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MINISTRY OF AGRICULTURE AND FOOD

MARITIME, FISHERIES AND AQUACULTURE PROGRAMME

PELAGIC TRAWL SURVEYS IN THE BULGARIAN MARINE AREA, SEPTEMBER 2024

SCIENTIFIC REPORT

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Project No. BG14MFOP001-1.002-0001 "Collection, management and use of data for the purposes of scientific analysis and implementation of the Common Fisheries Policy for the period 2023-2024", 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 2024 in the Bulgarian Black Sea area on board of R/V HAITHABU in execution of the National Program of Bulgaria for data collection.

BULGARIAN ACADEMY OF SCIENCES

INSTITUTE OF OCEANOLOGY

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1. Introduction

Pelagic Trawl Survey was accomplished in September 2024 in the Bulgarian Black Sea zone. The biological analysis is based on the biomass of the species found during the study. Besides, an analysis of the distribution and abundance of the other species caught as by-catch is presented. Sprat (*Sprattus sprattus*) is a key species for the Black Sea ecosystem. Together with the anchovy, sprat is one of the most abundant, planktivorous, pelagic species. The level of its stocks depends on the conditions of the environment mainly and on the fishing effort.

The changes in the environment due to anthropogenic impact affect the dry land as well as the World Ocean. The level of sea pollution and its "self-purifying" ability is completely different. There is a clear indication of changes in the natural equilibrium in the corresponding ecological niches (Prodanov et al., 1997). The biggest impact in the World Ocean is fishing, which directly destroys a significant part of the species' populations. As a result of overexploitation and climate change, many commercially exploited species are critically endangered or vulnerable. The abundance of fish stocks depends on various abiotic and biotic factors, the most important of which are the level of fishing mortality, changes in trophic levels due to the mass reproduction of *Mnemiopsis leidyi*, algal blooms that lead to hypoxia in shallower also leads to mass mortality of benthic organisms, etc.

The state of the biomass (agglomerations) of the sprat from the Bulgarian coast shows relative stability, despite the constant level of exploitation (in the western and northwestern part of the Black Sea) and climatic fluctuations in recent years.

Estimates of abundance and size distributions of fish stocks based on experimental trawls have become a necessity in fisheries management (GodØ et al., 1990). A basic assumption in these studies is that the catch rate is constant, no matter how long the trawling is. Any deviation from the linear relationship between catch and fishing effort can have a significant impact on catch composition and abundance estimates, as well as bias the results of trawl surveys (Wassenberg et al., 1998). The duration of fishing effort during the relevant trawling period can last up to 200 minutes (Godø, 1990), but for economic reasons, together with the need for a large number of replicates and to maintain statistical validity, the duration of trawling is reduced. Thus, the standard duration of trawls varies from 30 to 120 minutes for each selected station. Some authors (Godø, 1990; Wassenberg et al., 1998; Somerton et al., 2002) suggest that larger specimens may swim in the trawl without entering the bag and that trawling of different durations may affect levels of the catch and of the size distributions in the trawl. Thus, some size groups may not be caught in short-duration trawls.

Average catch (in units of weight or in numbers) per unit effort or per unit area are indices of stock abundance (assumed to be proportional to abundance). These indices can be converted into an absolute measure of biomass through the so-called "area method", which belongs to the so-called holistic methods (www.fao.org).

The theoretical justification of the method is given by Gulland (1975), Saville (1977), Troadec (1980), Doubleday (1980), and Grosslein and Laurec (1982). Planning, design, data collection, data recording, analysis and reporting are summarized in Butler et al. (1986), ICOD (1991) and Strømme (1992).

The area method extrapolates the average catch by the research vessel per unit net area trawled to the entire study area (Saville, 1977). This method assumes a random distribution of fish in a given area and 100% gear efficiency in catching all fish. But in practice, catchability is not 100% in all cases (Kock, 1992). Thus the biomass estimate can be underestimated if there is a lack of balancing of the trawl boards, stops and weights, i.e. the so-called a "drive-through" effect to the trawl inlet (Kock, 1985).

The pelagic trawl survey (OTM) was carried out on board the fishing vessel "HaitHabu" (Picture 1).

Picture 1. R/V HaitHabu

The main characteristics of the ship:
IMO: 8862686
MMSI: 207139000
Call sign: LZHC
Flag: Bulgaria [BG]
AIS Vessel Type: Other
Gross Tonnage: 142
Length Overall x Breadth Extreme: 24.53m × 8m
Crew: 6
The size of the pelagic trawl are as follows:

- Pelagic trawl type 50/35 – 74 m
- Headroap length – 40 m
- Horizontal opening – 16 m
- Vertical opening – 7 m
- Mesh size – 7x7 mm
- Effective part of trawl – 27 m
- Pelagic doors – 3.5 m^2

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).

2. Material and Methods

Pelagic trawl survey was accomplished following the National Programs for Data Collection in the Fisheries sector of Bulgaria for 2024. The study was conducted in September 2024, in the area enclosed between Durankulak and Ahtopol (Bulgaria) with a total length of the coastline of 370 km. The study area encloses waters between 42°05’ and 43°45’ N and 27°55’ and 29°55’ E.

During the survey, a total of 36 trawls were carried out in the Bulgarian area. The survey was conducted during the day, and 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
- Sample storage

2.1. 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 the depth – **Strata 1** (15–30 m), **Strata 2** (30–50 m), and **Strata 3** (50–100 m). The research area in Bulgarian waters is divided into 128 non-overlapping polygons of equal size, located at a depth between 15–100 m. In 36 of the sites randomly selected, sampling was carried out using pelagic trawling (Picture 2.1.1.).

Picture 2.1.1. Trawling operation

Each field is a rectangle with sides 5″ Lat x 5″ Long and an area of about 62.58 km^2 (measured by applying GIS), large enough to trawl for a corresponding time in the meridional direction. The fields are grouped into larger sectors - the so-called layers, whose geographical and depth limits are selected according to the distribution and density of the species in the survey process. Only one trawling was carried out on each of the fields, lasting between 30–40 min at a speed of 2.7–2.9 knots (Picture 2.1.2.).

Picture 2.1.2. Catch in trawl with R/V HaitHabu

2.2. Onboard sample processing

During the observations, the following number of specimens of the registered species were processed:

Table 2.2.1. Number of processed individuals

Species	Number
sprat	1200
whiting	1000
red mullet	500
horse mackerel	1000
anchovy	10

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Picture 2.2.1. Catch and by-catch in OTM

The data for the samples collected at each trawl included measurement of the following parameters (Gulland, 1966):

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

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

2.3. Laboratory analyses

The processing of the samples collected on board continues in laboratory conditions, determining the age and nutritional composition of the stomach contents of the trison.

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

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Dietary spectrum was determined by partitioning the stomach contents of species into taxonomic groups identified to the lowest possible taxonomic level.

2.4. Statistical analyses

Swept area method

This method is based on (near) bottom trawling (protrawled area), a widely used direct method for estimating the instantaneous biomass of benthic and benthic organisms (Fig. 2.4.1, 2.4.2).

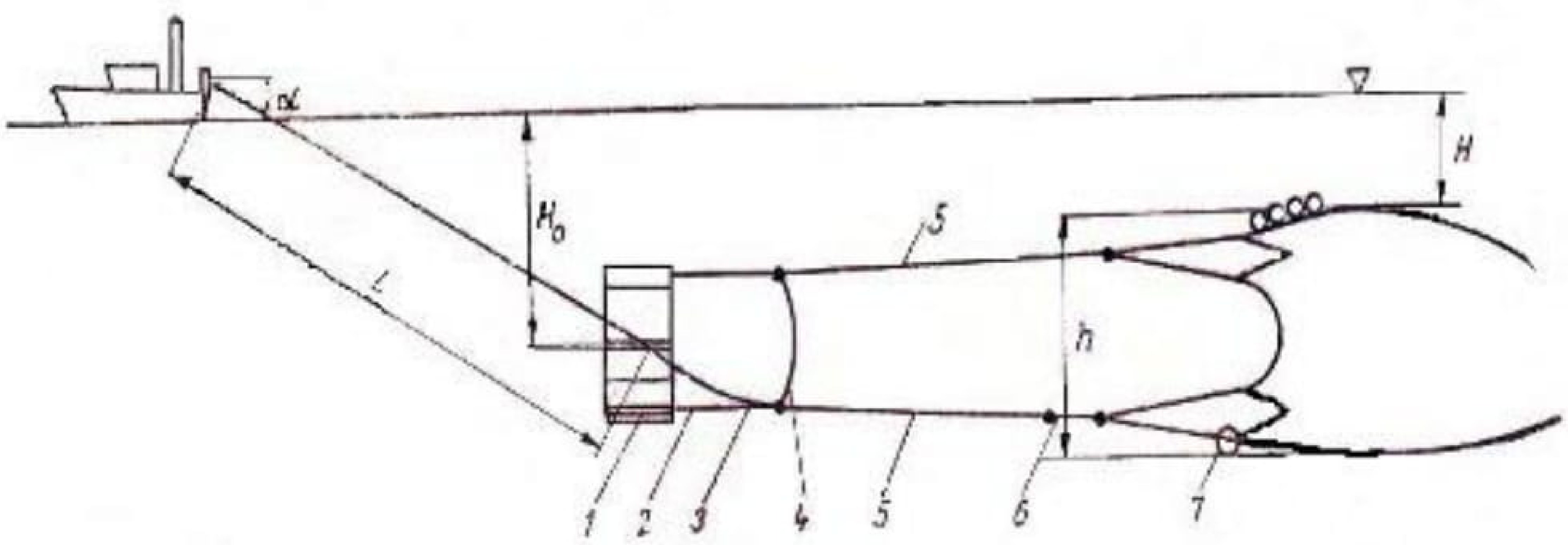


Figure 2.4.1. Scheme of the trawl, used in the Swept area method (according to Grudev et al., 1981) 1 - trawl door; 2 - conjections; 3 - transitional wire; 4 - compensator; 5 - wires; 6 - extention cord; 7- deepener

In Figure 2.4.2. the scheme of the so-called bathy-pelagic trawl for catching sprat is represented.

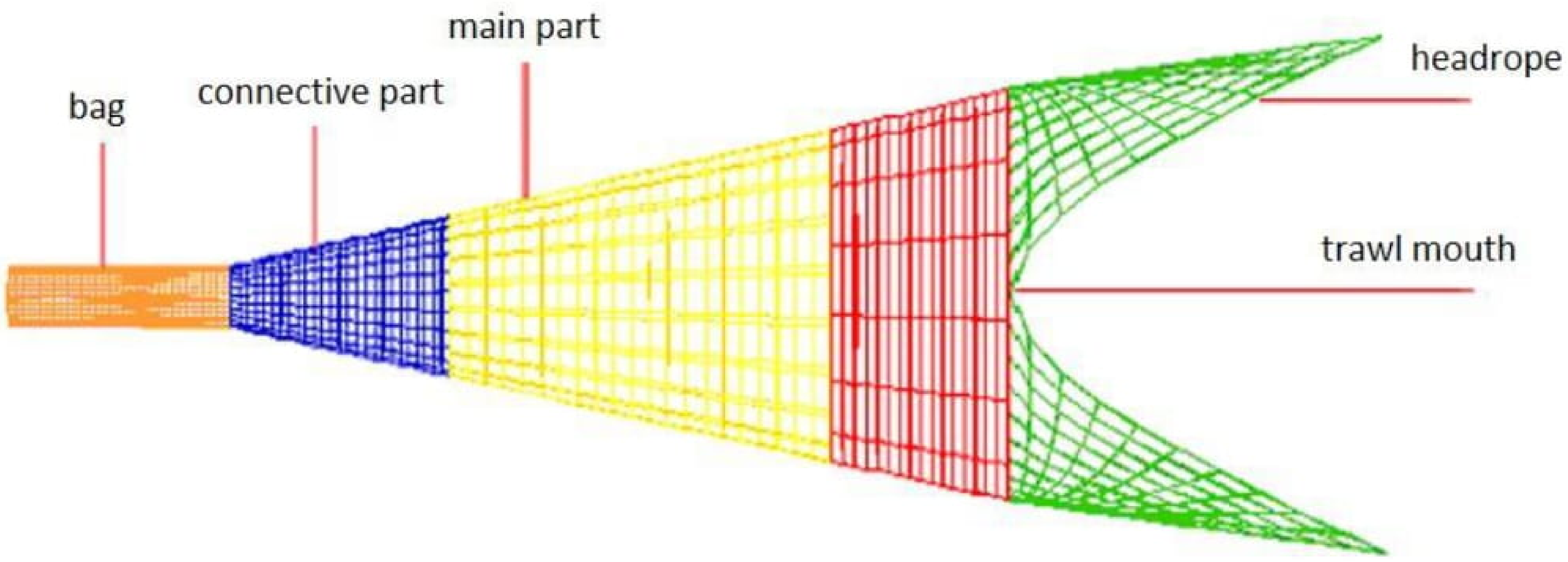


Figure 2.4.2. Scheme of bathy-pelagic trawl for sprat catch

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:

(1) $a = D * hr * X2$
$D = V * t$

(where: a – trawling area, V – trawling velocity, hr* 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), dir$V$ 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) $(\frac{C_{w/t}}{a/t}) = C_{w/a} kg / sq.km$

where: *Cw/t* – catch per unit effort, a/t – trawling area (km^2) 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) $$VAR(B) = A^2 * \frac{1}{n} * \frac{1}{n-1} * \sum_{i=1}^{n} \left[Ca(i) - \overline{Ca}\right]^2$$

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:

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

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

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) MSY = 0.5*M*Bv

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

A relative yield-per-recruit model with uncertainties:

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

where: U = 1-(Lc/L∞)
m = (1-E)/(M/k) = k/Z
E = F/Z – exploitation coefficient

Converted catch curve

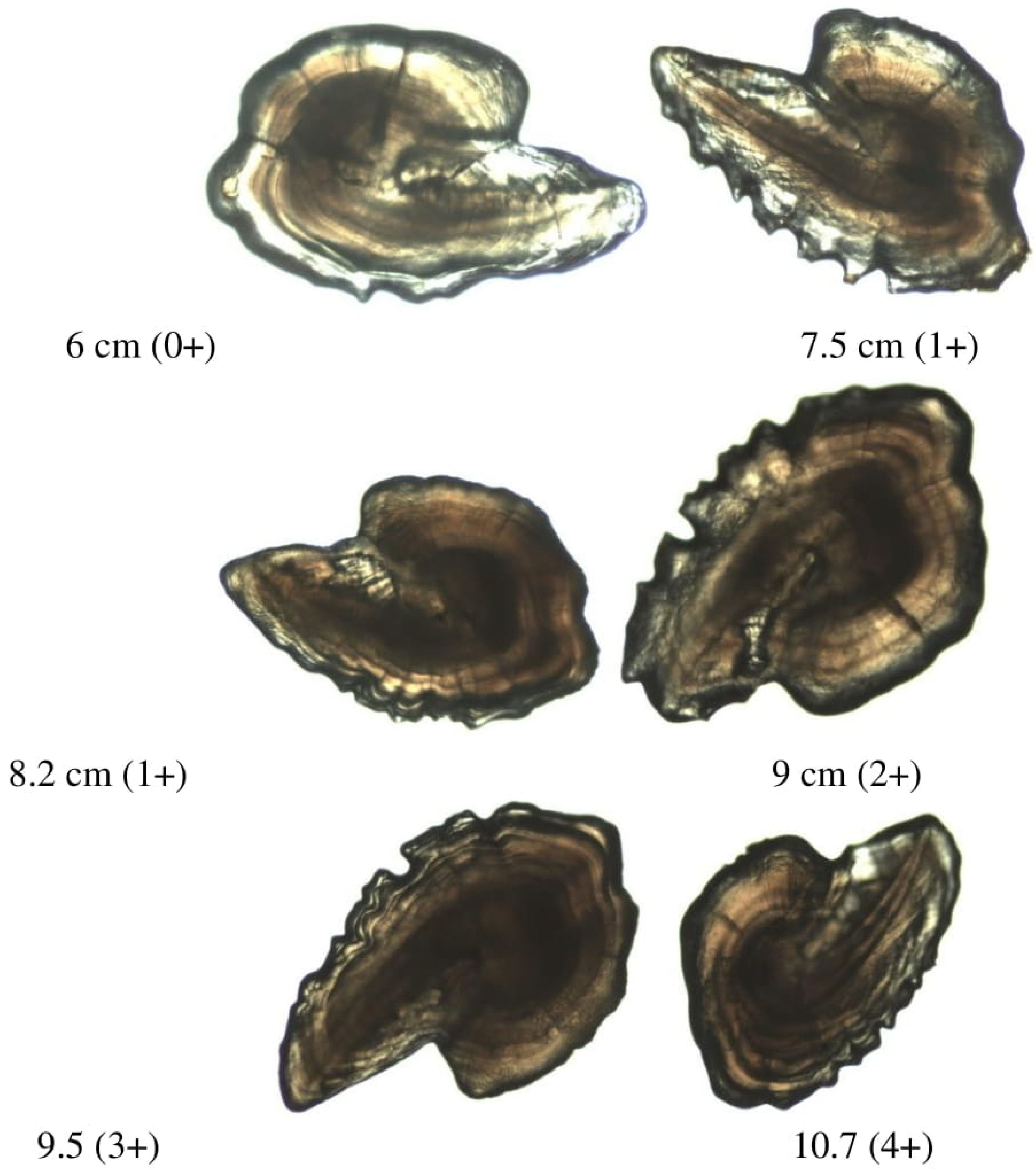
Several methods are available by which total mortality (Z) can be estimated from length-frequency data. Thus, it is possible to obtain reliable estimates of Z (total mortality) from the mean length in a representative sample or the slope of cumulative Jones' plot. A variety of approaches have been presented to analyze length-frequency data, which are the functional equivalent of (age structured) catch curves. These "length-converted catch curves" are built around assumptions similar to those involved in age-structured catch curves.

2.5. 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 2.5.1). Otoliths have a characteristic shape that is highly specific but varies greatly among species.



Picture 2.5.1. 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.

2.5.1. 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 (±0.01g), sex, maturation stage (I-V), and gonad weight (±0.01g) 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.

2.5.2. Preparation of the otoliths for the age determination

Otoliths are placed in small black convex laboratory glasses containing 96% ethyl alcohol for age determinations under a binocular stereo microscope that is side and top illuminated (Fig.

2.5.2.1.) (Polat and Beamish, 1992). The magnification used depends on the size of the otolith, with 4X magnification being optimal for the sprat.

Figure 2.5.2.1. Binocular stereo microscope

2.5.3. Age determination and analysis of annual rings

The first step is to clarify the location of the center and the first age ring. The observation of consecutive rings, whether continuous or not, is then important. Identify the fish in growth or the end of the growth period by checking the characteristics of the otolith rim ring to decide whether it is opaque or hyaline. After these procedures, the otoliths can be read according to these protocols, which are very important to provide age data to determine realistic population parameters and reduce abnormal procedures and biases through standardized age reading criteria.

Isometric growth is observed in the sprat in the left and right otoliths. These are small and transparent formations (Fig. 2.5.3.1.). It has summer and winter rings and a core in the center. There are spring rings - opaque, and rings in late autumn – hyaline, which are taken into account during age calculations (Pısıl, 2006).

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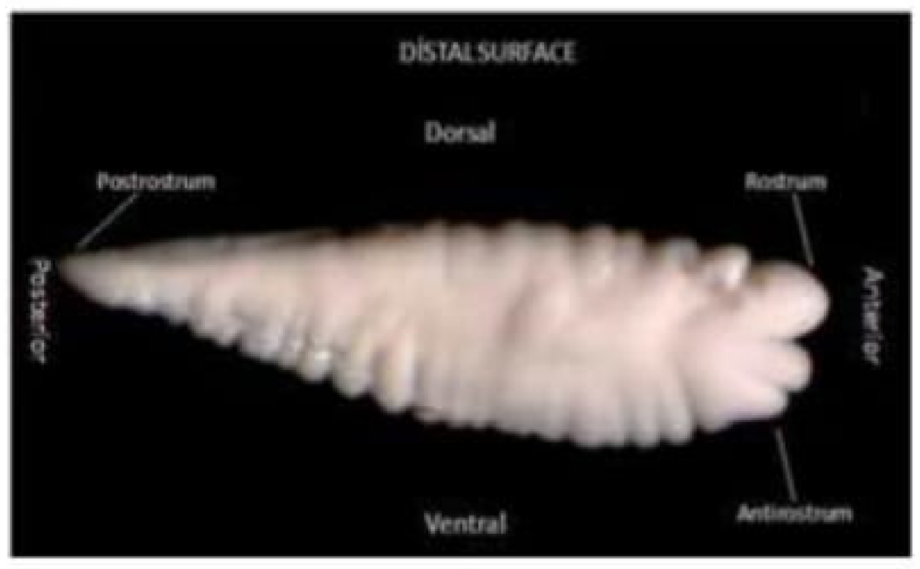
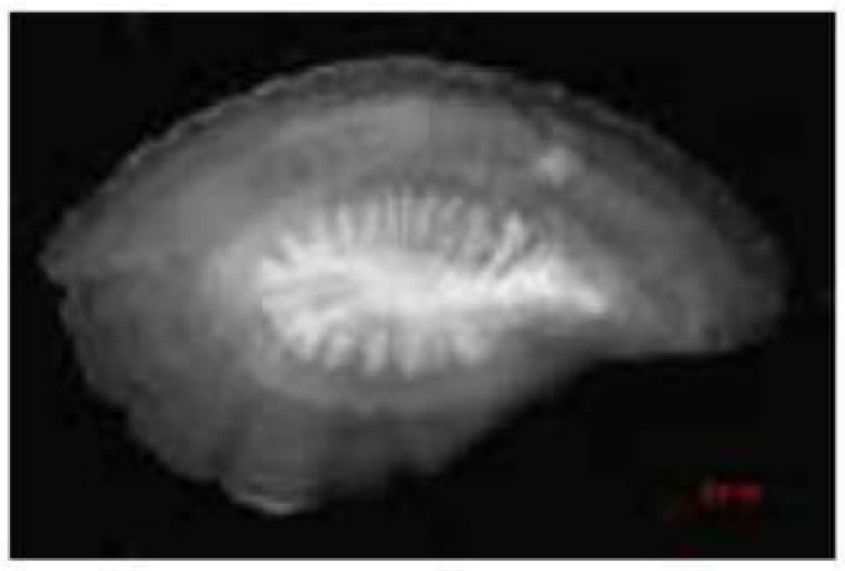
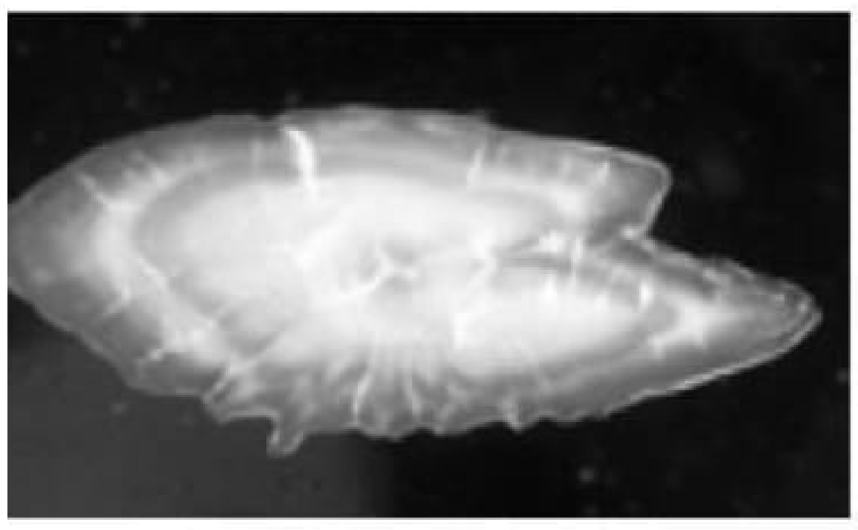
Sprattus sprattus



Merlangius merlangus



Trachurus mediterraneus



Engraulis encrasicolus

Pomatomus salstarix

Mullus barbatus

Figure 2.5.3.1. Sprat, whiting, horse mackerel, anchovy, bluefish, and red mullet otoliths

2.5.4. Age reading protocol for sprat

1. The dissected otoliths are rinsed and 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 determined by the size of the corresponding otolith. This increase is intended not to change the velocity, which may allow rings to be seen that are unrepresentative for age determination in the larger otoliths. A magnification of four times allows the hyaline zones to be best seen in the sprat otoliths.
4. Otolith are observed from their distal surface.
5. January 1st of the respective year is considered as the starting date of hatching of the sprat.
6. A central point surrounded by hyaline rings is formed after the end of consumption of 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 and continuous concentric rings elongated close to the real hyaline ringe are counted together with the real one as one age. This ring may be either very small and opaque inside the hyaline band, or a small hyaline ring near the outer edge of the opaque ring.
8. Sprat and some other species with a short life cycle have a very rapid growth rate, especially in the first years. The width of the growth rings after the second year becomes relatively narrower. This should be taken into account when counting the rings of older speciemens.

The number of small and weak hyaline rings known as false rings in the opaque region is not so high and their separation from age rings is rather easy. When numerous and indistinguishable, these otoliths should not be used.

2.6. Sex and maturity estimation

2.6.1. Maturity stages

It is very important to use standardized maturity scales for sprat (and all species) to evaluate sampling strategies and timing for accurate maturity classification for both sexes. For sprat, the small gonad size and the batch spawnings from several egg cohorts over a long period of time are the main challenges for standardizing the maturity scale.

According to the ICES (2011), the the standardized sex product maturation tables for sprat include 6-stages for both sexes (Fig. 2.6.1.1, Table 2.6.1.1).

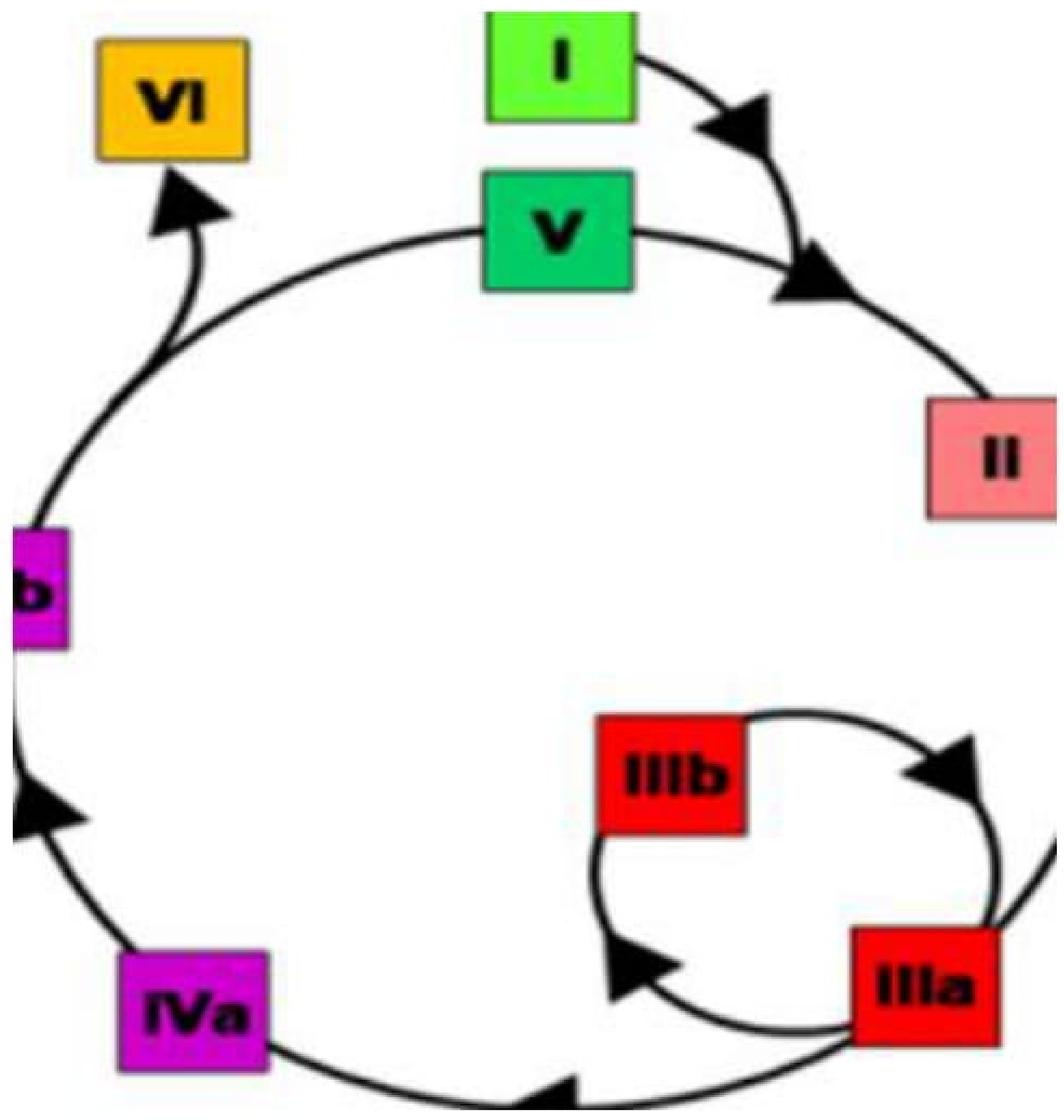


Figure 2.6.1.1. Scale with six maturity stages in sprat (Name of the stages are given in Table 2.6.1.1)

In particular, specimens without visible gland development were combined into Immature and Preparation, given that the spawning stage is subdivided into a stage of inactive spawning (maturation and re-maturation, which characterized by visible gamete development) and an active spawning stage, which is evident from the hydrated eggs. The integration of maturation and re-maturation into the spawning stage allows accurate determination of the maturing and spawning individuals of the population.

Table 2.6.1.1. Macroscopic and histological characteristics of gonad developmental stages

Stages	*Macroscopic Characteristics*	*Histological characteristics*
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-Immature	*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*	*OG+/-PGI*
II. Preparation	*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.*	*PG1, PG2, CA*
III. Spawning		

a. Inactive	*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 color and less firm than an ovary maturing the first batch, few hydrated oocytes may be left*	*PG1, PG2, CA, VT1, VT2, VT3, +/- POF*
b. Active	*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 ½ 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*	*SG, PS, SS, ST, SZ*

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b. Active	*reddish or brownish blotches and grey at the lower edge with partly whitish remains of sperm* *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*
IV.a. Cessation *IV.b. Recovery*	*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.* *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, atretic SS, ST and SZ* *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*

2.7. Batch fecundity

All fish were measured to the nearest 1 mm in total length (TL) and weighed to the nearest 1 gram. The gonads of the fish are examined under a microscope for external characteristics such as hardness and color to determine the stage of maturity. Sex ratio is also calculated in this study i.e. no. of males / no. of females (Simon et al., 2012). Females were identified by macroscopic observation of a mature ovary (Laevastu, 1965). Fecundity rates can vary considerably during the short spawning season, being low at the beginning, peaking during the high spawning and declining again towards the end. Batch fecundity of sprat was determined using the 'Hydrated Oocyte Method' (Hunter et al., 1985). Fat hydrated females are used. After sampling, their body cavity is opened and preserved in buffered formalin solution (Hunter et al., 1985). The ovary-free female weight and the ovary weight are determined. Three tissue samples of ca. 50 mg are removed from different parts of the ovary and their exact weight is determined. The number of hydrated oocytes in each of the three subsamples is determined under binoculars. Hydrated oocytes can be easily distinguished from all other types of oocytes due to their large size and translucent appearance and their wrinkled surface due to formalin preservation. Batch fecundity is estimated based on the average number of hydrated oocytes per unit weight of the three samples.

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

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

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

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

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

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

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_o – 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:

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

$$(15)\quad \log M = -0{\cdot}2107 - 0{\cdot}0824 \log W_\infty + 0{\cdot}6757 \log K + 0{\cdot}4627 \log T^\circ C$$

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

3. Planktivorous fish species feeding

Material and methodology

The study on the diet of planktivorous fish (horse mackerel, anchovy, whiting, and sprat) in the western Black Sea was based on the analysis of stomach contents of 173 specimens (63 - sprat; 10 - anchovy; 90 - horse mackerel, 10 - whiting) collected between 8. IX and 15.IX 2024.

During this period, data on the composition and quantity of mesozooplankton in the marine environment were collected, as this group of organisms forms the main food base of the fish species studied.

The coordinates of the study area and descriptions of the data are presented in Table 3.1.

Table 3.1. Study areas in September 2024

Date	Trawl №	Coordinates		Depth (m)	Temperature (°C)
		Latitude	Longitude		
08.09.2024	T9	42.688307	27.774790	20	25.8
09.09.2024	T10	42.796667	28.119333	52	22.6
09.09.2024	T11	42.824231	28.143323	53	22.8
09.09.2024	T14	42.953097	28.222699	52	22.6
10.09.2024	T16	43.393233	28.857102	78	22.4
10.09.2024	T18	43.369842	28.303860	18	24
11.09.2024	T20	43.257746	28.089223	21	23.4
11.09.2024	T22	42.974390	28.112211	35	23.8
12.09.2024	T24	42.459813	28.012180	50	23.2
12.09.2024	T26	42.550287	27.903054	37	24
13.09.2024	T28	42.324325	28.022602	52	24.2
13.09.2024	T30	42.372789	28.021577	47	24.2
14.09.2024	T32	42.440157	27.709912	40	24

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14.09.2024	T34	42.463126	27.726403	35	24.2
15.09.2024	T36	42.596958	27.730651	30	23.6

From the trawl catch, approximately 10 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.

1. Index of stomach fullness (ISF) as a percentage of body mass: (weight of stomach contents/weight of fish body) × 100

2. Index of relative importance (IRI; PINKAS et al., 1971): IRI = (N + M) × 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 µm 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 (Mordukhai-Boltovsky et al., 1968) and the quantity in a Bogorov chamber, according to the methodology of Korshenko and Aleksandrov (2013).

4. Species diversity

The total number of species identified during the study was 22, of which 15 fish, 2 crustaceans, 2 molluscs and 3 macrozooplankton species. The most common species in trawls (presence/absence) are: *M. merlangius* (34.8%), *T. mediterraneus* (22.76%), *M. barbatus* (16.03%). *S. sprattus* and *E. encrasicholus* were observed sporadically in the catches. Other species such as *A. immaculata*, *N. melanostomus*, *G. niger*, *M. batrachocephalus*, *Z. ophiocephalus*, *R. clavata*, *D. pastinaca*, *P. lascaris*, *T. draco*, *S. Maximus*, *Sq. acanthias* and *A.stellatus* have a negligible presence in catches.

During the research period, 36 trawls were processed in the Bulgarian region of the Black Sea on board the R/V "HaitHabu". The research was conducted in September 2024 (Fig. 4.1.).

Figure 4.1. Location of the stations in September 2024

Trawling time for the survey period was between 30 and 40 min at depths between 15 m and 100 m in the area between Ahtopol, Kiten and Durankulak. Sprat was observed in depth exceeding 18 m.

5. Whiting (*Merlangius merlangus*)

5.1. Distribution

Whiting inhabits the layer near the bottom and feeds mainly on sprat. The species is a predator and is an important component of the food chain of other larger predators such as turbot and dolphins. Whiting was not significantly represented in the catches. This may be related to relatively high temperatures during the study.

5.2. Whiting biomass from different depths

During the survey, the whiting was ubiquitous, with biomass values being highest in the 30–50 m layer: 1589.8 t, followed by 1030.6 t (50–75 m) and 472.8 t (15–30 m) (Fig. 5.2.1).

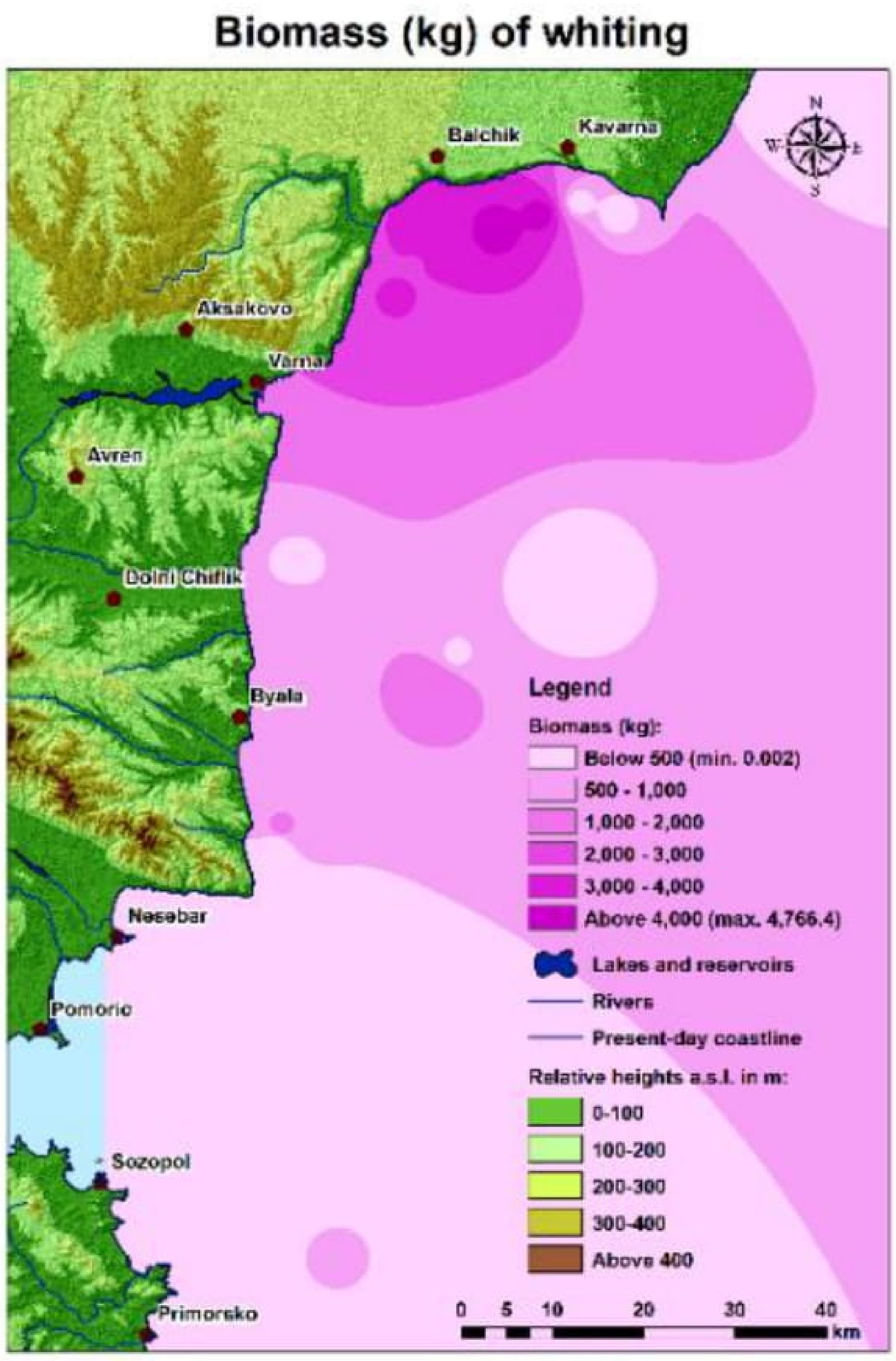

Figure 5.2.1. Whiting biomass at different depth layers in September 2024

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The total investigated area was 8010.24 km^2, and the amount of the total biomass of whiting was 3093.2 t (Tables 5.2.1, 5.2.2; Fig. 5.2.2). The densest aggregations were observed in front of Balchik, "Zlatni pyasatsi" resort, and Aladzha Bank.

Table 5.2.1. Area method for surveying stocks in the month of September 2024 – average values of catch per unit area (CPUA), biomass (kg), Ax – area and number of fields

CPUA, average	Depth	Biomass	Ax area	Number of the field
228.94	15-30	472.7932	2065.14	33
567.9	30-50	1589.745	1814.82	29
384.9	50-75	1030.636	4130.28	66
		3093.174	8010.24	128

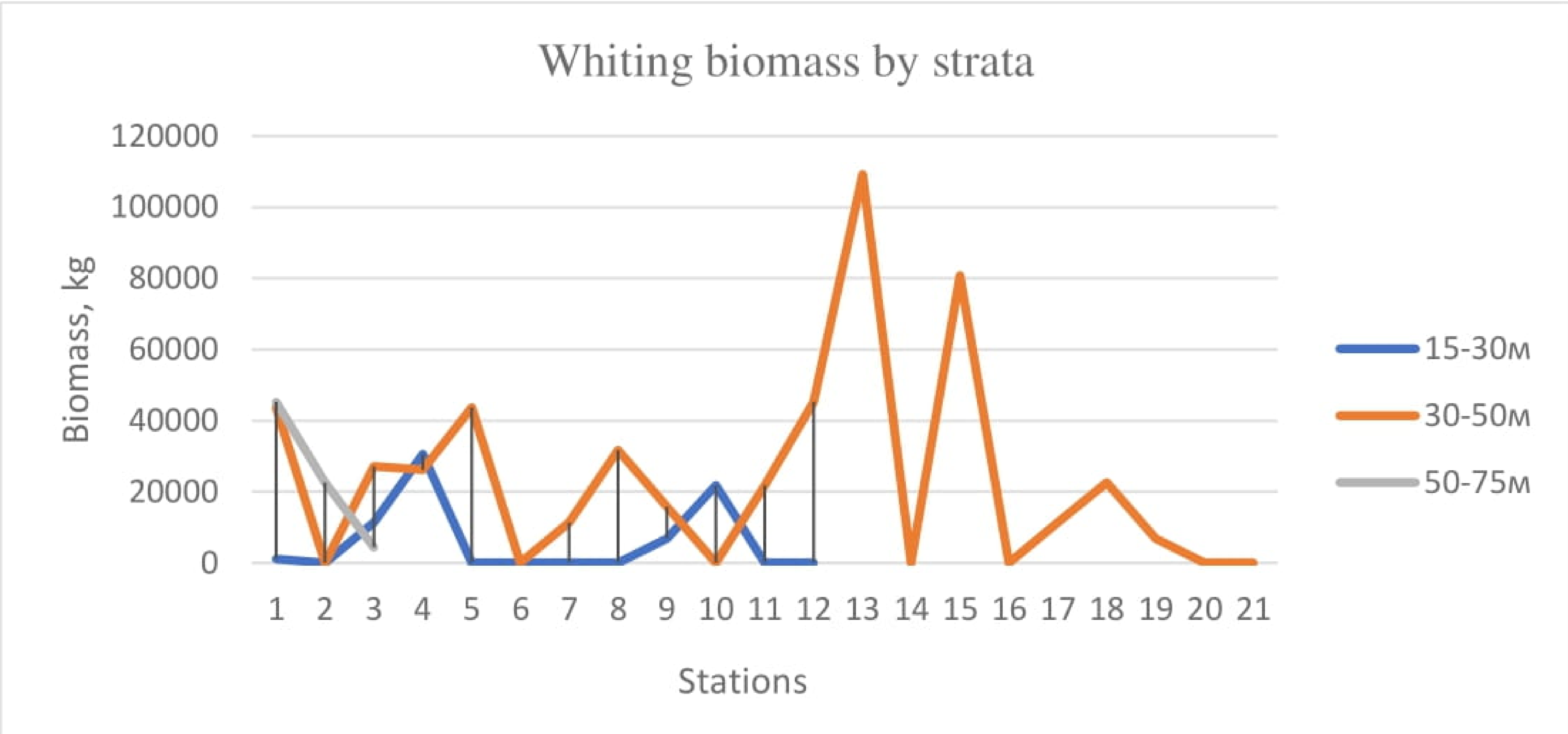

Figure 5.2.2. Whiting biomass (kg) by strata in September 2024

Table 5.2.2. Descriptive statistics of the CPUA indices (t) of whiting in September 2024

	15-30 m	30-50 m	50-100 m
Average	228.94	567.9	384.9
Standard error	145.3255	212.455	100.02144
Median	216.4522	238.02955	370.26818
Fashion	#N/A	105,79091	#N/A
Standard deviation	302.32271	255.63373	203.49288
Variation	91399.019	65348.603	41409.351
Excess	-1.648688	-0.307774	0.3095325
Asymmetry	0.385634	0.948337	0.3319474
Range	687.64091	740.53637	528.95455
Minimum	105.79091	52.895455	105.79091
Maximum	793.43182	793.43182	634.74546
Amount	1692.6546	3755.5773	1745.55
Number	4	12	5
Greatest Value (1)	766.256	985.365	634.74546
Smallest value (1)	161.2441	187.3325	106.79091
Confidence level (95.0%)	481.06289	162.42192	252.66978

5.3. Catch per unit area

Whiting was represented in the composition of catches during the first part of the expedition conducted in September 2024 with the highest distribution density of the species recorded in the area of Balchik, Kavarna, Aladzha Bank, in front of the mouth of the river Kamchia, Burgas Bay (Fig. 5.3.1.). In a depth layer of 30–50 m, the highest values for CPUA were recorded – 1745.7 $kg.km^{-2}$, with an average value of 228.9 $kg.km^{-2}$. In the depth layer 15–30 m, 488.8 $kg.km^{-2}$ and 50–75 m – 723.2 $kg.km^{-2}$, the species was recorded in separate trawls (Fig. 5.3.1.).

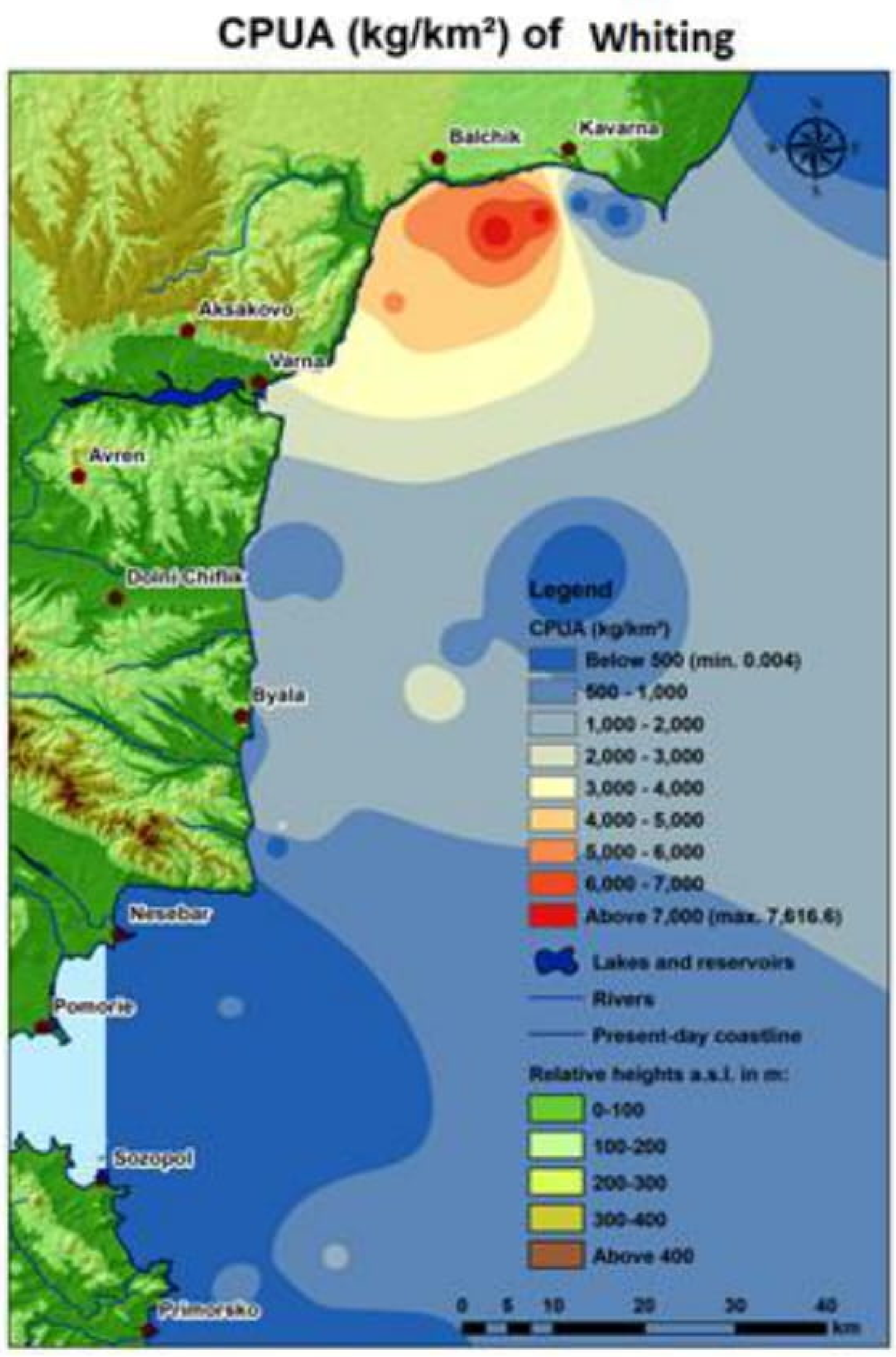

Figure 5.3.1. Catch per unit area (CPUA kg.km^{-2}), September 2024

5.4. Catch per unit effort

The catch per unit effort (CPUE) for the species is presented graphically on Fig. 5.4.1. The highest CPUE values (kg.h^{-1}) were observed in front of Balchik, Kavarna, and Aladzha Bank ("Zlatni pyasatsi" resort).

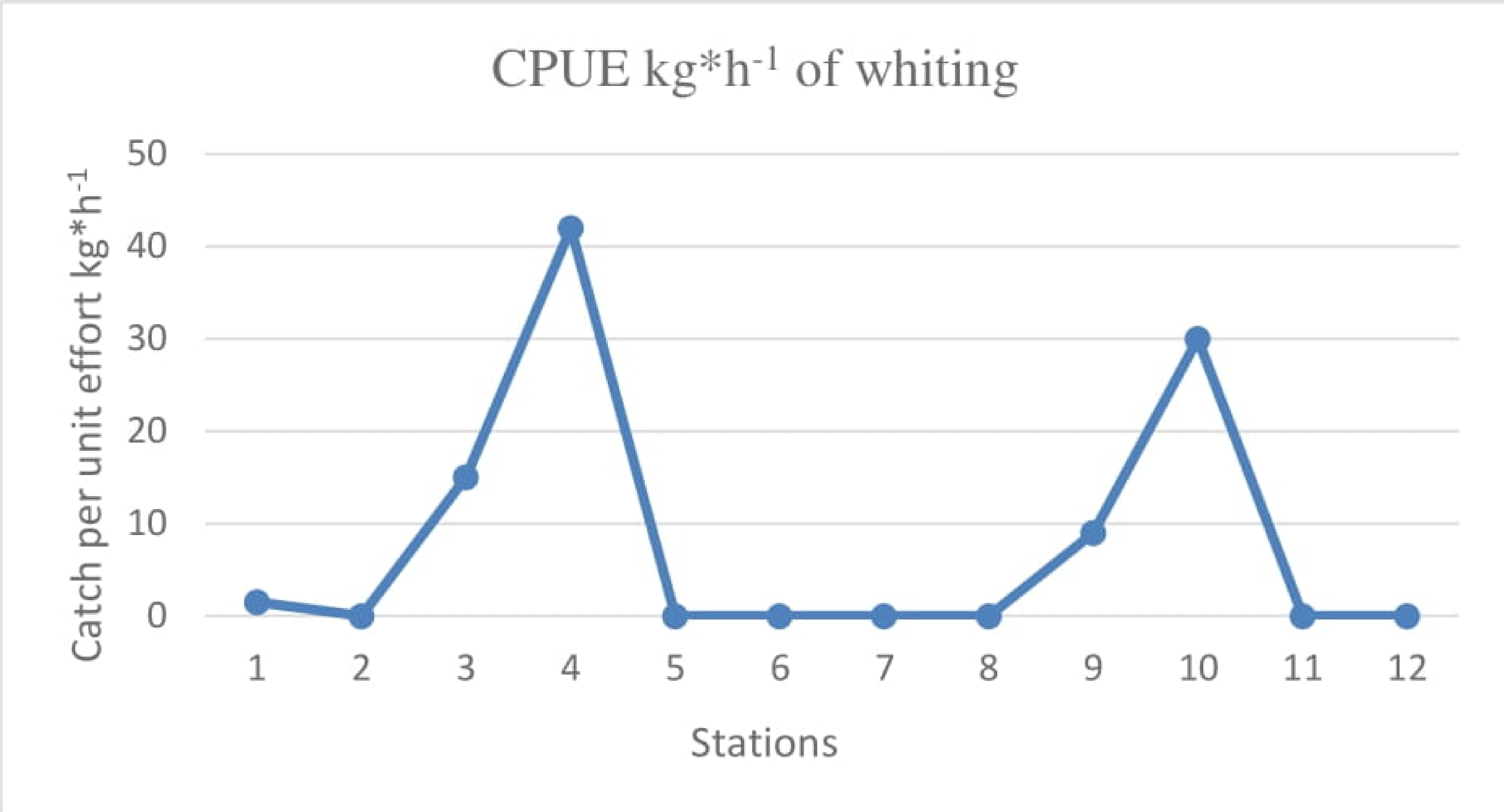

Figure 5.4.1. Catch per unit effort (CPUE kg*h^{-1}) of whiting by depth strata

5.5. Length – weight relationship

The length – weight relationship of whiting is described by the model W = 0.008.L^{2,89}, coefficient of allometric growth > 3, and the obtained nonlinear model of dependence length-weight has a high degree of determination (R^2 = 0.9903) (Fig. 5.5.1).

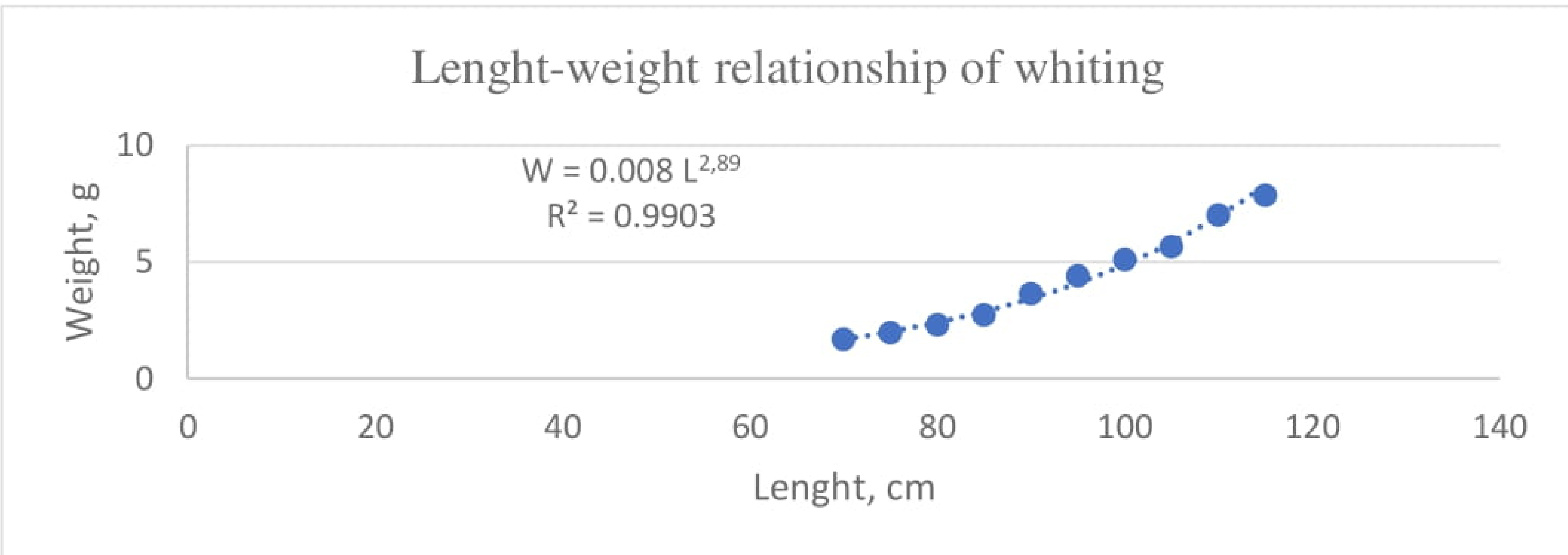

Figure 5.5.1. Length-weight relationship of whiting, September 2024

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The size structure of the whiting stock is presented in figure 5.5.2. The distribution of lengths in the whiting was normal (Gaussian), with 1 – bell shape, as the most common lengths in the samples were in the range 8.5–10 cm. A peak was observed in the 10.5 cm size group.

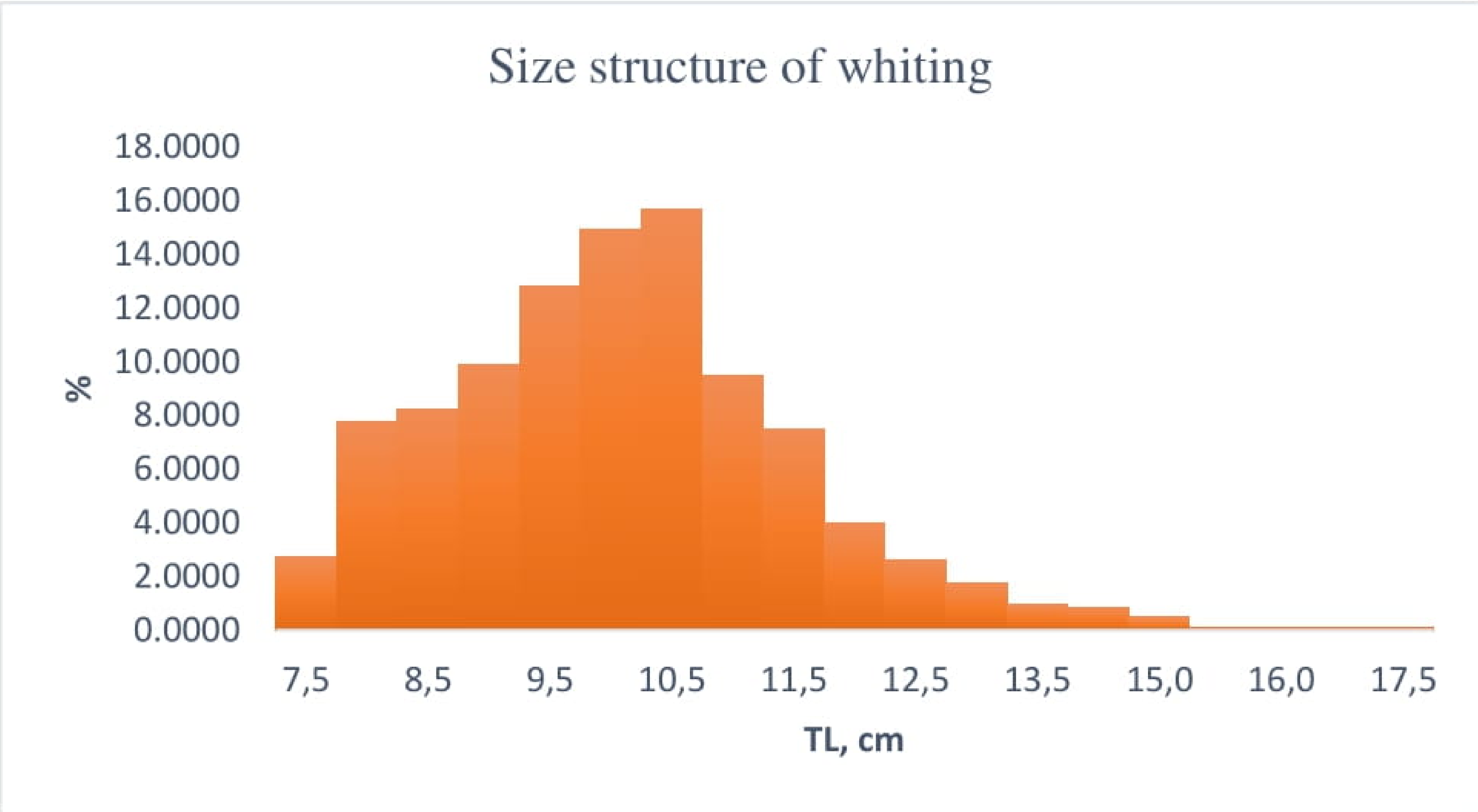

Figure 5.5.2. Size structure of whiting, September 2024

The weight distribution (Fig.5.5.3) in the whiting samples is normal (Gaussian), with 1 – bell-shaped, since the most common weights in the samples are in the range 3 - 42.6 grams. A peak was observed in weight group 7. 98 grams.

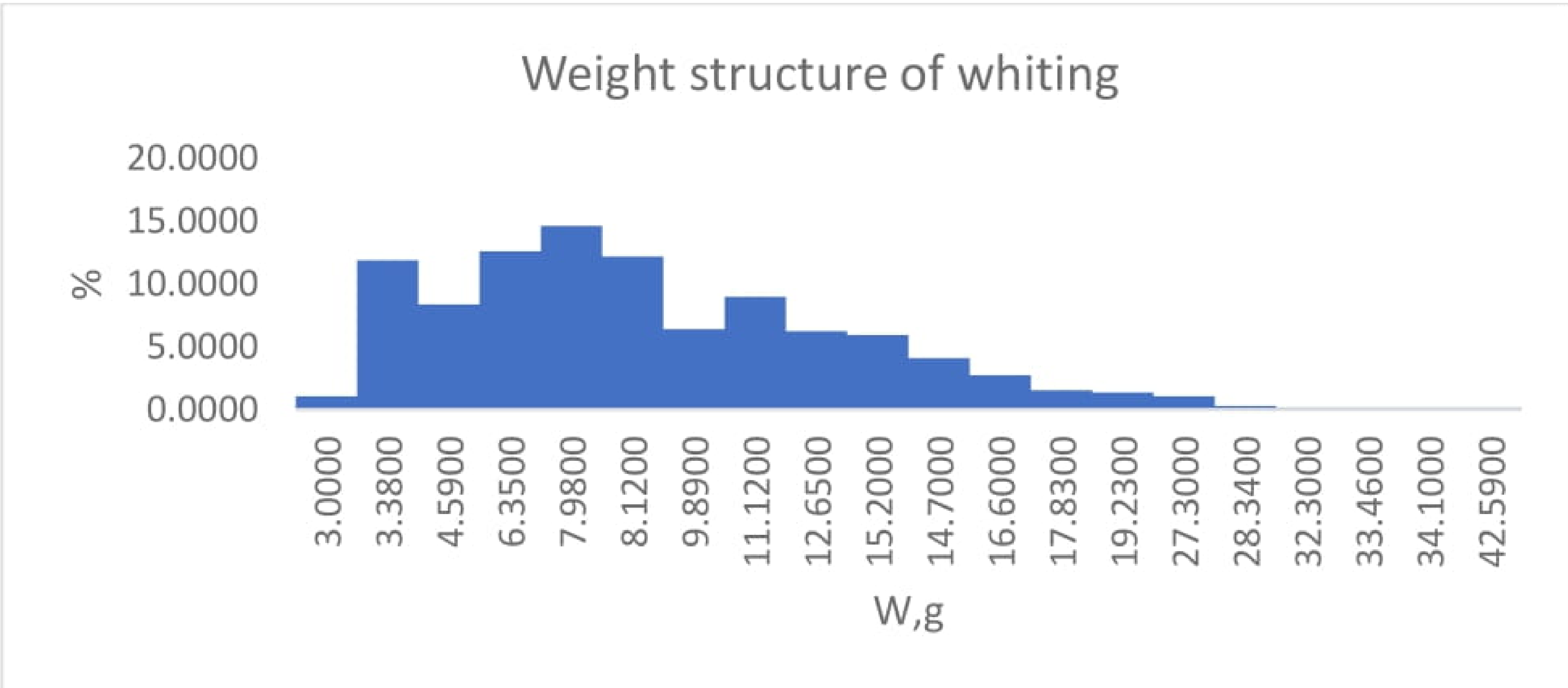

Figure 5.5.3. Weight structure of whiting in September 2024

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6. Horse mackerel (*Trachurus mediterraneus*)

6.1. Distribution

Horse mackerel is a migratory species off the Bulgarian coast. The species is a carnivore and is an important component of the food chain of other larger predators such as turbot and dolphins. Horse mackerel was not significantly represented in the catches.

6.2. Horse mackerel biomass by strata

During the study, horse mackerel was ubiquitous, with biomass values highest in the 50–100 m layer: 956.5 t (Fig. 6.2.1), followed by 612.32 t (30–50m) and 593.38 t (15–30m).

Biomass (kg) of horse mackerel - First expedition

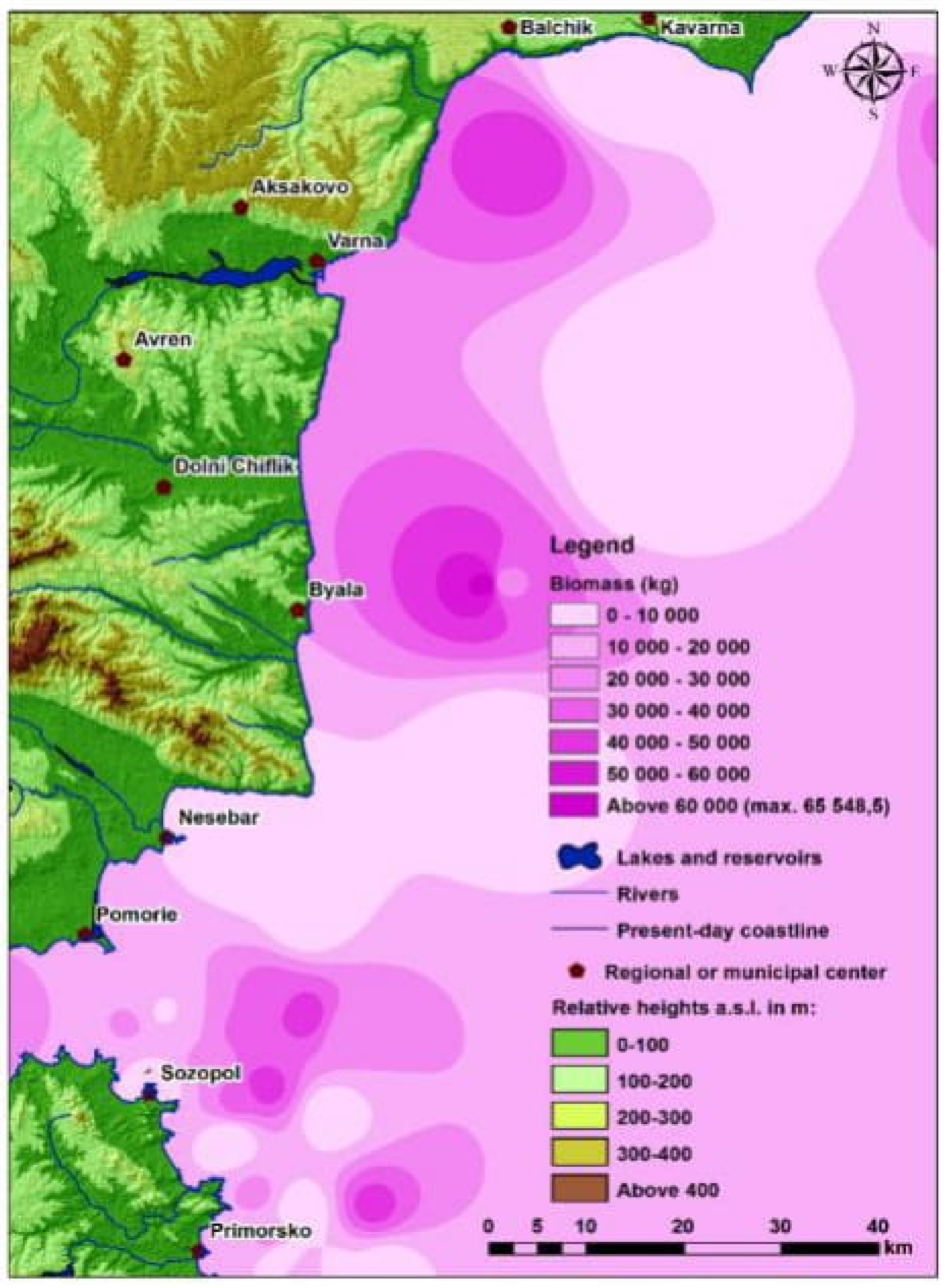

Figure 6.2.1. Horse mackerel biomass by strata, September 2024

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The total investigated area was 8010.24 km^2, and the total biomass of horse mackerel was 2162.2 t (Table 6.2.1, Fig. 6.2.2). The densest aggregations were observed in front of Byala, Sozopol, Primorsko, Burgas Bay, and Maslen Nos.

Table 6.2.1. Swept area method for stock survey in September 2024 – average values of catch per unit area (CPUA), biomass (kg), Ax – area and number of fields

CPUA average	strata	Biomass (kg)	Ax Surface	No. of stations
287.332	15-30	593.3808065	2065.14	33
337.4	30-50	612.320268	1814.82	29
321.58	50-100	956.4902424	4130.28	66
		2162.191	**8010.24**	**128**

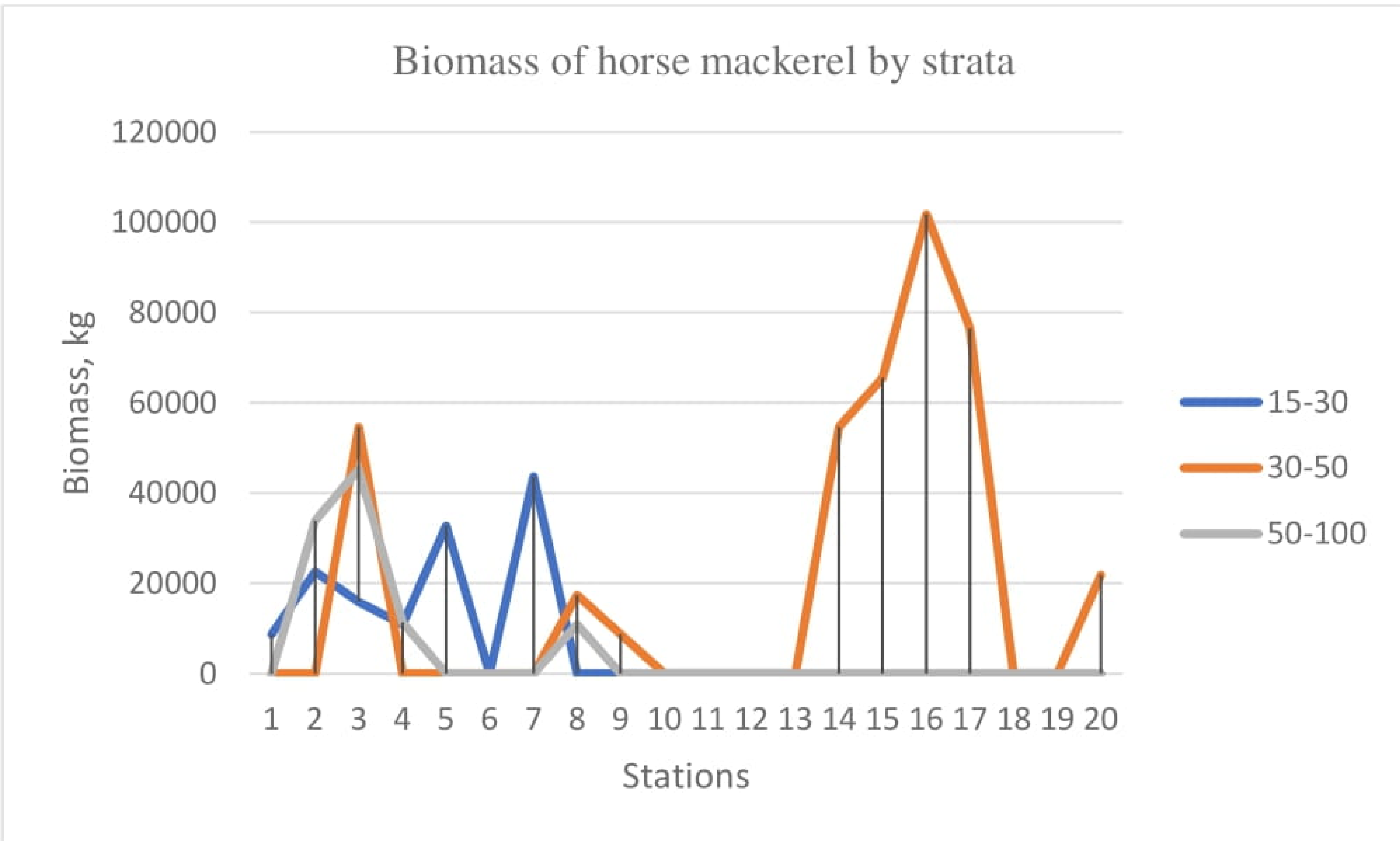

Figure 6.2.2. Horse mackerel biomass (kg) by strata in September 2024

Table 6.2.2. Descriptive statistics of horse mackerel CPUA indices (t) in September 2024

	15-30 m	30-50 m	50-100 m
Average	287.33	337.4	231.6
Standard error	145.3255	212.455	100.02144
Median	215.4522	269.02955	178.26818
Fashion	#N/A	105.79091	#N/A
Standard deviation	302.32271	255.63373	203.49288
Variation	91399.019	65348.603	41409.351
Excess	-1.648688	-0.307774	0.3095325
Asymmetry	0.385634	0.948337	0.3319474
Range	687.64091	740.53637	528.95455
Minimum	139.79091	139	182
Maximum	683.43182	1627.85	542.2568
Amount	1692.6546	3755.5773	1745.55
Number	4	12	5
Greatest Value (1)	766.256	985.365	634.74546
Smallest value (1)	161.2441	187.3325	106.79091
Confidence level (95.0%)	481.06289	162.42192	252.66978

6.3. Catch per unit area

Horse mackerel was represented in the composition of the catches during the first part of the expedition conducted in September 2024 with the highest density of the species recorded in the water area of Byala, "Aladzha Bank", Sozopol, Maslen Nos, Primorsko (Fig. 6.3.1.). In the depth layer 30–50 m, the highest values for CPUA were recorded – 1627.27 kg.km^{-2}, with an average value of 337.4 kg.km^{-2}. In the depth layer 15–30 m, 698.3 kg.km^{-2} and 50–75 m – 723.2 kg.km^{-2}, the species was recorded in separate trawls (Fig. 6.3.1.).

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CPUA (kg/km²) of horse mackerel - First expedition

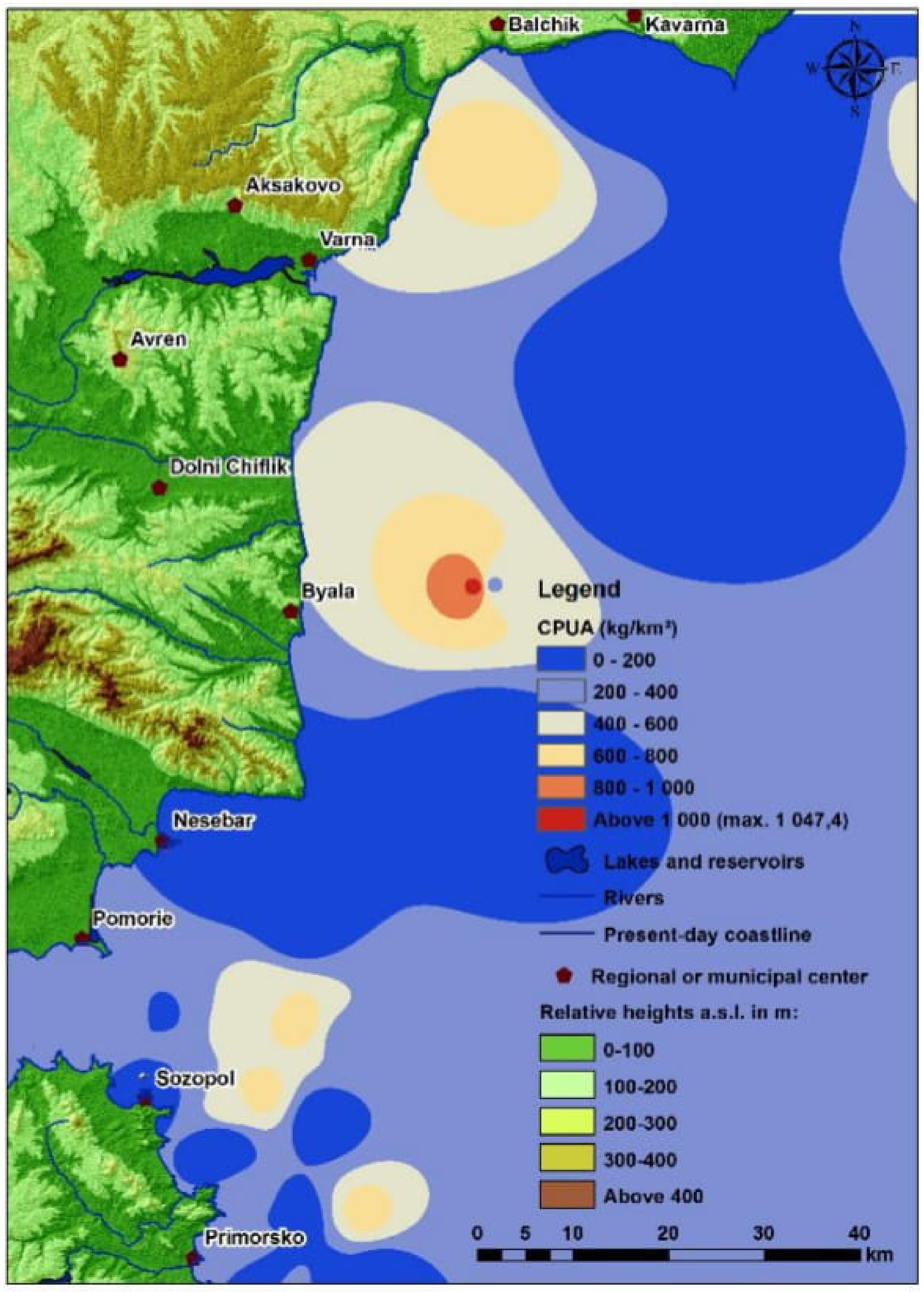

Figure 6.3.1. Catch per unit area (CPUA kg.km^{-2}), September 2024

6.4. Catch per unit effort

The catch per unit effort (CPUE) for the species is presented graphically in Figure 6.4.1. The highest CPUE values (kg.h^{-1}) were observed off Byala, Primorsko, Sozopol, and Aladzha Bank ("Zlatni Pyasatsi" resort).

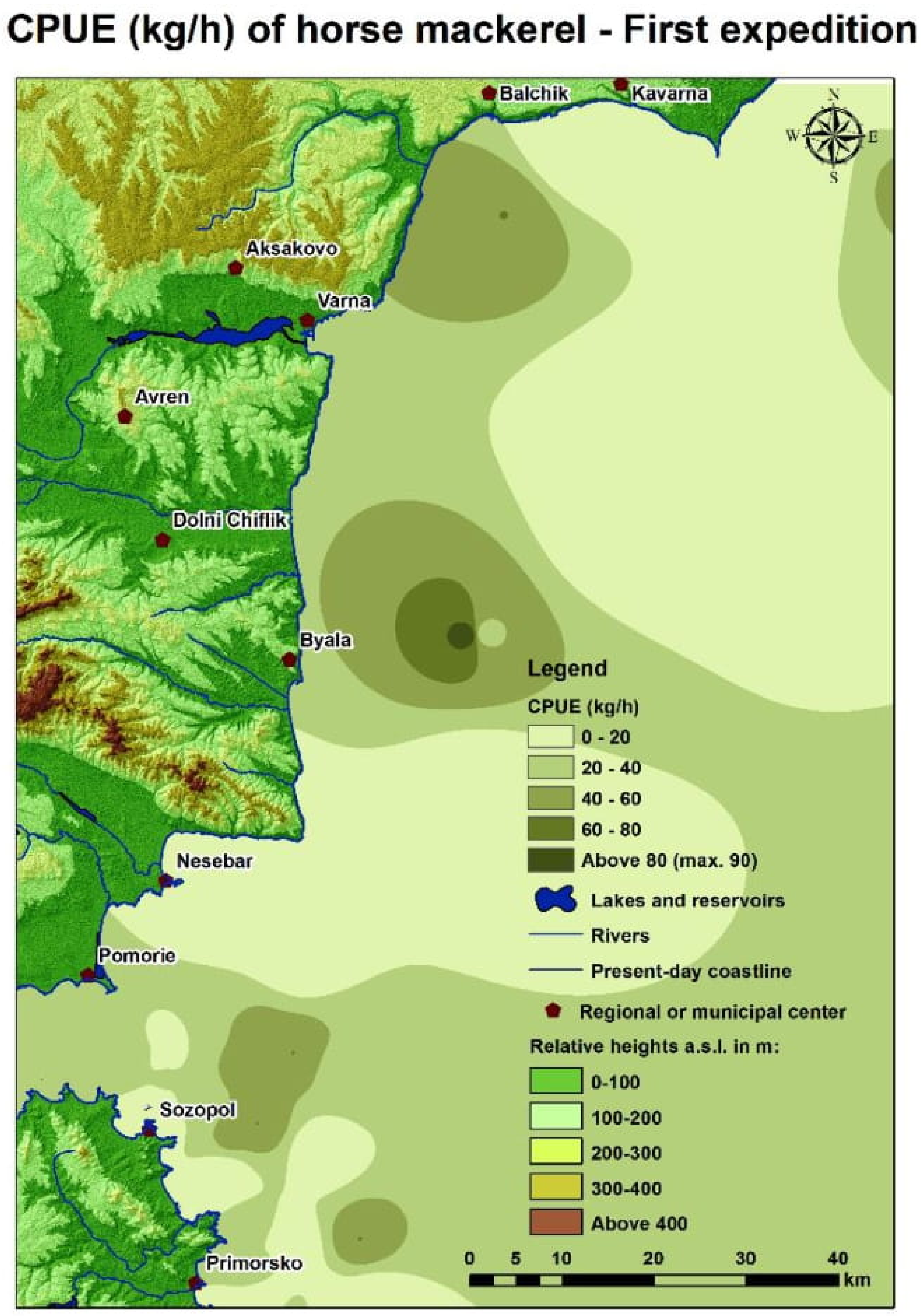

Figure 6.4.1. Catch per unit effort (CPUE kg kg*h^{-1}) for horse mackerel by strata

6.5. Lenght-weight relationship

The length-weight relationship in horse mackerel is described by the model $W = 0.008.L^{3.154}$, allometric growth coefficient >3, the resulting nonlinear length-weight relationship model has a high degree of determination ($R^2 = 0.9768$) (Fig. 6.5.1.).

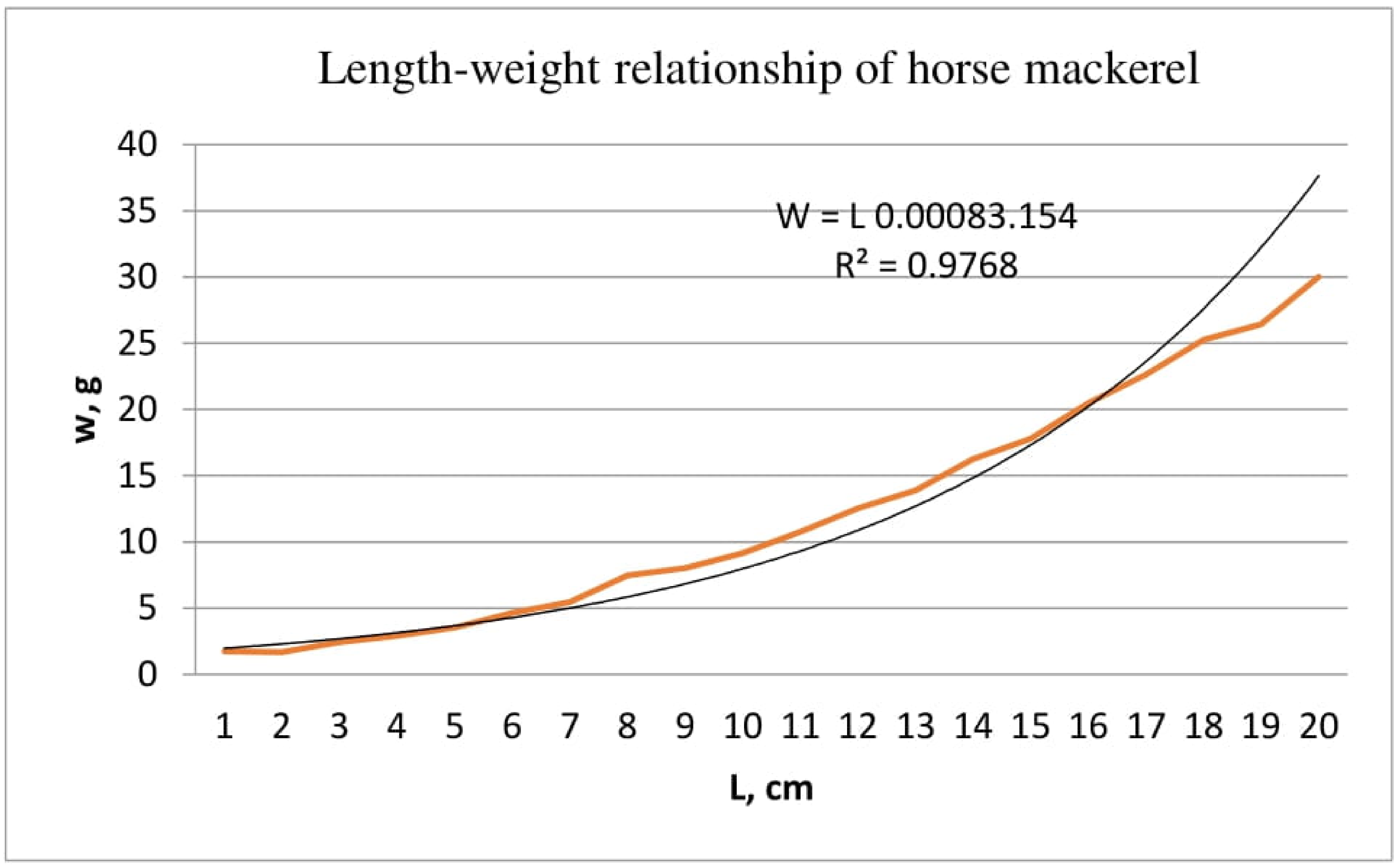

Figure 6.5.1. Length-weight relationship of horse mackerel, September 2024

The size structure of the horse mackerel stock is presented in Figure 6.5.2. The length distribution in the horse mackerel samples is bimodal with 2 peaks – bell-shaped, as the most common lengths in the samples are in the range 7.5–8; 9.5 cm. A peak was observed in the 11.5 cm size group.

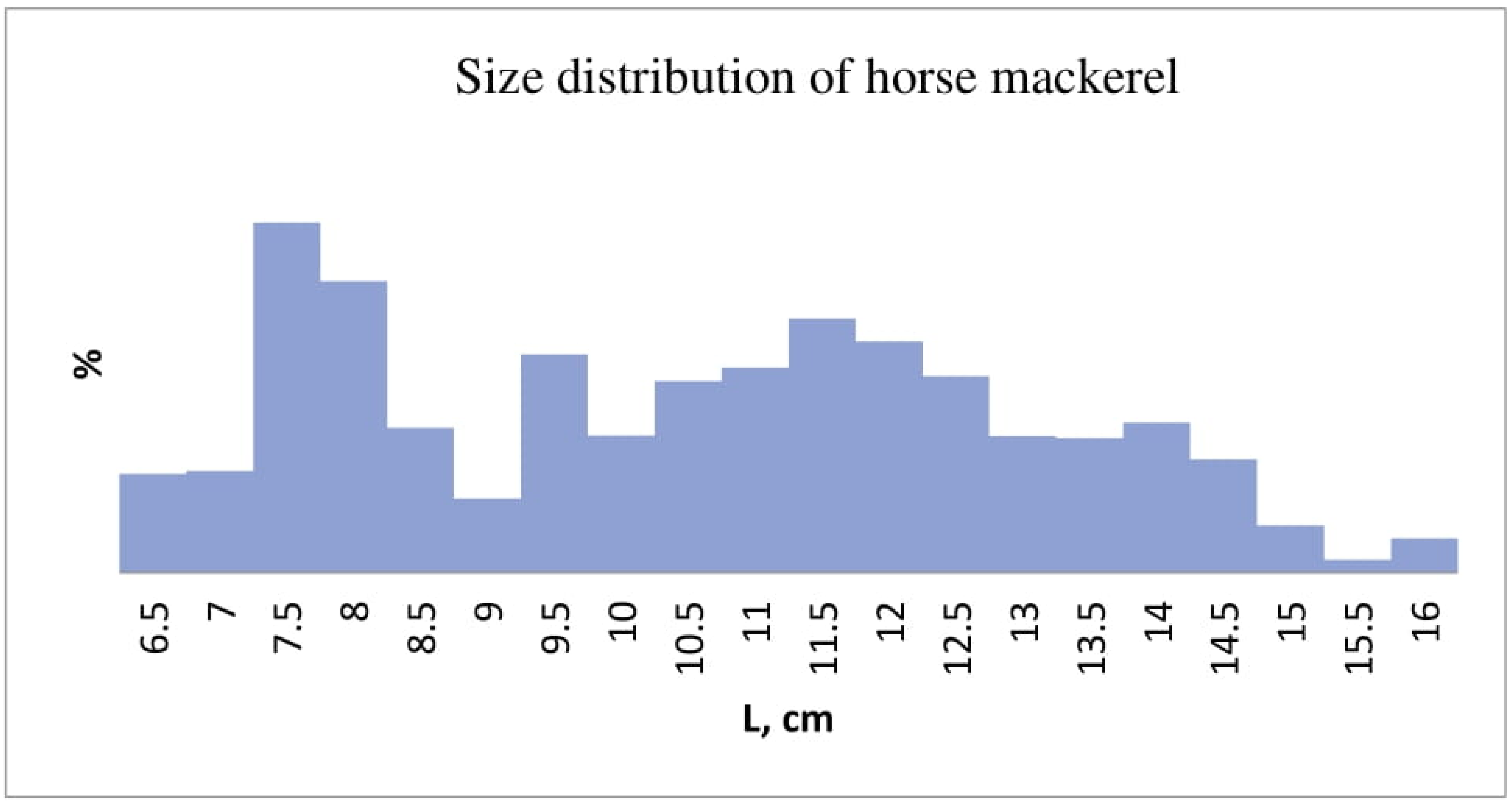

Figure 6.5.2. Horse mackerel size structure in September 2024

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The weight distribution in the horse mackerel samples is bimodal with 2 peaks, as the most common weights in the samples are in the range of 10 -12 and 18.4 - 22 grams. A peak was observed in the 20 gram weight group.

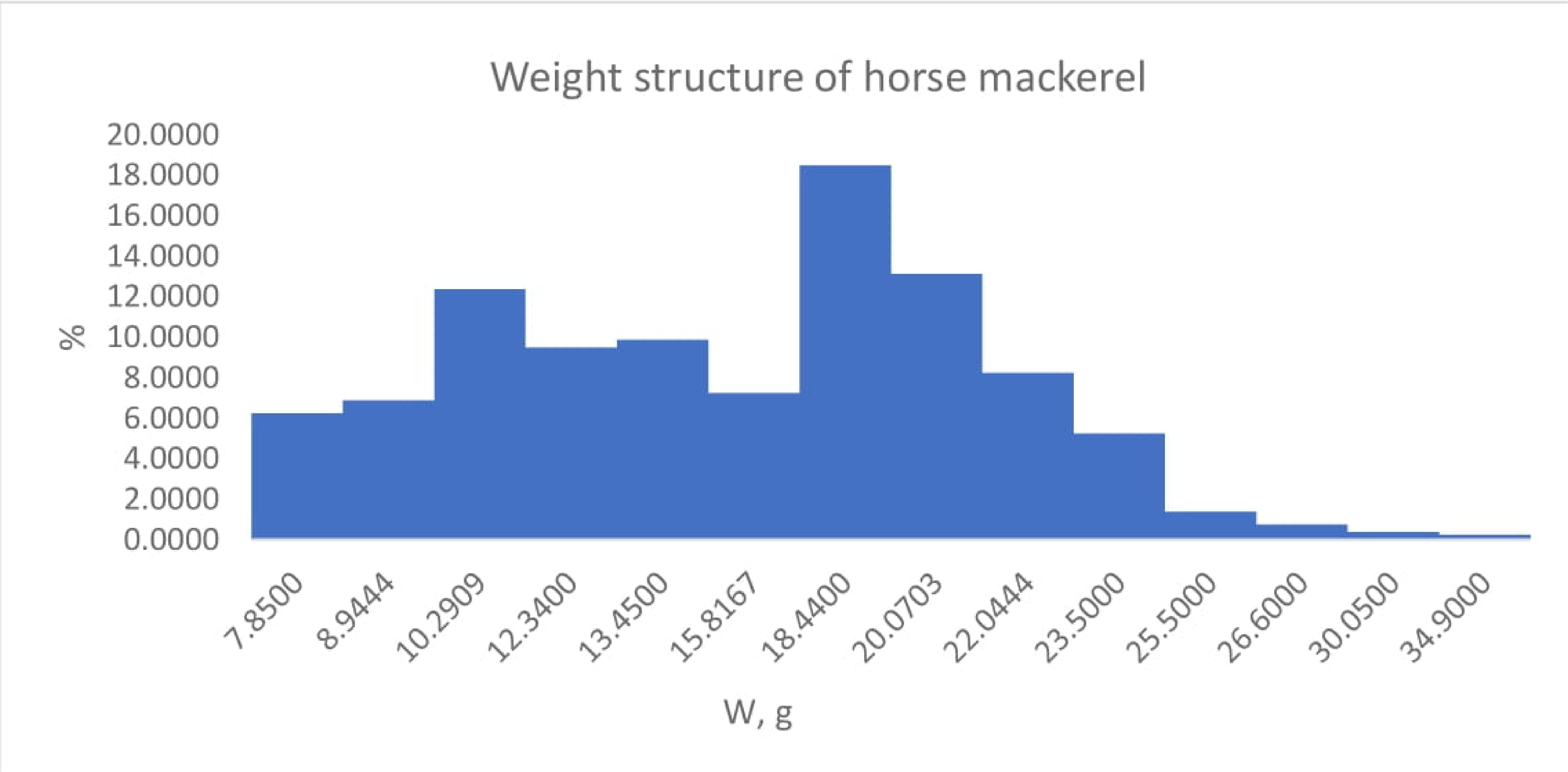

Figure 6.5.3. Horse mackerel weight structure in September 2024.

7. Red mullet (*Mullus barbatus*)

The total surveyed area was 8010.24 km^{-2}, and the amount of total red mullet biomass was 1336.92 t (Table 7.1.1., Fig. 7.1). The densest aggregations were observed in front of Pasha Dere, in front of Albena resort, in front of Balchik below Kaliakra and in the Nessebar Bay at depths of 30 – 50 m, and west of Sozopol at depths of 50 – 100 m. The species was recorded in 24 stations (out of 38), with the highest density in the 30 – 50 m stratum.

7.1. Red mullet biomass

The densest aggregations and biomass peaks were observed in the range 30–50 m (525.3 t) 15–30 m (407.31 t) and 50–100 m (404.3 t). The length-weight relationship in red mullet is strong, showing positive allometry with a high coefficient of determination (n = 3.114), R^2 = 0.9944 (Fig. 7.1.1, Table 7.1.1 and Table 7.1.2).

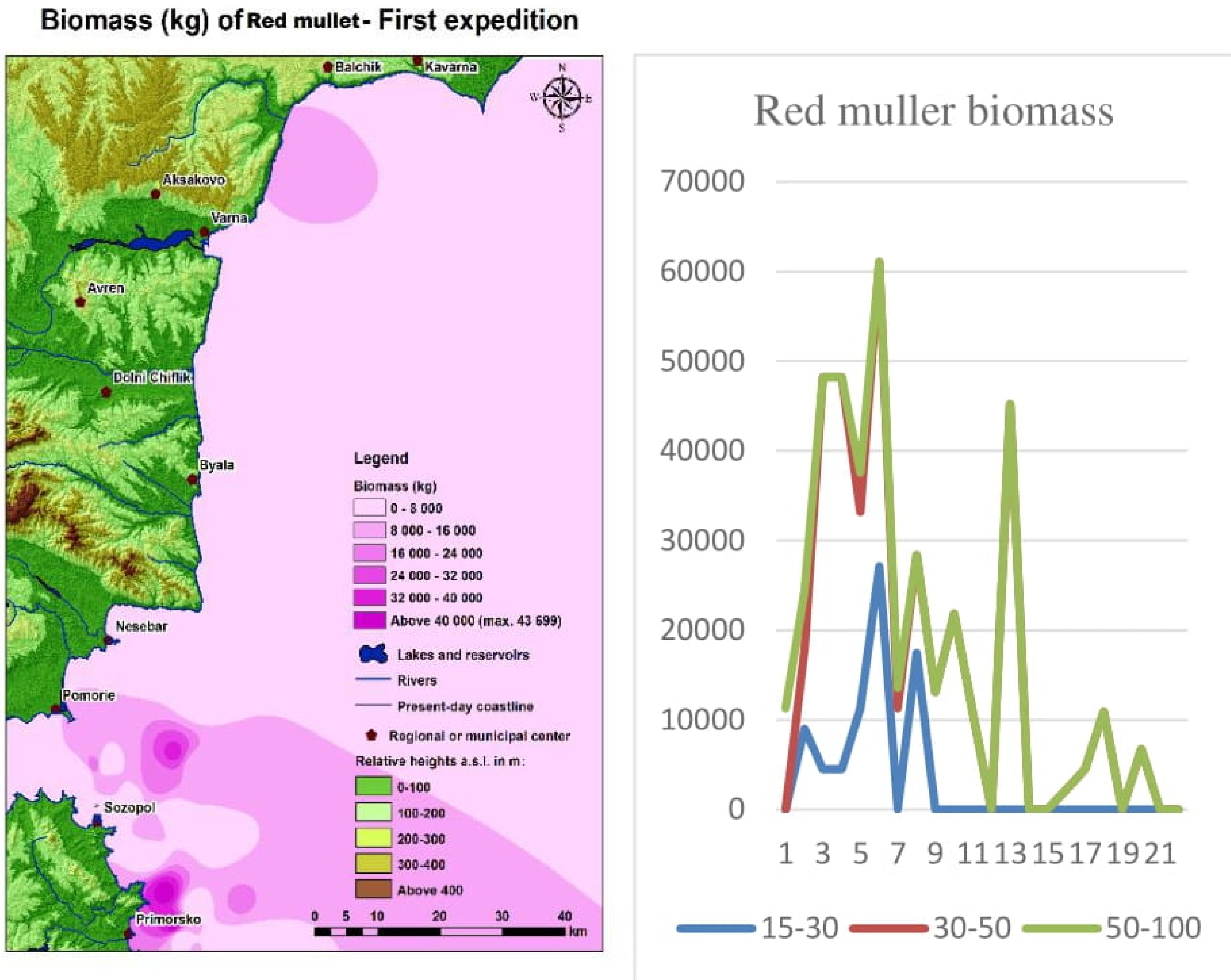

Figure 7.1.1. Red mullet biomass in September 2024

Table 7.1.1. Area method for stock survey in September 2024 – average catch per unit area (CPUA), biomass (kg), Ax – area and number of fields

CPUA average	strata	Biomass (kg)	Area	Fields
197.23	15-30	407.3076	2065.14	33
289.45	30-50	525.2996	1814.82	29
97.89	50-75	404.3131	4130.28	66
		1336.92	8010.24	128

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Table 7.1.2. Descriptive statistics of CPUA indices (t) of red mullet in September 2024

	15–30 m	30–50 m	50–100 m
Average	197.23	289.45	97.89
Standard error	115.223	189.225	77.23
Median	155.555	178.2365	69.42552
Fashion	#N/A	201,325	#N/A
Standard deviation	18919	15997.56	12734.58
Variation	4E+08	2.56E+08	1.62E+08
Excess	-1.649	-0.30777	-0.30953
Asymmetry	0.386	0.948337	0.331947
Range	43033	46342.77	33101.98
Minimum	6620	3310.198	6620.395
Maximum	49653	49652.96	39722.37
Amount	1E+05	235024	109236.5
Number	4	12	5
Greatest Value (1)	433.94	723.33	180.81
Smallest value (1)	72.33	36.16	36.16
Confidence level (95.0%)	30105	10164.36	15812.07

7.2. Catch per unit area (CPUA kg.km^{-2})

The catch per unit area in the 15–30 m stratum was 423 kg.km^{-2}; In the 30–50 and 50–100 m strata the average catch per unit area values varied between 313 and 349 kg.km^{-2} (Fig.7.2.1).

From the analysis of the catch per unit area and the catch per unit effort (Fig.7.2.2.) it is evident that the densest concentrations and numbers were found in the 30–50 m depth zone, followed by the 15–30 m zone.

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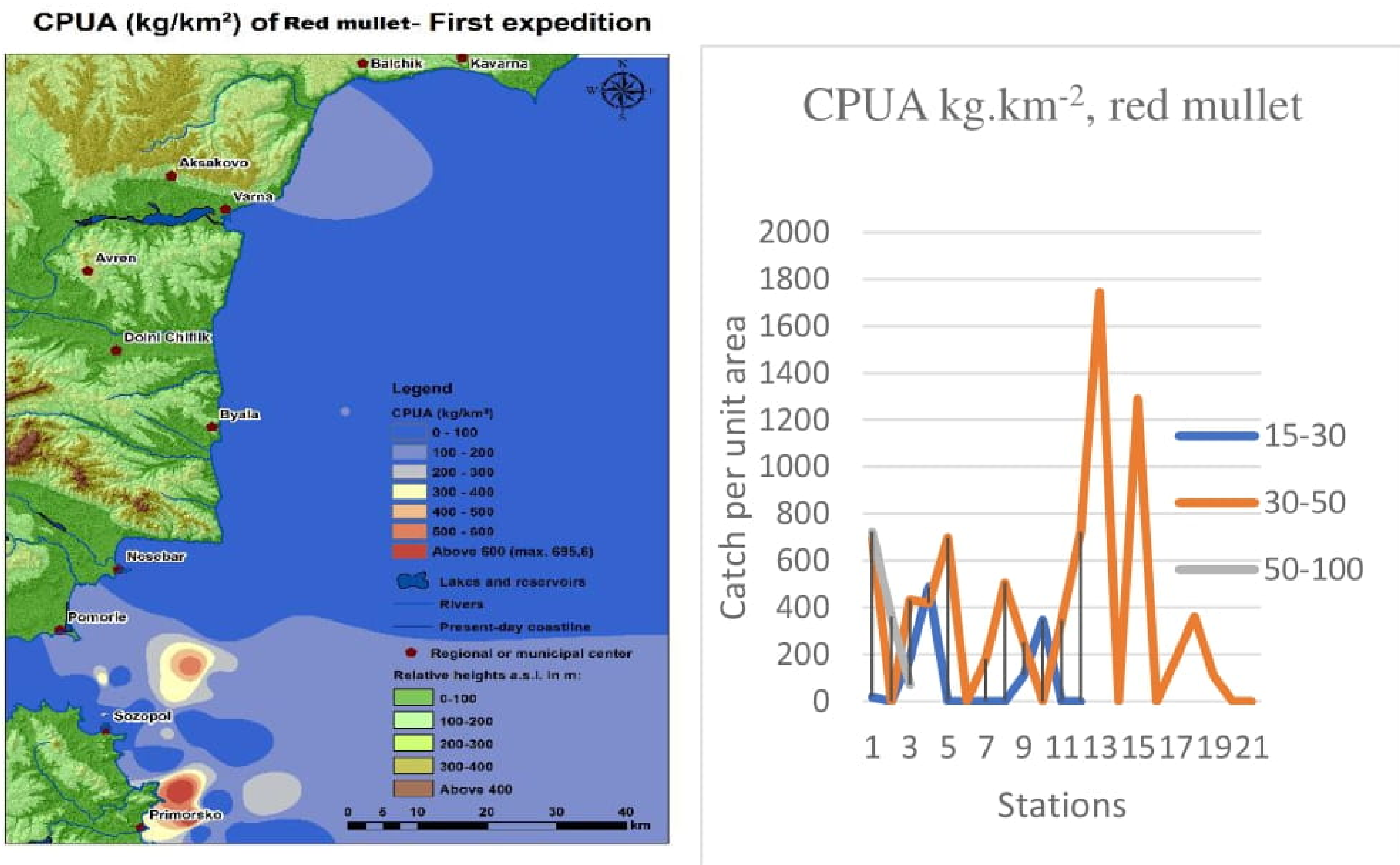

Figure 7.2.1. Catch per unit area (CPUA kg.km^{-2}) of red mullet, September 2024

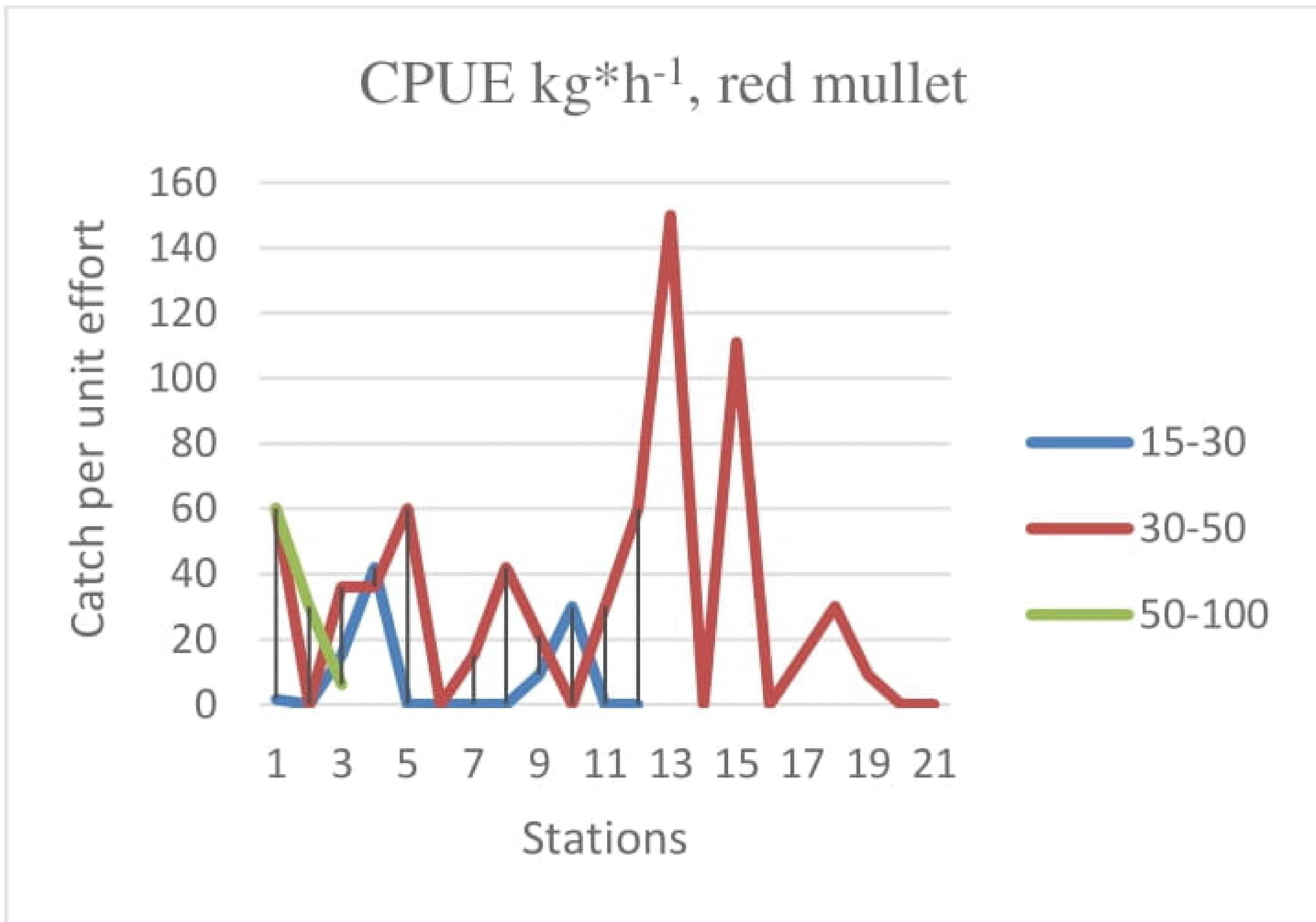

Figure 7.2.2. Catch per unit effort (CPUE kg*h^{-1}) of red mullet, September 2024

Length-weight analysis of red mullet (L-W) in September 2024 (Fig. 7.2.3.) shows a very high dependence between the size and weight of the species, with a well-pronounced allometric growth (R^2 = 0.9944).

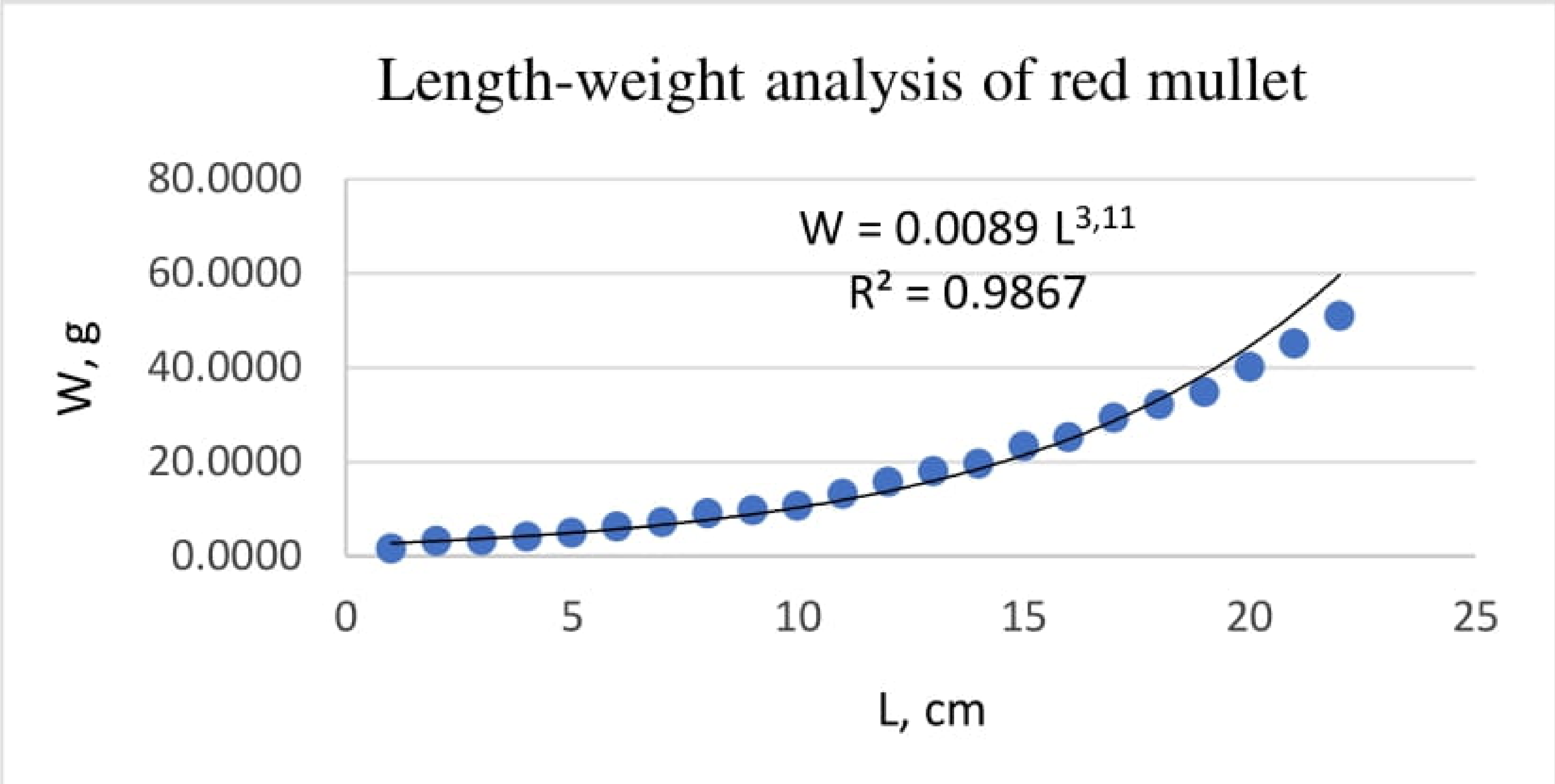

Figure 7.2.3. Length-weight analysis of red mullet (L-W), September 2024

The size structure of red mullet is presented in Figure 7.2.4. During the study, the predominant size class in the catch composition was 11–12.0 cm.

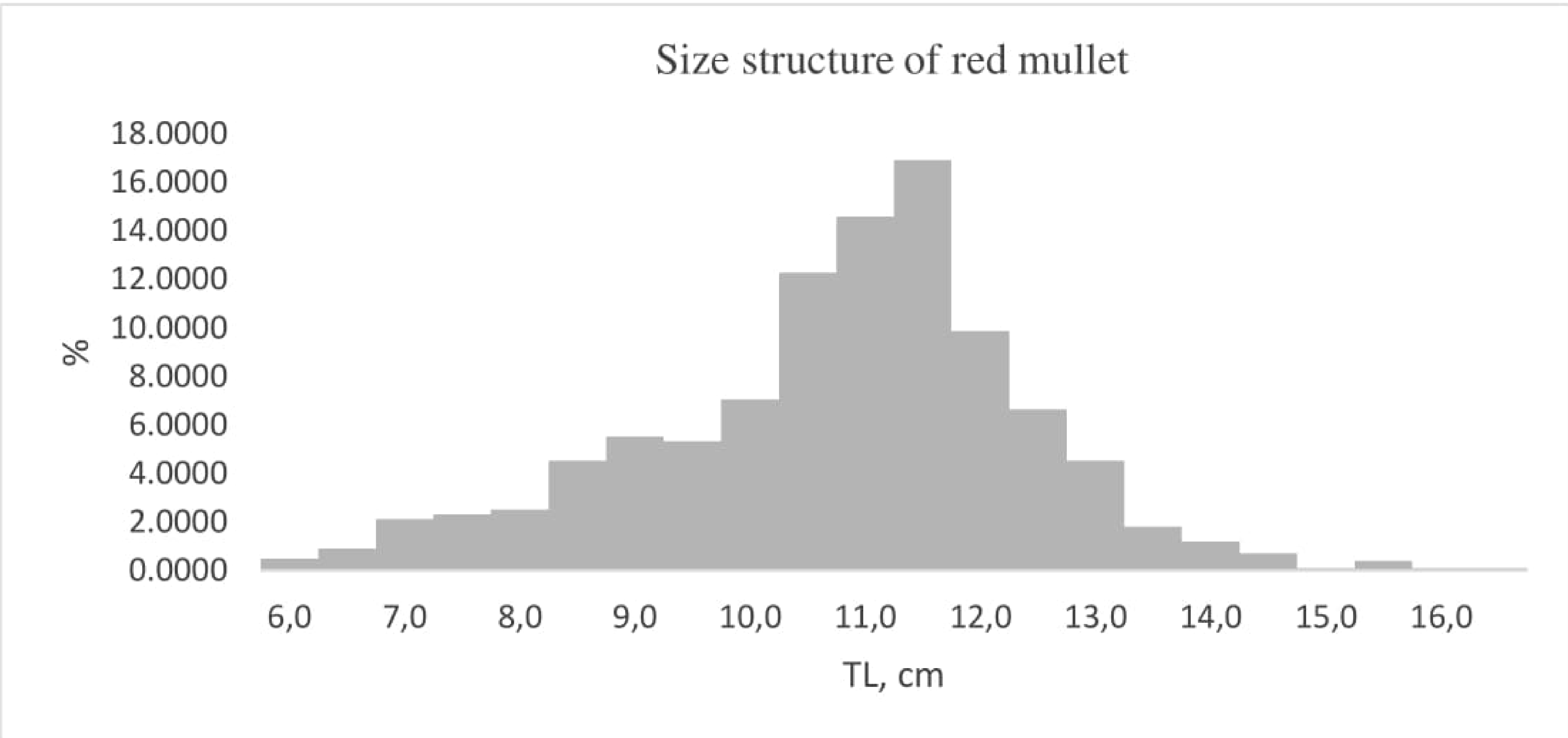

Figure 7.2.4. Size structure of red mullet

The weight structure of the red mullet ranged from 6.5 to 34.54 grams and is presented in Fig. 7.2.5.

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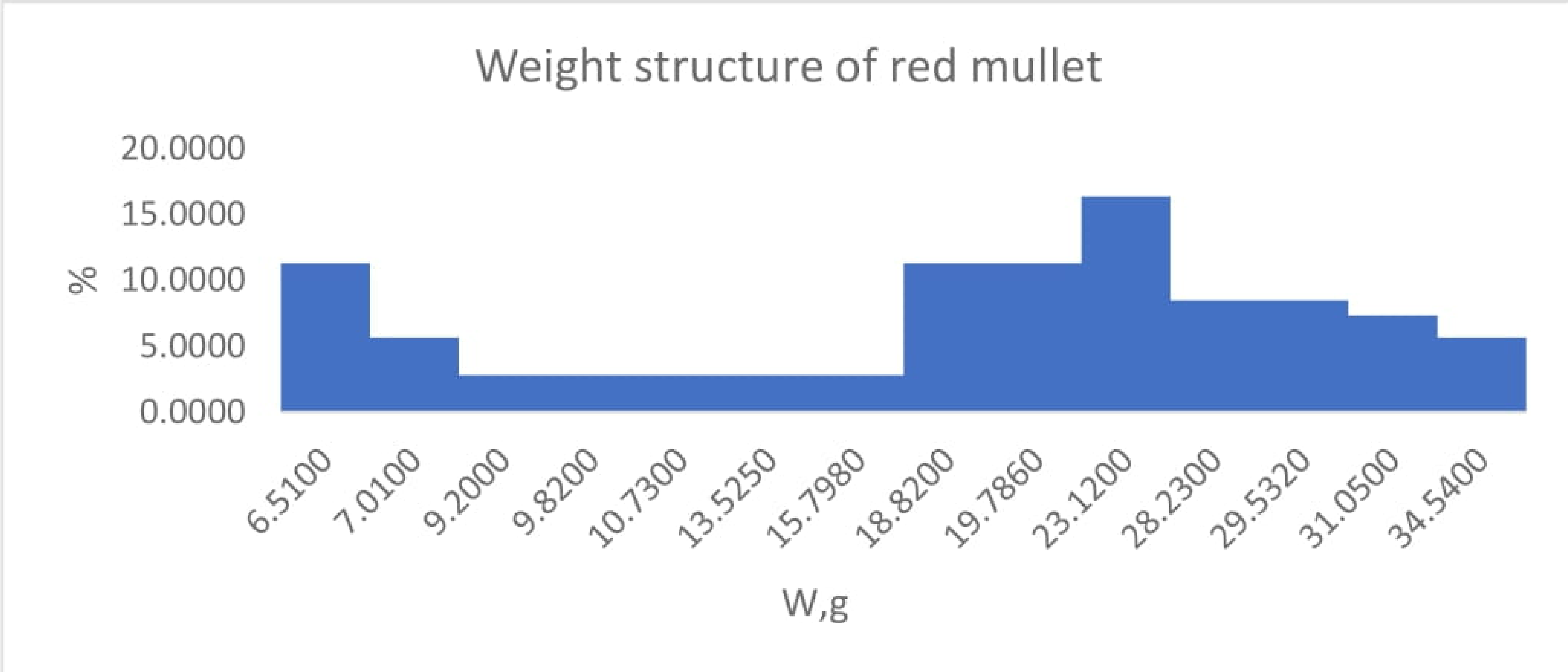

Figure 7.2.5. Weight structure of red mullet

8. Species poorly represented in catches

Anchovy (*E. encrasicolus* L.) and sprat (*Sprattus sprattus*) - although they are among the most widespread pelagic species in the Black Sea, during the research period they were represented by very low catches and in some cases with single specimens. Four species of Gobies (*G. niger*, *N. melanostomus*, *M. batrachocephalus*, and *Z. ophiocephalus*) and single specimens of *A. immaculata* were observed in the catches. A quantitate assessment was not possible due to the small number of different species in the individual trawls.

8.1. Sprat (*Sprattus sprattus*)

The species was found sporadically, only in individual trawls during the described study; probably the sprat shoals were highly dispersed due to the hydrometeorological conditions and the presence of migratory predatory species in the studied areas. Due to these facts and the lack of coverage, it was not possible to carry out quantitative assessments and analysis of the distribution of the species in September 2024.

The size structure of sprat showed a normal distribution, with a predominance of size groups 8.00–8.5–9.00 cm (Fig. 8.1.1.).

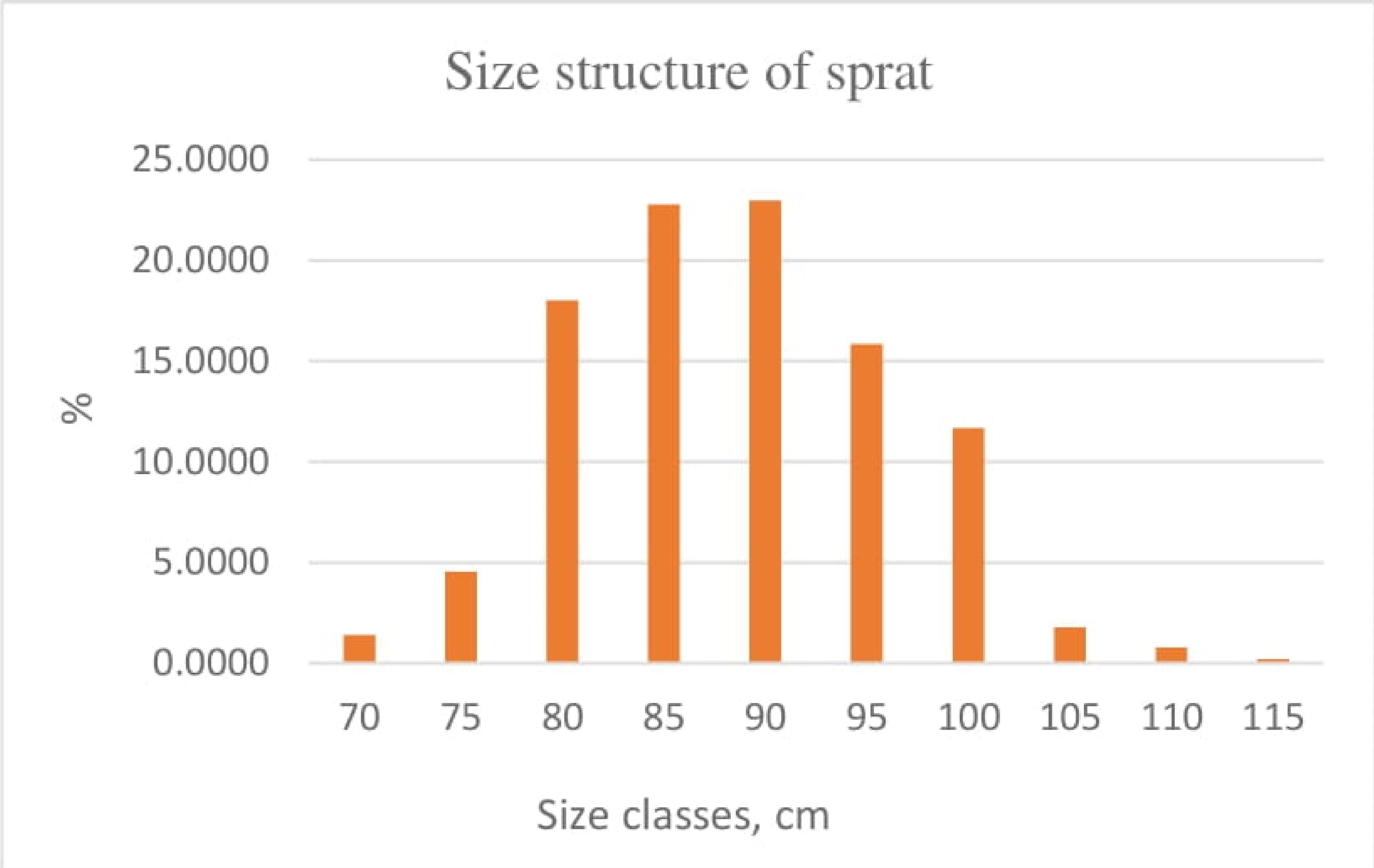

Figure 8.1.1. Size structure of sprat in September 2024

The weight structure of the sprat showed a normal distribution with a predominance of groups from 2.3 to 3.65 grams.

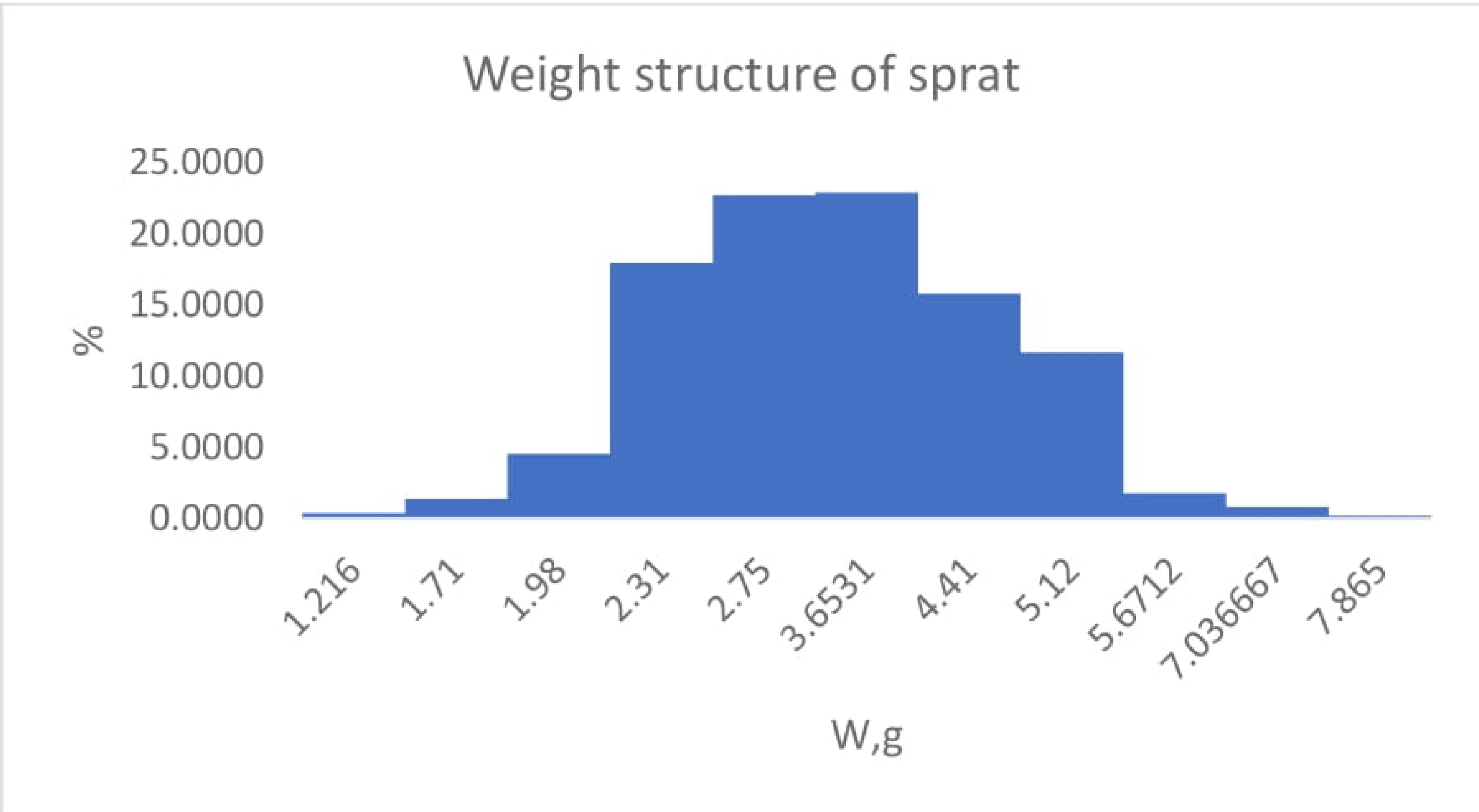

Fig.8.1.2. Weight structure of the sprat from September, 2024

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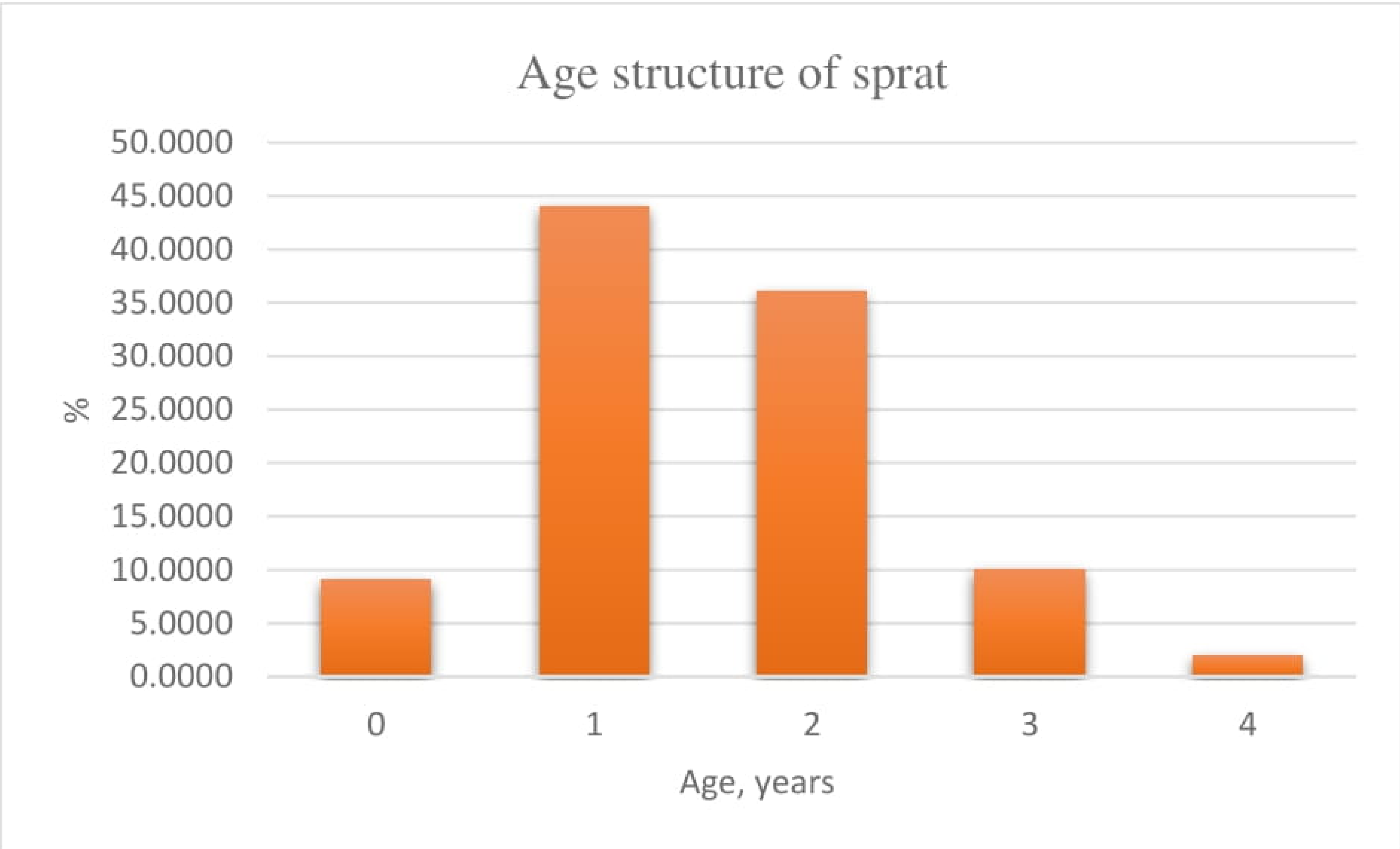
9. Age structure

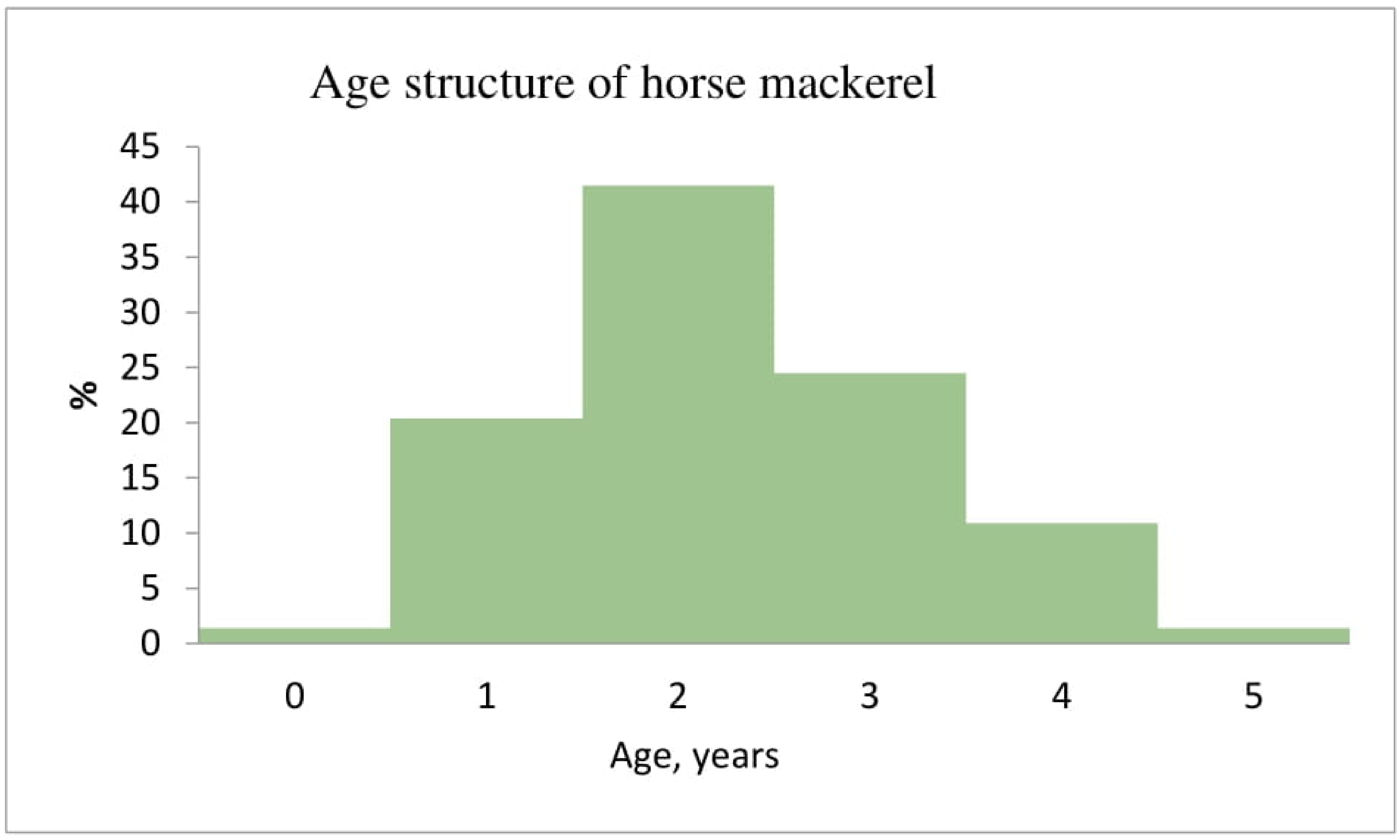
The predominant age group in the sprat during the study period was 1-1+ (44%), followed by 2-2+ y-1 (36%). The replenishment was represented by 9%. The age structure of the sprat varied from 0 to 4 + y^{-1} years, with the most significant representation of the age group 1+y^{-1}.

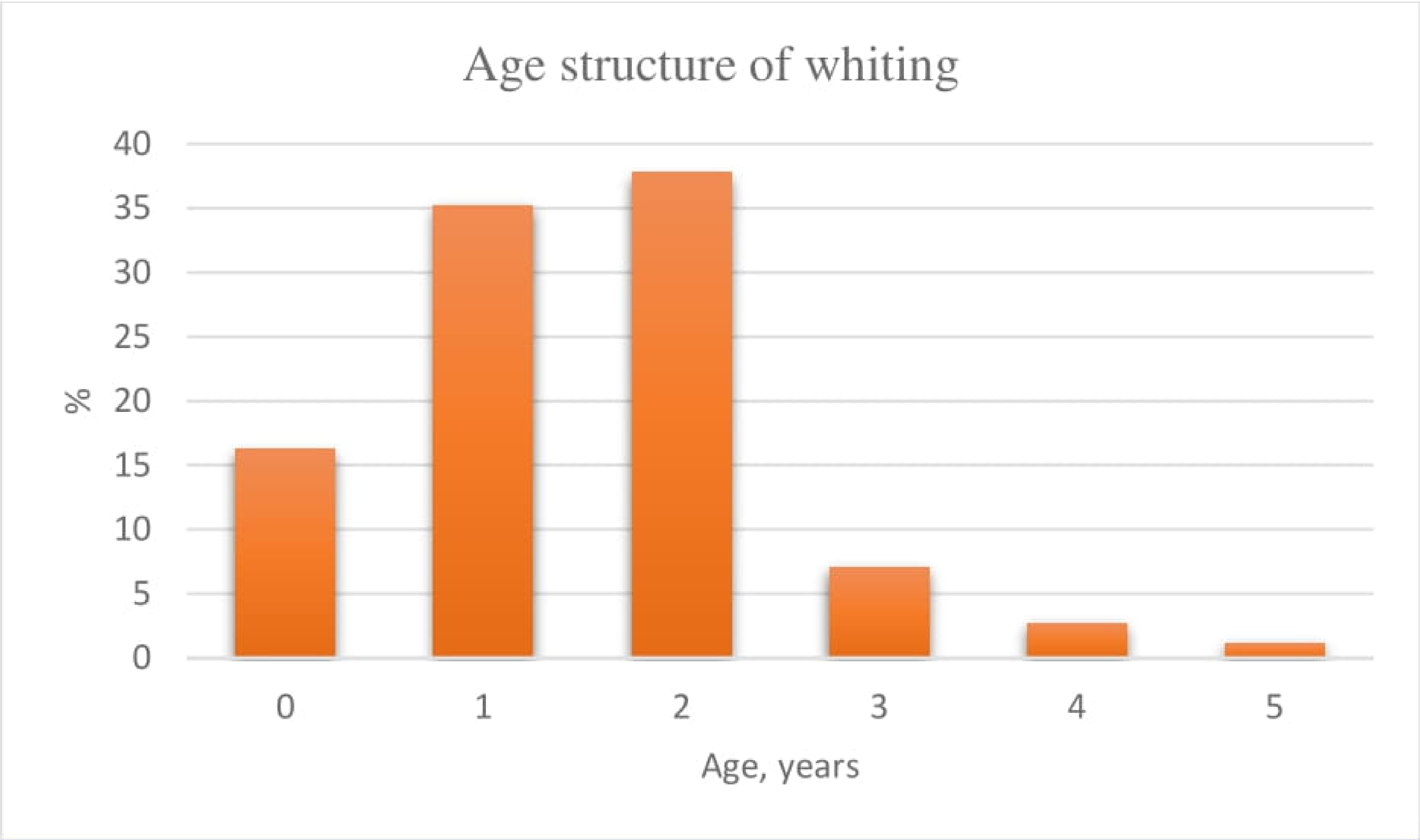
The age distribution in horse mackerel corresponded to a predominance of 2-2+ y^{-1} (41.5%), followed by 3-3+ y^{-1} (23.44%) and 1-1+ y^{-1} (20.4%).

The age distribution in whiting corresponded to a predominance of 2-2+ y^{-1} (37.73%), followed by 1-1+ y^{-1} (35.24 %) and 0 + y^{-1} (16.23%). The remaining age groups (3-3+; 4 and 5+ y^{-1}) were in a subordinate role in terms of their presence in the catches.

The distribution of age groups in red mullet is similar, with the replenishment being represented by a smaller share (8.78%). The age structure in red mullet is represented by 5 groups, with the predominant class 1-1+ y^{-1} with 32.67% (Fig. 9.1).







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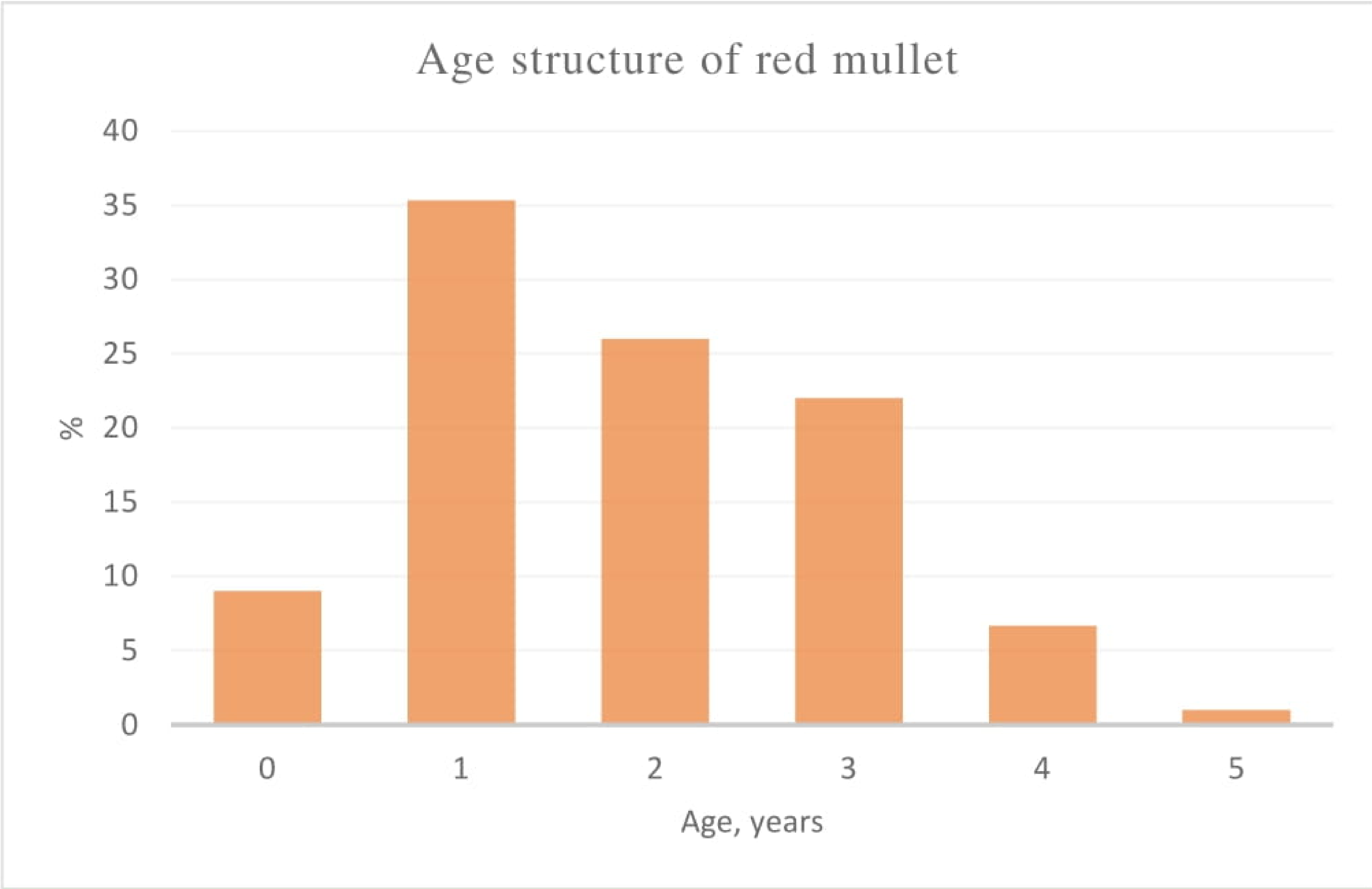

Figure 9.1. Age structure of the studied species in September 2024

10. Individual growth

The growth parameters of the sprat, calculated using the von Bertalanffy model, show an asymptotic length of 12.45 cm and higher values of the coefficient determining the rate of reaching the asymptote. Whiting and red mullet are characterized by lower growth rates but a relatively high value of the asymptotic length, with the exception of horse mackerel, due to the small number of individuals caught and analysed (Table 10.1.).

Table 10.1. Von Bertalanffy growth model (VBGF) for sprat, whiting, red mullet and horse mackerel

Species	Asymptotic lenght	Growth rate	Growth parameter	Growth coefficient	Allometric coefficient
S. sprattus	L_∞ = 12.45	K = 0.42	t_0 = -1.015	a = 0.05	n = 2.3311
M. merlangus	L_∞ = 27.82	K = 0.23	t_0 = -2.102	a = 0.007	n = 2.9958
M. barbatus	L_∞ = 18.41	K = 0.24	t_0 = -1.232	q = 0.009	n = 3.1194

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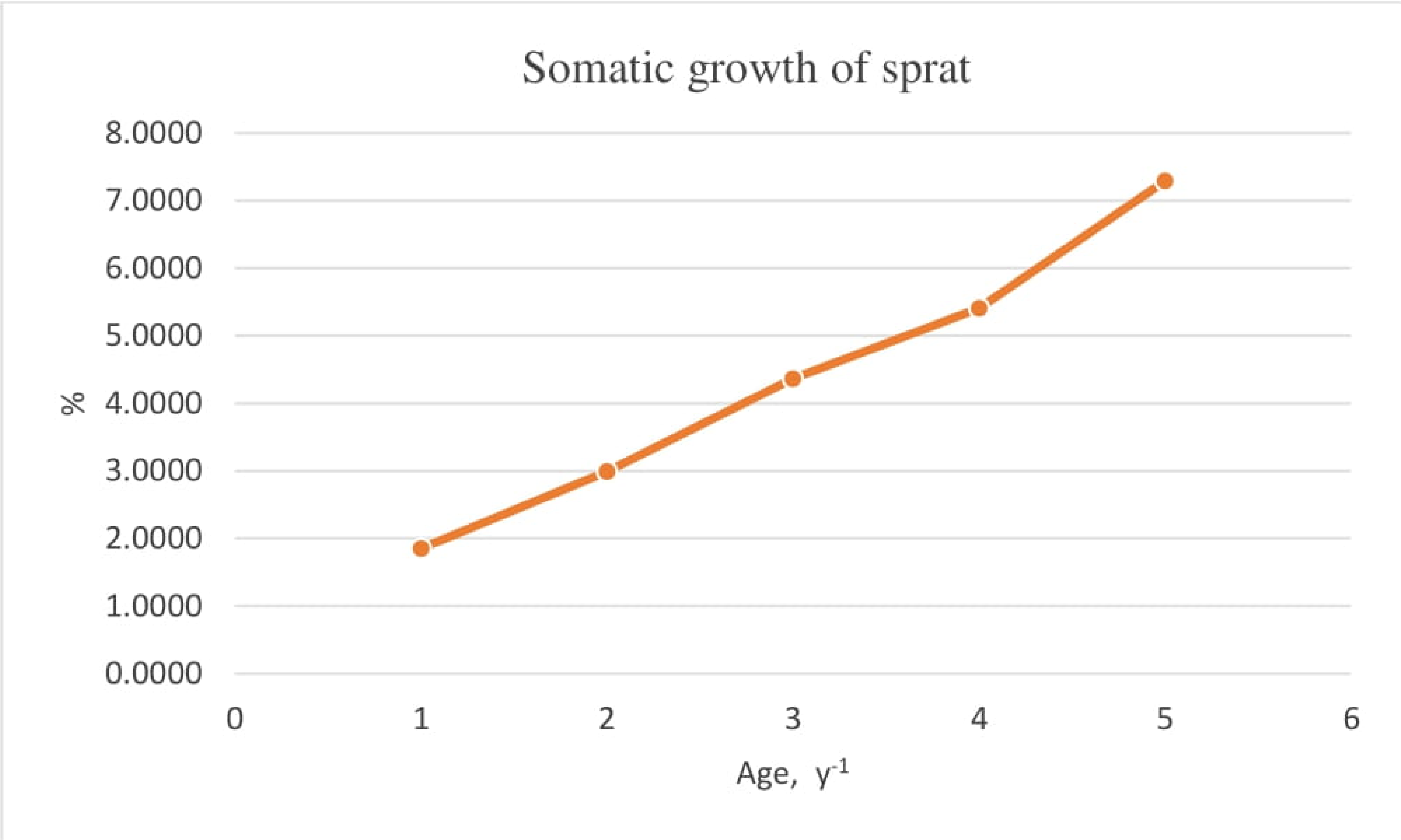
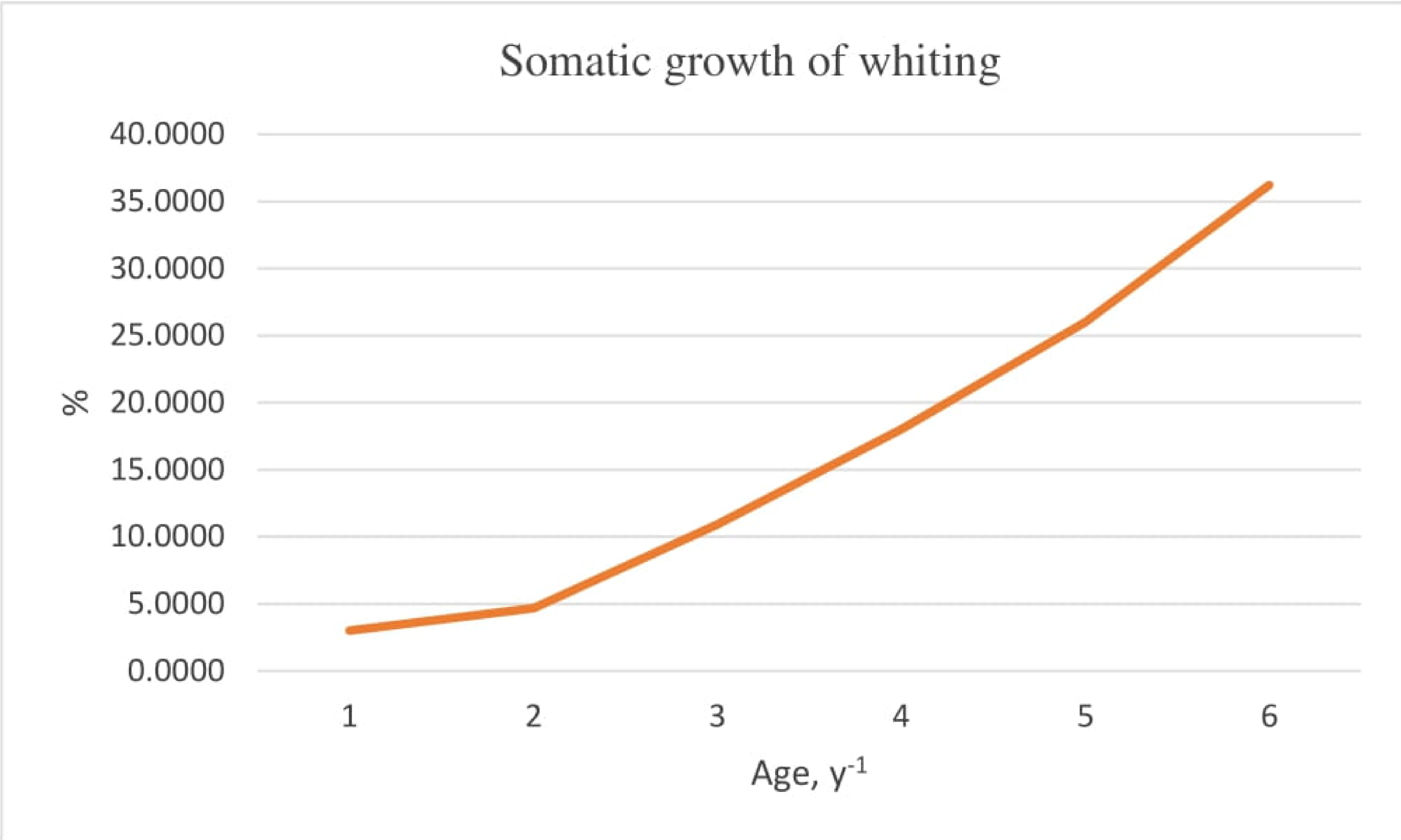
Tr. mediterraneus	L∞ = 18.68	K = 0.25	t_0 = -1.15	a = 0.009	n = 3.0911

10.1. Somatic growth

The average weights of the sprat, whiting, red mullet and horse mackerel by age groups are presented in Figure 10.1.1.



a.



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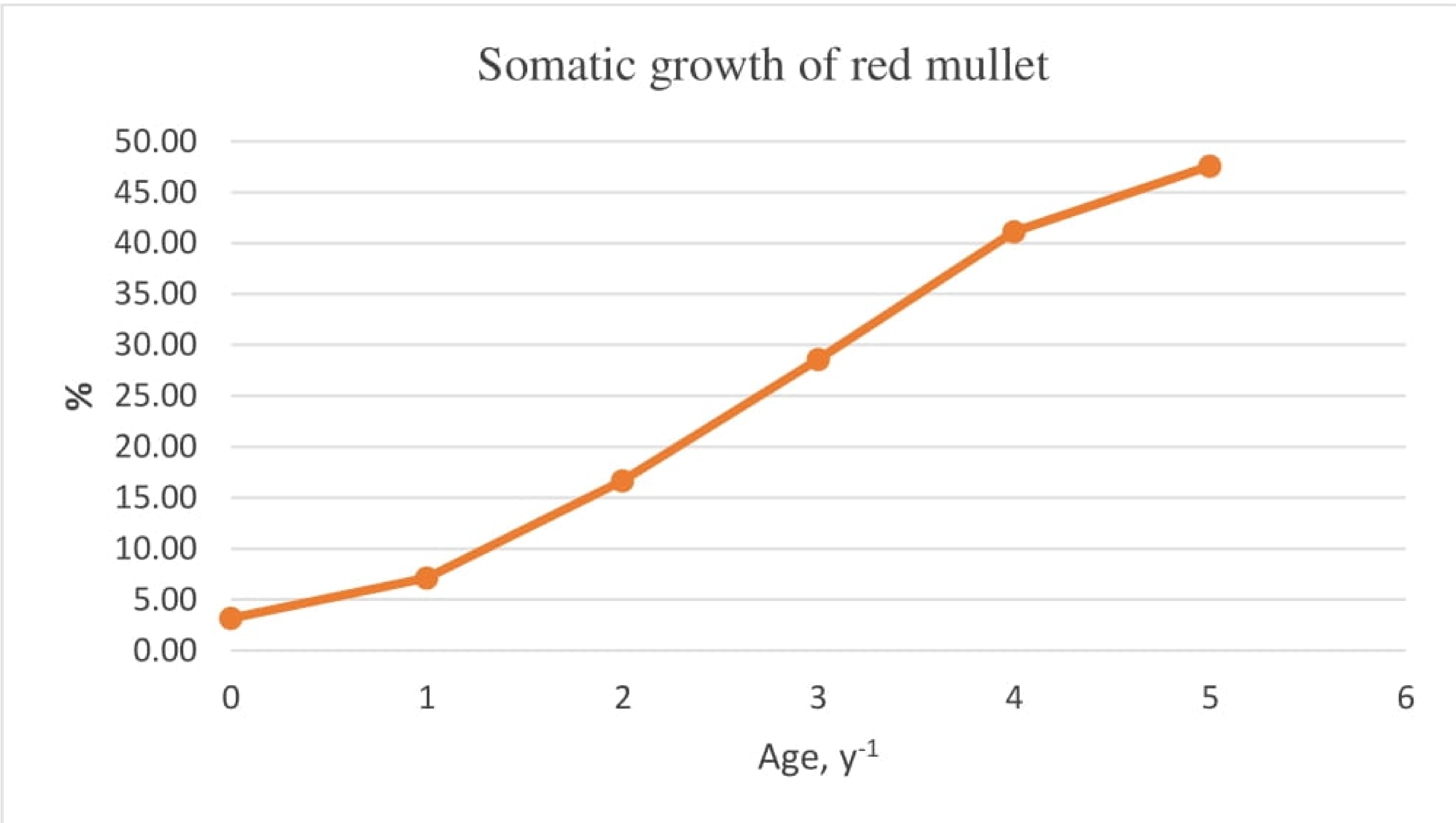

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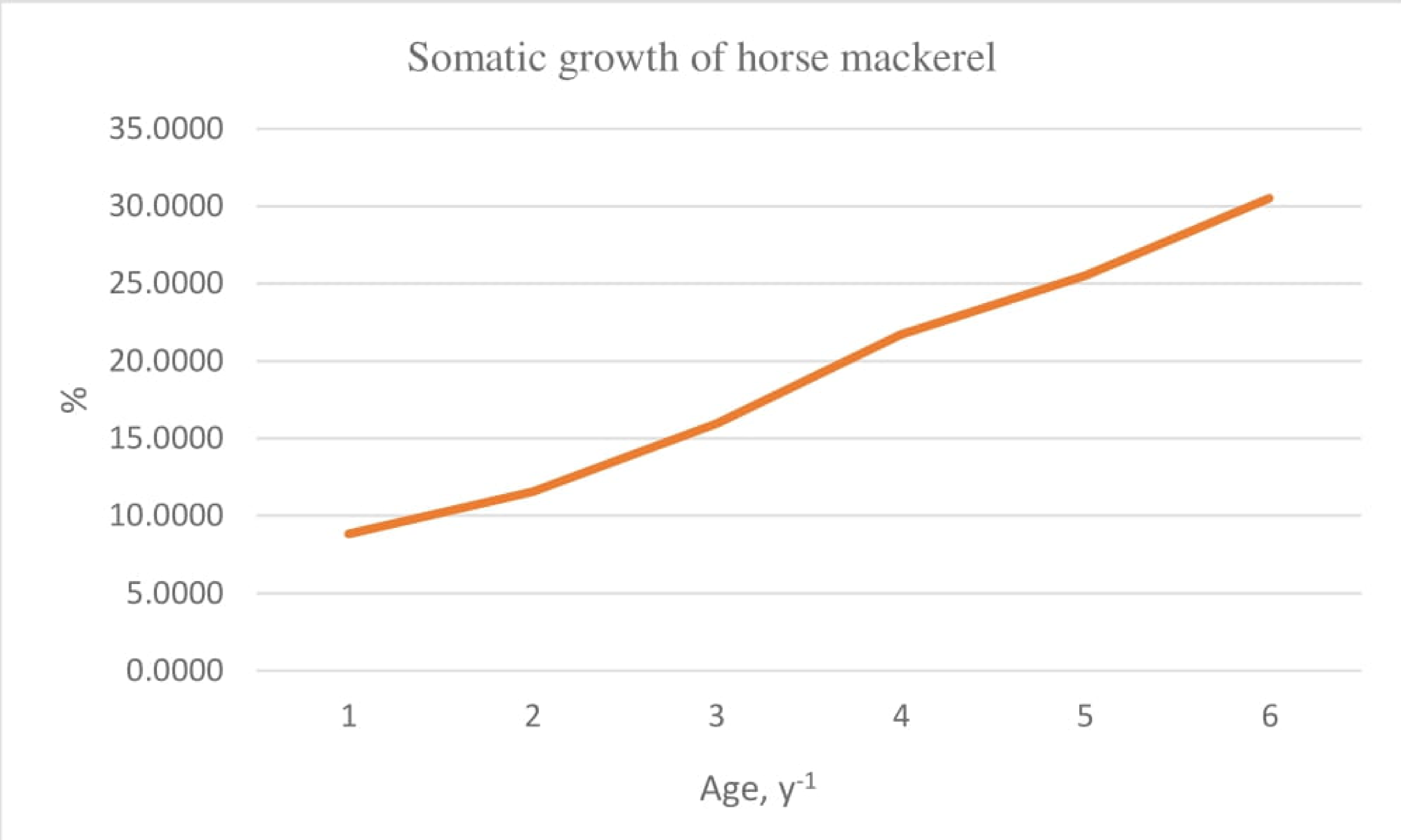

d.

Figure 10.1.1. Somatic growth of: a) sprat b) whiting c) red mullet d) horse mackerel in September 2024

11. Catch numbers

The size classes of 7.0–9.0–11.0 cm dominated the red mullet catches, with the larger size classes being represented by a smaller percentage. In September 2024, the largest percentage of representation in the catches was the 9.0 cm size class, followed by the 11.0 cm size class (Fig. 11.1.).

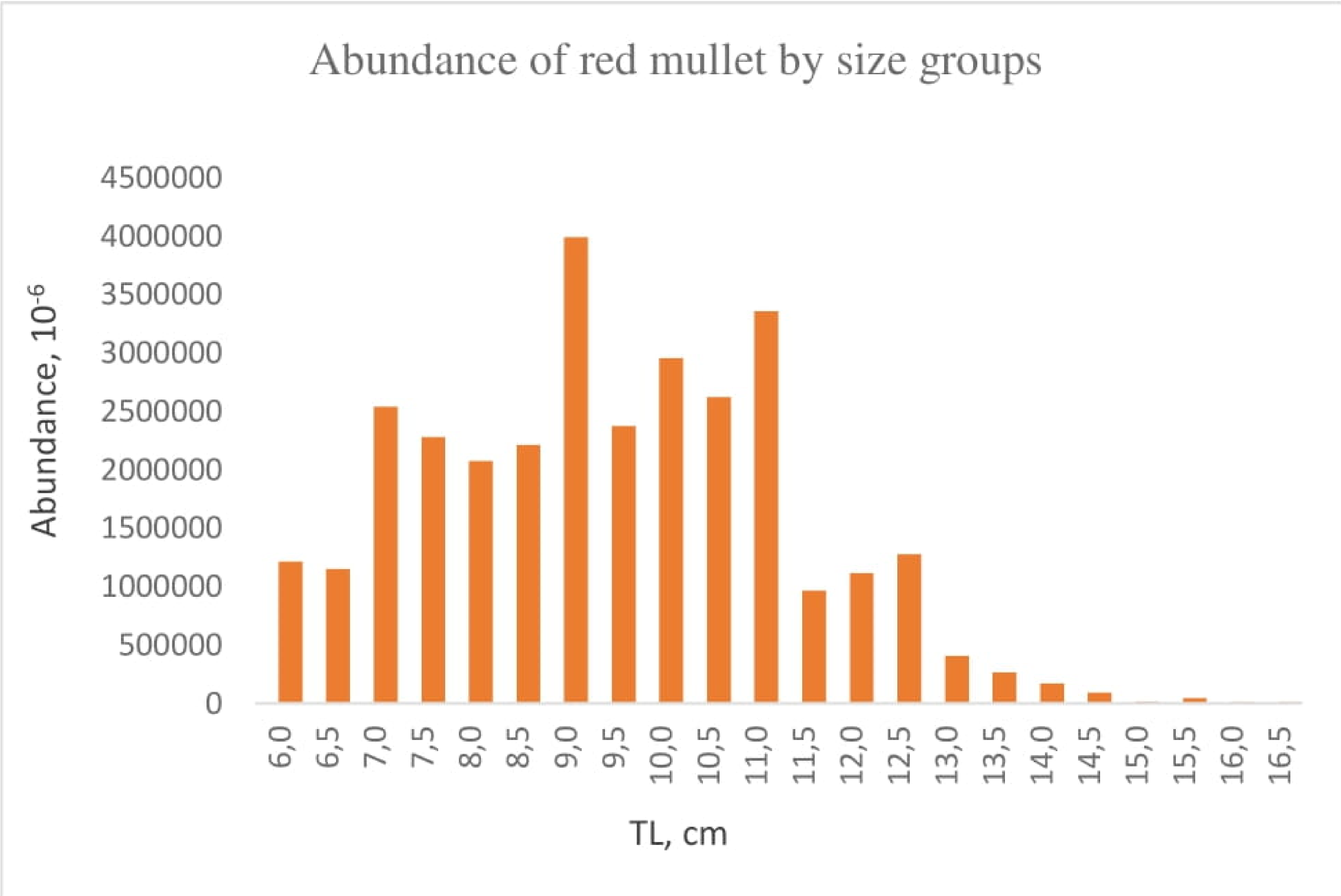

Figure 11.1. Abundance of red mullet by size classes in September 2024

In terms of the abundance of red mullet by age classes in September 2024, 1-1+ and 2-2+ year-old individuals predominated (Fig. 11.2).

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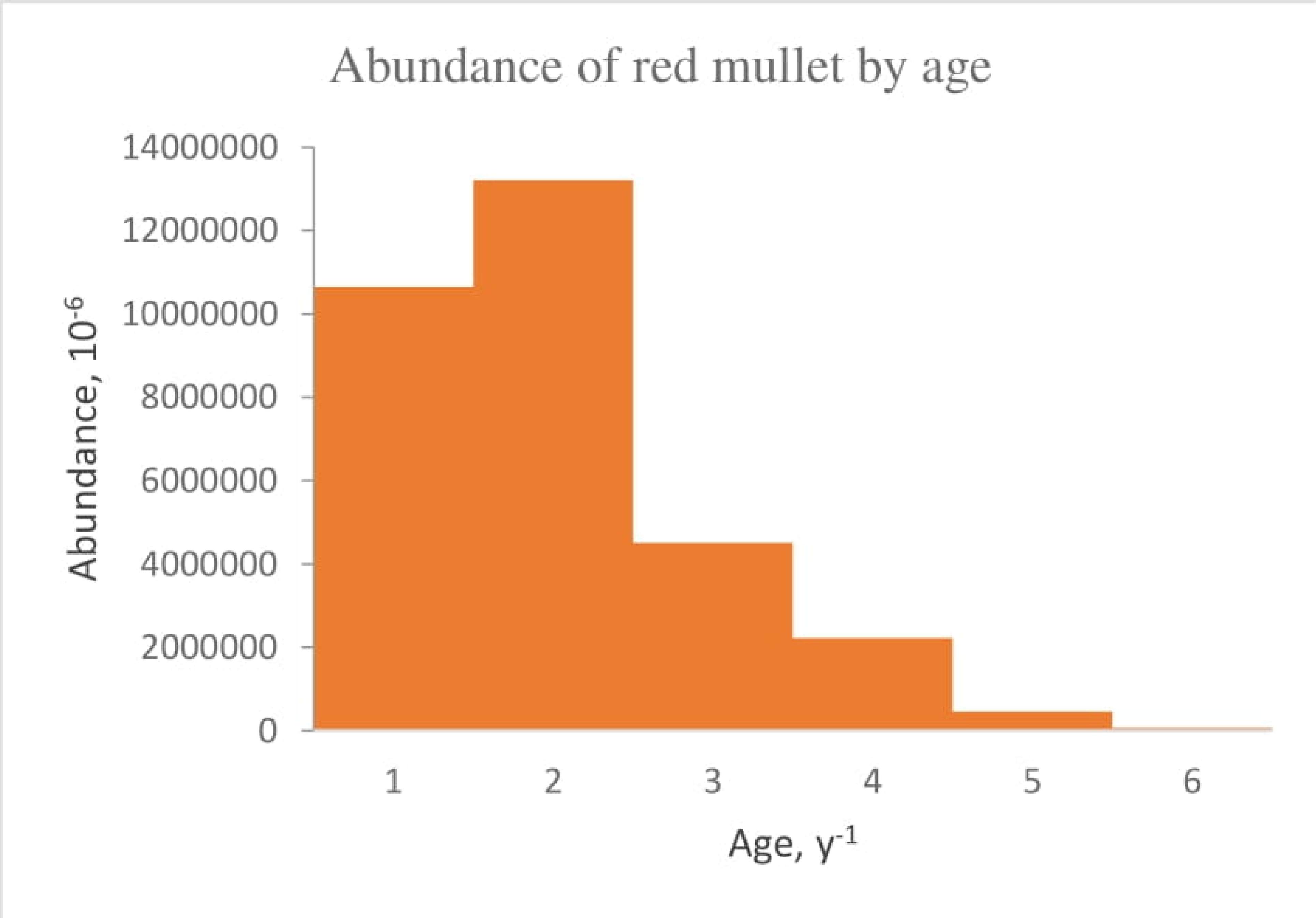

Figure 11.2. Abundance of red mullet by age classes in September 2024

Biomass, similar to abundance, showed a predominance of the 11.0 cm size group, followed by the 10.5 cm size group (Fig. 11.3). The biomass of 1-1+ y^{-1} individuals was the largest, followed by that of 2-2+ y^{-1} (Fig. 11.4.).

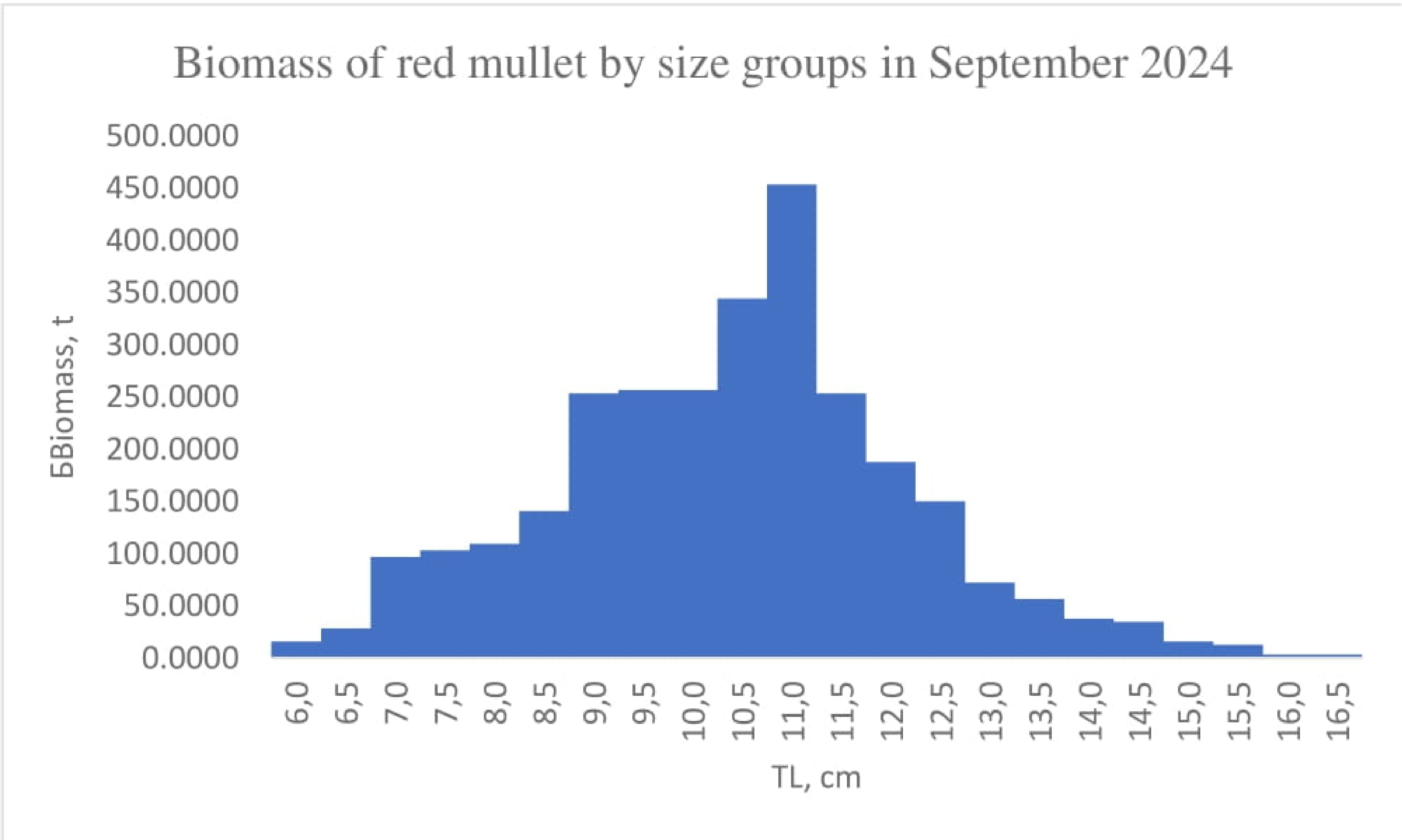

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Figure 11.3. Biomass of red mullet by size groups in September 2024

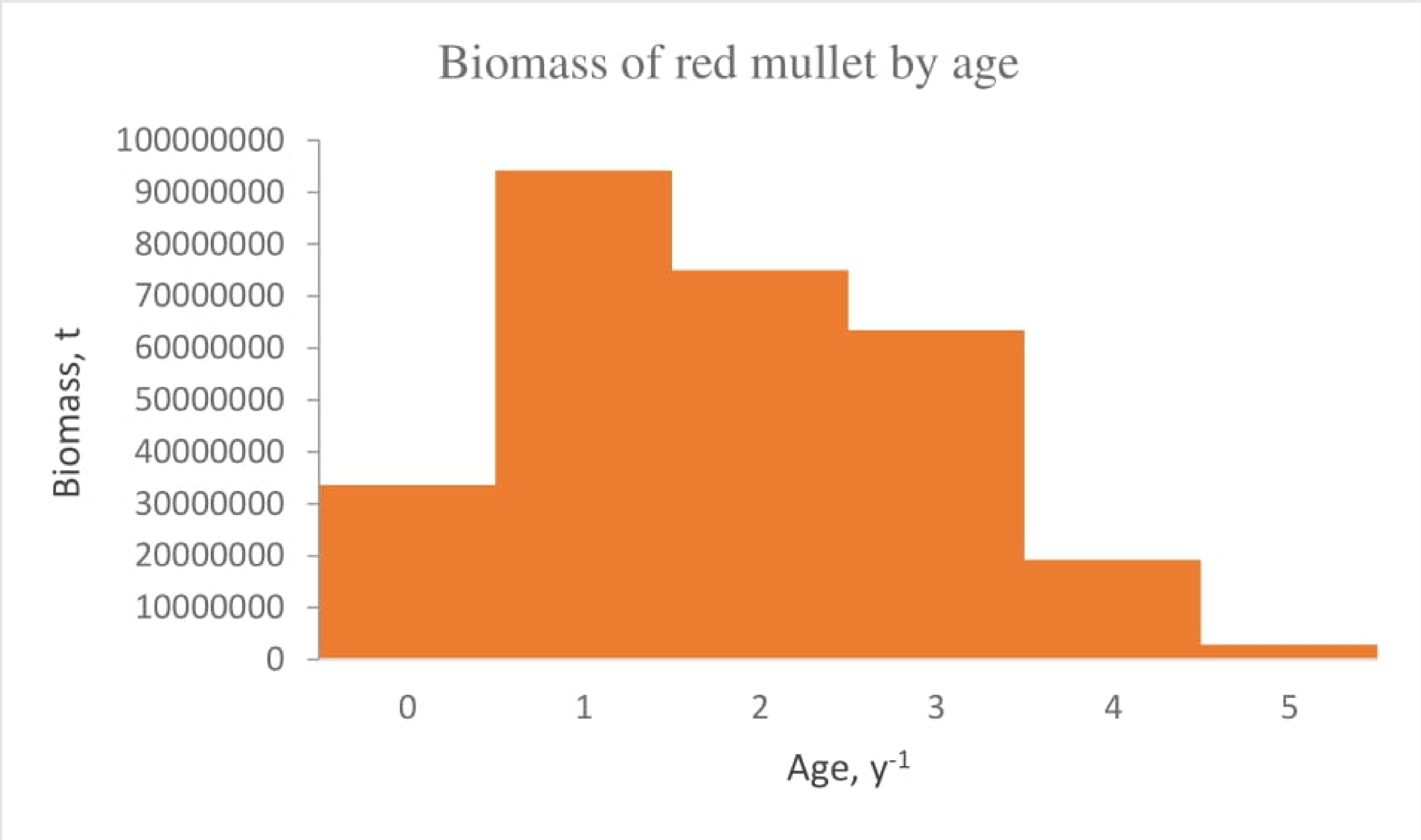

Figure 11.4. Biomass of red mullet by age groups in September 2024

The abundance of whiting by size group (Fig. 11.5.), showed the highest presence in the groups between 8.0 cm and 9.0 cm (with a peak at 8.5 cm). Very high presence of 0+ y^{-1} and 1-1+ y^{-1} individuals of whiting was noted during the present study.

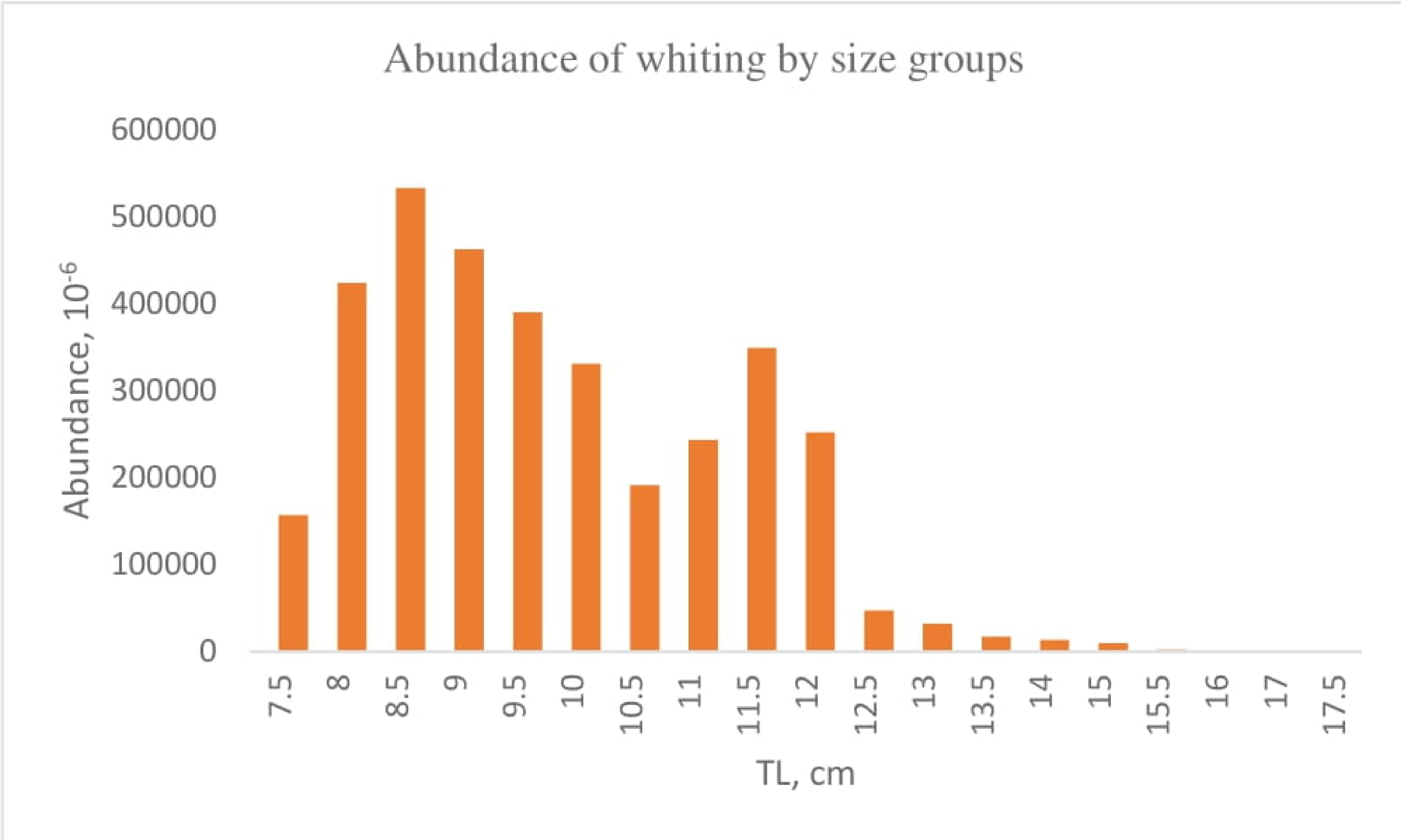

Figure 11.5. Abundance of whiting by size classes

The analysis of abundance by age groups shows a peak in groups 0+, 1,1+, and a significant decline in age groups from 2+ to 5 years (Fig. 11.7.).

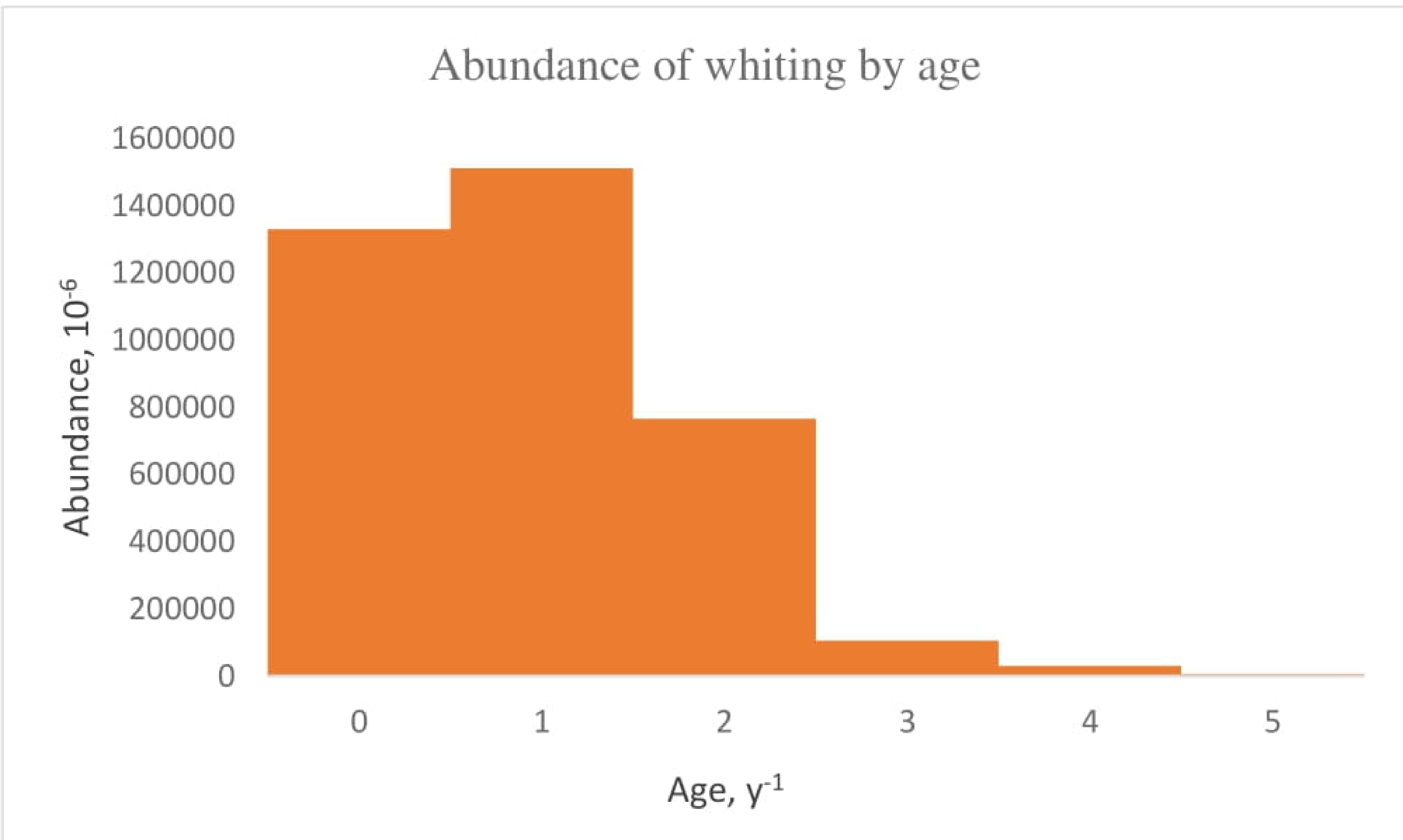

Figure 11.7. Abundance of whiting by age, September 2024

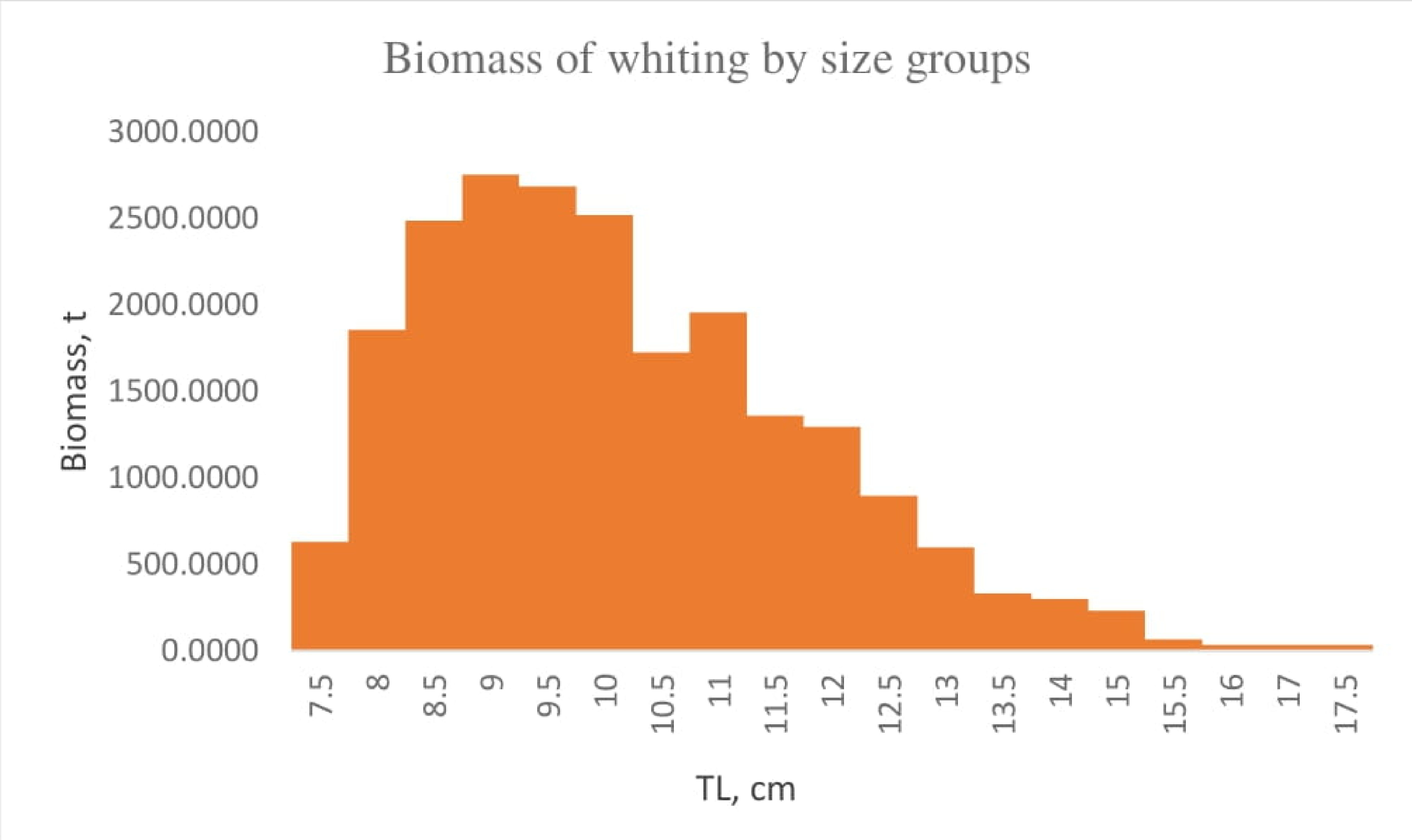

Figure 11.8. Biomass of whiting by size in September 2024

The peak of biomass by size group was from 8 to 10 cm (Fig. 11.8), and by age group the biomass was greatest in 3-year-olds, with age groups 4, 5 and 6 characterized by low biomass indices in September 2024 (Fig. 11.9.).

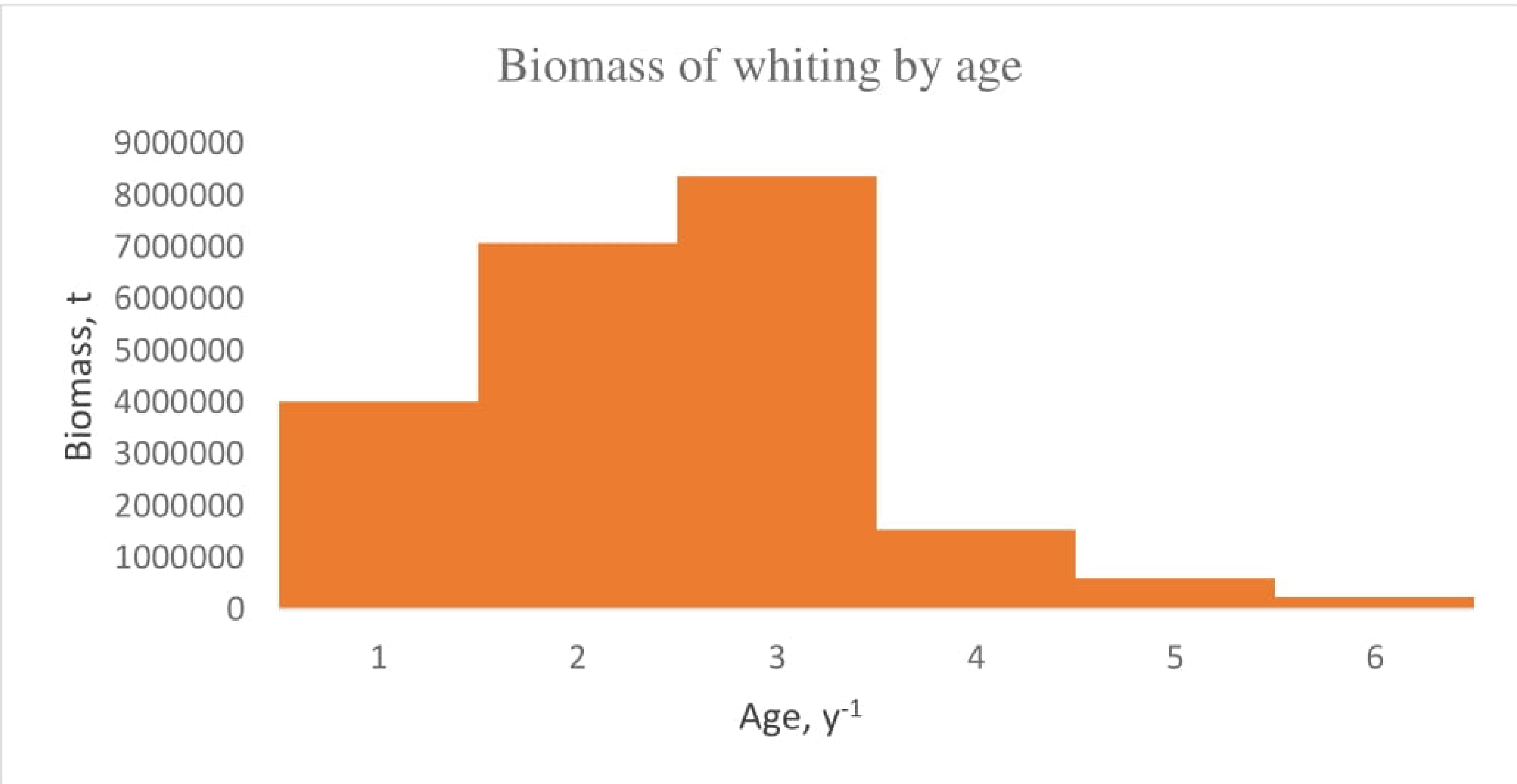

Figure 11.9. Biomass of whiting by age in September 2024

Horse mackerel abundance peaks in the 10.5 and 12.5 cm size groups in September 2024, with biomass peaking at 12.5 cm (Fig. 11.10). Biomass by size group has two peaks, one at 10.5 cm and the other at 12.5 cm (Fig. 11.11).

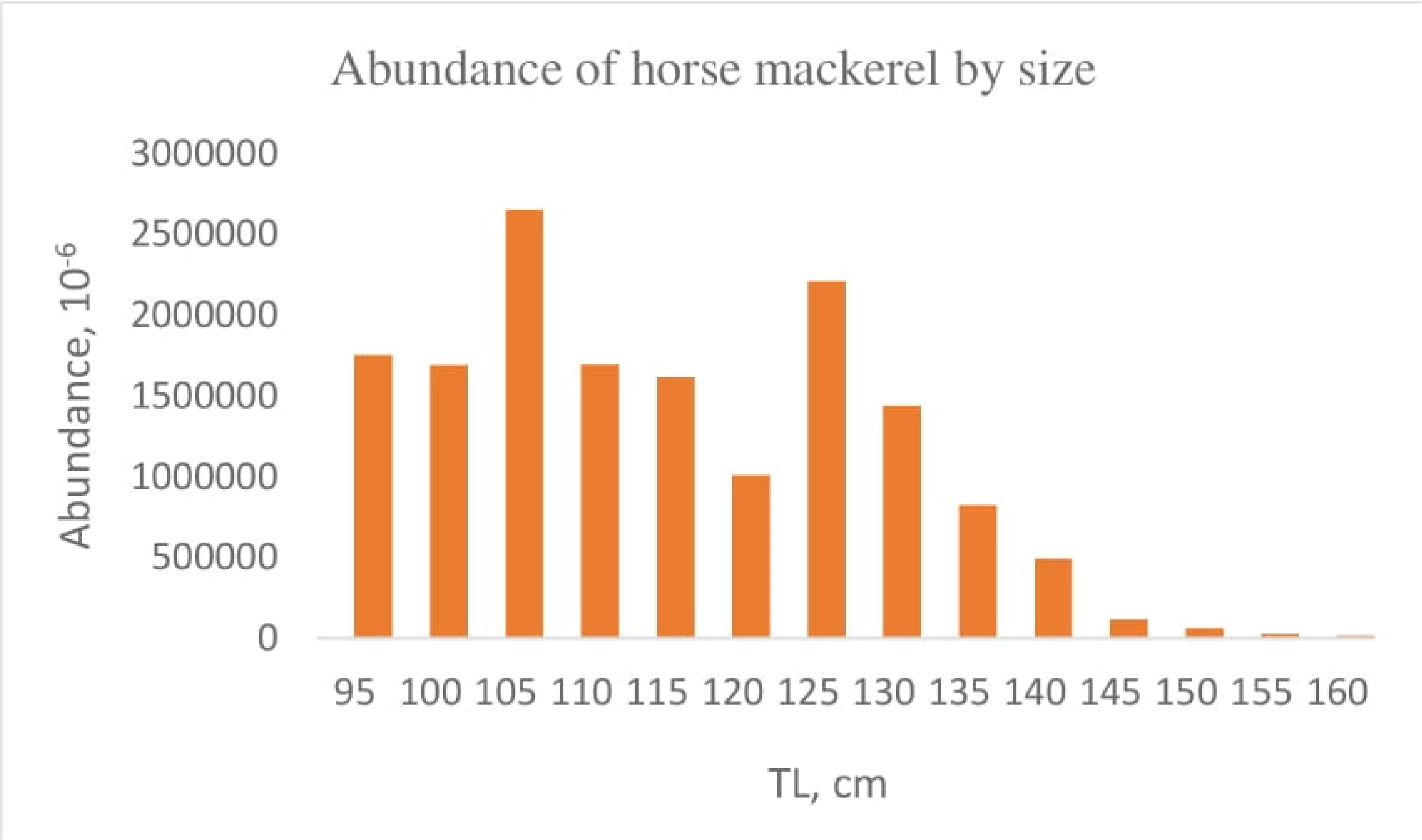

Figure 11.10. Abundance of horse mackerel by size in September 2024

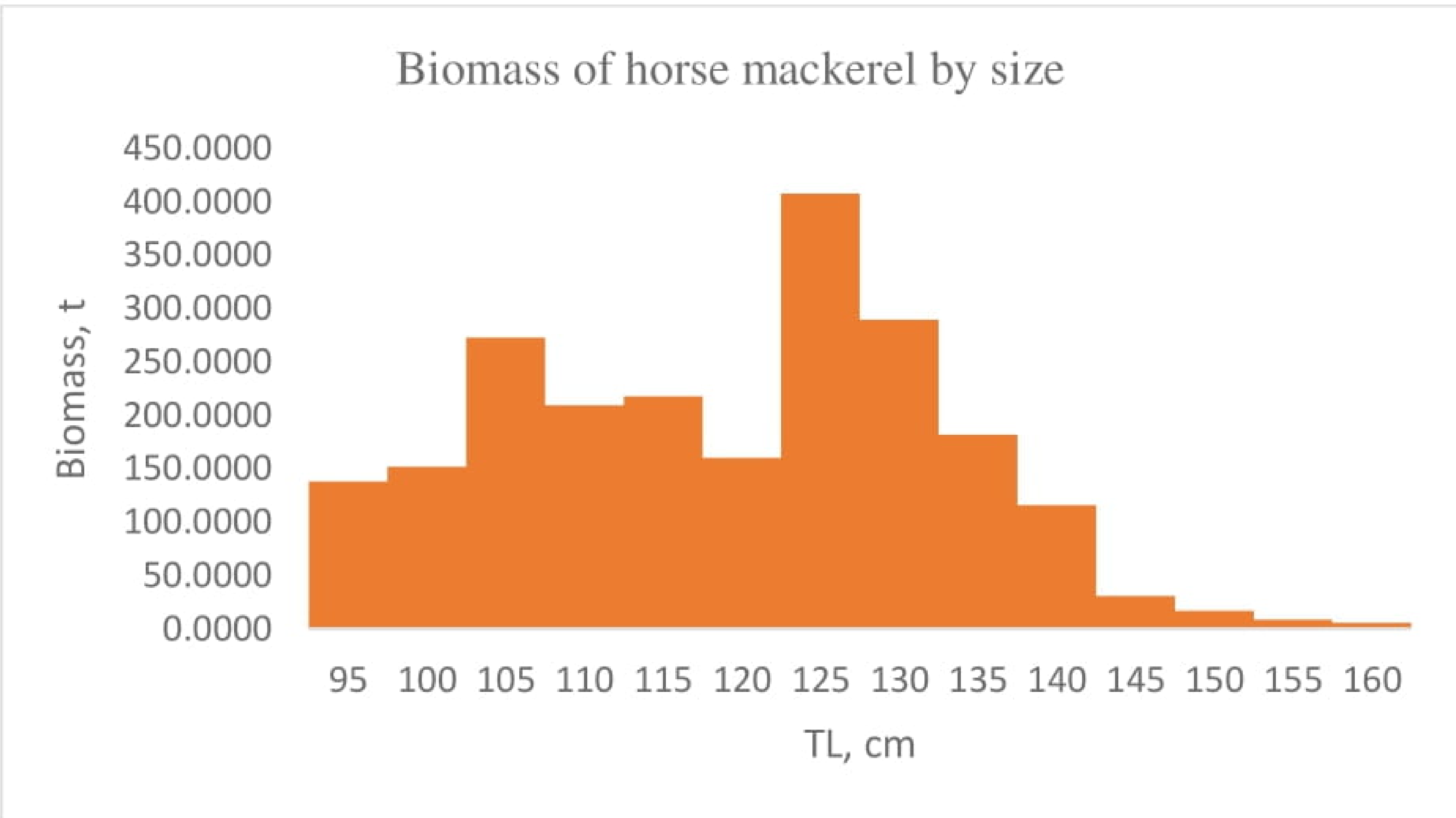

Figure 11.11. Biomass of horse mackerel by size in September 2024

The peak abundance and biomass of horse mackerel age groups were at 2-2+ years, with age groups 5 and 6 characterized by low biomass indices in September 2024 (Fig 11.12).

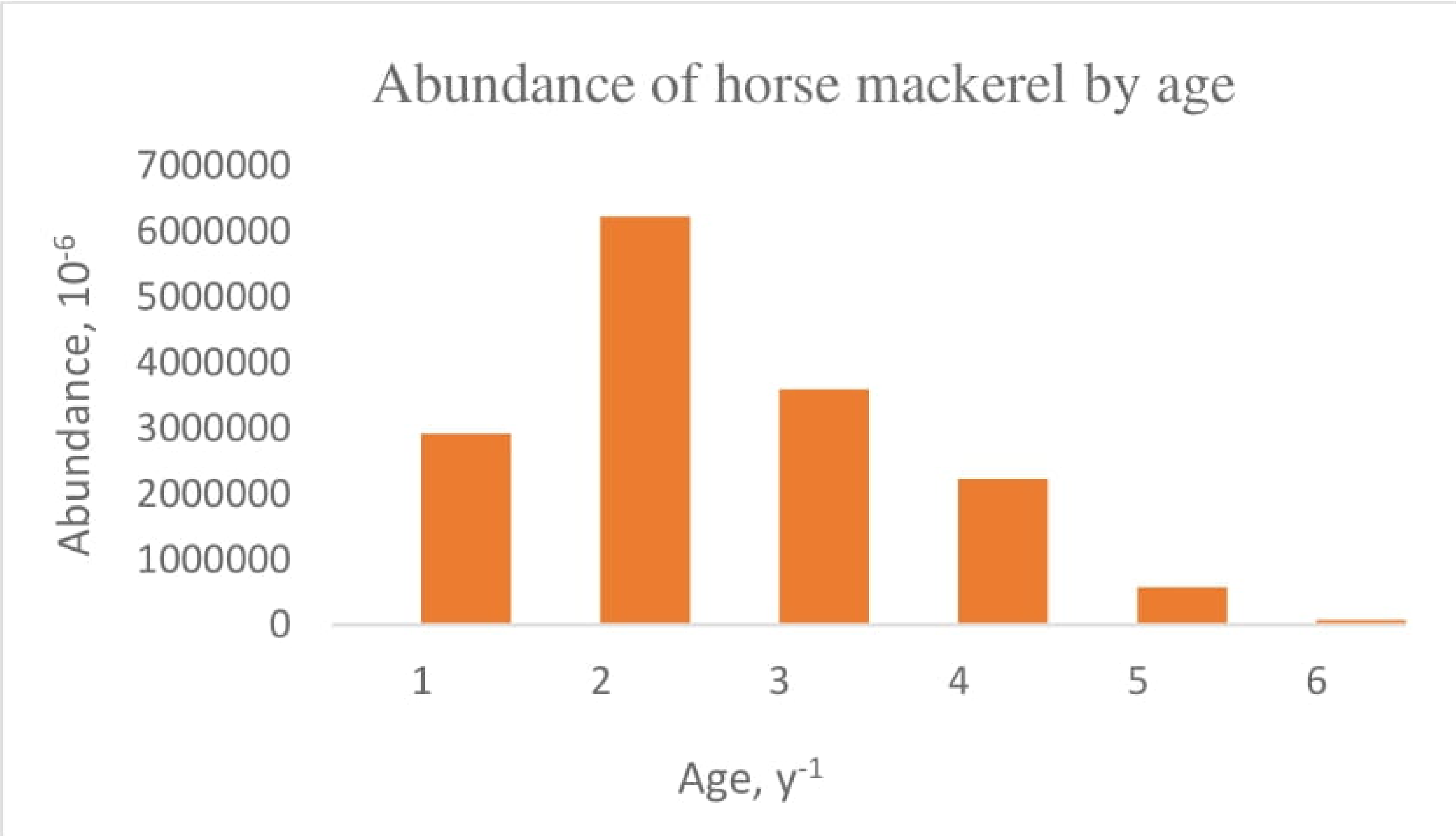

Figure 11.12. Abundance of horse mackerel by age in September 2024

Horse mackerel abundance peaks at 2-2+ y, and in biomass 1-1+ y have a higher percentage, followed by 2-2+ y (Fig. 11.13.).

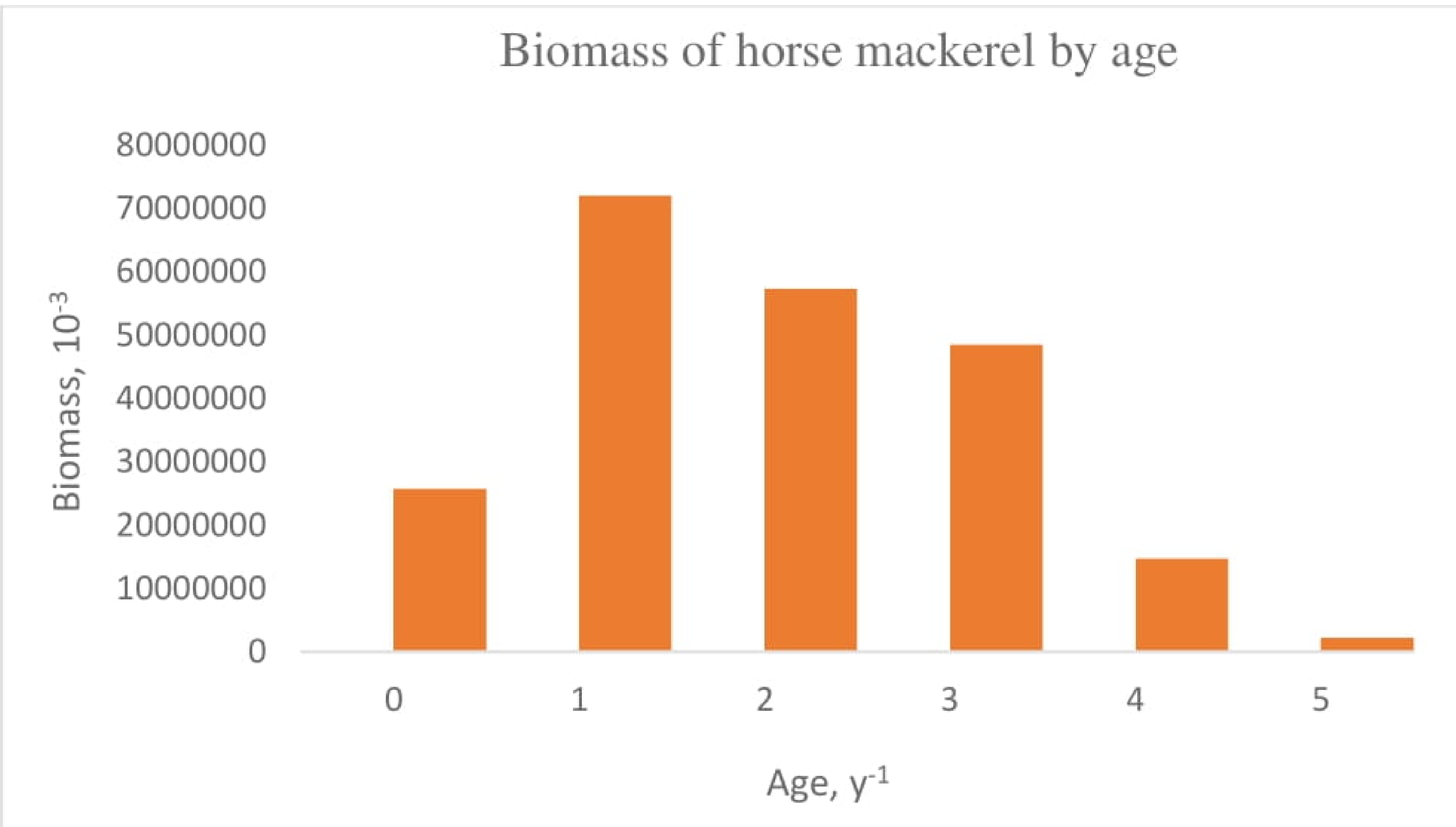

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Figure 11.13. Biomass of horse mackerel by age in September 2024

12. Sex ratio and maturity

The percentages of females, males and immatures in sprat, red mullet and horse mackerel were as follows: 50:45:5%; 48:44:8%; 50:45:5%; 46:48:6% (Fig. 12.1).

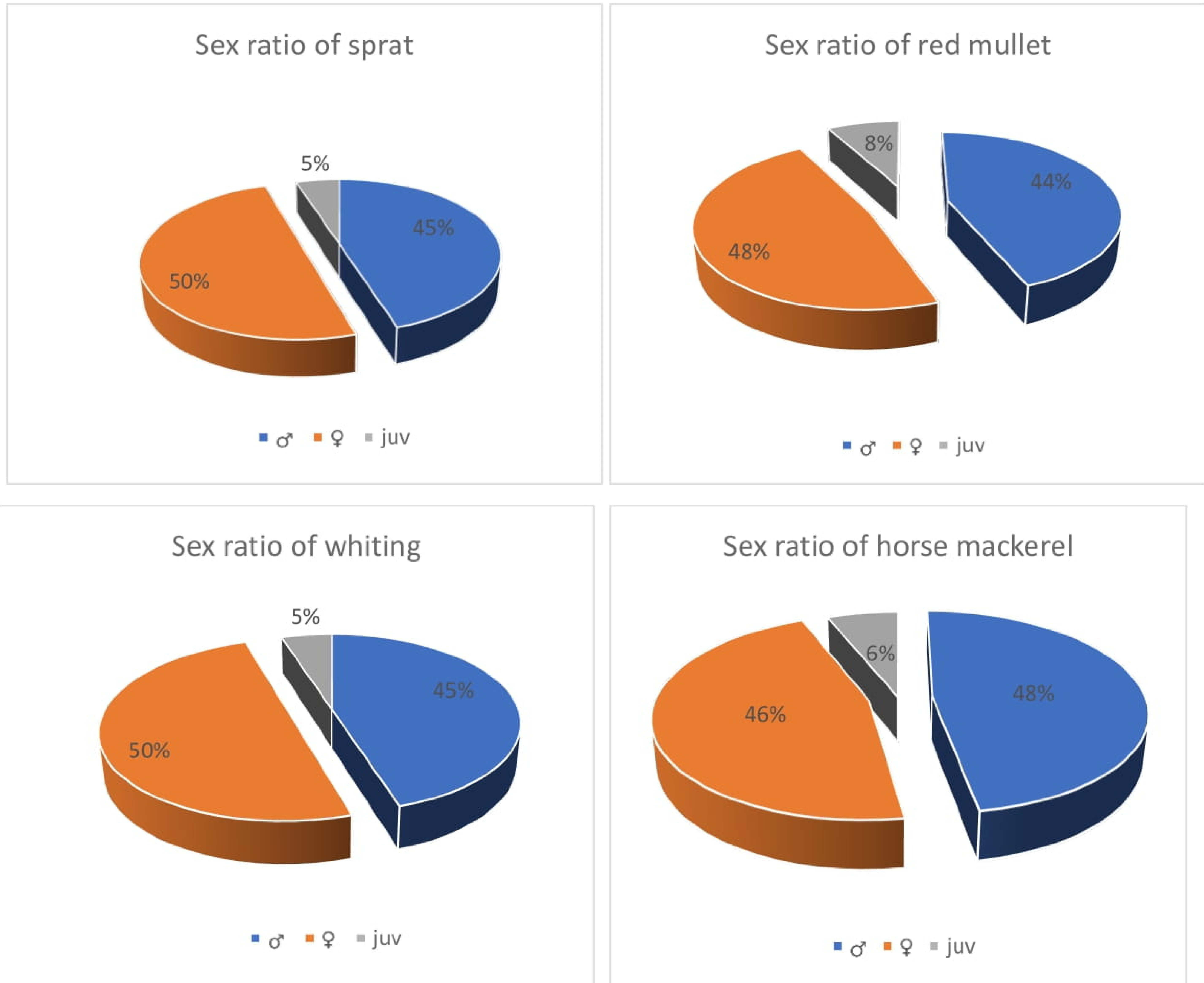
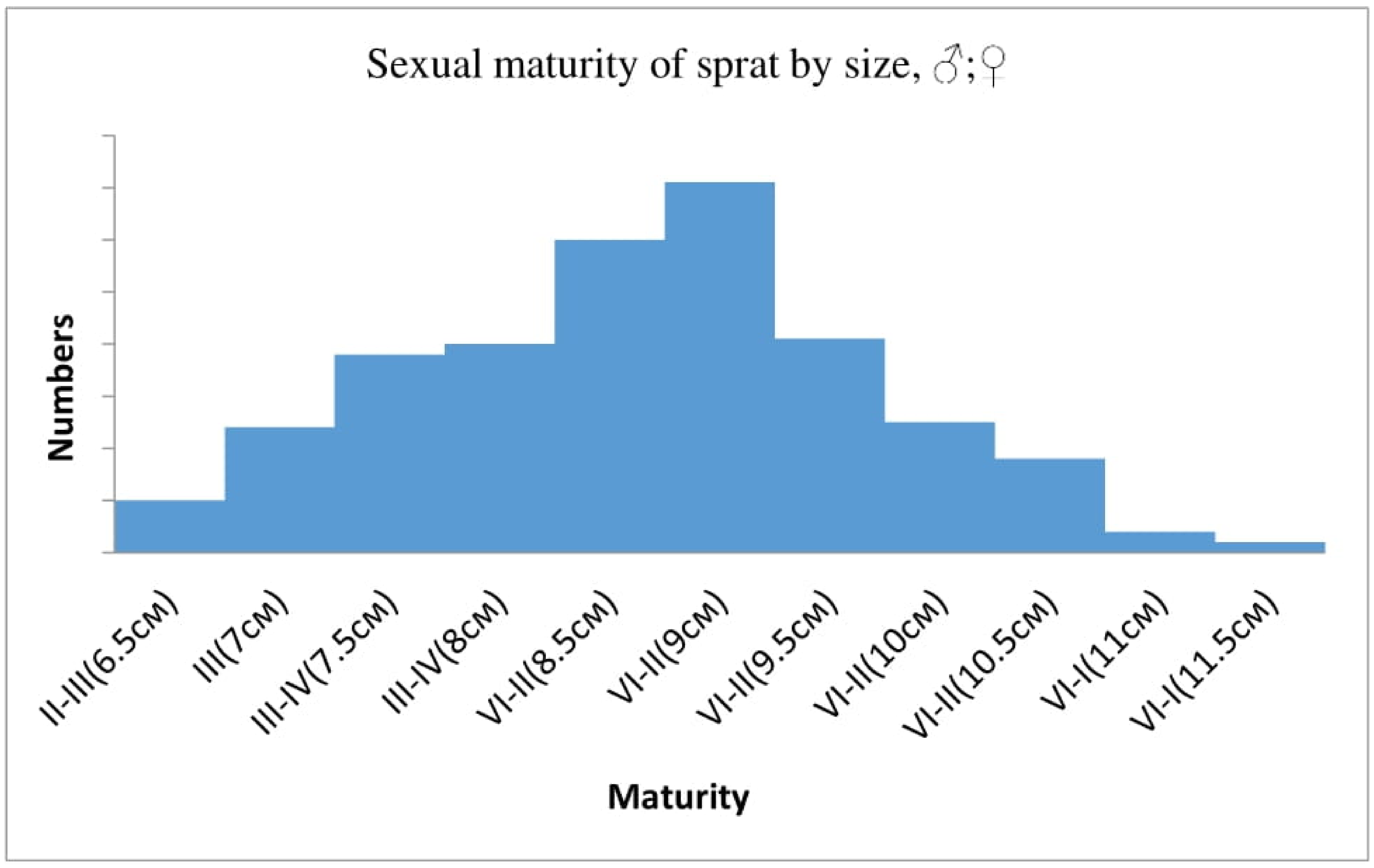


Figure 12.1. Sex ratio (females – ♀, males – ♂ и juv – juveniles) for the studied species, September 2024

The sexual maturity of the analyzed species by size classes is presented in Figure 12.2, and by age groups in Figure 12.3.



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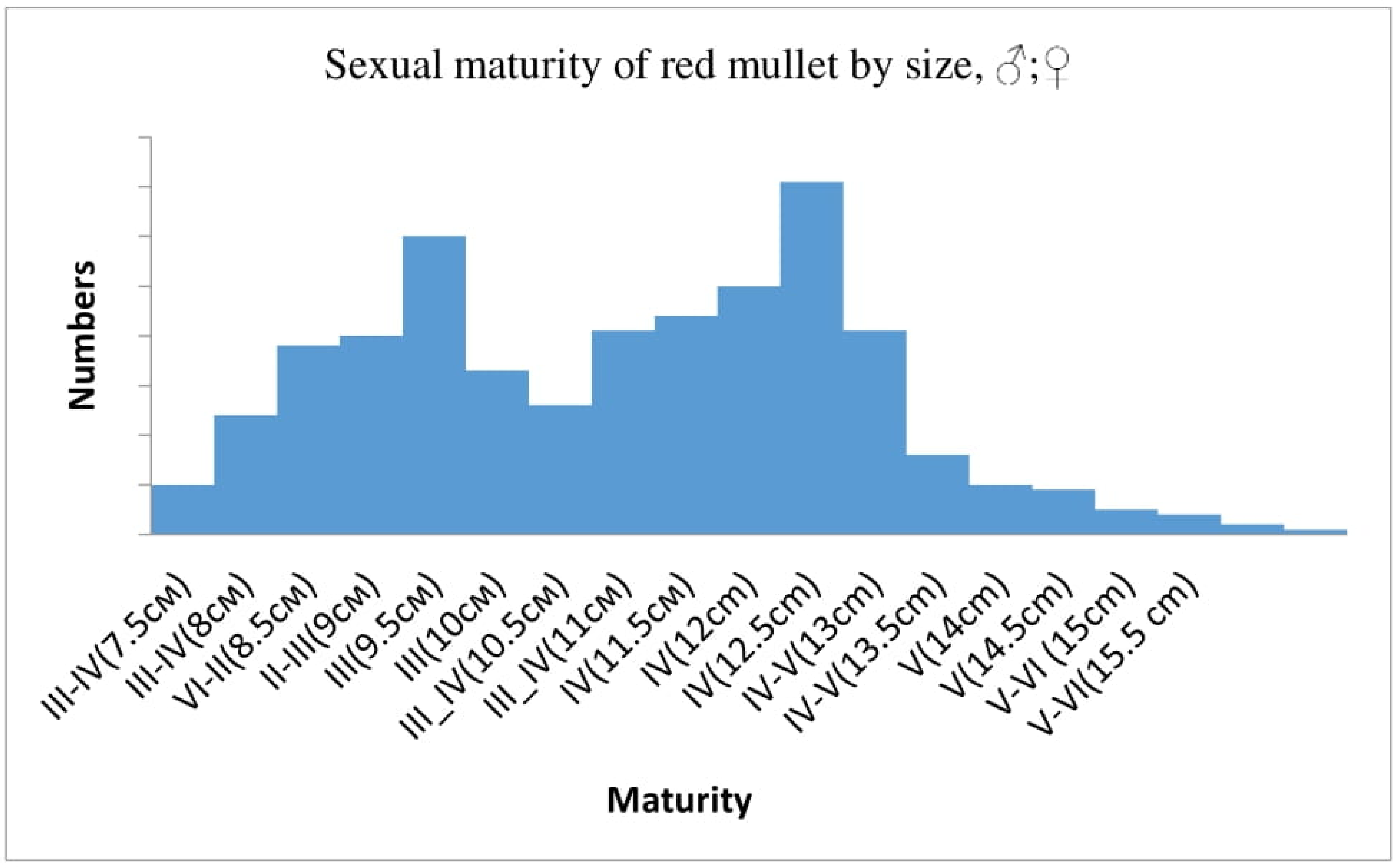

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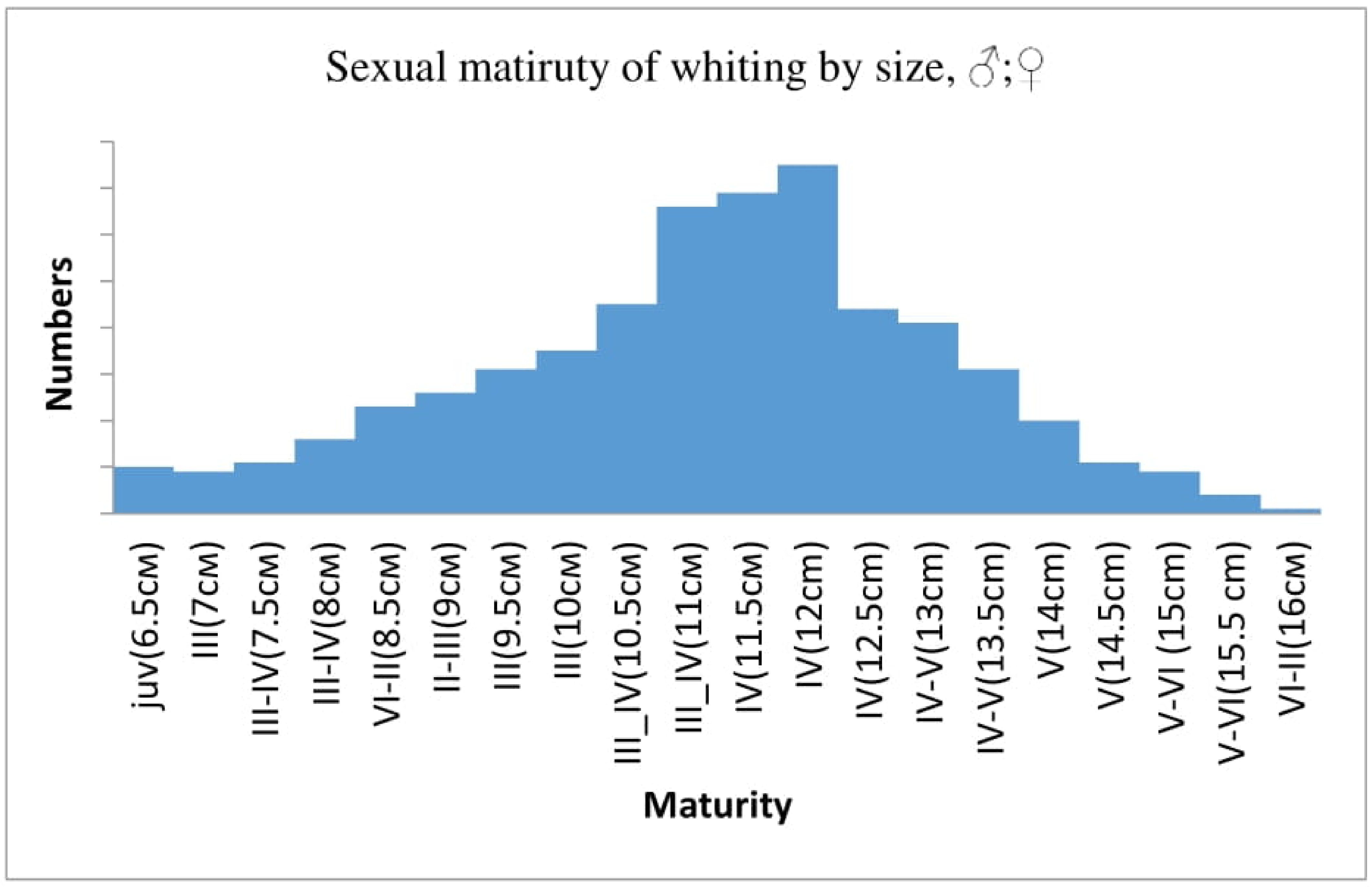

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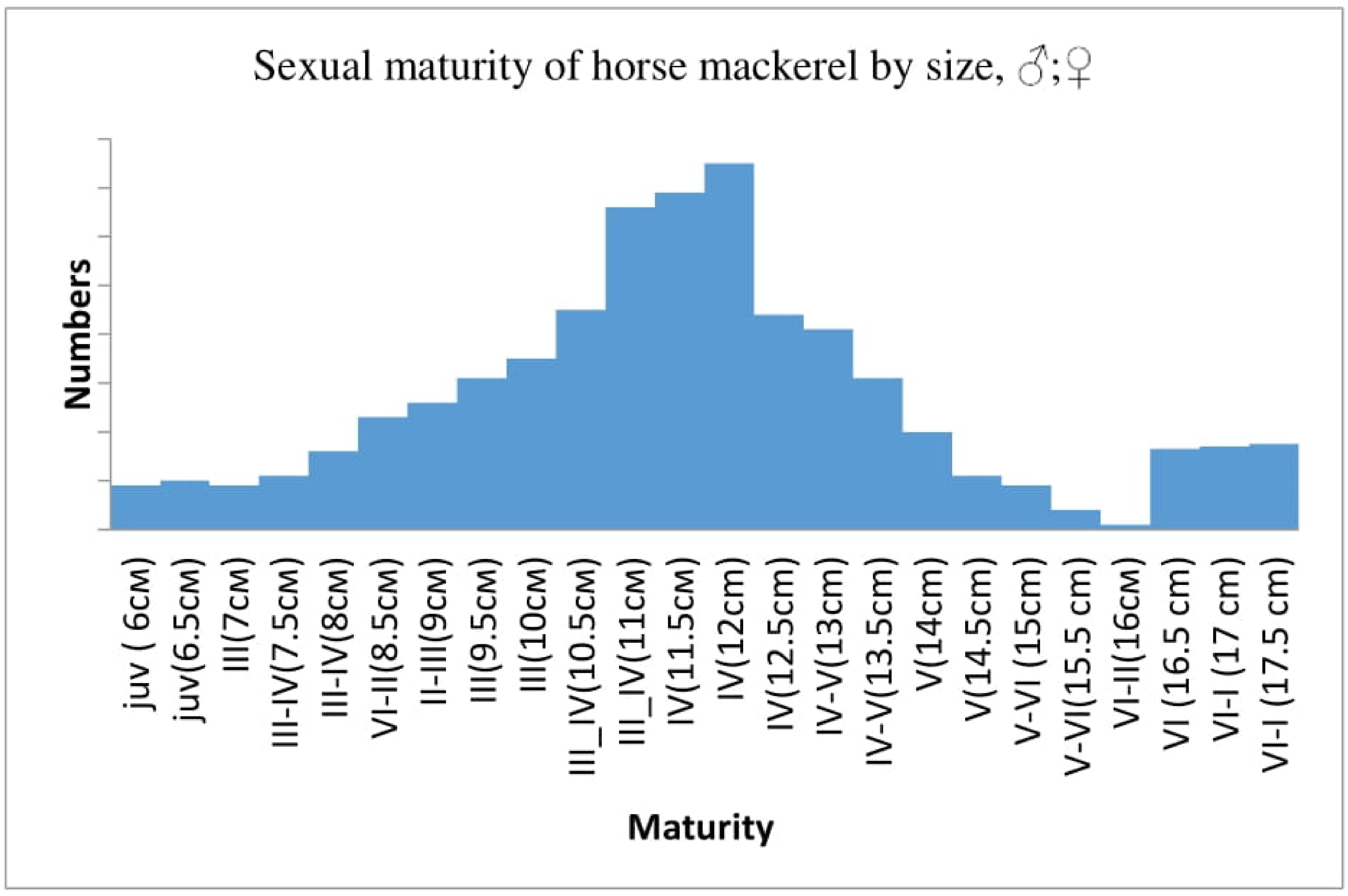

d

Figure 12.2. Sexual maturity of the stidued species, analysed by size classes (females – ♀, males – ♂ и juv – juveniles) a) sprat b) red mullet c) whiting d) horse mackerel

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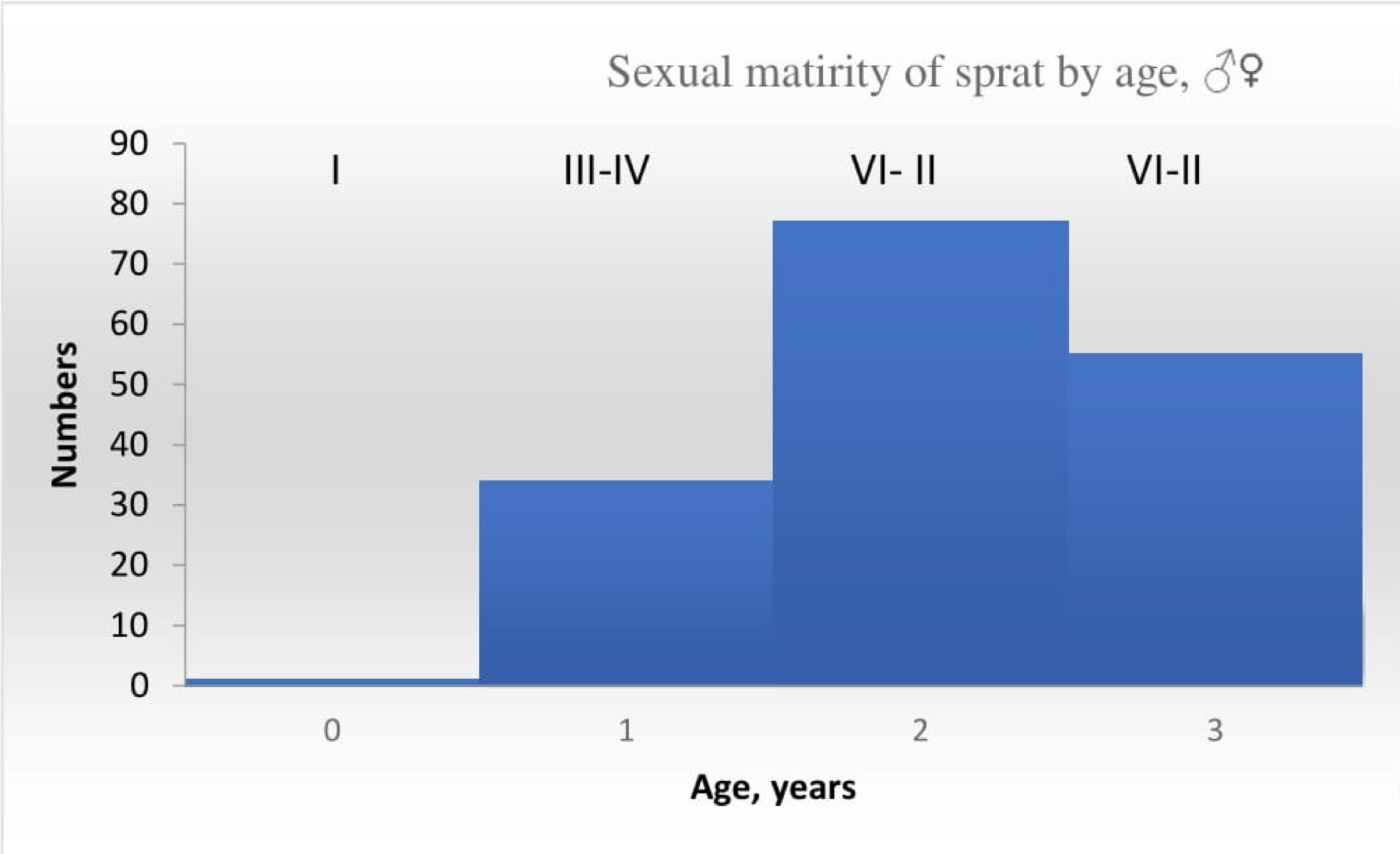

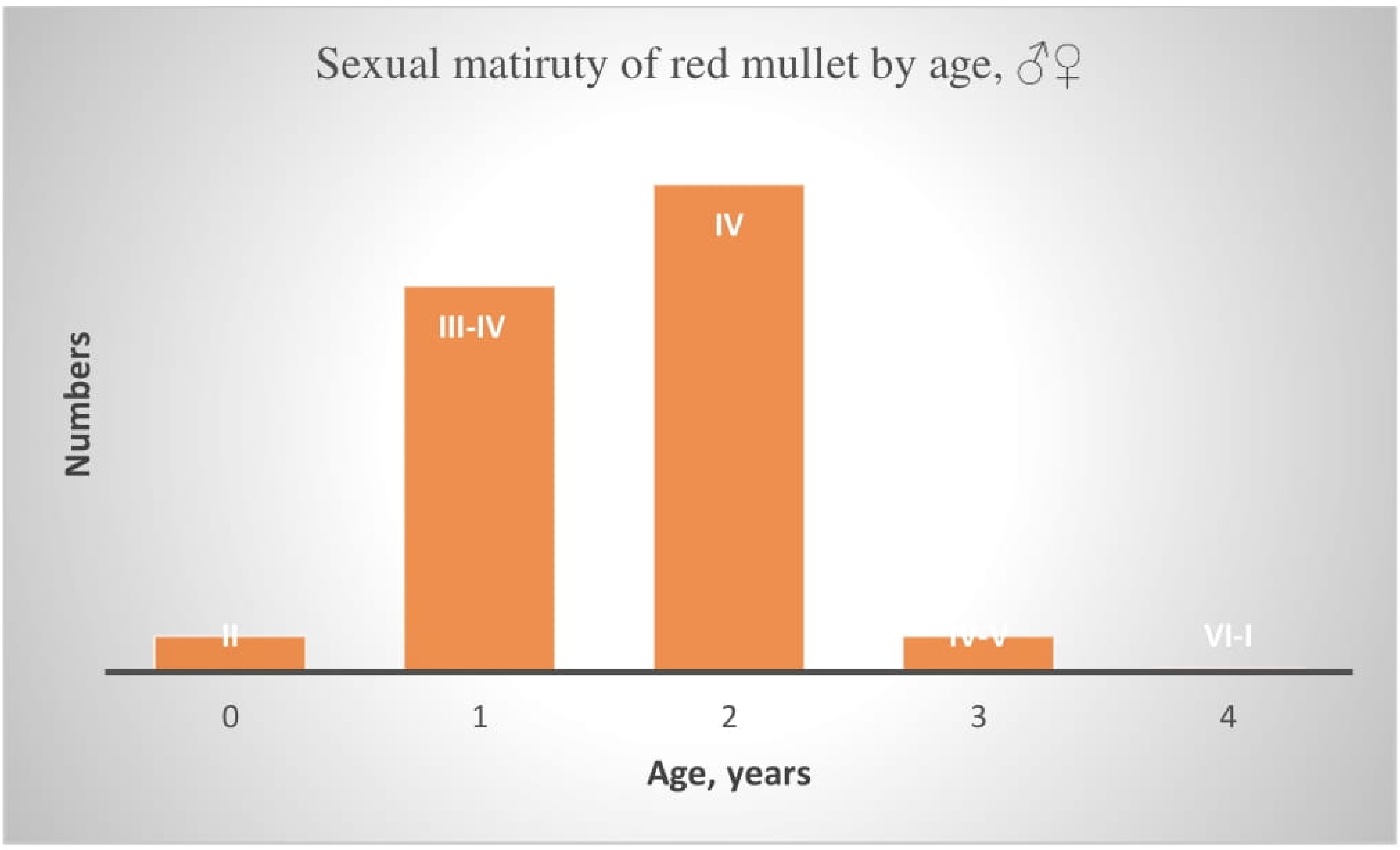

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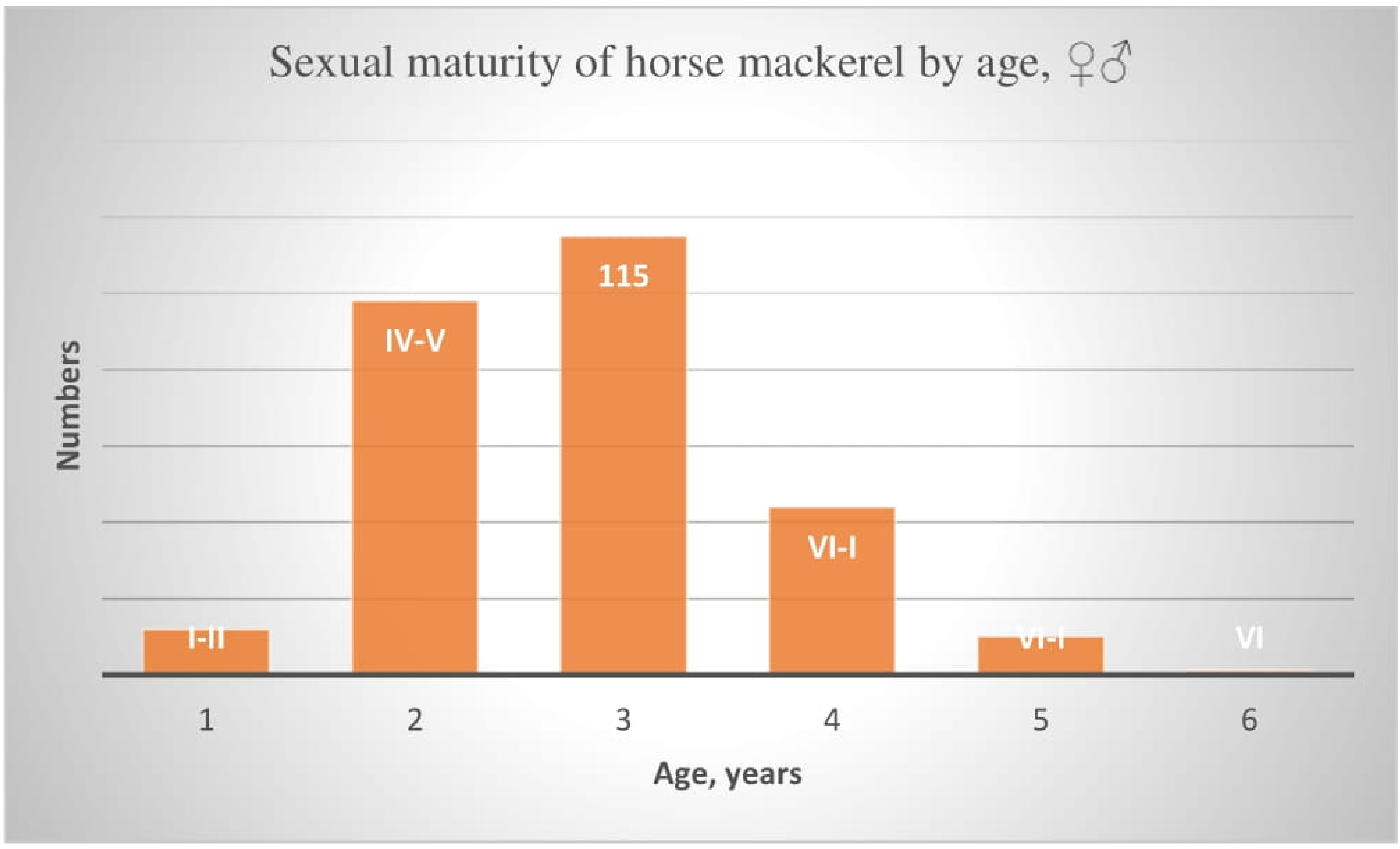

Figure 12.3. Sexual matiruty (females – ♀, males – ♂ и juv – juveniles) of the studied apecies, analysed by age gropus

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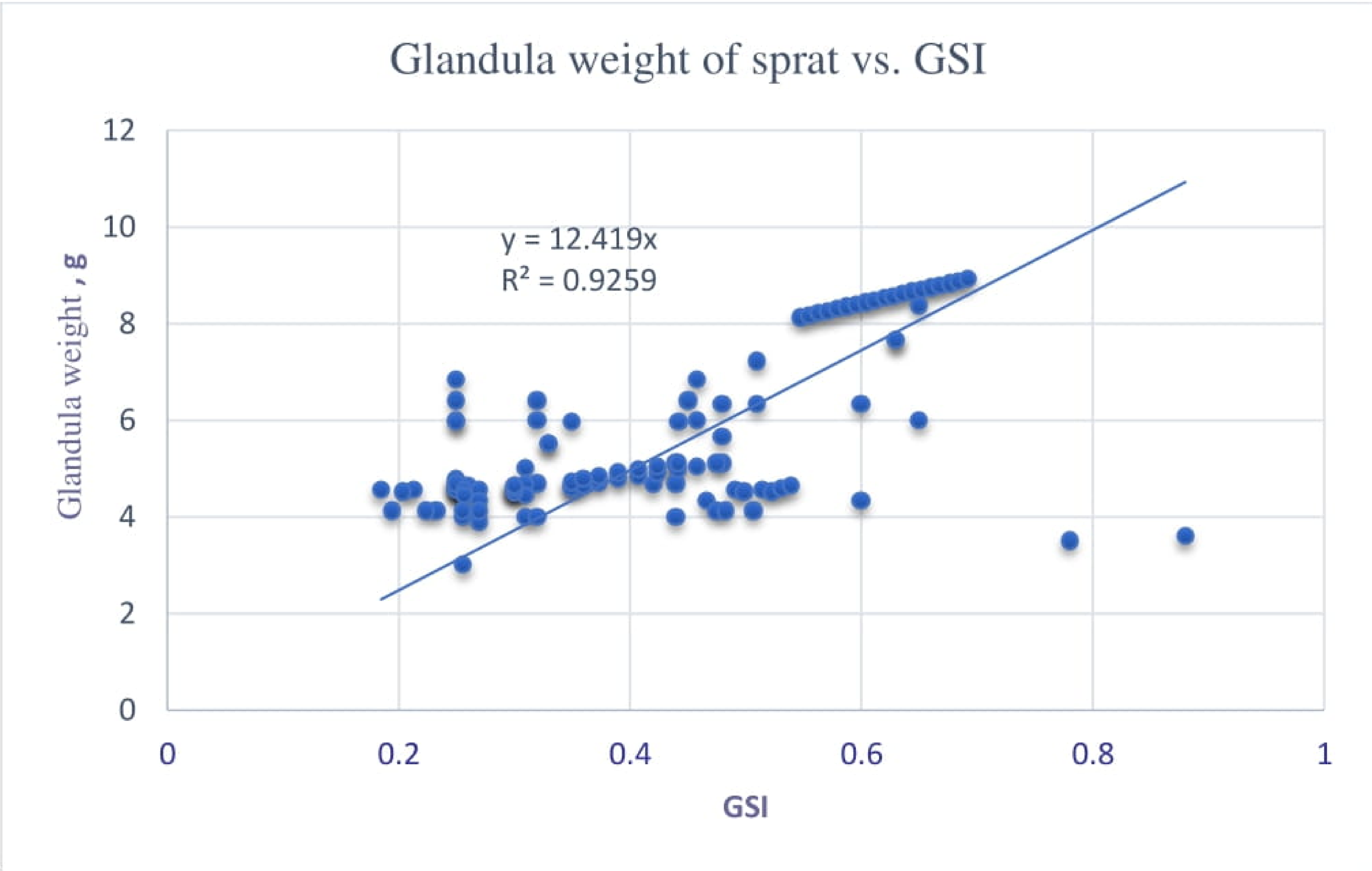
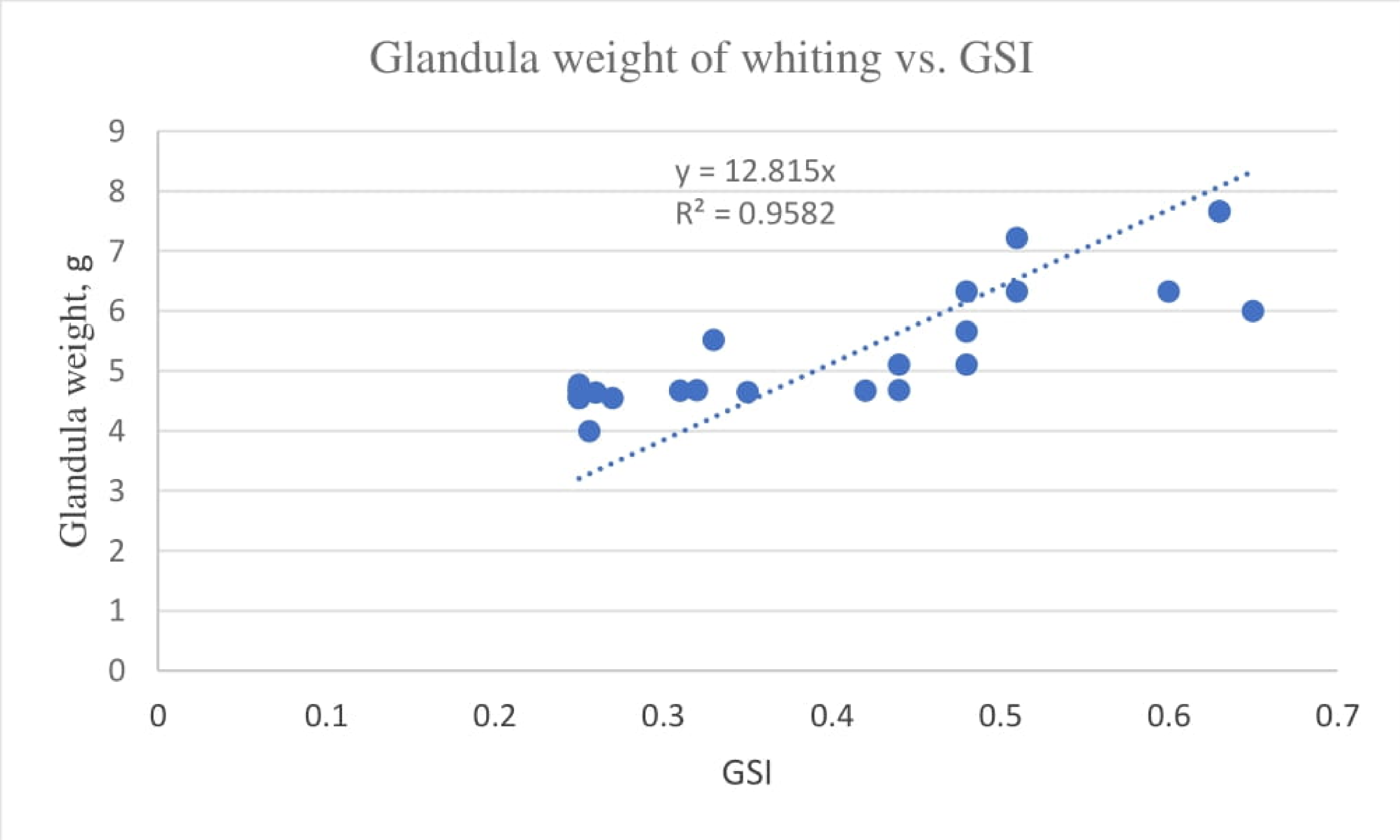
13. Fecundity and Gonado-somatic index (GSI)

The gonadosomatic index GSI (%) of sprat is indicative of the portioned spawning $R^2 = 0.93$ (Fig.13.1). For red mullet and whiting there is a very strong correlation between the weight of the glands and the gonadosomatic index ($R^2 = 0.66–0.96$), which is an indication of mass reproduction processes and active maturity of the sexual products during the studied period (Fig.13.1). For horse mackerel, the coefficient of determination was $R^2 = 0.76$.

a. 



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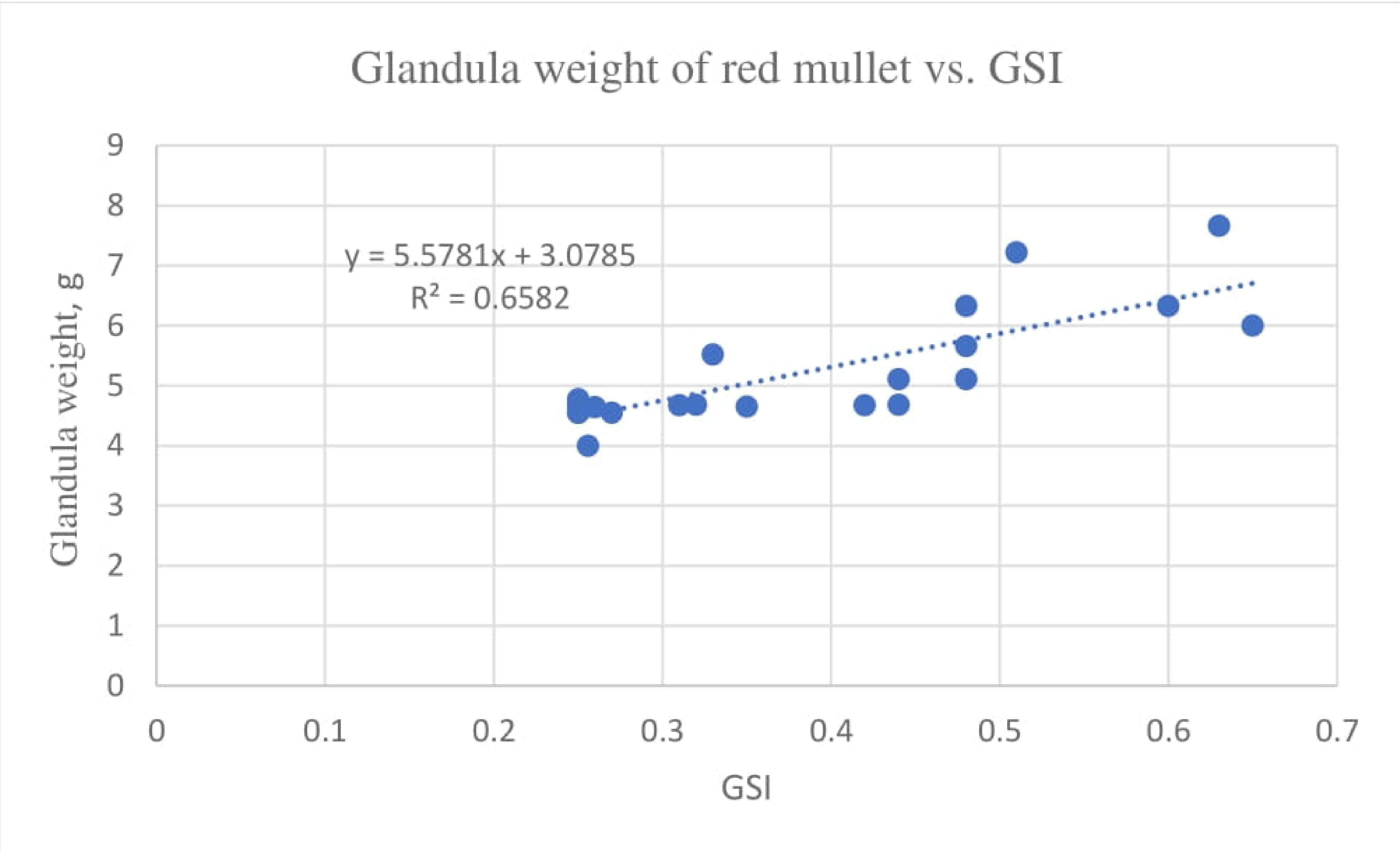

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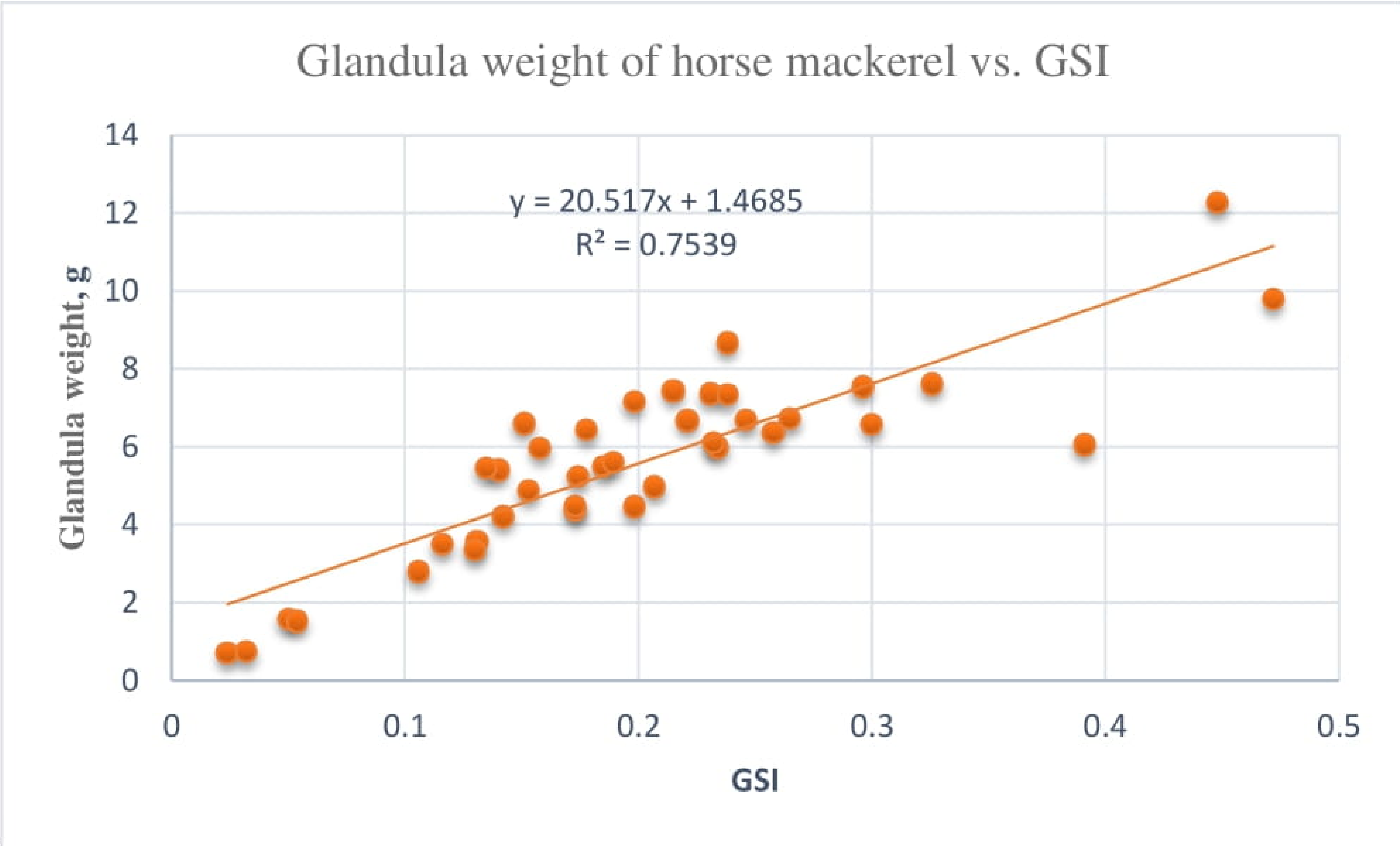

d.

Figure 13.1. Gonadosomatic index of a) sprat, b) red mullet, c) whiting, d) horse mackerel during the studied period (GSI,% vs. glandula weight)

14. Natural mortality

The Pauly formula (Pauly, 1980) was used to determine the natural mortality of sprat. The natural mortality values for the species were calculated as follows: When applying the asymptotic length in the formula: M = 0.763. When applying the asymptotic weight in the formula: M = 0.582. In the present study, the natural mortality value for sprat was used as 0.95 (Ivanov and Beverton, 1985; Prodanov et al., 1997).

15. Feeding

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

In the measured sprat specimens, the absolute length averaged 9.26 cm ± 0.87 (SD) and the average weight was 4.56 g ± 1.51 (SD). Correspondingly, the mean length of the horse mackerel was 9.98 cm ± 2.13 (SD), with a mean weight of 9.39 g ± 6.03 (SD), for anchovy these parameters were 10.34 cm ± 1.26 (SD) and 6.13 g ± 1.94 (SD), and for whiting 10.73 cm ± 1.76 (SD) and 9.86 g ± 4.60 (SD) (Table 15.1.1.).

Table 15.1.1. Summary data for length (L, cm), weight (W, g), and ISF (% of BW) of plankton-eating fish: sprat (1), horse mackerel (2), anchovy (3), and whiting (4), as determined by stomach content analysis in IX.2024.

1. Sprat

	L, cm	W, g	ISF, % BW
Average value	9.26	4.56	0.23
Standard error	0.28	0.48	0.04
Median	9.45	4.45	0.21
Mode	10.30	#N/A	#N/A
Standard deviation	0.87	1.51	0.13
Sample Variance	0.76	2.28	0.02
Kurtosis	-1.87	-1.10	-0.33
Skewness	0.02	0.50	0.57
Range	2.00	4.20	0.41
Minimum	8.30	2.90	0.06
Maximum	10.30	7.10	0.47
Confidence interval (95.0%)	0.63	1.08	0.09

2. Horse mackerel

	L, cm	W, g	ISF, % BW
Average value	9.98	9.388	0.45
Standard error	0.24	0.665	0.07
Median	9.05	6.100	0.22
Mode	12.50	17.900	#N/A
Standard deviation	2.13	6.025	0.66
Sample Variance	4.55	36.296	0.44
Kurtosis	-1.28	-1.218	13.96
Skewness	0.23	0.602	3.40
Range	8.30	21.000	3.93
Minimum	5.50	1.200	0.00

Maximum	13.80	22.200	3.94
Confidence interval (95.0%)	0.47	1.324	0.15

3. Anchovy

	L, cm	W, g	ISF, % BW
Average value	10.34	6.134	0.47
Standard error	0.16	0.248	0.13
Median	10.80	6.500	0.17
Mode	11.00	6.300	#N/A
Standard deviation	1.26	1.937	1.01
Sample Variance	1.60	3.753	1.01
Kurtosis	-0.28	-0.601	16.74
Skewness	-0.91	-0.553	3.86
Range	4.90	7.900	5.98
Minimum	7.30	1.900	0.00
Maximum	12.20	9.800	5.99
Confidence interval (95.0%)	0.32	0.496	0.26

4. Whiting

	L, cm	W, g	ISF, % BW
Average value	10.73	9.86	1.12
Standard error	0.39	1.03	0.38
Median	10.85	10.65	0.56
Mode	12.50	11.40	#N/A
Standard deviation	1.76	4.60	1.70
Sample Variance	3.11	21.20	2.90
Kurtosis	-0.62	-0.66	6.15
Skewness	0.06	0.37	2.65
Range	6.50	16.50	6.17
Minimum	7.50	3.10	0.09
Maximum	14.00	19.60	6.26
Confidence interval (95.0%)	0.82	2.16	0.80

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

(1) Sprat: $W (g) = 0.0023*L (cm)^{3.3889}$; ($R2 = 0.93$, $p<0.001$, Fig. 15.1.1 (1))

(2) Horse mackerel: $W (g) = 0.0063*L (cm)^{3.1142}$; ($R2 = 0.98$, $p<0.001$, Fig. 15.1.1 (2))

(3) Anchovy: $W (g) = 0.0072L (cm)^{2.8695}$; ($R2 = 0.96$, $p<0.001$, Fig. 15.1.1 (3))

(4) Whiting: $W (g) = 0.0068*L (cm)^{3.0329}$; ($R2 = 0.93$, $p<0.001$, Fig. 15.1.1 (4))

The growth of all species except anchovy is positively allometric, with a coefficient b > 3, while that of anchovy is negatively allometric.

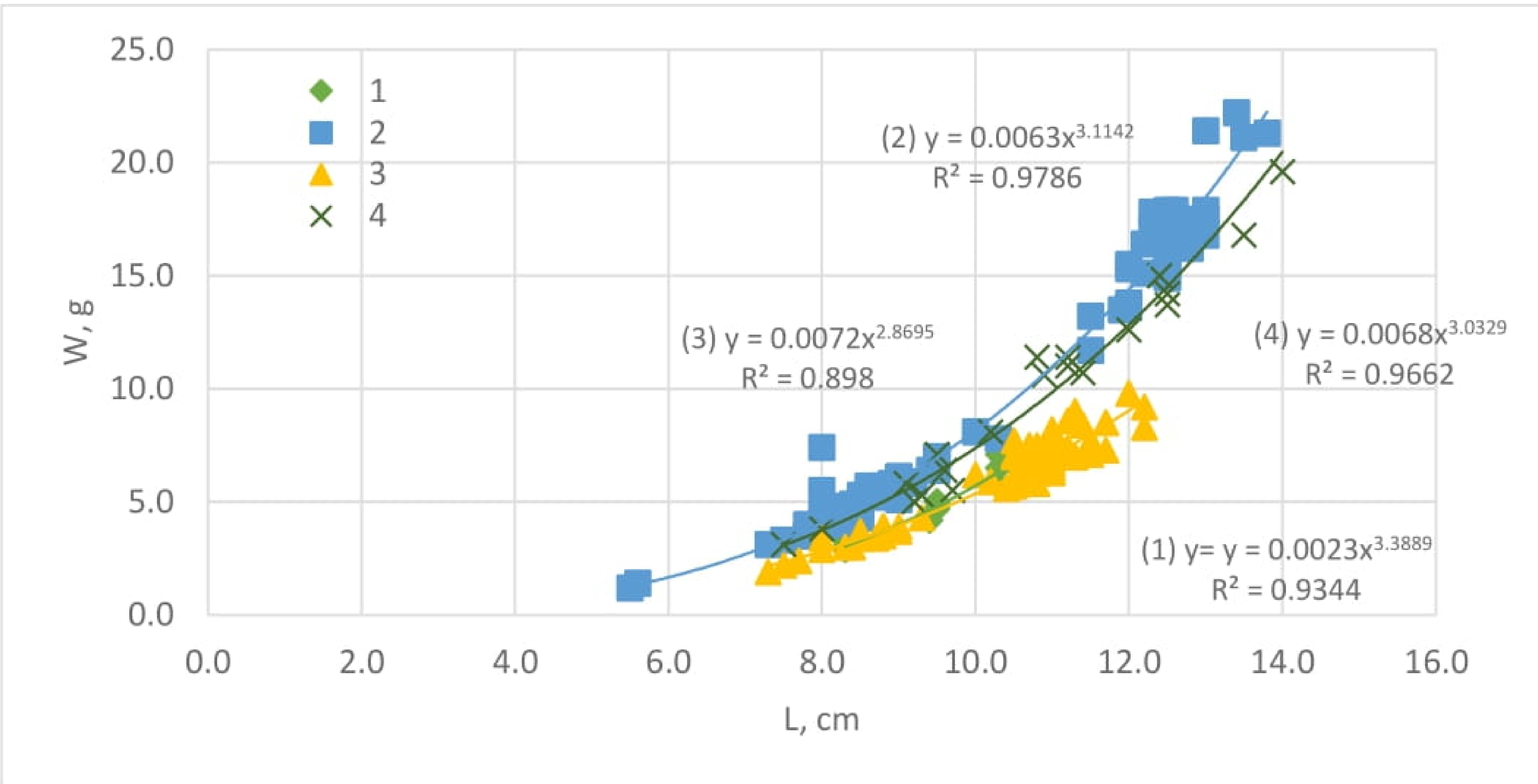

Figure 15.1.1. Linear-weight relationships for the studied specimens of sprat (1), horse mackerel (2), anchovy (3), and whiting (4) in IX. 2024.

The mean stomach fullness index for sprat was 0.23 % BW ± 0.13 (SD), for horse mackerel - 0.45 % ± 0.66 (SD), for anchovy - 0.47 % ± 1.01 (SD), and for whiting 1.12 % ± 1.70 (SD) (Fig. 15.1.2).

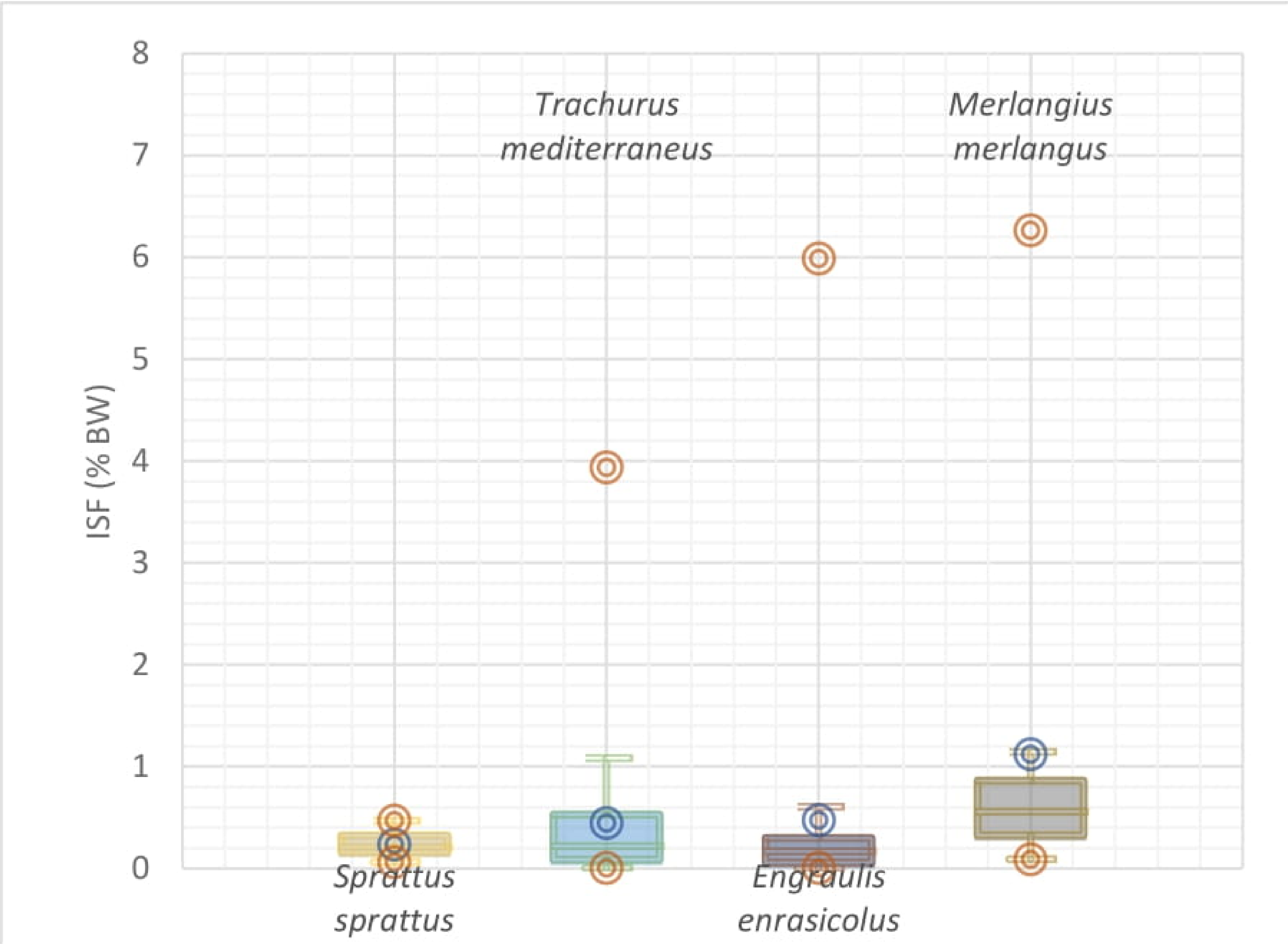

Figure 15.1.2. Box plot: ISF values (% BW) by species in IX. 2024 (median, range of values: 25–75%; minimum and maximum values are indicated):

Correspondingly, the mean multiannual ISF value for spratis was 0.91 % BW, while for horse mackerel, data in 2021 showed a mean value of 0.35 % BW ± 0.27 SD, in 2022–0.66 % BW ± 0.59 SD, and in 2023 – 0.37 % ± 1.24 (SD). The current study found lower feeding intensity for sprat compared to the 2023 data, but for horse mackerel, it was comparable to the average.

An analysis of the spatial distribution of ISF (% BW) can only be performed for horse mackerel and anchovy data, as sprat and whiting samples were sparse during the survey season. More intensive feeding of horse mackerel and anchovy was found off the central and southern coasts between Obzor/Eminne and Cape Maslen (Fig. 15.1.3).

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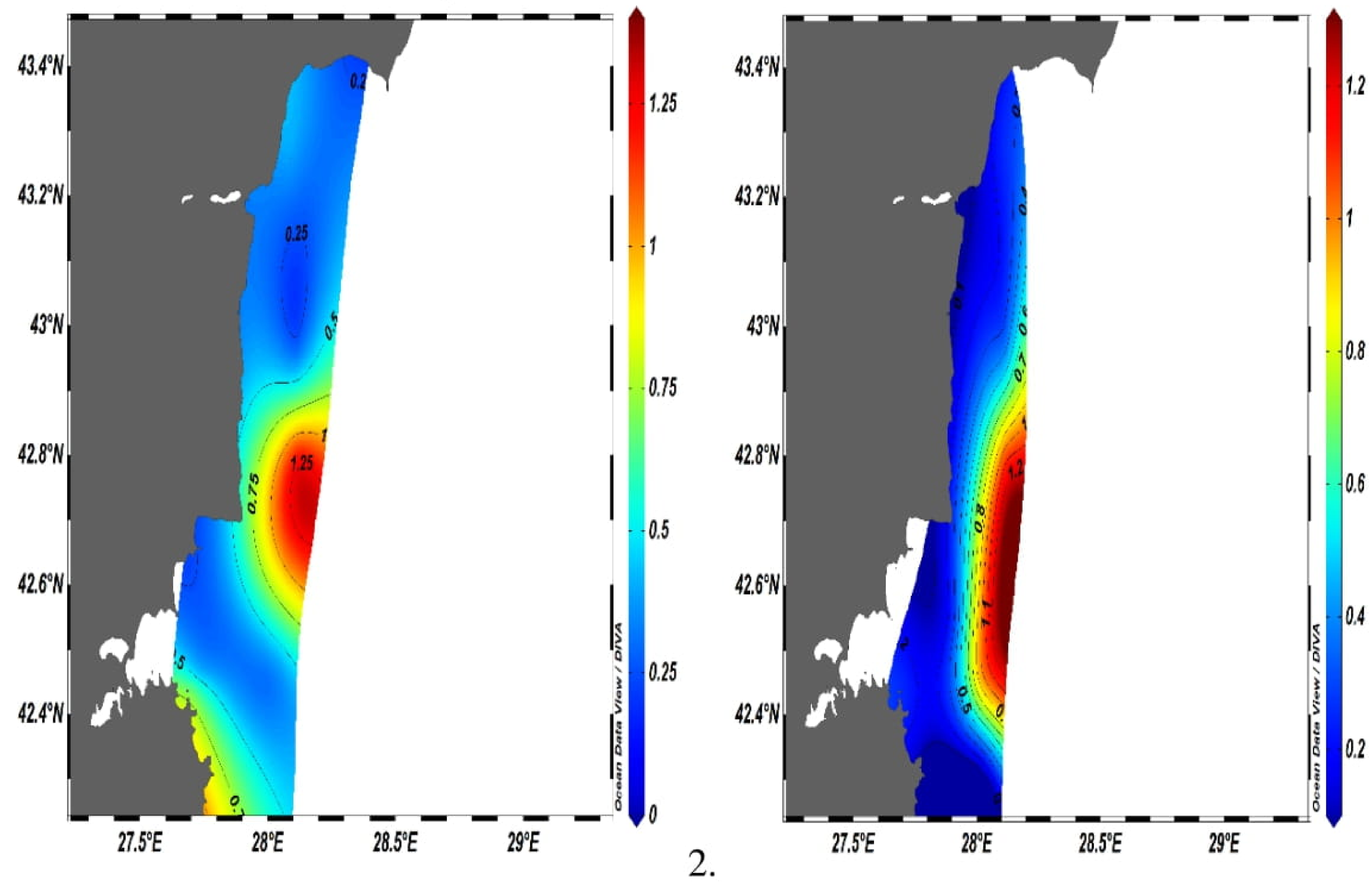

Figure 15.1.3. Spatial distribution of ISF (% BW) of horse mackerel (1) and anchovy (2) in IX. 2024.

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

The highest mean number of prey was found in horse mackerel stomachs, 64.11 ind/stomach ± 14.86 SE, with a maximum number of prey organisms, 834 ind/stomach, in relation to consumption of *Decapoda larvae*. The mean number of prey items in the diet of anchovy was 29.20 ind/stomach ± 6.09 SI, that of whiting was 1.40 ind/stomach ± 0.42 SI, and that of sprat was 1.2 ind/stomach ± 0.66 SI (Fig. 15.1.4).

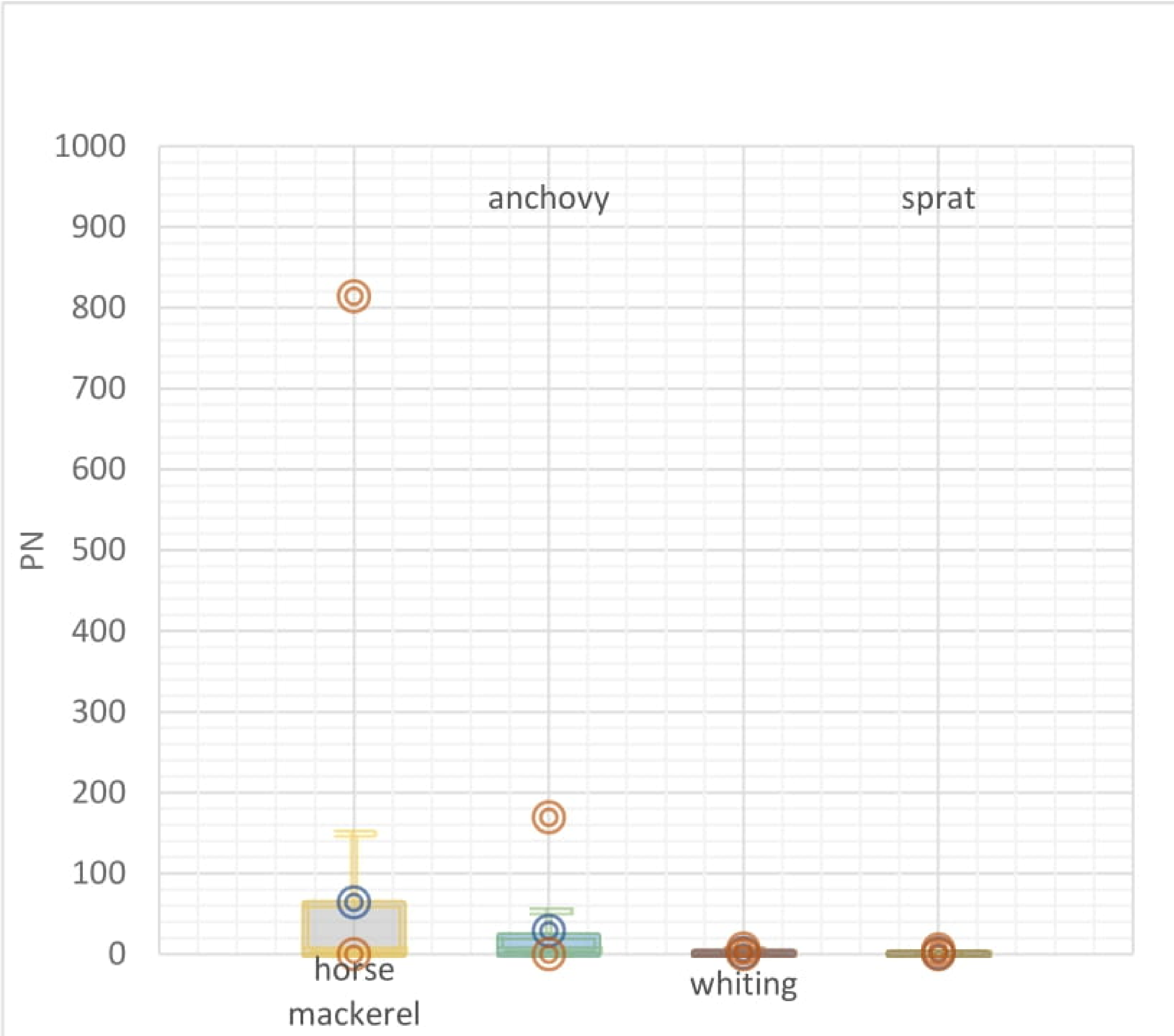

Figure 15.1.4. Box plot: Number of prey (PN, ind/stomach) in the stomach contents of the surveyed specimens by species (IX). 2024 (median, range of values: 25–75%; minimum and maximum values are indicated).

In zooplankton samples from the marine environment, 28 species and groups were identified, and a significant proportion (20 species/groups) were present as components in the diet of horse mackerel and anchovy, as well as seven species/groups in the diet of whiting and two species/groups in the diet of sprats.

The following groups and species are present in the sprat diet: Copepoda (oar-footed crustaceans), mainly *Calanus euxinus*.

Horse mackerel diet was composed of the following groups and species: Mysida - *Paramysis spp.*; Copepoda - *Calanus euxinus, Paracalanus parvus, Acartia clausi, Oithona davisae, Centropages ponticus, Harpacticoida spp;* Cladocera - *Penilia avirostris;* meroplankton - *Lamellibranchia veliger, Gastropoda veliger, Polychaeta larvae, Cirripedia larvae, Decapoda larvae*; class Appendicularia was represented from the species *Oicopleura dioica*; phylum

Chaetognatha was represented by *Parasagitta setosa*, and from phylum Chordata there are single larvae of *Branchiostoma lanceolatum*, as well as larval stages of fishes.

The anchovy diet consisted of Mysida - *Paramysis spp*.; Copepoda - *Calanus euxinus, Pseudocalanus elongatus, Paracalanus parvus, Acartia clausi, Oithona davisae, Centropages ponticus, Harpacticoida spp*.; Cladocera, *Penilia avirostris, Pleopis polyphemoides, Pseudevadne tergestina*; Meroplankton, Lamellibranchia veliger; Gastropoda veliger, phylum Chaetognatha is represented by *Parasagitta setosa*, and phylum Chordata is represented by larval stages in fishes.

The diet of the whiting includes various arthropods, such as representatives of Mysida (*Paramysis sp*.), Decapoda, Amphipoda (family Caprellidae) and Tanaidacea. In addition, their diet included polychaete worms (Polychaeta) and unspecified fish species.

The indices of the relative importance of the main food components in the diet of the studied pelagic fish species, their percentage contribution by abundance and biomass, and their frequency of occurrence are presented in Table 15.1.2.

Table 15.1.2. The diet composition of pelagic fish species (IX. 2024)

1. **Sprat**

Food composition	*N (%, of the total abundance)*	*M (%, of total biomass)*	*FO - Frequency of Occurrence*	*IRI - Relative Importance Index*
Calanus euxinus	83.33	98.16	30.00	5444.81
Copepoda	16.67	1.84	20.00	370.13
Total	***100.00***	***100.00***		

2. **Horse mackerel**

Food composition	*N (%, of the total abundance)*	*M (%, of total biomass)*	*FO - Frequency of Occurrence*	*IRI - Relative Importance Index*
Decapoda larvae	23.964	46.721	39.37	2782.5

Lamellibranchia veliger	25.883	2.873	40.00	1150.3
Acartia clausi	5.940	9.341	29.37	448.7
Pisces juvenile	18.996	14.199	8.10	268.7
Cirripedia cypris	4.170	3.036	32.22	232.2
Centropages ponticus	4.879	3.544	25.56	215.3
Parasagitta setosa	8.157	10.602	3.33	62.5
others	8.01	9.32		
Total	100.00	100.00		

3. Anchovy

Food composition	***N (%, of the total abundance)***	***M (%, of total biomass)***	***FO - Frequency of Occurrence***	***IRI - Relative Importance Index***
Decapoda larvae	8.586	39.835	41.905	2029.08
Acartia clausi	13.439	21.008	45.391	1563.59
Lamellibranchia veliger	24.886	2.606	39.609	1088.93
Penilia avirostris	5.457	8.208	23.469	320.70
Oikopleura dioica	11.756	4.815	17.024	282.11
Gastropoda veliger	4.027	4.009	29.473	236.86
Oithona davisae	5.772	0.559	28.810	182.41
Pisces juvenile	9.368	6.388	9.643	151.94
others	16.707	12.571		
Total	***100.00***	***100.00***		

4. Whiting

Food composition	***N (%, of the total abundance)***	***M (%, of total biomass)***	***FO - Frequency of Occurrence***	***IRI - Relative Importance Index***
***Paramysis* sp.**	43.333	43.929	15.71	3054.17
Polychaeta (Terebellides)	27.222	19.931	20.00	1178.82
Decapoda	8.333	18.853	15.00	271.87
Amphipoda	7.778	0.318	15.00	80.96

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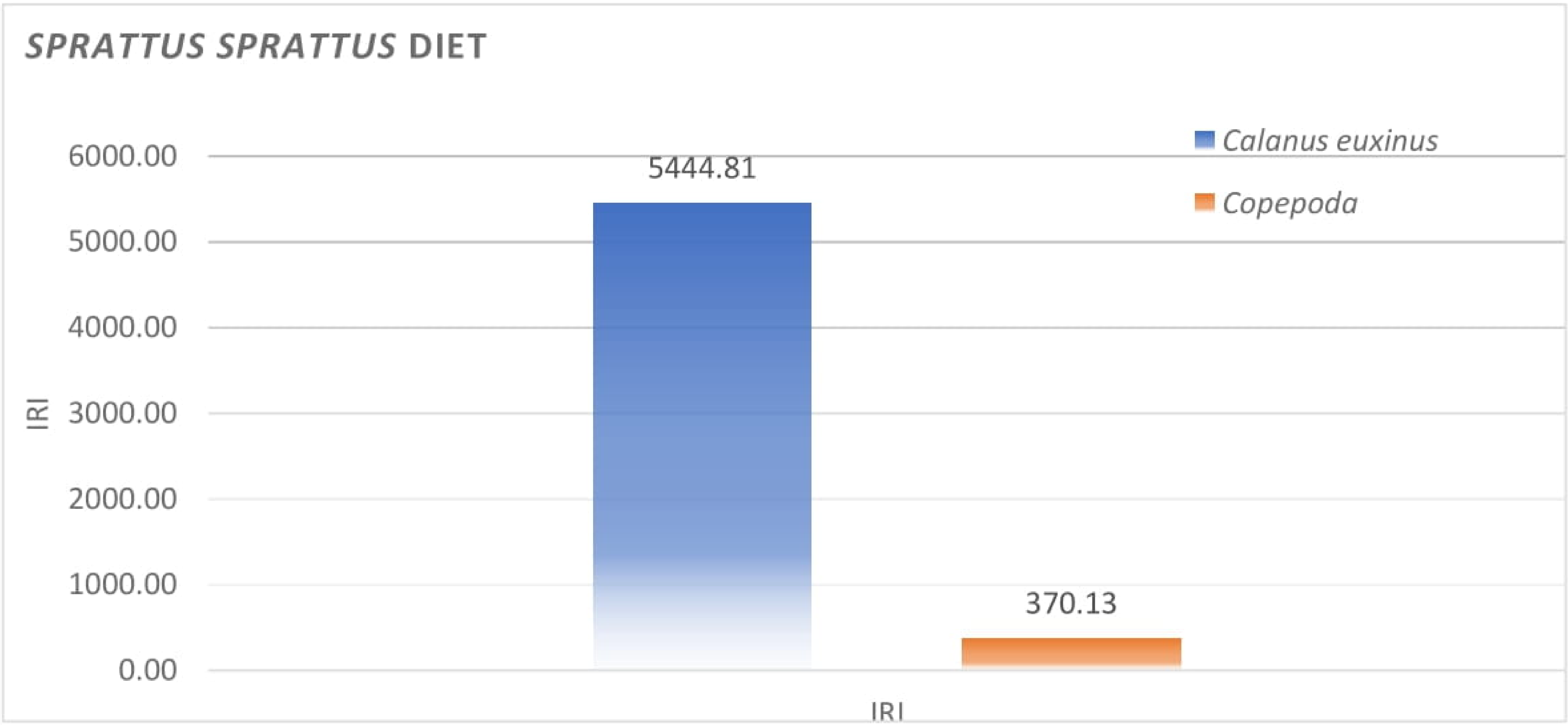
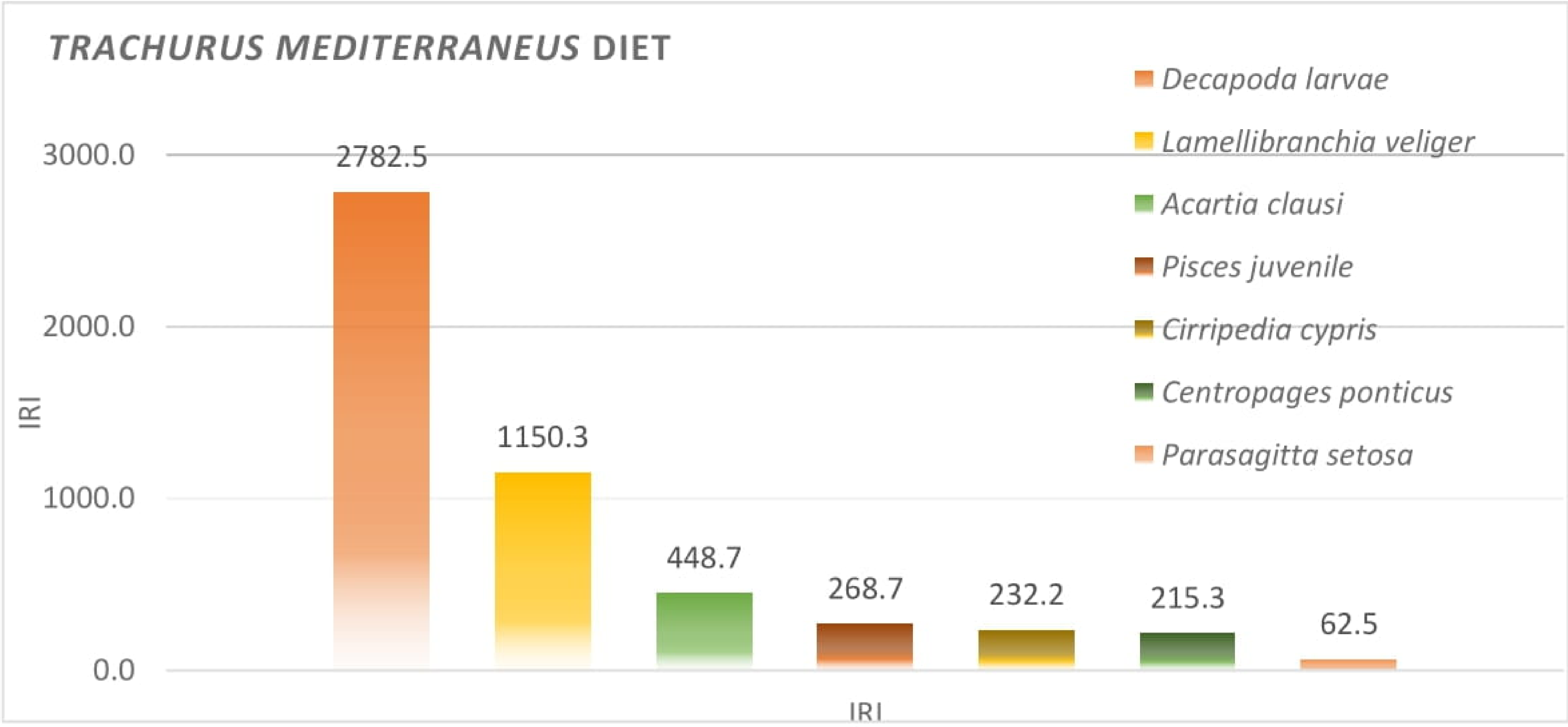
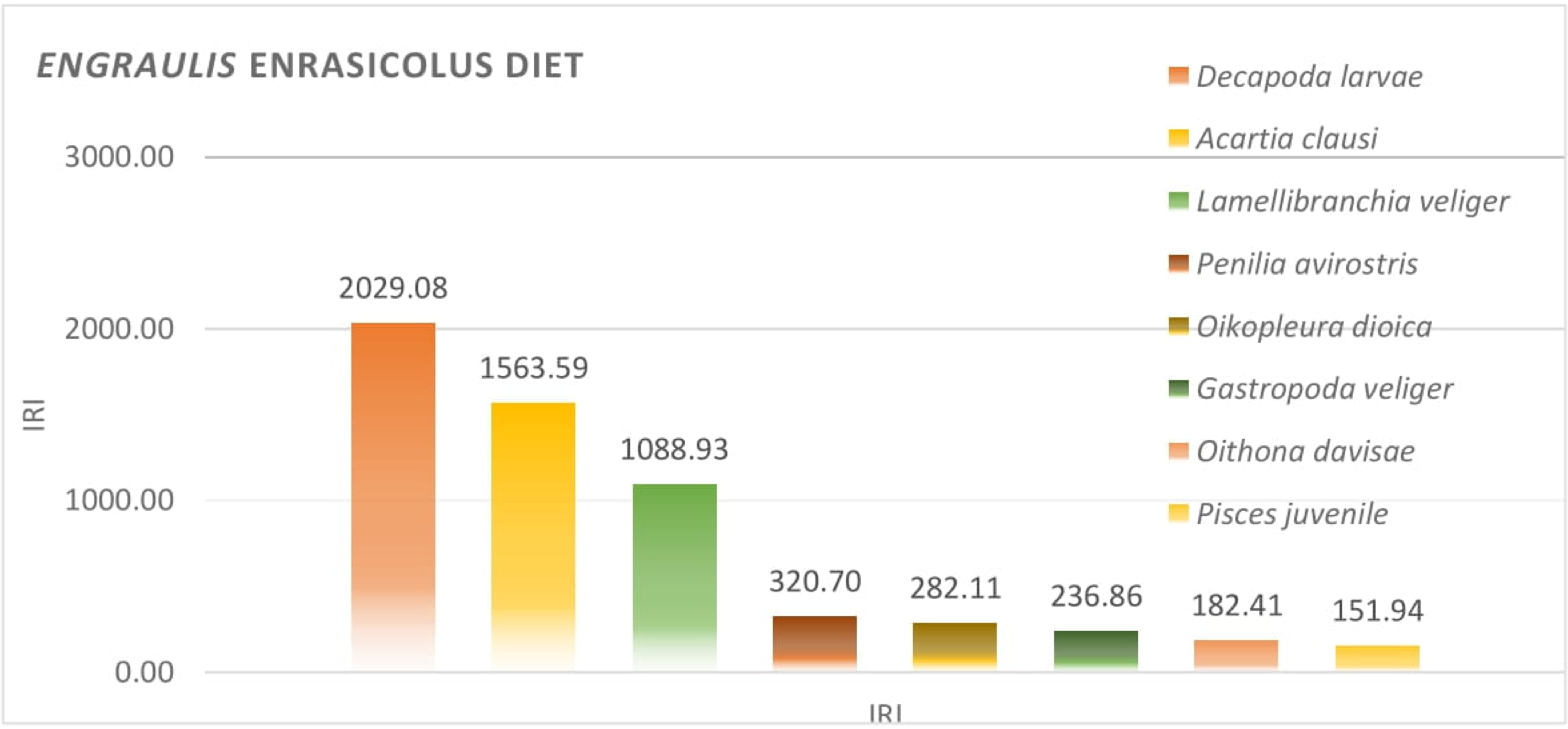
***Pisces* sp.**	2.778	16.554	10.00	96.66
Caprellidae	5.556	0.038	16.67	55.93
***Tanaidacea (Apseudopsis* sp.)**	5.000	0.378	16.67	26.89
Total	100.00	100.00		

In the samples studied, Copepoda, mainly *C. euxinus* played a dominant role in the diet of the sprat (Table 15.1.2, Fig. 15.1.5). The diet of horse mackerel was dominated by meroplanktonic larvae - *Decapoda larvae* and *L. veliger*, and that of anchovy by meroplanktonic larvae and zooplanktonic copepods. The whiting diet is mainly composed of mysids and polychaetes (Table 15.1.2, Fig. 15.1.5).

1. 

2. 
TRACHURUS MEDITERRANEUS DIET
3000.0
2000.0
1000.0
0.0
IRI
2782.5
1150.3
448.7
268.7
232.2
215.3
62.5
IRI
Decapoda larvae
Lamellibranchia veliger
Acartia clausi
Pisces juvenile
Cirripedia cypris
Centropages ponticus
Parasagitta setosa

3. 
ENGRAULIS ENRASICOLUS DIET
3000.00
2000.00
1000.00
0.00
IRI
2029.08
1563.59
1088.93
320.70
282.11
236.86
182.41
151.94
IRI
Decapoda larvae
Acartia clausi
Lamellibranchia veliger
Penilia avirostris
Oikopleura dioica
Gastropoda veliger
Oithona davisae
Pisces juvenile

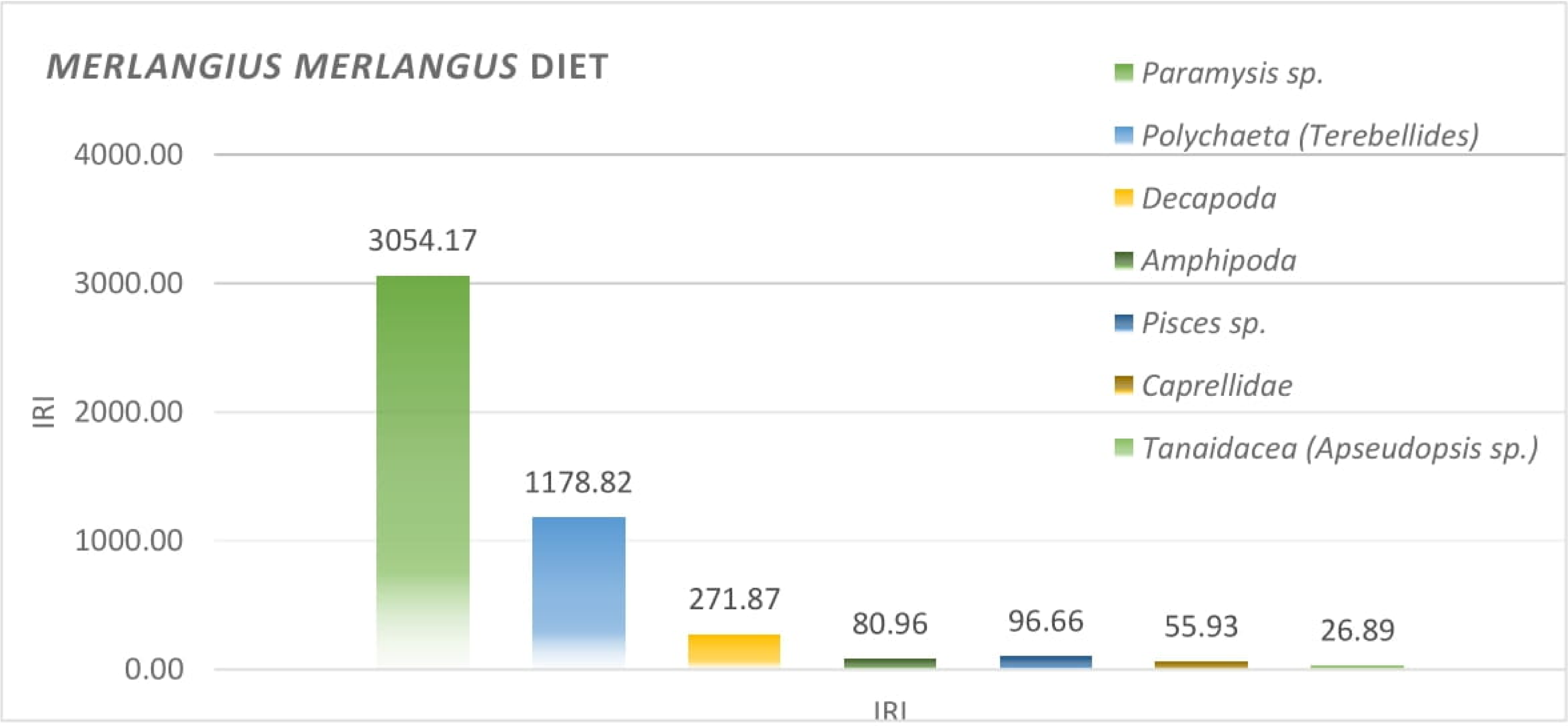
4. 

Figure 15.1.5. Average relative importance index (IRI) of the main species in the diets of newt (1), anchovy (2), horse mackerel (3), and whiting (4) in IX. 2024.

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

During the study period, zooplankton biodiversity comprised 28 species and groups of organisms (Table 15.2.1.).

Table 15.2.1. Species composition of zooplankton

	IX. 2024
1	*Noctiluca scintillans*
2	*Tintinidae* spp.
3	*Aurelia autria*
4	*Beroe ovata*
5	*Pleurobrachia pileus*
6	*Sarsia tubulosa*
7	*Pseudocalanus elongatus*
8	*Oithona similis*
9	*Oithona davisae*

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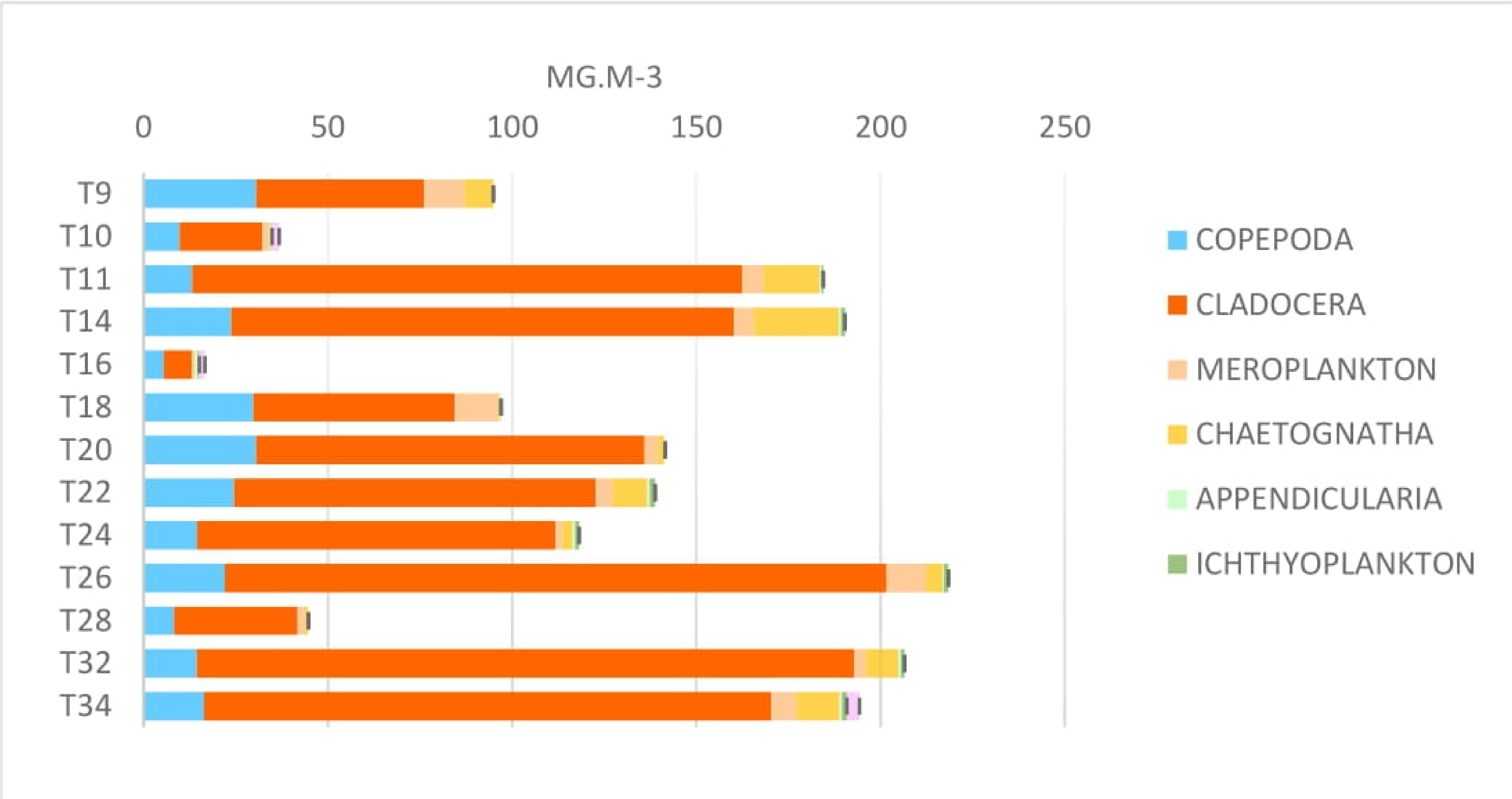
10	*Acartia clausi*
11	*Acartia tonsa*
12	*Centropages ponticus*
13	*Pontella mediterranea*
14	*Harpacticoida* spp.
15	*Pleopis polyphemoides*
16	*Penilia avirostris*
17	*Evadne spinifera*
18	*Pseudevadne tergestina*
19	*Polychaeta larvae*
20	*Lamellibranchia veliger*
21	*Gastropoda veliger*
22	Cirripedia larvae
23	Decapoda larvae
24	Phoronis larvae
25	Bryozoa larvae
26	*Parasagitta setosa*
27	*Oicopleura dioica*
28	*Pisces ova* larvae

The groups Cladocera (45.30%), Copepoda (10.15%), and Chaetognatha (2.71%) played dominant roles in the formation of the mesozooplankton biomass (Fig. 15.2.1, Table 15.2.2), while the gelatinous zooplankton were represented by four species, *Aurelia aurita, Pleurobrachia pileus, Beroe ovata*, and *Sarsia tubulosa*, with *Beroe ovata* playing a dominant role (Fig. 15.2.1). The dominant groups in terms of abundance were Cladocera (58.38 %), Copepoda (26.19 %), and Meroplankton (11.09 %).



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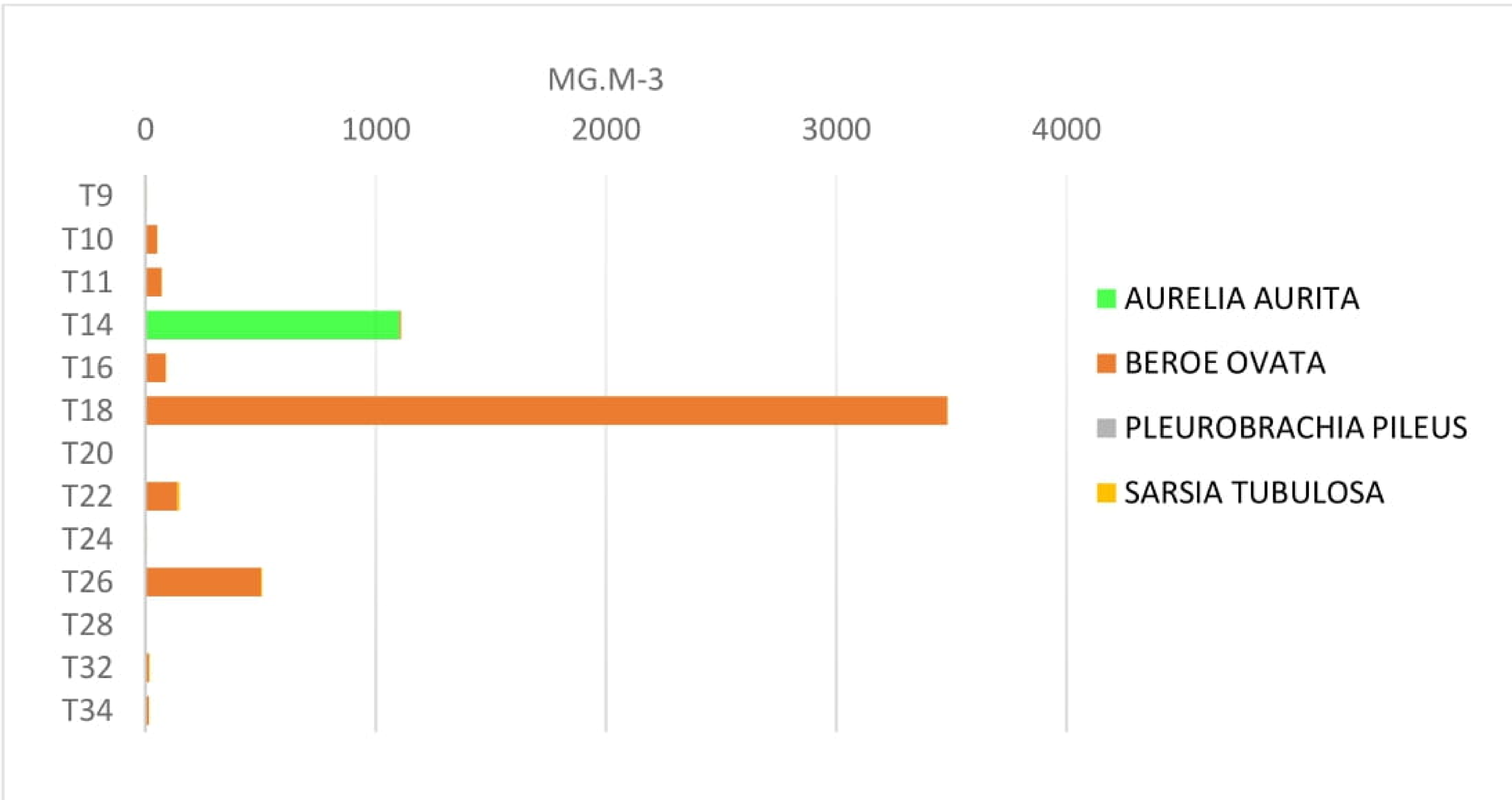

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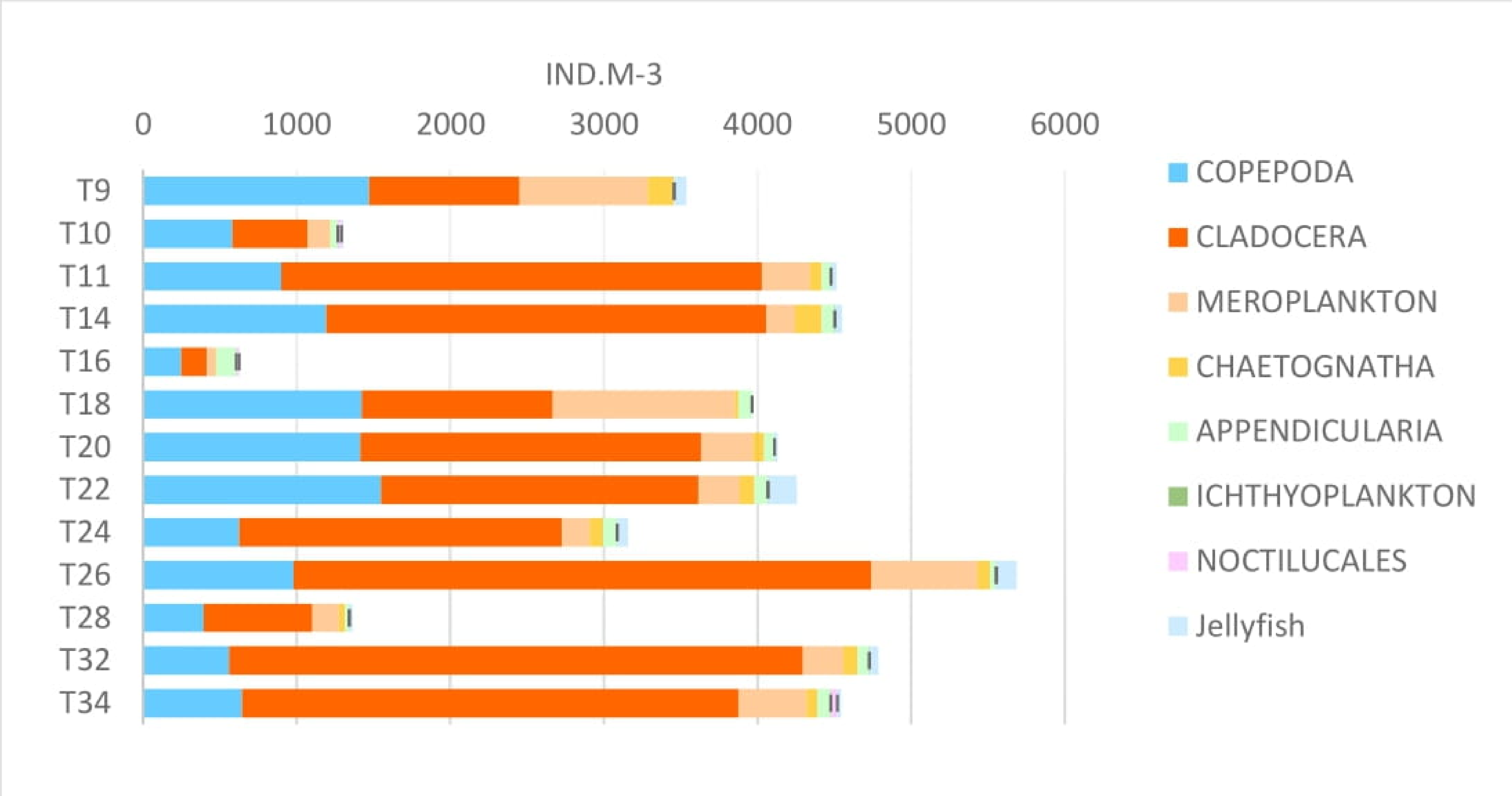

3.

Figure 15.2.1. Distribution of mesozooplankton biomass (1, mg.m^{-3}) and gelatinous zooplankton (2, mg.m^{-3}), and abundance of major zooplankton groups (3, ind.m^{-3}) by station in IX. 2024

Таблица 15.2.2. Percentages (%, relative to biomass mg.m^{-3}) of the major zooplankton groups by station in IX. 2024

station	*Cope-poda*	*Clado-cera*	*Mero-plankton*	*Chaeto-gnatha*	*Appen-dicularia*	*Ichthyo-plankton*	*Noctilucales*
T9	30.93	46.35	11.01	7.98	0.00	0.00	0.00
T10	11.22	26.03	1.81	0.41	0.43	0.31	2.22
T11	5.14	58.35	2.23	6.06	0.18	0.18	0.00
T14	1.82	10.49	0.41	1.78	0.05	0.09	0.00
T16	5.19	7.16	0.90	0.01	0.72	0.41	1.45
T18	0.83	1.53	0.33	0.01	0.01	0.00	0.00
T20	21.35	73.96	2.57	1.10	0.27	0.00	0.00
T22	8.53	34.25	1.59	3.32	0.23	0.51	0.00
T24	11.79	79.38	1.56	2.26	0.52	0.86	0.00

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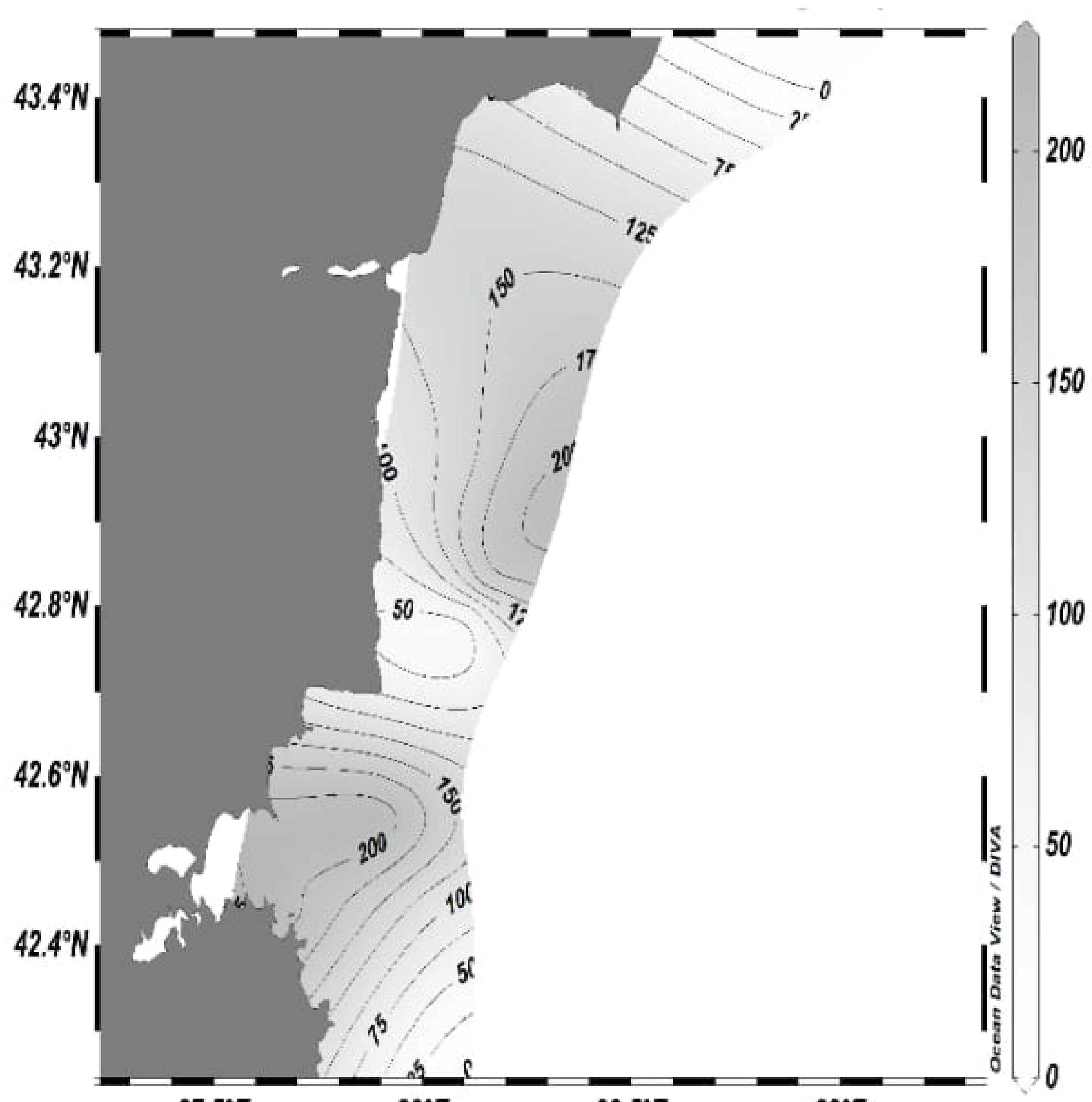
T26	3.03	24.77	1.48	0.63	0.03	0.17	0.00
T28	17.84	73.26	4.24	1.89	0.35	0.00	0.00
T32	6.40	79.61	1.40	4.05	0.26	0.45	0.00
T34	7.85	73.78	3.23	5.66	0.32	0.61	1.65
average	***10.15***	***45.30***	***2.52***	***2.71***	***0.26***	***0.28***	***0.41***

Table 15.2.3. presents summary statistics on the total zooplankton biomass and the major constituent subgroups - mesozooplankton, gelatinous zooplankton, and protozoa. Total zooplankton biomass averages 562.47 mg.m^{-3} ± 269.95 (SE), and is mainly composed of gelatinous species - 423.03 mg.m^{-3} ± 269.45 (SE). The biomass of food zooplankton was relatively high during the season at 128.91 mg.m^{-3}.

Table 15.2.3. Summary data on the total biomass (mg.m^{-3}) of zooplankton and major groups in IX. 2024

	Meso - zooplankton	*Gelatinous zooplankton*	*Protozoa*	*Total zoo-plankton biomass*
Mean	128.905	423.034	0.529	552.468
Standard error	18.977	269.459	0.302	269.951
Median	138.785	49.876	0.000	208.687
Standard deviation	68.422	971.550	1.087	973.320
Kurtosis	-1.173	9.693	3.693	9.057
Skewness	-0.352	3.046	2.056	2.933
Minimum	15.096	1.060	0.000	45.843
Maximum	218.410	3481.968	3.440	3578.983
Confidence interval (95.0%)	41.347	587.102	0.657	588.172

At the time of the survey, the mesozooplankton biomass peaked at ~200 mg.m^{-3} along the central and southern parts of the coast (Fig. 15.2.2. (1)). Protozoa were distributed in areas above Capes Kalikara and Emine, and in Burgas Bay, but with a low biomass of < 4 mg.m^{-3} (Fig. 15.2.2 (2)), and the main accumulation of gelatinous zooplankton, 3.48 g.m^{-3}, was found in front of Cape Kalikara (Fig.15.2.2 (3)).



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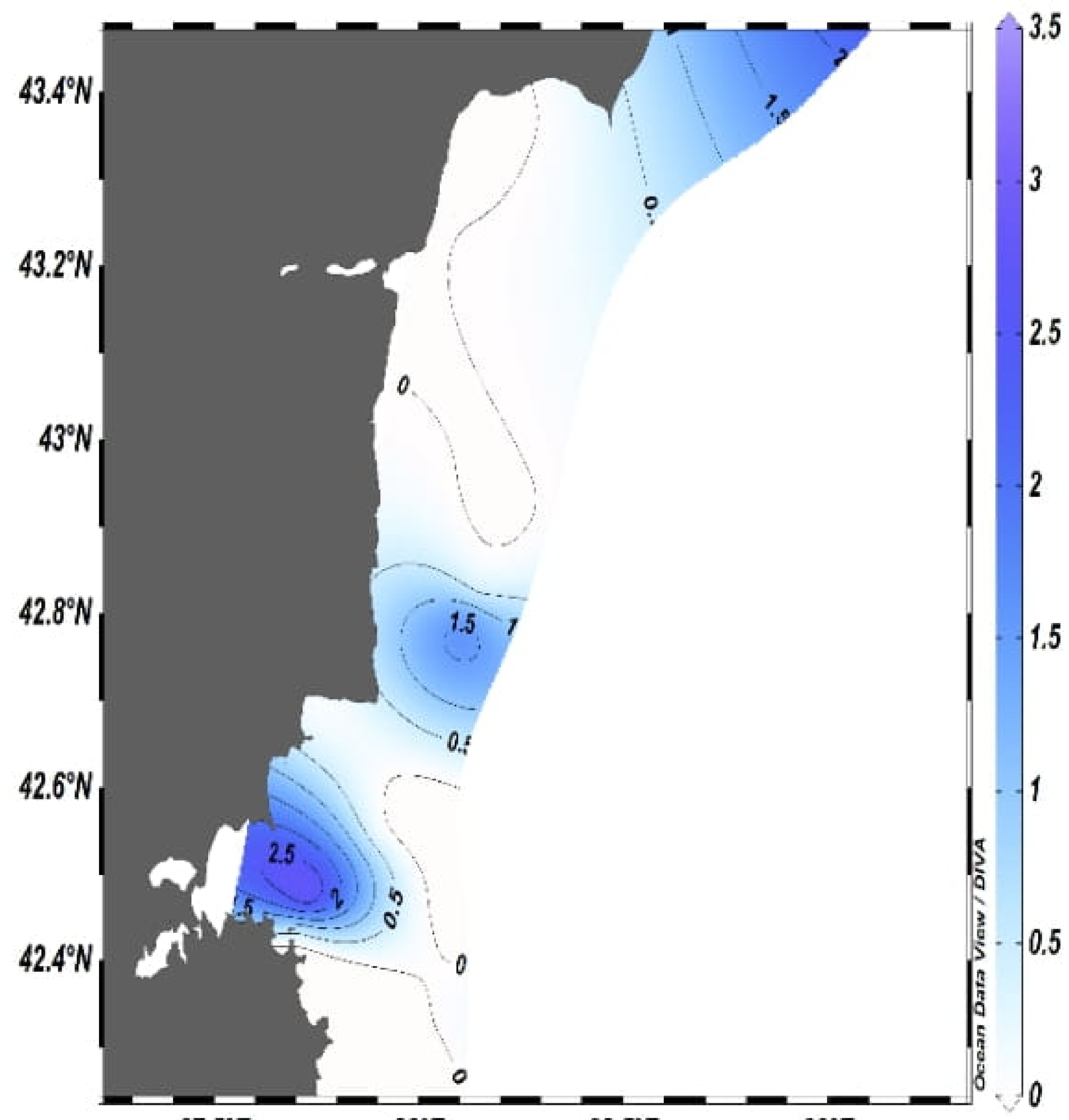

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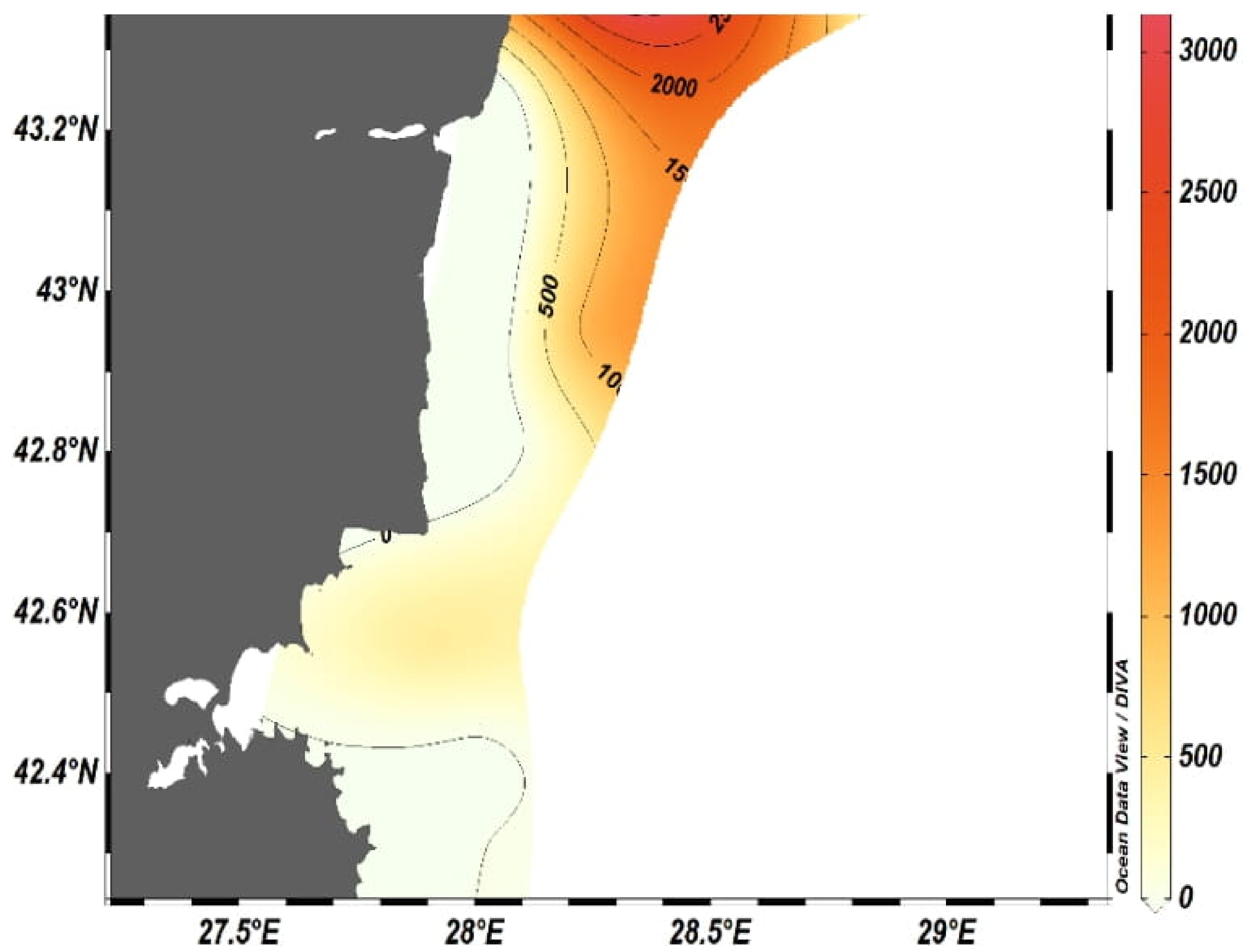

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Figure 15.2.2. Spatial distribution of biomass ($mg.m^{-3}$) of mesozooplankton (1), protozoa (2), and gelatinous zooplankton (3) in IX. 2024

16. Maximum Sustainable Catch (MSY)

- The maximum allowable catch, as a proportion of the current biomass for the red mullet:

$B_{msy} = 0.5 * 1336.92\ t = 668.46\ t$

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

$B_{pr}\ (2/3MSY) = 445.64\ t$

The maximum allowable catch in the Bulgarian part of the Black Sea for red mullet should be around 445 t;

- The maximum allowable catch, as a proportion of the current biomass for the whiting:

$B_{msy} = 0.5 * 3093.174\ t = 1546.6\ t$

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

$B_{pr}\ (2/3MSY) = 1031.06\ t$

The maximum allowable catch in the Bulgarian part of the Black Sea for whiting should be around 1000 t;

- The maximum allowable catch, as a proportion of the current biomass for the horse mackerel:

$B_{msy} = 0.5 * 2162.19\ t = 1081.1\ t$

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

$B_{pr}\ (2/3MSY) = 720.7\ t$

The maximum allowable catch in the Bulgarian part of the Black Sea for horse mackerel should be around 720 t;

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17. Conclusions

- During the study period, 36 trawls were processed on board the R/V "HaitHabu" in the Bulgarian region of the Black Sea. The study was carried out in September 2024. 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, Kiten and Durankulak. Sprat was observed at depths above 18 m.
- The total number of species identified during the study is 22, of which 15 fish, 2 crustaceans, 2 molluscs and 3 macrozooplankton species. The most common species in the trawls (presence/absence) are: *M. merlangius* (34.8%), *T. mediterraneus* (22.76%), and *M. barbatus* (16.03%). *S. sprattus* and *E. encrasicholus* were observed sporadically in the catches. Other species such as *A. immaculata*, *N. melanostomus*, *G. niger*, *M. batrachocephalus*, *Z. ophiocephalus*, *R. clavata*, *D. pastinaca*, *P. lascaris*, *T. draco*, *S.* maximus, *Sq. acanthias* and *A. stellatus* have negligible presence in the catches.
- Anchovy (*E. encrasicolus* L.) and sprat (*Sprattus sprattus*) - although they are one of the most common pelagic species in the Black Sea, during the research period they were represented by very low catches and in places with single specimens. This fact is most likely related to the migration of predatory species and the dispersed nature of the shoals of the mentioned species.
- 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 was not possible due to the small number of different species in individual trawls.

Sprat

- The size structure of the trizone showed a normal distribution, with a predominance of size groups 8.00 - 8.5 - 9.00 cm;
- The predominant age group in sprat during the studied period was 1-1+ (44%), followed by 2-2+ y^{-1} (36%). The replenishment was represented by 9%. The age structure of sprat varied from 0 to 4 + y^{-1} years, with the most significant representation of the age group 1+y^{-1};
- Growth of sprat according to von Bertalanffy:

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Species	Asymptotic length	Growth rate	Growth parameter	Growth coefficient	Allometric coefficient
S. sprattus	**$L\infty$ = 12.45**	**K = 0.42**	t_0 = -1.015	q = 0.05	n = 2.3311

- Females, males and juvemiles of sprat are represented in percentages as follows 50:45:5%;
- The gonadosomatic index GSI (%) of sprat is indicative of the portioned spawning R^2 = 0.93;
- The species was found sporadically, only in individual trawls during the described study; probably the sprat shoals were highly dispersed due to the hydrometeorological conditions and the presence of migratory predatory species in the studied areas. Due to these facts and the insufficiency of the coverage, it was not possible to carry out quantitative assessments and analysis of the distribution of the species in September 2024;

Whiting

- During the study, a widespread distribution of whiting was observed, with the highest biomass values in the 30–50 m layer: 1589.8 t, followed by 1030.6 t (50–100 m) and 472.8 t (15–30 m);
- The total studied area was 8010.24 km^2, and the amount of total whiting biomass - 3093.2 t. The densest accumulations were observed in front of Balchik, “Zlatni Pyasatsi” resort and Aladzha Bank;
- Whiting was represented in the composition of the catches during the first part of the expedition conducted in September 2024 with the highest density of distribution of the species recorded in the water area of Balchik, Kavarna, Aladzha Bank, in front of the mouth of the Kamchia River, Burgas Bay;
- In the depth layer 30–50 m the highest values for CPUA were recorded – 1745.7 kg.km^{-2}, with an average value of 228.9 kg.km^{-2}. In the depth layer 15–30 m, 488.8 kg.km^{-2} and 50–75 m – 723.2 kg.km^{-2}, the species was recorded in separate trawls;
- The highest values for CPUE (kg.h^{-1}) were observed off Balchik, Kavarna, and Aladzha Bank (“Zlatni Pyasatsi” resort);

- The length distribution in the whiting samples was normal (Gaussian), with 1 – bell-shaped, since the most common lengths in the samples are in the range 8.5–10.5 cm. A peak was observed in the 10.5 cm size group;
- The age distribution of whiting corresponded to a predominance of 2-2+ y^{-1} (37.73%), followed by 1-1+ y^{-1} (35.24%) and 0 + y^{-1} (16.23%). The remaining age groups (3-3+;4 and 5+ y^{-1}) were in a subordinate role in terms of their presence in the catches;
- The length-weight relationship in whiting is described by the model $W = 0.008.L^{2,89}$, allometric growth coefficient > 3, the obtained nonlinear model of length-weight relationship has a high degree of determination ($R^2 = 0.9903$);
- Growth of whiting according to von Bertalanffy:

Species	Asymptotic length	Growth rate	Growth parameter	Growth coefficient	Allometric coefficient
M. merlangus	**L_∞ = 27.82**	**K = 0.23**	t_0 = 2.102	q = 0.007	n = 2.9958

- Females, males and juvenils of whiting were represented in percentages as follows: 50:45:5%;
- In whiting there was a very strong correlation between the weight of the glands and the gonadosomatic index ($R^2 = 0.96$), which is an indication of mass reproduction processes and active maturity of the sexual products during the studied period;
- The maximum allowable catch, as a proportion of the current biomass for whiting:

  B msy = 0.5* 3093.174 t = 1546.6 t

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

  B pr (2/3MSY) = 1031.06 t

  The maximum allowable catch in the Bulgarian part of the Black Sea for whiting should be about 1000 t;

Horse mackerel

- Horse mackerel is a migratory species off the Bulgarian coast. The species is a predator and is an important component of the food chain of other larger predators such as turbot and dolphins. Horse mackerel was not significantly represented in catches;

- During the study, horse mackerel was widely distributed, with biomass values being highest in the 50–100 m layer: 956.5 t followed by 612.32 t (30–50 m) and 593.38 t (15–30 m);
- The total area surveyed was 8010.24 km^2, and the amount of total horse mackerel biomass was 2162.2 t. The densest concentrations were observed off Byala, Sozopol, Primorsko, Burgas Bay, Maslen Nos;
- Horse mackerel was represented in the composition of the catches during the first part of the expedition conducted in September 2024 with the highest density of the species recorded in the water area of Byala, Aladzha Bank, Sozopol, Maslen Nos, and Primorsko. In the depth layer 30–50 m, the highest values for CPUA were recorded – 1627.27 kg.km-2, with an average value of 337.4 $kg.km^{-2}$. In the depth layer 15-30 m, 698.3 $kg.km^{-2}$ and 50–75 m – 723.2 $kg.km^{-2}$, the species was recorded in separate trawls;
- The highest values for CPUE ($kg.h^{-1}$) were observed in front of Byala, Primorsko, Sozopol, and Aladzha Bank ("Zlatni Pyasatsi" resort);
- The length distribution in the horse mackerel samples was bimodal with a 2-bell shape, as the most common lengths in the samples are in the range of 7.5–8; 9.5 cm. A peak was observed in the 11.5 cm size group;
- The age distribution in horse mackerel corresponded to a predominance of 2-2+ y^{-1} (41.5%), followed by 3-3+ y^{-1} (23.44%) and 1-1+ y^{-1} (20.4%);
- Horse mackerel growth according to von Bertalanffy:

Species	Asymptotic length	Growth rate	Growth parameter	Growth coefficient	Allometric coefficient
Tr.mediterraneus	**$L\infty$ = 18.68**	**K = 0.25**	$t_0 = -1.15$	q = 0.009	n = 3.0911

- Females, males and juveniles in horse mackerel were represented as follows: 46:48:6%;
- Maximum allowable catch, as a proportion of the current biomass for horse mackerel:

  B msy = 0.5* 2162.19 t = 1081.1 t

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

  B pr (2/3MSY) = 720.7 t

  The maximum allowable catch in the Bulgarian part of the Black Sea for horse mackerel should be about 720 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 1336.92 t. The densest aggregations were observed in front of Pasha Dere, in front of Albena resort, in front of Balchik below Kaliakra and in the Nessebar Bay at depths of 30–50 m, and west of Sozopol at depths of 50–100 m. The species was recorded in 24 stations (out of 38), with the highest density in the 30–50 m stratum;
- Females, males and juvenils of red mullet were represented in percentages as follows: 48:44:8%;
- Maximum allowable catch, as a proportion of the current biomass for red mullet:

B msy = 0.5* 1336.92 t = 668.46 t

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

B pr (2/3MSY) = 445.64 t

The maximum allowable catch in the Bulgarian part of the Black Sea for red mullet should be about 445 t.

Feeding

- At the end of the summer of 2024, the food composition of horse mackerel and anchovy included 20 species/groups, while whiting consumed 7 species/groups, and two species/groups were recorded in the food of the trizona. Sprat mainly feeds on Copepoda, in particular *Calanus euxinus*. The diet of horse mackerel was more diverse, including various species of Mysida, Copepoda, Cladocera, meroplankton, Appendicularia, Chaetognatha and fish larvae. The consumption patterns of anchovy reflect those of horse mackerel with slight variations. Whiting feeds on arthropods including Mysida, Decapoda, Amphipoda and Tanaidacea, as well as polychaetes and unidentified fish species;
- The representative of Copepoda, *C. euxinus*, dominates the diet of sprat (IRI = 5444.81). The diet of horse mackerel was dominated by meroplankton larvae, especially larvae of Decapoda (IRI = 2782.5) and *L. veliger* (IRI = 1150.3). Anchovy mainly consumed larvae of Decapoda (IRI = 2029.08) and zooplankton copepods (IRI = 1563.59). Mysids

(IRI = 3054.17) and polychaetes (IRI = 1178.82) constitute the main part of the whiting diet;

- The mean ISF index varied between species: sprat – 0.23% BW ± 0.13 (SD), horse mackerel – 0.45% ± 0.66 (SD), anchovy – 0.47% ± 1.01 (SD) and whiting – 1.12% ± 1.70 (SD). The feeding intensity of sprat has decreased compared to the 2023 data, while that of horse mackerel remains in line with the multi-year average;
- Horse mackerel stomachs contained the highest mean number of prey (64.11 individuals/stomach ± 14.86 SE), with a maximum of 834 individuals/stomach due to the consumption of Decapoda larvae. This value for anchovy was on average 29.20 individuals/stomach ± 6.09 SE, for whiting it is 1.40 individuals/stomach ± 0.42 SE, and for sprat – 1.2 individuals/stomach ± 0.66 SE;
- The average biomass of zooplankton in the marine environment was 562.47 $mg.m^{-3}$ ± 269.95 (SE), composed mainly of gelatinous species – 423.03 $mg.m^{-3}$ ± 269.45 (SE). The biomass of food zooplankton is relatively high for the season - 128.91 $mg.m^{-3}$, with maximum values of ~ 200 $mg.m^{-3}$, off the central and southern coasts;

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