Seasonal dynamics of the total lipid content in the body of the anchovy *Engraulis encrasicolus* (Linnaeus, 1758) in 2017-2020

Anna Voykina 1,2*, Leonid Bugaev 1, Olga Kirichenko 1,3, and Ksenya Urchenko 1,2

1 Azov-Black Sea Branch of FSBSI “VNIRO” (“AzNIIRKH”), Rostov-on-Don 344002, Russia
2 Don State Technical University, Gagarin Sq., 1, Rostov-on-Don, 344000, Russia
3 Southern Federal University, Bolshaya Sadovaya St., 105/42, Rostov-on-Don, 344006, Russia

Abstract. The analysis of the dynamics of lipid content in the body of anchovy (*Engraulis encrasicolus*) in various periods of its life cycle from 2017 to 2020 inclusive. The article shows that the difference in the content of energy-plastic substances in the body of anchovy is clearly traced depending on the age of the fish: the number of lipids in fingerlings is lower than in older individuals. Based on the analysis of the inter-seasonal dynamics of the lipid content in the body of the anchovy, it was found that the minimum lipid content is typical for fish in April, and the maximum is observed in October. Analysis of the interannual dynamics of the lipid content in the anchovy body at the end of the feeding period showed that in the last three years there has been a trend towards a gradual increase in their number to the level of 16-18%.

1 Introduction

The anchovy from the Sea of Azov (*Engraulis encrasicolus macoticus* Pusanov, 1926) is a typically marine pelagic schooling fish that cannot live at temperatures below 6°C. The anchovy spends the summer in the Sea of Azov, where it spawns and fattens. In spring (in April-May), anchovy annually migrates through the Kerch Strait from the Black Sea to the Sea of Azov, and in autumn, with a decrease in water temperature (in October-November, depending on the nature of autumn cooling) – back from the Sea of Azov to the Black Sea.

The life cycle of anchovy is short: in the second summer of its life, i.e. at the age of one year, the anchovy reaches maturation and spawns. The age of two and three years for fish of this species is commercial [1]. The European anchovy plays a huge role in marine trophodynamics, as it consumes the energy stored by plankton and thus provides higher order predators, including marine mammals and birds, large piscivorous fish and humans, with a highly nutritious and energy source of food. At the same time, being a short-cycle species, the dynamics of the anchovy population largely depends on both the quality of the habitat and the biomass of the food supply [2, 3]. The seasonal dynamics of the plankton biomass, in turn, determines the ability of the anchovy to accumulate reserve substances in its body.

* Corresponding author: voykina_a_v@azniirkh.ru
Lipids and their components (classes and fatty acids) are important macronutrients for energy storage in marine fish and perform a wide range of functions, including cell structural integrity and bioeffector roles [4, 5]. The dynamics of lipids in the body of fish is a reflection of the balance of anaerobic (energy gain) and catabolic (energy loss) processes that play a central role in the body's fitness [6]. The important role of lipids manifests itself in literally all elements of biology: sources of metabolic energy in fish, ensuring growth, reproduction, and movement, including migration [5].

This work is aimed at the investigation of the dynamics of lipid content in the body of the Azov anchovy as a reflection of its physiological state in various periods of the life cycle from 2020 to 2022.

2 Materials and methods

The object of the study was anchovy. Fish for research were selected year-round from 2020 to 2022 during census and trawl surveys in the Sea of Azov and in the wintering areas of anchovy during the monitoring of fishing from trawl catches of fishing vessels in the territorial waters of the Russian Federation.

After catching the fish, they were visually examined for the presence of various external injuries, signs of diseases and parasitic infestations. 100–200 specimens were selected from each catch, the length of the fish body was measured with an accuracy of 0.1 cm, after which the sample was divided into size groups: < 75 mm, 76–85 mm, 86–100 mm, 101–115 mm, >115 mm. In each size group, the number and average weight of fish were determined. Fish in each size group were minced whole without removing the viscera using a special device.

The minced meat samples obtained were used for the quantitative determination of water and total lipids based on the Russian state standard 7636-85. Determination of the mass fraction of water was carried out by drying the biomaterial at 100–105°C. The method is based on the release (evaporation) of water from the product during heat treatment and determining the change in mass by weighing.

Lipids were determined by continuous extraction according to the Soxhlet method using a semi-automatic analyzer of fat content FA-46 (OOO Vilitek, Moscow). This method is based on the extraction of lipids with an organic solvent (diethyl ether) from a dry sample and determination of its mass by weighing.

Mathematical data processing was performed by use of specialized software: MS Excel V. 13, Statsoft Statistica V. 12. The obtained results are represented as the mean and the standard error of the mean (M±m). The analysis of the differences between two sexes in the analyzed fish samples was carried out using the nonparametric Mann–Whitney U test for two independent samples. The results were considered reliable if p < 0.05.

3 Results

The fat content of fish is one of the indicators of the state of populations, which can serve as an indicator of the well-being of the herd and its reproductive properties. The content of lipids in the body of anchovy is subject to annual ontogenetic cycles. The maximum lipid content in the context of the year is observed at the end of autumn, the minimum in May [7].

According to Zlatanos and Laskaridis [8], obtained during the study of anchovy in the northeastern Mediterranean Sea, the lowest values in the lipid content were observed in mid-summer. The dependence of the amount of lipids in the body of anchovies on reproductive parameters and related periods during the year, including spawning, summer somatic growth and wintering phases, has also been shown by other authors. The importance of quantitative indicators of the food base for anchovies during the spawning period (June–August in the
Mediterranean) for successful spawning [9, 10] is also shown, which is also reflected in the amount of lipids accumulated in the body, which are the main source of metabolic energy for reproduction. For successful reproduction, the stored fat must meet not only the current energy needs of the fish preparing for spawning, but also the future needs of the offspring.

To analyze the level of lipid accumulation in the body of Azov anchovy individuals of different ages, fish were analyzed that were caught during the autumn migration through the Kerch Strait to the Black Sea in each year under study. By the end of the feeding period in the Sea of Azov and preparation for migration to the wintering grounds, the maximum level of lipid accumulation is noted in the body of the anchovy and the difference depending on age is clearly visible.

Studies have shown that in all years of observation, the amount of lipids in the body of the Azov anchovy at the end of the feeding period increased with an increase in the length of the fish and, accordingly, with age (Fig. 1). The smallest amount of lipids was noted in anchovy underyearlings. It is known that the intensive growth of anchovies is observed in the first year of life, the increase in the length and weight of fish at this stage of development is more associated with protein synthesis in the body and to a lesser extent due to the accumulation of lipids.

Fig. 1. The content of total lipids in the body of anchovies at the end of the feeding period, depending on the size group (mm), % (per wet substance)
The obtained values were at the level of average long-term values. The highest amount of lipids (19%) in the body of fish was noted for individuals caught in October 2020 and 2022 and in September 2021.

In older individuals of the anchovy population (fish more than 101 mm long), a regular decrease in the level of lipids in the body was observed in comparison with mature individuals. It is known that from a certain age, fish show signs of aging due to a decrease in the synthetic ability of the body, first of all, the efficiency of protein synthesis decreases and, as a result, the growth rate and increase in body weight of fish slow down, and later lipid synthesis in the body also decreases.

In the pre-spawning period, in the body of mature anchovy individuals, generative processes predominate, aimed at the rapid development and growth of germ cells. These metabolic processes require high expenditures of a significant part of the plastic and energy resources of the body, primarily the catabolism of lipid components in fish tissues. Studies have shown that the average lipid content in the body of mature anchovy individuals in March in the studied range of years varied from 3.2 to 9.9%, the average value was 7.2% (Fig. 2).

In general, it can be noted that in the last four years of research in the body of mature anchovy individuals during the spring migration to the Sea of Azov, an increased level of accumulated lipids has been noted than in previous years. It can be assumed that a high level of lipids is associated with favorable abiotic environmental factors and a good food supply during the feeding and wintering periods.

The minimum amount of lipids in the body of the examined fish was noted in April during the active development of reproductive products, the average value for a three-year period of research was 2.1%. By May, the level of lipids in the body of the Azov anchovy increased by 2 times in the studied years and, on average, was 4.5%. During the spawning period, the amount of lipids in the body of anchovies varied from 4.8% in June to 8.0% in July. Taking into account the fact that the anchovies belongs to batch spawning fish species, it can be assumed that the increase in lipid content during the spawning period is associated with intensive feeding of fish between the spawning of individual portions of eggs.

The level of accumulation of fat reserves during the winter migration of anchovies is directly related to their preparation and migration: the higher the fat content, the more intense:

Fig. 2. Change in the content of total lipids in the body of anchovies for fish from 76 to 100 mm in size during the annual cycle, % (per wet substance)
the migration, which begins at higher temperatures. Accordingly, with a low fat content, anchovy begins migration at lower temperatures.

Analysis of the obtained data showed that in August the level of accumulated lipids in the body of the main mature part of the anchovy population increased by 2 times compared to the spawning period, the average content was 16.3%. According to the results of long-term monitoring of the Laboratory of Molecular Genetics and Fish Physiology, the level of accumulated fat reserves of anchovies by the time the feeding was completed slightly varied over the years relative to the long-term average value (17.7%) in the range from 16.8 to 18.9%.

During the period of autumn migration to the Black Sea and the formation of wintering aggregations, the average lipid content in the body of older anchovy individuals decreased by 1-3%, and then, during the wintering period (from December to March), a regular decrease in lipid levels continued. The most intensive drop in the level of lipids in the body of anchovies occurred in 2022: the fat content of fish, reaching a maximum of 18.9% in October, then decreased to 6.7% in February, the values obtained were significantly lower than the reference values obtained on the basis of long-term data.

For anchovy underyearlings during the premigratory feeding period, the content of lipids in the body varied in the range from 6.8 to 23.2% (Fig. 3). During the autumn migration to the Black Sea, the average lipid content in the body of young fish was 16.7%. In winter, a characteristic decrease in the lipid content in the body of young anchovy individuals from 12.4 to 6.2% was observed, as a result of the expenditure of energy resources on motor functions associated with the search for food resources to maintain homeostasis in the fish body.

During the spring migration to the Sea of Azov, the level of lipid accumulation was 1.8%.

By the time of the increase in water temperature and the active development of the food supply in the Sea of Azov, a gradual increase in the level of lipids in the body of anchovy of the younger age group was also noted from 1.8% in April to 3.0% in June, as a result of the start of intensive feeding in the study period.

Fig. 3. Change in the content of total lipids in the body of anchovies for fish < 75 mm in size during the annual cycle, % (per wet substance)
Since 2007, the amount of lipids in the body of anchovies at the end of the feeding period has decreased from year to year: from 19.0% in 2007 to 14.3% in 2019, with the exception of 2017, when the lipid level rose again to 19.1%.

Fig. 4. Long-term dynamics of lipid content in the body of anchovies at the end of the feeding period, % (per raw material)

Note: - the critical level of lipid accumulation in the body of anchovy, characterizing satisfactory feeding conditions; - trend line

Comparison of the obtained data on the dynamics of lipid content in the body of anchovy at the end of the feeding period with the data of previous years showed that in the last three years there has been a slight increase in the amount of lipids: in 2020, the average lipid content was 16.9%, in 2021-15.9%, in 2022 year-17.9%. The obtained values did not fall below the 10% mark, which indicated satisfactory feeding conditions in the studied range of years.

4 Conclusion

The analyzed material showed a trend between fat accumulation in the anchovy body and such indicators as the age and annual cycles of fish. Lipids are especially intensively consumed in the body of mature anchovy individuals during the maturation of gonads and batch spawning, which indicates a significant role of energy-plastic substances in the pre-spawning and spawning periods. In young anchovy individuals, fluctuations in lipid levels are due to food supply and abiotic factors of the habitat in feeding areas.

An analysis of the interannual dynamics of lipid content in the body of anchovies showed that in the last few years, the amount of lipids in the body of anchovy at the end of the feeding period compared to the previous period of 2007-2019. increased by 2-4%. It can be assumed that the gradual increase in the amount of reserve substances accumulated in the body of fish is due, to a certain extent, to an improvement in feeding conditions due to an increase in the biomass of forage zooplankton and a decrease in trophic competition from Mnemiopsis leidyi [11].

The results obtained indicate the need to study the dynamics of lipid accumulation in the body of the Azov anchovy at various stages of its life cycle in order to characterize its physiological state associated with the issues of the efficiency of the formation of commercial concentrations and replenishment of the population.
References