LIMNOFISH-Journal of Limnology and Freshwater Fisheries Research 9(3): 159-169 (2023)

Journal of Limnology and Freshwater Fisheries Research

http://www.limnofish.org

Black Sea Salmon' (*Salmo labrax* Pallas, 1814) Journey: From Pond To Plate

Esin BATIR[1*], Eyüp ÇAKMAK [1], Osman Tolga ÖZEL [1]

[1]Central Fisheries Research Institute, Department of Aquaculture, 61250, Trabzon, Türkiye

ABSTRACT

Black Sea salmon is from the Salmonidae family and is an endemic species distributed in the Black Sea. These fish, which exhibit anadromous behavior, prefer parts of rivers close to their source for reproduction and the Black Sea for feeding. The first cultivation study of this species, which has high consumer preference and economic value, was started by SUMAE in 1998. As a result of 24 years of work, F7 generation broodstock was created. In order to popularize the production of the species, the private sector was supported with broodstock. In this study, the breeding process of Black Sea salmon was examined and the introduction of the species was aimed. Today, 25 private sector enterprises have production licenses and many enterprises carry out commercial production of the species in the form of trial production with 1603 tons in total. Commercial production is concentrated in the Eastern Black Sea Region, which is the natural distribution area of the species. While enterprises that produce portion size in ponds and have restaurants prefer the red-spotted stream ecotype in production, enterprises that produce large-sized fish in dam lakes and the sea prefer the marine ecotype, which reaches sexual maturity late and has a better growth performance than other ecotypes. Since Black Sea salmon is our only endemic trout species showing typical salmon characteristics, its adaptation to the natural environmental conditions of our country for sea net cage and freshwater aquaculture is quite good.

Keywords: Black Sea Salmon, aquaculture, farming management, production, food

ARTICLE INFO

REVIEW

Received : 09.01.2023
Revised : 10.08.2023
Accepted : 11.08.2023
Published : 25.12.2023

DOI:10.17216/LimnoFish.1231429

**** CORRESPONDING AUTHOR***

esinbatir@gmail.com
Phone : +90 462 341 10 53
Fax : +90 462 341 11 52

Karadeniz Somonunun Yolculuğu: Havuzdan Sofraya

Öz: Karadeniz somonu, Salmonidae ailesinden olup Karadeniz'de dağılım gösteren endemik bir türdür. Anadrom davranış gösteren bu balıklar üremek için akarsuların kaynağına yakın kısımları, beslenmek için ise Karadeniz'i tercih ederler. Tüketici tercihi ve ekonomik değeri yüksek olan bu türün ilk kültür çalışması SUMAE tarafından 1998 yılında başlatılmıştır. 24 yıl devam eden çalışmalar sonunda F7 nesil damızlık stok oluşturulmuştur. Türün yetiştiriciliğinin yaygınlaştırılması amacıyla, damızlık balıklarla özel sektör desteklenmiştir. Bu çalışmada, Karadeniz somonunun kültür süreci irdelenmiş, türün tanıtımı amaçlanmıştır. Günümüzde 25 özel sektör işletmesi üretim ruhsatlı ve birçok işletme de deneme üretimi şeklinde toplamda 1603 ton olarak türün ticari üretimini yapmaktadır. Türün doğal yayılım alanı olan Doğu Karadeniz Bölgesinde ticari üretim yoğunlaşmıştır. Karada havuzlarda porsiyonluk üretim yapan ve restoranı olan işletmeler kırmızı benekli dere ekotipini üretimde tercih ederken baraj gölü ve denizde büyük boy balık üretimi yapan işletmeler ise geç cinsel olgunluğa ulaşan ve diğer ekotiplere nazaran daha iyi büyüme performansı gösteren deniz ekotipini tercih etmektedir. Karadeniz somonu tipik salmon karakteri gösteren tek endemik alabalık türümüz olduğundan deniz ağ kafes yetiştiriciliği ve tatlısu yetiştiriciliği için ülkemizin doğal çevre koşullarına adaptasyonu oldukça iyi durumdadır.

Anahtar kelimeler: Karadeniz Somonu, su ürünleri yetiştiriciliği, çiftlik yönetimi, üretim, yiyecek

How to Cite
Batır E, Çakmak E, Özel OT. 2023. Black Sea Salmon' (*Salmo labrax* Pallas, 1814) Journey: From Pond To Plate 9(3): 159-169. doi: 10.17216/LimnoFish.1231429

Introduction

Fish from the Salmonidae family have great importance economically as a food source, environmental in terms of species diversity and aquatic ecosystem health, as well as socially as they are preferred in angling (Latiu et al. 2020). Black Sea

salmon (*Salmo labrax*) is one of the less studied salmonid species compared to other species (Figure 1). This species was first identified by Peter Simon Pallas in 1814. Since then, it has been evaluated as a subspecies of *Salmo trutta* with the name *Salmo trutta labrax*. Black Sea salmon is a species with many synonyms (Froese and Pauly 2018). There are phenotypic differences between *Salmo trutta* populations found in Europe, the Mediterranean and the Adriatic. These taxonomic groups with different morphology have been defined by many species or subspecies names. It is possible to consider Black Sea salmon as a species, subspecies or local population (Çiftçi et al. 2007). Therefore, although the species name has been accepted as *Salmo trutta labrax* in studies on this species, this binomial nomenclature is now accepted as a synonym. Currently, the accepted name of the species is *Salmo labrax* (Black Sea salmon) according to Fishbase (Froese and Pauly 2018) and World Register of Marine Species (WORMS 2017) databases and it is one of the largest sized species among migratory salmonids (Nikandrov and Shindavina 2007).

Figure 1. Black Sea Salmon (*Salmo labrax*)

The natural distribution area of the Black Sea salmon is the Black Sea and the rivers flowing into the Black Sea briefly (IUCN 2022). It has been reported that anadromous forms of Black Sea salmon were previously found in many streams flowing into the Azov and Black Sea (Svetovidov 1984, Solomon 2000). It mainly spreads in the northeastern coasts of the Black, Azov and Caspian Sea basins (Okumuş et al. 2004). This species, which migrates to the Danube river for breeding (Dudu et al. 2011), has also been reported in the Balkan peninsula and the Czech Republic (Lusk et al. 2004, Georgiev 2011).

Many local databases of Bulgaria, Czech Republic, Georgia and Russia report that this species is endangered (GRID 1999, Lusk et al. 2004, Vassilev and Pehlivanov 2005, Peev et al. 2011). The stocks of this species in nature are endangered especially due to the pressure of overfishing in Türkiye as well(Çakmak et al. 2019). In this context, this species is stated as one of the important endangered species in the Black Sea Biodiversity and Environmental Protection Protocol(Black Sea Biodiversity and Landscape Conservation Protocol, 2003). While Black Sea salmon (*Salmo labrax*) is considered to be in the category of Least Concern according to the IUCN Red list (2022), a decreasing structure is observed in the natural stocks of the species due to human activities today. The species, which was mostly seen in the Fırtına and Çağlayan streams in the past, is almost impossible to come across in the region from the Georgian border to Giresun, including these rivers now.

In the countries neighboring the Black Sea (Russia, Ukraine, Romania, Bulgaria, Georgia, Türkiye), the bioecological characteristics and stock status of Black Sea salmon have been studied in general, but there is a lack of information (Solomon 2000, Nikandrov and Shindavina 2007, Makhrov et al. 2018). In our country, studies have been carried out mainly to determine the cultural characteristics and to produce them under farming conditions. In this context, the first cultivation studies were initiated in 1998 with the adaptation of individuals caught from the natural environment to farming conditions.

The cycle of the species was closed, some culture characteristics were determined, the broodstock of the species was brought to the private sector, the obtained culture line was used to support the natural stocks, the nutritional needs were determined and feeding studies were carried out with different feed additives with subsequent projects. The selective breeding program, which is continued with different projects in order to improve the culture characteristics after the adaptation of the species to the captivity, still continues with the breeding studies

with genetic approach.

Black Sea Salmon (*Salmo labrax*)

The population structure and life cycle of Black Sea salmon are similar to sea trout in Northwest Europe. The fish that hatch in freshwater stay in the river environment for one or three years and migrate to the sea after their smoltification is completed in the coastal region. Salmon, which develop rapidly in the Black Sea, return to the river to breed after being in the sea for one or two years (Solomon 2000, Tabak et al. 2001). Adult individuals with reproductive activity migrate to the sea without staying in a stream environment, as is the case with Atlantic salmon, and can reproduce several times during their lifetime (Barach 1962).

It is suggested that there are three different ecotypes of the Black Sea salmon in the natural distribution area: sea, lake and stream (Tabak et al. 2001). The most obvious difference between marine and stream ecotypes is the silvery coloration resulting from the accumulation of guanine layer on the skin after smoltification. Lake ecotype (*natio lacustris*) individuals are trapped in a certain lake and spend their entire lives there. In other words, they do not migrate between the sea and freshwater during the breeding and feeding periods (Slastenenko 1956, Çelikkale 1994, Geldiay and Balık 1996). Great variations in color are seen in all three ecotypes of the *Salmo labrax*. Since the marine ecotype is migratory between sea and freshwater, there are great differences in morphology, especially in color and pattern, between juveniles and adults. Although the young offspring of this ecotype carry scattered black and red spots on the sides of their bodies in freshwater, when they return to the sea, they gradually lose this color and pattern, turning into a silvery-white color and take on the color of their sea parents (Slastenenko 1956, Svetovidov 1984). While such a situation is observed in the marine ecotype, there is no significant color and pattern difference between juveniles and adults in lake and stream ecotypes. Red spots, which are much more characteristic in juveniles, especially in the stream ecotype, remain the same when they become adults and do not disappear throughout their lives (Svetovidov 1984, Çelikkale 1994). It is possible to encounter individuals with different appearances according to color, form, mottling and smoltification in the same basin (Figure 2).

Figure 2. Black Sea Salmon ecotypes (a) lake, (b) stream, (c) sea

Economic Importance

Natural trout fishing production, which was 518 tons in 2011, decreased by 42% and reached 301 tons in 2019 in our country. Overfishing, pollution of rivers, climate change, interventions in the river valley (due to the establishment of hydroelectric power plants on rivers) have been effective in the reduction of natural stocks. Regulations of fisheries were issued in order to prevent the declining stocks from being completely extinct. Regional and seasonal time period bans were introduced, fishing gear restrictions were made and length ban was introduced with these regulations. SUMAE (Central Fisheries Research Institute) brought Black Sea salmon that was adapted to captivity, in the private sector through on-site practical training in 2010. Trial production, which continued until 2013, became official from this year and started to take place in the aquaculture statistics. Culture production, which started with 1248 tons in 2014, has reached 1603 tons/year today (Figure 3). The species was introduced to private enterprises and they were allowed to start breeding after the private sector project. The number of enterprises producing the species reached 25 in 2021. The total fry production capacity of these enterprises is 23,256,000 and the fish production capacity is 3,287,000 kg. These enterprises are located in the provinces of Trabzon, Rize, Artvin, Giresun, Gümüşhane and Muş (BSGM 2021, TUİK 2022).

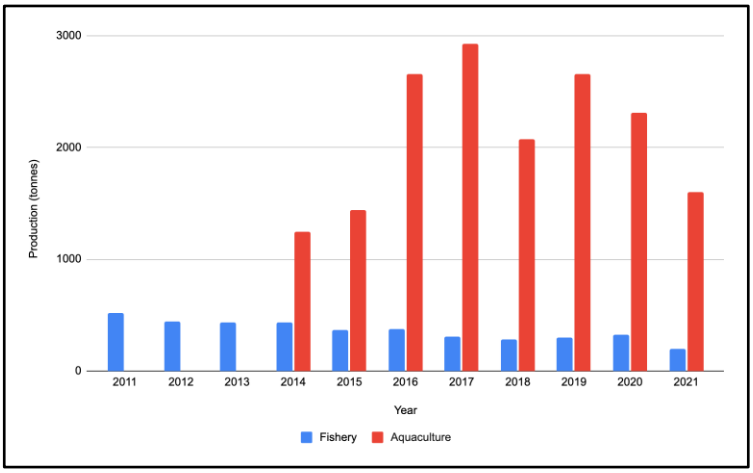

Figure 3. Trout fishery and aquaculture production statistics (ton/year) (TUİK, 2022).

Our native species has gained importance in culture conditions in recent years due to its resistance to local disease strains, rapid growth in Black Sea salinity, high adaptation to culture conditions, high commercial value, attractive in appearance and being consumed by the people of the region. It is especially preferred by trout producers with restaurants that appeal to domestic and foreign tourism, and even some businesses prefer only this species in production. Today, in the provinces of Artvin, Rize and Trabzon, portion size (200-250g) fish are sold at a price of 40-50 ₺/piece (2-3 $/piece), and in restaurants, they are cooked and served for about twice the price of rainbow trout.

Black Sea Salmon Characteristics

Broodstock Management

Ideally, broodstock should be kept as close as possible to the environmental conditions to which they are exposed in nature. However, in practice it may not be possible to provide ideal growing conditions for all factors. Water quality, feeding regime and feed formulation quality, stocking density, exposure to pathogens and stress factors during various treatments can be optimized with appropriate management and aquaculture practices (Okumuş 2002b).

Commercial trout feeds can be used in the feeding of Black Sea salmon broodstock apart from the reproduction period. However, it is essential to meet the nutritional needs of the species in order to obtain good quality eggs and good hatchability when gonad development begins in August. The use of diets containing 15%-20% fish oil, 45%-50% protein (anchovy meal) for broodstock in terms of polyunsaturated fatty acids, especially DHA, which is an important parameter in terms of hatching efficiency and egg quality affects the survival rate positively (Çakmak 2019).

Black Sea salmon will be exposed to stress at different levels from various practices (such as gonad development control, male-female separation, marking, transport and stripping) during the breeding period. This situation adversely affects the health of the broodstock and the viability of the progeny. In order to keep the stress at a minimum, reproductive period controls should be done at the appropriate time and as often as possible, taking into account the previous reproduction time, and anesthetics should be used if necessary. If the water quality is suitable, a stock density of 10 kg/m³ is optimum for Black Sea salmon broodstock, taking into account the welfare of the fish (Çakmak et al. 2010). The criterias such as reaching smolt height (11.5 cm) in the first November after stripping, reaching sexual maturity at 34 months, feed conversion ratio (FCR) close to 1, species-specific normal body shape and silver-spotted coloration (marine ecotype), not showing morphological deformation and skeletal anomaly and early adaptation to culture conditions should be considered while the broodstock were created. It is recommended that the broodstock should be created from at least 650 individuals in order to preserve genetic variation, the sex ratio should be kept as equal as possible, and broodstock older than 6 years old with low reproductive performance should be removed from the stock (Çakmak et al. 2018). It has been determined that the egg production of the broodstock varies between 2159-2629 eggs/kg depending on age in the conducted studies (Çakmak et al. 2018).

The dissolved oxygen in the water to be given to the ponds where the broodstock are stocked should be at least 6 mg/l. The CO_2 level should not exceed 25 mg/l. Total suspended solids in broodstock ponds should be reduced by using suitable filters. Fluctuations close to the lower or upper tolerance limits that may occur in the water temperature during

the day adversely affect the performance of the broodstock. Sudden changes (±5°C) should be avoided particularly. It has been experienced that Black Sea salmon broodstock are kept in ponds with a water temperature of 5-16°C throughout the year as much as possible in order to get healthy gonad development. Feeding should be stopped when the temperature rises above 20°C, especially in summer. The daily water change should be at a flow rate that will not drag the fish, and should not be below the level of 8 times/day In the broodstock ponds (Çakmak et al. 2010).

Hatchery Management

The breeding season of the Black Sea salmon in the natural environment starts from mid-October and continues until the end of December (Tabak et al. 2001). Taking into account the natural life cycle of the species, breeding controls of broodstock in culture conditions should be started in the first week of October every year. During the spawning season, egg maturity checks should be made at weekly intervals. Individuals with matured gonads should be taken into separate ponds for stripping. Broodstock to be stripped can be anesthetized by applying 50 ppm benzocaine (Oswald 1978) for height-weight measurements and easy stripping. Dry stripping method affects stripping efficiency positively (Billard and Cosson 1992).

The water temperature is required to be 7-12°C (average 10°C) during the incubation and hatching periods for Black Sea salmon eggs. Especially in the Black Sea salmon, since the incubation period is relatively long compared to other species, losses may increase if the eggs are kept in multiple layers. It is a correct approach to place a maximum of two layers of eggs in the incubation trays for Black Sea salmon. Detecting the dead eggs and removing them from the environment without causing any disease can give the larvae a chance to be kept in the same environment, especially during the period from hatching to free swimming and pre-feeding stages in this way. Dead eggs are removed from the tray by siphoning, collecting with forceps or other methods within the first 36 hours after stripping (at 10°C water temperature). After fertilization, eyed stage occurs in 28-32 days at 10°C, and hatching occurs in 38-41 days. Free swimming begins 67-77 days after hatching, thus the incubation phase is completed.

The most appropriate time to start feeding is when the larvae consume 60-70% of their yolk sacs. Fish should be fed with diets containing 15% fish oil and 45% fish meal protein during pre-feeding and feeding acclimation stages (Çakmak et al. 2019).

Stocking in the pre-feeding and fry stage according to the size of the floor area provides an advantage in reaching the planned survival and feed utilization performance. 7,000–10,000 larvae/m_2 is the appropriate stock density range in the larval tanks where pre-feeding will be made. When the fish reach an average weight of 600-750 mg, they should be taken into fry rearing tanks. If the water to be used in the pre-feeding ponds contains sufficient dissolved oxygen (> 7 mg/L), is clear and has a constant water temperature (average 10°C), it will be sufficient to change it 4 times per hour. Adjusting the water depth to 15 cm will prevent the larvae from having the problem of not being able to fill the air bladders (Çakmak et al. 2010). It was determined that the FCR ranged between 0.98-1.08 during the growth process from the pre-feeding stage to 2 g of fish kept in suitable rearing conditions in the studies carried out (Özel 2022).

It is important for the success of production that the fish are raised in hatcheries with optimum water quality until at least smolt size in Black Sea salmon farming. In fry rearing systems (tank, pool, etc.), it is recommended that the water is changed at a rate of 4 times/hour and its depth should not exceed 50 cm. (Çakmak et al. 2010).

Fry harvested as 2 g from nursery ponds are placed in rearing ponds where they will be grown up to smolt size, considering the average fish size of 10-15 kg/m3. The feed to be used to grow up fry to smolt size should have 10% fish oil and 47.5% protein (Çakmak et al. 2022). The FCR was determined as 0.73-1.08 (Özel 2022), 0.77-1.08 (Özel et al. 2021), 1.20-2.70 (Çakmak et al. 2022) in the studies performed. It takes an average of 10 months after the fertilization stage for the offspring to reach smolt size (11.6 cm, 18.72 g) (Özel 2022).

Fish Rearing to Portion Size

Pond and dam lake net cage enterprises are used in order to produce portion size or fillet candidate fish.It is sufficient to provide 2-3 times/hour water changes in portion size production pools. Pool dimensions, water inlets and outlets, ground slopes, pool depth should be such that they benefit the most from fresh water by fish and producers.

While the FCR ranges from 1.16 to 1.35 in the period from smolt to portion size (Çakmak et al. 2022, Özel 2022), this value may vary entirely depending on the business management. The stock density can be increased to 25-30 kg/m_3 considering the average harvest weight in this period (Çakmak et al. 2010). The fish reach a portion size (approximately 250 g) at the 16th month after the eggs are fertilized (Çakmak et al. 2018). In another study, it was determined that the weight of the broodstock caught as 300-350 g reached 2500-3000 grams when kept under controlled conditions for a year (Güven et al. 2016).

It was determined that the oxygen consumption was 95.2-140.0 mgO_2kg/hour at a water temperature of 10°C in the study using Black Sea salmon of different sizes. It has been determined that oxygen consumption increases in the light period (Akbulut et al. 2012).

It has been observed that the Black Sea salmon completes gastric emptying in 44 hours during the feed adaptation and pre-feeding stages, also in 68-72 hours during the breeding stage (Başçınar and Çakmak 2011). Feed formulation, feeding method, amount of feed and number of feeding are among the most important criterias affecting the growth of fish in culture production. The amount of feed and the number of feeding should be determined by considering the gastric digestion time in order for the whole culture stock to benefit equally from the given feed.

Fish Farming to Fillet Size in Sea Cages

Black Sea salmon is an opportunistic marine environment user in nature. It grows in marine water significantly faster than freshwater in aquaculture systems. It has been determined that the Black Sea salmon should be at least 12 cm in length and 15 g in weight (smolt length) for adapting to the Black Sea salinity. These sizes of fish can adapt physiologically in 7-8 days, and all blood values remain at normal levels after a period of 17 days in Black Sea (Çakmak et al. 2010).

Although daily feed consumption varies according to water temperature, fish size and flow rate in the area where the cages are located, feeding 1.5-2% of their live weight for fish has a positive effect on weight gain and feed utilization rate. A stocking density of 30 kg/m_3 can be reached depending on the suitability of the water quality in the net cages in the marine environment (Çakmak et al. 2010). When the Black Sea water is suitable for salmon/trout farming in November -the beginning of the season-, fish with an average weight of 40 g are transported to the cages and reach an average of 400 g at the June -end of the season-. Fish with an average weight of 1,500 g can be obtained from fish that are transported to sea cages with an average weight of 200 g at the end of the production season (Çakmak et al. 2010). For the production of fillet size (>2500 g), it would be appropriate to transfer larger fish (400-500 g) to sea water at the beginning of the production season.

Meat Yield and Quality

The body proportions of Black Sea salmon males are according to their live weight have determined as for fin 4.66%, head 13.04%, carcass 68.32%, gonad 5.15%, skin 7.17%, liver 1.04%, bone 2.33%, internal organs 13,98%, meat yield was 58,82%, body proportions of females were 4.02% fin, 11.37%, carcass 70.55%, gonad 4.21%, skin 6.22%, liver. 1.59%, bone 2.41%, internal organs 14.06% and meat yield 61.99%. It has been determined that the meat yield of female individuals is 3.17% higher than male individuals (Çakmak et al. 2008). Preferring female individuals in conventional production is important for business profitability.

The average protein, fat, water and ash ratios of Black Sea salmon fillets were found to be 17.69%, 6.13%, 73.34%, and 1.38%, respectively. In addition, the ratio of omega 3 (n-3) and omega 6 (n-6) fatty acids, which are known to be important in human nutrition, is 30.79% and 14.10%, respectively. Among the fatty acids in the omega 3 group, EPA is 5.10% and DHA is 1.39% (Çankırılıgil 2019).

A total of 250-1000 mg of EPA and DHA is recommended daily usage in adult human nutrition, but three billion people worldwide receive less than 100 mg per day (Panchal and Brown 2021). When at least 64 g of Black Sea salmon meat is consumed per person a day, the minimum daily requirement will be met, and the average of European fish consumption will be reached, and if this amount is up to 256 g, the average of Japan will be reached. However, our country consumes an average of 18 g of fish per day (TUIK 2022), which is below the minimum requirement and world standards.

It is known that consumption of fish oil in human nutrition contributes to heart, intestine, inflammatory diseases, joint rheumatism and brain development. In case of dietary deficiency, behavioral disorders, depression, bipolar disorder and cognitive impairment in advanced age have been observed. In addition, studies have shown positive effects against various types of cancer and diabetes (Sidhu 2003, Balami et al. 2019, Yıldız 2019, Tacon et al. 2020).

Widespread Impact

Twenty five enterprises producing the species after the private sector project of SUMAE are located in the provinces of Trabzon, Rize, Artvin, Giresun, Gümüşhane and Muş (BSGM 2021).

Fish farm enterprises with restaurants in the region serve Black Sea salmon as fried in butter, grilled and steamed. In addition, different presentations are made (Figure 4).

Figure 4. Various plates of Black Sea salmon served at Abu Trout Farm and Restaurant in Fındıklı, Rize

Figure 4. Various plates of Black Sea salmon served at Abu Trout Farm and Restaurant in Fındıklı, Rize(continue)

The commercial distribution of Black Sea salmon is also supported by the pictures below (Figures 5).

Figure 5. Various newspaper news in Turkish, translations were given below respectively from left to right; Black sea salmon instead of Norway salmon, 115 cm salmon in Fırtına river, Black sea salmon will grow faster by breeding studies.

The information about the Black Sea salmon is given in the İnan Kardeşler museum, which is visited by tourists coming to Trabzon, (Figure 6).

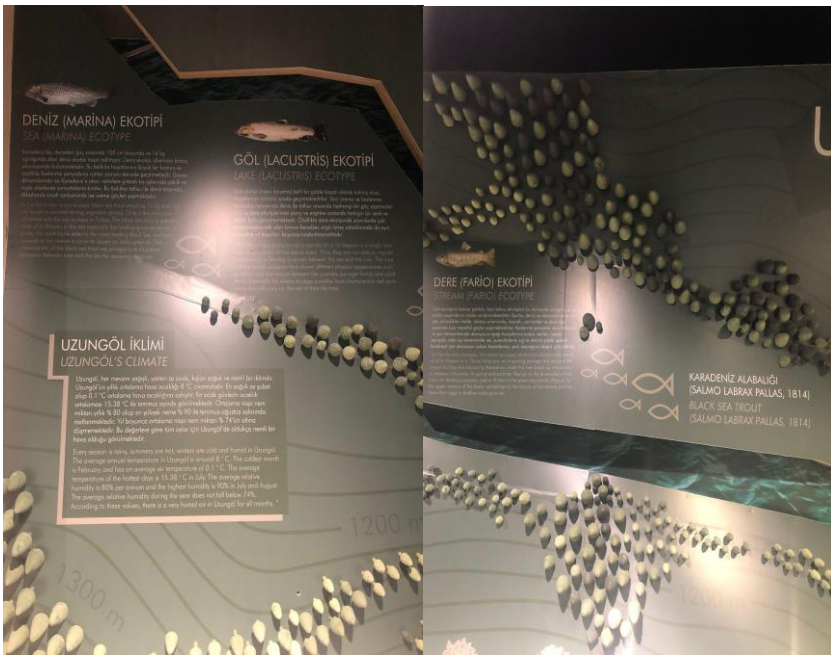

Figure 6. İnan Kardeşler Museum in Uzungöl, Trabzon

Conclusion

Today, 1603 tons of Black Sea Salmon is produced in our country by 25 private sector enterprises that have production licenses and many enterprises carry out commercial production in the form of trial production. Commercial production is concentrated in the Eastern Black Sea Region, which is the natural distribution area of the species. Enterprises that produce portion sizes in ponds on land and have restaurants prefer the red-spotted stream ecotype for production, while enterprises that produce large fish in dams and seas prefer the marine ecotype, which reaches late sexual maturity and shows better growth performance than other ecotypes. Since the Black Sea salmon is the only endemic trout species showing typical salmon character, our country's adaptation to natural environmental conditions is quite good for marine net cage farming and freshwater aquaculture. The point reached in the production of Black Sea salmon, which has similar nutritional values with other cultured salmonid species, shows that the new culture lines to be created may have the potential to compete with the Atlantic salmon. The contribution of this situation to the economy of our country will be very important.

Acknowledgement: We would like to thank SUMAE for all of the projects conducted on the Black Sea salmon.

Author Contribution: All authors contributed equally to this work.

Funding: No financial support was received for this study.

Conflict of Interest: The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Ethical Approval: There is no need for ethical approval for this study.

Data Availability Statement: There is no data availability for this study.

References

Akbulut B, Çakmak E, Kurtoğlu İZ, Alkan A. 2012. Routine Oxygen Consumption Rate of the Black Sea Trout Salmo trutta labrax Pallas 1811. jour. of fish. scien. com 6(2):88-95.

Aksungur M, Eroğlu O, Firidin Ş, Aksungur N, Çakmak E, Çavdar Y, Tan H, Seymen F. 2013. Karadeniz Alabalığı Anaç Stok Yönetim Sistemi Oluşturulmasında Moleküler Genetik Tekniklerin Kullanımı. Proje Sonuç Raporu. Tübitak Proje No: 1110o852.

Balami S, Sharma A, Karn R. 2019. Significance Of Nutritional Value Of Fish For Human Health. MJHR . 2(2):32–34. https://doi.org/10.2478/mjhr-2019-0012

Barach GP. The Black Sea Kumzha. Black Sea Trout (Salmon trout). Translation by N. Terdzishvili and D. Solomon. Izd-vo AN GSSR, Tbilisi, 1962. 64 pp.

Başçınar NS, Çakmak E. 2011. Determination of gastric evacuation time and rate of Black Sea trout (Salmo trutta labrax Pallas, 1811) larvae through live feed utilization. . jour. of fish. scien. com. 5:300-307. https://doi.org/10.3153/jfscom.2011034

Berg LS. 1948. Freshwater fishes of the U.S.S.R. and adjacent countries. Volume 1, 4th edition. Israel Program for Scientific Translations Ltd, Jerusalem. (Russian version published 1948).

Billard R, Cosson MP. 1992. Some problems related to the assessment of sperm motility in freshwater fish. J. Exp. Zool. 261(2):122-131. https://doi.org/10.1002/jez.1402610203

Black Sea Biodiversity and Landscape Conservation Protocol. 2003. Annex 2 List of Species of Black Sea Importance. Sofia, Bulgaria.

BSGM. 2021. Balıkçılık ve Su Ürünleri Genel Müdürlüğü. https://www.tarimorman.gov.tr/BSGM/Menu/32/Bilgi-Dokumanlari

Çakmak E, Firidin S, Duzgunes ZD, Parlak R. 2019. The Age-Dependent Reproductive Performance of 4th Generation Black Sea Trout (Salmo labrax Pallas, 1814) Females. Turkish J. Fish. Aquat. Sci. 19(6). https://doi.org/10.4194/1303-2712-v19_6_05

Çakmak E, Başçınar N, Çavdar Y, Aksungur N, Firidin Ş. 2008. Kültür Şartlarında Yetiştirilen Karadeniz Alabalığının (Salmo trutta labrax PALLAS, 1811) Yaş ve Cinsiyete Bağlı Bazı Vücut İndekslerinin Belirlenmesi. Süleyman Demirel Üniversitesi Eğirdir Su Ürünleri Fakültesi Dergisi. 4(1):38-44.

Çakmak E, Aksungur M, Kurtoğlu İZ, Savaş H, Aksungur N, Firidin Ş, Başçınar N. 2011. Karadeniz Alabalığı (Salmo trutta labrax Pallas, 1811)'nın Özel Sektöre Kazandırılması, Project Book. Project no: TAGEM/HAYSÜD/2006/09/03/02, Trabzon: Central Fisheries Research Institute (SUMAE).

Çakmak E, Aksungur M, Kurtoğlu İZ, Başçınar N, Çavdar Y, Eroğlu O, Üstündağ E, Aksungur N, Firidin Ş. 2010. Karadeniz Alabalığı (Salmo trutta labrax) Yetiştiriciliği El Kitabı, Su Ürünleri Merkez Araştırma Enstitüsü Müdürlüğü, Yayın No: 2010–2 Trabzon, 58 s.

Çakmak E, Çankırılıgil EC, Özel OT. 2018. The fifth culture generation of Black Sea Trout (Salmo trutta labrax): Culture characteristics, meat yield and proximate composition. EgeJFAS. 35(1):103-110. https://doi.org/10.12714/egejfas.2018.35.1.16

Çakmak E, Firidin Ş, Duzgunes ZD, Parlak R. 2019. The age-dependent reproductive performance of 4th generation Black Sea Trout (Salmo labrax Pallas, 1814) Females. Turkish J. Fish. Aquat. Sci. 19(6):496-502. https://doi.org/10.4194/1303-2712-v19_6_05

Çakmak E, Firidin Ş, Çavdar Y, Aksungur N, Haliloğlu HI, Bayır A, Sirkecioğlu N, Eroğlu O, Aksungur M, Küçük E, Ergün H. 2014. Karadeniz Alabalığı (Salmo trutta labrax)'nın Besin Madde İhtiyaçlarının

Belirlenmesi, Proje Sonuç Raporu. TAGEM/HAYSÜD 2011/09/01/02.

Çakmak E, Firidin Ş, Eroğlu O, Bayır A, Aksungur N, Özel OT, Aksungur M, Çankırılıgil EC, Düzgüneş ZD, Kutlu İ, Çavdar Y, Ergün H, Türe M, Akpınar Z, Bayır M, Dülger N, Altun E. 2019. Karadeniz Alabalığı (Salmo trutta labrax Pallas, 1811)'nın Besin İhtiyaçlarının Belirlenmesi, Proje Sonuç Raporu Kitabı, Su Ürünleri Merkez Araştırma Enstitüsü Müdürlüğü, Trabzon, 114 s.

Çakmak E, Kurtoğlu İZ, Çavdar Y, Firidin Ş, Aksungur N, Başçınar N, Esenbuğa H, Zengin B. 2007. Karadeniz Alabalığının Yetiştiriciliği ve Balıklandırma Amacıyla Kullanımı, Proje Sonuç Raporu. TAGEM/HAYSÜD/2001/07/01/20 Trabzon 128s.

Çankırılıgil E. 2019. Karotenoid katkılı yemlerle beslenen Karadeniz alabalığı (Salmo labrax Pallas, 1814)'nın et kalitesinin belirlenmesi. Doktora tezi, Onsekiz Mart Üniversitesi.

Çelikkale MS. 1994. İç Su Balıkları ve Yetiştiriciliği, Cilt 1, İkinci Baskı KTÜ Deniz Bilimleri Fakültesi Yayınları, Fakülte Yayın No: 2, Trabzon.

Çiftçi Y, Eroğlu O, Firidin Ş, Erteken A. 2007. Türkiye Kahverengi Alabalık (Salmo trutta L.) Populasyonlarının genetik yapısının belirlenmesi, Proje Sonuç Raporu, Gıda ve Orman Bakanlığı, Trabzon Türkiye.

Dudu A, Georgescu SE, Popa O, Dinischiotu A, Costache M. 2011. Mitochondrial 16s and 12s rRNA Sequence Analysis in Four Salmonid Species from Romania. Acta Zool Acad Scientiarum Hungaricae. 57(3):233–246.

Edwards D, Doroshov S. 1991. Appraisal of the sturgeon and sea trout fisheries and proposals for a rehabilitation programme. 38 p. FAO Accession No: XF90:295183 (Available on Microfiche).

Elliot JM. 1994. Quantitative ecology and the Brown trout. Oxford Series in Ecology and Evolution. Oxford University Press, Oxford, Anglaterra.

Froese R, Pauly D. 2018. FishBase, Version (10/2018).

Geldiay R, Balık S. 1996. Türkiye Tatlı Su Balıkları, Ege Üniversitesi, Su Ürünleri Fakültesi Yayın No: 46. Ders Kitabı. Dizin No: 16, Ege Üniversitesi Basımevi, Bornova, İzmir.

Georgiev S. 2011. Study of Salmo Genus (Pisces, Salmonidae) on the Balkan Peninsula. Croat. J. Fish. Ribar. 69(1):11–20.

Güven E, Yıldız M, Baltacı MA. 2016. A study on incubation of Brown Trout (Salmo trutta sp.) eggs and feeding of fry. EgeJFAS. 33(3):209. https://doi.org/10.12714/egejfas.2016.33.3.04

GRID. 1999. Biodiversity Report Georgia '99, Endangered Species. Retrieved 5 February 2018, from http://enrin.grida.no/biodiv/biodiv/national/georgia/State/species.htm

IUCN. 2022. The IUCN Red List of Threatened Species. Retrieved 10 November 2022, from http://www.iucnredlist.org.

Latiu C, Cocan D, Uiuiu PA, Ihut A, Nicula SA, Constantinescu R, Mireşan V. 2020. The Black Sea Trout, Salmo labrax Pallas, 1814 (Pisces: Salmonidae) in Romanian Waters. Bulletin UASVM Anim. Sci. Biotechnol. 77(2). https://doi.org/10.15835/buasvmcn-asb:2020.0017

Lusk S, Hanel L, Lusková V. 2004. Red List of the Ichthyofauna of the Czech Republic: Development and Present Status. Folia Zool. 53(2):215–226.

Makhrov AA, Artamonova VS, Murza IG, Pashkov AN, Ponomareva MV, Reshetnikov SI, Christoforov OL. 2018. Ecological Forms of Black Sea Brown Trout (Salmo trutta labrax) in the Mzymta River as Manifestation of Ontogenetic Plasticity. Russ J Dev Biol. 49:117–127. https://doi.org/10.1134/S1062360418020054

Nikandrov VY, Shindavina NI. 2007. Characteristics of the hatchery-reared Black Sea salmon Salmo trutta labrax. J. Ichthyol. 47(2):184-193. https://doi.org/10.1134/S0032945207020063

Okumuş İ, Kurtoğlu İZ, Atasaral Ş. 2004. General Overview Of Turkish Sea Trout (Salmo trutta L.) Populations. In: Harris G, Milner N, eds. Sea Trout: Biology, Conservation and Management. Proceedings of the First International Sea Trout Symposium, Cardiff, July. Blackwell Publishing, 115–116.

Okumuş İ. 2002b. Damızlık Stok Yönetimi-I: Stok Oluşturma, Trabzon Su Ürünleri Merkez Araştırma Enstitüsü Müdürlüğü, Yunus Araştırma Bülteni. 21:5-7.

Oswald RL. 1978. Injection anesthesia 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

Özel OT, Çakmak E, Çankırılıgil EC, Coşkun İ, Ertürk-Gürkan E, Düzgüneş ZD, Türe M, Çimagil R, Yılmaz HA, Evliyaoğlu E, Eroldoğan OT, Kutlu İ, Alp-Erbay E, Dağtekin BB, Yeşilsu AF, Berik N. 2021. Bazı Fitobiyotik Katkılı Diyetlerin Karadeniz Alabalığı (Salmo trutta labrax Pallas, 1811) Beslenmesinde Kullanım Olanaklarının Araştırılması, Proje Sonuç Raporu. TAGEM/HAYSUD/2017/A11/P-01/3.

Özel OT. 2022. The zootechnical performance of the seventh generation Black Sea salmon in recirculating aquaculture system. VI. International Congress on Domestic Animal Breeding Genetics and Husbandry. 03-05 October 2022. Samsun (Oral).

Panchal SK, Brown L. 2021. Addressing the Insufficient Availability of EPA and DHA to Meet Current and Future Nutritional Demands. Nutrients. 13(8):2855. https://doi.org/10.3390/nu13082855

Peev D, Vladimirov V, Petrova AS, Anchev M, Temniskova D, Denchev CM, Ganeva A, Gussev C. 2011. Red Data Book of The Republic of Bulgaria, Volume 2 - Animals. Sofia Bulg. Acad. Sci. Minist. Environ. Water.

Sidhu KS. 2003. Health benefits and potential risks related to consumption of fish or fish oil. Regul. Toxicol. Pharmacol. 38(3):336-344. https://doi.org/10.1016/j.yrtph.2003.07.002

Slastenenko E. 1956. The fishes of the Black Sea basin, Çeviri: H. E Altan, Et ve Balık Kurumu Umum Müdürlüğü, İstanbul, 711 s.

Solomon DJ. 2000. The Biology and Status of The Black Sea Salmon, Salmo trutta labrax. EU Tacis Black Sea Environmental Programme. Black Sea Salmon Project. Draft report. 24 pp.

Svetovidov AN. 1964. Black Sea Fishes. Leningrad, 552 pp.

Svetovidov AN. 1984. Salmonidae. In: P.J.P. Whitehead, M.–L.Bauchot, J.-C. Hureau, J. Nielsen ve E. Tortonese (eds.), Fishes of the North-Eastern Atlantic ve the Mediterranean, Unesco, Paris. 1:373–385.

Tabak İ, Aksungur M, Zengin M, Yılmaz C, Aksungur N, Alkan A, Zengin B, Mısır M. 2001. Karadeniz Alabalığının Biyoekolojik Özelliklerinin ve Kültür İmkanlarının Araştırılması, project book. Project no: TAGEM/HAYSUD/98/12/01/007, Trabzon: Central Fisheries Research Institute (SUMAE). 207 s.

Tacon AG, Lemos D, Metian M. 2020. Fish for health: improved nutritional quality of cultured fish for human consumption. Rev. Fish. Sci. Aquac. 28(4):449-458. https://doi.org/10.1080/23308249.2020.1762163

TUIK, Türkiye İstatistik Kurumu. 2022. Kültür Balıkları Üretim Miktarı.

Vassilev MV, Pehlivanov LZ. 2005. Checklist of The Bulgarian Freshwater Fishes. Acta Zool. Bulg. 57(2):161–190.

WORMS. 2018. World Register of Marine Species. Retrieved 10 February from http://www.marinespecies.org

Yıldız M. 2019. Sağlıklı Bir Yaşam İçin Balık Yağının Önemi. 20. Ulusal Su Ürünleri Sempozyumu. 24-26 Eylül, Mersin. (Oral).