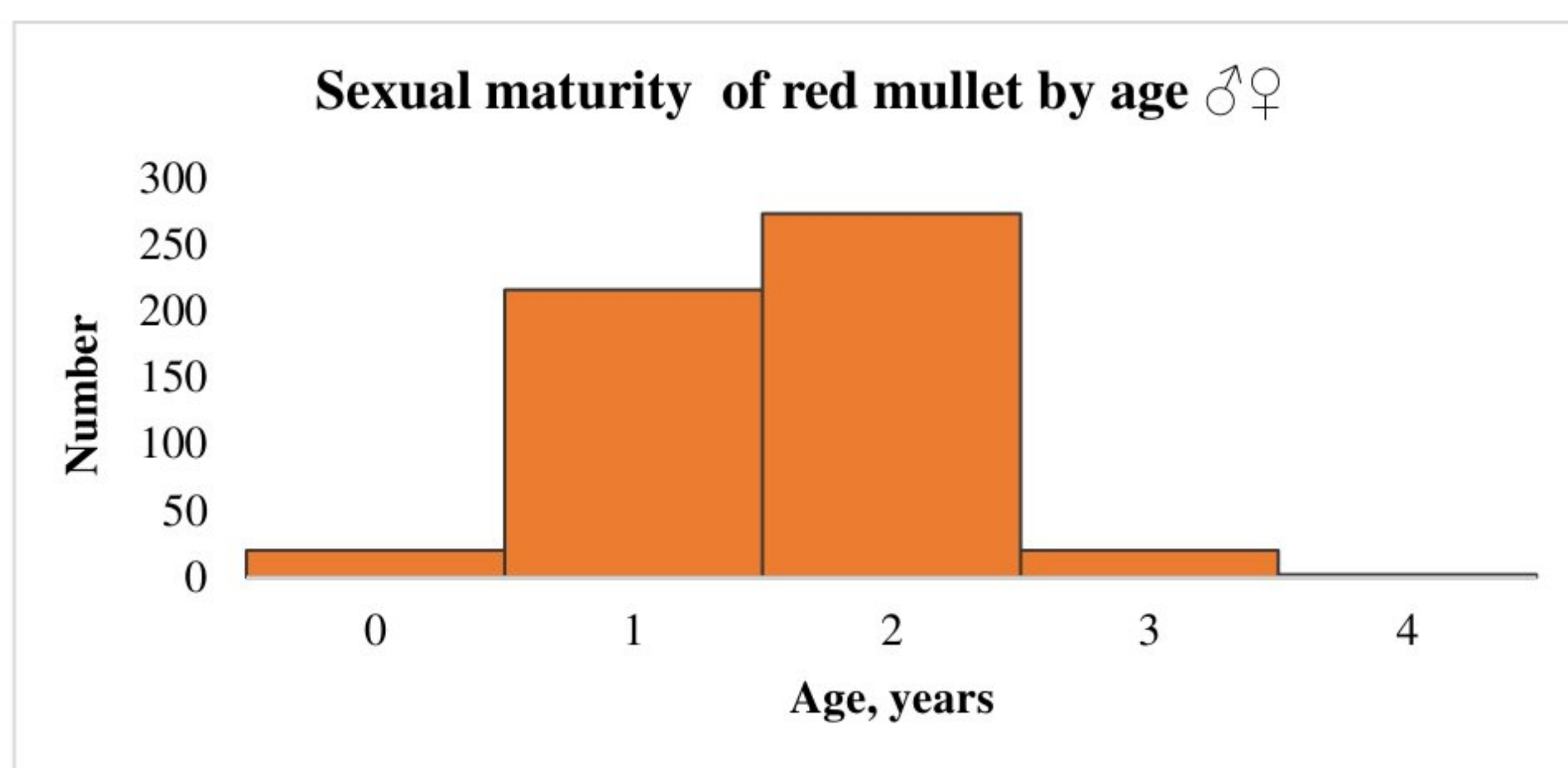


Figure 2.3.4.3. Sexual maturity (females – ♀ and males – ♂) of the studied species, analysed by age groups.

2.3.5. Fecundity and Gonado-somatic index (GSI)

Red mullet (250 ind.) was in an active phase of gonadal development, likely related to the high sea water temperatures (Fig. 2.3.5.1).

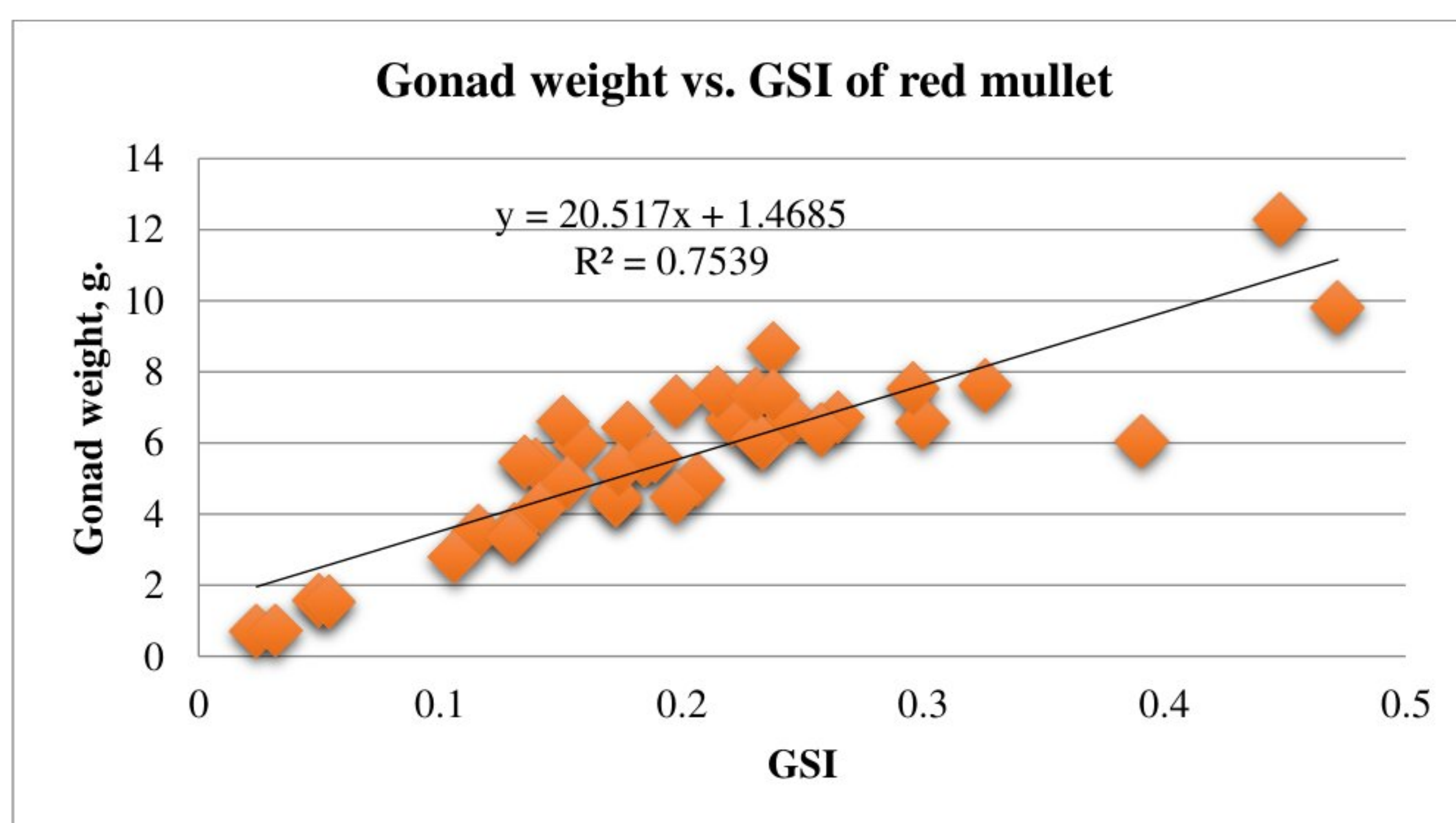


Figure 2.3.5.1. Sexual maturity (females – ♀, males – ♂ and juveniles – Juv) of red mullet by age groups.

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2.3.6. Absolute and relative fecundity of red mullet

Absolute fecundity (measured on 250 ind) at length of 16.5 cm was the highest: 11500 cavier grains. In terms of relative fecundity, the highest was detected at 9.5 cm TL individuals: 779.6. The mean values of absolute and relative fecundity of red mullet were as follows: 8738 and 372 (Table 2.3.6.1).

Table 2.3.6.1. Absolute and relative fecundity of red mullet

Size classes, cm	Mean weight, w,g)	Mean length, (cm)	Absolute fecundity F, хайверни зърна	Relative fecundity	No. ♀
9	8.03	9.01	6001±102	747.32254	10
9.5	9.11	9.5	7102±408	779.58288	10
10	11	10.12	7333±407	545.54545	10
10.5	13.54	10.55	7000±202	516.98671	20
11	14.8	11	7452±311	405.47297	20
11.5	16.19	11.51	8001±299	494.19395	20
12	18.2	12.33	8102±401	329.72527	20
12.5	21.17	12.62	8112±508	383.18375	20
13	23	13.05	8324±545	260.91304	20
13.5	26.2	13.44	9005±444	343.70229	20
14	26	14.21	9502±614	230.80769	20
14.5	28.5	14.21	9560±644	335.4386	10
15	33.9	15.11	10208±522	177.02065	10
15.5	38.3	15.49	10325±412	269.58225	10
16	45	16.25	10690±444	133.35556	10
16.5	47.23	17	11500±966	243.48931	10
17	49.33	17.22	10325±842	121.65011	10
Mean			8737.7647	371.6455	250



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2.4. Whiting (*Merlangius merlangus*)

2.4.1. Distribution

Whiting inhabits the bottom depths and its main food is the sprat. The studied species is a predator and represents an important component of the food chain of other larger predators such as turbot and dolphins. During the study, whiting was not strongly represented in the catch composition, which is most likely a result of the higher than usual temperatures during the study period.

2.4.2 Biomass of whiting by strata

The highest value of whiting biomass was observed in the 50–100 m stratum – 1407 t. In the 30–50 m depth layer the values were 1125 t and 124 t in the 15–30 m layer (Fig. 2.4.2.1.).

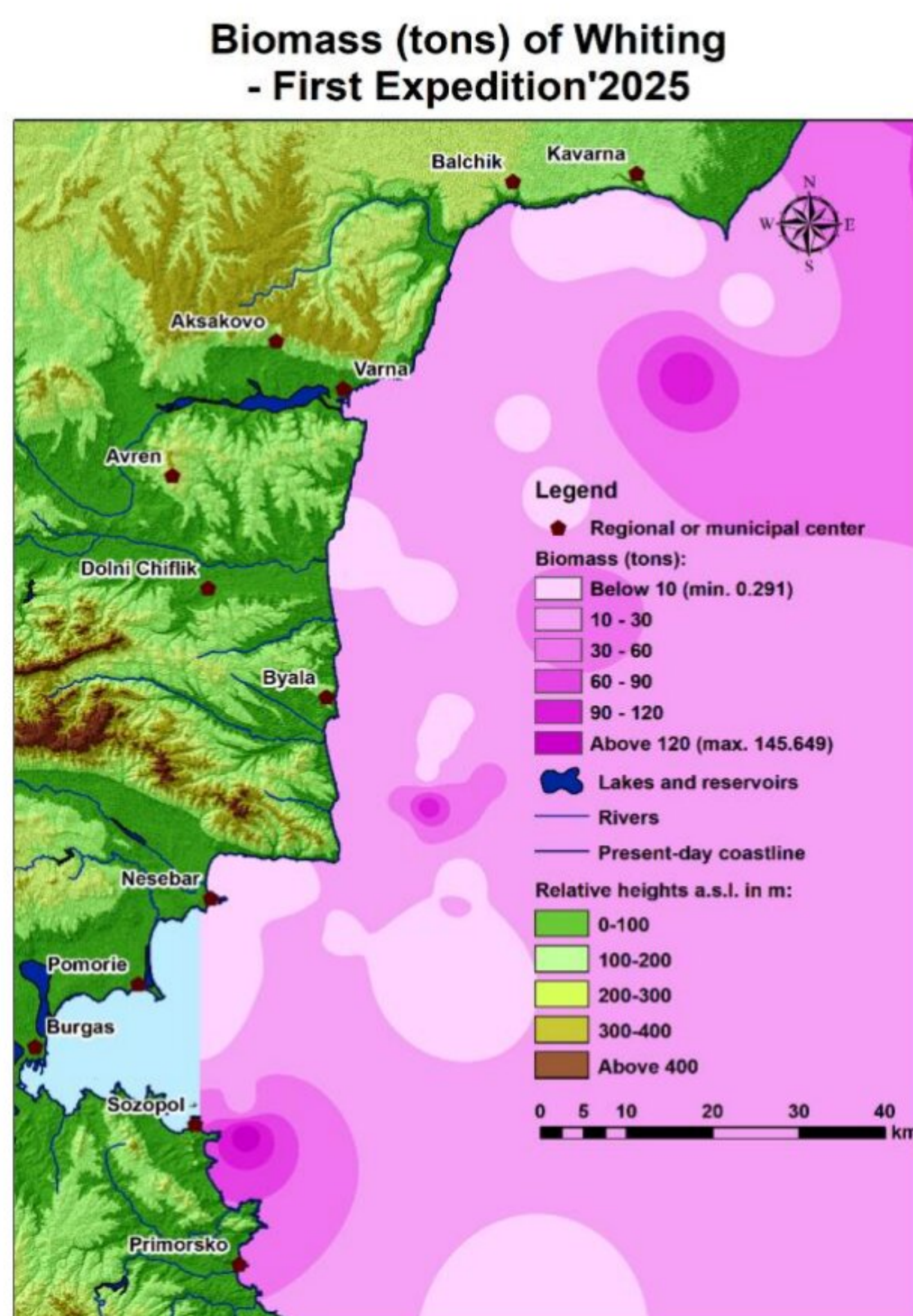


Figure 2.4.2.1. Distribution of whiting biomass by depth in September 2025.

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The total surveyed area was 8010.24 km², and the amount of total whiting biomass in the Bulgarian waters of the Black Sea in September 2025 amounted to 8109.2 tons (Table 2.4.2.1).

Table 2.4.2.1. Area method for stock survey in September 2025 – average values of catch per unit area (CPUA), Biomass (in kg), Ax – area and number of fields.

CPUA mean		Biomass (kg)	Area	Number of fields
124.128	15-30	256.3416996	2065.14	33
1125.427	30-50	2042.447804	1814.82	29
1406.784	50-100	5810.411857	4130.28	66
		8109.20136	8010.24	128

The descriptive statistics of the catch per unit area of whiting from September 2025 are presented in Table 2.4.2.2.

Table 2.4.2.2. Descriptive statistics of biomass indices by strata in September 2025.

Parameters	Descriptive statistics in stratum 15-30m	Descriptive statistics in stratum 30 - 50 m	Descriptive statistics in stratum 50 - 100 m
Maximum	124.1280008	1125.427207	1406.784009
Minimum	38.38826538	362.5144408	462.6902564
Range	62.0640004	372.3840024	993.0240064
Size	62.0640004	310.320002	#N/A
Sum	132.9808521	1255.78686	1133.355037
Average	17683.90703	1577000.637	1284493.64
Median	2.64401856	-1.34377871	-1.253454236

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Moda	1.979605911	0.833675877	0.804483196
Standart deviation	403.4160026	3096.99362	2792.880018
Varians	31.0320002	6.20640004	310.320002
Avg. range	434.4480028	3103.20002	3103.20002
Int.quartile	1489.53601	13505.12649	8440.704054
Deviation	12	12	6
Standard Error	434.4480028	3103.20002	3103.20002
Skewness	31.0320002	6.20640004	310.320002
Kurtosis	84.49200243	797.8889044	1189.383169
Coefficient of variation	124.1280008	1125.427207	1406.784009
Relative Standard Deviation	215.80%	190.33%	123.95%

2.4.3. Catch per unit area

Whiting was represented in the composition of the catches with the highest density of distribution of the species, recorded in the Sozopol region, north of Emine and Kavarna (Fig. 2.4.3.1.). In the depth layer 15–30 m the species is registered in all 12 stations of this stratum. In the depth layer 30–50 m whiting is present in 13 stations. In the depth layer 50–100 m, the species is registered in 7 stations. In the depth layer 50–100 m, the highest recorded value for CPUA was 3103 kg.km⁻², with an average value of CPUA – 1407 kg.km⁻². In the depth layer 15–30 m, 124 kg.km⁻² and 30–50 m – 1125 kg.km⁻². (Fig. 2.4.3.1.).



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CPUA (kg/km²) of Whiting - First Expedition'2025

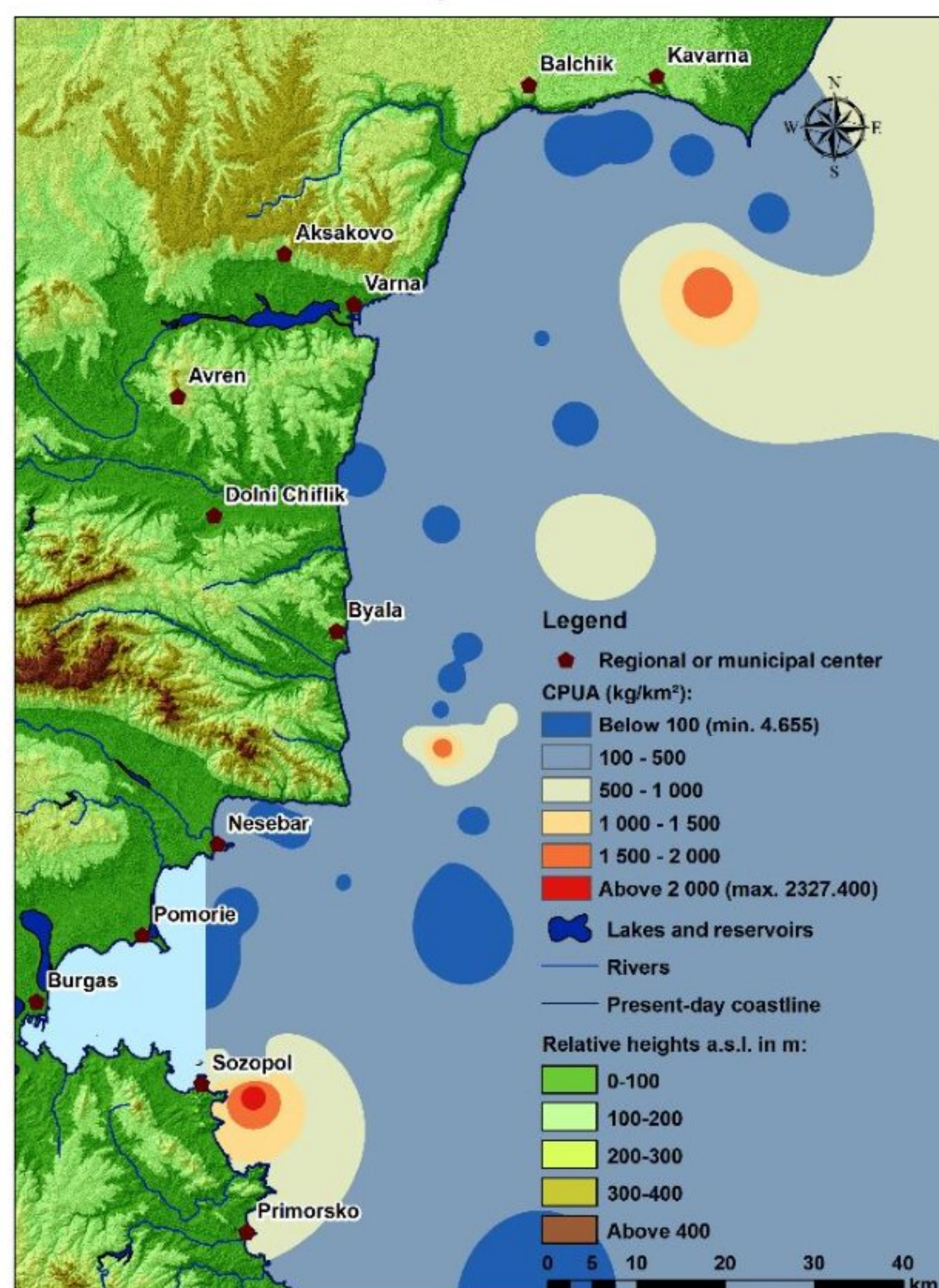


Figure 2.4.3.1. Catch per unit area (CPUA kg.km⁻²) and biomass of whiting for September 2025.

2.4.4. Catch per unit effort

Catch per unit effort for the identified species is presented in Fig. 2.4.4.1, with the highest value of CPUE kg.h⁻¹ being recorded in the area off Sozopol.

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CPUE (kg/h) of Whiting - First Expedition'2025

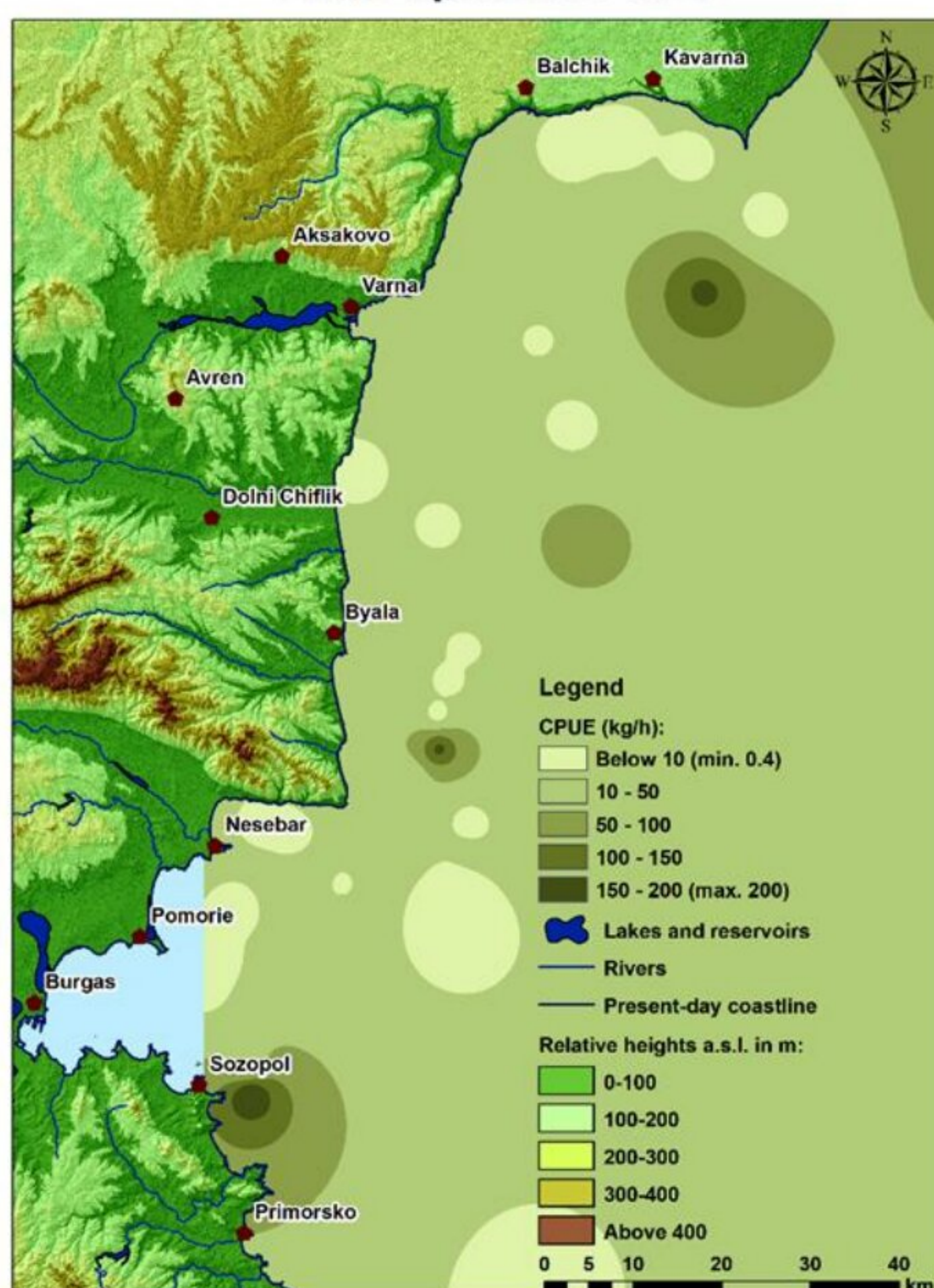


Figure 2.4.4.1. Catch per unit effort (CPUE $\text{kg} \cdot \text{h}^{-1}$) of whiting.

2.4.5. Size structure

The size distribution of whiting (1200 ind.) showed a normal pattern, with peaks at 10.5 cm and 12.5cm (Fig. 2.4.5.1).

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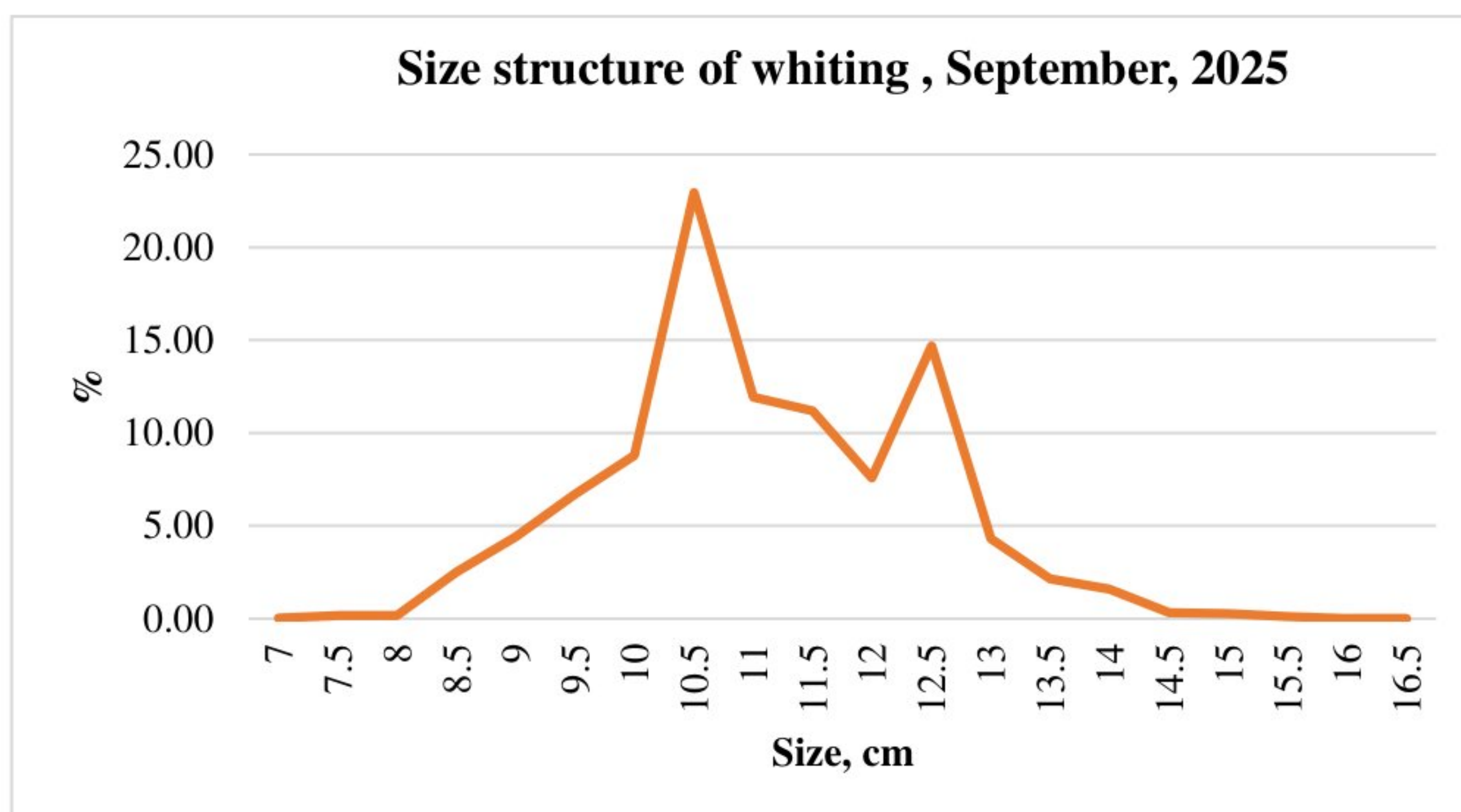


Figure 2.4.5.1. Size structure of whiting in September 2025

The weights of the whiting specimens (1200 ind.) ranged from 3.18 to 26.91 g in the present study (Fig. 2.4.5.2).

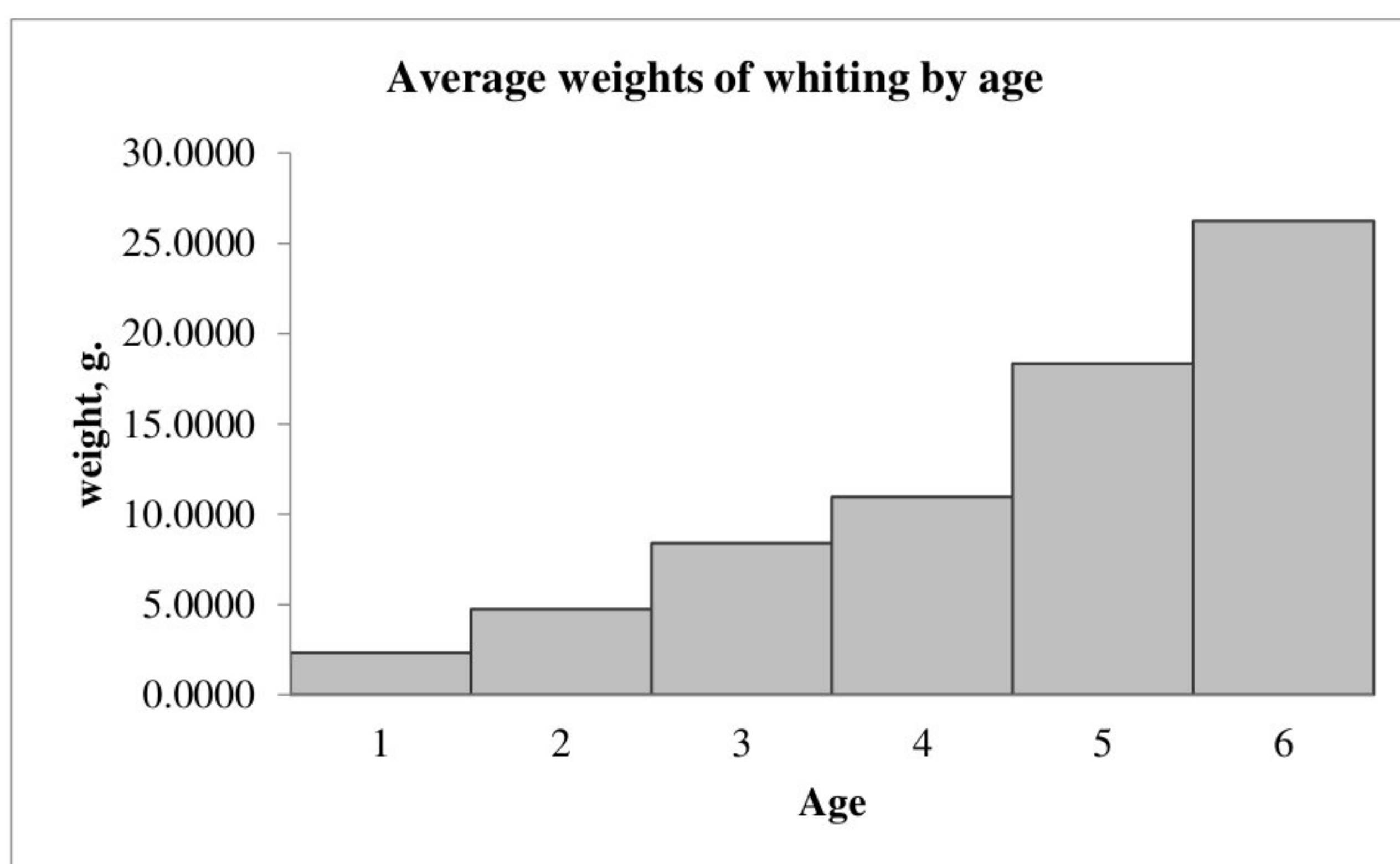


Figure 2.4.5.2. Average weights of whiting by age in September 2025



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In the catches from the autumn 2025 survey, individuals aged 3–3+ years (38%) was predominant based on the sampling of 1200 individuals (Fig. 2.4.5.3).

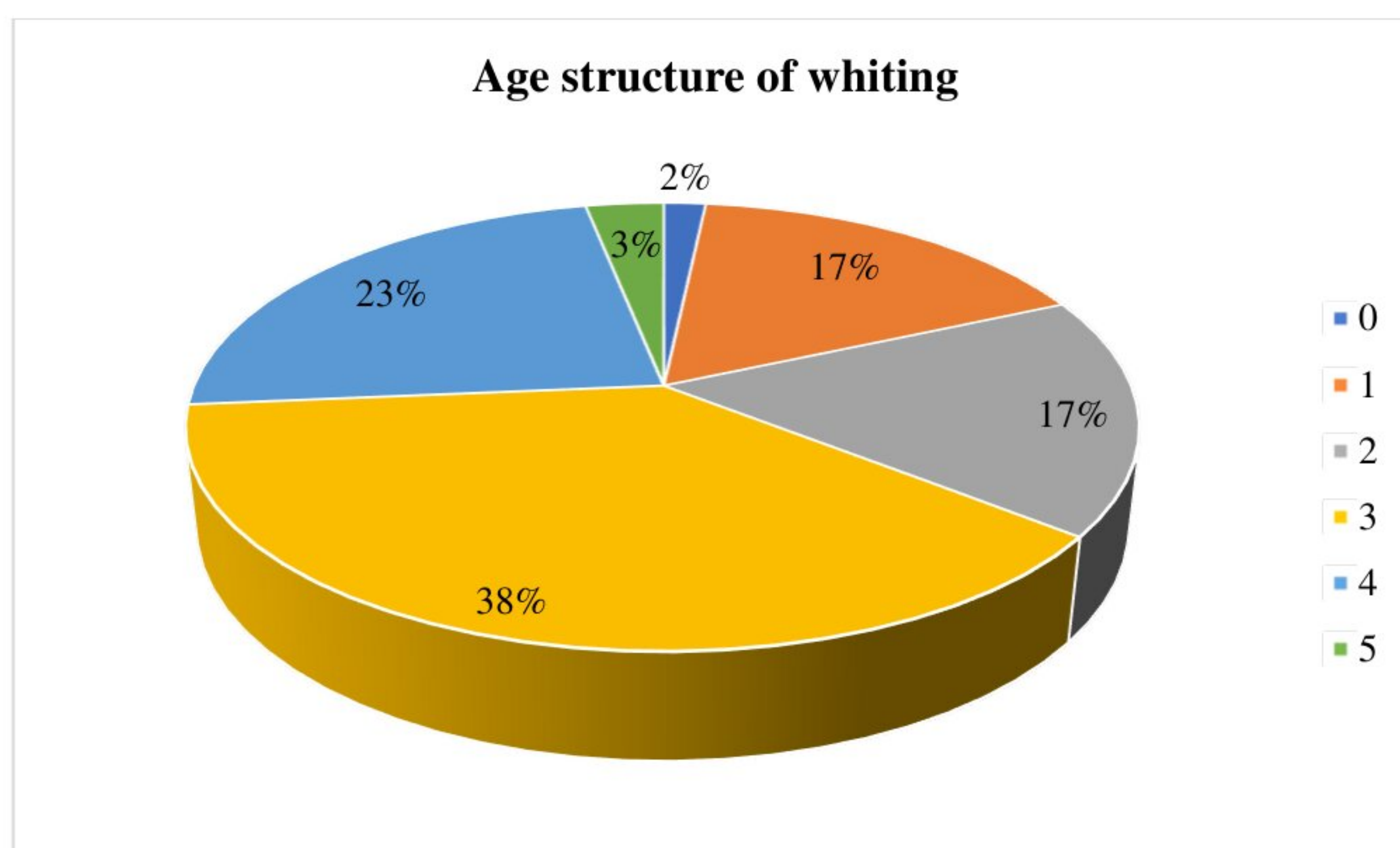


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The length–weight relationship for the species showed a very high degree of reliability ($R^2 = 0.96$) (Fig. 2.4.5.4).

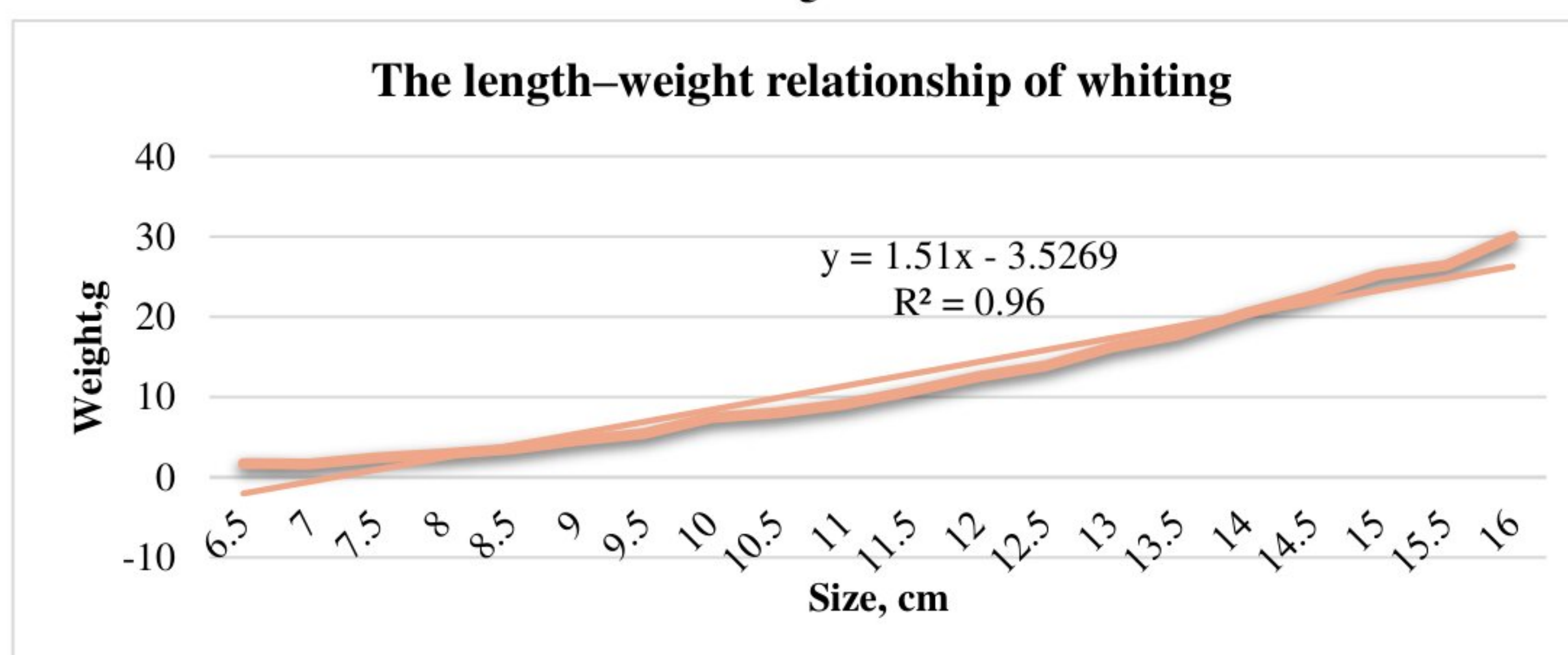


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To determine the growth parameters, the von Bertalanffy Growth Function (VBGF) was applied. The calculated growth parameters (1200 ind.) are presented in Table 2.4.5.1. The asymptotic length (L_{∞}) of whiting reached 27.6 cm, with a growth rate that can be classified as low ($k = 0.23$) (Table 2.4.5.1).

Изчислените растежни параметри (1200 екземпляра) са показани в Таблица 2.4.5.1. Асимптотичната дължина (L_{∞}) на меджида достигна 27.6 cm, като скоростта на растежа може да бъде определена като ниска ($k = 0.23$).

Table 2.4.5.1. von Bertalanffy Growth Function of whiting.

Species	Asymptotic length	Growth rate	Growth parameter	Growth coefficient	Allometric coefficient
<i>M. merlangus</i>	$L_{\infty} = 27.6$	$K = 0.23$	$t_0 = -2.0112$	$q = 0.009$	$n = 3.111$

In terms of sex ratio, females made up 50%, males 49%, and larvae 1% of the population (Fig. 2.4.5.5).

2.4.6. Fecundity and gonadosomatic index (GSI)

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n



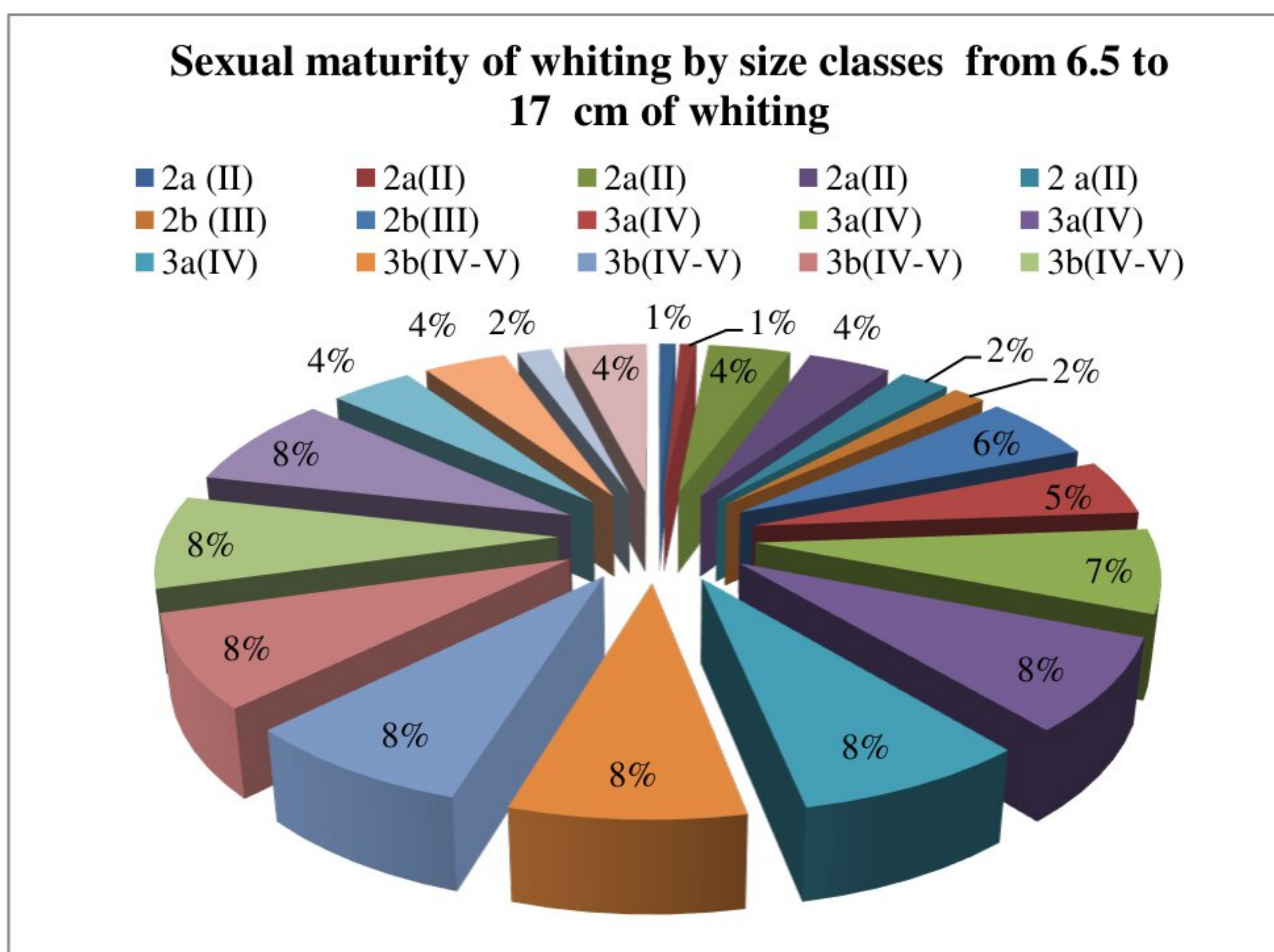
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Figure

Male and female individuals of whiting aged 4+ years had the highest presence in the catches, with a maturity stage of III (2.4.6.2).

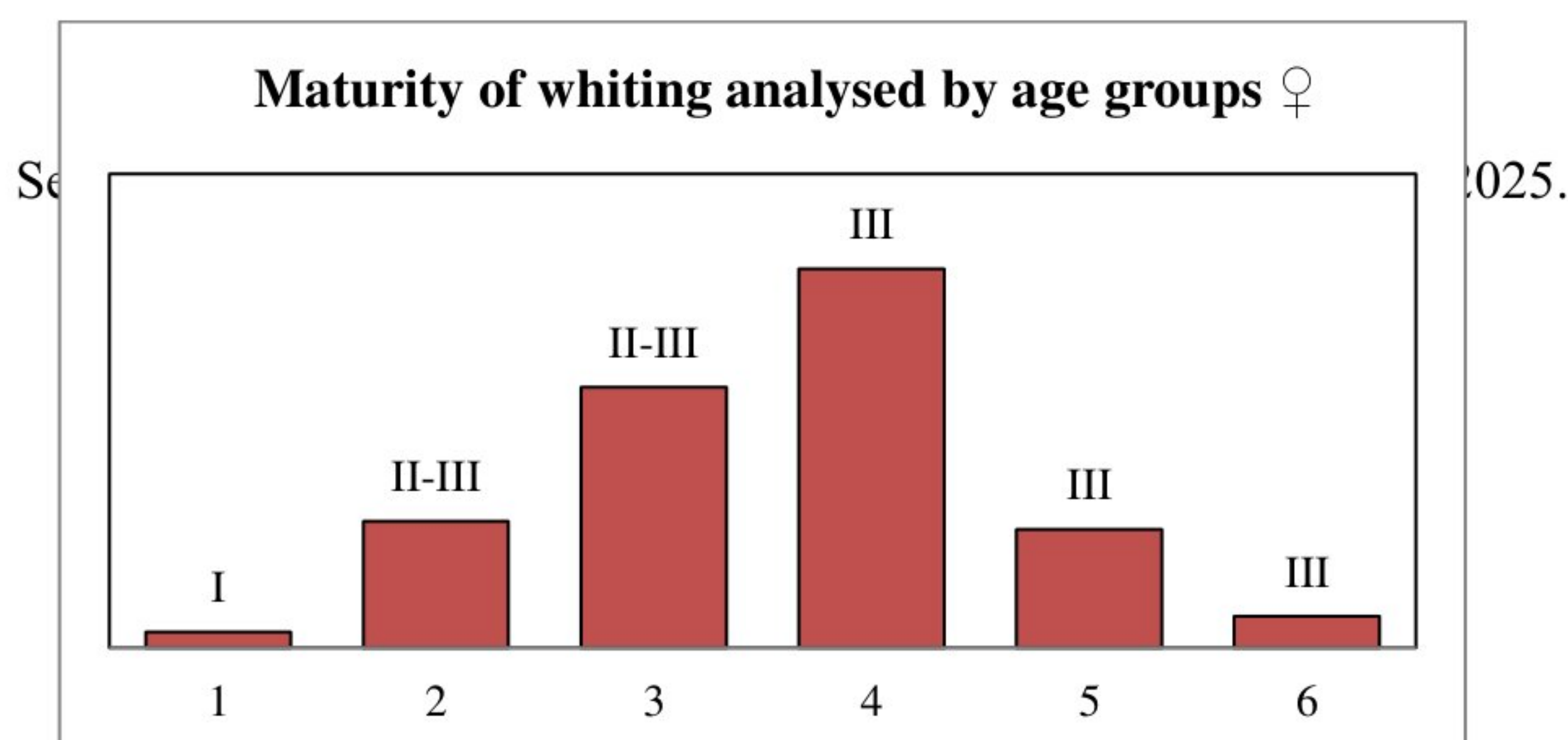


Figure 2.4.6.2. Maturity of whiting analysed by age groups.

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The weight of the gonads, compared to the gonadosomatic index, showed a high degree of reliability ($R^2 = 0.83$) (Fig. 2.4.6.3).

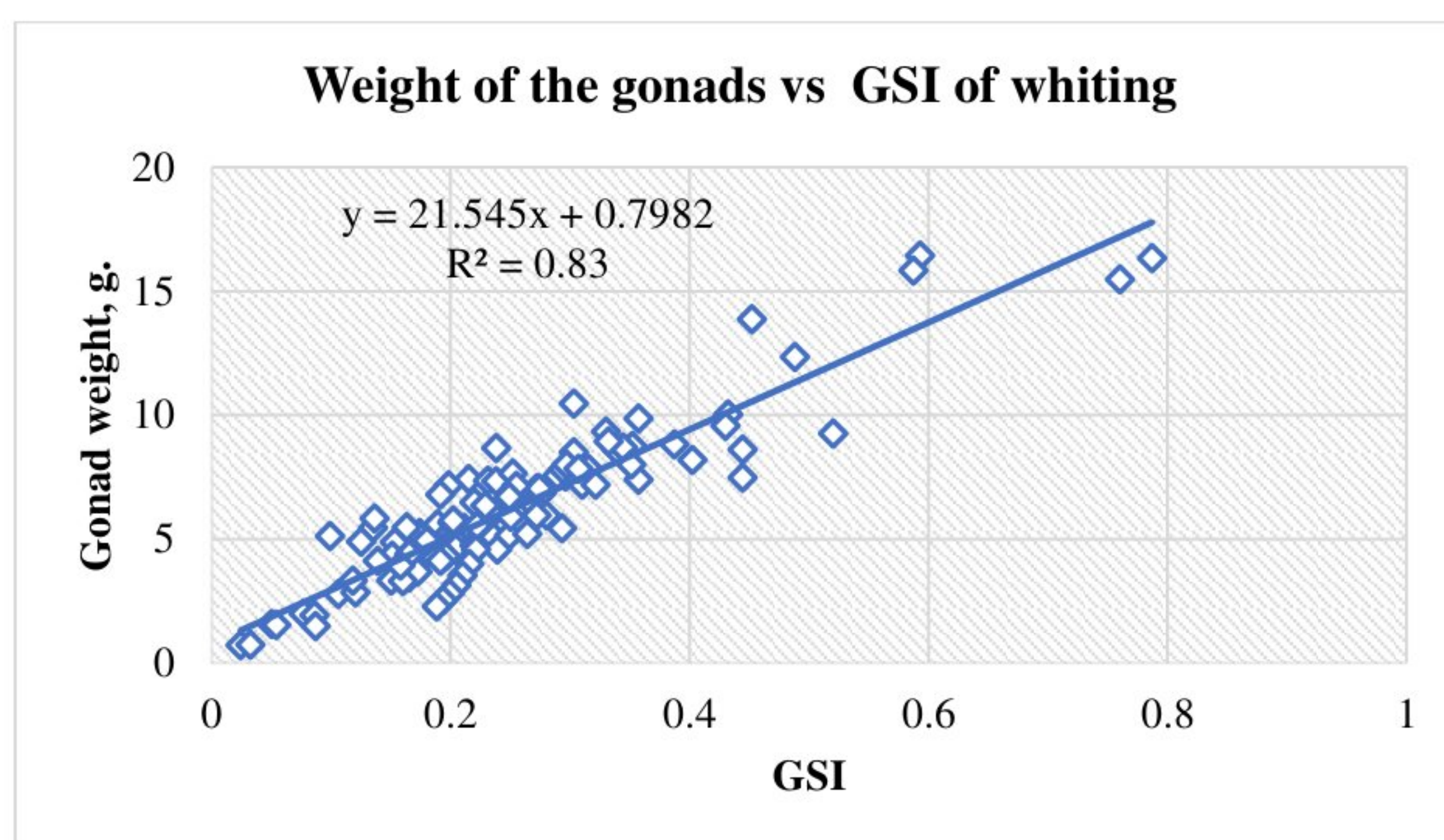


Figure 2.4.6.3. Weight of the gonads, compared to the gonadosomatic index of whiting in September 2025.

2.4.7. Absolute and relative fecundity

Absolute fecundity (measured on 250 ind) at length of 17.5 cm was the highest: 60 322 cavier grains. In terms of relative fecundity, the highest was detected at 14 cm TL individuals: 3247,66. The mean values of absolute and relative fecundity of the whiting were as follows: 36252 and 1596 (Table 2.4.7.1).

Table 2.4.7.1. Absolute and relative fecundity of whiting, September 2025.

Size class	Average body weight (W, g)	Absolute fecundity (F, caviar grains)	Relative fecundity	Number
10	7.22	8300±242	1146.58±106	10
10.5	8.37	8522±112	1017.57±111	10
11	9.18	9835±212	1071.61±211	20
11.5	10.66	11706±146	1098.42±99	20

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12	15.29	14800±112	973.68±77	20
12,5	14.6	28180±241	1926.03±112	20
13	15.63	36035±356	2305.02±89	20
13.5	17.65	44250±388	2497.18±111	20
14	18	56744±412	3247.66±146	10
14.5	27.3	50112±455	1835.60±256	20
15	28.34	52418±652	1849.61±199	20
15.5	31.23	51115±705	1636.73±56	20
16	33.45	56425±1184	1686.25±63	10
16.5	36.58	46332±922	1362.71±58	10
17	49.1	36898±602	751.49±45	10
17.5	55.33	60322±512	1086.86±99	10
Mean		36252	1596.06	250

2.5. Anchovy (*Engraulis encrasicolus* L.)

2.5.1. Size and age structure

In the catches from the Bulgarian waters of the Black Sea during the study period of 2025, the size composition is represented by individuals with a body length of 6.0 cm to 12.5 cm (Fig. 2.5.1.1).



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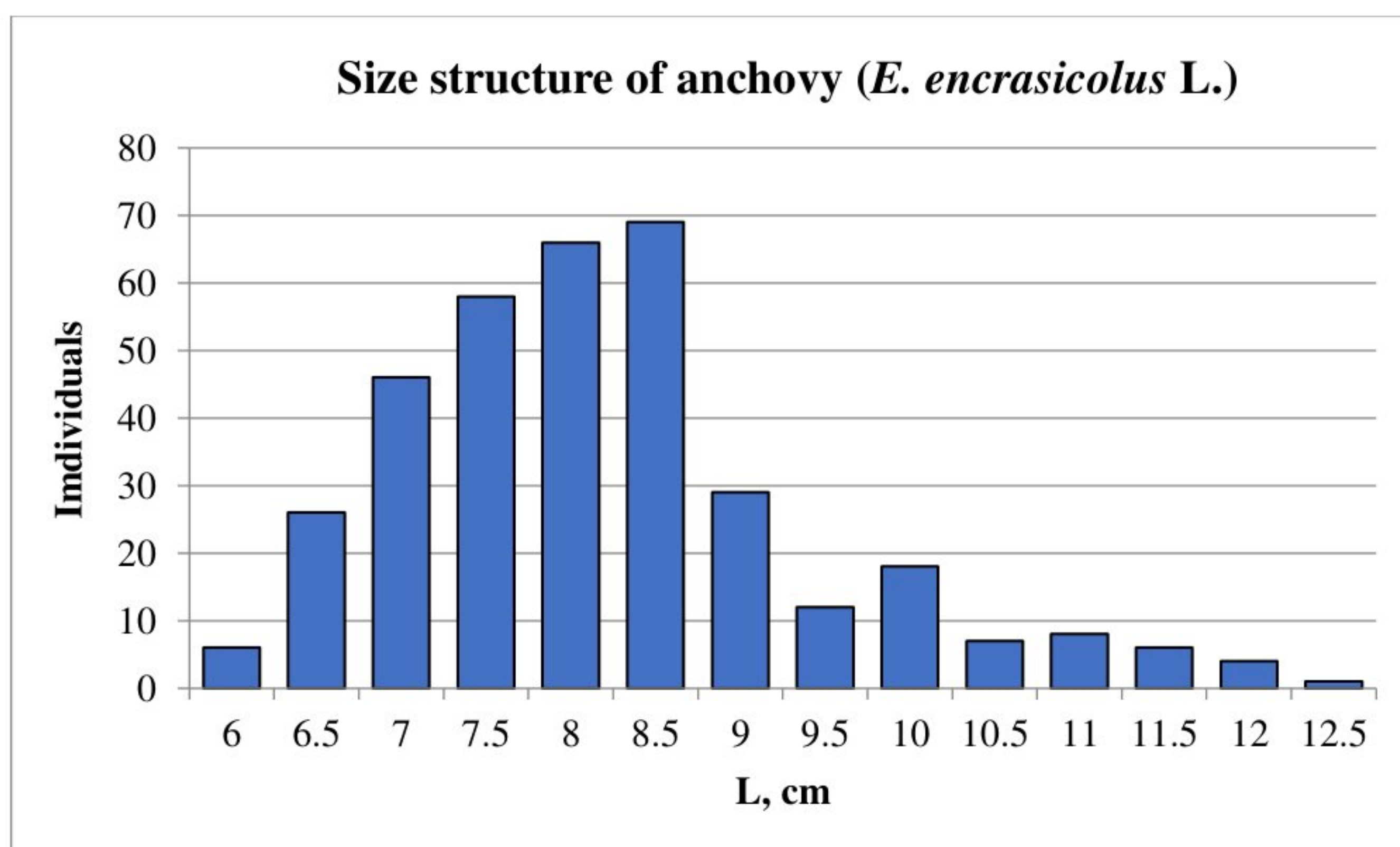


Figure 2.5.1.1. Anchovy length frequency in September, 2025.

In September 2025, the proportion of zero-year-old specimens was high (46.50%), and the presence of two-year-olds reached ~ 24.20% (Fig. 2.5.1.2.).

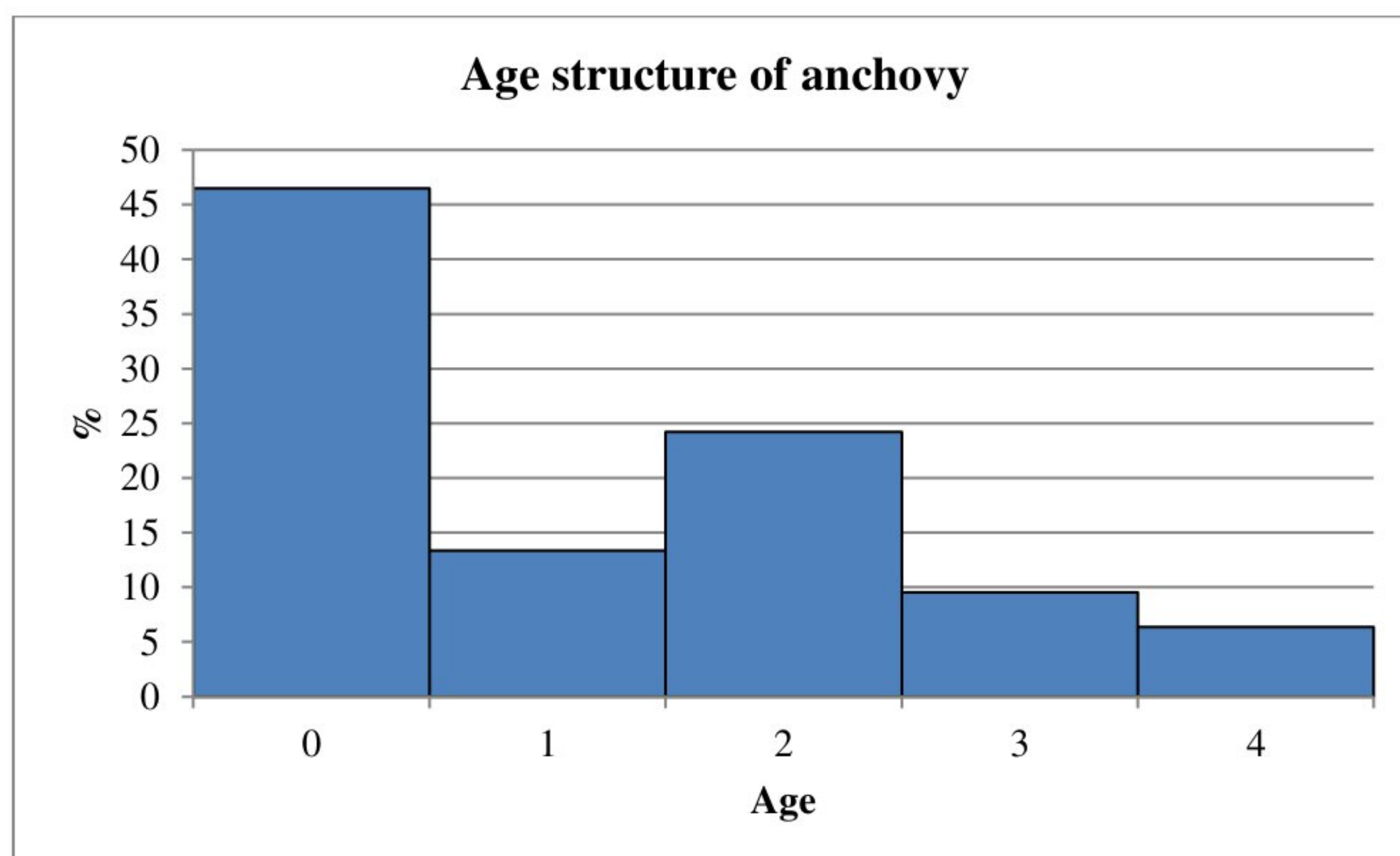


Figure 2.5.1.2. Age structure of anchovy (%).

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Figure 2.5.1.3. shows the weight structure of anchovies by age. At the time of stocking (0+y) the average weight was 2.66 g, and at the oldest age group (4-4+y) it was 9.46 g.

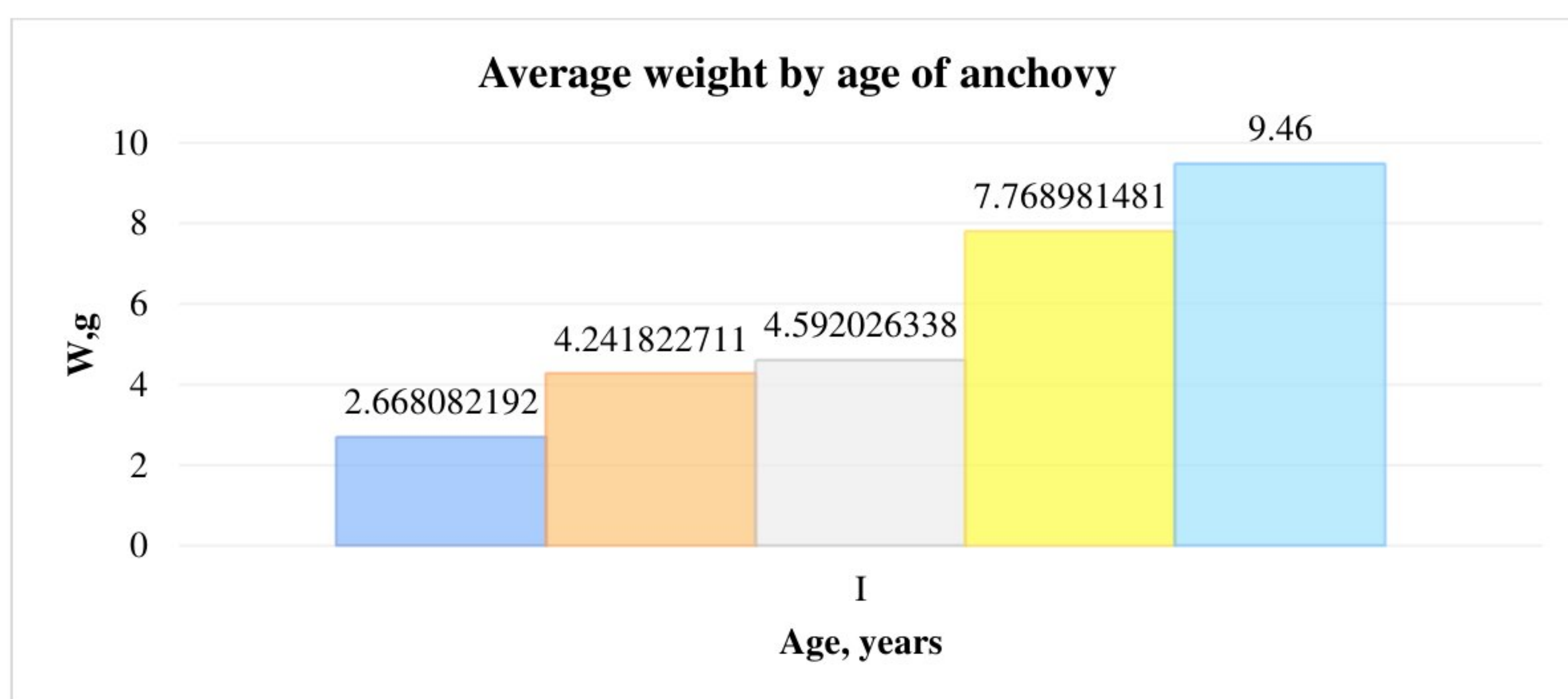


Figure 2.5.1.3. Average weight by age of anchovy, September 2025.

2.5.2. Length-weight relationships

Relationship between length (L) and weight (W) of the studied specimens is described by the equation: $W = 0.021 * L^{2.8986}$ (Fig. 2.5.2.2, Table 2.5.2.1.)

The analysis shows that the growth of anchovy is allometric.

Table 2.5.2.1. The parameters (q – growth constant, condition factor) and (n – allometric coefficient) of the length-weight relationships.

Year	q	n
2025, September	0.021	2.8986



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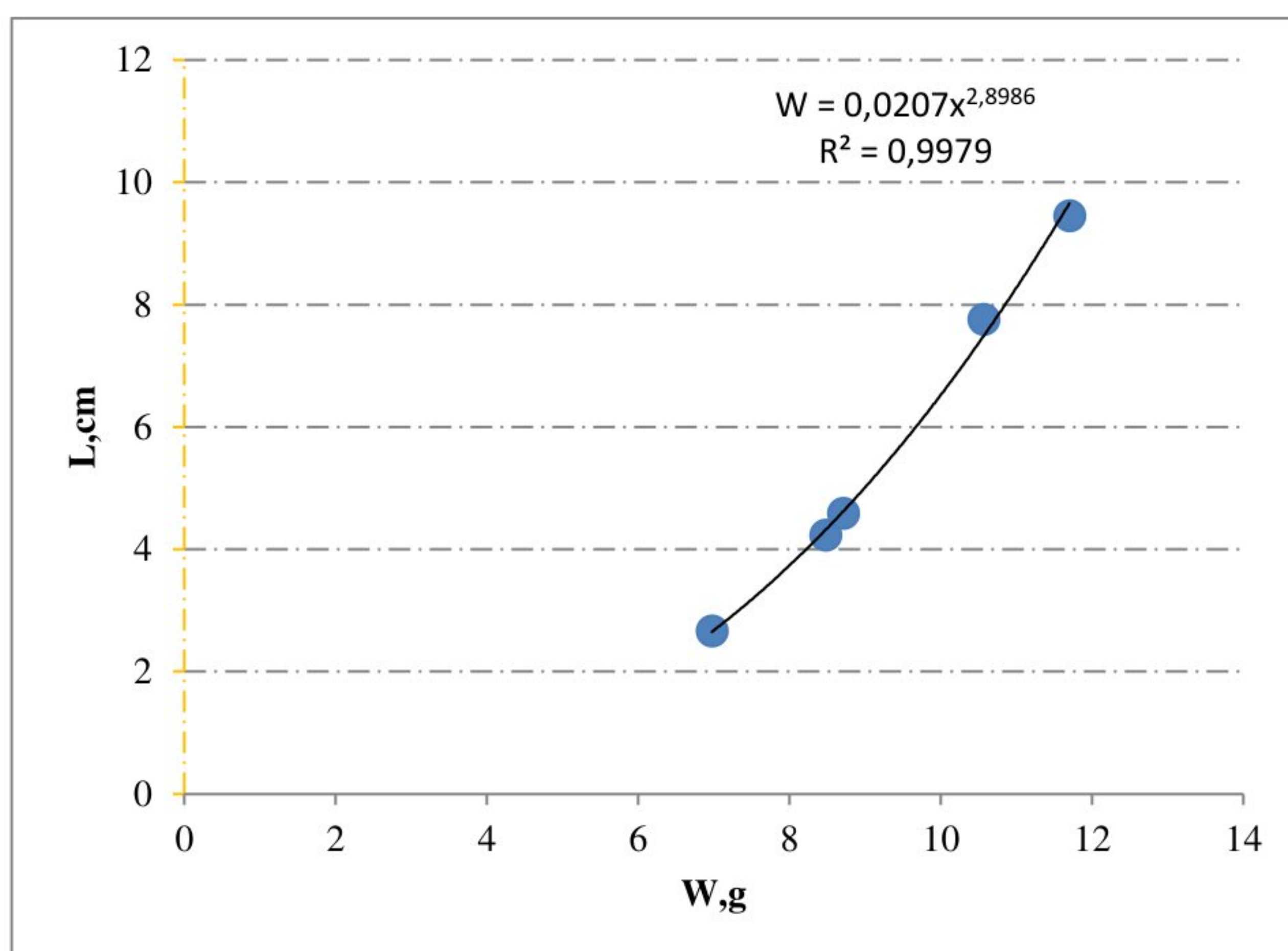


Figure 2.5.2.2. Linear regression of the relationship between length (L) and weight (W) of anchovy.

2.5.3. Sex Ratio

The sex ratio was determined on 250 specimens. Females (♀) predominated with 64%, followed by males (♂) specimens with (36%) (Fig. 3.5.3.1).

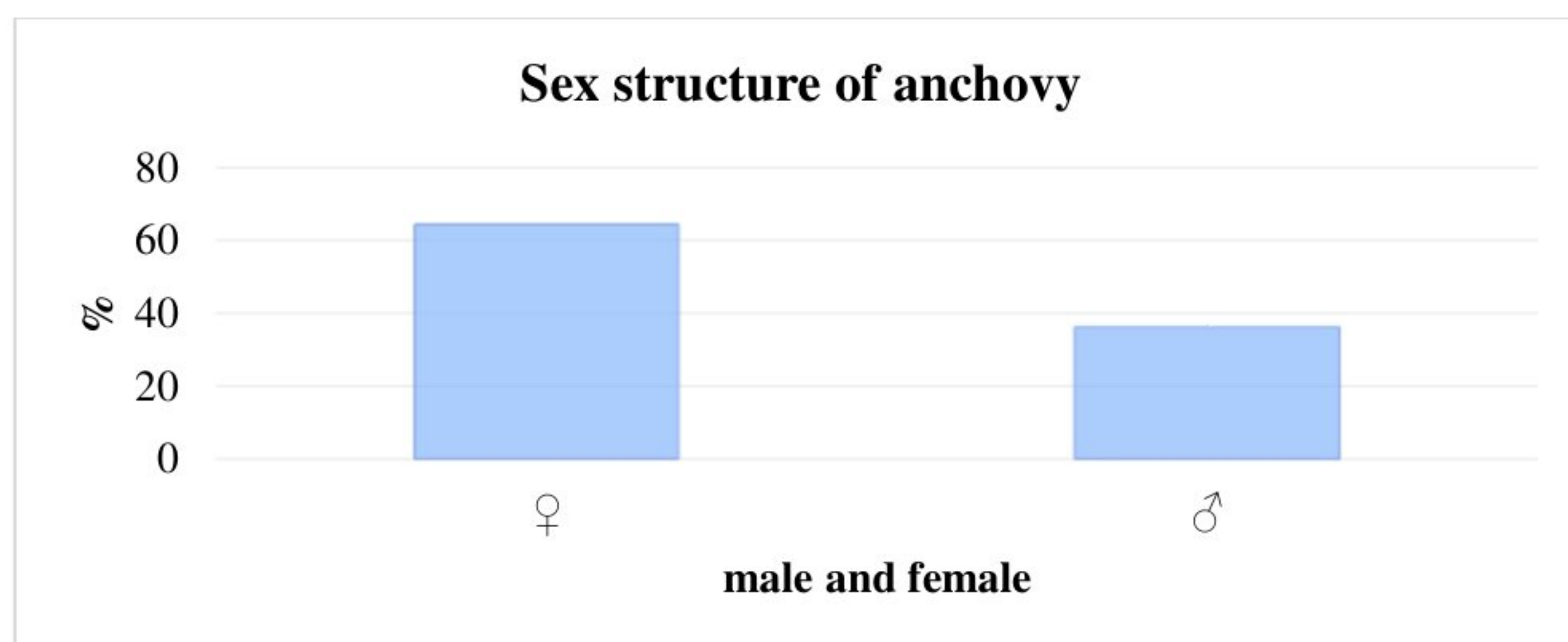


Figure 2.5.3.1. Sex structure of anchovy, September 2025.

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The average lengths of females ♀ are higher (Fig.2.5.3.2.)

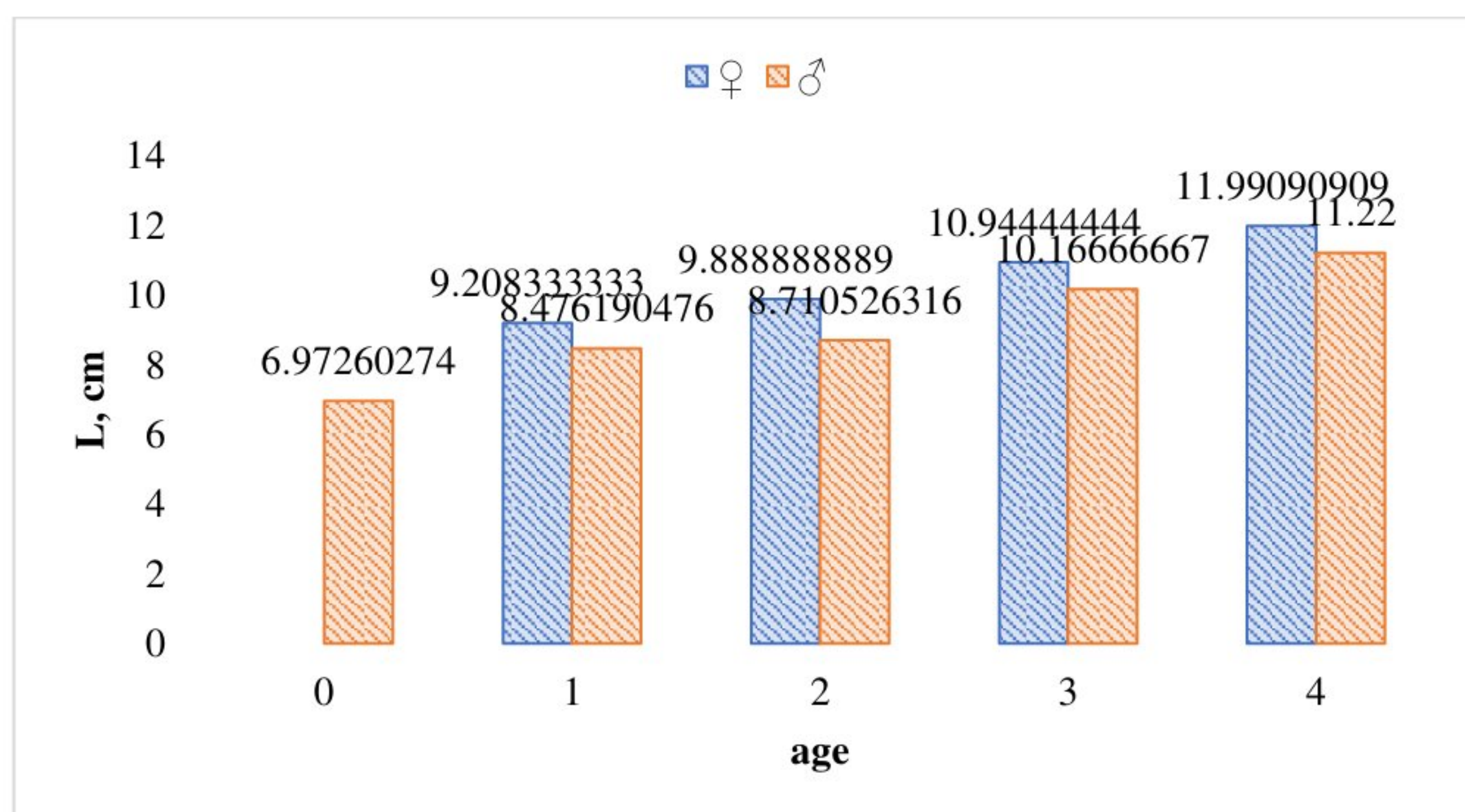
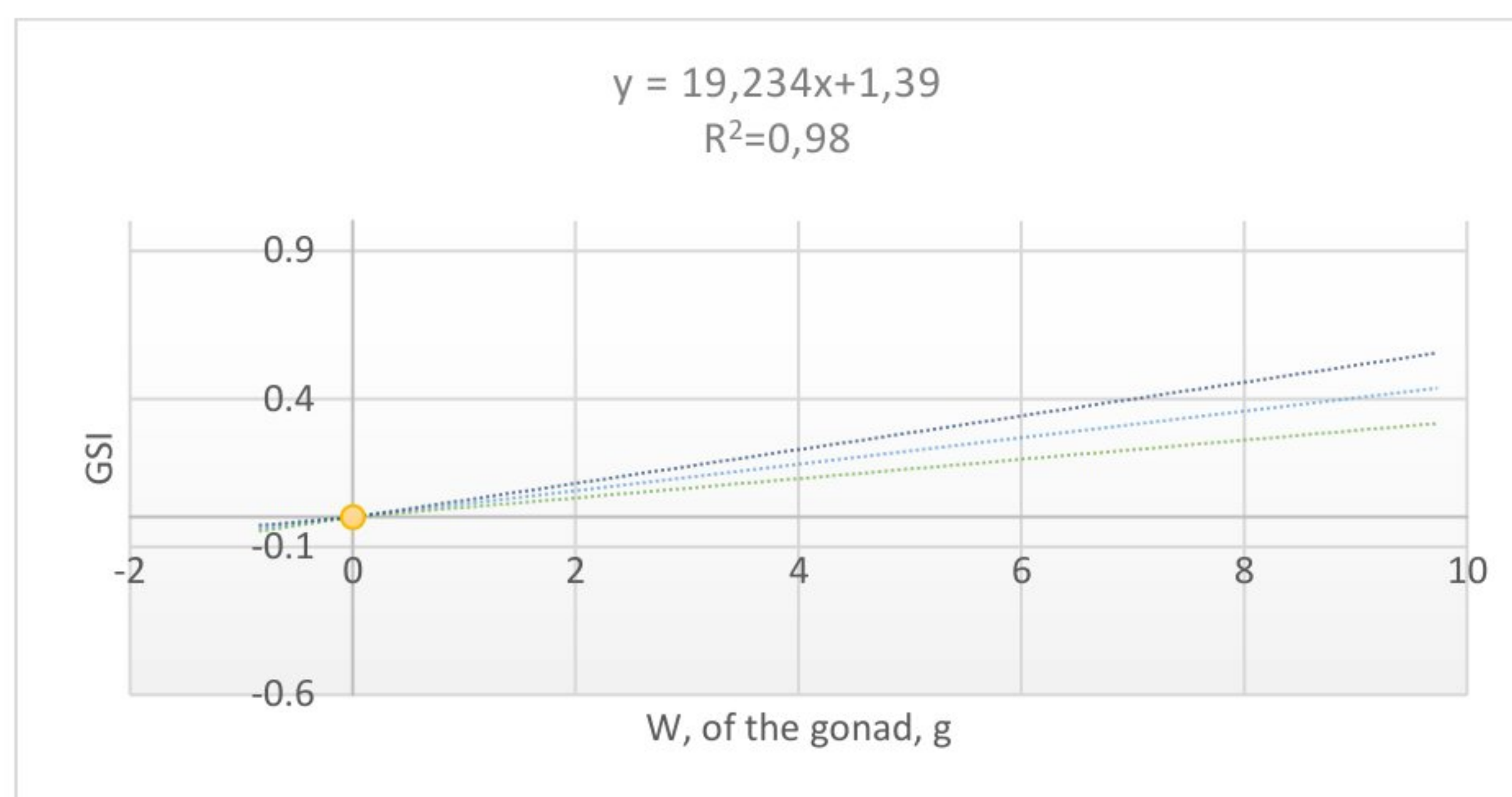


Figure 2.5.3.2. Sex ratio by size and age of anchovy in September 2025.

2.5.4. Fecundity

Fertility was determined on 100 specimens. The gonad-somatic index is strongly dependent on the weight of the gonads ($R^2 = 0.9822$), which is associated with the high rate of maturation of females in late spring and summer and the reproductive process of the anchovy (Fig. 3.5.4.1).



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Figure 2.5.4.1. Dependence of gland weight on gonadosomatic index (GSI).

A strong dependence of GSI on portion fecundity was observed in anchovy ($R^2 = 0.85$ (Fig. 2.5.4.2.)).

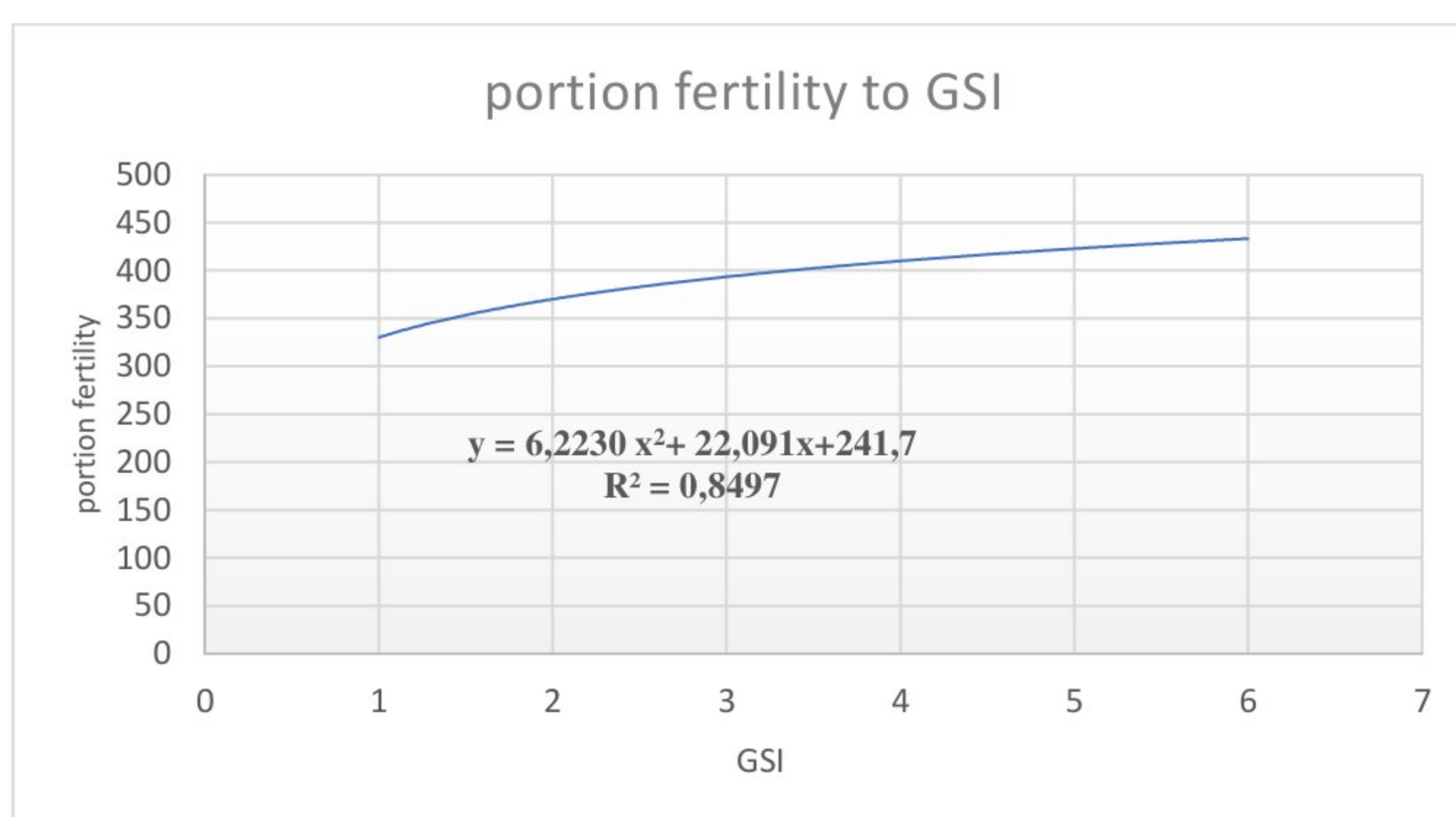


Figure 2.5.4.2. Dependence of portional discharge of sexual products on the gonadosomatic index (GSI) of anchovy.

2.5.5. Sexual maturity

Sexual maturity was determined in 250 specimens. All examined specimens showed a degree of flowing gonads (V-III). In September, we observed massively mature sexual products in 100% of the examined female individuals.

In females and males, the stage of maturity was V-III (in all age groups, Fig.2.5.5.1). In terms of size, males with a size of 10.5 and maturity stages V-III predominate, and in females the peak was at a size of 12.5 cm (stages V-III, Fig.2.5.5.2).



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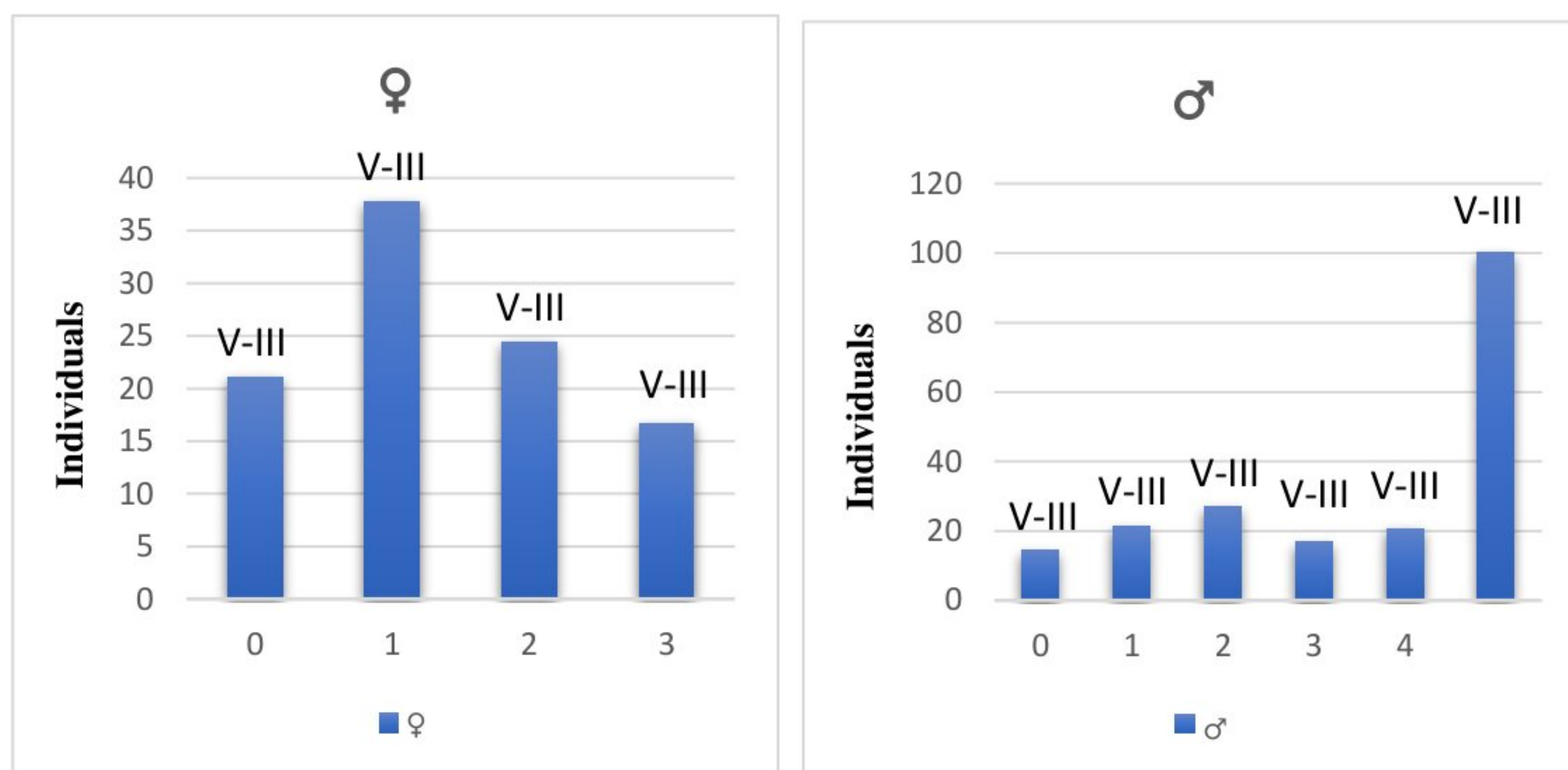


Figure 2.5.5.1 Sexual maturity by age of anchovy - female (♀) and male (♂).

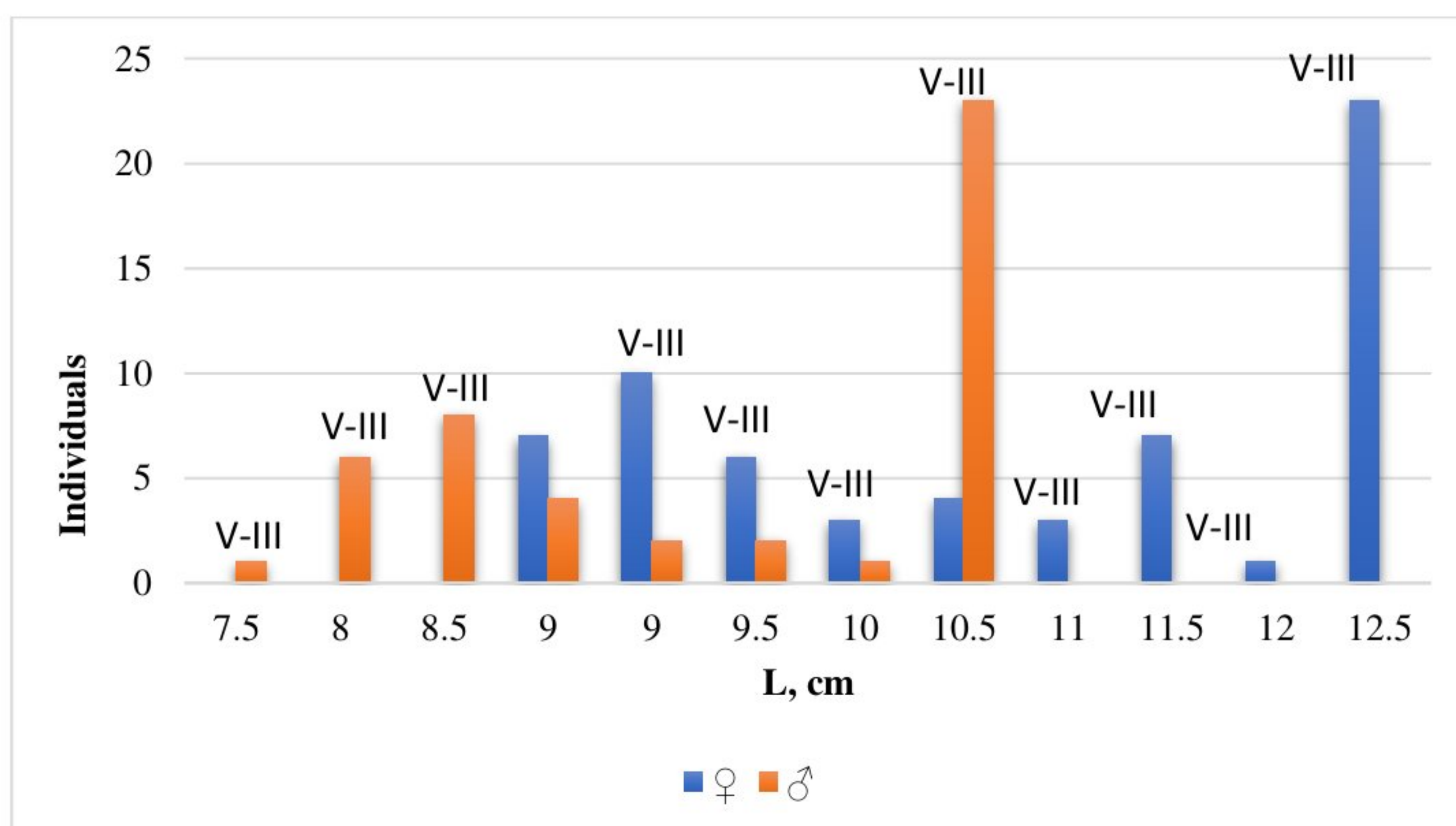


Figure 2.5.5.2. Sexual maturity by length of anchovy - female ♀ and male ♂.



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2.6. Sprat (*Sprattus sprattus* L.)

2.6.1. Spatial distribution

In September 2025, the sprat was scattered in the near-shore area, mainly due to high water temperatures. The highest biomass values were recorded at greater depths of 50–100 m.

2.6.2. Sprat biomass in different depth layers

In September 2025, the biomass of the sprat in the 15–30 m stratum was estimated at 42.75 tons, followed by the 30–50m stratum – 6009 tons and 50–100m – 91297 tons (Fig. 2.6.2.1.).

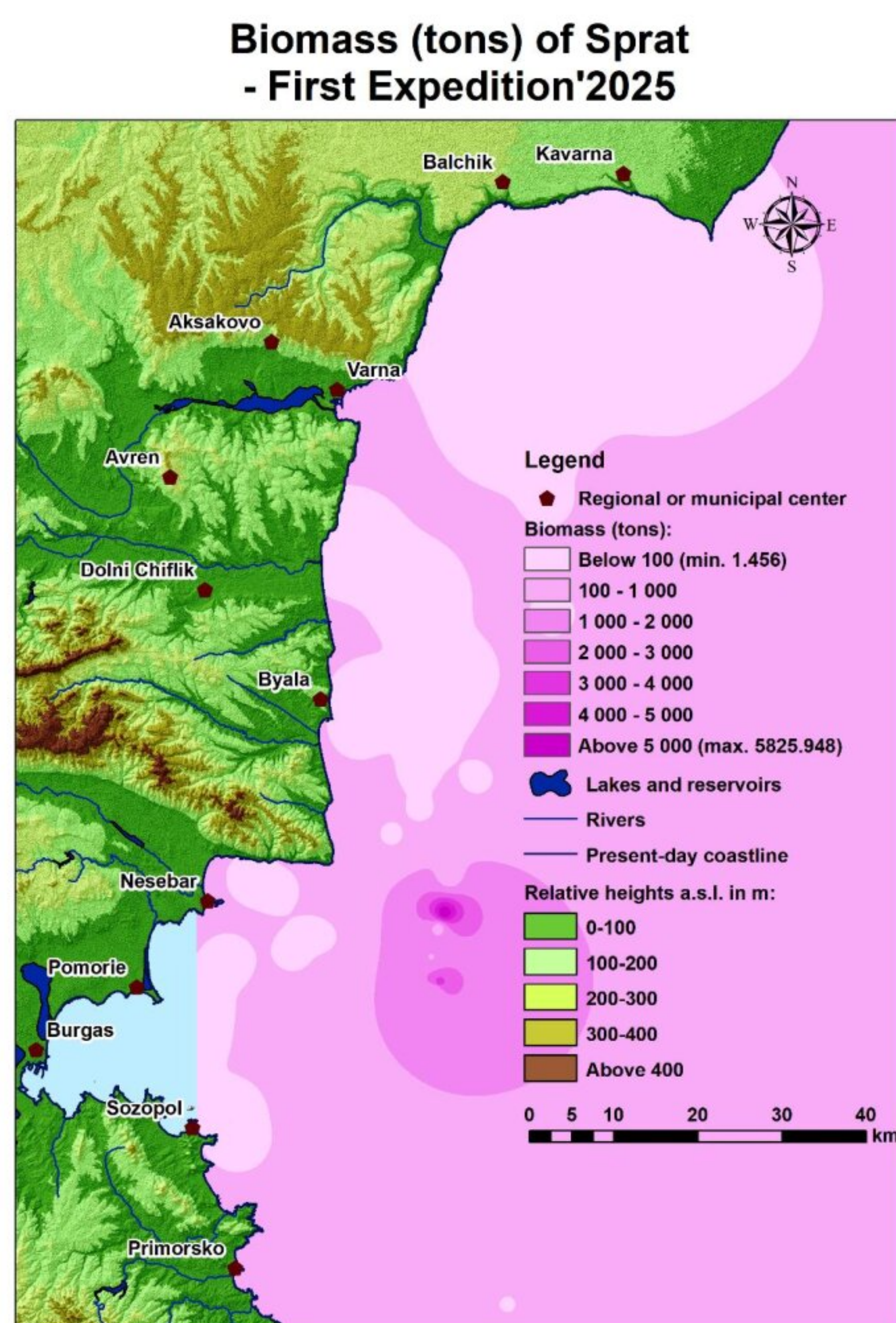


Figure 2.6.2.1. Distribution of the sprat biomass by depth layers (strata) in September 2025.

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The biomass in the 50–100 m stratum is of the highest value, due to the high water temperatures in the coastal zone (Tables 2.6.2.1. and 2.6.2.2.). The total surveyed area was 8010.24 km², and the estimate of the total biomass of the sprat stock was 97349 t.

Table 2.6.2.1. Area method for surveying the sprat stock in September 2025 – average values of catch per unit area (CPUA), biomass (in kg), Ax – area and number of fields.

CPUA avg	Strata	Biomass (kg)	Ax area	Number of fields
20.7	15–30	42.748398	2065.14	33
3311.3	30–50	6009.413466	1814.82	29
22104.33	50–100	91297.07211	4130.28	66
		97349.23398	8010.24	128

Table 2.6.2.2. Descriptive statistics of biomass indices by strata in September 2025.

Parameters	Descriptive statistics in 15–30 m stratum	Descriptive statistics in 30–50 m stratum	Descriptive statistics in 50–100 m stratum
Maximum	20.688	3311.297	22104.33
Minimum	7.951496	3092.773	10094.62
Range	0	0	9930.24
Size	0	0	1551.6
Sum	27.54479	12751.83	36396.66
Average	758.7155	1.63E+08	1.32E+09
Median	-1.26923	16.93184	5.25621
Mode	0.797287	4.11161	2.356402
Standard error	62.064	52754.4	123817.7
Variance	0	0	310.32
Mid-range	62.064	52754.4	124128
Int.quartile	248.256	56292.05	287356.3
Deviation	12	17	13
Skewness	0	0	310.32
Kurtosis	17.50112	6556.385	21994.28
C.of variation	20.688		
Rel.St.Dev.	7.951496		

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2.6.3. Catch per unit area

The catch per unit area (CPUA $\text{kg} \cdot \text{km}^{-2}$) was relatively high in the 50–100 m stratum with the formation of agglomerations uncharacteristic for the sprat. The densest passages were registered in front of Nessebar, Emine, while in the other studied areas the species was scattered in terms of spatial distribution (Fig. 2.6.3.1.).

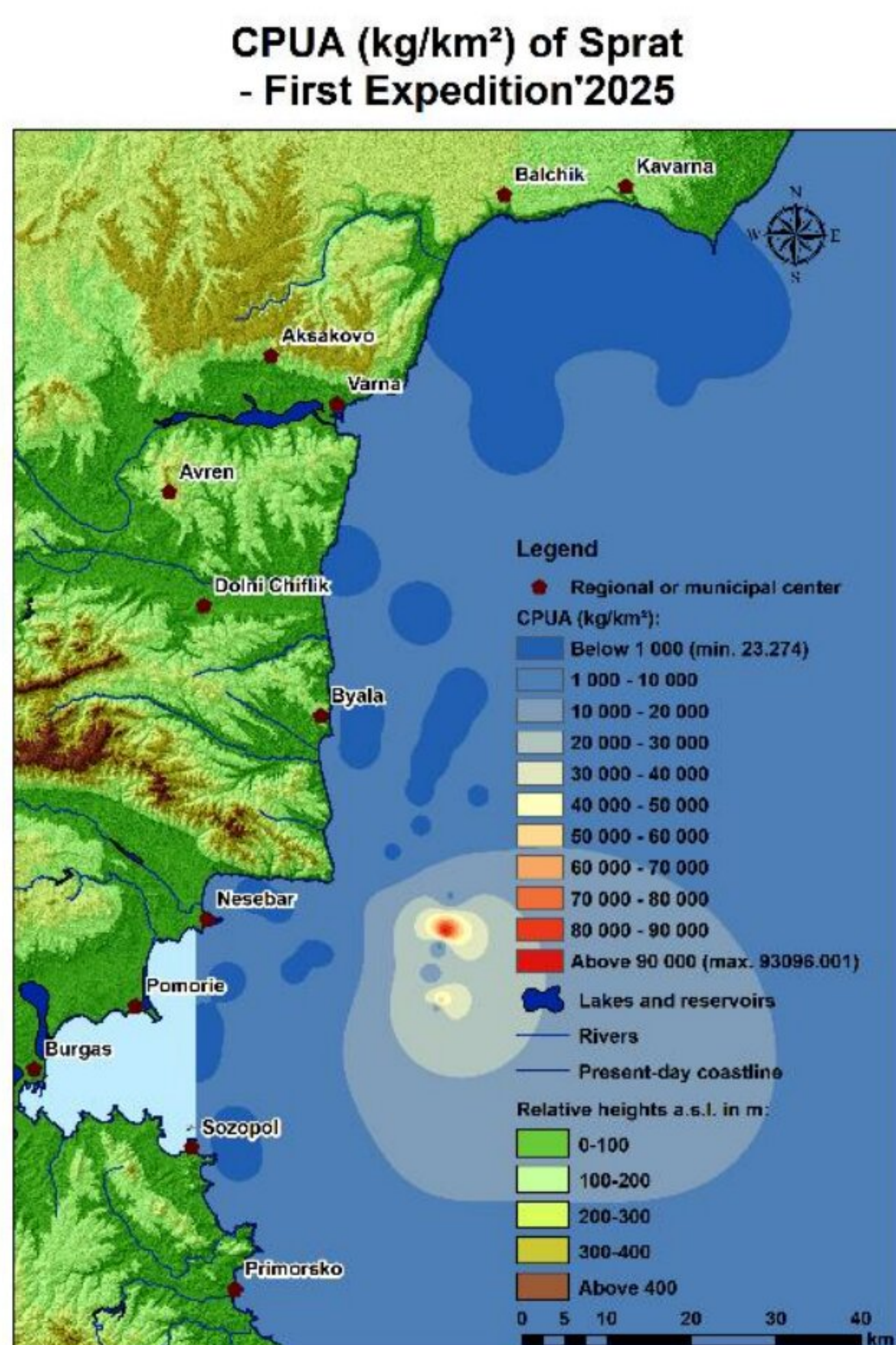


Figure 2.6.3.1. Catch per unit area (CPUA $\text{kg} \cdot \text{km}^{-2}$) of the sprat by depth layers - spatial distribution, September 2025.

2.6.4. Catch per unit effort

The catch per unit effort (CPUE) for the identified species is spatially represented with GIS (Fig. 2.5.4.1.).

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CPUE (kg/h) of Sprat - First Expedition'2025

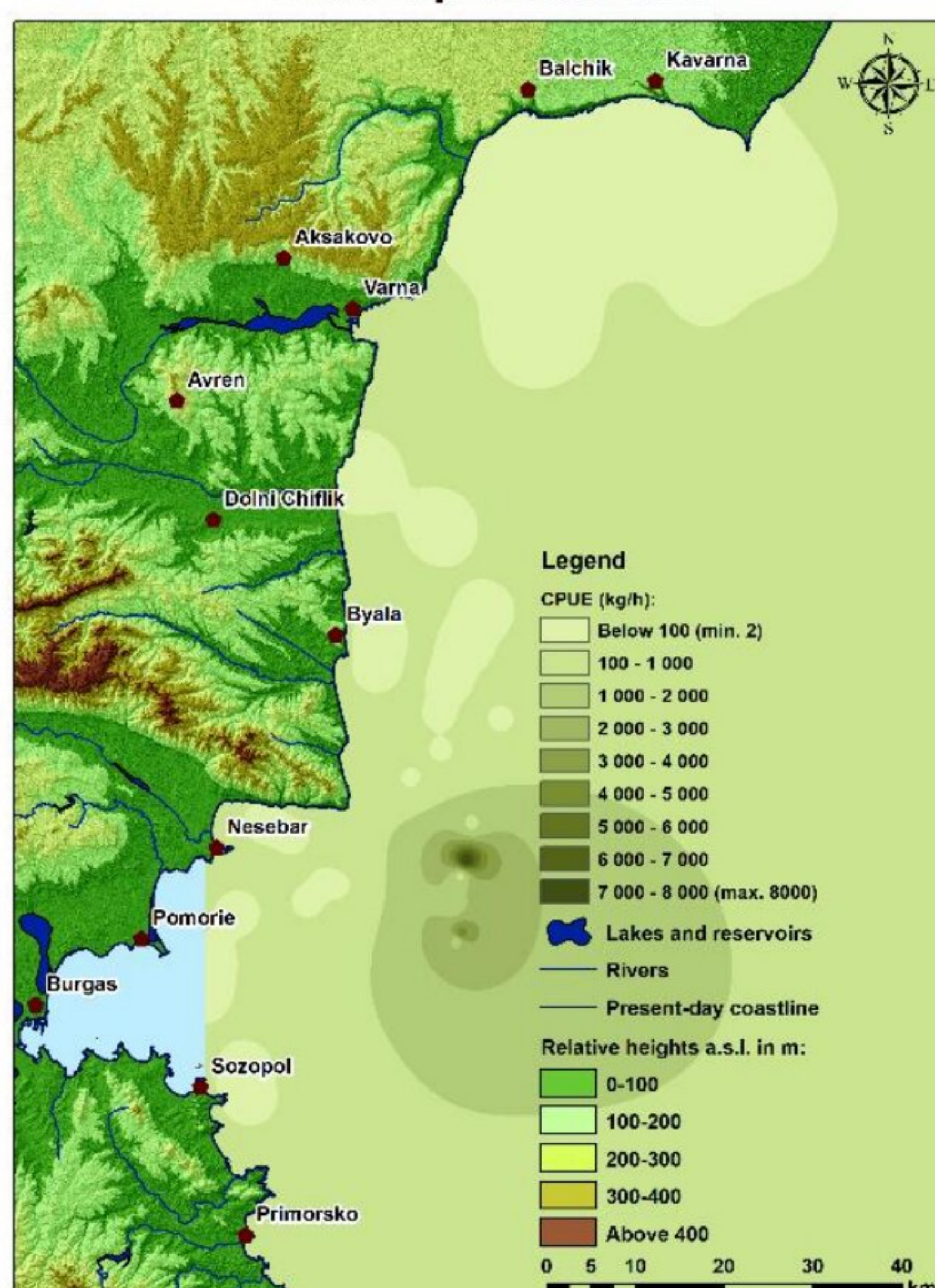


Figure 2.6.4.1. Catch per unit effort by depth layers for the sprat in September 2025.

The size structure of the sprat stock is presented in Figure 2.6.4.2. During the survey in September 2025, the smallest size class identified was 6 cm and the largest – 11.5 cm, with the predominant size classes (Gaussian distributed) in the catch composition being 8.5– 9 cm. The other size classes were less represented in the catch composition.



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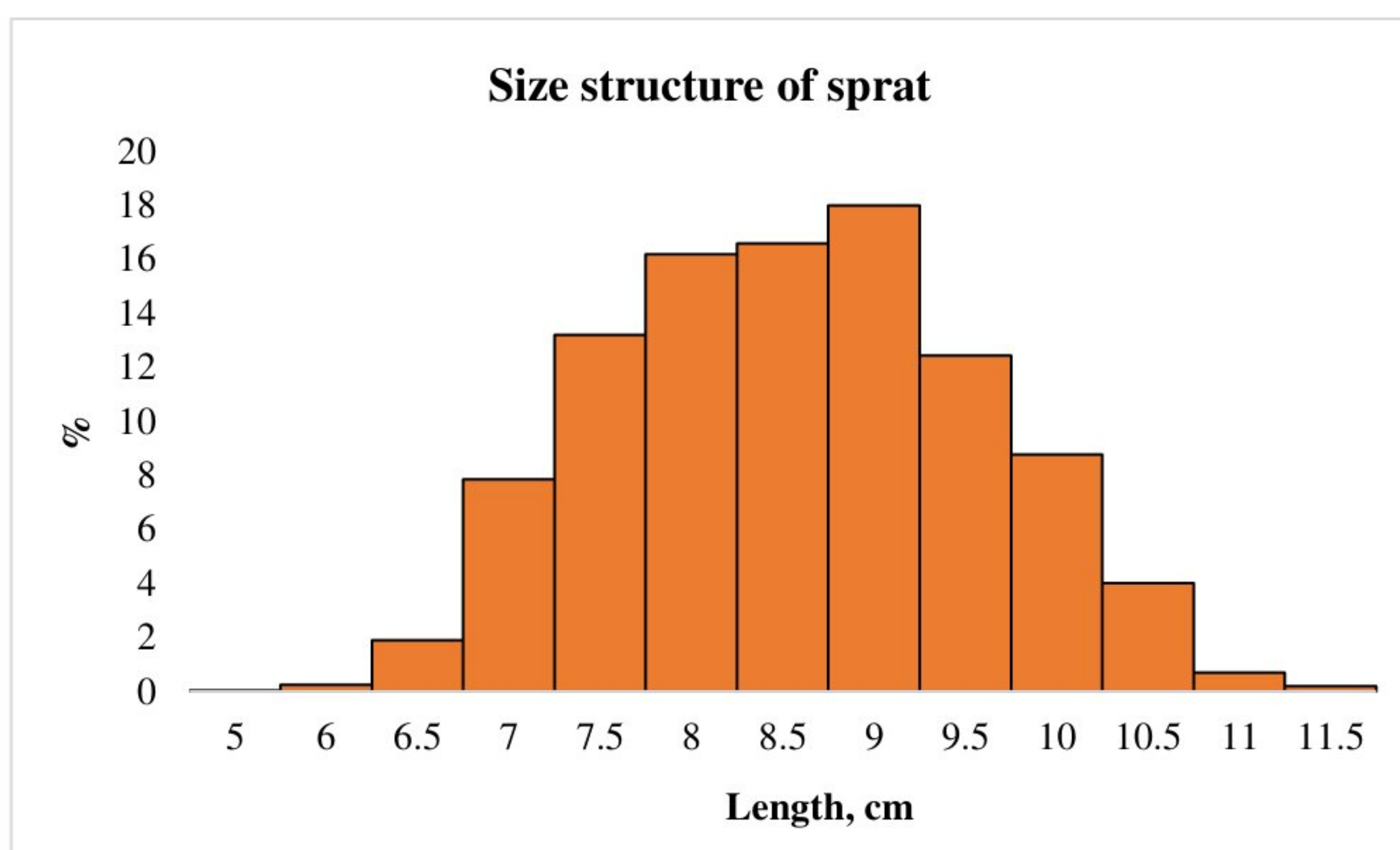


Figure 2.6.4.2. Size structure of sprat, September 2025.

By age, the sprat was represented with a peak at age 1-1+g, followed by 2-2+ and 3-3+g. The replenishment (0+g) and the senior group 4-4+g were in a subordinate position (Fig. 2.6.4.3.).

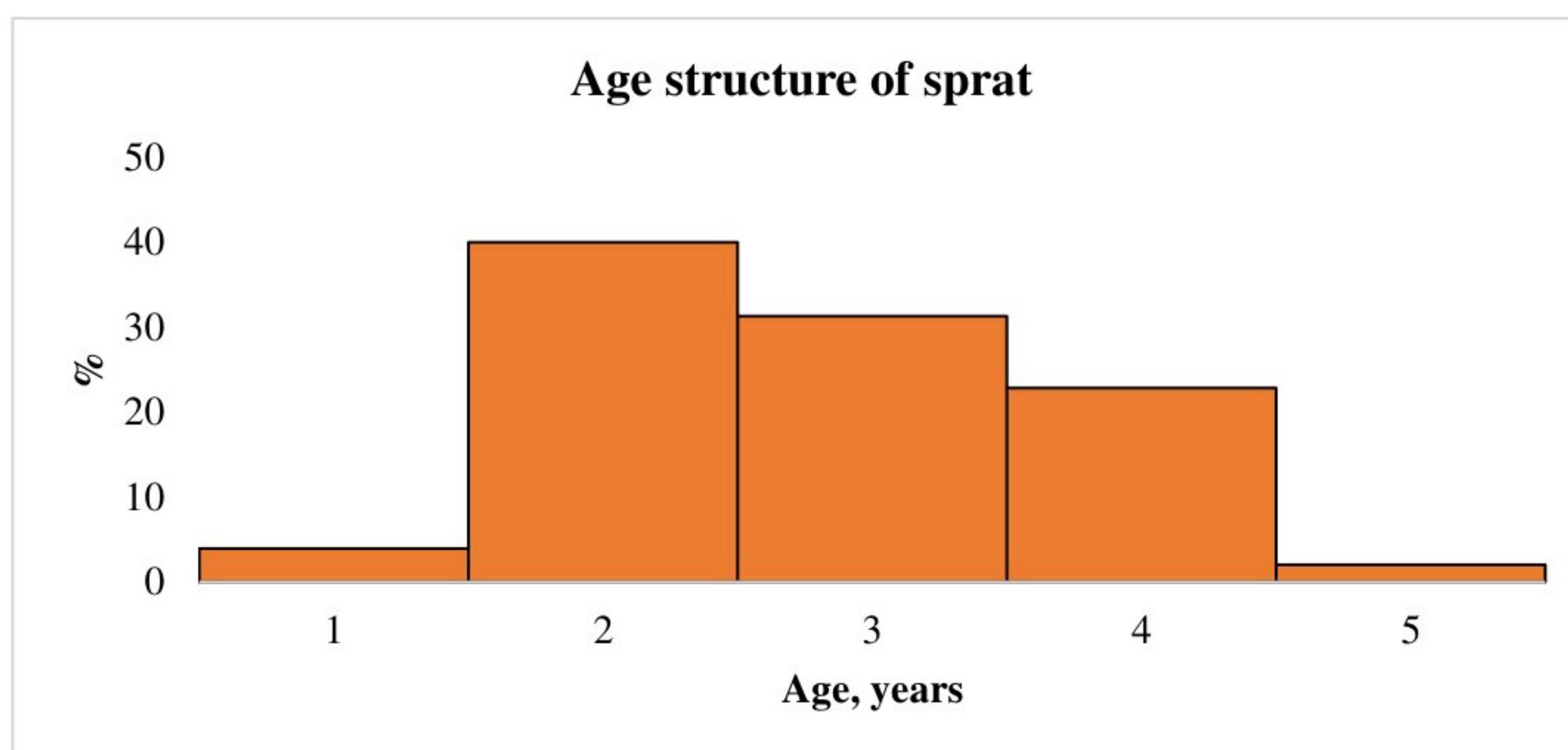


Figure 2.6.4.3. Age structure of sprat, September 2025.

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The somatic growth of the sprat showed no deviations, with individual weight being directly proportional to age (Fig.2.6.4.4.).

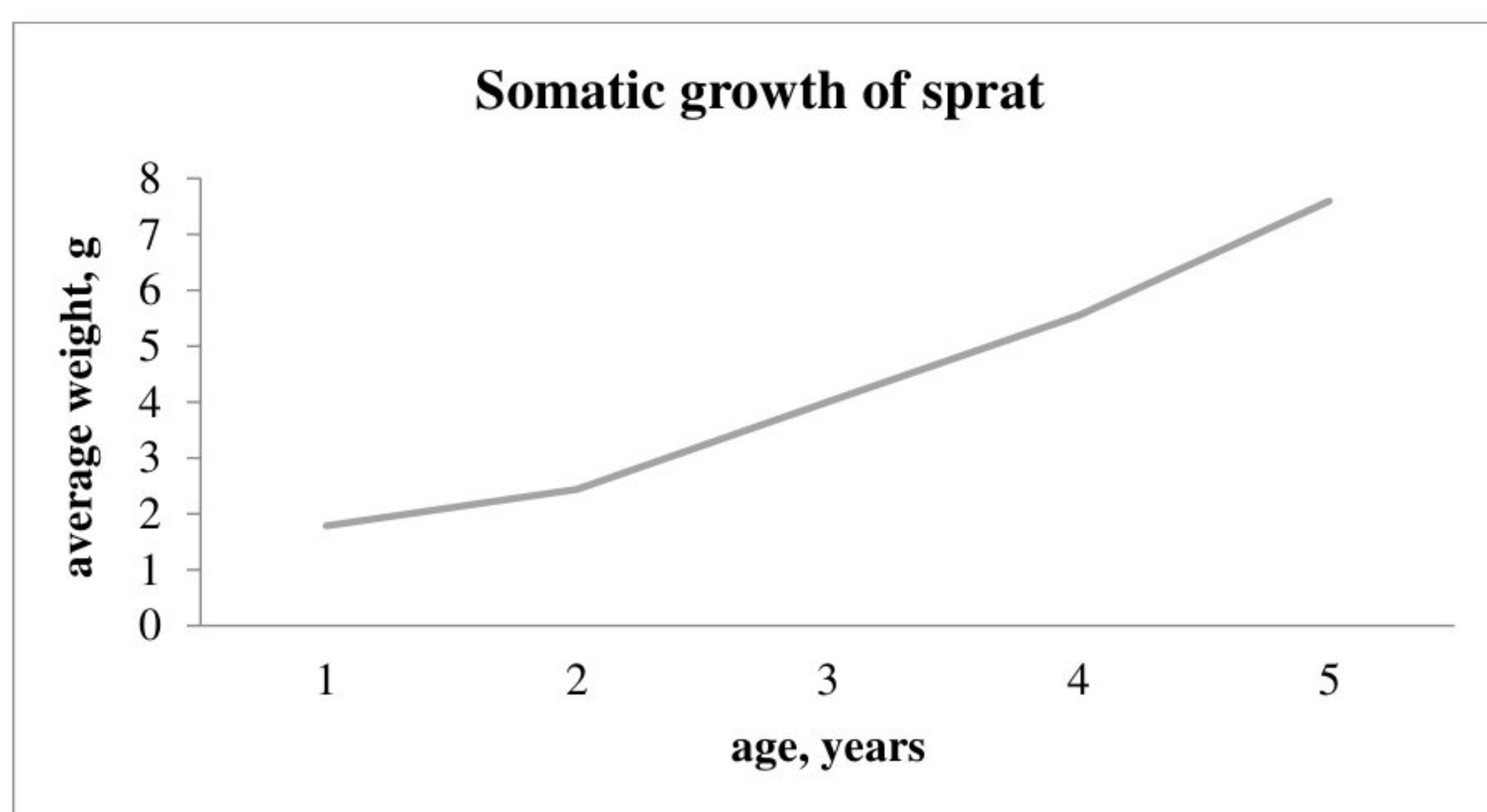


Figure 2.6.4.4. Somatic growth of sprat.

2.6.5. Sex ratio

The sex ratio was 49:49 (males and females), sexually mature individuals represented 2% of the sample (Fig.2.6.5.1.)

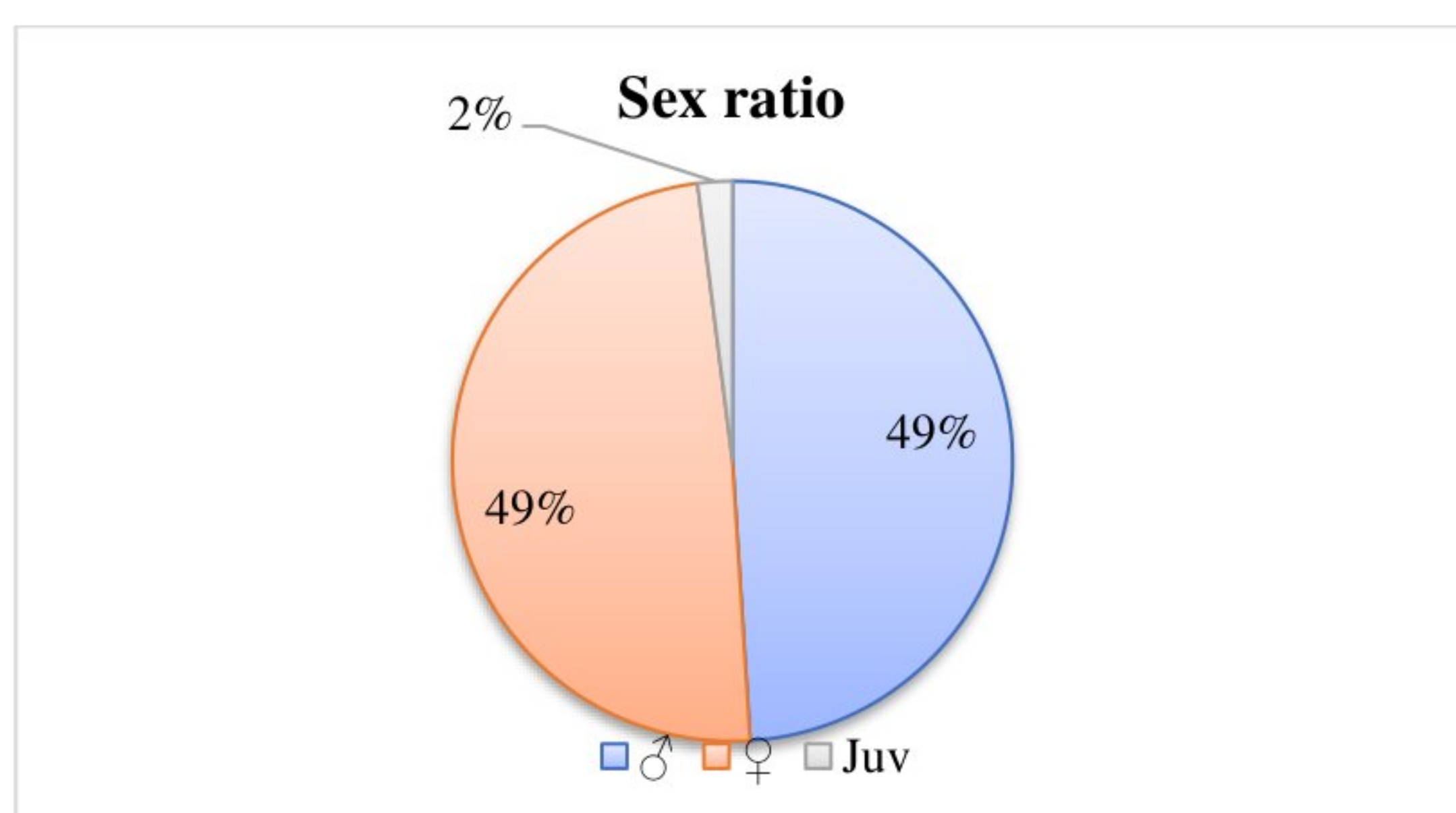


Figure 2.6.5.1. Sex ratio (♀,♂ and juveniles) of the sprat, September 2025.



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The structure of sexual maturity by size is presented in Fig. 2.6.5.2. According to the analysis, the following maturity levels prevail: 3a (IV) - 8-8.5 cm, 3b (IV-V) - 10.5 cm; 4a (V) - 11 cm.

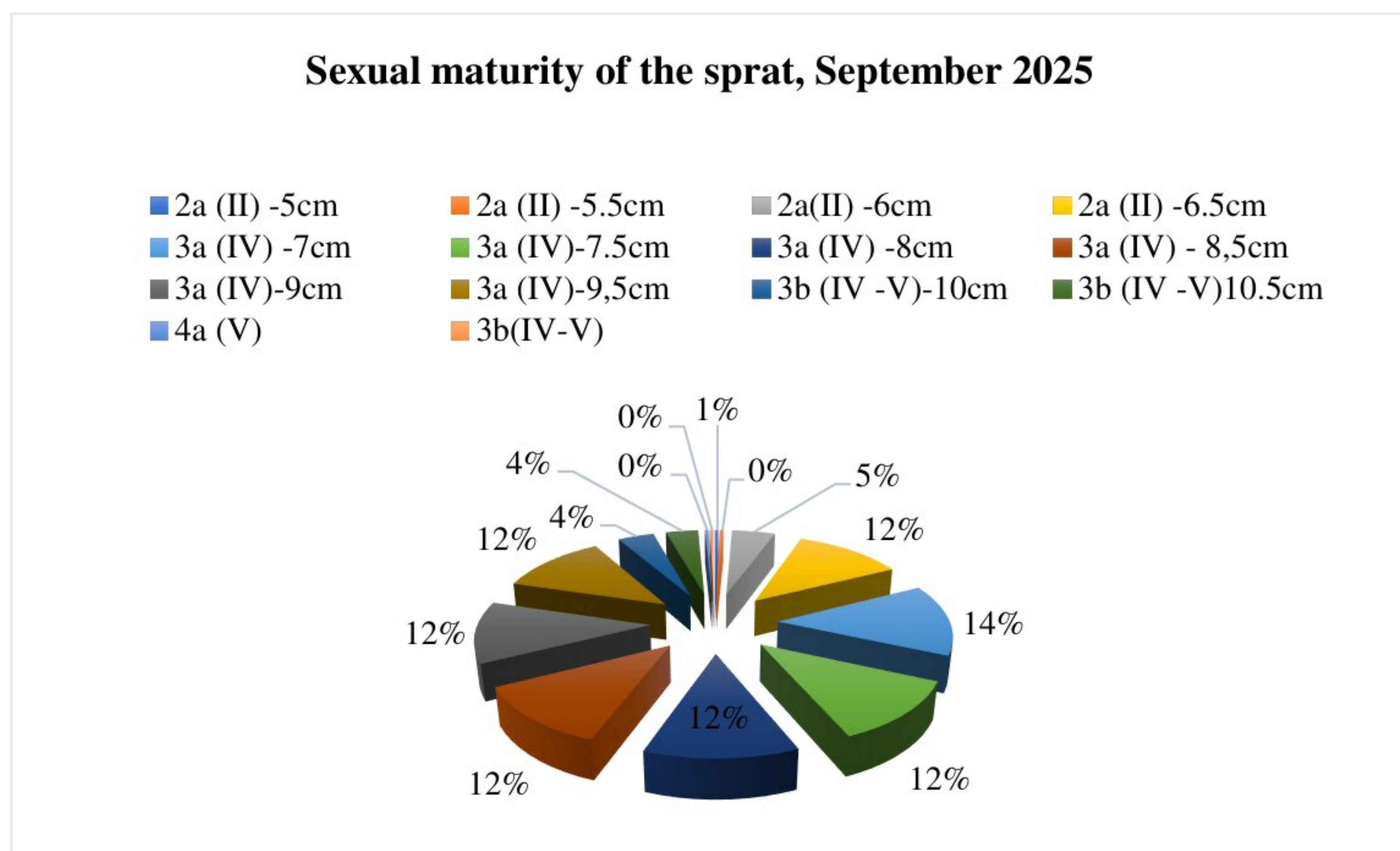


Figure 2.6.5.2. Sexual maturity of the sprat, analyzed by size classes, September 2025.

The analysis of the sex structure by age showed a predominance of individuals of 1-1+ and 2-2+ years (in males' maturity - III-IV) and in 1-1+ years (in females' maturity - IV-V) (Fig 2.6.5.3).



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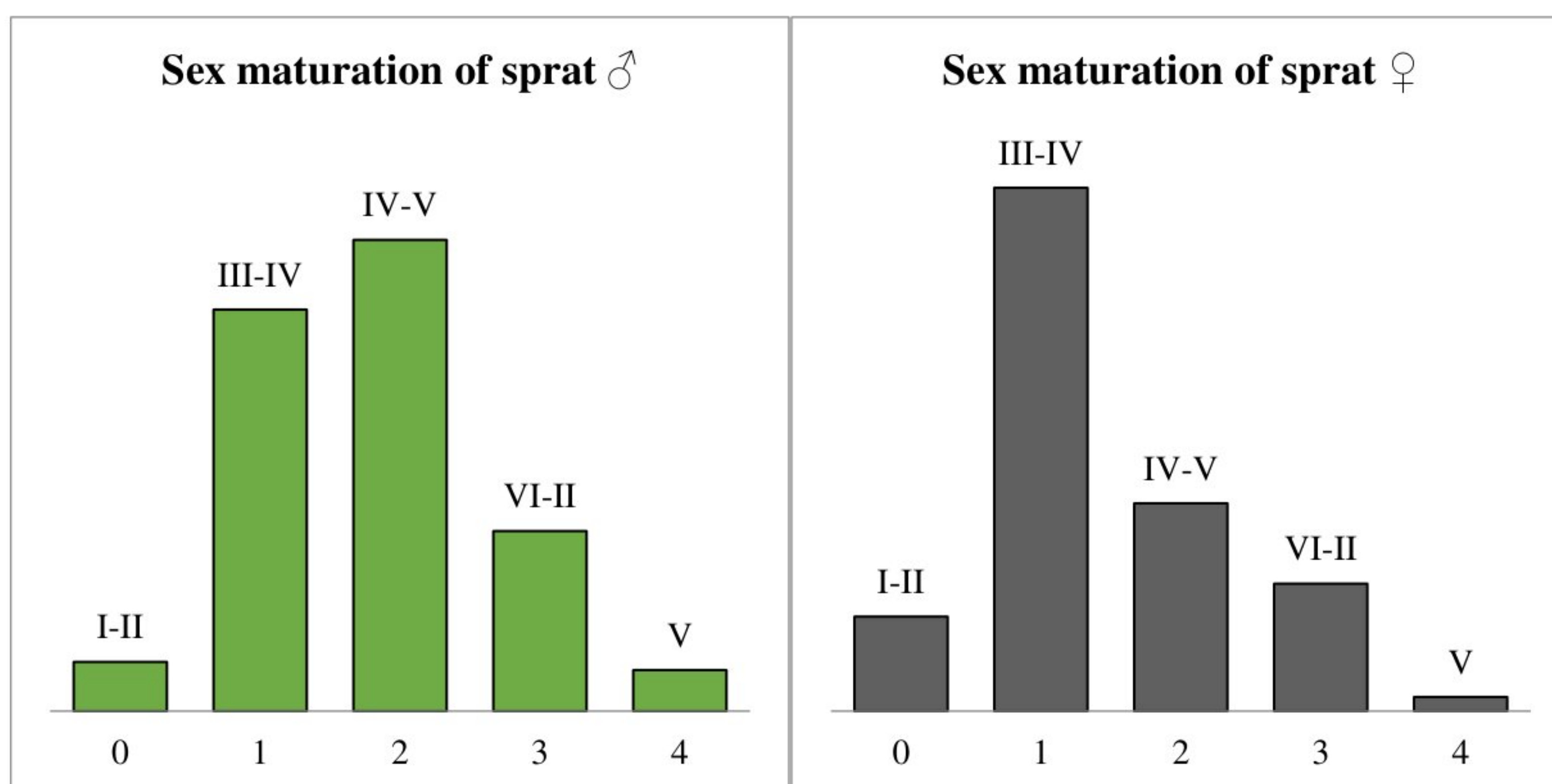


Figure 2.6.5.3. Sexual maturity of the sprat (males and females), analyzed by age groups.

Table 3.6.5.1 shows the absolute and relative fertility of the sprat in September 2025. The average value of absolute fertility was 35555 eggs, and of relative fertility – 7471 eggs.

Table 2.6.5.1. Absolute and relative fertility of the sprat.

Size, cm	Average weight, g	Average length, cm	Absolute fertility F, caviar grains	Relative fertility	Number ♀
6	1.34	6.01	na		2
6.5	2.3	7.12	15999	6956.087	12
7	2.51	7.59	26110	10402.39	26
7.5	2.94	8.26	26888	9145.578	28
8	3.71	8.61	33258	8964.42	29
8.5	4.445	8.63	36001	8099.213	40
9	5.08	9.22	36985	7280.512	39
9.5	5.38	9.4	41578	7728.253	38
10	5.91	10.25	42555	7200.508	23
10.5	7.12	10.58	42666	5992.416	7
11	8.05	11.22	44187	5489.068	4
11.5	9.11	11.68	44888	4927.333	2
average			35555.91	7471.434	250

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GSI of sprat in the reserch period corresponded to the beginning of the spawning season with very strong relation between goand weights and goando-somatic index (Fig. 2.6.5.4.).

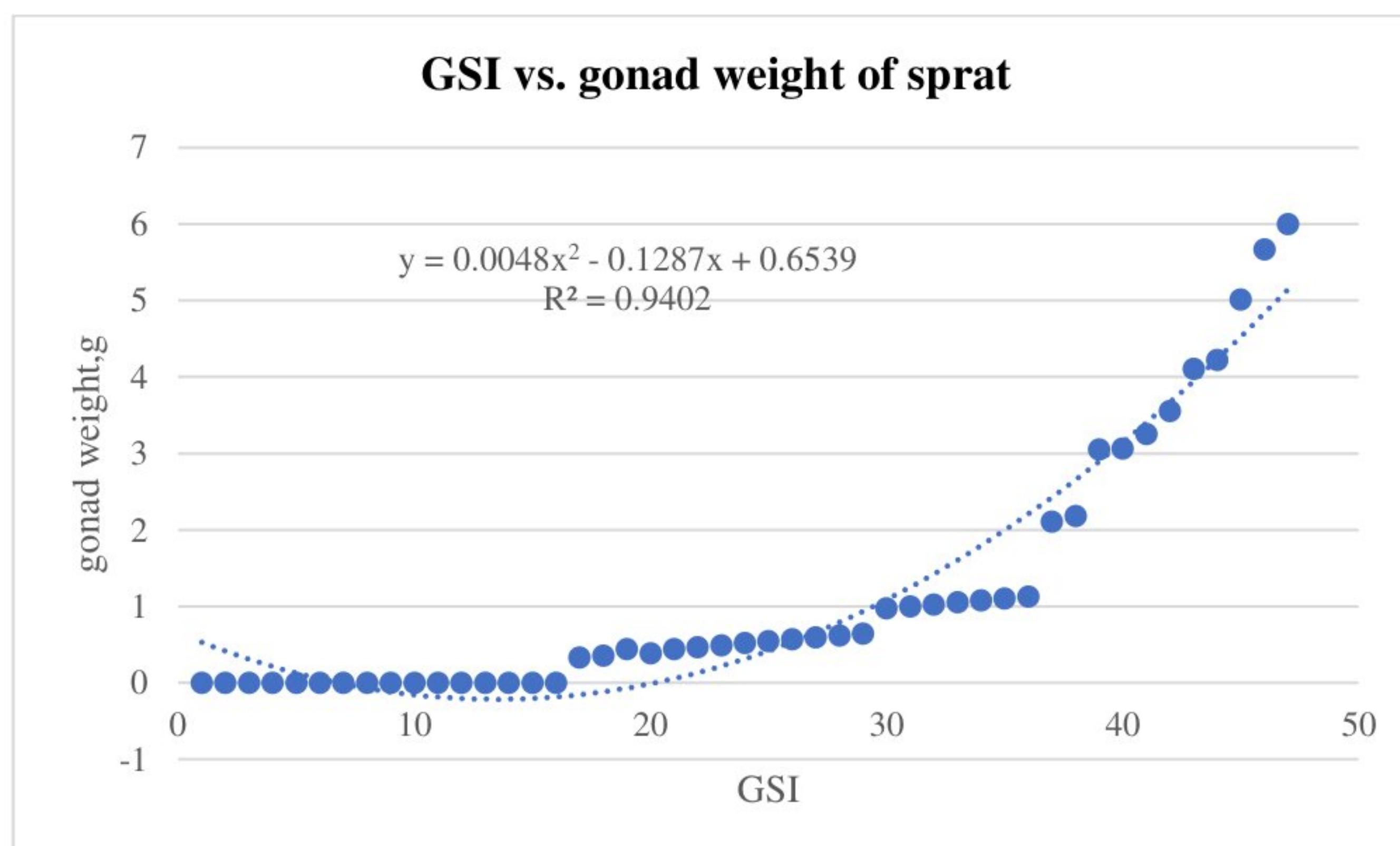


Figure 2.6.5.4. Gonado-somatic index of sprat in September, 2025.

2.7. Picked dogfish (*Squalus acanthias*)

The picked dogfish species was represented, with 6 individuals caught by chance. The growth parameters of the individuals are presented in Table 2.7.1.

Table 2.7.1. Picked dogfish (*Squalus acanthias*), catch in September 2025.

Sex	Total lenght (TL), cm	Weight (W), kg
male	116	5.95
male	122	6.3
female	118	6.02
male	117.5	6.15
male	121	6.224
female	118	6.055



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2.8. Planktivorous fish species feeding

2.8.1. Length-weight relationships (LWR), index of stomach fullness (ISF)

For the measured sprat specimens, the absolute length reached an average of $8.38 \text{ cm} \pm 0.81$ (SD), and the average weight was $3.29 \text{ g} \pm 0.99$ (SD). Accordingly, the average length of the horse mackerel was $10.92 \text{ cm} \pm 0.7$ (SD), with an average weight of $11.19 \text{ g} \pm 6.03$ (SD) (Table 2.8.1.1). The coefficient of variation (CV) of the absolute length of the sprat was approximately 10%, indicating moderate variability in terms of size in the population. The data on the coefficients of variation of the studied parameters in horse mackerel showed weak variations in terms of the average length (6.37%), while the weight (17.32%) and especially the fullness of the stomach (148.73%) had a much higher variability, reflecting significant individual differences in the nutrition and condition of the studied specimens.

Table 2.8.1.1. Summary data for length (L, cm), weight (W, g) and ISF (% of BW) of planktivorous fish: sprat (1) and horse mackerel (2), as determined by stomach content analysis in IX.2025.

1. Sprat

	L, cm	W, g	ISF, % BW
Average value	8.38	3.29	0.86
Standard error	0.08	0.10	0.08
Median	8.25	3.20	0.66
Mode	8.00	2.50	#N/A
Standard deviation	0.81	0.99	0.81
Dispersion	0.66	0.98	0.66
Kurtosis	0.33	0.38	8.23
Skewness	0.80	0.94	2.55
Range	3.70	4.40	4.99
Minimum	7.10	1.80	0.05
Maximum	10.80	6.20	5.04
Confidence interval (95.0%)	0.16	0.20	0.16
CV, Coefficient of variation	9.70	30.07	94.02



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2. Horse mackerel

	L, cm	W, g	ISF, % BW
Average value	10.92	11.19	0.96
Standard error	0.10	0.28	0.21
Median	10.90	10.95	0.39
Mode	10.50	10.00	#N/A
Standard deviation	0.70	1.94	1.42
Dispersion	0.48	3.76	2.02
Kurtosis	1.28	0.78	6.16
Skewness	0.10	0.12	2.52
Range	3.80	10.50	6.59
Minimum	9.00	5.90	0.09
Maximum	12.80	16.40	6.68
Confidence interval (95.0%)	0.20	0.56	0.41
CV, Coefficient of variation	6.37	17.32	148.73

The dependence of the weight (W, g) on the linear dimensions (L, cm) of the studied specimens is described by the following formulas:

$$(1) \text{ sprat: } W (g) = 0.0065 * L (cm)^{2.9168}; (R^2 = 0.94, p < 0.001, 2.8.1.1. (1))$$

$$(2) \text{ horse mackerel: } W (g) = 0.0227 * L (cm)^{2.5886}; (R^2 = 0.85, p < 0.001, 2.8.1.1. (2))$$

The growth of both species is negatively allometric, with a coefficient $b < 3$.



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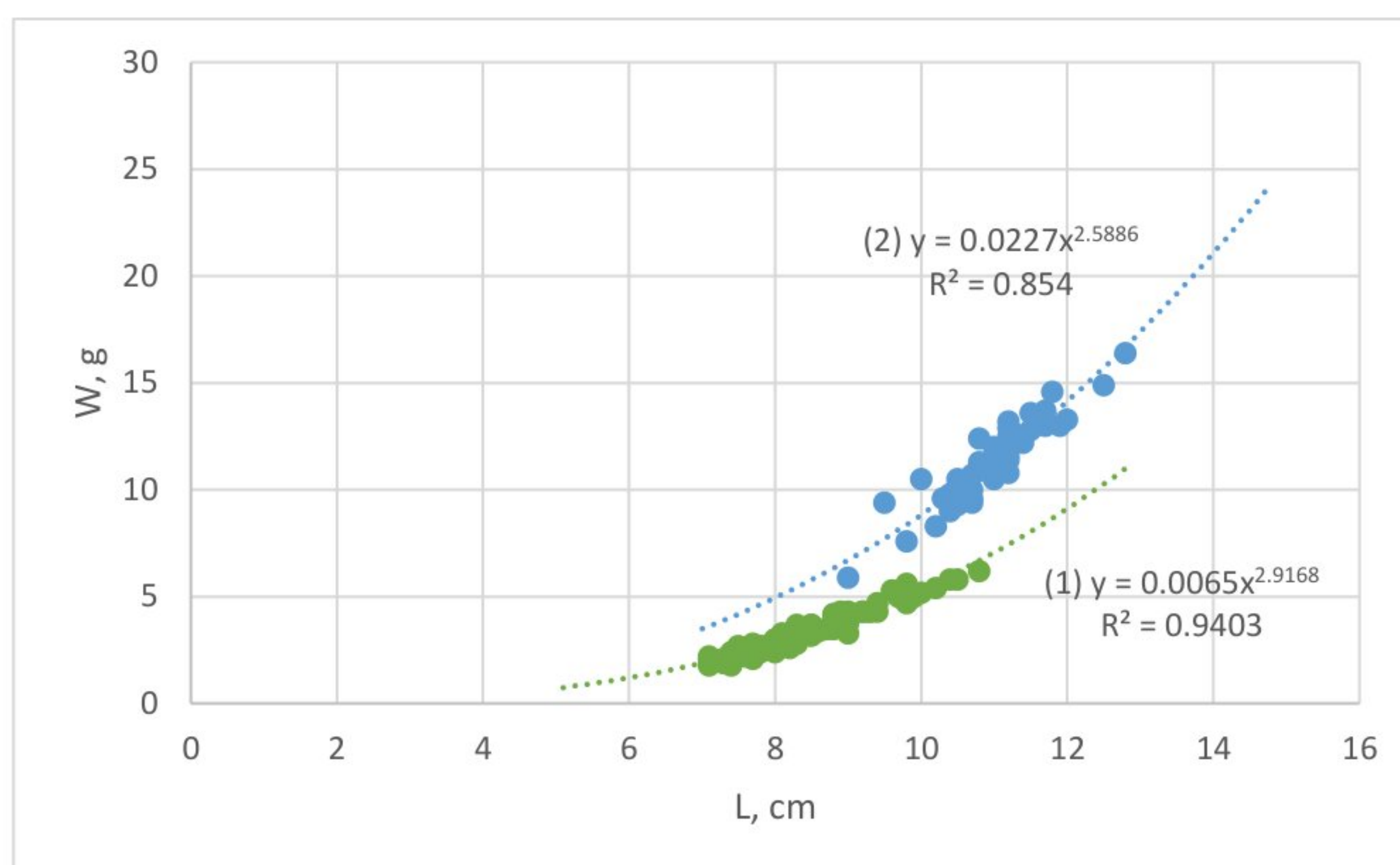


Figure 2.8.1.1. Length-weight relationships for sprat (1) and horse mackerel (2) in IX. 2025.

The mean value of the stomach fullness index in the sprat is $0.86 \% \text{ BW} \pm 0.81 \text{ (SD)}$, and in the horse mackerel - $0.96 \% \pm 1.42 \text{ (SD)}$ (Fig 2.8.1.2.). In the sprat, the distribution of the index showed that in 75% of the individuals an ISF below 0.91% was observed, and the highest recorded value was 5.04%. At the same time, in the horse mackerel, the median was significantly lower than the mean value, 0.39%, which indicates a highly variable distribution. This condition may reflect some differences in feeding strategies and/or access to food, as the horse mackerel demonstrates an extreme feeding pattern: feeding of some specimens is minimal, while intensive feeding is recorded in others.



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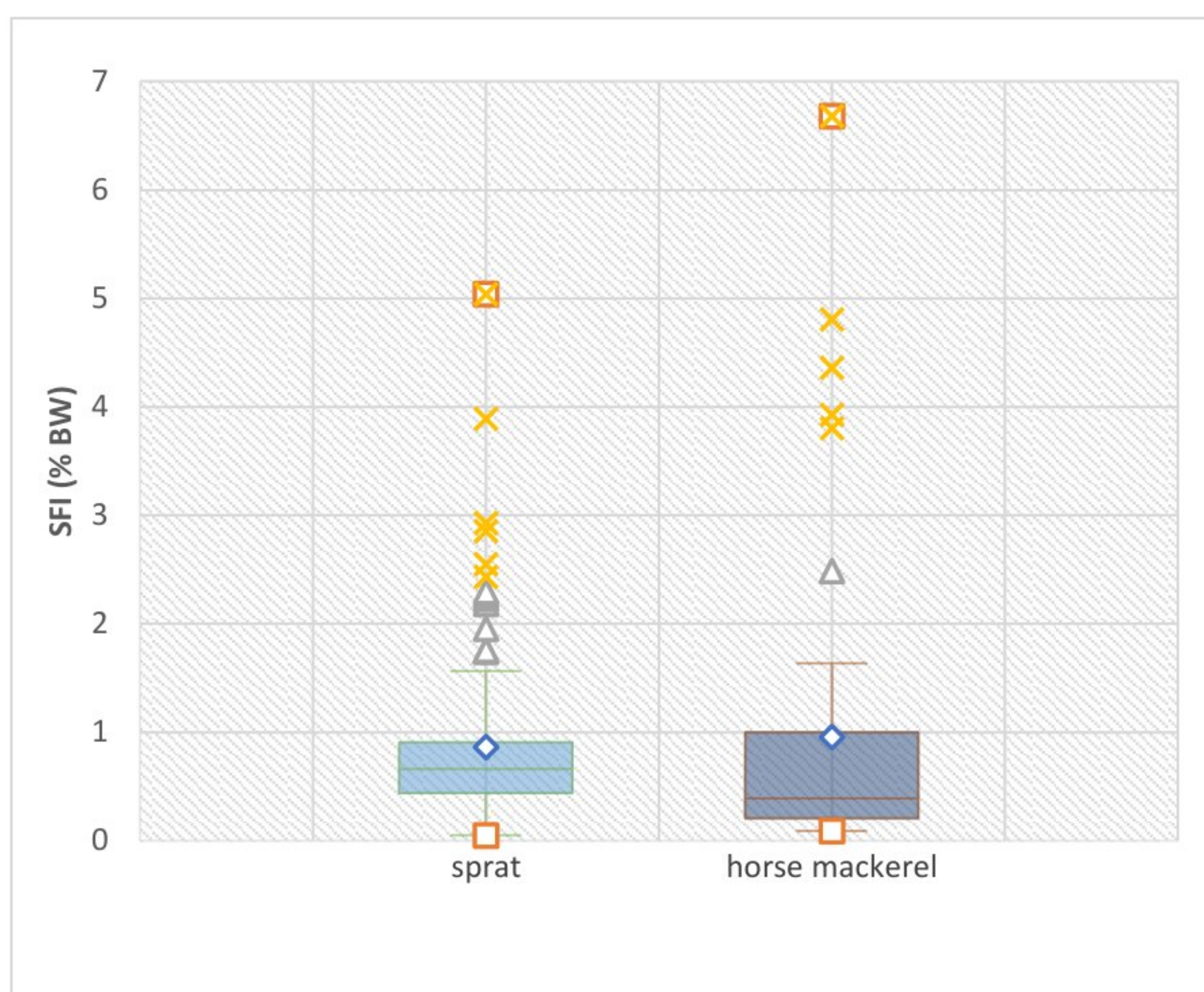


Figure 2.8.1.2. Box plot: ISF values (% BW) by species in IX. 2025 (median, range of values: 25–75%; minimum and maximum values are indicated).

The analysis of the spatial distribution of ISF (% BW) showed more intensive feeding of the sprat in front of the northern coasts (Fig. 2.8.1.3.(1)), probably related to favorable feeding conditions in these areas. Accordingly, the southern stations have lower ISF values (below 0.8% BW). For horse mackerel, high ISF values are recorded in the coast of the central and southern part of the shelf, while towards the open sea ISF decreases (Fig. 2.8.1.3(2)). These data support the observations of significant fluctuations in the feeding intensity of horse mackerel during the period.

On the other hand, no clear correlation pattern is observed between the ISF of the two planktonic species. For example, in some areas where the sprat has a high ISF, the horse mackerel has a low one (0.38%), but in other areas we find the opposite trend. This suggests that the two populations, despite their overlapping presence, likely have different nutritional niches or strategies.



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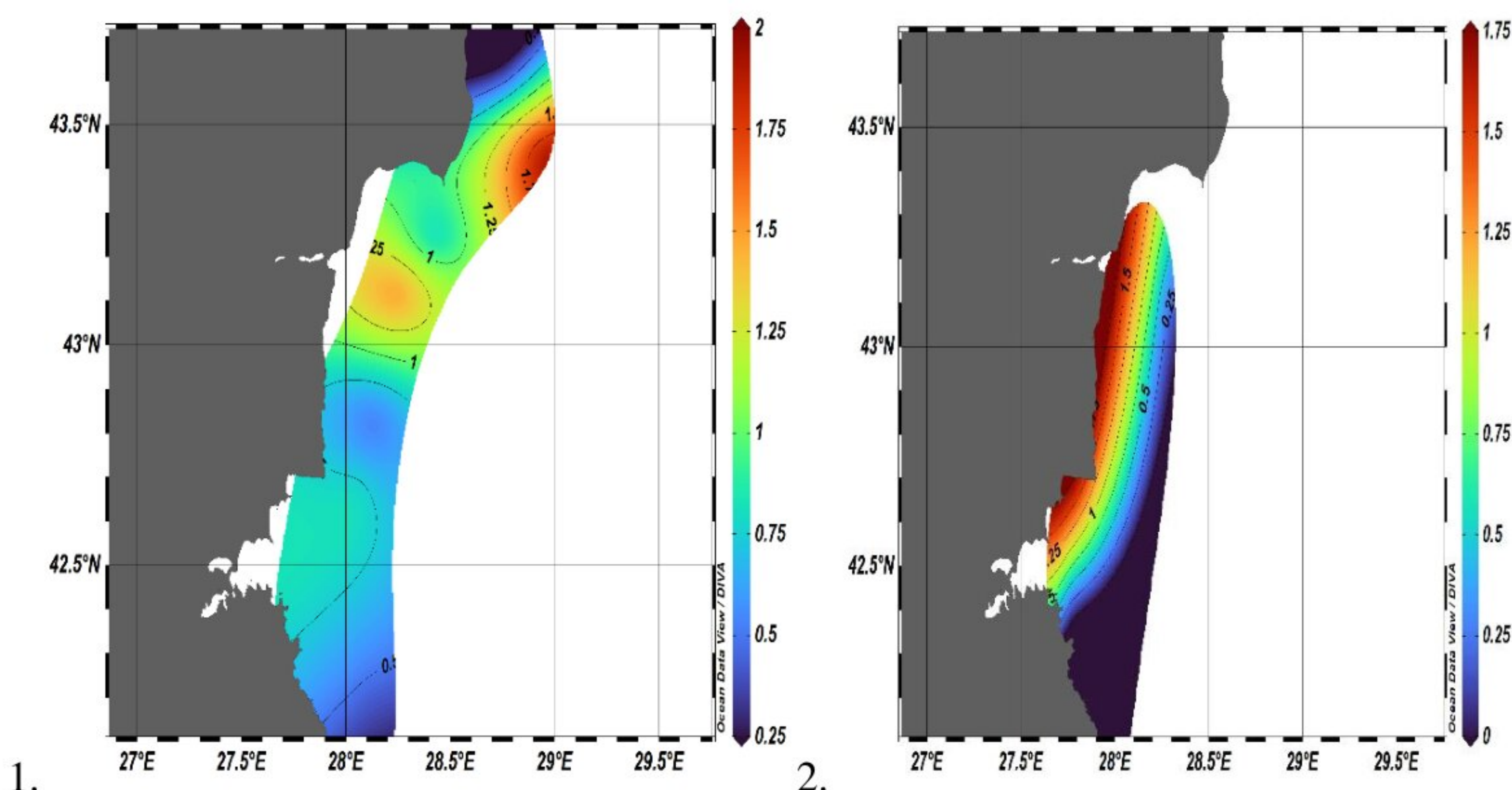


Figure 2.8.1.3. Spatial distribution of ISF (% BW) of sprat (1) and horse mackerel (2) in IX. 2025.

2.8.2. Prey number (PN), species composition of food and index of relative importance (IRI) of zooplankton

The highest average number of prey was found in horse mackerel - 210 ind/stomach $\pm$ 55 SE, with a maximum number of food organisms - 1393 ind/stomach, in connection with active consumption of *Paracalanus parvus*. Accordingly, the median PN was with a value of 8.0 ind/stomach. In the diet of the sprat, the average number of prey was 155 ind/stomach $\pm$ 21 SE, with a median of 76 ind/stomach (Fig. 2.8.2.1), which reflects a less extreme, but still variable feeding pattern.



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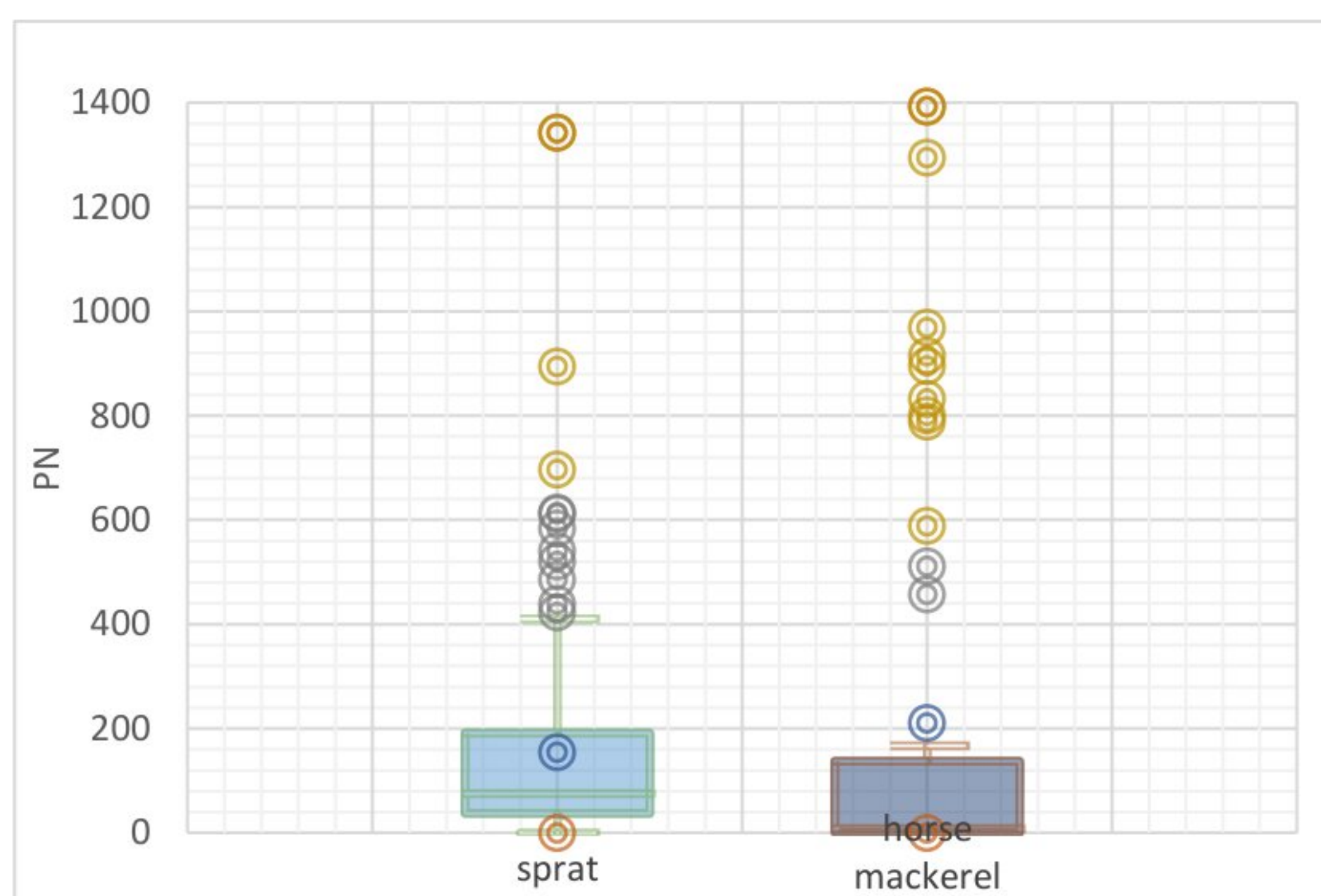


Figure 2.8.2.1. Box plot: Number of prey (PN, ind/stomach) in the stomach contents of surveyed specimens by species in IX. 2025 (median, range of values: 25–75%; minimum and maximum values are indicated)

These data indicate a predominantly moderate consumption of zooplankton by the sprat, with a relatively small number of individuals with high consumption. On the other hand, the presence of a large difference between the median and mean values for the horse mackerel indicates that a significant part of the specimens had very little prey (< 10 ind/stomach), while a small number of individuals fed intensively (1393 ind/stomach), suggesting active feeding on zooplankton accumulations. Accordingly, 32 species/groups were identified in the zooplankton samples from the marine environment, and a significant part of them, 24 species/groups, were present as components in the diet of the sprat, as well as 17 species/groups - in the diet of the horse mackerel. The sprat's diet includes a wide range of zooplankton groups - Copepoda (copipeds) - *Salanus euxinus*, *Paracalanus parvus*, *Pseudocalanus elongatus*, *Acartia clausi*, *Oithona davisae*, *Oithona similis*, *Centropages ponticus*, *Harpacticoida* spp.; Cladocera - *Penilia avirostris*, *Pleopis polyphemoides*, *Evadne spinifera*, *Pseudevadne tergestina*, meroplankton - *Lamellibranchia veliger*, *Gastropoda veliger*, *Cirripedia larvae*, Decapoda larvae; class Appendicularia is represented by the species *Oicopleura dioica*; type Annelida is represented by larvae of the class Polychaeta, type Chaetognatha - by *Parasagitta setosa*, and fish eggs are found by Chordata. Type Ctenophora are represented by *Beroe ovata* larvae.

The food of the horse mackerel consists of the following groups and species: Copepoda - *Paracalanus parvus*, *Pseudocalanus elongatus*, *Acartia clausi*, *Centropages ponticus*;

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Cladocera - *Penilia avirostris*, *Evadne spinifera*, *Pseudevadne tergestina*, meroplankton - *Lamellibranchia veliger*, *Gastropoda veliger*, Cirripedia larvae, Decapoda larvae; phylum Annelida is represented by larvae of the class Polychaeta, phylum Chaetognatha - by *Parasagitta setosa*, and from Chordata larval stages of fish are found, phylum Coelenterata is represented by polyp stages of Hydrozoa.

The indices of relative importance of the main food components in the studied pelagic fish species, their percentage participation in abundance and biomass, as well as the frequency of occurrence are presented in Table. 2.8.2.1.

Table 2.8.2.1. Food composition of pelagic fish species (IX. 2025).

1. Sprat

Food composition	<i>N</i> (% of the total abundance)	<i>M</i> (% of the total biomass)	<i>FO</i> – frequency of occurrence	<i>IRI</i> - index of relative importance
<i>Pseudocalanus elongatus</i>	22.59	19.47	73.00	3071
<i>Paracalanus parvus</i>	18.79	6.17	70.00	1747
<i>Decapoda larvae</i>	13.56	19.36	46.00	1514
<i>Acartia clausi</i>	8.49	13.58	65.00	1435
<i>Oikopleura dioica</i>	14.31	7.48	32.00	697
<i>Lamellibranchia veliger</i>	8.86	1.39	49.00	503
<i>Parasagitta setosa</i>	7.05	20.21	16.00	436
<i>Calanus euxinus</i>	1.69	7.93	9.00	87
<i>others</i>	4.66	4.39		
Total	100.00	100.00		

2. Horse mackerel

Food composition	<i>N</i> (% of the total abundance)	<i>M</i> (% of the total biomass)	<i>FO</i> – frequency of occurrence	<i>IRI</i> - index of relative importance
<i>Decapoda larvae</i>	56.37	67.79	52.00	6456.47
<i>Pseudocalanus elongatus</i>	10.35	6.79	12.00	205.67
<i>Pisces juvenile (E. encrasicolus)</i>	7.37	4.37	12.00	140.93

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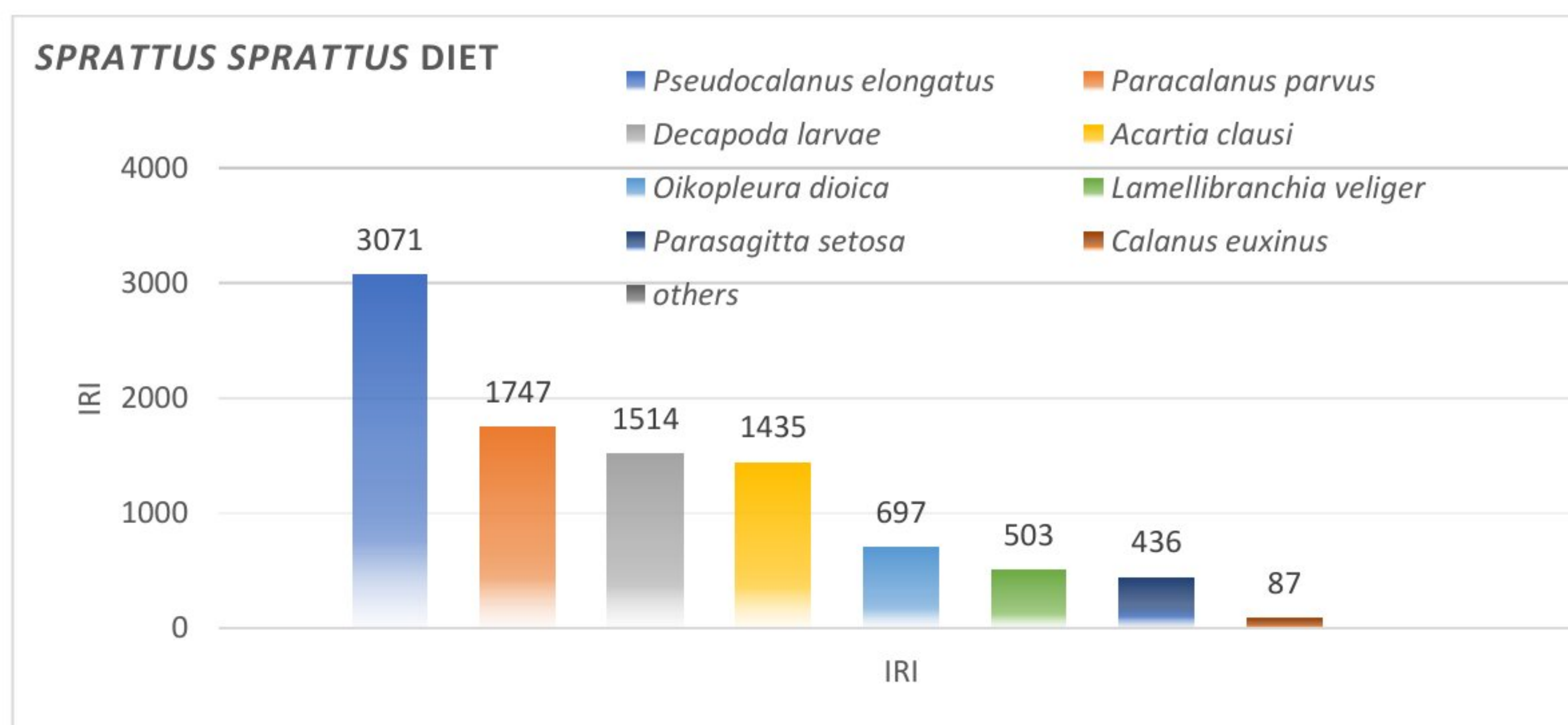
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<i>Paracalanus parvus</i>	6.39	1.38	15.00	116.47
<i>Lamellibranchia veliger</i>	2.64	0.10	30.50	83.74
<i>others</i>	16.87	19.58		
Total	100.00	100.00		

The analysis of the digestive contents of the sprat, measured by the index of relative importance (IRI), shows that this species feeds mainly on small zooplankton organisms, with the main prey being represented by several key taxa. The most important component in the diet of the sprat is the species *Pseudocalanus elongatus* (Table 2.8.2.1., Fig. 2.8.2.2.), with the highest IRI (3071), in connection with the high frequency of occurrence (73%) and the significant share in both abundance (22.6%) and biomass (19.5%). In second place is *Paracalanus parvus* (IRI = 1747), with a high frequency of occurrence (70%) and a significant share in abundance (18.8%), although with a lower share in biomass (6.2%). Third in importance are Decapoda larvae (IRI = 1514), with moderate frequency (46%), but relatively high share in biomass (19.4%) and number (13.6%). Fourth in importance is *Acartia clausi* (IRI = 1435), with high frequency (65%) and share in biomass (13.6%), but lower share in number (8.5%). The remaining species - *Oikopleura dioica*, *Lamellibranchia veliger*, *Parasagitta setosa* and *Calanus euxinus* play a secondary role, with their IRI being below 700.



1.



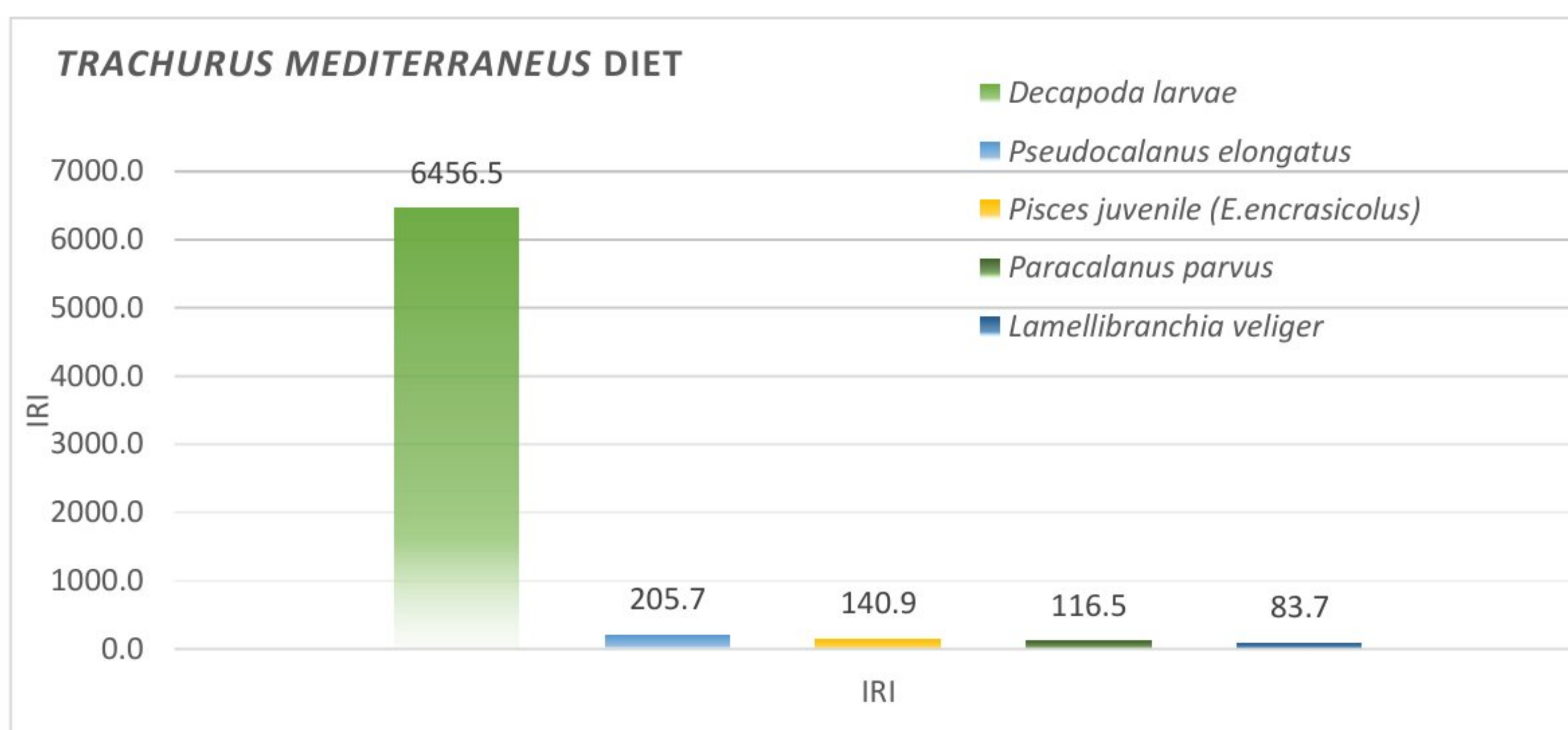
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Figure 2.8.2.2. Average values of the relative importance indices (IRI) of the main species in the diet of the sprat (1) and horse mackerel (2) in IX. 2025.

In horse mackerel, the main prey are Decapoda larvae (decapod crustacean larvae), with a high IRI - 6456.47, and a significant share in both numbers (56.4%) and biomass (67.8%), as well as with a moderate frequency of occurrence (52%). In second place is the copepod species *Ps. elongatus*, followed by Pisces juvenile (*Engraulis encrasicolus*) - young ex. anchovies, which are also important prey (IRI = 140.93). Although they are rarely found (12% frequency), they contribute to the biomass (4.4%) and abundance (7.4%) and confirm the predatory feeding mode of horse mackerel. The remaining zooplankton species, *Paracalanus parvus* and *Lamellibranchia veliger*, play a minor role in the diet of horse mackerel, with IRI < 206. Overall, the horse mackerel diet is directed towards larger, energy-rich organisms, with crustacean larvae being dominant. These data indicate that horse mackerel is an active predator that selects prey that provides maximum energetic benefit, even if it is less common.



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2.8.3. Species composition and quantities of zooplankton in the marine environment

During the study period, zooplankton biodiversity was comprised of 33 species and groups of organisms (Table 2.8.3.1.).

Table 2.8.3.1 Species composition of zooplankton.

IX. 2025
<i>Noctiluca scintillans</i>
<i>Rathkea octopunctata</i>
<i>Sarsia tubulosa</i>
<i>Hydrozoas spp.</i>
<i>Aurelia autria</i>
<i>Beroe ovata</i>
<i>Pleurobrachia pileus</i>
<i>Sarsia tubulosa</i>
<i>Calanus euxinus</i>
<i>Pseudocalanus elongatus</i>
<i>Paracalanus parvus</i>
<i>Oithona similis</i>
<i>Oithona davisae</i>
<i>Acartia clausi</i>
<i>Acartia tonsa</i>
<i>Centropages ponticus</i>
<i>Pontella mediterranea</i>
<i>Harpacticoida spp.</i>
<i>Pleopis polyphemoides</i>
<i>Penilia avirostris</i>
<i>Evadne spinifera</i>
<i>Pseudevadne tergestina</i>
<i>Polychaeta larvae</i>
<i>Lamellibranchia veliger</i>
<i>Gastropoda veliger</i>
<i>Cirripedia larvae</i>
<i>Decapoda larvae</i>
<i>Phoronis larvae</i>
<i>Bryozoa larvae</i>
<i>Nematoda larvae</i>
<i>Parasagitta setosa</i>
<i>Oicopleura dioica</i>
<i>Pisces ova, larvae</i>

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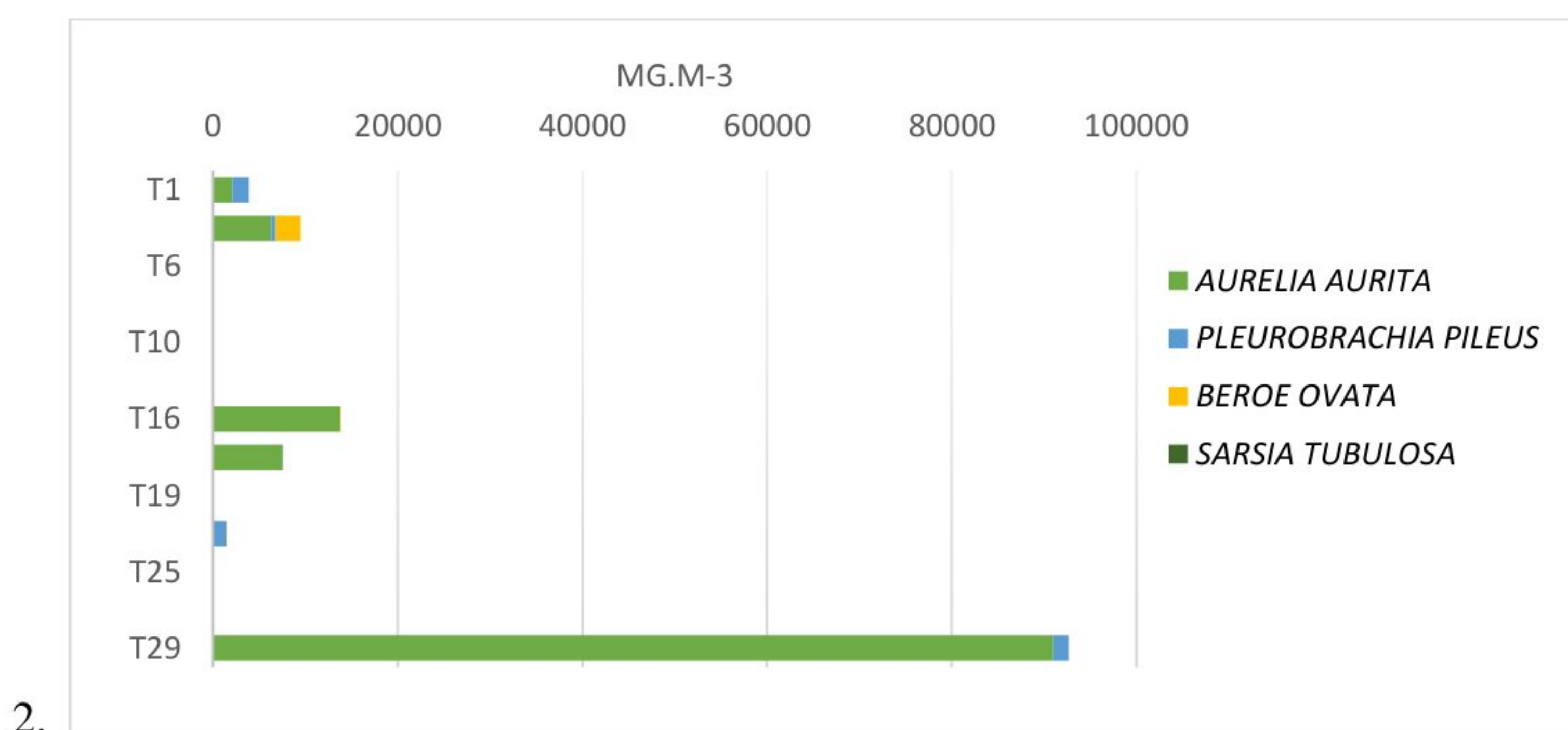
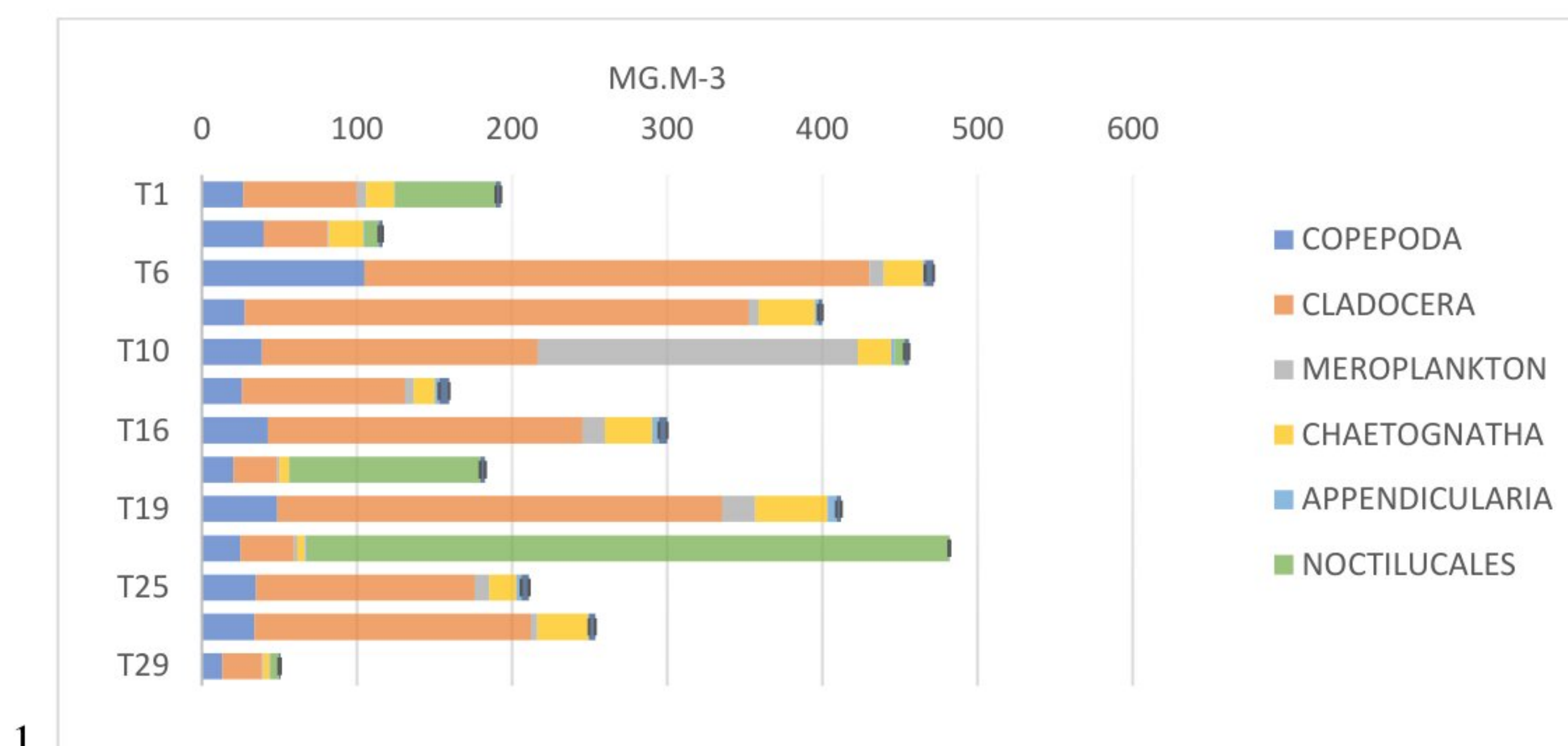
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The groups Cladocera (52 %), Copepoda (15.4 %) and Chaetognatha (8.6 %) have a dominant role in building the mesozooplankton biomass (Fig. 2.8.3.1(1), Table 2.8.3.2), and the gelatinous zooplankton is represented mainly by the species *Aurelia aurita*, *Pleurobrachia pileus*, *Beroe ovata* and *Sarsia tubulosa* with a dominant role of *Aurelia aurita* (94 % of the biomass; Fig. 2.8.3.1(2)).

Dominant groups in terms of abundance are Cladocera - 44.55 %, Copepoda - 31.55 %, followed by meroplankton - 7.19 % (Fig. 2.8.3.1 (3)).





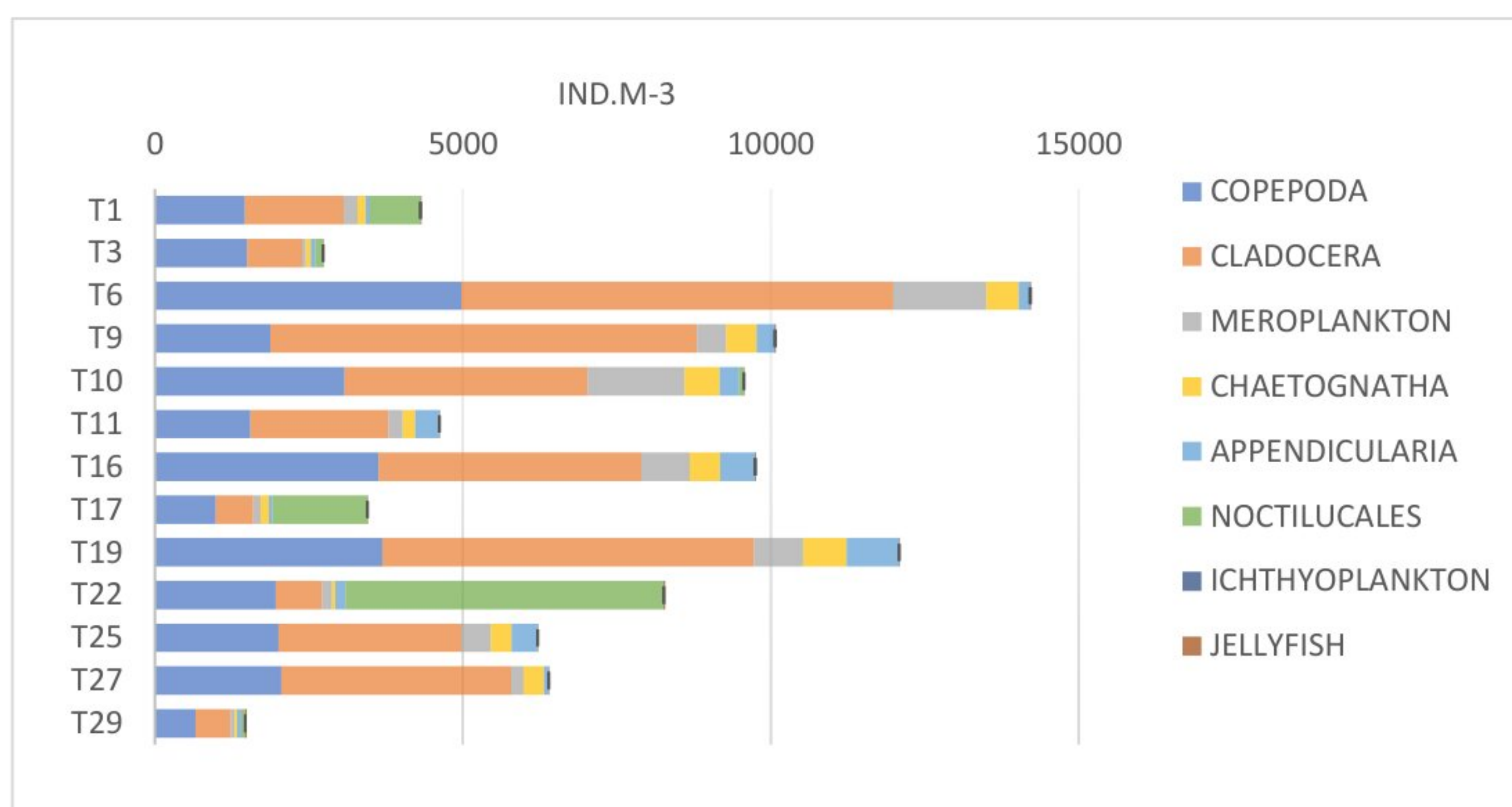
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Figure 2.8.3.1. Distribution of mesozooplankton biomass (1, mg.m^{-3}) and gelatinous zooplankton (2, mg.m^{-3}), as well as abundance of major zooplankton groups (3, ind.m^{-3}) by station in IX. 2025.

Table 2.8.3.2 Percentage shares (% , relative to biomass mg.m^{-3}) of the main zooplankton groups by stations in IX. 2025.

station	Cope-poda	Clado-cera	Mero-plankton	Chaeto-gnatha	Appen-dicularia	Noctilucales	Ichthyo-plankton
T1	13.9	38.1	3.1	9.3	0.3	33.7	1.7
T3	34.3	35.5	0.6	19.2	0.4	8.0	2.0
T6	22.3	68.9	2.0	5.3	0.3	0.0	1.2
T9	7.0	81.1	1.6	9.0	0.6	0.0	0.6
T10	8.5	39.1	45.2	4.8	0.5	1.4	0.6
T11	16.3	65.8	3.5	8.5	1.8	0.0	4.0
T16	14.3	67.6	4.7	10.3	1.4	0.0	1.8
T17	11.3	15.5	0.8	3.2	0.2	67.3	1.7
T19	11.8	69.6	5.2	11.3	1.4	0.0	0.7
T22	5.2	7.1	0.5	1.1	0.2	85.8	0.1
T25	16.5	67.0	4.4	8.3	1.5	0.0	2.3
T27	13.4	70.2	1.7	12.9	0.2	0.0	1.6
T29	26.1	50.3	1.8	8.4	0.9	10.4	2.1
средно	15.4	52.0	5.8	8.6	0.8	15.9	1.6

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Table 2.8.3.3 presents the summarized statistical data on the total biomass of zooplankton and the main constituent subgroups – mesozooplankton, gelatinous zooplankton and protozoa. The total biomass of zooplankton has average levels of $10.20 \text{ g.m}^{-3} \pm 6.987 \text{ (SE)}$, and is formed mainly by gelatinous species - $9.91 \text{ g.m}^{-3} \pm 7.01 \text{ (SE)}$. The biomass of food zooplankton is relatively high for the season - 235.87 mg.m^{-3} .

Table 2.8.3.3. Summary data on the total biomass (mg.m^{-3}) of zooplankton and the main groups in IX. 2025.

	mesozooplankton	gelatinous zooplankton	protozoa	total zooplankton biomass
Mean	235.87	9913.91	47.90	10197.69
Standard error	43.39	7008.97	32.11	6987.30
Median	210.95	1.82	0.00	471.86
Standard deviation	156.46	25271.20	115.78	25193.06
Kurtosis	-1.54	11.95	9.88	11.96
Skewness	0.31	3.41	3.07	3.41
Minimum	45.49	0.04	0.00	159.59
Maximum	471.82	92660.13	413.76	92710.90
Confidence interval (95.0%)	94.55	15271.23	69.97	15224.01

During the study, the biomass of mesozooplankton reached the highest value of $\sim 450 \text{ mg.m}^{-3}$ in front of the central and northern parts of the coast (Fig. 2.8.3.2. (1)). Protozoa are mainly distributed in the areas of the wide Burgas Bay, with biomasses $\sim 400 \text{ mg.m}^{-3}$ (Fig. 2.8.3.2. (2)), and the main accumulation of gelatinous zooplankton $\sim 90 \text{ g.m}^{-3}$, was found south of Sozopol (Fig. 2.8.3.2 (3)).



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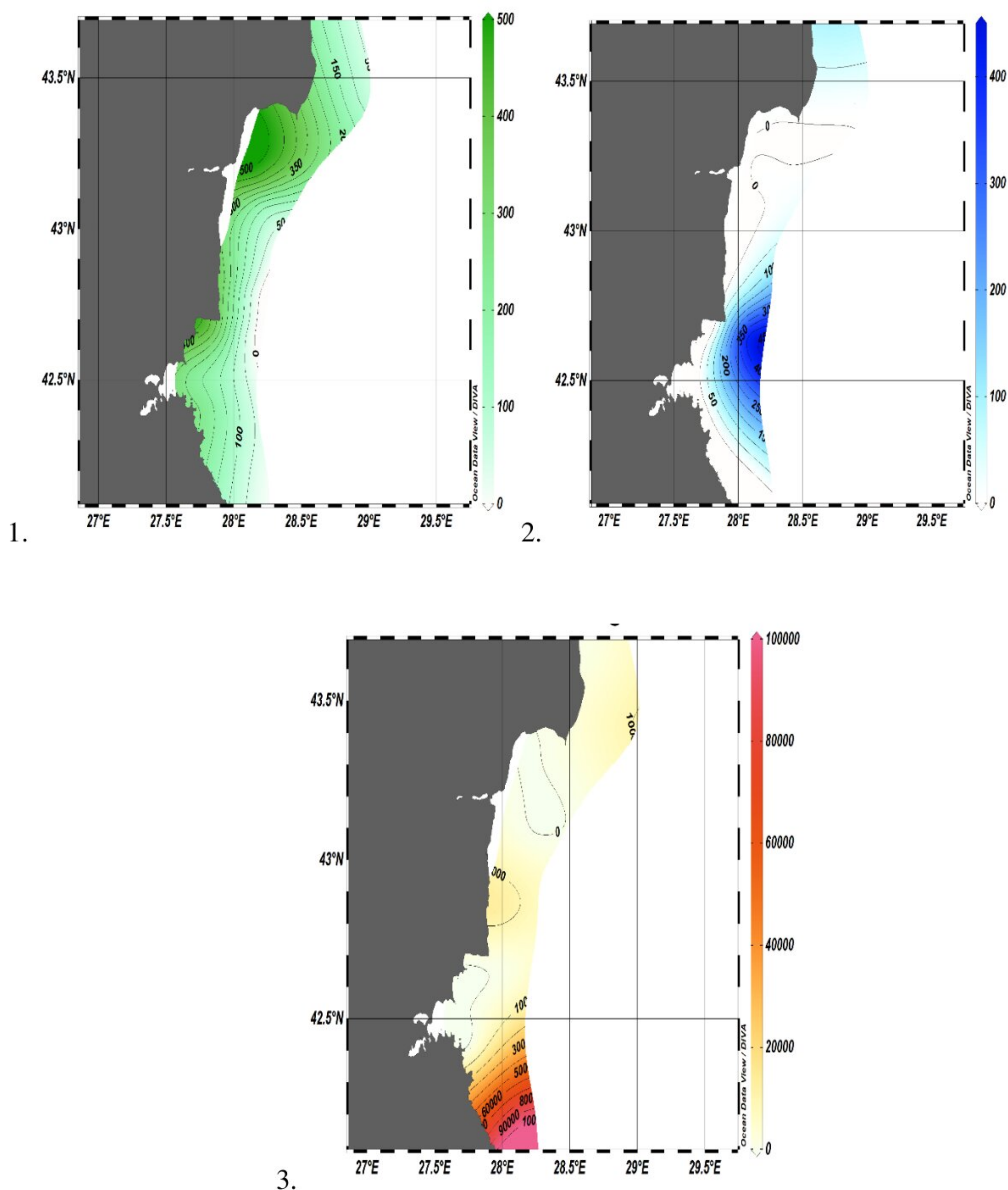


Figure 2.8.3.2. Spatial distribution of the biomass (mg.m^{-3}) of mesozooplankton (1), protozoa (2), and gelatinous zooplankton (3) in IX. 2025.

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3. Conclusions

- During the study period, 36 trawls were processed on board the NIK “HaitHabu” in the Bulgarian region of the Black Sea. The study was carried out in September 2025. The time of trawling during the study period varied between 30 and 40 minutes at depths between 15 m and 100 m in the area between Ahtopol and Durankulak. Sprat was observed at depths above 18 m;
- The total number of species identified during the study is 26, of which 18 fish, 2 crustaceans, molluscs – 2 and 3 macrozooplankton species. The most common species in the trawls (presence/absence) are: *Sprattus sprattus* (50.15%) *Merlangius merlangus* (19.22%), *Mullus barbatus* (16.9%), *Trachurus mediterraneus* (10.4%) is observed sporadically in the catches. Other species such as *Alosa immaculata*, *Neogobius melanostomus*, *Gobius niger*, *Mesogobius batrachocephalus*, *Zosterisessor ophiocephalus*, *Raja clavata*, *Dasyatis pastinaca*, *Pegusa lascaris*, *Aphia minuta*, *Uranoscopus scaber*, *Trachinus draco*, *Scophthalmus maximus* and *Squalus acanthias*, *Acipenser gueldenstaedtii* и *Acipenser stellatus* have a negligible presence in the catches;
- In September 2025, the sprat was scattered in the near-shore area, mainly due to high water temperatures. The highest biomass values were recorded at greater depths of 50-100 m;
- Four species of gobies (*G. niger*, *N. melanostomus*, *M. batrachocephalus* and *Z. ophiocephalus*) and single specimens of *A. immaculata* were observed in the catches. Quantitative assessment is not possible due to the small number of different species in individual trawls.

Horse mackerel

- The total surveyed area was 8010.24 km², and the amount of total horse mackerel biomass was 3093.2 tons. The densest concentrations were observed in front of Byala and Nessebar Bays. The biomass in the 15–30 m stratum was the highest: 1057 t, followed by 624 t (30–50 m) and 14 t (50–100m).
- Sprat is represented with the highest density of distribution in the water area of Byala, Nessebar Bay, Varna, Pomorie, Nessebar (St. Vlas), Kavarna.
- In the depth layer 15–30 m the highest values for CPUA were recorded – 1241 kg.km⁻², with an average value of 512 kg.km⁻². In the layers 30–50 m - 124–869 kg.km⁻² and 50–100 m with very low values of 3.41 kg.km⁻².

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- The highest CPUE values (kg.h^{-1}) were observed off Varna, Obzor, Kavarna and St. Vlas;
- The length distribution in the horse mackerel samples is bimodal (Gaussian), with a 2-bell shape, as the most common lengths in the samples are in the range 9–9.5, 12.5–13.5 cm. A peak is observed in the 9 cm size group.
- The predominant age group in horse mackerel during the study period was 2-2+ (27.27%), followed by 1-1+ y^{-1} (23.11%). The recruitment was represented by 7.55%. The age structure of horse mackerel varied from 0 to 5 + y^{-1} years, with a significant representation of the age group 3-3+ y^{-1} with 12.99%.
- The length-weight relationship in horse mackerel is described by the model $W = 0.009 \cdot L^{2.1935}$, allometric growth coefficient > 3 , the resulting nonlinear length-weight relationship model has a high degree of determination ($R^2 = 0.94$).
- The growth parameters of horse mackerel, calculated using the von Bertalanffy model, show an asymptotic length of 26.405 cm and higher values of the coefficient determining the rate of reaching the asymptote;
- In September 2025, the largest percentage share of representation in the catches has the size class 9.0 cm, followed by the size class 13 cm. Age groups 2-2+ and 3-3+ y^{-1} have high abundance indices and dominate the catches;
- Biomass, similar to abundance, showed a predominance of the 90 mm size group, followed by the 95 mm size group;
- The gonadosomatic index GSI (%) of horse mackerel is indicative of a later stage of spawning $R^2 = 0.328$ there is a strong correlation between the weight of the glands and the gonadosomatic index, which is an indication of mass reproduction processes and active maturity of the sex products during the studied period;
- The percentage of female and male horse mackerel specimens is as follows: 51:49%;
- Maximum allowable catch based on current biomass:

$$B_{\text{MSY}} = B \cdot 0.5 = 1696 \cdot 0.5 = B_{\text{pr}} = 848.25;$$

$$C_{\text{msy}} = 2/3 \text{ MSY} = 565.5 \text{ t}$$

Recommended catch levels in the western Black Sea are those that should not exceed 688.4 t.

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Red mullet

- The total surveyed area was 8010.24 km^{-2} , and the amount of total red mullet biomass was 2065.2 tons;
- The densest aggregations were observed in front of the Kaliakra peninsula, in front of the town of Byala at depths of 30–50. The species was registered in 16 stations (out of a total of 41), with the highest density in the stratum 30–50 m (the town of Byala and Kaliakra peninsula);
- The densest aggregations were observed in front of the Kaliakra peninsula, in front of the town of Byala at depths of 30–50. The species was registered in 16 stations (out of a total of 41), with the highest density in the stratum 30–50 m (the town of Byala and Kaliakra peninsula);
- The catch per unit area in the 15–30 m stratum was 80 kg.km^{-2} ; in the 30–50 stratum – 1047 kg.km^{-2} and at 50–100 m – 0 kg.km^{-2} ;
- Size-weight analysis of red mullet (L-W) in September 2025 shows a very high dependence of the size and weight of the species, with a well-pronounced allometric growth ($R^2 = 0.99$);
- During the study, the predominant size classes in the catch composition were 11 and 13.0 cm;
- 2-2+ have the majority, followed by $1-1+y^{-1}$. The remaining age groups have a negligible share in the catches in September, 2025;
- The growth parameters of the red mullet, calculated using the von Bertalanffy model, show an asymptotic length of 18.4 cm and higher values of the coefficient determining the rate of reaching the asymptote;
- Females, males and immatures of the red mullet are represented in percentages as follows, 47:45:8%;
- The red mullet was in an active phase of sexual maturation, probably related to the high seawater temperatures;
- Maximum allowable catch, as a proportion of the current biomass for red mullet:

$$B_{\text{MSY}} = B * 0.5 = 2065.2 * 0.5 = B_{\text{pr}} = 1032.6;$$

$$C_{\text{msy}} = 2/3 \text{ MSY} = 688.4 \text{ t}$$

Recommended catch levels in the western Black Sea are those that should not exceed 688.4 t.

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Whiting

- The total surveyed area was 8010.24 km², and the amount of total whiting biomass in the Bulgarian waters of the Black Sea in September 2025 amounted to 8109.2 tons.
- The highest value of whiting biomass was observed in the 50–100m stratum – 1407 t. In the 30–50m depth layer the values were 1125 t and 124 t in the 15–30m layer;
- Whiting was represented in the composition of the catches with the highest density of distribution of the species, recorded in the Sozopol region, north of Emine and Kavarna.
- In the depth layer 50–100 m, the highest recorded value for CPUA was 3103 kg.km⁻², with an average value of CPUA – 1407 kg.km⁻². In the depth layer 15-30 m, 124 kg.km⁻² and 30–50 m – 1125 kg.km⁻².
- Whiting sizes showed a normal distribution, with peaks at 10.5 and 12.5 cm;
- In the catches from the autumn survey of 2025, 3-3+ (38%) individuals were predominant;
- The length-weight relationship in whiting was presented with a very high degree of reliability ($R^2 = 0.96$);
- The von Bertalanffy growth model (VBGF) was applied to determine the growth parameters. The asymptotic length (L_{∞}) of whiting reached 27.6 cm, and the growth rate can be defined as low ($k = 0.23$);
- In whiting, females were represented by 50%, males by 49%, and larvae by 1%.
- The maturation of the reproductive products indicates the beginning of active reproduction of the species. Due to the warmer weather, the reproduction process will probably intensify in the coming months, at relatively lower sea water temperatures;
- The weight of the gland compared to the gonadosomatic index shows a high degree of reliability ($R^2 = 0.83$);
- Maximum allowable catch, as a proportion of the current biomass for whiting:

$$BMSY = B * 0.5 = 8109.2 * 0.5 = Br = 4054.64;$$

$$Cmsy = 2/3 MSY = 2703 \text{ t}$$

Recommended catch levels in the western Black Sea are those that should not exceed 2700 t.

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Anchovy

- In the catches from the Bulgarian waters of the Black Sea during the studied period of 2025, the size composition is represented by individuals with a body length of 6.0 cm to 12.5 cm;
- In September 2025, the share of zero-year-old specimens is high (46.50%), and the presence of two-year-olds reaches ~24.20%;
- The weight structure of anchovy by age shows that at the replenishment (0+) the average weight is 2.66 g, and in the oldest age group (4-4+g) it is 9.46 g;
- In anchovy, females were represented by 64%, followed by males by 36%;
- The gonad-somatic index is highly dependent on the weight of the gonads ($R^2 = 0.9822$), which is related to the high rate of maturation of females in late spring and summer and the reproductive process of the anchovy.

Sprat

- In September 2025, the sprat was scattered in the near-coastal zone, mainly due to high water temperatures. The highest biomass values were recorded in deeper depths of 50–100 m.;
- The total surveyed area was 8010.24 km², and the estimate of the total biomass of the sprat stock was 97349 t.
- In September 2025, the biomass of the sprat in the 15–30m stratum was estimated at 42.75 tons, followed by the 30–50m stratum – 6009 tons and 50–100m – 91297 tons;
- The catch per unit area (CPUA kg.km⁻²) was relatively high in the 50–100m stratum with the formation of agglomerations uncharacteristic for the sprat. The densest passages were registered in front of Nessebar, Emine;
- During the study, the smallest identified size class was 6 cm, and the largest – 11.5 cm, with the predominant size classes (Gaussian distributed) in the composition of the catch being 8.5–9 cm. The other size classes were less represented in the composition of the catch;
- By age, the sprat was represented with a peak at age 1-1+g, followed by 2-2+ and 3-3+g. the replenishment (0+g) and the senior group 4-4+g were in a subordinate position;
- The sex ratio was 49:49 (males and females), the non-sexually mature ones represented 2% of the sample;
- The GSI of the sprat during the studied period corresponds to the beginning of the reproductive season, with a very strong correlation between gland weights and the gonadosomatic index;

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- Maximum allowable catch, as a proportion of the current biomass for the sprat:

$$BMSY = B * 0.5 = 97349.2 * 0.5 = 48674.6;$$

$$Cmsy = 2/3 MSY = 32500 \text{ t}$$

Recommended catch levels in the western Black Sea are those that should not exceed 3250 t.

Feeding

- At the end of summer 2025, the food composition of the horse mackerel includes 17 species/groups, while 24 species/groups are recorded in the food of the sprat. The food of the sprat is mainly found small zooplankton - mainly Copepoda and meroplankton. The horse mackerel feeds mainly on meroplankton larvae, but the diet also includes fish larvae and other zooplankton groups,
- The main food objects for the sprat are *Pseudocalanus elongatus* (IRI = 3071), *Paracalanus parvus* (IRI = 1747), Decapoda larvae (IRI = 1514), as well as *Acartia clausi* (IRI = 1435). Horse mackerel has a pronounced predatory diet, dominated by Decapoda larvae (IRI = 6456.47), which constitute 56.4% in abundance and 67.8% in biomass, with juvenile anchovies also found (IRI = 140.93). These results characterize the sprat as a planktonic filter feeder, while the horse mackerel is an active predator, oriented towards larger and more energetic prey.
- Stomach fullness index (ISF) data for the sprat and horse mackerel confirm the differences in the feeding behavior of the two species. In the sprat, the mean ISF value is 0.86 % BW (SD = 0.81), and the median is 0.91 % BW, indicating a relatively stable diet. In horse mackerel the mean value is 0.96 % BW (SD = 1.42), but the median is significantly lower - 0.39 % BW, which reflects a highly asymmetric distribution and extreme feeding patterns - some individuals feed minimally while others feed intensively. These results, together with the lack of a clear spatial correlation between the ISF of the two species, suggest different feeding niches or strategies, despite overlapping presence in certain areas.
- Analysis of the prey number (PN) in the stomach contents shows differences in feeding activity between horse mackerel and sprat. In horse mackerel the mean number of victims is 210 ind/stomach (SE = 55), but the median is significantly lower - 8 ind/stomach, which again reflects uneven feeding: most individuals feed minimally, while a small proportion consume significant amounts of zooplankton (up to 1393 ind/stomach). In the case of the sprat, the average prey number was 155 ind/stomach (SE = 21) with a median of 76 ind/stomach, indicating a more moderate and even feeding. These results indicate different feeding strategies of the two species, the horse mackerel exhibits episodic, intensive feeding in the presence of zooplankton aggregations, while the sprat maintains a more stable and moderate consumption.

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- In September 2025, the average biomass of the zooplankton was $10.20 \text{ g} \cdot \text{m}^{-3} \pm 6.99$ (SE), with the main component being the gelatinous zooplankton (average $9.91 \text{ g} \cdot \text{m}^{-3} \pm 7.01$ SE), with local maxima of $\sim 90 \text{ g} \cdot \text{m}^{-3}$ south of Sozopol, indicating “bloom” phenomena. The biomass of food mesozooplankton is $235.87 \text{ mg} \cdot \text{m}^{-3}$, with the highest values ($\sim 450 \text{ mg} \cdot \text{m}^{-3}$) off the central and northern coasts. Protozoa have a low average contribution ($47.90 \text{ mg} \cdot \text{m}^{-3}$), but form local concentrations ($\sim 400 \text{ mg} \cdot \text{m}^{-3}$) in the wide part of the Burgas Bay.

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ANNEX

CPUE kg.h⁻¹ and CPUA kg.km⁻² and Biomass, kg for species of interest:

a) sprat

	start coordinates		end coordinates		CPUEkg/ h	CPUAkg/km 2	Biomass
15-30 m	43.370801	28.357654	43.350056	28.387964	4	46.548	2.9129739
15-30 m	43.372028	28.328369	43.370120	28.294406	4	46.548	2.9129739
15-30 m	43.358221	28.239688	43.359791	28.219847	2	23.274	1.4564869
15-30 m	43.322266	28.157832	43.298071	28.125714	0	0	0
15-30 m	43.203428	28.172309	43.169576	28.174166	0	0	0
15-30 m	42.963239	28.087742	42.980602	28.033573	0	0	0
15-30 m	43.000332	27.923083	43.037153	27.919640	0	0	0
15-30 m	42.857846	27.941503	42.836582	27.941211	0	0	0
15-30 m	42.688001	27.760000	42.686085	27.786268	4	46.548	2.9129739
15-30 m	42.682053	27.799807	42.671669	27.825016	0	0	0
15-30 m	42.648926	27.855245	42.621159	27.887504	2	23.274	1.4564869
15-30 m	42.622297	27.758329	42.594568	27.749814	0	0	0
30-50 m	42.725270	28.011403	42.756042	28.029273	0	0	0
30-50 m	43.308601	28.518299	43.289914	28.488888	0	0	0
30-50 m	42.768666	28.029011	42.792439	28.027821	0	0	0
30-50 m	42.802031	28.030039	42.824407	28.043859	0	0	0
30-50 m	42.832796	28.051796	42.860007	28.067552	0	0	0
30-50 m	42.872839	28.073854	42.896099	28.094279	0	0	0
30-50 m	42.761509	28.021350	42.729184	27.987388	0	0	0
30-50 m	42.640573	27.886163	42.624158	27.871030	0	0	0
30-50 m	42.618076	27.864911	42.604032	27.844954	0	0	0
30-50 m	42.560062	27.716347	42.543514	27.710318	0	0	0
30-50 m	42.535484	27.707996	42.513719	27.702046	0	0	0
30-50 m	42.459710	27.756028	42.438698	27.759763	0	0	0
30-50 m	42.426811	27.766065	42.406131	27.764898	8	93.096001	5.8259477
30-50 m	42.891534	27.946643	42.873672	27.945821	20	232.74	14.564869
30-50 m	43.308601	28.518299	43.289914	28.488888	3400	39565.8	2476.0278
30-50 m	43.237638	28.424200	43.215358	28.405059	80	930.96001	58.259477
30-50 m	43.117724	28.257153	43.080970	28.219897	120	1396.44	87.389216
50-100 m	42.242343	28.157656	42.223896	28.144979	100	1163.7	72.824346
50-100 m	42.216290	28.138676	42.194374	28.128002	640	7447.68	466.07582
50-100 m	42.649398	28.057878	42.629076	28.053270	720	8378.6401	524.33529
50-100 m	42.617741	28.047901	42.598228	28.042182	1320	15360.84	961.28137
50-100 m	42.593049	28.036570	42.563804	28.048022	1360	15826.32	990.41111
50-100 m	42.551296	28.070314	42.571025	28.053682	4800	55857.6	3495.5686
50-100 m	42.707168	28.080788	42.682209	28.069568	800	9309.6001	582.59477
50-100 m	42.670968	28.064083	42.645219	28.062099	8000	93096.001	5825.9477
50-100 m	42.820441	28.132121	42.787046	28.111579	20	232.74	14.564869
50-100 m	43.004885	28.219897	42.961853	28.225733	100	1163.7	72.824346
50-100 m	43.614000	28.765666	43.589378	28.765824	120	1396.44	87.389216
50-100 m	43.530521	28.837627	43.499564	28.843069	140	1629.18	101.95409
50-100 m	43.450772	28.908346	43.426197	28.902977	400	4654.8	291.29739

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B) whiting

strata	start coordinates		end coordinates		CPUEkg/h	CPUAg/km	Biomass
15-30m	43.370801	28.357654	43.350056	28.387964	4	46.548	2.9129739
15-30m	43.372028	28.328369	43.370120	28.294406	4	46.548	2.9129739
15-30m	43.358221	28.239688	43.359791	28.219847	2	23.274	1.4564869
15-30m	43.322266	28.157832	43.298071	28.125714	28	325.836	20.390817
15-30m	43.203428	28.172309	43.169576	28.174166	8	93.096001	5.8259477
15-30m	42.963239	28.087742	42.980602	28.033573	4	46.548	2.9129739
15-30m	43.000332	27.923083	43.037153	27.919640	4	46.548	2.9129739
15-30m	42.857846	27.941503	42.836582	27.941211	24	279.288	17.477843
15-30m	42.688001	27.760000	42.686085	27.786268	6	69.822	4.3694608
15-30m	42.682053	27.799807	42.671669	27.825016	4	46.548	2.9129739
15-30m	42.648926	27.855245	42.621159	27.887504	4	46.548	2.9129739
15-30m	42.622297	27.758329	42.594568	27.749814	4	46.548	2.9129739
30-50 m	42.725270	28.011403	42.756042	28.029273	160	1861.92	116.51895
30-50 m	43.308601	28.518299	43.289914	28.488888	0.4	4.6548	0.2912974
30-50 m	42.768666	28.029011	42.792439	28.027821	0	0	0
30-50 m	42.802031	28.030039	42.824407	28.043859	0	0	0
30-50 m	42.832796	28.051796	42.860007	28.067552	0	0	0
30-50 m	42.872839	28.073854	42.896099	28.094279	40	465.48	29.129739
30-50 m	42.761509	28.021350	42.729184	27.987388	20	232.74	14.564869
30-50 m	42.640573	27.886163	42.624158	27.871030	20	232.74	14.564869
30-50 m	42.618076	27.864911	42.604032	27.844954	28	325.836	20.390817
30-50 m	42.560062	27.716347	42.543514	27.710318	0	0	0
30-50 m	42.535484	27.707996	42.513719	27.702046	0	0	0
30-50 m	42.459710	27.756028	42.438698	27.759763	20	232.74	14.564869
30-50 m	42.426811	27.766065	42.406131	27.764898	200	2327.4	145.64869
30-50 m	42.891534	27.946643	42.873672	27.945821	20	232.74	14.564869
30-50 m	43.308601	28.518299	43.289914	28.488888	200	2327.4	145.64869
30-50 m	43.237638	28.424200	43.215358	28.405059	160	1861.92	116.51895
30-50 m	43.117724	28.257153	43.080970	28.219897	2	23.274	1.4564869
50-100 m	42.242343	28.157656	42.223896	28.144979	0	0	0
50-100 m	42.216290	28.138676	42.194374	28.128002	0	0	0
50-100 m	42.649398	28.057878	42.629076	28.053270	0	0	0
50-100 m	42.617741	28.047901	42.598228	28.042182	0	0	0
50-100 m	42.593049	28.036570	42.563804	28.048022	0	0	0
50-100 m	42.551296	28.070314	42.571025	28.053682	0	0	0
50-100 m	42.707168	28.080788	42.682209	28.069568	0	0	0
50-100 m	42.670968	28.064083	42.645219	28.062099	20	232.74	14.564869
50-100 m	42.820441	28.132121	42.787046	28.111579	48	558.576	34.955686
50-100 m	43.004885	28.219897	42.961853	28.225733	80	930.96001	58.259477
50-100 m	43.614000	28.765666	43.589378	28.765824	160	1861.92	116.51895
50-100 m	43.530521	28.837627	43.499564	28.843069	36	418.932	26.216765
50-100 m	43.450772	28.908346	43.426197	28.902977	200	2327.4	145.64869

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C) red mullet

strata	start coordinates		end coordinates		CPUEkg/h	CPUAkg/km	Biomass
15-30m	43.370801	28.357654	43.350056	28.387964	4	46.548	2.9129739
15-30m	43.372028	28.328369	43.370120	28.294406	8	93.096001	5.8259477
15-30m	43.358221	28.239688	43.359791	28.219847	0	0	0
15-30m	43.322266	28.157832	43.298071	28.125714	28	325.836	20.390817
15-30m	43.203428	28.172309	43.169576	28.174166	0.8	9.3096001	0.5825948
15-30m	42.963239	28.087742	42.980602	28.033573	0.8	9.3096001	0.5825948
15-30m	43.000332	27.923083	43.037153	27.919640	0	0	0
15-30m	42.857846	27.941503	42.836582	27.941211	20	232.74	14.564869
15-30m	42.688001	27.760000	42.686085	27.786268	0	0	0
15-30m	42.682053	27.799807	42.671669	27.825016	0	0	0
15-30m	42.648926	27.855245	42.621159	27.887504	0	0	0
15-30m	42.622297	27.758329	42.594568	27.749814	0	0	0
30-50m	42.725270	28.011403	42.756042	28.029273	20	232.74	14.564869
30-50m	43.308601	28.518299	43.289914	28.488888	320	3723.84	233.03791
30-50m	42.768666	28.029011	42.792439	28.027821	0	0	0
30-50m	42.802031	28.030039	42.824407	28.043859	280	3258.36	203.90817
30-50m	42.832796	28.051796	42.860007	28.067552	300	3491.1	218.47304
30-50m	42.872839	28.073854	42.896099	28.094279	80	930.96001	58.259477
30-50m	42.761509	28.021350	42.729184	27.987388	28	325.836	20.390817
30-50m	42.640573	27.886163	42.624158	27.871030	28	325.836	20.390817
30-50m	42.618076	27.864911	42.604032	27.844954	0	0	0
30-50m	42.560062	27.716347	42.543514	27.710318	0	0	0
30-50m	42.535484	27.707996	42.513719	27.702046	0	0	0
30-50m	42.459710	27.756028	42.438698	27.759763	16	186.192	11.651895
30-50m	42.426811	27.766065	42.406131	27.764898	0	0	0
30-50m	42.891534	27.946643	42.873672	27.945821	0	0	0
30-50m	43.308601	28.518299	43.289914	28.488888	0	0	0
30-50m	43.237638	28.424200	43.215358	28.405059	8	93.096001	5.8259477
30-50m	43.117724	28.257153	43.080970	28.219897	0	0	0
50-100m	42.242343	28.157656	42.223896	28.144979	0	0	0
50-100m	42.216290	28.138676	42.194374	28.128002	0	0	0
50-100m	42.649398	28.057878	42.629076	28.053270	0	0	0
50-100m	42.617741	28.047901	42.598228	28.042182	0	0	0
50-100m	42.593049	28.036570	42.563804	28.048022	0	0	0
50-100m	42.551296	28.070314	42.571025	28.053682	0	0	0
50-100m	42.707168	28.080788	42.682209	28.069568	0	0	0
50-100m	42.670968	28.064083	42.645219	28.062099	0	0	0
50-100m	42.820441	28.132121	42.787046	28.111579	0	0	0
50-100m	43.004885	28.219897	42.961853	28.225733	0	0	0
50-100m	43.614000	28.765666	43.589378	28.765824	0	0	0
50-100m	43.530521	28.837627	43.499564	28.843069	0	0	0
50-100m	43.450772	28.908346	43.426197	28.902977	0	0	0

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d) horse mackerel

strata	start coordinates		end coordinates		CPUEkg/h	CPUAkg/km2	Biomass
15-30m	43.370801	28.357654	43.350056	28.387964	4	46.548	2.9129739
15-30m	43.372028	28.328369	43.370120	28.294406	48	558.576	34.955686
15-30m	43.358221	28.239688	43.359791	28.219847	8	93.096001	5.8259477
15-30m	43.322266	28.157832	43.298071	28.125714	24	279.288	17.477843
15-30m	43.203428	28.172309	43.169576	28.174166	80	930.96001	58.259477
15-30m	42.963239	28.087742	42.980602	28.033573	28	325.836	20.390817
15-30m	43.000332	27.923083	43.037153	27.919640	24	279.288	17.477843
15-30m	42.857846	27.941503	42.836582	27.941211	20	232.74	14.564869
15-30m	42.688001	27.760000	42.686085	27.786268	56	651.672	40.781634
15-30m	42.682053	27.799807	42.671669	27.825016	60	698.22	43.694608
15-30m	42.648926	27.855245	42.621159	27.887504	4	46.548	2.9129739
15-30m	42.622297	27.758329	42.594568	27.749814	40	465.48	29.129739
30-50m	42.725270	28.011403	42.756042	28.029273	56	651.672	40.781634
30-50m	43.308601	28.518299	43.289914	28.488888	12	139.644	8.7389216
30-50m	42.768666	28.029011	42.792439	28.027821	0	0	0
30-50m	42.802031	28.030039	42.824407	28.043859	8	93.096001	5.8259477
30-50m	42.832796	28.051796	42.860007	28.067552	8	93.096001	5.8259477
30-50m	42.872839	28.073854	42.896099	28.094279	8	93.096001	5.8259477
30-50m	42.761509	28.021350	42.729184	27.987388	32	372.384	23.303791
30-50m	42.640573	27.886163	42.624158	27.871030	32	372.384	23.303791
30-50m	42.618076	27.864911	42.604032	27.844954	36	418.932	26.216765
30-50m	42.560062	27.716347	42.543514	27.710318	16	186.192	11.651895
30-50m	42.535484	27.707996	42.513719	27.702046	16	186.192	11.651895
30-50m	42.459710	27.756028	42.438698	27.759763	20	232.74	14.564869
30-50m	42.426811	27.766065	42.406131	27.764898	0	0	0
30-50m	42.891534	27.946643	42.873672	27.945821	0	0	0
30-50m	43.308601	28.518299	43.289914	28.488888	0	0	0
30-50m	43.237638	28.424200	43.215358	28.405059	0	0	0
30-50m	43.117724	28.257153	43.080970	28.219897	0	0	0
50-100m	42.242343	28.157656	42.223896	28.144979	0	0	0
50-100m	42.216290	28.138676	42.194374	28.128002	0	0	0
50-100m	42.649398	28.057878	42.629076	28.053270	0	0	0
50-100m	42.617741	28.047901	42.598228	28.042182	0	0	0
50-100m	42.593049	28.036570	42.563804	28.048022	0	0	0
50-100m	42.551296	28.070314	42.571025	28.053682	0	0	0
50-100m	42.707168	28.080788	42.682209	28.069568	0	0	0
50-100m	42.670968	28.064083	42.645219	28.062099	0	0	0
50-100m	42.820441	28.132121	42.787046	28.111579	0.22	2.56014	0.1602136
50-100m	43.004885	28.219897	42.961853	28.225733	0	0	0
50-100m	43.614000	28.765666	43.589378	28.765824	0	0	0
50-100m	43.530521	28.837627	43.499564	28.843069	0	0	0
50-100m	43.450772	28.908346	43.426197	28.902977	0	0	0

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