PART I

A BRIEF HISTORY AND THE PRESENT SITUATION
CHAPTER 1

DEVELOPMENTS OF TURKISH AQUACULTURE INDUSTRY

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1. Introduction

As a country with significant infrastructure and long history in fish farming, Turkish aquaculture is in a rapid growth period, ranking among major producers in the World and the largest producer among the non-EU and EU member countries, together with Norway, UK, and Russia. The Rainbow trout (Oncorhynchus mykiss), European seabass (Dicentrarchus labrax) and gilthead seabream (Sparus aurata) are the main three species dominating aquaculture harvest from Turkish farms. According to the latest statistics supplied by the Food and Agricultural Organizations of the United Nations, production volume for these three key species was in the order of 165.683 tons, 155.151 tons, and 133.476 tons, respectively in 2021, representing 35%, 33%, and 28% of the total production in the Turkish aquaculture industry. Considering economic returns from for the country, European seabass production takes the lead with 41%, the highest share of the total income that was reported as 855.483 $, followed by gilthead seabream with a share of 31% and 637.187 $ contribution, and rainbow trout with 23% and 482.848 $ contribution in 2021. Fish species, other than the main key players represent 5% with an economic value of 112.798 $ for the Turkish aquaculture sector, that
has achieved a remarkable growth trend over the last two decades. The development of the Turkish fish farming industry was initiated with simple cage systems that has shifted to smart farm facilities with high-technologies over the years. However, there is still a way to go, and there is an urgent need to identify new production areas in response to shrinking carrying capacities, and to develop innovative methods and technologies for environmentally-sound and sustainable production in order to use the existing potential more efficiently. All these aspects have been evaluated in this chapter with insight to the strengths and prominent features that have brought Turkish aquaculture to an important position. Efforts and success of the Turkish aquaculture industry, as well as weak points that need considerations for future developments have been highlighted with comparative evaluation from past to present.

2. Importance of Food Security and Diversity

The aquaculture sector worldwide has recorded significant growth in recent years. The increasing food and water need of the world, which exceeds 8 billion people today, is one of the most important issues to be tackled for the future of human beings. The importance of the need for food and water becomes even more prominent in processes such as regional conflicts, epidemics, etc.

Because the break in the international trade flow that started with lock-downs and the closure of intercountry borders during the recent Covid-19 pandemic period, it has been noted that some countries faced severe difficulties in reaching healthy food (Yigit et al., 2023a). The regional crisis caused by the Ukraine-Russia war, which started with the growth of political disagreements in the north of the Black Sea, did not only affect the conditions in these two countries, but also became a global issue. In particular, the relative resolution of the grain crisis in the European continent, with the intervention of Turkish State, provided a fresh breath both for European countries and for many others struggling with hunger and poverty.

In times of global crisis, it has been observed that self-sufficient countries such as Türkiye, in terms of food security and diversity, could overcome these difficult periods more easily and with less damage, compared to those with foreign dependency (Yigit, 2023b). Therefore, ensuring food security along with food diversity is one of the most important issues for the future of nations, that it should be addressed together with energy resources, which are important for all kinds of industrial production and human life. Despite the fact that several countries have different production strategies, intercontinental collaboration on food safety management for the continuity of food flow between countries is important for food safety at global level.
3. Global Trends and Recent Developments in Turkish Aquaculture

Due to stagnations in capture-fisheries, natural resources are not enough to cover the increasing demand of the world population, hence the aquaculture became into foreground with a remarkable potential in meeting the increase of seafood consumption (López-Mas et al., 2021). The development and wider use of stabilization of fishing yields and the use of technological devises such eco-sounders in fisheries, challenged more pressure on natural populations. Global capture fisheries supply in 2021 was reported as 76.912.786,8 tons for finfish, which increased by only 1.6% over the previous year of 2020 and only 2.3% over the last 5 years from 2016 to 2021 (FAO, 2023a). Considering the total of all aquatic organisms from capture fisheries including fish, crustaceans and molluscs, aquatic plants, and other marine and freshwater animals, world capture-based fisheries supply was around 183.250.671,8 tons in 2021, with 1.6% growth from 2020 to 2021, but only 0.9% increase over the last 5 years from 2016 to 2020 (FAO, 2023a). The 1.5% increase of the wild harvest yields from 2020 to 2021 might be explained by the resurgence in 2021 of the serious decrease (-3.1%) in fishing activities during the pandemic period of 2020. In contrast, seafood supply from aquaculture activities is in a steady growth trend, with a harvest yield of 59.295.095,3 tons that gave around 3.1% increase from 2020 to 2021, and 16.3% increase over the past 5-years span from 2016 to 2021 (FAO, 2023b). This is a clear indication that the global aquaculture growth was around 8-times bigger than the capture fisheries that is in a stagnation due to the dependence on wild populations.

The total aquaculture production of 59.295.095,3 tons in 2021 is a sum of seafood harvest from 197 countries in total. The number of countries with a production volume of more than 100.000 tons is 32, while those producing over 200.000 tons of finfish is 19, whereas only 14 countries have an annual production of over 400.00 tons. Turkish aquaculture is within the top 14 countries with an annual harvest of 467.048 tons of finfish, that is mainly represented by the European seabass, gilthead seabream and rainbow trout, and comprises around 0.8% of the global production in 2021, according to the latest statistics (FAO, 2023b).

Considering the European finfish aquaculture, the total production yielded 2.953.601,9 tons in 2021, including the non-EU member states of Norway and Russia as the main key players in the European continents. When the Turkish production is included as another non-EU state, the total production rises to 3.420.650 tons, among which the percent share from Turkish farms would be around 13.7% of the total European finfish aquaculture (FAO, 2023b). In regards to the main key species in the Turkish aquaculture industry, Turkish aquaculture provides around 45% of the total harvest for seabass, seabream and rainbow trout in Europe.
Production yields over the last 40 years from 1980 to 2021 for the main producers have been illustrated in Figure 1. The total production of seabass, seabream and Rainbow trout for the main countries with over 40,000 tons of harvest in 2021 have been given in Figure 2, and the percent share of the volume among the main key players is shown in Figure 3.

**Figure 1.** Production trends from 1980 to 2021 for the main producers with over 40,000 tons of harvest in 2021 (sum of seabass, seabream and rainbow trout, tons)

**Figure 2.** Production volume (tons) for the main countries with over 40,000 tons of seabass, seabream and rainbow trout harvest in 2021. Countries with less than 40,000 tons production are classified under “Others”
Figure 3. Percent share of the total production volume (tons) for seabass, seabream and rainbow trout among the main European countries with >40,000 tons harvest in 2021. Countries with <40,000 tons production are listed under “Others”

Turkish aquaculture industry, which occupies the first place as the largest producer of seabream and seabass in the world, ranks second in the world in trout production, after Iran. The quantitative share of the total production for seabass, seabream and trout by 2021, based on the latest statistics (FAO, 2023) has been presented in Figure 4, and the percent share of the production volume for the fish species dominating Turkish aquaculture is given in Figure 5.

Figure 4. The quantitative (tons) share of seabass, seabream and trout production from Turkish farms in 2021
In regards to the rainbow trout, Turkish aquaculture ranked first in Europe and second in the World after Iran. Turkish rainbow trout production hit 165,683 tons in 2021 with a share of 17% of the global harvest, whereas Iran produced 193,852 tons comprising nearly 20% of the World total, with only 3% difference by share between the main two key players of Türkiye and Iran (FAO, 2023b).

Rainbow trout production in quantity (tons) among world countries with over 10,000 tons of production in 2021 has been given in Figure 6, whereas the percentage share of the total trout production for Türkiye and other countries is presented in Figure 7.
Figure 6. Rainbow trout production quantities (tons) among world countries with over 10,000 tons of harvest in 2021

Figure 7. Percentage share of the total trout production among world countries with 10,000 tons of harvest in 2021

The production in quantity for Rainbow trout in Europe has been provided for the main countries with over 20,000 tons a year and presented in Figure 8, and the percent share among countries is given in Figure 9.
**Figure 8.** Rainbow trout production quantity (tons) in European countries with over 20,000 tons of harvest in 2021. Countries with less than 20,000 tons of annual production have been classified under “Others”

**Figure 9.** Percent share of rainbow trout production among European countries with over 20,000 tons of harvest in 2021. Countries with less than 20,000 tons of annual production have been listed under “Others”

For the seabream production in quantity (tons), data are illustrated in Figure 10, showing the World production yields for 2021, and percent share of the world production has been illustrated in Figure 11.
The production in quantity (tons) for seabream in the European aquaculture has been provided for the main countries with over 1,000 tons a year and presented in Figure 12, while the percent share among countries has been illustrated in Figure 13.
Figure 12. Rainbow trout production in quantity (tons) for the main countries in Europe with over 1,000 tons of production by 2021.

Figure 13. Percent share of seabream production in Europe by 2021.
The world aquaculture production in quantity (tons) for seabass farming is given in Figure 14, and percent share of the world production among countries has been shown in Figure 15.

**Figure 14.** World aquaculture production for seabass (tons). Countries with less than 1.000 tons production in 2021 are listed under “Others”

**Figure 15.** Percent share of the world production of seabass among countries with over 1.000 tons of annual harvest in 2021. Countries with less than 1.000 tons production are listed under “Others”
Seabass production in quantity (tons) for the main producers with over 1,000 tons a year in Europe has been given in Figure 16, and the percent share among countries is presented in Figure 17.

**Figure 16.** Seabass production in quantity (tons) for the main producers with over 1,000 tons of annual harvest in Europe. Countries with less than 1,000 tons production are listed under “Others”

**Figure 17.** Percent share of seabass production among European countries with over 1,000 tons of annual harvest in 2021. Countries with less than 1,000 tons production are listed under “Others”
4. Early Stages and Progressive Development of the Turkish Aquaculture With Main Key Species Supplied to the World Markets

4.1. Carp

Although the beginning of fish farming in Turkiye dates back to the 1950s, those days the production was initiated with small-scale carp farms. The first carp harvest, recorded by the United Nations Food and Agriculture Organization, was 10 tons in 1954. Over the next 10 years, production increased by 15-fold to 150 tons of carp in 1964. In the following years, 390 tons of production was achieved in 1970 and 1180 tons in 1980, while the production reached its peak in 1988 with 2200 tons of carp harvest. However, after 1988, carp production decreased gradually, and immediately afterwards, it fell to 1033 tons in 1989 and 364 tons in 1991. Carp production, which showed a fluctuating course over the following years, decreased to 171 tons in 2021. The production trends of carp in the Turkish aquaculture from 1954 to 2021 have been given in Figure 18.

4.2. Rainbow trout

The rainbow trout (Oncorhynchus mykiss) is among the main key species that shifts Turkish aquaculture to the foreground as the biggest producer in Europe and the second biggest in the world after Iran. First official records regarding the trout production in Türkiye were realized as 10 tons of Rainbow trout in 1968. According to the statistics provided by the Food and Agriculture Organization of the United Nations, 110 tons of trout production was
recorded in 1978, that reached to 1765 tons in 1988, which is the year when carp production peaked and then declined rapidly afterwards. Trout production reached 68.649 tons in 2008 and 112.427 tons in 2018. With the production volume of 165.683 tons in 2021, the Turkish aquaculture sector has now become the largest trout producer in Europe and the second largest in the world after Iran, comprising around 31% of the European, and nearly 17% of the world total production.

While rainbow trout farming in Türkiye was carried out in freshwater facilities until the 1990s, it became a major industry, destined for international markets followed by the investigations of Yigit (1996) and Yigit and Aral (1999) who underlined better growth performance for rainbow trout in seawater conditions of the Black Sea compared to the rainbow trout in freshwater facilities (Yigit et al., 2023a).

Today, the rainbow trout is most widely farmed salmonid worldwide (Candiotto et al., 2011; Stanković et al., 2015). The rainbow trout was formerly named as *Salmo gairdneri* classified under the genus “*Salmo*”. However, this species was later reclassified and listed under the Pacific salmons following the research by Laird (2001) on genetic and native distribution of the species. Laird (2001) noted that the rainbow trout is among the main three farmed Pacific salmons with remarkable production volumes, along with the chinook salmon (*O. tshawytscha*), and the coho salmon (*O. kisutch*).

Nowadays, the harvest of 2.5 kg or bigger size rainbow trout (also known as Steelhead) is a new farm strategy of the Turkish aquaculture sector, providing large fish to the domestic and international market, that is sold as Turkish salmon (Yigit et al., 2023b). This has been reported as a new marketing strategy for the large steelhead harvested from the Black Sea (Yigit et al., 2023a,b), that increased profits and economic returns for the Turkish cage aquaculture business, which is in line with the report of Fernández-Sánchez et al. (2022), who underlined that fish farms with larger sized seabass harvest in the Mediterranean received better profits as result of consumer demands. Figure 19 shows the quantities (tons) of Rainbow trout harvested from Turkish farms between 1968 and 2021.
4.3. Seabream and seabass

Marine aquaculture activities in Türkiye were initiated with seabream production in 1986, which was followed by seabass farming a year later in 1987. First, simple cage systems made of wood were used in those days. Cages with iron frames and buoyancy force created with drums set underneath were also used over the time. However, these cage frames were rectangular in shape and the fish nets attached to the frames had to be rectangular as well.

Over the years, the development of octagonal-cage frames made it possible to use circular-shaped net bags, which provided a healthier environment where fish could demonstrate schooling behavior. Introducing circular cage nettings was also the beginning for higher biomass per cubic meter, which moved farmers forward with increased production capacities per unit volume.

In the early 80’s, both seabream and seabass juveniles were caught from wild populations and stocked into the cages, where feeding was conducted until market size. However, when it was understood that this type of production would not be sustainable over time, marine hatcheries were introduced, which was actually the beginning of the marine aquaculture industry in Türkiye. Production quantities (tons) of seabream and seabass harvested from Turkish farms from 1986 to 2021 have been illustrated in Figures 20 and 21, respectively.
Today, the gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) production has become one of the main drivers for the Turkish aquaculture, ranking at the top among the main producers in Europe and the World.

The annual harvest of seabass and seabream from Turkish fish farms comprises 62 and 57% of the total harvest in Europe, whereas it contributes to 52 and 42% of the total product in the World. The harvest of 155,151 tons and revenue of $855,483 for seabass and 133,475...
tons with a sales income of 637.187$ for seabream from Turkish farms is followed by the second largest producer of Greece, which production hit around 51.232 tons for seabass and 66.891 tons for seabream, with around 20 and 28% contribution to the total production in Europe, and nearly 17 and 21% of the World production, respectively in 2021 (FAO, 2023b).

Spain is the third biggest producer of seabass in Europe with an annual harvest of 23.037 tons in 2021, followed by Croatia (9.039 tons), and Italy (7.27 tons), with shares of 9, 4, and 3%, respectively, to the total production in European waters. Among the World producers, Egypt reserved its third place in seabass production with 33.245 tons that equaled to 11% of the global production in 2021.

After the Turkish and Greek production, Italy and Spain shared the 3rd and 4th ranking in Europe with 8.176 and 7.823 tons, representing 4 and 3% of the total production. Egypt and Tunisia shared around 13 and 6% of the total world production of seabream with 42.743 and 17.799 tons, after Türkiye and Greece, based on 2021 data provided by FAO (2023b).

5. Conclusions and Future Challenges

The rapid development process experienced in the Turkish aquaculture sector and the increase in production capacities have led to a significant improvement in the competition of international trade. However, the increased production volume in the Turkish aquaculture industry is mainly concentrated on three key species of trout, seabream and seabass that indeed shrinks the product range in the market. Increasing production amounts may cause unbalanced price fluctuations from time to time. New marketing strategies can be developed with the supply of alternative products that in turns may increase the product diversity for the market. Therefore, the search for new candidate species is encouraged for further development of the Turkish aquaculture business, which is also an important step for the sustainable growth of fish farming activities in the country. In fact, attempts for the production of new finfish species other than seabream, seabass or rainbow trout have been noted between 1986 and 1993, with several quantities of annual harvests ranging from 5 to 100 tons of common two-banded seabream (*Diplodus vulgaris*) and mullets (*Mugil cephalus*). The culture of mullets were tested from 1991 to 1992, however it is likely that the consumer demands for mullets were quite low, as fish farms no longer supplied mullets after 1992, and no records were noted for the common two-banded seabream production after 1993. This was just after the disappointment that was experienced in the production of Atlantic salmon (*Salmo salar*) in offshore cages deployed off the Kefken Is-
land in the Western Black Sea between 1992 and 1994. The drastically loss of fish due to some technical failures such as using un-painted nets, which was torn of during a severe storm and all fish escaped into the cold waters of the Black Sea. This incidence may not be the only one, but a strong reason, among others, for the discouragement of farmers in the search of new species during that period. It is known that some companies continued small-scale operations for new candidate species, including Black Sea turbot (Kalkan), however, these were not reflected to the sales records until 2012. The price imbalances in the market put farmers into financial distress and bottlenecks were experienced in cash flow by the early 2010s. The decrease in prices probably due to the increased production volumes of the main key species, triggered the search for alternative species in order to provide product diversity in the market. Finally, the production of alternative species has been revived in the Aegean Sea by 2012, with meagre (Argyrosomus regius), sciaena sp., pink dentex (Dentex gibbosus), shi drum (Umbrina cirrosa), red porgy (Pagrus pagrus), common dentex (Dentex dentex), blue spotted seabream (Pagrus coeruleostictus), red-banded seabream (Pagrus auriga) and sharsnout seabream (Diplodus puntazzo). Around 500 tons of porgies and 1.000 tons of sciaena sp. were harvested as alternative species in 2012, which was followed by over 100 tons of Red porgy and Common dentex in 2014, Pink dentex, Shi drum and Bluespotted seabream in 2017. The production volumes for the Redbanded seabream and Sharsnout seabream remained below 100 tons, ranging from 1 to 66 tons between 2017-2018, and from 2 to 59 tons between 2014 and 2016, respectively. Apart from these, the Meagre shifted forward with increasing production volumes from around 3.000 tons to nearly 6.000 tons between the years 2014 and 2021, according to the statistical data provided by the Food and Agriculture Organization of the United Nations. With the introduction of Atlantic Bluefin tuna in 2004, the annual harvest increased gradually from around 400 tons to over 1.000 tons in 2014, and to around 5.000 tons in 2021.

In conclusion, the aquaculture activities that was initiated with carp farming in the 1950s in the Turkish fish farming business, achieved a significant success as the biggest producer for seabream, seabass and trout in Europe, and among top producers in the world. However, fluctuations in market prices or changes of consumer demands forces farmers to expand their product range for both domestic and international markets. Introducing new candidate species could be a novel marketing strategy with diverse products, alternative to the already-available fish species.
References


