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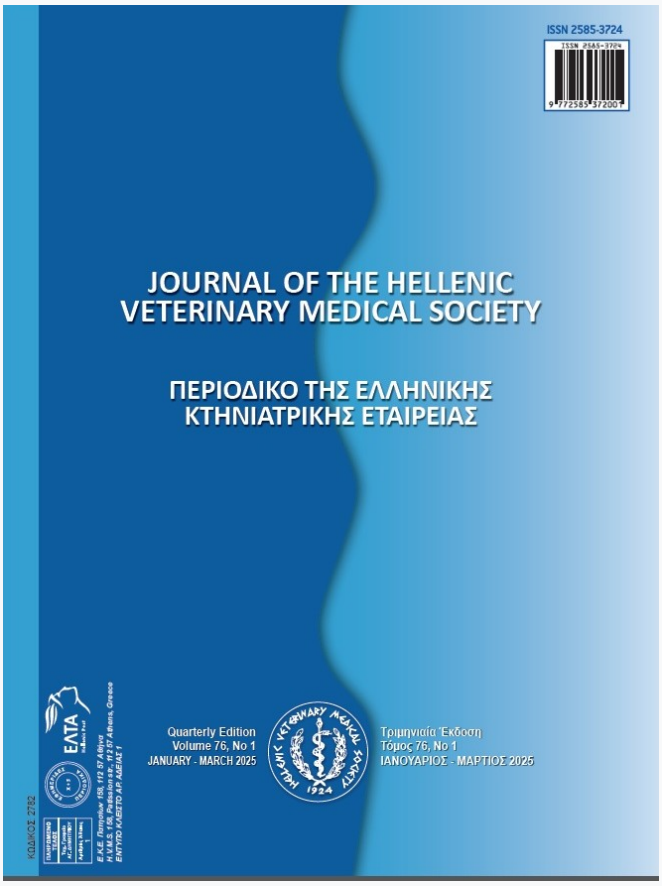

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Research article
Ερευνητικό άρθρο

Freshwater and Brackish Pre and Post-Reproductive Biological and Ecological Characteristics of the *Sander lucioperca*

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ABSTRACT: This research presents the results of study of the biological and ecological pre, post and reproduction characteristics of pike-perch (*Sander lucioperca*) in the Ponto-Caspian Basin, Dagestan area brackish and fresh waters. Samples were collected from Delta of the Terek River and the northwestern coast of the Caspian Sea, Dagestan. The reproductive biology was studied in two periods of life, in Dagestan sea waters and rivers through one year, 2019. Results state facts regarding age at first maturity, onset of spawning, fecundity, sex ratio, and the process of maturation of the reproductive organs. It was determined and found to be complementing each other for the populations of the two habitats. The pike-perch most important identified pre-reproductive, reproductive and post reproductive ethology characteristics are that after spawning in freshwater ecosystems, with its yearlings, migrates for foraging and sexual recovery and maturity to the sea to return then to the rivers of Dagestan for spawning again later. This specificity allows pike-perch both to use various ecosystems types trophic resources along its ontogeny, and keep a biological and ecological reproduction evolutionary potential in fresh, brackish and salty water ecosystems.

Keywords: Caspian Basin; top predator fish; pre, post and reproductive biology and ecology.

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INTRODUCTION

The salt content of the Caspian Sea is just about three times lesser than in the global oceans. The uppermost variability of water salt content can be found in the north part of the Caspian Sea, partly influenced by the tributaries coming from the Ural Mountains (inflow to the sea of 7.2 km^3), where the water is almost fresh, with less than 1% of salt content. In this context, the Volga River runoff mainly accounts for about 80% (inflow to the sea 230 km^3), so fluctuations in the salinity of the sea are largely due to these sources induced variability. Dissimilarities in salt content between the north part and the south part of the Caspian Sea are relatively minor; the salinity rises somewhat on a northwest-southeast gradient, to a 13.6% value in the Turkmen Gulf. The vertical changes of salinity are minor hardly overdo 0.3%, a fact which reveal the presence of an active vertical water mixing. The water clearness fluctuates broadly from 0.2 m in the local large rivers estuaries to 15-17 m in the middle parts of the Caspian Sea [Mikhailov, 2013].

The salinity off the studied Dagestan coasts is under the impact of both salty sea and fresh river waters. Back in the 1970s, the Tersko-Caspian coast could be attributed to brackish reservoirs. The dynamic of this state is influenced by seasonal changes, for example in summer the water it is desalinated due to fresh water Volga runoff [Mikhailov, 2013].

In the last few years, the salinity of the coastal waters varied between 3.3‰ in the Northern Caspian to 12.94‰ in the Middle Caspian Sea [Vinetskaya, 1959; Glazovsky, 1972; Mankova, 2003].

Consequently, in this matchless Ponto-Caspian biogeographical and ecological area, an outstanding particular and opulent fauna developed and spread, including fish [Glazovsky, 1972; Bănăduc et al., 2020].

In our view, the unique natural conditions in the region, combined with significant human influence, create an ideal "laboratory" environment for conducting applied studies on fish characteristics in the open air. These studies are particularly valuable as they allow us to observe the impact of obvious environmental changes on various organisms, including fish, and how they adapt to these changes through constant evolutionary processes.

Belonging to the rich Ponto-Caspian fauna, one of the major ecologically and economically main potamodromous and pelagic fish species, and a top hunter both in fresh and brackish water, is *Sander lucioperca* (Linnaeus, 1758) [Riede, 2004; Bănăduc, 2023; Alieva, 2023]. This fish which reaches a full length of over one meter can be found in turbid rivers and eutrophic lakes, brackish coastal lakes, estuaries, and deltas [Kottelat and Freyhof, 2007].

After reviewing scientific publications on reproduction of pike-perch in the waters of Dagestan in particular and the Caspian Sea in general, we found little information [Abdolmalaki et al., 2007; Rabazanov, 2017; Lehtonen, 1996; Abdusamadov et al., 2020]. Detailed data, in this researched special biogeographic and ecologic area, about this fish species, are needed related to its reproductive biological and ecological aspects and those related directly or indirectly to its evolutionary success, distribution range, abundance, productivity, etc.

The pike-perch is an ecologically important mainly ichthyophages top hunter in the Russian Federation and Eastern Europe countries waters, is of great value for fishing and lately, for fish farming [Mishenko et al., 2016; Magomedov et al., 2014]. It usually plays a key ecologic role in eutrophic inland waters in controlling the number of carnivorous and omnivorous fish. Since the beginning of the XIX century, its acclimatization began in the Netherlands, and then it spread throughout Western Europe and the Maghreb countries [Abdusamadov et al., 2020].

In the Tersko-Caspian fishery area, pike-perch is characterized by high plasticity and adaptation to fresh and brackish waters [Magomedov et al., 2014]. The most numerous and economically valuable populations of pike-perch in the Russian Federation waters are confined to the lower reaches of large rivers of the Azov-Black Sea and Caspian basins [Kudersky,1966; Reshetnikov, 2010]. Nevertheless, in recent years, stocks of pike-perch in these fishing areas are estimated as low, and catches too often tend to decrease. This also applies to the Tersko-Caspian fisheries subdistrict [Brazhnik et al., 2012; Levashina, 2018]. The common pike-perch in the Caspian Sea is represented by the semi-anadromous species *Sander lucioperca*. It is living mainly in the rivers of Russia, Kazakhstan and Azerbaijan, Volga, Ural, Terek, Kura; enters the bays: Kizlyar, Agrakhan and Kyzylagach; in lakes and reservoirs in which local herds live. In the Caspian Sea, the pike-perch is mainly found in the zone of desalinated waters [Abdurakhmanov, 1962; Kazancheev, 1981].

In the Tersko-Caspian subdistrict, pike-perch, like most semi-anadromous fish, forages and apparently winters and then spawning.

This category of research is not a thematic scientific exercise, but their overall goal is to provide *in situ* adapted pictures of the present needed information on fish reproductive biology, extremely valuable for regional fish communities' assessment and monitoring, for a realistic improvement of this valuable resource management strategies.

The study of biology of the semi-anadromous pike-perch makes it possible, with other researches, to better understand and recommend the right measures to improve its stock and maintain its sustainability. Farther more, for the development of scientific and practical measures aimed to preserving and increasing its population, based on the identification of reproductive optimum, as biological reference benchmarks. Accordingly, we found it necessary to conduct this research, the purpose of which is to analyze the cycle of maturation and indicators of expected natural reproduction and to propel the gap in knowledge in this aspect.

Due to the pike-perch high plasticity, it is expected that there will be changes in biological indicators and lifestyle. That is why our work is aimed at creating a more complete picture of reproductive variability in one of the areas of the ecological optimum of this species, which is undergoing a serious anthropogenic transformation. Therefore, it is of practical interest to study the reproductive biology and ecology of this fish.

MATERIALS AND METHODS

Sampling site

All experimental procedures used in this study were approved by the Authors' Institution's Ethic Committee. Care was taken to minimize the number of fish used.

The Tersko-Caspian fishery subdistrict is a place of reproduction of valuable commercial fish species and a place of their feeding and the most convenient part of the Caspian Sea for the winter occurrence of fish. It is also a good place of industrial fishing, fishing of marine, semi-anadromous and lake-river fish species is carried out here. The Terek, the largest of the rivers of Dagestan, occupies a significant place in the reproduction of valuable fish. The Tersko-Caspian Fishery region occupies a shallow coastal zone on the western coast of the Northern and Central Caspian Sea and is of significant importance for fishing. Geographically, the Tersko-Caspian region borders on the north with the North Caspian Fisheries sub-region. In the south, it runs along a line north of the city of Makhachkala, the capital of Dagestan. In the east, in the sea – it is located above a depth of 15 - 50 meters, along the coast of Dagestan. Inland water bodies, in particular the Terek and Sulak rivers, in Dagestan also belong to this sub-region.

The Terek, Sulak, and Samur rivers flow directly into the Dagestan waters of the Middle Caspian, which have a significant impact on the hydrological and hydrochemical regime of the coastal waters of the Caspian area. According to its hydrological, hydrochemical, and hydrobiological indicators, the coastal zone of the Dagestan is characterized as an area with fluctuating environmental factors - temperature, salinity, oxygen content, currents, and biogenic composition, and depending on the amount of the latter, an abundance of hydrobiont.

Data sampling

Samples of water and pikeperch (*S. lucioperca*) were collected in 2019 from Delta of the Terek River and the northwestern region of the Caspian Sea in the water area between 43º30' and 45º10' North latitudes and 46º15' and 48º45' East longitudes according to a standard grid of stations, with a total of 11 stations, with a uniform distribution over the water area (Fig. 1). Materials for biological data were collected from experimental catches of Terek and Solak Rivers and deltas (mesh sizes of 24, 30, 40, 50, 60, 70 and 100 mm, 3 m high and 100-300 m long). Catches in the sea carried out by marine pelagic trawls with a coded mesh size of 34 mm. We have intentionally selected the material (samples) collected between February and November 2019 inclusively. Random sampling produced a sample (N = 846) comprising 470 (157 males + 313 females) the sea and 376 fish (198 males + 178 females) from rivers. The wet weight (w/w) and length (standard length, SL) of each fish were measured using standard procedures. Age readings were performed on scales and otoliths of 325 males and 436 females captured in 2019 in both sea and inland Dagestan waters.

Each specimen was dissected to determine sex and gonadal stages. The gonads were weighed to the nearest 0.1 g. From 178 females with mature oocytes, five

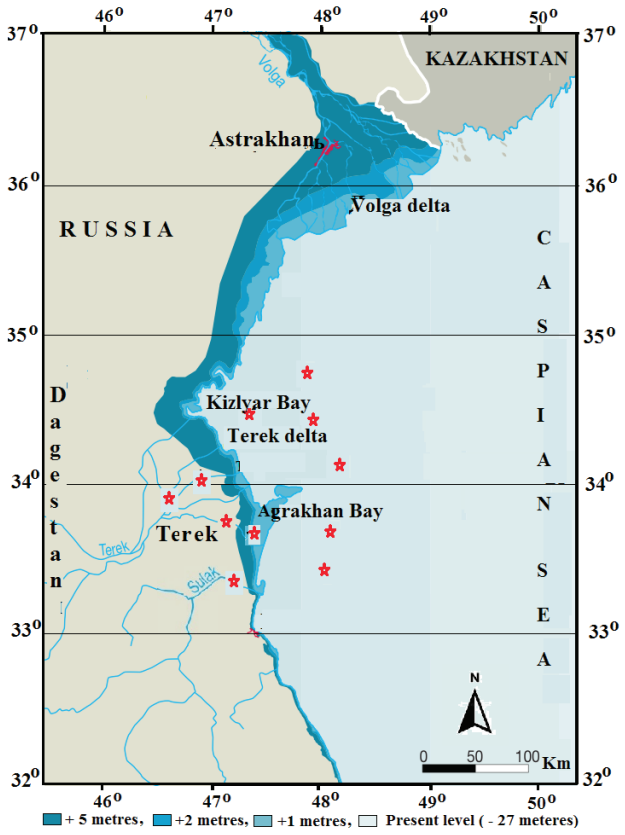

Figure 1. The location of pike-perch study area, Terek river delta and Northwestern Caspian Sea, 2019 (asterisks are the locality of samples stations).

grams of eggs were taken from different parts of the gonad (proximal, median, and distal), the number of eggs counted and the diameter measured to 0.01 mm accuracy using a microscope fitted with micrometer.

The length at the first maturity (Lm50) defined as the length at which 50% individuals within certain population are sexually mature. As well the age at which individuals (Am50) conceders mature at first time is the age at which 50% of certain population are sexually mature. The size at first maturity was determined during the spawning season. The fishes were considered as mature when their maturity was in stage three up to the sixth stage inclusively

Gonadosomatic index (GSI) was calculated as the ratio of the gonad mass to the eviscerated body weight of the fish as a percentage: GSI (in %) = (wg/wf) x100, where wg = total gonad weight (in g) and wf is eviscerated weight of the fish (in g) [Bagenal and Braum, 1978]. The spawning period was determined based on the frequency of occurrence of sexually mature individuals during each month and the analysis of the gonadosomatic index.

Absolute fecundity (AF) was estimated using the gravimetric method: AF = OW × S/ ws, where OW = Weight of ovary, S = No. of ova in the sub sample, ws = Weight of sub sample. The relative fecundity (Fr) of individuals (Fr = AF/EBW), where EBW is eviscerated body weight.

The maturity of the gonads was determined macroscopically, and the stages of development have been described using a six-point scale to determine the reproductive phase [Nikolsky, 1963]. There are six stages: (1) immature; not mature juveniles. The gonads look like thin transparent thread; (2) Early maturation, maturing individuals or individuals with developing sexual products after spawning; (3) Sexual glands are not fully developed; this stage of ovarian maturity is characterized by the presence of oocytes of the period of trophoplasmic growth. The ovaries contain oocytes visible to the naked eye. (4) Ripeness, the growth of the eggs has ended. The ovaries and testes have reached their maximum volume and mass, but light pressure on the female's abdomen does not lead to leakage of eggs. (5) Fluidity. The eggs and semen are ripe. Gonads occupy almost the entire body cavity. With light pressure on the abdomen, eggs and seminal fluid flow out; and (6) Spent. The eggs have been swept out, the semen has flowed out. Gonads are in the form of flabby bags. In the ovaries, some remaining eggs may be observed, in the testes - the remnants of sperm. Stages 1 and 2 in late autumn, winter and spring were considered immature (spawning did not occur current year), stages 3-6 were considered mature (they contribute or contributed to the reproduction of the year) [Nikolsky, 1963].

Pike-perch belongs to a group of fish with synchronous egg growth, a one-time and short-term type of spawning, which means that it is an annual spawner. According to the peculiarities of ontogenesis and our field monitoring, pike-perch females wintering with ovaries at the 4th stage of maturity [Tyler and Sumpter, 1996; Fontaine et al., 2015]. The Total sex ratio of Males and females was evaluated using the chi-squared Test. SPSS and Excel software packages were used for data analysis.

RESULTS

According to the survey conducted by Kasp-NIRKh in collaboration with our data from 2019, the average temperature of the surface water in the spring in the Dagestan part of the Caspian Sea was 17.2°C, in summer it was 24.1°C, and in Jan-

uary, it remained within the range of 2.5-5.8°C. In early April, the temperature rose smoothly from 7.8°C to 12.3°C. By the end of May, it had warmed up to an average of 19.2°C. During our research, we found that the salinity of the coastal waters in the Dagestan part of the Caspian Sea ranged from 4.0 ºoo in the northern part (station 44°00′ N, 48°14′ E) opposite the village of Krainovka in Kizlyar district to 13 ºoo in the Middle Caspian Sea near Kaspiysk. In the spring period, the oxygen activity index in the surface layer of the area we studied ranged from 6.31 to 7.86 milliliters per liter, while in the summer; it was between 6.70 and 7.12 milliliters per liter. The concentration of dissolved oxygen in the rivers Terek and Sulak's deltas varied between 7.48 and 15.26 milligrams per liter and 8.8 to 15.8 milligrams per liter, respectively. During our study it was found that the migration of pike-perch to the spawning grounds from the sea coast to the Terek and Sulak rivers starts under low temperature degree, at end of February. The first few mature males specimens appear in Terek delta fishing gears are in end of February. The mature pike-perch numbers continue to decline in the coast until end of March when the single catch become equal 0-3 specimens. This is due to the departure of mature pike-perch from the mouth of the riverbed to spawning grounds in more upstream of river currents and delta.

The sex ratio offers data for assessing the reproductive capacity and the size of fish population stocks. In our yearly marine sample, sex ratio of males to females corresponded to about 33.4: 66.6 % (males: females) in sea period, where females were more than the males during the study period. This unbalance between sexes retained as long as the population was foraging in the sea. Apparently this picture does not change, not by age, not by size groups; except for the disappearance of males from the older ages. The same manner was observed in the indicator of the sex ratio during the foraging of pike-perch in the sea, where the females dominated over males throughout the three seasons, spring, summer and autumn, creating an ascending rate by November (Fig. 2). The sex ratio in the Pike perch population during the marine period was 1:1.99. This means that the number of females significantly exceeds the number of males. Such a deviation from the 1:1 ratio is statistically significant ($\chi 2$=59.83, significance level sig=0.000, number of degrees of freedom df=1).

When it comes to the sex ratio of the pike-perch populations of Terek and Solak rivers period, there is almost the opposite picture, when the females are slightly dominated by males: 52.7: 47.3, which does not deviate much from what is expected 1:1 sex ratio (Fig. 3).

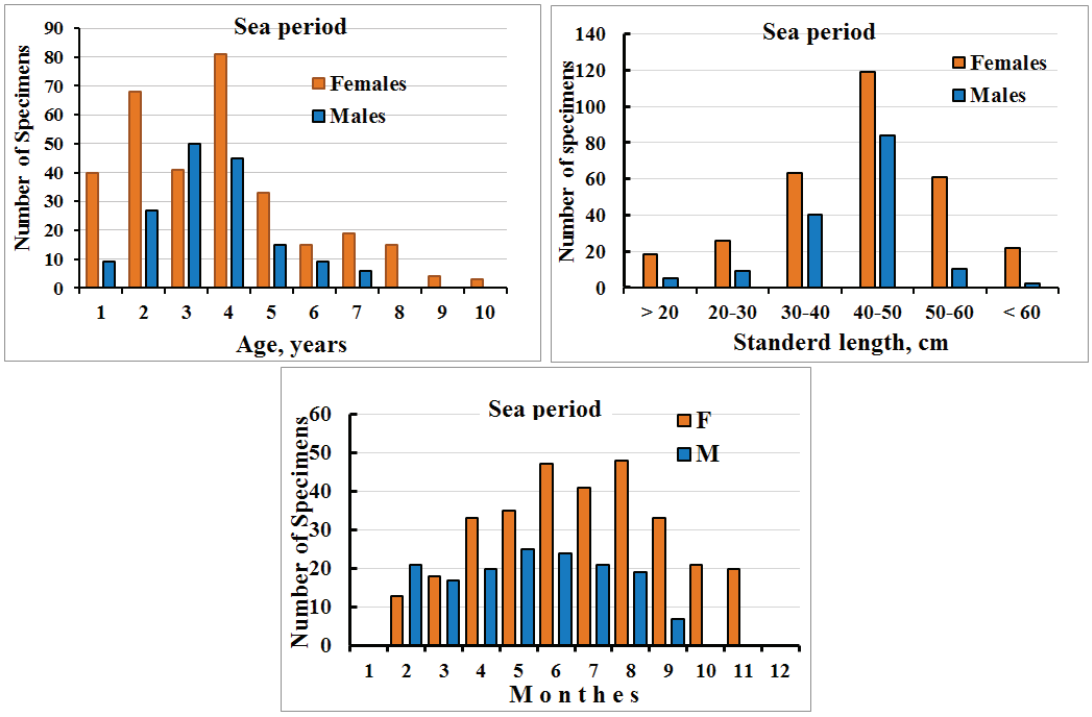

Figure 2: Illustration of sex ratio dynamic of *Sander lucioperca*, according to Age, Length and seasons in Northwestern Caspian Sea, 2019.

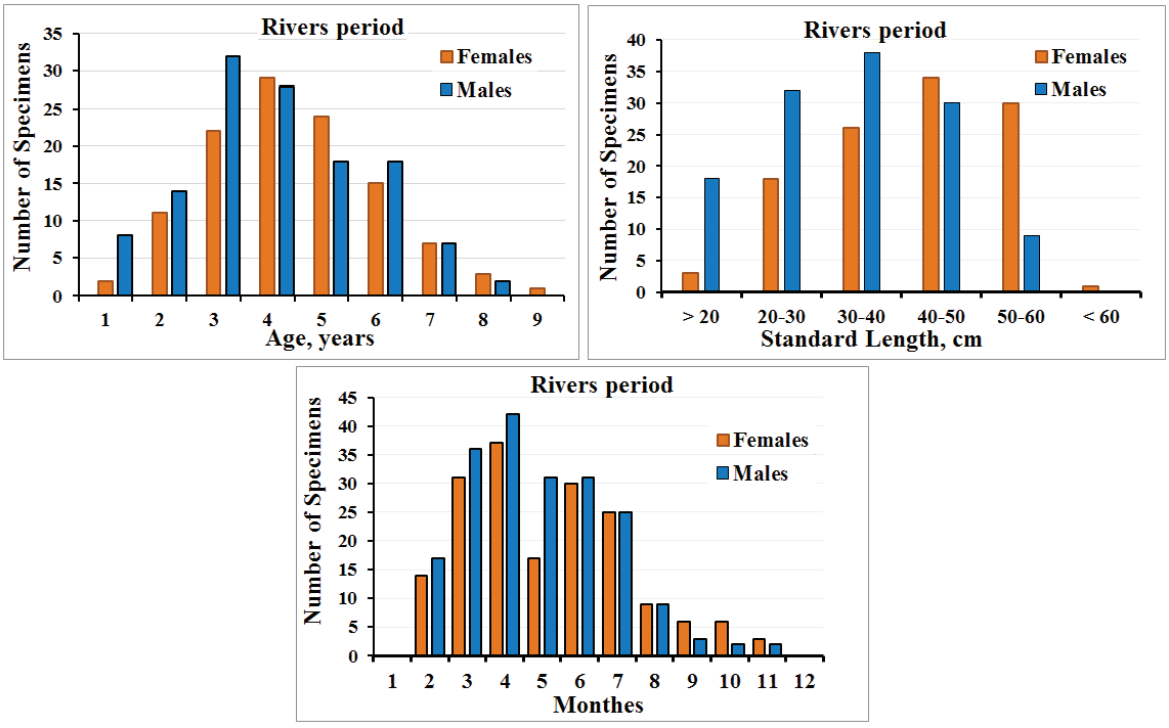

Figure 3: Illustration of sex ratio dynamic of *Sander lucioperca*, according to Age, Length and seasons in the Terek and Sulak Rivers, 2019.

Overall, the sex ratio was different between marine and river populations. This is especially noticeable when it comes to monthly groups, where there was a clear predominance of females in the sea and almost equally in rivers during all months except the month of May, where the proportion of males grew noticeably ($\chi 2=39.15$, $p < 0.05$).

The length at the first maturity defined as the length at which 50% individuals within certain population are sexually mature (Lm50 or Am50) and the mature individuals most have developing germ cells in gonads.

Females usually mature a year later than males (Fig. 4 A). As for the length sexual maturity (Lm50) occurs in males at 20-30 cm length (Fig. 4 B) and a weight of 290-375 g. At this time, for the first time mature males exceed the number of females by 50%. For the first time mature females are found at 20-30 cm length, 368-480 g weight. Fully sexual maturity is completed at 30-50 cm length. The bases of the spawning herd are males at three to four years of age and 30-40 cm in length, females at three to five years of age and 40-50 cm (Fig. 4). The length of the first maturation was proven on the basis of the smallest fishes in catches in spring, with their gonads at the 4th stage of maturity. In Terek and Sulak the smallest mature female (Lm50) was 24.4 cm; male was 22.6 cm in standard length. Empirical data show that 50% of females reached the full 4th stage of maturity and began to reproduce after they reached a standard length of 38.8 cm; males were 34 cm.

The nature of fertility changes can express by the indicator of gonadosomatic index (GSI). During foraging in the sea both females and males had quite significant monthly changes in GSI values. For both sexes, it reaches its highest levels at the end of autumn, rising from August to November up to 11, 2% and obviously remains at an increasing rate until the end of autumn and within winter, after what they migrate toward spawning areas in rivers. In the river population, GSI was at its peak in February and March, with females accounting for 13,1 ± 2,65 and 14,2± 1,69 %, respectively, while males reached the highest level after winter, 4.7% in April. For females, lower values of GSI, from 3.6 to 3.5%, were in June and July, as well as males, dropping to its minimum of -1.3 in July. Lowering the GSI indicators in May means that producer's gonads have already spawned and are moving into new maturation phases (Fig. 5). In females, the value of GSI, in rivers case, increased gradually from July to November. In November the value of GSI was 11.2 and 10.8 in sea and rivers samples respective-

ly (Fig. 5). The spawning happened here from end of March to the first days of May, at a temperature of 10°C - 15°C. The rest of gonads take place along summer and from September to March the gonads are in a developing state.

Female of pike-perch in rivers at the 4th and 4th-5th stages of maturity had a relatively high gonado-somatic index (GSI), which constitutes an average of 13.48 ± 2.15% in February and March and 9, 6± 1.58 in April (Fig. 5). The values of the GSI differed significantly between males and females in different months ($\chi 2=19.317$, $p < 0.05$), as well it differed significantly between the habitats ($\chi 2=28.73$, $p < 0.05$).

Due to fact that given population of Caspian pike-perch are been here not to spawn but to fattening, growing and prepare itself to migrates back to the rivers, to the spawning grounds because the fact that some of the population of pike-perch in the northwest of the Caspian Sea migrates in winter and spring to the deltas and estuaries of the Terek and Sulak rivers is certain. At the same time, naturally, they are in the process of maturation, the indicators of which we discussed earlier. So, it's worthy interesting to looking at this process monthly: the monthly proportion (Fig. 6) of mature stages along the year showed that stage 2nd individuals (which will be spawned the next year) there were single specimens within female and males between February and May in spring-summer period; while their portion increases in August and October in both sexes. Meanwhile the most advanced maturity stages (3rd-4th+) were concentrated mainly from September to May next year (Fig. 6). Moreover, the pattern in spawning seasonality was similar between genders, further supporting the period between October and March/April next year, as a spawning period. We believe that, about a month prior to spawning, beginning from February the herds migrating into shallow areas, usually around April-May, or when temperatures reach 10-14°C in the spawning grounds.

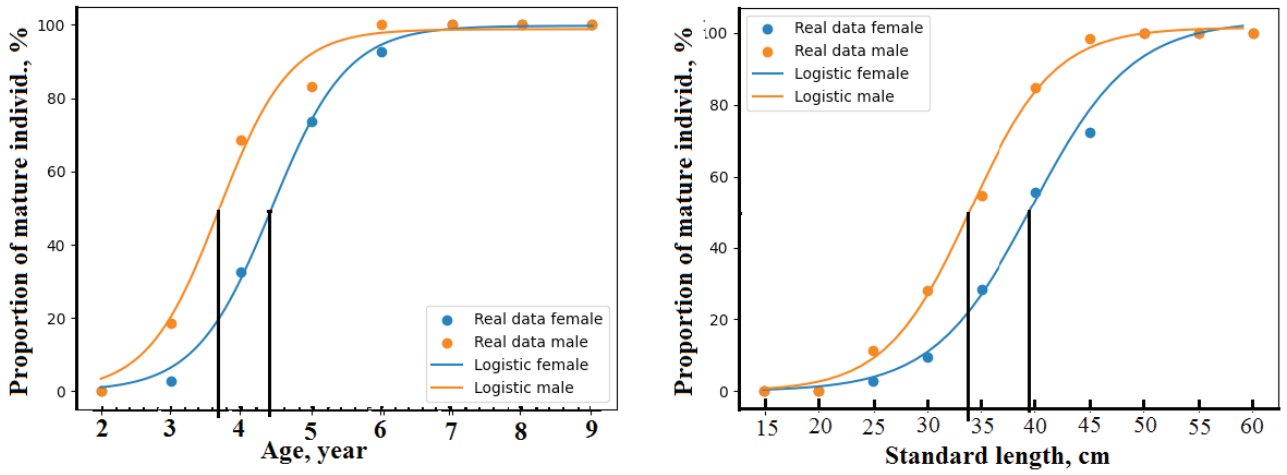

Figure. 4: Fitted logistic regression for the proportion of pike-perch maturity by Ages and standard length.

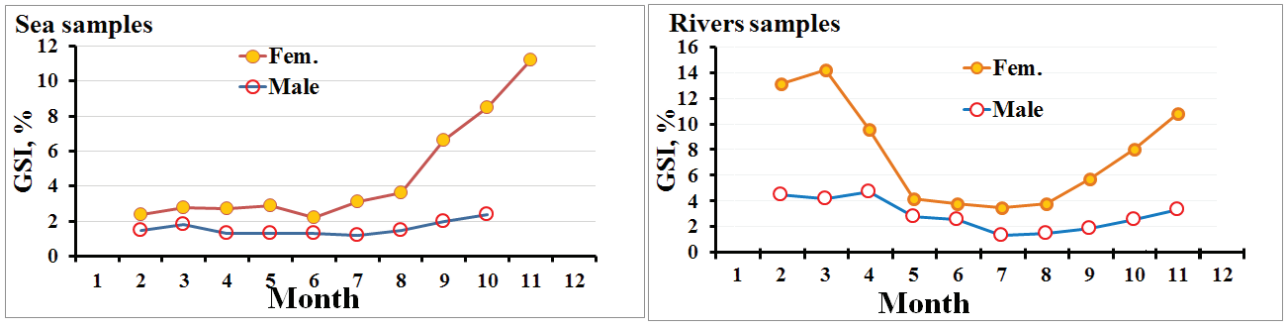

Figure 5: The seasonal nature of Gonadosomatic index. (N = 846, comprising 470 and 376 fish from the sea and rivers respectively

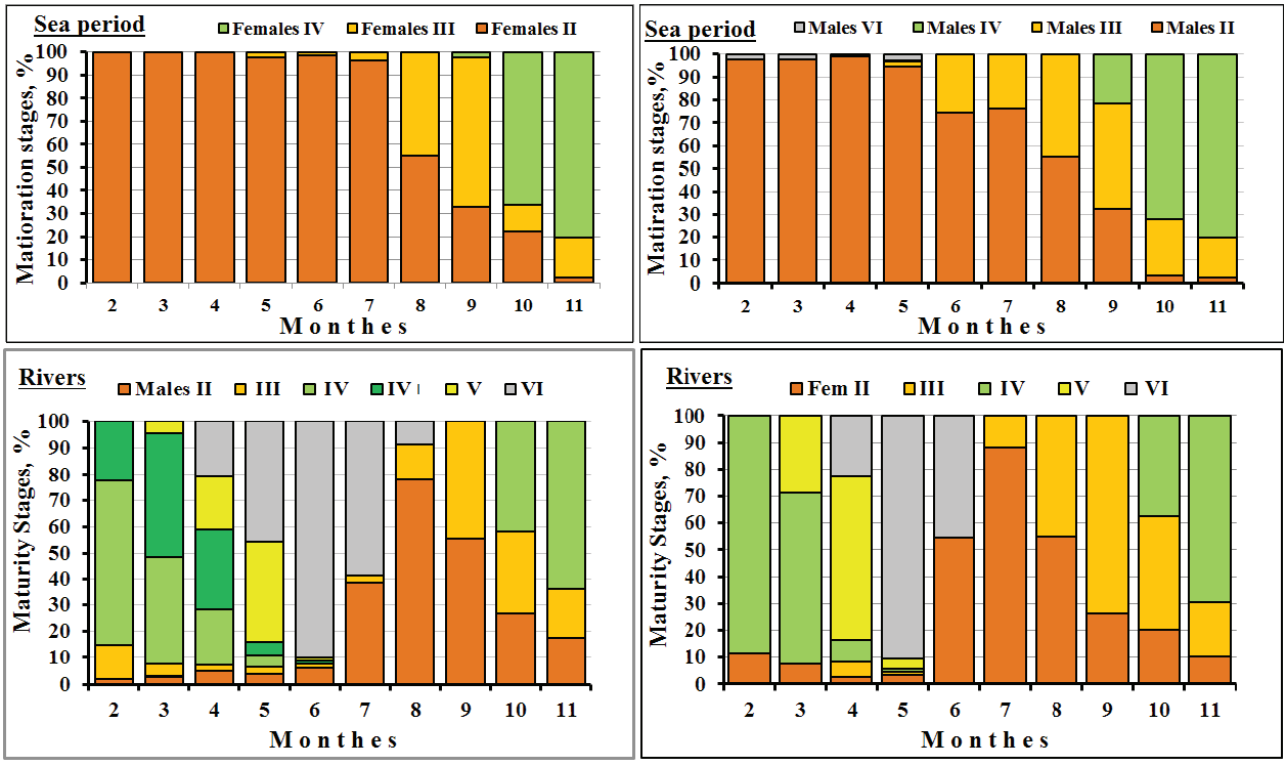

Figure 6: The monthly proportion of maturation stages of pike-perch Northwestern Caspian Sea.

Studies of the fecundity of pike-perch were carried out by counting the eggs of 112 females with mature ovaries and SL values ranging from 24 to 61 cm and eviscerated weight 368-4980 grams.

Absolute Fecundity ranged from 86950 to 920650 eggs, on average 427 815± 102498 eggs. The relative Fecundity ranged from 76.8 to 283.2 eggs per gram of eviscerated mass. According to age groups, Fecundity increased from 102845 eggs for age group 2 to 800,849 eggs for the age group of 10, which led to an increase in fertility with age from 51716 eggs per year in the first years to 57782 eggs per year in the oldest specimens, which indicates a slight increase with age, which is confirmed by a relatively moderately related correlation coefficient- R2= 0.81 (Fig. 7 C). It is well known that the level of fertility depends on the length, age and, to the greatest extent, on the mass of females. Data on changes in the fecundity of pike-perch of the same size of the rivers of Dagestan in the modern period indicate a significant variation ($P<0.05$). With the increase in the length and weight of the pikeperch at the present time, fertility increases significantly on average, but its fluctuations in individuals of the same size and weight are very large. So, in the group of fish with a length of 25-35 cm, fertility ranges from 87 to 226 thousand eggs; in the most numerous size groups - 46-55 cm, it is 245 - 775 thousand eggs. The same large fluctuations in fertility (2-3 times) are observed in the same weight categories of pike-perch in the year of observations. However, this trend is not observed in all age groups, except between five-year-old females, where the fluctuations were from 186 to 548 thousand eggs (Fig. 7, A, B and C). The relation between absolute fecundity and fork length, eviscerated weight, and age is presented in figure 7 too. Thus the results demonstrate a relatively high correlation between the absolute fecundity of fish and their length ($r = 0.83$, $p<0.01$), eviscerated weight ($r = 0.91$, $p<0.01$), and age ($r=0.80$, $p<0.01$).

The Dagestan waters relative fecundity of pike-perch was found to range within 76.8 - 283.2 eggs per 1 g body eviscerated weight. The correlation coefficients (R^2) calculation indicate to a lack of any straightforward relationship between the relative fecundity and body length, eviscerated weight, and age (correlation coefficients are statistically insignificant) (R2 = 0.24, 0.32, and 0, 11 respectively) (Fig. 8 A, B, and C).

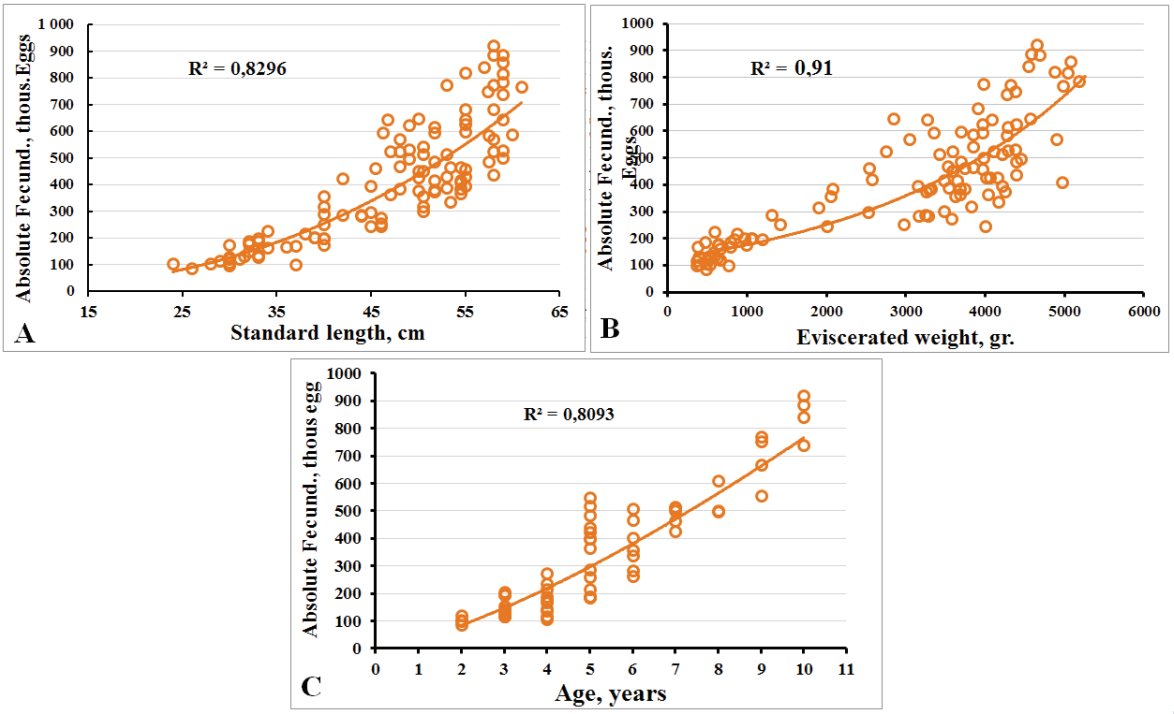

Figure 7: The relation between absolute fecundity and fork length, eviscerated weight, and age of Dagestan waters. 112 females with mature ovaries and SL values ranging from 24 to 61 cm

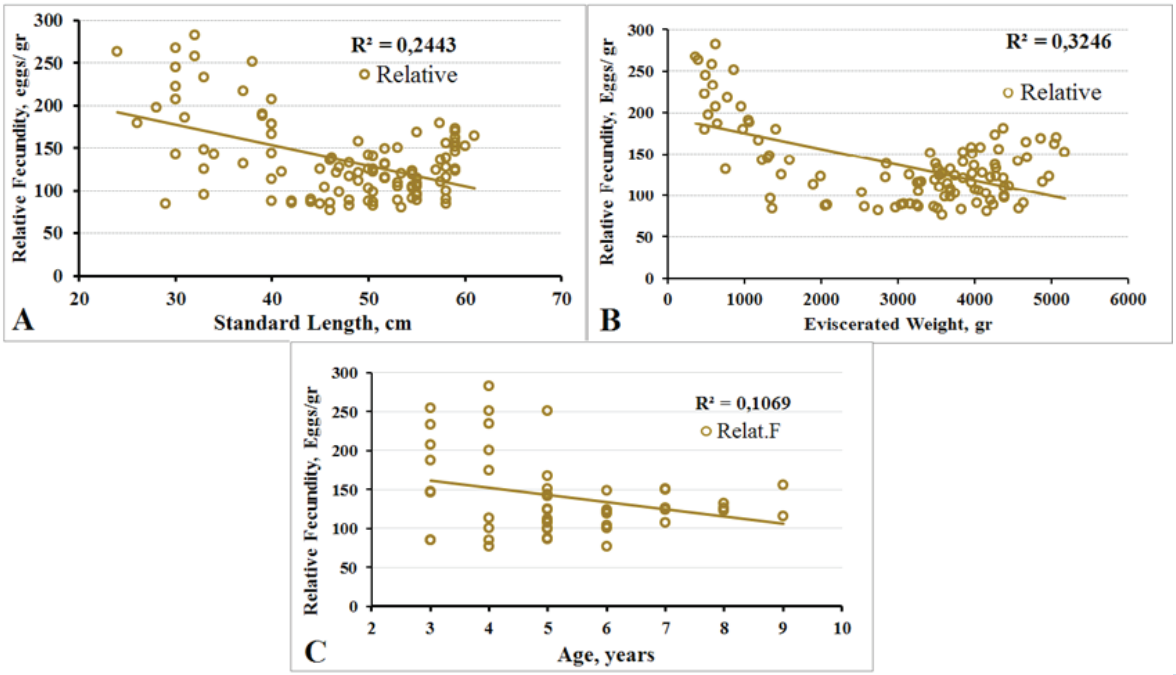

Figure 8: relationship between the relative fecundity and body length, eviscerated weight, and age. 112 females with mature ovaries and SL values ranging from 24 to 61 cm.

DISCUSSION

According to the results of our research in 2019, the spawning period of Pike perch in the waters of Dagestan lasted from the end of March to May inclusive, and it was most active in April. These results coincide with the findings of previous and recent authors [Shikhshabekov, 1974; Abdusamadov, 2020; Shikhshabekova, 2006].

The sex ratio may differ from the anticipated 1:1 in the same population at different times and in different habitats under the influence of several factors, such

as population adaptation, reproductive behavior, food availability and environmental conditions [Nikolsky, 1963].

The dominance of female pike perch over males in the marine period, in our results, can be explained by the fact that, on the one hand, as a rule, mature males leave the marine feeding environment and are the first to arrive at the spawning grounds, followed by females [Kovalev, 1973], and secondly, males guard the nests throughout the incubation period and hatching of larvae [Lappalainen et al., 2003], and this will delay them from feeding in the sea.

According to our results, the sexually mature pike-perch in Dagestan waters has rather not small eggs. On average, the diameter of the egg is 0.95±0.12 mm in the range from 0.7 to 1.45 mm. This may explain the relatively slight absolute fecundity, since absolute fecundity estimates depend largely on the egg size [Bagenal and Braum, 1978; Zivkov and Raikova-Petrova, 1998].

Fecundity and egg production are affected by several factors, including environmental variations, food availability, breeding season duration, and spawning frequencies [Vazzoler, 1996]. Furthermore, fecundity also increases with fish age and size, but the number of oocytes produced decreases in aging fish [Lappalainen et al., 2003].

If we compare our results with other areas of distribution of pike-perch, we find that, in almost all sexual indicators, they are close to what is found in Lake Ceyhan in southern Turkey [Ozyurt et al., 2011]. The value of GSI in both females and males increased in the period from September to January and reached the highest values in February and March, after which spawning begins, and lasts until the end of March, that is, one month ahead of the pike-perch of Dagestan waters. Maturity is almost the same if we take into account the standard length (females-21.6 cm, males - 20.6 cm). Our results are not so different from those in some reservoirs of the south of Russia on the example of the Krasnodar reservoir, where, for example, males reach sexual maturity for the first time at the age of 2 years, with a length of 18-22 cm, females - at 3-4 years, with a length of 20-26 cm [Kovalenko, 2015]. The age of sexual maturity of pike-perch in different areas is not so much varied [Kuzmin, 1958; Popov, 2014; Kovalenko, 2015]. However, the difference is only in the fecundity, which in the Krasnodar reservoir is inferior to ours - i.e. it ranges in age from 18.40 to 596.20 thousand eggs, averaging 290.67 ± 4.02 thousand eggs. The relative fecundity of the pike-perch population of the Krasnodar reservoir is equal to 226 eggs/1 gr. The most prolific (252 eggs/ g) are females 43.0-52.0 cm long, weighing 900-1750 g, while the absolute fecundity varied in our pike-perch from 86.950 to 920.650 eggs, on average 427.815 ± 102.498 eggs. The relative fecundity ranged from 76.8 to 283.2 eggs per gram of gutted mass [Kovalenko, 2015].

In the area of the northern borders of its distribution (south of Finland), the pike-perch, experiencing slow growth (24.8 cm is reached in 4+ years), also turns out to be, in terms of maturity, not so far from our indicators. However, unlike the pike-perch of Dagestan waters, there, females reach maturity earlier than males by as much as 3.5 cm, within the same age - 4+ years [Milardi et al., 2011]. In addition, the length of pike-perch in adulthood was within the lowest range recorded for this species [Lappalainen et al., 2003], the lowest recorded in Finland [Ruuhijärvi and Sutela, 2002]. In lakes of northern latitudes, the length of the beginning of maturation is about 30-40 cm, but the age of the beginning is the same (4-6 years) as in Lake Sahayarvi [Lehtonen et al.,1996; Lehtonen and Mina, 1988; Kosior and Wandzel, 2001]. In warmer conditions in southern Europe and North Africa, as well as in the middle of the Caspian Sea, maturity is reached at the age of 1 or 2 years [Karabatak, 1992; Raikova-Petrova and Zivkov, 1998; Toujani and Kraiem, 2002; Poulet et al., 2004). Usually, in fast-growing populations, individuals mature at an earlier age and of a larger size [Javid Rahmdel and Falahatkar, 2020], while a slow-growing population should include individuals maturing in small sizes, as was found in Lake Lahayarvi [Milardi et al., 2011].

In southern France, 50% of pike-perch males reach sexual maturity at a length of 24.6 cm by 11 months, and 50% of females - 32.2 cm by 18 months; the first sexual maturity of males and females here was 21.5 and 24.2 cm, respectively [Poulet et al., 2004].

With regard to the sexual fertility of pike-perch females from the Rhone River Delta in southern France, the relative fecundity was 255.4 ± 16.7 eggs per one gram of fish body weight and absolute fecundity increases significantly with increasing length (R^2=0.77) while the relative fecundity decreases with increasing length (R2=0.46) [Poulet et al., 2004]. This is consistent with our results in Dagestan waters. What is noteworthy is that the relative fecundity of pike-perch

in the southern Caspian (Iran) is ranged between 150 and 400 eggs per gram of female body weight, which almost coincides with our data, but the absolute fecundity reaches 2.4 million eggs [Javid Rahmdel and Falahatkar, 2020] which is significantly different from our results on this indicator, but almost coincides with the absolute fecundity of pike-perch in the south coast of the Baltic Sea [Kosior and Wandzel, 2001].

CONCLUSIONS

The pike-perch age at first maturity, onset of spawning, fecundity, sex ratio, and the process of maturation of the reproductive organs, is complementing each other for the populations of the two types of studied habitats.

The pike-perch most important identified pre-reproductive, reproductive and post reproductive ecology characteristics are that after spawning in freshwater ecosystems, with its yearlings, migrates for foraging, sexual recovery and maturity to the sea to return then to the rivers of Dagestan for spawning again later.

This specificity allows pike-perch both to use various ecosystems types trophic resources along its ontogeny as it was already proved, and now we found out that keep a biological and ecological reproduction evolutionary potential in fresh, brackish and salty water ecosystems.

This fish species proved to be resilient base on its adaptability to significantly different habitat characteristics in the context of the present human activities related impact.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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