http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 40(3), 166-173 (2023)

Su Ürünleri Dergisi (2023)
DOI: 10.12714/egejfas.40.3.02

RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Comparison of reproductive performance of Black Sea salmon broodstock (*Salmo labrax* PALLAS, 1814) reaching first sexual maturity at different ages

Farklı yaşlarda ilk cinsel olgunluğa ulaşan Karadeniz somonu (*Salmo labrax* PALLAS, 1814) anaçlarının üreme performansının karşılaştırılması

Osman Tolga Özel[1] ● Eyüp Çakmak[2*] ● Ekrem Cem Çankırılıgil[3] ● Zehra Duygu Düzgüneş[4] Recayi Çimagil[5] ● Esin Batır[6]

[1]Central Fisheries Research Institute, Department of Aquaculture, 61250, Yomra, Trabzon, Türkiye https://orcid.org/0000-0002-5414-6975
[2]Central Fisheries Research Institute, Department of Aquaculture, 61250, Yomra, Trabzon, Türkiye https://orcid.org/0000-0003-3075-9862
[3]Sheep Breeding Research Institute, Department of Fisheries, Bandırma, Balıkesir, Türkiye https://orcid.org/0000-0001-5898-4469
[4]Central Fisheries Research Institute, Department of Breeding and Genetics, 61250, Yomra, Trabzon, Türkiye https://orcid.org/0000-0001-6243-4101
[5]Central Fisheries Research Institute, Department of Aquaculture, 61250, Yomra, Trabzon, Türkiye https://orcid.org/0000-0002-6046-0477
[6]Central Fisheries Research Institute, Department of Aquaculture, 61250, Yomra, Trabzon, Türkiye https://orcid.org/0000-0001-6623-1379

*Corresponding author: esfcakmak@gmail.com

Received date: 03.02.2023 *Accepted date: 21.06.2023*

How to cite this paper:
Özel, O.T., Çakmak, E., Çankırılıgil, E.C., Düzgüneş, Z.D., Çimagil, R., & Batır, E. (2023). Comparison of reproductive performance of Black Sea salmon broodstock (S*almo labrax* PALLAS, 1814) reaching first sexual maturity at different ages. *Ege Journal of Fisheries and Aquatic Sciences, 40*(3), 166-173. https://doi.org/10.12714/egejfas.40.3.02

Abstract: The aim of this study was to determine the individual first maturation age diversity in hatchery-originated F6 generation of Black Sea salmon (*Salmo labrax*) broodstock created by applying for a selective breeding program. Research was carried out in freshwater ponds and marine net cage systems between 2018-2021. In the study, 136, 87 and 3 individuals from the broodstocks that reached the first sexual maturity at the age of 22, 34 and 46 months were used, respectively. Total egg production, relative egg production, egg diameter and fertilization rates were determined at the first stripping of broodstock that reached sexual maturity at different ages. The first gonadal development controls and stripping studies were carried out in the period of 2018-2019 for 22 months old broodstock, 2019-2020 for 34 months old and 2020-2021 for 46 months old. Total fecundity of 22, 34 and 46 months old broodstocks that were stripped, were calculated at 1108.98±40.73, 3869.02±138.43 and 5899.52±1143.78 egg/kg broodstock, relative fecundity was 3024.87±87.52, 2291.90±89.52 and 1816.00±284.51 egg/kg broodstock, egg diameters were 4.40±0.01, 5.07±0.02 and 5.35±0.09 mm and fertilization rates were determined as 92.21±0.87%, 95.69±1.65% and 89.83±2.77%, respectively. The condition factor values of the rootstocks were determined as 1.05±0.02 (22 months old), 1.09±0.01 (34 months old) and 1.08±0.03 (46 months old). In the broodstock, individuals with a first maturation age of 22 months have predominantly red spots with a white halo around the perimeter, silvery coloration with black spots at 34 months of age, and silvery coloration with black spots at 46 months of age were detected. While enterprises that reared Black Sea salmon in freshwater and have restaurants prefer the red-spotted river ecotype for production, enterprises that produce in marine net cages prefer the black-spotted-silver-colored marine ecotype, whose body coloration is similar to Atlantic salmon.

Keywords: Black Sea salmon, first maturation size, reproductive traits, maturation age

Öz: Bu çalışmada, seçici ıslah programı uygulanarak oluşturulan kuluçkahane kökenli F6 nesil Karadeniz somonu (*Salmo labrax*) anaçlarında bireysel ilk üreme yaşı çeşitliliğinin belirlenmesi amaçlanmıştır. Araştırma, 2018-2021 tarihleri arasında tatlısu havuzlarında ve deniz ağ kafes sistemlerinde yürütülmüştür. Araştırmada, 22, 34 ve 46 aylık yaşta iken ilk cinsel olgunluğa ulaşan anaçlardan136, 87 ve 3 adet birey sırası ile kullanılmıştır. Farklı yaşlarda cinsel olgunluğa ulaşan anaçların ilk sağımlarındaki toplam yumurta verimi, nispi yumurta verimi, yumurta çapı ve döllenme oranları belirlenmiştir. İlk gonad gelişim kontrolleri ve sağım çalışmaları 22 aylık anaçlarda 2018-2019, 34 aylıklarda 2019-2020, 46 aylıklarda ise 2020-2021 döneminde yapılmıştır. Sağımı gerçekleştirilen 22, 34 ve 46 aylık anaçların sırasıyla toplam yumurta verimleri 1108,98±40,73, 3869,02±138,43 ve 5899,52±1143,78 adet/anaç, nispi yumurta verimleri 3024,87±87,52, 2291,90±89,52 ve 1816,00±284,51 adet/kg anaç, yumurta çapları 4,40±0,01, 5,07±0,02 ve 5,35±0,09 mm ve döllenme oranları ise %92,21±0,87, %95,69±1,65 ve %89,83±2,77 olarak hesaplanmıştır. Anaçların kondisyon faktörü değerleri 1,05±0,02 (22 aylık), 1,09±0,01 (34 aylık) ve 1,08±0,03 (46 aylık) olarak saptanmıştır. 22 aylık iken ilk üremeye ulaşan anaçlarda vücut çevresi beyaz haleli kırmızı benekler, 34 aylıklarda siyah benekli gümüşi renklenme, 46 aylıklarda ise tamamen siyah benekli gümüşi renklenme tespit edilmiştir. Tatlı suda Karadeniz somonu yetiştiren ve restoranı olan işletmeler üretim için kırmızı benekli dere ekotipini tercih ederken, denizde ağ kafeslerde üretim yapan işletmeler ise vücut renklenmesi Atlantik somonuna benzeyen siyah benekli-gümüşi renkli deniz ekotipini tercih etmektedir. Karadeniz somonu yetiştiren işletmelerde daha geç yaşta cinsel olgunluğa ulaşan bireylerden damızlık stok oluşturması, büyük boy balık üretiminde hasada kadar birçok avantaj sağlayacaktır.

Anahtar kelimeler: Karadeniz somonu, ilk üreme boyu, üreme özellikleri, cinsel olgunluk yaşı

INTRODUCTION

The aquaculture sector has been in constant search for the introduction of species with high consumer preference into aquaculture production. Salmonids, which were focused on farmed production for conservation and recreational fishing in the early days, are among the species with high commercial potential and consumer appreciation. One of these species is the Black Sea salmon. Today, anadromous lines that reach late sexual maturity are preferred by the private sector, especially

for large size trout production made in marine net cage systems. Although the Black Sea salmon, which is one of the endemic species of the Black Sea, was named differently by some researchers, *Salmo labrax* is still valid today. Slastenenko (1956) and later scientists (Svetovidov, 1984; Lelek, 1980; Solomon, 2000) named the individuals sampled from the rivers in the Caucasia and the Eastern Black Sea, as Black Sea trout and Black Sea salmon to indicate their origin and transition features to the sea. It is known that the species continues to exist in the Black Sea in three ecotypes: sea, river and lake. Svetovidov (1984), Geldiay and Balık (1996) reported that marine ecotype individuals spend most of their lives in the sea, especially the time that includes the feeding period, and they release their eggs by entering the rivers flowing into the Black Sea during the reproduction period. Fish belonging to the salmon genus can easily adapt to aquatic areas with suitable environmental conditions, more than one interspecies form can coexist in the same aquatic area. Some of these can be defined as separate species (Günther, 1866). Several studies have confirmed the coexistence of Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), as well as endemic species (*S. marmoratus, S. letnica, S. ischchan, S. carpio,* and *S. platycephalis*) (Frost et al., 1967; Behnke, 1968; Dorofeeva, 2002).

Çakmak et al. (2019) found that anadromous Black Sea salmon differs from other ecotypes with its large size, egg diameter and yield. In the study on the reproductive yield of anadromous Black Sea salmon broodstock with an average weight of 2439.21±139.28 g raised under culture conditions, the mean egg diameter was measured as 5.28±0.05 mm, and the relative fecundity was calculated as 2159±115 units/kg. Serezli et al. (2010) reported that rainbow trout, Black Sea trout and brook trout had mean hatching weights of 1357.27±406, 532±673.7 and 310.40±85.0 g, mean egg diameters of 4.95±0.2, 4.51±0.67 and 4.49±, respectively. They measured 0.21 and fecundity was calculated as 2180±676, 3558±1307 and 2571±1530 units/kg. Nikandrov and Shindavina (2007) reported that Black Sea salmon is one of the species with the largest size among migratory salmonids. In the literature, several size values have been reported for the species. Kocabaş (2009) reported that Black Sea salmon spend most of their life in the sea and can grow up to 100 cm in length and 26 kg in weight. Barach (1962) reported that a female Black Sea salmon sampled in the Kodori River was 16.7 kg and 116 cm. Similarly, Solomon (2000) reported that the largest Black Sea salmon individual obtained by fishing operations was 16 kg weight, in Batumi fish market. Kottelat and Freyhof (2007) found size of the largest Black Sea salmon as 80 cm. Çakmak et al. (2022) reported that the largest Black Sea salmon caught to date in Türkiye was 98 cm long, weighed 16.5 kg, and had an obvious marine ecotype (anadromic) character.

Adaptation of the Black Sea salmon to the culture conditions in Türkiye was achieved with the studies started in 1998. Since 2007, aquaculture operations of the species started to become more common practice in the country, especially in the Eastern Black Sea Region (Çakmak et al. 2011). In this study, F6 broodstock which has mainly anadromous individuals with high adaptation capability, was formed with a selective breeding program. This study aimed to determine the reproductive yield of 6th generation farmed broodstock of Black Sea salmon that reach their first sexual maturity at the age of 22, 34 and 46 months.

MATERIALS AND METHODS

Broodstock

In the study, hatchery originated F6 generation Black Sea salmon broodstock was used. The total number of broodstock in the F6 generation stock is 850, which is equally distributed among male and female individuals. Amongst them, 226 female and 83 male individuals were used for this study.

In this stock, 136 (32.53±0.28 cm, 364.67±8.34 g), 87 (50.45±0.42 cm, 1425.68±37.80 g) and 3 (62.6±1.10 cm, 2650.35±18.45 g) individuals reached their first sexual maturity at 22, 34 and 46 months respectively, and they were used to get reproductive data that evaluated in this study (Table 1).

Commercial trout feed with 10% moisture, 45% protein, 20% lipid, 10% ash, 3% crude fiber and 4801 Kcal/kg energy content was used in feeding. Feeding was carried out twice a day from June until one month before stripping, and once a day for the last month up to apparent satiation. All broodstock were marked with electronic markers (12 mm, 134 KHz) for individual monitoring of reproductive efficiency (Figure 1). In the study, 83 males from F6 generation Black Sea salmon broodstock of hatchery origin with an average length of 49.67±18.20 cm and a weight of 1478.58±947.32 g were used.

Broodstock rearing

The rearing of the broodstock was carried out at the Gürpınar aquaculture facility in Trabzon Province and marine cage research unit which has 17‰ salinity of the Central Fisheries Research Institute (SUMAE) in Yomra shore (Figure 2). Water temperatures were measured daily in both marine cages and freshwater units. The broodstock was transferred to the freshwater unit in June when the Black Sea water started to warm (18°C), and they were transferred again to the marine cages in February after stripping. At the freshwater units, the water change was adjusted to be 18-20 times/day. Stocking density in both freshwater ponds and marine cages was 15 kg/m³. The fish after stripping was brought to the marine cage unit with a continuous oxygen-assisted transport tank containing half fresh water and half salt water on the second day after stripping. It ensured that the water was gradually replaced with salt water in the same tank for two hours. Afterward, the broodstock was transferred to the marine cages. In the transfer from saltwater to freshwater, this procedure was reversed, the broodstock was not fed for two days before the transfer time.

Figure 1. Individual markers applied to broodstock (a: Tag reader, b: tag injector and tags, c: application of the tag to the muscle tissue, d: the view of the tag in the muscle tissue)

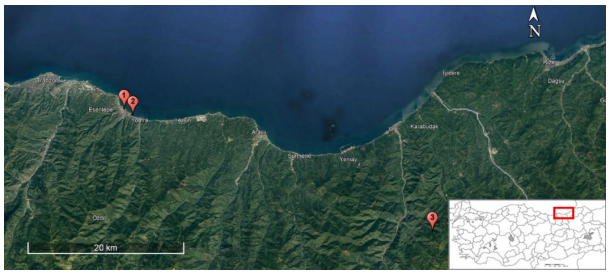

Figure 2. The sites where the broodstock was kept (**1**: SUMAE, **2**: Marine cage research unit (40°57'35,05"N, 40°19'17,44"E, Altitude:0m), **3**: Freshwater unit (40°49'20,59"N, 40°19'17,44"E, Altitude:644 m)

Reproductive controls and stripping

Controls for gonadal development of the broodstock were made 15 days in advance, taking into account the time of the previous stripping start. In all breeding season, stripping starts mostly after the second week of October. Maturity controls were performed every two weeks and continued until all broodstock were stripped. Male and female individuals, during stripping controls, were placed into tanks kept in the hatchery unit separately according to their gender. In stripping, benzocaine (Oswald, 1978) solution was used with an application dose of 50 ppm. Dry stripping method was applied. Firstly, at least 3 male individuals were stripped and sperm stock was created. The sperm stock was used to fertilize the eggs of 5 female fish. 5 minutes after fertilization, water was added until 3 cm above the eggs and until the stripping container was full after 15 minutes. In order to prevent the eggs from being without oxygen, water was added and the eggs were mixed. This treatment continued until the eggs hardened. Approximately 25 minutes later, hardened eggs were washed with hatchery water to remove residues and prepared for incubation. Seperate incubation pans were used for each broodstock's eggs and these pans were labeled with the tag number of broodstock. The incubation period of Black Sea salmon is 60 days on average (600 days/degrees) until the first feed intake, and the first feed intake date is accepted as zero in the age calculation.

Measurements and calculations

A length scale with ±1 cm precision was used for the total length measurements of the broodstock, and ±0.01 g precision scales were used for weight measurements. For the average egg diameter, 20 eggs from each broodstock were measured in a Von Bayer (1910) vessel and the mean value was calculated by dividing the number of eggs. The same eggs were weighed with a balance with a precision of 0.001 g, and the total weight of 20 eggs was found, and the weight of one egg was calculated by dividing the number by the number of eggs.

Fecundity was determined by gravimetric method (MacGregor, 1957) as total fecundity (number of eggs per broodstock) and relative fecundity (number of eggs per kg body weight). Eggs were placed in cabinet incubators with vertical flow filled with spring water using separate pans for each broodstock. One day after fertilization, the white and opaque eggs were considered unfertilized or dead and they were discarded after counting. Fertilization rate was determined by calculating the ratio of the number of unfertilized eggs to the total number of eggs. Besides, the relationship between total and relative fecundity weight was examined.

Statistical analysis

The results were analyzed with one-way ANOVA test via SPSS 14 statistical analysis program. Duncan's multiple comparison test was applied for the difference between groups. Differences were evaluated at the 5% significance level ($P<0.05$). Relationship between total and relative fecundity-weight was performed using Statistica 10 software.

RESULTS

The average water temperature of the marine net cage unit was measured at 11.27±3.06°C (min: 8.6°C, max: 20.7°C), while average water temperature was 11.91±4.28°C (min: 4.0°C, max: 18.5°C) (Figure 3).

According to the results, mean length and weights of 22, 34 and 46 months old broodstock were measured as 32.53±0.28 cm, 364.67±8.34g, 50.45±0.42 cm in length, and, 1425.68±37.80 g and 62.6±1.10 cm, 2650.35±18.45 g in weight, respectively. The proportional increase in the average length and weight of broodstock depending on the increase in first maturation age was found to be statistically significant (Table 1) ($P<0.05$).

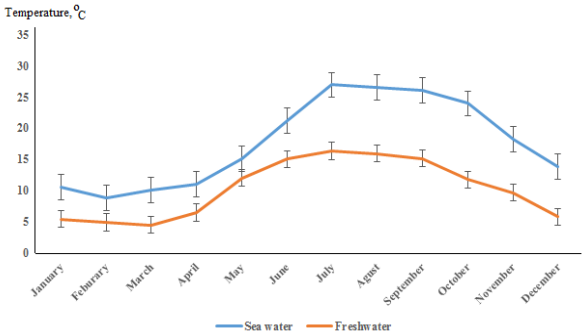

Figure 3. Water temperatures of marine net cage research unit and freshwater unit

Table 1. Reproductive data of broodstocks reaching first sexual maturity at 22, 34 and 46 months

Parameters	22 Months Old (n:136)	34 Months Old (n:87)	46 Months Old (n:3)
Length (cm)	32.53±0.28^{c}	50.45±0.42^{b}	62.6±1.10^{a}
Weight after stripping (g)	364.67±8.34^{c}	1425.68±37.80^{b}	2650.35±18.45^{a}
Condition factor	1.05±0.02	1.09±0.01	1.08±0.03
Total egg weight (g)	58.13±1.96^{c}	321.13±12.38^{b}	571.35±127.39^{a}
Egg weight (g)	0.05±0.01^{c}	0.08±0.02^{b}	0.09±0.09^{a}
Egg diameter (mm)	4.40±0.01^{c}	5.07±0.02^{b}	5.35±0.09^{a}
Egg number (egg/broodstock)	1108.98±40.73^{c}	3869.02±138.43^{b}	5899.52±1143.78^{a}
Fecundity (egg/kg)	3024.87±87.52^{a}	2291.90±89.52^{ab}	1816.00±284.51^{b}
Fertilization rate (%)	92.21±0.87	95.69±1.65	89.83±2.77

The stripping data was recorded between 2018-2021, and the reproduction was started in the second week of November and continued until the end of December. 31.62% of the broodstock reaching the first sexual maturity at the age of 22 months were stripped in November and 68.38% of them were stripped in December. Likewise, 63.22% of the broodstock reaching the first sexual maturity at the age of 34 months were stripped in November and 36.78% of those were stripped in December. However, all of the broodstock that reached the first sexual maturity at the age of 46 months were stripped in December. While the stripping of 22 and 34 months groups were continued for two months, the stripping period of the 46 months group was conducted within one month in December (Figure 4).

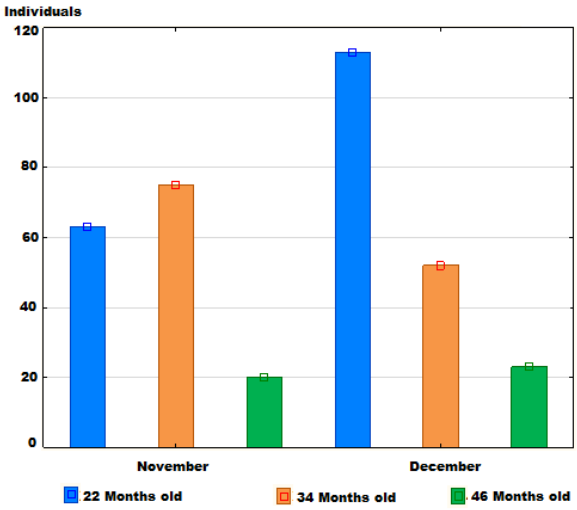

Figure 4. Number of broodstock reaching sexual maturity at different ages during the reproductive period

The total fecundity of broodstock that reached the first sexual maturity at 22, 34 and 46 months, were found as 1108.98±40.73, 3869.02±138.43 and 5899.52±1143.78 eggs/broodstock, respectively. Moreover, their relative fecundities were 3024. 87±87.52, 2291.90±89.52 and 1816.00±284.51 eggs/kg. It was observed that the increase in total fecundity in direct proportion to the first reproduction age of the fish was statistically significant. In the evaluation of the relative fecundity between stocks, it was found that relative fecundity decreased when the sexual maturation was late from 22 to 46 months (Table 1).

In addition, it was observed that the relative fecundity decreased inversely with fish weight in 34 and 46 months stocks, but this situation was statistically insignificant in 22 months old stock. This is thought to be due to the fact that this stock reaches sexual maturity at an early age and therefore in small size compared to other stocks (Table 1, Figure 5, 6, 7) ($P<0.05$).

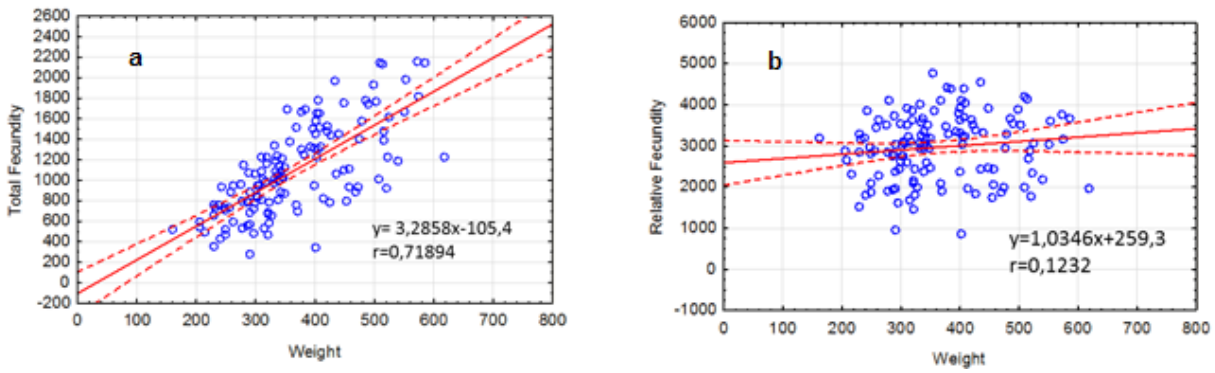

Figure 5. Relationship between total (a) and relative fecundity-weight (b) of stock reaching first sexual maturity at 22 months of age

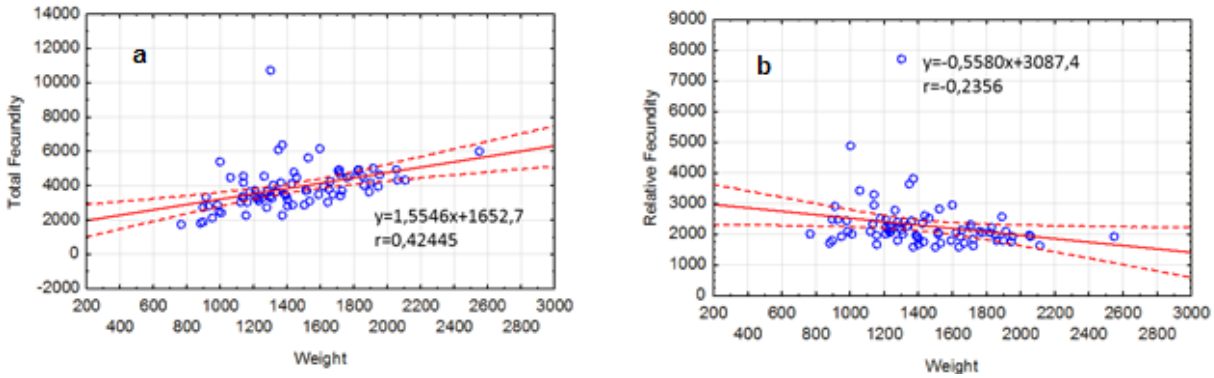

Figure 6. Relationship between total (a) and relative fecundity-weight (b) of stock reaching first sexual maturity at 34 months of age

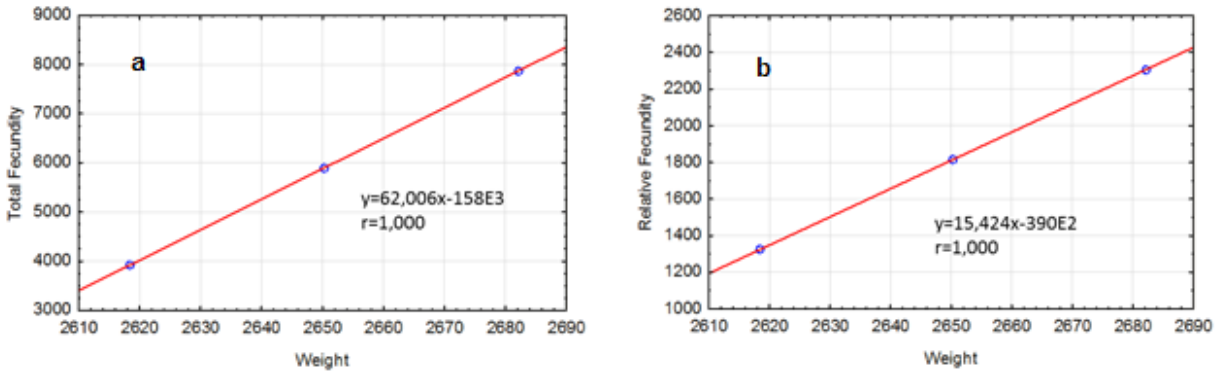

Figure 7. Relationship between total (a) and relative fecundity-weight (b) of stock reaching first sexual maturity at 46 months of age

Avarage egg diameters and weights of broodstock reaching the first sexual maturity at 22, 34 and 46 months were measured as 4.40±0.01cm-0.05±0.01g, 5.07±0.02cm-0.08±0.02g and 5.35±0.09cm-0.09±0.09g respectively. Egg diameters and weights increased in accordance with the increasing in the fish size. The difference in egg diameter and weight gain depending on fish size between stocks were statistically significant. The mean fertilization rates of broodstock that reached the first sexual maturity at 22, 34 and 46 months were calculated as 92.21±0.87%, 95.69±1.65% and 89.83±2.77, respectively (Table 1).

It has been observed that individuals reaching the first sexual maturity at the age of 22 months have red spots covered with a white halo, individuals reaching the first sexual maturity at the age of 34 months have red spots and silvery body color, while individuals reaching the first sexual maturity at the age of 46 months have black spots and silvery body color.

DISCUSSION

Several studies have been conducted regards with spawning season, natural behavior and culture characteristics of brown trout. Also, several key studies (Needham, 1945; Horton, 1961; Thomas, 1964; Moyle, 1976) have reported that brown trout give offspring within 3 months period between October and December in the northern hemisphere, similar to our findings. In contrast, in the southern hemisphere, reproduction occurs between the end of May and July (Hopkins, 1970; MacDowall, 1978).

Tabak et al. (2001) found that Black Sea salmon broodstock reproduce mainly in November and rarely until mid-December in their natural environment on the Turkish coasts. Similarly, Çakmak et al. (2022) found that the cultured Black Sea salmon started to spawn in November under culture conditions, peaking in December and finishing until late February. Salihoğlu et al. (2013) reported that this species gave offspring between the last quarter of December and the last quarter of February. In the southern hemisphere, Estay et al., (2004) determined that brown trout start to give offspring in Chile in June, reaching the highest point in July, and continues until September. Makhrov et al. (2011) revealed that the maturation and spawning times of Black Sea salmon reared in aquaculture units and natural waterways in the Northwest Caucasia show significant differences depending on environmental conditions just as temperature, mostly. It is clear fact that environmental conditions influence the reproduction period.

In this study, the broodstock that reached the first sexual maturity at 22 and 34 months of age were stripped in November and December, and the broodstock that reached the first sexual maturity at the age of 46 months was stripped in December. The stripping season were observed in this study is similar to brown trout species of northern hemisphere and

rainbow trout cultured in Eastern Black Sea region of Türkiye. Aquaculture of Black Sea salmon and rainbow trout together can be more advantageous in hatchery management considering their different reproduction periods such as early for Black Sea salmon and late for rainbow trout.

Salmonids are amongst the most demanding fish species with high nutritional value and consumer appreciation on a global scale. Thus, several studies have been carried out regarding their natural behavior, culture characteristics, and breeding. Species that reach late sexual maturity and having rapid growth rate in seawater are generally preferred in fillet production. Zama and Cardenas (1983) reported that the age of sexual maturity of brown trout (*Salmo trutta*) is 2-5, and maturation occurs mainly at 3 and 4 years old. Gjerde (1984) recommended in the creation of breeding stock of Atlantic salmon, female broodstock should be selected from fish reached sexual maturity in 4 and 5 years, in Norway. Tabak et al. (2001) found that natural individuals of Black Sea salmon reach their first sexual maturity between the ages of 2-4. In this study showed that, egg diameter of marine ecotype broodstock is 5.8±0.03 mm, relative egg production is 1747±70 units/kg, egg diameter of brook ecotype broodstock is 4.85±0,19 mm, relative fecundity is 2865±354 units/kg. Estay et al. (2004) evaluated first sexual maturity of 3 years old fish individuals in their study conducted in Chile with Brown trout (*Salmo trutta* L.), which is originated from Germany as a culture form. They found total egg production of these broodstocks varied between 1182±344 - 2744±605 units/broodstocks, the relative egg production ranged between 3577±471 - 2181±360 units/kg and the egg diameters varied between 4.64±0.11 - 5.24±0.12 mm. Heinimaa and Heinimaa (2003) reported that egg diameter of Atlantic salmon is 5.3±0.2 mm (*Salmo salar* L.) in females with an average weight of 9.0±3.0 kg having 1845±392 pieces/kg fecundity. Rainbow trout, Black Sea trout and brook trout weighted as 1.357.27±406, 532±673.7, 310.40±85.0 g, had the egg diameters of 4.95±0.2, 4.51±0.67 and 4.49±, respectively (Serezli et al., 2010). They measured it as 0.21, and the fecundity was calculated as 2.180±676, 3.558±1307, 2.571±1530 pieces/kg, respectively. Çakmak et al. (2019) found that the mean egg diameter was 5.28±0.05 mm and the relative fecundity was 2159±115 pieces/kg in Black Sea salmon broodstocks with an average weight of 2439.21±139.28 g produced under culture conditions. In general, egg production and size in fish are affected by various factors such as broodstock size, age, genotypic structure and feeding conditions (Haeley and Heard 1984; Bromage et al., 1990, 1992). In our study, body weight, egg production and egg diameters of Black Sea salmon reaching the first sexual maturity at the age of 22 months were found to be similar to those of other researchers with non-anadromic Brown trout. However, the broodstocks reaching the first sexual maturity at the age of 34 and 46 months was consistent with the studies conducted with anadromous brown trout. Besides, the difference in total egg production, relative egg production, egg diameter and egg weight of the broodstock that reach the first sexual maturity at different ages used in our study can be caused by the first reproductive age (size) and genotypic structure (anadromic characteristic) of the broodstock. In 6th generation, broodstock individuals who reached the first sexual maturity at an average age of 22 (364.67±8.34 g), 34 (1425.68±37.80 g) and 46 (2650.35±18.45 g) months are observed. This broodstock has some beneficial characteristics such as opportunity of rearing to different harvest sizes and spotting until the first breeding age. It is possible to create a breeding stock from individuals of different ages and different appearances, taking into account consumer preference and increasing culture trend of the species day by day. Tourism establishments with restaurants, can create a breeding stock from individuals with white spots and red spots (reaching the first sexual maturity at the age of 22 months) considering customer demand. The net cage enterprises that produce large sizes can create a breeding stock from individuals who reach late sexual maturity (first sexual maturity at 46 months), and operating profitability in favor of feed expenses can be achieved.

Estay et al. (2004) calculated that the fertilization rate ranged from 92.0±13.7% to 98.5±4.01% in the study they carried out with brown trout, a cultured form in Chile. Çakmak et al. (2022) calculated the fertilization rate as 93.46±5.35% in the wild Black Sea salmon production studies adapted to the culture conditions in Türkiye and reported that the fertilization rate of eggs stripped from F1, F2, F3 and F4 generation broodstock varied between 95.28±6.29 - 98.25±1.81%. It is seen that the fertilization rate findings obtained in this study are similar to the results of the study conducted with cultured brown trout.

CONCLUSION

Black Sea salmon, which is among the species with high socio-economic value for human consumption and sportive fishing, is similar to brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*) in terms of reaching to first maturation age and some characteristics. Individuals with the first reproductive age of 22 months have the typical characteristics of brown trout with early sexual maturity, red-colored white halo mottling, slow growth and being settled, while individuals with first reproductive age of 34 and 46 months have the characteristics of Atlantic salmon like late sexual maturity, black mottling, silvery coloration, rapid growth in especially marine water and being anadromous. Different ecotypes of the species, which are still in the domestication stage, are preferred by commercial enterprises with different marketing networks. The general characteristics of ecotypes should be taken into account, considering producer and consumer preferences in future studies to be carried out on genetically supported breeding of Black Sea salmon. Different ecotypes of the species, which are still in the domestication phase and whose breeding studies are still in progress, are preferred by commercial enterprises with different marketing networks. In studies to be carried out on genetically assisted breeding of Black Sea salmon, breeding efficiency, migration behavior and

morphological characteristics of ecotypes should be taken into account for stock management.

ACKNOWLEDGMENTS AND FUNDING

This work has been prepared by using the data obtained from the studies of the "Investigation of possibilities of using some phytobiotic added feeds in feeding of Black Sea salmon (*Salmo labrax*)" project conducted by the Trabzon Central Fisheries Research Institute. This work was presented orally on 15-16th September 2022 in 6th National Trout Symposium in Isparta-Turkey.

General Directorate of Agricultural Research and Policies of Türkiye (TAGEM/HAYSUD/2017/A11/P-01/3).

AUTHORSHIP CONTRIBUTIONS

Osman Tolga Özel: Conceptualization, methodology, and design of the experiments, data analysis, validation, broodstock management, stripping, nursery. Eyüp Çakmak: Conceptualization, methodology, and design of the experiments, manuscript writing, data analysis, validation, reviewing, broodstock management, stripping, nursery. Ekrem Cem Çankırılıgil: stripping, nursery. Zehra Duygu Düzgüneş: stripping, data analysis, validation. Recayi Çimagil: stripping, nursery. Esin Batır: broodstock management, stripping, nursery, reviewing.

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest.

ETHICAL STATEMENT

The experimental protocols were conducted in accordance with the approval of the experimental animals ethics committee of the Trabzon Central Fisheries Research Institute (protocol No.: ETIK-2017/1).

DATA AVAILABILITY STATEMENT

The data presented here is not available online.

REFERENCES

Barach, G.P. (1962). *Chernomorskaya kumzha (losos'-forel')* (The Black Sea trout (Salmon-Trout)), Tbilisi: Izd. Akad. Nauk GruzSSR

Behnke, R.J. (1968). A new subgenus and species of trout *Salmo (Platysalmo) platycephalus*, from south-central Turkey with comments on the classification of the subfamily Salmoninae. *Mitteilungen aus dem Hamburgischen Museum und Institut, 66*, 1–15.

Bromage, N., Hardiman, P., Jones, J., Springate, J., & Bye, V. (1990). Fecundity, egg size and total egg volume differences in 12 stocks of rainbow trout, *Oncorhynchus mykiss* Richardson. *Aquaculture Research*, *21*(3), 269-284. https://doi.org/10.1111/j.1365-2109.1990.tb00465.x

Bromage, N., Jones, J., Randall, C., Thrush, M., Davies, B., Springate, J., Duston, J., & Barker, G. (1992). Broodstock management, fecundity, egg quality and the timing of egg production in the rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, *100*(1-3), 141-166. https://doi.org/10.1016/0044-8486(92)90355-O

Çakmak, E., Aksungur, N., Firidin, Ş., Akbulut, B., Başçınar, N.S., Çavdar, Y., Kurtoğlu, İ.Z., Ergün, H., Savaş, H., Üstündağ, E., Alkan, A., Aksungur, M., Zengin, B., Serdar, S., Fidan, D., Özkan, B., Erteken, A. (2011). Bringing Black Sea trout (*Salmo trutta labrax* Pallas, 1811) to the private sector. Project final report. (TAGEM/HAYSÜD/2006/09/03/02). Trabzon-2011/2, 157 pp. (in Turkish)

Çakmak, E., Firidin, Ş., Düzgüneş, Z. D., & Parlak, R. (2019). The age-dependent reproductive performance of 4th generation Black Sea Trout (*Salmo labrax* Pallas, 1814) Females. *Turkish Journal of Fisheries and Aquatic Sciences, 19*(6), 496-502. https://doi.org/10.4194/1303-2712-v19_6_05

Çakmak, E., Firidin, Ş., Aksungur, N., Çavdar, Y., Kurtoğlu, İ., Aksungur, M., Özel, O.T, Çankırılıgil, E. C., Düzgüneş, Z., & Batır, E. (2022). Improving the Reproductive Yield of Black Sea Salmon (*Salmo labrax* PALLAS, 1814) with a Selective Breeding Program. *Aquatic Sciences and Engineering*, *37*(3), 161-168. https://doi.org/10.26650/ASE20221079847

Dorofeeva, E.A. (2002). The Genus Thymallus. *Atlas of Freshwater Fish of Russia*, 163-169.

Estay, F.J., Noriega, R., Ureta, J. P., Martin, W., & Colihueque, N. (2004). Reproductive performance of cultured brown trout (*Salmo trutta* L.) in Chile. *Aquaculture Research*, *35*(5), 447-452. https://doi.org/10.1111/j.1365-2109.2004.01036.x

Frost, W. E., Brown, M. E., & Varley, M. E. (1967). *The trout* (Vol. 21). London Collins. 286 pp.

Geldiay, R., & Balik, S. (1996). Freshwater Fishes of Türkiye, Ege University, Faculty of Fisheries, Publication No: 46. Course Book. Ege University Publications, Bornova, Izmir. (in Turkish)

Gjerde, B. (1984). Response to individual selection for age at sexual maturity in Atlantic salmon. *Aquaculture*, *38*(3), 229-240. https://doi.org/10.1016/0044-8486(84)90147-9

Günther, A. (1866). Family 9. Galaxiidae. *Catalogue of the fishes of the British Museum*. 6, 208- 213. (London: British Museum).

Healey, M.C., & Heard, W.R. (1984). Inter- and Intra-population variation in the fecundity of Chinook salmon (*Oncorhynchus tshawytscha*) and its relevance to life history theory. *Canadian Journal of Fisheries and Aquatic Sciences*, *41*(3), 476-483. https://doi.org/10.1139/f84-057

Heinimaa, S., & Heinimaa, P. (2003). Effect of the female size on egg quality and fecundity of the wild Atlantic salmon in the sub-arctic River Teno. *Boreal Environment Research*. 9 (1), 55.

Hopkins, C.L. (1970). Some aspects of the bionomic fish in the brown trout nursery stream. *Fisheries Research Bulletin of New Zealand, 4*, (1)-38.

Horton P.A. (1961). The bionomics of brown trout in a Dartmoor Stream. *Journal of Animal Ecology, 30*(2), 311-338. https://doi.org/10.2307/2301

Kocabaş, M. (2009). Comparison of growth performance and morphologic characteristics of brown trout (*Salmo trutta*) ecotypes of Turkey, Karadeniz Technical University, Institute of Science, PhD Thesis. (in Turkish)

Kottelat, M., & Freyhof, J. (2007). *Handbook of European freshwater fishes*, Publications Kottelat, Cornol and Freyhof, Berlin. 646 pp.

Lelek. A. (1980*). Threatened freshwater fishes of Europe*. Council of Europe. Strasbourg. 269 pp.

MacDowal, R.M. (1978). *New Zealand Freshwater Fishes-A Guide and Natural History*. Heinemann Educational Books (NZ), Auckland, New Zealand.

MacGregor, J.S. (1957). Fecundity of the Pacific sardine (*Sardenops caerula*). US Fish and Wild Service. *Fisheries Bulletin*. *121*:427-449.

Makhrov, A.A., Artamonova, V.S., Sumarokov, V.S., Pashkov, A.N., Reshetnikov, S.I., Ganchenko, M.V., & Kulyan, S.A. (2011). Variation in the timing of spawning of the black sea brown trout *Salmo trutta labrax* Pallas under artificial and natural conditions. *Biology Bulletin*, *38*(2), 138-145. https://doi.org/10.1134/S1062359011020075

Moyle, P.B. (1976). *Inland Fishes of California*. University of California Press, Berkeley, CA, USA.

Needham, P.R., Mo¡ert J.W., & Slater A.W. (1945). Fluctuations in wild brown trout populations in Convict Creek, California. *Journal of Wildlife Management, 9*, 9-15. https://doi.org/10.2307/3795940

Nikandrov, V.Y., & Shindavina, N.I. (2007). Characteristics of the hatchery-reared Black Sea salmon *Salmo trutta labrax*. *Journal of Ichthyology*, *47*(2), 184-193. https://doi.org/10.1134/S0032945207020063

Oswald, R.L. (1978). Injection anaesthesia for experimental studies in fish. *Comparative Biochemistry and Physiology Part C: Comparative Pharmacology*, *60*(1), 19-26. https://doi.org/10.1016/0306-4492(78)90021-7

Salihoğlu, H.,Başçınar, N., Akhan, S., Sonay, F.D., Sayıl, E., Melek, H., Bayçelebi, H., Kuloğlu, T., Kara, F., & Sırtkaya, N. (2013) Establishment of Broodstock Management System and Application of Biotechnological Techniques in Trout Farms of Eastern Black Sea Region, Ministry of Agriculture, Research and Development Supports, Project Final Report, TAGEM/10/R&D/18, Trabzon, 113 pp. (in Turkish).

Serezli, R., Guzel, S., & Kocabas, M. (2010). Fecundity and egg size of three salmonid species (*Oncorhynchus mykiss*, *Salmo labrax*, *Salvelinus fontinalis*) cultured at the same farm condition in North-Eastern, Turkey. Journal of Animal and Veterinary Advances, *9*(3), 576-580. https://doi.org/10.3923/javaa.2010.576.580

Slastenenko, E. (1956). *The fishes of Black Sea Region*. Meat and Fish Association General Directorate Publications, İstanbul, 711 pp.

Solomon, D.J. (2000). *The biology and status of the Black Sea salmon, Salmo trutta labrax*, EU TACIS BSEP, Black Sea Salmon Project, Draft report, 26 pp.

Svetovidov, A.N. (1984). *Salmonidae*. In P.J.P. Whitehead, M.–L. Bauchot, J.-C. Hureau, J. Nielsen , E. Tortonese (Eds.). *Fishes of the North-Eastern Atlantic and the Mediterranean*, Unesco, Paris, 1, 373–385 pp.

Tabak, İ., Aksungur, M., Zengin, M., Yılmaz, C., Aksungur, N., Alkan, A., Zengin, B., & Mısır, M. (2001). Investigation of Bio-Ecological Characteristics and Culture Opportunities of Black Sea Trout. Central Fisheries Research Institute, TAGEM/HAYSUD/98/12/01/007 Project Final Report, Trabzon. 207 pp. (in Turkish)

Thomas, J.D. (1964). Study on the growth of trout, *Salmo trutta* from four contrasting habitats. *Proceedings of the Zoological Society of London*, 142, 459-510. https://doi.org/10.1111/j.1469-7998.1964.tb04510.x

Von Bayer, H. (1910). Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A.

Zama, A., & Cardenas, E. (1983). Some biological observations of wild brown trout, (*Salmo trutta)* in the Aysen and Salto rivers, Southern Chile. Servicio Nacional de Pesca, Ministerio de Economia Fomento Y Reconstrucción, Republica De Chile. Japan International Cooperation Agency (JICA), pp.35.