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THE INFLUENCE OF THE TEMPERATURE FACTOR ON THE CHANGES IN THE GROWTH PARAMETERS OF SPRAT (2000 - 2020)

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ABSTRACT

A study was conducted on the changes in sea surface temperature (SST) on the southwestern shelf of the Crimea between 2000 and 2020. The equations of trends in the change of SST were found. It is shown that the following three periods can be distinguished according to the nature of changes in the average annual sea temperature: 2000 - 2007, 2008 - 2013 and 2014 - 2020. The influence of changes in the average annual SST on the development of pelagic fish of the cold-water complex was considered (using the example of the Black Sea sprat). Changes in the main parameters of the populations and their relationship with the change in the average annual SST were determined. It was found that the increase in sea temperature negatively affected the development of the sprat population, and the average age of the population decreased by 1.3 times. In general, the population was rejuvenated, and the average size and weight of individuals decreased.

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INTRODUCTION

Over the past 20 years, the ecosystem of the Black Sea has undergone noticeable structural and regime changes caused by a combination of various factors, the main of which are fishing (press fishing) and climate change (warming). This is reflected in the species composition, length-weight and age structure, abundance and spatial distribution of the fish community (Pauly, 1988; Kideys, 2002; Daskalov et al., 2002; Shlyakhov and Shlyakhova, 2011; Goulding et al., 2014; Gucu et al., 2017).

It is known that the thermal regime of the water reservoir regulates the life cycle of fish at all its stages. Sea surface temperature (SST) determines the winter and spring migrations of fish, the timing and duration of spawning, the growth rate of fish, changes of length, weight and age structure, and the intensity of nutrition. As is known (Sinovčič, 2004; Froese, 2006), one of the main indicators of the state of populations and the degree of their well-being is the size and age structure, reflecting such important processes of vital activity as the growth rate and increase in the size of individuals, the intensity of their reproduction, the mortality rate and the rate of generational change. The length-age structure depends both on the internal characteristics of the population and the impact of external climatic (temperature) factors (Bellido et al., 2000; Zuyev and Melnikova et al., 2004; Giragosov et al., 2006; Melnikova and Kuzminova, 2022).

Many researchers (Klyashtorin and Lyubushin, 2005; Oguz, 2005; Polonsky et al., 2018; Panov et al., 2020) have noted in their work that one of the main factors affecting the state of the pelagic ecosystem is the climatic factor and, above all, temperature changes. The temperature determines the intensity of the circulation of water masses and thus affects the production processes of various trophic levels.

The length, weight, age and growth pattern are important characteristics of the fish life cycle. The study of ecological and spatial (geographical) variability of the characteristics of life cycles is necessary to understand the influence of environmental factors on the vector of evolutionary changes, which is especially important in the conditions of climate change. Without this knowledge, the realization of rational fishing and the protection of the species is impossible.

The purpose of our research is to determine changes in both the growth characteristics of individuals and the parameters of the population of the Black Sea sprat living on the southwestern shelf of the Crimea, taking into account the influence of the temperature factor for 2000 - 2020.

MATERIALS AND METHODS

The individuals used in the research were the Black Sea sprat *Sprattus sprattus phalericus* (Risso, 1826) from trawl catches of fishing vessels on the southwestern shelf of the Crimea. The material was collected during the spawning season (November - March). The article is based on the results of our long-term research, as well as data from literary sources.

The total and standard lengths were determined and the measurement error was up to 0.1 cm. When studying the dimensional structure, the results of individual measurements were grouped by size classes with a length interval of 0.5 cm. To assess the age structure of the catch, a size-age key was used (Mel'nikova, 2011). The average length and the average population age were determined as the normalized average of the length (age) groups.

The age of the fish was determined by otoliths, according to standard methods (Pravdin, 1966). The von Bertalanffy equations were used to describe length and weight growth (Bertalanffy, 1938; Riker, 1979):

$$L = L_{\infty}(1-e^{-k(t-t_0)}) \text{ and } W = W_{\infty}(-e^{-k(t-t_0)})^b. \quad (1)$$

The growth performance indexes (ϕ) and (ϕ') were estimated by the equation (Pauly et al., 1988):

$$\phi = lgk + 2lgL_{\infty} \text{ and } \phi' = lgk + (2lgW_{\infty})/3 \quad (2)$$

where L_{∞} is the asymptotic length, W_{∞} is the asymptotic mass, k is the growth rate constant, t_0 is the age of the fish when its length and mass in the model under consideration are zero, b is the indicator of the degree of dependence "mass–length" ($W = a \cdot TL^b$).

The relationship between total length and weight was determined using the equation:

$$W = a \cdot TL^b, \quad (3)$$

where W is the total body weight (g), TL is the total length of the fish (cm), a is the coefficient associated with the body shape, b is defined as the coefficient of allometry (allometric growth indicator).

Information on the water temperature in the research area was obtained from the Sevastopol Center for Hydrometeorology and Environmental Monitoring (Sevastopol CGMS), as well as SST in the research area was determined using satellite data (from the Global Sea Temperature website, 2020).

The reliability of the differences in the average values for length, weight of the fish and age composition of the populations was determined using Student's *t*-test. The reliability of the coincidence of theoretical trend lines with experimental data was calculated using Pearson's Chi-squared test. The normality of the distributions of experimental data was evaluated using the Shapiro-Wilk test. The mathematical processing of the results was carried out on a personal computer using Microsoft Excel 5.0, Statistica 6.0, SigmaPlot 12.5 and Surfer 13.0.

RESULTS

Water temperature

Water temperature is an important indicator that determines the productivity of all components of the ecosystem of the Black Sea, including the development of fish. The long-term changeability of SST over the last two decades (2000 - 2020) was characterized by significant variability in the average annual values (Fig. 1). The general direction of long-term changes, the amplitude and rate of changes in the average annual temperature characteristics of the sea surface during the period under review is illustrated in Fig. 1.

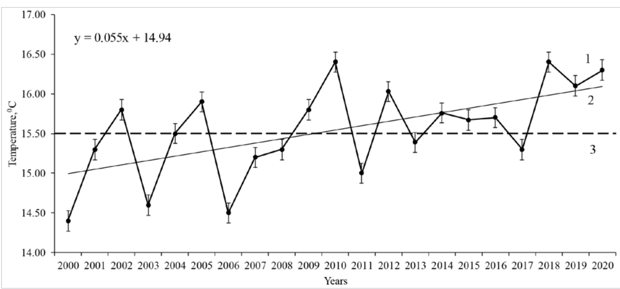

Fig 1. Changes in the average annual water temperature from 2000 to 2020 (1), standard deviations, trend line (2), average SST for the study period (3)

The trend line shows that over the past 20 years there has been a general trend towards an increase in average annual SST values compared to the long-term average (2000 - 2020). The results obtained show that the average rate of SST increase over 20 years in the coastal waters of the southwestern Crimea is k = 0.055 ± 0.017 °C/year (see the trend equation in Fig. 1). The difference in the trend angle from zero is statistically significant (t-test, t = 3.119, P > 95%). Calculations using the Shapiro-Wilk test confirmed the normality of the deviation of the average annual temperature from the trend line (SW-test, n = 21, W = 0.703, W_{calc} = 0.968, α = 0.05). Experimental data of the SST changes do not statistically differ from the theoretical trend line (criterion χ^2, χ^2 = 0.297, df = 20, α < 0.05).

The analysis of temperature changes in SST shows that the 20 years can be divided into three periods based on the nature of temperature changes:

Period I (2000 - 2007): during this period, the line indicating changes in the average annual SST was low in almost all years and the average annual SST (15.2 ± 0.208 °C) was 0.3 °C lower than the average over 20 years (15.5 ± 0.128 °C). The fluctuations in temperature changes were greater and amounted to 1.5 °C.

Period II (2008 - 2013): during this period, the line showing changes in the average annual SST fluctuated almost annually in both positive and negative directions from the twenty-year average temperature, and the average annual SST (15.7 ± 0.190 °C) during this period was 0.2 °C higher than the twenty-year average. In addition, the fluctuations in temperature change decreased to 1.4 °C.

Period III (2014-2020): during this period (except 2017), the line showing changes in the average annual SST was higher and the value of the average annual SST (15.9 ± 0.148 °C) was 0.3 °C higher than the twenty-year average. Against a background of a general increase in SST, the fluctuations during this period decreased to 1.1 °C (Table 1).

The values of the average annual SST and its rate of change for the three periods under consideration are shown in Table 1.

Trend lines were also found for the three periods, which made it possible to determine tendencies in the rate of change of the average annual SST. The equations of the trend lines are given in Table 1. In the equations of the trend lines, the letter "x" indicates the year in the study period.

From the trend equations presented in the table, it can be seen that the largest coefficient with the parameter "x" k = 0.114 °C/year, characterizing the angle of inclination of the trend line, was observed for 2014 - 2020. During this period, the increase in the average annual SST was the highest. From Table 1, it can be seen that the temperature increased during 2000-2007 (0.231 °C) and 2014 - 2020 (0.684 °C). The temperature increase during Period III exceeded the temperature increase for periods I and II by 2.2 - 3.0 times, that is, in recent years (2014 - 2020) the increase in SST occurred at a higher rate.

In order to identify the relationship between trends in the temperature parameters of the marine environment on the southwestern shelf of the Crimea and the peculiarities of fish development, a comparison of changes in the average annual values of water temperature was made both in general over the past 20 years and separately for the periods (2000 - 2007, 2008 - 2013 and 2014 - 2020) with the parameters of fish growth, using the example of the cold–water *S. sprattus*.

The relative cold tolerance of sprat determined the change in its biological rhythm in the Black Sea and caused reproduction in the winter months. Earlier studies have shown that more than half of all individual simultaneous spawning of sprats on the southwestern shelf of the Crimea were recorded in the temperature range from 8 °C to 9 °C. This feature of sprat spawning was preserved during the study period (Giragosov at el., 2006).

Length and weight studies

In the studied period (2000 - 2020), the commercial part of the *S. sprattus* population was represented by fish with a length of 5.0 - 11.0 cm. Individuals with a length of 6.0 - 8.0 cm dominated (69.1%). Individuals longer than 9 cm were rare. The average length of the fish in the study period was 6.5 ± 0.782 cm, the average weight was 3.08 ± 0.705 g, and the average age was 1.2 ± 0.413 (Table 2).

Table 1. The main parameters of changes in SST for the studied periods

Study period	Average annual temperature, °C	Min-max temperature, °C	Temperature increase per year, °C/year	Temperature increase over the period, °C	Trend equations
2000 - 2007	15.2 ± 0.208	14.4 - 15.9	0.033	0.231	y = 0.033·x + 15.00
2008 - 2013	15.7 ± 0.190	15.0 - 16.4	0.044	0.308	y = 0.044·x + 15.41
2014 - 2020	15.9 ± 0.148	15.3 - 16.4	0.114	0.684	y = 0.114·x + 15.44

Table 2. Dynamics of the age and length-weight structure of sprat for 2000 - 2020

Study period	Average annual temperature, °C	Relative numbers, %			Average age, year	Average length, cm	Average weight, g
		1 year old	2 years old	3 years old			
2000 - 2007	15.2 ± 0.208	62.8 ± 5.644	34.7 ± 5.278	2.5 ± 1.761	1.4 ± 0.482	7.2 ± 0.903	3.65 ± 0.863
2008 - 2013	15.7 ± 0.190	84.13 ± 2.356	15.6 ± 1.441	0.27 ± 0.433	1.16 ± 0.181	6.4 ± 0.752	2.82 ± 0.622
2014 - 2020	15.9 ± 0.148	93.3 ± 1.438	6.6 ± 2.070	0.1 ± 0.286	1.07 ± 0.232	6.0 ± 0.324	2.76 ± 0.513

When studying the dynamics of the length-weight structure, we used parameters for the length and mass of sprat average over separate periods (2000 - 2007, 2008 - 2013 and 2014 - 2020) (Table 2).

The length distribution of fish of each age class in each of the studied periods is reliably normal (SW test, n = 100/500, $\alpha = 0.05$).

Table 2 shows that over the past 20 years, the length and weight structure of sprat has not remained constant. During the periods under analysis, there is a tendency to decrease the average length and weight of sprats. The average length of the fish for the period 2000 - 2020 significantly decreased by 1.2 times (from 7.2 ± 0.903 to 6.0 ± 0.324 cm) (t-test, $t = 12.63$, $P > 95\%$), and the average weight decreased by 1.32 times (from 3.65 ± 0.863 to 2.76 ± 0.513 g) (t-test, $t = 8.9$, $P > 95\%$).

The decrease in length and weight has become especially apparent in recent years (2014 - 2020). The analysis of the length-age structure shows that this is due to a relative increase (by 1.5 times) in the proportion of small individuals in a school (t-test, $t > 10.0$, $P > 95\%$).

The dependence of mass on length is well approximated by the following equations:

2000 - 2007 – $W = 0.0085 \cdot SL^{2.95}$;

2008 - 2013 – $W = 0.009 \cdot SL^{2.82}$;

2014 - 2020 – $W = 0.0102 \cdot SL^{2.78}$ (Table 3).

The low allometric growth indicator $b < 3$ indicates that the average annual sprat length increases slightly faster during development than the average annual transverse dimensions. It follows that fish having a longer length are characterized by a more elongated shape and a slower rate of mass build-up. At the same time, the allometric growth indicator b in these equations is consistently reduced from the period 2000 - 2007 to 2014 - 2020. Taking into account the existing relationship between the parameter b and Fulton's condition factor (Rikker, 1979; Bagenal and Tesch, 1978), it can be stated that the lowest value of fat content in sprat was observed for 2014 - 2020 at the highest SST of 15.9 °C.

It can be seen from Table 3 that the asymptotic mass W_∞ of sprat decreased by 1.4 times with an increase in SST from 15.2 °C (2000 - 2007) to 15.9 °C (2014 - 2020).

Fish growth

The growth of fish is closely related to the ambient temperature, which is manifested in the variability of the parameters of the von Bertalanffy growth equation. In the compiled von Bertalanffy growth equations for the sprat population, the *k coefficient*, characterizing the rate of length and weight growth, was the lowest (k = 0.311) during 2014 - 2020, with a higher SST of 15.9 °C, compared to the other periods (Tables 2, 3). A decrease in the *k coefficient* during periods characterized by higher average annual temperatures shows a negative effect of increased temperature on the sprat growth rate. This can be explained by the fact that *S. sprattus* is a Boreatlantic relic and belongs to the cold-water species.

Sprat reaches its maximum length of 9 cm at 5 years of age in the study period at higher average annual temperature indicators - 15.9 °C (2014 - 2020), whereas at lower temperatures of 15.2 °C (2000 - 2007) at an earlier age, 3 - 3.5 years (Fig. 2).

Table 3. Parameters of *S. sprattus* growth equations during the research period

Study period	L_∞	k	t_0	W_∞	φ	φ'	a	b	R^2
2000 - 2007	11.5	0.345	-1.123	11.441	1.659	0.243	0.0085	2.95	0.90
2008 - 2013	11.3	0.321	-0.85	9.026	1.613	0.144	0.009	2.82	0.86
2014 - 2020	11.0	0.311	-0.53	8.011	1.576	0.095	0.0102	2.78	0.85

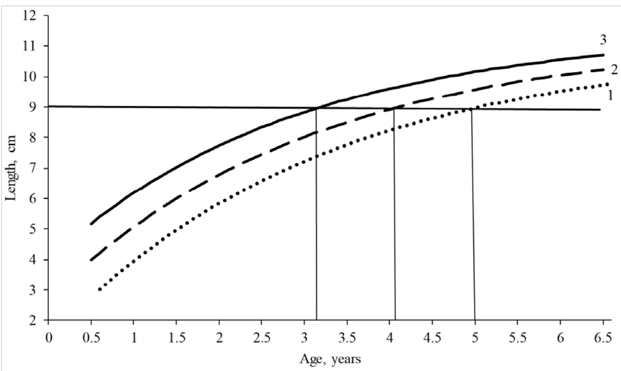

Fig 2. The growth of *S. sprattus* in the coastal waters of the southwestern Crimea for the following periods: I (2014 - 2020); II (2008 - 2013); III (2000 - 2007)

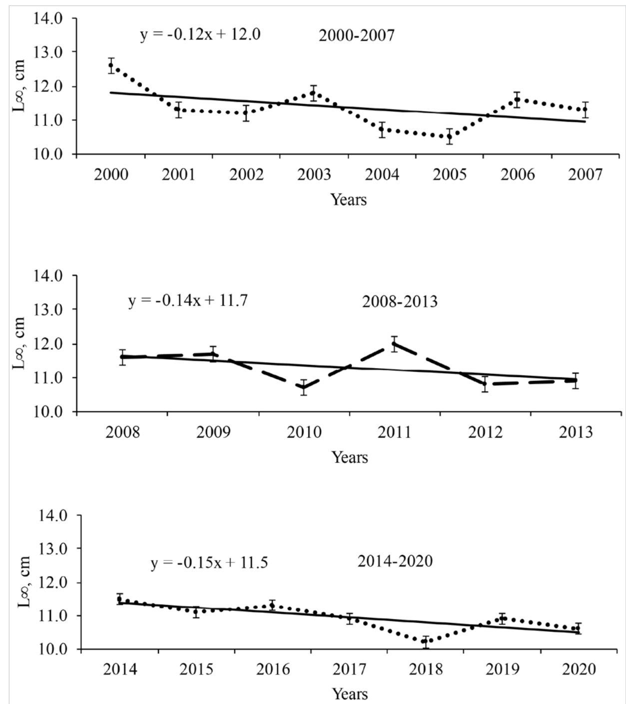

Fig 3. The change in the asymptotic length of *S. sprattus* for 2000 - 2020; "*" – the calculated value of L_∞ of the corresponding year

This leads to the fact that the values of the growth performance indexes φ and φ' in sprat decrease and reach the lowest values φ = 1.576 and φ' = 0.095 during 2014 - 2020, characterized by a higher SST (Tables 2, 3).

From 2000 to 2020, the von Bertalanffy growth equations were found and their parameters were determined for each year. The average value of the asymptotic sprat length (L_∞) for 2000 - 2020 was 11.2 ± 0.582 cm. The analysis showed that, in general, the asymptotic length of the sprat decreased during 2000 - 2020. A negative correlation was established between the changes in L_∞ and SST ($r = -0.86$, $P < 0.001$).

Figure 3 shows the changes in the asymptotic length L_∞ and the standard deviations for the periods 2000 - 2007, 2008 - 2010 and 2014 - 2020, as well as the equations and trend lines.

From the trend equations, it can be seen that the greatest rate of decrease in L_∞ was observed during 2014 - 2020 (trend angle $k = -0.15$ cm/year), compared to the previous periods $k = -0.12$ and $k = -0.14$ cm/year, respectively (see Fig. 3). Analysis of changes in the parameters of growth of length L_∞, k, φ and weight φ' during the study period showed that an increase in SST negatively affected the state of the *S. sprattus* population. As the growth rate slowed down, the fish got smaller.

Age structure

S. sprattus is a short-lived fish species. Their maximum lifespan off the Crimean coast is no more than three years, the average is one and a half years (Zuyev and Mel'nikova et al., 2002). Consequently, the age structure of sprat reacts quickly to changing environmental conditions.

During the research period, along with changes in the length and weight characteristics of sprat, the age structure also underwent changes. The age composition of the sprat population off the Crimean coast was represented by three age classes (generations): one-year-olds, two-year-olds and three-year-olds. Four-year-olds occurred infrequently and not every year (Table 2).

One-year-olds were the most numerous age group. On average, over the entire study period 2000 - 2020, their share was 80.1%, rising with an increase in the average annual SST from 62.8% (2000 - 2007) to 93.3% (2014 - 2020). The second largest age group was two-year-olds: their share in the population on average for 2000 - 2020 did not exceed 19.0%, varying from 34.7% (2000 - 2007) to 6.6% (2014 - 2020). Only about 1.0% of the total population in the study period were three-year-olds.

The average age in general for the entire study period was 1.2 years. Studies have shown that with an increase in the average annual SST, there was a decrease in the average age from 1.4 (2000 - 2007) to 1.07 years (2014 - 2020). From Table 2, it can be seen that the average age of sprat decreased by 1.3 times.

In general, over the period 2000 - 2020, the relative number of three-year-olds decreased by 25 times (t-test α < 0.05, P > 95%,), two-year-olds decreased by more than 5 times and the relative number of one-year-olds increased by 1.5 times (t-test, α <0.05, P > 95%,). It follows from this that the changes in the age structure of sprat were expressed in a consistent decrease in the proportion of older ages and an increase in younger ones.

Based on the analysis of the age structure, it can be concluded that against the background of the observed warming (increase in SST), the sprat population is rejuvenating, which leads to a decrease in the average size and mass of individuals in general.

DISCUSSION

It is known that the length-weight and age structure of a species is characterized by both population and spatio-temporal specificity. This is due to the fact that the biological parameters of the species adaptively change in accordance with changes in the habitat (Bellido et al., 2000; Sinovčič, 2004; Froese, 2006; Goulding et al., 2014). The analysis of the relationship between the length-weight and age structure of fish and the characteristics of the habitat, taking into account the trends of climatic changes, allows us to predict the tendency of adaptive changes in the biological parameters of the species.

The studies provided have shown that during 2000 - 2020 there was a tendency to increase the average annual SST at an average rate of 0.055 °C/year. It has caused changes in the length and weight values of the cold-water *S. sprattus*. It was found that during 2000 - 2020, the average age of *S. sprattus* decreased by 1.3 times, average length by 1.2 times and average weight by 1.32 times.

Analysis of the literature data showed that a similar trend in the length of sprat was observed in other regions of the Black Sea. In 1991, the minimum length of sprat in catches in the southeastern regions of the Black Sea was 7.2 cm, for 2002 - 2003 it was 6.4 cm, for 2006 - 2008 in the western part of the Black Sea it was 6.0 cm, in 2014 it was 5.5 cm and for 2017 - 2019 it was 4.5 cm (Sahin, 1999; Satilmis et al., 2014; Yankova et al., 2011, Özsandıkçı, 2020; Dagtekin et al., 2022). It can be concluded that the length of sprat from catches has decreased by 1.6 times over 20 years. The share of younger age groups in catches has increased, which was also noted in our studies.

A considerable change in the age structure of the commercial *S. sprattus* observed for 1996 - 2012 was indicated by V.D. Dakhno and O.A. Perevalov (Dakhno and Perevalov, 2013). They found that during 1996 - 2000 two-year-old and four-year-old fish dominated in May-June, and during 2001 - 2012 two–year-old and three-year-old individuals, and in some years individuals aged 0 - 2 years. The tendency to decrease the average length and weight of the most numerous age groups (from 0+ to 2+ age group) has especially clearly been observed in the last decade. According to the authors, this indicates a deterioration in the habitat conditions of the sprat population, in particular, a disorder in the feeding conditions of the cold-water sprat, since intensive warming of the coastal shallow marine waters in summer leads to a significant reduction in the feeding area, increased food competition with the warm-water fish, an increase in the number of predators of the warm-water Mediterranean complex, such as *Trachurus mediterraneus*, *Pomatomus saltatrix* and also *E. encrasicolus*, its competition for food.

In her research, T.I. Glushchenko (Glushchenko, 2011) noted that there were practically no cold-water organisms that represented the category of "main food" in previous years in the diet of fish of older age groups during 2009 - 2010. As shown in our studies, during 2008 - 2013 the average annual SST increased by 0.5 °C (see Table 1), compared to the previous 2000 - 2007 period. Maybe this negatively affected both the organisms of the cold-water complex which were noted by T.I. Glushchenko, and the state of the population of the cold-water sprat.

V.A. Shlyakhov and O.V. Shlyakhova (Shlyakhov and Shlyakhova, 2011) showed trends towards a consecutive decrease in the average weight of sprat individuals in trawling from 1976 - 1980 to 2005 - 2009. To characterize the weight growth of sprat, the parameters of the «mass-length» relationship were calculated. During 1976 - 1980, the coefficient b was on average more than three (the range of monthly averages was 2.96 - 3.28). During 1990 - 1994, the values of the coefficient b fit into a wider range - from 2.80 to 3.45, and during 2005 - 2009, its monthly average values decreased and became lower than $b < 3$.

A decrease in parameter b in the "mass-length" ratio with an increase in SST was also observed in the southern and western regions of the Black Sea. In 1991, in the southeastern part of the Black Sea, sprat had a positive allometric growth of b = 3.46 (Sahin, 1999). During 2002 - 2003, with an increase in SST, a decrease in the growth parameter b = 3.00 was observed (Satilmis et al., 2022). During 2004 - 2005, Kalayci et al. (2007) described a negative allometric growth of b = 2.87. During 2006 - 2008, Yankova et al. (2011) showed a further decrease in the parameter b = 2.73 in the Bulgarian waters of the Black Sea.

Almost all of the above estimates characterizing the state of the sprat population fit within the range of our estimates for the periods 2000 - 2007 and 2008 - 2013. Among the many factors that can affect the length and weight structure of sprat catches, the authors pointed to climate, food supply and fishing, noting that these factors are interrelated.

At the same time, the authors noted that the greatest impact of the first two factors can be manifested in weight growth, seasonal and interannual dynamics of its parameters (average weight of individuals, fat content and condition factor), and the latter – in the changes in the length (and age) structure of catches. In principle, changes in climate and food supply can lead to a deceleration or acceleration of growth and thus to a change in the length of fish in the catches.

All these results confirm our conclusions about the negative impact of the increase in SST observed on the biological state of the *S. sprattus* population in recent years – the growth rate slows down and the fish becomes smaller.

CONCLUSION

Expressions of the trends of SST change on the southwestern shelf of the Crimea were obtained. Over the period 2000 - 2020, SST increased on average at a rate of 0.055 °C/year. It is shown that 20 years can be divided into three periods according to the nature of the SST change: 2000 - 2007, 2008 - 2013 and 2014 - 2020.

It was found that the observed increase in the average annual SST negatively affected the growth of *S. sprattus* which belongs to the cold-water complex of fish. So, during 2014 - 2020, compared with the period 2000 - 2007, the average length of *S. sprattus* decreased by 1.2 times, the average weight - by 1.32 times, and the average age - by 1.3 times. The values of linear and weight growth performance index decreased. There was a negative correlation (r = – 0.86) between the change in SST and the asymptotic length.

During 2000 - 2020, against the background of the observed warming, there was a decrease in the proportion of older age groups in the sprat population and an increase in younger ones. During this period, the average age of the sprat population decreased by 1.3 times (from 1.4 to 1.07 years). In general, there was a rejuvenation of the *S. sprattus* population, and the average length and weight of individuals have decreased.

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UTJECAJ TEMPERATURNOG FAKTORA NA PROMJENE PARAMETARA RASTA PAPALINA OD 2000. DO 2020.

SAŽETAK

Istraživanje promjena temperature površine mora (TPM) provedeno je na jugozapadnoj polici Krima u razdoblju od 2000. do 2020. Nađene su jednadžbe trendova promjene TPM. Pokazalo se da se razlikuju tri razdoblja prema prirodi promjena srednje godišnje temperature mora: 2000. - 2007., 2008. - 2013. i 2014. - 2020. Razmatran je utjecaj promjena prosječne godišnje TPM na razvoj pelagičnih riba hladnovodnog kompleksa (na primjeru crnomorske papaline). Pronađene su promjene u glavnim parametrima populacija i njihov odnos s promjenom prosječne godišnje TPM. Utvrđeno je da je uočeno povećanje temperature mora negativno utjecalo na razvoj populacije papalina, prosječna starost populacije smanjena je za 1,3 puta, te je općenito došlo do pomlađivanja populacije, smanjenja prosječne veličine i težine jedinki.

Ključne riječi: Crno more, promjene temperature, papalina, duljina, masa, jednadžbe rasta

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