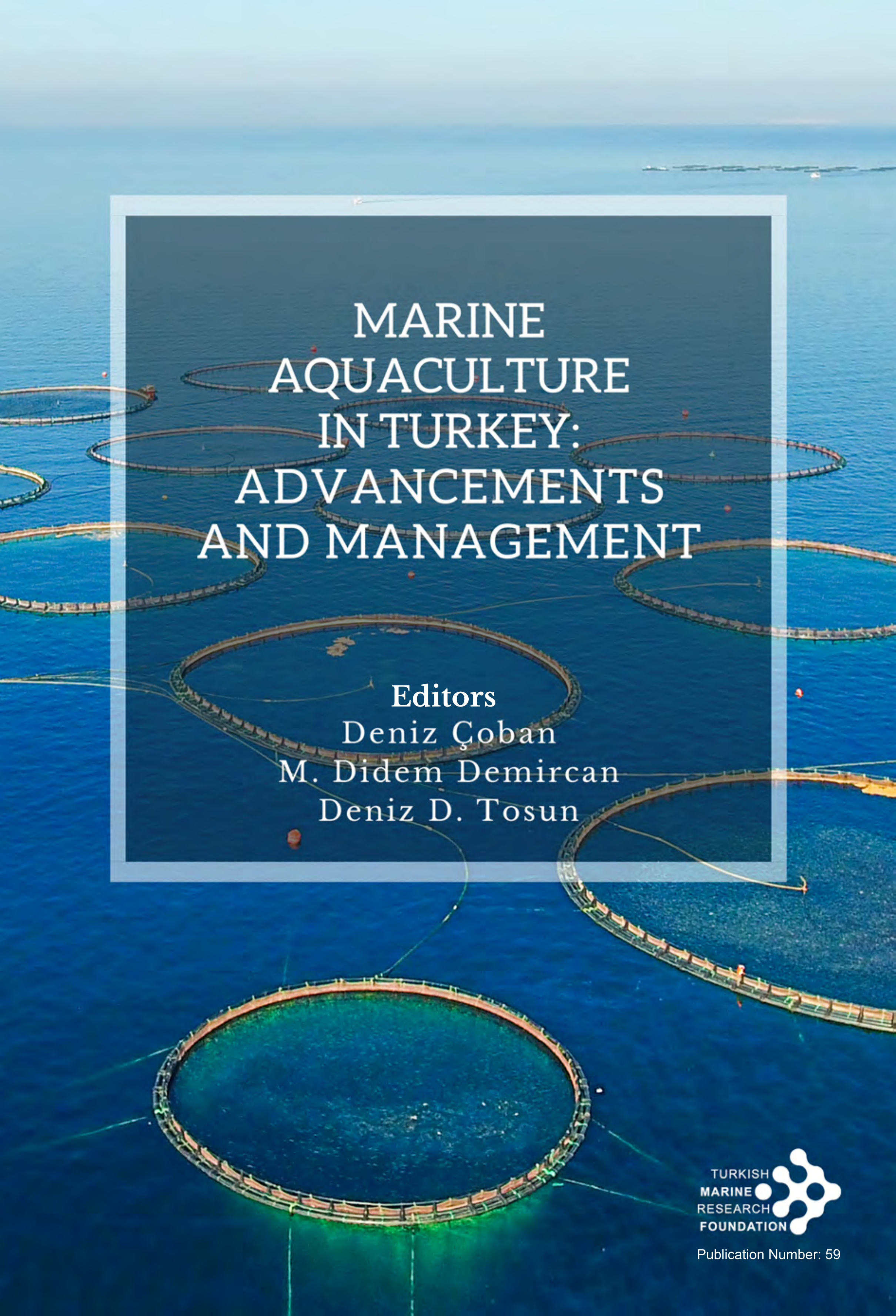

MARINE AQUACULTURE IN TURKEY: ADVANCEMENTS AND MANAGEMENT

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Foreword

This book contains up-to-date information about marine aquaculture that has been developing rapidly in Turkey since the last decade. The important aspect, however, is to make it sustainable without considering management and protection of the stocks as well. This aspect is considered through new production techniques that have succeeded for new species and new market demands.

Each chapter in the book presents current situations, new ideas, specific species, trends of consumption, added-value products, blue growth and economy, sectoral milestones of aquaculture, and several issues.

Turkey has been a focus for two reasons. First, fish farming is a necessity for Turkey because it produces healthy protein for the population and it provides economic security to millions of people who are working in the industry. The second one is because of the long coastline of Turkey, which results in a competitive aquaculture scene, signaling towards the need for Turkey to be more ambitious in investing in new strategies and species, such as the Trout in the Black Sea. However, whilst considering aquaculture from these scopes, we must be careful in considering the challenges of aquaculture and sustainability.

One of the threats for the aquaculture industry has been in the past few years and will be a massive obstacle in the future is climate change. This will have serious implications for the fisheries and aquaculture sector, and thereby for food security and the livelihoods of millions of people. Thus, this book also attempts to suggest ways to make the sector collaborate with the environment that it is working with.

Finally, I would like to thank all authors who contributed to this book with their effort, namely their time and extent of knowledge, as well as their continuous passion for sustainable aquaculture all around Turkey. Additionally, I would like to send my gratitude to the editors who have spent hours revising and editing works to make a high-quality scientific book.

Prof. Dr. Bayram ÖZTÜRK
Head of Turkish Marine Research Foundation

Preface

Providing food and livelihood to growing world population is among the most important policies of countries. The United Nations, which helps countries form national policies and provide advisory decisions, has determined 17 items. These items do not leave anyone behind, stipulate living in a sustainable life cycle, and include unifying developmental goals. The United Nations declared achieving “Zero Hunger” as the second goal. Here, the United Nations emphasized that it is essential for all people to access safe and indigenous food; and highlighted the importance of protecting food production for agricultural purposes and the ecosystem with small-scale producers while achieving this goal. Similarly, in the “Blue Growth” initiative, founded by the European Commission in 2012, business and food creation using oceans and seas were brought up. They stated that aquaculture came to the fore.

As in the whole world, nutrition and subsistence economy come to the fore in Turkey. Aquaculture, which began in Turkey in the late 1970s in inland waters and marine in the mid-1980s, has become a giant sector. In its first years, the industry was in bad condition, it was nowhere near the concept of environmental consciousness, and it had adopted an approach solely based on making money. With the knowledge that polluting was adversely affecting the production as well as the ecosystem, the industry presently produces based on the principals of animal welfare, sustainable environment and food safety, and trades fresh, frozen, and processed products to almost all countries around the world.

This book aims to show the long way aquaculture in Turkey has come since the former book which was published by TÜDAV in 2007, and provide an overview of what needs to be done next. In sections, issues such as aquaculture policies, production of existing and new species, their diseases, nutrition, environmental effects of aquaculture, certification, and occupational health were addressed. Though some of the issues mentioned here are new for the aquaculture sector in Turkey and some are new in the world, they are important issues. This book aimed to cover all topics of aquaculture.

I want to express my appreciations to all the authors who devotedly wrote sections of the book during challenging pandemic and earthquake disasters; I would like to express my gratitude to my editors who worked with me in the editing process. I want to thank Dr. M. Arda Tonay, who conducted technical edits, and Ms. Zeynep Gülenç for her continuous support during the publication stage. Finally, I would like to express my respect and gratitude to Prof. Dr. Bayram Öztürk, the founder and president of TÜDAV who brought forth the idea of creating this book and offered me the head editorship of the book while working together in an aquaculture facility in Mersin.

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Aydın, Turkey

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Aquaculture legislation and management of Turkey

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Current status of aquaculture in the world

Aquaculture is a sector that continues to grow worldwide. Aquaculture production in the world has increased almost 12 fold in the last 30 years, with an average annual increase of 8.8%. The aquaculture sector has been reported by FAO as the fastest and most continuously growing sector amongst all food sectors. In parallel with developing fishing technology and worldwide subsidies, fishing production increased until the 1990s, then stabilized and has remained steady since. Unlike fisheries, there was no significant development in aquaculture production until the 1990s. After 1990, aquaculture production has grown rapidly (Table 1).

Table 1. World fisheries capture and aquaculture production (FAO 2020a)

Years	Capture production (million metric tons)			Aquaculture production (million metric tons)			Total production (million metric tons)
	Marine	Inland	Total	Marine	Inland	Total	
1990	77.73	6.44	84.17	5.43	7.66	13.09	97.25
1995	84.70	7.29	91.99	10.80	13.58	24.38	116.37
2000	84.78	8.59	93.37	13.73	18.69	32.42	125.79
2005	83.02	9.43	92.45	18.36	25.96	44.32	136.76
2010	76.26	10.86	87.12	21.86	35.95	57.81	144.93
2015	80.46	11.15	91.61	27.04	45.77	72.81	164.42
2016	78.26	11.37	89.63	28.58	47.98	76.56	166.19
2017	81.21	11.91	93.12	30.06	49.55	79.61	172.73
2018	84.41	12.02	96.43	30.78	51.34	82.12	178.55

Note: Production figures do not include aquatic plants and marine mammals.

While fishing production has remained stable since 90 ies, aquaculture production has shown the fastest increase in all food production in the last 10 years. Moreover, in addition to the increase in the quantity of aquaculture production, the average financial values of aquaculture products have also increased. This provides an additional acceleration to the aquaculture sector.

World fisheries and aquaculture production was 178.6 million metric tons in 2018, of which 96.4 million metric tons were obtained from fisheries capture (54%) and 82.1 million metric tons were obtained from aquaculture (46%). According to the estimations made based on statistical data, it is foreseen that world aquaculture production and fisheries capture production will be equalized by 2030. According to 2018 data in world fisheries and aquaculture production, China ranks first with 47.56 million metric tons, India ranks second with 7.07 million metric tons and Indonesia ranks third 5.45 million metric tons in aquaculture production. In fisheries capture; China ranks first with 14.65 million metric tons, Indonesia ranks second with 7.22 million metric tons, Peru ranks third with 7.17 million metric tons. Fisheries and aquaculture production have important places in the trade and economy of many countries. While Far East Asian countries such as India, Indonesia, Vietnam, Bangladesh and mainly China are the main producers, the US, Japan and the European Union (EU) are the most important importer markets.

Current status of aquaculture in Turkey

The geographic location and existing natural resources of Turkey provide suitable opportunities for fisheries and aquaculture production. Turkey is surrounded by the Black Sea, Aegean and The Mediterranean Seas and surrounds the Marmara Sea, an interior sea, each having specific characteristics and different production potentials. There are 33 river systems 26 of which are major, 200 natural lakes, 822 dam lakes and 507 ponds (DGSHW 2019).

In 1986, the government of Turkey reported for the first time a total of 3,075 metric tons of aquaculture production. 3,040 metric tons of trout were produced inland, while 35 metric tons of seabass and gilt-head seabream were produced in marine areas.

In 1988, total aquaculture production was 4,100 metric tons. Aquaculture production rose to 21.6 thousand metric tons in 1995, and reached 61.2 thousand metric tons in 2002. In 2003, the aquaculture sector was, for the first time, included in the scope of financial supports. Subsequently, aquaculture production has increased annually and it rose to 167.1 thousand metric tons in 2010, and reached 314.5 thousand metric tons in 2018, and 373.4 thousand metric tons in 2019. From 2002 to 2019, aquaculture production grew by more than 500%.

In the second half of the 80ies when aquaculture started in Turkey, trout production was undertaken by relatively small family based facilities established on rivers. Cage culture in dam lakes gained importance as aquaculture production gradually increased. During this period, marine aquaculture activities also rapidly developed due to increasing technical expertise in the sector and developments in feed and cage technologies. In 2019, marine aquaculture production reached more than twice the level of inland aquaculture production. Total aquaculture production was 373.4 thousand metric tons in 2019, and 256.9 thousand metric tons (68.82%) of which were provided from the marine aquaculture facilities and 116.4 thousand metric tons (31.18%) of which were provided from the inland aquaculture facilities (Table 2).

Table 2. Marine and inland aquaculture production in Turkey (TSI 2020; DGFA 2020a)

Years	Aquaculture Production				
	Marine (metric tons)	**Share of total (%)**	**Inland (metric tons)**	**Share of total (%)**	**Total (metric tons)**
1986	35	1.13	3,040	98.87	3,075
1990	1,545	26.72	4,237	73.28	5,782
1995	8,494	39.31	13,113	60.69	21,607
2000	35,646	45.10	43,385	54.90	79,031
2005	69,673	58.90	48,604	41.10	118,277
2010	88,573	53.00	78,568	47.00	167,141
2015	138,879	57.80	101,455	42.20	240,334
2018	209,370	66.60	105,167	33.40	314,537
2019	256,930	68.82	116,426	31.18	373,356

Although great importance and government support has been given to the cultivation of new species in our country recently, trout, gilt-head seabream and seabass are still the most cultivated species. In the period of 2010-2019, trout aquaculture production in inland waters increased until 2013. Production decreased slightly in 2014 and has been steady at the level of 101 thousand metric tons per year in 2015-2016. Trout aquaculture production in inland waters reached 104.9 thousand metric tons in 2018, 116.1 thousand metric tons in 2019. Marine trout aquaculture production is undertaken in the Black Sea. While it was 7.1 thousand metric tons in 2010 in the Black Sea, it reached 9.7 thousand metric tons in 2019. Due to increasing demand for the Turkish salmon, which has been favored in the international market in recent years, an increase in the production of trout is expected in the Black Sea.

Gilthead seabream and seabass production continued to increase in the period of 2010-2019. Gilt-head seabream aquaculture production, which was 28.2 thousand metric tons in 2010, reached 99.7 thousand metric tons in 2019 with an increase of 254% and seabass aquaculture production, which was 50.8 thousand metric tons in 2010 reached 137.4 thousand metric tons in 2019 with an increase of 171% (Figure 1).

The Ministry of Agriculture and Forestry via aquaculture supports implemented since 2003 aims to contribute to the national economy by increasing the productivity, diversity and quality in aquaculture production and to ensure the sustainable use of the existing water resources in Turkey.

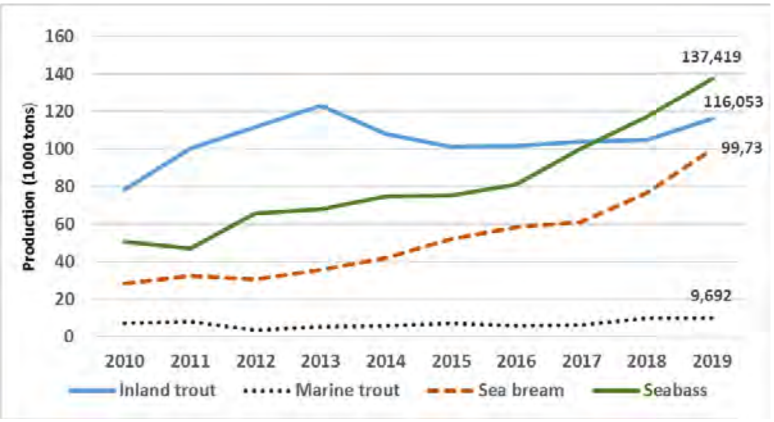


Figure 1. Change in production of the most cultivated species (TSI 2020; DGFA 2020a)

In 2003, aquaculture subsidies began in order to support production of gilt-head seabream, seabass and trout species. These subsides continued to be expanded and implemented in line with developments in the sector. Among the subsidies that contribute to the development of the sector and aim to direct development as an alternative to support for direct production are "Fry" (between 2005 and 2012), "New Species," "Mussels," "Recirculating Aquaculture Systems," "Trout Over a Kilogram" "Fish Recognition Card" and "Trout Broodstocks Free of Diseases in Hatcheries". Within the scope of aquaculture supports implemented since 2003, approximately 1.35 TRY billion, which is approximately $743 million in the current exchange rate, was paid to the producers engaged in aquaculture activities between 2003 and 2019. Thanks to these supports and technological developments, production has increased and the facilities have been modernized. The environmentally friendly production model has been adopted by moving the marine aquaculture facilities further from the coast (Figure 2). In this context, aquaculture production was 61 thousand metric tons in 2002, it increased by 510% in 2019 to 373.4 thousand metric tons and the share of aquaculture in total fisheries and aquaculture production increased from 9% in 2002 to 44.6% in 2019.

The Ministry of Agriculture and Forestry, gives direction to aquaculture in Turkey by supports that have been paid depending on production. Although the subsidy payment to seabass and gilt-head seabream was cut in 2016 in order to adapt to international trade rules, the continuation of the growth in this area is an important indicator that the aquaculture sector can stand on its own feet.

The Ministry of Agriculture and Forestry, General Directorate of Agricultural Reform has 50% grant support in Rural Development Supports. Within this scope, various tools and equipment for the aquaculture facilities and processing facilities during the installation stage and supporting aquaculture activities are provided as grants. In addition to these supports, Ziraat Bank and Agricultural Credit

Cooperatives provide investment and operating loans with much more suitable interest rates than usual market interest rates up to 10TRY million, to the entrepreneurs wishing to establish aquaculture facilities. Additionally, the Agriculture and Rural Development Support Institution provides 55-65% grants to aquaculture enterprises in 42 provinces within the scope of IPARD supports. Turkey ranks 19th in aquaculture in the world, according to 2018 data. In addition, Turkey ranked 2nd in aquaculture production of 2018 among the European Union countries (28 countries) (Table 3 and 4).

Figure 2. 2010 off-shore facility in the Aegean Sea (DGFA 2020b)

Table 3. Turkey's place in world fisheries capture and aquaculture production (FAO 2020a)

Years	In marine capture	In inland capture	In aquaculture	In total production
2011	Ranked 29th	Ranked 32nd	Ranked 23rd	Ranked 32nd
2012	Ranked 36th	Ranked 35th	Ranked 22nd	Ranked 31st
2013	Ranked 38th	Ranked 35th	Ranked 21st	Ranked 34th
2014	Ranked 43rd	Ranked 37th	Ranked 22nd	Ranked 39th
2015	Ranked 36th	Ranked 42nd	Ranked 22nd	Ranked 33rd
2016	Ranked 41st	Ranked 34th	Ranked 21st	Ranked 37th
2017	Ranked 42nd	Ranked 37th	Ranked 21st	Ranked 36th
2018	Ranked 44th	Ranked 40th	Ranked 19th	Ranked 36th

Table 4. Turkey's place among the European Union countries (28 countries) in fisheries capture and aquaculture production (FAO 2020a)

Years	In marine capture	In inland capture	In aquaculture	In total production
2011	Ranked 4th	Ranked 1st	Ranked 3rd	Ranked 4th
2012	Ranked 5th	Ranked 1st	Ranked 2nd	Ranked 3rd
2013	Ranked 5th	Ranked 1st	Ranked 1st	Ranked 5th
2014	Ranked 7th	Ranked 1st	Ranked 2nd	Ranked 5th
2015	Ranked 5th	Ranked 1st	Ranked 2nd	Ranked 5th
2016	Ranked 6th	Ranked 1st	Ranked 2nd	Ranked 5th
2017	Ranked 6th	Ranked 1st	Ranked 2nd	Ranked 5th
2018	Ranked 6th	Ranked 1st	Ranked 2nd	Ranked 5th

In Turkey, there was a significant increase in the export of fishery products in parallel with the increase in aquaculture production between 2002 and 2019. While the amount of fishery product exports in 2002 was 26.8 thousand metric tons and $ 96.7 million in value, according to 2019 data, the amount of fishery product exports reached 200.2 thousand metric tons and $ 1.03 billion in value. According to 2019 data obtained from the Turkish Statistical Institute, as monetary value, 68.6 % of the exported fishery products constituted seabass, gilt-head seabream and trout obtained through aquaculture, and also 80% of fishery exports were made to EU countries (TSI 2020; DGFA 2020a).

According to the records of the Ministry of Agriculture and Forestry, there are 2.127 aquaculture facilities in Turkey as of 2019. Of these, 434 operate in seas and 1.693 operate in inland waters. Mainly gilt-head seabream, seabass and rainbow trout have been produced in these facilities (Figure 3.).

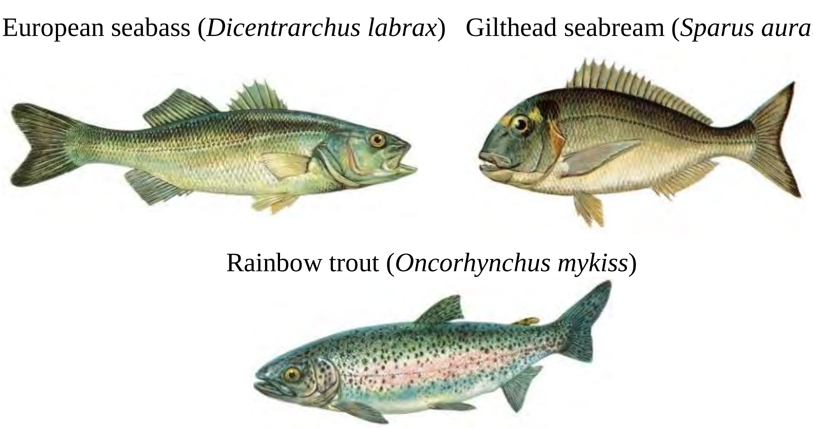


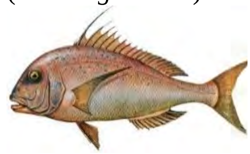
Figure 3. Most cultivated species of aquaculture in Turkey (DGFA 2020b)

In addition, large marine trout aquaculture, called as Black Sea Salmon or Turkish Salmon, which are grown to a certain size in inland waters and complete their growth process in cages in the Black Sea, have been carried out in recent years. Other marine aquaculture species consist of red porgy, porgies, pink dentex, common dentex, white grouper, sharpsnout seabream, shi drum, brown meagre, white seabream, sand steenbras, meagre, greater amberjack, turbot, shrimp, mussel and Black Sea trout (Figure 4).

Meagre
(*Argyrosomus regius*)

Common dentex
(*Dentex dentex*)

Pink dentex
(*Dentex gibbosus*)



Shi drum
(*Umbrina cirrosa*)

Sharpsnout seabream
(*Diplodus puntazzo*)

Porgies (*Sparidae*)

Mediterranean mussels
(*Mytilus galloprovincialis*)

Figure 4. Other marine aquaculture species in Turkey (DGFA 2020b)

European Union harmonization studies

Turkey's first step through the EU was the application for accession in 1959. After 40 years from this date, Turkey's candidateship was officially announced in the EU Summit of Heads and State Governments, which was held in Helsinki on 10-11 December 1999 and it was stated that Turkey would have the same status as the other candidate countries. In the Brussels Summit, which was held on 17 December 2004, it was stated that the negotiations between Turkey and EU could start. Finally, Negotiation Framework Document was accepted and the Accession Negotiations were officially started as of 3 October 2005.

Accession negotiations to EU are carried out in 35 chapters and negotiations on fisheries are carried out under Chapter 13 Fisheries. In the screening process, which means analytical examination of the EU acquis, candidate countries are informed in detail about the acquis and the EU determines the extent to which the national legislation of the candidate country is in line with the EU acquis. The explanatory screening of the fisheries chapter was made on 24 February 2006, and the detailed screening was made on 31 March 2006. However, the screening report was not prepared by the EU Commission and submitted to the approval of the EU Council. The reason for this is that Turkey places a reservation to the recognition of the Greek Cypriot administration so chapter 13 is currently closed.

Developments in aquaculture within the framework of European Union harmonization

An important step has been achieved in CFP reform by the Common Fisheries Policy Regulation dated 11 December 2013 and numbered 1380/2013 which was published within the scope of the Common Fisheries Policy Reform.

Regulation No. 1380/2013 addresses the protection and management of marine biological resources, as well as freshwater biological resources and market and fiscal measures. Common Fisheries Policy targets have been expanded compared to the 2002 reform and the targets regarding aquaculture have been included for the first time in CFPs targets. The targets for aquaculture are as follows;

- Ensuring long-term sustainability of fisheries and aquaculture activities consistent with economic, social and job opportunities
- Providing the necessary conditions for economically appropriate and competitive hunting, processing industry and activities on land fishing,
- Supporting the development of aquaculture.

Ten years before the aquaculture objectives of Common Fisheries policy published in 2013 in our country, planning and legislative studies to support aquaculture, ensure sustainable production and develop the sector have been made by the Ministry of Agriculture and Forestry and they are still being continued and developed.

Another EU ruling on aquaculture is Council Regulation (EC) No 708/2007 concerning use of alien and locally absent species in aquaculture. This Regulation has been published to establish a framework to govern aquaculture practices in relation to alien and locally absent species to assess and minimize the possible impact of these and any associated non-target species on aquatic habitats and in this manner contribute to the sustainable development of the sector. There is a legal basis in Fisheries Law No. 1380 to manage the issues in Regulation 708/2007 with secondary legislation in Turkish legislation system.

The protection and welfare of farm animals have been on the agenda of societies frequently in recent years, and accordingly, regulations regarding this have been made in the legal systems of the states. *"Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes"* was published by the European Union on 20 July 1998 for this purpose. The parts of the Council directive related to aquaculture have been adapted into national legislation with the Circular on the Welfare of Fish Farmed Fish (2018/3) published by the Ministry of Agriculture and Forestry. As a result, aquaculture is relatively much less regulated than fisheries in EU, and when a limited number of aquaculture regulations in EU are analyzed, it can be seen that these are mostly technical rules, and can be transferred to the Turkish legal system with secondary legislation if needed.

The activities within the scope of EU administrative and financial cooperation

The European Union has been assisting candidate countries with various support tools and programs to overcome the technical and financial difficulties that will arise during the harmonization studies. The Ministry of Agriculture and Forestry benefited from these aids for fisheries and aquaculture projects.

The Twinning Project called "Legal and Institutional Alignment to The EU Acquis of Turkish Fisheries Sector" was completed in July 2007 in order to sustainably increase the contribution of the fisheries sector to the national economy and prepare the fisheries sector and Turkey for participation to European Union. With this project, studies on legislation, which are necessary in terms of compliance to EU Acquis and other institutional practices, were examined and the human resources and institutional capacity needed in this field were increased.

In harmony with the renewed Common Fisheries Policy (CFP), with the aim of legally and technically strengthening the Turkish fisheries management system, another twinning project in partnership with Turkey and Spain, called "Reinforcement of Turkish Fisheries Management System Project," was started on 8 March 2017 and was completed on 8 March 2018. The aim of this project was to develop the legal and technical capacity of the monitoring, control and surveillance for fisheries activities, to create more deterrent measures to prevent illegal fishing, to support sustainable fisheries management and to develop a national fisheries data collection system. In addition, EU practices on fisheries were examined in Spain that is a member country of EU, and trainings on EU practices were provided to Turkish experts by foreign experts.

The Instrument for Pre-Accession Assistance (IPA) created by the EU for candidate and potential candidate countries is another program carried out within the scope of EU Financial Cooperation. The Rural Development component of the Instrument for Pre-Accession Assistance (IPA) addresses the establishment and modernization of aquaculture facilities in inland waters and establishment and modernization of fisheries and aquaculture processing facilities. These investments are supported with a view to implement the acquis on the relevant policies in the EU accession process and to be able to contribute to Turkey's preparation process to EU.

Mission and vision of the directorate general of fisheries and aquaculture

In the period of 1923-1971, duties and services related to fisheries were carried out by the Ministry of Economy, the Ministry of Transport, the Ministry of Finance and the Ministry of Economy and Trade. After the Fisheries Law came into force in 1971, these duties and services related to fisheries were carried out under the Ministry of Agriculture.

After the Fisheries Law came into force, the first Fisheries Department was established in 1972 and then General Directorate of Fisheries was established. In 1982, General Directorate of Fisheries was closed and turned into Fisheries Department and this department was closed in 1983. After the reorganization of Ministry in 1985, duties and services related to fisheries and aquaculture were distributed to several general directorates of Ministry. After this change, the duties and services related to aquaculture were transferred to the Directorate General of Project Implementation (DGPI), the duties and services related to control of fisheries were moved to the Directorate General of Protection and Control (DGPC), the duties and services related to fisheries cooperatives were moved to the Directorate General of Organization and Supporting (DGOS) and the duties and services related to fisheries research were distributed to the Directorate General of Agricultural Research (DGAR).

The General Directorate of Fisheries and Aquaculture (DGFA) has been reestablished within the Ministry of Food, Agriculture and Livestock (MFAL), which was established in 2011 with the reorganizing of the Ministry of Agriculture and Rural Affairs. General Directorate of Agricultural Research (DGAR) has been renamed as the General Directorate of Agricultural Research and Policies. While Directorate General of Organization and Supporting has been closed, duties related to fisheries cooperatives have been given to the newly established General Directorate of Agricultural Reform.

With the Presidential Decree No. 1 on the Presidential Organization, the Ministry was reorganized in 2018 and the Ministry was renamed as the Ministry of Agriculture and Forestry (MAF). The structure and duties of the General Directorate of Fisheries and Aquaculture, the General Directorate of Agricultural Research and Policies and the General Directorate of Agricultural Reform have not changed. The duties of the Directorate General of Fisheries and Aquaculture are stated in Article 416 of the Presidential Decree numbered 1.

The mission of Directorate General of Fisheries and Aquaculture is to operate the resources and habitats in a sustainable manner by considering the balance between protection and use of fisheries. In addition, it is to improve aquaculture in marine and inland waters.

The vision of Directorate General of Fisheries and Aquaculture is to be an authorized institution that directs the fisheries and aquaculture sector with a sense of responsibility, to increase the income and welfare of our producers and to ensure the security of supply in fisheries and aquaculture.

Turkey continues its sectoral growth in accordance with the "Responsible Fisheries Principles" published by FAO. Together with the Blue Growth, which is closely monitored in the world and in our country, sustainable aquaculture is among the priorities of our Ministry's mission. In order to continue the aquaculture activities of our country within the framework of blue growth and sustainable aquaculture; activities related to the protection, development and regulation of aquaculture areas are of great importance for the Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture.

Aquaculture legislation

The first regulation on fisheries in Turkey was made with the Zabıtai Saydiye Ordinance dated 1882. This Regulation, which is at the level of law, remained in force until the Fisheries Law was enacted in 1971. This regulation predominantly determined the fishing rules. The work and operations related to aquaculture are carried out within the framework of the Law on Fisheries No.1380, provisional article 12 of the law No.6111 and the Law on Environment No.2872 and the related secondary legislation, which are enacted according to the laws mentioned above. Legislation has been implemented effectively in order to make aquaculture activities more efficient, to ensure sustainability, to protect the environment, to make investments in a planned way and to ensure effective inspection during production.

Legislation on aquaculture is as follows;

- Fisheries Law No. 1380,
- Provisional Article 12 of the Law no. 6111, (The effective period expired on 1/1/2020. The issues specified in the article have been added to the Fisheries Law No. 1380 and entered into force on 1/1/2020.)
- Environmental Law No. 2872,
- Aquaculture Regulation, published in the official gazette dated 29/06/2004 and numbered 25507,

- Leasing Regulation in aquaculture and fisheries production, published in the Official Gazette dated October 31, 2020 and numbered 31290,
- Circular on the implementing principles with regard to the Regulation on Aquaculture (2006/1)
- Circular on the implementing principles with regard to the Leasing Regulation on fishing right in seas and inland waters and right to use water and water area needed in aquaculture investments (2011/9),
- Circular on the implementing principles on the production of bivalve molluscs (2010/1),
- Circular of welfare of fish on aquaculture (2018/3),
- Notification on supporting aquaculture (Notification No. 2020/39) (The notification has been issued for supporting aquaculture facilities for the year of 2020. If the supports continue, it is renewed annually),
- Notification on support for trout broodstocks free of diseases in hatcheries of aquaculture (Notification No. 2020/40) (The notification has been issued for supporting aquaculture facilities for the year of 2020. If the supports continue, it is renewed annually).

Regulations and amendments under the aquaculture legislation

Fisheries law no. 1380

The Fisheries Law contains provisions on the protection, production and control of fisheries and aquaculture. The main provisions on aquaculture are also included in this Law.

The regulations regarding aquaculture in the Fisheries Law are as follows:

Article 4 of the fisheries law titled "Leasing of production area belonging to public legal entities": It regulates the issues related to the leasing of the water and water areas needed by aquaculture facilities. Since some problems were encountered in the implementation of the current article 4, a legal regulation was enacted between 2011 and 2020 with the provisional article 12 of the Law No. 6111, which is given in detail below.

Article 13 of the law titled "Aquaculture": It regulates the permits for the establishment of aquaculture facilities and the principles and procedures regarding aquaculture. With the amendment made in the article in 2003, a legal basis was established to regulate with secondary regulation the principles and procedures related to aquaculture in line with the needs of the sector.

Article 33 of the law titled "Protection and Control": It regulates the issues related to the control and inspection of aquaculture facilities.
Article 36 of the law titled "Penalties": It regulates the sanctions if acts against the rules are committed. The administrative fines and other administrative measures to be applied in case of violation of rules have been updated with the amendments made in 2003 and 2019 in this article. Especially on unauthorized aquaculture facilities have been enacted deterrent fines with the amendment made in 2019. If the irregularity is not resolved by the owners of aquaculture facilities within the periods given by Ministry, a penalty for the closure of the facilities has been enacted.

Provisional article 12 of law no. 6111: The law, which was implemented between 2011 and 2020 is a temporary regulation which regulates the leasing of water and water areas needed for aquaculture investments. Within the framework of *"Leasing Regulation on fishing right in seas and inland waters and right to use water needed in aquaculture investments"* prepared on the basis of this article of law, procedures and principles regarding leasing were determined. Prior to the provisional article 12 of law no. 6111 enacted in 2011, the leasing of the water and water areas needed in aquaculture were being fulfilled by the Special Provincial Administrations and there were problems due to different practices and high rental charges. The authority to lease water and water areas needed for aquaculture investments was given to our Ministry temporarily with the regulation made with the provisional article 12 of the Law No. 6111 for the solution of the problem. In order to avoid any problems in implementation and by taking into consideration the benefit provided by the article provision, the effective period of this provisional regulation extended three times and the last extension date expired on 1/1/2020. With the amendment made to the Fisheries Law adopted in the Turkish Grand National Assembly on 6 November 2019, a permanent solution for problems was provided by authorizing the Ministry to carry out leasing transactions. After 1/1/2020, the provisional article 12 of Law No. 6111 was not needed to be extended after the enforcement period expired.

Environmental law no. 2872

Environmental Law No. 2872 has been enacted in order to protect the environment, which is the common asset of all living things, in line with the principles of sustainable development and a healthy environment. In subparagraph h of article 9 titled "Environmental Protection" of the Law, there is a regulation regarding where marine fish farms are prohibited to establish. *"Environmental Management Regulation of Fish Farms Operating in the Seas"*, were enacted based on Environmental Law No. 2872.

Aquaculture Regulation, published in the Official Gazette No. 25507 dated 29.06.2004: The Aquaculture Regulation, which was prepared in accordance with Article 13 of the Fisheries Law No. 1380, regulating the procedures and principles regarding aquaculture, has entered into force by being published in the Official Gazette dated 29.06.2004 and numbered 25507. This regulation is intended to use the water resources potential of our country efficiently, to ensure sustainability in aquaculture, to protect the environment and, to make investments in aquaculture in a planned manner for providing quality and safe food and to ensure effective inspection during production. The aquaculture regulation was amended in 2005, 2007, 2009 and 2020, due to the developing and changing conditions. After the amendment to the Fisheries Law dated 6/11/2019, work on the necessary amendments to the aquaculture regulation has been ongoing.

Circular on the implementing principles with regard to the Regulation on Aquaculture (2006/1): The circular on implementing principles dated 28/12/2004 and numbered 18362 (2004/1) was written based on the article 24 of the Aquaculture Regulation. It was created to explain the application procedures and principles of the aquaculture regulation. Some articles of this Circular were revised with Circular numbered 2006/1 in line with the developments and needs in the sector.

Leasing Regulation in aquaculture and fisheries production, published in the Official Gazette dated October 31, 2020 and numbered 31290:

Circular on the implementing principles with regard to the Leasing Regulation on fishing right in seas and inland waters and right to use water and water area needed in aquaculture investments (2011/9):
In order to ensure the efficient use of the water resources of our country and the sustainability of aquaculture activities, the Leasing Regulation and the related implementing circular which is based on the Leasing Regulation, were issued to regulate the procedures and principles regarding fishing right in seas and inland waters, the right to use water and the water area needed for aquaculture investments.

With this regulation, in metropolitan provinces revenues from leasing were assigned to the Ministry of Treasury and Finance. Since the amendment made in the Fisheries Law on 6 November in 2019, these revenues have been included in the Investment Monitoring and Coordinating Presidencies in metropolitan cities. In provinces having the Special Provincial Administrations, the lease revenues are assigned to the Special Provincial Administrations. The lease of water and water areas and the lease of the right to fishing in marine and inland waters have been carried out by the Provincial Directorate of Agriculture and Forestry on behalf of the Ministry of Agriculture and Forestry.

In order to determine leasing prices, an important criterion is the development level of the regions of the country which were formerly evaluated by the abolished State Planning Organization (SPO), which is now called Strategy and Budget Directorate Presidency of Turkish Republic. These practices have ensured a fair lease across the country, eliminated the imbalance between regions in rental duration and prices, encouraged enterprises that used modern technology and environmentally friendly production, and encouraged investments in rural areas.

Circular on the implementation principles for the aquaculture of bivalve molluscs (2010/1): This circular has been prepared to clarify the bivalve mollusc aquaculture which will be determined by the Central Organization of the Ministry according to Aquaculture Regulation and to develop unified practices (Figure 5). In addition, there is an implementation instruction in the legislation of the Directorate General of Food and Control, under the Ministry of Agriculture and Forestry called "Implementation Instruction on Determination, Classification, Opening and Closing of Product Intake and Sampling Collection of Bivalve Mollusc Production Areas Obtained from Fishing and Aquaculture." In order to meet the hygiene requirements specified in Chapter 11 of the Regulation on Special Hygiene Rules for Animal Foods, the procedures and principles for classification and monitoring of production areas, opening and closure of product intake of bivalve molluscs obtained through fishing and aquaculture are set in this instruction.

Circular on welfare of fish in aquaculture (2018/3): Based on paragraph (j) of Article 21 of the Aquaculture Regulation; The Circular on the Welfare of Fish in Aquaculture" was enacted to ensure the welfare of the fish cultivated for food production and other purposes in terms of breeding and care. This circular aims to determine the minimum standards of rearing, care and welfare of fish grown for food production and other purposes taking into account general biological characteristics and to harmonize the national regulation with the European Union Council Directive 98/58/EC on concerning the protection of animals kept for farming purposes.

Notification on supporting aquaculture (Notification No. 2020/39): Detailed procedures and principles regarding the support to be given to the farm owners who are engaged in aquaculture are regulated by this notification, within the scope of the agricultural support decision made in 2020, which is put into effect by the decision of the Presidency published annually. With this notification, changes are made according to the developing and changing production methods and needs every year, in the issues related to the aquaculture support to be made to farmers who have Aquaculture certificate approved by the Ministry and registered in the aquaculture registration system. Entrepreneurs who want to benefit from aquaculture support apply to the Provincial/District Directorates of Ministry where the aquaculture facility is located by preparing the documents specified in the notification. In accordance with the provisions of the Notification on Supporting Aquaculture, payment lists are prepared by evaluating the applications by the Provincial Directorates of Agriculture and Forestry and sent to the Directorate General of Fisheries and Aquaculture. Payment lists prepared after the controls made by the General Directorate are sent to the relevant units of the

Ministry of Agriculture and Forestry in order to make payments to aquaculture farmers. In this context, the aquaculture supports for 2020 are as follows (Table 5).

Figure 5. Mussel aquaculture facility (DGFA 2020b)

Table 5. Aquaculture Supports (PRT 2020)

<table>
<tr><th>Types of Aquaculture Supports</th><th>Support Amount (TRY/kg)</th><th>Support Limitation Per Facility</th></tr>
<tr><td>Trout production</td><td>0.75</td><td rowspan="6">Up to 350,000 kg (including 350,000 kg)</td></tr>
<tr><td>New species production</td><td>1.50</td></tr>
<tr><td>Recirculating aquaculture system production</td><td>1.50</td></tr>
<tr><td>Trout production over kilogram</td><td>1.50</td></tr>
<tr><td>Mussel Production</td><td>0.10</td></tr>
<tr><td>Carp Production</td><td>0.50</td></tr>
<tr><td>Aquaculture in soil ponds</td><td>1.00</td><td>Up to 30,000 kg (including 30,000 kg)</td></tr>
</table>

Notification on support for trout broodstock free of diseases in hatcheries of aquaculture (Notification No. 2020/40): The aim of this annual notification is to regulate the procedures and principles regarding brood stock support to the trout hatcheries producing eggs/fry free of diseases, within the scope of the agricultural support decisions made in 2020, which are put into effect by the decision of the Presidency (PRT 2020). Applicants must have an aquaculture hatchery certificate approved by the Ministry of Agriculture and Forestry and be registered in the aquaculture registration system. Support per disease-free brood stock trout was 60TRY for 2019. This support is limited to a maximum 10.000 brood stock per enterprise.

Developments and Turkey's perspective on sustainable marine aquaculture

Economic and environmental sustainability, integration and standardization are very important for the continuity of the aquaculture sector. In addition to achieving increased production, and developing value-added products, aquaculture sector and government also emphasizes marketing and consumer preferences.

In Turkey, aquaculture production started with 3 thousand metric tons in the middle of 1980s and reached 373.4 thousand metric tons as of 2019. In marine aquaculture, the sector has been trapped in two fish species, gilt-head seabream and seabass. Meager has just been starting to be preferred in the market. It is necessary to develop the cultivation of alternative species in aquaculture for the growth of the sector. Although important improvements have been recorded in the cultivation of alternative species, commercially intensive cultivation of new species is not at the desired point. One of the most important reasons for this is the insufficient market demand.

Within the scope of environmental sustainability in aquaculture in Turkey, site selection, feed quality and feed consumption (FCR) ratio, use of modern technology, integrated multi-trophic aquaculture models, stocking density and water quality (discharge criteria) criteria are taken into consideration for planning (Figure 6). Each cultivation activity has more or less an impact on the environment. The impact of aquaculture on the environment is of organic origin and compared to other sectors, the impact can be considered less and relatively easy to recycle.

When aquaculture facilities are allowed, they are subject to the Environmental Impact and Assessment (EIA) process and the relevant legislation. No aquaculture facility is permitted to operate without being approved for conformity to the EIA process. All kinds of measures have been taken to avoid not only environmental pollution but also visual pollution while the aquaculture facility is operating.

Based on article 13 of the Fisheries Law no. 1380, the regulation and circular on aquaculture ensure that all aquaculture facilities are planned to minimize their environmental impact. Regular inspections are carried out in aquaculture facilities by the Provincial Directorates of the Ministry of Agriculture and Forestry, and the production process is continuously controlled by water sampling.

Figure 6. An offshore facility in marine aquaculture in the Aegean Sea (DGFA 2020b)

As of 28/10/2020, for fish farms to be newly established in enclosed bays and gulfs near the shoreline in marine areas that are defined as sensitive areas the minimum distance from the shoreline has been changed to 1250 meters, the minimum depth has been changed to 40 meters. In addition, minimum 1000 meters distance obligation between fish farms has been introduced. In addition as of 28/10/2020, for fish farms to be newly established in the marine areas except for in enclosed bays and gulfs near the shore that are defined as sensitive areas, the obligations that are minimum distance of 500 meters from the shoreline, minimum 30 meters depth, minimum flow velocity of 0.1 meter / second and minimum 1000 meters distance between fish farms have been introduced. The environmental impacts of these aquaculture facilities are closely monitored within the framework of the *"Environmental Management Regulation of Fish Farms Operating in the Seas"*. Relocation of marine aquaculture facilities to offshore sites has set an example for Mediterranean countries.

Allocated zone for aquaculture

The first studies for determining aquaculture areas in the seas were initiated by the abolished Ministry of Agriculture and Rural Affairs, Bodrum Aquaculture Research Institute in 1988. A study, which was supported by the World Bank, titled "The Determination of Appropriate Areas for Aquaculture in the Turkish Coasts" was conducted and published as a 2 volume book (Elliott and partners 1996a). In addition, another scientific study, which was supported by the World Bank, on *"The Environmental Impact of Aquaculture in Turkey and Its Relationship with Tourism, Recreation and Special Protected Areas"* was conducted and published into a book (Elliott and partners 1996b). As a result of these studies, "Fisheries Production Zones" were determined and published in the

Official Gazette by General Directorate of Protection and Control, Ministry of Agriculture and Rural Affairs.

Aquaculture areas were approved by marking on the maps of 1/25.000 scaled Environmental Plans (1996, 1998, 2000 and 2005, 1/25.000 scaled Environmental Plans / Environmental Plan Revised Plans). The goal of this work was to identify areas where developing technology, tourism, terrestrial pollution loads, and field conflicts with other sectors would not be experienced and the environmental impacts of aquaculture would be minimized (2006-2008). Within the scope of this activity, onshore aquaculture facilities were moved to offshore areas where sustainable aquaculture could be done in accordance with the legislation (2008-2009).

In order to reach the production and export targets of 2023 and to strengthen the advantageous position of our country in marine aquaculture; the evaluation of new aquaculture production areas in Adana, Aydın, Artvin, Mersin, Sinop, Rize, Trabzon, Giresun and Ordu provinces have been completed and the investment process has begun by giving necessary permits in 2018-2019. As a result of an amendment made to the Fisheries Law, which was adopted by the Turkish Grand National Assembly on 6 November 2019, the new aquaculture regions will be determined by the Ministry of Agriculture and Forestry, by obtaining a positive opinion from the Ministry of Environment and Urbanization and the Ministry of Culture and Tourism. With this regulation, new aquaculture regions will be determined by taking into consideration environmental and tourism sensitivity and will be allocated to investors. In this way, investments in aquaculture will be guaranteed to continue.

In 2017, aquaculture was included in legislation creating the Organized Industrial Zone based on Agriculture. As a result, the first Specialized Aquaculture-Based Fisheries and Aquaculture Organized Industrial Zone based on Agriculture in Turkey was established in the 5^{th} and 6^{th} class agricultural lands in Karataş District of Adana Province which were not suitable for agricultural production and the process for investment was initiated (Figure 7). The goal of this project is to provide 16,500 metric tons of annual production. 1.6TRY billion investment and employment for 3,000 people are expected with this project. Installation of specialized organized industrial zones based on agriculture is also continued in Aydın province. If the process of the Specialized Aquaculture-Based Organized Industrial Zone is completed and opened for investment, it will be very important both in terms of being a first for our country and an example for the aquaculture countries in the world.

Feed

Feed expenditures constitute the biggest share in operating expenses in aquaculture. In the fish feed ration, providing the energy needed by the fish, there are macronutrients consisting of protein, fat and carbohydrates, micronutrients consisting of various vitamins and minerals and also additives. Research shows that tissue formation in fish is mediated by amino acids, which are the building blocks of proteins. The speed of this formation and the quality of the tissues are directly proportional to the raw materials used in the feed ration. The protein requirement in the feeds is provided by a high proportion of fishmeal, and energy is also provided by a high proportion of fish oil and this offers significant advantages in terms of digestibility, growth rate and feed conversion rate (FCR). Due to the rapid development of aquaculture sector in recent years, the demand on fish feed has increased significantly in Turkey. The increasing number and production capacities of aquaculture facilities and the increasing demand for fish feed has stimulated the development of the aquaculture feed industry. In 1999, aquaculture production was around 60,000 metric tons while fish feed production was 38,000 metric tons. 2015 figures show the dramatic growth of the aquaculture feed industry: in 2015 aquaculture production was 240,000 metric tons, while fish feed production was recorded as 375,000 metric tons. Between 1999 and 2016, while the aquaculture production increased by 4 times, fish feed production increased by 12 times (Emiroğlu *et al.* 2019).

Figure 7. Adana Province Specialized Aquaculture-Based Fisheries and Aquaculture Organized Industrial Zone (DGFA 2020b)

Aquaculture in Turkey tends to be dominated by carnivorous and marine fish, which causes greater needs for fishmeal to be used in fish feed. Fish, such as anchovy and sardines, which are the main raw material of the fish feed needed by the aquaculture sector, are mostly used in human nutrition in our country. This should be the right approach. For this reason, fish meal and fish oil are imported, since the fish meal and fish oil produced in our country cannot meet the needs of the aquaculture sector.

Today, there are 23 facilities engaged in fish feed production in Turkey. 70% of these enterprises produce fish feed up to 30,000 metric tons. It is expected that aquaculture production will reach 600,000 metric tons and fish feed production will reach 900,000 metric tons in 2023, considering the production amount forecast based on 20 years of production values between 1999-2019 and the new areas to be opened for aquaculture.

Innovative practices

Innovative practices and the use of high technology are encouraged in the aquaculture sector in Turkey. New developments, methods and technologies provided in the aquaculture field in the world are being followed and applied concurrently. It is a well-known fact that in order to increase the production in aquaculture, it is necessary to increase feed production as well as decrease feed-related costs due to feed waste. Thanks to technological developments, it is possible to produce fish feeds of the desired quality targeted for individual species. With the introduction of automatic feeding systems that respond quickly, it has been possible to determine the amount of feed, the number of feedings and to monitor feed intake rates to be given to the fish depending on the computer programs and the behaviour of fish monitored continuously through cameras. These techniques contribute greatly to environmentally and economically sustainable aquaculture by preventing the cost increase and pollution due to excessive and unnecessary feeding. The use fish farm feeding barges started in 2006 with the relocation of aquaculture facilities offshore. The barges consists of areas in different sizes according to the capacities of aquaculture facilities, such as the control room (the room where the feeding system is managed), the diver's room (the room where the diver materials are placed, and the divers dress or undress), the dormitory (especially for the divers to rest after the dive), the kitchen, the dining room, the toilet-bathroom, dirty and clean water tanks, fuel tank, generator room, material storage areas, ventilation room and feed silos (Figure 8). Operations such as starting and stopping feeding, determining the amount of feed to be given to the fish can be performed easily from the control rooms, via computer systems. Depending on the automatic feeding systems, the aquaculture cages are monitored continuously for 24 hours and according to the feed intake of the fish, feeding continues automatically or stops.

Thanks to developing technology, organic pollution caused by aquaculture is largely prevented by using modern techniques, automatic feeding systems and by planned and scheduled feeding and monitoring in marine aquaculture. With underwater probes in some automatic feeding systems, parameters such as water temperature, oxygen and flow rate can be monitored in real time. However, these systems are preferred by large enterprises because of their higher costs than other methods. With the amendment to the Fisheries Law No. 1380 made by the Turkish Grand National Assembly on 6 November 2019, In order to detect environmental effect of aquaculture facilities, Legal arrangements have been made to achieve real time monitoring of some physical and chemical water quality parameters (turbidity, oxygen, temperature, pH and salinity, etc.) of the aquaculture facilities that are above the capacity determined by the Ministry, through remote sensing systems and devices. Recirculating aquaculture systems have been used as a solution and encouraged by the Ministry of Agriculture and Forestry in recent years in cases where there is not enough water for large-scale production and water with regular and optimal temperature cannot be provided for the growth of the fish throughout the year.

Figure 8. Automatic feeding barge system and feeding system management room (DGFA 2020b)

Recirculating Aquaculture Systems are fully controlled aquaculture systems, where water quality and quantity are prepared according to the biological needs of the fish grown and water is used continuously by circulation through purification systems (Figure 9). Recirculating aquaculture systems have many advantages such as preventing escape of the grown products to the natural environment, minimal risk of being affected by diseases, more conversion of feed, higher efficiency in the unit area, freedom in choice of location, reduced risk of spreading disease factors and enabling egg, fry and serving size production throughout the year. High investment and operating costs and the need to work with an expert team are among the disadvantages. In light of the high investment and operating costs of these systems, and the many advantages that recirculating aquaculture offers, particularly to the environment, additional support payments are made by the Ministry of Agriculture and Forestry to the aquaculture facilities owner using these systems. As a result, we can provide a more profitable operation with recirculating aquaculture systems and aquaculture products will be regarded more positively by the public due to less water use and a more environmentally friendly production in recirculating aquaculture systems.

Figure 9. Recirculating Aquaculture System Facility (DGFA 2020b)

Integrated multi-trophic aquaculture systems

Integrated Multi-Trophic Systems, which are encouraged because of their ability to reduce the pressure and nutrient burden on the environment and simultaneous multiple species culture, have recently started to become widespread in the context of sustainable aquaculture in our country and in the world. Integrated Multi-Trophic Systems have contributed to sustainable aquaculture production by providing an environmental and economic advantage both by reducing the negative impact of organic wastes from aquaculture and increasing the production types and capacity of a limited product area.

In the world, the aquaculture of mussels and other bivalve species have been carried out in ropes in the opposite direction of the prevailing current in the seas, in order to reduce the wastes caused by the feed consumption of fish in aquaculture. Similarly, Integrated Multi-Trophic Systems where sea cucumber or sea urchins are grown at the sea bottom are becoming widespread and encouraged in order to reduce feed, etc. solid waste that is not consumed by the fish in the cages and accumulates under or around the sea bottom under the cages or waste from the aquaculture of mussels and other bivalve species. Aquaculture support is paid to aquaculture growers 1.50TRY per kg for new species, 0.10TRY per kg for mussels for 2019 within the scope of the supports administered by the Ministry of Agriculture and Forestry. Production up to 350 metric tons per facility is supported, and this amount increases up to 525,000TRY per year for an aquaculture facility producing new species and 35,000TRY per year in mussel aquaculture. Considering the growth of aquaculture in Turkey; the application of these aquaculture systems, where environmental impacts can be monitored, potential impacts are minimized and which can provide additional economic contribution to the producer will provide an important opportunity for sustainability and the blue growth economy that has been developing in recent years. In addition, the use and dissemination of such systems contributes to sustainable aquaculture production by supporting the development of environmentally compatible production techniques, one of the R & D activities of the aquaculture sector in our country.

Stocking Density:

The stocking density in aquaculture has generally varied according to the fish type, size and amount of dissolved oxygen in the water. The amount of dissolved oxygen is related to the temperature of the water. For example, the decrease in the amount of dissolved oxygen in the water in parallel with the increase of seawater temperature in June, July and August in the Black Sea is one of the biggest obstacles in front of aquaculture in this region. In order to ensure the continuity of fish welfare and fish health in accordance with experiences and scientific data, it is crucial that the stocking density and the selection of production pond/cage/tank models be suitable for the physical and ecological needs of grown fish. Therefore, the above-mentioned issues have been taken into consideration by the Ministry in the approval stages of aquaculture projects prepared by entrepreneurs. Regulations regarding the stocking density were made in the "Circular on Welfare of Fish in Aquaculture" prepared by the Ministry in line with the EU legislation.

Product Quality:

Aquaculture companies in Turkey have certification documents issued by many national and international quality management systems with the aim of improving quality and reliable products (Figure 10). Each of these certification documents issued by the national or international certification bodies includes the stages of sustainable aquaculture and quality fish standards, and the entire production process is continuously monitored in this way. 80% of the aquaculture products grown in our country is exported to European Union Countries. EU Countries do not buy products from companies that do not have international certification documents. None of the exported fisheries and aquaculture products have been returned to our country so far, due to health and quality problems.

In line with Turkey's 2023 export targets, together with the relevant institutions and exporters' associations, we participate in international fairs and other events organized in many countries in order to reach new markets in the world, and in order to ensure that aquaculture products are introduced and marketed to more countries. It has been observed in international fairs and other events that Turkish fish produced under advanced technology and hygiene conditions received intense interest and appreciation by visitors, in terms of both quality and taste.

Figure 10. International and national certification documents and emblems widely received by the aquaculture companies in our country

Thanks to the success of the harmonization with EU legislation on processed fish products and the aquaculture and processing industry's success with hygiene and quality, gilt-head seabream and seabass grown in our country have received international quality certificates and have been given numerous awards from international quality institutions (Figure 11). Laws, regulations, notifications and circulars have been updated and implemented effectively in order to make aquaculture activities more efficient, to ensure sustainability, to protect the environment, to realize investments in a planned manner and to ensure effective inspections during production.

Figure 11. International Superior Taste Awards in Turkey (ITQI 2017; 2018)

International member organizations

Natural dynamics of fisheries that are independent from physical boundaries in the ecosystem, shared stocks, international regulations and rules on aquaculture and fisheries require international cooperation. The Ministry of Agriculture and Forestry has cooperated with international organizations in order to share knowledge and experience with the international organizations to which our country belongs, to ensure sustainable production in the aquaculture sector, to develop standards in international platforms, to contribute to its sustainable development and to integrate with the world. In this context, the international organizations (DGEUFR 2020a, b) that our country cooperates with in the field of fisheries and aquaculture are listed below.

FAO (Food and Agriculture Organization): The Food and Agriculture Organization (FAO), which was established under the United Nations in 1945, is an international organization that operates on food and agriculture worldwide. The organization's purpose can be listed as helping to eliminate hunger, malnutrition, making agriculture, forestry and fisheries more productive and sustainable, reducing rural poverty, activating inclusive and effective agriculture and food systems, and increasing the resilience of sources of the livelihood against threats and crises. Ensuring sustainable development and use of fisheries and aquaculture resources in the long term are also among the Food and Agriculture Organization duties. FAO has 5 Regional Offices and 9 Sub-Regional Offices worldwide. Turkey has been a member of FAO since April 6, 1948. Our relations with FAO have been developing strongly in recent years. Turkey, rather than being only a beneficiary of FAO's technical capacity, has become a contributing country in terms of cooperation and financing.

ICCAT (International Commission for the Conservation of Atlantic Tunas): International Commission for The Conservation of Atlantic Tunas (ICCAT) was established by the United Nations Food and Agriculture Organization (FAO), to conserve the tuna and tuna-like fish species in the Atlantic Ocean and the Mediterranean and connected seas, based on the International Convention for the conservation of Atlantic tuna, which came into force in 1969. It is an international regional fisheries management organization currently composed of 52 contracting parties. Turkey became a member of ICCAT in 2003 with the Law No. 4859 dated May 22, 2003. The activities on swordfish and tuna fishing and aquaculture in the Mediterranean are carried out according to the rules set by ICCAT. The fishing, trade and aquaculture of these species, which are an important export element for Turkey, are carried out in accordance with the compulsory regulations introduced by ICCAT.

GFCM (General Fisheries Commission for the Mediterranean): The General Fisheries Commission for The Mediterranean (GFCM) was established on February 20, 1952 as a Regional Fisheries Management Organization (RFMO) according to Article 14 of the FAO Constitution. The main goal of GFCM is to ensure the good use, rational management, protection and development of marine resources, as well as sustainable development of fisheries in the Commission's field of activity Turkey became a member of GFCM in 1954. The GFCM has 24 members, consisting of 23 countries and the EU (Figure 12). Member States finance the Commission by contributing to the GFCM budget annually. Turkey holds an important place among the member states that provide financing. The General Fisheries Commission for The Mediterranean (GFCM) operates to protect thirty pelagic fish species of economic value.

CACFISH (Central Asian and Caucasus Regional Fisheries and Aquaculture Commission): The commission was established on 3 December 2010. Its headquarters is in Ankara. It has five members and our country became a member on 19 December 2011. Other member countries are Kyrgyzstan, Armenia, Tajikistan, and Azerbaijan. The Commission was established under the FAO Constitution in a framework of cooperation between Turkish Ministry of Agriculture and Forestry and the FAO Central Asia Sub-Regional Office. It has the goal of establishing a common mechanism for the sustainable use of water resources in Central Asia and the Caucasus, ensuring fisheries management based on scientific data, managing and planning of aquaculture and sharing experiences in this field. Commission mainly serves for transferring Turkey's fisheries and aquaculture capacity to other member countries. The highest financial contribution to the budget of the commission is made by our country.

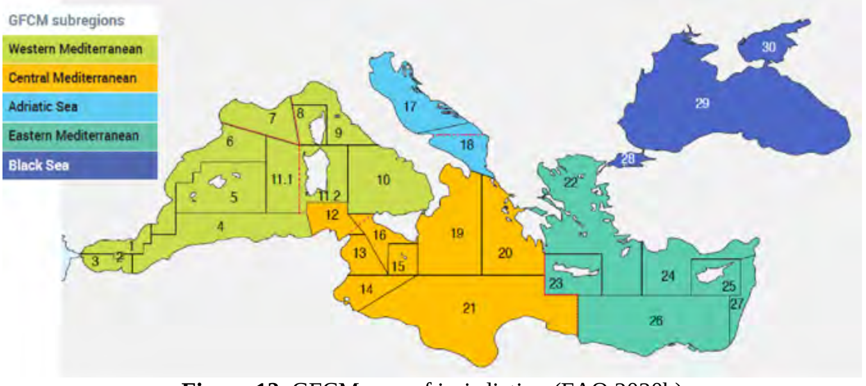


Figure 12. GFCM area of jurisdiction (FAO 2020b)

EUROFISH (International Organization for the Development of Fisheries in Central and Eastern Europe): The EUROFISH was established in 2002 by the United Nations Food and Agriculture Organization. EUROFISH member countries are Albania, Croatia, Denmark, Estonia, Italy, Latvia, Lithuania, Norway, Poland, Romania, Spain and Turkey (Figure 13). The Agreement Text on EUROFISH membership of our country was signed on 5 March 2002 and accepted by the Turkish Grand National Assembly on 23 June 2004. The organization was established to encourage private sector investments and partnerships related to aquaculture, to develop projects, to accelerate trade and marketing opportunities and to ensure regular flow of information on aquaculture.

Figure 13. EUROFISH member states (EUROFISH 2020)

Priorities

Innovative practices in aquaculture, dissemination of the use of high technology and developing processed fisheries and aquaculture products with high added value are among the primary priorities of our country in aquaculture. Our other priority is to determine new areas suitable for aquaculture in our marine and inland waters. By opening new areas to production, both bureaucratic procedures will be facilitated for the investor and investments will be guaranteed in planned areas. When the sea areas of our country are considered in terms of aquaculture, we can see that our seas were not sufficiently utilized until the 2000s, and a limited progress has been achieved from trout aquaculture in inland waters. Increasing aquaculture of large trout, which emerged as an alternative to imported salmon, is another priority. Large trout are grown in inland waters up to a certain size, then are transported to cages in the Black Sea, and complete their growth in the sea (Figure 14). The aquaculture of large trout has been encouraged by governmental policies in recent years, and has found a place as Turkish salmon in domestic and foreign markets.

In addition to seabass and gilt-head seabream, which are two of our delicious species and grown commonly in the Aegean and Mediterranean Seas, the aquaculture of meagre and white grouper which are commercially important species, is also supported. Due to the fact that there is a significant demand for domestic consumption in our country, increased export potential and environmental friendliness, bivalve aquaculture is among the aquaculture types that have been supported in recent years and the government aims to increase its production. We are working to increase production by developing new models in aquaculture support. Within the scope of these studies, environmentally friendly production techniques such as Recirculating Aquaculture Systems are widespread and our water resources are protected and thus, sustainable aquaculture is encouraged. Moreover, multi-trophic aquaculture, which can obtain better quality products by preserving water quality, has attracted the attention of the enterprises operating in our country and studies have been started in this direction. In addition to expanding sustainable environmentally friendly aquaculture practices, we continue to endeavor to monitor environmental impacts of aquaculture facilities, increase species diversity for restocking and aquaculture, preserve and maintain endangered species and develop new and preferred aquaculture species in the world. Products obtained from aquaculture provides an important opportunity to meet the demand for fish throughout the year in our country. Especially in the summer months where there is a prohibition on fishing, fish supply is provided to the market through products obtained from aquaculture, and thus an important contribution is made for meeting the animal protein needs of our people. Aquaculture products, which have an increasing share in production every year, and are present in the market throughout the year, play an important role in balancing price increases especially during periods of low fishing production. Moreover, relations and collaborations with international organizations are closely followed in order to represent our country in the international platform and to integrate sustainable aquaculture into the world.

Figure 14. Turkish salmon grown in the Black Sea and exported and a processing-packaging facility (DGFA 2020b)

Objectives

With the awareness that it is an economic necessity to use natural resources effectively and rationally in the world; in order to ensure the sustainability of the aquaculture sector, it is of great importance to protect the resources and our marine and inland waters, continue the development of aquaculture, monitor the environmental impacts of aquaculture activities, record production data, ensure sustainable product supply and include new species into production. The aquaculture export target of our country for 2023 was set at $ 1 billion, but it was seen that this target would be achieved before 2020. The new aquaculture production target for 2023 has been updated to 600,000 metric tons and the export target to $ 2 billion. While reaching this goal, environmentally and economically sustainable production has to be ensured without sacrificing quality.

Some of the activities that need to be carried out in order to reach the targets can be listed as follows;

- Planning potential aquaculture areas and making them ready for investment,
- Supporting and expanding recirculating aquaculture systems,
- Development of new species in aquaculture,
- Support and development of processed seafood with high added value,
- Support and dissemination of biotechnology and breeding studies,
- Improving polyculture aquaculture,
- Development of crustacean, bivalve and mollusc aquaculture,
- Improving the production and aquaculture of aquatic plants,
- Increasing industrial fisheries and aquaculture specialized industrial zones based on agriculture,
- Improving the aquaculture of the herbivorous aquaculture species that are relatively low in need of fishmeal in their diet.

References

DGEUFR (2020a) Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of European Union and Foreign Relations. Available at: https://www.tarimorman.gov.tr/ABDGM/Menu/66/Bm-Gida-Ve-Tarim-Orgutu-fao_(accessed 05 Jun 2020).

DGEUFR (2020b) Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of European Union and Foreign Relations. Available at: https://www.tarimorman.gov.tr/ABDGM/Menu/73/Balikcilikla-Ilgili-Uluslararasi-Kuruluslar (accessed 05 Jun 2020).

DGFA (2020a) Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture, Fisheries Statistics, Ankara, Ankara, pp. 182. (in Turkish).

DGFA (2020b) Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture, Visual Archive. Available at: https://www.tarimorman.gov.tr/sgb/Belgeler/SagMenuVeriler/BSGM.pdf (accessed 05 Jun 2020).

DGSHW (2019) State Hydraulic Works Archive Data, General Directorate of State Hydraulic Works, Ankara, Turkey (in Turkish).

Elliot, M and partners (1996a) Identification of Fish Culture Sites in Marine and Brackish Water. General Directorate of Agricultural Production and Development, Ministry of Agriculture and Rural Affairs, Ankara, Turkey.

Elliot, M and partners (1996b) Environmental Impact of Aquaculture in Turkey and its Relationship and Sites of Special Protection. General Directorate of Agricultural Production and Development, Ministry of Agriculture and Rural Affairs, Ankara, Turkey.

Emiroğlu İşgören, D., Tolon, M.T., Günay, D.B., Yapıcı, S.N. (2019) Development of Turkish fish feed industry. *Ege Journal of Fisheries and Aquatic Sciences* 36(1): 75-80.

EUROFISH (2020) International Organization. Available at: https://www.eurofish.dk/ (accessed 12 May 2020).

FAO (2020a) FAO Global Aquaculture Production. Available at: http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en (accessed 29 Jun 2020).

FAO (2020b) General Fisheries Commission for the Mediterranean-Area of application. Available at: http://www.fao.org/gfcm/about/area-of-application/en (accessed 29 Jun 2020).

ITQI (2017) International Taste Institute, Superior Taste Award, Sea Bream and Sea Bass. Available at: https://www.taste-institute.com/en/home (accessed 29 Jun 2020).

ITQI (2018) International Taste Institute, Superior Taste Award, Sea Bream and Sea Bass. Available at: https://www.taste-institute.com/en/awarded-products/awards-2018 (accessed 29 Jun 2020).

PRT (2020) Presidency of Republic of Turkey, Official Gazette. Available at: https://www.resmigazete.gov.tr/fihrist?tarih=2020-11-05&mukerrer=1 (accessed 5 Nov 2020).

TSI (2020) Turkish Statistical Institute, Fisheries Statistics Database. Available at: https://biruni.tuik.gov.tr/medas/?kn=97&locale=en (accessed 5 Jun 2020).

Spatial planning and site selection for marine aquaculture in Turkey

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Introduction

Seafood has globally a significant role in the maintenance of food security considering its contribution to essential nutrition for more than one billion people and livelihoods for some 57 million (FAO 2016). Aquaculture has become a major source of seafood as the world's fastest growing food production system during the last few decades. Global fish production (when excluding aquatic mammals, reptiles, seaweeds and aquatic plants) reached about 171 million tonnes in 2016, with an 88 percent direct use as human food. Aquaculture contribution to total fish production is about 47 percent but this contribution increases to 53 percent if non-food uses (including reduction to fishmeal and fish oil) are excluded (FAO 2018). In other words, despite its short history, aquaculture surpassed capture fisheries as the major source of seafood produced for direct human consumption. It is projected that the aquaculture production will provide 62 percent of global seafood produced by 2030 (World Bank 2013). In that context, aquaculture industry is recognised as a necessity to secure food supply for the increasing population as well as to provide a significant investment opportunity.

Aside from its current success story and growth potential in the foreseeable future, some aquaculture practices have also caused negative effects in terms of social, economic and environmental aspects (FAO 2009). Although these impacts largely depend on the factors such as species, culture method, stocking density, feed composition and hydrography, the direct environmental impacts of aquaculture include nutrient and organic loadings that contribute to poor water quality, sediment deposition on sea bottom and habitat losses. Other concerns related to those impacts are the possibility of introduction of invasive species, genetic risks from escapes and the spread of pathogens. Environmental impacts of marine aquaculture have widely been documented in the literature (Fernandes *et al.* 2001; Tacon and Forster 2003; Felsing *et al.* 2005; Buschmann *et al.* 2006; Mendiguchía *et al.* 2006; Pusceddu *et al.* 2007; Navarro *et al.* 2008; Aubin *et al.* 2009;

Tomassetti *et al.* 2009; Brigolin *et al.* 2010; Grigorakis and Rigos 2011; Wang *et al.* 2012; Edwards 2015; Watts *et al.* 2017). With the rapid volumetric expansion of aquaculture, these impacts have created severe social conflicts and threatened the sustainability of the industry. In general, ecological impact results from a lack of or inadequate coastal planning and poor management of the environmental compatibility of particular sites (GESAMP 1991).

Sustainability of aquaculture heavily depends on environmental characteristics, ecological interactions as well as social and economic considerations. Marine aquaculture is resource-based business and therefore competes for these resources (economic, social, physical and ecological) with other industries such as coastal fisheries, tourism and maritime traffic which can have social, aesthetic and economic implications (Asmah 2013). Therefore, correct site selection and carrying capacity estimation are accepted as the key factors for the success and sustainability of any aquaculture operations (Ross *et al*. 2013).

Marine spatial planning

The rapid intensification of human uses of the coastal areas and sea-spaces has been the case during the past century due to its vast socioeconomic opportunities. Therefore, there is a requirement for strategical planning that can make a balance of the location, type and intensity between sea-space user groups or sectors. Marine Spatial Planning (MSP) is a multi-sectoral decision-making approach that reduces negative environmental and socioeconomic impacts as well as the conflicts between the users (Lester *et al.* 2018).

UNESCO (2019) describes the MSP as "a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process". Considering all users, it aims to make integration in the use of sea-space, covering retention and improvement of ecological endowments of associated habitats, species and environment (Meaden *et al.* 2016). In many coastal states, MSP is increasingly being used as an efficient tool for Integrated Coastal Zone Management (ICZM) in marine areas, incorporating into their legal systems (Oral 2008).

In Turkey, ICZM is implemented under Spatial Planning Regulation (Official Journal 2014), which aims to determine the procedures of spatial plans for land use and settlement, to protect and develop the physical, natural, historical and cultural values, to provide a balance between protection and use, and to support the sustainable development at national, regional and local scales. The major human activities in the coastal zone classified by General Directorate for Spatial Planning under auspices Ministry of Environment and Urbanization can be listed as follow:

- Coastal settlements, rural areas and secondary housing
- Tourism, recreation, yachting and cruiser tourism
- Maritime traffic, ports and wharfs
- Logistical centres, highway and railway connections
- Shipyard, shipbuilding, repair and maintenance industry
- Wastewater treatment plant and deep-sea discharge pipeline, natural gas pipeline, and submarine power cable line
- Fisheries and aquaculture
- Energy specialization areas, industrial zones and free zones
- Oil refineries, petrochemical industry, and gas and oil storage
- Military exclusion zones, security zones and coastguard
- Protected areas (national parks, special environmental protected areas, archaeological sites, marine protected areas, biodiversity reserves)
- Agricultural and forestry activities

The MSP does not guarantee the sustainability for any individual marine activity but it specifically aims at achieving sustainability for all activities. When it comes to fisheries, it is historically among the main activities in the coastal zones. Aquaculture, however, is a relatively new industry and MSP can contribute to a sustainable aquaculture operation in harmony with the marine ecosystems (Meaden *et al.* 2016).

An inappropriate spatial planning is the main limiting factor for sustainable development and expansion of the aquaculture industry. An improperly selected site of an aquaculture farm or zone will not only create environmental problems, but it may also have socio-economic impacts that can bring more harm than benefit. Aguilar-Manjarrez *et al*. (2017) summarized main problems due to the lack/insufficient spatial planning and aquaculture with seven categories: “(a) fish disease; (b) environmental issues; (c) production issues; (d) social conflicts; (e) post-harvest and marketing issues; (f) risk financing, and (g) lack of resilience to climatic variability, climate change and other external threats and disasters”.

Due to the conflicts and competition in sea-space use by rapidly growing global aquaculture and other sectors, the Food and Agriculture Organization of the United Nations (FAO) adopted the concept “Ecosystem Approach to Aquaculture” (EAA) based on ICZM policies to minimize environmental and socio-economic impacts. The EAA concept is a strategy which helps to establish the limits of aquaculture production at a certain environmental and social acceptability without unacceptable changes and includes four strategic carrying capacity analysis. The physical carrying capacity takes into account the environmental factors and the farming system related to the suitability of aquaculture activity in a given area. The production carrying capacity is an estimation of the maximum production at the farm scale and it depends on the technology, production system and the investment required. The ecological carrying capacity is the acceptable amount of aquaculture production that can be supported by the environment without causing unacceptable changes in ecological processes, services and species diversity and abundance in a certain area. The social carrying capacity represents the acceptability of aquaculture and its amount and governance objectives in a given environment without any adverse social impacts (Ross *et al.* 2013; Aguilar-Manjarrez *et al.* 2010).

Although environmental and social impacts of aquaculture are highly depended on the type and location of rearing systems and interactions between systems and environments, management with an appropriate site selection and carrying capacity estimation may contribute to the sustainability of aquaculture.

Spatial planning and site selection for marine aquaculture in Turkey

Marine aquaculture in Turkey started with nearshore cage culture of European seabass (*Dicentrarchus labrax*) and gilthead seabream (*Sparus aurata*) in closed bays of the Aegean Sea in the last quarter of the twentieth century. However, marine aquaculture in the country has recently showed a spectacular burst for production capacity together with the other services and currently the country is the second largest finfish supplier in Europe.

Turkish marine aquaculture is historically dominated with cage culture of seabass and seabream in the Mediterranean. Large rainbow trout (*Oncorhynchus mykiss*) (>2.5 kg) in the Black Sea and the Atlantic bluefin tuna (*Thunnus thynnus*) in the Mediterranean are the other cage cultured fish. Some candidate fish species including meagre (*Argyrosomus regius*), common dentex (*Dentex dentex*), shi drum (*Umbrina cirrosa*), pink dentex (*Dentex gibbosus*) and sharp snout seabream (*Diplodus puntazzo*) can be produced depending on market demands. Despite relatively low production amounts, aquaculture of the Mediterranean mussel (*Mytilus galloprovincialis*) using long lines and grooved carpet shell (*Ruditapes decussatus*) on deep culture are drawing more attention during the last years.

Development of aquaculture in Turkey took place in the absence of an effective regulatory framework on spatial planning. Turkish marine aquaculture started with wooden sea cages in the closed and/or sheltered bays as mentioned above. In the beginning years, management of aquaculture was mainly based on a licencing system by the former ministry, Ministry of Agriculture and Rural Affairs. Due to absence of a guidance providing principles and criteria of site selection and carrying capacity estimations, water quality problems and social conflicts occurred in a short time in those closed and sheltered bays which had been already used by other activities such as tourism, yachting, coastal fisheries and secondary housing. Marine aquaculture zones were firstly declared in the inshore areas in 1988 and the fish cages were moved a bit away from the shore during the end of 20^{th} century. During the beginning of the 2000s, the twinning projects on environmental policies in the harmonization process with the European Union (EU) of Turkey were intensified, which led to the more effective management of aquaculture regarding environmental issues.

The efforts gave fruit and Environmental Impact Assessment (EIA) Regulation was declared (Official Journal 2003). Aquaculture farms with a production capacity of ≥1000 tons per year were subjected to EIA procedures and classified as an integrated meat production facility while those farms with capacities between ≥30 and 999 tons per year were listed among the projects subjected to a set of pre-selection/elimination criteria which determines whether the EIA procedures are required or not.

Aquaculture Regulation as major legislation for the management of aquaculture activities in Turkey was firstly declared (Official Journal 2004), to ensure effective use of water resources, the sustainability of aquaculture and food security by protecting the environment. The regulation set up a general framework for site selection of aquaculture for both in inland and marine areas. Then, the notification on closed and sheltered bays which were characterized as marine sensitive areas where aquaculture farms cannot be established was declared (Official Journal 2007). After the notification came into force, new allocated offshore aquaculture zones for marine fish farms were determined with a consensus of all related institutions and stakeholders. The inshore cage farms had to move to offshore sites. In 2009, the notification on monitoring of marine fish farms was also declared (Official Journal 2009), assigning a methodology in the monitoring of fish farming activities in terms of their environmental impacts. The regulation on environmental management of marine fish farms which aims to identify the marine sensitive areas that are not allowed for aquaculture activities and to define the methods for monitoring of fish farming activities has been recently declared. According to the regulation, the farms are responsible for preparing an environmental management plan to prevent negative environmental impacts of aquaculture to marine areas (Official Journal 2020).

A preliminary survey report prepared by local authority assessing the site is the first step of licencing procedure based on Aquaculture Regulation. At this stage, aquaculture activities are not allowed in sites listed below as in harmony with the MSP;

- Military exclusion zones and security zones
- Ports and mooring areas
- Marine traffic routes
- Protected areas (national parks, special environmental protected areas, archaeological sites, marine protected areas, biodiversity reserves)
- Underwater discharge and natural gas pipelines, power cable lines
- Tourism development zones
- Underwater cultural and natural properties

Physical carrying capacity

The criteria and rules on site selection and physical carrying capacity estimation of a coastal area for marine aquaculture are determined both with Aquaculture Regulation, the notification and the recent regulation for site selection and zoning for marine aquaculture. The framework includes physicochemical factors such as depth, current speed, distance from coastline, the distance between the farms and water quality.

The obligatory rules for physical carrying capacity described by the regulation and the notification are summarized below;

- In bays, the marine sensitive areas defined by the regulation, minimum proximity to coastline and sea depth for aquaculture cages settings must be over 0.7 nautical miles and 40 meters, respectively. Moreover, in the areas meeting these two conditions, sea water current speed should be higher than 0.1 meters per second for setting up a farm operation. The minimum distance between the aquaculture farms must be 1000 meters.
- In sites other than the marine sensitive areas, minimum proximity to the coastline and minimum depth must be over 0.27 nautical miles and 30 meters respectively while the rules for distances between farms and the current speed are the same. In these areas, if there is an application of an integrated multi-trophic system, the minimum 30-meter-depth rule is not compulsory anymore.
- On the condition that a total area of cages setting is not wider than the allocated area for the farm, the production capacity is determined depending on species and culture method.
- In an area that is not spatially planned, the distance between the two Bluefin tuna farms and the distance between a Bluefin tuna farm and the other finfish farm must be at least two kilometres. The latter distance is also valid for between other two finfish farms.
- In offshore areas which do not have the characteristics of closed or sheltered bays, the depth of site for cage settings must be over 40 meters. However, if current speed and the distance from coastline are sufficient and culture technique is suitable, the operation can be allowed in areas lower than 40 meters with the permission of the central authority.

The Code of Practice for the Aquaculture Regulation (Circular 2006/1) also restricts the maximum production capacity, specifically pointing to coastal areas where marine finfish cage farms with an annual production capacity over 250 tons are not allowed to provide efficient use of the area. In addition to general rules, the circular also regulates the physical carrying capacity of marine aquaculture farms based on water quality criteria given in Table 1.

Table 1. Water quality criteria for site selection of marine aquaculture (adopted from Circular 2006/1)

	Gilthead seabream	**European seabass**	**Bluefin tuna**	**Turbot**	**Sturgeon**	**Shrimp**	**Bivalve**
Dissolved oxygen (mg/L)	≥4	≥4	≥5	≥3	≥4	≥5	≥5
Salinity (‰)	5-40	5-40	12-40	10-40	0-20	15-35	10-37
Temperature (°C)	15-25	10-25	12-30	10-25	7-25	20-35	12-30
pH	6.5-8.5						
Free carbondioxide (mg/L)	0.1-10						
Ammonia (mg/L)	0.05-1.5						
Nitrite (mg/L)	<0.5						
Nitrate (mg/L)	<40						
o-phosphate (mg/L)*	<1						
Silica (mg/L)*	2-5						
Sulphide (mg/L)*	<1						
Suspended solids (mg/L)*	5-80						
Hydrocarbons (mg/L)*	<0.031						
Turbidity (NTU)*	<29						
Faecal coliforms (col/100 mL)*	<1000						≤300**
Free chlorine (mg/L)*	<0.2						
HEAVY METALS							
Total iron (mg/L)*	0.5-1						
Total mercury (mg/L)*	0.004-0.1						
Cadmium (mg/L)*	<0.01						
Lead (mg/L)*	<0.1						
Total chromium (mg/L)*	<0.1						
Arsenic (mg/L)*	0.1-1						
Copper (mg/L)*	0.025-0.1						
Zinc (mg/L)*	0.03-0.1						
PESTICIDES							
DDT (mg/L)*	<0.01						
Aldrin (mg/L)*	<0.004						
Dieldrin (mg/L)*	<0.003						
2.4 DEP (mg/L)*	<0.001						
BHC (mg/L)*	<0.04						
Endrin (mg/L)*	<0.08						
Heptachlor(mg/L)*	<0.03						
Pentachlorophenol (mg/L)*	<0.01						

* If needed according to local or central authority, the parameters must be analysed

** In shellfish flesh, as the most probable numbers/100 mL

In terms of bivalve aquaculture, site selection is out of the scope of the above-mentioned notification. Specific procedures, environmental quality and physical carrying capacity for wild bivalve harvest and bivalve aquaculture are determined with the Code of Practice for the Bivalve Aquaculture (Circular 2010/1) and "the notification on water quality criteria for bivalve fisheries and aquaculture" for harmonization of EU legislation in Turkey. According to the Circular 2010/1, the potential sites for bivalve aquaculture should be announced for the harvest in the Official Journal of the European Union as Class A or Class B. If the area is not classified, the classification firstly should be completed for the new sites. For the preliminary classification based on *Escherichia coli* in shellfish flesh, the area is monitored by taking minimum 6 or 12 samples for successive three or six months respectively, and then the areas classified A or B are permitted for bivalve aquaculture. In addition to these criteria, toxic phytoplankton abundance and bloom periodicity are used for a qualitative assessment.

Ecological carrying capacity

The regulation on environmental management of marine fish farms regulates the ecological carrying capacities of the coastal areas depending on the trophic status. It defines eutrophication risk by the trophic status index (TRIX), which was validated especially for many European Seas (Vollenweider *et al.* 1998; Giovanardi and Vollenweider 2004; Primpas and Karydis 2011). The TRIX is calculated using the absolute oxygen saturation and the concentrations of chlorophyll *a*, dissolved inorganic nitrogen and total phosphorus.

$$TRIX = [log(Chl_a \ x \ DO \ x \ TIN \ x \ TP) + 1.5] \ x \ 0.833$$

Where;

Chl_a is chlorophyll *a* concentration (µg/L),
DO is the absolute oxygen saturation deviated from saturated concentration (= recorded percent saturation -100)
TIN is total dissolved nitrogen (NH_4-N + NO_2-N + NO_3-N; µg/L)
TP is total phosphorus (µg/L)

TRIX scores are represented with values between 0 and 10 to classify the trophic status of the coastal area (Table 2). Depending on the rules of the regulation, in sites with a moderate eutrophication risk, marine finfish aquaculture activities are restricted and no permission is given for new facilities. In sites with a high eutrophication risk, marine finfish aquaculture activities cannot be applied and the existing production is terminated.

Although an ecological carrying capacity estimation based on suspended solids, phytoplankton and zooplankton biomass is forced by the Circular (2010/1), the methodology of such estimation or assessment is not clearly defined. However, the regulation (Official Journal 2020) has assigned an ecological carrying capacity concept by assimilation capacity of the aquaculture zone. According to the regulation, an assimilation capacity of the production sites or allocated zones are determined by considering depth, water current speed and a potential of water exchange rate together with activities of other users in the sites.

Table 2. The scale for eutrophication risk according to trophic status index (TRIX) scores (Official Journal 2020).

TRIX score*	Trophic condition	Notes
< 4	No eutrophication risk	permission for aquaculture
4-5	Low risk	no permission for new cages
5-6	Moderate risk	no permission for new cages, restriction for existing cages
TRIX > 6	High risk	aquaculture is not allowed, existing production is ended

*It is applied as +1 for the Black Sea.

Production carrying capacity

The production carrying capacity in Turkey is under control of the Aquaculture Regulation, which empowers the local or central authority to assess feasibility reports of aquaculture farm applications. The feasibility reports cover the issues related to production and economic sustainability of aquaculture activity in a certain area including site specifications, production plans, production achievement potential, investment, profitability, distance to port or wharves, marketing opportunities and risk management etc.

Social carrying capacity

The social carrying capacity is described as the amount of fish farming at a level with no adverse social impacts. Although the ultimate goal of determinations of social carrying capacity is the quantification of stakeholder's participation using a science-based effort, it is the most difficult one to quantify and the most critical from the management perspective (Byron and Costa-Pierce 2013; Ross *et al.* 2013).

For social carrying capacity, the acceptability of aquaculture activities in a certain area is commonly estimated based on participation of the decision-makers consisting of local and/or central authorities. The positive opinions of the governmental authorities and local administrations dealing with public health, tourism, maritime traffic, transportation, environment, water resources management, spatial planning and, if required, the other relevant institutions should be taken during the decision making process for a site selection of aquaculture farm. Although involvement of the non-governmental organizations (NGOs) or cooperatives in decision making is required, there is no clear procedure associated with it. Accordingly, such NGOs' involvements are not common in the current practice.

Site selection for marine aquaculture in the world

In 2016, marine and coastal aquaculture production for human consumption were reported as 28.7 million tonnes (FAO 2018). A major contribution to marine and coastal aquaculture with 16.9 million tonnes (58.8%) came from shelled molluscs while finfish (6.6 million tonnes) and crustaceans (4.8 million tonnes) contributions were 39.9 percent. Most of the marine and coastal finfish production was recorded in the Americas, Asia and Europe (Table 3).

Table 3. Marine aquaculture production by continents, 2016 (x1.000 tonnes, live weight; FAO 2018)

	Africa	Americas	Asia	Europe	Oceania	World
Finfish	17	906	3.739	1.830	82	6.575
Crustacea	5	727	4.091	0	6	4.829
Molluscs	6	574	15.550	613	112	16.853
Other aquatic animals	0	0	402	0	5	407
Subtotal	28	2.207	23.781	2.443	205	28.664

Coastal aquaculture in Asia is practised in completely or partially human-made structures in areas adjacent to the sea (FAO 2018). Indeed, total production of 1.272.398 tonnes of diadromous and marine fish was recorded in Asia in 2016, with the major contributions of Indonesia (707.895 tonnes), Philippines (244.442 tonnes) and Bangladesh (113.239 tonnes). On the other hand, in the same year, a production of 906.353 tonnes diadromous and marine fish in the Americas was realized in marine areas with a contribution of Chili (726.914 tonnes) and Canada (149.310 tonnes). Similarly, in Europe, 98 percent of the production of diadromous and marine fish came from marine areas, with a major contribution of Norway (1.323.867 tonnes), United Kingdom (166.963 tonnes) and Greece (98.230 tonnes) (FAO 2019).

Striking features of the production of these countries are strict environmental regulations, various site selection criteria and best management practices for new farm licences as summarized in Table 4.

Table 4. Regulations and best management practices for marine finfish farm siting (adopted from MNR 2007; MPI 2013; Stefani 2015)

Country	Regulations
Global salmon standard (Global Aquaculture Alliance)	▪ Baseline data required for new farms and an expert report is required attesting that the farm can meet the required environmental standards ▪ Farms must not be located in areas that are ‘sensitive or critical’ to other species

Table 4. Continued

Global salmon standard (Aquaculture Stewardship Council)	Farms must not be located in high conservation value areas
Norway	▪ Some baseline data required prior to a new consent including average current speed, sediment characteristics, salinity and seabed topography ▪ New farms require an EIA if production volume is ≥36,000 m^3 for permanently sited cages, or ≥48,000 m^3 for movable cages ▪ Farm separation buffer ≥1 km ▪ Farms must be ≥5 km from 'important' rivers
Scotland	▪ Baseline site information for benthic monitoring, sampling and reporting, and compliance with standards for chemical indicators in the benthic environment are required ▪ New farms require an EIA if they will produce >100t yr^{-1}, or are >1000 m^2 or located in a sensitive habitat ▪ Farm separation buffer ≥8 km^2 ▪ The location of cages should provide adequate water flow for fish, but not be so strong that fish cannot maintain their position
Greece	▪ A formation of allocated zones where more than 5 aquaculture farms, totalizing a surface superior to 100.000 m^2 having farm separation buffer ≥ 500 m ▪ A formation of informal zones where less than 5 aquaculture farms and a surface inferior to 100.000 m^2 having farm separation buffer 500 m to 2 km ▪ The distance between allocated zones ≥ 3 km ▪ Limits of the leased areas ≥ 50 m from coastline ▪ The distance between fish cages and shellfish unit ≥ 200 m ▪ Depth ≥ 18 m ▪ Cages should have at least a distance of 1 km from a functioning tourism facility, existing residential development, industrial plants, mining facilities, harbours, oil refinery ▪ Cages should have at least a distance of 500 m from diving sites and beaches designated for swimming to tourism facilities and residential areas.
Chile	▪ EIA either in the form of an Environmental Impact Declaration or an Environmental Impact Study prior to the development of a cage site ▪ Concession plan and location layout must be approved my Marine Authority ▪ Farm separation buffer ≥ 2.78 km ▪ The additional regulations include fish movement, siting, and disease control

Table 4. Continued

Canada (British Columbia (BC), Nova Scotia (NS), and New Brunswick (NB))	▪ Baseline data required, e.g. average current speed, redox, % organic matter and sulphide. Baseline data requirements for BC are more specific than for any other jurisdiction ▪ BC: Farm separation buffer ≥1 km from farms owned by the same company, salmon-bearing rivers and major herring spawning sites; ≥3 km from farms owned by other companies; and ≥300 m from intertidal shellfish beds ▪ NS: Farm separation buffer ≥1 km ▪ NB: Farm separation buffer ≥300 m
USA (Washington (WA), Maine (ME))	▪ Baseline site information for benthic monitoring, sampling and reporting, and compliance with standards for chemical indicators is required for all farms in ME and for farms producing >45 t per year in WA ▪ ME: Farm separation buffer ≥610 m ▪ ME: Mean current speed mid-water under the pens must be ≥5 cm s^{-1} ▪ ME: Farms must not be located in areas that have persistent water stratification ▪ ME: Horizontal predator nets must be >1 m above the sea floor
Australia (South Australia (SA), Tasmania (T))	▪ Regulatory authorities are required to prepare marine farming development plans for areas where marine farming is permitted. Aquaculture is not allowed outside designated aquaculture zones ▪ T: Regulatory authority collects baseline data on lease areas to include benthic habitat (flora, fauna and sediments) and water quality information ▪ Baseline site information for benthic monitoring required prior to a new site consent ▪ T: EIA required for new farms that produce >100 t yr^{-1} ▪ T: Farm separation buffer ≥1 km between farms owned by the same company and/or between different companies ▪ SA: ≥3 m clearance is required between the bottom of the cages and the seabed ▪ T: ≥1 m clearance is required between the bottom of the net-pen and the seabed
New Zealand	General requirement for baseline data and EIA for all new farms

Results

Aquaculture industry has made a trifold growth in the past two decades as the fastest growing industry in Turkey. Turkish marine aquaculture is historically dominated with cage culture of seabass and seabream in the Mediterranean, starting with nearshore wooden cages in closed bays in the last quarter of the twentieth century. As observed in many parts of the world during early stages of aquaculture development, water quality problems and social conflicts were experienced in the marine habitats. As a result of intensification of environmental policies during the beginning of 2000s, more efficient management of marine aquaculture was achieved, followed by the relocations of coastal cages to offshore sites.

Marine aquaculture is strictly governed with various regulations including EIA and Aquaculture Regulation. The regulations also set up a general framework and the specific rules for site selection of marine aquaculture, defining an appropriate site with physical, production, social and ecological carrying capacities as well as water quality criteria. The spatial framework for marine aquaculture related to physical carrying covers the criteria such as minimum depth of the sea, minimum distance from coastline, minimum current speed, minimum distance between the farms and maximum percentage for coverage of the leased area, and the rules for the prohibition such as military sites, tourism areas, and marine protected and special environment areas. Although a carrying capacity estimation based on suspended solids, phytoplankton and zooplankton biomass is enforced by the regulation, the methodology is not clear and therefore, ecological carrying capacity and environmental impact is assessed using TRIX.

At the present status, Turkey have strict criteria and rules on spatial planning and site selection for marine aquaculture which are compatible for EU regulations. However, there is a potential for new aquaculture sites for finfish culture especially in the eastern Mediterranean and a significant potential for shellfish aquaculture in the Aegean and Marmara Seas. There are also high expectations of aquaculturists, new investors and politicians for capacity increase, which may face serious limitations with these strict rules.

References

Aguilar-Manjarrez, J., Kapetsky, J.M., Soto, D. (2010) The potential of spatial planning tools to support the ecosystem approach to aquaculture. Fisheries and Aquaculture Proceedings No. 17, Food and Agriculture Organization of the United Nations, FAO, Rome, 176pp.

Aguilar-Manjarrez, J., Soto, D., Brummett, R. (2017) Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Food and Agriculture Organization of the United Nations with contribution of the World Bank, Rome, 62pp.

Asmah, R. (2013) Aquaculture site selection and carrying capacity estimates for inland and coastal aquaculture in West Africa. In: Site selection and carrying capacities for inland and coastal aquaculture (eds., Ross, L.G., Telfer, T.C., Falconer, L., Soto, D., Aguilar-Manjarrez, J.), Fisheries and Aquaculture Proceedings No. 21. Food and Agriculture Organization of the United Nations, FAO, Rome, pp. 197-205.

Aubin, J., Papatryphon, E., Van der Werf, H.M.G., Chatzifotis, S. (2009) Assessment of the environmental impact of carnivorous finfish production systems using life cycle assessment. *J Clean Prod* 17(3): 354-361.

Brigolin, D., Pastres, R., Tomassetti, P., Porrello, S. (2010) Modelling the biomass yield and the impact of seabream mariculture in the Adriatic and Tyrrhenian Seas (Italy). *Aquac Int* 18(2): 149-163.

Buschmann, A.H., Riquelme, V.A., Hernández-González, M.C., Varela, D., Jiménez, J.E., Henríquez, L.A., Vergara, P.A., Guíñez, R., Filún, L. (2006) A review of the impacts of salmonid farming on marine coastal ecosystems in the southeast Pacific. *ICES J Mar Sci* 63(7): 1338-1345.

Byron, C.J., Costa-Pierce, B.A. (2013) Carrying capacity tools for use in the implementation of an ecosystems approach to aquaculture. In: Site selection and carrying capacities for inland and coastal aquaculture (eds., Ross, L.G., Telfer, T.C., Falconer, L., Soto, D., Aguilar-Manjarrez, J.), Fisheries and Aquaculture Proceedings No. 21. Food and Agriculture Organization of the United Nations, FAO, Rome, pp. 87-101.

Circular (2006/1) Code of Practice for the Aquaculture Regulation. Ministry of Agriculture and Forestry. Available at: https://www.tarimorman.gov.tr/Belgeler/Mevzuat/Genelgeler/2006_1genelge.pdf (accessed 10 Oct 2019). (in Turkish).

Circular (2010/1) Code of Practice for the Bivalve Aquaculture. Ministry of Agriculture and Forestry. Available at: https://kms.kaysis.gov.tr/(X(1)S(yon3ru5guxmtqquhpwtveyoe))/Home/Goster/46038 (accessed 10 Oct 2019). (in Turkish).

Edwards, P. (2015) Aquaculture environment interactions: Past, present and likely future trends. *Aquaculture* 447: 2-14.

FAO (2009) Environmental impact assessment and monitoring in aquaculture: Requirements, practices, effectiveness and improvements. Fisheries and Aquaculture Technical Paper 527, Food and Agriculture Organization of the United Nations, FAO, Rome, 57pp.

FAO (2016) The State of World Fisheries and Aquaculture 2016-Contributing to food security and nutrition for all. Food and Agriculture Organization of the United Nations, FAO, Rome, 190pp.

FAO (2018) The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Food and Agriculture Organization of the United Nations, Rome, 210pp.

FAO (2019) Fisheries and Aquaculture Statistics. Food and Agriculture Organization of United Nations. Available at: http://www.fao.org/fishery/statistics/en (accessed 10 Oct 2019).

Felsing, M., Glencross, B., Telfer, T. (2005) Preliminary study on the effects of exclusion of wild fauna from aquaculture cages in a shallow marine environment. *Aquaculture* 243(1-4): 159-174.

Fernandes, T.F., Eleftheriou, A., Ackefors, H., Eleftheriou, M., Ervik, A., Sanchez-Mata, A., Scanlon, T., White, P., Cochrane, S., Pearson, T. H., Read, P. A. (2001) The scientific principles underlying the monitoring of the environmental impacts of aquaculture. *J Appl Ichthyol* 17: 181-193.

GESAMP (1991) Reducing Environmental Impacts of Coastal Aquaculture. Group of Experts on the Scientific Aspects of Marine Environmental Protection Report and Studies (47), 35pp.

Giovanardi, F., Vollenweider, R.A. (2004) Trophic conditions of marine coastal waters: experience in applying the Trophic Index TRIX to two areas of the Adriatic and Tyrrhenian seas. *J Limnol* 63(2): 199-218.

Grigorakis, K., Rigos, G. (2011) Aquaculture effects on environmental and public welfare–the case of Mediterranean mariculture. *Chemosphere* 85(6): 899-919.

Lester, S.E., Stevens, J.M., Gentry, R.R., Kappel, C.V., Bell, T.W., Costello, C.J., Gaines, S.D., Kiefer, D.A., Maue, C.C., Rensel, J.E., Simons, R.D., Washburn, L., White, C. (2018) Marine spatial planning makes room for offshore aquaculture in crowded coastal waters. *Nat Commun* 9: 945.

Meaden, G.J., Aguilar-Manjarrez, J., Corner, R.A., O'Hagan, A.M., Cardia, F. (2016) Marine spatial planning for enhanced fisheries and aquaculture sustainability – its application in the Near East. Fisheries and Aquaculture Technical Paper No. 604, Food and Agriculture Organization of the United Nations, FAO, Rome, 89pp.

Mendiguchía, C., Moreno, C., Mánuel-Vez, M.P., García-Vargas, M. (2006) Preliminary investigation on the enrichment of heavy metals in marine sediments originated from intensive aquaculture effluents. *Aquaculture* 254(1-4): 317-325.

MNR (2007) Coordinated application and review guide and a decision support tool for cage aquaculture sites in Ontario. Ministry of Natural Resources, Ontario, 36pp. Available at: http://www.ontla.on.ca/library/repository/mon/16000/272008.pdf (accessed 14 Oct 2019)

MPI (2013) Comparison of the international regulations and best management practices for marine finfish farming. Ministry for Primary Industries of New Zealand, Technical Paper No: 2013/47, Wellington, 76pp.

Navarro, N., Leakey, R. J., Black, K.D. (2008) Effect of salmon cage aquaculture on the pelagic environment of temperate coastal waters: seasonal changes in nutrients and microbial community. *Mar Ecol Prog Ser* 361: 47-58.

Official Journal (2003) Environmental Impact Assessment Regulation, Republic of Turkey Official Journal Date: 16.12.2003 and No: 25318, Ankara (in Turkish).

Official Journal (2004) Aquaculture Regulation, Republic of Turkey Official Journal Date: 29.06.2004 and No: 25507, Ankara (in Turkish).

Official Journal (2007) The notification on closed and sheltered bays that it is characterized as marine sensitive areas where aquaculture farms cannot be established, Republic of Turkey Official Journal Date: 24.01.2007 and No: 26413, Ankara (in Turkish).

Official Journal (2009) The notification on monitoring of marine fish farms, Republic of Turkey Official Journal Date: 13.06.2009 and No: 27257, Ankara (in Turkish).

Official Journal (2014) Spatial planning regulation, Republic of Turkey Official Journal Date: 14.06.2014 and No: 29030, Ankara (in Turkish).

Official Journal (2020) The regulation on environmental management of marine fish farms, Republic of Turkey Official Journal Date: 28.10.2020 and No: 31288, Ankara (in Turkish).

Oral, N. (2008) Integrated coastal zone management and marine spatial planning for hydrocarbon activities in the Black Sea. *The International Journal of Marine and Coastal Law* 23(3): 453-476.

Primpas, I., Karydis, M. (2011). Scaling the trophic index (TRIX) in oligotrophic marine environments. *Environ Monit Assess* 178(1-4): 257-269.

Pusceddu, A., Fraschetti, S., Mirto, S., Holmer, M., Danovaro, R. (2007) Effects of intensive mariculture on sediment biochemistry. *Ecol Appl* 17(5): 1366-1378.

Ross, L.G., Telfer, T.C., Falconer, L., Soto, D., Aguilar-Manjarrez, J., Asmah, R., Bermúdez, J., Beveridge, M.C.M., Byron, C.J., Clément, A., Corner, R., Costa-Pierce, B.A., Cross, S., De Wit, M., Dong, S., Ferreira, J.G., Kapetsky, J.M., Karakassis, I., Leschen, W., Little, D., Lundebye, A.-K., Murray, F.J., Phillips, M., Ramos, L., Sadek, S., Scott, P.C., Valle-levinson, A., Waley, D., White, P.G., Zhu, C. (2013) Carrying capacities and site selection within the ecosystem approach to aquaculture. In: Site Selection and Carrying Capacities for Inland and Coastal Aquaculture, (eds., Ross, L.G., Telfer, T.C., Falconer, L., Soto, D., Aguilar-Manjarrez, J.), Fisheries and Aquaculture Proceedings No. 21. Food and Agriculture Organization of the United Nations, FAO, Rome, pp. 19-46.

Stefani, F. (2015) Special Framework for the Aquaculture: Greece. Seminar Good Practices in administrative simplification for the promotion of sustainable aquaculture, Brussels. Available at: https://ec.europa.eu/fisheries/sites/fisheries/files/docs/pages/spatial-planning-for-aquaculture-el.pdf (accessed 21 Oct 2019).

Tacon, A.G.J., Forster, I.P. (2003) Aquafeeds and the environment: policy implications. *Aquaculture* 226: 181-189.

Tomassetti, P., Persia, E., Mercatali, I., Vani, D., Marussso, V., Porrello, S. (2009) Effects of mariculture on macrobenthic assemblages in a western Mediterranean site. *Mar Pollut Bull* 58(4): 533-541.

UNESCO (2019) UNESCO Marine Spatial Planning Programme: Concepts and Terminology. Available at: http://msp.ioc-unesco.org/msp-good-practices/concepts-and-terminology/ (accessed 10 Oct 2019).

Vollenweider, R.A., Giovanardi, F., Montanari, G., Rinaldi, A. (1998) Characterization of the trophic conditions of marine coastal waters with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. *Environmetrics* 9(3): 329-357.

Wang, X., Olsen, L.M., Reitan, K.I., Olsen, Y. (2012) Discharge of nutrient wastes from salmon farms: environmental effects, and potential for integrated multi-trophic aquaculture. *Aquacult Env Interac* 2(3): 267-283.

Watts, J.E., Schreier, H.J., Lanska, L., Hale, M.S. (2017) The rising tide of antimicrobial resistance in aquaculture: sources, sinks and solutions. *Mar Drugs* 15(6): 158.

World Bank (2013) Fish to 2030: Prospects for Fisheries and Aquaculture. The World Bank, Washington DC, 80p.

Current status of gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) production in Turkey

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Introduction

During the past three decades, marine finfish culture has been rapidly increasing amongst Mediterranean countries. Especially, the main troubles and obstacles related with seabass and seabream culture have been solved, thus more knowledge and technology has been introduced to the culture operations. Besides, description of biological characteristics and requirements and also rapid improvements on aquacultural engineering has been main components of this increase of production and its success (Suzer 2018). According to this knowledge, application of different broodstock, systems larval and feeding protocols has brought success with high technology equipment. Additionally, improvements on sea cage technology and feeding systems played a major role on this rapid increase of production. In 2019, total marine finfish culture was achieved as 323.214 t in the Mediterranean countries consisted 49% seabass and 47% seabream (FEAP 2020). Turkey is the leading country which supplied approximately 49% of total production by modern hatcheries, feed factories, sea cage systems and fish processing facilities. In this study, current status of seabass and seabream production are investigated in detail on the basis of the aquaculture sector.

Production cycle of gilthead seabream (*Sparus aurata*)

Main species characteristics

Seabream is a member of Sparidae family and also naturally distributed not only in the Mediterranean basin but also found in around The Canary Islands, and also coast of the United Kingdom and the Black Sea (62°N-15°N, 17°W-43°E). It is abundantly distributed at the river mouths, lagoons and in order to spawn it migrates to deep waters in autumn (FAO 2019a; Figure 1).

Seabream is a carnivore and mostly found in the Mediterranean Sea, the Aegean Sea and the Marmara Sea in Turkey. Adult seabream generally feeds on the members of the crustacean and the molluscan family. It has a high dorsal body flattened from both sides. Mouth is terminal shaped, head is big and nose is flat. There are canine (4 in lower jaw, 4 in front side of upper jaw) and molar (4 raw in back side of lower jaw, 3 raw in back side of upper jaw) teeth and also V-shape gilt band between eyes. The operculum and preoperculum is covered by scales and also lateral line is elongated from operculum to caudal fin and between 73 and 85 scales are located on this line. Anal fin is relatively longer than dorsal fin and elongated to the anus. There are 11 spines, and 13-14 soft rays on dorsal fin, whilst 3 spines, and 11-12 soft rays are found on anal fin. The colour of seabream is mainly grey-dark on dorsal side but silver on ventral side. Moreover, there is characteristic red-purple coloured stain on operculum and dorsal side of pectoral fin (Moretti *et al.* 1999).

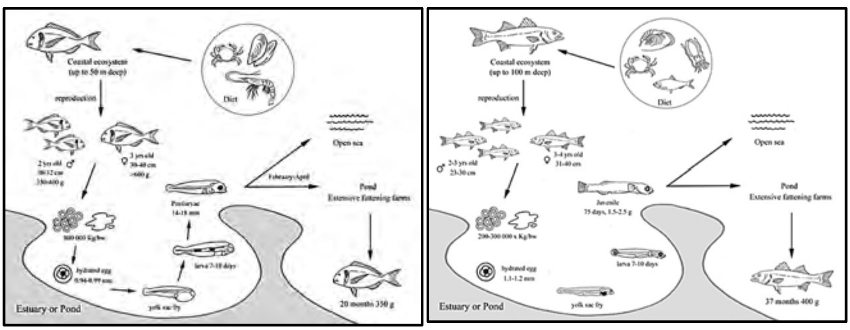

Figure 1. Production cycle of *S. aurata* and *D. labrax* (FAO 2019 a, b)

Seabream is a protandric hermaphrodite so it presents female characteristics with the formation of ovary at 8th month of its life cycle. During the first season of reproduction, at 12th month, all individuals have male properties. In this stage, mature testicular formation are found on the ventral side of gonads but no development is observed at the female part of the gonads. During the second reproduction season, at 23-24th month, conversion from male to female characteristics occurs. This stage is slow and intersex characteristics are formed especially for 3-age fish but sex inversion is observed for about 80% of the population. It is well reported that not only genetic and environmental factors but also nutrition plays a major role for this conversion (Zohar *et al.* 1978; Devlin and Nagahama 2002). Male fish generally reach sexual maturation at 2-age and 20-30 cm length whilst third age and 33-40 cm length are observed for females. Females spawn about 20.000-80.000 eggs/kg per day during the 4 months and spawning lasts from December to April at between 13 and 17 °C water temperatures (Cataudella *et al.* 1995). Eggs have 0.9 mm diameter, single oil globule and they are also pelagic.

Seabream usually reproduces from October to December and also gonadal development is clearly observed between 22 and 25 °C water temperatures. However, it can live between 2 and 34 °C water temperatures and from 5 to 40‰ salinity. It is generally distributed between 5 to 30 m depth but adult individuals can be found up to 150 m depths. In this sense, it is possible to find adult seabream in lagoon areas. During summer, they are naturally found at 0.5-9 m while they migrate to 35-40 m depths at winter. Seabream can reach to 75 cm total length and 17.2 kg weight but average of total length varies between 25 and 40 cm.

Production cycle

Seabream juveniles are produced during the year in high technological modern hatcheries which has 30-150 million juveniles/year capacity. Broodstock which are mainly collected from the wild and/or cultured in hatcheries are usually stocked into PVC tanks with 10-20 m^3 volumes. Most of the hatcheries are managed according to their breeding program and also breeders between 3 and 6 ages are usually used for production. Generally, breeders spawn for 3 years in production process and then are renewed by fresh breeders. In some hatcheries, breeders from Atlantic origin are rarely used. Stocking changes between 8 and 12 kg/m^3 and also female:male ratio is adjusted as 1:1 and/or 2:3 kg. Broodstock is fed by breed extruder pellet, wet feed including cuttlefish, squid, octopus and discard fish during the year. For this reason, some hatcheries prepare these feed in their facilities containing high HUFA/PUFA. Breeders are usually fed ad-libitum and feeding frequency is adjusted 1-2 times a day.

For spawning, natural and photo-thermo manipulation method (decalage) are commonly used under culture conditions. Hatcheries mainly carry out production one and/or two times in a year. Spawning period usually lasts for two months, in some hatcheries this is elongated up to 4 months. In natural period of spawning, about 0.5-1 million eggs/kg is obtained in most of the hatcheries whilst some of them reports that this ratio is over 1 million eggs/kg. According to breeding procedure, hormonal administration is not applied in most hatcheries. Fertilization rate of the eggs mainly changes between 85 and 90%. However, due to decalage application, a few oil globules, differences in blastomere sizes, decrease in egg diameter, mortality at gastrulation stage, decrease in fertilization and hatching rate, variations in hatching duration, and smaller and malformed larvae are rarely recorded by some producers. Obtained eggs are incubated between 14 and 18°C, at 6000-7000 eggs/l stocking rate, in 100-200 L capacity incubators with 300-425 µm sized mesh. Incubation period lasts in a specific room and hatching duration changes between 50 to 80 h depending on water temperature. Hatching rate is calculated around 90%.

After hatching, larvae are stocked into larval tanks at 80-100 ind/l density. Larval tanks are generally dark coloured and their volumes varies between 6 and 8 m^3 depending on the culture methods. Larviculture is carried out in recirculated culture systems using green water techniques. For this technique, algal species of

Chlorella sp., *Nannochloropsis* sp., *Nannochloris* sp., *Isochrysis* sp. and *Tetraselmis* sp. are generally used in $5\text{-}7 \times 10^5$ ind/ml density in the most hatcheries. Larval stage is completed at 18-22 ºC and also salinity is adjusted as 30‰.

During the larval stage, different rotifer species (*Brachionus plicatilis* and *Brachionus rotundiformis*) and *Artemia* sp. in different sizes are used for larval feeding. In hatcheries, *Artemia* sp. originated from USA and Vietnam is commonly used. Besides, alternatively water flea *Daphnia* sp. is used by a few hatcheries. Larval feeding is performed according to larval tank volumes and it should be adjusted to always reserve available live food in the tanks. Successful survival rates for seabream larviculture fluctuates amongst hatcheries but it varies between 5 and 30% under culture conditions. Generally, larviculture is completed 30-35 days after hatching and weaning stage is starts.

Weaning stage begins mainly at 15-30 mg in weight and this stage is completed in 10 days. During this stage, PVC tanks with 15-20 m^3 volume are usually used and larvae are stocked as 15-20 ind/l in flow thorough systems. Water temperature is around 20-22 ºC, feeding rate is adjusted as 6-12% of biomass and also micro-particulate food 100-200 µm in size is commonly used. *Artemia* sp. and copepod are also used as live food. Until leaving the weaning unit, larvae reach about 200-300 mg weight. Survival rate changes between 80 and 95% at this stage. Some hatcheries calculate this rate as 30% together with larval stage. Larvae leaves the weaning unit around 60-70 days after hatching. They reach 0.3-0.4 g and in order to select non-functional swim bladder, larvae are exposed to very high salinities.

After weaning, juveniles are transferred to on growing unit and adapted to natural sea conditions. At the on-growing unit, flow thorough system is usually used and volumes of tanks are usually around 15-30 m^3 however a few hatcheries use tanks with 80 to 130 m^3 volume. In these tanks, stocking rate is generally 4000-5000 juveniles/m^3 but most of the hatcheries usually operate with 2 to 3-fold increased stocking density by using liquid oxygen support and ozone equipment. Water temperature is commonly adjusted around 19-21 ºC in this unit whilst temperature of natural sea water is applied in some hatcheries. Besides, size of the extruder pellet feed varies between 0.5 and 2 mm and feeding rate is around 3.5-6% of biomass. In this unit, juveniles are grown up to 5-8 gr in weight with respect to demand of sea cage farms, in addition, some hatcheries keep growing juveniles up to 50 g. At the end of the culture period, deformation rate is calculated between 3 and 5%.

After leaving hatchery, seabream juveniles are transferred to sea cages and/or earthen ponds in order to grow to marketable size. In sea cage farming, HDPE sea cages with diameter around 30-50 m are commonly used and they are equipped with PE knotless nets with 7-10 mm mesh size. During this period, in order to protect from fouling organisms, knotless nets are subjected to antifouling staining.

Stocking rate of fish varies from 7 to 15 kg/m^3 and feed conversion ratio is around 1.7-2.2 in sea cages conditions. Due to differences in geographic locations, juveniles reach 350-400 gr average weight around 13-18 month. In the middle and Northern Aegean Sea, 4 g juveniles, are transferred to the cages in April-May, reaching 350 g after 13-14 months but, they reach the same weight in 15-17 months if the transfer is carried out in June-August. In the Southern Aegean Sea and the Western Mediterranean Sea, juveniles in similar weight reach to marketable size (350 g) within 12-14 months after transfer to sea cages in April-May, whilst this duration is completed 15-16 months for juveniles transferred in June-August (Yıldırım and Alpbaz 2005; Akpınar 2018).

In addition to sea cages, seabream is produced in earthen ponds. Capacity of these land based fish farms changes between 20 to 300 tonnes/year and also they are characterized as family-owned businesses. Ground water is commonly used. Earthen ponds are generally 20-100 m in length, 4-20 m in width and 1-3 m in depth. For earthen pond production, juveniles are supplied from hatcheries and stocking rate is kept between 2.5 and 4 kg/m^3. Fish are fed by extruder pellet feed and reach to 350-450 g within 16-20 months, additionally, feed conversion ratio decrease to 1.5 in some earthen pond plants (Şaşı and Tuzkaya 2012).

Production cycle of European seabass (*Dicentrarchus labrax*)

Main species characteristics

European seabass is distributed throughout the coasts of Norway, Morocco, The Canary Islands and Senegal, as well as in the Mediterranean Sea and the Black Sea (66 ° N-13 ° N, 19 ° W – 42 ° E). These fish generally spread in the mouths of the river and lagoon regions due to their tolerance to temperature and salinity in sandy, muddy shallow biotopes where marine phenograms exist. This carnivorous species rarely moves alone and /or uncommonly in small schools. In their young period, they consume arthropods (*Crangon* sp., *Gammarus* sp., *Ligia* sp.), in adult stage they consume smaller fishes (*Atherina* sp., *Gobius* sp., *Sardina* sp.), Cephalopod (*Sepiola, Loligo*) and also arthropod species. (*Carninus* sp., *Crangon* sp., *Macropipus* sp.) (FAO 2019b; Figure 1).

The body of the fish is slightly flattened laterally. The skin is covered with stenoid scales. It has 62-74 scales in the lateral line. The fish has a double dorsal fin and the anal fin does not differ. The first dorsal fin has 8-10 spines; the second one has one spine and 12-13 soft rays. However, the anal fin has three spines and 10-12 soft rays. There are no scales in their muso. There is a gray-black stain on the operculum and a hard spike beam in the preoperculum and operculum. The colour is white in the dorsal grey-dark ventral. There is a black stain on the eye bone. Mouth wide, teeth on the palate and tongue (Moretti *et al.* 1999).

Gonadal development is not observed during the first year in seabass. Differentiation starts in testicles and ovaries in 13-15 months. The development of sperm in the gonads begins with the proliferation of spermatogonium in the walls of the testicular canals. Primary spermatocytes occur from the spermatogoniums and secondary spermatocytes occur from them. Under natural conditions, seabass can produce sperm in the second year of life. However, their GSI is low. In 3 years, it can produce a high rate of sperm like an adult. Differentiation in ovaries starts between 13-15 months as in males and lasts relatively longer. Females spawn eggs only in the 3rd year under natural conditions. While males spend their energy resources to reach the mature maturity, females use them for their somatic development. 3-year-old females are 40% larger than males (Pickett and Pawson 1994). Sexual gonadal maturation is determined 23-46 cm length and the mean value is 32.3 cm. In natural environment, female individuals can produce 300.000-400.000 eggs per kg. Spawning continues between December and March when the temperature is between 11-14 ºC. Ovulation in the Atlantic continues until June. Eggs are 1.02-1.39 mm in diameter and are pelagic, with some oil globules, one centrally located.

In our waterbodies, the optimal reproductive period and temperatures for seabass are generally between January-March and at 22-25 °C. However, the fish can live in seawater salinity exceeding 40‰ and between 2-34 ºC water temperatures in lagoon zones. Entering the coastal waters in summer, the species migrates to the high seas in cold weather. However, the species is generally found in the littoral zone with a depth of up to 10 m, at the mouth of a river, lagoon and occasionally at the bottom of rivers. In the open sea it goes down to a depth of 100 m. Adult individuals can migrate more than a few hundred kilometers. The fish can reach a total height of 100-110 cm with a weight of 10-12 kg.

Production cycle

The systems used in seabass culture are similar to those of seabream production and there are some application differences. In seabass production, individuals with high performance during production are generally preferred as broodstock, but sometimes breeders caught from the natural environment are added to the broodstock. Some companies have been working on broodstock improvement to achieve high performance individuals for long time. Broodstocks in the facilities are usually stocked in 20 m^3 tanks. In these tanks, flow thorough system is used, as well as recirculated sea water system. Tanks are usually dark color and cylindrical shaped. Facilities prefer 3 to 6-year-old individuals as breeder for spawning. Stocking density of broodstock varies between 8-12 kg/m^3. The female:male ratios are 1:1, 1:2, 2:1, 3:2 and 2:3 kg depending on the condition of the breeders. Broodstock are renewed at a rate of 20-40% annually and broodstocks are used for 3 years in average.

Before spawning period, broodstock are usually fed with extruder pellet feed specially formulized for broodstock. During the preparation period for spawning, facilities use commercial pellets and wet feeds with high nutritional values. As feed sources for wet feed, cuttlefish (*Sepia officinalis*), squid (*Loligo vulgaris*), octopus (*Octopus vulgaris*), shrimp (*Paropaneaus longirostris*) and various low economical fish (*Diplodus vulgaris, Triglia lucerna, Diplodus annularis, Trachurus trachurus*) are used. Broodstock individuals are fed ad libitum 1-2 times a day.

Although the supply of eggs from broodstock is usually in the natural breeding period, some hatcheries also obtain eggs by decalage (photo-thermo manipulation) method. Several hatcheries obtain their eggs from other facilities that surplus eggs. Some companies perform decalage with the application of the photo-thermo period method to produce eggs, whereas some of them apply only photoperiod method to stimulate gonad growth and spawning. Although there are limitations in hormone administration, LHRHa hormone is usually used at a rate of 5-10 µg/kg in 12-hour intervals in spawning. Water temperature during spawning is around 14-15ºC. During the natural reproduction period 200.000-300.000 eggs per kg is taken from the breeders, sometimes this amount increases above 400,000 eggs per kg. The fertilization rate of the eggs is around 80-85%. Eggs are incubated in incubation rooms at 14-17ºC water temperature, 50-2000 L volume incubators and 4000-7000 eggs/l stock density. Depending on the water temperature, hatching duration varies between 60 and 80 hours.

In our country, intensive and hyper-intensive production methods are used for the culture of seabass larvae. The larvae hatching from the eggs are stocked in tanks as 100-120 ind/l. In some hatcheries, this rate is increased up to 150 ind/l. Larviculture is conducted in flow thorough and/or recirculated sea water system but the hatcheries commonly prefer recirculated sea water system. The culture tanks used in the system varies between 2 to 15 m^3. Generally, 4-6 m^3 volume dark-colored tanks with inner surfaces that are gel-coated are used. In seabass larvae, salinity reduction technique (26‰) is widely used and culture is only performed with natural seawater where there is no fresh water source. Larviculture starts with a water temperature of 15-16 ºC and it is gradually increased up to 19-20 °C. The light intensity and photoperiod are determined by each hatcheries' own culture protocols and generally low constant light or increasing light intensity is preferred.

In larval feeding, rotifer (*Brachionus plicatilis*) and also nauplii and metanauplii form of *Artemia* sp. from different origins are commonly used. Rotifer is usually fed for the first 5-10 days after hatching but a few hatcheries keep feeding up to 20-day old. However, a few hatcheries culture only seabass and they solely use nauplii and metanauplii form of *Artemia* sp. as live food. In these hatcheries, the seabass larvae are stored in the dark for 8-10 days and then the first feeding is started with *Artemia* nauplii in AF form. In the following stages, the transition to

EG type is done. Simultaneously, according to the protocol, the feeding with Artemia forms called EG_1, which is fed with enrichment substances, continues from the 15^{th} days after hatching. According to culture techniques, the success rate in larviculture has been increased up to 60% in the recent years.

European seabass larvae are generally transferred at 30 or 35 days after hatching to the weaning unit similar to seabream. During this period, the larvae reaches an average length of 20 mm and a weight of 30-40 mg. The stock density in weaning tanks can be up to 20 ind/l by supporting liquid oxygen. Cylindrical tanks (15-25 m^3) with a bottom slope are generally used during this period. Some hatcheries perform both larval and weaning processes in larger tanks. Additionally, race-way type tanks are also used for some processes during this period. The micro-particulate food is commonly used during weaning, similar to seabream, feeding starts with 100-200 µm size and increases up to 500 µm depending on larval age and size. Weaning period lasts around 15-18 days. The average water temperature is 20 ºC. The survival rate changes between 80 and 90% on average under culture conditions. The larvae are stored in this unit up to an average weight of 350-450 mg. According to larval age and size, larvae is graded at 70-80 days after hatching and then transferred from this unit, additionally, deformed and non-functional swim bladder larvae is separated from the population.

After weaning period, larvae are transferred to the on growing system. However, if the weaning tanks are not used again with new larvae for weaning, the population is divided into two tanks and the on growing process is continued. The technical characteristics of the tanks used in this system are the same as those used in the weaning unit. Although the volumes of the tanks are generally 15-30 m^3, some hatcheries prefer tanks up to 130 m^3. Race-way type tanks are also used in some hatcheries. Tanks using for natural seawater salinity can be stocked with 4000-6000 ind/m^3. Liquid oxygen system is widely used in our country and stock density can be increased up to 6000-12.000 ind/m^3 during on growing stage.

Water temperature in this period varies between 19 and 21 ºC and natural sea water temperature is also applied in some hatcheries. According to the larval age and size, extruder pellet feed is used (0.5-2 mm) and also feeding rate is between 3 and 6% of biomass. In this unit, fish can be stored up to 15 g in weight with regard to demands of the sea cage farms. In addition to this, on growing process is also performed in large concrete tanks and earthen ponds which are geomembrane-covered at the inner surface in our country. Water temperature up to 26 °C is applied and ground water is used in these facilities. Before transfer of fish to sea cages, the deformed juveniles are separated by handling separation on the underlit tables. The survival rate varies between 85 and 95% if there are no disease outbreaks.

Similar to gilthead seabream culture, European seabass juveniles are also transferred to the sea cages and earthen ponds facilities. Fish are stocked between

6 and 12 kg/m^3 in sea cages. In this period, feed conversion ratio varies between 1.8 and 2.3. Due to differences in geographic locations, fish reached to around 350-450 g between 18 and 21 months after transfer to the sea cages. In the Black Sea region, seabass juveniles are transferred in to the sea cages weighing 2-3 g in June, then they reach to 350 g weight around 19-20 months and 500 g weight in about 28-30 months. In this period, duration for reaching marketable size of seabass juveniles (2-3 gr) at the sea cages is between 13 and 15 months. For juveniles transferred in April-May, this period similarly lasts around 13-15 months. Moreover, reaching 500 g weight for seabass juveniles in sea cages is completed between in 18 to 20 months.

Similarly, seabass is produced in earthen ponds although not as much as seabream. The stocking density in ponds varies between 2 to 4 kg/m^3. Juveniles are transferred to these ponds in a smaller size (1-5 g) than sea cages. Depending on the temperature of the groundwater, fish reach 300-350 g weight in 16-20 months with 1.5-1.7 FCR.

Sector characteristics

Turkey has an important status in terms of marine fish farming and thus studies and efforts related with aquaculture increased after 1980s. In the first years, seabream and seabass fry were collected from the natural environment and were grown out to marketable size in wooden sea cages localized in bays. The first hatchery and also cage culture production facility from fry to marketable size designed in a modern structure was established in 1984 by a private enterprise located in Ildırı, Çeşme/İzmir. During the same period, Ege University, Faculty of Fisheries, started to produce larvae of seabream and European seabass in experimental scale. After the first marine fish hatchery established in 1984, the number increased rapidly and reached 21 marine fish hatcheries in 2000. However, this number decreased to 9 facilities in 2004 due to economic crises, lack of mechanization and experienced technical personnel, and raised again to 12 hatcheries in 2006. Nevertheless, the reduction in the number of hatcheries did not cause any decline in the amount of juvenile produced. Only the old fashioned and/or small plants that were unable to renew themselves technologically disappeared and/or consolidated to bigger plants and some of the companies developed their production systems, capacities, technologies and marketing systems. The production of juvenile fish presented a rapid increase especially after the 2000s, in 2002 about 45 million seabass and seabream juveniles were produced and this number increased to 80 million in 2003. The production of juveniles reached to 150 and 190 million in 2006 and 2010, respectively. After this date, seabass and seabream production steadily increased and as of 2017, aquaculture industry has reached a capacity of 760 million juvenile fish per year with 18 private and 2 ministry hatcheries operating with modern technology (TURKSTAT 2018; GDFA 2018) (Figure 2).

Figure 2. Hatchery facilities (Photographed by Cüneyt Suzer and Şahin Saka)

In these hatcheries, while reduced salinity production technology is only used in flow thorough and closed recirculated systems for seabass production, green water technique is used for both seabream and seabass production. However, during the past two decades, problems encountered in marine environments have been leading the producers to use groundwater in terrestrial areas. For this purpose, 8 hatcheries that use geothermal groundwater in the southern Aegean region had been established by large-scale industrial production enterprisers and started production. In addition to these, the other 14 hatcheries maintained production in the coastal area around the South Aegean, North Aegean and Izmir. On the other hand, investments for hatchery and sea cage farming facilities are continued by private sector in overseas foreign countries.

The seabream and European seabass juveniles from the hatchery are transferred to net cages and earthen pond facilities where they are grown to marketable size (Figure 3). The production of seabass and seabream in the sea cages is spread in the regions of the Black Sea (Ordu, Sinop, Trabzon), the Aegean Sea (Aydın, Muğla and İzmir) and the Mediterranean Sea (Antalya). In the Black Sea region, only seabass is grown in sea cages. Aquaculture activities in modern and large diameter HDPE cages (30-50 m diameter) have been playing an important role for increasing the production. According to the Regulation no. 26413 of 24 January 2007 declared by Ministry of Environment and Forestry, sea cage facilities cannot be established in closed bays and gulfs in the nature of sensitive areas. Also, fish farms can be constructed at least 1.1 km away from the coast and deeper than 30 m. This regulation has played a major role in the development of sea cage technology. After this communiqué, production quantities have increased considerably due to relocation to off-shore areas with large-scale net cage enterprises. On the other hand, earthen ponds are localized in the South Aegean region.

Fish farms operating in the sea uses a large part of their production capacity. The amount of production in the sea cages is approximately 96% of the total seabass and seabream production. Approximately 20% of the plants have a capacity of 1000 tons and over per year (GDFA 2018). These plants are also large producers, mainly engaged in industrial production at the holding status. These indicators reveal that seafood producers have expanded their capacities in order to be productive in the recent years due to production in deep and open waters. In addition, 4% of the total production is run in earthen pond plants. These establishments are generally established as family-operational based (Table 1).

Table 1. Distribution of facilities according to the production type (GDFA 2018)

Production Type	Number of Facility	Ratio (%)	Capacity (tons-inds)	Ratio (%)
Net cage	237	72.99	252.560	95.91
Earthen pond	173	28.01	10.762	4.09
Hatchery	22		760 millions	
Total	432	100	263.322	100

The fish transferred to earthen ponds and sea cages are fed with high quality extruder feeds and grown up to marketable size according to market demands. The content of high-quality feeds, which are still produced in 25 feed factories, can be prepared seasonally by the fish feed producers according to the requests of the companies. When the production data are examined within the scope of all these evaluations, it is seen that the seabream production, which was 33.500 tons in 2007, increased to 76.680 tons at the end of 2018, and the seabass production which was 41.900 tons in 2007 increased to 116.915 tons at the end of 2018. During the past decade, more than 2-fold increase has been observed in seabream and seabass production.

Figure 3. Sea cage and earthen pond facilities
(Photo: Kürşat FIRAT and Şükrü YILDIRIM)

Production costs of seabream and seabass to marketable size has variations according to fry quality, geographical location of plants, capacity and culture methods. In addition, production cost in earthen ponds also differ among plantations.

Production costs of juveniles of seabream and seabass mainly fluctuates around 9-12 ¢ (Euro). Moreover, these costs for seabream grown up to 400-600 gr in sea cages changes between 3.1 and 3.3€, and also around 2-3.4€ for seabass at the same size. Production costs of seabream and seabass sized 400-600 g in earthen ponds usually varies between 3.4-3.5€ and 3.7-3.8€, respectively.

In large local markets, however, 300-400 g of seabream fish are sold to the final consumer for 4.1-4.3€, 400-600 g for 5.5-5.7€ and 600-800 g for 6.0-6.2€. Similarly, seabass with a weight of 300-400 g will cost 4.4-4.6€, those with 400-600 g will cost 5.8-6.1€, those with 600-800 g will cost 6.2-6.3€ and those with 800-1000 g will cost 7.7-7.9€.

The whole production of cultured seabream and seabass in marketable size are not consumed in the domestic markets and are exported to the foreign markets. In the past years, fresh and chilled seafood was the main characteristics of export and consumption, especially after 2000, added value has been embedded as frozen and processed products to the domestic and foreign markets. A large proportion of aquaculture fish are still exported as frozen whole body, fillet or smoked. As a result of changing in consumption habits and social life, the demand for semi-processed or processed products has started to increase and has expanded its range of products to meet this need in the sector. In accordance with the Fisheries Law and related regulations, all processing facilities have to be registered. In addition, processing plants exporting to the EU countries need approval from the Ministry of Agriculture and Forestry and these approvals should be accepted by the EU.

Cultured seabass and seabream are mostly processed as fresh-chilled, frozen and fillets. Fish and fishery products constitutes 99% of all animal products exported from Turkey to EU countries. Despite the presence of processing facilities, 74% of the total aquaculture production in our country is consumed and/or exported as fresh or chilled. However, the rate of fishes transferred to fish meal and oil plants in total production is 14%. According to TURKSTAT and GDFA data, total export of fisheries in 2017 is 156.681 tons and the import is 100.044 tons (Aksoy 2018; GDFA 2018; TURKSTAT 2018). Approximately 75% of the produced seabream and seabass are exported to 85 foreign countries including countries of EU, Far East, Middle East, Asia and the American continent. Total annual income is estimated approximately 900 million USD in 2017 (EIB 2018; GDFA 2018). It is expected that this value will exceed 1 billion $ within a few years.

In the export of seabream, freshly chilled products constitute the largest share, and are followed by fresh and frozen fillet products. In the same way, seabass is preferred as freshly chilled followed by frozen and fresh fillet products. The sector came to the fore in the European market and two production companies won the ITQI (International Taste & Quality Institute) quality award in 2017, which is accepted as a highly prestigious award.

Overall comments

In the assessment of the gilthead seabream and European seabass production sector, it is very important to analyse the strengths and weaknesses of the situation and the opportunities and threats. In this sense, the sector has a very strong potential, due to especially physical-chemical parameters of the sea water. It is known that the quality of sea water does not have any negative effect in the regions close to the Çanakkale Strait side of the Marmara Sea and also the Mediterranean Sea, the Aegean Sea, the Black Sea; especially the waters of the Aegean and Mediterranean regions are extremely clean. In this context, the sector is very strong in terms of new production sites. This situation makes it possible not only for the production of seabream and seabass, but also for the production of promising candidate species such as common dentex (*Dentex dentex*), red porgy (*Pagrus pagrus*), bluespotted seabream (*Pagrus caeruleostictus*), shi drum (*Sciaena umbra*), sharpsnout seabream (*Diplodus puntazzo*), white seabream (*Diplodus sargus*), meagre (*Argyrosomus regius*), turbot (*Psetta maxima*), and tuna (*Thunnus thynnus*) (fattening). Naturally, culture experience for 35 years has played major role for this situation. Particularly, continuously monitoring of new technologies by the sector makes it stronger in the competition with other countries. Besides, international partnerships resulted in stronger companies for the marketing of these products. Also, expansion of the insurance system in production has strengthened the sector. On the other hand, it is quite advantageous that labour supply and costs are halved compared to other producer countries. Due to improving technical knowledge, it is possible to produce not only juvenile but also marketable-sized fish throughout the year. The quality-control system and production documents are adequate for trading fishery products to both EU countries and countries around the world. In this context, while the life and property safety is targeted primarily through the standardization process, the production of goods and services below the level determined by detection the lower limit of the quality is not allowed. Being close to the main market (EU) is our important advantage and our export capability is quite high. The aquaculture sector has the ability to provide fishery products suitable for the desired quality and quantity. In addition, many mechanical systems and/or modern equipment required by the industry are successfully manufactured domestically and exported abroad. Moreover, the strong relationships between the Ministry of Agriculture and Forestry and the sector has been very valuable for the development of the industry. Also, there are some strong multidisciplinary research infrastructures and centres in fishery research institutes and some universities.

Apart from the strong sides of the sector, there are some weak points. The most important deficiency is the lack of integrated targets in the short, medium and long term between the stakeholders for the future projection. In this context, the basic production policy has not been determined. However, the production sites designated by the government which are currently in use are very limited. There is almost no space available for new sea cage facilities and issue new licenses.

Unfortunately, organizations of the potential production areas by the government are not completed in most of the cities that have coastal areas. Although rental prices have been reduced, reduction of the rental duration from 20 to 10 years and obligation of prior signed agreements for evacuation caused some obstacles and problems for the investors. Also, inadequate incentives caused loss of time and cash. In addition, the lack of information and its sharing, the difficulty of collaborating and insecurity weakened the sector. Aquaculture in the Mediterranean basin is dominated by seabass and seabream, yet culture of these two species is not widespread around the world which prevents their recognition abroad as much as it is desired by the producers. This domination also caused economic pressure on pricing. The weakest point in production is the effect of feed costs. Feed prices constitutes 50% of the costs of fish prices in Greece, whereas, this rate is about 38% in Spain, 22% in Italy, 50% in Croatia and 45% in Israel, but it is between 66 and 74% in our country. In Turkey, fish feed production depends highly (%80) on imported raw materials such as fish meal and oil which negatively effects the end product prices due to high prices. The import of probiotics, prebiotics, immunostimulants, micro-particulate food, enzymes and enrichment media in the technology-based manufacturing subsidiary industry adversely affects costs, depending on foreign exchange movements. At the same time, many technical devices used in the sector are imported. Throughout the sector, there is a serious shortage of capital due to exchange rate fluctuations. In addition, indirect taxes complicate foreign competition. The fact that most of the sector's production is performed by a few companies is another weakening factor. In addition, in the recent years, reduction of the support rates for products by the government caused commercial weakening of the sector.

The lack of the desired level of non-governmental organizations; the abolition of the federation (inability to have a say in pricing, this structure exists in all other countries), the lack of a fisheries chamber, the limited effectiveness of associations and the close cooperation with each other weakens the sector. In addition, the effectiveness of aquaculture lobby on political power is not as strong as other production and service areas, but rather weak. The ministry-sector relations except the Ministry of Agriculture and Forestry are extremely weak (especially Ministry of Environment and Urbanization, Ministry of Culture and Tourism, Ministry of Transport). The legislation, long permitting procedures and laws and regulations separately created by many ministries discourages the entrepreneurs. In addition, as in the production of livestock, it is not possible to pledge cultured fish as collateral. At the same time, production license is not accepted as a pledge. In particular, the problems in the logistic support points of sea cage facilities needed in the coastal area still continues. In addition to these, the so-called image pollution caused by sea cage facilities and its modular structures in the coastal zone amplified the problems.

The lack of diversification of species is another important issue. At the same time, consumer choice being mainly fresh products increased the risk of product deterioration with less shelf life compared to processed products. In addition, there is a significant difference between the price paid by the customer and the producer price and the market network has not spread to the bottom. The market is largely confined to Europe, which makes the customer dominant in price. In recent years, almost at cost sales caused great pressure on profitability. Low domestic consumption increases this effect and makes the product dependent on foreign market prices.

Except our strengths and weaknesses, we also have important opportunities for the development of the sector. Aquaculture production areas will be commissioned in 28 coastal cities (15 in the Black Sea region, 6 in the Aegean region, 3 in the Marmara region, 4 in the Mediterranean region) by the government and seems to be our strong side, although reluctance causes us to see the situation as an opportunity. On the other hand, if the necessary improvements are made at approximately 80 lagoon areas which are closed for natural reasons, the number of the aquaculture activities in 25 lagoons could be put into operation together. This is an important opportunity for sustainable aquaculture. The fact that the EU's Common Fisheries Platform supports traditional production (lagoon) reinforces this situation. Using renewable energy sources (solar, wind, wave and geothermal energy) directly and/or indirectly in aquaculture production is important in terms of costs. The introduction of certification systems like organic farming and good agricultural practices provides the opportunity to create new markets and this is accepted all over the world. In addition to these, the ability to adapt to new technological advances supports our ability to produce in more demanding conditions. Particularly with sea cage technologies, we always have the potential to produce in offshore systems. Increased international relations create new markets with capital inflow.

However, the main threat of the sector will be the restriction of production areas due to the deterioration of water quality. Currently, wastewater from 50% of the population is not treated. This situation will increase to the top level with the settlements approaching the production sites in time, so that the water quality will not be made directly or through the flow of the currents to the production regions. In addition, the escaped fish from the production area causes a serious threat to the gene pool of the wild population. This is an important threat not only for our region, but also for the whole Mediterranean basin. The strains with increased resistance to diseases carry the risk of transmitting pathogens to wild populations and disrupting the natural stock structure. Breeding studies may change some of the expected properties of fish in nature (Alarcon *et al.* 2004; Sola *et al.* 2007; Haffray *et al.* 2007). In addition, studies on biotechnology and especially on the production of two kilograms of seabass in two years and then two kilograms of seabass in one year will seriously challenge the sector. Besides, the production of juveniles which can be adapted to the environmental conditions faster and with a better feed evaluation capacity will cause problems on a sectoral basis with the transfer of genes applied abroad. In addition to these, the producers are inadequate in terms of the media communication they are using and/or trying to carry out against sectors such as tourism, transportation and marina management, which use the area together and are stronger. It is not possible to change this situation in a short time period.

The deterioration of economic indicators and exchange rate fluctuations caused to serious pressure on capital adequacy and this situation negatively affects foreign investments. On the other hand, it is possible that the companies, living financial bottleneck could be seized by foreign enterprises at low prices. Continuous and/or hard fluctuations in the exchange rates upwards are a great danger for the sector which takes raw material from abroad. Increasing exchange rate is caused to increase the cost of raw materials and technological products. More than 80% of the ingredients used in fish feed, which is the biggest expense in production, is mainly foreign-dependent. In addition, although alternative and compensatory products are used in fish feeds, it is inevitable that their foreign-dependence will be continued (FAO 2014; Turchini *et al.* 2019). All these processes continue to put pressure on the narrowing of the scissors between production and sales prices. Especially in 2019, the scissors between the production entitlements of the fish and the net cage sales prices narrowed. Some companies even had to sell seabass below their production prices. Lack of production organization carries the risk of meeting such situations in the coming years. In addition, due to the low salaries paid by the companies and the difficult working conditions, the trained personnel do not prefer the sector. On the other hand, in countries such as Tunisia, Algeria, Egypt and Morocco, if the production increases, the competition is expected to be challenged due to the cheapness of investment and operating costs. In addition, large investments in both Turkey and the Mediterranean countries, which led to an increase in supply, have made pricing less than rational (Bjørndal and Guillen 2017). Despite the fact that we produce better quality fish on a sectoral basis, the fact that the brand value of the products of other countries are higher than us is another threat in international competition.

In conclusion, it is clearly emphasizing that the introduction of new production areas for seabream and seabass production, which is increasing more than several animal production types on an annual basis, seems to be a very important need. However, this issue should be handled in a healthy and coherently growth model without negative impact on fish prices. Otherwise, the deterioration in the supply-demand balance will be cause to serious fluctuations on pricing of products. Also, it is estimated that fish consumption per capita in Turkey and European countries presented not desirable increase. This situation caused considerable obstacles and pressure on the investments for many years. Nevertheless, in order to support the sustainable growth of the sector, in the first phase of the studies carried out by the Ministry, some regions in the Mersin and Aydın province new production areas which has the capacity of 90,000 tons per year for each one were declared. Moreover, it is inevitable that innovative searching and new solutions should be conducted in order to sustain sectoral development. Such searching and solutions should be focused on not only increase in production but also culture of promising candidate species to diversify aquaculture production. Nowadays, the continuity of success and the increase in production quality can be achieved with biological and technological know-how in production. For this purpose, it is inevitable to increase biotechnological studies related with aquaculture. In addition, it is well reported that some studies have been focused on the determination of species-specific larval rearing protocols, improvement of recent larval feeding strategies, description of problems and troubles during larval stage, sex control studies, determination of the ideal period for artificial sex inversion and the appropriate experimental topics for ploidy manipulations. Especially in seabass culture, it is commonly known that weight gain of male fish is relatively lower than female individuals due to early development of sexual organs and this is the crucial phenomenon that should be overcome under culture conditions.

It will be very useful to conduct some studies specifically related with prevention of the presence of premature females, reducing deformity rates and increasing growth rates. However, when considering the sector in detail, it is evident that there are some serious and/or unsolved problems currently present. The most important and current problems in the sector can clearly be emphasized as use of water area, transfer of license for production, insurance, mortgage (pledge of license), pledge of livestock, obtaining loans, marketing sector, increasing input costs depend on imported raw materials and fluctuations of exchange rate. In this sense, it is well stated that new collaborations and/or policies should be established within this scope and in order to sustain development and solutions for the problems of the aquaculture sector, qualified working partnerships and innovative projects to be implemented in cooperation with the University-Ministry-Industry are inevitable.

References

Akpınar, A. (2018) Development of Gilthead Sea Bream (*Sparus aurata*) in Offshore Cage Culture. Ege Univ. Graduate School of Natural and Applied Science, Aquaculture Department, Bornova, İzmir, Master Thesis, 55 p. (in Turkish).

Aksoy, İ. (2018) Presentation of Aegean Exporters' Association. Fisheries and Fisheries Workshop, 8 August 2018, Izmir Chamber of Commerce (in Turkish).

Alarcon, J.A., Magoulas, A., Georgakopoulos, T., Zouros, E., Alvarez, M.C. (2004) Genetic comparison of wild and cultivated European populations of the gilthead sea bream (*Sparus aurata*). *Aquaculture* 230: 65-80.

Bjørndal, T., Guillen, J. (2017) Market integration between wild and farmed seabream and seabass in Spain. *Applied Economics* 49(45): 4567-4578.

Cataudella, S., Crosetti, D., Marino, G. (1995) The sea breams. In: Production of Aquatic Animals (eds., Nash, C.E., Navotny, A.J.), Fishes, Elsevier, Amsterdam, pp. 289-303.

Devlin, R.H., Nagahama, Y. (2002) Sex determination and sex differentiation in fish: an overview of genetic, physiological, and environmental influences. *Aquaculture* 208: 191-364.

EIB (2018) Aegean Exporters' Association. Available at: http://www.eib.org.tr/bilgi-merkezi-raporlar-su-urunleri.asp (accessed 20 Jun 2019) (in Turkish).

FEAP (2020) Annual Report. Available at: http://feap.info/index.php/data/ (accessed 27 Dec 2020).

FAO (2014) The state of world fisheries and aquaculture, Rome. Available at: http://www.fao.org/3/a-i3720e.pdf (accessed 11 Jul 2019).

FAO (2019a) Cultured Aquatic Species Information Programme (*Sparus aurata*). Available at: http://www.fao.org/fishery/culturedspecies/Sparus_aurata/en (accessed 29 June 2019).

FAO (2019b) Cultured Aquatic Species Information Programme (*Dicentrarchus labrax*). Available at: http://www.fao.org/fishery/culturedspecies/Dicentrarchus_labrax/en (accessed 29 Jun 2019).

GDFA (2018) Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Fisheries and Aquaculture. Available at: https://www.tarimorman.gov.tr/BSGM/Menu/32/Bilgi-Dokumanlari (accessed 08 July 2019) (in Turkish).

Haffray, P., Tsigenopoulos, C.S., Bonhomme, F., Chatain, B., Magoulas, A., Rye, M., Triantafyllidis, A., Triantaphyllidis, C. (2007) European sea bass– *Dicentrarchus labrax*. In: Genetic impact of aquaculture activities on native populations, Genimpact final scientific report (EU contract n.RICA-CT-2005-022802). (eds., Svåsand, T., Crosetti, D., García-Vázquez, E., Verspoor, E.), pp. 40-46.

Moretti, A., Pedini Fernandez-Criado, M., Cittolin, G., Guidastri, R. (1999) Manual on Hatchery Production of Seabass and Gilthead Seabream, FAO, Rome, Vol. 1, 194 p., Available at: http://www.fao.org/docrep/005/x3980e/x3980e00.

htm (accessed 08 July 2019).

Sola, L., Moretti, A., Crosetti, D., Karaiskou, N., Magoulas, A., Rossi, A.R., Rye, M., Triantafyllidis, A., Tsigenopoulos, C.S. (2007) Gilthead seabream–*Sparus aurata*. In: Genetic impact of aquaculture activities on native populations, Genimpact final scientific report (EU contract n. RICA-CT-2005-022802). (eds., Svåsand, T., Crosetti, D., García-Vázquez, E., Verspoor, E.), pp. 47-55.

Pickett, G.D., Pawson, M.G. (1994) Sea Bass: Biology, Exploitation and Conservation. Fish and Fisheries Series 12, Chapman and Hall, London.

Suzer, C. (2018) A success story: Production of gilthead sea bream (*Sparus aurata*) and European sea bass (*Dicentrarchus labrax*) in Turkey. *Agriculture Turkish Fisheries Journal Special Issue* 27-36 (in Turkish).

Şaşı, H., Tuzkaya, T. (2012) The Investigation of some physical–chemical properties and aquaculture activities from fish farming waters in south Aegean region Savran Locality (Milas, Muğla). *Journal of Eğirdir Fisheries Faculty* 8 (2): 25-37.

Turchini, G.M., Trushenski, J.T., Glencross, B.D. (2019) Thoughts for the future of aquaculture nutrition: Realigning perspectives to reflect contemporary issues related to judicious use of marine resources in aquafeeds. *North American Journal of Aquaculture* 81(1): 13-39.

TURKSTAT (2018) Turkish Statistical Institute, Fisheries Statistics. Available at http://www.tuik.gov.tr/ PreTablo.do? alt_id=1005 (accessed 08 July 2019). (in Turkish).

Yıldırım, Ş., Alpbaz, A. (2005) An investigation on some of the production characteristics of the fish farms in Turkish Seas whose annual productions are 100 tonnes and over. *J of Fisheries & Aquatic Sciences* 22(3-4): 251-255.

Zohar, Y., Abraham, M., Gordon, H. (1978) The gonad cycle of the captivity-reared hermaphroditic teleost *Sparus aurata* during the first two years of life. *Ann Biol Biochem Biophys* 18: 877-882.

Candidate species of marine aquaculture in Turkey: *Thunnus thynnus, Seriola dumerili* and *Chelon ramada*

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Introduction

The seas and oceans are the driving force of the European and world economy, and they have great potential for growth. Economic utilization of seas and marine or their contribution to humanity as food is among the most important development plans of countries within the framework of a rational, sustainable and inclusive growth strategy. About 5.4 million jobs and about 500 billion EURO gross value added are generated annually from this strategic growth plan, called "Blue Economy" or "Blue Growth" (Anonym 2020). This strategic growth consists of three components. These are as follows:

- The first component is sectors with sustainable growth projections;
  1) Aquaculture,
  2) Coastal tourism,
  3) Marine biotechnology,
  4) Ocean energy,
  5) Seabed mining
- The second component is the basic constituents that provide information, legal and effective security in the Blue Economy:
- Improving knowledge about the sea and increasing access to sea,
- Marine spatial planning to ensure efficient and sustainable management of marine activities,
- Integrated marine surveillance to give authorities a better idea of what is happening at sea.
- The third and the final component, sea basin strategies to provide tailor-made measures and encourage cooperation between countries, preparing a structure integration where the dynamics of each sea can be evaluated within itself.

Aquaculture, the first ingredient of this blue growth strategic plan, is one of the sine qua non for human nutrition. For this reason, Food and Agriculture Organization (FAO) of the United Nations published a report (GFCM-41-2017-

1) that will determine international strategies within the scope of the sustainability principle of the GFCM (General Fisheries Commission for the Mediterranean). This strategy report predicts a globally competitive, productive, profitable and egalitarian future for the Mediterranean and Black Sea aquaculture industry by 2030. In addition, FAO recommends that countries with coasts in the Mediterranean and Black Sea should add this prediction to their policies on a national basis. For this purpose, 17 "Sustainable Development Goals (SDGs)" were determined and these goals were accepted by the world leaders at the United Nations Summit held in September 2015 and brought into force in January 2016. SDG 14, which aims to "conserve and sustainably use the oceans, seas and marine resources for sustainable development", underlines the vital importance of the vision and mission of the seas in an international and institutional context for the protection and sustainable use of the environment. In addition to this article, there are recommendations to improve the aquaculture of the Mediterranean and Black Sea coastal countries in the articles about food security, safe and accessible water, sustainable economic growth and decent employment, sustainable consumption and production, climate, biodiversity, forests and desertification, and global partnership.

Aquaculture is an important source of food and income for hundreds of millions of people around the world. It is thought that 56.6 million people earn a living from fisheries and aquaculture all over the world, and 18 million people (33% of all those working in the aquaculture sector) work in fish farms in 136 countries (FAO 2016). The significant growth in the aquaculture sector in the last 20 years has increased the capacity of people to consume diversified and qualified nutritious foods. Fish consumption per capita has doubled (19.7 kg) since the 1960s despite the increasing world population. The main reason for the growth of this number is the production originating from aquaculture, which has increased in the last 20 years. Today, aquaculture meets half of the fish consumption in the world (FAO 2017). So much so that the high demand for aquaculture will be met mostly from farmed fish in 2025 and aquaculture production is expected to reach 102 million tons in the world. Fish farming constitutes an important pillar of exports, especially in developing countries, accounting for half of the exports made worldwide. Although aquaculture in Oceania and inland waters is prominent in the export now, aquaculture-based production is seen as a healthy food security for the world population, which is expected to be 9.7 billion in 2050. While the annual increase in fish farming in the world in the last ten years was 5.8%, it increased by 7.2% compared to the production figures in the previous decade. Considering the increase in these aquaculture figures and comparing the production areas, fish production was mostly in earthen ponds, followed by brackish water and sea water. Besides the changes in the quality and quantity of water resources, feed is seen as the biggest limiting factor in aquaculture. For this reason, the world chooses to culture without external feeding. Aquaculture species made without external feeding are microalgae (27%), filter feed animal species (22.5%), and seaweeds which constitute half of the world's aquaculture production. In addition, 30.8% of the total fish production are bred without feeding from outside, and silver carp and bighead carp are the leading ones (FAO 2017).

The increasing number of artificial breeding, breeding and feeding techniques have led to the introduction of more species into culturing worldwide. FAO's production statistics (1996) reported 167 species being cultured in the world, 103 of them are fish species, 21 are crustacean species and 43 mollusc species. Today, it is reported that a total of 484 species are commercially cultured in the world (FAO 2017). This number is thought to be around 750-800 species together with scientific studies. These cultured species include 309 finfishes (including hybrids), 90 molluscs, 48 crustaceans, 5 frogs and reptiles, 6 aquatic invertebrates and 26 aquatic plants (FAO 2017). China alone cultivate and commercially utilizes around 180 species, 76 of which are fish species (Elder 2017).

European countries are a big market for the aquaculture industry with around 9 billion Euros worldwide. So much so that 5 billion juvenile fish, 2 million tons of marine fish, 680000 tons of molluscs and 330000 tons of freshwater fish were cultured in these countries. 3.2 million tons of formulated feeds were produced and approximately 200 thousand people work directly in the field of aquaculture. Currently, more than 40 species are bred commercially in European countries (EATIP 2017). The most cultured species are mussel, trout, salmon, oyster, carp, gilthead seabream and European seabass. Molluscs and crustaceans constitute 50% of the total production. 9 out of 10 mussels consumed from European countries are of aquaculture origin.

Aquaculture has increased rapidly in the last decade in Turkey, and this increase has caused an increase in the cultured species. While gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) (62% of total aquaculture) are the most cultured species in the seas of Turkey, rainbow trout (*Onchorynchus mykiss*) (37.6% of total aquaculture) is the most cultured species in inland waters in Turkey. Turkey provides 2 out of 5 gilthead seabream, European seabass and rainbow trout consumed in Europe. While Turkey's export/import ratio was 0.32 in 2000, this rate is 1.55 today. While 2.5% of the total aquaculture was exported in 2000, today 35% is exported. Approximately 10500 people work in 2308 aquaculture enterprises in total. And also, 34 species are cultivated in total in Turkey, that are 27 finfishes, 4 molluscs, 2 crustaceans, 1 frogs and reptiles, 2 gastropods and 4 algae (BSGM 2019).

The demand for increasing aquaculture has led to a rise in fish farming in Turkey, that is, an increase in the number of hatcheries. So much so that millions of fish is cultured today in 20 hatcheries. The amount of gilthead seabream and seabass bred in hatcheries only in Aydın province is more than the sum of gilthead seabream and European seabass cultured in France and Spain. Five of these hatcheries breed only gilthead seabream and European seabass, while the remaining 15 hatcheries breed greater amberjack (*Seriola dumerilii*), red porgy (*Pagrus pagrus*), flathead grey mullet (*Mugil cephalus*), common dentex (*Dentex dentex*), striped seabream (*Lithognathus mormyrus*), sharpsnout seabream (*Diplodus puntazzo*), white grouper (*Epinephelus aeneus*), meagre (*Argyrosomus regius*), Atlantic bluefin tuna (*Thunnus thynnus*), shi drum (*Umbrina cirrosa*) in addition to gilthead seabream and European seabass.

In addition to these increasing production amounts, our country's aquaculture policy has also been in search of a number of new species that will increase competition. Atlantic bluefin tuna (*Thunnus thynnus*), greater amberjack (*Seriola dumerilii*), and Thinlip grey mullet (*Chelon ramada*) species are only a few of those which are cultured as promising candidate species in Turkey. Therefore, the next sections are devoted to the cultivating methods of these species in Turkey due to the increasing importance of these species in the European and world global aquaculture market. The culture experiments of these species have been carried out within the scope of university-industry cooperation.

Atlantic bluefin tuna (*Thunnus thynnus*)

The Atlantic bluefin tuna *Thunnus thynnus* (Linnaeus, 1758) is a long-lived species of tuna that lives and migrates in the North Atlantic and its contiguous seas (Corriero *et al.* 2007; Ottolenghi 2008). Japan started ranching this tuna species in the 1970s and some Mediterranean countries in the early 1990s, but it appears to be a relatively new activity in Turkey. Three commercial businesses began tuna farming with offshore cage systems in 2002 as the first occurrences in Turkey. Today, there are six enterprises with a total capacity of 6340 tons. Since this species is obtained from nature by fishing, the continuation of production is only possible with the continuous and balanced use of natural stocks. ICCAT (International Commission for the Conservation of Atlantic Tunas) is one of the leading international foundations established in order to ensure a balanced distribution of stocks among countries and to prevent the extinction of fish through overfishing.

ICCAT was established in Rio de Janeiro in 1966, after the International Convention for the Conservation of Atlantic Tunas (ICCAT Convention). The agreement for the application of the convention entered into force in 1969, following its ratification process. There are 50 states that are members of the commission. Grand National Assembly of Turkey adopted the draft law prepared to be a member of ICCAT on May 15, 2003, and published in the Official Gazette (No 25121) and carried into effect with Law No 4859 on May 28, 2003. Before becoming a member of ICCAT in 2003, Turkey was attending the meetings in observer status. Until then Turkey had benefited from the bluefin tuna quota share under the name of "other countries", together with some other Mediterranean countries. Following the membership, a special Atlantic bluefin tuna (ABFT) fishing quota has been allocated to Turkey since 2004 as a result of the initiatives made at the ICCAT.

Unlike gilthead seabream and European seabass farming, ABFT farming is carried out not starting from the larval stage, but by stocking the caught fish in marine cages. ICCAT reported that the cultivating of this species is carried out in two ways. The first method is called "fattening" where fish caught from natural breeding areas are subjected to a short feeding period of 3-7 months. The fish caught here are 30 kg and above. The other method is called "farming". Smaller caught fish (8-30 kg) are fed for longer periods (close to 2 years) and then put on the market (Myolanas *et al.* 2010). As can be seen in both methods, fish fed in offshore cage systems are caught from natural breeding areas, so the pressure on natural stocks is high. The aquaculture activity of this fish is shaped by the demand of Japan, which is the most important tuna market. While the average selling price of tuna is 25-40 Euros/kg to the end consumer in Japan, this number increases up to 100-120 Euros/kg during periods of high demand. Today, 58 farming facilities are officially recognized by ICCAT for ABFT in the world (ICCAT 2019) (Figure 1). Although the initial prices of this extremely valuable fish vary according to the years and the fat rate of the fish, the approximate price varies between 15-25 USD/kg in Turkey.

As can be understood from all the above literature, the breeding culture of the species has not yet been commercialized due to the difficult biological characteristics of the species and the cultivation of broodfish requires high knowledge and experience, although many studies have been conducted on the adult periods of ABFTs.

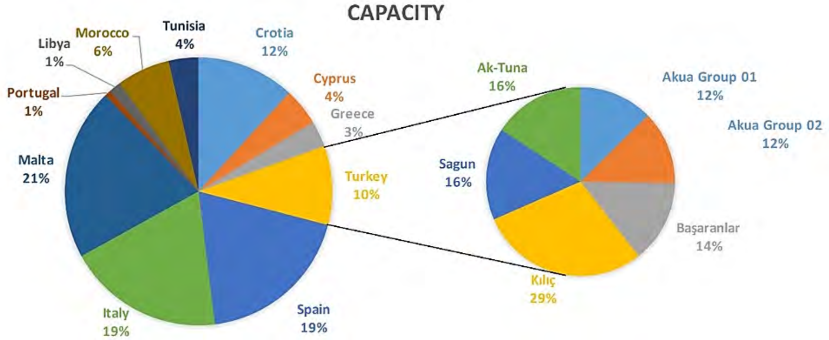

Figure 1. Atlantic bluefin tuna farming according to country in Mediterranean and company name of farming facilities in Turkey.

Spawning, hatching and larval culture

When the water temperature reached 24 °C (late May - early June), the eggs from the broodstock in the cage facilities were collected from the cage surface with a plankton net bucket with a 500µm mesh size at sunrise. Fifteen days before the spawning period, the cages were surrounded by a 2-3m. deep nylon cover in order to prevent the eggs of other species or predators feeding with Bluefin tuna eggs from entering. In this way, only ABFT eggs remained in the cage and were collected with a plankton net bucket. The eggs were transferred to the hatchery in the shortest period, with a storage density of 50 eggs/L, with vehicles specially designed for this task, maintaining the water temperature and light.

The diameters of the obtained ellipsoidal and transparent eggs were 1100 to 1200µ with single oil droplet (Figure 2). Living eggs were weighed and disinfected, then placed in incubators as 20-50 eggs/L. During incubation, the eggs were distributed homogeneously in the water with sufficient ventilation in a dark environment and the dead eggs were collected by siphon method at regular intervals until the hatching. In addition, the embryological development stages of the eggs were observed under the light microscope at certain periods. All studies were carried out in geothermal sea water with a temperature of 26°C. While hatching took place between 28-30 hours, the hatching rate was calculated as 90%. The hatched larvae opened their mouth in the 41st hour after hatching and were fed after the 48th hour. The stomach fullness rate was between 80-100% in all controlled larvae. Two major problems were encountered in the early larval period. The first was “sinking syndrome” on the 2nd and 3rd days after hatching (DAH) (because the density of the larva was higher than the density of sea water). And the second one was that their entire head area got white until the gill arc on the 10th and 11th DAH. ABFT larvae showed flock swimming behaviour after the oil drop was completely finished on the 5th DAH.

Figure 2. Egg collector in cage systems and egg of ABFT (Photo: Kılıç Co.).

All ABFT in the tanks were fed according to the feeding chart containing rotifer (*Brachionus rotundiformis* and *Brachionus plicatilis*) from the 2nd to the 18th DAH, and *Artemia nauplii* from the 5th to the 23rd DAH. The commercial powder feed was introduced to ABFT larval tanks from day 12. Gilthead seabream prelarva, dead fish and pieces of fish meat were put into the tanks according to ABFT age in the following days. During this period, ABFT larvae was kept in polyester circular shaped tanks with a volume of 23 m^3, with a maximum stocking density of 10 fish/L. Fluorescent lighting system and artificial lighting (16/8 hours light/dark) were used during the whole larval period. The water temperature was 25 °C, salinity was 38 ppt, dissolved oxygen was 6.2-6.9 mg/L during the larval period. Green water technique was performed during the larval period, and for this purpose, microalgae (enriched *Chlorella* sp. and *Isochrysis* sp.) were put into ABFT tanks at 2-3x10^5 cells/ml for 2-23 DAH.

ABFT had 2.5-3.1 mm TB when hatched, 1.2-1.5 cm total length (TL) on the 15th day, 5-6 cm TL on the 28th DAH, 7-8cm on the 35th DAH, 8-9 cm TL on the 39th DAH (Figure 3 and 4).

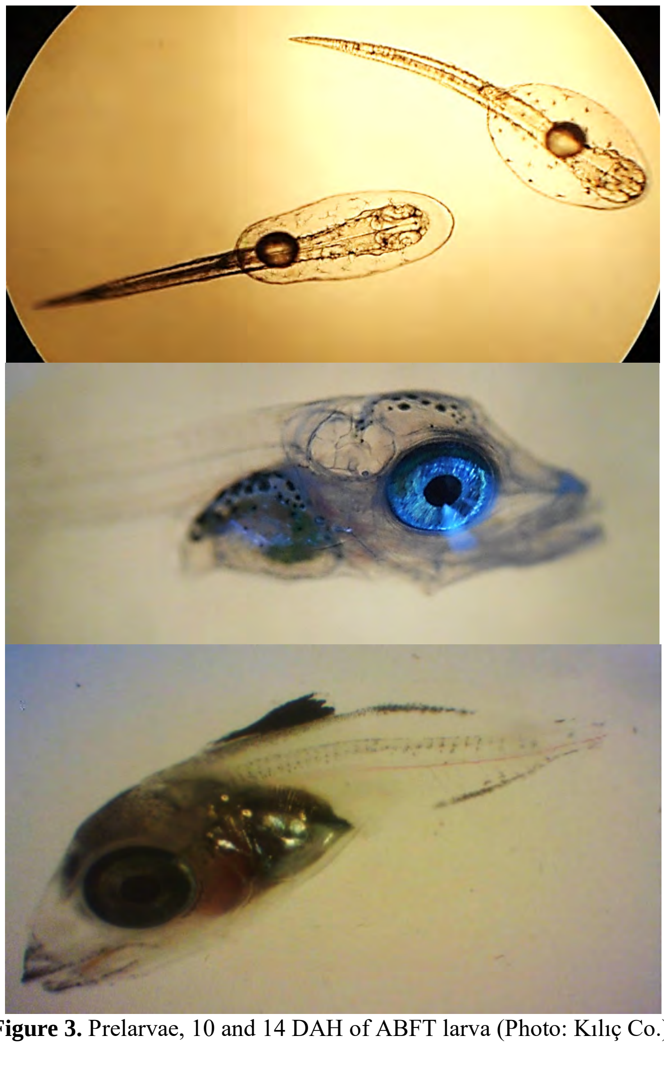

Figure 3. Prelarvae, 10 and 14 DAH of ABFT larva (Photo: Kılıç Co.).

Figure 4. ABFT juveniles in 12, 25, and 27 DAH (Photo: Kılıç Co.).

Cage culture

ICCAT member countries may go fishing under the supervision of ICCAT during the fishing period of 45 days (May 24th – June 24th) by the quotas allocated by ICCAT. Most of ABFT are caught by purse seiners, which have an overall length of 32-62 meters. Fishing operations are conducted intensively off Antalya Bay in the south of Turkey and in the Eastern Mediterranean region. The lower limit for ABFT is 30 kg. Every stage of the fishing is carried out restricted under the supervision of observers assigned by ICCAT. The caught fish are carried to the farms by vessels transporting at 0.5-1 miles per hour with transfer cages. Divers checked the cage nets constantly during transportation. The cages used for transportation are 50m in diameter and 25 m in depth. There are six fish farming enterprises in Turkey. All of these businesses are located in the Izmir province in western of Turkey (Table 1).

Table 1. Atlantic bluefin tunas farming facilities in Turkey (Adapted from ICCAT Record of ABFT Farming Facilities)

ICCAT Serial number	Name of AFFB	Location	Capacity (t)
AT0001TUR0004	Akua Group	Küçükbahçe, Karaburun, İzmir	800
AT0001TUR0005	Akua Group	Karaburun, Çeşme, İzmir	800
AT0001TUR0014	Başaranlar Co.	Karaburun, Çeşme, İzmir	900
AT001TUR00010	Kılıç Sea Food Co.	Karaburun, İzmir	1840
AT001TUR00011	Sagun Group	Karaburun, İzmir	1000
AT001TUR00013	AK-TUNA Co	Ildırı, Çeşme, İzmir	1000

As in all over the world, the principle of aquaculture of ABFT is to feed them with fish such as sardines, chub mackerel, mackerel, herring for 6-7 months and then harvest them in cage enterprises in Turkey. All enterprises prefer "mooring cage systems" during the fattening process. Correctly calculated and applied anchoring system is the most important component in these systems that will protect fish from offshore sea conditions (Figure 5 and 6). The cage parts in mooring systems are made of HDPE material, which is flexible and resistant to waves and wind. Cages are fitted with knotless nets with 70x70 mm mesh size (ropes are made of polypropylene material and 2 mm thick). These cages generally have a diameter of 50 m to 66 m and a depth of 20-25-32 m. The diameter of HDPE cylinder tube is Ø 450, and the inside of the cylinder is filled with styrofoam.

The number of cages varies according to the capacity, culturing area, net cage diameter and net depth of the enterprises in Turkey, and ABFT fattening occurs in circular net cages. A fishing net with a depth of 32 m is preferred for a cage with a diameter of 66 m in cage systems, and a net with a depth of 20-25 m is used for a cage with a diameter of 50 m. While two enterprises prefer six 66 m diameter cages, the majority use 50 m diameter cages. The distance between two cages is generally between 25-40 m in the facilities, the current and wind direction of the facility determines the distance between the cages. The distance of the established ABFT cage facilities to the nearest land varies between 1300 – 9250 m. Velocity of the sea current varies between 0.13-0.51 m/sec in their area. All ABFT cage farms in Turkey are established in an offshore sea area with a water depth of 55-80 m. The sea surface area that the ABFT cage farm owners rented from the state varies according to their capacity between 40-78 thousand m^2, and it is approximately 285 thousand m^2 in total. The number of personnel working in all enterprises is 125 people, and approximately 25% of these employees are deep-sea divers.

Figure 5. Farming facilities of ABFT in İzmir, Turkey (Photo: Kılıç Co.).

When the ABFT is transferred from the fishing area to the cages where it will be fattened in the offshore sea, the divers constantly check them to see whether the fish are fed or not. The divers continue to monitor the feeding process, which is performed 1-2 times a day, even after the fish get used to the feed. The cage facilities acquire the feed daily and delivers it to the cages from the ship with the help of pipes and/or shovels after thawing. In Turkey, the conversion of feed to meat (FCR - The Feed Conversion Ratio) ratio of ABFTs varies between 1:15 and 1:25 depending on the water temperature, feeding strategy, and food quality.

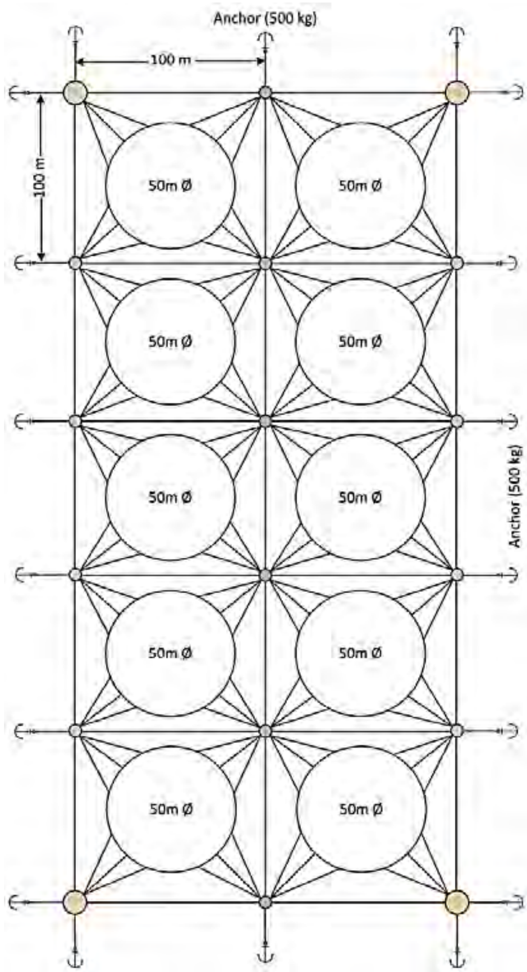

Figure 6. Mooring system of 1000 ton/year ABFT offshore cage culture in Turkey.

The harvest process is the same in all ABFT enterprises in Turkey unless the buyer has special demands, it is based on the method of removing the blood from the body as soon as possible and cooling the meat rapidly. First the divers catch ABFT in the cage, and then they are taken to the harvesting ship. The alive but immobile ABFT is rapidly skewered in the head to allow a rapid death. After some blood flows, it is taken to the cooling tank and immediately transferred to the buyer ship (Figure 7). The blood flows on the sloping deck of the harvesting ship and is collected in a tank at a suitable place on the ship. In this way, blood flow to the sea and various related problems are prevented. So the fish gets harvested, delivered (exported) fresh and as a whole to the recipient ship, and then processed there. In addition, the harvested fish get packaged in the companies' own ships or facilities and processed as freshly chilled or frozen and exported to many countries of the world, especially to Japan.

Figure 7. Transfer of ABFT from offshore cage to cooling tank in buyer ship (Photo: Dr. D. Tosun)

Greater amberjack (*Seriola dumerili*)

Greater amberjack (*Seriola dumerili*) is a pelagic species living in warm and tropical waters. This species has commercial importance in Japan and Mediterranean countries due to its rapid growth and high economic value. Therefore, countries conduct many scientific studies on this species. Greece sharing the same waters with Turkey started studies on the breeding of this species in 1997. Similarly, Italy has worked to obtain larvae from broodstock caught from the wild, and continues to work on breeding from the egg.

The most important factors in the selection of a new species for aquaculture are its high economic value, its rapid growth to reach the market size, and most importantly its adaptation to cultural conditions. The Japanese buy between 3.5-5.5 kg of this species to make Sashimi, and deliver it to the end consumer paying 1500-3000 Japanese Yen (15-30 $) per kilo. For this reason, the high economic value makes fish farming of greater amberjack species tempting.

Today, many researchers conduct various studies on both culture and natural stocks of the *Seriola* sp. species (Andaloro *et al.* 1992; Divanach 2002; Harris *et al.* 2007; Fernandez-Palacios *et al.* 2015). Specifically, the species of this family attract attention with their adaptation to culture conditions, high growth feature and quality meat yield (Greco *et al.* 1993; Garcia and Diaz 1995; Nakada 2008). Among the nine species of the *Seriola* genus; *S. dumerili, S. quinqueradiata* and *S. lalandi* are commercially fishfarmed in Japan, *S. lalandi* in Australia and New Zealand, and *S. rivoliana* in the USA.

Only greater amberjack (*S. dumerili*) are naturally found in the coastal waters of the Mediterranean like Turkey, Greece, Italy and Spain among this species. Therefore, these countries except Turkey started studies on the cultivation of this species in 1992 and continue until today (Grau 1992; De la Gandara *et al.* 2004; Roo *et al.* 2009; Rodriguez-Barreto *et al.* 2012; Fernandez-Palacios *et al.* 2015). Turkey has three separate commercial companies that have licenses for fishfarming this species in six hatcheries, but there has been no commercial success in this area. Kılıç Seafood Co. and Aydın Adnan Menderes University succeeded in obtaining eggs of this species in the studies carried out together firstly in 2015 and then in the 2016 production season, and reached commercial size.

Spawning, hatching and larval culture

At the end of the first year, eggs were taken naturally from greater amberjack broodstock in 50 m^3 poliester tank volume, under natural light and seawater conditions. Eggs were taken in May and August at 23.5-24.0ºC sea water temperature early in the morning. Cultivation trials started with a total of 18 broodstock, with an average of 27 kg/m^3 of broodstock in the tank. Broodstock were kept in cylindrical tanks with 1/1 female/male ratio. The broodstock were kept under natural light and sea water temperature in culture conditions. When the broodstock were caught from the sea, they were kept in quarantine for 3 days. During this period, they were exposed to 100 ppm formaline for an hour, and then left in five ppt water for four hours. This process continued throughout the quarantine period.

Approximately 500-600 g eggs were taken in total from the broodstock. While the diameters of the eggs were between 1000-1200 µm, the diameters of the oil drops were between 240-300 µm (Figure 8). The prelarvae hatched after about 48 hours, and they were measured between 3.0-3.5 mm in total length. Although the mouth and anus opened approximately 48 hours after hatching, the lights of the culture tanks were turned on after 72 hours. All larval production took place in cylindrical tanks with a volume of 15 m^3, at natural seawater temperature (22.5 ºC). During the larval period, green water technique (2-3x10^5 cells/ml *Nannochloropsis* sp.) and open system cultivation technique were maintained. Salinity was set at 25 ppt throughout larval stage. On the 3rd day after hatching, the greater amberjack larvae started to develop air sac at the total length of 3.5 mm and completed the development in a short time.

A feeding protocol similar to the gilthead seabream was applied to the larvae whose mouth and anus had opened. Accordingly, after the mouth and anus opening, 230 mil/day rotifer (*Brachinus plicatilis*) has been introduced to the tanks on the 3rd day after hatching (DAH), 5 mil/day *Artemia nauplii* on the 11th DAH, 9 mil/day *Artemia metanauplii* with 75 µm microparticle feed (10 gr/day/biomas) on the 15th DAH. Live feed intake stopped for greater amberjack on the 35th DAH. After that day, commercial powder feeds have been preferred that are suitable for the mouth opening and energy needs of the fish.

Figure 8. Eggs and prelarva of *S. dumerilii* (Photo: Kılıç Co.).

Cultivation of greater amberjack in salty geothermal water

The fish were grow up to 350-450 grams in a fully controlled environment with natural sea water, and then transported to the aquaculture facility located within 2 hours drive by specially equipped live fish transport vehicles (Figure 9). The salinity (25 ppt), temperature (20°C) and oxygen (12-13 ppm) were ensured to be constant during transportation. Sedanol (100 ppm) was applied to the fish as sedative during the transfer.

When the fish first arrived at the growth facility, they were exposed to a 100 ppm formalin bath for 1 hour. After the disinfection process, they were stored in polyester tanks with a volume of 130 m^3 and an initial density was 9 fish/m^3. The water temperature was kept constant at 26°C, salinity at 30 ppt and oxygen between 12-13 ppm in the growth facility. The water change was 30% tank-volume/hour in the tanks. Greater amberjacks remained in the grow facility for approximately 300 days. They were fed 6 mm seabass feed (45% crude protein, 15% crude fat) during this time. Feeding was done twice a day in the morning and evening as *ad libitum*.

The salty geothermal seawater used in the growth facility was pumped approximately 40-120 meters. The pumped seawater was at 26 °C and the salinity was 30 ppt. Water extracted from underground was used in aquaculture units after mechanical filtration, oxygenation and ozonisation processes. The biggest advantage of this facility was that keeping seawater at the same temperature costs zero throughout the year.

Figure 9. Cultured greater amberjack (Photo: Kılıç Co.).

The fish were separated according to size 3 times during the 300 days in the fattening facility. The survival rate was 47% and the final density was 16 kg/m^3. The 3455 greater amberjacks placed at the fattening facility with a weight of 425±120 gr reached 2300±1120 gr at the end of 300 days. The harvest age was 482 DAH in total. When the death causes at the fattening facility were examined, it was observed that spinal breaks were high. That is the result of the fish hitting the tank wall hard due to various reasons (stress factors such as sound, light, etc.), although they are taken into cultivation in polyester tanks with a volume of 130 m3 and low stock density (Figure 10).

Figure 10. Culture system of greater amberjack (Photo: Kılıç Co.)

Thinlip grey mullet (*Chelon ramada*)

Mullets (Family: Mugilidae) are one of the most important commercial fish species in many countries on the Mediterranean coast. Four mullet species stand out in terms of their economic value especially in the Mediterranean. These species are *Mugil cephalus*, *Chelon labrosus*, *Chelon ramada* and *Chelon auratus*. These species dominate fish stocks in many places due to their extraordinary adaptation to extreme changes in salinity, temperature and pollution. It has an important place in the food chain in nature because of this effect. Since mullet stands out as human food due to its high nutritional value, it is cultivated in many countries, especially in Egypt.

There are eight species of Mugildae in Turkey, which are *Mugil cephalus*, *Chelon labrosus*, *Oedalechilus labeo, Chelon auratus, Chelon ramada, Chelon saliens, Liza carinata*, *Planiliza haematocheila* (Nelson 2006; Turan 2007; Crosetti and Blaber 2015). Of these, *L. carinata* entered the waters of Turkey by passing through the Suez Canal, and *P. haematocheila* entered the Azov Sea and Black Sea from the North Pacific in the early 1980s (Crosetti and Blaber 2015). Since mullets are difficult to identify with only external morphology, internal morphology comes to the fore in the determination of the species. For this reason, Mugilidae taxonomy and nomenclature have been renewed many times and critical updates have been made by scientists until today. The development of molecular techniques as well as classical taxonomy classifications based on morphology have been effective in these updates. For this reason, the species that caused this chapter to be written was known as *Liza ramada* until a few years ago, today it is called *Chelon ramada*. Its synonyms are *Mugil ramada* (Risso 1827), *Mugil capito* (Cuvier 1829), and *Liza ramada* (Risso 1827).

Habitats such as estuaries, lagoons and coastal areas are richer areas in terms of organic material (10-250mg.g^{-1} dry weight) than most marine sediments (<10mg.g^{-1} dry weight). For this reason, like many fish species, the larvae and fry of Mullets prefer the estuaries, lagoons and coastal habitats, where they feed on planktonic organisms. Small invertebrates that migrate vertically in the water column especially in coastal areas and lagoons, become the first food of mullets, while benthic organisms and plant materials are the next food in the following days due to growth. Benthic microalgae, mainly diatoms and detritus, form their nutrients in older ages and at the adult level (Crosetti and Blaber 2015). For this reason, the mouth in many mullet species is in the terminal or sub-terminal position (Drake *et al.* 1984). Premaxilla is protruding in all species (Thomson 1954). Gray mullet species have gonochoristic or bisexual reproduction characteristics. Although females are normally larger than males, sexual dimorphism cannot be mentioned and therefore gender cannot be determined by external examination. Mugilidae species have oviparous reproduction characteristics and they usually leave their eggs in water in the coastal areas to fertilize.

Mullet cultivation excels in Egypt in the Mediterranean, along with countries such as Taiwan and China in the Far East. Although its meat is generally considered as human food, there are aquaculture practices to obtain roe. Two types of culture stands out for mullets. The first is to feed the caught fry in the aquaculture ponds until they reach the portion size or the roe is obtained, the other is the production of eggs from the broodstock. Both methods bring along many uncertainties. So much so that not knowing how many juvenile fish are collected from nature causes us to not know what their effects on natural stocks are. The other method, on the other hand, leads to a loss of money and effort with high mortality of the broodstock and their healthy fry. Mullet culture has been dependant on juvenile fish collection from nature and growing them in ponds for the last 40 years, and the stock destruction is indefinite. While the cost of a 10gr juvenile wild mullet is 0.3 USD in Egypt, the cost of the same size juvenile cultured mullet varies between 0.1-0.12 USD at the same location. Again in the same country, the cost of 1 kg. mullet obtained by semi-intensive farming varies between 0.75-1 USD (FAO 2009). Although these costs vary in other countries, obtaining eggs from broodstock and cultivating them rather than collecting juvenile fish from their natural habitats is more important in terms of food traceability, sustainability and reduction of the pressure on natural stocks.

Thinlip gray mullet is the second most cultivated type in the Mediterranean, after *Chelon ramada, Mugil cephalus*. Although it grows slower than *M. cephalus*, it grows faster than other mullet species, thus, *C. ramada* excels in terms of its commercial value. *C. ramada* spreads naturally in the Mediterranean and Black Sea along with Azores, Madeira, Morocco coasts, the British Isles and Scandinavia, which are the eastern coasts of the Atlantic (Thomson 1990; Panicz and Keszka 2016). Like mullet species, *C. ramada* prefers different habitats such as lagoons, deltas and estuaries. The species has a small mouth, a rigid head, and fusiform body structure, pectoral fins are located on both sides of its body. The distance between the eyes is at the same spacing as the oral cavity. Pectoral fin is shorter than the distance from the posterior border of the eye. The most important measurement in the distinction of the species is the unequal number of pyloric caeca between 7 and 8. The number of fish scales on the lateral line of the species is between 40-46. This species can reach up to 70 cm in total length in wild.

Broodstock, spawning, hatching and larval culture

C. ramada were found in the discharge of the earthen ponds in Milas, Muğla, Turkey, entering here in an uncontrolled manner. These fish were used as broodstock in the experimental *C. ramada* breeding. The fish selected as broodstock were transferred to the tank with more controlled environmental conditions than earthen ponds in the second half of August. Here, the fish were given 100 ppm formol for 3 days, then a water bath at 5ppt salinity for 4 hours, and then taken into the production tank. In these culture condition, 22 broodstock were stocked in a circular tank of 5 tons as 1.5 $kg.m^{-3}$. The weights of broodstock varied between 0.7-2 kg. They were stocked with the ratio of 1:1 (F:M). The water temperature was fixed at 21.5ºC and the natural light period was used. Broodstock were kept at 25ppt salinity during the whole breeding period, and spawning took place at this salinity rate (Figure 11).

Eggs were obtained from broodstock for three consecutive days by natural means in October. Spawning took place towards the evening and a total of about 300 grams of eggs were taken. Fertilized eggs were disinfected with a povidone iodine bath of 500 ppm for 15 minutes. The diameters of the eggs were between 800-900µ. Additionally, 120 eggs per liter were kept at a temperature of 21.5°C for 36 hours with ventilation to prevent the eggs from collapsing in incubators with a mesh size of 300 microns. Eggs had a single oil droplet and were transparent (Figure 12).

Embryological development maintained about 36 hours and at the end of this period, 80% of the eggs hatched (Figure 13). The hatched larva was 2.5-3.0 mm in total length. The larvae were left in the dark for 72 hours until the mouth and anus opened. After consideration that they were ready to feed when the mouth and anus were open at the end of the 72^{nd} hour of the larvae, the lights were turned on and food and algae were put into the tank. Green water technique was used during the larval period culture similar to the gilthead seabream production protocol. Accordingly, phytoplankton was introduced into the tank environment 12 hours before the lights were turned on (500 $million.ml^{-1}$). Rotifer (*B. pilicatilis*, 5 $indv.ml^{-1}$) were introduced into the environment on the 5^{th} day, *Artemia nauplii* (2 $indv.ml^{-1}$) on the 15^{th} day, and microparticles (200-300 microns) on the 20^{th} day. After the 35^{th} day, live feed was cut into pieces and the larvae were fed with microparticle diet suitable for the mouth opening and biomass. Green water applied culture environment was terminated in 26 days. Air bladder formation in larvae started at 3.0-3.5 mm TB on the 3rd day and was completed within approximately 24 hours.


Figure 11. Broodstock and broodstock tank of *C. ramada* (Photo: Kılıç Co.)

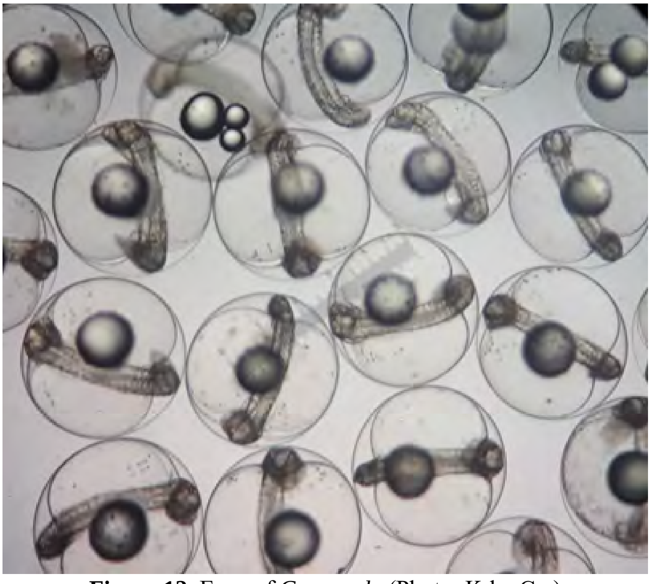
Figure 12. Eggs of *C. ramada* (Photo: Kılıç Co.)

Mass deaths occurred periodically in the *C. ramada* larvae. There were heavy deaths in 2 separate periods (3-7th and 10-15th days after hatching) especially in the first 25-30 days, while deaths almost never occurred in fish who survived these days. The day with the most mortality and peak number of death is the 6th

DAH with 5.0-6.0 mm TL. After the fish hatched, they were on the water surface while they were in the prelarva stage, then the larvae went down to the bottom of the tank completely with the formation of the air bladder (3th DAH). All the larvae stood upside down in an area 20 cm above the base at the bottom, inactive, without swimming. All the *C. ramada* larvae were distributed in several clusters in the bottom area of the culture tank. During this time, they did not eat. They started to swim towards the surface on the 7th DAH, then larvae swam as clusters in the middle between the bottom and the surface. In the following days, the larvae started to swim as clusters at several points 10 cm below the tank water surface after the 10-11th DAH. Massive deaths occurred in all tanks for 4 days among the larvae that surfaced, the deaths started the day after they surfaced. The cause of deaths was inexplicable. The dead larvae had full stomachs, functional air bladder, and no signs of infection. Under culture condition, *C. ramada* had slow development during the 225 DAH according to other economic cultured marine fish species (Table 2 and 3).

Table 2. Total length (mm) development of *Chelon ramada*.

DAH	Mean	Std. Error	Min.	Max.
0	2.68	0.01	2.67	2.71
7	3.21	0.08	3.01	3.39
9	3.38	0.02	3.34	3.49
15	3.64	0.05	3.46	3.80
20	3.95	0.13	3.57	4.29
80	21.6	2.04	16.10	26.80
100	31.8	2.79	22.40	37.40

Table 3. Total weight (g) development of *Chelon ramada* under controlled conditions.

DAH	N	Weight
108	209	0.62
123	185	1.04
143	216	1.97
159	249	2.53
168	308	3.20
180	328	3.63
187	275	4.12
194	315	5.62
201	331	6.84
215	309	9.71
222	227	11.01

Figure 13. Larval development of *C. ramada* in 0, 6, and 20 DAH (Photo: Kılıç Co.).

The *C. ramada* larvae have become quite active after the 16-18th DAH, that is, after this period. Death, on the other hand, occurred very little, almost negligible until the fish went to the earthen ponds. All fish were taken from the larvae unit on the 90th DAH, into 2x5x1.8 m concrete tanks with natural light and temperature. Here they were fed *ad libitum* every 2 hours a day. They were fed with powder and granular feeds (55% protein, 12% fat, 12% ash, 1% cellulose, 1.5% phosphorus, 7% moisture, 0.5-3.5% calcium, 1% sodium). When they were in the weight range of 10-15 g about 225 DAH later, all fish were transported to earthen ponds (Figure 14 and 15).

Figure 14. *Chelon ramada* juvenile in different size (Photo: Kılıç Co.)

Figure 15. Transfer from hatchery to land based culture systems of *Chelon ramada* juveniles (Photo: Kılıç Co.).

Conclusion

Aquaculture production must grow and contribute to the economy of Turkey using shores, offshore, inland waters, and lands in an ecological, sustainable and globally competitive manner. This dynamic structure must not only provide the consumer with a significant amount of high quality and nutritious food, but also increase variety in order to offer a range of new products and integrated services. Turkey must bring the approaches to the forefront that prioritize aquatic animal health and welfare, data management, and production technology within technical and commercial components in order to ensure the sustainability of aquaculture and sustainability of its global role. For this reason, it is very important to culture new species and bring them to the economy. Various scientific studies are required to develop production-oriented technology and to take measures to reduce foreign dependency in feed and feed raw materials. As for all industries, it is very important to create and develop "know-what" (facts), "know-why" (science), "know-who" (networking), or "know-how" (practical knowledge on how to do something), especially for companies in the aquaculture sector in terms of their competitiveness. For this reason, it is very important to add crustaceans, cephalopods and aquatic plants in addition to the marine fish species fishfarmed in our country, and to formulate and support national strategies in this direction.

References

Andaloro, F., Potoschi, A., Porrello, S. (1992) Contribution to the knowledge of growth of greater amberjack, *Seriola dumerili* (Cuv., 1817) in the Sicilian Channel (Mediterranean Sea). *Rapp Comm Int Mer Mediterr* 33: 282.

Anonym (2020) Blue growth Available at: https://ec.europa.eu/maritimeaffairs/policy/blue_growth_en (accessed 06 Oct 2020).

BSGM (2019) General Directorate of Fisheries and Aquaculture. Available at: https://www.tarimorman.gov.tr/BSGM/Belgeler/Icerikler/Su%20%C3%9Cr%C3%BCnleri%20Veri%20ve%20D%C3%B6k%C3%BCmanlar%C4%B1/Su-%C3%9Cr%C3%BCnleri-%C4%B0statistikleri.pdf (accessed 06 Oct 2020).

Corriero, A., Medina, A., Mylonas, C.C., Abascal, F.J., Deflorio, M., Aragón, L., Bridges, C.R., Santamaria, N., Heinisch, G, Vassallo-Agius, R., Belmonte, A., Fauvel, C., Garcia, A., Gordin, H., De Metrio, G. (2007) Histological study of the effects of treatment with gonadotropin-releasing hormone agonist (GnRHa) on the reproductive maturation of captive-reared Atlantic bluefin tuna (*Thunnus thynnus* L.). *Aquaculture* 272(1-4): 675-686.

Crosetti, D., Blaber, S.J.M. (2015) Biology, Ecology and Culture of Grey Mullets (Mugilidae). Boca Raton, Florida, USA: CRC Press, 539 pp.

De la Gandara, F., Alonso, I., Garcia-Gomez, A. (2004) Constitution and management of a Mediterranean yellowtail (*Seriola dumerili*) broodstock in land based facilities: problematic and perspectives. *European Aquaculture Society Special Publication* 34: 282-283.

Divanach, P. (2002) Recent developments in the domestication of new mediterranian species. *European Aquaculture Society Special Publication* 32: 35-41.

Drake, P., Arias, A.M., Gállego, L. (1984) Biología de los mugílidos (Osteichthyes, Mugilidae) en los esteros de las salinas de San Fernando (Cádiz). III. Hábitos alimentarios y su relación con la morfometría del aparato digetivo. *Inv Pesq* 48: 337-367.

EATIP (2017) European Aquaculture Technology and Innovation Platform. A review of the strategic research and innovation agenda. Available at: http://eatip.eu/wp-content/uploads/2018/02/EATIP-SRIA-2017 (accessed 06 Oct 2020).

Elder, M. (2017) Aquaculture in China: Challenges and Opportunities. Harvard Workshop on Animal Agriculture from the Middle East to Asia Cambridge, Massachusetts May 11-12.

FAO (2009) Culture aquatic species fact sheets, *Mugil cephalus*. Available at: http://www.fao.org/tempref/FI/DOCUMENT/aquaculture/CulturedSpecies/file/en/en_flatheadgreymullet.htm (accessed 06 Oct 2020).

FAO (2016) The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. Rome, 200 pp.

FAO (2017) Fishery and Aquaculture Statistics Yearbook. 639 pp.

Fernandez-Palacios, H., Schuchardt, D., Roo, J., Hernandez-Cruz, C.M., Izquierdo, M. (2015) Multiple GnRHa injections to induce successful spawning of wild caught greater amberjack (*Seriola dumerili*) matured in captivity. *Aquaculture Research* 46: 1748-1759.

García A., Díaz M.V. (1995) Culture of *Seriola dumerilii*. Marine aquaculture finfish species diversification. Zaragoza: CIHEAM, (Cahiers Options Méditerranéennes; n. 16). Seminar of the CIHEAM Network on Technology of Aquaculture in the Mediterranean (TECAM), 1995/06/14-17, Nicosia (Cyprus). p. 103-114.

Grau, A. (1992) Aspectos histoloigicos, ciclo reproductory principales procesos patoloigicos de *Seriola dumerilii*, Risso 1810 (Carangidae). PhD thesis, Faculty of Veterinary, Universitat Autoinoma de Barcelona, Spain. 451 pp.

Greco, S., Caridi, D., Cammaroto, S., Genovese, L. (1993) Preliminary studies on artificial feeding of amberjack fingerlings. *European Aquaculture Society Special Publication* 18: 247-253.

Harris, P.J., Wyanski, D.M., White, D.B., Mikell, P.P. (2007) Age, growth, and reproduction of greater amberjack of the southeastern Atlantic coast. *Transactions of the American Fisheries Society* 136: 1534-1545.

ICCAT (2019) International Commission for the Conservation of Atlantic Tunas. Available at: https://www.iccat.int/en/Ffb.asp (accessed 01 Nov 2019).

Mylonas, C.C., Fostier A., Zanuy, S. (2010) Broodstock management and hormonal manipulations of fish reproduction. *General and Comparative Endocrinology* 165: 516–534.

Nakada, M. (2008) Yellowtail and related species culture. In: Encyclopedia of Aquaculture (ed., Stickney, R.R). Wiley, London, pp. 1007-1036.

Nelson, J.S. (2006) Fishes of the World, 4th ed. John Wiley and Sons, New York.

Ottolenghi, F. (2008) Capture-based aquaculture of bluefin tuna. In: Capture-Based Aquaculture (eds., Lovatelli, A., Holthus, P.F.), Food and Agriculture Organization of the United Nations, FAO, Rome, pp. 169-182.

Panicz, R., Keszka, S. (2016) First occurence of thinlip grey mullet, *Liza ramada* (Risso, 1827) in the Odra River estuary (NW Poland): genetic identification. *Oceanologia* 58: 196-200.

Rodriguez-Barreto, D., Jerez, S., Cejas, J.R., Martin, M.V., Acosta, N.C., Bolanos, A., Lorenzo, A. (2012) Comparative study of lipid and fatty acid composition in different tissues of wild and cultured female broodstockof greater amberjack (*Seriola dumerili*). *Aquaculture* 360-361: 1-9.

Roo, J., Schuchardt, D., Socorro, J.A., Guirao, R., Hernan-dez-Cruz, C.M., Fernandez-Palacios, H. (2009) Evolucion de la maduraci on gonadal de ejemplares de Seriola dumerili mantenidos en cautividad. In: Actas del XII Congreso Nacional de Acuicultura (eds., Baez, D., Villaroel, M., Cardenas, S.) Fundacion Observatorio Espanol de Acuicultura, Madrid, Spain. pp. 596-597.

Thomson, J.M. (1954) The organs of feeding and the food of some Australian mullet. *Aust J Mar Freshw Res* 5: 469-485.

Thomson, J.M. (1990) Mugilidae. In: Checklist of the Fishes of the Eastern Tropical Atlantic (CLOFETA) (eds., Quero, J.C., Hureau, J.C., Karrer, C., Post, A., Saldanha, L.). JNICT, Lisbon; SEI, Paris; and UNESCO, Paris: Vol. 2. pp. 855-859.

Turan, C. (2007) Atlas and Systematics of Marine Bony Fishes of Turkey. Nobel Publishing, Adana, Turkey. 549 p.

Trout mariculture in Turkey

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Introduction

Turkey has a total of 8333 km of coastline (Figure 1). Catch fisheries have a very long history in Turkey. The Anatolian peninsula harboured many ancient civilizations for thousands of years and benefited the rich marine and freshwater ecosystems of this land in terms of both nutrition and economic income. Once a primitive way of life, catch fisheries changed into a giant Industry after the industrial revolution. This giant industry, as well as others, brought ecological and environmental problems with its progress. Incentives by the government also had a positive impact on the growth. Aquaculture has great importance especially in developing countries. As aquaculture advanced, its importance in terms of food security was better understood. This industry increased and diversified economic opportunities and employment. In comparison to catch fisheries, aquaculture is a very young production concept in Turkey with half a century. The starting point for aquaculture is around the late 1960'ies with government trials. The first established private trout farm in Turkey was located at Bilecik-Bozüyük in 1971. This farm was operated with mostly earthen ponds, which were supplied with water from Karasu River (Akbulut 2009; Aydın and Baltacı 2017; Balcı Akova 2015; Bozoğlu *et al.* 2006).

The success of freshwater trout farming was the initiator for marine aquaculture, which started in early 1980'ies and increased its production steadily to present day with the improving intensive aquaculture technologies. Better feeding practices with adequate nutritional quality fish feed resulted in more production in less unit of area. Species-specific feed formulations achieved better feed conversion ratios (FCR). The Fisheries Faculties supported these advances, established in a number of universities around Turkey, educating a much-needed technical workforce for the industrial growth. In the last three decades, the aquaculture sector achieved a 10-15% growth rate, which was the third best global ranking following China and India. Aquaculture in Turkey is typically dependent on intensive farming systems producing carnivorous fish species in cage farms (Kayhan and Olmez 2014).

The northern Turkish peninsula borders the Black Sea with 1695 km of shoreline. Although this region, especially eastern part, is known for its catch fisheries abundance, has a new important aquaculture potential. The main cultured marine species along the coast of the Black Sea region are rainbow trout, brown trout and seabass. In the last decade, marine trout farming has been drawing attention from international fish traders. Recent trade success with Japan was a real important progress for the future of the Black Sea marine trout production (Deniz *et al.* 2000).

Figure 1. Map of Turkish coastline

Overview of fisheries and aquaculture production in Turkey

Turkey is a major fish producer amongst European countries. The surrounding seas and freshwater resources of the Anatolian peninsula has a great potential for aquaculture production. The Black Sea region contributed about 70 percent of the total catch fisheries until the late 1990'ies. A total of 628631 tons of catch fisheries and aquaculture production was recorded in 2018. In 2000, catch fisheries constituted 86% of the total production (503345 tons) with 14% from aquaculture. Presently catch fisheries constitute 49.9% (314094 tons) of the total production whereas; aquaculture surpassed fisheries with 50.1% (314537 tons). This was the first ever record for aquaculture to top catch fisheries in Turkey (Figure 2) (Şener 2002; TUIK 2019).

Both marine and fresh water aquaculture has been increasing since the beginning of 1980'ies (Figure 3). Main target species for aquaculture production in Turkey are rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792), gilthead seabream *Sparus aurata* (Linnaeus, 1758) and European seabass (*Dicentrarchus labrax* Linnaeus 1758) (Figure 4). European seabass and gilthead seabream culture established in the Aegean region raised significantly in the last three decades in comparison to marine trout farming which was mainly established in the Black Sea Region.

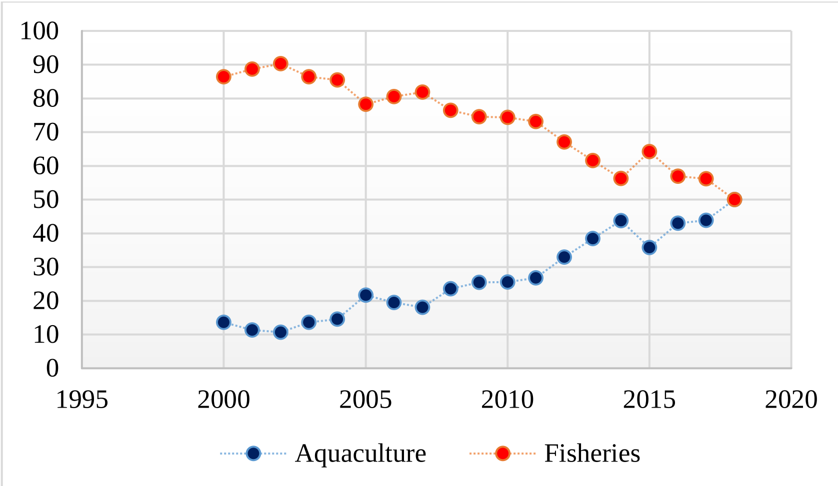

Figure 2. Comparison of catch fisheries and aquaculture shares in total production of Turkey (%) (Data compiled from TUİK, TurkStat, Fishery Statistics 1985-2018)

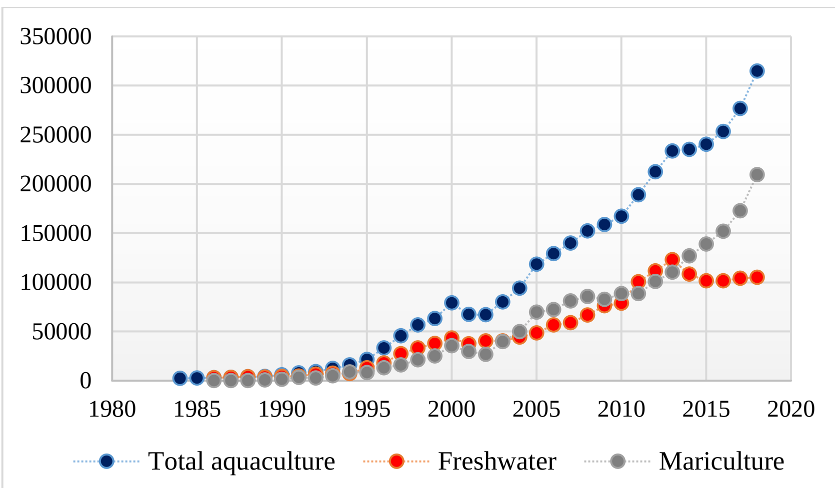

Figure 3. Aquaculture progression since 1980 until 2018
(Data compiled from TUİK, TurkStat, Fishery Statistics 1985-2018)

Global fisheries production is expected to stay stagnant contrary to aquaculture production. The need for fishery products will increasingly be provided by the aquaculture industry in the near future (Rashid Sumaila *et al.* 2014). Mediterranean and the Black Sea stocks are amongst the most unsustainable wild fish stocks around the world according to FAO reports (FAO 2018). Fisheries production is in a decline trend in Turkey (Figure 5). There are many reasons for the decline in fisheries. In addition to environmental pollution, development of industrial fishing in the Black Sea region resulted in over exploitation of wild fish stocks. Depletion of wild stocks adversely affected marine ecosystems as well as the economy of capture fisheries.

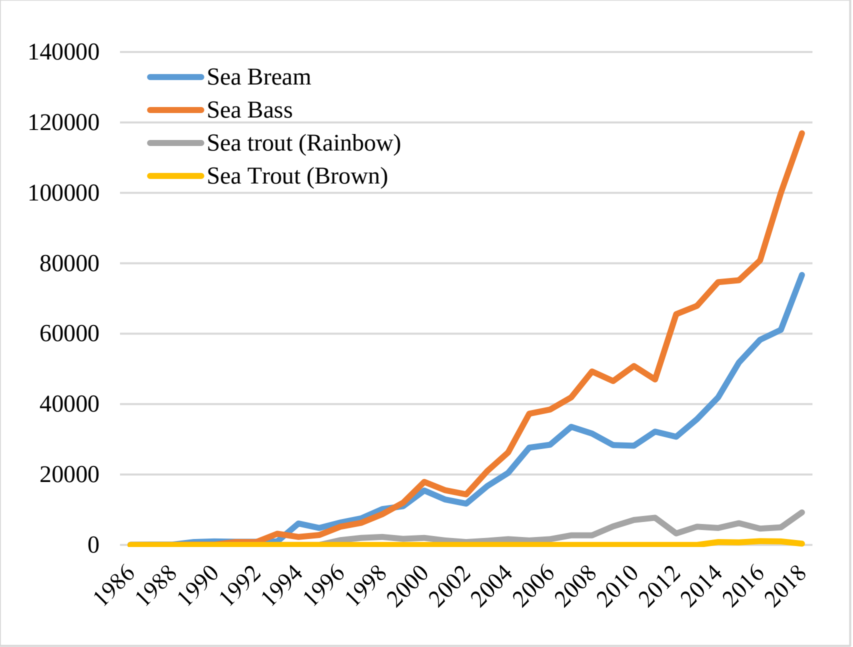

Figure 4. Mariculture production according to major species in Turkey (ton) (Data compiled from TUİK, TurkStat, Fishery Statistics 1985-2018)

Development of Black Sea trout mariculture in Turkey

Black Sea shoreline does not have protected coves because of its geographical features. As a result, there are few suitable areas for coastal aquaculture practices. Yet, developments in offshore aquaculture technologies allows aquaculture to establish and flourish in this region (Tas 2007). Decline in catch fisheries caused by environmental pollution and overfishing resulted in orientation towards coastal aquaculture activities towards the end of the 1980'ies. Turkey started salmonid farming in marine ecosystems in 1990 with Atlantic salmon (*Salmo salar*, Linnaeus 1758). A private company from Norway in the scope of an agreement with Turkish Public University Institution (Istanbul University, Fisheries Faculty, Inland Fisheries Production, Research and Application Unit) supplied eyed eggs. Fish were kept until smoltification and then transferred to the fish farms located in the Black Sea. The lack of research and technical knowledge about salmon farming resulted in a failed attempt for this species in 1998 (Figure 6). High water temperatures seen in summer season were the reason for the salmon production failure in the Black Sea. Salmon needs to stay in saltwater in the summer to reach

2-3 kg yet they cannot survive warm summer water temperatures during summer months. Black Sea has high seasonal variations in surface water temperatures. In winter, the temperature varies between 6-9°C while in summer it is measured between 24-28°C. Harsh sea conditions like high waves and lack of protected coves along the coastline were additional limiting factors (Aydın and Baltacı 2017; Ginzburg *et al.* 2004; Memis *et al.* 2002; Özsoy and Ünlüata 1997).

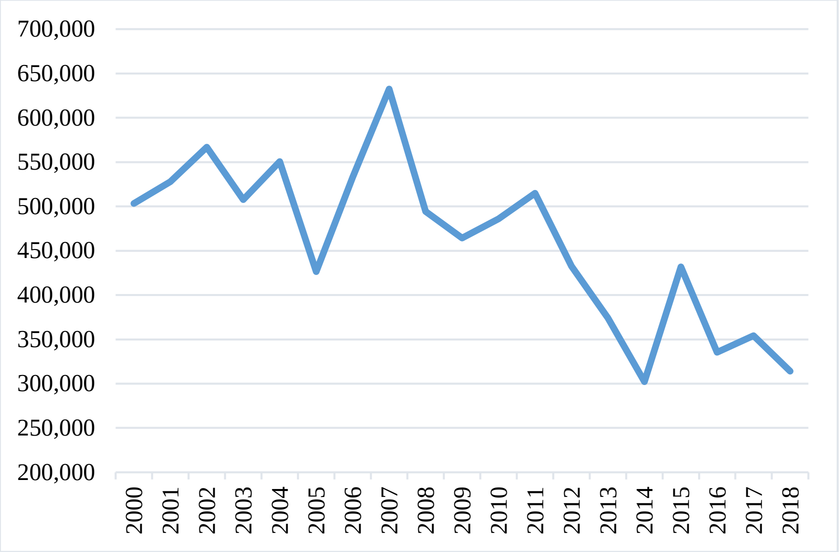

Figure 5. Decline in Turkish fisheries production since 2000 until 2018 (Data compiled from TUİK, TurkStat, Fishery Statistics 1985-2018)

Trout mariculture started in the early 1990'ies in the Black Sea region. First marine trout venture followed the scientific research conducted in Central Research Center (SÜMAE) in Trabzon in 1989 (Akbulut 2009). There are no official production values recorded before 1996 for rainbow trout (*O. mykiss*) and 2014 for Black Sea trout (*Salmo trutta labrax* Pallas 1814). Small and medium family farms were established during 1991-1993 in the eastern Black Sea region. Most of the farms had technical difficulties and disease problems leading to a limited production or failure. Unofficial production value was estimated as 100 tonnes for the 93-94 season. Main form of trout mariculture in the Black Sea is ranching in cages. There are many scientific publications reporting that rainbow trout grows better in salt water rearing conditions compared to freshwater rearing (Sedwick and Landles 1970; Galbreath and Thorgaard 1997; Yiğit and Aral 1999).

Rainbow trout reared in land based trout farms are transferred to sea cages at 5-30 gr in autumn (October-November) with decreasing water temperatures. Trout are fed in the sea cages until June when they reach over 500-600 gr and harvested for sale. Farmers prefer to harvest their fish before seawater temperatures reach 22ºC (Özsoy 2017). Commercial production started as the production increases achieved with seabass (*Dicentrarchus labrax*) and seabream (*Sparus aurata*) in 1990'ies (Çelikkale *et al.* 1999; Yildiz and Şener 2003). Yet, marine trout production increase was very limited in comparison to seabass and seabream production. Marine trout production showed an increasing trend although there are some recorded production downfalls in the last three decades. The production was reported as 1330 tons for rainbow trout in 1996 whereas it was 9235 tons for rainbow trout and 375 tons for Black Sea trout in 2018 (Figure 7). In the recent years, marine trout production in Turkey received attention in terms of potential trade from other countries, which resulted in renewed attention by the investors.

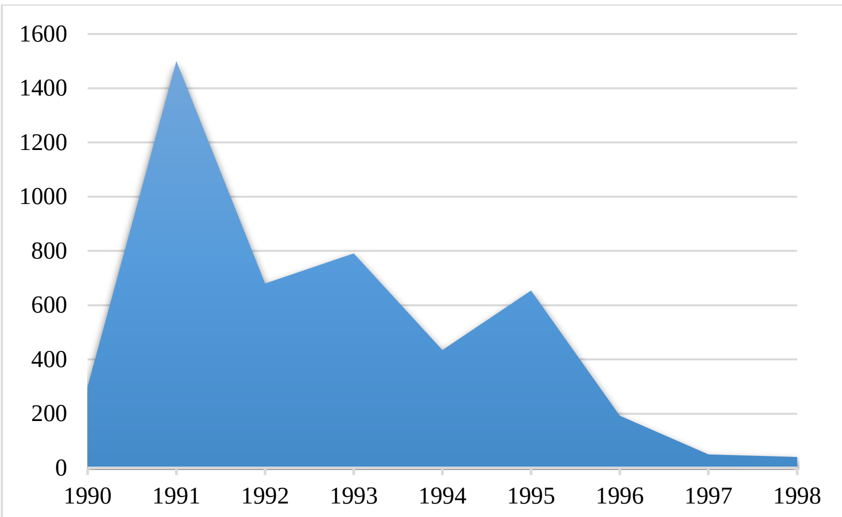

Figure 6. Historical development of *Salmo salar* production in Turkey.

Technologic advances in mechanization and appropriate investments proved better production values could be achieved. Tosun (2010) reported the use of wooden and HDPE floating cages with knotted nets for production (Figure 8-9). At present, farms dominantly use HDPE cages and knotless nets for production (Figure 10-11). Farmers reported high mortality (>50) related with knotted net use which caused skin damage resulting in diseases. The same farmers reported the similar problem for seabass, which they were farming at the same site. Although knotted net use had been known to cause mortality problems farm owners insisted on low cost knotted nets (Tosun 2010). One of the major reasons of mismanagement was due to lack of educated personnel. Most of the farms did not employ aquaculture/fisheries engineers, which were readily available from several Fisheries Faculties in Turkey and proved their worth in seabass and seabream culture. As the legislative necessities changed, most of the farms were obligated to employ educated personnel according to their production capacities, which led to better production processes and as a result better aquaculture practice.

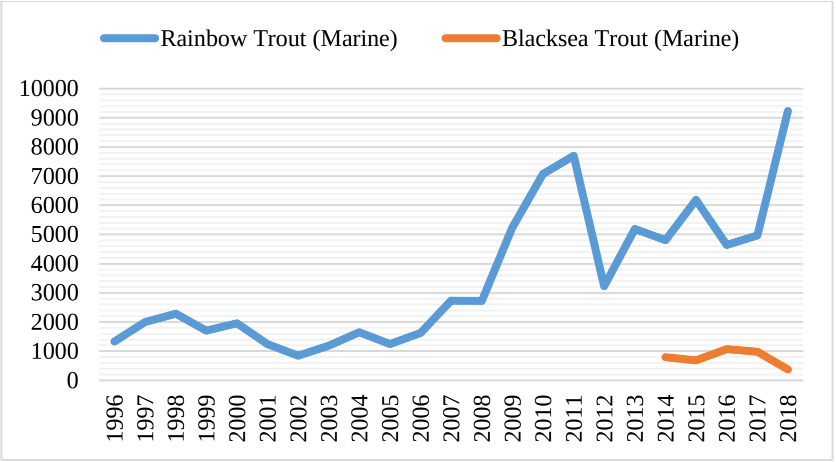

Figure 7. Progression of marine trout farming in the Black Sea in the last three decades (Data compiled from TUİK, TurkStat, Fishery Statistics 1985-2018).

Figure 8. Aerial view of a marine trout farm located in the eastern Black Sea region, Perşembe, Ordu, Turkey, 2009 (Photo by Deniz D. Tosun)

Figure 9. Aerial view of a marine trout/ European seabass farm located in the eastern Black Sea region, Perşembe, Ordu, Turkey, 2009 (Photo by Deniz D. Tosun)

Figure 10. Marine trout/ European seabass farm located in the eastern Black Sea region, Perşembe, Ordu, Turkey, 2019 (Photo by Noyan Çoluk)

As of March 2019, there are 38 licensed farms producing marine trout according to the published list of aquaculture farms by the Ministry of Agriculture and Forestry. Emre *et al.* (2007) reported only twelve with two-thousand-ton capacity. The number of farms dramatically increased in 12 years as well as the production capacity. These farms have a ranging production capacity between 100 tons to 3000 tons for *O. mykiss and Salmo trutta labrax* (Figure 12). The total production capacity of licensed farms is about 22590 tons for these species, which is not used to its total capacity, as the latest yearly production is 9610 tons. Most of the farms produce seabass at the same farm location. Farms are located dominantly at Artvin, Ordu, Samsun, Sinop and Trabzon (Figure 13).

Figure 11. Marine trout/ European seabass farm located in the eastern Black Sea region, Ordu, Perşembe, Turkey, 2019 (Photo by Noyan Çoluk)

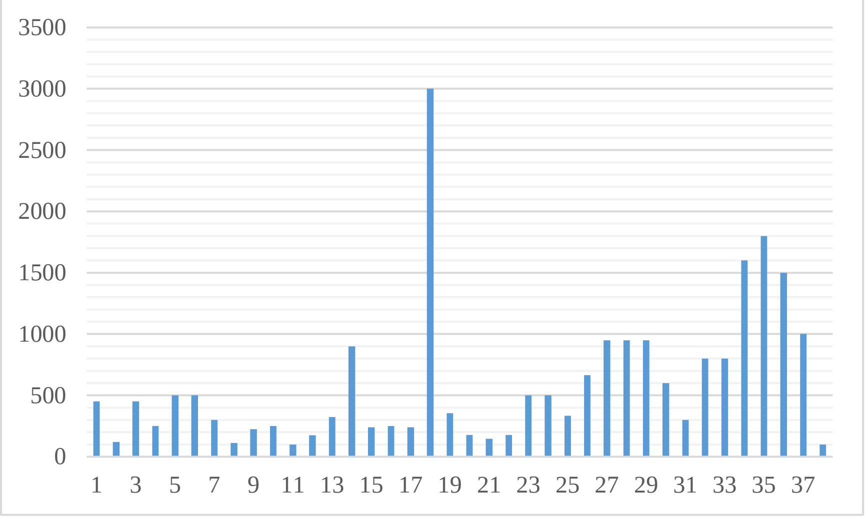

Figure 12. Distribution of licensed production capacities (ton) between the 38 farms

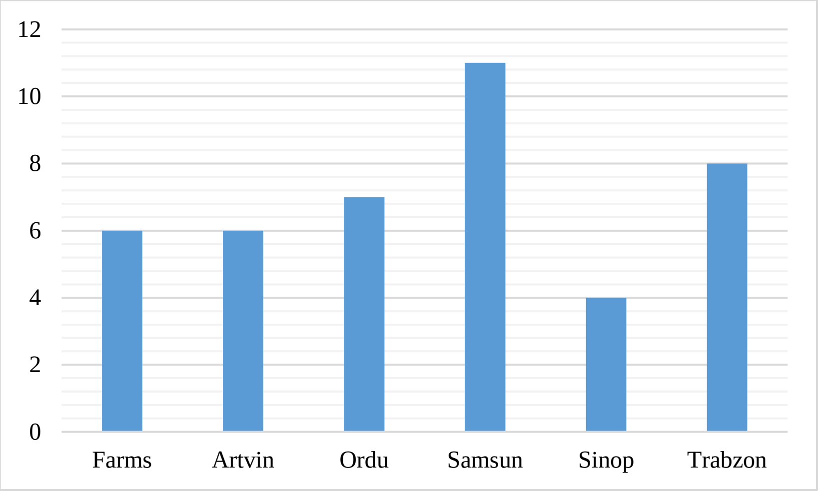

Figure 13. Distribution of marine trout farms to the cities

Future of trout mariculture in Turkey

The driving force behind the increasing aquaculture production in Turkey is the ability to export produced goods to foreign countries, especially to Europe. Turkey has vast resources in terms of fisheries and aquaculture but the majority of the public is not accustomed to consume high amounts of seafood. Seafood consumption decreased from 6.2 kg/person in 2015 to 5.4 kg/person in 2016, which is well below the global average, which is 16 kg/person and European average 22 kg/person (Öksüz *et al.* 2018; Ergün *et al.* 2019). This is a limiting factor for the future increase of aquaculture production in Turkey. The production volume is directly linked to the foreign export demand. Turkey exports its majority of aquaculture production to mainly Europe and other countries. The increase in aquaculture production will continue as long as the demand remains. To ensure this increase, producers will need to expand their target markets around the globe with better promotion of the produced seafood.

Black Sea region has great potential to increase trout mariculture in the future. Presently, half of the licensed potential, approximately 10000 tons of the total 20.000 tons is used and it will not take long to fulfil the capacity. Producers are promoting their goods in the Far East, especially Japan more aggressively after some successful trade. Promotion will result in better value and more demand which will enable more production in the coming years.

References

Akbulut, B. (2009) Historical development and future projection of aquaculture in the Black Sea Region. *Journal of Fisheries Sciences* 3(2): 76-85.

Aydın, H., Baltacı, M.A. (2017) The place of İstanbul University Sapanca inland waters research and application unit in the spread of trout production in Turkey. *Turkish Journal of Aquatic Sciences* 32(3): 129-134.

Balcı Akova, S. (2015) Aquaculture and its distribution in Turkey. *Journal of Aquaculture Engineering and Fisheries Research* 1(4): 160-190.

Bozoğlu, M., Ceyhan, V., Cinemre, H.A., Demiryürek, K., Kiliç, O. (2006) Evaluation of different trout farming systems and some policy issues in the Black Sea region, Turkey. *Journal of Applied Sciences* 6(14): 2882-2888.

Çelikkale, M.S., Düzgüneş, E., Okumuş, İ. (1999) Turkish Aquaculture Sector: Potential, Current status, Problems and Solutions. Istanbul Chamber of Commerce Publication No: 1999-2, Istanbul, Turkey, 397p.

Deniz, H., Korkut, A.Y., Tekelioglu, N. (2000) Developments in the Turkish marine aquaculture sector. In: Mediterranean Offshore Mariculture, (eds., Muir, J., Basurco, B.). Zaragoza, CIHEAM, pp. 71-77.

Emre, Y., Diler, İ., Sevgili, H., Oskay, D.A., Sayın, C. (2007) The investigation of structural properties of rainbow trout farms in Mediterranean region (2000-2003) *Turkish J Aquatic Life*, National Aqua Days 2007, Special Edition 5-8: 476-489.

Ergün, S., Bayraktar, S., Ayvaz, Z. (2019) Seafood consumption preferences and habits in Ankara and Çanakkale. *Acta Aquatica Turcica* 15(2): 213-226. (in Turkish).

FAO (2018) The State of World Fisheries and Aquaculture 2018 - Meeting the Sustainable Development Goals. Rome. Licence: CC BY-NC-SA 3.0 IGO.

Galbreath, P.F., Thorgaard, G.H. (1997) Saltwater performance of Triploid Atlantic Salmon *Salmo salar L.* x Brown Trout *Salmo trutta L.* hybrids. *Aquaculture Research* 28(1): 1-8.

Ginzburg, A.I., Kostianoy, A.G., Sheremet, N.A. (2004) Seasonal and inter annual variability of the Black Sea surface temperature as revealed from satellite data (1982-2000). *Journal of Marine Systems* 52: 33-55.

Kayhan, M.H., Olmez, M. (2014) Aquaculture and organic aquaculture in Turkey. *Journal of Aquaculture Research and Development* 5: 259. doi: 10.4172/2155-9546.1000259.

Memis, D., Demir, N., Eroldogan, O. T., Kucuk, S. (2002) Aquaculture in Turkey. *The Israeli Journal of Aquaculture-Bamidgeh* 54(1): 3-9.

Öksüz, A., Alkan, Ş.B., Taşkın, H., Ayrancı, M. (2018) Benefits of fish consumption for healthy and balanced nutrition during lifelong time. *Food and Health* 4(1): 43-62.

Özsoy, E. (2017) Identifying the most Suitable Areas for Sea Cage Fish Farming in Ordu Province. University of Ordu, Institute for Graduate Studies in Science and Technology, Department of Fisheries Technology Engineering, 2017 MSc. Thesis, 57p. (in Turkish).

Özsoy, E., Ünlüata, Ü. (1997) Oceanography of the Black Sea: A review of some recent results. *Earth-Science Reviews* 42: 231-272.

Rashid Sumaila, U., Bellmann, C., Tipping, A., Samans, R. (2014) Fishing for the Future: Trends and Issues in Global Fisheries Trade. E15Initiative. Geneva: International Centre for Trade and Sustainable Development (ICTSD) and World Economic Forum.

Sedwick, S.D., Landless, P. (1970) Rainbow trout farming in Scotland: Farming trout in salt water. *The Scottish journal of Agriculture* 49: 180-185.

Şener, E. (2002) Farming of the rainbow trout, *Oncorhynchus mykiss*, in the Black Sea region of Turkey. *Turkish Journal of Fisheries and Aquatic Sciences* 2: 93-96.

Taş, B. (2007) Aquaculture in the Vona Bay (Southern Black Sea, Ordu, Turkey). *Journal of Fisheries Sciences* 1(4): 176-183. (in Turkish).

Tosun, D.D. (2010) Structural and Economical Analysis of Sea Bass (*Dicentrarchus labrax*, L., 1758) Farms in Black Sea and Aegean Regions. Istanbul University, Institute of Science, PhD. Thesis, 114p.

TÜİK (2020) Newsletter, aquaculture and fisheries. Available at : https://tuikweb.tuik.gov.tr/PreHaberBultenleri.do?id=33734#:~:text=Su%20%C3%BCr%C3%BCnleri%20%C3%BCretimi%202019%20y%C4%B1l%C4%B1nda%20bir%20%C3%B6nceki%20y%C4%B1la%20g%C3%B6re%20%33,bin%20524%20ton%20olarak%20ger%C3%A7ekle%C5%9Fti. (accessed 25 Sept 2020)

Yiğit, M., Aral, O. (1999) A comparison of the growth differences of rainbow trout (*Oncorhynchus mykiss* W. 1792) in freshwater and seawater (The Black Sea). *Turkish Journal of Veterinary & Animal Sciences* 23(23): 53-59.

Yildiz, M., Şener, E. (2003) Structural and biotechnological properties of rainbow trout (*Oncorhynchus mykiss*) and seabass (*Dicentrarchus labrax*) farms in the Black Sea region. *J Fac Vet Med İstanbul Univ* 29(2): 241-252. (in Turkish).

Turbot and flounder aquaculture

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Introduction

The competition in the production of seabass and seabream among the cultivated species has directed the breeders to search for different potential species. In this context, flat fish with high nutritional value and economic value, and especially turbot, whose production is rapidly increasing in the world, stand out as potential species.

In our country, with the cooperation of the Ministry of Agriculture and Rural Affairs and the Japan International Cooperation Agency (JICA), the Trabzon Fisheries Central Research Institute started the "Development of Aquaculture Techniques of Black Sea Turbot" project in 1997, followed by the "Investigation of the Cultivation on Flounder" project in 2007. Under this chapter, the data obtained in these projects are mentioned and it is aimed to guide those who want to breed these species.

Life history and biology

Turbot (*Psetta maxima*) is a member of family Scophthalmidae and the Black Sea flounder (*Platichthys flesus luscus*) is a member of family Pleuronectidae, both in the order of Pleuronectiformes or as it's commonly called flatfishes. European flounder is mainly distributed amongst Eastern Atlantic waters; from Western Europe coasts and White Sea to the Mediterranean and the Black Sea. Ballast-water introduced self-sustaining populations have been reported from Canada and USA. Turbot is mainly distributed amongst Northeast Atlantic waters; from Europeans coasts to Arctic Circle, Mediterranean Sea, Baltic Sea and the Black Sea.

Flatfishes are known with oval shaped view from top and a flattened bottom (dorso-ventrally flattened) such as in flounder and turbot. At early life stages, flatfishes go through a phase called "metamorphosis". At that stage flatfish morphology is like many other vertebrate larvae; transparent body with two eyes on either side of skull with bilateral symmetry. During this unique physical metamorphosis one eye of a flatfish migrates to the other side –righteye flounder term is a result of this stage, Black Sea flounder, right-sided (dextral) and turbot left-sided (sinistral)– the body start flattening, and later top side of the body becomes speckled while the bottom side becomes white like colour (Figure 1). In some cases, reverse asymmetry could also be observed (Aydın *et al.* 2015). The classification of the species is given in Table 1.

Black Sea flounder and turbot are demersal carnivorous marine fishes mainly fed on demersal fishes and Crustaceans and can be found in shallow coastal waters as well as in deep waters up to 80-100 meters on sandy, muddy, rocky or mixed substrates. The depress form body type allows flatfishes to hold on to the ground even in flowing water bodies such as rivers and streams or, hide using a layer of sand as a camouflage to rest and forage while waiting for a prey. Younger specimens are often found in shallow coastal waters. After length of 10 cm, the Black Sea turbot starts feeding on pelagic and demersal fishes such as; red mullet, Gobiiformes and anchovy. Turbot lifespan can be as much as 25 years and they can reach 80-90 cm in length. Flatfishes are commonly caught by bottom set gillnets (STECF 2017).

Table 1. The classification of Black Sea flounder and turbot

Flounder		
Class	:	Actinopterygii
Order	:	Pleuronectiformes
Family	:	Pleuronectidae
Genus	:	*Platichthys*
Species	:	*Platichthys flesus* (Linnaeus, 1758)
Subspecies	:	*Platichthys flesus luscus* (Pallas, 1814)
Turbot		
Class	:	Actinopterygii
Order	:	Pleuronectiformes
Family	:	Scophthalmidae
Genus	:	*Psetta*
Species	:	*Psetta maxima* (Linnaeus, 1758)

Flounder spawns transparent and sphere-shaped eggs. The eggs are pelagic and contains no oil droplets. Their size varies between 1.07-1.21 mm in diameter and approximately a thousand eggs weights about 1 g. A female flounder can produce under natural conditions (UNC) from 123,000 to 1,262,000 and under culture conditions (UCC) from 550,000 to 1,240,000 eggs in a spawning period (Aydın *et al.* 2013). On the other hand, while turbot eggs are also transparent and sphere-shaped, they contain one oil droplet (Figure 2). Their size varies between 1.02 to 1.15 mm (Polat 2011). A female turbot can produce UNC from 3M to 13M and UCC from 100,000 to 4,700,000 eggs in a spawning period (Zengin 2000; Samsun 2004; Aydın *et al.* 2019). Spawning occurs usually between April to June repeatedly at 20 to 40 meters depth. Fertilization is external. Hatching occurs in 5-7 days after fertilization and hatched larvae has a transparent body (Baloon 1990; Çiloğlu 1997; Aydın *et al.* 2019).

Turbot is oceanodromous and inhabits marine and/or brackish waters while flounder inhabits fresh and brackish waters. Flounder is an euryhaline species and can tolerate low salinity levels as well as high salinity levels up to 45 ppm (Jensen *et al.* 2002). They both often can be found in temperate waters from 5°C to 25°C. Turbot migrates to the shallow coastal waters mainly in spring for spawning purposes and leaves to deeper and colder open waters after the spawning period. Spawning occurs mainly from April to June especially in May depending on water temperature (Genç *et al.* 1998).

Figure 1. Dorsal and ventral views of turbot (top left and right) (top row) and flounder (bottom left and right) (bottom row) (Polat 2011; Aydın *et al.* 2015).

Flounder naturally migrates into the river openings and estuaries. Adults are often seen in shallow coastal waters. Spawning occurs in deeper, warmer waters at the end of winter and in spring. Larvae and early life forms migrates to coastal waters using tidal movements and spends their life on the bottom until they are ready to migrate and spawn. Thus, the migration of an adult flounder occurs between feeding and spawning grounds (Aro 1989). This behaviour can be categorized in two stages; saline water stage or hatching and brackish (low salinity) water stage or growing. Migration is not common amongst juvenile forms and the larvae make use of the tidal currents for relocating itself on their journey to nursery grounds (Campos *et al.* 1994; Bos 1999). While normal form of flounder spawn pelagic eggs at least 30 m away from the coast, there are populations adopted to the brackish water environment so well that they spawn smaller benthic eggs on the coastal area (Solemdal 1973; Aro 1989; Drevs *et al.* 1999; Nissling *et al*. 2002; Morais *et al.* 2011). This adaptation assures the survival of the eggs in low salinity waters where the buoyancy of water is low while the pelagic eggs can avoid anoxic environments of deep water (Solemdal 1973; Nissling *et al.* 2002). This adaptation occurs in years naturally under specific environmental conditions. An examination of migration patterns of flounder in the Minho estuary located in Portugal and Spain boundaries is a good example of such adaptation (Morais *et al.* 2011).

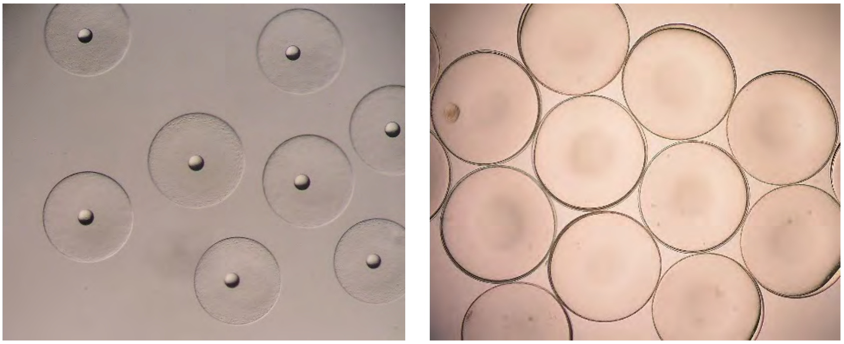

Figure 2. Turbot (left) and flounder (right) eggs under stereomicroscope (Polat 2011; Aydın *et al.* 2015).

History of flatfish culture

Flounder and turbot are commercially important to the world and the Black Sea fisheries. Their capture fisheries records are going back to 1950s with a cumulative number of 17,600 tonnes from Northern regions of Europe. In the last few decades, the total catches have been fluctuating approximately between 25 and 30 thousand tonnes per year. Given the stagnated status of capture fisheries and the increase in world population and the demand for food have pushed aquaculture into an inevitable rapid growth. This growth necessitates a continuously developing technology and techniques for housing, culturing, transporting, storing and for other related activities and eventually leading to introducing new species to aquaculture. Few members of Pleuronectidae family are cultured by few countries (Alvial and Manriquez 1999; Bengston 1999; Olsen *et al.* 1999). Basic flatfish culture studies carried out mainly in UK and France. First cultured turbot is produced by France with 5 tonnes in 1984 (FAO 2019b). France and UK became the pioneers of turbot seed production in 1980s with well-developed techniques. Spain imported several millions of juveniles from France until they have established their own hatcheries. Turbot culture became popular amongst the European countries such as Norway, Portugal and Ireland. Chile, Korea and China produce turbot, but they have no wild turbot stocks in their natural environment (Han *et al.* 2018). Today, turbot is mainly being cultured by China and Spain with an estimated number of 45,500 and 8,771 tonnes, respectively (Figure 3 and 4) (FAO 2019b). On the other hand, the Black Sea turbot productions had taken place in Russia back in 1990s (Maslova 2002). Black Sea turbot production started in Turkey between 1997 and 2007 as a joint project with Japan International Cooperation Agency (JICA) at Central Fisheries Research Institute (SUMAE), Trabzon. The turbot production line in Trabzon is still active and funded by the Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies (TAGEM). There are only experimental records for the European flounder *P. flesus* and/or the Black Sea flounder *P. flesus luscus* culture fisheries, mainly conducted by researchers and scientists. In Denmark, for the purpose of stock enhancement 153,000 specimens are cultured annually (Sorensen *et al.* 2004). Experimental productions are recorded in United Kingdom (Hutchinson and Hawkins 2004). It is known that a few trials are put forward by Ukraine in the last decade. In Turkey, experimental and research aimed culturing activities are conducted mainly by Central Fisheries Research Institute, Trabzon; effects of temperature (Aydın *et al.*2015), feed efficiency and nutrition (Küçük *et al.* 2014), abnormalities (Aydın 2012), reproductive performance (Aydın *et al.* 2011).

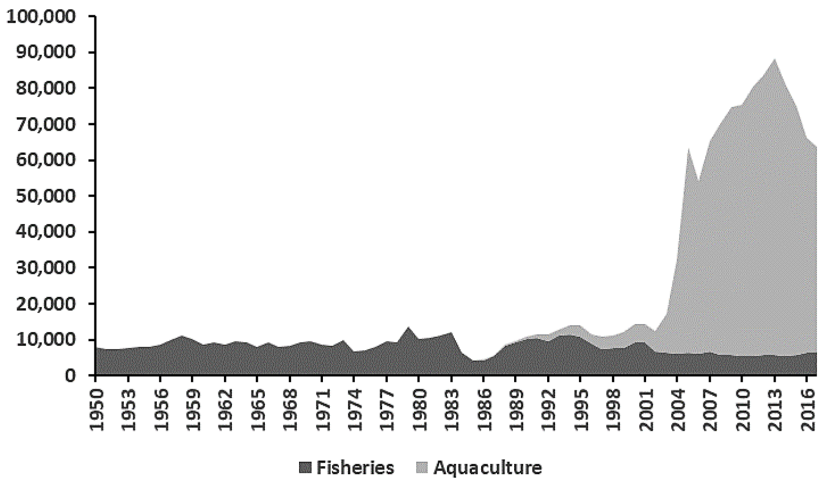

Figure 3. Fisheries and aquaculture statistics of turbot in tonnes between 1950 and 2017. (FAO 2019 a; b).

Wild stocks of turbot and flounder are in a declining trend in the last decades not only in Turkish waters but also globally. Therefore, culture production of these species are important for stock enhancement and aquaculture (STECF 2017). Nowadays, culture production methods are in a continuous development.

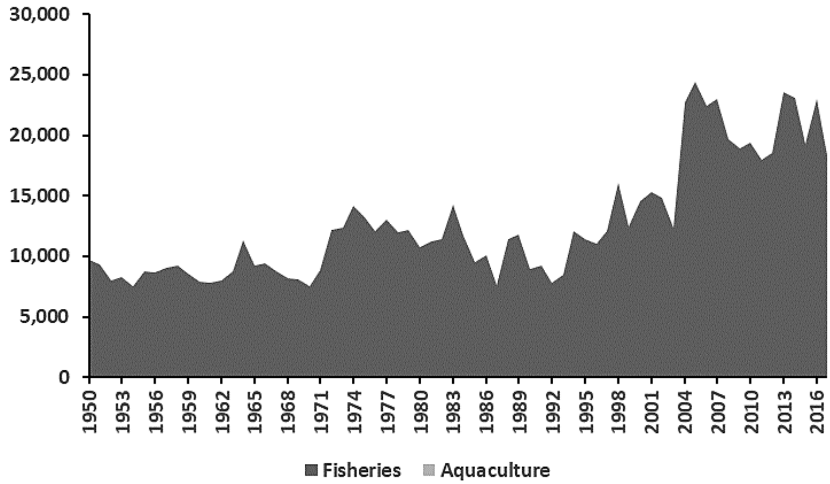

Figure 4. Fisheries and aquaculture statistics of European flounder in tonnes between 1950 and 2017 (FAO 2019 a; b).

Turbot and flounder aquaculture treatment

Turbot and flounder reach sexual maturity at age 2-4. There are few records suggesting sexual maturity can occur at age 2, a research study from Bulgaria and a few from Turkey (Ivanov and Beverton 1985; Genç *et al.* 1998). Wild captured turbot specimens can start producing eggs at a weight of 2.5-3 kg for male and 3.5-4 kg for female specimens. Cultured specimens tend to spawn at a later time around age of 4-5 at 2,5 kg for females and at age of 3-4 at >2kg for males (Aydın 2008).

Rearing

A successful production is dependent on the determination of optimum conditions for incubation, larval rearing, grow-out and broodstock management. The health and welfare of the fish and the efficiency of the production system is limited or determined by such conditions. These conditions can be categorized as; environmental conditions, nutrition and diet, and stocking densities.

Required conditions

Light, one of the few important conditions, is affecting the hatching time and rate depending on lighting time, density and colour but also the development of larvae and grow-out (Helvik and Walther 1992; Watson and Chapman 2002). For the optimum growth the preferred lighting is 12 hours light and 12 hours dark for flatfish culture as well as many other cultured fish species (Stefánsson *et al.*

2002). In SUMAE hatchery its 0-35 dpf (days post fertilization) 24h light 300 lux, after 35dpf 12h dark and light.

Temperature, one of the most important conditions for a successful aquaculture practice, is affecting every life stage of fishes. Especially, the feed conversation and growth rate are being affected by the temperature. In natural conditions Black Sea water temperature reaches at its lowest with 7-8°C in March and its highest with 27-28°C in August. The vertical distribution of temperature in the Black Sea is declining up to 50 meters and after 50m depth there is not much difference in temperature. Natural conditions for Black Sea flounder and turbot can be simulated for rearing purposes. But to achieve optimum growth and efficient ways to reproduce, different temperatures can be set. This will be explained in further sections for different life stages.

Oxygen levels along with the pH in culture conditions should be kept under control and monitored continuously. In Black Sea conditions oxygen levels at its lowest in August with approximately 6-7 mg/L and its highest in March with approximately 10-11 mg/L. Because of the relationship between the temperature and the oxygen, different levels of oxygen can be measured at different depths of water bodies. This can be as low as 1.15 mg/L at 100m. Because of their natural benthic lifestyle, flatfishes can be very tolerant to oxygen depletion, but in aquaculture to provide good living conditions for productivity, oxygen levels should not drop below 5 mg/L levels and if possible should be kept at approximately 9.5 mg/L. Person Le-Ruyet (2002) suggests a minimum 6.0 mg/L oxygen is necessary for optimum growth of turbot and claims the growth stops at 3 mg/L while low levels such as 0.75-1.3 mg/L can be lethal. Depending on the temperature, pH is also showing declining or increasing trends in water bodies, but this change is limited in Black Sea conditions and it can be as low as 7.5 (at 200 m depth) or as high as 8.7 (surface water). Thus, pH level required for Black Sea flounder and turbot culture can be set between 7.5-8.5.

Other conditions such as salinity can be kept at its natural conditions because of the high tolerance ability of flounders and turbot. This is between 17-20 ppm in Black Sea conditions. Imsland *et al.* 2001 suggests that the growth rate at low salinity levels such as 19 ppm is higher than the growth at 35 ppm salinity and claims 20 ppm salinity with 18-22°C of water temperature can be set for the optimum growth. It is known that salinity effects fertilization rate in flounders and it increases at higher salinity levels such as 35 ppm (Aydın 2013).

Nutrition and diet

Feeding plays a key role in maintaining water quality while improving growth, meat quality and body composition. The feeding regime, composition and rate must be hold at optimum conditions for both economical and biological reasons. A good feeding strategy effects growth performance, feed conversation ratio, survival rate along with minimizing uneaten feed and weight-length variations between specimens resulting in an improved productivity under culture conditions while shortening the time necessary to reach market size which effects the operation costs (Goddard 1996; Kubitza and Lovshin 1999; Thompson *et al.* 2000; Türker 2006; Kim *et al.* 2007).

As mentioned earlier, flounder and turbot are carnivorous species which mainly feed on benthic fish species and Crustaceans. This means they require feed with high protein content. Initial feeding starts with a combination of rotifer and Artemia. And in time when the larvae start growing, artificial feed forms of microgranule and pelleted feeds can be used depending on the size. Flatfish feed is not widely produced around the world. This may create a challenge in acquiring commercial diets. Feeds with high protein contents about 45% and more can be used instead, or feeds produced for turbot by choice. The researchers suggest the protein requirements for a juvenile is 45-65% and in comparison to growth data the amount of protein needed in the turbot feed is 49.4-55% (Lee *et al.* 2003; Cho *et al.* 2005).

Stocking

In aquaculture practices, stocking density -which is calculated in relation to volume of water per kg fish or surface area per unit fish- plays a vital role in the efficiency of the system built. Defining the optimum stocking density can help to protect and provide the welfare and health of the species cultured, and also can protect and provide economic feasibility while providing necessary space and enough number of individuals for social interactions. Many researchers have sought the connection between growth, welfare and health in relationship with stocking density (Holm *et al.* 1990; Bjørnsson 1994; Huang and Chiu 1997; Irwin *et al.* 1999; Aksungur *et al.* 2007) and sought optimum conditions to enhance growth.

Cultured species can be stocked in different densities at different stages of life. Those stages can be divided into three, the advised optimum stocking density for larval rearing is 20.000-30.000 unit per m^3, 10 kg per m^3 for pre-growing and/or 150 fish per m^2 for on-growing and lastly 40-50 kg per m^2 for later stages (Imsland *et al.* 2001).

Reproduction and breeding

Under culture conditions, sperm of a male specimen can be collected from November to September. Gonad development of female specimens starts around March-April and eggs can be collected from May to August. Turbot and flounder spawn asynchronously. Mainly artificial fertilization method is used in production which requires stripping procedures.

Artificial spawning by stripping method (putting pressure on gonads to obtain sperms and eggs, abdominal part of the body) is mainly used under culture conditions (Figure 5). Specimens can be checked for their eggs and sperm quality under laboratory conditions to obtain best fertilization rates and sperms that shows low motility should be avoided in fertilization process (Aydın *et al.* 2013; Polat 2011). This is often done by recording motility and motility time following activation of the sperm with sea water (0.5µl sperm with 50µl sea water) under a microscope (Chen *et al.* 2004; Bozkurt *et al.* 2006). Motility time can be measured with a chronometer starting from the activation of the sperm till no movement is detected. Motility of sperm can last about 30 minutes. Eggs fertilized with low quality sperms often results in low rates of fertilization and survival. Eggs can be checked under microscope for maturity and size. If not well developed eggs are seen, hormones such as LHRH-a can be applied to promote oocyte growth (Aydın 2008). Fertilization can be completed by mixing sperms and eggs in a sterile glass container at 14°C. Eggs lose their ability of fertilization dramatically within 10 minutes after collection. This should be taken under consideration for the fertilization process. No fertilization occurs at salinity levels below 9 ppm and fertilization rates are in increasing trends with increased salinity levels. Fertilized eggs can be washed with filtered sea water 5-10 minutes after the fertilization (Çiftci *et al.* 2002).

Figure 5. Flatfish stripping. Left: Female, Right: Male (Polat 2011; Aydın *et al.* 2015).

After the fertilization, fertilized eggs can be moved to incubation tanks of 50 to 100 L in size. Black Sea flounder eggs could be kept at salinity of 18 ppm and a temperature of 10°C. A water movement is usually created inside the incubation tanks with the help of the water drainage. The drainage pipe must be covered with polyethylene material to avoid losing fertilized eggs.

Hatching time is highly dependent on temperature (Turbot: 110 hours at 14-15°C, flounder: 117 hours at 10°C, 103 hours at 11.3°C, 98 hours at 12.4°C and 77.5 hours at 13.5°C). Quantity of sperms fluctuates between individuals. A single male specimen has a sperm of 0.1-0.3 ml (Aydın *et al.* 2013).

Broodstock management

Broodstock specimens can be acquired from wild stocks or from culture facilities. As mentioned earlier, wild specimens can be captured using bottom gill set method. A standard method for bottom gill set can be used with a mesh size of 14 mm and a gate length of 22.5 meters at depths up to 60 meters. It is advised to keep specimens in a 500 L fiberglass tank with oxygenation equipment till they complete their transfer to the facilities.

Broodstock specimens can be kept in circular or rectangular tanks in the hatchery with a sex ratio of 1:1 (equal numbers of female and male fishes) for a better spawning period. Adult specimens can be moved to adaptation tanks and the temperature can be set at 14°C. A temperature adjustment of 0.5°C by day is advised to ease that process.

Determination of sex in flounders can be achieved with naked eyes under the light. On the ventral side of the flounder female specimen gonads are spread from abdominal cavity to the tail while the male gonads are only located around abdominal cavity (Figure 6).

Larval development

Larval development of turbot lasts 70 days at 16-19°C in three stages (morphologically). The first stage is the pre-larval period at day 0-2. The larvae are about 2.5 mm long, eyes are transparent, mouth and anus is not yet developed. Often seen as suspended in the water column upside down. The post-larval stage occurs at days 3-29. Eye coloration becomes visible, mouth and anus starts developing at this stage. At 4dph the first feeding takes place. Dorsal and anal fin rays complete at 25dph. Juvenile stage occurs at day 30-70. Samples can be taken and examined under the stereo microscope to observe the embryonic development of the egg (Ciftci *et al.* 2002). Detailed development stages are given in Figure 7 and 8 (Polat 2011).

Figure 6. Broodstock specimens of Black Sea flounder. Left: Male, Right: Female (Aydın *et al.* 2013).

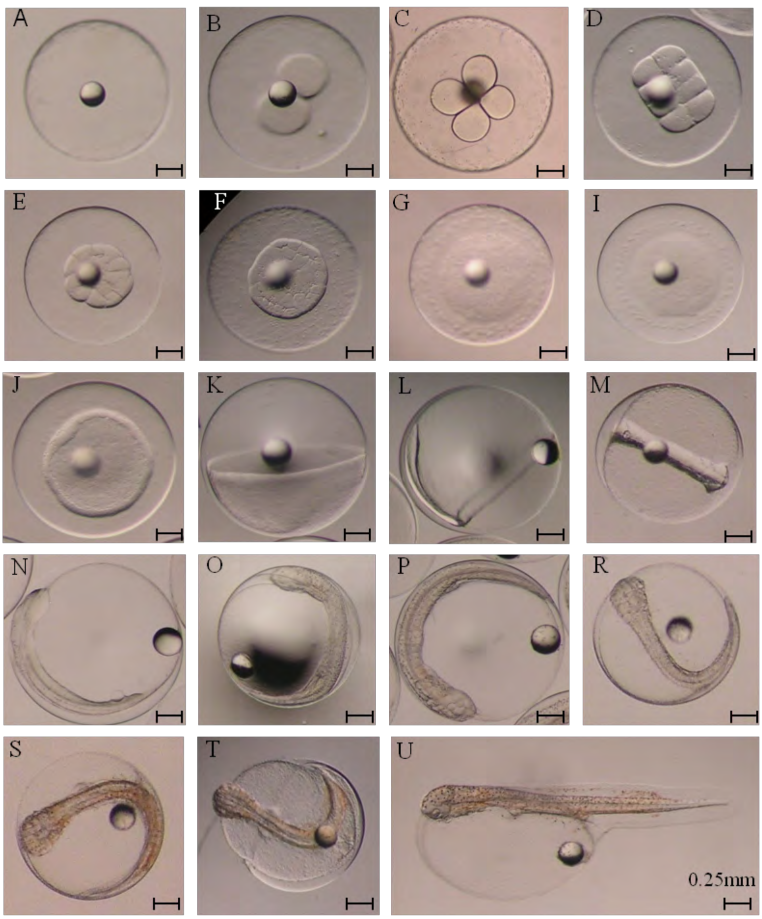

Figure 7. A- Fertilized egg, B- 2-cell stage, C- 4-cell stage, D- 8-cell stage, E- 16-cell stage, F- 32-cell stage, G- Morula stage, I- Blastula, J- Pre-Gastrula, K- Gastrula, L- Pre-Embryonic stage, M- Neurula, N- Post-Neurula, O,P,R- Embryonic stages I-III, S-Larval stage, T,U- Hatching (Polat 2011)

Flounder and turbot species start going through a stage called "metamorphosis" at around 25 dpf and 30dpf and finish at 50 dpf and 70 dpf, respectively. At this stage flounder is vulnerable to changes in environmental conditions, especially to temperature. Abnormalities, discolouration or other malformation can be seen at this stage. The growth and survival rate is in a reverse correlation with the rearing temperature. The best larval survival rate is around 13,5 % at 15°C (Aydın *et al.* 2013) for flounder and 22,6 % at 21°C for turbot (Ciftci *et al.* 2002).

Turbot starts inhabiting bottom of the tank while the eye starts migrating to the other side. Pectoral fin completes its ray development at day 51. The survival rate of turbot at day 0-40 is about 10%, day 40-110 is above 75%. Many different abnormalities can pop up at early development stages, such as; discoloration, incomplete eye migration and abnormalities in operculum (Çiftçi *et al.* 2002).

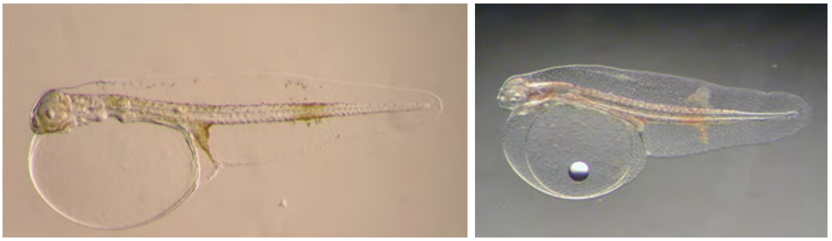

Figure 8. Flounder (left) and turbot (right) larval view under stereomicroscope (Aydın *et al.* 2015).

Grow out

Grow-out stage of turbot culture can be divided into two stages; the pre grow-out stage and the grow-out stage. Turbot larvae reaches approximately 10g body weight in 4-5 months at nursery station. Nursery stage is followed by pre grow-out stage where the fish reach 50-60g body weight also in 4-5 months. At this stage stocking density starts with 10 kg/m^2 and reaches about 30 kg/m^2. The growth is highly dependent on water temperature, larval quality and other factors such as feed, light and other external factors. By the end of the 9-month period turbot is expected to reach 200g body weight under good care. But few records suggest it's also possible for turbot to stay below 100g depending on the factors mentioned before. At this stage survival rate is about 75-85% and the feed conversation ratio (FCR) is 0.8 (Person Le-Ruyet 2002).

Turbot production is occurring in land based systems, mainly RAS. The sea cage systems had been used before but found unsuitable for turbot productions (Person Le-Ruyet, 2002; Aksungur *et al.* 2003). Grow-out stage stocking density for 300g is 30-35 kg/m^2 and for <750g is about 45 kg/m^2. Turbot mainly use the bottom of the tank and they accumulate one top of another, this allows them to be stocked in high densities. Expected FCR at this stage is 1.2-1.3. Turbot species reaches 3kg body-weight in three-year time. As mentioned earlier, temperature plays a major role in growth, records show that fish can reach 2-2.5 kg at 14-18°C, 1-1.5 kg at 9-19°C in a three-year period (Person Le-Ruyet 2002).

Grow-out temperature is the most important factor in flounder culture. The optimum temperature for grow-out tanks is 20-21°C. At below or higher temperatures, the total weight gain is significantly less. Feed conversation ratio is also at its best level at approximately 21°C. Flounders fed 3 times a day has higher specific growth rate compared to 1.2 or 4 times a day fed flounders. Total feed consumption is in correlation with the feeding frequency. Also, the protein and fat contents of flounder specimen is affected by the feeding frequency. The increase in feeding frequency increases fat contents (Aydın *et al.* 2013).

Abnormalities

After the metamorphosis stage, a normal turbot is considered to have a left eye migration to the right (sinistral form) with adult like pigmentation and body type. Aydın *et al.* 2019 documented malformations in 100 days old turbot juveniles with a total length of 80 mm. His findings shown a malformation rate below 5% with abnormal jaw, eye immigration (Figure 9A), abnormal body, undeveloped gill and mal pigmentation (Figure 9B).

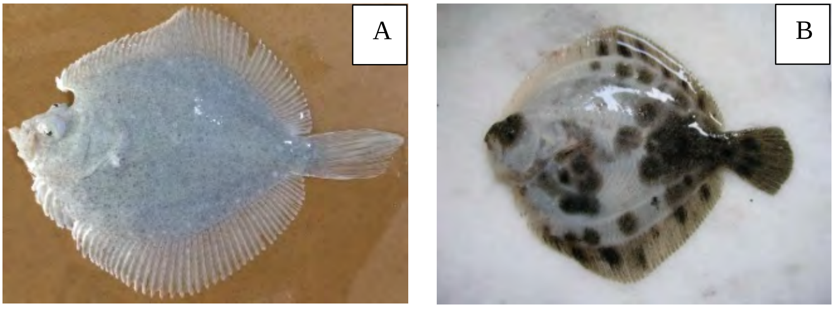

Figure 9. Turbot malformations. A-eye immigration, and B-mal pigmentation (Polat 2011).

Similar to turbot, a normal flounder is considered to have a right eye migration to the left (dextral form) with adult like pigmentation around eyes and a white like colour on the bottom side. Malformations occurred in flounder specimens became more visible after the completion of metamorphosis stage. Specimens cultured in flatfish aquaculture facilities at SUMAE had been examined at 130 dpf and a malformation rate of 40.6 % was documented (Aydın 2012). Most common anomalies in flounders are jaw malformations and eye migration to opposite side showing sinistrality. Other malformations seen in flounders are; incomplete eye migration, abnormal pigmentation, unpigmented juvenile and under-developed operculum (Aydın 2012).

Larval culture

Rearing facilities

Larval rearing facilities should be located in an isolated area inside the production facility. Any interference and/or contact from other parts of the facility and/or the equipment used elsewhere should be limited or eliminated. After each batch of production all equipment and tanks should be sterilized. Human contact should be minimized, only the responsible technicians and engineers can be allowed. A constant access to filtered sea water and a constant water quality monitoring is necessary. Equipment to control and manipulate temperature, oxygen, light and water flow is also required for the system setup.

Stocking

After hatching, Black Sea flounder larvae should be moved to larval growth tanks. 200 to 500 L tanks fiberglass tanks can be used for this purpose. Stocking density of 20 specimens per liter is often applied to promote health and growth. The initial stocking water temperature for larvae is 14°C. But it should be gradually increased to 20°C in 5-6 days.

Turbot larvae should be stocked at 20 specimens per liter. The water must be filtered (5µm) and if possible sterilized with U.V. Starting from day 4, water exchange and bottom siphoning should be carried out. The oil and other particles must be removed from the surface periodically (Şahin 2001).

Feeding

The initial feeding of the Black Sea flounder is at 4 dpf. At this stage, the larvae have consumed its yolk sac and ready for the initial feeding. Rotifer is usually used for the initial feeding, gradually increasing (4-13dpf) and decreasing (13-25dpf) rates from 2-5 individuals per ml. Phytoplankton species such as *Nannochloropsis oculata* can also be given as 0.5 x 10^6 cells per ml along with the rotifer. Rotifer will feed on the phytoplankton and this will help the almost transparent rotifer to be seen by the larvae. 2 times a day feeding up to 25 dpf is usually applied. After 12 dpf till the 30 dpf *Artemia* nauplii can be given once a day at rates of 0.2 units per ml. Starting from 21 dpf "Red Pepper" (Bern Aqua, Belgium) enriched *Artemia* metanauplii can also be used once a day for feeding at rates of 0.1-0.4 units per ml (Aydın *et al.* 2013).

The first artificial feeding in powder form of 100-200 µm starts at 25 dpf with 3 times a day and can be gradually increased in size to a granule form; 300µ at 32dpf, 300-500µ at 36dpf, 500µ at 39dpf, 500-800µ at 45dpf, 800µ at 55dpf and 800-1000µ at 70dpf. The feed size should be increased according to the size of the larvae. Pelleted feeds of 1mm at 110dpf, 2mm at 180dpf, 2.5mm at 215dpf and 3mm at 670dpf can be used for feeding three times a day.

Management

In the first few days after the fertilization up to 5dpf water exchange should be avoided. At early life stages the larvae has no swimming ability and usually suspends inside the water column upside down. A light water flow is required at this stage.

Water exchange should be avoided till the first feeding. And should be gradually increased afterwards. Advised water exchange rates are; 30% at 4-8 dpf, 50% at 8-10 dpf, 100% at 10-15 dpf, 150% at 15-20 dpf, 200% at 20-30 dpf, 300% at 30-40 dpf, 400% at 40-50 dpf and 500% at over 50 dpf. Water exchange is required to maintain water quality inside the system.

Oxygenation or aeration of the tanks is important for a healthy production. Depending on the equipment used a gentle aeration is advised to prevent disturbing the larvae. 2.5 L per minute is enough to maintain oxygen levels inside tanks. A quadruple set of 5 cm in length and 2 cm in diameter air stones can be used for this purpose.

The seawater used inside the facility must be filtered to maintain health and welfare of the fish. A set of mechanical and biological filters along with a UV filter can be used to eliminate unwanted parasites and microorganisms while improving the water quality.

Siphoning is often used to remove organic wastes and death organisms from the tanks bottom. Siphoning can be applied to tanks once in every two days after 15dpf and daily after 30dpf. The gentle application of this process is required to prevent organic matters to mix with the water body and ineffective application.

Larvae and water should be sampled daily or weekly to control existence and/or density of parasites. The most common parasite found in flounder cultures is *Scuticociliate*. If high densities of parasites are observed a very common method of formaldehyde (37%) application at 150-200 ppm for 2 hours is used depending on the size of the larvae.

Adaptation and grow out

Black Sea flounders can be kept in filtered sea water with a salinity of 18-19 ppm. Temperature is usually set at 16-18°C. Depending on the equipment and systems available at the facility, it is advised to monitor adult specimens weekly.

Adult specimens acquired with wild capture methods should go through an adaptation period. During the adaptation period newly acquired adults should be kept in separate tanks and monitored for changes in behaviour and the state of their health. Disease and/or parasite checks can be carried out at this stage. During the adaptation period, it is often observed that the adult specimens lose their appetite while losing weight. This can last up to five months. At this stage, the weakened adult specimens of flounder often face with parasite challenges (*Gyrodactylus* sp.) and approximately 50% of adult stocks may be lost due to parasite infestation. After the adaptation period, a quick recovery and gain in weight and length is documented in different studies (Aydın *et al.* 2013).

Conclusion

Protocol for regular housing, feeding, breeding, and raising of turbot specimens standardized as resultant of studies conducted. Teething troubles such as egg and sperm quality or malpigmentation have been largely overcome. However, the insufficient amount of eggs and sperm availability in flounder culture continues to be an important factor limiting mass production. Continued efforts should be made to fix issues with malpigmentation and abnormalities. Prevention of acute losses occurring at larval stages of turbot would provide important contributions to turbot aquaculture. For both species, controlling the parasite problem especially when the larvae settle and use the bottom structure of the production tank is of vital importance in achieving the desired production targets.

Turbot is an important species with high economic value for our country. Though it’s under a constant pressure of overfishing. Natural stocks of turbot are depleting and need to be repopulated. Ideally, turbot farming, which has not gone beyond trial production by commercial enterprises in our country, should also be planned to support natural stocks with implemented releasing procedures. Flounder on the other hand has not received enough attention in the market but it’s planned production as an ornamental fish due to its visual quality and slow growth or to support natural stocks would be a great value.

References

Aro, E. (1989) A review of fish migration patterns in the Baltic. *Rapp P-V Cons Int Explor Mer* 190: 72-96.

Aksungur, N., Akbulut, B., Şahin, T., Üstündağ, C., Çiftçi, Y., Kutlu, İ. (2003) Investigation of Turbot (*Psetta maxima*) Breeding in the Black Sea, Final report, Su Ürünleri Merkez Araştırma Enstitüsü, Trabzon, 65 p. (in Turkish).

Aksungur, N., Aksungur, M., Akbulut, B., Kutlu, İ. (2007) Effects of stocking density on growth performance, survival and food conversion ratio of Turbot

(*Psetta maxima*) in the net cages on the southeastern coast of the Black Sea. *Turkish Journal of Fisheries and Aquatic Sciences* 7(2): 147-152.

Alvial, A., Manriquez, J. (1999) Diversification of flatfish culture in Chile. *Aquaculture* 176: 65-73.

Aydın, İ. (2008) Prediction of egg quality with blastomere morphology and determination of the effects of triploid application on egg quality in Black Sea Turbot (*Psetta maxima* Linnaeus, 1758). Rize University The Institute of Applied Sciences Department of Fisheries and Aquatic Sciences, Rize, Master Thesis, 78 p. (in Turkish).

Aydın, İ., Şahin, T., Polat, H., Güneş, E. (2011) The reproductive performance of wild and hatchery-reared flounder, *Platichthys flesus luscus*, in the southern Black Sea coast. *Turk J Zool* 35(6): 811-817.

Aydın, İ. (2012) The external abnormalities of hatchery-reared Black Sea flounder (*Platichthys flesus luscus* Pallas, 1814) in Turkey. *Turkish Journal of Fisheries and Aquatic Sciences* 12(1): 127-133.

Aydın, İ., Ak, O., Polat, H., Küçük, E., Eroğlu, O., Ceylan, B., Özdemir, G., Kutlu, S., Haşimoğlu, A., Firidin, S., Zengin, B., Çiftci, Y., Türe, M. (2013) Investigation on Cultivation of Flounder (*Platichthys flesus luscus* PALLAS, 1811), Final Report (TAGEM / HAYSÜD / 2006 /09/ 03 / 02.

Aydın, İ., Küçük, E., Şahin, T., Kumlu, M. (2015) Effect of temperature on reversed asymmetry in hatchery-reared flounder (*Platichthys flesus luscus* Pallas, 1811). *Turkish Journal of Fisheries and Aquatic Sciences* 15(3): 737-740.

Aydın, İ., Küçük, E., Polat, H., Haşimoğlu, A., Güven, A. (2019) Technical Manual on Seed Production of Black Sea Turbot, Food and Agriculture Organization of the United Nation, General Fisheries Commission for the Mediterranean, 84p.

Baloon, E.K. (1990) Epigenesis of an epigeneticist: the development of some alternative concepts on the early ontogeny and evolution of fishes. *Guelph Ichthyol Rev* 1: 1-48.

Bengston, D.A. (1999) Aquaculture of summer flounder (*Paralichthys dentatus*): status of knowledge, current research and future research priorities. *Aquaculture* 176: 39-49.

Bjørnsson, B. (1994) Effects of stocking density on growth rate of halibut (*Hippoglossus hippoglossus* L.) reared in large circular tanks for three years. *Aquaculture* 123(3-4): 259-270.

Bos, A.R. (1999) Tidal transport of flounder larvae (*Pleuronectes flesus*) in the Elbe River, Germany. *Arch Fish Mar Res* 47: 47-60.

Bozkurt, Y., Seçer, S., Bekcan, S. (2006) Relationship between spermatozoa motility, egg size, fecundity and fertilization success in *Salmo trutta abanticus*. *Tarım Bilimleri Dergisi* 12(4): 345-348.

Campos, W.L., Kloppmann, M., Von Westemhagen, H. (1994) Inferences from the horizontal distribution of dab *Limanda limanda* (L.) and flounder *Platichthys flesus* (L.) larvae in the South-eastern North Sea. *Neth J Sea Res* 32: 277-286.

Chen, S.L., Ji, X.S., Yu, G.C., Tian, Y.S, Sha, Z.X. (2004) Cryopreservation of sperm from turbot (*Scophthalmus maximus*) and application to large-scale fertilization. *Aquaculture* 236: 547-556.

Cho, S.H., Lee, S.M., Lee, S.M., Lee, J.H. (2005) Effect of dietary protein and lipid levels on growth and body composition of juvenile turbot (*Scophthalmus maximus* L) reared under optimum salinity and temperature conditions. *Aquaculture Nutrition* 11(4): 235-240.

Çiftci, Y., Üstündağ, C., Erteken, A., Özongun, M., Ceylan, B., Haşimoğlu, A., Güneş, E., Yoseda, K., Sakamoto, F., Nezaki, G., Hara, S. (2002) Manual for the Seed Production of Turbot, *Psetta maxima* in the Black Sea. Special Publication No. 2, Central Fisheries Research Institute, Trabzon, 80 p.

Çiloğlu, E. (1997) Vertical distribution and population parameters of whiting Eastern coast of Trabzon, İstanbul University, İstanbul, Master's Thesis, 59p. (in Turkish).

Drevs, T., Kadakas, V., Lang, T., Mellergaard, S. (1999) Geographical variation in the age/length relationship in Baltic flounder (*Platichthys flesus*). *ICES J of Mar Sci* 56: 134-137.

FAO (2019a) FAO Fisheries and Aquaculture Department Fishery and Aquaculture Statistics. Global capture production 1950-2017 (FishstatJ). Available at: www.fao.org/fishery/statistics/software/fishstatj/en

FAO (2019b) FAO Fisheries and Aquaculture Department Fishery and Aquaculture Statistics. Global aquaculture production 1950-2017 (FishstatJ). Available at: www.fao.org/fishery/statistics/software/fishstatj/en

Genç, Y., Zengin, M., Bahar, S., Tabak, İ., Ceylan, B., Çiftçi, Y., Üstündağ, C., Akbulut, B. Şahin, T. (1998) Economic Seafood Research Project. Final Report. Central Fisheries Research Institute (SUMAE), Trabzon 157p. (in Turkish).

Goddard, S. (1996) Feed Management in Intensive Aquaculture. Chapman and Hall, New York, 194 pp.

Han, J., Lee, W., Jung, T.S., Aydin, I., Lee, W. (2018) Evaluation of genetic diversity and population genetic parameters of farmed turbot species (*Scophtalmus maximus*) from France, Turkey, and Korea. *Genetics of Aquatic Organisms* 2: 1-6.

Helvik, J.V., Walther, B.T. (1992) Photo-regulation of the hatching process of halibut (*Hippoglossus hippoglossus*) eggs. *J Exp Zool* 263: 204-209.

Holm, J.C., Refstie, T., Bø, S. (1990) The effect of fish density and feeding regimes on individual growth rate and mortality in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture* 89(3-4): 225-232.

Huang, W. B., Chiu, T. S. (1997) Effects of stocking density on survival, growth, size variation, and production of Tilapia fry. *Aquaculture Research* 28(3): 165-173.

Hutchinson, S., Hawkins, L.E. (2004) The relationship between temperature and the size and age of larvae and peri-metamorphic stages of *Pleuronectus flesus*. *J Fish Biol* 65: 445-459.

Imsland, A.K., Foss, A., Gunnarsson, S., Berntssen, M.H.G., Fitz Gerald, R., Bonga, S.W., Ham, E.V., Naevdal, G., Stefansson, S.O. (2001) The interaction of temperature and salinity on growth and food conversion in juvenile turbot (*Scophthalmus maximus*). *Aquaculture* 198: 353-367.

Irwin, S., O'halloran, J., FitzGerald, R.D. (1999) Stocking density, growth and growth variation in juvenile turbot, *Scophthalmus maximus* (Rafinesque). *Aquaculture* 178(1-2): 77-88.

Ivanov, L., Beverton, R.J.H. (1985) The Fisheries Resources of the Mediterranean, Part 2, Black Sea Etud. Rev., CGPM, 135 p.

Jensen, F.B., Lecklin, T., Busk, M., Bury, N.R., Wilson, R.W., Wood, C.M., Grosell, M. (2002) Physiological impact of salinity increase at organism and red blood cell levels in the European Xounder (*Platichthys xesus*). *J Exp Mar Biol Ecol* 274: 159-174.

Kim, K.D., Kim, K.M., Kang, Y.J. (2007) Influences of feeding frequency of extruded pellet and moist pellet on growth and body composition of juvenile Japanese flounder *Paralichthys olivaceus* in suboptimal water temperatures. *Fisheries Science* 73: 745-749.

Kubitza, F., Lovshin, L.L. (1999) Formulated diets, feeding strategies, and cannibalism control during intensive culture of juvenile fishes. *Reviews in Fisheries Science* 7: 1-22.

Küçük, E., Aydın, İ., Polat, H., Eroldoğan, O.T., Şahin, T. (2014) Effect of feeding frequency on growth, feed efficiency and nutrient utilization of juvenile flounder (*Platichthys flesus luscus*). *Aquaculture International* 22(2): 723-732.

Lee, J.K., Cho, S.H., Park, S.U., Kim, K.D., Lee, S.M. (2003) Dietary protein requirement for young turbot (*Scophthalmus maximus* L.). *Aquaculture Nutrition* 9(4): 283-286.

Maslova, O.N. (2002) Problems and achievements in seed production of the Black Sea turbot in Russia. *Turkish J Fish Aquat Sci* 2:23-27.

Morais, P., Dias, E., Babaluk, J., Antunes, C. (2011) The migration patterns of the European flounder *Platichthys flesus* (Linnaeus, 1758) (Pleuronectidae, Pisces) at the southern limit of its distribution range: ecological implications and fishery management. *Journal of Sea Research* 65(2): 235-246.

Nissling, A., Westin, L., Hjerne, O. (2002) Reproductive success in relation to salinity for three flatfish species, dab (*Limanda limanda*), plaice (*Pleuronectes platessa*), and flounder (*Pleuronectes flesus*), in the brackish water Baltic Sea. *ICES J Mar Sci* 59: 93-108.

Olsen, Y., Evjemo, J.O., Olsen, A. (1999) Status of the cultivation technology fry production of Atlantic halibut (*Hippoglossus hippoglossus*) juveniles in Norway/Europe. *Aquaculture* 176: 3-13.

Person-Le Ruyet, J. (2002) Turbot (*Scophthalmus maximus*) grow-out in Europe: Practices, results and prospects. *Turkish Journal of Fisheries and Aquatic Sciences* 2: 29-39.

Polat, H. (2011) The Effects of Different Temperature and Salinity on the Embryonic Development of Black Sea Turbot (*Psetta maxima* Linnaeus, 1758) Eggs. Süleyman Demirel University Institute of Science, Isparta, Master Thesis, 86 p. (in Turkish).

Samsun, N. (2004) A study on the determination of biological characteristics of turbot (*Scophthalmus maeoticus* Pallas, 1811) caught in Sinop region. On Dokuz Mayıs University, Institute of Science, Samsun, PhD Thesis, 171 p.

Solemdal, P. (1973) Transfer of Baltic flatfish to a marine environment and long term effects on reproduction. *Oikos* (supplement) 15: 268-276.

Sorensen, K., Stottrup, J.G., Holmstrup, M. (2004) Rearing of flounder (*Platichthys flesus*) juveniles in semiextensive systems. *Aquaculture* 230: 475-491.

STECF (2017) Scientific, Technical and Economic Committee for Fisheries (STECF) – Stock assessments in the Black Sea (STECF-17-14). Publications Office of the European Union, Luxembourg.

Stefánsson, M.Ö., Fitzgerhard, R.D., Cross, T.F. (2002) Growth, feed utilization and growth heterogeneity in juvenile turbot *Scophthalmus maximus* (Rafinesque) under different photoperiod regimes. *Aquaculture Research* 33: 177-187.

Şahin, T. (2001) Effect of water temperature on growth of hatchery reared Black Sea Turbot, *Scophthalmus maximus* (Linnaeus, 1758). *Turk J Zool* 25: 183-186.

Thompson, K.R., Webster, C.D., Morgan, A.M., Grisby, E.J. (2000) Effects of different feeding frequencies on growth, body composition, and fillet composition of juvenile sunshine bass, *Morone chrysops* x *M. saxatilis*, grown indoors. *Journal of Applied Aquaculture* 10: 55-65.

Türker, A. (2006) Effect of feeding frequency on growth, feed consumption, and body composition in juvenile turbot (*Psetta maxima* Linnaeus, 1758) at low temperature. *Turkish Journal of Veterinary and Animal Sciences* 30: 251-256.

Watson, C.A., Chapman, F.A. (2002) Artificial Incubation of Fish Eggs. Fact Sheet FA-32, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 5 p.

Zengin, M. (2000) Bio-ecological characteristics and population parameters of turbot (*Scophthalmus meaoticus* Pallas, 1811) in eastern Black Sea Coast of Turkey in Turkish. Karadeniz Technical University Institute of Science, Trabzon, PhD Thesis, 221 p.

General perspectives of shellfish aquaculture in Turkey

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Introduction

Nowadays, it has gradually become difficult to meet the rising food needs from terrestrial sources and has led people to use different sources more effectively. In this case, oceans, seas, and inland waters are the largest sources for meeting the nutrient needs of the human population in the world, which two-thirds of its surface is covered by water. In addition to the products of fish and other aquatic organisms by fishing from natural stocks, fish breeding from the larvae is also very advanced today. Invertebrates constitute the most important group of food sources obtained from aquatic environments other than fish. Bivalve species such as mussels, oysters, clam and scallops, which belong to the phylum of Mollusca, have been among the aquatic organisms that have been liked and consumed by humans throughout history. The popularity of these species has increased because their meat is delicious, has a high nutritional value, can be consumed as raw or cooked with different cooking techniques. Their shells have also been used for jewellery, ornaments, buttons or decorative purposes for ages, thus attracting people. The culture pace of bivalve species has been increasing due to the decrease in their natural stocks as a result of various reasons like marine pollution, gradually increasing demand for the consumption and the need for reaching the desired amount of safe seafood products at any time.

The production of bivalve species by culture has a long history. In about 350 BC, Aristotle mentioned oyster culture in Greece. In about 100 BC, Pliny stated that oysters were kept in ponds for commercial production in Italy (Gosling 2003). Quayle and Newkirk (1989) reported that culture activities of oysters date back to the Roman period. However, it was reported that systematic oyster farming started on Hiroshima Bay in Japan in 1624 (Fujiya 1970). It was reported that the mussel culture started in 1265 when an Irish sailor had a ship accident on the Atlantic coast of France. To catch the birds, the sailor placed a net on the stakes and discovered that the stakes were covered with mussels in a short time. Nowadays, the method of mussel culture on bouchot (wooden stake) still used in France began in this way (Jeffs *et al*. 1999; Gosling 2003). The culture of clams was reported to have been started in the Far East in the 8th century BC (Bourne, 1981). Although the first spat collection attempt for the cultivation of sea scallop species was carried out in the Saroma Lagoon (Hokkaido) in 1934, the most successful spat collection technique was discovered by a fisherman using the onion bag to collect spat in 1965 in Japan (Ito 1991). According to the data of the FAO (2018), worldwide Mollusca production by aquaculture was 17.1 million tons in 2016. Most of this production consisted of oyster and clam species (Table 1).

Table 1. The amounts (1000 t) of worldwide bivalve production by aquaculture between 2010 and 2016 (FAO 2018).

Species group	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Oysters	4474	4489	4725	4953	5146	5316	5595
Mussels	1800	1868	1814	1736	1859	1857	2008
Scallops, pectens	1727	1520	1651	1868	1915	2082	2127
Clams, cockles, ark shells	4885	4927	4989	5157	5354	5395	5570

In the world, the most produced bivalve species by aquaculture are *Ruditapes philippinarum* (4.2 million tons), *Sinonovacula constricta* (823 thousand tons), *Crassostrea gigas* (573 thousand tons), *Anadara granosa* (440 thousand tons), *Mytilus edulis* (182 thousand tons), *Mytilus galloprovincialis* (102 thousand tons) and *Patinopecten yessoensis* (223 thousand tons) (FAO 2018).

Site selection for bivalve culture

The first and important step in the cultivation of bivalve molluscs is site selection for successful rearing. Therefore, environmental parameters should be monitored at the selected farm location. However, well growth is not the only requirement of a successful culture. At the same time, the impact of marketing and administration of culture should be considered (Quayle and Newkirk 1989). When choosing a farm site for bivalve culture, food availability, water depth, bottom structure, protection from wave movements, water quality, current and tidal amount, turbidity, predation, fouling, pollution, conflicts related to the use of the site, accessibility and official permissions are the most important factors. At the same time, the species to be produced and the culture system should be suitable for the selected region (Lutz 1985; Lutz *et al*. 1991; Nowak and Kozlowski 2013).

Since the bivalve species are filter feeding organisms, the amount of microbiological load in the environment is one of the factors that must be monitored and which is important in site selection. In Europe and America, bivalve production sites are divided into three groups as A, B, and C according to their microbiological loads. In Turkey, bivalve production sites are also divided into 3 classes such as A, B and C according to microbiological loads, within the framework of European Union harmonization laws. Bivalves from Class A production sites contain with less than 230 EMS *Escherichia coli* per 100 gr shellfish flesh and less than 300 EMS fecal coliforms in intravalvular liquid. Shellfish from this region can be consumed directly or after being processed without any depuration and can be exported. Bivalves from Class B production sites contains 230 and 4600 EMS *E. coli* in 100 gr shellfish flesh and between 300 and 6000 EMS fecal coliforms in intravalvular liquid. Bivalves collected from these production areas should be subjected to certain depuration processes before they come to the consumption stage. Class C production includes shellfish with less than 46000 *E. coli* in 100 gr shellfish flesh and 6000 and 60000 EMS fecal coliforms in intravalvular liquid. Bivalves obtained from these production areas should not be put on the market for consumption.

Sites selection by considering all these criteria in bivalve farming is very important for the success of the farm to be established.

Bivalve farming applications in Turkey

The production of bivalve species in Turkey is done by collecting natural stocks. However, especially in the recent years, mussel farming has gained importance in terms of supplying healthy, reliable and sustainable products. Therefore, mussel culture has also started on the coasts of Turkey (Serdar and Yıldırım 2018).

The main important bivalve species in Turkey coasts are 13 species, such as *Venus gallina, Ruditapes decussatus, Ruditapes philippinarum, Mytilus galloprovincialis, Modiolus barbatus, Ostrea edulis, Venus verrucosa, Donax trunculus, Callista chione, Pecten jacobaeus, Flexopecten glaber, Solen marginatus,* and *Pinctada radiata.* Although some of these species are collected from nature and marketed, unfortunately, they are not included in statistical reports (Table 2) (Alpbaz 1993; Serdar 2016 a, b; 2017; 2018a).

Table 2. The amount (t) of bivalves provided by collecting in Turkey in the last 10 years

	R.decussatus	***V.gallina***	***O.edulis***	***V.verrucosa***	***M.galloprovincialis***	***P.jacobaeus***	***M.barbatus***
2008	1 255,0	36 896,0	13,0	1,0	342,0	-	-
2009	68,0	24 574,0	-	11,0	1 660,0	-	4 601,0
2010	56,0	26 931,0	1,0	8,0	735,0	4	246,0
2011	26,7	30 175,6	5,9	-	1 458,8	17,8	347,2
2012	14,9	61 225,4	-	-	2 093,4	-	-
2013	83,4	28 029,7	11,2	-	887,4	3,0	-
2014	8,8	21 827,6	0,1	-	48,7	0,1	155,1
2015	5,3	37 404,1	0,2	-	192,4	0,9	47,6
2016	4,8	20 931,7	-	-	77,5	-	-
2017	-	34 941,1	-	-	535,6	-	-
2018	0,8	44 532,8	-	-	603,8	-	-
2019	14,1	36 612,8	-	-	1 170,3	-	-

Black mussel is the only bivalve species in Turkey that is produced by cultivation. Although the amount of production is still low, it is predicted that this amount will increase very soon (Serdar and Yıldırım 2018) (Table 3). Although there have been attempts to produce clam by cultivation, production on a commercial scale has not been reported yet.

Commercial mussel cultivation is always applied semi-extensively, although it varies depending on the regions and the hierarchy of needs of countries. Each country has developed its aquaculture system which is suitable for its marine conditions, coastal structure, and water conditions. In general, mussel cultivation is performed using 4 different main methods as the bottom, stake, raft, and long rope systems (Lutz 1985; Figueras 1989)

Table 3. The amount (t) of *M. galloprovincialis* produced by aquaculture in Turkey (There is no production between 2012 and 2014)

	2009	**2010**	**2011**	**2015**	**2016**	**2017**	**2018**	**2019**
M. galloprovincialis	89	340	5	3	329	489	907	4168

Bottom cultivation

This method is generally applied in shallow waters in the Netherlands and Germany. Mussel spats are collected from natural breeding areas, transferred to coastal waters where they will be cultivated, and grown to harvestable size (Lutz 1985; Garen *et al*. 2004).

Cultivation on bouchot

This method is used especially on the Atlantic coast of France where the tide is high (Figure 1). In the cultivation of mussels, oak stakes of 20 cm in diameter and 3 m in length are used. Although this method is one of the early systems developed in mussel farming, it is still successfully in use today (Lutz 1985; Figueras 1989; Garen *et al*. 2004)

Figure 1. Bouchot culture system in France (Photo: Serpil Serdar)

Cultivation on rafts

It is especially applied on the northern coast of Spain (Figure 2). Aquaculture system is formed with rafts made of wooden material resistant to marine conditions. The mussels are grown in vertical ropes hung from these rafts (Lutz 1985; Figueras 1989; Karayücel *et al*. 2010).

Longline system

This system is commonly used in Sweden, England, and Greece, as well as in the countries having coasts on open seas or oceans, such as Chile, New Zealand, and Brazil (Figure 3). The system is generally constructed with floaters arranged along a long line, and mussel farming is carried out by hanging the mussel growth ropes from the long lines (Lutz 1985; Garen *et al*. 2004).

In Turkey, mussel farming was first established in Çanakkale, Balıkesir, and İzmir in the 90s. This mussel farming activity was carried out by a private firm by wooden raft system (5 m x 5 m) in Kilye Bay (Eceabat) in the Dardanelles Strait. In the same years, a pilot mussel production test was started by a private firm by placing stakes in the east of Cunda Island in Ayvalık district of Balıkesir. After a while, this farm has left the activity of mussel farming in bouchot system in this region. In a mussel farming study conducted in İzmir in those years, a raft system (6 m x 6 m) was established by a private firm and mussel farming was performed. This mussel farming was conducted in a region in the southern part of İzmir in the Gulf of Mersin, where approximately 15 fish farms (seabream and seabass) were located. However, after the fish farms were moved out of the gulf in the mid-2000s, mussel farming in this region had to be terminated.

Figure 2. Raft culture system in Spain (Photo: Serpil Serdar)

Figure 3. Long-line culture system in Brazil (Photo: Şükrü Yıldırım)

Unfortunately, these three mussel-farming attempts in the 90s on the coasts of Turkey failed, and the enterprises could not achieve sustainable production. In 2010, Turkish entrepreneurs wanted to reconsider mussel farming and started mussel production on the outer shore of Izmir and the southern coast of the Marmara Sea. There are also many other enterprises to produce mussels on a commercial scale in the same regions (Serdar 2017; Serdar and Yıldırım 2018). There are also requests for new sites for mussel farming from the Turkish Ministry of Agriculture and Forestry and Provincial Directorates of Agriculture (Table 4).

Today, nearly all of the activities carried out in terms of commercial bivalve farming on the coasts of Turkey are based on mussel production. In the Aegean, Marmara, and Black Seas, mussel farming enterprises use long line systems. In this system, two different types of floaters are utilized. Some establishments (farmers) use classical mussel floats, while others prefer to use pipe floats (Figure 4 and 5). In the system constructed with the classical mussel floats, the floaters having a volume of 300 to 600 liters are arranged along a straight line at intervals of 5 to 8 m. Iron anchor (screw or plow type) or concrete vault is used for fixing the system to the bottom. The configuration of the components of this system (float, rope, and anchor) varies according to the characteristics of the farming site. These characteristics include water depth, the velocity and direction of flow, the length and frequency of ropes, the total surface area used by the enterprise and the annual production capacity of the enterprise.

The pipe-type float was firstly used in a project supported by the TAGEM (Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies) in South Marmara Sea in Turkey, and successful results were obtained (Yıldırım *et al*. 2018). This type of floats began to be preferred, especially in the newly established mussel farms. This system is generally constructed by using 30-40 cm diameter and 10-12 m long PE 100 type pipes. The method used to fix this system to the sea is the same as the method used for other systems. On the other hand, the hanging of the collectors in the system is performed in a similar way to the farms in which conventional floats are used.

One of the most essential points in mussel farming is spat collection. Therefore, the material to be used for spat collection and the time of placing these materials in the sea are very important. In the stage of mussel collection, rope collectors with threadlike structure are generally used (Yıldırım 2004; Yıldız *et al*. 2005; Yıldırım *et al*. 2018). In the seas around Turkey, mussels can produce offspring almost every month. However, especially when the weather starts to cool in the autumn, extensive spawning occurs. This period continues until the months of May-June when the weather starts to warm up. Each enterprise leaves its spat collectors to the water according to their needs during these periods. The collectors and growth nets are usually 5 to 8 m long, with some enterprises modifying the type of connection as endless. Both collectors and growth ropes are also placed in the system at intervals of 50 to 80 cm (Figure 6).

Table 4. Capacity (t/year) and number of mussel and clam farms in the coast of Turkey

Location	Product Type	Active	Project	Official Permission	Application
İzmir	Mussel	300 (3 farms)	300 (2 farms)	300 (1 farm)	
		500 (1 farm)	500 (3 farms)		
		630 (1 farm)	750 (1 farm)		
	Clam	300 (1 farm)			
		100 (1 farm)	100 (1 farm)		
Balıkesir	Mussel	1000 (1 farm)	300 (1 farm)		260 (1 farm)
		1500 (2 farms)	900 (2 farms)		900 (1 farm)
		2000 (1 farm)	1000 (1 farm)		950 (1 farm)
		3000 (1 farm)	2000 (1 farm)		1000 (1 farm)
			3000 (1 farm)		1500 (2 farms)
Çanakkale	Mussel	1400 (1 farm)		1000 (1 farm)	
				1400 (1 farm)	
Muğla	Mussel			100 (2 farms)	
				1000 (1 farm)	
Sinop	Mussel		1000 (1 farm)	1000 (1 farm)	
Tekirdağ	Mussel			2000 (1 farm)	

Figure 4. Long-line system with classical mussel floats in Turkey (Photo: Şükrü Yıldırım)

The separation process is carried out according to the sizes of mussels attached to these ropes within 4-6 months after the collectors are placed into the sea. In this process, the ropes are drawn on the boat and divided into groups according to size. They are immediately placed into the growth nets and hung down again in the sea. Thus, the growth process is performed by separating the larger mussels that grow faster from the newly attached small mussels. As a result, enterprises make a sustainable production and constantly offer products to the market.

Figure 5. Long-line system with pipe floats in Turkey (Yıldırım *et al.* 2018)

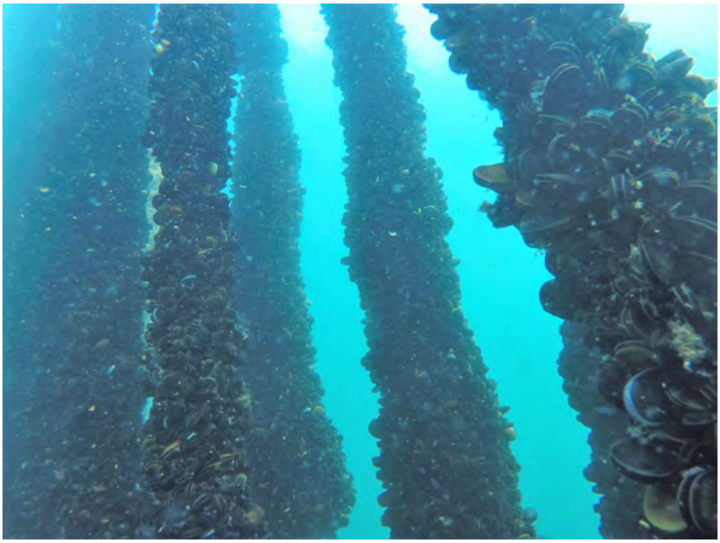

Figure 6. Scene of mussel collectors and growth ropes underwater (Photo: Ali Ulaş)

Problems related to the production mussel farming

- In the farms established in the sites exposed to harsh sea conditions, mussels are detached from the ropes. To solve this problem, site selection should be made appropriately or the configuration of the aquaculture system should be redesigned for the environmental conditions during the establishment of the farm.
- Excessive mussel growth in some regions causes the spats to cling together, and therefore the growth of mussels slows down. This situation can be solved by performing the grading process more frequently.
- Especially in the summer after the breeding period, mussel condition decreases in some farms. In this case, this situation can be prevented by placing the mussels harvested in the summer period less frequently in the growth nets.

Other problems in mussel farming

- For investors, problems with the other stakeholders, especially the tourism sector.
- License processes required to establish an aquaculture farm takes too long time.
- High fees paid for periodical monitoring of the aquaculture area (analyses of water conditions, mussel meat, biotoxin, heavy metal, etc.).

- Barriers to the sale of mussels produced by aquaculture to the European Union.
- Unrecorded marketing of mussels collected from nature without any permission, usually as stuffed mussels.
- Free of tariff import of frozen and fresh mussels.

Conclusion

With the domestic consumption and the exportation ($ 1 billion), the aquaculture sector makes a gradually increasing contribution to the livestock sector in Turkey. The 2 out of every 5 fishes produced by aquaculture and consumed in Europe come from Turkey.

Bivalve farming (such as mussels and clams), known to be eco-friendly, has a market of around $ 30 billion in the world and 5 billion € in Europe. In Turkey, the southern Marmara and Aegean coasts are suitable areas for bivalve farming, especially for mussel farming. Nowadays, black mussel farming facilities were established in the outer gulf of İzmir and the coasts of Southern Marmara (Bandırma and Erdek); there are attempts to establish new facilities. When the mussel farms that are established or are being established in addition to the active farms start to produce at full capacity, approximately 40000 tons of mussels will be produced annually. Additionally, it has been also reported that some bivalves can be cultured in inland waters (Serdar 2016c, Serdar 2018b; Serdar *et al*. 2018; Serdar *et al.* 2019). These areas need to be well planned for the efficient and sustainable use of both sea and inland waters. It should be taken into consideration that both depuration plant and processing units will be needed when planning.

In conclusion, Turkish people will be able to reach healthy and reliable bivalve species at any time by producing mussels, clams, etc. via aquaculture. Thus, the way will be paved for new enterprises and exportable products with high added value will be obtained. The start of production by such facilities also provide new areas of employment.

References

Alpbaz, A. (1993) Culture of Shellfish and Crustacean. Ege University, Fisheries Faculty Published, No: 26, pp. 317 (in Turkish).

Bourne, N. (1981) Clam Farming- fact or fancy. B.C. Shellfish Maricult Newsl 1(3): 1-5.

FAO (2018) FAO yearbook. Fishery and Aquaculture Statistics 2016. Rome, 104 pp.

Figueras, A. (1989) Mussel culture in Spain and France. *World Aquaculture* 20: 8-17.

Fujiya, M. (1970) Oyster farming in Japan. *Helgo Wiss Meeresunters* 20: 464-479.

Garen, P., Robert, S., Bougrier, S. (2004) Comparison of growth of mussel, *Mytilus edulis*, on longline, pole and bottom culture sites in the Pertuis Breton, France. *Aquaculture* 232: 511-524.

Gosling, E. (2003) Bivalve Molluscs: Biology, Ecology and farming. Fishing News Books, Blackwell, Oxford, 456 pp.

Ito, S. (1991) *Patinopecten* (*Mizuhopecten*) *yessoensis* (Jay) in Japan. In: Estuarine and Marine Bivalve Mollusk Culture (ed, Menzel, W.). CRC Press Inc, Boca Raton, pp. 211-225.

Jeffs, A.G., Holland, R.C., Hooker, S.H., Hayden, B.J. (1999) Overview and bibliography on the greenshell mussel, *Perna canaliculus*, from New Zealand waters. *Journal of Shellfish Research* 18: 347-360.

Karayücel, S., Çelik, M.Y., Karayücel, İ., Erik, G. (2010) Growth and production of raft cultivated Mediterranean mussel (*Mytilus galloprovincialis* Lamarck, 1819) in Sinop, Black Sea. *Turkish Journal of Fisheries and Aquatic Sciences* 10: 09-17.

Lutz, R.A. (1985) Mussel aquaculture in the United States, in Crustacean and Mollusk Aquaculture in the United States, (eds., Huner, J.V., Brown, E.E.), AVI Publishing, Westport, CT, 311.

Lutz, R.A., Chalermwat, K., Figueras, A.J., Gustafson, R.G., Newell, C. (1991) Mussel aquaculture in marine and estuarine environments throughout the world. In: Estuarine and Marine Bivalve Mollusk Culture, (ed. Menzel, W.) Boston, CRC Press Inc, pp. 57-97.

Nowak, J., Kozlowski, M. (2013) Mussels Ecology Life Habits and Control. Nova Science Publisher, New York, 157 p.

Quayle, D.B., Newkirk, G.F. (1989) Farming Bivalve Molluscs: Methods for Study and Development. The World Aquaculture Society and the International Development Research Centre, Baton Rouge.

Serdar, S. (2016a) Country report from Turkey. *Bull Jap Fish Res Edu Agen* 42: 125-127.

Serdar S. (2016b) Shellfish production and new approaches in Turkey. *Bulletin of Japan Fisheries Research and Education Agency* 90.

Serdar, S. (2016c) Potential cultured species of shellfish in freshwater. Workshop on farming of an alternative freshwater species. 11-13 January 2016, Antalya, Turkey (in Turkish).

Serdar, S. (2017) Shellfish Production: Turkish Experiences. Training Course on Development of Aquaculture Production and Technologies in the INOC Member States. 15-20 May, Tunisia.

Serdar, S. (2018a) Cultured species of shellfish in Turkey. First National Shellfish Workshop, Antalya, Turkey 9-11 October 2018 (in Turkish).

Serdar, S. (2018b) Growth of the Asian Clam *Corbicula fluminea* (Müller, 1774) Cultured in Çine Creek, Aydin, Turkey. *Journal of Shellfish Research* 37(3): 491-496.

Serdar, S., Eden, M., Bulut, H. (2018) Cultivation of the threatened freshwater mussel *Unio crassus* Philipsson, 1788 (Bivalvia: Unionidae) in the Çine Creek, Aydın, Turkey. *Acta Zoologica Bulgarica* 70(4): 585-592.

Serdar, S., Eden, M., Bulut, H., Özdemir, Y. (2019) Determination of bioecological and biometric properties of freshwater mussels (*Unio crassus* Philipsson, 1788) in Aydın-Çine Creek, Turkey. *Polish Journal of Environmental Studies* 29: 1917-1924.

Serdar, S., Yıldırım, Ş. (2018) An Increasing Trend in Turkey: Mussel Culture. The 2nd International Fisheries Symposium, Girne, Turkish Republic of Northern Cyprus, 4-8 November 2018, pp.106-107.

Yıldırım, Ş. (2004) A preliminary study on the attachment rates of the Mediterranean mussel to various materials in Mersin Bay (Urla-İzmir) where net cage fish farming is practiced. *Journal of Fisheries and Aquatic Science* 21(3-4): 249-251 (in Turkish).

Yıldırım, Ş., Serdar, S., Sabancı, F., Erdem, Ö.A., Ertan, A., Gökvardar, A., Yücel, B.K., Öztürk, O., Şentürk, S. (2018) Research of mussel culture (*Mytilus galloprovincialis*) by two different long-line systems in the Southern Marmara Sea. Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies, R&D Project, Project Number TAGEM 15 AR-GE 27.

Yıldız, H., Lök, A., Serdar, S., Acarlı, S., Köse, A. (2005) Mussel (*Mytilus galloprovincialis* Lamarck, 1819) spat settlement and growth performances on artificial collectors in Dardanelles. *Journal of Fisheries and Aquatic Science* 22 (3-4): 257-261 (in Turkish with English abstract).

Candidate invertebrate species for marine aquaculture

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Introduction

Global invertebrate aquaculture production exceeded 26 million tons in 2017 (FAO 2019). Although the mainstream culture trends mostly focus on bivalves and shrimps-prawns (about 22 million tonnes aquaculture production, FAO 2019), improvement studies on the culture methods of other invertebrate species and efforts to explore new/candidate species for aquaculture are continuing. In general, a species has to meet several requirements to be considered as a candidate for aquaculture, such as market demand, high prices, high growing out potential, high reproductive rate, adaptation capacity to artificial and/or captivity conditions, feasibility, availability of biological-technical knowledge. Additionally, environmental effects of the culture, genetic risks and legal requirements should be taken into account (Webber and Riordan 1976; Avault 1993; Bartley 1998; Williams and Primavera 2001; Quéméner *et al*. 2002; Vaz-Pires *et al*. 2004; Purcell *et al.* 2012). On the other hand, candidate species may not necessarily be aimed for human consumption, may not have to be cultured intensively and may not be the main subject of the production. They can be cultured to be used in pharmaceutical industry, they can be cultured as part of stock management-enhancement studies, to be used as a part of integrated multi-trophic aquaculture applications or can be cultured extensively or intensively. In this section, some representative species from Turkish seas were evaluated in terms of their aquaculture potential with the aim of providing brief and practical information that can be of interest to aquaculture entrepreneurs and researchers; using the aforementioned approaches. Additionally, information on the culture techniques of the selected species was summarized from experimental studies or from applications on similar species, in order to create a general idea on the feasibility of commercial endeavours.

Cephalopod culture

Cephalopod culture began in the second half of the last century (Choe and Ohshima 1961, 1963; Itami *et al*. 1963). Development of cephalopod culture was initially started for their use as biomedical experimental animals (Gilbert *et al*.

1990). The experiments on their complicated nervous system and vision increased the general knowledge on their aquaculture methods (Hanlon 1987; Koueta and Boucaud-Camou 1999). In addition, there was a demand for ornamental cephalopods and trends to use in human diet increased aquaculture efforts for these animals (Vidal *et al*. 2014). As a result of this rising interest on cephalopod culture, aquaculture potential of some species were studied intensively (Lee *et al*. 1994; Vaz-Pires *et al*. 2004; Sykes *et al*. 2006; Rosas *et al*. 2013).

Cephalopods have many advantages in terms of being considered candidate species for aquaculture. For example, short life cycles, high growth rates (for some species daily 5–13% of wet body weight increment), high food conversion rates, the possibility to obtain eggs in the captive conditions and having a high protein content (O'Dor and Wells 1987; Lee 1994; Vidal *et al*. 2014). However, even if their biological features seem sufficient, market demand and prices should be considered in the evaluation of cephalopod aquaculture potential (Vidal *et al*. 2014). At present, cephalopod demand is covered using wild-caught stocks which fluctuates. Annual global cephalopod landings have taken place as 4.8 million tones with 8% of the total fisheries; the most caught species are squids with 72% (FAO 2016). At the same time, there is a global sustainable and profitable market for cephalopods. According to the report (FAO 2018) the most important exporting countries for octopus are China and Morocco. China, Peru and India are the most important exporting countries for squid and cuttlefish. In the same report, Japan, United States, Spain, Italy, China and Thailand are identified as the most important consumer and importer countries. Currently, the demand for the cephalopods tends to increase especially in Europe and in Japan (Globefish 2012; Pierce and Portela 2014; Vidal *et al*. 2014).

The low catches meant declining supplies in 2016 and 2017, and prices rose considerably (FAO 2018). Therefore, cephalopod culture may be a reasonable alternative to supply the demand. However, cephalopod culture is at the beginning (searching) phase when compared to other commercial marine aquaculture species, and there is no commercial culture so far. Cephalopods are carnivores and high protein and amino acid contents are necessary to feed them to grow out and essential fatty acids, phospholipids and cholesterol are also needed (Lee 1994).

Currently, culture attempts can be made only in small quantities, and species diversity is limited with *Octopus vulgaris* and *O. maya*, cuttlefish *Sepia officinalis* and *Sepioteuthis lessoniana* (Vidal *et al*. 2014). Early life phases of cephalopods are quite sensitive like experienced in many other aquatic animals, additionally larval and juvenile forms require live feed of specific conditions. Therefore, it would be reasonable to focus on the early life phases and general nutrition issues at the larval stages for commercial aquaculture (Hanlon 1987; Segawa 1990; Vidal *et al*. 2014).

In Turkey, there are 24 cephalopod species of the 70 cephalopods that are caught economically worldwide (Table 1). The most important economical species in Turkey are *Octopus vulgaris*, *Loligo vulgaris* and *Sepia officinalis* (TÜİK 2019a; Salman 2012). The cephalopod fishing in Turkey is lower than that of the world. The reason for this can be explained as cephalopod fishing being limited to the territorial waters of Turkey. However, it is known that many coastal countries have developed and used special methods for squid and octopus fishing in their territorial waters and international waters (oceans).

Table 1. Economical cephalopod species of Turkey (Şen 2005a).

Octopus	Squid	Cuttlefish	Argonat
Bathypolypus sponsalis	*Alloteuthis media*	*Sepia officinalis*	*Argonauta argo*
Eledone cirrhosa	*Alloteuthis subulata*	*Sepia orbignyana*	
Eledone moschata	*Loligo vulgaris*	*Sepia elegans*	
Octopus vulgaris	*Loligo forbesi*	*Rossia macrosoma*	
Octopus salutii	*Sepioteuthis lessoniana*	*Sepiola rondeleti*	
Octopus aegina	*Illex coindetii*		
Octopus macropus	*Todaropsis eblanae*		
Pteroctopus tetracirrhus	*Todarodes sagittatus*		
Scaeurgus unicirrhus	*Ommastrephes bartramii*		

A lot of scientific studies have been performed related to biology, distribution, behavior, and rearing of cephalopods in Turkey (Gücü and Salman 1993; Katağan *et al*. 1993; Sinanoglu and Meimaroglu 1998; Özyurt *et al*. 2006; Özoğul *et al*. 2008; Salman 2002; Salman 2009; Salman 2012; Salman *et al*. 1997; Salman *et al*. 2002; Salman *et al*. 2007; Salman *et al*. 2017; Şen 2004a, 2004b, 2004c; Akyol and Şen, 2004; Şen 2005b, 2005c, 2005d, 2005e; Şen 2006a, 2006b, 2006c; Akyol *et al*. 2007; Şen and Sunlu 2007; Şen 2007; Şen *et al*. 2008; Şen 2009; Şen and Tanrıkul 2009; Şen and Akyol 2011; Şen 2012; Tanrıkul *et al*. 2012; Şen and Tanrıkul 2013; Şen 2013a, 2013b; Şen, 2014). However, there is no commercial cephalopod farming in Turkey, yet.

Especially octopus fishing has been declining dramatically year by year (Salman 2012; TÜİK 2019a). The most important reasons are the wrong restriction time regulations related to the fishing season, and overfishing by illegal fishing methods (Salman 2012). This can be corrected in two ways; firstly, the legal octopus fishing season should be rearranged to the natural octopus' production cycles (from November to May) and secondly, illegal fishing or overfishing should be restricted and tightly supervised. These recommendations apply to other cephalopods as well.

In conclusion, these days, the aquaculture sector is in search of alternative species. Economically important cephalopods have found buyers at high prices (10-20 USD/kg), detailed research needs to be conducted without losing time to gain economic advantage and promote sustainable fishing.

Crab culture

Interest for the crab aquaculture has been increasing due to the high market demand and remarkable success has been achieved in some species. Currently, most of the aquaculture production comes from Chinese mitten crab culture (FAO 2019). This species lives in freshwater except for breeding times and despite its commercial importance generally stated as unwanted and invasive species. Aquaculture of other crab species is also increasing in the world; aquaculture production of the members of family Portunidae have increased more than thirty times in the last twenty years and reached to 380000 t (FAO 2019); Indo-Pacific species (mud crabs, swimming crabs etc.) are the most cultured species. In general, these species have good growth rates, large sizes and high fecundity rates (Williams and Primavera 2001; Romano and Zeng 2006, 2008). Blue swimming crabs have a relatively short and less complex larval stages and rapid growth under favourable temperatures, and produce high number of eggs (Josileen and Menon 2005; Romano and Zeng 2008; De Lestang *et al*. 2010; Pazooki *et al*. 2012; Safaie *et al*. 2013). Thus, they have been identified as target species for aquaculture in many countries (Andrés *et al*. 2010; Pazooki *et al*. 2012; Safaie *et al*. 2013). In Turkish shores, one of the members of swimming crab from family Portunidae has already been captured and traded especially in the eastern Mediterranean region, *Portunus segnis* (Özcan and Akyurt 2006; Özcan 2012; Türeli and Yeşilyurt 2018). *P. segnis* is native to Indian Ocean and before the taxonomic revision it was known as *Portunus pelagicus* (Lai *et al*. 2010); one of the commercially important marine crab species. Many of the previous studies on improvement of aquaculture techniques for the swimming crabs were made on *P. pelagicus*. However, *P. segnis* still has aquaculture potential and studies on the improvement of culture techniques on this species are remaining in coastal waters of Iran (Pazooki *et al*. 2012; Safaie *et al*. 2013; Safaie 2016) and in Mediterranean (Ben Abdallah-Ben Hadj Hamida *et al*. 2019).

In the aquaculture of Portunidae species mainly wild juveniles are grown but egg-to-harvest production is possible (Williams and Primavera 2001; Soundarapandian and Tamizhazhagan 2009). Berried females can be collected from the sea at the breeding seasons or broodstock can be maintained in an aquaculture facility and fecundity increases with the broodstock size (Williams and Primavera 2001; Ikhwanuddin *et al*. 2012; Josileen 2013). Berried females are kept in individual tanks before the hatching. Like the other crab species *Portunus* has larval phases in its early life, named zoea and megalopa. For *P. pelagicus*, larvae are stocked at about 500 individuals/l after hatching and fed with microalgae, rotifer and *Artemia* according to their development stage and throughout the larval development, salinity adjustments are made to provide optimum conditions to achieve high survival rates (Williams and Primavera 2001; Romano and Zeng 2006; Ikhwanuddin *et al*. 2012; Azra and Ikhwanuddin 2015). With the completion of the larval phases remaining crabs are fed with *Artemia* nauplii. According to the development stage, blended fish, pellets, shrimp feed and clam meat etc. can be suitable for juvenile grow out (Williams and Primavera 2001; Romano and Zeng 2006, 2007). At this phase some hides/shelters must be placed at the bottom of the tanks to reduce the cannibalism (Romano and Zeng 2007). After the end of the juvenile phases crabs are placed in containers, onshore tanks, semi enclosed inshore net pens or other suitable grow out systems. Eventually, experiences gained from species like *P. pelagicus* as well as the available knowledge on the aquaculture of *P. segnis* can be used to improve the culture techniques of the blue swimming crab species at the Turkish coasts.

Another commercially valuable crab species captured and traded at the Turkish shores is Atlantic blue crab or blue crab, *Callinectes sapidus* (again family Portunidae). *C. sapidus* is native to the Western Atlantic but widely distributed in the Mediterranean Sea as well as many other parts of the world (Williams 2007). It is a high priced commercially important species as seafood and its fishery has been made widely along the Atlantic coast of the United States. Blue crabs have been considered as aquaculture candidate at least for 40 years in the United States (Webber and Riordan 1976) but commercial/large-scale egg to harvest culture of this species (especially larval culture) has not started. Similar difficulties in general crab culture (will be mentioned briefly at the next paragraph) might be the reason. Additionally, this species has relatively complex early life stages that might increase the difficulties faced in its culture. For example, while blue swimming crab, *P. pelagicus* has 4 zoea and one megalopa stages at the larval development, *C. sapidus* has 8 zoea, one megalopa stages (Zmora *et al*. 2005; Romano and Zeng 2006; Ikhwanuddin *et al*. 2012). Nevertheless, larviculture and large-scale juvenile production is possible for this species. According to the detailed protocols established by Zmora *et al*. (2005), inseminated female broodstock are caught, and hatching occurs in the broodstock tanks. After hatching, larvae are fed with algae, rotifers, *Artemia* etc. according to the larval development phases. Zmora *et al*. (2005) recorded ~43 % average survival rates at the megalopa stage but at the later stages survival rates dropped; at the end of the study, ~40,000 juvenile crabs were produced from 20 broodstock in four culture cycles.

In general, deaths at the larval phases are major problems in aquaculture of the crab species. Molt death syndrome is one of the causes of death at the larval stages; this syndrome can be defined as inability to shed the old exoskeleton during the molting (Romano and Zeng 2006; Fujaya *et al*. 2014) (crabs must shed their shells/exoskeletons periodically). Cannibalism is another problem at the early stages even if the hides may be useful (Moksnes *et al*. 1997; Zmora *et al*. 2005). For both crab species mentioned, larvae from each female should be reared separately; lack of synchronization in larval growth can lead to cannibalism (Williams and Primavera 2001). Other problems that can be seen in the larval rearing are fungal infections, morphological abnormalities and some undefined factors (Fujaya *et al*. 2014). Survival duration of the species under emersion should be considered in the different stages of aquaculture process, for example in transferring. It also should be considered that many of the crab species are predators of bivalves and many other benthic species. Therefore, the species selected to be cultured can be in a nuisance status. For example, *C. sapidus* has been reported to tear fishnets and traps occasionally and it is a voracious predator of clams, mussels and oysters (Blundon and Kennedy 1982; Beqiraj and Kashta 2010).

Aquaculture of these two species may be arguable beyond their native range. For example, in the European coastal waters, blue crab (*C. sapidus*) culture may be inappropriate due to its invasive status (EU 2011; Nehring 2011; Mancinelli *et al*. 2017a, 2017b). Nevertheless, *C. sapidus* is widely established and commercially captured in the Turkish coasts currently. Moreover, blue crab fishing is restricted in the Turkish Seas to protect the wild stocks and fishing is only allowed for 13 cm (carapace width) or larger species from October to May. Status of the other species, *P. segnis* can be considered in a similar way; in fact, experimental studies on the future farming projects on *P. segnis* in the Mediterranean shores have already been started (Ben Abdallah-Ben Hadj Hamida 2019).

Aquaculture of some crab species can be performed for a different purpose, performed only at the adult stages of the animal and generally dependent on the wild stocks. Crabs shed their shells (moulting) many times in their life to maintain their growth. In the molting process, crab exits from the old exoskeleton/shell and at that time the body of the crab remains soft for a little while. The crab at that stage is named as “soft shell crab”, has a different flavour and can be consumed almost entirely; its price is high compared to a normal crab. In general, only a small number of crab species are traded as “soft shell-crab” (Tavares *et al*. 2018; Spitznagel *et al*. 2019). *Portunus* species are suitable to produce as soft shell crab but there is no certain information on the status of *P. segnis* (species in the Turkish coasts) specifically, but the other species, blue crab, *C. sapidus*, is one of the main species of the soft shell crab trade (Perry *et al*. 2010; Hungria *et al*. 2017). Most of the soft shell crab production depends on the capturing and placing the wild pre-molt crabs in open systems, semi closed or closed systems; individually or together (Hungria *et al*. 2017; Tavares *et al*. 2018). After placing, crabs are monitored until they molt into soft-shell crabs and harvested after this phase. Identifying the ready to molt individuals requires the knowledge on the characteristics of the animal at this stage; after molting, processing must be ended in a very short time before the shell begins to harden (Hungria *et al*. 2017). These products are sold for higher prices than other kind of crab products (Perry *et al*. 2010; Hungria *et al*. 2017) but besides its advantages, soft shell crab aquaculture has some problems and risks. Stress resulted from crowded or closed conditions, molting stress and diseases increase mortality (Spitznagel *et al*. 2019) and capture dependent culture methods decrease the sustainability and affect wild populations; larval and juvenile culture may solve this problem (Perry *et al*. 2010), but hatchery technology has not yet been developed enough to support production (Hungria *et al*. 2017).

Gastropod culture

The most of the marine gastropod aquaculture is made on the species of *Haliotis* (abalone) and some members of family Muricidae in general (FAO 2019). Abalone aquaculture production is limited in European territories and juvenile supply can be problem but studies on the improvement of culture techniques on these animals are remaining (for example in Ireland and France, Brittany) (Hannon *et al*. 2013). Members of the family Muricidae are represented by many species in Mediterranean Sea and Black Sea but their flesh is mostly seen as waste. Nevertheless, some species have commercial value and may have aquaculture potential; banded dye murex (*Hexaplex trunculus*) can be given as one of the examples. This species is known for its ecologically role in the Mediterranean shores as a benthic predator (Güler and Lök 2016, 2019). However, *H. trunculus* is being considered as a potential candidate for aquaculture (Peharda and Morton 2006; Lahbib *et al*. 2010) and there is some evidence on its decreasing population due to the warming of coastal waters (Rilov 2016). *H. trunculus* is an edible marine snail and consumed in western Mediterranean countries (Vasconcelos *et al*. 2006), additionally this species is used as fish bait and is one of the main sources of the ancient dyes that were used in the Roman Empire and earlier eras (McGovern and Michel 1985; Vasileiadou *et al*. 2019). *H. trunculus* and some other few muricid species were used to produce purple and blue colours that were used in luxury materials as symbols of royalty or nobility. These dyes are still needed today to use in restoration of ancient paintings, clothes etc. and studies on the production of these ancient dyes are remaining but thousands of snails are necessary to make 1 gr dye with natural ways (Cooksey 2001; Imming *et al*. 2001).

Breeding can be achieved in artificial environment in *H. trunculus*; individuals can mate at the laboratory (Vasconcelos *et al*. 2004; Güler and Lök 2014). After mating, females spawn special egg capsules that contain eggs. Females cement these egg capsules on any substratum or on another egg mass. Viable embryos grow in these capsules via consuming on the other eggs that arrested their development in earlier phases (Güler and Lök 2014). After 35-40 d (up to 55) intracapsular period, larvae complete (nearly) their metamorphosis and escape from the egg capsules as miniatures of their adults (Lahbib *et al*. 2010; Güler and Lök 2014). Only about 3-7 per cent of the eggs live and complete the larval period and hatch from the egg capsules; others serve as a food supply to the developing embryos (Güler and Lök 2014). After short planktonic phase, they settle to any suitable place with remarkably high survival rates. However, high mortality occurs at the next phase (at least in artificial environment) due to intense cannibalism (Lahbib *et al*. 2010; Güler and Lök 2014). If cannibalism problems are solved juvenile culture can be possible. If market demand occurs *H. trunculus* can be suitable to growth extensively due to its opportunistic generalist feeding behaviour. For example, juveniles may be grown in coastal lagoons and they can be allowed to feed on non-commercial bivalves, gastropods or other invertebrates and carrion.

The second gastropod species may be more arguable for aquaculture, *Rapana venosa*. This Muricid species has negative reputation due to its drastic impacts on natural and farmed populations of economically important bivalves (Hu *et al*. 2016) as well as its ecological impacts on the benthic communities as an invasive predator species, in many regions of the world (Mann and Harding 2000). However, Rapana is commercially important, edible seafood and it has market demand especially in the south Asia countries. *R. venosa* is native to eastern Asia Seas and colonized in the many parts of the Black Sea since the middle of the last century (Zolotarev 1996; Kosyan 2016). In contrast to the impacts on the benthic life in the Black Sea, this species has been harvested and exported to the Eastern Asia markets as a luxury product since the 1980s (Sağlam *et al*. 2015). Currently there is an established industry that depends on this animal in the Turkish coasts of the Black Sea; 2018 capture production was recorded about 10 thousand tons (Degtiareva 2012; Sağlam and Duzgunes 2014; Sağlam *et al*. 2015; Kaykaç *et al*. 2018; TÜİK 2019b). When considering its well-known capturing and processing methods by the local fisheries industry, and marketing experiences that have been gained at least for 30 years, this infamous species may have aquaculture potential in the future (in locally available regions). Moreover, there is a tendency to overexploit this species in the Black Sea and sizes of the individuals caught are decreasing (Aydın *et al*. 2016); capture of this species is restricted in Turkish seas, and allowed circumstances are described in detail at the ministry regulations. However, the issues on its nuisance status and possible negative effects of the culture process on the ecosystem should be discussed in detail taking into account the future prospects/plans on the status of Rapana in Turkish seas before choosing this species as an aquaculture candidate.

Experimental aquaculture attempts for *R. venosa* have already begun in China (Yang *et al*. 2015; Song *et al*. 2016a; Yu *et al*. 2019) where the natural stocks cannot support the market demands. Artificial breeding is possible for this species, broodstock can mate and females can spawn in laboratory conditions (Zhang *et al*. 2017). Females spawn egg capsules that contain eggs like seen in *H. trunculus* but in contrast to *H. trunculus*, viable embryos do not feed on the other eggs in the capsules and most of the fertilized eggs can reach later stages of the larval phases (Harding 2006; Sağlam and Duzgunes 2007). Intracapsular period takes about 20-25 d but larval development remains at the water column after the intracapsular period. At this phase, planktonic larvae have to feed on the plankton (planktotrophy). After completing the metamorphosis at the water column and the larval stages are finished, individuals settle on any substratum. It is possible to obtain planktonic larvae from the egg capsules in artificial environment, and it is possible to feed the planktonic larva, and some successful feeding techniques using algae diets are available (Harding 2006; Yang *et al*. 2015; Song *et al*. 2016b). However, in later stages, mortality occurs due to cannibalism, inefficient feeding regimes and unknown factors (Yu *et al*. 2019). Generally, extensive growth methods after larviculture or rearing wild juveniles may be applicable for this species like mentioned for *H. trunculus*.

Sea cucumber culture

Sea cucumbers are deposit feeders, they ingest organic material in the sediment and play active role in the biological processing of the benthos (Purcell *et al*. 2016). Sea cucumbers are valuable-luxury seafood in the Asian countries with high market value and high market demand, additionally they have a potential in pharmaceutical industry (Benkendorff 2009; Anderson *et al*. 2011; Purcell *et al*. 2013; Purcell *et al*. 2014). More than 60 species of sea cucumbers are harvested globally; their natural stocks are decreasing due to overfishing and some species are under the risk of extinction (Friedman *et al*. 2011; Purcell *et al*. 2013; 2014). Due to their importance on the benthic ecosystems and their commercial value, efforts on the improvement of farming techniques of these animals have been increasing since the first attempts. However, it can be said that the cultivation is at the beginning level of its development and limited with some species (Toral-Granda *et al*. 2008).

In Turkish seas, the most captured commercially important species are *Holothuria polii*, *H. tubulosa* and *H. mammata* (González-Wangüemert *et al*. 2014; Öztoprak *et al*. 2014; Aydın 2017). Harvesting this species has been restricted in the Turkish Seas and allowed in particular years depending on the area. However, illegal activities can be encountered beside the authorized activities. Commercial interest on sea cucumbers is increasing in the Mediterranean Sea as well as Aegean Sea and negative effects of the over-exploitation continue (Aydın 2017, 2019; González-Wangüemert *et al*. 2018).

Holothuria polii is a valuable seafood and recently become an exploited target species especially in the Asian countries (Sicuro *et al*. 2012; Rakaj *et al*. 2019). *H. polii* may have a potential as a candidate species for aquaculture especially after some successful artificial reproduction and larval development studies. *H. tubulosa* is another species with high market price and it may have aquaculture potential in the Turkish seas. Similarly, artificial reproduction and larval development success were reported for this species (Rakaj *et al*. 2018). Recently successful larval culture studies were made on the *H. mammata*, and this species is considered a candidate species for aquaculture too (Domínguez-Godino and González-Wangüemert 2018). According to the recently developed protocols on broodstock maintenance, spawning induction, fertilization and larval-juvenile culture by Domínguez-Godino and González-Wangüemert (2018), Rakaj *et al*. (2018) and Rakaj *et al*. (2019) for this three species (*H. mammata*, *H. tubulosa*, *H. polii*):

Broodstock can be collected by snorkelling in shallow coastal waters up to 5-6 m for all three species. After placing indoor tanks, more than 500 L they are allowed to adopt the artificial environment. In general, the bottoms of the tanks are filled with sediment collected from natural environment of the sea cucumbers. Broodstock are fed with pelleted fish feed, dried macro algae etc. For this period, water temperatures are kept at 23-24 °C for *H. tubulosa* and *H. polii*, and similar for *H. mammata*. Thermal shock or mechanical shock can be used to induce spawning; in general, water temperature increments or dry environment and water jet methods are applied (Agudo 2006; Duy 2010). After releasing eggs, sperms from the males that were separately stocked before are added in to the female spawning buckets and fertilized eggs are transferred to different containers. (*i*) Larval phases complete in about 15 days in *H. polii*. According to the protocol applied by Rakaj *et al*. (2019) algae mixture are used for larval feeding, and diatom-biofilm that prepared earlier on settlement panels are used for later larval stages. At this study, maximum 14% survival rate was recorded for the first 15 days. (*ii*) Larval metamorphosis takes longer in *H. tubulosa*; about 27 days (Rakaj *et al*. 2018). According to the protocol of Rakaj *et al*. (2018), juveniles can reach ~1.5 mm in 45 days after the fertilization with 4% survival rate; algae mixture and diatom-biofilm are used for larval feeding. (*iii*) According to the experimental larval rearing study of Domínguez-Godino and González-Wangüemert (2018), first juveniles appear at 21st day after fertilization in *H. mammata*. Survival rate at the first juvenile stage was recorded below 10% at this study; larvae were fed with algae mixture. In general, survival rates in larval culture of the sea cucumbers are poor. According to an earlier estimate, rates are roughly around 1% and further researches are needed especially on larval feeding (Purcell *et al*. 2012). According to FAO (2019) yearly sea cucumber aquaculture production throughout the world is about 220 thousand tones. Although this is a significant amount, it should be considered that most of the production is depending on a single species, Japanese sea cucumber (FAO 2019).

Juvenile nursery can be made in mesh bags/chambers in sea or in ponds, the mesh sizes change with the size of the individuals, or culture can be made directly in nursery tanks (Pitt *et al*. 2004; Lavitra *et al*. 2010). Grow out can be made in ponds with appropriate water exchange or marine structures; for some species, higher survival rates were recorded in earthen pond culture than the directly marine systems like sea pens but this situation may change depending on the species and culture methods (Giraspy and Walsalam 2010; Purcell *et al*. 2012). Sea cucumbers have potential to be used in co-culture and integrated multi-trophic aquaculture (IMTA) as “extractive species” with a couple of ways (Bell *et al*. 2005; Park *et al*. 2018; Israel *et al*. 2019). There are some studies on their active role at the biological processing of the benthos and the possible benefits of this process. According to this approach, sea cucumbers can be grown extensively under the fish cages so their food is provided by the organic outputs of the cages and in addition to growth, the sea cucumbers will reduce organic accumulation under the cages (Tolon *et al*. 2017; Neofitou *et al*. 2019). IMTA and co-culture can be made with shrimps, snails, some fish species that are suitable to grow in ponds, seaweed and so on. In general, grow out periods of the co-cultured species should be compatible and it should be taken into consideration that this type of aquaculture cannot be successful for all species combinations (Bell *et al*. 2007; Purcell *et al*. 2012; Zamora *et al*. 2018; Israel *et al*. 2019).

Conclusion

When considering the length and variable characteristics of Turkish coasts the species that are mentioned in this section probably constitute only a part of the species that are suitable for aquaculture in Turkey. For example, sea urchin culture techniques developed rapidly in the last decades; economically important sea urchin species *Paracentrotus lividus* from Turkish coasts can be evaluated in terms of its aquaculture potential. Examples can be expanded. In addition to species selection, deciding culture system-species combination poses great importance. Many of the marine invertebrates are less mobile than fish, they live in various habitats (sandy bottoms, hard substrates and so on) and have highly different foraging behaviours. Thus, it is possible to grow these species in various systems and in different ways than conventional aquaculture methods, and species selection can be made based on the available culture site and condition. Moreover, many marine invertebrates are suitable to be grown in environmentally friendly and economically feasible culture applications as a single species or within integrated multi-trophic aquaculture operations. However, in spite of these advantages, culture techniques are still inadequate for many potential marine invertebrate species and should be improved, and more studies should be conducted, especially on the larval stages / production of viable juveniles.

References

Agudo, N.S. (2006) Sandfish Hatchery Techniques. Australian Centre for International Agricultural Research, Secretariat of the Pacific Community and the World Fish Center, Nouméa, New Caledonia. 43 pp.

Akyol, O., Şen, H. (2004) A new large pelagic squid record for the Northern Aegean Sea of Turkey; Neon flying squid, *Ommastrephes bartrami* (Lesueur, 1821) (Cephalopoda: Ommastephidae). *Turkish Journal of Fisheries and Aquatic Science* 4(2): 111-113.

Akyol, O., Şen, H., Kınacıgil, T. (2007) Reproductive biology of *Eledone moschata* (Cephalopoda: Octopodidae) in the Aegean Sea (Izmir Bay, Turkey). *J Mar Biol Ass UK* 87: 967-970.

Anderson, S.C., Flemming, J.M., Watson, R., Lotze, H.K. (2011) Serial exploitation of global sea cucumber fisheries. *Fish Fish* 12: 317-339.

Andrés, M., Rotllant, G., Zeng, C. (2010). Survival, development and growth of larvae of the blue swimmer crab, *Portunus pelagicus*, cultured under different photoperiod conditions. *Aquaculture* 300: 218-222.

Avault, J.W. (1993) Ten requirements for culturing a “new” species: a checklist. *Aquac Mag* 19: 68-73.

Aydın, M., Duzgunes, E., Durmus, U. (2016) Rapa whelk (*Rapana venosa* Valenciennes, 1846) fishery along the Turkish coast of the Black Sea. *Journal of Aquaculture Engineering and Fisheries Research* 2: 85-96.

Aydın, M. (2017) Present status of the sea cucumber fishery in Turkey. *SPC Beche-de-Mer Information Bulletins* 37: 30-34.

Aydin, M. (2019) Biometry, density and the biomass of the commercial sea cucumber population of the Aegean Sea. *Turkish J Fish Aquat Sci* 19: 463-474.

Azra, M.N., Ikhwanuddin, M. (2015) Larval culture and rearing techniques of commercially important crab, *Portunus pelagicus* (Linnaeus, 1758): present status and future prospects. *Songklanakarin J Sci Technol* 37: 135-145.

Bartley, D.M. (1998) A precautionary approach for the introduction of new species in aquaculture. In: New Species for Mediterranean Aquaculture, (eds., Enne, G., Greppi, G.F.). Proceedings of 33rd International Symposium on New Species for Mediterranean Aquaculture, 22–26 April, pp. 5-17.

Bell, J.D., Rothlisberg, P.C., Munro, J.L., Loneragan, N.R., Nash, W.J., Ward, R.D., Andrew, N.L. (2005) Restocking and stock enhancement of marine invertebrate fisheries. *Advances in Marine Biology* 49: 1-370.

Bell, J.D., Agudo, N.S., Purcell, S.W., Blazer, P., Simutoga, M., Pham, D., Della Patrona, L. (2007) Grow-out of sandfish *Holothuria scabra* in ponds shows that co-culture with shrimp *Litopenaeus stylirostris* is not viable. *Aquaculture* 273: 509-519.

Ben Abdallah-Ben Hadj Hamida, O., Ben Hadj Hamida, N., Ammar, R., Chaouch, H., Missaoui, H. (2019) Feeding habits of the swimming blue crab *Portunus segnis* (Forskål, 1775) (Brachyura: Portunidae) in the Mediterranean. *Journal of the Marine Biological Association of the United Kingdom* 99(6): 1343-1351.

Benkendorff, K. (2009) Aquaculture and the production of pharmaceuticals and nutraceuticals. In: New Technologies in Aquaculture, (eds., Burnell, G., Allan, G.), Woodhead Publishing Series in Food Science, Technology and Nutrition. Woodhead Publishing, pp. 866–891.

Beqiraj, S., Kashta, L. (2010) The establishment of blue crab *Callinectes sapidus* Rathbun, 1896 in the Lagoon of Patok, Albania (south-east Adriatic Sea). *Aquatic Invasions* 5(2): 219-221.

Blundon, J.A., Kennedy, V.S. (1982) Mechanical and behavioral aspects of blue crab, *Callinectes sapidus* (rathbun), predation on Chesapeake Bay bivalves. *Journal of Experimental Marine Biology and Ecology* 65(1): 47-65.

Choe, S., Ohshima, Y. (1961) On the embryonal development and the growth of the squid. *Sepioteuthis lessoniana Lesson Venus* 21(2): 462-476.

Choe, S., Ohshima, Y. (1963) Rearing of cuttlefishes and squids. *Nature* 197: 307.

Cooksey, C.J. (2001) Tyrian purple: 6,6′-Dibromoindigo and related compounds. *Molecules* 6: 736-769.

De Lestang, S., Bellchambers, L.M., Caputi, N., Thomson, A.W., Pember, M.B., Johnston, D.J., Harris, D.C., (2010) Stock–recruitment–environment relationship for a *Portunus pelagicus* fishery in Western Australia. In: Biology and Management of Exploited Crab Populations under Climate Change (eds., Kruse, G.H., Eckert, G.L., Foy, R.J., Lipcius, R.N., Sainte-Marie, B., Stram, D.L., Woodby, D.). Alaska Sea Grant, University of Alaska Fairbanks.

Degtiareva, I.A. (2012) Investigation of the distribution of exotic gastropod species *Rapana venosa* (Valenciennes, 1846) in the Black Sea coasts of Şile. Istanbul University, Institute of Science, Deparment of Basic Sciences, Marine Biology Program , Master's Thesis. (in Turkish).

Domínguez-Godino, J.A., González-Wangüemert, M. (2018) Breeding and larval development of *Holothuria mammata*, a new target species for aquaculture. *Aquac Res* 49: 1430-1440.

Duy, N.D.Q. (2010) Seed production of sandfish (*Holothuria scabra*) in Vietnam. Aquaculture Extension Manual, 48. Southeast Asian Fisheries Development Center, Iloilo, Philippines.

EU (2011) Regulation (EU) No 304/2011 of the European Parliament and of the Council of 9 March 2011 amending Council Regulation (EC) No 708/2007 concerning use of alien and locally absent species in aquaculture. *Off J Eur Union Lex*, 88: 1-4.

FAO (2016) The State of World Fisheries and Aquaculture. Available at: http://www.fao.org/3/a-i5555e.pdf (accessed 24 Aug 2019).

FAO (2018) The State of World Fisheries and Aquaculture. Meeting The Sustainable Development Goals, Rome, 227 pp.

FAO (2019) Statistical Query Results. Available at: http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en (accessed 24 Aug 2019).

Friedman, K., Eriksson, H., Tardy, E., Pakoa, K. (2011) Management of sea cucumber stocks: Patterns of vulnerability and recovery of sea cucumber stocks impacted by fishing. *Fish and Fisheries* 12: 75-93.

Fujaya, Y., Trijuno, D.D., Nikhlani, A., Cahyono, I., Hasnidar, H. (2014) The use of mulberry (*Morus alba*) extract in the mass production of blue swimming crab (*Portunus pelagicus* L.) larvae to overcome the mortality rate due to molting syndrome. *Aquatic Science and Technology* 2: 1-14.

Gilbert, D.L., Adelman Jr., W.J., Arnold, J.M. (1990) Squid as Experimental Animals. Plenum Press, New York, NY.

Giraspy, D.A.B., Walsalam, I.G. (2010) Aquaculture potential of the tropical sea cucumbers *Holothuria scabra* and *H. lessoni* in the Indo-Pacific region. *SPC Beche-de-mer Information Bulletin* 30: 29-32.

Globefish. (2012) Globefish highlights. FAO/Globefish 3/2012, p. 58.

González-Wangüemert, M., Aydin, M., Conand, C. (2014) Assessment of sea cucumber populations from the Aegean Sea (Turkey): First insights to sustainable management of new fisheries. *Ocean Coast Manag* 92: 87-94.

González-Wangüemert, M., Domínguez-Godino, J.A., Cánovas, F. (2018) The fast development of sea cucumber fisheries in the Mediterranean and NE Atlantic waters: From a new marine resource to its over-exploitation. *Ocean Coast Manag* 151: 165-177.

Gücü, A.C., Salman, A. (1993) A preliminary study on the growth of the octopus *Octopus vulgaris* (Cuvier, 1797). *Doğa-Tr J of Zoology* 17: 151-160.

Güler, M., Lök, A. (2014) Embryonic development and intracapsular feeding in *Hexaplex trunculus* (Gastropoda: Muricidae). *Mar Ecol* 35: 193-203.

Güler, M., Lök, A. (2016) Foraging behaviors of *Hexaplex trunculus* (Gastropoda: Muricidae) juveniles. *J Shellfish Res* 35: 911-919.

Güler, M., Lök, A. (2019) Foraging behaviors of a predatory Snail (*Hexaplex trunculus*) in group attacking. *Turkish J Fish Aquat Sci* 19: 391-398.

Hanlon, R.T. (1987) Mariculture. In: Cephalopod Life Cycles, Volume II-Comparative Reviews (ed. Boyle P.R.). Academic Press, London, pp. 291-305.

Hannon, C., Officer, R.A., Le Dorven, J. (2013) Review of the technical challenges facing aquaculture of the European abalone *Haliotis tuberculata* in Ireland. *Aquaculture International* 21(2): 243-254.

Harding, J.M. (2006) Growth and development of veined rapa whelk *Rapana venosa* veligers. *J Shellfish Res* 25: 941-946.

Hu, N., Wang, F., Zhang, T., Song, H., Yu, Z.L., Liu, D.P. (2016) Prey selection and foraging behavior of the whelk *Rapana venosa*. *Mar Biol* 163: 1-12.

Hungria, D.B., dos Santos Tavares, C.P., Pereira, L.Â., de Assis Teixeira da Silva, U., Ostrensky, A. (2017) Global status of production and commercialization of soft-shell crabs. *Aquaculture International* 25(6): 2213-2226.

Ikhwanuddin, M., Mansor, J.H., Bolong, A.-M.A., Long, S.M. (2012) Improved hatchery-rearing techniques for juvenile production of blue swimming crab, *Portunus pelagicus*. *Aquaculture Research* 43: 1251-1259.

Imming, P., Imhof, I., Zentgraf, M. (2001) An improved synthetic procedure for 6,6′-dibromoindigo (tyrian purple). *Synthetic Communications* 31(23): 3721-3727.

Israel, D., Lupatsch, I., Angel, D.L. (2019) Testing the digestibility of seabream wastes in three candidates for integrated multi-trophic aquaculture: Grey mullet, sea urchin and sea cucumber. *Aquaculture* 510: 364-370.

Itami, K., Izawa, Y., Maeda, S., Nakai, K. (1963) Notes on the laboratory culture of the octopus larvae. *Bull Jpn Soc Sci Fish* 29 (6): 514-520.

Josileen, J. (2013) Seed production and farming of blue swimmer crab *Portunus pelagicus*. Teaching Resource, *Central Marine Fisheries Research Institute*, India, pp: 243-248.

Josileen, J., Menon, N.G. (2005) Growth of the blue swimmer crab, *Portunus pelagicus* (Linnaeus, 1758) (Decapoda, Brachyura) in captivity. *Crustaceana* 78 (1): 1-18.

Katağan, T., Salman, A., Benli, H.A. (1993) The Cephalopod fauna of the sea of Marmara. *Isr J Zool* 39: 255-261.

Kaykaç, M., Gümüş, A., Zengin, M., Süer, S., Rüzgar, M., Van, A., Tosunoğlu, Z. (2018) Effect of steel wire and claw size on the sea snail (*Rapana venosa*) catch in a Black Sea beam trawl fishery. *Turkish Journal of Veterinary and Animal Sciences* 42(4): 251-258.

Kosyan, A. (2016) Predation mechanisms of *Rapana venosa* (gastropod: Muricidae) in different biotopes along the black sea coast. *Marine Pollution Bulletin* 102(2): 265-270.

Koueta, N., Boucaud-Camou, E. (1999) Food intake and growth in reared early juvenile cuttlefish *Sepia officinalis* L. (Mollusca Cephalopoda). *J Exp Mar Biol Ecol* 240: 93-109.

Lahbib, Y., Abidli, S., Trigui El Menif, N. (2010) Laboratory study of the intracapsular development and juvenile growth of the banded murex, *Hexaplex trunculus*. *J World Aquacult Soc* 41: 18-34.

Lai, J.C.Y., Ng, P.K.L., Davie, P.J.F. (2010) A revision of the *Portunus pelagicus* (Linnaeus, 1758) species complex (Crustacea: Brachyura: Portunidae), with the recognition of four species. *Raffles Bulletin of Zoology* 58(2): 199-237.

Lavitra, T., Rasolofonirina, R., Eeckhaut, I. (2010) The effect of sediment quality and stocking density on survival and growth of the sea cucumber *Holothuria scabra* reared in nursery ponds and sea pens. *Western Indian Ocean Journal of Marine Science* 9(2): 153-164.

Lee, P.G. (1994) Nutrition of cephalopods: fueling the system. *Mar Freshw Behav Physiol* 25(1-3): 35-51.

Lee, P.G., Turk, P.E., Yang, W.T., Hanlon, R.T. (1994) Biological characteristics and biomedical applications of the squid *Sepioteuthis lessoniana* cultured through multiple generations. *Biol Bull* 186: 328-341.

Mancinelli, G., Chainho, P., Cilenti, L., Falco, S., Kapiris, K., Katselis, G., Ribeiro, F. (2017a) The Atlantic blue crab *Callinectes sapidus* in southern European coastal waters: distribution, impact and prospective invasion management strategies. *Mar Pollut Bull* 119: 5-11.

Mancinelli, G., Chainho, P., Cilenti, L., Falco, S., Kapiris, K., Katselis, G., Ribeiro, F. (2017b) On the Atlantic blue crab (*Callinectes sapidus* Rathbun 1896) in southern European coastal waters: time to turn a threat into a resource? *Fish Res* 194: 1-8.

Mann, R., Harding, J.M. (2000) Invasion of the North American Atlantic coast by a large predatory Asian mollusc. *Biol Invasions* 2: 7-22.

McGovern, P.E., Michel, R.H. (1985). Royal purple dye: Tracing chemical origins of the industry. *Anal Chem* 57: 1514A-1522A. doi:10.1021/ac00291a753

Moksnes, P.-O., Lipcius, R.N., Pihl, L., Van Montfrans, J. (1997) Cannibal-prey dynamics in young juveniles and postlarvae of the blue crab. *Journal of Experimental Marine Biology and Ecology* 215(2): 157-187.

Nehring, S. (2011) Invasion History and Success of the American Blue Crab *Callinectes sapidus* in European and Adjacent Waters. In: In the Wrong Place - Alien Marine Crustaceans: Distribution, Biology and Impacts (eds., Galil, B.S., Clark, P.F., Carlton, J.T.), Invading Nature - Springer Series in Invasion Ecology, vol 6. Springer, Dordrecht, doi:10.1007/978-94-007-0591-3_21.

Neofitou, N., Lolas, A., Ballios, I., Skordas, K., Tziantziou, L., Vafidis, D. (2019) Contribution of sea cucumber *Holothuria tubulosa* on organic load reduction from fish farming operation. *Aquaculture* 501: 97-103.

O'Dor, R.K., Wells, M.J. (1987) Energy and nutrient flow. In: Boyle P.R. (Ed.), Cephalopod Life Cycles, Volume II—Comparative Reviews. Academic Press, London, pp. 109-133.

Özcan, T., Akyurt, İ., (2006) Population biology of sand crab (*Portunus pelagicus* (Linneaus, 1758) and blue crab (*Callinectes sapidus* Rathbun, 1896) in İskenderun Bay. *Journal of Fisheries and Aquatic Sciences* 23(3-4): 407-411 (in Turkish).

Özcan, T., (2012) The swimming crab *Portunus segnis* (Forskål, 1775): Host for the barnacle *Chelonibia platula* (Ranzani, 1818) from the Turkish coast. *J. Black Sea/Medit Environ* 18(3): 271-278

Özoğul, Y., Duysak, Ö., Özoğul, F., Özkütük, A.S., Türeli, C. (2008) Seasonal effects in the nutritional quality of the body structural tissue of cephalopods. *Food Chemistry* 108: 847-852.

Öztoprak, B., Doğan, A., Dağli, E. (2014) Checklist of Echinodermata from the coasts of Turkey. *Turkish J Zool* 38: 892-900.

Özyurt, G., Duysak, Ö., Akamca, E., Türeli, C. (2006) Seasonal changes of fatty acids of cuttlefish *Sepia officinalis* L. (Mollusca: Cephalopoda) in the northern eastern Mediterranean. *Food Chemistry* 95: 382-385.

Park, M., Shin, S.K., Do, Y.H., Yarish, C., Kim, J.K. (2018) Application of open water integrated multi-trophic aquaculture to intensive monoculture: A review of the current status and challenges in Korea. *Aquaculture* 497: 174-183.

Pazooki, J, Mehdi, H., Amir, V. (2012) The dietary compositions of the blue swimming crab, *Portunus segnis* (Forskal, 1775) from Persian Gulf, South Iran. *World Applied Sciences Journal* 20(3): 416-422.

Peharda, M., Morton, B. (2006) Experimental prey species preferences of *Hexaplex trunculus* (Gastropoda: Muricidae) and predator-prey interactions with the Black mussel *Mytilus galloprovincialis* (Bivalvia: Mytilidae). *Mar Biol* 148: 1011-1019.

Perry, H., Graham, D., Trigg, C., Crochet, G. (2010) Expansion of the Soft Crab Fishery in Mississippi Using Cultured Blue Crabs. Proceedings of the 63rd Gulf and Caribbean Fisheries Institute, pp 482-486.

Pierce, G.J., Portela, J. (2014) Fisheries production and market demand. In: Cephalopod Culture (eds. Iglesias J., Fuentes L., Villanueva R.), Springer Netherlands, London, pp. 41-58.

Pitt, R., Duy, N.D.Q., Duy, T.V., Long, H.T.C. (2004) Sandfish (*Holothuria scabra*) with shrimp (*Penaeus monodon*) co-culture tank trials. *SPC Beche-de-mer Information Bulletin* 20: 12-22.

Purcell, S.W., Hair, C.A., Mills, D.J. (2012) Sea cucumber culture, farming and sea ranching in the tropics: Progress, problems and opportunities. *Aquaculture* 368–369, 68–81.

Purcell, S.W., Mercier, A., Conand, C., Hamel, J., Toral-Granda, M.V., Lovatelli, A., Uthicke, S. (2013) Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. *Fish and Fisheries* 14: 34-59.

Purcell, S.W., Polidoro, B.A., Hamel, J.F., Gamboa, R.U., Mercier, A. (2014) The cost of being valuable: predictors of extinction risk in marine invertebrates exploited as luxury seafood. *Proceedings of the Royal Society B: Biological Sciences* 281(1781): 2013-3296.

Purcell, S.W., Conand, C., Uthicke, S., Byrne, M. (2016) Ecological roles of exploited sea cucumbers. *Oceanogr Mar Biol* 54: 367-386..

Quéméner, L., Suquet, M., Mero, D., Gaignon, J. (2002) Selection method of new candidates for finfish aquaculture: The case of the French Atlantic, the channel and the North Sea coasts. *Aquatic Living Resources* 15(5): 293-302.

Rakaj, A., Fianchini, A., Boncagni, P., Lovatelli, A., Scardi, M., Cataudella, S., (2018) Spawning and rearing of *Holothuria tubulosa*: A new candidate for aquaculture in the Mediterranean region. *Aquac Res* 49: 557-568.

Rakaj, A., Fianchini, A., Boncagni, P., Scardi, M., Cataudella, S. (2019) Artificial reproduction of *Holothuria polii*: A new candidate for aquaculture. *Aquaculture* 498: 444-453.

Rilov, G. (2016) Multi-species collapses at the warm edge of a warming sea. *Sci Rep* 6: 36897 doi:10.1038/srep36897

Romano, N., Zeng, C. (2006) The effects of salinity on the survival, growth and haemolymph osmolality of early juvenile blue swimmer crab, *Portunus pelagicus*. *Aquaculture* 260: 151-162.

Romano, N., Zeng, C. (2007) Ontogenetic changes in tolerance to acute ammonia exposure and associated gill histological alterations during early juvenile development of the blue swimmer crab, *Portunus pelagicus*. *Aquaculture* 266: 246-254.

Romano, N., Zeng, C., (2008) Blue swimmer crabs - emerging species in Asia, *Glob Aquacul Advoc* 11:34–36.

Rosas, C., Valero, A., Caamal-Monsreal, C., Uriarte, I., Farias, A., Gallardo, P., Sa´nchez, A., Domingues, P. (2013) Effects of dietary protein sources on growth, survival and digestive capacity of *Octopus maya* juveniles (Mollusca: Cephalopoda). *Aquac Res* 44(7): 1029-1044.

Safaie, M. (2016) Feeding habits of blue swimming crab *Portunus segnis* (Forskal, 1775) in the northern coastal waters of Iran. *Mar. Biodivers Rec* 9: 1-9.

Safaie, M., Pazooki, J., Kiabi, B., Shokri, M.R. (2013) Reproductive biology of blue swimming crab, *Portunus segnis* (Forskal, 1775) in coastal waters of Persian Gulf and Oman Sea, Iran. *Iranian Journal of Fisheries Sciences* 12(2): 430-444.

Sağlam, H., Duzgunes, E., (2007) Deposition of egg capsule and larval development of *Rapana venosa* (Gastropoda: Muricidae) from the south-eastern Black Sea. *J Mar Biol Assoc UK* 87: 953. doi:10.1017/S0025315407056330

Sağlam H., Duzgunes E. (2014). *Rapa whelk* (*Rapana venosa* Valenciennes, 1846) fisheries in the Black Sea. In: Turkish Fisheries in the Black Sea. (eds. Duzgunes, E., Öztürk, B., Zengin, M.) TUDAV Publication no:40, Istanbul, Turkey, pp. 361-395.

Sağlam, H., Kutlu, S., Dagtekin, M., Bascinar, S., Sahin, A., Selen, H., Duzgunes, E. (2015) Population biology of *Rapana venosa* (Valenciennes, 1846) (Gastropoda: Neogastropoda) in the south-eastern Black Sea of Turkey. *Cahiers De Biologie Marine* 56(4): 363-368.

Salman, A. (2002) New report of the loliginid squid *Sepioteuthis lessoniana*, Lesson, 1830 in the Mediterranean. *Isr J Zool* 48: 249-250.

Salman, A. (2009) Cephalopod research in the eastern Mediterranean (East of 23°E): a review. *Bolletino Malacologico* 45: 47-59.

Salman, A. (2012) Cephalopods (Mollusca: Cephalopoda) and their status in Turkey. Denizel Değerlerimiz Serisi 2: 1-7 Available at: https://www.surkoopekutuphane.org/images/dosya/kafadanbacakl%C4%B1lar-(Mollusca-Cephalopoda)-ve-Turkiyedeki-durumu.pdf (accessed 24 Aug 2019) (in Turkish).

Salman, A., Katagan, T., Benli, H.A. (1997) Bottom trawl teuthofauna of the Aegean Sea, Arch. *Fish Mar Res* 45(2): 183-196.

Salman, A., Katagan, T., Benli, H.A. (2002) Cephalopod fauna of the Eastern Mediterranean. *Turkish Journal of Zoology* 26: 47-52.

Salman, Y.G., Salman, A., Ozkızılcık, S. (2007) The fatty acid profile of marine cephalopod *Loligo vulgaris*. *Israeli Journal of Aquaculture Bamidgeh* 59(3): 133-136.

Salman, A., Akalin, M., Şen, H. (2017) Residual eggs in post-mortem *Sepia officinalis* (Mollusca: Cephalopoda). *Turkish Journal of Fisheries and Aquatic Science* 17: 251-256.

Segawa, S. (1990) Food consumption, food conversion and growth rates of the oval squid *Sepioteuthis lessoniana* by laboratory experiments. *Nippon Suisan Gakk* 56(2): 217-222.

Şen, H. (2004a) A preliminary study on the effects of salinity on egg development of European squid (*Loligo vulgaris* Lamarck, 1798). *The Israeli Journal of Aquaculture-Bamidgeh* 56(2): 95-101.

Şen, H. (2004b) Effects of photoperiodicity on development and incubation of squid (*Loligo vulgaris* Lamarck, 1798) eggs. *Ege JFAS* 21(3-4): 211-214. (in Turkish).

Şen, H. (2004c) A preliminary study on the effects of different light intensities on hatching of European squid (*Loligo vulgaris* Lamarck, 1798) eggs. *Turkish Journal of Fisheries and Aquatic Science* 4 (1):1-4.

Şen, H. (2005a) Importance of cephalopods and the status in aquaculture sector. *Aqua Life of Turkey* 4: 31-35 (in Turkish).

Şen, H. (2005b) Incubation of European squid (*Loligo vulgaris* Lamarck, 1798) eggs at different salinities. *Aquac Res* 36: 876-881.

Şen, H. (2005c) Temperature tolerance of loliginid squid (*Loligo vulgaris* Lamarck, 1798) eggs in controlled conditions. *Turkish Journal of Fisheries and Aquatic Science* 5 (1): 53-56.

Şen, H. (2005d) Occupancy of PVC tubes as a shelter in musky octopus (*Eledone moschata* Lamarck, 1799) (Cephalopoda: Octopodae). *EgeJFAS* 22 (3-4): 427-429 (in Turkish).

Şen, H. (2005e) Effects of shelter on adaptation to controlled conditions of musky octopus (*Eledone moschata* Lamarck, 1799). *EgeJFAS* 22 (3-4): 453-456 (in Turkish).

Şen, H. (2006a) The funnel tube development of *Loligo vulgaris* (Lamarck, 1798) in its embryogenesis. *EgeJFAS* 23 (1-2): 153-156 (in Turkish).

Şen, H. (2006b) The ink-sac development of European squid's (*Loligo vulgaris* Lamarck, 1798) eggs during the embryogenesis. *EgeJFAS* 23 (1-2): 291-293 (in Turkish).

Şen, H. (2006c) A survey on cannibalism in musky octopus (*Eledone moschata* Lamarck, 1799) in controlled conditions. *EgeJFAS* 23 (3-4): 385-387 (in Turkish).

Şen, H. (2007) Food preference of *Eledone moschata* Lamarck, 1799 (Cephalopoda: Octopodidade) in captive conditions. *Int J Nat Eng Sci* 1(2): 29-31.

Şen, H. (2009) Spawning, egg development and incubation of cuttlefish (*Sepia officinalis* L. 1758) in controlled conditions. *jfscom* 3(3): 169-180 (in Turkish).

Şen, H. (2012) Preliminary study on adaptation of common octopus (*Octopus vulgaris* Cuvier) by individually stocking technique. *EgeJFAS* 29 (4): 171-174 (in Turkish).

Şen, H. (2013a) Effects of string diameter preference of *Sepia officinalis* (L. 1758) during spawning in captivity. *jfscom* 7(4): 297-301.

Şen, H. (2013b) The cuttlebone development of common cuttlefish [*Sepia officinalis* (Linneaus, 1758)]. *EgeJFAS* 30(3): 105-108 (in Turkish).

Şen, H., (2014) Sex distinction by its morphologic view of European squid (*Loligo vulgaris* Lamarck, 1798). *jfscom* 8(1): 67-71 (in Turkish).

Şen, H., Akyol, O. (2011) A preliminary study on feeding preference of the musky octopus, *Eledone moschata*, (Cephalopoda: Octopodidae) in Izmir Bay, Aegean Sea. *jfscom* 5(2): 141-145.

Şen, H., Fırat, K., Saka, Ş. (2008) Effects of stocking density on incubation of *Loligo vulgaris* (Lamarck 1798) eggs in controlled conditions. *Science and Eng J of Fırat Univ* 20(2): 289-294 (in Turkish).

Şen, H., Sunlu, U. (2007) Effects of cadmium ($CdCl_2$) on development and hatching of eggs in European squid (*Loligo vulgaris* Lamarck, 1798) (Cephalopoda: Loliginidae). *Environ Mont Assess* 133: 371-378.

Şen, H., Tanrıkul T.T. (2009) Efficacy of 2-phenoxyethanol as an anaesthetic for the musky octopus, *Eledone moschata* (Lamarck, 1799), (Cephalopoda: Octopodidae). *Turk J Vet Anim Sci* 33(6): 463-467.

Şen, H., Tanrıkul T.T. (2013) Effects of 2-phenoxyethanol on cuttlefish, *Sepia officinalis* L. (Cephalopoda: Sepiidae). *EgeJFAS* 30(1): 21-24.

Sicuro, B., Piccinno, M., Gai, F., Abete, M.C., Danieli, A., Dapra, F., Mioletti, S., Vilella, S. (2012) Food quality and safety of Mediterranean sea cucumbers *Holothuria tubulosa* and *Holothuria polii* in Southern Adriatic Sea. *Asian J Anim Vet Adv* doi:10.3923/ajava.(2012).851.859.

Sinanoglu, V.J., Meimaroglu, S.M. (1998) Fatty acid of neutral and polar lipids of (edible) Mediterranean cephalopods. *Food Research International* 31: 467-473.

Song, H., Yu, Z.L., Sun, L.N., Gao, Y., Zhang, T., Wang, H.Y. (2016a) De novo transcriptome sequencing and analysis of *Rapana venosa* from six different developmental stages using Hi-seq 2500. *Comp. Biochem. Physiol. - Part D Genomics Proteomics* 17: 48-57.

Song, H., Yuan, L., Zheng, S., Yu, L., Na, L., Dong, S., Xue, X., (2016b) Metabolomic analysis of competent larvae and juvenile veined rapa whelks (*Rapana venosa*). *Mar Biol* 163: 264003. doi: 10.1007/s00227-016-2919-6

Soundarapandian, P., Tamizhazhagan T., (2009) Embryonic development of commercially important swimming crab *Portunus pelagicus* (Linnaeus). *Current Research Journal of Biological Sciences* 1(3):106-108.

Spitznagel, M. I., Small, H. J., Lively, J. A., Shields, J. D., Schott, E. J. (2019) Investigating risk factors for mortality and reovirus infection in aquaculture production of soft-shell blue crabs (*Callinectes sapidus*). *Aquaculture* 502: 289-295.

Sykes, A.V., Domingues, P.M., Correia, M., Andrade, J.P. (2006) Cuttlefish culture – state of the art and future trends. *Vie Milieu* 56 (2): 129-137.

Tanrıkul, T.T., Şen, H., Gültepe, N. (2012) Effects of potassium dichromate on skin ulcers of musky octopus (*Eledone moschata* Lamarck, 1799) (Mollusca: Cephalopoda). *Asian Journal of Chemistry* 24(11): 5187-5189.

Tavares, C.P., Silva, U.A., Pereira, L.A., Ostrensky, A. (2018) Systems and techniques used in the culture of soft-shell swimming crabs. *Rev Aquacult* 10: 913-923.

Tolon, M.T., Emiroglu, D., Gunay, D., Ozgul, A., (2017) Sea cucumber (*Holothuria tubulosa* Gmelin, 1790) culture under marine fish net cages for potential use in integrated multi-trophic aquaculture (IMTA). *Indian J Geo-Mar Sci* 46: 749-756.

Toral-Granda, V., Lovatelli, A., Vasconcellos, M. (eds.) (2008) Sea cucumbers: a global review of fisheries and trade (Rome: Food and Agriculture Organization of the United Nations. Fisheries and Aquaculture Technical Paper, 516. Rome, FAO, 317.

Türeli, C., Yeşilyurt, I. (2018) Reproductive biology of blue swimming crab, *Portunus segnis* (Forskal, 1775) in Yumurtalık Cove, Northeastern Mediterranean, Turkey. *Mediterranean Marine Science* 18(3): 424-432.

TÜİK (2019a) Turkish Statistical Institute. Capture quantities of other sea products, Fishery Statistics, Ankara. Available at: https://tuikweb.tuik.gov.tr/PreTablo.do?alt_id=1005 (accessed 11 May 2020).

TÜİK (2019b) Turkish Statistical Institute. Landing of other sea products for intended use, 2018 Fishery Statistics, Ankara. Available at: https://tuikweb.tuik.gov.tr/PreTablo.do?alt_id=1005 (accessed 11 May 2020).

Vasconcelos, P., Gaspar, M.B., Joaquim, S., Matias D., Castro M. (2004). Spawning of *Hexaplex (Trunculariopsis) trunculus* (Gastropoda: Muricidae) in the laboratory: description of spawning behaviour, egg masses, embryonic development, hatchling and juvenile growth rates. *Invertebr. Reprod. Dev*. 46: 2-3, 125-138.

Vasconcelos, P., Gaspar, M.B., Pereira, A.M., Castro, M. (2006) Growth rate estimation of *Hexaplex* (*Trunculariopsis*) *trunculus* (gastropoda: Muricidae) based on mark/recapture experiments in the ria formosa lagoon (Algarve coast, southern Portugal). *Journal of Shellfish Research* 25(1): 249-256.

Vasileiadou, A., Karapanagiotis, I., Zotou, A. (2019) UV-induced degradation of wool and silk dyed with shellfish purple. *Dyes and Pigments* 168: 317-326.

Vaz-Pires, P., Seixas, P., Barbosa, A. (2004) Aquaculture potential of the common octopus (*Octopus vulgaris* Cuvier, 1797): a review. *Aquaculture* 238: 221-238.

Vidal, E.A.G., Villanueva, R., Andrade, J.P., Gleadall, I.G., Iglesias, J., Kouetajj, N., Rosas, C., Segawa, S., Grasse, B., Franco-Santos, R.M., Albertin, C.B., Caamal-Monsreal, C., Chimal, M.E., Gonzales, E.E., Gallardo, P., Pabicjj, C.L., Pascual, C., Roumbedakis, K., Wood, J. (2014) Cephalopod culture: Current status of main biological models and research priorities. *Adv Mar Biol* 67: 1-98

Webber, H.H., Riordan, P.F. (1976) Criteria for candidate species for aquaculture. *Aquaculture* 7(2): 107-123.

Williams, A.B. (2007) Systematics and evolution. In: The blue crab *Callinectes sapidus* (eds., Kennedy, V.S., Cronin, L.E.). Maryland Sea Grant College, College Park pp. 1-21.

Williams, M.J., Primavera, J.H. (2001) Choosing tropical portunid species for culture, domestication and stock enhancement in the Indo-Pacific. *Asian Fisheries Science* 14(2): 121-142.

Yang, Z., Yu, H., Yu, R., Li, Q. (2015) Induced metamorphosis in larvae of the veined rapa whelk *Rapana venosa* using chemical cues. *Mar Biol Res* 1000: 584-591.

Yu, Z.-L., Hu, N., Yang, M.-J., Song, H., Hu, Z., Wang, X.-L., Zhou, C., Zhang, Z.-X., Zhang, T. (2019) Environmental water flow can boost foraging success of the juvenile rapa whelk *Rapana venosa* (Muricidae) in aquaculture tanks with still or flowing water: Indication of chemosensory foraging. *Aquaculture* 513: 734392.

Zamora, L.N., Yuan, X., Carton, A.G., Slater, M.J. (2018) Role of deposit-feeding sea cucumbers in integrated multitrophic aquaculture: progress, problems, potential and future challenges. *Reviews in Aquaculture* 10(1): 57-74.

Zhang, T., Song, H., Bai, Y.C., Sun, J.C., Zhang, X.F., Ban, S.J., Yu, Z.L., Yang, M.J., Wang, H.Y. (2017) Effects of temperature, salinity, diet and stocking density on development of the veined Rapa whelk, *Rapana venosa* (Valenciennes, 1846) larvae. *Aquac Int* 25: 1577-1590.

Zmora, O., Findiesen, A., Stubblefield, J., Frenkel, V., Zohar, Y. (2005) Large-scale juvenile production of the blue crab *Callinectes sapidus*. *Aquaculture* 244(1-4): 129-139.

Zolotarev, V. (1996) The Black Sea ecosystem changes related to the introduction of new mollusc species. *Marine Ecology* 17: 227-236.

Disease problems of marine cultured fish in Turkey: Agents, detection and treatments

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Introduction

In the last two decades, with the increasing Aquaculture production, fish health started to be an important subject for aquaculture farms in Turkey. Prophylaxis of fish health begins with ensuring fish welfare. Water quality management must be a priority for aquaculturist. Lack of good management practices will result in immediate fish health problems. New infection agents have been manifested and spread between various fish species continuously. Uncontrolled antibiotic treatments are the best reasoning behind this phenomenon. New in vitro techniques and vaccine technologies are already developed or being researched for treatment and prevention of these diseases (Subasinghe 2009; Roberts 2012).

Fish diseases are divided into two categories as infectious and non-infectious. Infectious diseases affecting marine fish culture in Turkey will be explained in the following sections in this chapter. Academics and representatives of fish health consulting companies compiled this section with a joint effort to combine scientific approaches and field experiences together.

Bacterial diseases

Vibriosis

Vibriosis is known as an epizootic disease, it affects marine and freshwater fish species. It’s a well-known disease, there are lots of Vibrionaceae species which are related to health problems in marine animals. Most common and important *Vibrio* species is *Vibrio anguillarum*, also others *Vibrio parahaemolyticus, V. alginolyticus, V. salmonicida, V. ordalii, V. vulnificus V. harveyi* and *V. campbellii* are infecting aquatic animals. They are Gram negative, straight or curved rods and motile with polar flagella. *V. anguillarum* has 23 serotypes (O1-O23), but only serotypes O1, O2 and O3 are related with mortalities in farmed fish. In cultured fish *V. anguillarum* may occur all throughout the year but mostly encountered in late summer. Mortalities generally were observed higher in cultured younger fish (Silva-Rubia *et al.* 2008; Roberts 2012; Sitja-Bobadilla *et al.* 2014).

In Turkey, *V. anguillarum, V. ordalii, V. alginolyticus, V. vulnificus, V. harveyi* were reported in European seabass. *V. ordalii, V. vulnificus* and *V. harveyi* were reported in gilthead seabream. *V.harveyi* was reported in common dentex, *Dentex dentex* (Türk 2002; Tanrıkul *et al.* 2004; Demircan and Candan 2006; Savaş *et al.* 2006a; Korun and Timur 2008; Çanak *et al.* 2014; Turgay and Karataş Steinum 2016). Vibriosis is still an important problem in Turkey.

Vibrio spp. can be grown on general purpose media with 1-2% NaCl. Beside routine bacteriological methods and biochemical tests, there are various developed PCR protocols which are amplifying the *rpoN* gene, *rpoS* gene, *empA* gene, *amiB* gene, *groEL* gene, a peptidoglycan hydrolase, encoding bacterial chaperonins of *V. anguillarum*. These protocols are very useful especially to differentiate *V. anguillarum* from *V. ordalii* (Demircan and Candan 2006; Kim *et al.* 2008, 2010). Also loop-mediated isothermal amplification method (LAMP) is used for specificity and amplification efficiency (Frans *et al.* 2011). In our country, Çanak *et al.* (2014) showed membrane protein profiles of different serotypes after identification serotype O1 and O2 by slide-agglutination test and SDS-PAGE (sodium dodecyl sulphate polyacrylamide gel electrophoresis) analysis. In another study, transferrin level of European seabass which was affected by pJM1 plasmid of *V. anguillarum*, was investigate for the understanding its role in storing, using and transporting of ferrous iron in blood during Vibriosis infection (Ercan *et al.* 2013).

Antibiotic therapy is an important controlling method in clinical outbreaks, unless fish is not anorexic (Roberts 2012). Against diseases, vaccination is very effective. For successful vaccine production, serotyping methods are very important (Silva-Rubio *et al.* 2008). Generally, *Vibrio anguillarum* vaccines have been used by bath or injection. Also there are polyvalent oil-adjuvanted vaccines which are combinations of *V. anguillarum* with *V. ordalii, V. salmonicida, Aeromonas salmonicida, Moritella viscosa* and infectious pancreatic necrosis virus (Toranzo *et al.* 2009; Muktar *et al.* 2016). Against *V. anguillarum,* a DNA vaccine as using chitosan nanoparticles was used orally in European seabass with 46% protection rate (Kim *et al.* 2008). In another study, a recombinant DNA plasmid encoded the VAA gene of *V. anguillarum* and its potential as a DNA vaccine is under research (Xing *et al.* 2019).

For *V. harveyi,* outer membrane proteins (OMPs) were used with alginates in rainbow trout (*Oncorhynchus mykiss*) (15 g) after 12 weeks of vaccination protection was 90% with ip. route (Arijo *et al.* 2008). For *V. parahaemolyticus,* outer membrane protein K in DNA plasmid were used as antigen in black seabream (*Acanthopagrus schlegeli*) (80g) with 80% protection after 3 week im. vaccination (Li *et al.* 2013).

Photobacteriosis (Pasteurellosis)

Photobacteriosis formerly was known as pasteurellosis. It was isolated first time from white perch (*Morone americana*) and striped bass (*Morone saxatilis*) in 1963. Nowadays, it is one of the most dangerous bacterial diseases in Japan, Europe and Mediterrenean. Pathogen of photobacteriosis is *P. damselae* comprises two subspecies which are *P. damselae* subsp. *piscicida* and *P. damselae* subsp. *damselae*. *P. damselae* subsp. *piscicida*, is a very dangerous and septicaemic bacterial pathogen which is known as the most important fish disease in Photobacteriaceae family in mariculture. It causes summer epizootics with heavy mortality in marine fish during the summer months, serious outbreaks developed at 20-25˚C (Toranzo *et al.* 1991). Nevertheless, there is a study which showed that the disease occured at a low temperature of 18-19°C in Turkey (Korun and Timur 2005). It is responsible for acute fish photobacteriosis worldwide, because of having a very wide host range and widespread antibiotic resistance with lack of efficient vaccines. Also, pathogen was transmitted from fish to fish and surviving in the sea water, and able to infects susceptible fishes. *P. damselae* subsp. *damselae,* infects well known both wild and cultured many marine fish (Roberts 2012; Eissa *et al.* 2018).

In Turkey, *P. damselae* subsp. *piscicida* has been isolated from gilthead seabream and European seabass (Çağırgan 1993; Savaş *et al.* 2006a; Avcı *et al.* 2013; Terceti *et al.* 2016). In a study, after isolation *P. damselae* subsp. *piscicida* isolates had the most sensitivity to florfenicol (30 µg) as 81.25% ratio, and all isolates were resistant to amoxicillin (30 µg) (Avsever *et al.* 2012).

This bacterium is cultured on general purpose media with nutrients and 1-3% NaCl. API-20E system were used for confirmation in diagnosis (Roberts 2012; Eissa *et al.* 2018). Molecular methods have been used efficiently for a rapid diagnosis of photobacteriosis and identification of *P. damselae* subsp. *piscicida*. For separate two subspecies, the multiplex PCR method has been developed based on 16S rRNA and ureC genes. The importance of the methods related to *P. damselae* subsp. *damselae* genome has ureC gene but *P. damselae* subsp. *piscicida* not. However, two subspecies have the same sequence in their 16s rRNA gene (Osorio *et al.* 2000; Essam *et al.* 2016).

In recent studies, *P. damselae* subsp. *piscicida* strains were resistant to ampicillin, cefotaxime, ciprofloxacin, gentamicin, rifampicin and in another study conversely resistant to Erythromycin, Spectinomycin. On the other hand, *P. damselae* subsp. *damselae* strains were resistant to ampicillin, cefotaxime, ciprofloxacin, erythromycin, gentamicin, rifampicin, oxytetracycline, spectinomycin, lincomycin, ampicillin and novobiocin but sensitive to trimethoprim+sulfamethoxazole, oxolinic acid and nitrofurantoine (Labella *et al.* 2010, Essam *et al.* 2016, Eissa *et al.* 2018).

There are some vaccine researches related to photobacteriosis. Non- encapsulated antigen technology is used as oral vaccines experimentally. For *Photobacterium damselae* pathogen, one time vaccines gave the fish by gavage as whole *P. damselae* and extracellular components (antigen) to European seabass (20g) by bath. Whole *P. damselae* supplied 64% protection and extracellular components supplied 55% protection (Bakopoulos *et al.* 2003).

Aeromonad infections

This family represents with especially *Aeromonas salmonicida, A. hydrophila, A. sobria* as fish pathogens. They are Gram negative bacilli. Except *Aeromonas salmonicida*, they are motile by a single polar flagellum (Roberts 2012). *Aeromonas hydrophila*, showed similar pathology, with *A. caviae and A. sobria*. *A. hydrophila* is distributed in generally fresh water and in also marine systems, clean or organically polluted. In addition, it is found in healthy fish intestinal flora (Holmes *et al.* 1996). It causes bacterial haemorrhagic septicaemia. Pathogen can develop on ordinary nutrient media. Colonies are white to buff colour and circular and convex shapes. *A. hydrophila* was isolated from European seabass, gilthead seabream and Atlantic salmon in marine ecosystems (Candan *et al.* 1995; Türk 2002; Savaş *et al.* 2006a). This microorganism causes darkening on skin with large haemorrhages which may be ulcerated and necrotic on skin, ascites in the abdomen and haemorrhages on viscera (Roberts 2012).

Another important *Aeromonas* species is *A. salmonicida* which is called furunculosis of salmonids with high mortalities of Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*). Also it has been isolated from non-salmonid fish, and marine fish gilthead seabream (*Sparus aurata*), Senegale sole (*Solea senegalensis*), Atlantic cod (*Gadus morhua*) and turbot (*Scophthalmus maximus*) (Fernandez-Alvarez *et al.* 2016). However, European seabass was infected by *A. salmonicida achromogenes* in Turkey (Karataş *et al.* 2005). Also, *A. salmonicida* subsp. *salmonicida* was isolated from cultured European seabass (Fernandez-Alvarez *et al.* 2016).

Atypical *A. salmonicida* infections caused loss of appetite, darkening patch on skin and finally mortality like furunculosis. Externally, hemorrhage at fin base and skin lesions or ulcers were seen with pale gills (Karataş *et al.* 2005). In some progressed disease, there were ulcers on the skin and muscle (Fernandez-Alvarez *et al.* 2016).

In further identification, for typical *A. salmonicida*, spesific primers Fer3 and Fer4 were used which was 422 bp of the fstA gene in PCR amplification. Strains were cultured on BD Columbia III Agar with 3% NaCl and 5% Sheep Blood and incubated at 18±1˚C for 24-96 h. (Fernandez-Alvarez *et al.* 2016).

Vaccination trials of *Aeromonas* spp. usually were made for freshwater fish and protection success rate range between 20- 100% (Irie *et al.* 2005; Tu *et al.* 2010; Anuradha *et al.* 2010; Behera and Swain 2014).

Yersiniosis

Yersinia ruckeri is the causative agent of Yersiniosis or enteric redmouth disease (ERM). It is a Gram-negative bacilli or cocobacilli which is facultative anaerobic, non-spore forming with motile or non-motile depending on strain. It is a highly pathogenic bacterium and fresh water pathogen, generally salmonids and also non- salmonid fish like eel (*Anguilla* sp.) and sturgeon (*Acipenser* sp.) are affected. Atlantic salmon (*Salmo salar*) is affected in the freshwater phase and rarely at sea (Onuk *et al.* 2011; Muktar *et al.* 2016).

There are five different serotypes of *Y. ruckeri* strains but especially biotype 1, O1a (Hagerman strain) and O2b (O'Leary strain) are responsible from epizootics (Üstünakın *et al.* 2015). Disease causes hemorrhagic or congestive zones especially around the mouth and in the intestine, also exophthalmus appears. Bacteria reservoir is commonly carrier fish, also aquatic environment and pond mud where it survives for two months (Ryckaert *et al.* 2010). Pathogen can be isolated on general nutrient media (TSA, Columbia blood agar and MacConkey agar) after 24 hours at 22 °C. Colonies are glistening and buff- coloured (Kumar *et al.* 2015).

In Turkey, first isolation was made in a trout farm in 1990. Later this pathogen was isolated in terrestrial pools and sea cages in Black Sea, Turkey, from cultured rainbow trout between 1996-2000 (Balta *et al.* 2005). Also some researchers reported that *Y. ruckeri* were isolated from European seabass (Karataş *et al.* 2004; Savaş *et al.* 2006a; Savaş and Türe 2007).

Clinically congestion was around the oral area with pathognomic lesions. Also, in acute cases there is darkened colour and may be accompanied by mortality (Kawula *et al.* 1996). In necropsy, there are commonly haemorrhagia over visceral organs with swelling and reddening of the kidney and spleen. Histologically in chronic cases, liver, kidney and spleen have necrotic granulomatous areas (Roberts 2012).

In biochemical diagnosis, serological tests and molecular biological techniques are used in combination. Restriction fragment length polymorphism, loop-mediated isothermal amplification (LAMP) and polymerase chain reaction (PCR) have been used (Saleh *et al.* 2008; Bastardo *et al.* 2012). Another diagnostic method is gold nanoparticle-based assays which may be popular because of rapid, direct and sensitive detection from unamplified *Y. ruckeri* nucleic acids in clinical samples (Saleh *et al.* 2015).

Generally, compounds of amoxicillin, florfenicol, oxolonic acid, oxytetracycline, sulphadiazine and trimethroprim are used for treatment (Michel *et al.* 2003). According to some studies, *Y. ruckeri* strains were found resistant to 97,5% ampicillin and 62,8% oxytetracycline (Balta *et al.* 2016), on the other hand, different strains were found sensitive to 100% ciprofloxacin and enrofloxacin (Üstünakın *et al.* 2015).

Commercially available vaccine is formalin inactivated whole cell cultures of *Y. ruckeri* serovar I, Hagerman strain (Toranzo *et al.* 2009; Muktar *et al.* 2016). According to another vaccination, non-encapsulated antigens were used one time or boosted after 4 months, mixed with feed for rainbow trout. As antigen formalin inactivated *Y. ruckeri* or AquaVac ERM Oral (AV) were used with bath. They were used as $5x10^7$ CFU booster dose and $5x10^9$ CFU plus booster after 2 month of vaccination. Protection rates were 80% for AV and 100% for *Y. ruckeri* respectively (Villumsen *et al.* 2014). Also, recombinant flagellin protein of *Y. ruckeri* biotype 1 was used as antigen in a vaccine which made by intraperitoneal route supported 68-72% protection (Scott *et al.* 2013).

Bacterial kidney disease (BKD)

Bacterial kidney disease is caused by a Gram positive diplobacillus short rod bacterium, *Renibacterium salmoninarum* which is aerobic, non-motile, non-spore forming. Disease mostly affects wild and cultured salmonid fishes worldwide (Evenden *et al.* 1993; Muktar *et al.* 2016). The disease was first detected in wild Atlantic salmon (*Salmo salar*) in Scottish farm in 1930. After that similar lesions were observed in cultured fish in both fresh and salt water in North America, Canada, Europe and Japan. However, *R. salmoninarum* is a fastidious pathogen and has been first isolated in 1956 by culturing on cysteine-blood enriched medium (Ordal and Earp 1956; Roberts 2012).

R. salmoninarum needs L-cysteine in the media and produces white to yellowish circular colonies after 1-9 weeks at 15°C. It produces catalase but not cytochrome oxidase. Bacterium lives extracellular and intracellular. Also, its transmission is horizontally by water, digestion of infected food, or vertically by egg from parent which makes control of the vaccine difficult (Wolffrom and Midtlyng 2004).

Pathogen has typically chronic symptoms with low levels of mortality. In farm conditions mortalities are highest in early summer in salmonids. In chronic infection, these lesions become large granulomas. Also, the abdominal cavity fills with ascites and hemorrhage on peritoneum and visceral organs (Savaş *et al.*

2006b; Roberts 2012). Fluorescent antibody test and molecular biology methods became important to confirm the traditional methods. Real-time PCR and ELISA tests are used widely. Also, msa gene amplification by real-time PCR is very useful for detecting *R. salmoninarum* (Chase *et al.* 2006; Suzuki and Sakai 2007).

Pathogen free broodstock and eggs are very important for prophylaxis. Sulphonamide and antibiotic therapy have been used but control is a more profitable attempt (Roberts 2012). There are some different types of vaccines which are bacterins, recombinant vaccines or attenuated live vaccines present but because of the intracellular lifestyle of the pathogen, all these vaccines are questionable (Wood and Kaattari 1996). Recently, a commercial aqueous live vaccine produced from live cells of *Arthrobacter davidanieli* was developed by Novartis, for BKD prevention (Salonius *et al.* 2003). It has been confirmed that the vaccine has long-term protection on Atlantic salmon with a protection rate of 79% and protection period was 24 months after vaccination (Toranzo *et al.* 2009).

Marine flexibacteriosis

Tenacibaculum maritimum was first isolated from farmed European seabass (*Dicentrarchus labrax*) in France (Pepin and Emery 1993), later from Malta and Greece across the Mediterrenean Sea. In Turkey it was isolated from farmed gilthead seabream and European seabass in Aegean Sea, from rainbow trout sea farms in Black Sea and from meagre (*Argyrosomus regius*), turbot (*Scophthalmus maximus*), corb (*Umbrina cirrosa*), sharpsnout seabream (*Diplodus puntazzo*) and snapper (*Sparus pagrus*) (Türk 2006; Van-Gelderen *et al.* 2009; Yardımcı and Timur 2015, 2016).

Clinically, infected fish show erythema and erosion on jaws and operculum, fins, tail rot and on the skin surface. There are characteristic black necrotic patches, branchiomycosis, hemorrhage and erytem on fins and mild exophthalmus in infected fish. Bacteria can be cultured on *Flexibacter maritimus* medium (FMM) with flat and pale coloured colonies. Histopathologically, infected fish showed degeneration and liquefaciens in liver, kidney, and spleen. It is an obligate marine microorganism, Gram negative, slender bacilli, inhabitant of the mucosa of marine animals. Pathogen generally affects young fish from hatchery up to 6 cm. Also it is an important secondary infection factor (Roberts 2012, Yardımcı and Timur 2015).

PCR with universal primers (pA and pH) and specific primers (MAR1 and MAR2) and some serological methods which were slide agglutination, IFAT, ELISA and dot-blot were used for rapid diagnosis of *F. maritimus* (Toyama *et al.* 1996; Avendano- Herrera *et al.* 2004; Yardımcı and Timur 2015, 2016).

There was some attempt to develop a vaccine of this pathogen. A developed vaccine had a higher survival value as 94% in laboratory trials by i.p. injection for cultured sole (*Solea solea*) (Romalde *et al.* 2005).

Mycobacteriosis

Mycobacterium marinum is a straight or slightly curved and nonmotile Gram positive rod. Although they are not stainable by Gram staining, they are considered as Gram positive (Chinabut 1999).

M. marinum is a wide effective and highly lethal pathogen for a variety of cultured and wild fish species. Also, there were reported epizootics in few human infections (Jacobs *et al.* 2009). Diseases known as swimming pool granuloma in humans and it was reported from persons who worked in tropical fish aquariums. Bacterium was first diagnosed from marine aquarium fish in Philadelphia in 1926. *M. marinum* is a slow growing microorganism and generally it infects tropical marine and freshwater fish. (Roberts 2012). *Mycobacterium* spp. are cultured on Lowenstein-Jensen media and produces yellow-orange coloured, photochromogenic acid-fast colonies in 3-4 weeks (Timur *et al.* 2015; Ürkü *et al.* 2018). Disease transmission can be from fish to fish by release of infected materials. Also, infected water, feed and external parasites are infection routes. However, transovarian passage is known to be possible (Ramsay *et al.* 2009).

In Turkey, cultured European seabass was infected by *M. marinum*, showed lethargy, low appetite, slow moves at the surface. Clinically, loss of scale, hemorrhages on fin, operculum and ocular, pale gills and exophthalmus were seen. Internally, the liver, spleen and kidney were pale with grayish-white nodules. Splenomegaly, hepatomegaly, and abdominal swelling were observed (Korun *et al.* 2005). *Mycobacterium marinum* was isolated from affected meagre which had growth problems, cachexia, ascites, exophtalmia, pale gills and high mortality (Timur *et al.* 2015). *Mycobacterium frederiksbergense* were isolated in a seabream farm in Turkey. Fish (15- 20 g) were seen clinically lethargic with inhibited growth and pale skin, dorsal fin necrosis, and high level of mortality (40%). Internally, there were not any findings in the visceral organs. Histopathologically, acid-fast bacteria were identified from liver, kidney, spleen, and heart tissue (Ürkü *et al.* 2018).

For *Mycobacterium marinum* ZN positive isolates identification, line probe assay and 16S rRNA and hsp65 gene sequencing analyses were used (Timur *et al.* 2015; Ürkü *et al.* 2018). There are no treatments and only destroying of fish is accepted (Roberts 2012).

Rickettsia-like organisms Infections

Rickettsia or rickettsia-like organism (RLO) is a Gram negative and obligate intracellular microorganism. It is distributed worldwide amongst many fish species and the ecosystems. Disease known as salmon rickettsia syndrome and was demonstrated in salmonids during marine stage and freshwater rainbow trout with lesions which are red marks (Roberts 2012).

In Europe, RLO infected juvenile European seabass (*Dicentrarchus labrax*) clinically showed abnormal swimming related to nervous tissue necrosis with high mortality for the first time in 1994 (Comps *et al.* 1996). Another infection in European seabass was seen in Greece with 30% mortality in hatcheries and 80% mortality in cages (Athanassopoulou *et al.* 2004). In Turkey first observation of rickettsia- like organisms was reported in cultured European seabass in Black Sea (Timur *et al.* 2005).

Clinically signs can be acute or chronic. In peracute, there are no external differences. Chronically affected fish showed lethargy, anorexia and dark colouring with ulcerative lesions. Also pale gills, discoloured liver, enlarged spleen, swollen kidney with haemorrhages on viscera and on muscle were observed. Especially, white to yellow diffuse nodules and microscopic granulomas can be seen on the kidney, liver, and spleen with hemopoietic tissue necrosis (Mauel *et al.* 2003; Timur *et al.* 2005, 2013; Roberts 2012).

For treatment, quinolones are useful in normal injection. Vaccination is important for vulnerable stocks (Roberts 2012).

Shewanella infections

Shewanella spp. is a Gram negative and oxidative fish pathogen genus. Pathogen generally represents *Shewanella putrefaciens. S. putrefaciens* is a Gram negative, motile rods, oxidase, catalase positive, H_2S produce and sensitive to the vibriostatic agent O/129 (150 µg). It grew well on solid media like MacConkey Agar. It produces 1-2 mm yellow-brown colonies after 18-24 h (Holt *et al.* 2005).

Although it is distributed in marine and freshwater environments, it is generally isolated from sea water and putrefied fish. It is a zoonotic microorganism (Stenstram and Molin 1990; Chen *et al.* 1997). In Turkey, it was first reported from European seabass in Aegean Sea (Korun *et al.* 2009) and from rainbow trout in Trabzon (Kayış *et al.* 2009).

Clinically there was lethargy with loss of appetite, pale gills, exophthalmus, ulcers on the body and haemorrhages on the fins and operculum. In necropsy there were liver haemorrhages, spleen enlargement with pale of spleen, liver and kidney and empty gastro-intestinal tract and ascites in the abdominal cavity. For identification, strains streak onto TCBS with 0-7% NaCl at 4, 22 and 37°C. Isolates were hemolysis positive on sheep blood (Korun *et al.* 2009). Based on 16S rRNA gene sequences, bacteria were clustered into groups *S. putrefaciens, S. xiamenensis* and *S. oneidensis*. ERIC-PCR was used for advanced typing (Pazdzior *et al.* 2019).

Staphylococcal infections

According to Bergey's Manual of Systematic Bacteriology, *Staphylococcus* sp. is Gram positive coccus, not producing spores, aerobe or facultative anaerobe, catalase positive and mesophile microorganism genus belonging to Micrococcaceae family. They grow on media which includes 1% NaCl at 18-40°C (Smeltzer and Beenken 2013). Under microscope, isolates were seen as Gram positive cocci, which were single cells or irregular grape-like clusters.

S. epidermidis has been the most reported strain from both marine and freshwater fish. Generally, epizootics have been reported from fish farms in red seabream (*Chrysophrys major*) and yellowtail (*Seriola quinqueradiata*) in Japan, grass carp (*Ctenopharyngedon idella*) and tilapia (*Oreochromis* spp.) in Taiwan and seabream (*Sparus aurata*) and European seabass (*Dicenthrarchus labrax*) in Greece (Huang *et al.* 1999).

In Turkey *S. epidermidis* and *Staphylococcus hominis* were isolated from cultured seabream (Kubilay and Uluköy 2004; Yılmaz *et al.* 2017). Also, in a study *S. capitis* subsp. *capitis, S. epidermidis, S. lentus* and *S. aureus, S. hominis* subsp. *hominis* and *S. sciuri* subsp. *sciuri* were isolated from cultured gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*) and sharpsnout seabream (*Diplodus puntazzo*) (Çanak and Timur 2017). In addition, *Staphylococcus cohnii* subsp. *cohnii* was isolated from common dentex (Akaylı *et al.* 2011). Also, *S. iniae, S. agalactiae, S. cobuii, S. lentus, S. schleiferi* and *S. warneri* were isolated from seabream (Yılmaz *et al.* 2017).

Clinical symptoms of *Staphylococcus spp.* are lethargy, haemorrhages on the pectoral and caudal fins, darkened colour on the skin, hyperplasia in the gill filaments, hemorrhages in the eye and increased secretion of mucus from the skin and gills with anemia. Internally, ascites in the abdomen, enlarged spleen and liver with pale colour, showed congested blood vessels and dark areas (Kubilay and Uluköy 2004; Akaylı *et al.* 2011; Yılmaz *et al.* 2017; Çanak and Timur 2017). After determination of the phenotypic characteristic, 16S rDNA sequencing analysis with universal primers (B27F and U1492R) can be used for verification (Yılmaz *et al.* 2017).

Viral diseases

Lymphocystis is the first described virus in seabream in 1991 (Candan 1991). Affected fish have largely nodules on their body surface. The virus is known as a secondary infection agent. But today, it is still effectively causing deaths. In 2012, studies on molecular diagnosis were started by a private enterprise and are still ongoing.

Viral hemorrhagic septicemia (VHS) or Egtved disease is observed in seabass and turbot in Turkey (Işıdan and Bolat 2011; Albayrak *et al.* 2018). This viral disease occurs in cold-water conditions between 7-11 °C and shows high mortality. Identification of the virus were made by culture in EPC and RTG-2 cell lines a confirmation with immunoperoxidase test (IP), immunofluorescence test (IFT) and enzyme linked immunosorbent assay (ELISA) in turbot fry (Kalayci *et al.* 2006). In another study, VHS virus isolates were genetically analysed for determination of proximity (Albayrak *et al.* 2018).

Viral erythrocytic infection (VEN) occurred only once in cultured European seabass in Black Sea in 2008 (Timur *et al.* 2008). Also once, infectious pancreatic necrosis (IPN) virus was isolated from rainbow trout that was cultured in cages in the Black Sea (Ogut and Altuntas 2012). Nowadays, there are some DNA vaccines for viral diseases, but no treatments.

Parasitic diseases

Parasites show variability according to the species (Table 1) and region.

Arthropoda

Isopoda infestation

In European seabass, the mature form of parasitic isopod species is usually seen in pairs in the caudal region and caudal fin. Larval stages are found in the mouth and opercular space. The most common Isopod species, *Ceratothoa oestroides,* can proliferate throughout the year in Turkey. Parasites in larval stage can be found in the mouth cavity of European seabass. Young forms of parasites can be usually found in the oral cavity, also at the head of the fish, behind the eyes and operculum, on the gills, on the border of the lateral line, on the caudal fin or in the caudal pendulum. They cause severe tissue destruction and necrosis in the areas where they settle on the fish (Papapanagiotou and Trilles 2001). Although the article also observed that in the bream, isopods are seen mostly in European seabass in Turkey. Effective treatment is carried out with preparations called Emamectin benzoate.

Lernanthropus infestation

It is a parasite living in the gills of the European seabass. Necrosis of epithelial tissue and sometimes connective tissue causes an increase in mucus secretion. The most characteristic features of the Lernanthropidae family parasites is that third feet of the gill filament clings to the capillary vessels, while narrowing, cracks and splits (Manera and Dezfuli 2003; Tokşen *et al.* 2008; Khidr *et al.* 2014). Since Emamectin benzoate has been used widespread periodically, Lernanthropus infestation rate decreased significantly in Turkey.

Monogenean ectoparasites

There are different kind monogeneous parasites in European seabass and gilthead seabream. They can be treated with different administration of chemotherapeutics (Table 2)

Dactylogyrus infestation

Dactylogyrids are often found in freshwater and marine fish, although gill parasites are common in freshwater fish. They are ovipar and settle in the gill tissue. The parasites reach up to about 1 mm. They have a symmetrical and dorsoventrally flattened structure. There are 2 central hooks and 14 small hooks behind the body. There are 4 protrusions and 4 eye points on the front of the body that are capable of pulling back and forth. Their bodies are capable of contracting and loosening and can therefore extend twice as long (Bruno *et al.* 1995; Purivirojkul 2012). They are commonly seen in cultured seabream in Turkey. The incidence varies depending on the fish density, water quality and the presence of secondary infections. Formaldehyde can be easily treated with hydrogen peroxide baths.

Microcotyle infestation

It is found in the gills of seabream. Anorexia, lethargy, swimming on the water surface and occasional splashes are seen. Parasitic feeding on epithelial tissue, blood and mucus causes anemia of gills to appear and fusion of gill lamellae (Sitja-Bobadilla and Alvarez-Pellitero 2009). Dying seabream fish are very weak and have difficulty breathing. The cause of death in fish infected with Microcotyle species is anemia. The average length of the parasite is 3-5 mm and the width is 0.5-0.7 mm. There are hooks on the tail (Bruno *et al.* 1995; Vico *et al.* 2008). It covers more surface area of the gills than the other monogeneous parasites. Its damage is high and difficult to treat. In Turkey, parasites are treated orally with garlic extract food additives which are believed to be more effective than bath administration.

Protozoan ectoparasites

Protozoan ectoparasites are the most common parasites observed in cultured fish and also frequently found in fish in nature. Protozoan ectoparasites; mainly infest the uppermost layer of skin, ie, ciliates and flagellates fed by the epithelium. Clinical findings are due to damage caused by the feeding activity of the parasite. The parasites are destructive, which can cause symptoms such as hyperactivity. This destruction often results in increased mucus production and blurred appearance in the skin or eyes. Protozoan ectoparasites have a direct life cycle that is faster at high temperatures (Noga 2010).

Cryptocaryon infestation (marine ich)

Cryptocaryon irritans are considered to be the marine form of *Ichthyophthirius multifilis* (Wright and Colorni 2002). It causes white spots on skin. The parasites are slightly smaller than the ich and therefore appear as slightly smaller nodules. Skin lesions may appear more like multifocal white spots, sometimes discrete white spots (Lom 1984). It completes its life cycle in as little as 6 days. 200 to 300 theront can be produced from a tomont. The causative agent of cryptocaryon is most easily diagnosed when seen in subcutaneous or gills. It does not have a C-shaped macronucleus. Histopathological sections show a granulated macronucleus with a large cytoplasm consisting of four bead-like sections connected to each other. Multi-granular macronuclei are seen in native examinations (Yanong 2017). Cryptocaryon infestation responds well to copper treatment. Rather than offshore facilities in the sea, it is more common in fish that are cultivated in earthen ponds.

Trichodina infestation

Trichodina is a parasite that causes infestation in many marine or freshwater fish. There is no host specificity. The most common cilliate in seabream and seabass in Turkey. Many species cause infestation in both the skin and the gills. Trichodina infestation is a relatively mild disease, usually associated with chronic morbidity or mortality (Hoffman 1999). However, in some cases it can cause significant losses, especially in young fish. Excessive mucus production is seen in the skin. In severe cases, it leads to skin ulceration and breathing difficulties (Bruno *et al.* 1995). Microscopic appearance of the parasite is in the form of a tea plate and sills surround the entire body. When viewed from above, there is a hooked part called a toothed ring. The number, shape and body size of the teeth in this section are used for determination of lineage and species. On the other hand, it can be seen as a circle, a dome or a hat (Noga 2010). Trichodinas easily destructible by application of formaldehyde, hydrogen peroxide baths. If the water quality is improved, the fish can usually recover without the use of chemicals, depending on the intensity of the infestation.

Chilodonella infestation

Two species of the genus Chilodonella (*C. piscicola* and *C. hexasticha*) are pathogens. Chilodonella infestation is more insidious than ich. Because the pathological findings can cause serious problems before they become clear. They penetrate host cells with cytosomes and feed on their contents by absorbing them (Wiles *et al.* 1985; Bowater and Danoghue 2015). In advanced Chilodonella infestations, the skin may have a rough appearance. High numbers of Chilodonella agents can cause secondary bacterial infections and serious deaths. Outbreaks are observed highest at 25 °C. Edema and hemorrhages are observed in the gills (Basson and Van As 2006; Padua *et al.* 2013). Generally, the body structure of the parasite is seen as oval. Its average size is 60x45 µm and it is covered with cilia. It has two nuclei, one macro and the other micro. The macronucleus is egg-shaped and the micronucleus is round and variable. In native examination preparations, the Chilodonella agents slowly glide over the gill lamellae, sometimes drawing large circles. It is distinguished by the flatness of the shape of its holotrics (Noga 2010; Bowater and Donoghue 2015). In Turkey, it has been observed in mostly 200-250 g weighing European seabass that is cultured in offshore net-pens, accompanied with other protozoan ciliate. Formaldehyde and hydrogen peroxide bath administrations are used for easily destroying it.

Scuticociliate (uronema) infestation

It is a serious problem for turbots and European seabass in the Mediterranean (Munday *et al.* 1997). It is mostly observed in earthen pond cultured fish in Turkey. The most common Scuticociliate species, *Uronema marinum* and *Philasterides dicentrarchi*, cause infestation in seabream and European seabass (Iglesias *et al.* 2001; Kim *et al.* 2004). Unlike typical ectoparasitic protozoa, Scuticociliate agents often invade internal organs and cause deep ulcers (Ramos *et al.* 2007). Skin hemorrhage, necrosis and gill telangiectasis is observed. Even if skin lesions are present, the agents may not be present in the sections prepared from the skin, as the agents may be deep. Therefore, it is necessary to make histopathological sections from sublayer muscle tissue or take samples from internal organs and brain (Kim *et al.* 2004). It responds better to copper preparations in treatment.

Amyloodinium infestation (sea velvet disease)

Amyloodinium infestation, which is widespread all over the world, is one of the important diseases of warm water marine fish (Noga and Levy 2006). It is an active species of dinoflagellate. Especially for cultured fish in earthen ponds, it is one of the biggest problem in Turkey. Typical dinoflagellate morphology occurs only during the propagation (dinospor) stage. The life cycle is almost the same as that of *Ichthyophthirius multifilis*. Trophonts bind to and feed on the epithelium of the host. The protoplasmic extension of *Amyloodinium ocellatum* clings to the skin and gills of fish like the root of a tree, affecting epithelial cells and causing tissue disintegration. Gills are usually the primary site of infestation. It can also be observed in the skin and eyes in severe infestations. In this case, a dusty appearance may occur on the skin (velvet disease). However, fish usually die without skin lesions. The parasite is flagellated during the free swimming phase and then loses its flagellas when it is attached to the fish. Definitive diagnosis can be made easily by identification of trophozoid and trophonts in biopsies or by histopathological sections (Bower *et al.* 1987). *Amyloodinium ocellatum* is a very high virulence parasite. The free-floating dinospor form is sensitive to drugs, but trophont and tomont forms are resistant and make eradication difficult. Tomonts tolerates the levels of copper 10 times that are toxic to dinospores. Periodic examination after post-treatment is recommended for reinfestation risk.

Ichthyobodo (Costia) infestation

Ichthyobodo necator (formerly *Costia necatrix*) is one of the smallest (such as size of erythrocyte) ectoparasites that infect fish. It is the size of erythrocytes. The agent is particularly dangerous for young fish and can attack healthy fry and eggs (Noga 2010). There are two forms of Ichthyobodo agents: tissue-bound and free-floating motile. The mobile form has two or four flagellas that allow movement of the parasite and are difficult to see. When the parasite is fed on the fish, it binds to the epithelium within a few minutes by curling up in a piriform form. The free-floating form makes a characteristic vibratory movement when it moves, which is due to the rotation of its hull in a crescent shape. The Ichthyobodo agent leaves the dead host very quickly, making it difficult to see the parasite density in histopathological sections (Isaksen *et al.* 2007). In Turkey, it can be seen in all sizes of fish. If there are bacterial agents such as *Flexibacter* sp. in fish gills, mortality can be high. Due to its small size, formaldehyde affects them easily with hydrogen peroxide by bath.

Cryptobia infestation

Cryptobia branchialis, which is one of the most common species in salty and fresh waters, is a parasite with a drop form. It has weak virulans. The causative agent can also be found in the blood and remains alive even if fish died. Provides superficial adhesion to gill tissue with its flagella. The best examination is done by wet preparations prepared from the kidney (Bruno *et al.* 1995; Noga 2010). Immediately after the parasite dies, the parasite begins to swell with water, making the diagnosis difficult. The agent has a large nucleus. In Turkey, it is a common infestation for seabass weighing over 250 grams. Cryptobia agents in gills are easily treated with formaldehyde.

Epistylis infestation

Epistylis agents; common, stemless, colonial, ectocommensal, ciliate pathogens. It is generally thought to be associated with Gram-negative bacterial infections. It is more commonly observed in warmer months. Like other ectocommensal protozoa, they feed on bacteria and other small foodstuffs found in water. They use the fish as a surface to stick to. The presence of Epistylis agents is therefore indicative of contaminated water with a high concentration of bacteria. Epistylis agents can also live freely, but some species can only colonize cachectic fish (Foissner *et al.* 1985). It is a ciliate that attaches to the skin or fins of the host. By secreting proteolytic enzymes, it creates a wound in the area of attachment and prepares an environment for bacterial infection. Epistylis agents cause white or hemorrhagic lesions on the fins, on the bone ends such as the jaw or gill cover, the rim and the gills. Recent lesions may appear similar to fungal infections (Padua *et al.* 2016). Epistylis agents have long stalks with no contraction properties and an inverted bell-shaped body. Other peritric agents such as vorticella, zoothamnium and carchesium are contractile and branched (Noga 2010; Pala *et al.* 2018). Mostly it has been seen in fish in the hatchery stage, especially in European seabass in Turkey. Parasites are susceptible to formaldehyde and hydrogen peroxide.

Myxosporidia infestation

There are a large number of genera and species, most of which are fish parasites of the Myxosporea class. Some species are common species known for freshwater fish, but marine fish that have been cultured in recent years also have a large number of Myxosporean parasites. The most common species in marine fish; *Ceratomyxa, Enteromyxum, Kudoa, Lepthoteca* and *Sphaerospora* (Le Breton *et al.* 1999). Most frequently isolated Myxospore species in Turkey; *Ceratomyxa labracis, C. diplodae, C. sparusaurati, Enteromyxum leei, Sphaerospora dicentrarchi, S. sparis* and *S. testicularis*. *Enteromyxum leei* has been seen in seabream and more common in fish reared in earthen ponds in Turkey. Factors that are mostly present in the bile fluid affect muscle quality due to the staining of the muscles with the bile fluid in the fish in the packaging stage. Preparations such as levamisole and amprolium are treated with salinomycin or sulfonamides.

Coccidia infestation

There are many species of Coccidia that have been seen in marine and freshwater fish, but their pathological effects are very variable for aquaculture. In the seabream, mostly *Cryptosporidium molnari, Eimeria sparis* and *Goussia sparis* are seen, while the European seabass is affected by *E. dicentrarchi* and *E. bouixi*. In recent studies on European seabass, the most commonly isolated species is *C. molnari* (Le Breton *et al.* 1999). The diagnosis of fish coccidiosis agents is mainly based on native examination and histopathological controls. Preparations of Levamisole and Amprolium are used for treatment.

Fungal Diseases

Lately, there have been few studies published about fungal pathogens in marine fish. These studies showed that fungal diseases could be seen in economically important fish species as a primary or secondary disease. Most fungal agents have a saprophytic or parasitic lifestyle. Taxonomically they are separated two groups, Fungi and Oomycetes. Oomycetes is a more important group as fish pathogens (Neish and Hughes 1980; Daugherty *et al.* 1998).

Table 1. Parasite species that affect marine fish in Turkey

Parasites name	Class	Host
Isopoda spp.	Arthropoda	*D. labrax*
Lernantrophus spp.	Arthropoda	*D. labrax*
Diplectanum spp.	Monogenea	*D. labrax*
Dactylogyrus spp.	Monogenea	*S. aurata*
Furnestinia spp.	Monogenea	*S. aurata*
Microcotyle spp.	Monogenea	*S. aurata*
Cryptocaryon spp.	Protozoa	*D. labrax* and *S. aurata*
Trichodina spp.	Protozoa	*D. labrax* and *S. aurata*
Chilodonella spp.	Protozoa	*D. labrax*
Scuticociliate spp.	Protozoa	*D. labrax*
Amyloodinium spp.	Protozoa	*D. labrax* and *S. aurata*
Ichthyobodo spp.	Protozoa	*D. labrax* and *S. aurata*
Cryptobia spp.	Protozoa	*D. labrax* and *S. aurata*
Epistylis spp.	Protozoa	*D. labrax* and *S. aurata*
Myxosporidia spp.	Protozoa	*D. labrax* and *S. aurata*
Coccidia spp.	Protozoa	*D. labrax* and *S. aurata*

Table 2. Therapeutics used for parasite infestations in Turkey (MacMillan 1991; Athanassopoulou *et al*. 2009)

Pathogens	Therapeutics	Administrative Route	Dosage
Arthropoda	Emamectin benzoate	Oral	50 µg/kg x 10 days
Monogenean	Formaldehyde	Immersion	200 ppm x 1 hr
	Hydrogen peroxide	Immersion	500-1500 ppm x 30 min
	Food additives with garlic extract	Oral	3 kg/ tonne food
Protozoan	Formaldehyde	Immersion	100-250 ppm x 1 hr
	Hydrogen peroxide	Immersion	500 ppm x 30 min
	Copper Sulphate	Immersion	0.75 ppm x every other day during 2 weeks
	Levamisole	Oral	100 g/ tonne weight
	Amprolium	Oral	190 g/ tonne weight
	Salinomycin	Oral	5 mg/ kg food x 14 days
	Sulphonamides	Oral	30 mg/kg food x 10 days

Saprolegniasis

Saprolegnia parasitica was isolated in seabream, seabass and meagre (Abou El-Atta and Saleh 2010; Dinçtürk *et al.* 2018). Generally, it has been seen as a secondary pathogen causing skin lesions, especially after skin trauma and handling stress, and during some life stages for example smolting and spawning. In addition, polluted environment conditions and other pathogens induce the disease. Clinically, skin lesions are focal and generally white cotton wool-like appearance and grey patches. Disease agents can be cultured on specific Sabouraud agar. In Turkey, molecular identification techniques are used for this pathogen isolated from European seabass and meagre (Dinçtürk *et al.* 2018, 2019). For protection, good husbandry and environment conditions are important. Also for treatment copper sulphate, formalin, potassium permanganate and salt can be used (Willoughby and Roberts 1992; Dinçtürk *et al.* 2019).

Rosette-like agent

Due to morphological similarities with the rosette, *Sphaerothecum destruens* was initially referred to as a "rosette-like agent". This intracellular pathogen belongs to Mesomycetozoean and it was first described from Chinook salmon held in seawater net pens in Washington State. It was responsible for disease outbreaks in salmonids with losses of over 90% in North America. (Harrell *et al.* 1986; Gozlan *et al.* 2009). *Sphaerothecum destruens* causes chronic but steady mortality in adult salmon. Fish to fish transmission may occur when infected fish release the parasite with whole body fluids or shedding from the gut, skin and gills epithelium. The pathogen has an extracellular, motile zoospore stage which could spread to naïve hosts (Arkush *et al.* 1998, 2003). Although it has slow-growing nature in the fish, parasitism results in host cell death and often causes widespread degenerations of various tissues such as kidney, gonad, spleen and liver. Especially, macroscopical nodules can be seen in the kidney. In Turkey, *S. destruens* was detected in cultured seabass in earthen ponds at Milas in 2012 (Ercan *et al.* 2015) (Figure 1). Diagnosis was made by histopathologically, nested PCR with ITS genes and after that sequencing analysis (Figure 2). After this date, occasionally, it has been detected in seabass at the same region especially mid-autumn. Unfortunately, there is no treatment yet.

Conclusion

For healthy fish, monitoring, disease control, accurate detection of pathogens, prompt and correct treatment are essential. Dietary supplementation with probiotics (beneficial microbes) and prebiotics (nondigestible substances but necessary for bacterial growth) can improve fish health by stimulating the immune system. The microbial colonization, establishment and diversity in the gastrointestinal tract of fish starts immediately after hatching and is completed within a few hours. Gastrointestinal microbiota is variable from individual to individual. Probiotics in diets can colonize in the gut and interact with the immune cells to enhance innate immune responses in fish. Fructooligosaccharide, transgalactooligosaccharide, inulin and mannan oligosaccharide are most commonly used prebiotics as the dietary supplementation of fish and crustacean species to promote growth of probiotics (Geraylou 2018).

In Turkey, probiotics, herbal immunostimulants and vitamins are readily included in the feed. But sometimes the feed content ratio may change due to increased costs. Frankly, food quality is important for fish health. Especially the first six months of fish life, DHA and EPA is the most important food source for innate immunity. Fish larvae and fry are most susceptible to disease agents because specific immune system development in early life is incomplete. Regular and adequate dietary supplements can support the development of fish's immune system and as a result increase resistance to diseases.

There are different types of vaccines in fish culture. These can be classified as killed vaccines, attenuated vaccines, DNA vaccines, recombinant technology vaccines, and synthetic peptide vaccines (Assefa and Abunna 2018). Although already licensed vaccines are safe because of inactivated pathogens, there is very big interest for the use of non-encapsulated (inactivated) bacteria, yeast or plants expressing bacterial or viral antigens in many studies. Besides mentioned vaccines, there are other vulnerable vaccine technology products like DNA plasmids, purified recombinant proteins and sub-unit vaccines which need protection to prevent breakdown and ensure antigen uptake in the gut of fish. There are some studies about non-encapsulated antigens technology which can be used as oral vaccines at experimental stages (Embregts and Forlenza 2016). In Turkey, DNA vaccines are not used but oil adjuvant and polyvalent vaccines are commonly used for fish before they are transferred to net pen and during on-growing.

Figure 1. Lesions on the body of seabass infected with *S. destruens* (Photo: D. Demircan).

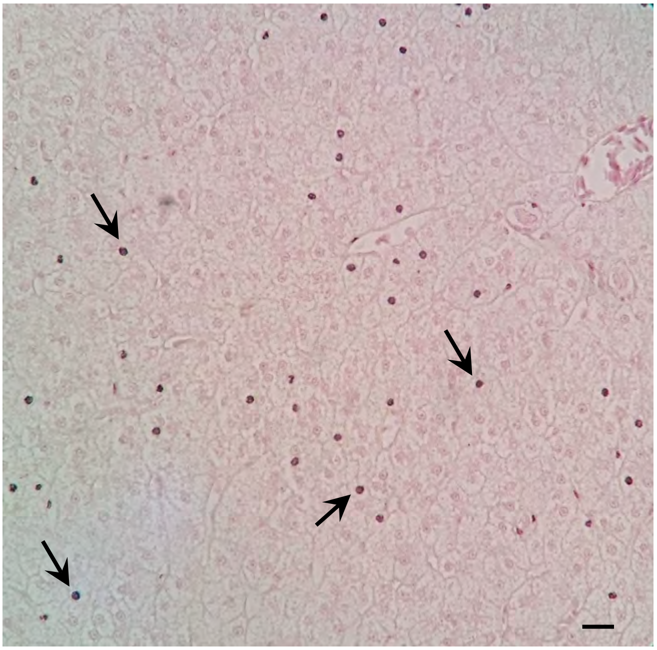

Figure 2. *D. labrax* liver section stained with H&E, arrow indicates *S. destruens* spores, Scale bar 20µm (Photo: D. Demircan).

Diseases can occur despite all preventions. Diagnosis needs to be achieved rapidly as soon as the disease is realized. In the routine, microbiological methods are used for detection and identification of fish pathogens. Molecular identification by polymerase chain reaction (PCR) is the most common technique and used for DNA replication in vitro. It provides very fast and accurate diagnosis but it is suggested to be used in tandem with biochemical identification methods. In 2012, a private enterprise started using PCR methods for detection of fish pathogens in Turkey. Following, another attempt was made with using Loop Mediated Isothermal Amplification (LAMP) technique for detection of fish pathogens in 2016 by Özge Otgucuoğlu. This technique is designed to perform, display, finalize and report isothermal DNA amplification in real time (Figure 3). With all stages, pathogen can be identified in less than 2 hours. Pure DNA is obtained by DNA extraction in 15 minutes, DNA amplification, verification and reporting is performed using pure DNA in 45 to 60 minutes. It can work with 16 samples at the same time (Figure 4), with minimum equipment requirement and minimum contamination risk with capped strips. GENIE's portable form provides maximum suitability and instant diagnosis. Genie is used for detection of *Vibrio anguillarum, V. harveyi, V. vulnificus, V. alginolyticus, Aeromonas hydrophila, A. veronii, Tenacibaculum maritimum, Photobacterium damselae, P. damselae* subsp. *piscicida*, Lymphocystis, IPN and VHS at present in her company's laboratory.

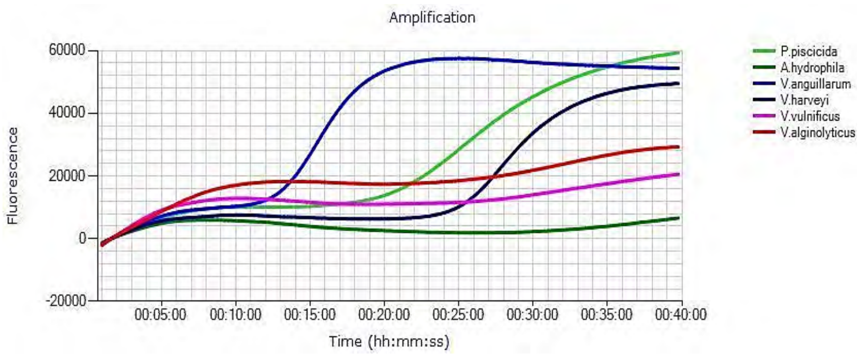

Figure 3. Real-time monitorable amplification graphic of LAMP methods by equipment (Photo: Ö. Otgucuoglu)

Figure 4. The equipment for LAMP method (Photo: Ö. Otgucuoglu)

After the diagnosis, therapy starts with proper antibiotics or chemotherapeutants. However, because of the prohibitions imposed by the quality certification systems (GLOBAL GAP, ASC) that support the export leg of the sector and the factors prohibited because of its use in human medicine, the bacterial treatment option has started to decrease day by day. In Turkey, there are few therapeutic agents (amoxicillin trihydrate, emamectin benzoate, enrofloxacin HCl, florfenicol, gentamicin, oxytetracycline HCl, sulfadiazine+trimethoprim) licensed for fish by ministry of agriculture and forestry in 2019. But antibiotics should be used on time with proper dosage and duration. When the disease occurs, if environmental conditions can't be improved, the treatment will be insufficient. After 20 days, reinfection can occur with higher virulence because the pathogen has gained resistance to the antibiotic. Already, there are restrictions on the use of antibiotics all over the world due to resistance development and as we mentioned before, solutions with preventive medicine are researched.

References

Abou El Atta, M.E., Saleh, O.A. (2010) Study on some diseases problems facing the culturing of meagre (*Argyrosomus regius*) fish in Domieta Governorate. *Abbassa Int J Aqua* 3(1): 231-245.

Akaylı, T., Ürkü, Ç., Başaran, B. (2011) Infection of *Staphylococcus cohnii* subsp. *cohnii* in cultured fishes. *J Fish Aquat Sci* 26: 1-12 (in Turkish).

Albayrak, H., Isidan, H., Kalayci, G., Ozan, E., Vakharia, V. (2018) Genetic analysis of the complete G gene of viral hemorrhagic septicemia virus (VHSV) genotype Ie isolates from Turkey. *IJFS* 17(1): 67-73.

Anuradha, K., Foo, H.L., Mariana, N.S., Loh, T.C., Yusoff, K., Hassan, M.D., Sasan, H., Raha, A.R. (2010) Live recombinant *Lactococcus lactis* vaccine expressing aerolysin genes D1 and D4 for protection against *Aeromonas hydrophila* in tilapia (*Oreochromis niloticus*). *Journal of Applied Microbiology* 109: 1632-1642.

Arijo, S., Brunt, J., Chabrillon, M., Diaz-Rosales, P., Austin, B. (2008) Subcellular components of *Vibrio harveyi* and probiotics induce immune responses in rainbow trout, *Oncorhynchus mykiss* (Walbaum), against *V. harveyi*. *J Fish Dis* 31: 579-590.

Arkush, K.D., Frasca, S.J., Hedrick, R.P. (1998) Pathology associated with the rosette agent, a systemic protist infecting salmonid fishes. *J Aquat Anim Health* 10: 1-11.

Arkush, K.D., Mendoza, L., Adkison, M.A., Hedrick, R.P. (2003) Observations on the life stages of *Sphaerothecum destruens* n. g., n. sp., a Mesomycetozoean fish pathogen formerly referred to as the rosette agent *J Eukaryot Microbiol* 50: 430-438.

Assefa, A., Abunna, F. (2018) Maintenance of fish health in aquaculture: Review of epidemiological approaches for prevention and control of infectious disease of fish. *Veterinary Medicine International* 2018: 1-10.

Athanassopoulou, F., Sabatakou, O., Groman, D., Prapas, T. (2004) Pathological and epidemiological observations on rickettsiosis in cultured sea bass (*Dicentrarchus labrax* L.) from Greece. *J Appl Ichthyol* 20:525-529.

Athanassopoulou, F., Pappas, I.S., Bitchava, K., Rogers, C., Basurco, B. (2009) An overview of the treatments for parasitic disease in Mediterranean aquaculture in the use of veterinary drugs and vaccines in Mediterranean aquaculture. *Options Méditerranéennes* 86: 65- 83.

Avcı, H., Birincioğlu, S.S., Epikmen, E.T., Dereli, M. (2013) Comparative histopathological and immunohistochemical evaluations in juvenile sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*) naturally infected with *Photobacterium damselae* subsp. *piscicida*. *Revue de Medecine Veterinaire* 164 (2): 72-79.

Avendano Herrera, R., Magarinos, B., Toranzo, A.E., Beaz, R., Romalde, J.L. (2004) Species-specific polymerase chain reaction primer sets for the diagnosis of *Tenacibaculum maritimum* infection. *Dis Aquat Org* 62: 75-83.

Avsever, M.L., Onuk, E.E., Türk, N., Tunalıgil, S., Eskiizmirliler, S., İnçoğlu, Ş., Yabanlı, M. (2012) Pasteurellozis cases in sea bass and sea bream cultured in the Aegean region and other bacteria isolated from these cases. *Bornova Veteriner Bilimleri Dergisi* 34(48): 9-16.

Bakopoulos, V., Volpatti, D., Gusmani, L., Galeotti, M., Adams, A., Dimitriadis, G.J. (2003) Vaccination trials of sea bass, *Dicentrarchus labrax* (L.), against *Photobacterium damsela* subsp. *piscicida*, using novel vaccine mixture. *J Fish Dis* 26: 77-90.

Balta, F., Çağırgan, H., Kayış, Ş. (2005) Usefulness of the API 20E system for the identification of *Yersinia ruckeri* isolated from farmed rainbow trout. *Turkish Journal of Aquatic Life* 3(4):434-437.

Balta, F., Balta, Z.D., Özgümüş, O.B., Çağırgan, H. (2016) The antimicrobial resistance and investigation of *Yersinia ruckeri* from rainbow trout (*Oncorhynchus mykiss*) farms in the eastern Black Sea region. *J Anatolian Env and Anim Sciences* 1(3): 72-76.

Basson, L, Van As, J. (2006) Trichodinidae and other ciliophorans (Phylum Ciliophora). Fish Diseases and Disorders, Vol. 1 Protozoan and Metazoan Infections, 2nd ed. CABI, Oxford, p: 154-182. In: Fish Diseases and Disorders Vol. 1. (eds., Woo, P.T.K., Bruno, D.W.) CABI, Wallingford, UK.

Bastardo, A., Ravelo, C., Romalde, J.L. (2012) Highly sensitive detection and quantification of the pathogen *Yersinia ruckeri* in fish tissue by using real-time PCR. *Appl Microbiol Biotechnol* 96: 511-520.

Behera, T., Swain, P. (2014) Antigen encapsulated alginate-coated chitosan microspheres stimulate both innate and adaptive immune responses in fish through oral immunization. *Aquac Int* 22:673-688.

Bowater, R.O, Donoghue, J.O. (2015) An epizootic of Chilodonelliasis in farmed barramundi (*Lates calcarifer*) (Bloch), A case report. *Journal of Fish Diseases* 38: 931-936.

Bower, C.E, Turner, D.T, Biever, R.C. (1987) A standardized method of propagating the marine fish parasite, *Amyloodinium ocellatum. Journal of Parasitology* 73: 85-88.

Bruno, D.W, Alderman, D.J., Schlotfeldt, H.J., Baudin-Laurencin, F., Bernoth, E.-M., Daelman, W., Palmer, R., Thorud, K. (1997) What Should I do? A Practical Guide for the Marine Fish Farmer. European Association of Fish Pathologists, Aberdeen, Scotland, UK 64 pp.

Candan, A. (1991) Lymphocystis disease of *Sparus aurata* in marine culture at Aegean and Mediterranean coast of Turkey. Mediterranean Regional Aquaculture Project. Basic Level Training Course on Disease, İstanbul.

Candan, A., Kucuker, M.A., Karatas, S. (1995) Motile aeromonad septicaemia in *Salmo salar* cultured in the Black Sea in Turkey. *Bulletin of the European Association of Fish Pathologists* 15(6): 195-196.

Chase, D.M., Elliott, D.G., Pascho, R.J. (2006) Detection and quantification of *Renibacterium salmoninarum* DNA in salmonid tissues by real-time quantitative polymerase chain reaction analysis. *J Vet Diagn Invest* 18 (4): 375-380.

Chen, Y.S., Liu, Y.C., Yen, M.Y., Wang, J.H., Wann, S.R., Cheng, D.L. (1997) Skin and soft-tissue manifestations of *Shewanella putrefaciens*. *Clin Infect Dis* 25: 225-229.

Chinabut, S. (1999) Mycobacteriosis and Nocardiosis. In: Fish Diseases and Disorders Vol. 3. (eds., Woo, P.T.K., Bruno, D.W.) CABI, Wallingford, UK.

Comps, M., Raymond, J., Plassiart, G.N. (1996) Rickettsia-like organism infecting juvenile sea-bass *Dicentrarchus labrax*. *Bulletin of the European Association Fish Pathologists* 16(1): 30-33.

Çağırgan, H. (1993) The first isolation *Pasteurella piscicida* from cultured Sea bream. *Hay Arastirma Dergisi* 3:82-83.

Çanak, Ö., Akaylı, T., Toranzo, A.E., Castro, N. (2014) Characterization of *Vibrio anguillarum* isolated from cultured gilt-head seabream (*Sparus aurata*) in Turkey. Conference Paper, Aquaculture Europe 14, San Sebastian, Spain.

Çanak, Ö., Timur, G. (2017) Staphylococcal infections of marine fishes cultured in Turkey. Conference Paper, Aquaculture Europe 2017, Dubrovnik, Croatia, pp. 175-176.

Daugherty, J., Evans, T.M., Skillom, T., Watson, L.E., Money, N.P. (1998) Evolution of spore release mechanisms in the Saprolegniaceae (Oomycetes):

evidence from a phylogenetic analysis of internal transcribed spacer sequences. *Fungal Genetics and Biology* 24: 354-363.

Demircan, D., Candan, A. (2006) Identification of *Vibrio anguillarum* by PCR (rpoN Gene) associated with Vibriosis in marine fish in Turkey. *Turk J Vet Anim Sci* 30: 305-310.

Dinçturk, E., Tanrıkul, T.T., Turk Culha, S. (2018) Fungal and bacterial co-infection of sea bass (*Dicentrarchus labrax*, Linnaeus 1758) in a recirculating aquaculture system: *Saprolegnia parasitica* and *Aeromonas hydrophila*. *Aquatic Sciences and Engineering* 33(3): 67-71.

Dinçtürk, E., Tanrıkul, T., Birincioğlu, S. (2019) First report of *Saprolegnia parasitica* from a marine species: gilthead seabream (*Sparus aurata*) in brackish water conditions. *Journal of the Hellenic Veterinary Medical Society* 70(2): 1503-1510.

Eissa, I.A.M., Derwa, H.I., Ismail, M., El-lamie, M. Dessouki, A.A., Elsheshtawy, H., Bayoumy, E.M. (2018) Molecular and phenotypic characterization of Photobacterium damselae among some marine fishes in Lake Temsah. *Microbial Pathogenesis* 114: 315-322.

Embregts, C.W.E., Forlenza, M. (2016) Oral vaccination of fish: Lessons from humans and veterinary species, *Developmental & Comparative Immunology* 64: 118-137.

Ercan, M.D., Karataş, S., Turgay, E., Kolukırık, M., İnce, O., İnce, B. (2013) Changes in transferrin gene expression in sea bass (*Dicentrarchus labrax*) challenged with *Vibrio anguillarum*. *Turk J Vet Anim Sci* 37: 141-146.

Ercan, D, Andreou, D, Sana, S, Öntaş, C. Baba, E., Top, N., Karakuş U., Tarkan, A.S., Gozlan, R.E. (2015) Evidence of threat to European economy and biodiversity following the introduction of an alien pathogen on the fungal–animal boundary. *Emerging Microbes & Infections* 4: e52.

Essam, H.M., Abdellrazeq, G.S., Tayel, S.I., Torky, H.A., Fadel, A.H. (2016) Pathogenesis of *Photobacterium damselae* subspecies infections in sea bass and sea bream. *Microbial Pathogenesis* 99: 41-50.

Evenden, A.J., Grayson, T.H., Gilpin, M.L., Munn, C.B. (1993) *Renibacterium salmoninarum* and bacterial kidney disease- the unfinished jigsaw. *Annu Rev Fish Dis* 3: 87-104.

Fernandez-Alvarez, C., Gijon, D., Alvarez, M., Santos, Y. (2016) First isolation of *Aeromonas salmonicida* subspecies *salmonicida* from diseased sea bass, *Dicentrarchus labrax* (L.), cultured in Spain. *Aquaculture Reports* 4: 36-41.

Frans, I., Michiels, C.W., Bossier, P., Willems, K.A., Lievens, B., Rediers, H. (2011) *Vibrio anguillarum* as a fish pathogen: virulence factors, diagnosis and prevention. *Journal of Fish Diseases* 34: 643-661.

Foissner, W., Hoffman, G.L., Mitchell, A.J. (1985) *Heteropolaria colisarum* (*Protozoa: Epistylidae*) of North American freshwater fish. *Journal of Fish Diseases* 8: 145-160.

Geraylou, Z. (2018) Pre- and Probiotics and immunostimulants in Siberian Sturgeon: Gut microbiota and immunomodulation. In: The Siberian Sturgeon (*Acipenser baerii*, Brandt, 1869) Volume 2 Farming. (eds. P. Williot, G., Nonnotte, Chebanov, M.), Springer International Publishing AG, pp. 125-149.

Gozlan, R.E., Whipps, C.M., Andreou, D., Arkush, K.D. (2009) Identification of a rosette-like agent as Sphaerothecum destruens, a multi-host fish pathogen. *International Journal for Parasitology* 39(10): 1055-1058.

Harrell, L.W. Elston, R.A., Scott, T.M., Wilkinson, M.T. (1986) A significant new systemic disease of net-pen reared chinook salmon (*Oncorhynchus tshawytscha*) brood stock. *Aquaculture* 55: 249-262.

Hoffman GL. (1999) Parasites of North American Freshwater Fish, 2nd ed. Cornell University Press, Ithaca, 539 p.

Holmes, P., Niccols, L.M., Sartory, D.P. (1996) The ecology of mesophilic Aeromonas in the aquatic environment. In The genus Aeromonas, (eds., Austin, B., Altwegg, M., Gosling, P.J., Joseph, S.) John Wiley & Sons, Ltd., Chichester, UK, pp. 127-50.

Holt, H.M., Gahrn-Hansen, B., Bruun, B. (2005) *Shewanella algae* and *Shewanella putrefaciens*: clinical and microbiological characteristics. *Clin Microbiol Infect* 11: 347-352.

Huang, S., Chen, W., She, M., Liao, I., Chen, S. (1999) Studies on epizootiology and pathogenecity of *Staphylococcus epidermidis* in tilapia (*Oreochromis* spp.) cultured in Taiwan. *Zoological Studies* 38(2): 178-188.

Iglesias, R., Parama, A., Alvarez, M.F., Leiro J., Fernandez J., Sanmart M.L. (2001) *Philasterides dicentrarchi* (Ciliophora, Scuticociliatida) as the causative agent of scuticociliatosis in farmed turbot *Scophthalmus maximus* in Galicia. *Diseases of Aquatic Organisms* 46: 47-55.

Irie, T., Watarai, S., Iwasaki, T., Kodama, H. (2005) Protection against experimental *Aeromonas salmonicida* infection in carp by oral immunisation with bacterial antigen entrapped liposomes. *Fish Shellfish Immunol* 18: 235-242.

Isaksen, T.E., Karlsbakk, E., Nylund, A. (2007). *Ichthyobodo hippoglossi* (Kinetoplastea: Prokinetoplastida: Ichthyobodonidae an ectoparasitic flagellate infecting farmed Atlantic halibut *Hippoglossus hippoglossus*. *Diseases of Aquatic Organisms* 73: 207-217.

Işıdan, H., Bolat, Y., 2011. A survey of viral hemorrhagic septicemia (VHS) in Turkey. *Turkish Journal of Fisheries and Aquatic Sciences* 11: 507-513.

Jacobs, J.M., Stine, C.B., Baya, A.M., Kent, M.L. (2009) A review of mycobacteriosis in marine fish. *J Fish Dis* 32: 119-130.

Kalayci, G., Incoglu, S., Ozkan, B., 2006. First isolation of viral haemorrhagic septicaemia (VHS) virus from turbot (*Scophthalmus maximus*) cultured in the Trabzon coastal area of the Black Sea in Turkey. *Bulletin of the European Association of Fish Pathologists* 26: 157-161.

Karatas, S., Candan, A., Demircan, D. (2004). Enteric red mouth disease in cultured rainbow trout (*Oncorhynchus mykiss*) on the black sea coast of Turkey. *Israeli Journal of Aquaculture–Bamidgeh* 56(3): 226-231.

Karataş, S., Candan, A., Demircan, D. (2005) Atypical aeromonas infection in cultured sea bass (*Dicentrarchus labrax*) in the Black Sea. *The Israeli Journal of Aquaculture – Bamidgeh* 57(4): 255-263.

Kawula, T.H., Lelivelt, M.J., Orndorff, P.E. (1996) A new inbred fish model and fish tissue/cells to study Aeromonas *hydrophila* and Yersinia *ruckeri* pathogenesis. *Microb Path* 20: 119-125.

Kayış, S., Çapkın, E., Fikri, B., Altinok, I. (2009) Bacteria in rainbow trout (*Oncorhynchus mykiss*) in the southern Black Sea region of Turkey- a survey. *Israeli Journal of Aquaculture-Bamidgeh* 61 (4): 339-344.

Khidr AA, Samak OAA, Said AE, Ghoneim AM & Fahmy SA. (2014) Structural and functional observations on the appendages of gill parasite *Lernantrophus kroyeri* (Copepoda: Lernanthropidae) infesting the sea bass *Dicentrarchus labrax*. *Nature and Science* 2: 12.

Kim, S.M., Cho, J.B., Kim, S.K., Nam, Y.K., Kim, K.H. (2004). Occurrence of scuticociliatosis in olive flounder *Paralichthys olivaceus* by *Phiasterides dicentrarchi* (Ciliophora: Scuticociliatida). *Diseases of Aquatic Organisms* 62: 233-238.

Kim, D.G., Bae, J.Y., Hong, G.E., Min, M.K., Kim, J.K., Kong, I.S. (2008) Application of the rpoS gene for the detection of *Vibrio anguillarum* in flounder and prawn by polymerase chain reaction. *J Fish Dis* 31:639-647.

Kim, D.G., Kim, Y.R., Kim, E.Y., Cho, H.M., Ahn, S.H., Kong, I.S. (2010) Isolation of the groESL cluster from *Vibrio anguillarum* and PCR detection targeting groEL gene. *Fisheries Science* 76: 803-810.

Korun, J., Olgac, V., Akgun-Dar, K., Colorni, A., Diamant, A. (2005) Mycobacteriosis in European sea bass, *Dicentrarchus labrax* l., cultured in Turkey. *The Israeli Journal of Aquaculture – Bamidgeh* 57(4): 215-222.

Korun, J., Timur, G. (2005) The first pasteurellosis case in cultured sea bass (*Dicentrarchus labrax* l.) at low marine water temperatures in Turkey. *The Israeli Journal of Aquaculture – Bamidgeh* 57(3): 197-206.

Korun, J., Timur, G. (2008) Marine vibrios associated with diseased sea bass (*Dicentrarchus labrax*) in Turkey. *Journal of FisheriesSciences.com* 2(1): 66-76.

Korun, J., Akgün-Dar, K., Yazıcı, M. (2009) Isolation of *Shewanella putrefaciens* from cultured European sea bass, (*Dicentrarchus labrax*) in Turkey. *Revue Méd Vét* 160(11): 532-536.

Kubilay, A., Uluköy, G. (2004) First isolation of *Staphylococcus epidermidis* from cultured gilthead sea bream (*Sparus aurata*) in Turkey. *Bull Eur Ass Fish Pathol* 24(3): 137-143.

Kumar, G., Menanteau-Ledouble, S., Saleh, M., El-Matbouli, M. (2015) *Yersinia ruckeri*, the causative agent of enteric redmouth disease in fish. *Veterinary Research* 46(103): 1-10.

Labella, A., Sanchez-Montes, N., Berbel, C., Aparicio, M., Castro, D., Manchado, M., Borrego, J.J. (2010) Toxicity of *Photobacterium damselae* subsp. *damselae* strains isolated from new cultured marine fish. *Diseases of Aquatic Organisms* 92: 31-40.

Le Breton, A., Brich Iversen, H., Spiteri, D., Meyer, T. (1999) Endo-microparasitic infestation of cultured sea bass *Dicentrarchus labrax* and seabream *Sparus aurata*: A case study on the economical impact in the Maltese Islands. 9th Intern. Conf. Eur. Ass. Fish Pathol., p. 186.

Li, L., Lin, S.L., Deng, L., Liu, Z.G. (2013) Potential use of chitosan nanoparticles for oral delivery of DNA vaccine in black seabream *Acanthopagrus schlegelii* Bleeker to protect from *Vibrio parahaemolyticus*. *J Fish Dis* 36: 987-995.

Lom, J. (1984) Diseases Caused by Protistans. In: Diseases of Marine Animals, Vol. 4 (ed., Kinne O,), Hamburg, Germany: Biologische Anstalt Helgoland, p: 114-168.

MacMillan, J.R. (1991) Biological factors impinging upon control of external protozoan fish parasites. *Annual Review of Fish Diseases* 1: 119-131.

Manera, M., Dezfuli, B.S. (2003) *Lernanthropus kroyeri* infections in farmed sea bass *Dicentrarchus labrax*: pathological features. *Diseases Aquatic Organisms* 57: 177-180

Mauel, M.J., Miller, D.L., Frazier, K., Liggett, A.D., Styer, L., Montgomery-Brock, D., Brock, J. (2003) Characterization of a piscirickettsiosis-like disease in Hawaiian tilapia. *Dis Aquat Organ* 53: 249-255.

Smeltzer, M.S., Beenken, K.E. (2013) Staphylococcus. In: Veterinary Microbiology, 3rd edition, (eds., McVey, D.S., Kennedy, M., Chengappa, M.M.), Wiley- Blackwell, Ames, USA, pp.184-192.

Michel, C., Kerouault, B., Martin, C. (2003) Chloramphenicol and florfenicol susceptibility of fish-pathogenic bacteria isolated in France: Comparison of minimum inhibitory concentration, using recommended provisory standards for fish bacteria. *J Appl Microbiol* 95: 1008-1015.

Muktar, Y., Shimels, T., Tesfaye, B. (2016) Present status and future prospects of fish vaccination: A review. *J Veterinar Sci Technol* 7(2): 1-7.

Munday, B.L., Donoghue, P.J.O., Watt, M., Rough, K., Hawkesford, T. (1997) Fatal encephalitis due to the scuticociliate *Uronema nigricans* in sea - caged, southern bluefin tuna *Thunnus maccoyii*. *Diseases of Aquatic Organisms* 30: 17-25.

Neish, G.A., Hughes, G.C. (1980) Fungal Diseases of Fishes: Book 6. TFH Publications, Neptune City, NJ, USA. 159pp.

Noga, E.J., Levy, M.G. (2006) Phylum Dinoflagellata. In: Fish Diseases and Disorders, Vol. 1. Protozoan and Metazoan Infections 2nd ed. (eds., Woo, P.T.K., Bruno, D.W.) CABI, Oxford, UK, p: 16 – 45.

Noga, E.J. (2010) Fish disease diagnosis and treatment, 2nd ed. Wiley-Blackwell, Ames, IA, USA,p. 183-214.

Ogut, H., Altuntas, C. (2012) Occurrence and prevalence of infectious pancreatic necrosis virus in rainbow trout (*Oncorhynchus mykiss*) cultured in cages in the Black Sea. *Aquaculture Research* 43(10): 1550-1556.

Onuk, E.E., Çiftçi, A., Fındık, A., Çiftçi, G., Altun, S., Balta, F., Özer, S., Çoban, A.Y. (2011) Phenotypic and molecular characterization of *Yersinia ruckeri* isolates from rainbow trout (*Oncorhynchus mykiss*, Walbaum, 1792) in Turkey, *Berliner und Münchener Tierarztliche Wochenschrift* 124(7-8): 320-328.

Ordal, E.J., Earp, B.J. (1956) Cultivation and transmission of the etiological agent of bacterial kidney disease. *Proceeding of the society of experimental Biology and Medicine* 92: 85-88.

Osorio, C.R., Toranzo, A.E., Romalde, J.L., Barja, J.L. (2000) Multiplex pcr assay for ureC and 16s rRNA genes clearly discriminates between both subspecies of *Photobacterium damselae. Dis Aquat Org* 40: 177-183.

Padua, S.B., Martin, M.L., Carrijo-Mauad, J.R., Ishikawa, M.M., Jeronimo, G.T. (2013) First record of *Chilodonella hexasticha* (Ciliophora: Chilodonellidae) in Brazilian cultured fish: A morphological and pathological assessment. *Veterinary Parasitology* 191: 154-160.

Padua, S.B., Martins, M.L., Valladao, G.M.R., Utz, L., Zara, F.J., Ishikawa, M.M., Belo, M.A.A. (2016) Host-parasite relationship during *Epistylis* sp. (Ciliophora: Epistylididae) infestation in farmed cichlid and pimelodid fish. *Pesq Agropec Bras* 51(5): 520-526.

Pazdzior, E., Pekala-Safinska, A., Wasyl, D. (2019) Genotypic diversity among *Shewanella* spp. collected from freshwater fish. *J Fish Dis* 42: 677-684.

Pala, G., Farias, T.H., Alves, L.O., Pilarski, F., Hoppe, E.G.L. (2018) Association of *Epistylis* spp. (Ciliophora: Peritrichia) with parasitic crustaceans in farmed piava *Megaleporinus obtusidens* (Characiformes: Anostomidae) *Brazilian Journal Veterinary Parasitology* 27(3): 348-353.

Papapanagiotou, E.P., Trilles, J.P. (2001) Cymothoid parasite Ceratothoa parallela inflicts great losses on cultured gilthead sea bream *Sparus aurata* in Greece. *Diseases of Aquatic Organisms* 45: 237-239.

Pepin, J.F., Emery, E. (1993) Marine cytophaga -like bacteria (CLB) isolated from diseased reared sea bass (*Dicentrarchus labrax* L.) from french Mediterranean coast. *Bull Eur Assoc Fish Pathol* 13: 165-167.

Purivirojkul, W. (2012) Histological change of aquatic animals by parasitic infection. *Histopathology-Reviews and Recent Advances* 9: 153-176.

Ramos, M.F., Costa, A.R., Barandela, T., Saraiva, A., Rodrigues, P.N. (2007) Scuticociliate infection and pathology in cultured turbot *Scophthalmus maximus* from the north of Portugal. *Diseases of Aquatic Organisms* 74: 249-253.

Ramsay, J.M., Watral, V., Schreck, C.B., Kent, M.L. (2009) Husbandry stress exacerbates mycobacterial infections in adult zebrafish, *Danio rerio* (Hamilton). *J Fish Dis* 32: 931-41.

Roberts, R.J. (2012) The bacteriology of Teleosts. In: Fish Pathology, (ed., Roberts, R.J.), 4th edition. Wiley-Blackwell, US, pp. 353-359.

Romalde J.L., Ravelo C., López-Romalde, S., Avendaño-Herrera, R., Magariños, B., Toranzo, A.E. (2005) Vaccination strategies to prevent important emerging diseases for Spanish aquaculture. *Developments in Biologicals* 121: 85-95.

Ryckaert, J., Bossier, P., Haesebrouck, F., Sorgeloos, P., Pasmans, F. (2010) *Yersinia ruckeri* is a facultative intracellular pathogen in trout, persisting in the host macrophages. *Fish and Shellfish Immunology* 29: 648-655.

Savaş, H., Yıldırım, Y., Kurtoğlu, İ.Z., Başçınar, N., Alkan, A., Gürel, M., Ergün, H., Firidin, Ş., Kutlu, İ., Serdar, S., Zengin, B. (2006a) Final report of the project of monitoring floating cage enterprises operating in the district of Ordu, Perşembe, in terms of environmental impact and fisheries health. The Ministry of Agriculture and Forestry, Central Fisheries Research Institute (SUMAE). pp. 1-17. (in Turkish).

Savaş, H., Altinok, I., Cakmak, E., Firidin, S. (2006b) Isolation of *Renibacterium salmoninarum* from cultured Black Sea Salmon (*Salmo trutta labrax*): First report in Turkey. *Bulletin of the European Association of Fish Pathologists* 26(6): 238-246.

Savaş, H., Türe, M. (2007) Diseases seen in natural and cultured fish in our region. *Sümae Yunus Araştırma Bülteni* 7(2): 10-13. (in Turkish).

Saleh, M., Soliman, H., El-Matbouli, M. (2008) Loop-mediated isothermal amplification as an emerging technology for detection of *Yersinia ruckeri* the causative agent of enteric red mouth disease in fish. *BMC Vet Res* 4(31): 1-10.

Saleh, M., Soliman, H., El-Matbouli, M. (2015) Gold nanoparticles as a potential tool for diagnosis of fish diseases. *Methods Mol Biol* 1247: 245-252.

Salonius, K., Siderakis, C.V., Griffiths, S.G. (2003) Further characterization of *Arthrobacter davidanieli* and use as a live vaccine to immunize against intracellular pathogens of salmonids. In: Abstracts 3rd. International Symposium on Fish Vaccinology, Bergen, Norway, pp. 41.

Scott, C.J., Austin, B., Austin, D.A., Morris, P.C. (2013) Non-adjuvanted flagellin elicits a non-specific protective immune response in rainbow trout

(*Oncorhynchus mykiss*, Walbaum) towards bacterial infections. *Vaccine* 31: 3262-3267.

Silva- Rubio, A., Avendano- Herrera, R., Jaureguiberry, B., Toranzo, A.E., Magarinos, B. (2008) First description of serotype O3 in *Vibrio anguillarum* strains isolated from salmonids in Chile. *J Fish Dis* 31(3): 235-239.

Sitja-Bobadilla, A., Alvarez-Pellitero, P. (2009) Experimental transmission of *Sparicotyle chrysophrii* (Monogenea: Polyopisthocotylea) to gilthead seabream (*Sparus aurata*) and histopathology of the infection. *Folia Parasitologica* 56 (2): 143-151.

Sitjà-Bobadilla, A., Zarza, C., Fouz, B. (2014) Pathology. In: Biology of European Sea bass (eds., Sánchez-Vázquez, F.J., Muñoz-Cueto, J.A.), CRC Press, Boca Raton. pp. 287-341.

Stenstram, J.M., Molin, G. (1990) Classification of the spoilage flora of fish, with special reference to Shewanella putrefaciens. *J Appl Bacteriol* 68: 601-618.

Subasinghe, R. (2009) Disease control in aquaculture and the responsible use of veterinary drugs and vaccines: The issues, prospects and challenges. In: The Use of Veterinary Drugs and Vaccines In Mediterrenean Aquaculture, (eds., Rogers, C., Basurco, B.), Options Mediterraneennes, Series A: Mediterranean Seminars 2009- Number 86, Paris, France. pp. 5-11.

Suzuki, K., Sakai, D.K. (2007) Real-time PCR for quantification of viable *Renibacterium salmoninarum* in chum salmon *Oncorhynchus keta*. *Dis Aquat Org* 74: 209-223.

Tanrıkul, T.T., Cagirgan, H., Toksen, E. (2004) Identification of Vibriosis by API20E methods isolated from sea bass (*Dicentrarchus labrax* l., 1758). *Ege Journal of Fisheries and Aquatic Sciences* 3-4: 243-247 (in Turkish).

Terceti, M.S., Ogut, H., Osorio, C.R. (2016). *Photobacterium damselae* subsp. *damselae*, an emerging fish pathogen in the Black Sea: Evidence of a Multiclonal Origin. *Applied and Environmental Microbiology* 82(13): 3736-3745.

Timur, G., Timur, M., Akaylı, T., Korun, J., Thomson, K.D. (2005) First observation of rickettsia- like organisms in cultured sea bass (*Dicentrarchus labrax*) in Turkey. *Bull Eur Ass Fish Pathol* 25(5): 196-202.

Timur, G., Timur, M., Akayli, T., Korun, J., Erkan, M. (2008) The first observation of viral erythrocytic infection associated with pathogenic bacteria and some ectoparasites in cultured Mediterranean Sea bass (*Dicentrarchus labrax* L.) in Turkey. *Bull Eur Ass Fish Pathol* 28(2): 58-65.

Timur, G., Erkan, M., Yardımcı, R.E., Ercan, M.D., Çanak, Ö., Ürkü, Ç. (2013) Light and electron microscopic study of Rickettsia-like organisms causing systemic granulomas in farmed sea bass (*Dicentrarchus labrax*) *The Israeli Journal of Aquaculture - Bamidgeh*, IJA_65.2013.874, 1-7.

Timur, G., Ürkü, Ç., Çanak, Ö., Erköse Genç, G., Erturan, Z. (2015) Systemic Mycobacteriosis caused by *Mycobacterium marinum* in Farmed Meagre (*Argyrosomus regius*), in Turkey. *The Israeli Journal of Aquaculture - Bamidgeh,* IJA_67.2015.1162.

Tokşen, E., Nemli, E., Değirmenci, U. (2008) The morphology of *Lernantrophus kroyeri* van Beneden, 1851 (Copepoda: Lernanthropidae) parasitic on sea bass *Dicentrarchus labrax* (L. 1758) from the Aegean Sea, Turkey. *Türkiye Parazitoloji Dergisi* 32(4): 386-389.

Toranzo, A.E., Barreiro, S., Casal, J.F., Figueras, A., Magariños B., Barja, J.L. (1991) Pasteurellosis in cultured gilthead seabream (*Sparus auratus*): First report in Spain. *Aquaculture* 99: 1-15.

Toranzo, A.E., Romalde, J.L., Magarinos, B., Barja, J.L. (2009) Present and future of aquaculture vaccines against fish bacterial diseases. In : The use of veterinary drugs and vaccines in Mediterranean aquaculture. Zaragoza: CIHEAM (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 86), (eds., Rogers, C., Basurco, B.), pp. 155-176.

Toyama, T., Tsukamoto, K.K., Wakabayashi, H. (1996) Identification of *Flexibacter maritimus, Flavobacterium branchiophilum* and *Cytophaga columnaris* by PCR targeted 16S ribosomal DNA. *Fish Pathol* 31: 25-31.

Tu, F.P., Chu, W.H., Zhuang, X.Y., Lu, C.P. (2010) Effect of oral immunization with *Aeromonas hydrophila* ghosts on protection againsts experimental fish infection. *Lett Appl Microbiol* 50: 13-17.

Turgay, E., Karataş Steinum, S. (2016) First report of *Vibrio harveyi* infection in diseased common dentex (*Dentex dentex*) cultured in Turkey. *Süleyman Demirel Üniversitesi Eğirdir Su Ürünleri Fakültesi Dergisi*, 12: 170-176 (in Turkish).

Türk, N. (2002) Isolation of bacteria from sea bream and sea bass and determination of their sensitivity to antibiotics. *Bornova Veteriner Kontrol ve Araştırma Enstitüsü Dergisi* 27: 7-14 (in Turkish).

Türk, N. (2006) Fish Disease, Flexibacteriosis. *Aquaculture and Fisheries* 2: 53-54.

Ürkü, Ç., Genç, G.E., Wittwer, F., Erturan, Z., Pfyffer, G. (2018) Mycobacteriosis in farmed sea bream (*Sparus aurata*) caused by *Mycobacterium frederiksbergense* in Turkey. *Acta Veterinaria-Beograd* 68(4): 391-400.

Üstünakın, K., Durmaz, Y., Gürcan, Ö.C. (2015) Isolation of *Yersinia ruckeri* in rainbow trout farms in middle and east Black Sea region and determination of antibiotic susceptibility profiles. *Yunus Araştırma Bülteni* 1: 59-65 (in Turkish).

Van-Gelderen, R., Carson, J., Nowak, B. (2009) Effect of extracellular products of *Tenacibaculum maritimum* in Atlantic salmon, *Salmo salar* L. *Journal of Fish Diseases* 32: 727-731.

Villumsen, K.R., Neumann, L., Ohtani, M., Strom, H.K., Raida, M.K. (2014) Oral and anal vaccination confers full protection against enteric redmouth disease (ERM) in rainbow trout. *PLoS One* 9, e93845, 9(4): 1-10.

Vico, G.V., Cataldi, M., Carella, F., Marino, F., Passantino, A. (2008) Histological, histochemical and morphometric changes of splenic melanomacrophage centers (Smmcs) in Sparicotyle-infected cultured sea breams (*Sparus aurata*). *Immunopharmacology and Immunotoxicology* 30: 27-35.

Wiles, M., Cone, D., Odense, P.H. (1985) Studies on *Chilodonella cyprini* and *Chilodonella Hexasticha* (Protozoa: ciliata) by scanning electron microscopy. *Canadian Journal of Zoology* 63: 2483-2487.

Willoughby, L.G., Roberts, R.J. (1992) Towards strategic use of fungicides against *Saprolegnia parasitica* in salmonid fish hatcheries. *J Fish Dis* 15: 1-13.

Wolffrom, T., Midtlyng, P.J. (2004) Vertical transfer of fish disease. *Bulletin of the European Association of Fish Pathologists* 24: 58-60.

Wood, P.A., Kaattari, S.L. (1996) Enhanced immunogenicity of *Renibacterium salmoninarum* in chinook salmon after removal of the bacterial cell surface associated 57 KDa proteins. *Dis Aquat Org* 25: 71-79.

Wright, A.D.G., Colorni, A. (2002) Taxonomic re-assignment of *Cryptocaryon irritans*, a marine fish parasite. *European Journal of Protistology* 37: 375-378.

Xing, J., Xu, H., Tang, X., Sheng, X., Zhan, W. (2019) A DNA vaccine encoding the VAA gene of *Vibrio anguillarum* induces a protective immune response in flounder. *Front Immunol* 10(499): 1- 39.

Yanong, R.P.E. (2017) *Cryptocaryon irritans* infections (Marine White Spot Disease) in Fish. Fisheries and Aquatic Sciences, Available at: http://edis.ifas.ufl.edu (accessed 20 May 2019).

Yardımcı, R.E., Timur, G. (2015) Isolation and identification of *Tenacibaculum maritimum*, the causative agent of Tenacibaculosis in farmed sea bass (*Dicentrarchus labrax*) on the Aegean Sea coast of Turkey. *The Israeli Journal of Aquaculture - Bamidgeh,* IJA_67.2015.1172*,* 1-10.

Yardımcı, R.E., Timur, G. (2016) Antigenic characterisation of *Tenacibaculum maritimum* isolates from sea bass (*Dicentrarchus labrax*, L.) farmed on the Aegean Sea coasts of Turkey. *J Aquac Res Development* 7(2): 1-4.

Yılmaz, M., Korun, J., Gökoğlu, M., Çelik, Y.S. (2017) Isolation of *Staphylococcus hominis* from cultured gilthead sea bream (*Sparus aurata* L.) in Antalya Bay, Turkey. *Journal of Agricultural Sciences* 25: 123-128.

Çoban, D., Demircan, M.D., Tosun, D.D. (Eds.) 2020. Marine Aquaculture in Turkey: Advancements and Management. Turkish Marine Research Foundation (TUDAV) Publication No: 59, İstanbul, Turkey.

Genetic breeding studies of marine fish farming species

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Introduction

Since the existence of fish is endangered due to anthropogenic effects, the creation of gene banks of these species has been one of the most important issues of recent years. In addition, in order to meet the increasing food needs due to the increase of the world population, production studies are carried out for fish species and for this purpose breeding studies including biotechnological applications are also utilized. As in the world, biotechnological studies used in scientific aquaculture practices in Turkey have been carried out extensively in freshwater fish species. Since gamet production is obtained by natural means in the production of marine fish species, biotechnological applications on these species have been limited. In Turkey, applications in marine fish have been developed within the framework of selection and hybridization issues. In addition, commercial firms do not invest in biotechnological applications due to the need for a separate budget and labor force, so they have not developed enough in this area. In the scientific field, the current studies are very limited, as well as having problems in catching up with current issues.

In this section, current information on breeding studies including biotechnological applications carried out in the world on the species cultivated in Turkey and the families of these species was compiled. In this context, biotechnological methods applied in fish farming are discussed under 5 main headings; chromosome manipulations, sperm cryopreservation, gene transfer studies, surrogate broodstock technology and gene editing.

Chromosome manipulation techniques

There are various manipulation procedures that are performed during meiosis and mitosis cell division at chromosome level. These manipulation techniques can be classified as; androgenesis, gynogenesis and polyploidization applications. The first chromosome manipulation technique performed in fish is the triploidization application which is performed in 1959 by H. Swarup on *Gasterosteus aculeatus*.

Gynogenesis and androgenesis techniques are applied on flounder, carp, sturgeon and loach species in the following years. Chromosome manipulation techniques which are applied mostly in freshwater fish presently, are used in marine fish which have high economic values or high breeding potentials as well. These applications are developed with the aim to be used in studies for obtaining lines with increased feed consumption and rapid growth, for gene-centromere mapping, as a marker during sequencing studies, for breeding single-sex fish, for isogenic fish breeding, for obtaining only female eggs or only sterile (3n) eggs, for observing primordial germ cell formation, for observing gametogenesis and gonadogenesis (Table 1).

Protocols used in chromosome manipulation studies in aquaculture domain are performed based on the species. Each fish species has different biological and physiological features and mostly species with simple sex mechanisms are used in research. This is the reason why, while the use of chromosome manipulation techniques in seabream is low, studies have been performed to determine the method and timing of heat shock application, which is one of the basic parameters of the technique in the European seabass (*Dicentrarhus labrax*). Additionally, proper heat shock degree detection studies have been performed in seabream for triploidy application.

Success rate in androgenesis application which is a chromosome manipulation application is lower than gynogenesis application. However, production of isogenic or inbred lines is possible by androgenesis application. Generally androgenetic production yield is low in fish (i.e. seabass) due to the fact that luminous transmittance is low because of egg cell membrane structure and therefore egg cells being damaged as a result of high dosage of beam application (Colleter *et al.* 2014). Although the productivity is less, androgenetic production can be used in seabass for the aim of gene-centromere mapping (Oral *et al.* 2017), genome unification and reproduction (Tine *et al.* 2014), obtaining isogenic line (Bertotto *et al.* 2005) and to identify QTL in low frequency in a population (Verrier *et al.* 2012).

Female European seabass show higher somatic growth (20-50%) (Gorshkov *et al.* 2003). Studies on female line production through gynogenesis have been performed several times for optimization. While survival rate remained limited (30%) in gynogenetic larvae (Colombo *et al.* 1995; Felip *et al.* 1999), larval survival rate of meiotic gynogenetic fish is increased to 76% (Peruzzi and Chatain 2000). However, as a result of mitogynogenetic fish production which is essential for an isogenic line production, larval survival rate remained low (0.07%) (Francescon *et al.* 2004; Bertotto *et al.* 2005).

Table 1. Chromosome Manipulation Techniques on some marine fish

Fish	Ploidy Variation	Gamete inactivation [1]	Shock Conditions [2]	Results [3]	References
S. maximus (♀+♂)	T	No	0°C, 20 min, 5 maf	90% 3n, SR 80%	Piferrer *et al.* 2000
S. maximus (♀+♂)	T	No	–1 to 0°C, 25 min, 6.5 maf	95–100% 3n, SR 60%	Cnaani and Levavi 2009
S. maximus (♀)	MiG	*P. major* ♂, UV, 6480-7200 erg.mm^{-2}	85–90 maf, 75 MPa for 6 min	SR 1.10% ± 0.32% 1.19% ± 0.34% 99% G2*n*	Meng *et al.* (2016)
S. maeotica (♀+♂)	T	No	–1 to 0°C, 20 min, 6.5 maf	91-96% 3n	Aydın and Okumuş 2017
S. maeotica (♀)	MeG	*S. maximus* ♂, UV, 30,000 erg mm^{-2}, 1:10	−1 to 0°C, 25 min, 6.5 maf	100% G2n	Piferrer *et al.* 2004; Cal *et al.* 2006
S. maeotica (♀)	MeG	*P. olivaceus* ♂, UV, 36,000 erg.mm^{-2}, 1:50	1°C, 25 min, 6 maf	39.58% G2n, ≈ 30% at 8 dph	Xu *et al.* 2008
S. maeotica (♀)	MiG	*P. major* ♂, UV, 6480-7200 erg.mm^{-2}, 1:20	75 MPa, 6 min, 85–90 maf	≈1.46% G2n, ≈ 18%, 62% from 40–60 dph	Ayala *et al.* 2013
D. labrax (♀+♂)	T	No	55.1 MPa, 2–3 min, 5 maf	3*n*, 13% SR	Zanuy *et al.* 1994
D. labrax (♀+♂)	T	No	58.6 MPa, 2 min, 6 maf	100% 3*n*, 71% SR	Peruzzi and Chatain 2000
D. labrax (♀+♂)	T	No	0-2°C, 20 min, 5 maf	89–90% 3*n*, 40-50% SR	Colombo *et al.* 1995

Table 1. Continued

D. labrax (♀+♂)	T	No	0–1°C, 15–20 min, 5 maf	100% 3*n*, 56% SR	Peruzzi and Chatain 2000
D. labrax (♀+♂)	T	No	0° C, 10 min, 5 maf	95–100% 3*n*, SR 80%; 3*n* > 2*n* in females at 7 yrs	Felip *et al.* 1997; Felip *et al.* 2009
D. labrax (♀+♂)	MeG	UV, 1:100, 3,300-6,600 erg.mm $^{-2}$	0–2°C, 20 min, 5 maf	83–100% G2*n*, SR 17%	Colombo *et al.* 1995
D. labrax (♀+♂)	MeG	UV, 1:10, 35,000-40,000 erg.mm $^{-2}$	0°C, 10 min, 5 maf	95% G2*n*, SR 30–35%	Felip *et al.* 1999
D. labrax (♀+♂)	MeG	UV, to sperm 1:20, 32,000 erg.mm $^{-2}$	0–1°C, 15–20 min, 5 maf or 58,6 MPa, 2 min, 6 maf	100% G2*n*, SR 76%	Peruzzi and Chatain 2000
D. labrax (♀+♂)	MiG	UV to sperm at 3,300 erg.mm $^{-2}$	81-91 MPa, 4 min, 64–79 maf	92–100% G2*n*, SR 7–18%, the overall SR (0.07%)	Francescon *et al.* 2004; Bertotto *et al.* 2005
D. labrax (♀+♂)	A	UV to eggs at 0,072-0,72 erg.mm $^{-2}$, 1:4	No shock treatment	Small percentage of haploid androgenetics.	Colleter *et al.* 2014

T – triploid; MeG – meiotic gynogenesis; MiG – mitotic gynogenesis; A – Androgenesis; dph – days post-hatch; maf – minutes after fertilization; MPa – MegaPascal; SR – survival rate.

[1] the species of sperm origin, the type of radiation, the dose used, and the dilution of sperm.

[2] the type of shock, its intensity, duration, and time of start.

[3] the yield in T or gynogenetic diploids (G2n) and percent survival relative to diploid controls.

In addition to the optimization of methodologies used during chromosome manipulation studies, gametes from different species were used to be an indicator in determining the success of manipulation application as in gynogenetic studies (Sugama *et al.* 1990). In parallel with developed molecular detection studies, more specific studies and new detection methods were developed in the following years. As an outcome of hybridization and gynogene studies that are performed for this purpose, depending on the differences in enzymatic regions, the success of these applications are determined (Sugama *et al.* 1990). With the application of gynogenesis gene-centromere mapping studies are carried out after meiotic gynogenetic production with the purpose of determining if there is a genetic contribution of the male, creating a gene-centered map of the fish species of the same family and detecting telomere markers (Oral *et al.* 2017). Through isogenic or inbred lines which shall be obtained by gynogenetic production, just like in gilt-head seabream (*S. aurata*) which is a protandrous hermaphrodite species, data enabling to determine quantitative trait locations (QTL) such as water temperature and salinity adaptation, stress, tolerance against diseases, timing of sex reversal and gene locations showing genetic recovery can be detected (Franch *et al.* 2006) and it is also aimed to contribute to the development of aquaculture.

Only embryo development and rarely hatching is observed in haploid fish, however larval development phases do not proceed. Although haploid fish has no survival chance, studies are conducted to obtain haploid fish. Haploid fish are used in studies aiming to create genome and transcriptome drafts. For example, haploid gynogenetic Japanese amberjack (*Seriola quinqueradiata*) genome and transcriptome map of digestive canal is created to help the development of feed compositions specific to this species (Yasuike *et al.* 2018).

During triploid studies which are the result of another chromosome manipulation application, it is aimed to obtain infertile fish and use the energy to be consumed for gonad development in the growth of the somatic. However, in gilt head seabream, it is observed that there is no difference between triploid and diploid fish (Haffray *et al.* 2005) and that growth performance is weak (Peruzzi *et al.* 2004). It is determined that body shape of triploid fish are thinner compared to control group and that the condition factor in triploid group is lower (12%) than diploid groups (control and gynogenetic) (Peruzzi *et al.* 2010). Turbot (*Scophthalmus maximus*) (Piferrer *et al.* 2000) which is indicated to have higher somatic yield in triploid was subject to study to determine the effects of cold shock application on blastomere morphologies and its mortality correlation with embryos (Aydın and Okumuş 2017).

Applications related with chromosome manipulations

Sex determining and monosex or infertile fish production

Breeding procedures may be developed and production capacities may be increased by determining the sex mechanism of species which were subject to aquaculture procedures. Sex mechanism; is a flexible mechanism that can be changed by the effect of environmental variables such as hormones, temperature, pH, lux intensity and hypoxia besides the interaction between genetic and environmental factors. Sex mechanism in gonochoristic fish species can be detected by examining critical gene or polygene locations on sex chromosomes or autosomes. Sex in a mono sex system is determined by a critical gene which is part of the sex chromosome (Devlin and Nagahama 2002). XX/XY male heterogametic system and ZZ/ZW female heterogametic system are the two main sex determination systems in fish species. It is difficult to detect sex chromosomes in fish with heteromorphic sex chromosomes, by cytogenetic and fluorescent *in situ* hybridization techniques (Gui 2007; Arkhipchuk 1995). Apart from these techniques; modular mesh formation method is used based on molecular identification that uses sex detection genes (SD) and specific locations of these genes (Mei and Gui 2015). Accordingly, with the purpose of carrying out the detection of synaptic behaviours related with sex in turbot fish (*S. maximus*) triploidization applications (Cuñado *et al.* 2002) and in flounders, bastard halibut and red seabream gynogenesis applications (Sugama *et al.* 1990; Tabata 1991; Howell *et al.* 1995) are performed to determine sex mechanism and to increase production capacity.

As fish are spending most of their energy for gonad development when they are sexually matured, somatic growth and meat quality decreases while mortality is increased. In order to realize the breeding conditions at the best level, whether there is a difference in sex-related growth or not is very important for producers, scientific studies have been carried out within this framework. In aquaculture, with the purpose of controlling the development depending on the sex, somatic yield can be increased by creating monosex or infertile fish populations. In some fish species, while females have higher vital weight compared to the males in unit of time (*A. anguilla*, *S. salar, O. mykiss* etc.) some species (*O. niloticus*) show an opposite case (Beardmore *et al.* 2001).

There are many studies conducted to determine sex depending parameters and sex reversal mechanisms of hybrid species on intensively bred species apart from seabass. For example; no differentiation is determined in the growth of red seabream (*P. major*) (Sugama *et al.* 1990). A study carried out for meagre (*Argyrosomus regius*) revealed sexual maturity period for males as 32 months and as 42 months for females (Gil *et al.* 2013). All the studies mentioned above help to determine breeding conditions out of these species.

Hybridization

Hybridization studies in aquaculture are used with the purpose of increasing the resistance of fish against temperature, salinity and diseases as well as increasing somatic growth. Hybrid species produced for this purpose are expected to be infertile. Hybridization studies are carried out in marine fish breeding since the end of 1980s for species with high economic value. Hybridization studies have been carried out for many species from Sparidae family (*S. aurata* ♀ x *D. puntazzo* ♂ and *S. aurata* ♀ x *D. vulgaris* ♂) (Dujakovic and Glamuzina 1990) and the relationship between hybridization and sterility has also been shown (Gorshkova *et al.* 1995).

Success of the hybridization studies carried out in Turkey on marine fish species is evaluated on the survival rates and growth parameters of the obtained hybrids differently from other studies mentioned above. It is determined that the juveniles of A. *regius* X U. *cirrosa* hybrids have higher growth rate compared to their parents (Karahan *et al.* 2013) and by detecting specific alleles inherited from their parents, it is determined which features show in hybrid fish genotypically (Karahan *et al.* 2014). It is also determined that the hybrids of these species phenotypically look like their parents but morphologically they have different features. (Gürkan *et al.* 2017). *Morone* species that are not of natural population of Turkey's seas, are brought to Turkey at the end of 90s by two private companies and cultured; however, these fish escaped to natural environment as the mesh of the cages had been damaged. (*Morone chrysops* ♀ x *Morone saxatilis* ♂) (Güner *et al.* 2007). The most important feature required in the production of hybrid fish species is that they are infertile. It is determined that the hybrid of *M. chrysops* ♀ x *M. saxatilis* ♂ can reproduce (Kızak and Güner 2014).

Hormonal sex reversal

Gonadal differentiation is formed in fish under the effect of external factors such as steroids that administered in proper times can provide sex differentiation in both gonochoristic and hermaphrodite species. Female and male steroids (estrogens and androgens) changing gonadal differentiation direction in fish functionally, can provide fish with different genetic and phenotypic sex (neomale/neofemale). Neomales/neofemales are providing sustainable and environment friendly production of mono sex populations through simple production schemes (Beardmore *et al.* 2001). Phenotypic sex can be changed by allowing exposure of primordial germ cells that are in embryonic or larval phase to steroids for a certain time and dose before the formation of egg and sperm cells (Pandian and Sheela 1995). In hormone application studies, new approaches can be developed on the understanding of the sex reversal mechanism of fish species by using enzyme activity and expression of estrogen receptors. As there are few information on short term histological and steroidogenic changes occurring during natural and stimulated sex, the effect of estrogen on gonads in hermaphrodite gilt-head seabream and the conversion of androstenedione to testosterone, 11-ketotestosterone and estradiol-17β is examined under in vitro conditions and understanding the mechanism of sex reversal together with steroidogenic enzyme activities and estrogen receptor expression (Condeça and Canario 1999).

Monosex production can be carried out without any application through F_2 generation which is obtained by the application of chromosome manipulation techniques to the population that have reversed sex by the help of hormone applications carried out on F_1 generation obtained by chromosome manipulation techniques in the first place. Following the gynogenetic application conducted in turbots (*S. maximus*) for this purpose, methyl-testosterone added to the feed (1mg/kg) provided male fish with a rate of 65% (Baynes *et al.* 2006). It is reported that with 17a-methyl testosterone which is administrated to flounders (*Paralichthys olivaceus*) by 1-10ppm in order to determine sex mechanism resulted in all gynogenetic diploids to become male (Tabata 1991). When in Summer flounder (*P. dentatus*) meiotic gynogenes are treated with 17α-methyl-testosterone in the beginning of metamorphosis, 100% female (XX) that became males are obtained (Yang 2009). Production capacity shall be decreased due to the fact that the long maturity time of F_2 generation of the species which is aquacultured and that the operation pools are to be used during all this period. Although unisexual egg and lineage productions are realized in fresh water fish by hormone application, studies on its use together with chromosome manipulation are very few. This technic which is not used at an industrial level remained limited with technical laboratory studies and small scaled applications.

Sperm cryopreservation

The technology of cryopreservation enables assisted reproduction by preserving cells with liquid nitrogen at a very low temperature usually -196°C, without losing cell viability and preservation once thawed. The use of this technology in aquaculture has helped facilitate long term sperm preservation from year to year, allowing the possibility of sperm carriers and laboratory experiments. Also this application helps protect important genotypes in order for new generations to develop these.

Until today, apart from numerous fresh water fish species, cryopreservation of sperms from approximately 40 marine fish has been carried out. When compared to the fresh water fish species, one of the reasons of the limited studies on breeding level of cryopreservation technics in marine fish species and also of the limited studies is that most of the commercial marine species -breed naturally in tanks having no need of artificial fertilization. For the fertilization which is performed after the thawing of marine fish species' sperms that were cryopreserved, it is determined that survival rate of the embryos is higher than the ones of fresh water fish species. It is indicated that one of the factors that is effecting this achievement is that marine fish sperm is more resistant to osmolality variations, it is also indicated that this fact can be due to the ATP content and high cholesterol /phospholipid proportion in the sperm membrane. While fish spermatozoa is extracted from the testicles, their flagella gain mobility capability because of a variation that is generally observed in osmotic pressure differences, in marine fish this activation happens in hyperosmotic pressure environments. Apart from the osmolality balancing specification of glucose which can be used in the content of the extender in cryopreservation, DMSO that is used as cryoprotectant preserves the osmotic pressure of the sperm as well as the structure of the cell membrane. Due to the fact that DMSO's penetrating particularity is significant and the rate of fertilization of the egg by the sperm and survival of the larva is high, it is a rate that is preferred during cryopreservation studies. For instance; for *S. aurata* (Tırpan *et al.* 2016), *S. maximus, D. labrax, T. thynnus* and E. *marginatus* (Cabrita *et al.* 2009) 10% of DMSO is used. Equilibration step used for the cryopreservation of mammals' sperms, is not preferred for fish species as it has toxic effect on the cell. The time spent till the transfer into liquid nitrogen, after the treatment of the sperm with extender, must be as short as possible. For instance, while this duration is 2 minutes for the gilt-head seabream, it is maximum 10 minutes for the rainbow trout.

Besides several commercial mediums that are developed to be used during the long term preservation, dilution and sperm activation of certain fresh water and marine fish species' sperms, there are also mediums developed to be used only in the cryopreservation of marine fish species' sperm cryopreservation (IMV-technologies 2019). There is also a company which is established in Norway with the purpose of preserving aquatic gene resources, which is also selling cryopreserved sperms with the purpose to be used in breeding practices and to preserve genetic diversity of natural stocks (Spermvital 2019). Fish breeders in France can have their sperm samples sent to a commercial company and have cryopreservation procedures applied and be safeguarded in that company till the time when sperm samples shall be needed.

The results are assessed objectively using Computer-assisted sperm analysis (CASA) system which, besides its importance in breeding studies, is used in the determination of sperm motility parameters that are essential in evaluating sperm cryopreservation procedures in laboratory practices. A system which is similar to the latter and which is named Computer-assisted sperm analysis (BASA-Sperm Aqua) system that is developed by the support of TÜBİTAK-TEYDEB, is used in evaluating sperm quality parameters in rainbow trout (*O. mykiss*). The use of this system in aquaculture sector, shall enable the evaluation of sperm motility parameters that are considered as important criteria in the achievement of fertilization studies (Özgür *et al.* 2019). The studies to be conducted in this field shall provide developments both in scientific and sectorial basis.

E. aenues, *E. marginatus*, *T. thynnus* and *Sciaena umbra* species that are among the population of Turkey's seas are endangered and it is deemed that sperm cryopreservation studies conducted on these species, to develop breeding strategies and accelerate the breeding studies in Turkey. Sperm cryopreservation is a practice which can be used with the purpose to support breeding studies of marine species of Turkey that have no capability of reproducing gamete and sperm simultaneously in fish of same age such as; protogynous hermaphrodite *Pagrus auriga* and *Epinephelus aeneus* having their males attaining sexual maturity much more later than females and *Lithognathus mormyrus* which is protandrous hermaphrodite. In Turkey, parameters affecting the sperm, which are important to orientate sperm cryopreservation studies, have been studied on basses and a negative effect is determined when the motility duration of the spermatozoa and the percentage of the pH value are low (Öğretmen 2016). Sperm parameters are studied on gilt-head seabream (Engin *et al.* 2018) and cryopreservation practice in straws of 0,25ml in extender have been concluded successfully (Engin 2012). It is necessary to extend gamete cryopreservation in marine fish species as much as fresh water fish species to preserve the species that are important for Turkey and to provide sustainability (Table 2).

Genetically modified fish

Breeding of fish species having requested specifications is performed since a very long time through selection and crossbreeding studies that are among conventional breeding applications. While these applications are performed based on morphological specifications, in fact genetic structure is also subject to a selection causing the emergence of morphological specifications on the genotype. This selection which is carried out on the genetic structure of the living being even if it is indirect, has been replaced by faster applications in nowadays and studies have been carried out directly on the genetic structure of the living being. In parallel with the current development of genetic engineering, additionally to the gene constructs created in laboratory environment, by changes carried out on the genes of a living being through gene-editing applications, modifications are made on the genetic structure.

One of the most important matters is, besides that fish bred in aquaculture applications reach the serving sizes in a shorter time than normal period, that fish consume less fish-feed. Most of the transgenic studies carried out with the purpose of breeding "fast growing fish" are focused on the growth hormone gene transfer. While in most of the first tests, heterologous growth hormone genes and promotors are used, however no success has been reached (Penman *et al.* 1990), in some fish species (Atlantic salmon, various Pacific salmon species and loach) it is observed that they are grown more than the normal criteria (Devlin *et al.* 1994). Furthermore, it is also an application which allows, by the transfer of a gene enabling cold resistance, for the species that cannot be bred in cold water, to be bred afterwards in cold waters. Transgenic techniques are applied especially to develop in freshwater fish, specifications with high commercial values such as growth performance, disease or freezing resistance.

Table 2. Sperm cryopreservation studies in marine fish species

Species	Sperm Motility (%)	Fertilization (%)	Cryoprotectants	References
M. cephalus	30-80	0.03-15.63	%5-10 Glycerine, %5-10 DMSO	Chao *et al.* 1975
T. thynnus	80	×	Glycerine and DMSO	Hoshino *et al.* 1982
E. marginatus	36.8±10.2	69.5±17.7	%10 DMSO	Cabrita *et al.* 2009
E. coioides x *E. lanceolatus*	67±8-100	65.41±5.32	%10 DMSO	Kiriyakit *et al.* 2011
	75-87.5±8	64.03±4.35	%15 Trehalose	
E. akaara x *E. lanceolatus*	71.56±18.97 67.42±2.75	94.56±1.03	%15 DMSO %10 FBS	Tian *et al.* 2015
D. labrax	< 80	62.4±0.7-68.8±0.7	%10 DMSO	Fauvel *et al.* 1998
D. labrax	> 50	×	%10 EG	Sansone *et al.* 2002
D. labrax	80±5-95±5	69±5-85±8	%10 DMSO	Zilli *et al.* 2005
D. labrax	35.3±2.5	×	%10 DMSO	Martinez-Paramo *et al.* 2012
S. aurata	70-80	92±3.2	%10 DMSO	Chambeyron and Zohar 1990
S. aurata	40-60	×	%5 DMSO	Fabbrocini *et al.* 2000
S. aurata	58.3±7.9-70.0±4.7	75.6±6.0	%5 DMSO	Cabrita *et al.* 2005a
S. aurata	×	×	%5 DMSO	Cabrita *et al.* 2005b
S. aurata	72.7±0.3	×	%10 DMSO	Engin 2018
S. aurata	68	×	%5 DMSO	Gallego *et al.* 2012
S. aurata	54.45±1.18-58.25±1.97	28.63-29.20	%10 DMSO	Tırpan *et al.* 2016
P. major	64.8	> 90	%15 DMSO	Liu *et al.* 2007
S. maximus	46.7±6.78-63.3±4.6	58.5±4.2	%15 DMSO	Dreanno *et al.* 1997
S. maximus	×	75	%10 DMSO	Chereguini *et al.* 2003
S. maximus	75	68	%10 DMSO	Suquet *et al.* 2009

Although microinjection and electroporation methods are used while carrying out gene transfer and transgenic fish lines formation, microinjection method is frequently used in the studies. However, this method is considerably limited in marine fish as small sized pelagic eggs and larvae are not resistant to manipulation and the studies are focused on freshwater fish species.

As marine fish breeding is costlier than freshwater fish species and takes longer, manipulation applications carried out on marine fish species haven't developed as much as it did for freshwater fish. Therefore, it is believed that by the creation of gene transfer method specific to species in marine fish, it shall constitute a strong element in increasing the quality and quantity of seafood.

While in mid-1980s, first transgenic fish breeding studies are carried out by microinjection in freshwater fish species, the first gene transfer on marine species had been conducted by Cavari *et al.* (1993) in gilthead seabream by two different gene construct microinjection transfer tests. The study carried out by Lu *et al.* (2002) in silver seabream (*S. sarba*) besides the transfer of transgene constructs to the sperm by electroporation method, the mixture of liposome – transgene is injected into the testicle. Furthermore, studies are carried out on microinjection of transgene constructs into marine fish's pelagic eggs and on temporary green fluorescent protein (GFP) expression on these embryos in red seabream (*P. major*) (Kato *et al.* 2007) and Pacific bluefin tuna (*T. orientalis*) (Otani *et al.* 2008). Due to the fact that most economically important marine fish species have eggs with hard chorion of 0,8–1 mm diameter demonstrating pelagic specifications, it is stated that methods like electroporation enabling manipulation of multiple eggs at once are more suitable than microinjection for gene transfers into marine embryos (Yamamoto 2011).

Besides that deaths observed in marine fish embryos and larvae may be due to manipulations applied to them, as well as egg quality, environmental conditions, nutrition and cannibalism (Kaji *et al.* 1999). it is stated that obtaining fertilized eggs through natural ways to increase survival rates following manipulations shall also increase the success rates (Otani *et al.* 2008). In addition, the need to use large volume tanks, an important handicap in experimental studies, has been eliminated by using smaller tanks (30L) for embryos following microinjection, till they attain their juvenile stage, increased the success rate and this success allowed to work on developing transgenic applications (Yamamoto 2011).

In spite of considerably limited scientific studies conducted on marine fish about transgenic fish breeding, AquAdvantage salmon which is an anadromous fish created by gene transfer performed on Atlantic salmon (*Salmo salar*), is the only product that is accredited for human consumption by food and drug administration (FDA). AquAdvantage salmon, which is developed by AquaBounty Technologies in 1989, carries a gene construct (opAFP-GHc2) that is created using ocean pout (*Macrozoarces americanus*) antifreeze protein (AFP) gene and chinook salmon (*O. tshawytscha*) growth hormone. Due to the AFP gene that is transferred in the blood of AquAdvantage salmon which carries this gene construct, antifreeze proteins increase and allow this fish to continue to grow not only through spring and summer, but throughout the year and as a result of triploidy and gynogenetic applications, this fish is produced as both sterile and all-female respectively (AquaBounty 2010).

Following the announce made by FDA of the USA on November 16, 2015 that consuming genetically modified AquaAdvantage Salmon is safe, is considered as an important development in aquaculture sector with regard to genetically modified fish marketing as food products. Only Canada and the USA are allowing consumption of these fish species for the moment that are sterile as they are only female and triploid. Another example is the transfer of GFP, red fluorescent protein (RFP) and yellow fluorescent protein (YFP) genes to the eggs of zebrafish under the brand Glofish™ in aquarium fish breeding. Commercially it is applied not only to zebra fish but also to barb, tetra ad sharks and they are accredited as commercial commodities in aquarium market. These fish are lines that are bred to determine environmental pollutants and later on they are marketed in ornamental fish sector due to their morphological appearances (Debode *et al.* 2020). As mentioned here above, besides aquaculture sector, biotechnological applications have provided product based results successfully in ornamental fish sector too and they became regular elements of our lives. Due to the insufficiency of natural resources, in parallel with the increase in world's population, several studies are carried out especially with the purpose of closing the gap in food products. As classical breeding, improvement and biotechnological applications which are among these applications, became insufficient, biotechnological products that are obtained by modern breeding, improvement and biotechnical applications started to be sold in the sector. Although there is no study in Turkey carried out on transgenic marine fish reproduction, EGFP gene is transferred by microinjection in 2007 into zebra fish, which is used as a model organism and which is a species that is bred in aquariums (Ekici 2007). However, no further studies have been conducted afterwards in Turkey.

Surrogate broodstock technology

Surrogate broodstock technology is an application adapted to aquaculture practices being inspired by surrogate motherhood which was on the agenda approximately 30 years ago. This practice involves the process of transplantation of an embryo to another mother's womb as a result of in vitro fertilization in order to ensure infertile women to have children and the process of the embryo development. The practice is being tried in fish species. The donor-based germ cells, which can differentiate to sperm and egg cells, are transplanted to surrogate fish. Thus, germ cells that belong to donor fish develop in the gonads of the recipient fish. The first steps in the application of surrogate technology are the isolation and cryopreservation of the germ cells and the transplantation of isolated donor germ cells to the surrogate fish.

Germ cell isolation

The germ cell studies in fish have been started by Gamo in 1961 and by Hamaguchi in 1982 and have been carried out on many species until today. Germ cells (GC), unlike somatic cells, can differentiate to functional gametes and transfer the genetic information to future generations with the fertilization process. These cells have particular importance for the studies on surrogate broodstock technology since they are separated from other cells at the primitive development stage and migrate to the region where the gonad will be formed (genital ridge) (Nishimura and Tanaka 2014).

The ratio of early/late germ cells is determined by histological examination in order to determine the right time for the isolation of early GC (eGC) to be used in germ cell transplantation (Güngör 2015). The ratio of germ cells in different developmental stages in gonads is an important parameter since it will determine the amount of eGH to be obtained from gonad in the isolation stage (Timmermans and Taverne 1989). Percoll-gradient (Atmaca 2017), cell culture (Lacerda *et al.* 2013), and flow cytometric isolation (Yano *et al.* 2008) methods are used manually for the isolation of germ cells. Among these, percoll gradient and flow cytometer methods are the most commonly used methods after enzymatic separation. These isolated cells can be labelled with various dyes and after the transplantation to the embryo or larvae their migration in the body can be monitored (Güralp *et al.* 2017).

A limited number of marine fish species have been studied. In these studies, the cells are isolated from testicular tissue by enzymatic separation; donor cells are labelled with PKH26 and made ready for transplantation. The enzymatic separation has been achieved using collagenase, dispase and trypsin (Yoshikawa *et al.* 2017) enzymes from testicular tissue of yellowtail (Higuchi *et al.* 2011) from the Carangidae family and Nibecroacker (Yoshikawa *et al.* 2017) from Sciaenidae family. In Turkey, testicular cells of rainbow trout have been isolated using percoll gradient after enzymatic separation (Atmaca 2017) and no application has been made for marine fish.

Production of sterile fish and germ cell transplantation studies

For a successful GC transfer, the surrogate fish must be infertile for the development of germ cells only belonging to the donor. The triploidization procedure is widely preferred due to the ease of application in transplantation studies conducted for sterilization. Healthy, donor-derived offspring is obtained from the surrogate with the proliferation of these cells in the gonads of triploid surrogate fish and differentiation through gametogenesis (Okutsu *et al.* 2008).

Although the meiosis mechanism of triploid GCs obtained as a result of triploidization is prevented, triploid fish gonad has the ability to synthesize sex steroids required for the gametogenesis of donor GCs. Thus, the surrogate triploid fish brings donor-derived diploid germ cells to maturity although the GCs of the triploid surrogate fish are not developed (Felip *et al.* 2001). In a study conducted on Nibe croaker (*N. mitsukurii*) in marine fish, fertilized eggs were exposed to cold shock for 15 minutes at 10 °C during meiosis II to prevent the separation of polar body and triploidy was achieved (Takeuchi *et al.* 2018). In these studies, progenitor germ cells such as A-type spermatogonia or oogonia isolated from diploid donor fish were transplanted to the peritoneal cavity of newly hatched triploid (3n) larvae through microinjection.

In fish, the first transplantation of embryonic GCs was performed from one zebrafish embryo to another (Lin *et al.* 1992). Since then, this technique has become a useful biotechnological tool by adaption to different species and improvement using different application methods. In aquaculture applications, surrogate broodstock technology can be used for control of the reproductive cycle, reduction of the area where the breeding species are stored, control of egg and sperm production, conservation of genetic diversity, and cryopreservation. This technique can also be used for transgenic application on animals, conservation of genetic stocks of economically valuable animals or endangered species and aquaculture studies of species that can not be cultivated (Okutsu *et al.* 2008). It covers the subjects involving the examination of processes related to GC development and differentiation, the production of transgenic organisms with genetically modified germline cells, and the establishment of broodstock systems for surrogate parents that are replaced for target species (Yoshizaki *et al.* 2010). GC transfer is performed in order to shorten the time of reaching sexual maturity in species that take a long time to reach reproductive maturity in aquaculture applications, to protect and conserve genetic resources of important species with cryopreservation of GCs (Pšenička *et al.* 2016), to produce fish by growing GCs in vitro without preserving broodstock fish in the enterprise (Shikina *et al.* 2013) and to carry out aquaculture studies using easily-produced species for species that are difficult to produce. It is thought that the donor-derived gametes may be produced faster and easier in recipient fish species and production may be achieved in small fish tanks located on land by transplanting the spermatogonia of marine fish species which are difficult to maintain in cages (area, time, and labor cost) to smaller species present in the same family (Yoshizaki *et al.* 2010).

The first transplantation study of marine fish species was conducted by Takeuchi *et al.* (2009) for Nibe crocker species. In this study, the appropriate time for transplantation was identified. It was determined that when the Nibe crocker larva is 3-5mm long, donor cells begin to migrate and proliferate. In chromosome manipulation applications, the larval length is an important criterion for evaluating the success of germ cell transfer as well as the time and duration of the shock application.

In transplantation studies conducted on marine fish species, spermatogonia have been transplanted into the larvae and differentiated after the proliferation of donor-derived GC mature eggs and sperm in allogeneic gonads. As a result, normal generations with donor-derived phenotypes have been produced. Thanks to the sexual plasticity of testicular germ cells, yellowtail sperms have been successfully produced from marine fish species in jack mackerel (Morita *et al.* 2015). In addition, the applicability of this method has been ensured for other marine fish species such as yellowtail and yellowmouth (Takeuchi *et al.* 2009; Higuchi *et al.* 2011) (Table 3).

Gene editing technology; CRISPR/Cas9

Adding, removing or replacing a gene in desired areas is performed by creating double strand breaks (DSBs) through genome editing technology on the genome of an organism. Genome editing studies were tested for the first time approximately three decades ago in mice that were living models. There are four different genome editing techniques that are actually applied in our days. They are; TILLING, ZFN, TALEN and CRISPR/Cas9 techniques. CRISPR/Cas9 application has more advantages than the others due to its low-cost, high transfer efficiency, easy oligo synthesis and cloning steps. Researches are conducted on the applicability of CRISPR/Cas9 application, which is a relatively new application compared to other ones, at aquaculture studies. Although the product obtained as a result of CRISPR/Cas9 application is a genetically modified product, is not called as a transgenic since it doesn’t contain foreign gene constructs of any species in its genome. Therefore, it is believed that in case these fish are presented as a food for consumption by humans, they shall not create a negative perception as it is the case in transgenic fish. As it is expected that in obtaining species with desired specifications, requested changes occur within natural process through mating application in classical breeding technics, this process, although shows differences as per fish species, takes a long time. CRISPR/Cas9 application which is applied just after the fertilization of the ovule by the sperm and before the first DNA replication in the zygote, is used since 2012. Application time of the manipulations performed on fish gametes and embryosespecially after fertilization is important. Within these manipulations; while embryo in single cell stage is generally preferred in gene transfer studies, for chromosome manipulation applications, time and duration of second polar body expulsion depending on fertilization time, although it can differ depending on fish species, are important. Similarly, during CRISPR/Cas9 application, first DNA replication time which is realizing after the fertilization is important (Figure 1). CRISPR/Cas9 technology is applied in fish to eliminate pigmentation losses, to obtain sterile fish, to increase Omega-3 quantity in body composition, to enable the fish to attain market size in a short time, to obtain fish with high carcass density, to determine and differentiate their sex, to arrange genes that shall increase resistance to disease and to increase the production in the sector and to enhance disease resistance.

Table 3. Transplantation studies in marine fish species

Donor	Host	Donor age	Recipient age	Cell size	Cell strainer pore size (µm)	Germ cell marker	Testicular cell concentration	Testicular cell migration	References
S.quinqueradiata	*T.japonicus*	13 month old	10 and 12 dph	nm	35	PKH26	20.000 tc	nm	Morita *et al.* 2015
S.quinqueradiata	*S.quinqueradiata*	10 month old	8 dph	nm	35	PKH26	20.000 tc	nm	Morita *et al.* 2012
T.maccoyii	*S. lalandi*	immature and spermiating males	6–10 dph	nm	150 and 50	PKH26	nm	Migrated and colonised	Bar *et al.* 2016
N.mitsukurii	*S.japonicus*	3 month old	5-7-9 dpf	nm	42	PKH26	10 000 tc	Migrated and colonised	Yazawa *et al.* 2010
N.mitsukurii	*N.mitsukurii*	3, 6, and 16 month old	12-17-23-30 dpf	nuclear diameter larger than 9 µm	42	PKH26	nm	Migrated and colonised	Takeuchi *et al.* 2009
N.mitsukurii	*N. mitsukurii*	Adult - nm	1- to 2-cell stage embryo	nm	nm	eGfp gene	nm	Migrated, colonised and produced functional gametes	Yamamoto *et al.* 2011
N.mitsukurii	*Nibea mitsukurii* ♀ x *Pennahia argentata* ♂	5 month old	3 month old	nm	42	eGfp gene, PKH26	nm	Migrated, proliferated, and differentiated to transplantcells	Xu *et al.* 2019

nm: not mentioned

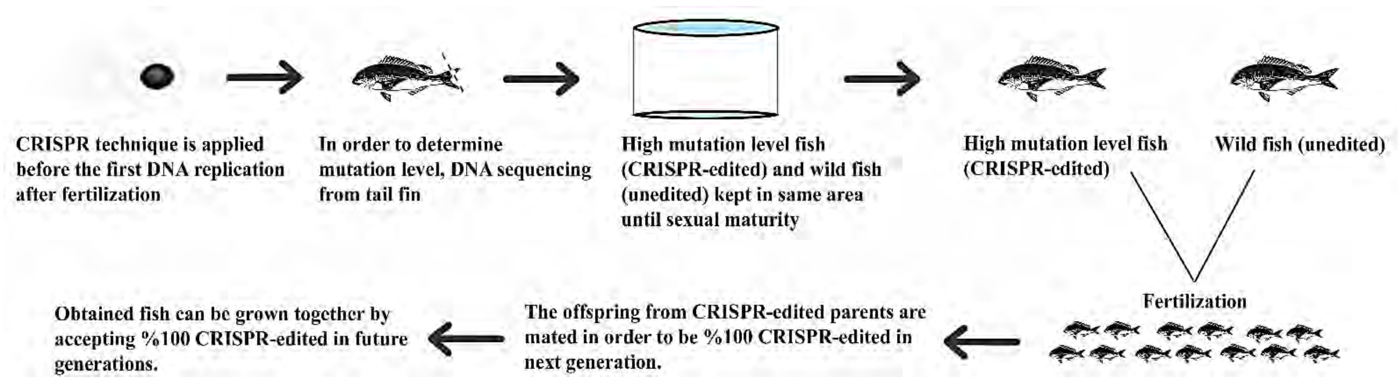

Figure 1. Schematization of CRISPR/Cas9 technique in fish

Studies performed on marine fish are much more limited compared to fresh water fish with CRISPR/Cas9 application as in other applications. In a study that can be given as an example to this technique in marine fish, it is aimed to increase meat yield. The red seabream (*Pagrus major*) was regulated on the gene that hormonally restricts muscle development to increase fillet quantity (more muscle, less fat) (Kishimoto *et al.* 2018).

In marine fish elovl-2 gene is effective on unsaturated fatty acids (in PUFAs) synthesis and strand elongation skills. When the gene (elovl-2) which plays an important role in the synthesis of multiple unsaturated fatty acids (PUFA) such as eicosapentaenoic acid (EPA) (20: 5n-3), arachidonic acid (20: 4n-6) and docosahexaenoic acid (DHA) (22: 6n-3) in Atlantic salmons which has the skill to synthesize them, is eliminated, the fish samples not having this gene are observed to accumulate arachidonic acid in the liver, brain and white muscle tissues (Datsomor *et al.* 2019).

Dnd which is a necessary factor for germ cells to stay alive in vertebrates, is neutralized by the application of CRISPR/Cas9 and fish producing no germ cells in F0 are obtained. By this application, results which shall be obtained as a consequence of long production periods (F_3) shall be obtained in a short time (F_0) (Wargelius *et al.* 2016).

Modifications at gene levels are realized in aquaculture product sector through gene-editing applications. Furthermore, solution of problems which can be solved after few generations is obtained in a shorter period of time. When obtained results are examined, it is believed that in the coming years, use of CRISPR/Cas9 technology shall provide studies supporting aquaculture and increase breeding using different species of fish, such as fish with heavier carcass than their normal peers in teleost species, breeding sterile individuals in order to prevent manipulated fish grown in farms from escaping to natural environment and harming genetic integrity and breeding fish with higher omega-3 levels and it shall accelerate the sector.

Conclusions and recommendations

1. When we evaluate breeding studies from the past to present, it is understood that each application is complementary to the other. Depending on the aim of the study, microinjection, cryopreservation and triploidy studies are needed in surrogate technology. Likewise, cryopreservation may be needed in hybridization and gynogen studies. So; a single developed application is insufficient to achieve the purpose alone. When a successful production is targeted, a production strategy should be developed depending on the needs of the species to be cultured.

2. With the support of research and development activities; In addition to sperm analysis systems, long term sperm preservation solutions will be developed and disseminated. Since the production of marine fish in tanks is carried out naturally without the need for artificial insemination applications, sperm cryopreservation applications have not developed as much as in freshwater species. However, sperm cryopreservation is an application that can be used to facilitate the production of protogynus and protandric hermaphrodite species in the waters of Turkey and ensure their sustainability.

3. Compared to freshwater fish species (Salmonid species 15mm), marine fish larvae (seabass 3.5mm, turbot 2.5mm) are shorter in length, making germ cell transfer difficult. Production success can be increased by using surrogate technology in species with high market demand like turbot, rock grouper and tuna.

4. The use of chromosome manipulation techniques, which are among the classical aquaculture techniques, has been realized by using freshwater fish species in Turkey in the late 80s. Its use on marine fish species has been limited. In order to monitor the development of the fish lineages to be obtained by the use of these applications in marine fish species and to evaluate them in terms of aquaculture performance, a separate area is needed within the enterprise. In marine fish, a minimum of 3-4 years is needed to achieve this objective and the use of branded broodstock during this period will be useful for traceability.

5. It has been understood that the studies applied in marine fishes in Turkey are carried out within the framework of hybridization and sperm cryopreservation, but these studies are limited to a few research articles and dissertation studies. No studies have been conducted to determine whether it is commercially feasible in production or suitable for the purpose of conserving gene resources.

6. In this section, in order to follow actual developments in other countries, apart the studies which are currently applied in Turkey, reproductive biotechnology studies that are not applied locally are also mentioned. Since the gametes, embryos and larvae of marine fish species are less resistant to manipulation than freshwater fish species, studies on marine fish have been limited. The reasons why applications of biotechnology in fish breeding do not develop on a sectoral basis in Turkey include the fact that keeping broodstock for breeding is more feasible by producers and that no budget is allocated for research and development applications.

7. As noted above, fish farms in Turkey remains reluctant to use biotechnological applications. For this reason, it is thought that the establishment of companies performing cryopreservation practices will ensure the sustainability of species as well as contribute to the culture of new species. In order to achieve continued success by the aquaculture sector in Turkey in the production of seabream and seabass, it is considered that species-specific problems can be avoided by supporting them with biotechnological applications.

The diversity of species grown in fish farms can be increased by facilitating the production activities of the new species where there is market demand but the hatchery success is low (*E. aeneus*, *Seriola dumerilii*, *Psetta maxima*). For example, the application of sperm cryopreservation in species such as *E. aeneus*, a protogynus hermaphrodite species, eliminates the problem of the simultaneous release of gametes of the same age fish.

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References

Arkhipchuk, V.V. (1995) Role of chromosomal and genome mutations in the evolution of bony fishes. *Hydrobiological Journal* 31(1): 55-65.

Atmaca, S. (2017) A study on the isolation of germ cell in rainbow trout (*Oncorhynchus mykiss*). Master's Thesis. Republic of Turkey Istanbul University Institute of Science and Technology, İstanbul. (in Turkish).

AquaBounty. (2010) Environmental Assessment for AquAdvantage® Salmon. Available at: https://cban.ca/wp-content/uploads/AAS_EA-redacted.pdf (accessed 28 May 2020).

Ayala-Florenciano, M.D., Cal, R., Hernandez-Urcera, J., Blanco, A., Lopez-Albors, O. (2013) Post-mortem degradation of the muscle tissue in diploid and triploid turbots (*Scophthalmus maximus* L.). *Aquaculture International* 21 (5): 1077-1090.

Aydın, İ., Okumuş, İ. (2017) Effects of triploid induction to the early cleavage patterns of black sea turbot (*Psetta maxima*) embryos. *Genetics of Aquatic Organisms* 1(1): 15-20.

Bar, I., Smith, A., Bubner, E., Yoshizaki, G., Takeuchi, Y., Yazawa, R., Elizur, A. (2016) Assessment of yellowtail kingfish (*Seriola lalandi*) as a surrogate host for the production of southern bluefin tuna (*Thunnus maccoyii*) seed via spermatogonial germ cell transplantation. *Reproduction, Fertility and Development* 28(12): 2051-2064.

Baynes, S.M., Verner-Jeffreys, D., Howell, B.R. (2006) Research on finfish cultivation. *Science Series Technical Report (CEFAS, Lowestoft, UK)* 32: 1-64.

Bertotto, D., Cepollaro, F., Libertini, A., Barbaro, A., Francescon, A., Belvedere, P., Barbaro, J., Colombo, L. (2005) Production of clonal founders in the European sea bass, *Dicentrarchus labrax* L., by mitotic gynogenesis. *Aquaculture* 246(1-4): 115-124.

Beardmore, J.A., Mair, G.C., Lewis, R.I. (2001) Monosex male production in finfish as exemplified by tilapia: applications, problems, and prospects. In Reproductive Biotechnology in Finfish Aquaculture. *Elsevier*. 283-301.

Cabrita, E., Engrola, S., Conceição, L.E.C., Pousão-Ferreira, P., Dinis, M.T. (2009) Successful cryopreservation of sperm from sex-reversed dusky grouper, *Epinephelus marginatus*. *Aquaculture* 287(1-2): 152-157.

Cabrita, E., Robles, V., Cuñado, S., Wallace, J.C., Sarasquete, C., Herráez, M.P. (2005a) Evaluation of gilthead sea bream, *Sparus aurata*, sperm quality after cryopreservation in 5 ml macrotubes. *Cryobiology* 50(3): 273-284.

Cabrita, E., Robles, V., Rebordinos, L., Sarasquete, C., Herráez, M.P. (2005b) Evaluation of DNA damage in rainbow trout (*Oncorhynchus mykiss*) and gilthead sea bream (*Sparus aurata*) cryopreserved sperm. *Cryobiology* 50(2): 144-153.

Cal, R.M., Vidal, S., Martínez, P., Álvarez-Blázquez, B., Gómez, C., Piferrer, F. (2006) Growth and gonadal development of gynogenetic diploid *Scophthalmus maximus*. *Journal of Fish Biology* 68(2): 401-413.

Cavari, B., Funkenstein, B., Chen, T.T., Gonzalez-Villasenor, L.I., Schartl, M. (1993) Effect of growth hormone on the growth rate of the gilthead seabream (*Sparus aurata*), and use of different constructs for the production of transgenic fish. *Aquaculture* 111: 189-197.

Chambeyron, F., Zohar, Y. (1990) A diluent for sperm cryopreservation of gilthead seabream, *Sparus aurata*. *Aquaculture* 90(3-4): 345-352.

Chao, N.H., Chen, H.P., Liao, I.C. (1975) Study on cryogenic preservation of grey mullet sperm. *Aquaculture* 5(4): 389-406.

Chereguini, O., García de la Banda, I., Herrera, M., Martinez, C., De la Hera, M. (2003) Cryopreservation of turbot *Scophthalmus maximus* (L.) sperm: Fertilization and hatching rates. *Aquaculture Research* 34(9): 739-747.

Cnaani, A., Levavi-Sivan, B. (2009) Sexual development in fish, practical applications for aquaculture. *Sexual Development* 3 (2-3): 164-175.

Condeça, J.B., Canario, A.V.M. (1999) The effect of estrogen on the gonads and on in vitro conversion of Androstenedione to Testosterone, 11-Ketotestosterone, and Estradiol-17β in *Sparus aurata* (Teleostei, Sparidae). *General and Comparative Endocrinology* 116(1): 59-72.

Colleter, J., Penman, D.J., Lallement, S., Fauvel, C., Hanebrekke, T., Osvik, R.D., Peruzzi, S. (2014) Genetic inactivation of European sea bass (*Dicentrarchus labrax* L.) eggs using UV-irradiation: Observations and perspectives. *PloS one* 9(10): e109572.

Colombo, L., Barbaro, A., Libertini, A., Benedetti, P., Francescon, A., Lombardo, I. (1995) Artificial fertilization and induction of triploidy and meiogynogenesis in the European sea bass, *Dicentrarchus labrax* L. *Journal of Applied Ichthyology* 11(1-2): 118-125.

Cuñado, N., Terrones, J., Sanchez, L., Martinez, P., Santos, J. (2002) Sex-dependent synaptic behaviour in triploid turbot, *Scophthalmus maximus* (Pisces, Scophthalmidae). *Heredity* 89(6): 460-4.

Datsomor, A.K., Zic, N., Li, K., Olsen, R.E., Jin, Y., Vik, J.O., Edvardsen, R.B., Grammes, F., Wargelius A., Winge, P. (2019) CRISPR/Cas9-mediated ablation of elovl2 in Atlantic salmon (*Salmo salar* L.) inhibits elongation of polyunsaturated fatty acids and induces Srebp-1 and target genes. *Scientific Reports* 9(1): 1-13.

Debode, F., Aline Marien, A., Ledoux, Q., Janssen, E., Ancion, C., Berben, G. (2020) Detection of ornamental transgenic fish by real-time PCR and fluorescence microscopy. *Transgenic Research* 29: 283-294.

Devlin, R.H., Nagahama, Y. (2002) Sex determination and sex differentiation in fish: an overview of genetic, physiological, and environmental influences. *Aquaculture* 208(3-4): 191-364.

Devlin, R.H., Yesaki., T.Y. Biagi, C.A., Donaldson, E.M., Swanson, P., Chan, W.K. (1994) Extraordinary salmon growth. *Nature* 371: 209-210.

Dreanno, C., Suquet, M., Quemener, L., Cosson, J., Fierville, F., Normant, Y., Billard, R. (1997) Cryopreservation of turbot (*Scophthalmus maximus*) spermatozoa. *Theriogenology* 48(4): 589-603.

Dujakovic J.J., Glamuzina, B. (1990) Intergeneric hybridization in Sparidae. 1. *Sparus aurata* (female) x *Diplodus puntazzo* (male) and *Sparus aurata* (female) x *Diplodus vulgaris* (male). *Aquaculture* 86: 369-378.

Ekici, A. (2007) A study on the gene (GFP) transfer in fertilized zebrafish (*Danio rerio* Hamilton-Buchanan, 1822) eggs. Doctoral dissertation. Istanbul University. Institute of Science and Technology. (in Turkish).

Engin, S. (2012) Cryopreservation of gilthead sea bream (*Sparus aurata*, L.1758) spermatozoa. Doctoral dissertation. Ege University. Graduate Faculty of Natural and Applied Science (in Turkish).

Engin, S., Saka, Ş., Fırat, K. (2018) Short term storage of gilthead sea bream (*Sparus aurata,* Linneaus, 1758) spermatazoa and investigation of spematological characteristic with parental relationships. *Turkish Journal of Agriculture-Food Science and Technology* 6(3): 372-379 (in Turkish).

Fabbrocini, A., Lavadera, L., Rispoli, S., Sansone, G. (2000) Cryopreservation of seabream (*Sparus aurata*) spermatozoa. *Cryobiology* 40: 46-53.

Fauvel, C., Suquet, M., Dreanno, C., Zonno, V., Menu, B. (1998) Cryopreservation of sea bass (*Dicentrarchus labrax*) spermatozoa in experimental and production simulating conditions. *Aquatic Living Resources* 11(6): 387-394.

Felip, A., Carrillo, M., Zanuy, S. (2009) Older triploid fish retain impaired reproductive endocrinology in the European sea bass *Dicentrarchus labrax*. *Journal of fish biology* 75(10): 2657-2669.

Felip, A., Piferrer, F., Carrillo, M., Zanuy, S. (1999) The relationship between the effects of UV light and thermal shock on gametes and the viability of early developmental stages in a marine teleost fish, the sea bass (*Dicentrarchus labrax* L.). *Heredity* 83(4): 387-397.

Felip, A., Zanuy, S., Carrillo, M., Martínez, G., Ramos, J., Piferrer, F. (1997) Optimal conditions for the induction of triploidy in the sea bass (*Dicentrarchus labrax* L.). *Aquaculture* 152(1-4): 287-298.

Felip, A., Zanuy, S., Carrillo, M. Piferrer, F. (2001) Induction of triploidy and gynogenesis in teleost fish with emphasis on marine species. *Genetica* 111: 175-195.

Francescon, A., Libertini, A., Bertotto, D., Barbaro, A. (2004) Shock timing in mitogynogenesis and tetraploidization of the European sea bass *Dicentrarchus labrax*. *Aquaculture* 236: 201-209.

Franch, R., Louro, B., Tsalavouta, M., Chatziplis, D., Tsigenopoulos, C.S., Sarropoulou, E., Antonello, J., Magoulas, A., Mylonas, C.C., Babbucci, M., Patarnello, T., Power, D.M., Kotoulas, G., Bargelloni, L. (2006). A genetic linkage map of the hermaphrodite teleost fish *Sparus aurata* L. *Genetics* 174(2): 851-861.

Gallego, V., Peñaranda, D.S., Marco-Jiménez, F., Mazzeo, I., Pérez, L., Asturiano, J.F. (2012) Comparison of two techniques for the morphometry study on gilthead seabream (*Sparus aurata*) spermatozoa and evaluation of changes induced by cryopreservation. *Theriogenology* 77(6): 1078-1087.

Gil, M.D.M., Grau, A., Basilone, G., Ferreri, R., Palmer, M. (2013) Reproductive strategy and fecundity of meagre *Argyrosomus regius* Asso, 1801 (Pisces: Sciaenidae): implications for restocking programs. *Scientia Marina* 77(1): 105-118.

Gorshkov, S., Meiri, I., Rosenfeld, H., Ben-Atia, S., Lutzki, S., Peduel, A., Ron, B., Skvortzov, A., Gorshkova, G., Tandler, A. (2003) Parental effects on sex ratios in progeny of the European sea bass (*Dicentrarchus labrax*). *The Israeli Journal of Aquaculture – Bamidgeh* 55(4): 265-273.

Gorshkova, G., Gorshkov, S., Hadani, A., Gordin, H., Knibb, W. (1995) Chromosome set manipulations in marine fish. *Aquaculture* 137(1-4): 157-158.

Gui J.F. (2007) Genetic basis and artificial control of sexuality and reproduction in fish. Science Press, Beijing, China.

Güner Y., Altunok, M., Kizak, V., Toksen, E. (2007) A new morone species "hybrid striped bass (*Morone chrysops* ♀ x *Morone saxatilis* ♂)" from Aydin Bozdoğan dam lake in Turkey. *Ecology* 16: 49-52.

Güngör, E. (2015) Isolation of early stages of germ cells in pikeperch (*Sander lucioperca*). Master's thesis. University of South Bohemia in České Budějovice.

Güralp, H., Pocherniaieva, K., Blecha, M., Policar, T., Pšenička, M., Saito, T. (2017) Migration of primordial germ cells during late embryogenesis of pikeperch *Sander lucioperca* relative to blastomere transplantation. *Czech Journal of Animal Science* 62(3): 121-129.

Gürkan, Ş., Gamsız, K., Karahan, B., Özcan Gökçek, E. (2017) Some morphometric features and length-weight relationships of F1 hybrid juveniles (*Umbrina cirrosa* ♀ X *Argyrosomus regius* ♂). *Ege Journal of Fisheries and Aquatic Sciences* 34(3): 287-291.

Haffray, P., Bruant, J.S., Facqueur, J.M., Fostier, A. (2005) Gonad development, growth, survival and quality traits in triploids of the protandrous hermaphrodyte gilthead seabream *Sparus aurata* (L.). *Aquaculture* 247(1-4): 107-117.

Higuchi, K., Takeuchi, Y., Miwa, M., Yamamoto, Y., Tsunemoto, K., Yoshizaki, G. (2011) Colonization, proliferation, and survival of intraperitoneally transplanted yellowtail *Seriola quinqueradiata* spermatogonia in nibe croaker *Nibea mitsukurii* recipient. *Fisheries Science* 77(1): 69-77.

Hoshino, T., Taki, Y., Ogasawara, Y. (1982) Activity of the sperm of the bluefin tuna *Thunnus thynnus* under fresh and preserved conditions [of semen]. *Bulletin of the Japanese Society of Scientific Fisheries* (Japan).

Howell, B.R., Baynes, S.M., Thompson, D. (1995) Progress towards the identification of the sex-determining mechanism of the sole, *Solea solea* (L.), by the induction of diploid gynogenesis. *Aquaculture Research* 26(2): 135-140.

IMV-technologies. (2019) Marine freeze kit web site. Available at: https://www.imv-technologies.com/product/marinefreeze-kit-of-3-bottles (accessed 25 Dec 2019).

Kaji, T., Tanaka, M., Tagawa, M. (1999) Laboratory study of density-dependent survival after handling in yolk-sac larvae of tunas and a grouper. *Fisheries science* 65(3): 482-483.

Karahan, B., Gamsız, K., Gökçek, E.Ö. (2013) Early growth and survival rate of hybrids from male meagre (*Argyrosomus regius*)× female shi drum (*Umbrina cirrosa*) compared to their parent species. *Israeli Journal of Aquaculture-Bamidgeh*: 65.

Karahan, B., Gamsız, K., Gökçek, E.Ö., Mahla, R., Haffray, P. (2014) Diploid and triploid unilateral Shi-Meagre hybrid between two Sciaenid species: the meager (*Argyrosomus regius*) and the shi-drum (*Umbrina cirrosa*). EAS Aquaculture Europe 2014. Donostia –San Sebastián, Spain.

Kato, K., Takagi, M., Tamaru, Y., Akiyama, S.I., Konishi, T., Murata, O., Kumai, H. (2007) Construction of an expression vector containing a β-actin promoter region for gene transfer by microinjection in red sea bream *Pagrus major*. *Fisheries Science* 73(2): 440-445.

Kiriyakit, A., Gallardo, W.G., Bart, A.N. (2011) Successful hybridization of groupers (*Epinephelus coioides* x *Epinephelus lanceolatus*) using cryopreserved sperm. *Aquaculture* 320(1-2): 106-112.

Kishimoto, K., Washio, Y., Yoshiura, Y., Toyoda, A., Ueno, T., Fukuyama, H., Kinoshita, M. (2018) Production of a breed of red sea bream *Pagrus major* with an increase of skeletal muscle muss and reduced body length by genome editing with CRISPR/Cas9. *Aquaculture* 495: 415-427.

Kızak, V., Güner, Y. (2014) First record of F2 hybrid striped bass (*Morone chrysops* ♀ × *Morone saxatilis* ♂ × *Morone chrysops* ♀ × *Morone saxatilis* ♂) in Kemer Dam Lake. *Turkish Journal of Zoology* 28(5): 637-641.

Lacerda, S.M.S.N., Costa, G.M.J., Campos-Junior, P.H.A., Segatelli, T.M., Yazawa, R., Takeuchi, Y., Morita, T., Yoshizaki, G., França, L.R. (2013) Germ cell transplantation as a potential biotechnological approach to fish reproduction. *Fish Physiology and Biochemistry* 39(1): 3-11.

Lin, S., Long, W., Chen, J., Hopkins, N. (1992) Production of germ-line chimeras in zebrafish by cell transplants from genetically pigmented to albino embryos. *Proceedings of the National Academy of Sciences* 89(10): 4519-4523.

Liu, Q.H., Li, J., Xiao, Z.Z., Ding, F.H., Yu, D.D., Xu, X.Z. (2007) Use of computer-assisted sperm analysis (CASA) to evaluate the quality of cryopreserved sperm in red seabream (*Pagrus major*). *Aquaculture* 263 (1-4): 20-25.

Lu, J.K., Fu, B.H., Wu, J.L., Chen, T.T. (2002) Production of transgenic silver sea bream (*Sparus sarba*) by different gene transfer methods. *Marine Biotechnology* 4(3): 328-337.

Martínez-Páramo, S., Diogo, P., Dinis, M.T., Herráez, M.P., Sarasquete, C., Cabrita, E. (2012) Sea bass sperm freezability is influenced by motility variables and membrane lipid composition but not by membrane integrity and lipid peroxidation. *Animal reproduction science* 131(3-4): 211-218.

Mei, J., Gui, J.F. (2015) Genetic basis and biotechnological manipulation of sexual dimorphism and sex determination in fish. *Science China Life Sciences* 58(2): 124-136.

Meng, Z., Liu, X., Liu, B., Hu, P., Jia, Y., Yang, Z., Zhang, H., Liu, X., Lei, J. (2016) Induction of mitotic gynogenesis in turbot *Scophthalmus maximus*. *Aquaculture* 451: 429-435.

Morita, T., Kumakura, N., Morishima, K., Mitsuboshi, T., Ishida, M., Hara, T., Takeuchi, Y. (2012) Production of donor-derived offspring by allogeneic transplantation of spermatogonia in the yellowtail (*Seriola quinqueradiata*). *Biology of Reproduction* 86(6): 176

Morita, T., Morishima, K., Miwa, M., Kumakura, N., Kudo, S., Ichida, K., Yoshizaki, G. (2015) Functional sperm of the yellowtail (*Seriola quinqueradiata*) were produced in the small-bodied surrogate, jack mackerel (*Trachurus japonicus*). *Marine Biotechnology* 17(5): 644-654.

Nishimura, T., Tanaka, M. (2014) Gonadal development in fish. *Sexual Development* 8: 252-261.

Okutsu, T., Takeuchi, Y., Yoshizaki, G. (2008) Spermatogonial transplantation in fish: Production of trout offspring from salmon parents. *Fisheries for Global Welfare and Environment* 209-219.

Oral, M., Colléter, J., Bekaert, M., Taggart, J.B., Palaiokostas, C., McAndrew, B.J., Peruzzi, S. (2017) Gene-centromere mapping in meiotic gynogenetic European seabass. *BMC genomics* 18(1): 449.

Otani, S., Ohara, M., Miyashita, S., Kobayashi, T. (2008) A method for the microinjection into naturally spawned eggs of marine fish, especially cultured Pacific bluefin tuna *Thunnus orientalis*. *Fisheries Science* 74: 208-210.

Öğretmen, F., İnanan, B.E., Kutluyer, F. (2016) Combined effects of physicochemical variables (pH and salinity) on sperm motility: characterization of sperm motility in European sea bass *Dicentrarchus labrax*. *Marine and Freshwater Behaviour and Physiology* 49(3): 217-222.

Özgür, M.E., Okumuş, F., Kocamaz, A.F. (2019) A novel computer assisted sperm analyzer for assessment of spermatozoa motility in fish; BASA-Sperm Aqua. *El-Cezeri Journal of Science and Engineering* 6(1): 208-219.

Pandian, T.J., Sheela, S.G. (1995) Hormonal induction of sex reversal in fish. *Aquaculture* 138(1-4): 1-22.

Penman, D.J., Beeching, A.J., Penn, S., Maclean, N. (1990) Factors affecting survival and integration following microinjection of novel DNA into rainbow trout eggs. *Aquaculture* 85(1-4): 35-50.

Peruzzi, S., Chatain, B. (2000) Pressure and cold shock induction of meiotic gynogenesis and triploidy in the European sea bass, *Dicentrarchus labrax* L.: relative efficiency of methods and parental variability. *Aquaculture* 189: 23-37.

Peruzzi S., Chatain B., Saillant E., Haffray P., Menu B., Falguière J.C. (2004) Production of meiotic gynogenetic and triploid sea bass, *Dicentrarchus labrax* L.: 1. Performances, maturation and carcass quality. *Aquaculture* 230: 41-64.

Peruzzi, S., Wiborg-Dahle, S., Haffray, P., Chatain, B., Primicerio, R. (2010) Body shape variation in meiotic gynogenetic and triploid sea bass, *Dicentrarchus labrax*. *Aquatic Living Resources* 23(3): 297-302.

Piferrer, F., Cal, R. M., Álvarez-Blázquez, B., Sánchez, L., Martinez, P. (2000) Induction of triploidy in the turbot (*Scophthalmus maximus*): I. Ploidy determination and the effects of cold shocks. *Aquaculture* 188(1-2): 79-90.

Piferrer, F., Cal, R.M., Gómez, C., Álvarez-Blázquez, B., Castro, J., Martínez, P. (2004) Induction of gynogenesis in the turbot (*Scophthalmus maximus*): Effects of UV irradiation on sperm motility, the Hertwig effect and viability during the first 6 months of age. *Aquaculture* 238(1-4): 403-419.

Pšenička, M., Saito, T., Rodina, M., Dzyuba, B. (2016) Cryopreservation of early stage Siberian sturgeon *Acipenser baerii* germ cells, comparison of whole tissue and dissociated cells. *Cryobiology* 72: 119-122.

Sansone, G., Fabbrocini, A., Ieropoli, S., Langellotti, A. L., Occidente, M., Matassino, D. (2002) Effects of extender composition, cooling rate, and freezing on the motility of sea bass (*Dicentrarchus labrax*, L.) spermatozoa after thawing. *Cryobiology* 44(3): 229-239.

Shikina, S., Nagasawa, K., Hayashi, M., Furuya, M., Iwasaki, Y., Yoshizaki, G. (2013) Short-term in vitro culturing improves transplantability of type A spermatogonia in rainbow trout (*Oncorhynchus mykiss*). *Molecular reproduction and development* 80(9): 763-773.

Spermvital (2019) SpermVital Norwegian cattle breeding company Geno and the SINTEF Group Norway. Available at: http://www.spermvital.com/Nyheter/New-research-project-through-Regional-Research-Funds-in-Norway/ (accessed 25 Dec 2019).

Sugama, K., Taniguchi, N., Seki, S., Nabeshima, H., Hasegawa, Y. (1990) Gynogenetic diploid production in the red sea bream using UV-irradiated sperm of black sea bream and heat shock. *Nippon Suisan Gakkaishi* 56: 1427-1433.

Suquet, M., Chereguini, O., Fauvel, C. (2009) Cryopreservation of sperm in turbot (*Psetta maxima*). In: Methods in Reproductive Aquaculture: Marine and Freshwater Species, Biology Series (eds., Cabrita, E., Robles, V., Herráez, M.P.), *CRC Press* (Taylor and Francis group), pp. 463-468.

Tabata, K. (1991) Induction of gynogenetic diploid males and presumption of sex determination mechanisms in the hirame *Paralichthys olivaceus*. *Nippon Suisan Gakkaishi* 57 (5): 845-850.

Takeuchi, Y., Higuchi, K., Yatabe, T., Miwa, M., Yoshizaki, G. (2009) Development of spermatogonial cell transplantation in Nibe Croaker, *Nibea mitsukurii* (Perciformes, Sciaenidae). *Biology of Reproduction* 81(6): 1055-1063.

Takeuchi, Y., Yatabe, T., Yoshikawa, H., Ino, Y., Kabeya, N., Yazawa, R., Yoshizaki, G. (2018) Production of functionally sterile triploid Nibe croaker *Nibea mitsukurii* induced by cold-shock treatment with special emphasis on triploid aptitude as surrogate broodstock. *Aquaculture* 494: 45-56.

Tian, Y., Jiang, J., Wang, N., Qi, W., Zhai, J., Li, B., Chen, S. (2015) Sperm of the giant grouper: cryopreservation, physiological and morphological analysis and application in hybridizations with red-spotted grouper. *Journal of Reproduction and Development* 2014: 087.

Timmermans, L.P.M., Taverne, N. (1989) Segregation of primordial germ cells: their numbers and fate during early development of *Barbus conchonius* (Cyprinidae, Teleostei) as indicated by 3H-thymidine incorporation. *Journal of morphology* 202(2): 225-237.

Tine, M., Kuhl, H., Gagnaire, P.A., Louro, B., Desmarais, E., Martins, R.S., Dieterich, R. (2014) European sea bass genome and its variation provide insights into adaptation to euryhalinity and speciation. *Nature communications* 5: 5770.

Tırpan, M.B., Özgöray, E.D., Alemdar, H., Akçay, E. (2016) Cryopreservation of seabream (*Sparus aurata*) semen and fertility. *Turkish Journal of Veterinary and Animal Sciences* 40(2): 200-206.

Wargelius, A., Leininger, S., Skaftnesmo, K.O., Kleppe, L., Andersson, E., Taranger, G.L., Edvardsen, R.B. (2016) Dnd knockout ablates germ cells and demonstrates germ cell independent sex differentiation in Atlantic salmon. *Scientific Reports* 6: 21284.

Xu, J., You, F., Sun, W., Yan, B., Zhang, P., Jing, B. (2008). Induction of diploid gynogenesis in turbot *Scophthalmus maximus* with left-eyed flounder *Paralichthys olivaceus* sperm. *Aquaculture International* 16: 623-634.

Xu, D., Yoshino, T., Konishi, J., Yoshikawa, H., Ino, Y., Yazawa, R., Takeuchi, Y. (2019) Germ cell-less hybrid fish: ideal recipient for spermatogonial transplantation for the rapid production of donor-derived sperm. *Biology of Reproduction* 101(2):492-500.

Verrier, E.R., Langevin, C., Tohry, C., Houel, A., Ducrocq, V., Benmansour, A., Quillet, E., Boudinot, P. (2012) Genetic resistance to rhabdovirus infection in Teleost fish is paralleled to the derived cell resistance status. *Plos One* 7: e33935.

Yamamoto, Y., Kabeya, N., Takeuchi, Y., Higuchi, K., Yatabe, T., Tsunemoto, K., Yoshizaki, G. (2011) Establishment of a stable transgenic strain in a pelagic egg spawning marine teleost, Nibe croaker *Nibea mitsukurii*. *Aquaculture* 313(1-4): 42-49.

Yang, J.F. (2009) Study on gynogenesis and sex control in four flounder fish. Doctoral dissertation, China Ocean University, pp. 24-33 (In Chinese with English abstract).

Yano, A., Suzuki, K., Yoshizaki, G. (2008). Flow-cytometric isolation of testicular germ cells from rainbow trout (*Oncorhynchus mykiss*) carrying the green fluorescent protein gene driven by trout vasa regulatory regions. *Biology of Reproduction* 78(1): 151-158.

Yasuike, M., Iwasaki, Y., Nishiki, I., Nakamura, Y., Matsuura, A., Yoshida, K., Fujiwara, A. (2018) The yellowtail (*Seriola quinqueradiata*) genome and transcriptome atlas of the digestive tract. *DNA Research* 25(5): 547-560.

Yazawa, R., Takeuchi, Y., Higuchi, K., Yatabe, T., Kabeya, N., Yoshizaki, G. (2010) Chub mackerel gonads support colonization, survival, and proliferation of intraperitoneally transplanted xenogenic germ cells. *Biology of Reproduction* 82(5): 896-904.

Yoshikawa, H., Takeuchi, Y., Ino, Y., Wang, J., Iwata, G., Kabeya, N., Yazawa, R., Yoshizaki, G. (2017) Efficient production of donor-derived gametes from triploid recipients following intra-peritoneal germ cell transplantation into a marine teleost, Nibe croaker (*Nibea mitsukurii*). *Aquaculture* 478: 35-47.

Yoshizaki, G., Okutsu, T., Ichikawa, M., Hayashi, M., Takeuchi, Y. (2010) Sexual plasticity of rainbow trout germ cells. *Animal Reproduction* 7(3): 187-96.

Zanuy, S., Carillo, M., Blazquez, M., Ramos, J., Piferrer, F., Donaldson, E.M. (1994) Production of monosex and sterile sea bass by hormonal and genetic approaches. *Publ Assoc Devélop Aquacult* 119: 409-423.

Zilli, L., Schiavone, R., Zonno, V., Rossano, R., Storelli, C., Vilella, S. (2005) Effect of cryopreservation on sea bass sperm proteins. *Biology of Reproduction* 72(5): 1262-1267.

Turkish aqua-feed industry and future challenges

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Global trends and recent developments in Turkish marine aquaculture industry

Conventional aquaculture has become a growing industry with the development of marine Technologies and the introduction of new production systems in fish farming. As a rapid growing industry, the total amount of aquaculture production in the World (including plants) significantly increased over the last 10 years from 66 302 224 tons (first-sale value of US$ 98.3 billion) in 2007 to 111 946 623 tons with a direct sale value of US$ 249.6 billion in 2017, among which 80 133 588 tons comprised food fish with economic value of US$ 237.6 billion, and 31.810.863 tons of aquatic plant sources with a value of US$ 11.8 billion (FAO 2019a). It has been estimated that about 88 % of the total fish production in 2016 was used for direct human consumption, which showed an increase in recent years. Approximately 12 % was used as fishmeal and fish oil which is listed as non-food purposes (FAO 2018).

Turkey has increased the target for marine products from 1 billion USD to $ 2 billion. By the end of 2018, 952 million dollars of exports were realized from aquaculture and the previous target of 1 billion USD for year 2023 has already been achieved in 2019. Therefore, the new target has been raised to 2 billion for 2023. Turkey, with its rapid growing aquaculture industry increased aquaculture production from 33 500 tons (first-sale value 175 875 000 USD) to 61 090 tons (first-sale value 278 981 000 USD) for gilthead seabream, from 41 900 tons (first-sale value 205 310 000 USD) to 99 971 tons (first-sale value 508 606 000 USD) for European seabass, and from 61 173 tons (first-sale value 212 270 000 USD) to 106 733 tons (first-sale value 249 464 000 USD) for rainbow trout, and became the biggest producer of rainbow trout (*Oncorhynchus mykiss*), gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) in its region as well as amongst European countries with a total of 267 794 tons and first-sale value of 1 037 051 000 USD. The grand total for all aquaculture species in Turkey sums around 273 477 tons (first-sale value of 1 068 685 000 USD), including newly introduced aquaculture species such as Meagre (*Argyrosomus regius*, 697 tons), Shi-drum (*Umbrina cirrosa*, 125 tons), Bluespotted seabream (*Pagrus caeruleostictus*, 122 tons), Pink dentex (*Dentex gibbosus*, 107 tons), Redbanded seabream (*Pagrus auriga*, 66 tons), Common dentex (*Dentex dentex*, 51 tons), Red porgy (*Pagrus pagrus*, 20 tons), etc. (FAO 2019a).

The interest for new marine species in the Turkish aquaculture industry remarkably increased from year 2012 and reached a total production of 13.783 tons between 2012 and 2017, with a direct value of 105,371,000 USD for meagre shi-drum, bluespotted seabream pink dentex, redbanded seabream, common dentex, porgies, sciaenas, and sharpsnout seabream. With the consistent efforts of Turkish Tuna farming industry, Turkey became one of the leading tuna producers within the top 4 countries in Europe with a production of around 777 tons and a first-sale value of 10.596.000 USD in 2017 (FAO 2019a). Turkish aquaculture exports to nearly 100 countries including Japan, Korea and the United States, which are also important marine fish producers. The increasing amounts of fish consumption in Russia and Gulf countries provide an important export market for the Turkish aquaculture industry in the region.

World top-five producers of rainbow trout, European seabass, and gilthead seabream have been compared within European and Mediterranean countries and their percent distribution are presented in Table 1. Main producers of recently introduced marine fish species in the Mediterranean aquaculture are shown in Table 2.

Production trends and future estimations for the Turkish aqua-feed industry

The compound feed sector in Turkey backs to the early 1955s (Kop 2018), and the first diets for fish production was manufactured in Bilecik Province by a company called Bilecik Feed Company “BILYEMTAS” in 1978. BILYEMTAS Co. operated its own fleet of fishing vessels in the Black Sea for the supply of anchovy to process fishmeal and fish oil. Early 1980s when small enterprises initiated seabream and seabass grow-out practices with primitive wooden cage construction deployed in nearshore marine areas in the Aegean Sea, a private-run company fulfilled the market gap for the newly developing sector and established its first aqua-feed manufacture plant as Pınar (Çamlı) Feeds Company in Pınarbaşı town of Izmir province in 1983.

The first legal regulation for compound feeds to be implemented in the Turkish aqua-feed industry was amended on 7.7.1973 with the law number of 1734 (Ergül 1994). The first animal feed production in Turkey initiated by the private sector in 1955 was followed by a state enterprise “Yem Sanayi Türk AS” established in 1956, which continued its activities until 1996. Turkey produced 3533 tons of feed in 1959, reaching today a production of around 13.5 million tons in 2017. The feeds used in the aquaculture sector were considered as "fish feed" for the first time in 1999 with a production of 38415 tons, which was considered under other feed groups until 1998 (Kop 2018).

There is a growing demand for compound feeds for the drastic increase of fish production in Turkey. Aqua-feed production followed the growth trend of aquaculture fish produced, and increased from 355 387 tons in 2013 to 512 726 tons in 2017, with the biggest share of seabass diets (275 293 tons) and seabream diets (121 907 tons), followed by trout and salmon feed production of 76 290 and 2560 tons, respectively.

Today, there are 23 fish feed producing plants in Turkey. About 70% of these enterprises supply a production quantity of 30 000 tons or less. Around 63% of the companies offer a production quantity between 10 000 and 30 0000 tons (Emiroglu *et al*. 2019; GTHB 2019). It was pleasant to see that about 56% of the total enterprises investigated were producing fish feed only, showing the remarkable growth trend of the aquaculture sector (Emiroglu *et al.* 2019). The majority of aquaculture equipment supporters and service suppliers including feed production facilities, or consultants are based along the Aegean coasts of Turkey, and in Istanbul area (FAO 2019b).

Fish feed production in Turkey begun with pressed pellet systems in late 1980's and early 1990's, mainly produced for carp and trout, whereas the use of extrusion systems has started in 1998. Most of the aqua feed producing plants today use well developed extruder feed production technologies. Some of them are also operating with expander and pellet press technologies, but most of these plants prefer using extrusion feed processing technology (Kop 2018).

Based on estimations for 2023 and beyond, under similar circumstances to the last ten years, it could be expected that Turkish trout culture may reach a 153 600 tons and the estimated needs for aquaculture feeds might be around 199 700 tons for rainbow trout production in year 2023. A similar scenario might show a production of 95 600 and 175 000 tons with feed demands of around 162 600 and 297 600 tons for gilthead seabream and European seabass, respectively in 2023. With similar growth trends the production could be expected to reach 791 500, 719 400, and 2 178 800 tons with feed demands of around 1 028 00, 1 223 000, and 3 704 000 tons for rainbow trout, gilthead seabream, and European seabass, respectively for 2050 (Table 3, Figure 1).

Table 1. Top five producers of main three fish species of rainbow trout, gilthead seabream and European seabass (2017 data - FAO 2019a)

Rainbow trout *Oncorhynchus mykiss*		**Gilthead seabream** *Sparus aurata*		**European seabass** *Dicentrarchus labrax*	
World main producers (tons - % of World total)					
Iran	(167,830 - 20.7)	Turkey	(61,090 - 28.0)	Turkey	(99,971 - 46.4)
Turkey	(106,733 - 13.1)	Greece	(55,948 - 25.6)	Greece	(44,285 - 20.5)
Chile	(79,971 - 9.8)	Egypt	(35,221 - 16.1)	Spain	(17,656 - 8.2)
Norway	(66,902 - 8.2)	Spain	(17,005 - 7.8)	Egypt	(30,720 - 14.2)
Peru	(54,878 - 6.7)	Tunisia	(16,841 - 7.7)	Italy	(6,800 - 3.1)
∑ World	(811,590-100)		(218,099-100)		(215,636-100)
Europe main producers (tons - % of Europe total)					
Turkey	(106,733 - 26.4)	Turkey	(61,090 - 39.7)	Turkey	(99,971 - 56.1)
Norway	(66,902 - 16.5)	Greece	(55,948 - 36.3)	Greece	(44,285 - 24.8)
Italy	(35,000 - 8.6)	Spain	(17,005 - 11.0)	Spain	(17,656 - 9.9)
Russia	(33,806 - 8.4)	Italy	(7,600 - 4.9)	Italy	(6,800 - 3.8)
Denmark	(33,036 - 8.2)	Croatia	(4,830 - 3.1)	Croatia	(5,616 - 3.1)
∑ Europe	(404,687-100)		(154,088-100)		(178,202-100)
Mediterranean main producers (tons - % of Mediterranean total)					
Turkey	(106,733 - 26.4)	Turkey	(61,090 - 39.6)	Turkey	99,971 - 56.1)
Italy	(35,000 - 8.6)	Greece	(55,948 - 36.3)	Greece	(44,285 - 24.8)
France	(26,000 - 6.4)	Spain	(17,005 - 11.0)	Spain	(17,656 - 9.9)
Spain	(16,902 - 4.2)	Italy	(7,600 - 4.9)	Italy	(6,800 - 3.8)
Bosnia Herz	(2,962 - 0,7)	Croatia	(4,830 - 3.1)	Croatia	(5,616 - 3.1)
∑ Mediterranean	(404,687-100)		(154,088-100)		(178,202-100)

Table 2. Main producers of recently introduced marine fish species in the Turkish -and Mediterranean aquaculture (tons - % of Mediterranean total in parenthesis) (∑2012-2017 / FAO 2019a)

Meagre		**Sciaenas nei**		**Shi drum**		**Pink dentex**	
Argyrosomus regius		*Sciaena spp*		*Sciaena spp*		*Dentex gibbosus*	
Egypt	(69587-71.4)	Greece	(2057-73.2)	Turkey	(2055-99)	Turkey	(333-100)
Turkey	(9242-9.5)	Italy	(510-18.2)	Greece	(21-1.0)		
Spain	(8762-8.9)	Turkey	(245-8.7)				
Greece	(5333-5.5)						
France	(3400-3.5)						
Croatia	(574-0.6)						
Italy	(394-0.4)						
Portugal	(208-0.2)						
Tunisia	(82-0.1)						
∑ **Mediterranean**	(97502-100)		(2809-100)		(2076-100)		(333-100)
Sharpsnout seabream		**Porgies, seabream nei**		**Red porgy**		**Common dentex**	
Diplodus puntazzo		*Sparidae*		*Pagrus pagrus*		*Dentex dentex*	
Greece	(1616-88.9)	Turkey	(884-91.2)	Greece	(7152-93.5)	Turkey	(339-100)
Italy	(132-7.3)	Italy	(85-8.8)	Turkey	(494-6.5)		
Turkey	(69-3.8)						
∑ **Mediterranean**	(1817-100)		(969-100)		(7646-100)		(339-100)

Table 3. Estimations for production and feed demand for main three marine fish species of rainbow trout, gilthead seabream and European seabass in Turkish aquaculture towards 2050

	Rainbow trout				Gilthead seabream				European seabass			
Year	∑Pro[1]	G(%/y)[2]	EFCR[3]	∑Feed[4]	∑Pro[1]	G(%/y)[2]	EFCR[3]	∑Feed[4]	∑Pro[1]	G(%/y)[2]	EFCR[3]	∑Feed[4]
2007	61173	6.1	1.3	79525	33500	17.7	1.4	46900	41900	9.09	1.6	67040
2008	68649	12.2	1.3	89244	31670	-5.5	1.4	44338	49270	17.6	1.6	78832
2009	80886	17.8	1.3	105152	28362	-10.4	1.4	39707	46554	-5.5	1.6	74486
2010	85244	5.4	1.3	110817	28157	-0.7	1.4	39420	50796		1.6	81274
									9.1			
2011	107936	26.6	1.3	140317	32187	14.3	1.4	45062	47013	-7.4	1.6	75221
2012	114569	6.1	1.3	148940	30743	-4.5	1.4	43040	65512	39.4	1.6	104819
2013	128059	11.8	1.3	166477	35701	16.1	1.4	49981	67912	3.7	1.6	108659
2014	112345	-12.3	1.3	146049	41873	17.3	1.4	58622	74653	9.9	1.6	119445
2015	106598	-5.1	1.3	138577	51844	23.8	1.4	72582	75164	0.7	1.6	120262
2016	104355	-2.1	1.3	135662	58254	12.4	1.4	81556	80847	7.6	1.6	129355
2017	106733	-2.3	1.3	138753	61090	4.9	1.4	85526	99971	23.6	1.6	159954
2023	153600			199700	95600			133900	175000			280100
2030	235000			305500	161300			225900	336500			538500
2040	431200			560600	340700			477000	856300			1370200
2050	791500			1028900	719400			1007100	2178800			3486100

[1]∑Pro: total production; [2]G(%/y): percent growth per year; [3]EFCR: estimated average economic feed conversion rate (total feed supply / total biomass increase) Tacon (2018); [4]∑Feed: estimated total feed used (total production x EFCR); [5]EFCR (commercial farm data for seabream); [6]EFCR (commercial farm data for seabass)

Total production of fish species from 2007 to 2017 are obtained from FAO statistical records (FAO, 2019a), and estimations towards for 2023 and beyond are calculated based on average growth for the last 10 years (2007-2017) of each species listed.

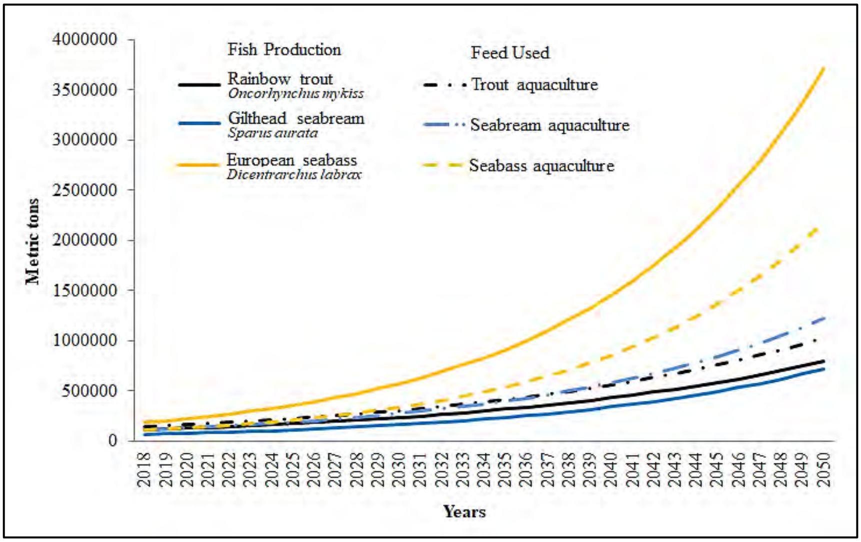

Figure 1. Growth trends and estimates - fish production and feed used for 2023 and beyond

Estimated data in Table 3 and Figure 1 clearly demonstrate that the demand for aquaculture feed will significantly increase over the next 30 years, which will coerce fishmeal and fish oil replacements with alternative dietary ingredients.

The annual production trend of the aquaculture sector and aqua-feed industry in Turkey are given in Table 4 and Figure 2.

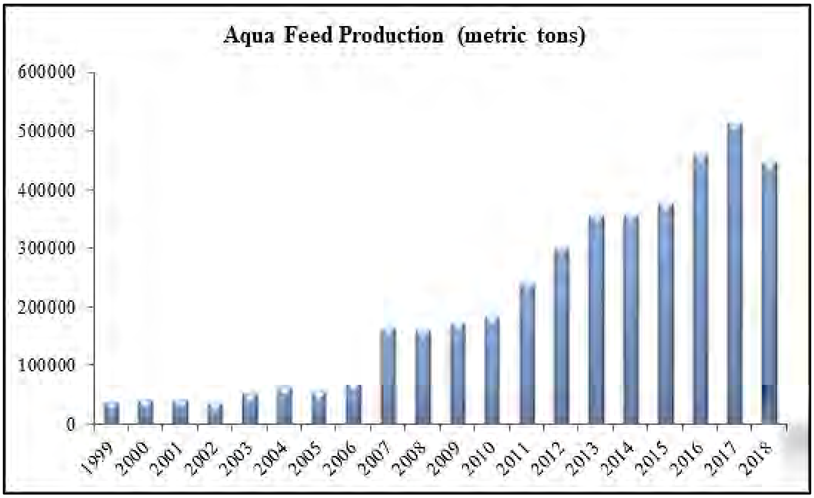

Figure 2. Aqua-feed production in Turkey

Table 4. Annual production trend of aquaculture and aqua-diets between 1999-2018 (TÜİK 2019; TURKIYEMBIR 2019)

Year	Aquaculture Production (tons)	Aqua Feed Production (tons)	Change of Feed Production (%)
1999	60023	38415	
2000	79031	40646	5.8
2001	67241	39396	- 3.1
2002	61165	35368	- 10.2
2003	79943	52260	47.8
2004	94010	64414	23.3
2005	119177	55058	- 14.5
2006	129073	70153	27.4
2007	140021	164611	134.6
2008	152260	159152	- 3.3
2009	158762	171514	7.8
2010	167141	184810	7.8
2011	188790	239273	29.5
2012	212410	300022	25.4
2013	233394	355387	18.5
2014	235133	355621	0.1
2015	240334	375515	5.6
2016	253394	461154	22.8
2017	276502	512761	11.2
2018	314537	446078	- 13.0

According to Turkish fish and fish feed statistics (Emiroglu *et al* 2019; TÜİK 2019; TURKIYEMBIR 2019), aquaculture production in Turkey was around 60.000 tons, while aqua-feed production was recorded as 38.000 tons in 1999. In 2018, fish production reached 314.000 tons with fish feed production around 446.000 tons (Table 4 and Figure 2). Over the past 20 years, it can be noted that the fish production increased 5-fold, while the increase of fish feed production was recorded as 10-fold from 1999 to 2018.

Feed conversion rate and estimated feed demand for recently introduced marine species

Thanks to the increasing quality of aqua-diets with a remarkable support and inputs of recent scientific reports, the feed conversion rates are in an improving trend. Tacon (2018) reported an FCR value of 1.3 for trout, a declining trend of FCR from 2.0 in 2000 to 1.7 in 2016, for seabream and seabass, with an expected value of 1.6 in year 2020, and 1.5 in 2025. Direct information provided by commercial fish farmers in Turkey gives an FCR estimate of 1.3 for rainbow trout in marine cage farms, while 1.4 and 1.6 FCR values are given for seabream and seabass, respectively, which remain less than the FCRs provided by Tacon (2018).

Estimations for future trends of production and feed demand for the newly introduced aquaculture species such as meagre, shi-drum, bluespotted seabream, pink dentex, redbanded seabream, common dentex, or red porgy have not been included in Table 3 or Figure 1, because these estimations would not be reliable since the production trend of these new fish species do not show an increasing trend, rather a declining trend or fluctuation from 2012 to present. It could be more credible to follow general or bulk estimation for feed demand of these new species for marine aquaculture industry.

Direct information obtained from commercial fish farms presents an FCR of 1.1 for meagre, and about 1.7 to 2.0 (1.85 in average) for shi-drum, bluespotted seabream, pink dentex, redbanded seabream, common dentex, and red porgy. The total production of 9242 tons of meagre between 2012 and 2017 would account to an FCR of around 10160 tons of feed. The same estimation for the rest of the new fish species mentioned above could result in a feed consumption of 8170 tons for the total production from 2012 to 2017 with an average FCR of 1.85. These data show that the total estimated demand for rainbow trout, seabream, and seabass provided in Table 3, needs alterations and corrections based on the introduction and production increase of the new species for the Turkish marine aquaculture industry. Providing an estimated bulk value for the additional demand of the new aquaculture species would be too early at this stage. A more reliable estimation could be reached when the production of the new species would become an increasing market interest, rather than fluctuation or declining trends.

Feeding strategies and management for improving feed efficiency

Until the early 1990's hand-feeding was commonly applied in smaller-sized fish cages with less volume (Figure 3). Soon thereafter, beginning in 1995, hopper type small-volume feed containments were used as an automatic feeder controlled with a timer and run by an accumulator or even with small wind turbines (Figure 4). However, with the increase of the aquaculture industry from small-scale to well-developed facilities with technological infrastructure in the early 2000s, hand-feeding was no more affordable and machinery feeding equipment was introduced. Today, cage farms comprise bigger sized cage constructions with up to 50 m in diameter and remarkable numbers of cages per farm, hence automated feeding systems are nowadays in use from a barge system anchored and deployed next to the cage site (Figure 5).

Feeding management and strategies are directly related to operational success, and good feeding practice may lessen feed losses, improve feed efficiency and increase operational benefits in aquaculture facilities. There is no specific consensus on best feeding management, and recommended feeding methods are not in agreement with each other. Generally, fish farms develop their own feeding methods based on their experiences in the field. Feeding to satiation level is a common approach in aquaculture operations. Similarly, Einen *et al.* (1995) also reported that best feed efficiency could be gained at maximum growth point. In contrast however, best feed efficiency was obtained when fish were fed at a rate below the satiation level for trout (Wurtsbaugh and Davis 1977), striped perch (Cox and Coutant 1981), and catfish (Li and Lovell 1992). In turbot, best growth performance was recorded when feed was supplied at saturation level, however better feed conversion rate (the ratio between the amount of food consumed and the biomass of fish produced) was recorded when fish was fed at the level of 65% of the saturation (Van Ham *et al*. 2003). It is likely that the highest growth and best feed conversion rates are not always equidistant indicators. Additionally, body composition of fish fed 65% less of saturation was similar to those fed at saturation level. Adjustment of feeding levels is important for estimating the production rates in fish farms. Eventually, it might be advisable to feed close to but lower than the saturation level (about 1/3 of the saturation), and this type of feeding may not influence the meat quality or feed conversion rates (Yigit and Celikkol 2011).

Figure 3. Hand-feeding of salmon in octagonal-shaped wooden-frame small-scale fish cages (Photo original, July 1992 Kefken Island, Kocaeli, Turkey)

It is acceptable that the amount of feed consumption, and so the fishmeal and fish oil share per unit weight of farmed fish can be remarkably reduced through the combination of “good-aquaculture-practice” and proper “feeding management”.

With remarkable technological improvements and scientific achievements in compound feed formulation and manufacturing, feed conversion rates overall lowered significantly over the last decades, especially with a better understanding of feeding management with innovative strategies in aquaculture facilities.

Figure 4. Semi-automated feeders with timer control and energy supply of wind turbines (Photo original, July 1992 Kefken Island, Kocaeli,Turkey).

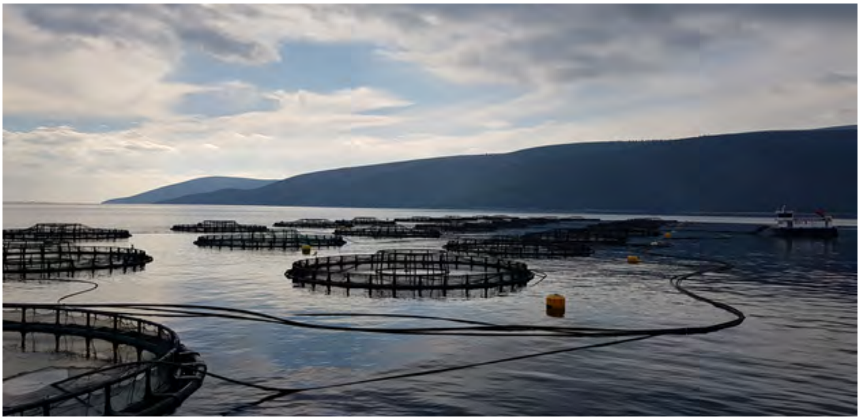

Figure 5. Full-automated pneumatic feeding systems controlled from a central platform (Photo original, November 2018 Sığacık Bay, İzmir, Turkey)

The state of compound feeds and efforts for sustainable development

Challenge of fishmeal -and fish oil use in marine aquaculture

The Food and Agriculture Organization of the United Nations estimated 60% growth for the global food demand by 2050 (FAO 2018), with an annual increase of 1.7% for animal protein production from 2010 to 2050 with meat production estimated to increase by around 70%, aquaculture by 90% and dairy products by nearly 55%. The world aquaculture industry seems to be capable to provide high quality protein for the increasing demand of human population in the world which is expected to hit nearly 10 billion in year 2050, and over 11 billion in 2100 (UN-WPP 2019). However, the rapid growth in intensive culture conditions arise significant risk concerns and pressure on the ocean ecosystem. The production of feed for the increasing aquaculture sector is highly dependent on marine resources, since fishmeal is the main source for dietary protein, which is compensated by wild fish catch of anchovy, sardines, herring, sprats etc. Annual fluctuations catch yields of these menhaden fishes precludes the forecast of prices which in terms becomes crucial for market strategies and advancing business development. Further, the world catch yields and the portion of menhaden fish transferred to fish production are scarce and not capable to cover the needs of the aquaculture industry. Hence, lowering the contribution of fishmeal in diets through replacement with alternative protein sources such as plant based proteins is a significant challenge that the aqua-feed industry faces.

In most fish species such as seabream, seabass, trout or turbot, about 50-70% of the total production costs comes from feed expenses (Yigit *et al*. 2003, 2005a, 2005b, 2006, 2010; Ergün *et al*. 2006, 2008a, 2008b; Hasan 2017; Sahinyilmaz and Yigit 2018; McNally 2019). Therefore, providing nutritionally balanced diets is of critical importance for best feed conversion and efficiency to reach superior growth by the time the fish reach targeted market size which will obviously influence the production success and economic returns in long term.

Despite huge efforts of researchers directed involved in novel feedstuffs, including animal by-products, seaweed, plant-based, -or insect sources, etc. for reducing the proportional share of fishmeal and fish oil in fish feed (Ergün *et al*. 2006; Turker *et al*. 2005; Yigit *et al.* 2006; Ergün *et al*. 2008a, 2008b; Yılmaz and Ergün 2013; Sahin *et al*. 2018), fishmeal and fish oil are still the most important and highly reliable ingredients in aqua-diets, however, the proportional rate of fishmeal or fish oil inclusion in fish feed are in a remarkable declining trend in recent years due to selective use and incorporation of other alternative protein sources. Even though special attention has been given for novel protein and oil sources to gradually replace with fishmeal and fish oil, the sustainable growth of the aquaculture industry is closely dependent on commercially availabilities of terrestrial animals or plant protein sources, oils and carbohydrates (Troell *et al*. 2014), because it is possible that it may take several years until these alternative sources can be available and affordable commercially.

An important amount of the global wild caught fish is transferred to fish oil -and meal processing plants, which in fact indirectly contributes to human food consumption through compound feed process for fish diets in aquaculture. Several small pelagic fishes, especially the so-called trash fish usually not preferred for direct human consumption are processed to fish oil and fishmeal. Among those, the anchovies (*Engraulis* sp.) provide reasonably high oil and protein, however a variety of anchovy species are also well preferred for human consumption, achieving high demand in the market, hence making it difficult to keep the supply-demand balance for anchovies, whether to use for human consumption or process into fishmeal or fish oil.

The prices of fishmeal and fish-oil show fluctuation depending on the catch yields of menhaden fishes. The catch yields of anchovies are influenced by harsh weather and sea condition such as the El Niño-Southern Oscillation, for example, which is known a global ocean-atmosphere phenomenon, the large fluctuations in the surface water temperatures in the Eastern Pacific Ocean and the atmospheric phenomena caused by these fluctuations.

Application of proper fishery management and implementing new regulations have contributed in the declining trend of fish catches targeted for fishmeal. A peak in fishmeal production was recorded in 1994 with around 30 million tons of fish in wet weight basis, with fluctuations over the past years but a declining trend has been observed in general up to date. The most important proportion of fishmeal today is being produced from fishery by-products equalizing to around 25-35% of total production for fishmeal or fish oil with differences in various regions (FAO 2018). The use of fishery by-product, which was earlier seen as a waste is reported to be around 54 % in European countries according to Jackson and Newton (2016).

The long-chain polyunsaturated fatty acids (PUFA) that is vital for human diets in terms of significant critical health functions can mostly be provided from fish oil. However, Auchterlonie (2018) reported that about 75% of annual fish oil production is used in the fish oil process for the aquaculture industry according to estimates of the Marine Ingredients Organization (IFFO). Similar to the case of fishmeal, declining trend of supply and fluctuations of fish oil, research interests have arisen to seek for alternative PUFA sources. Overall, fishmeal and fish oil are still among the most important ingredients for the aquaculture feed sector, but a remarkable decline in their contribution in fish feed can be seen. The incorporation of dietary fishmeal and fish oil in grow-out diets for carnivorous fish species such as salmon has decreased to around 10% over time (FAO 2018). Recently, a more careful and selective incorporation of fishmeal and fish oil in compound diets are practiced, especially in hatcheries, broodstock, or as finishing diets given for a certain period prior to harvest.

Challenge of new fish species with low-protein requirements in marine aquaculture

The majority of finfish species produced in Turkey are rainbow trout, gilthead seabream and European seabass, which are all carnivorous species requiring high levels of dietary protein (~44%). World quotations for fishmeal and fish oil are estimated to increase by 90% and 70% for fishmeal and fish oil, respectively

(Msangi *et al*. 2013). Therefore, a stepwise reduction of capture based wild fish as protein or oil source for aqua-diets is in great importance for the sustainability of the growing aquaculture industry (Nengas *et al*. 1996). In fact, the increasing trend of fishmeal and fish oil prices in the world may reduce the incorporation of fishmeal in aqua-feeds in long term (Tacon and Metian 2008). Recently, investigations have focused on substitution of fishmeal or fish oil with novel low-cost dietary ingredients (Yigit *et al*. 2010). It is also highly advisable to introduce new fish species with low protein requirements for the marine aquaculture sector (Msangi *et al*. 2013). For example, the salema porgy (*Sarpa salpa*) is a sparid fish, belonging to the same family with gilthead seabream (*S. aurata*), has been reported to school around cage farm facilities and feeding on pellets lost from the cage systems in the Aegean and Mediterranean Sea (Colorni and Diamant 2014; Sahinyilmaz and Yigit 2017, 2018), and salema together with striped mullet (*Mugil sephalus*) or White trevally (*Pseudocaranx dentex*) captured around fish farms operating in the Mediterranean Sea had a stomach with pellets of significant quantities (Neofitou 2016). Further, Sahinyilmaz and Yigit (2018) reported successful adaptation of salema porgy in cage nets with a feeding behavior similar to gilthead seabream or European seabass when fed compound diets. The optimum protein level in diets for juvenile salema porgy were reported as 33.6%, based on specific growth rate data analyzed via broken-line regression by Sahinyilmaz and Yigit (2017), who found increasing trend for ammonia nitrogen excretion in relation to the increase of dietary protein levels, and noted highest rates of ammonia nitrogen retention per intake when fish were fed the low-protein diets of 30 % or 37 % compared to the higher protein diets. The salema porgy can be seen as a marine fish species with relatively low protein requirement and a new species suitable for cage aquaculture conditions. Similar to salema porgy, the twoband seabream (*Diplodus vulgaris*) was also reported to demonstrate best growth with lower dietary protein levels compared to other marine aquaculture species such as gilthead seabream or European seabass. Bulut *et al.* (2014) tested increasing levels of dietary protein from 35% to 50% with two lipid levels of 10% and 15%, and reported best growth of twoband bream when fed a diet containing 35% protein and 15% lipid. This was also supported by Ozorio *et al*. (2009) who found best growth for this species with a 36.6% protein-diet. The low-protein diet for best growth in twoband bream was also underlined in a most recent study by Yigit *et al*. (2018), who recorded lowest excretion rates and highest retention rates of ammonia nitrogen in fish fed a diet containing 36 % protein. Hence, these most recent reports provide empirical evidence for the benefits of low-protein diets in some marine fish species such as salema porgy or twoband bream suitable for cage aquaculture. Considering the scarcity of global fishmeal and fish oil resources, new candidate fish species with less protein requirements are encouraged for sustainable extension of the cage aquaculture industry in the Mediterranean.

Ingredients used in compound diets in Turkish aqua-feed manufacture and new debates

A wide range of crops, wild fish and their by-products, as well as terrestrial livestock processing are used in the aqua-feed manufacture. In recent years, the share of fish from wild fisheries processed into fishmeal and fish oil has been in a declining trend with the increase of fish processing by-products. Further, dietary incorporation of fishmeal and fish oil in aqua-feed are also in a declining trend with remarkable substitution by animal by-products, crops and oilseeds (Ergün *et al*. 2006; Turker *et al*. 2005; Yigit *et al*. 2006; Ergün *et al.* 2008; Tacon *et al*. 2011; Yılmaz and Ergün 2013; Hasan and New 2013; Little *et al*. 2016). For example, Ytrestøyl *et al*. (2015) reported that the incorporation level of dietary fishmeal and fish oil in salmon feeds reduced from 65 % to 24 % and from 19 % to 11 %, respectively, from the 1990's to year 2013. Nevertheless, commercial availability is a significant key factor for the use of novel aquaculture ingredients, hence the success in research efforts are challenging issues for transferring scientific knowledge into the field.

Tuna fattening farms in Turkey use on-farm thawed frozen fresh fish, but commercially manufactured dry feeds are used for feeding rainbow trout, seabream or seabass. Therefore, different than the tuna farms, trout, seabream and seabass farmers have to rely on the quality of compound feed available in the market with fluctuation in prices. The incorporation level of other ingredients differs in a remarkable range between feed manufacturers. Ingredients other than fishmeal and fish oil used in the Turkish Aqua-feed industry can be listed as plant-based sources such as soybean (~30%), sunflower (~10%), rapeseeds (~20%), wheat (~10%), corn (~30%); by-products from terrestrial animal (for ex. blood meal) (~10%), poultry by-products (for ex. feather meal) (~50%) according to Turkish fish feed producers communication. Latest investigations show that dietary incorporation of alternative fish feed ingredients such as microalgae, yeast and bacteria (~5%), insect meal (~50%), etc. might be increased in the aqua-feed manufacture in the near future.

Today, the most frequently and commonly used ingredient alternative to fishmeal is soybean meal. Despite the similarity of amino acid balance of soybean with fishmeal, with only small differences in mainly lysine or methionine, one of the main reasons why it is widely preferred in aqua-diet manufacturing is the abundance of soybean in the market with high production and supply. Other plant-based protein sources as mentioned above are also highly potential for the replacement of fishmeal in aqua-diets with remarkable amino acid composition. The mixed use of several plant sources can even improve the amino acid balance with significant similarity to fishmeal. The only limiting issue here might be the shortage in product supply at quantities requested based on the demand of the growing aquaculture production.

Nowadays, about 70% of the fish meal used in aqua-diets in Turkey is provided through import (Kop 2018), and a remarkable part of the raw materials used in compound feeds such as soybean, soybean meal, full-fat soybean meal, corn -and wheat gluten, and corn meal are also imported (Yıldırım 2008; Kop 2018). According to the most recent report of TURKIYEMBIR, the turnover of the total compound feed sector in Turkey was $ 7.2 billion in 2018. A significant amount of $ 3.8 billion (11.1 million tons) comprises the imports of corn, oilseed meal and soybean meal, which is almost half of the total turnover of the feed industry (TURKIYEMBIR 2019). Therefore, it can be estimated that the dependency on foreign import could be reduced remarkably with introducing local ingredients, which in turns might increase the profitability through a reduction in foreign currency losses as well.

Novel feed additives for improving fish performance, welfare and disease resistance

Fish production in intensive culture conditions has increased outbreak risks of infectious diseases in over-stocked biomass conditions, water quality or environmental degradation, underwater acoustic noise beyond ambient sound level from machinery equipment in recirculating systems, etc. Depending on husbandry conditions and management, deterioration of the water environment and outbreak of bacterial diseases have been reported with fish losses of up to 30-40% in aquaculture facilities in Turkey. Some fish diseases that are most frequently reported in Turkish aquaculture facilities are *Furunculosis* sp., *Vibriosis* sp., motile *Aeromonas septicemia*, *Yersiniosis* sp., *Photobacteriosis* sp., and *Flavobacteriosis* sp. (Öztürk and Altınok 2014).

The antibiotics and chemotherapeutics are usually preferred for the control of several infectious diseases in culture systems. Among the well-known and widely-used antibiotics such as florfenicol, sulphadiazine+trimethoprim, oxytetracycline, amoxicillin, oxolinic acid and enrofloxacin for disease control of several marine aquaculture fish species are also in use as active ingredients in 41 different licensed drugs used in treatment of fish diseases in Turkey (Akşit 2016).

The use of chemotherapeutics and antibiotics in Turkish aquaculture facilities are linked to residual problems in the surrounding water environment, human body, as well as antibiotic-resistant pathogenic strains (Capkin *et al*. 2015; Yilmaz and Ergün 2018; Yilmaz *et al*. 2018; Yilmaz 2019a, b; Yilmaz *et al.* 2020). Furthermore, resistance may be acquired by genes, which are located on transposable elements of environmental, human -or animal-origin of current bacteria that could be transferred to bacteria isolated from fish (Capkin *et al.* 2015).

These detrimental effects caused important concerns towards the need to devise biologically-safe feeding strategies for cultured fish. Hence aqua-diets used in

Turkish marine aquaculture facilities have been improved with dietary incorporation of immune-stimulants, organic acids, herbs, essential oils, prebiotics, probiotics, synbiotics and potentially immune-reactive dietary feed additives. These supplements, just as growth promoters and synthetic antibiotics, mainly boost growth performance and immune-system to fight pathogens, respectively.

Future challenge and conclusions

Significant issues and challenges that the Turkish aqua-feed sector faces can be outlined as follows:

- Fluctuating prices of raw materials
- Import of raw materials with foreign currency
- Variation in the quality of feeds produced

Among the imported ingredients, soybean meal and feed additives are the major imported feed-stuffs for the Turkish aqua-feed companies. It is advisable and encouraged to produce those crucial raw materials inside the country in order to avoid import-dependency. Further, regulations and strategies need to be developed for the use and processing of alternative feed materials such as by-catch or trash fish, by-products, olive-cake, hazelnut, or other national products in the Turkish aqua-feed industry (Turker *et al*. 2005; Ergun *et al*. 2008; Yıldırım 2008; Sahin *et al*. 2018).

Main problems for the Turkish aquaculture sector could be summarized as follows:

- Lack of fish meal and fish oil with limited production
- Lack of plant production such as soya, and others
- High price of raw materials
- Foreign dependency for raw materials and feed additives
- Instability and inadequate standards of quality for feed raw materials

Estimations for the next 30 years clearly show that the demand for aqua-diets will significantly increase, with even more impacts and pressure on wild fish resources for producing fishmeal or fish oil. Therefore, replacement of fishmeal or fish oil with alternative and novel feed protein and oil sources is the main challenging point for ensuring sustainability of the marine aquaculture industry. Further, a novel marketing strategy for reforming consumer preferences towards new fish species with relatively low protein requirements as described earlier also may lessen the proportional share of fishmeal incorporation in aqua-diets in long term. This strategic approach of shifting consumer preferences to fish species produced with low-protein diets could provide significant contribution in reducing fishmeal or fish oil dependence, which in long term might improve the growth of the Marine aquaculture sector in a sustainable manner with ecological benefits and economic achievements.

References

Akşit, D. (2016) Antibacterial resistance and importance in fish farming. *Turkiye Klinikleri Veterinary Sciences-Pharmacology and Toxicology-Special Topics* 2(1): 47-54 (in Turkish).

Auchterlonie, N. (2018) The continuing importance of fishmeal and fish oil in aquafeeds. Presented at the Aquafarm Conference, Pordenone, Italy, 15p.

Bulut, M., Yiğit, M., Ergün, S., Kesbiç, O. S., Acar, Ü., Gültepe, N., Karga, M. Yilmaz, S. Güroy, D. (2014) Evaluation of dietary protein and lipid requirements of two-banded seabream (*Diplodus vulgaris*) cultured in a recirculating aquaculture system. *Aquaculture international* 22(3): 965-973.

Capkin, E., Terzi, E., Altinok, I. (2015) Occurrence of antibiotic resistance genes in culturable bacteria isolated from Turkish trout farms and their local aquatic environment. *Dis Aquat Org* 114(2): 127-137.

Colorni, A., Diamant, A. (2014) Infectious Diseases of Warmwater Fish in Marine and Brackish Waters. In: Diseases and Disorders of Finfish in Cage Culture, (eds., Woo, P.T.K., Bruno, D.W.), CABI Publishing, Wallingford UK, pp. 155-192.

Cox, D.K., Coutant C.C. (1981) Growth dynamics of juvenile striped bass as functions of temperature and ration. *Transaction of the American Fisheries Society* 110: 226-238.

Einen, O., Holmefjord, I., Asgard, T., Talbot, C. (1995) Auditing nutrient discharges from fish farms: theoretical and practical considerations. *Aquaculture Research* 26: 701-713.

Emiroglu, D., Tolon, M.T., Günay, D.B., Yapıcı, S.N. (2019) The development of the fish feed industry in Turkey. *Ege Journal of Fisheries and Aquatic Sciences* 36(1): 75-80 (in Turkish).

Ergül, M. (1994) Compound Feed and Compound Feed Technology. Ege Üniversitesi Ziraat Fakültesi Yayın No: 384, Izmir, 280 pp. (in Turkish).

Ergün, S., Yiğit, M., Türker, A., Önal, U. (2006) Evaluation of anchovy as a feed for turbot (*Psetta maeotica*). *Ege Journal of Fisheries and Aquatic Sciences* 23 (1/2): 219-222.

Ergun, S., Yigit, M., Turker, A., Harmantepe, B. (2008a). Partial replacement of fishmeal by defatted soybean meal in diets for Black Sea turbot (*Psetta maeotica*): Growth and nutrient utilization in winter. *Israeli Journal of Aquaculture–Bamidgeh*, 60(3), 177-184.

Ergun, S., Yigit, M., Turker, A., & Harmantepe, B. (2008b). Incorporation of soybean meal and hazelnut meal in diets for Black Sea turbot (*Scophthalmus maeoticus*). *Israeli Journal of Aquaculture–Bamidgeh*, 60(1), 27-36.

FAO (2018) The state of world fisheries and aquaculture 2018 presents FAO's official world fishery and aquaculture statistics. Available at: http://www.fao.org/state-of-fisheries-aquaculture (accessed 14 July 2019).

FAO. (2019a) United Nations food and agricultural organization, fisheries and aquaculture department, statistics - global aquaculture production (online query) (accessed 5 Aug 2019). http://www.fao.org/fishery/statistics/global-aquaculture-production/en

FAO (2019b) 2005-2019 National Aquaculture Sector Overview. Turkey. National Aquaculture Sector Overview Fact Sheets. Text by Deniz, H. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 8 February 2011 (Accessed on 21 Sept. 2019) http://www.fao.org/fishery/countrysector/naso_turkey/en

GTHB (2019) Fish feed manufacturing plants. Available at: http://www.tarim.gov.tr/Konu/1311/Balik-Yemi-Ureten-Yem-Fabrikalari (accessed 15 Aug 2019) (in Turkish).

Hasan, M.R. (2017) Feeding Global Aquaculture Growth. FAO Aquaculture Newsletter, No. 56, April 2017.

Hasan, M.R., New, M.B. (2013) On-Farm Feeding and Feed Management in Aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 583. FAO, Rome.

Jackson, A., Newton, R.W. (2016) Project to model the use of fisheries by-products in the production of marine ingredients with special reference to omega-3 fatty acids EPA and DHA. Institute of Aquaculture, University of Stirling & IFFO, the Marine Ingredients Organisation.

Kop, A. (2018) Turkey's aquaculture potential and developments in the fish feed sector. *International Journal of Oceanography & Aquaculture* 2(4): 1-3.

Li, M., Lovell, R.T. (1992) Growth, feed efficiency, and body composition of second- and third-year channel catfish fed various concentrations of dietary protein to satiety in production ponds. *Aquaculture* 103: 153-163.

Little, D.C., Newton, R. Beveridge, M.C.M. (2016) Aquaculture: a rapidly growing and significant source of sustainable food? Status, transitions and potential. Conference on 'The future of animal products in the human diet: health and environmental concerns', Symposium 3: Alternatives to meat, Nottingham, UK, 6–9 July 2015. Proceedings of the Nutrition Society 75(3): 274-286.

McNally, N. (2019) 5 Tips for reducing aquaculture farm costs. Available at: https://www.alltech.com/blog/5-tips-reducing-aquaculture-farm-costs (accessed 5 Aug. 2019).

Msangi, S., Kobayashi, M., Batka, M., Vannuccini, S., Dey, M.M., Anderson, J.L. (2013) Fish to 2030. Prospects for Fisheries and Aquaculture. Washington, USA: The World Bank Publication, report no. 83177-GLB.

Nengas, I., Alexis, M.N., Davies, S.J. (1996) Partial substitution of fishmeal with soybean meal products and derivatives in diets for the gilthead sea bream *Sparus aurata* (L.). *Aquaculture Research* 27(3): 147-156.

Neofitou, N. (2016) Waste feed from fish farms of the Eastern Mediterranean and attraction of wild fish. *Universal Journal of Geoscience* 4(5): 112-115.

Ozório, R.O.A., Valente, L.M.P., Correia, S., Pousao-Ferreira, P., Damasceno-Oliveira, A., Escorcio, C., Olivia-Teles, A. (2009) Protein requirement for maintenance and maximum growth of two-banded seabream (*Diplodus vulgaris*) juveniles. *Aquaculture Nutrition* 15: 85-93.

Öztürk, R.Ç., Altinok İ. (2014) Bacterial and viral fish diseases in Turkey. *Turkish Journal of Fish Aquatic Science* 14: 275-297.

Sahin, T., Yilmaz, S., Ergun, S. (2018) A potential substitute to fish meal: the veined rapa whelk, *Rapana venosa*. *International Journal of Oceanography & Aquaculture* 2(3): 1-8.

Sahinyilmaz, M., Yiğit, M. (2017) Evaluation of protein levels in diets for Salema Porgy (*Sarpa salpa*) juveniles, a new candidate species for the Mediterranean aquaculture. *Journal of Food and Nutrition Sciences* 5: 107-115.

Sahinyilmaz, M., Yigit, M. (2018) Adaptation, growth and bio-economic evaluation of wild-caught Salema (*Sarpa salpa* Linnaeus, 1758) juveniles in culture conditions. *Journal of Geo-Marine Sciences* 47(3): 697-701.

Tacon, A.G.J. (2018) Global trends in aquaculture and compound aquafeed production. Available at www.was.org (accessed 1 June 2018).

Tacon, A.G.J., Hasan, M.R., Metian, M. (2011) Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects. FAO Fisheries and Aquaculture Technic Paper No: 564. FAO, Rome.

Tacon, A.G.J., Metian, M. (2008) Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. *Aquaculture* 285: 146-158.

Troell, M., Naylor, R.L., Metian, M., Beveridge, M., Tyedmers, P.H., Folke, C., Arrow, K. J., Barrett, S., Crépin, A.-S., Ehrlich, P.R., Å. Gren, Kautsky, N., Levin, S.A., Nyborg, K., Österblom, H., Polasky, S., Scheffer, M., Walker, B.H., Xepapadeas, T., de Zeeuw, A. (2014) Does aquaculture add resilience to the global food system? *Proc Natl Acad Sci* 111(37): 13257-13263.

TÜİK (2019) Fishery Statistics. Turkish Statistical Institute. Available at: http://www.tuik.gov.tr/PreTablo.do?alt_id=1005 (accessed 15 Sept 2019).

Turker, A., Yigit, M., Ergun, S., Karaali, B., Erteken, A. (2005) Potential of poultry by-product meal as a substitute for fishmeal in diets for Black Sea turbot *Scophthalmus maeoticus*: Growth and nutrient utilization in winter. *Israeli Journal of Aquaculture–Bamidgeh* 57(1): 49-61.

TURKIYEMBIR (2019) Feed industry report 2019. Ankara, Turkey, 54 pp.

UN-WPP (2019) World Population Projects: The 2019 Revision – United Nations Population Division. Available at: https://population.un.org/wpp/

Van Ham, E.H., Berntssen, M.H.G., Imsland, A.K., Parpoura, A.C., Bonga, S.E.W., Stefansson, S.O. (2003) The influence of temperature and ration on growth, feed conversion, body composition and nutrient retention of juvenile turbot (*Scophthalmus maximus*). *Aquaculture* 217: 547-558.

Wurtsbaugh, W.A., Davis, G.E. (1977) Effects of temperature and ration level on the growth and food conversion efficiency of *Salmo gairdneri*, Richardson. *Journal of Fish Biology* 11: 87-98.

Yigit, M., Celikkol, B. (2011) Feeding strategy in aquaculture. *Su Ürünleri Mühendisligi Dergisi (SUMDER)* 43/48: 39-45.

Yigit, M., Ergün, S., Türker, A., Harmantepe, F.B., Bilgin, S. (2005a) Using ammonia nitrogen excretion rates as an index for evaluating protein quality of prawns in turbot *Psetta maeotica* nutrition. *Turkish Journal of Veterinary & Animal Sciences* 29: 1343-1349.

Yigit, M., Erdem, M., Aral, M.O., Harmantepe, F.B. (2005b) Nitrogen excretion patterns and postprandial ammonia profiles in Black Sea Turbot *Scophthalmus maeoticus* under controlled conditions. *Israeli Journal of Aquaculture-Bamidgeh* 57: 231-240.

Yigit, M., Erdem, M., Koshio, S., Ergün, S., Türker, A., Harmantepe, F.B. (2006) Substituting fish meal with poultry by product meal in diets for Black Sea Turbot *Psetta maeotica*. *Aquaculture Nutrition* 12: 340-347

Yigit, M., Ergün, S., Türker, A., Harmantepe, B., Erteken, A. (2010) Evaluation of soybean meal as a protein source and its effect on growth and nitrogen utilization of Black Sea turbot (*Psetta maeotica*) juveniles. *Journal of Marine Science and Technology* 18(5): 682-688.

Yigit, M., Koshio, S., Aral, M.O., Harmantepe, F.B., Karayücel, S. (2003) Ammonia nitrogen excretion rate an index for evaluating protein quality of three feed fishes for the Black Sea turbot. *Israeli Journal of Aquaculture-Bamidgeh* 55: 69-76.

Yigit, M., Sahinyilmaz, M., Acar, Ü., Kesbic, O., Yilmaz, S., Bulut, M., Gürses, R.K., Maita, M. (2018) Evaluation of dietary protein level in practical feed for twoband bream *Diplodus vulgaris*. *North American Journal of Aquaculture* 80 (4): 379-387.

Yıldırım, Ö. (2008) Aquafeed industry in Turkey: its aquafeed projections towards the year 2015. *Turkish Journal of Fisheries and Aquatic Sciences* 8: 93-98.

Yilmaz, S. (2019a) Effects of dietary blackberry syrup supplement on growth performance, antioxidant, and immunological responses, and resistance of Nile tilapia, *Oreochromis niloticus* to *Plesiomonas shigelloides*. *Fish & Shellfish Immunology* 84: 1125-1133.

Yilmaz, S. (2019b) Effects of dietary caffeic acid supplement on antioxidant, immunological and liver gene expression responses, and resistance of Nile tilapia, *Oreochromis niloticus* to *Aeromonas veronii*. *Fish & Shellfish Immunology* 86: 384-392.

Yılmaz, S., Ergün, S. (2013) Chickweed (*Stellaria media*) leaf meal as a feed ingredient for Tilapia (*Oreochromis mossambicus*). *Journal of Applied Aquaculture* 25 (4): 329-336.

Yılmaz, S., Ergun, S., Çelik, E.Ş., Yigit, M. (2018) Effects of dietary humic acid on growth performance, haemato-immunological and physiological responses and resistance of Rainbow trout, *Oncorhynchus mykiss* to *Yersinia ruckeri*. *Aquaculture Research* 49(10): 3338-3349.

Yilmaz, S., Ergün, S., Yigit, M., Yilmaz, E., Ahmadifar, E. (2020). Dietary supplementation of black mulberry (*Morus nigra*) syrup improves the growth performance, innate immune response, antioxidant status, gene expression responses, and disease resistance of Nile tilapia (*Oreochromis niloticus*). *Fish & Shellfish Immunology* 107: 211-217.

Ytrestøyl, T., Aas, S., Åsgård, T. (2015) Utilisation of feed resources in production of Atlantic salmon (*Salmo salar*) in Norway. *Aquaculture* 448: 365-374.

Advanced aquaculture systems in Turkey

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Introduction

The history of aquaculture in the world is quite old. For thousands of years, fish has played an essential role in the food preferences of human communities. It is reported that there is archaeological evidence that fisheries go back to 90 thousand years ago and fish culture under captivity conditions has been continuing since 4 thousand years (Bardach 1997; Stickney 2000; Costa-Pierce 2002; Lackey 2005; Marte and Toledo 2015). The history of aquaculture in Turkey is based on approximately 40 years ago.

Turkey has 7.200 km of coastlines bordering the Mediterranean Sea, Aegean Sea and the Black Sea. With many of the areas sheltered in bays, Turkey has an ideal position to become a global aquaculture producer. There are 426 facilities in Turkey with a total capacity of 254.430 tons/year engaged in the marine aquaculture sector. Growing production has been realized since the beginning of aquaculture studies. While 35.646 tons of marine fish were produced in 2000, the marine fish production reached 172.492 tons in 2017 (TUIK 2019).

The marine aquaculture production started with gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) and has continued to focus mainly on these two species over the years. The new species which have been produced in the Turkish marine aquaculture sector can be listed as meagre (*Argyrosomus regius*), common dentex (*Dentex dentex*), common seabream (*Sparus pagrus*) and common drum (*Umbrina cirrosa*).

It is a fact that the contribution of professionally specialised fisheries and aquaculture engineers in the process of increasing the production of aquaculture is quite high. In the process of aquaculture production, the population, which has public knowledge about nutrition and healthy living, has increased day by day and consumer preferences in Europe and Central America have improved in favour of seafood. Our country has also been affected by this positive approach, and projections have emerged to gain conscious consumption habits and to increase the diversity of species from aquaculture in the market. Consumer demands have led to an increase in the production of aquatic organisms which is a rich nutritional value such as long-chain highly unsaturated fatty acids and essential amino acids. In this context, large-scale and intensive systems have been replaced by small-scale traditional methods. Small-scale enterprises have entered into a production and commercial method implementation process to produce multiple different types in closed systems with small but high market prices by using technological infrastructures called niche products. Turkey is one of the top three countries in Europe regarding marine fish hatchery production rates and is in the first place in the Mediterranean countries with respect to the diversity for finfish species. These successes have been obtained from the modernisation of aquaculture mechanisation and the application of rational scientific production management (Genç 2011; Yıldırım 2019).

All aspects of aquaculture, hatchery, adaptation units, and cage culture systems, equipment, critical features, advantages and disadvantages of modernisation, consumer demands, market rates, pathogen-host relationship, energy, labour and feed costs and also climate change perspectives have been evaluated for many years (Hobday and Poloczanska 2010; Jensen *et al.* 2010; Fitridge *et al.* 2012; Badiola *et al.* 2012; Ioakeimidis *et al.* 2013; Buchmann 2015; Joyce and Utting 2015; Beveridge *et al.* 2018; Fredheim and Reve 2018; Tacon 2018; Ertör and Ortega-Cerdà 2019).

This section "Advanced Aquaculture Systems in Turkey" aims to provide information on the advanced aquaculture mechanisation systems suitable for marine fish stock/broodstock management, egg hatching, hatching, and post-hatching sensitive period, nursery (pre-larval feeding), larval/juvenile breeding, adaptation units, recirculating aquaculture systems and off-shore cage aquaculture systems. Mechanisation equipment, which is used in aquaculture applications and foreseen to be used in the near future, are introduced and the advantages and disadvantages of the systems are emphasized. To eliminate the current bottleneck of aquaculture in Turkey solutions to the problems has been given and discussed in this area.

Current industry status

Aquaculture is one of the industries that attracts attention with being one of the fastest-growing food sectors. More than 50% of the seafood consumed in the world is obtained from aquaculture. According to the United Nations Food and Agriculture Organization (FAO), it is foreseen that the production volume will have to expand by at least 40 million tons in order to provide per capita consumption by 2030 because of the estimated world population increase. The use of efficiency-oriented technology in marine aquaculture is becoming widespread all over the World. Because of the increasing production amounts, energy costs, competitive pressure and production studies on new species efficiency-oriented and environment-friendly sustainable production systems have been utilized in our country as in the World.

The global marine aquaculture industry is complicated to characterise, owing to the different approaches to marine fish cultivation around the world. In many cases, these different approaches are influenced by and dependent on culture and tradition. This is highlighted in Japan, which has the highest annual fish consumption per capita (75 kg) and consequently, cultures more than 60 different fish species to meet the high and varied national demand. The fish cultured in Japan are sold predominantly as live or whole fresh fish, similar to most other Asian nations. In contrast, the Mediterranean countries, which have a relatively high fish consumption (30-50 kg per capita per year), while there are several marine finfish species cultured, there are only two main fish species: the gilthead seabream and European seabass. The main products of these marine aquaculture industries are sold as a whole, fresh or chilled fish (FAO 2018; Yıldırım 2019).

Maturing industries (mainly Europe) and countries interested in developing marine aquaculture industry (especially the Gulf countries) are eagerly seeking the “next fish species” (i.e. an alternative species that will generate high demand and good market return). In Turkey, there are small production and/or trials have been conducted with several species including, meagre *Argyrosomus regius*, turbot *Scophthalmus maximus*, grey mullet *Mugil cephalus*, greater amberjack *Seriola dumerili* and groupers *Ephinephelus* sp. The two main criteria involved in the selection of species for marine aquaculture are fish biology/bio-ecology and market demand/structure. Other factors such as broodstock availability, egg collection and incubation success, suitable grow-out sites, environmental requirements, and industry regulations must also be considered (Eroldoğan *et al.* 2015; Genc *et al.* 2016; Güroy *et al.* 2017; Aktas *et al.* 2019; Evliyaoğlu *et al.* 2019).

Marine aquaculture systems and equipment

Hatcheries and hatchery design

Site selection and design prior to the installation of hatcheries and adaptation facilities is the most critical factor at the initial stage for a thriving culture. The selection of the location that provides the optimum natural conditions, the factors such as environment, water quality, logistics and energy, and subsequently design and installation will enable the facility to reach technically successful production. In the selection of the location, it is vital to monitor the suitability of water sources in terms of water quality and available amounts (Figure 1). Recirculating aquaculture systems (RAS) has become widespread in last ten years because of the limitation of water use, environmental conditions, changes in water quality, limitation of chemical and medications use, marketing factors and production of new species. Although the investment and operating costs are high, it is an efficient aquaculture system which is used around the World and in our country by using less water, less volume with the advantage of making high density and environment-friendly production under fully controlled conditions. The presence of RAS hatchery facilities that produce technically competitive levels with examples from the World in our country is an indicator of the growth and technical level of the Turkish aquaculture sector (Kaya and Genc 2018).

Marine fish hatcheries have different equipment and related mechanisation within the framework of management strategies. The hatcheries have egg collectors, hatchery tanks, pre-larva nursery tanks and larva feeding tank system including broodstock maintenance and feeding unit. These systems are generally localised at the seaside and are designed to receive the inlet water through different filtration devices. Well-filtered water entering the hatchery is used for both live feed production and larval feeding. After the coarse and fine filtration stages, water is sterilised by ultraviolet and passed through biofilter and then sent to hatchery tanks with minimum suspended solids and even minimum microorganism load. For this purpose, following the coarse filtration, it is ensured that the sand and cartridge filters are reduced to 1 μm mesh and therefore water is used as free of pathogenic microorganisms that may come from the environment. At this point, instantaneous warning and control system with automation controlled artificial intelligence technology allows measurement and monitoring of water quality parameters. In the hatchery management model, where fully controlled conditions are provided and environmental parameters are optimised, culture can be achieved with minimum loss by taking advantage of today's technology. The water used in this system is drained and re-filtered before being released back to nature with an environmentally friendly approach. By using drum filter and ozone/chlorine filtration devices, it is ensured that potential microorganism load and diversity caused by aquaculture is not left in the enterprises where wastewater treatment protocol is applied (Sorgeloos and Léger 1992; Sweetman 1992; Shields *et al.* 1999; Hussenot 2003; Sim *et al.* 2005; Alvarez-Lajonchère and Cittolin 2013).

Broodstock maintenance and feeding tanks (~15x3x1.2 m) are generally manufactured from reinforced concrete and fibreglass based materials in the dimensions required by the operation, and thus, it can be ensured that cleaning and disinfection operations can be performed successfully in hatchery management. All equipment, tools, devices, tanks and piping systems used in the hatchery should be manufactured from materials with good quality and minimum material release rate in order to prevent corrosion caused by water. In this way, it is possible to protect human, animal and environmental health.

Egg collectors in hatcheries consist of tanks and equipment designed by taking advantage of surface flow attraction. The most important part of this equipment is the carrier collector mechanism produced using the plankton nets. The mechanism should allow eggs to be collected and transported using the principle that the eggs remain on the water surface. Egg incubation and pre-larval maintenance and feeding tanks are equipped with a portable pump and pipe assembly that allows green water culture and rotifer reinforcement. It is provided to the tanks optimum ventilation with blower device and connections. To remove the thin film layer on the surface, an air blowing surface opening device should be used. Tanks should also have seawater and freshwater piping systems. In the standard modern hatchery design, at least three piping devices (air, freshwater, seawater) must be connected to each tank. Tanks are generally arranged in a cylindrical structure with central discharge and level adjustment. In nursery tanks where pre-larval maintenance and feeding is done, water exchange is applied to a minimum level. In this case, the rate of salinity in water may change due to evaporation. In order to keep the parameters at an optimum level, managerial measures and practices should be performed with water quality control measurements performed at least three times daily. In some hatchery management models, monitoring is considered a critical control and protection method since it is known that water quality measurements are performed hourly for 24 hours. For this purpose, there are monitoring systems that allow instant measurement of important water quality parameters. Besides, freshwater can be used for the purpose of washing and disinfection with salinity control in hatcheries and cultivation units applying closed system model. The freshwater connection to the tank systems may also allow the variation of the species type.

Different disinfectants are used to protect fish health in hatcheries. In case of diseases, therapy is performed with appropriate medicaments. In this context, wastewater quality not only consists of specific physical and chemical parameters of water but also includes denaturation of disinfectants and therapeutics in water. The use of chlorine, hydrogen peroxide and low levels of formaldehyde-based disinfectants, which can quickly move away from water in the management of environmentally friendly and conscious aquaculture hatcheries, is essential for the safety and quality of the discharge water (Genc 2011). The use of prebiotic and probiotic formulations that strengthen the immune system rather than the use of antibiotics in hatcheries within the scope of good management practices is another critical issue for the environment and human health and animal welfare applications (Genc *et al.* 2006; 2007a; 2007b; Yilmaz *et al.* 2007; Gelibolu 2018a; 2018b).

Adaptation units

Adaptation units are the enterprises that operate and manage according to the principle of gradual adaptation of sea fish fry to cage systems before they are stocked. These establishments are usually connected to hatcheries as well as cage farms. In Turkey, there are successful adaptation units working with full compliance controls used to improve the survival rate and the growth rate in the culture period. In the management of the adaptation unit, the physiological and immunological aspects of the fry are adapted to the natural seawater conditions. In this framework, it is possible to accustom the fish to commercial feed and to perform health parameters check before stocking to cages in adaptation units for a period ranging from fifteen days to several months. It is recommended that the fishes are adapted to artificial feed utilization and gain disease resistance for grow-out before stocking to cages. It is known that the fish which are kept in the adaptation units in order to adapt to the hand treatment processes encountered in the conditions of struggle against stress and growing conditions in captivity for a period of time, reach higher yields with less loss in cage production.

Figure 1. Marine hatchery (Photo: B. Serdar Yıldırım)

Equipment

In this section, the systems and equipment used in marine fish hatcheries and adaptation units were presented briefly stressing highlighted specifications.

Pumps, filtration and heater-cooler

In the marine aquaculture sector, heater-cooler systems used to maintain the optimum water temperature required by the species produced in hatcheries have been replaced with heat pumps over the years and the need for more efficient water heating/cooling with lower energy consumption.

The pump unit is the most essential equipment of a hatchery and adaptation facility in the water intake and RAS lines. With developing technology, the usage of pumps resistant to seawater and low energy consumption has become widespread. With the use of adjustable constant flow pumps, the supply of the water required by the tanks in all conditions has gained significant advantages.

The filtration is one of the most crucial elements affecting the quality of culture water. With the installation of filtration systems up to 1 µm in hatcheries, progress has been made in water quality of live feed, larva and broodstock units. The use of filters with low operating costs and high yields has become widespread both in the world and in our country in the marine aquaculture sector. Two types of filtration systems are used in the marine aquaculture sector: mechanical filtration and biological filtration. Mechanical filtration is used to remove solids from the system, and biological filters are especially used against ammonia and nitrite. The use of new technology filters in mechanical filter types has become widespread in the world and our country (Figure 2). The use of environmentally friendly and long-lasting filter elements in biological filters, which creates more surface area per unit volume compared to the previous periods, provided an increase in performance (Anonymous 2019a).

Figure 2. Mechanical filters (Photo: B. Serdar Yıldırım)

Ultra-violet (UV)

The small part of the electromagnetic spectrum wavelengths (100 and 400 nm) is defined as space of the ultra-violet irradiation. The UV-C is a part of the spectrum and the wavelengths, changes between 100 and 280 nm. Mainly the UV-C irradiation is known as a germicidal light with 254 nm wavelength. For the effective disinfection (in terms of killing the bacteria), the electromagnetic wave, specific effective wavelength (254 nm), volume, water flow, surface, the light intensity of UV-C irradiation and other specific features should be correctly calculated and arranged. If a UV steriliser is correctly designed, it is possible to apply a dose sufficient to kill almost all microorganisms present in the water. For successful disinfection, the dose of the UV system should be higher than 300 J/m^2. The Turkish aquaculture sector has pioneered the Mediterranean Area with UV usage with a minimum dosage of 400 J/m^2 (Figure 3). Over the years, the use of high-dose UV systems, especially in main water intake lines, has become widespread and has been one of the main factors supporting water quality (Anonymous 2019b).

Monitoring systems

Determining the amounts of dissolved oxygen, water temperature, pH and nitrogenous compounds, as well as monitoring instant fluctuations in water quality parameters are essential for the management and sustainability of the hatchery and adaptation facilities. Monitoring of the instant changes in water quality parameters can help for the preparation of emergency plans which enables the development of rapid response strategies. Monitoring water quality parameters changes means minimising the risks. Because keeping the water temperature and dissolved oxygen concentration at the optimum level for the specific requirements of the species improves feed utilisation and promotes healthy growth. Nowadays, manual measurement of water quality parameters in aquaculture enterprises causes labour and time loss. In the developed instant water quality measurement systems, there are no problems such as the inability to perform certain measurement-recording processes of the water parameters related to the personnel in charge and the calibration errors of the devices (Figure 4).

Figure 3. Ultra-violet (Photo: B. Serdar Yıldırım)

Figure 4. Monitoring land base (Photo: B. Serdar Yıldırım)

Monitoring systems are an essential factor due to production planning, stocking quantity, feeding rate calculations, fish transfer planning and applications, risk management that supports our production increase and enables us to make a controlled production in the Turkish marine aquaculture sector (Figure 5). Advantages such as instantaneous measurement of oxygen and temperature, keeping the produced species and facility in an amount sufficient to meet the needs and performing emergency management, ensure a controlled production in which risks are guaranteed. In marine aquaculture, the number of facilities equipped with monitoring systems is increasing. Monitoring has provided significant advantages in marine aquaculture production. The Turkish aquaculture sector has started leading Mediterranean countries in the use of a complete monitoring system from hatchery and adaptation facility to the harvest period at the cage facility and its usage has become widespread (Yıldırım 2019).

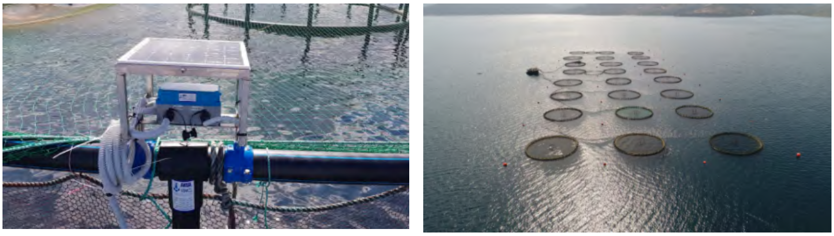

Figure 5. Cage monitoring (Photo: B. Serdar Yıldırım)

Ozone

The use of ozone systems has become widespread in recent years. Turkish Marine Aquaculture sector is one of the leading countries with its experience in this field. Ozone is a dangerous gas that must be produced and used in the field. It is used in different doses depending on factors such as hatchery or indoor type fish species and water features (Figure 6). For this reason, it is vital for each plant first to determine the ozone requirement and determine the appropriate equipment. Apart from the broodstock unit, it is used efficiently in the main input line and in RAS. Ozone usage has a vital role in increasing production figures in marine fish farming. The use of ozone is carried out in a fully controlled manner by measuring residual ozone. Hatcheries determine their dosages according to their conditions and operate their ozone systems safely.

Figure 6. Ozone generator (Photo: B. Serdar Yıldırım)

Photobioreactors

Algae from automated biosecure photobioreactors (PBRs) is perfect for the "green water" technique of larval rearing in recirculated aquaculture systems (RAS) in hatcheries. This technique is tinting water to create an environment that enhances larval survival and feeding, and can be used for many fish species, molluscs and crustaceans. The primary objective is to provide a backdrop against which larval fish can more effectively feed. PBRs technology emulates the natural environment of a bloom where phytoplankton grows in high numbers followed by a rise in zooplankton and other prey which provide food for larvae. In order to create the optimum environmental conditions for enhanced feeding in a recirculated aquaculture hatchery, there are many substitutes for live algae, but their benefits are low compared to high-density algae from PBRs. The two most popular substitutes for live algae are inorganic clays and condensed algae paste, or concentrates, which are easier to use than producing algae using traditional methods. Inorganic clay can be instrumental in increasing the turbidity to improve feeding efficiency but can leave a microbial void in niche space that can allow bacteria to proliferate in the larval tanks leading to increased mortality. Also, clays cannot provide the ecosystem function that live algae can. Live algae can help mitigate nitrogenous waste products like ammonia, through nitrification as they shift the equilibrium balance of ammonia, nitrite, and nitrate, as it absorbs nitrogen into its cell. Clays also cannot provide nutritional benefit to zooplankton or larvae in the water that consumes it (Anonymous 2018a).

Algae pastes and concentrates have nutritional value and are useful for tinting water, but their significant trade-off is that they consist of non-viable cells. These cannot help mitigate nitrogenous waste in the water and have the added disadvantage of contributing to the total available organic carbon in the water as they fall out of suspension and decompose. The additional carbon gives a food source which opportunistic pathogens, like *Vibrio* spp., can exploit to bloom and this can grossly increase mortality. Concentrated algae pastes are also quite expensive and inefficient to ship, costing $200 – $800 US per equivalent kg of dry biomass depending on the source and the strain of algae. When used incorrectly, both clays and concentrates can clump in the water and settle out fouling tanks, filters and screens, which then provide substrates for bacterial growth and issues for water management. Traditional methods of algae production provide algae with similar benefits to that of closed high-density PBRs, but they have significant challenges as well. Traditional algae production is very labour intensive and unreliable, so densities are more variable and bacterial contamination can be much higher than in closed PBRs.

Traditional methods also require skilled, trustworthy staff to maintain and operate effectively, and because of the low algal densities commonly achieved, traditional production methods require large swaths of floor space to produce enough algae. These challenges are why substitutes have gained so much popularity with their ease of use. Bio-secure live algae produced in automated PBRs such as those made by Industrial Plankton have all the benefits of algae substitutes, without any of the drawbacks as automation makes producing live algae on-site easier than traditional methods and cost comparable to, if not cheaper than, concentrates. The automation of PBRs means it does not require advanced expertise to operate or maintain. The importance of water quality in RAS is why live algae can be a valuable tool to help control waste metabolites. Also, live algae do not add as much to the decaying organic biomass in tanks as concentrates. Another benefit is algae from a PBRs is able to disperse and keep neutral buoyancy in the water column longer than concentrates and clays. Some algal strains used for green water (*Tetraselmis* spp., and *Nannochlorpsis* spp.) can even suppress the growth of many pathogenic strains of *Vibrio*, which is regarded as the costliest bacteria in all of aquaculture. In nature, live algae provide a thriving environment for larval growth and feeding, and using automated PBRs allows for easy, reliable and compact production of live algae on-site. Another place alga is used in RAS hatcheries is to feed directly to and enrich the live feeds used for larvae of many aquacultured species that cannot consume other food. Suspension feeders and zooplankton (Rotifers, Copepods and *Artemia*) require nutritious feeds to grow and proliferate, respectively.

Zooplankton delivers their accumulated nutrition to the larvae that consume them, while suspension feeders get their nutrients directly from the suspended algae. The common substitutes for live algae used in RAS are algal concentrates, yeast and specialised enrichment diets. Algal concentrates maintain the same drawbacks for feeding suspension feeders and zooplankton as they do for green water: inconsistent suspension and dispersion creating substrates for bacterial growth and increasing the organic load of the water leading to opportunistic pathogens. Yeast does not sufficiently enrich zooplankton, even though it is cost-effective for growing it and it is not suitable for directly feeding suspension feeder. This has led to the development of many enrichment diets specifically for zooplankton. These microencapsulated feeds are designed to provide the essential nutritional components for enhanced growth and survival to zooplankton for the larvae they will eventually be fed to.

The significant issues with specialised enrichment diets are that they are quite expensive and can be difficult to suspend appropriately. Their cost leads many producers to feed mostly yeast to zooplankton and only use enrichment diets for a final step before they are fed to larvae. Also, when the enrichment diets fall out of suspension and foul equipment, like clays and algal concentrates, they contribute heavily to the decaying organic load leading to issues of opportunistic pathogens and high mortality downstream. The same benefits that make high-density algae from PBRs beneficial for green-water, apply to live feeding. Live algae cultures from automated PBRs are cleaner than algae produced in traditional methods due to the closed nature and filters of PBRs.

Automated PBRs make growing sensitive strains, that would be costly or even impossible to produce using traditional methods, easy, and reliable. Maintenance of water quality is made more accessible by using live algae from a closed PBR as it can help maintain a lower organic load in the water as the live algae stay in suspension longer, and may even produce exudates that can limit the growth of pathogenic bacteria (Figure 7). This can lead to fewer pathogens being transferred downstream to larvae directly and through the guts fauna of zooplankton. Additionally, maintaining lower ammonia levels in zooplankton cultures allows for more reliable and higher density zooplankton cultures (Muller-Feuga 2013; Anonymous 2018a).

Figure 7. Photobioreactors (Photo: B. Serdar Yıldırım)

Feeders

The digestibility and nutritional properties of commercially available micronutrients have been advancing over the last decade due to continuous research and development. However, the micro-diet still has not been fully incorporated into practical feeding protocols for marine fish larvae. The first reason for not being included in the feeding protocols is the distribution behaviour of the micronutrient in the water column, which limits the larval feeding on the micronutrient. More scientific studies on larval feeding systems will play an effective role in eliminating the deficiencies of micro-diet technology in the future and expanding the use of micro-diets in larval rearing of different aquatic species. In the nursery tanks, new technological mechanisms can be utilized to deliver the micro-diets to larvae at regular intervals. The use of a new feeder provides fully controlled administrative advantages in synchronised feed applications, as well as reducing time and labour costs (O’Sullivan 2012; Anonymous 2018b).

Especially during the transition from the live feed to micro diet, the larvae of fish need to be introduced to the micro diet slowly and with little or less micro diet. This stage requires intensive labour and labour force. Furthermore, in the absence of automation, the acclimatisation stage may fail, as some of the fish larvae cannot entirely consume micro diets. Feeder use positively affects the adequate micro diet consumption, growth and survival rate of the fish. The use of feeders is recommended for fish larvae to adapt to changes in feed type. It is accepted that modern intensive production hatcheries need reliable automation in all production processes. It not only saves labour but also secures production protocols and provides more traceability to every stage of the process (Figure 8).

Furthermore, in modern hatcheries, the photoperiod is applied during larvae production (up to 24 hours of light). In order to allow feeding of fish larvae under light conditions, it is imperative to benefit from automation in the frequency distribution of the micro-diet at short intervals. It will give the larvae the chance to capture fresh micro-diets in the water column. Automation is also crucial in order to prevent bottoming out of feed and to save the feed. Regular automatic feeding reduces the amount of feed and consequently reduces a load of organic matter and bacteria in the tanks, thus reducing feed costs. Due to its profitability, the distribution of micro-diets and micron feed in hatcheries and adaptation units in the Mediterranean countries with automatic (centrally controlled) feeding systems is becoming widespread. In these systems, the micro-diets from 75 µm to 500 µm can be used with regular intervals up to doses of 5 grams. Automated feeders also allow for fish pellets up to 12 mm in size to be sent by arrangeable doses of 10 grams to 200 kg per process (Kolkovski *et al.* 2011; O'Sullivan 2012).

Figure 8. Feeder (Photo: B. Serdar Yıldırım)

Oxygenation – Aeration

In hatchery and adaptation facilities, oxygenation units use liquid oxygen tanks. The oxygen diffuser installed in each tank, as well as the jet system, operates under the continuous control of the monitoring unit and maintains the dissolved oxygen level in the tank optimally.

The optimum dissolved oxygen level determined according to the hatchery conditions can be adjusted via the monitoring system, and the oxygen usage is performed under safety and control. Due to the low oxygen costs in our country, liquid oxygen is preferred to oxygen generators with high maintenance and operating costs and failure risks.

In hatcheries, long-lasting air stones and air discs are used at every point where advanced blower units and distribution lines are needed for ventilation. In the removal of dissolved carbon dioxide, degassing units and air discs designed according to system requirements are used along with desaturation columns. In adaptation plants, large volume pools, mechanical aerators and air injectors are used. Depending on the stocking and feeding protocols, the dissolved oxygen level is maintained optimal by feeding the air injectors with the oxygen line against the increased oxygen demand. In hatcheries and adaptation facilities, the use of hand-held oxygen meters equipped with a new generation of optical probes has started in our country together with the whole world. It works with higher accuracy compared to older generation devices.

Fish pump – Grader – Counter

In marine fish farming, with the use of developing technology, fish transport and sorting operations performed by the workforce in the past are now realised effectively with fish pumps and grading machines. The number and records of fish processed by fish counting machines are kept. All these systems are operated in connection with each other. Vaccination of the fish to be sent to offshore cages is carried out by automatic vaccination machines and vaccination teams in adaptation facilities. Fish handling, counting and grading solutions are a perfect fit for a variety of commercial aquaculture applications (Loh *et al.* 2011). In modern aquaculture, the fish pumps, graders and counters (Figure 9) provide advanced technology which enables handling of stock and estimation of the fish biomass. Using this technological equipment in the aquaculture sector gives an advantage in terms of maximising operational efficiencies, facilitating resource planning and safe decision-making.

Figure 9. Fish counter (Photo: B. Serdar Yıldırım)

Cage aquaculture and equipment

Cages

Important factors limiting aquaculture include environmental, physical and chemical parameters, volume and carrying capacity. The initial investment cost is high in terrestrial origin aquaculture systems. The water needs to be constantly renewed. Intensive filtration is essential to optimise water quality in conditions where no water exchange is performed. At this point, aquaculture systems used in cages in open seas have significant advantages over terrestrial systems at present. Especially as the mass of water increases, the rate of instantaneous changes in physical and chemical parameters decreases. The optimisation of water parameters with high-energy costs is not required (Figure 10).

a b c

Figure 10. a. Injection bracket cages, b. cage view, c. rotation bracket cages (Source Güner Galipoglu)

Bird nets towers

In specific periods during the year, bird protection nets are used to protect fish in cages from heron birds. Bird protection nets can be produced in various features and shapes depending on the area in which they are used. Heron birds are one of the most critical problems in aquaculture. The problem that bird protection nets used on small square cages or small diameter cages touched the water was solved by tying the network mutually taut (Figure 11). However, as the cage dimensions grew, this technique became useless (Table 1). Therefore, nowadays, bird towers are used to prevent the contact of bird protection nets with the sea.

Mooring system

Buoys are warning and carrier products to keep the mooring systems suspended in and mark the production area on the water. Buoy dimensions vary according to the weight of the equipment used in Mooring systems and the size of the system. In 2018, Directorate General of Coastal Safety decided that buoys to be used in the cage aquaculture mooring systems should compulsorily use yellow light according to International transportation vehicles' Navigation and Lighthouse Authorities Association (IALA) standards (under RAL code standard).

The choice of anchor to be used in the area where the mooring system will be applied, depending on the current intensity in the water, the maximum wavelength and the underwater ground survey are the most essential elements to be considered. After evaluating this information, suitable mooring system fixing equipment and anchor should be selected. Chains are a fixing element used in mooring systems between the vault or anchor and rope. The main task of the chain is to keep the fixing element in line with the ground continuously. The chain provides the fixation of the mooring system with its weight. In general, the size and weight of the chain used in the mooring system must be at least the weight of the fixing element. In mooring systems installed in high-risk areas, the ratio of chain size and weight to the weight of the fixing element should be 1.5 times or two times higher. Because it is known that the chain is the primary fixing element called as the fuse. The chain used in the mooring system can be supplied from ship dismantling facilities to reduce investment costs (strength not less than 80%). In addition to the connection of the fastening element, the chains are also used in the connection between the float and the other equipment, the connection between the cage and the mooring (Figure 12 and 13).

Figure 11. Bird nets towers (Photo: Güner Galipoglu)

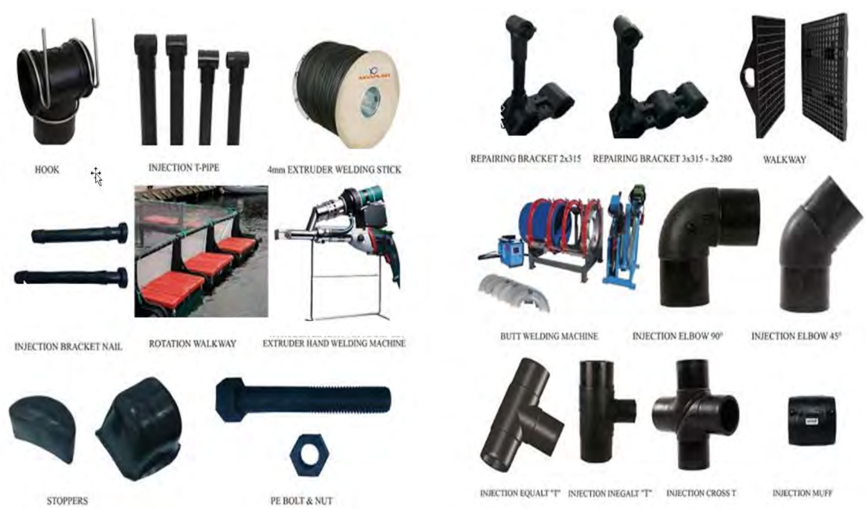

Figure 12. Cage accessories (Source Güner Galipoglu)

Table 1. Bird nets towers pipe types (Source: www.akvaplast.com.tr)

Pipe diameter &ATU	Pipe configuration	Pipe wall thickness	Pipe buoyancy
250/PN-8	SDR-21	11.9 mm	40 kg/m
250/PN-10	SDR-17	14.8 mm	38 kg/m
225/PN-8	SDR-21	10.8 mm	32 kg/m
225/PN-10	SDR-17	13.4 mm	30 kg/m
200/PN-8	SDR-21	9.6 mm	25 kg/m
200/PN-10	SDR-17	11.9 mm	24 kg/m
160/PN-8	SDR-21	7.7 mm	16 kg/m
160/PN-10	SDR-17	9.5 mm	15 kg/m
160/PN-10	SDR-17	9.5 mm	NA
160/PN-12.5	SDR-13.6	11.8 mm	NA
140/PN-10	SDR-17	8.3 mm	NA
140/PN-12.5	SDR-13.6	10.3 mm	NA
125/PN-10	SDR-17	7.4 mm	NA
125/PN-12.5	SDR-13.6	9.2 mm	NA
110/PN-10	SDR-17	6.6 mm	NA
110/PN-12.5	SDR-13.6	8.1 mm	NA
90/PN-10	SDR-17	5.4 mm	NA
90/PN-12.5	SDR-13.6	6.7 mm	NA

Rope types are classified according to raw material properties and knitting structures. When making rope selections in Mooring systems, the weather conditions in the region, current intensity, maximum wavelength and estimated drive loads arising from these should be calculated. Mooring system anchors, vaults, ropes, chains, buoys and cages as connecting elements; Collector / Chain Locks / Rings / Radians / Swivels are used. When selecting fasteners, the drive loads caused by external factors must be taken into consideration before product selection. When coupling the fasteners, the strength of all adjacent products must be equivalent. Otherwise, the weakest one will deform and damage the mooring system.

Nets

Nets are one of the leading items produced from plastic materials and used in many areas of the sector. Nets are used for cage structure in various mesh sizes between 1 cm and 5 cm. The durability of the nets varies according to the place of use. In open sea cages; high-density polyethene material is preferred by the sector. Nets are often affected by environmental conditions and can be blinded and eroded by a large number of fouling organisms. Since the closure of the nets will affect the circulation of water negatively, the time to clean the mesh should be determined with regular monitoring, and the nets should be kept open by performing administrative practices that will not interfere with intensive production. For this purpose, the nets are disembarked and cleaned and re-used by using pressurised water spray methods or shaking methods in the drums. In recent years, different solutions have been developed to prevent clogging of the eye openings by the effect of biofouling organisms of the nets. In this context, the nets are treated with dyes that will prevent adhesion of fouling organisms in order to extend the life of the nets, protect operational investment and provide more efficient production conditions.

Figure 13. Mooring equipment (Source Güner Galipoglu)

It is known that anti-fouling paints are similar to chemicals used to prevent corrosion on various wooden surfaces and corrosion (oxidation) on metal surfaces. Chemical preparations which are commonly used against sessile organisms such as mussels and macroalgae on the nets can be harmful and toxic for environment and human health. It is necessary to remind that the fish which is a healthy product can come into contact with the cage or that these toxic agents can be dissolved in water and accumulate in the fish and that conscious and responsible aquaculture practices should be performed. In Mediterranean conditions, it is traditionally common to perform rapid repairs in the event of ageing or tearing of the nets in general.

In Turkey, there are limited high predator species and It is known that the sector has been sustaining nets successfully by repairing for decades. Therefore, the use of metal alloy networks known to have a long service life and reported by researchers to have minimum water solubility is not widespread. It is known that copper mesh metal cages are used to prevent nets shredding by the aquatic mammals such as seals and sea lions and shark species in Japan, Australia, Chile and Norway. The mesh widths preferred by the sector are reported to be in the range of 1.5-4.5 cm. According to the purpose of use, location and strength characteristics, the nets are produced in square or diamond geometric shapes with or without knots and presented to the use of the sector. The preferred colour in these nets is generally green, black and red.

Harvest and transport tanks

In marine aquaculture, some tanks can be supplied and used according to need including fish transport from the adaptation unit to cages in different sizes which maintain the temperature by providing thermos feature for fast and sudden cooling in the harvest and to maintain the cold chain. The modular fish harvesting and waste tanks, which can be stacked reliably in empty and filled form, are produced in different volumes. These double-walled tanks are pressed with polyurethane foam filling in different densities between two walls. Fish harvesting and transporting tanks are commonly used in 1000-3000 L volume can be used effectively.

Boats

Boats are widely used to perform transfers between the logistic stations established on land and cages in order to carry out daily activities such as control, feeding, nets maintenance and repair. Besides, boats are also used for logistics activities in marine fish production facilities and on the platforms on which feed stock storage is connected to the feeding systems. According to their purpose, these boats are manufactured from wood, metal and plastic materials and have the opportunity to use in the sector by having different dimensions and engine power. Some boats are also equipped with crane equipment suitable for harvesting.

General assessment

In this review, marine fish aquaculture and mechanisation equipments, hatcheries, cage adaptation unit and grow-out unit, used in the industry in Turkey, which is one of the world's top 20 countries is introduced. Also, it is aimed to promote awareness and raise efforts to develop new applications and alternative solutions that will enable us to overcome existing bottlenecks and increase our competitiveness in order to support modern, healthy and efficient cultured marine fish production.

Aquaculture practices are positively affected by modern, scientific and technological developments. The use of mechanisation equipment produced by scientific methodology in hatchery, adaptation and offshore cage production meets the profitability expectations of the sector with increased productivity. In today's world, where consumer awareness has increased, the issue of food safety is considered to be an internationally important concept. Therefore, it should be taken into consideration that the tools and equipment used in all stages of aquaculture should be made of materials that will not adversely affect fish health or remand any residue in the tissue. In this context, it should be remembered that the mechanisation equipment producers for the aquaculture sector should care about the environment and human health and should pay attention to this issue with precision. Probably one of the first and most essential steps of aquaculture made according to conscious and ethical principles is to know the content and quality of the material used. It is the responsibility of the management to ensure that the materials used do not cause any detrimental effect/health problem and should be environmentally friendly.

It is considered that the products obtained from the aquaculture sector working according to ethical principles will not pose a risk for food safety. Safety testing and quality of the equipment used in mechanisation is one of the bottlenecks that must be solved in order to provide safe products to the international market for the environment and human health. Secondary elements are the feed source used, the origin of the aquatic organism produced and the regular monitoring of water quality parameters. The third element is the control of health parameters and vaccination. In this context, the use of appropriate equipment produced by using modern technology in sea hatchery, adaptation unit and cage units will increase the international competitiveness of the sector. It is also possible to use alternative equipment or methods soon based on the know-how developed by enterprises to solve existing problems.

As a result of monitoring and evaluation studies, it is possible to use alternative methods as a suitable model for other enterprises with similar working conditions. In order to develop alternative mechanisation equipment, fisheries engineers carry out intensive R&D studies taking into account the needs of the private sector (with multidisciplinary views from other disciplines if necessary). In the future, it is thought that the engineering and project offices, which closely monitor the problems of the sector, will play an active role in order to obtain higher yields from the unit area and to introduce healthy products to the market. In the next 20 years, we anticipate that the share of aquaculture within the framework of the World Bank and FAO projections will be realized with increasing acceleration in agricultural production statistics.

The authors of this book, who have worked for the development of aquaculture science and prepared the mechanisation equipment and infrastructure for the sector, have tried to give readers the primary knowledge about the use of scientific methodology and the modern mechanisation considering the needs of the marine aquaculture species. As a result, given our perspective, we strongly highlighted that food production is valuable and of course, it is compulsory. It is important to note that fish and other aquaculture products with high protein and fat content are needed for healthy and balanced nutrition of future generations.

References

Aktaş, M., Genç, M.A., Bozkurt, A., Genç, E., Naz, M. (2019) The changes in the molecular weight profiles and biochemical compositions of potential feed ingredients for sustainable aquaculture. *Journal of Aquaculture Engineering and Fisheries Research* 5(1):1-11.

Alvarez-Lajonchère, L., Cittolin, G. (2013) Operation and maintenance recommendations for a tropical marine fish hatchery. *Aquacultural Engineering* 57: 89-100.

Anonymous (2018a) Industrial Plankton. Aquaculture America 2018. Available at: https://industrialplankton.com/2018/03/30/aquaculture-america-2018/ (accessed 23 Sep 2019).

Anonymous (2018b) Feeder for all sizes. Hatchery International. November 15, 2018. Available at: https://www.hatcheryinternational.com/feeder-for-all-sizes-3282/ (accessed 23 Sep 2019).

Anonymous (2019a) Fish pump, grader and counter. Available at: https://pentairaes.com/products/stock-control-management/vaki/ (accessed 23 Sep 2019).

Anonymous (2019b) UV sterilizers. Available at: https://www.sitauv.com/en/company (accessed 23 Sep 2019).

Badiola, M., Mendiola, D., Bostock, J. (2012) Recirculating Aquaculture Systems (RAS) analysis: Main issues on management and future challenges. *Aquacultural Engineering* 51: 26-35.

Bardach, J.E. (1997) Fish as Food and the Case for Aquaculture. In: Sustainable Aquaculture. (ed. Bardach, J.E.) John Wiley and Sons, New York, pp.1-14.

Beveridge, M.C.M., Dabbadie, L., Soto D., Ross L.G., Bueno P.B., Aguilar-Manjarrez J. (2018) Climate change and aquaculture: interactions with fisheries and agriculture. In: Impacts of Climate Change on Fisheries and Aquaculture: Synthesis of Current Knowledge, Adaptation and Mitigation Options. (eds., Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S., Poulain Florence), FAO Fisheries and Aquaculture Technical Paper, 627, FAO, Rome, pp. 491-500.

Buchmann, K. (2015) Impact and control of protozoan parasites in maricultured fishes. *Parasitology* 142(1): 168-177.

Costa-Pierce, B.A. (2002) Ecology as the paradigm for the future of aquaculture. In: Ecological Aquaculture: The Evolution of the Blue Revolution, (ed. Costa-Pierce, B.A.) Blackwell Science, Malden, Massachusetts, pp. 339-372

Eroldoğan, O.T., Yilmaz, H., Evliyaoğlu, E., Genç, M.A., Genç, E., Aktaş, M. (2015) Induction of sex-reversed males using 17 α-methlytestosterone in the gold blotch grouper (*Epinephelus costae*). *Aquaculture Studies* 15(4): 021-027.

Ertör, I., Ortega-Cerdà, M. (2019) The expansion of intensive marine aquaculture in Turkey: The next-to-last commodity frontier? *Journal of Agrarian Change* 19(2): 337-360.

Evliyaoğlu, E., Eroldoğan, O.T., Yılmaz, H.A., Genç, M.A., Genç, E., Duncan, N., Aktaş, M., Güroy, D. (2019) Artificial sex reversal of white grouper (*Epinephelus aeneus*) utilizing aromatase inhibitor (Fadrozole). *Aquaculture Research* 50(5): 1539-1546.

FAO (2018) Fishery and aquaculture statistics. The state of world fisheries and aquaculture. Fisheries and Aquaculture Department, Rome. Available at: http://www.fao.org/fishery/statistics/software/fishstatj/en (accessed 23 Sep 2019).

Fitridge, I., Dempster, T., Guenther, J., De Nys, R. (2012) The impact and control of biofouling in marine aquaculture: a review. *Biofouling* 28(7): 649-669.

Fredheim, A., Reve, T. (2018) Future prospects of marine aquaculture. In October OCEANS 2018 MTS/IEEE Charleston, IEEE, pp. 1-8.

Gelibolu, S., Yanar, Y., Genc, M.A., Genc, E. (2018a) The effect of mannan-oligosaccharide (MOS) as a feed supplement on growth and some blood parameters of Gilthead Sea Bream (*Sparus aurata*). *Turkish Journal of Fisheries and Aquatic Sciences* 18(6): 817-823.

Gelibolu, S., Yanar, Y., Genc, M. A., Genc, E. (2018b) Effect of mannan-oligosaccharide supplementation on body growth, fatty acid profile and organ morphology of gilthead seabream, *Sparus aurata*. *Pakistan Journal of Zoology* 50(1): 229-240.

Genc, E. (2011) Diseases in wild and cultured fish in Turkey. Aquaculture in the Middle East and North Africa–Status and Research Needs (eds., Azad, I.S., Al-Ablani S.), Nova Science Publications, NY, USA. Available at: https://www.novapublishers. com/catalog/product_info. php. (accessed 23 Sep 2019).

Genç, M., Aktaş, M., Eroldoğan, O.T., Genç, E. (2016) Observations on the artificial sex inversion of dusky grouper (*Epinephelus marginatus*) from the north-east Mediterranean Sea. Turkey. *Natural and Engineering Sciences* 1(3): 25.

Genc, M. A., Aktas, M., Genc, E.,Yilmaz, E. (2007a) Effects of dietary mannan oligosaccharide on growth, body composition and hepatopancreas histology of *Penaeus semisulcatus* (de Haan 1844). *Aquaculture Nutrition* 13(2): 156-161.

Genc, M.A., Yilmaz, E., Genc, E. (2006) Effects of dietary Mannan-oligosaccharide on growth, intestine and liver histology of the African catfish (*Clarias gariepinus* (Burchell, 1822)). *Ege Journal of Fisheries and Aquatic Sciences* 23(1-2): 37-41.

Genc, M. A., Yilmaz, E., Genc, E., Aktas, M. (2007b) Effects of dietary mannan oligosaccharides (MOS) on growth, body composition, and intestine and liver histology of the hybrid tilapia (*Oreochromis niloticus*× *O. aureus*). *Israel Journal of Aquaculture* 59: 10-16.

Güroy, D., Karadal, O., Güroy, B., Mantoğlu, S., Çelebi, K., Şimşek, O., Eroldoğan, O.T., Genç, M.A., Genç, E. (2017) The effects of dietary protein levels with amino acid supplementation on the growth performance, haematological profile and histology of meagre (*Argyrosomus regius*) in two different size classes. *Aquaculture Research* 48(12): 5751-5764.

Hobday, A.J., Poloczanska, E.S. (2010) Marine fisheries and aquaculture. Adapting agriculture to climate change: preparing Australian agriculture, forestry and fisheries for the future, 205-228. Available at: http://dev.nutrakol.com/wp-content/uploads/2017/03/Austasia-Aquaculture-2012.pdf (accessed 23 Sep 2019).

Hussenot, J. M. (2003) Emerging effluent management strategies in marine fish-culture farms located in European coastal wetlands. *Aquaculture* 226(1-4): 113-128.

Ioakeimidis, C., Polatidis, H., Haralambopoulos, D. (2013) Use of renewable energy in aquaculture: an energy audit case-study analysis. *Global NEST Journal* 15(3): 282-294.

Jensen, Ø., Dempster, T., Thorstad, E. B., Uglem, I., Fredheim, A. (2010) Escapes of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Environment Interactions* 1(1): 71-83.

Joyce, A., Utting, S. (2015) The role of exopolymers in hatcheries: an overlooked factor in hatchery hygiene and feed quality. *Aquaculture* 446: 122-131.

Kaya, D., Genc, E. (2018) Biofloc technology in aquaculture. *Su Urunleri Dergisi* 35(2): 219-225 (in Turkish).

Kolkovski, S. (2011) Maturation diets for shrimp – Is there alternative to natural food? *International AquaFeed*. May-June 2011. Available at: https://documents.pub/document/maturation-diets-for-shrimp-is-there-alternative-to-natural-food.html (accessed 23 Sep 2019).

Lackey, R.T. (2005) Fisheries: history, science, and management. In: Water Encyclopedia: Surface and Agricultural Water (eds., Lehr J.H., Keeley, J.), John Wiley and Sons, Inc., Publishers, New York, pp. 121-129.

Loh, B.C., Raman, V., Then, P.H. (2011) First prototype of aquatic tool kit: towards low-cost intelligent larval fish counting in hatcheries. In: December 2011 IEEE Ninth International Conference on Dependable, Autonomic and Secure Computing, pp. 192-195.

Marte, C. L., Toledo, J. D. (2015) Marine fish hatchery: developments and future trends. In: Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia: Challenges in Responsible Production of Aquatic Species: Proceedings of the International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia 2014. (eds., Romana-Eguia, M.R.R., Parado-Estepa, F.D., Salayo, N.D., LebataRamos, M.J.H.), (RESA) Tigbauan, Iloilo, Philippines: Aquaculture Dept., Southeast Asian Fisheries Development Center, pp. 189-200.

Muller-Feuga, A. (2013) Microalgae for aquaculture: the current global situation and future trends. Handbook of Microalgal Cultures: Applied Phycology and Biotechnology. 2nd ed. Wiley Blackwell, West Sussex, pp 615-627.

O'Sullivan, D. (2012) Herbal success for fish and prawn culture. *Austasia Aquaculture* 26(3): 31-33.

Shields, R.J., Gara, B., Gillespie, M.J. (1999) A UK perspective on intensive hatchery rearing methods for Atlantic halibut (*Hippoglossus hippoglossus* L.). *Aquaculture* 176(1-2): 15-25.

Sim, S.Y., Rimmer, M.A., Toledo, J.D., Sugama, K., Rumengan, I., Williams, K., Phillips, M.J. (2005) A guide to small-scale marine finfish hatchery technology. NACA, Bangkok, Thailand, 17pp.

Sorgeloos, P., Léger, P. (1992) Improved larviculture outputs of marine fish, shrimp and prawn. *Journal of the World Aquaculture Society* 23(4): 251-264.

Stickney, R.R. (2000) Encyclopedia of Aquaculture. John Wiley & Sons, Inc. New York.

Sweetman, J.W. (1992) Larviculture of Mediterranean marine fish species: current status and future trends. *Journal of the World Aquaculture Society* 23(4): 330-337.

Tacon, A.G. (2018) Global trends in aquaculture and compound aquafeed production. *The Magazine of the World Aquaculture Society* 49: 33-46.

TUIK (2019) Fisheries statistics. Turkish Statistical Institute. No: 30697, 12 June 2019. Available at: http://www.turkstat.gov.tr (accessed 23 Sep 2019).

Yıldırım, B.S. (2019) Aquaculture: Why the need for measuring, monitoring, and data logging? International AquaFeed, April 20th, 2019. Available at: https://aquafeed.co.uk/entrada/aquaculture--why-the-need-for-measuring-monitoring-and-data-logging--20368/?fbclid=IwAR0BylGOCr45H_MAEd_m-PDJLIgIiZ3mHtXJpztccFnLhSgcuuef0pF3G5w (accessed 23 Sep 2019).

Yilmaz, E., Genc, M. A., Genc E. (2007) Effects of dietary mannan oligosaccharides on growth, body composition, and intestine and liver histology of rainbow trout, *Oncorhynchus mykiss*. *Israeli Journal of Aquaculture-Bamidgeh* 59(3): 182-158.

Potential environmental impacts of marine fish farming and mitigation measures

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Introduction

Aquaculture continues to develop faster than other large food businesses. Contribution of aquaculture to the global fisheries increased to 46.8% in 2016 from 25.7% in 2000 (FAO 2018). Aquaculture in Turkey started in 1970’s and progressed with seabream/seabass farms along the Aegean and Mediterranean seas in the mid-1980's, which is followed by cage culture of trout in the Black Sea during the 1990’s and more recently tuna rearing in the Aegean Sea and the Mediterranean Sea in the early 2000’s. In addition, according to the data of the Ministry of Agriculture and Forestry (MAF), the amount of aquaculture production (314537 tons/year) for the first time exceeded the amount of fisheries (314094 tons/year) in 2018. Turkey's exports of fishery products increased by 13% compared to 2018 and reached 958 million dollars (MAF 2019).

Bluefin tuna fattening in Turkey started in 2002 and rapidly developed (Aksu *et al.* 2010). Total production capacity reached to 6340 tons a year by 6 farms (ICCAT 2019).

Problems have occurred especially in marine aquaculture along the Aegean and Mediterranean coasts where seabass and seabream farm activities have been in a mutual conflict with other sectors (OECD 2010).

Of the sectors in rivalry with aquaculture production sites for the same resources, the fishing sector is by far the most prominent one, followed by tourism. Agricultural and maritime processes appear less critical accordingly. Other conflicting businesses include the environment/nature conservation, urban development and industries (OECD 2010).

To deal with steady increase in output and conflicts with other sectors in coastal use, finfish mariculture in the Mediterranean and Turkey has started to go offshore lately. Aquaculture operations are governed by a set of specified acts and regulations primarily enacted by the Ministry of Environment and Urbanization (MEU) and Ministry of Agriculture and Forestry (MAF) of Turkey.

Within the framework of the current legislation (Environmental Impact Assessment, EIA), fish farms with an annual capacity below 30 tons are not obliged to prepare an EIA report (Official Gazette 2014). Fish farms with an annual capacity between 30-1000 tons may require EIA, which is determined by EIA commissions in each province. Farms are obligated to submit an EIA report if they produce over 1000 tons per year.

A regulation dealing with the environmental management of marine fish farms has been issued recently (Official Gazette 2020). As stated in regulation, fish farms are not allowed to be established and operated in marine areas where any of the parameters specified in the Table 1 cannot be met. According to this regulation fish farms are required to prepare an “Environmental Management Plan” before starting their activities. In addition, the facilities owned by private and public institutions engaged in fish farming are to be monitored considering the environmental water quality parameters (Secchi disc depth, salinity, water temperature, dissolved oxygen, total inorganic nitrogen, total phosphorus, chlorophyll-a,) as soon as they start production. As well as those parameters, the distribution of *Beggiatoa* bacteria, sediment structure, redox potential, total organic carbon, total phosphorus is determined in the sediment environment. Water column analyses are carried out once a year in May while sediment analyses are performed every two years in the same month.

Table 1. Parameters for sensitive areas and non-sensitive areas

Parameter	**Sensitive areas criteria**	**Non-sensitive areas criteria**
Water depth	≤ 40 m	≤ 30 m
Distance from the coast	≤ 1250 m	≤ 500 m
Current speed	≤ 0.1 m/sec	≤ 0.1 m/sec
Distance between farms	≤ 1000 m	≤ 1000 m

The new fish farms must be monitored according to TRIX Index every year after they are operational. Those to continue their activities in areas where there is no risk of eutrophication are obliged to perform monitoring studies every year. Water samples must be taken in May. Water quality analysis is performed at seven points around the cage systems.

TRIX Index is defined as:

$$Trix\ Index = [log\ (Chl\ a \times \%O_2 \times TIN \times TP + 1.5)] \times 0.833$$

Components of TRIX: Chl-a = chlorophyll-a concentration, as µg/L; $\%O_2$ = Dissolve Oxygen Deficit percentage; TIN = Total dissolved inorganic nitrogen ($N–NO_3 + N–NO_2 + N–NH_4$), as µg/L; TP = total phosphorus, as µg/L (Yucel-Gier *et al.* 2009).

TRIX index values are expressed in coefficients ranging from 0-10 (Table 2).

Table 2. Scale for risk of eutrophication

TRIX Index	State of eutrophication
< 4	No eutrophication risk
4-5	Low eutrophication risk
5-6	There is eutrophication risk
> 6	High eutrophication risk

International policies have been developing lately to promote marine protected areas. Marine Strategy Framework Directive (2008/56/EC) to regulate the sustainable exploitation and management of coastal and marine waters according to the "Good Environmental Status" targets and with the "Ecosystem Approach Management" approach, a framework directive was published (MEU 2017). Coastal regions and seas, on the other hand, have been under intense pressure since the last century. Aquaculture activities, one of the coastal users are regarded as one of the pressure factors on the nutrient burden because of the use of treatment chemicals and interaction of the farmed/cultured species with those in nature and introduction of alien species. The monitoring carried out by the Ministry on water sediment and biota in aquaculture areas are of great importance to assess the current situation in the Turkish seas and realization of good environmental status in accordance with the Marine Strategy Framework Directive.

Environmental effects

Effects of aquaculture on water column

Scientific papers dealing with environmental impact of fish farming on nutrients and plankton (Pitta *et al.* 1999; Yucel-Gier *et al.* 2008) on nutrients and community structure (Katavić and Antolić 1999; Yucel-Gier *et al*. 2007; Moraitis *et al.* 2013; Mangion *et al.* 2018), on water column and sediment environment (Aksu and Kocataş 2007; Aksu *et al*. 2010), on seagrass (Delgado *et al.* 1999; Ruiz *et al.* 2010) had been published during last years.

Aquaculture generate wastes with considerable amounts of nitrogen (N) and phosphorous (P) being particularly discharged in dissolved form to water column (Hall *et al*. 1992). Unconsumed feed is an essential result of aquaculture causing organic and nutrient accumulation around aquatic farms (Figure 1). Feed loss may vary between 1 to 38% in various forms of intensive aquaculture (Wu 1995). Mediterranean aquaculture shows relatively low loss of feed (2–9%) (Dosdat 2001). Moreover, 17%, 52%, 31% and 39% of N, P, organic matter and dry matter have been estimated to be excreted through faeces of seabream, respectively (Lupatsch and Kissil 1998).

The nutrient discharge also shows an important variation from the natural fluctuation of nutrient levels in water (Pitta *et al*. 1999). In the Mediterranean basin, phytoplankton show a high seasonal increase in spring and autumn caused by nutrient availability owing to mixing and physical mechanisms along with fair light circumstances; surface nutrient loss in summer stratification cycle leads to decreased phytoplankton production in spite of the elevated light availability (Karakassis 2001). An investigation dealing with the water quality variations (physical, chemical and biological) was performed at the mariculture sites (Pitta *et al.* 1999). It was found that plankton abundance for the major taxonomic groups, microplankton diversity and community were defined by the impacts of season and region rather than by the existence of marine aquaculture. The study by Kaymakci-Basaran *et al*. 2010 in the Aegean Sea revealed that there were no substantial differences between cage and the control stations in terms of nutrient (nitrite, nitrate, ammonium, phosphate) concentrations. Aksu and Kocataş (2007) however, reported notable increases in the values of ammonium among cage and reference points in two of the three farms investigated. Correspondingly, Yucel Gier *et al.* (2007) studying nutrients and benthic community at a marine aquaculture location detected that the values of ammonium at farm stations were higher than the reference ones in spring, summer and fall. The studies carried out in Turkey are given in Table 3.

Summarizing global impacts of aquaculture on water quality, the study by Price *et al*. 2015, inferred the following; increased dissolved phosphorus is not generally regarded as a serious matter about aquaculture because it is nitrogen not phosphorus which restricts primary production in most marine areas. Concerning nitrogen, currents dispersing nutrients off the cage area minimize detectable impacts around cages. In general, some variations in nitrogen and phosphorus concentrations around aquaculture site are simultaneously noticeable and others not. Nevertheless, there are incidents in which rises in one dissolved nutrient do not resemble variations in the other with the result that nitrogen is the higher nutrient (Pitta *et al.* 2005).

The Atlantic bluefin tuna farming effects based on wastes have been recently investigated through monitoring (Aksu *et al.* 2010). Impact of tuna fattening on water column and sediment is supposed to be higher than that of rearing of seabass and seabream considering large amount of biomass and feed conversion ratios. However, most of the surveys report that the impacts are insignificant and confined around the cages (Vita and Marin 2007; Vezzulli *et al.* 2008). In addition, effects of aquaculture on marine ecosystem changes in accordance with handling of the aquaculture enterprise (Wu 1995), a case for which the capture fishery of tuna is not a constant operation and takes place only four to eight months. After rearing, the marine environment can regenerate itself.

It is known that organic wastes formed in aquaculture, affect the water column and benthic environment. However, the negativities that may occur in the environment and its magnitude vary depending on a lot of factors like characteristics of the fish farm (species, feeding, carrying capacity), hydrologic status (current, depth, temperatures) of the environment, sediment structure (coarse, fine, silty) and region (off-shore, coastal area) where the farm is established.

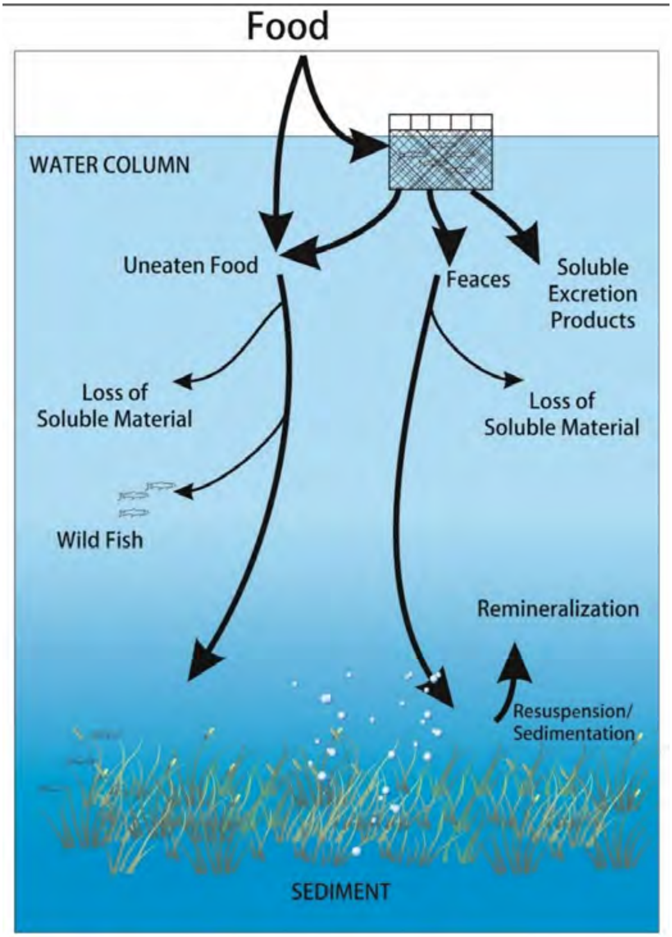

Figure 1. Consequences of waste material caused by cage fish farming (Redesigned according to Gowen *et al*. 1990 in FAO 1992).

Table 3. Sum of studies on ecological impacts of aquaculture on water and sediments in Turkey

Region	Farmed organism	Variables	Authors
İzmir Bay	Seabass-Seabream	Water column; ecological parameters (T, pH, D.O., S) Nutrients, Chl-a, Pheopigments	Aksu and Kocataş 2007
Güllük Bay	Seabass	Water column; ecological parameteres (T, D.O.) Nutrients, Chl-a	Demirak *et al.* 2006
Sığacık Bay	Seabass-Seabream	Water column; ecological parameteres (T, pH, D.O., S) Nutrients, Ca, Mg, Organic matter	Orçun and Sunlu 2007
Ildır Bay	Seabass-Seabream	Water column; ecological parameteres (T, pH, D.O., S) nutrients	Kaymakçı Başaran *et al.* 2007
İzmir Bay	Seabass	Water column; ecological parameteres (T, pH, D.O., S) Nutrients Sediment; organic carbon, grain size	Yucel-Gier *et al.* 2007
İzmir Bay	Seabass	Water column; ecological parameteres (T, pH, D.O., S) Nutrients,	Yucel-Gier *et al.* 2008
Gerence Bay	Blue Fin Tuna	Water column; ecological parameters, nutrients, Chl-a Sediment; TOC	Aksu *et al.* 2010
Güllük Bay	Seabass-Seabream	Water column; ecological parameters, nutrients, POC, Chl-a Sediment; TOC, LOİ, Zn, Cu, Fe	Kaymakci Basaran *et al.* 2010
Gerence Bay	Blue Fin Tuna	Water column; ecological parameters, nutrients, Chl-a Sediment; TOC	Aksu *et al.* 2016

T: Temperature; D.O: Dissolved oxygen; S: Salinity; TOC: Total Organic Carbon; POC, Particulate Organic Carbon; Chl-a: Chlorophyll a, LOI; Loss on Ignition

Chemical wastes (Trace elements, drugs, antifouling treatments, pesticides)

As a result of geochemical mechanisms and industrial activities, various metals inherently exist in the marine ecosystem and concentrated through food chain. The surrounding of the floating cages and especially the bottom environment, could become more contaminated by trace metals originating from feed residues that are not consumed by fish, fish feces and antifouling paints used in nets. Metals like zinc, copper and iron have been determined in the sediment below cage stations in the eastern Mediterranean (Kaymakci-Basaran *et al*. 2010). However, the authors suggest that, the metal levels at the bottom of cages have not yet reached dangerous levels for the aquatic environment. It is clear that comprehensive research is necessary before saying the last word.

The rapid growth in aquaculture has brought about an increase in bacterial, viral, fungal and parasitic diseases with environmental interactions. This situation has increased the use of antibiotics, pesticides and other chemicals to prevent and control diseases. Administration of antibiotics may be by solution in water, incorporation in feed or by injection. The number and variety of antibiotics used in edible fish is very limited. In Turkey, there are 35 licensed fish therapeutic agents which include florfenicol, sulphadiazine+trimethoprim, oxytetracycline, enrofloxacin, amoxicillin, oxolinic acid (Baydan *et al*. 2012).

In Europe and Turkey, medicines are typically added to the feed content and applied to the fish. However, this results in a certain part of the drug being taken by the fish. In a study, it was reported that 60-73% of oxetetracycline, an antibiotic applied to seabass in fish farms, is released into the marine environment with fish feces (Rigos *et al*. 2004). Therefore, the antibiotics used in aquaculture to deal with diseases may have the potential to contribute to the pool of resistant bacteria commonly found in the aquatic environment. Taylor *et al*. (2011) claimed that research is necessary to discover its related effects as compared to much more prevailing sources of resistant bacteria in treatment plants, in particular. Now that data of available toxicity is limited, levels of drugs in water and sediment in and around fish farms are unlikely to be enough to cause effects on wildlife.

Pesticides are often used in aquaculture to remove parasites. There are many factors in assessing the risks associated with pesticides in the aquatic environment. The most important factor is the hydrographic conditions of the fish farm site. Antifoulants used on farm cage nets can have impacts on the marine environment. Tributyltin (TBT) was commonly employed as an antifoulant until 1987, when it was totally prohibited. Long-term monitoring of pesticides and antifoulant in aquatic environment and their accumulation in benthic organisms would be useful to the sustainable development of the aquaculture.

Effects on benthic environment

The obvious impact of mariculture on sea bottom are accumulation of organic material and conversion of substrate to anoxic habitat (Gowen and Bradbury 1987). Fish farming is performed over a range of geographies, at locations of varying depth and on seabed of numerous sediment. The production capacity of farms, hydrodynamic conditions and the administration also play significant parts in discovering the impacts of aquaculture on the sea bottom (Kalantzhi and Karakassis 2006*)*. Fish farm sediment is identified with low figures of redox potential, high concentration of organic matter and aggregations of nutrients (Karakassis 2001).

Depth of farms is decisive in silty sediments, generally causing diminishing of impact indicators (decrease in TOC, TON, increase in diversity index) than that in coarse and sandy ones, where hydrodynamic mechanisms and sediment resuspension are more significant aspects in evaluating the spatial distribution of wastes than their straightforward dispersion in depth (Gowen and Bradbury 1987). The studies conducted below the cages at fish farms in Aegean Sea reported higher TOC values than those of the reference stations. (Kaymakci Basaran *et al*. 2010; Karakassis *et al.* 1998).

The literature investigates the effects of mariculture on the sediment organisms (Gao *et al*. 2008; Holmer *et al*. 2008; Moraitis *et al*. 2013; Mangion *et al*. 2018). Mostly, the paramount effect of aquacultural wastes on soft-bottom organisms is that the number of communities has been reduced (Maldonado *et al.* 2005, Aguado-Gimenez *et al.* 2007) and the species distribution differentiated. Nematodes, copepods and polychaeta controlled the fauna of disturbed area (La Rosa *et al*. 2001). The research made across Turkish Aegean Sea and Black Sea reported no significant effects caused by fish farms on benthic communities (Dağlı *et al*. 2008; Çulha *et al*. 2019; Bascinar *et al*. 2014). The study by Yücel Gier *et al*. (2007) in the Izmir bay reported significant differences in particle size of sediments sharply correlated with faunal groups especially with polychaeta and Mollusca between cage and the control stations. The control station is defined by a sandy sediment with the lowest TOC and highest variety whereas the farm sites with silty-clay sediments exhibit higher TOC and lower variety with increasing abundance of polychaeta. In general, impacts of aquaculture on benthos are more readily observable at silty sediment locations.

Ecological interactions

Fish stocks to be processed as feed

According to 2016 figures, the total amount of fish used for the production of fish meal and oil has reached 20.0 million tons (FAO 2018). Fish meal from pelagic fish is the main source of protein for most farmed fish. Small pelagic fish (*Engraulis ringens*, *Trachurus* sp., *Clupea harengus*, *Clupea sprattus*) are generally used in fish meal and oil production.

There is no clear information on how much fish meal and oil is used for fish farming in and around the Mediterranean Sea. However, the amount of total usage of these two ingredients could be predicted for the Mediterranean fish farming. The annual consumption for the dietary requirements of the major Mediterranean cultured fish has been calculated as 150000 tons fishmeal and 100000 tons' oil. From these figures, it can be understood why using wild fish stocks to feed cultured fish is a worldwide problem (Grigorakis and Rigos 2011).

Direct use of catch for feeding

One of the aquaculture activities is tuna fish farming, which is caught from wild nature and fattened in cages. Small pelagic fish (*Sardinella aurita, Sardina pilchardus, Clupea harengus, Scomber scombrus, Scomber japonicas, Boops boops*) and cephalopods (*Loligo vulgaris, Sepia officinalis*) which contain high levels of fat and lipids are used in the tuna fish fattening period (Ottolenghi 2008). A large amount of fish is used in tuna ranching. Therefore, the food conversion rate (FCR) is very high, which can cause uneaten bait fish to accumulate on the sediment. In addition, fishing pressure on the natural populations of small pelagic fish is an important issue for the sustainability of tuna farming.

Genetic interactions

It may be possible for fish species to escape from cages for various reasons and to breed with species found in nature. Cultivated species generally have features such as high growth and low predation compared to wild individuals of the same species. These characteristics of cultured species reduce its ability to survive and reproduce in the wild. Genetic interaction can occur even when there is no fish escape from the cages; In this case, the fertilized eggs of the cultured fish are released to the aquatic environment (Science for Environment Policy 2015).

Based on genetics data, Youngson *et al*. (2001) found a significant gene movement between seabream from the eastern Mediterranean to the Azores. For European seabass, Polymorphism of 12 microsatellite markers was analyzed to investigate genetic variability and structure in bloodstock populations of the Mediterranean seabass *Dicentrarchus labrax* by Karahan *et al*. 2014. Two bloodstocks of wild origin that had been collected from the different locations of the Aegean Sea, as well as one of culture origin (after three generations in captivity) were used in the analysis. The results showed that genetic variability was the lowest for the culture-originating bloodstock population, possibly due to the inbreeding effect. However, two wild bloodstock populations also showed a low genetic variability, indicating the importance of collecting fish from different geographic locations while establishing any bloodstock population in a hatchery (Karahan *et al*. 2014). Consequently, it was found that the genetic interactions between the reared fish and natural species in the Mediterranean and in the world are highly variable. Genetic studies on a larger scale are necessary.

Transfer of diseases

Disease factors (virus, bacteria and parasite) in aquaculture affects biodiversity and also sustainable growth of the aquaculture industry. High stocking density and environmental factors may surface epidemic diseases. Fish diseases can spread to wild stocks as a result of the interaction of fish escaping from farms with natural populations. However, similar situations reported on this issue are very rare (Arechavala-Lopez *et al*. 2013). It may be possible that infected cultured species escaping from cages due to technical failures carry disease factors into wild as well as other fish. In aquaculture, risks should be assessed well in order to prevent these occurrences. As a precaution, high fish stocking density should be avoided and health management plans should be established in farms against disease transmission.

Aquaculture-mediated species invasions

The main ways of invasive species or non-indigenous species (NIS) to enter the Mediterranean and European Seas are maritime transport (51%) and Suez Canal (37%), and activities related to aquaculture (17%). Some of the aquaculture activities may involve the cultivation of some foreign fish species far from their natural environment. Their deliberate use in aquaculture, aquarium activities, transport for scientific research and experimentation may result in their escape to the local natural environment. Since the 1990s, the spread of invasive species has been increasingly dispersed by maritime and corridors (especially the Suez Canal), while the species that have entered through aquaculture activities have decreased considerably as a result of the regulations of the European Union since the 2000s (EEA 2019).

64 NIS were introduced to the Mediterranean with aquaculture. Most of the species brought through aquaculture are macrophytes (41 species) and invertebrates (14 species). The richness of the species brought by fish farming activities is relatively lower in the Near East and North African coasts, except for Northern Tunisia (Katsanevaki *et al.* 2014). As a result of aquaculture activities, the number of NIS entering the Mediterranean is quite low (17%) compared to other entry methods.

Other ecological interactions

The aquaculture fittings and farming processes could lead to ecological changes, which could be caused by prey-predation interactions of reared fish with wild ones as a result of gathering of diverse wild species around the cages owing to modification of seawater and habitat aspects related to the physical existence of aquacultural installations (Grigorakis and Rigos 2011).

Prey predation interactions

The reason that attracts wild fish to the cages is that these species can benefit from standing stock through predation or from the waste (uneaten feed, feces and dead fish) that enters the water column as a result of feeding. Pinnipeds, birds and otters are documented to be primary predators visiting net cages across the world (Barrett 2018).

There are specific literatures to predators attracted by reared species or natural fish communities around the cages in the Mediterranean. They include fish, monk seals, sea turtles and dolphins (Guclusoy and Savas 2003; Addis *et al.* 2010) Interaction between aquaculture and marine mammals are detrimental to all those concerned. Mammals create scarring in the fish while stealing fish from the cages, increase fish susceptibility to disease or decrease growth owing to stress and destroy equipment, occasionally leading to massive fish escape.

Wild fish aggregations

Fish farms are an important food source for natural fish communities. Mediterranean aquacultural firms led to a serious rise in natural fish communities landing in the respective places, around where farms are based (Akyol and Ertosluk 2010). It was reported that the natural fish gathered around the farm area consume significant amount of organic matter and therefore the impact of the fish farm on the benthic environment is reduced (Sanz-Lazaro *et al*. 2011 in Grigorakis and Rigos 2011).

Reduction of Environmental Impacts

Processes of aquaculture production have an impact on the ecosystem where they have been constructed. The concept "*Sustainability in Aquaculture*" is important in terms of managing production correctly. Sustainability could particularly be realized by reasonable planning and appropriate management policy. "Sustainable fish farming is to balance the use of resources, employ the ecosystem to meet human needs and protect the environment as much as possible without disturbing it". Thanks to an ecosystem approach, the benefits from natural resources have recently contributed to the dimensions of sustainability in equal terms.

In order to overcome the planning difficulties of aquaculture, the "*Ecosystem Approach to Aquaculture*" (EAA) was considered. In this way, it has been possible to develop some methods and tools to maintain aquaculture in a more responsible way. The approach to determine the allocated zones for aquaculture (AZA) encouraged by General Fisheries Commission of Mediterranean is widely applied in the Mediterranean. In addition, EAA encouraged the use of the sustainability approach in aquaculture advancement. Integrated multitrophic aquaculture (IMTA), the straight implementation of EAA at the farm extent, is growing in value (Brugère *et al*. 2018).

Site selection

Achievement of an aquaculture investment is mostly based on selection of a suitable area for installation of a farm. In order to supply space for mariculture and prevent environmental deterioration and adverse interaction with other users of coasts, Allocated Zones for Aquaculture (AZA) concept should be taken into account (FAO 2012), which is described as: A marine site where the improvement of fish farms have been given precedence over other sectors and would be principally allocated to aquaculture (Sanchez-Jerez *et al.* 2016). AZA`s could be determined at coastal zones where there is a possibility for aquafarming and integrated into governmental or local administrative organs as well as other sectors, which acts as a means of integrating aquaculture into Coastal Zone Management (Sanchez-Jerez *et al.* 2016).

Developing a complete ecological administration of mariculture beyond what is called marine spatial planning may incorporate EIA's together with monitoring programs and description of the Allowable Zone of Effect (AZE) and Aquaculture Management Area (AMA) for each AZA (Figrue 2). Considering the ecosystem method, nationwide regulations could determine Environmental Quality Objectives (EQOs), which obviously make sure that ecosystem services be safeguarded.

A technical method for site selection through knowledge of biology and oceanography and based on ecological and social constraints (i.e. carrying capacities) is to be employed for describing the AZA as well.

It is specifically crucial to identify the carrying capacity of fish farms in bays and gulfs. To decrease the contamination level by increasing the specified capacity, it is of great importance to be consistent with the determined stock density. the stock density is recommended to range between 12-15 kg/m^3 for seabream and seabass production in Turkish Seas (MEU 2015).

Feed management

The most important factors in fish farms to affect the environment are /were related to fish feeding. Most of the farms based on the related regulations in Turkey have been forced to be carried to off shore and depths where there are strong currents. Therefore, environmental impacts of feeds have been reduced to almost nothing because feed is of great expenditure in aquaculture and in environment. The negative effects of water quality and sediment experienced in the farms were observed to decrease due to off shore regulations. Since early years of production techniques and feed use experience, minimizing the feed wastage have been very important in this sense. The feeds created considering the physiology of fish species and the energy requirements in seasonal changes managed to be consumed more efficiently. In addition, differentiation of feeding technologies in cages has led to a decrease in feed losses. In recent years, fish is fed with what is sufficiently needed by observing with divers or camera systems equipped with automatic control systems without handling.

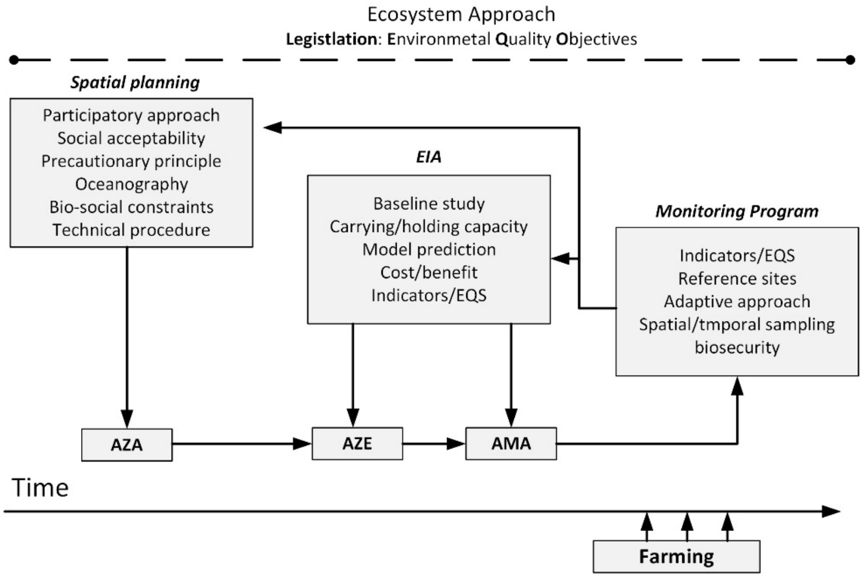

Figure 2. Combining spatial planning and environmental concepts for the sustainable expansion of aquaculture (Sanchez-Jerez *et al.* 2016).

Control of chemicals used in aquaculture

A variety of chemicals and antifoulants are used in aquaculture and deposited at benthos and sediments under the farm area. The environmental threat is lower in offshore farming practices in Turkey since such dangers and employment of drugs are expected to be decreased owing to improved water quality and fewer biofouling growth with raised disintegration.

In addition, the application of antibiotics for the treatment of bacterial diseases will be reduced thanks to effective vaccination programs. On the other hand, the difficulty of vaccination in the culture and the expensive vaccine costs requires that the enterprises should be more cautious in disease control and prevention (Demirdelen *et al*. 2018), which is easier to perform, more cost effective and more reliable for public health and the environment than treatment. Among the alternative solutions for this purpose, probiotic and prebiotic uses are the most important (Altıntaş *et al*. 2016). Probiotics are currently used in most hatching systems in Turkey.

Integrated multitrophic aquaculture (IMTA)

Integrated multi-trophic aquaculture (IMTA) has been aimed to obtain environmental sustainability by means of biomitigation of aquacultural wastes which is more advantageous than other accompanying approaches that may cover economic balance using processes of output variation and risk minimization, social trustworthiness through improved management (Troell *et al.* 2009; Barrington *et al*. 2009).

The integrated multi-trophic aquaculture is a method of cultivation based on the combination of organisms of different trophic levels and the use of wastes of one species in the feeding of another one. One of the major benefits of IMTA is to transform the waste nutrients into valuable products and remove them from the environment by providing production diversity, instead of cultivating a single species (monoculture) (Figure 3). IMTA is one of the most economical and environmentally friendly methods for farmers due to providing added economic crops without creating extra costs for the aquaculture enterprises.

Major differences from known operation of polyculture is that organisms from other nutritional levels are included in the similar process. Organisms in conventional polyculture could all involve in the equal biological- chemical processes only with some positive gains; actually they could incorporate a more diversity and occupy a variety of niches, as extensive cultures (low intensity, poor management) in the given pond (Barrington *et al*. 2009).

IMTA can reduce organic and inorganic contamination from aquaculture. Alternative species used in IMTA, especially invertebrates could remove dissolved nutrients, turbidity, microbial contaminants, heavy metals from the marine environment (sediment and water column).

The IMTA is quite an adjustable and the central ⁄ comprehensive concept about which many alternatives could be created. It is applicable to marine or land-based farms (also termed as aquaponics) and marine or freshwater and temperate or tropical processes. The latest studies on marine IMTA arrangements in modern countries have usually been developed experimental and scaled-down enterprises, which it is of course problematic to generalize to large scale industrial farms. A number of IMTA operations unique to Asia (China) in particular have commercially succeeded at industrial scale while preliminary enterprises are currently extending to commercialization in Chile, Canada, United States and several European nations (Troell *et al.* 2009).

IMTA suggests to biomitigate and vary fed aquafarm applications through linking them with extractive aquaculture to acquire environmental, economic and societal gains, for which purpose a radical reconsideration would be essential involving the definition ‘aquaculture farm’ by re-describing the concept “Site-Lease Areas” and regarding the way it works in a given environment and in a comprehensive context “Integrated Coastal Zone Management” (ICZM) (Chopin *et al.* 2012).

Doubt hardly exists that IMTA is still in its infancy but it presents high expectations that it could be the “aquaculture of the future”, via higher output diversity as well as with expanded quality and promoting sustainability (Granada *et al*. 2016).

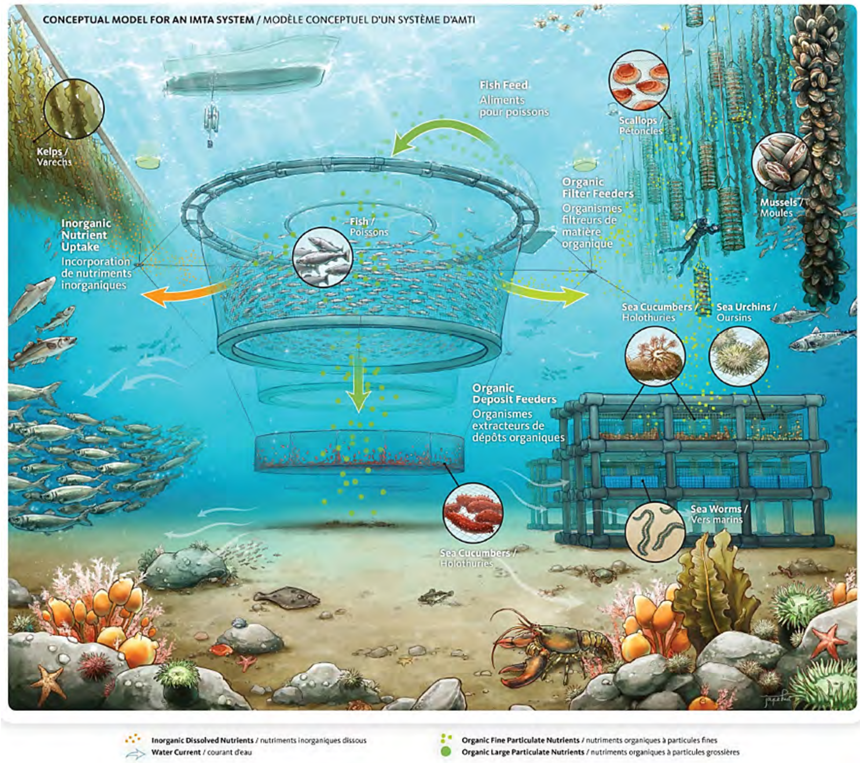

Figure 3. A visualizing for an IMTA (Fisheries and Oceans Canada 2019)

Life cycle assessment (LCA)

Life cycle assessment has been broadly administered to fish farms and fishery systems (Mendoza Beltran *et al.* 2018). Present attempts concentrate on combination of regional ecological and socio-economic effects with the LCA framework, which could play serious part in enlightening decision makers to obtain more sustainable seafood output and usage (Cao *et al*. 2013).

LCA has become a major instrument to identify significant environmental effects of seafood production systems. LCA is capable of assessing the sustainability of aquafarms quantitatively in terms of a cradle-to-grave approach. LCA give us an objective ground to be able to evaluate system advancement and maturation of authentication and eco-labelling criteria.

LCA exercises show that aquaculture enterprises with comparably lower intensity adopting more natural practice prove more environmentally friendly. Organic fish farming in low intensity appears promising as a system provided that animal-derived ingredients are replaced with appropriate plant-based ones in feeds.

Comparison of the environmental performance of agriculture with aquaculture products has indicated that agri-food outputs, apart from chicken, are generally more CO_2-intensive and worked worse in acidification and eutrophication than seafood outcomes of both fisheries and aquafarms. Beef is the most CO_2-intensive associated with the CFC gases emitted coming out of animals and manure (Cao *et al* 2013).

Organic aquaculture

Organic aquaculture is a form of production where environmental sustainability, product quality and safety are considered (IFOAM 2010). In the European Union, there has been a significant increment in organic aquaculture in recent years: among 2012 and 2015, there was a 24% rise in organic salmon production, 25% in seabass/seabream and a double in rainbow. There are also promising progress in organic shellfish production.

Organic seabass and seabream production reached 2.000 tons/year in 2015, the major producers being France, Greece and Spain (EUMOFA 2017). Turkey has also started organic aquaculture in 2006 for the first time. Currently, there are 4 farms in Muğla that produce 558 ton/year organic seabass and seabream (Arslan and Akhan 2018). The environmental policy of the European Union emphasizes the significance of managing environmental impacts in order to reduce the eutrophication risk and ecological issues caused by aquacultural waste (Dempster and Sanchez-Jerez 2008)

Organic aquaculture can be a way of sustainability in terms of minimizing environmental impacts. The organic farming was studied in a conventional farm by evaluating ecological effects by Marco *et al*. (2017). As a result of the study, while environmental effects were not observed in the area where organic cultivation was carried out, a considerable increase in phosphorus in sediment and some variations in the structure and composition of benthos at a distance of 25 m from the farm area was measured where conventional cultivation was carried out (Marco *et al*. 2017).

In order for organic aquaculture to be sustainable both economically and ecologically, scientific, practical and environmentally friendly standards must be established. Turkey is rich in water resources. The aquaculture industry will deal with socio-economic and ecological issues with the help of environmentally-friendly aquaculture practices (Kayhan and Ölmez 2014).

Conclusion

Aquaculture is also operated in a world where mass media influences the public opinion. Aquaculture has been criticized for supplements in farmed fish, levels of medication, hormones and genetically modified organisms which subsidize to an undesirable perception of the aquaculture in the public eye.

Consumers are also well acknowledged on and gradually related in sustainability and matters such as pollution, the unsustainable use of small pelagic fish in reared fish feed, effects on natural fish stocks and animal welfare particularly. In Turkey, attempts like awareness for aquaculture, new legislation and better locations for farms and technology growth were made to improve the sector's view, all of which have not resulted in an important progress of aquaculture in public belief. Currently, general image of the aquaculture hardly seems positive. It is of great importance that universities, producers and non-governmental organizations involved in aquaculture should work in collaboration to effectively change this negative perception of the aquaculture sector. Future progressing of the aquaculture industry is also relying on measures and responsibilities by the state authorities greatly to improve the business environment substantially.

In Turkey, aquaculture basically focuses on the production of high quality, certified products using innovative procedures commensurate with principles of sustainable development. The aquaculture production in Turkey in 2023 (including mussels and shrimp production) is planned to be increased to 600000 tons/year. Parallel to this increase in production, export figures will increase from 1 billion to 2 billion dollars.

References

Aguado-Giménez, F., Marin, A., Montoya, S., Marín-Guirao, L., Piedecausa, A., García-García, B. (2007) Comparison between some procedures for monitoring offshore cage culture in western Mediterranean Sea: sampling methods and impact indicators in soft substrata. *Aquaculture* 271: 357-370.

Addis, A., Diaz Lopez, B., Rabino, S., Fabiano, F., Bernal Shirai, J.A. (2010) Bottlenose dolphin presence in a marine fish farm from the Northwestern coast of Sardinia. *Biologia Marina Mediterranea* 17: 264-265.

Aksu, M., Kaymakci-Basaran, A., Egemen, O. (2010) Long-term monitoring of the impact of a capture-based bluefin tuna aquaculture on water column nutrient levels in the Eastern Aegean Sea, Turkey. *Environ Monit Assess* 171: 681-688.

Aksu, M., Kaymakçı-Basaran, A., Egemen, Ö. (2016) Effects of off-coast bluefin tuna fattening on water quality in the eastern Mediterranean Sea. *Turkish Journal of Fisheries and Aquatic Sciences* 16: 855-863.

Aksu, M., Kocataş, A. (2007) Environmental effects of the three fish farms in Izmir Bay (Aegean Sea-Turkey) on water column and sediment. *Rapp Comm Int Mer Médit* 38: 414.

Akyol, O., Ertosluk, O. (2010) Fishing near sea-cage farms along the coast of the Turkish Aegean Sea. *J Appl Ichthyol* 26: 11-15.

Altıntaş, L., Tutun, H., Sevin, S, Yarsan, E. (2016) Use of probiotics and prebiotics in aquaculture. *J Vet Sci Pharmacol Toxicol-Special Topics* 2(1): 29-37 (in Turkish).

Arechavala-Lopez, P., Sanchez-Jerez, P., Bayle-Sempere J.T., Uglem, I., Mladineo I. (2013) Reared fish, farmed escapees and wild fish stocks - a triangle of pathogen transmission of concern to Mediterranean aquaculture management *Aquacult Environ Interact* 3: 153-161.

Arslan, M.N., Akhan, S. (2018) Overview of organic aquaculture in Turkey and in the World. *Journal of Anatolian Environmental & Animal Sciences* 3(1): (9-18).

Barrett, L.T., Swearer, S.E., Dempster, T. (2018) Impacts of marine and freshwater aquaculture on wildlife: a global meta-analysis. *Reviews in Aquaculture* 1-23.

Barrington, K., Chopin, T., Robinson, S. (2009) Integrated multi-trophic aquaculture (IMTA) in marine temperate waters. In: Integrated mariculture: a global review, (ed. Soto, D.), FAO Fisheries and Aquaculture Technical Paper. No. 529, FAO, Rome. pp. 7-46.

Bascinar, N.S., Gozler, A.M., Şahin, C., Eruz, Ç., Tolun, L., Agirbas, E., Mantikci, M., Serdar, S., Verep, B. (2014) The impact assessment of cage aquaculture on benthic communities along the south eastern Black Sea. *Iranian Journal of Fisheries Sciences* 13(3): 719-738.

Baydan, E., Yurdakök, B., Aydın, F.G. (2012) Antibiotic Use in Fish. *J Vet Sci* 3(3): 45-52.

Brugère, C., Aguilar-Manjarrez, J., Beveridge, M.C.M., Soto, D. (2018) The ecosystem approach to aquaculture 10 years on - a critical review and consideration of its future role in blue growth. *Reviews in Aquaculture* 1-22.

Cao, L., Diana, J.S., Keoleian, G.A. (2013) Role of life cycle assessment in sustainable aquaculture. *Reviews in Aquaculture* 5: 61-71.

Chopin, T., Cooper, J.A., Reid, G., Cross, S., Moore, C. (2012) Open-water integrated multi-trophic aquaculture: environmental biomitigation and economic diversification of fed aquaculture by extractive aquaculture. *Reviews in Aquaculture* 209-220.

Çulha, M., Sömek, H., Aksoy, H. (2019) Impact of offshore aquaculture on molluscan biodiversity in Ildir Bay, Aegean Sea. *Turkey J Environ Biol* 40: 76-83.

Dağlı, E., Bakır, K., Doğan, A., Özcan, T., Kırkım, F., Çınar, M.E., Öztürk, B., Önen, M., Katağan, T. (2008) The effects of a fish farm on the benthic fauna near Markiz Island (Çandarlı Bay-Aegean Sea/Turkey). *Journal of Fisheries Sciences* 2(3): 576-586**.**

Delgado, O., Ruiz, J., Perez, M., Romero, J., Ballestreros, E. (1999) Effects of fish farming on seagrass (*Posidonia oceanica*) in the Mediterranean bay: seagrass decline after loading cessation. *Oceanol Acta* 22: 109-117.

Demirak, A., Balcı, A., Tüfekci, M. (2006) Environmental impact of the marine aquaculture in Güllük Bay. *Environmental Monitoring and Assesment* 123:1-12.

Demirdelen, D, Cengizler, İ., Aldık, R. (2018) The activity and use of vaccine in marine fish culture sector of the Aegean region**.** *Int J Pure Appl Sci* 4(2): 124-132 (in Turkish).

Dempster, T., Sanchez-Jerez, P. (2008) Aquaculture and coastal space management in Europe: an ecological perspective. In: Aquaculture in the Ecosystem (eds. Holmer, M., Black, K., Duarte, C.M., Marbà, N., Karakassis, I.) Springer- Netherlands, pp.87-116.

Dosdat, A. (2001) Environmental impact of aquaculture in the Mediterranean: nutritional and feeding aspects. *Cah Opt Med* 55: 23-36.

EEA (2019) European Environment Agency. Available at: https://www.eea.europa.eu/data-and-maps/indicators/trends-in-marine-alien-species/assessment (accessed 26 June 2019).

EUMOFA (2017) E.U. Organic Aquaculture. Available at: http://www.eumofa.eu./ (accessed 28 May 2019).

FAO (1992) Guidelines for the Promotion of Environmental Management of Coastal Aquaculture Development. FAO Fisheries Technical Paper 328, FAO, Rome, 122 pp.

FAO (2012) General Fisheries Commission for the Mediterranean–Resolution GFCM/36/2012/1 on guidelines on allocated zones for aquaculture (AZA), in FAO General Fisheries Commission for the Mediterranean, Report of the thirty-sixth session. Marrakech, Morocco, 14–19 May 2012, GFCM Report No. 36, FAO, Rome, pp. 38-9.

FAO (2018) The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Licence: CC BY-NC-SA 3.0 IGO. Available at: http://www.fao.org/3/I9540EN/i9540en.pdf (accessed 15 July 2019).

Fisheries and Oceans Canada (2019) Aquaculture in Canada: Integrated Multi-Trophic Aquaculture (IMTA). Available at: http://www.dfo-mpo.gc.ca/aquaculture/sci-res/imta-amti/imta-amti-eng.htm (accessed 06 Aug 2019).

Gao, Q., Shin, P.K.S., Xu, W.Z., Cheung, S.G. (2008) Amelioration of marine farming impact on the benthic environment using artificial reefs as biofilters. *Marine Pollution Bulletin* 57: 652-661.

Gowen, R.J., Bradbury, N.B. (1987) The ecological impact of salmonid farming in coastal waters: a review. *Oceanography Marine Biology Annual Review* 25: 563-575.

Gowen, R.J. Ezzi, I., Rosenthal, H. Maekinen, T. (1990) Environmental impact of aquaculture activities. *Eur Aquacult Soc Spec Publ* (12): 257-283.

Granada, L., Sousa, N., Lopes, S., Lemos, M.F.L. (2016) Is integrated multitrophic aquaculture the solution to the sectors' major challenges? A review. *Reviews in Aquaculture* 8(3): 283-300.

Grigorakis, K., Rigos, G. (2011) Aquaculture effects on environmental and public welfare – The case of Mediterranean mariculture. *Chemosphere* 85(6): 899-919.

Guclusoy, H., Savas, Y. (2003) Interaction between monk seals *Monachus monachus* (Hermann, 1779) and marine fish farms in the Turkish Aegean and management of the problem. *Aquacult Res* 34: 777-783.

Hall, P.O.J., Holby, O., Kollberg, S., Samuelsson, M.O. (1992) Chemical fluxes and mass balances in a marine fish cage farm. IV. Nitrogen. *Mar Ecol Prog Ser* 89: 81-91.

Holmer, M., Hansen, P.K., Karakassis, I., Borg, J., Schembri, P.J. (2008) Monitoring of Environmental Impacts of Marine Aquaculture. In Aquaculture in the Ecosystem (eds., Holmer, M., Black, K., Duarte, C.M., Marbà, N., Karakassis, I.) Springer, Netherlands, pp. 47-85.

ICCAT (2019) Available at: https://www.iccat.int/en/Ffb.asp (accessed 28 July 2019).

IFOAM EU Group (2010) Organic aquaculture EU Regulations (EC) 834/2007, (EC) 889/2008, (EC) 710/2009. In: Background, Assessment, Interpretation. (eds., Szeremeta, A., Winkler, L., Blake, F., Lembo, P.) Brussels, International Federation of Organic Agriculture Movements EU Group and Valenzano, Bari, CIHEAM/IAMB.

Kalantzi, I., Karakassis, I. (2006) Benthic impacts of fish farming: Meta-analysis of community and geochemical data. *Marine Pollution Bulletin* 52: 484-493.

Karahan, B., Gokcek, E.O., Gamsiz, K., Magoulas, A. (2014) Microsatellite Polymorphism of sea bass (*Dicentrarcus labrax*) breeders: Natural and cultural stocks. *Fresenius Environmental Bulletin* 23: 1289-1294.

Karakassis, I. (2001) Ecological effects of fish farming in the Mediterranean. In: Environmental impact assessment of Mediterranean aquaculture farms (eds., Uriarte, A., Basurco, B.). Cahiers Options Méditerranéennes, no. 55, Zaragoza, CIHEAM, pp. 15-22.

Karakassis, I., Tsapakis, M., Hatziyanni, E. (1998) Seasonal variability in sediment profiles beneath fish farm cages in the Mediterranean. *Mar Ecol Prog Ser* 162: 243-252.

Katavić, I. Antolić, B. (1999) On the impact of a sea bass (*Dicentrarchus labrax* L.) cage farm on water quality and macrobenthic communities. *Acta Adriat* 40: 19-32.

Katsanevaki, DS., Coll, M., Piroddi, C. Steenbeck, J., Lasram, F., Zenetos, A., Cardoso, A.C. (2014) Invading the Mediterranean Sea: Biodiversity patterns shaped by human activities. *Front Mar Sci* (accessed 18 Aug 2019).

Kayhan, MH, Olmez, M (2014) Aquaculture and organic aquaculture in Turkey. *J Aquac Res Development* 5: 259.

Kaymakçı-Basaran, A., Aksu, M., Egemen, Ö. (2007) Monitoring the impacts of the offshore cage fish farm on water quality located in Ildır Bay (İzmir-Aegean Sea). *AU Journal of Agricultural Sciences* 13: 22-28.

Kaymakci Basaran, A., Aksu, M., Egemen, Ö. (2010) Impacts of the fish farms on the water column nutrient concentrations and accumulation of heavy metals in the sediments in the eastern Aegean Sea (Turkey). *Environ Monit Assess* 162: 439-451.

La Rosa, T., Mirto, S., Mazzola, A., Danovaro, R. (2001) Differential responses of benthic microbes and meiofauna to fish-farm disturbance in coastal sediments. *Environ Pollut* 112: 427-434.

Lupatsch, I., Kissil, G.W. (1998) Predicting aquaculture waste from gilthead seabream (*Sparus aurata*) culture using a nutritional approach. *Aquat Living Resour* 11: 265-268.

MAF (2019) Ministry of Agriculture and Forestry. Available at: https://www.tarimorman.gov.tr/BSGM/Haber/152/Su-Urunleri-Yetistiriciligi-Avciligi-Ilk-Kez-Gecti (accessed 3 July 2019).

Maldonado, M., Carmona, M.C., Echeverria, Y., Riesgo, A. (2005) The environmental impact of Mediterranean cage fish farms at semi-exposed locations: Does it need a reassessment? *Helgol Mar Res* 59: 121-135

Mangion, M., Borg, J.A., Sanchez-Jerez, P. (2018) Differences in magnitude and spatial extent of impact of tuna farming on benthic macroinvertebrate assemblages. *Regional Studies in Marine Science* 18: 197-207.

Marco Di, P., Petochi, T., Marino, G., Priori, A., Finoia, M.G., Tomassetti, P., Poli, B.M. (2017) Insights into organic farming of European sea bass *Dicentrarchus labrax* and gilthead sea bream *Sparus aurata* through the assessment of environmental impact, growth performance, fish welfare and product quality. *Aquaculture* 471: 92-105.

Mendoza Beltran, A., Chiantore, M., Pecorino, D., Corner, R. A., Ferreira, J.G., Cò, R., Fanciulli, L., Guinée, J.B. (2018) Accounting for inventory data and methodological choice uncertainty in a comparative life cycle assessment: the case of integrated multi-trophic aquaculture in an offshore Mediterranean enterprise. *Int J Life Cycle Assess* 23(5): 1063-1077.

MEU (2015) Guidelines for creating the environmentally sustainable and environmentally friendly fish farming system. Ministry of Environment and Urbanization. 26p. (in Turkish).

MEU (2017) Guidelines for Marine Monitoring. Ministry of Environmental Urbanization. Available at: www.csb.gov.tr/gm/ced, 442 p. Ankara, (accessed 3 July 2019) (in Turkish).

Moraitis, M., Papageorgiou, N., Dimitriou, P. D., Petrou, A., Karakassis, I. (2013) Effects of offshore tuna farming on benthic assemblages in the Eastern Mediterranean. *Aquacult Environ Interact* 4: 41-51.

OECD (2010) Advancing The Aquaculture Agenda: Workshop Proceedings, Available at: https://www.oecd.org/publications/advancing-the-aquaculture-agenda-9789264088726-en.htm (accessed 3 July 2019).

Official Gazette (2014) Environmental Impact Assessment Regulation. Official Gazette Number: 29186.

Official Gazette (2020) Regulation of Environmental Management of Fish Farm operating in the sea. Official Gazette Number: 31288.

Orçun, E., Sunlu, U. (2007) Investigation on impacts of coastal cage aquaculture to aquatic environment in Sığacık (Seferihisar, Izmir). *E.U. Journal of Fisheries & Aquatic Sciences* 24(1-2): 01-09.

Ottolenghi, F. (2008) Capture-based aquaculture of bluefin tuna. In: Capture-based Aquaculture. Global Overview, (eds., Lovatelli, A., Holthus, P.F.), FAO Fisheries Technical Paper. No. 508. FAO, Rome, pp. 169-182.

Pitta, P., Apostolaki, E.T., Giannoulaki, M., Karakassis, I. (2005) Mesoscale changes in the water column in response to fish farming zones in three coastal areas in the Eastern Mediterranean Sea. *Estuarine, Coastal and Shelf Science* 65(3): 501-512.

Pitta, P., Karakassis, I., Tsapakis, M., Zivanovic, S. (1999) Natural vs. mariculture induced variability in nutrients and plankton in the eastern Mediterranean. *Hydrobiologia* 391: 181-194.

Price, C., Black, K.D., Hargrave, B.T., Morris, J.A. (2015) Marine cage culture and the environment: Effects on water quality and primary production. *Aquaculture Environment Interactions* 6(2): 151-174.

Rigos, G., Nengas, I., Alexis, M., Troisi, G.M. (2004) Potential drug (oxytetracycline and oxolinic acid) pollution from Mediterranean sparid fish farms. *Aquatic Toxicology* 69(3): 281-288.

Ruiz, J.M., Marco-Méndez, C., Sánchez-Lizaso, J.L. (2010) Remote influence of off-shore fish farm waste on Mediterranean seagrass (*Posidonia oceanica*) meadows. *Marine Environmental Research* 69(3): 118-126.

Sanchez-Jerez, P., Karakassis, I., Massa, F., Fezzardi, D., Aguilar-Manjarrez, J., Soto, D., Chapela, R., Avila, P., Macias, J. C., Tomassett, P., Marino, G., Borg,

J. A., Franicevic, V., Yucel-Gier, G., Fleming, I. A., Biao, X., Nhhala, H., Hamza, H., Forcada, A., Dempster, T. (2016) Aquaculture's struggle for space: The need for coastal spatial planning and the potential benefits of Allocated Zones for Aquaculture (AZAs) to avoid conflict and promote sustainability. *Aquaculture Environment Interactions* 8(1): 41-54.

Sanz-Lazaro, C., Belando, M.D., Marin-Guirao, L., Navarrete-Mier, F., Marin, A. (2011) Relationship between sedimentation rates and benthic impact on Maerl beds derived from fish farming in the Mediterranean. *Mar Environ Res* 71: 22-30.

Science for Environment Policy (2015) Sustainable Aquaculture. Future Brief 11. Brief produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol. Available at: http://ec.europa.eu/science-environment-policy. (accessed 3 July 2019).

Taylor, N.G.H., Verner-Jeffreys, D.W., Baker-Austin, C. (2011) Aquatic systems: maintaining, mixing and mobilising antimicrobial resistance? *Trends in Ecology & Evolution* 26(6): 278-284.

Troell, M., Joyce, A., Chopin, T., Neori, A., Buschmann, A. H., Fang, J. (2009) Ecological engineering in aquaculture — Potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems. *Aquaculture* 297(1-4): 1-9.

Vezzulli, L., Moreno, M., Marin, V., Pezzati, E., Bartoli, M., Fabiano, M. (2008) Organic waste impact of capture-based Atlantic bluefin tuna aquaculture at an exposed site in the Mediterranean Sea. *Estuar Coast Shelf Sci* 78: 369-384.

Vita, R., Marín, A. (2007) Environmental impact of capture-based bluefin tuna aquaculture on benthic communities in the western Mediterranean. *Aquaculture Research* 38: 331-339.

Wu, R.S.S. (1995) The environmental impact of marine fish culture: towards a sustainable future. *Marine Pollution Bulletin* 31: 159-166.

Youngson, A.F., Dosdat, A., Saroglia, M., Jordan, W.C. (2001) Genetic interactions between marine finfish species European aquaculture and wild conspecifics. *J Appl Ichthyol* 17: 153-162.

Yucel-Gier, G., Kücüksezgin, F., Kocak F. (2007) Effects of fish farming on nutrients and benthic community structure in the Eastern Aegean (Turkey). *Aquaculture Research* 38: 256-267.

Yucel-Gier, G., Uslu, O., Bizsel N. (2008) Effects of marine fish farming on nutrient composition and plankton communities in the Eastern Aegean Sea (Turkey). *Aquaculture Research* 39: 181-194.

Yucel-Gier, G., Uslu, O., Kucuksezgin, F. (2009) Regulating and monitoring marine finfish aquaculture in Turkey. *J Appl Ichthyol* 25(6): 686-694.

Occupational health and safety in Turkish marine aquaculture

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Introduction

Traces of the first aquaculture research in the world go back to 2000s BC. It is seen that studies on aquaculture of different species have been carried out in many parts of the world since this date. In our country too, the growth rate of the aquaculture sector is quite high, and it is more than the annual growth rate of many industries. However, there are inevitably problems in the sector such as the use of water areas, transfer of license, insurance, pledge of livestock, loan supply and marketing. Besides, considering the production capacities of the facilities in this production line, where the sectoral growth is quite high, it is observed that the labour force and mechanization are used at a very high intensity and the related negativities begin to occur over time.

The integration of occupational health and safety, which has become important in our country in recent years, to the aquaculture sector is also very important. 2% of occupational accidents occurring in enterprises depend on factors under human control, 10% on mechanical deficiencies and 88% on human factors. Generally, human errors in accidents can be explained as; not knowing the risks sufficiently and therefore being indifferent to or neglected to danger, not paying due attention to the use of personal protectors, having insufficient knowledge in the use of machinery and related equipment. In addition, other reasons for these accidents are factors such as the inability of the staff to reach a sufficient level in professional experience, lack of concentration, and haste during the work, not always being suitable for the physical and mental health.

In general, despite the measures taken, the enterprises are insufficient to prevent accidents caused by human mistakes. Enterprises should follow an in-depth policy of occupational health and safety culture in this regard. At this point, it is inevitable that both proactive studies (foreseeing the risks arising from dangers and dangers in advance and preventing risks before they occur) and occupational health and safety training are important for the prevention of work accidents and occupational diseases. The Social Security Administration, reported that in 2017 359 653 work accidents occurred in Turkey. 58 883 women and 300 770 male workers were affected by these accidents. At the same time, in this period, it is seen that there are 691 employees with occupational diseases and 53 of the people are women and 638 are men. In the same period, the number of employees who died as a result of an occupational accident is 1633, of which 1604 are male and 29 are female. The number of people who died as a result of the occupational disease has not been defined. Unfortunately, the level of knowledge and approach of workers in aquaculture in the field of occupational health and safety in our country is limited, compared to other professional groups. Within the scope of fisheries and aquaculture, the total number of work accidents in 2017 is 273249 of those involved in these accidents are 249 males and 24 are females. When the same data are analyzed, it is seen that there are no occupational diseases among those working in fisheries and aquaculture companies. Two male workers died from work accidents that occurred in these facilities (SGK 2020).

Occupational health and safety in Turkey

In our country, OHS studies are first encountered with the Maadin Regulation issued in 1869. In this context, it was provided to the families of employees and employees who had a work accident to be paid a compensation determined by the authorized institutions, and to have a doctor and pharmacy in the work environment. In 1921, working environments of coal mines were regulated by the Law No 151 on the Law of Ereğli Havza-i Fahmiye Mining Workers. Although this law is very important for being a direct protector, it has not been implemented. Again, with the law enacted in this period, the normal working time was determined as 10 hours a day and the working age as minimum 12. However, mining workers' working time was defined as 8 hours and working age as 18.

Besides, in 1926, the Law on Obligations, which includes legal provisions on occupational diseases and work accidents, was introduced. In this law, it is ensured that the necessary protective measures are taken by the employer to prevent occupational accidents and diseases. With the Municipalities Law, enacted in 1930, supervision mechanisms were introduced. With the Labor Law numbered 3008, which came into force in 1936, issues such as giving permission to women workers before and after childbirth, treating employees' illnesses and paying half wages on the days they could not work were regulated extensively. In 1945, the Workers Insurance Institution Law No 4792 was enacted. With the establishment of the Ministry of Labour in 1946, important steps were taken on Occupational Health and Safety. The First Labour Law came into force in 2003 with the law numbered 4857 in Turkey. With the Labour Law No 4857, occupational health and safety legislation has also changed in our country.

Besides, the Social Insurance and General Health Insurance Law No 5510 was adopted on June 16, 2006 (Karakule 2012; Çabuk 2016).

The Occupational Health and Safety Law No 6331, which came into force after being published in the Official Journal No. 28339 on June 30, 2012, in our country, is the latest study in this field and it is very important (Official Journal; Date-Issue: 20.06.2012/6331) In addition to this, Turkey, the International Labor Organization (ILO) in partnership with the signing of contracts pursuant to the provision of job security has committed at increasing quality standards. Especially in accordance with the provisions of ILO 155 (OHS Working Environment Agreement) and 161 (Health Services Agreement), the working environment and employee health issues are the focal points of OHS. Therefore, both conventions bring important responsibilities and binding obligations to the countries making the agreement. With the law numbered 6331, it is clearly stated who is responsible for the conditions related to occupational health and safety. The law divides these obligations into three as employees, employers, and the state. After the enactment of the Law, the state and employer feet of the subject started to be more careful to fulfil their legal obligations within the scope of the determined policies. When the employer does not fulfil its legal obligation, it may be subject to sanctions. However, it is seen that there is no clear sanction in cases where employees violate. Currently, the state can only control the employee through the employer. The employer is obliged to raise awareness of its employees with their occupational health and safety training and seminars. However, it is not known by the employer and the state that the occupational health and safety training achieved on employees are successful. The success rate of the training given and the measures taken can only be understood by comparing them with the periodic data in the relevant sectors. At the same time, practices should be planned to determine how much training practices change the perspectives and awareness levels of employees on occupational health and safety issues.

Occupational health and safety in Turkish aquaculture

General aquaculture production in Turkey

Aquaculture production in Turkey has increased after the 1980s and has become an increasingly important position in the aquaculture sector. According to the geographical, cultural and biotechnological structure in which our country is located, production is basically divided into 4 main groups; (a) Rainbow trout (*Oncorhynchus mykiss*) and carp (*Cyprinus carpio*) production in inland waters, b) seabream (*Sparus aurata*)-seabass (*Dicentrarchus labrax*), potential sea fish species and crustaceans production in the Aegean and Mediterranean coasts, c) Rainbow trout (*Oncorhynchus mykiss*), seabass (*Dicentrarchus labrax*)-seabream (*Sparus aurata*) production in the Black Sea) d) Atlantic Bluefin Tuna (*Thunnus thynnus*) production in Aegean and Mediterranean Sea (Figure 1).

The number of facilities is 2286 for aquaculture production in Turkey (1860 facilities for inland water product, 426 facilities for marine water product). The total project capacity of the facilities is 486 786 thousand tons. The number of facilities producing 1000 tons or more is 80 in the marine environment and 3 in inland water environment. In 2018, 105 167 tons of freshwater products and 200135 tons of marine water products were produced. Within the scope of 2018, our fisheries exports reached 177 539 tons and our imports reached 98 314 tons. In return, approximately 953 million dollars of input is provided, while the amount we provide for imports is 189 million dollars (BSGM 2019).

Figure 1. Examples of Turkey marine aquaculture operations. Clockwise from top left: Marine fish hatchery. Pond culture for seabass and sea bream production. Cage culture for seabass-seabream and other marine fish species. Cage culture for Atlantic Bluefin Tuna. Mussel farm (Photos: Kürşat Fırat, Şahin Saka, Serpil Serdar).

On the other hand, as in the whole world, there is a decrease in the number of people working in fisheries. However, the relative increase in the number of people employed due to the increase in production in the aquaculture sector is observed. When the 2019 data of the Social Security Institution is examined, it is seen that the total number of insured employees is 20 348 058 people (excluding 4a/4b/4c/Agriculture). It is observed that the total number of insured people working in the agricultural sector is 664 754. The number of establishments operating in plant and animal production, fisheries and related areas is 17 544. The number of insured people working in these facilities is reported to be 115905. The number of workplaces engaged in fisheries and aquaculture is 1174 and the number of insured persons working in these workplaces is 34 142 (SGK 2020).

Legal status of current occupational health and safety in the aquaculture sector

In our country, the status of aquaculture within the scope of occupational health and safety has been defined in the Official Journal dated 26.12.2012/28509, besides to the communiqué dated 18.04.2014/28976. In this context, aquaculture was shown with the code 03.2 NACE within the scope of the Communiqué on Hazard Classes Regarding Occupational Health and Safety (03.21 Marine Aquaculture, 03.22 Inland Aquaculture). Aquaculture is in the "dangerous" group within the hazard classes (Official Journal; Date-Issue, 26.12.2012/28509 Amendment: Date-Issue, 18.04.2014/28976).

On the other hand, according to Article 7 of the Regulation on the Duties, Authorities, Responsibilities, and Training of Occupational Safety Specialists published in the Official Journal dated 29.12.2012/28512 the persons to be appointed as occupational safety specialists must have a valid occupational safety certificate. Occupational safety experts; those who have the (C) class certificate can work in the less dangerous class, those who have the (B) class certificate can work in the workplaces in all the hazard classes (Official Journal; Date-Issue, 29.12.2012/28512, Amendment: Date-Issue, 30/4/2015-29342). Occupational safety specialists with B or A certificates are assigned in these enterprises since the fisheries enterprises are in the "dangerous" class. Occupational safety specialists work within the periods specified in Article 12 of this regulation (Official Journal; Date-Issue, 30/4/2015-29342) to fulfil their duties. In workplaces that are in the "dangerous" class, they work for at least 20 min. per employee per month. Besides, in workplaces with 500 or more employees in the "dangerous" class, at least one full-time occupational safety specialist is assigned for every 500 employees (Official Journal; Date-Issue, 29.12.2012/28512, Amendment: Date-Issue, 30/4/2015/29342).

Also, according to Article 12 of the Regulation on the Amendment to the Regulation on the Duties, Authorities, Responsibilities, and Training of Workplace Physicians and Other Health Personnel published in the Official

Journal dated 18.12.2014/29209; occupational physician should work at least 10 minutes for each employee for a month. At workplaces with 1000 or more employees in the dangerous class, at least one workplace physician is assigned for every 1000 employees (Official Journal; Date-Issue, 20.07.2013/28713, Amendment: Date-Issue, 18.12.2014/29209). Where there are more than fifty employees and more than six months of work, occupational safety boards are required for work on occupational health and safety. Occupational safety boards must meet immediately in extraordinary situations and bi-monthly in ordinary cases (Official Journal; Date-Issue, 18.01.2013/28532).

Occupational health and safety services in the aquaculture sector

In accordance with Article 6 of the Occupational Health and Safety Law No 6331, the employer is responsible for the determination and monitoring of the occupational health and safety measures to be taken in the workplace. Also, the employer has to carry out the prevention of work accidents and occupational diseases, first aid and emergency treatment of employees, and preventive health-safety services. Besides, according to the Occupational Health and Safety Services Regulation, the employer can meet the need from inside or outside the workplace to perform occupational health and safety services, taking into account the hazard class of the workplace and the number of employees.

National and international legislation and standards guide employers and professionals working in this field (occupational health and safety) in the implementation of occupational health and safety services. Also, the application of international contracts and standards by businesses is effective in the business relations of businesses. Today, TS ISO 45001 Occupational Health and Safety Management System standard has started to be implemented by businesses. This standard was signed by Turkey in February 2018. The meeting secretariat was headed by the British Standards Institute (BSI-British Standards Institute). 62 participants and 12 observer countries participated in the meeting. Unlike the previous standard (OHSAS 18001), TS ISO 45001 standard is primarily an ISO standard and is valid in the international platform. Also, this standard enables risk management and continuous improvement by taking precautions in the performance of occupational health and safety. Besides, he standard envisages strengthening of the organizational structure and continuous improvement of the system, more efficiency of employees, prevention of occupational accidents and occupational diseases, and provision of legal and regulatory conditions (Sevim and Gürcanlı 2018).

Legal status of risk assessment and emergency plans in the aquaculture sector

In this context, danger in the Occupational Health and Safety Law No 6331, has been described as the potential for harm or damage that exists in the workplace or that may come from outside, affect the employee or workplace. Similarly, the risk is explained as the possibility of loss, injury or other harmful consequences arising from the hazard. Risk assessment, on the other hand, is the necessary studies for determining the dangers existing in the workplace or coming from outside, analysing the factors that cause these hazards to turn into risks, and analysing and grading the risks arising from hazards and deciding control measures.

Risk assessment within the scope of Article 10 of the same law is explained as follows; The employer is obliged to make or have a risk assessment in terms of occupational health and safety. When conducting a risk assessment, the situation of the employees to be affected by certain risks, the equipment to be used, the choice of chemicals and medicines, the organization and layout of the workplace, groups that require special policy (such as young, old, disabled, pregnant or breastfeeding employees) and female employees should be considered. The employer should determine the occupational health and safety measures to be taken as a result of the risk assessment and the protective equipment or equipment to be used. Occupational health and safety measures, working methods and production methods to be applied in the workplace will increase the level of protection of employees in terms of health and safety and should be applicable at all levels of the administrative structure of the workplace. The employer should ensure that the necessary control, measurement, inspection, and investigations are carried out at the working environment and to identify the risks that employees are exposed to in this environment.

Besides, according to Article 11 of the Occupational Health and Safety Law No 6331 and Article 5 of the provisions of the "Regulation on Emergency Situations in the Workplaces" published in the Official Journal dated 18.6.2013/28681; Employer; it determines the possible threats and possible emergencies that may affect employees and the working environment by taking into account the working environment, the materials used, the work equipment and the environmental conditions, and takes precautionary and limiting measures. Management makes necessary measurements and evaluations and prepares emergency plans to protect against the negative effects of emergencies. Taking into consideration the size of the workplace and the special hazards it carries to combat emergencies, the nature of the work done, the number of employees and other persons at the workplace; It assigns a sufficient number of people who are suitably equipped and trained in prevention, protection, evacuation, firefighting, first aid, and similar issues, provides training and drills by providing tools and equipment and ensures that teams are always available. It makes the necessary arrangements to establish contact with organizations outside the workplace, especially in the fields of first aid, emergency medical intervention, rescue, and firefighting, makes the necessary arrangements for the deactivation of energy sources and potentially dangerous systems in emergencies without affecting the adverse conditions and preventing the protective systems. If any, it informs the employees of the employer who established a subcontractor and temporary employment relationship and other persons such as customers and visitors about emergencies in the workplace (Official Journal, Date-Issue; 18.06.2013-28681). Also, diving services in the cage facilities in the marine environment are extremely important and are life-threatening. In this context, within the scope of the Regulation on the Works that Require to Work Maximum of Seven and a Half Hours a Day or Less in Terms of Health Rules published in the Official Journal with the number 28709 on 16.07.2013; diving times for divers are expressed as up to 18 meters 3 hours and up to 40 meters 1/2 hours (Official Journal, Date-Issue; 16.07.2003/28709).

Occupational health and safety in marine aquaculture facilities

The workplace is the place where those who are considered to be insured to do their jobs with material and non-material factors. In this context, there are things to do to ensure the health and safety of the insured employees, subcontractors, trainees, apprentices and visitors in the workplaces. In the measures to be taken and determined within the scope of occupational health and safety practices, especially collective and personal protection measures should be given priority. Also, the measures to be implemented mustn't cause new risks.

In the study, the hazards in the seafood production facilities have been tried to be identified, the risks have been defined and the measures to be taken have been explained. In the evaluations made, besides the ideal facility environment, the current situation was determined. In this context, the risks and dangers of the facilities are explained and the precautions to be taken are expressed. For this, literature, observation, detection, and personal communications were used. Besides, some applications that are not suitable for occupational health and safety in Aquaculture applications are shown in Figure 2.

Building and Add-Ons

With the goods or services produced in the workplace, the places organized under the same management (resting, breastfeeding, eating, sleeping, washing, examination and care, physical or vocational training places, courtyards, offices and attachments and tools) are counted as workplaces. The building and additions to the building to establish a workplace must comply with the national legislation and the qualifications and features of the work to be done in that building, and have the features that will allow employees to feel comfortable and safe.

When the aquaculture facilities are considered, the study areas are structures established on both terrestrial and marine areas. In this context, health and safety hazards and risks are expressed in the workplace buildings and additions on land. In general, it is observed that attention was not paid in the placement of tanks, pools, and machines used in production and at least 80 cm gaps between them were not provided for comfortable operation. In particular, it can be seen that at least 10 cubic meters of fresh air per person and at least 3 m ceiling height that will allow air circulation is not facilitated and culverts are not formed. It has been determined that the roofing materials are not strong, there are no corridors (least 110 cm width) and passageways that allow employees to move comfortably in ordinary and extraordinary situations, and the walls are not resistant to explosion and fire. It has been observed that there are no handrails at least 90 cm high on stairs and platforms that allow passage between floors and tanks in workplaces, and there are broken steps on the stairs.

Figure 2. Unsuitable practice at marine aquaculture operations. Clockwise from top left: Deformed fish separation without protective equipment and chemical risk hazard. Fish vaccination and grading without protective equipment biological risk hazard. Overload and unstable loading. Fish harvest without protective equipment. Risk of microbial contamination. Exposure to the sunrays (Photos: Kürşat Fırat, Şahin Saka, Şükrü Yıldırım).

In the sections that make up the facility, there are pointed corners and iron protrusions on the floors, where there are gaps and threshold differences. It is observed that the water channels are open, there are no handrails around the water wells and tanks, and there are pressure-related deformations in high-volume polyester pools and cracks in concrete pools. Besides, it can be stated that the quality of the roads used for transportation to the facilities is low and the roads are often damaged due to the passage of high tonnage vehicles and there is no sign of health and safety on the roads.

In the side additions of the facilities, there are deficiencies in the quality and quantity of the warehouses of materials such as tools, chemicals, feeds, raw materials, and work equipment. It is observed that the characteristics of the relevant substances are not taken into consideration during storage in the warehouses and the emergency exits of the cold stores are not sufficient. Besides, there are no areas in the workshops to provide comfortable working opportunities. It is seen that there are no active lightning rods in buildings and additions, the generator is kept in open area and there is no generator room. Besides, the adequacy of social living spaces, lodgings, toilets and showers lags behind expected standards. It can also be seen that the facilities do not have a first aid room for emergency use and the necessary equipment for first aid.

Besides terrestrial facilities, most of the production is done in offshore cage systems located on the sea. When the studies are examined, it is seen that attention is paid to the location and mooring of the cage. Also, the established barge systems create a relatively comfortable living space on the sea. However, it is seen that there are no flat and continuous walking platforms with suitable widths that will allow easy movement and walking on many cage systems, the gap between the pipes where the employees walk is high, and it becomes slippery due to algae, and there are no handrails on the cage systems to prevent falling into the sea. The absence of platforms that allow the transition from boats to cage and cage to boats is also considered a negative situation.

Physical risk factors

Physical properties of the facility environment such as temperature, humidity, lighting, noise, vibration, dust and pressure significantly affect the health of employees. Especially those working in heavy and dangerous jobs are at high risk in terms of physical risk factors and it is important to eliminate the risks at the source for the protection of the employees. When the physical risk factors in the aquaculture sector are analyzed, it has been determined that the employees are adversely affected by noise, vibration, lighting, heat, dust, pressure and humidity, and the measures in this area are insufficient.

It is observed that especially in closed environments where the machines are working intensely and the water is flowing, there is not enough precaution for noise. It is exposed to high and low temperature values of personnel working in cage systems. It is observed that the ambient temperature is not always in the range of 15-30 ºC in the buildings and additions that constitute the facility, and its temperature is not applied according to the type of work, the strength of the employees and the ambient characteristics (toilet, shower, dressing places, lodging, etc.). Also, it has been determined that there is no necessary ventilation against organic dusts.

Chemical risk factors

When the chemicals are in contact with each other or with other substances; It is defined as substances that react chemically by forming one or more of the effects of heat, light, sound, and pressure. Failure to pay attention to safety precautions in transporting, storing and using chemicals, misuse by employees, and not using personal protective equipment suitable for the work done, causes work accidents and occupational diseases. Veterinary drugs, disinfectants, and sedatives, especially used in hatcheries, are a high level of chemical risk factors. In the aquaculture industry, it can be seen that a large amount of chemicals is used in applications and that the process takes a long time. At this time, it is observed that personal protective equipment is not used and necessary arrangements are not made for the transportation, storage, and disposal of chemicals. At the same time, it is observed that the material safety forms of chemical substances are missing and the measures related to chemical substances are not determined in the risk assessment. It is observed that there is no shower, eye wash and hand-face wash area in the areas where chemical studies are carried out to be used in emergencies.

Biological risk factors

This factor identifies microorganisms, cell cultures and human endoparasites, including genetically modified ones, that can cause any infection, allergy or poisoning. Biological factors can spread to society, as well as cause illness and harm to employees. In some cases, the effective prevention and treatment method of the agent may not be available. In the aquaculture industry, a biological risk factor is frequently encountered especially in vaccination procedures applied to fish. Unsuitable applications can cause serious skin problems and anaphylactic shocks. Also, frozen fish products used in the production of tuna may contain dangerous biological factors due to poor storage conditions. They are also suitable areas for the nesting of rodents in areas where fish feed is stored.

In the evaluations, it was observed that the necessary measures for the absence of pests, insects, and rodents were not sufficient in the facilities, and hygiene materials were missing in the add-ons (lodging, shower, toilet and dressing places). Besides, it was observed that employees did not pay attention to personal protection in thawing frozen fish products. It was determined that attention was not paid to the application conditions during the vaccination of the fish. Also, it is observed that the staff working in the dining hall do not use hygienic equipment such as bones, gloves, and masks and the disease examinations are not performed regularly. The lack of drugs that must be in the first aid cabinet and the presence of drugs that have expired is a biologically separate problem. It is also seen that at the first entry to the job, the medical report showing that a person is suitable for the work done from a full-fledged hospital is not requested. It is also determined that, appropriate health tests are not performed for employees before starting the job.

Psycho-social risk factors

Today, the biggest and the most important resource that all sectors cannot afford to lose is humans. Imitation and copying of humans are inadequate with the technology we have now. The main purpose of occupational health and safety practices in the workplace is the protection of human resources. Creating a healthy and safe working environment and improving this situation continuously is to make employees feel physically, mentally and socially well. Live production differs considerably from other branches of production and the individual that determines the basic production factor is again the individual. During the intensive production process, employees have to work in high concentrations. Among the psycho-social factors; the nature of the job and the structure of the enterprises, the distance of the enterprises to the central settlements, the intensive working tempo, the completion pressure of the job, the role conflict and some uncertainties, the uncertainty of the job descriptions, and the uncertainties in career development can be assumed.

In this context, it is necessary to protect employees socially, to eliminate uncertainties, to have clear job descriptions and to provide an environment of trust in the workplace. Besides, working, shift and leave periods must be following the law. Employees should be informed about these issues, pay attention to the principle of equality in wage policy and career development.

Ergonomic risk factors

Ergonomics is a branch of science that allows for appropriate living and working environments by taking into account the behavioural and biological features of human beings. The factors that make up the ergonomic risk can be explained as follows; psychological factors (mental fatigue, psycho-social factors, social communication, work organization), workplace risk factors (work and workplace-borne factors, repetitive jobs, inappropriate posture and jobs that require excessive force, cramped and closed working environments, physical-chemical-biological risk factors) and individual risk factors (employee age, gender, body weight, body measurements, etc.). It is observed that the ergonomics of the working environments, working conditions, furniture, and equipment are not taken into consideration. Especially, the height difference of the pools that are actively used throughout the production is at a level preventing the working conditions. It has been observed that the growing tank, pool and cage systems due to the increase in production amounts pose a big problem, especially for the employees. In this context, it can be seen that there are no platforms in the pools, employees are not provided with shoes or boots of suitable quality, and that the seats used in sitting jobs do not provide ergonomic conditions.

Pressure vessels

Factors such as not being used according to the instructions for use, lack of suitable safety equipment, lack of proper ventilation system in case of gas leakage, lack of periodic maintenance, lack of explosion-proof places and failure to comply with storage conditions may cause work accidents. Intense liquefied oxygen tanks, especially in marine fish hatcheries, carry a high risk of fire. In this context, it can be seen that the manufacturer company information is not found on the heating boilers and that the flame pipes are not cleaned. In the same way, it can be said that the necessary information on the compressor is not available, the use of mobile compressors is not paid attention and there is no automatic stopper that will allow the compressor to stop at the set pressure. Also, it can be seen that the compressors are used unshielded and that the pressurized gas cylinders are not fixed to the wall when using. Especially in cage systems, it is observed that the necessary precautions and remedial activities are not applied during the use of the diving tubes used by the divers. Some incompatibilities have been seen such as diving tubes not being fixed, filling air without fixing, stacking properly, leaving the tubes on walkways or even passages, and occasional periodic maintenance and checks.

Work equipment

In an ideal facility, it is inevitable to pay attention to the selection, placement, and use of the equipment so that the work equipment does not have any negative effects on the employees and the environment. Boats are the most used equipment used in the cages culture systems. Failure to meet the seaworthiness conditions of the boats, working principles of boat machines, lack of knowledge of the working personnel, job experience, and fatigue may cause undesired results. It can be seen that there are errors in the placement and use of all kinds of machinery, apparatus, auxiliary equipment, and tools used in the facilities. Especially in the positioning and application stages of the equipment used in the fish vaccination and fish grading period, there are important problems. The most common disadvantages are the absence of plates that provide information about the features of the equipment, the absence of emergency stop buttons on the work equipment, the protective equipment being removed or not used by the employees. Although the boats used in aquaculture are subject to the "Fishing Boat Regulations" procedures and principles, deficiencies can be seen in the hardware features of the boats used.

Loading and evaluation tools

Vehicles are used in the facilities to download, transport and store various materials (materials to be used in production, semi-finished materials, products that are finished for production or purchased directly for use). While forklifts are generally used in the terrestrial area, crane systems are used extensively in the cage systems operations. It has been observed that the relevant vehicles are not used in transportation and stacking of the materials. In the use of these tools; It is seen that only people who are authorized to use the forklift and who have the necessary documents are not used, while the truck is used, there are other people other than the operator on the forklift and there is no light and sound warning system on the forklift. Also, it can be seen that the truck has no side and top guards, and occasionally lifts more than its capacity. On the other hand, it has been determined that the daily, periodic maintenance of the lifting, transporting and stacking vehicles are not performed and no records are kept.

Hand tools

Portable or hand-operated power tools that are used to carry out simple tasks are simple but important. In this context, it has been observed that the instruments are not kept regularly and safely in the workplace. It was observed that the cables of the power tools were torn, cut, burned and plugged into the electrical outlet without a cable plug. There is no security vending machine to prevent electrical leakage in electrical devices without grounding lines. It was determined that the power tools were not checked by the authorized persons before use and that the tools that were defective or missing protection material were used.

Storage and hoarding

Storage and stacking of organic and inorganic materials, chemicals, vehicles, equipment in the facilities should be done under appropriate conditions. Especially heavy sacks should be placed diagonally. Sacks must be at most 5 rows in over and over and stacks must be placed with one bag missing. In this context, it is seen that there is no shelf system and cabinets in the warehouses, the storage and storage height of the materials are not paid attention, and an excessive load is placed on the shelves and cabinets. Also, it has been determined that the chemical storage matrix is not taken into account in the storage of chemicals and the necessary protective measures are not taken for leaks and impurities that may occur during the storage and use of chemicals. Besides, in the liquid oxygen storage tank where the pressure tubes are not securely stored in an upright position and warning signs, filling instructions and no grounding were determined.

Work at height

Work at height is defined according to the Regulation on Occupational Health and Safety in Construction Works published in the Official Journal dated 05.10.2013 and numbered 28786. According to this, "work in all areas where there is a possibility of injury due to level difference and falling" is working at high**.**

In the aquaculture sector, this situation is encountered at every stage of production. Fracture, dislocation, sprain, permanent disability and death may occur in bones as a result of falls that occur in working at height. Besides, these adverse conditions are caused by objects falling from the high ground too. In this context, it is observed that mobile ladders generally do not have the necessary features, there are no handrails on the platforms, no chain, rope or wooden handrails are placed around the ladder and personal protective equipment is not used against falls.

Manual lifting and transport

Falling of the load and moving backward while carrying or pushing loads can cause discomfort in the hands, back and waist areas of the employees. To prevent these situations, the minimum requirements specified in the Manual Transportation Regulation should be applied. Loads that are not suitable for manual transportation are carried by the workers. The weight of the load should not exceed 25 kg for male employees and 20 kg for female employees. The load to be transported must not be shapeless, pointed and without a handhold. It is known that especially in this situation, female personnel are affected quite intensely. In this context, it has been observed that employees are not informed about the rules to be considered during manual transportation, employees carry more than the weight they can carry by hand, and the physical characteristics of the employees in load transportation are not taken into consideration. Physical injuries and musculoskeletal disorders occur frequently, especially during the transport of feed bags.

Welding works

It was observed that the necessary protection measures were not taken during welding works and the working rules were not followed. It is important to take protective measures not only for metal welding but also for PVC welds, which are frequently used for maintenance and repair of tanks. In this context, it has been determined that the welding machine equipment in the workshops is missing, the existing materials are scattered, the carrying arm of the welding machine is not isolated and the grounding is not done. Also, it can be seen that there are flammable and explosive substances and pressurized tubes in the workshop. Besides, it was observed that workers were exposed to intense odour and smoke during PVC welding.

Maintenance and repair works

Maintenance and repair services is carried out to ensure that dangerous situations do not occur due to long-term problems and unexpected failures. This protects employees against unwanted incidents, accidents, and injuries. Also, it prevents the waste of material and time. From this point of view, it is observed that the instructions for the execution of the works are not prepared, the security measures are not taken, the periodic control of the devices and the maximum hydraulic pressure test are not performed regularly.

Health and safety signs

According to the results of the risk assessment conducted in the workplaces; Safety and health signs should be used in cases where the risks in the workplace cannot be eliminated or sufficiently reduced by working methods, work organization, collective protection measures. In this context, it can be seen that the signs of prohibition, warning, mandatory, emergency exit, first aid and firefighting in the facilities are not sufficient and not placed in suitable places. Besides, it is observed that obstacles and dangerous places in the facilities are not painted properly, and there are no suitable signs in containers and pipes containing dangerous substances. Also, it has been observed that employees do not work taking into account the safety and health signs found in the facilities.

Electric systems and operations

All electrical materials to be used in the facilities must have certificates by following TSE or accepted standards. The legislator has prepared a Regulation on Fire Protection of Buildings and it is very important to take the necessary measures accordingly. Especially in marine fish production facilities, electrical installations should be installed at high standards. Considering the high electrical conductivity of sea water, waterproof materials should be used in electrical equipment and connections. Grounding and residual current relay in insurance systems are of special importance. Despite these evaluations, it is seen that the electrical installations in wet, damp and dusty places in the facilities are not suitable, the doors and locks of the cabinets are not available, there are open cable ends in their panels and no grounding is made. It was observed that there was no emergency stop system on the panels, and there were no warning signs on the cabinets. It can be said that the electrical system of the aerators used especially in pond culture systems has been made quite dangerous. Also, it was observed that there were exposed electrical cables in some sections, not properly stacking, and fixed electrical cables were not included in electrical cable channels. Besides, it can be monitored that illumination by following the standards inside and outside of the facility is not made, electrical materials are below the standards, and there are no protective covers on the lamps. In addition, it was observed that measures preventing the formation of static electricity were not taken in the transfer of flammable liquids to storage tanks.

Order and arrangement

Disposal of waste and materials used in the facility environment irregularly can cause pollution, mess, irregularity and consequently occupational accidents and occupational diseases. It has been observed that the floors (due to wetness and/or chemicals) are slippery in the areas where the pools and tanks are located, the cables and hoses are left uneven on the ground and there are unsuitable materials on the passageways. In addition, it was determined that after completing the work of the employees, they left the work equipment and the environment without cleaning, and the hand tools used were not placed in the protection and regulation cabinet after use. Most importantly, the employees do not comply with the rules and regulations set in the facility. Besides, the presence of ropes and protection nets lying around in the cage systems environment was monitored.

Personal private protections

Collective protection measures should be prioritized to protect employees from health and safety risks, to prevent occupational accidents or occupational disease risks, and to improve health and safety conditions. However, when the risks cannot be prevented or fully limited by technical measures or work organization and working methods that will provide collective protection, personal protective equipment should be used. In this context, serious problems may arise as a result of the needle sticking to the worker accidentally, when protective gloves are not used for the vaccination of fish. In addition, cage systems operations create a risk of falling overboard for employees who are constantly in the marine environment. Falling during the operations using thick clothing and boots in winter increases the risk of suffocation even more. For this reason, it is appropriate to use protective equipment such as a life jacket and to assign good swimmers in these operations.

In this context, it has been observed that there is not enough personal protective equipment suitable for the standards and intended use for the employees, the personal protective materials to be used for each unit and machine are not determined, the material list is not made, and the personal protective equipment is not clean and strong. Besides, it can be seen that employees are not informed and trained on the use, maintenance and storage of personal protective equipment. On the other hand, in the cage systems operations, the use of life jackets of employees is very limited. Likewise, it is seen that the necessary precautions are not taken during vaccination and many cases of injuries and related allergic reactions occur. Besides, the presence of ropes and protection nets lying around in the cage systems was observed.

Health monitoring

In the workplace, it is necessary to conduct health examinations and inspections at the time of the job entry for all employees and at periodically determined periods thereafter. Also, those with a diagnosis or pre-diagnosis of occupational disease, chronic disease, substance abuse, multiple occupational accidents and those who have been away from work for a long time should undergo examination during their return to work. Taking into consideration the hazard class of the workplace and the nature of the work, a risk assessment should be made in the workplace with international standards. In line with the results, periodic examinations should be repeated at least once every 3 years for the jobs in the dangerous class, and for children, youth and pregnant employees who are in the group requiring a special policy, at least once every six months.

Occupational accidents and legal process

In the Article 13 of the Social Insurance and General Health Insurance Law No 5510; occupational accidents are defined as follows; while the insured is in the workplace, due to the work carried out by the employer, when the insured works independently in his name and account, due to the fact that the insured working under an employer is sent to another place outside the workplace as an officer (in the past without doing his own job), by following the labor legislation of the nursing mother insured, in the time allocated to give milk to her child, situations that occur during the arrival-departure of the insured with the vehicle provided by the employer to the place of work and affects the insured immediately or later physically or spiritually (Official Journal, Date-Issue; 31.05.2006/5510, Article Number: 13). Although the definition of a work accident is outlined in the law, the fact that there has been a causal relation with the employer in the precedent decisions taken in the labour courts in recent years puts the accident within the scope of a work accident.

Employers, society, the state and especially workers who work as a result of work accidents, suffer from direct and indirect costs. Necessary measures must be taken and implemented to prevent material and moral losses in all sectors, including the aquaculture sector. With the work to be done, work accidents at workplaces will be mostly prevented and will contribute to the continuity of the business. The effects of applications and environmental conditions in aquaculture facilities on occupational health and safety are very important. However, studies on the occupational diseases and occupational health and safety of aquaculture in Turkey is quite limited (Atayeter and Atar 2013; Çabuk 2016; Mert and Ercan 2014; Uyumsal 2017). As in every sector, work accidents and related traumas occur in aquaculture facilities. The most common dangers in aquaculture in terms of occupational health and safety in our country are concentrated on issues such as slipping, falling, crushing, buckling, electric shock and contact with chemicals. Consequently, fractures in the nasal bone, dislocations in the wrist and hand joints, sprains and crushes are observed. At the same time, superficial injury, crushing, and fracture are seen in the feet. Other events are burns and itching on the skin. Similar disadvantages arising from aquaculture production have been described by Holen *et al*. 2017a and 2017b for the production of salmon (*Salmo salar*) in cage systems as fall, crush, cut, sprain and fracture. In addition, the same researchers have reported that 34 people have lost their lives in the last 40 years due to the cessation of the main blood vessel, falling overboard and an object hit. This clearly shows how high-risk production is in the marine environment. Despite these disadvantages, it is stated that there are regulatory and observer problems in this industry and gaps continue in the understanding safety and health risk factors in aquaculture (Holen and Utne 2018). Similarly, the rate of seafood cultivation accidents in Australia is generally 17%, and these are reported as injuries and skin diseases. In addition, the most common problems are expressed as ergonomics, stress, object crash, slipping and falling (Mitchell and Lystad 2019).

Electric shock, solar radiation, and drowning are the most common occupational health and safety issues in oyster culture in Brazil. In addition, other hazards have been identified such as noise, biological risks (bites, stings, zoonotic diseases), ergonomic hazards (material handling and dangerous postures), and sliding-falling (slippery conditions, boat travel, debris). In addition, unsuitable structures, the use and lack of personal protective equipment and the lack of basic training bring additional risks to workers (Guertler *et al*. 2016). The problems in American aquaculture production are no different. In the reviews by the US Occupational Health and Safety Administration (OSHA), it has been reported that employees in aquaculture practices are exposed to many chemicals and biological risk factors (Jillian *et al*. 2019).

Occupational diseases and legal process

An occupational disease is defined as temporary or permanent illness, physical or mental disability that the insured suffers from a recurring reason due to the nature of the job he/she works or does, or due to the execution conditions of the job (Official Journal, Date-Issue; 31.05.2006/5510, Article Number: 14).

As in every sector, work accidents and related traumas occur in aquaculture facilities. In general, occupational disorders encountered in aquaculture are not different from those encountered in the entire fisheries sector. However, it can be said that the effect of the disease is more limited than the fisheries sector. Accordingly, the most common disorders are Musculoskeletal Disorders [Inguinal hernia (K40), Disorder of the meniscus, due to old rupture or injury (M23.2), Rheumatoid arthritis (M06), Joint pain (M25.5), Other specified joint disorders (M25.8), Kyphosis and lordosis (M40)), Scoliosis (M41), Intervertebral disc disorders (M51; M51.0), Cervical disc disorders (M50) Neck pain (M54.2), Sciatica (M54.3), Low back pain (M54.5), Other disorders of muscle (M62), Other disorders of synovia and tendon (M67), Soft tissue disorders (M70; M79), Rheumatism (M79.0), Myalgia (M79.1), Bone integrity disorders (fracture) (M84), Nasal bone fractures (S02.2), Dislocation, sprain and tension of joints and ligaments at wrist and hand level (S63), Crush injury of wrist and hand (S67), Other and unspecified injuries of wrist and hand (S69), Superficial injury of ankle and foot (S90), Foot fracture, except ankle (S92), Crush injury of ankle and foot (S97)] caused by intense physical work. In addition, some Respiratory System Diseases [Asthma (J45.0), Other diseases of the upper respiratory tract (J39), Respiratory diseases, inhaled chemical, gas, smoke (J68), Chest pain (R07.3)] and Skin Diseases [Allergic contact dermatitis (L23), Irritant contact dermatitis (L24), Pruritus (L29), Dermatitis (L30), Redness and other skin rashes (R21)] are observed as a result of activities such as laboratory applications, fish grading, and vaccination, feed preparation-thawing, network change and environment cleaning (Uyumsal 2017).

In addition, before and/or after hiring according to the equipment and environmental conditions used in the marine fish production facilities workers can see some disorders such as Circulatory System Problems [Heart rhythm disorder (I09), Blood pressure (I10; I11), Varicose veins of lower extremity (I83), Hemorrhoids (I84), Headache (G44)], Digestive System Problems [Gastric ulcer (K25), Anus and rectal region fissure and fistula (K60), Other diseases of the intestine (K63; K63.3), Intestinal infection (Z11.0)], Urinary System Problems [Kidney stone (N20), Urinary tract problems (C68)], Neurological Problems [Dizziness (R42), Epilepsy (G40), Cerebral cyst (G93.0)], Eye Disorders [Eye disorders (H23)], Ear, Nose and Throat Problems [Sore throat (R07.0), Conductive and sensorineural hearing loss (H90), Ear and hearing examination (Z01.1)], Endocrinological Problems [Endocrine disorders (E39)], Psycho-somatic Disorders [Reaction to severe stress and adjustment disorders (F43)], Oral and Dental Health Problems [Dental examination (Z01.2), Bad breath (R19.6)] and other disorders [Pedestrian injury, collision with vehicle, van or van (V03), Contact with power tool (W27), Tear and explosion of pressure equipment other, identified (W38), Noise exposure (W42), Sun exposure (X32)] was determined (Uyumsal 2017).

Besides, decompression times are not complied with due to the intensive diving tempo in tuna production especially. This situation causes embolism events. This condition, which occurs due to disruption of the circulatory system, can be defined as a serious risk and cause of death. In this context, deep-sea dives exceeding 30 meters are carried out from time to time to control the general condition of cage systems, and specially mixed gases should be used in these dives to prevent nitrogen intoxication. However, there is no record of whether such gases are used or not. In addition to this situation, it is known that there are hearing losses and bone loss due to long-term dives and because the divers work until advanced ages due to the absence of the necessary wear premiums. In this context, the pre-detection of existing ailments, the workers working in the facilities for the diagnosis and treatment of the diseases that occur, should be checked before and after the work in full-fledged hospitals, and health checks should be repeated periodically.

Emergency plan and teams

Emergencies that may occur in the facilities (fire, natural disasters, spread and explosion caused by hazardous chemicals, sabotage) cause serious injuries and deaths of workers, material damage at workplaces and environmental damage. In general, it is observed that the emergency action plan has not been prepared in the facilities and the duties of the personnel to be employed in emergencies have not been determined. It was also observed that employees were not trained, separate teams were not determined for day and night shifts, and there was no light and sound warning system for use in emergencies. Also, there is no table with the contact information of the authorized institutions and units to be sought during the emergency. First aid is a drug-free application made with existing tools and equipment, without seeking medical tools and equipment at the scene, in case of any accident or life-endangering situation. The first aid specialist is the person who can apply aid to the patient or injured person with the current tools and equipment, and who has received first aid training and certificate. In the aquaculture sector which is in the dangerous class, one first aid specialist should be determined for every 15 employees. The number of people identified should be sufficient for the day and night shifts. A business organization must be made for each shift.

It is vital to make the first interventions before the employees are taken to health institutions who are injured as a result of work accidents at the facilities. In addition to this, considering the distances of the cage systems to the land, speed boats that will immediately intervene in the event should be kept in the facilities. In this context, it can be counted that the first aid room and related equipment are not available or missing for the emergencies, the drugs in the first aid cabinet are missing or expired, the personnel who will work in the first aid team in the facilities.

Education

The most important step to take necessary precautions to create a safe and healthy working environment in the facilities and to prevent work accidents and occupational diseases is the training given to employees, trainees, and visitors. Occupational health and safety training, not less than 12 hours, should be provided at the times determined by the management in the facilities. This training should be carried out when new personnel are recruited, when the employee has insufficient knowledge and experience about the work done, in the way of working and change of work, and when new work equipment is purchased. In addition to Occupational Health and Safety, search and rescue, firefighting, first aid, job-specific training (work at height etc.) and professional development training should be provided for first aid personnel working in emergencies.

It is seen that general occupational health and safety training is not given to the newly recruited personnel, trainees, and those visiting the facility. In this context, it has been determined that training programs are not prepared, employees are not provided with vocational training on their job, and necessary training materials are not provided during the training to be given to employees, trainees and visitors.

Overall comments

The fisheries sector both in Turkey and the world in terms of both technological and employment is growing faster than in other industrial sectors. With continuous development, the sector brings risks along with its growth (Erondu *et al*. 2005; Myers 2010). New technologies are evolving into new mechanizations, and new mechanizations create new risks (Myers and Durborow 2012). At this point, the importance of occupational health and safety in the aquaculture sector increases day by day and the risk factors are updated (Oliveira *et al*. 2017). Increasing mechanization and labour force is felt most in the aquaculture sector. This can be attributed to the global-based dramatic decline in populations of economically important aquatic species due to overfishing, leading people to the aquaculture sector.

Similar to developments in the world, occupational health and safety are gaining importance in Turkey. Especially after the enactment of the Occupational Health and Safety Law No 6331 which entered into force in 2013, the issue gained a national and legal dimension. As in all other areas, the occupational health and safety law was of great importance in the aquaculture sector. The companies within the aquaculture sector, especially corporate companies, have implemented the necessary control mechanisms against risk factors. However, occupational health and safety and occupational risk awareness culture are relatively new and difficult ideas to grasp for those working in Turkey.

In our country, although the frequency of accidents in aquaculture seems acceptable, employers and employees should not ignore these dangers and continue their improvement. In addition, a significant part of the sector employees is aware of the dangers and risks in the environment in which they work. Before the risk factor can be identified, it must be recognized. Continuous observation and supervision is the first conscious action against accidents to avoid dangers. In addition, the health of employees is as important as the risk of an accident. An unhealthy work environment can be dangerous enough to lead employees to catch on occupational disease.

The general health problems of those working in aquaculture facilities are parallel to each other. However, it may not always be correct to think that these common health problems are caused by occupational disease. This phenomenon also falls within the field of workplace physicians and medical specialists. However, the number of institutions that will determine occupational disease in Turkey is limited. The state should develop policies to increase the diagnosis of occupational diseases. Occupational diseases are a huge waste of time and finance for employees, employers and the state.

In the evaluations, the perspectives of the individuals working in the marine fish facilities on job security have not been linked with age. However, in the training given to the employees, transferring the information by considering the educational status of the individuals may mean that a healthier flow of information will be provided. Occupational safety officials working in the sector should be investigated as to what the lack of information is in the employees. The person who will first notice the dangers in the work area is the employee. It is important that the individual is conscious and does not have any reservations about the risk factors. It is observed that people who state that they express themselves comfortably in the business environment are more aware of occupational health and safety. This situation positively affects occupational health and safety but also increases productivity.

Another issue observed in the facilities is that employees do not feel responsible for occupational safety issues. Employees often recriminate management or employer for accidents he occupational health and safety board should investigate why employees do not feel responsible for occupational health and safety. However, they expressed that they were generally satisfied with the work and working environment of those working in the aquaculture industry. Employees reported that the opportunities provided were sufficient and that they were doing their job comfortably in an unprinted environment. However, there is a contradictory situation regarding the satisfaction of employees' wages balance. This situation creates anxiety for people in the future. Employees express their opinions on “I would like to stay in the same sector but with a higher salary”. Accordingly, it is beneficial for aquaculture companies to review wages paid to employees within the sector and to improve wage balances. In addition to this, the extra fee such as double overtime pays, premiums, and bonuses will increase motivation. Employers should go over this issue and keep in mind that making improvements in wage balances does not harm the company, but on the contrary, this improvement will increase the job satisfaction of employees and this will reflect positively on production.

As a result, as in all production sectors, the main factor in aquaculture production is the individual. It is essential to ensure the integration of our country, which has an important place in aquaculture, especially marine and inland aquaculture products, in the framework of individual-oriented social, economic and ethical values, by maximizing occupational health and safety.

References

Atayeter, S., Atar, H. (2013) Occupational health and safety management system and floating fish cage production facilities occupational health and safety. *Yunus Research Bulletin* 1: 27-36 (in Turkish).

BSGM. (2019) Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Fisheries and Aquaculture. Available at: https://www.tarimorman.gov.tr/BSGM/Menu/32/Bilgi-Dokumanlari (accessed 09 Jan 2020) (in Turkish).

Çabuk, A. (2016) Planning of 10 Million Production Capacity Marine Fish Hatchery Pilot Plant According to Occupational Safety and Health. Ege University Graduate School of Natural and Applied Science, Postgraduate Thesis 113pp. (in Turkish).

Erondu, E.S., Anyanwu, P.E. (2005) Potential hazards and risks associated with the aquaculture industry. *African Journal of Biotechnology* 4(13): 1622-1627.

Guertler, C., Speck, G.M., Mannrich, G., Merino, G.S., Merino, E.A.D., Seiffert, W.Q. (2016) Occupational health and safety management in oyster culture. *Aquacultural Engineering* 70: 63-72.

Holen, S.M., Utne I.B., Holmen, I.M., Aasjord, H. (2017a) Occupational safety in aquaculture–Part 1: Injuries in Norway. *Marine Policy* 96: 184-192.

Holen, S.M., Utne I.B., Holmen, I.M., Aasjord, H. (2017b) Occupational safety in aquaculture–Part 2: fatalities in Norway 1982–2015. *Marine Policy* 96: 193-199.

Holen, S, Utne, I. (2018) A framework based on a systems approach to developing safety indicators in fish farming. *Safety* 4(2): 19.

Jillian, P., Fry, Caitlin, A. Ceryes, Jill, M. Voorhees, Nancy, A. Barnes, David, C. Love., Michael, E. Barnes. (2019) Occupational safety and health in U.S. aquaculture: A review. *Journal of Agromedicine* 24(4): 405-423.

Karakule, İ. (2012) Occupational Health and Safety in SMEs and a Research. Selçuk University, Institute of Social Sciences, Postgraduate Thesis 107pp. (in Turkish).

Mert, B., Ercan, P. (2014) Evaluation of occupational health and safety practices in fisheries sector. *TÜBAV Science Journal* 7(4): 16-27.

Mitchell, R.J., Lystad, R.P. (2019) occupational injury and disease in the Australian aquaculture industry. *Marine Policy* 99: 216-222.

Myers, M.L. (2010) Review of occupational hazards associated with aquaculture. *Journal of Agromedicine* 15(4): 412-426.

Myers, M.L., Durborow, R.M. (2012) Aquacultural Safety and Health. *INTECH* Open Access Publisher. Available at: https://www.intechopen.com/books/health-and-environment-in-aquaculture/aquacultural-safety-and-health (accessed 29 Jan 2020).

Official Journal, Communiqué on Hazard Classes Regarding Occupational Health and Safety. Date-Issue: 26.12.2012/28509 (Amendment: Date-Issue, 18.04.2014/28976) (in Turkish).

Official Journal, Regulation on Duties, Authorities, Responsibilities and Training of Occupational Safety Specialists. Date-Issue, 29.12.2012/28512, (Amendment: Date-Issue, 30/4/2015-29342) (in Turkish).

Official Journal, Implementing Regulation on the Duties, Authorities, Responsibilities and Training of Workplace Physicians and Other Health Personnel. Date-Issue, 20.07.2013/28713 (Amendment: Date-Issue, 18.12.2014/29209) (in Turkish).

Official Journal, Regulation on Occupational Health and Safety Boards. Date-Issue, 18.01.2013/28532 (in Turkish).

Official Journal, Occupational Health and Safety Law. Date-Issue: 20.06.2012/6331 (Published Date-Issue OJ-30.6.2012/28339 (in Turkish).

Official Journal, Regulation on Emergency Situations in Workplaces. Date-Issue; 18.06.2013-28681 (in Turkish).

Official Journal, Implementing Regulation on the Works Required to Work Maximum 7 and a Half Hours or Less in Terms of Health Rules. Date-Issue; 16.07.2003/28709 (in Turkish).

Official Journal, Social Insurance and General Health Insurance Law. Date-Issue; 31.05.2006/5510 (in Turkish).

Official Journal, Regulation on Occupational Health and Safety in Construction Works. Date-Issue; 05.10.2013/28786 (in Turkish).

Oliveira, P., Cavalli, R.S., Filho, H.C.K., Carvalho, D., Benedetti, N., Rotta, M.A. Ramos, A.S.P., Brito, K.C.T., Brito, B.G., Rocha, A.F., Stech, M.R., Cavalli, L.S. (2017) Occupational health and safety in aquaculture: Insights on Brazilian Public Policies. *Journal of Agromedicine* 22(2): 148-158.

Sevim, M., Gürcanlı, E. (2018) Integration of health and safety documentation system in to construction project schedule. *Beykent University Journal of Science and Engineering Sciences* 11(2): 19-33.

SGK (2020) Statistical Annual of Republic of Turkish Social Security Institution. Available at: http://www.sgk.gov.tr/wps/portal/sgk/tr/kurumsal/istatistik/sgk_istatistik_yilliklari (accessed 29 Jan 2020) (in Turkish).

Uyumsal, S. (2017) Determination of Occupational Risk Knowledge Levels of Employees in Marine Fish Hatcheries Operating in the Aegean Region. Ege University Graduate School of Natural and Applied Science, Postgraduate Thesis 56p. (in Turkish).

Management systems and certification in marine aquaculture

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Introduction

The terms "standard", "certificate" and "label" are used differently. Codex Alimentarius defines certification as follows: It can be expressed as a procedure by which formal certification bodies or officially defined certification bodies provide a written or equivalent assurance that food or food control systems meet these requirements (OECD 2011). The mandatory standard can be explained as a mandatory standard, depending on the general law or mandatory regulation (ISO/IEC 2004). When a standard is declared mandatory, it becomes a technical regulation (UNCTAD/WTO 2002). If it is desired to be expressed in general, technical arrangement can be defined as a document that specifies product features or related processes, production methods, where compliance is mandatory, with applicable administrative provisions (World Trade Organization 1997).

Sanitary or phytosanitary measures include: (i) all relevant laws, decrees, regulations, conditions and procedures, including final product criteria; (ii) Processes and production methods; (iii) Testing, inspection, certification and approval processes; (iv) Requirements for the transport of animals or plants, or quarantine processes, including materials necessary for survival during the transplant in question; (v) Relevant statistical methods, sampling stages, and principles regarding risk assessment methods; and (vi) Packaging and labeling requirements directly related to food safety (World Trade Organization 1997).

Seafood is an important part of the world's food production, yet it helps 3.1 billion people by meeting about 20 percent of daily animal protein intake (FAO 2016). The products in question are of particular importance in meeting protein needs and in providing certain micronutrients. Although fishing and aquaculture is one of the fastest growing food industries in the world, the concept of sustainability naturally came first because of many systemic features such as production, environment and health.

The sustainable seafood movement (Konefal 2013) was born partially from a perceived failure of public policy instruments to address the increasingly evident environmental challenges related to fisheries and aquaculture (Jonell *et al.* 2019). This is especially important in terms of legal regulations and approaches demanded by developed countries from developing countries. Market-oriented instruments such as eco-certification have been one of the major sustainability mechanisms used in the sustainable seafood movement. Implementation of aquaculture certification was gradual with organic farmed seafood (IFOAM) (Bergleiter 2008) and the Global Aquaculture Alliance's (GAA) Best Aquaculture Practices (BAP) standard (Lee 2008) being the first established schemes on the market (1996 and 2004 respectively). The latter was originally solely focusing on removing the worst performing shrimp farms (Steering Committee of the State-of-Knowledge Assessment of Standards and Certification 2012) (Table 1).

Table 1. Major aquaculture certification schemes (Source: Jonell *et al.* 2019).

Scheme	Year of establishment	Volume certified (million tons)	Species certified
ASC	2010	1.28	abalone, bivalve, pangasius, salmon, shrimp, tilapia, trout
GAA BAP	2004	1.80	catfish, pangasius, salmon, shrimp, tilapia, trout
FOS	2008	0.70	cod, clams, oysters, pangasius, salmon, seabream, shrimp/prawn, trout, other
GLOBALGAP	2004	2.10	pangasius, salmon, shrimp, tilapia, trout, seabream, seabass, meagre
IFOAM Organic	1996	0.19	carp, mussels, oysters, pangasius, rainbow trout, salmon, seabass, shrimp/prawn, trout

GlobalGAP, primarily a business to business scheme, label products as GGN and in cooperation with the Friend of the Sea (FoS) by allowing use of their logo on packages, started certifying farmed seafood in 2004 and today accounts for the largest portion of eco-certified farmed seafood available on the market (Potts *et al*. 2016). In 2010, the Aquaculture Stewardship Council (ASC) was initiated by a collaborative effort in the midst of the Dutch Sustainability Trade Initiative (IDH) and the World Wildlife Found, WWF. In contrast to the evaluation of certification schemes in other sectors, most aquaculture and fisheries schemes, e.g. the MSC, GAA/BAP and ASC, were established on a global level rather than starting off with local activities (Auld 2014). Volumes of certified farmed fish and shellfish form about 8 percent of global aquaculture production (76.7 million tons, 2015) (Jonell *et al*. 2019).

The Food and Agriculture Organization (FAO) is a specialized agency of the United Nations leading international efforts to overcome hunger. Its main purpose can be expressed as ensuring food safety for all individuals and ensuring that people have regular access to high quality food, sufficient to live an active and healthy life. Having more than 194 member countries, FAO operates in more than 130 countries worldwide. These are largely coordinated from International Standards Organization (ISO) documents, WTO Trade Technical Barriers (TBT) agreement, FAO Sea Catching Fisheries Fish and Fisheries Eco-Labeling and Fisheries Centers Network in Asia-Pacific (NACA) and studies are carried out (FAO 2019).

The voluntary, third-party certificate in question for fish and seafood was introduced as a market-based motivation tool in the 1990s to promote sustainable fishing. From the first establishment of the fishery certification system to the present day, the seafood certificate; eco-labeling - it can be stated that it has grown significantly in terms of quantity and criteria range. This development is a response to doubts and shortcomings regarding ineffective fisheries management practices, rapid depletion of stocks and deterioration of ecological balance. Often, non-governmental organizations (NGOs) and the private sector-dominated seafood certification programs are demanded by consumers who want to buy eco-labeled products, especially in the markets of industrialized North American and European countries, through awareness programs. Eco-labeled fish products are predicted to have a lower environmental impact than similar non-labeled products, and it can be stated that the labels enable consumers to make informed and sensible choices about the food they have purchased (Tsantiris *et al*. 2018).

It can be stated that the fish and fish products are one of the most widely processed food products in the world. The voluntary certification system is developing the potential for beneficial effects on global fisheries management. Considering that more than half of the fish exports are in developing countries, it can be said that it has the potential to ensure sustainable use of resources and increase livelihoods of small-scale fishermen. The principles of global fish trade are constantly changing and developing according to international trade rules, import requirements and trade agreements. However, it can be stated that the system in question has also been influenced by voluntary certificate programs, which are based on environmental and social responsibility criteria, but are not subject to any regulation and are not covered by the existing World Trade Organization (WTO) agreements (Tsantiris *et al.* 2018).

In this study, seafood certification systems and practices have been analyzed in detail, the effects of the overall economic framework of this system was defined and has sought to demonstrate applications in Turkey. In this framework, the seafood certification system has been tried to be evaluated in detail at the macro and micro level at a certain level. By determining the current situation, possible constraints, advantages and predictions for the future are tried to be revealed.

Some important certifications, authorities and food safety issues in marine aquaculture

Certification (which can be expressed as conformity assessment in its broadest sense) can be defined as a process in which a written or equivalent assurance, a product, process or service reports that it meets the specified requirements. In the aquaculture industry, the certificate can be applied to a process followed by a production unit (eg pool, cage, farm, processing facility), a particular product or commodity, or inputs applied to the system before or during production. An inspection or audit process (also known as an inspection) is often performed to assess the degree of compliance of the business to be certified with certain standards. The process of testing or auditing an enterprise is performed by an auditor or audit firm. In most cases, the supervisory board issues a certificate to the business. Based on this, it declares compliance with the standards and can continue its activities as a certification institution accordingly. In the context of certification, the word label can also be used to reveal that a particular product is generally in accordance with certain standards or manufactured from an organization in accordance with a particular set of standards or regulations. When these standards or regulations show a higher level of environmental sustainability, the word eco label can be used more often. However, this term can be used more intensively to describe a tag that is valid for fishing. Depending largely on the relationship between the certified entity and the certification body, the certification process can be classified as follows (FAO 2019): (i) First Party Certification the conformity assessment is done by the person or organization that provides the product (for example, manufacturers or producer organizations set out their compliance with a number of standards. (ii) Second Party Certification the conformity assessment is carried out by a user or organization that has its users. (Traders, retailers or consumers and their organizations) (iii) Third Party Certification covers an enterprise, product or process specific criteria or standards as a whole, independent of both supplier and consumer organizations. (iv) Fourth Party Certification, although not specified by ISO, is fourth by some organizations. Although this certification includes state or multinational agencies, the UN Global Compact, the human rights principles to be followed for the environment, workforce and Companies, companies' other parties contains internal updates (eg GO). In the certification definition, ISO refers only to third-party certification, which uses the term "conformity assessment" to describe first-party and second-party certification. However, the term "certification" will be used more broadly in this review, as it is still widely used to present other forms of conformity assessment (FAO 2019).

Privately initiated certification schemes in fisheries and aquaculture potentially encompass a broad framework of product and process quality properties (e.g. sustainability, organic production, origin). By the OECD, sustainability includes three dimensions. These are: economic, environmental and social. Implemented to fisheries and aquaculture, the focus of sustainability is primarily environmental: conserving the resource (fish, mollusks, aquatic animals and plants, etc.) and managing negative impacts on the surrounding eco-system (reduction in biodiversity, destruction of marine habitats, and contamination of water sources through aquaculture) (OECD 2011).

Markets based on natural resources are particularly relevant to sustainability concerns as public awareness of unsustainable production and consumption practices and their environmental impacts increases. Special certification by eco-labelling in fisheries and aquaculture is a result of this trend; consumer demands must have access to responsible choices in the market and retailers must demonstrate that they are providing them. It also promotes sustainable production and consumption patterns in periods of increasing concern about overfishing and loss of biodiversity. The use of special certification and eco-labeling is particularly strong in fishing and aquaculture. A recent survey showed that in 2008, 13% of the newly launched fish products sampled were marketed with an environmental or ethical claim, compared with an average of 5% of all new food and beverage products included in the survey. The two main private fisheries eco-labels, Marine Stewardship Council (MSC) and Friend of the Sea (FoS) have both seen strong growth in the volume of fisheries certified by these schemes (OECD 2011).

In the late 1990s, NGOs began developing sustainable seafood consumer guides, eco-labels and certification programs - particularly as a response to the perception that public mechanisms are not adequately meeting the resource management problem. The overall objective of these efforts is to direct consumers to a more sustainable choice of fish products (OECD 2011).

Some NGOs have developed standards and labelling plans for organic aquaculture of certain species. However, these were limited in practice (Franz 2005). At the global level, two major certification efforts predominate: The Best Aquaculture Practices of the Global Aquaculture Alliance and the WWF Aquaculture Dialogues. In addition, inspired by the model of the Marine Stewardship Council for capture fisheries, the Aquaculture Stewardship Council will be operative in 2011 and manage a range of standards (based on species) developed through the Aquaculture Dialogues. Concurrently, the FAO in 2011 adopted Guidelines for Aquaculture Certification, which should provide a level playing field for existing and future certification schemes. These guidelines have four areas: food safety, animal health and welfare, environmental issues and social issues (OECD 2011).

Economic coverage of eco-labelling is important. Thus, many key stakeholders are in the market for eco-labelling. Certification is thought to be very important for consumers. The certificate seeks to address market failure resulting from information asymmetry. Certification should help consumers make informed choices and manufacturers to respond to consumer demands. This is only effective if a large number of competitors avoid the confusion arising from the label (OECD 2011).

Primary producers in fisheries and aquaculture are heavily influenced by the processing and retail sectors. Primary manufacturers are increasingly exposed to complying with specific certificates, widely that they are often de facto for themselves to establish or maintain business relationships. While these are "standard takers", the food industry and certification industry, together with NGOs, are "standard makers". The expected positive effects of eco-labelling for primary producers stem from access to new markets, price premiums or improved market position, but in practice there is little evidence of this. On the contrary, primary manufacturers only need to provide certified products to the food industry to remain on the market. Encouraging primary manufacturers to adopt a specific eco-label is basically a strategic response to supply chain arrangements. Competition programs, which have different evaluation criteria and definitions, enable primary producers to choose among their interests (OECD 2011).

The development of eco-label standards in fisheries and aquaculture has begun in the private sphere, particularly by environmental NGOs that want to influence consumer behaviour, exert pressure on primary producers and processor and distributor procurement policies, thereby causing changes in fisheries management policies. In addition to increasing public awareness, NGO campaigns on sustainable seafood have been successful in transforming the seafood purchasing policies of major retail chains. The media also plays an important role in strengthening NGO messages (OECD 2011).

There are three main elements in the certification industry: certification scheme holders, certifiers and accreditors. Owners of private fishery eco-labelling programs often demand broad stakeholder engagement in the development of their plans. However, most of the time, the parties concerned already agree with the NGO / certifier (OECD 2011).

The certification industry has a clear interest in the wide availability of certified products. The absence of an internationally recognized benchmarking system for fishery and aquaculture eco labelling and unclear terminology (including the lack of an acceptable definition of sustainability) enables standard setting bodies to differentiate themselves and remain in the market. Since the definition of sustainability varies from schema to schema, there is a big difference between the duration, scope and cost of the certification process. This has enabled the development of various business models (OECD 2011).

Intergovernmental organizations are well established to ensure consistency and level playground in fisheries certification. The *FAO Guidelines for the Eco-labelling of Fish and Fisheries Products from Marine Capture Fisheries* have been developed in response to the emergence of specific certification programs and provide a set of voluntary minimum requirements and criteria, including procedural and institutional considerations. The FAO going along its effort to provide internationally agreed guidelines for eco-labelling as a reference point for standard development and for standard evaluation and comparison. Technical guidelines for aquaculture certification were adopted by the FAO in February 2011. Amendments to the *Guidelines for the Eco-labelling of Fish and Fishery Products from Marine and Capture Fisheries* were adopted in 2009 (OECD 2011).

In OECD countries, the demand for certified products is also increasing. In developing countries, it raises the issue of resource for fisheries from sustainable aquaculture. It is clear that certification costs in developing countries are beyond the reach of producers, especially where fisheries are small in nature. In such cases, costs are normally borne by processors, importers or exporters potentially supported by donors and NGOs. This applies to the majority of FOS and Naturland certified fishing products (OECD 2011).

The third party certificate of third fish and seafood (eco-labels), the first seafood eco-label, has evolved very rapidly since its introduction in the late 1990s. While developing country manufacturers and exporters have raised their concerns about eco-label requirements, which are expressed as technical barriers to trade, to access international markets, the consumers have not been expecting much in their domestic markets for seafood. This assessment provides a review of the current literature on seafood eco-labels that focus on Asian markets, where product supply by consumers and retailers is not as efficient as in the European and North American markets. The analysis of selected third-party certification schemes identifies the basic requirements that may impede the certification of small-scale producers in developing countries (Tsantiris *et al.* 2018).

Although fourth-party certification is not common, third-party certification is often perceived as the highest form of assurance of compliance with a particular set of standards due to the claim that there is no conflict of interest between the certified parties and the certification body. Therefore, it will be said that third-party certification is indeed the most frequently sought form of certification, as will be explained below. However, when evaluating the quality of a certification plan, an important criterion to consider is the identification of the business that recognizes that a particular certification body is eligible to issue certain certificates: This can be expressed as an accreditation body. The word accreditation is often used synonymous with "certification." However, such a match is not correct. However, as defined by ISO, accreditation is "the procedure by which a competent institution officially recognizes that an organ or person is competent to perform certain tasks". Although accreditation can be done by any institution, bodies have been established to ensure the quality and, consequently, the certification of the accreditation process. The International Accreditation Forum (IAF) serves as the world conformity assessment, association of accreditation institutions in the areas of management systems, products, services, personnel and other conformity assessment programs. For this reason, IAF membership is often perceived as a guarantee of the quality of an accreditation institution. Similarly, European Accreditation cooperation (EA) is an association of accreditation institutions. EA is a non-profit organization consisting of 39 European accreditation organizations and representing European accreditation organizations to IAF (FAO 2019). Although seafood certification is expected to promote and improve the sustainability and environmental sustainability of seafood production, factors such as certification cost, barriers to market access and lack of awareness, especially in developing countries, where such changes are most needed for seafood production and management emphasized that it is important (Tsantiris *et al.* 2018).

As mentioned above, certification is made for a product or process to evaluate its suitability for certain requirements. These requirements are often expressed as standards. Standards can be mandatory or optional. As an example of mandatory standards; standards set by governments that regulate the production or trade of seafood can be given. While it is sometimes difficult to clearly separate mandatory standards from voluntary programs, this reference will primarily focus on volunteer programs designed to separate farms or commodities according to quality criteria, particularly when referring to government-supported initiatives. It is important to note, however, that voluntary programs should be followed intensely with the laws applicable to certified organizations. However, this does not in any way explain that compliance with voluntary certification programs can replace any part of a country's legal framework (FAO 2019).

Expressions that examine the quality of a process or product cannot always be expressed as a standard and therefore can take place in different formats. As an example, the principles are statements that explain the philosophical and logical basis for the production, trade and consumption of a product, and are aimed at encouraging stakeholders to increase the sustainability of the industry. Principles can include sets of criteria that provide more detail for sustainability. While the Code of Conduct (CoC) and Code of Practice (CoP) provide examples of principles, the latter can be said to be more popular to define principles related to a particular commodity, unlike CoC, which will cover important issues for the industry's sustainability. CoC for Responsible Fisheries (i.e. both fishing and aquaculture) developed by FAO is an important example of the CoC to improve the sustainability of the fishing industry as a whole (FAO 2019).

The fulfilment of the principles is usually done by developing applications that evaluate issues that are important for a particular commodity and / or production system. Better Management Practices (BMP), Good Fisheries Practices (GAP), Better Fisheries Practices (BAP), and others are examples of practices for applying principles. BMP, GAP and equivalents are "indicative" in contrast to mandatory (eg Legal documents) or optional standards, which are more "normative" rules for a product or process. Although the terms BMP, GAP and others can be used interchangeably to describe practices for the sustainability of the aquaculture industry, GAP often focuses on environmental safety, social responsibility and disease management (FAO 2019). Although the certificate is often applied to assess compliance with well-defined standards, this document reviews a broader range of programs, including schemes that evaluate compliance with principles or general rules that target the quality of seafood or processes. Similarly, programs that address the sustainability of a country or globally produced goods, that is, do not evaluate the suitability of a particular business, are also evaluated (FAO 2019). Currently, there are at least 30 certification systems and eight major international agreements on aquaculture certification. In addition, at least nine other initiatives have been defined to create a framework to study sustainability issues and differentiate fisheries resources in this context. In main systems; existing standards, objectives, certification systems and types of organizations promoting the system have been examined as far as possible (FAO 2019). The schemes can be divided into broadly presented groups in Table 2.

The chronological order of the system is given below:
1959-1960: First works, National Aeronautics and Space Administration (NASA) wanted to produce food for astronauts to guarantee food safety with zero false meal program,
1963: World Health Organization (WHO) issued Hazard Analysis and Critical Control Points (HACCP) principles in Codex Alimentations.
1973: NASA (USA National Air Space Foundation), Natick American Army laboratory and Pillsbury group firm entered the literature by producing the joint project of astronauts in food production with the concept of zero false and HACCP.
1985: USA national science academy suggested that HACCP should be applied in food operations for food safety,
14 June 1993: HACCP entered to regulations of Europe Community Countries with directives “Hygiene of food matters”,
1996: It was applied in Europe to food industry as legal,
HACCP became mandatory in Turkey in the date of 16.11.1997 with Turkish food codex in food industry.
International reference framework for fisheries and aquaculture certification scheme development is represented in Table 3 basically.

Table 2. The main certification schemes relevant to aquaculture certification (Source: FAO. 2019)

Schemes promoted by retailers	
GLOBALGAP	www.GLOBALGAP.org
Safe Quality Food	www.sqfi.com & www.fmi.org
Carrefour	www.carrefour.com
Schemes promoted by the aquaculture industry	
Global Aquaculture Alliance & Aquaculture Certification Council	www.gaalliance.org www.aquaculturecertification.org
Shrimp Seal of Quality (SSoQ)	
SIGES – SalmonChile	www.siges-salmonchile.com/proysigesingles/ www.salmonchile.cl
Scottish Salmon Producers' Organisation Code of Good Practice	www.scottishsalmon.co.uk
Schemes promoted by governments	
Thai Quality Shrimp	www.thaiqualityshrimp.com
Certification schemes in China	Safety agri-food certification ChinaGAP Green food standard
Vietnam GAP and CoC programme	www.hkaffs.org/en/
Hong Kong Accredited Fish Farm Scheme	
Certification schemes provided by NGOs	
Marine Aquarium Council	www.aquariumcouncil.org
International Standards Organization	www.iso.org
Organic certification schemes	
International Federation of Organic Agriculture Movements	www.ifoam.org
Naturland	www.naturland.de
Soil Association	www.soilassociation.org

Table 2. Continued

BioGro New Zealand	www.bio-gro.co.nz
Bio Suisse	www.bio-suisse.ch/en/home.php
KRAV	www.krav.se
Fair trade certification schemes	
Alter-Trade Japan	www.altertrade.co.jp
Ethical Trading Initiative	www.ethicaltrade.org
Fairtrade Labelling Organizations International	www.fairtrade.org.uk
Animal welfare and "free-range" schemes	
Freedom food	www.rspca.org.uk
Label Rouge	
Other organizations and schemes which may have relevance to aquaculture certification	
WWF aquaculture dialogues and standards	www.worldwildlife.org/cci/aquaculture.cfm
Marine Stewardship Council	www.msc.org
Seafood Watch of the Monterey Bay Aquarium	www.seafoodwatch.org
Environmental Justice Foundation	www.ejfoundation.org
Federation of European Aquaculture Producers	www.FEAP.info
International Fair Trade Association	www.ifat.org
Swiss Import Promotion Programme	www.sippo.ch

Table 3. International reference framework for fisheries and aquaculture certification scheme development (Source: OECD 2011)

Organization	Reference	Main subject
International Standards Organization (ISO)	ISO 14040 (2006)	Environmental management Life cycle assessment, principles and framework
ISO/TC 234	ISO/DIS 12875	Traceability of finfish products Specification on the information to be recorded in captured finfish distribution chains
ISO/TC 234	ISO/DIS 12877	Traceability of finfish products Specification on the information to be recorded in farmed finfish distribution chains
ISO/TC 234	ISO/CD 12878	Environmental monitoring of the seabed impacts from marine finfish farms Codex
Codex Alimentarius Commission (CAC)	CAC/GL-1-1979 (revised 1991, amended 2009)	General Guidelines on Claims
Codex Alimentarius Commission (CAC)		Principles for Food Import and Export Inspection and Certification
Codex Alimentarius Commission (CAC)		Guidelines for the Design, Operation, Assessment and Accreditation of Food Import and Export Inspection and Certification Systems
Codex Alimentarius Commission (CAC)		Guidelines for the Development of Equivalence Agreements Regarding Food Import and Export Inspection and Certification Systems
Codex Alimentarius Commission (CAC)		Guidelines for the Judgment of Equivalence of Sanitary Measures Associated with Food Inspection and Certifications Systems
Codex Alimentarius Commission (CAC)		Principles for Electronic Certification as an Appendix to the Codex Guidelines for Generic Official Certificate Formats and the Production and Issuance of Certificates (CAC/GL 38-2001)
Codex Alimentarius Commission (CAC)		Principles for Traceability/Product Tracing as a Tool within a Food Inspection and Certification System.

The codex alimentarius

The Codex Alimentarius is a collection of internationally adopted food standards and related texts presented in a uniform manner. These food standards and related texts aim at protecting consumers' health and ensuring fair practices in the food trade. The publication of the Codex Alimentarius is intended to guide and promote the elaboration and establishment of definitions and requirements for foods to assist in their harmonization and Protecting Consumer Health. Public concerns about food safety issues often place Codex at the center of global debates. Veterinary drugs, pesticides, food additives and contaminants are some of the issues discussed in Codex meetings. Codex standards are based on sound science provided by independent international risk assessment bodies or ad-hoc consultations organized by FAO and WHO. While being recommendations for voluntary application by members, Codex standards serve in many cases as a basis for national legislation (ISO 2019).

The reference made to Codex food safety standards in the World Trade Organization's Agreement on Sanitary and Phytosanitary measures (SPS Agreement) means that Codex has far reaching implications for resolving trade disputes. WTO members that wish to apply stricter food safety measures than those set by Codex may be required to justify these measures scientifically. Since its foundation in 1963, the Codex system has evolved in an open, transparent and inclusive way to meet emerging challenges. International food trade is a 2000 billion dollars a year industry, with billions of tonnes of food produced, marketed and transported in doing so to facilitate international trade (ISO 2019).

ISO 22000

ISO 22000 is one of the first and most important of quality assurance systems. ISO 22000:2018 sets out the requirements for a food safety management system and can be certified to issues? It maps out what an organization needs to do to demonstrate its ability to control food safety hazards in order to ensure that food is safe. It can be used by any organization regardless of its size or position in the food chain. Major purposes of ISO 22000 may be explained below (ISO 2019):

- ISO 22000 ensures fair competition.
- -ISO 22000 consolidates that conditions regarding trade, communication, requirements etc. originates from a common frame. However the global food industry is constantly developing and there is a need for a generic standard as ISO 22000 to fit the entire food chain from primary production to consumer.
- ISO 22000 has the advantage over the many private standards as it covers the whole organization. ISO 22000 contributes to ensure food safety hazards throughout the whole food chain from farm-

to-table. This becomes essential as hazards occur at any stage of the food chain.
- ISO 22000 accommodates communication along the food chain and within the organization. Communication is substantial to secure that all relevant food safety hazards are identified and adequately controlled at each step within the food chain. This implies communication between organizations both upstream and downstream in the food chain.

The differences between HACCP and ISO 22000

HACCP and ISO 22000 are both food safety standards that any food production or food handling company can implement. HACCP was established in the 1980s, initially instigated by scientists working for the Pillsbury Company while ISO 22000 was introduced in 2005.

Many companies implement these standards at the same time and these two standards both address food safety hazards and controls. As such, it may be difficult to distinguish between the two; there is however a marked difference. Some differences and/or characteristics indicated below:

HACCP is one part of ISO 22000

HACCP has three main principles, namely:

- Identify and assess hazards associated with the food product
- Determine critical control points to regulate the identified hazards
- Establish a system to monitor the critical control points.

HACCP identifies hazards that may threaten food safety and implements control points. These hazards may include sources of bacteria, physical, allergenic or chemical contamination. HACCP can be used alone or with other regulations. HACCP is the subsection of ISO 22000 that addresses these hazards and creates procedures to monitor critical control points.

ISO 22000 is a broader, international system

ISO 22000 incorporates the principles and regulations of HACCP but is a broader framework used as a management system. ISO 22000 allows for constant performance improvement in the management of food safety and food manufacturing. This standard follows the model of ISO 9001 and other ISO Standards as of the publication of ISO 22000:2018. ISO 9001 is a quality standard that can be employed by corporations in any business and incorporates the eight quality management principles of this standard. ISO 22000 consists of numbered sections that correlate with sections of ISO 9001 for easier integration.

ISO 22000 is a worldwide standard, issued by the International Organization for Standardization and includes the requirements of other global standards whereas HACCP originated in the United States, derived from the guidelines and regulations of the Department of Agriculture and the Food and Drug Administration (FDA). The HACCP System has now been adopted globally via the Codex Alimentarius Commission as a validated and verified approach to hazard identification and mitigation within Food Safety and is often used in Pharmaceuticals manufacturing as well. Every country has been given permission to adopt HACCP as a Voluntary Standard to be implemented as part of the Legislative and/or Regulatory infrastructure as countries see fit.

FSSC 22000

The recent history of the FSSC (The Foundation for Food Safety Certification) 22000 scheme and its main landmarks are depicted chronologically in the diagram below. FFSC developed and has the legal ownership of the scheme. Founded in 2004 by a group of Dutch certification organizations, the FSSC is a nonprofit organization whose goal is to maintain and act as a legal basis for the Dutch HACCP, governed by strict bylaws to ensure its independence (FSSC 2019).

GLOBALG.A.P.

GLOBALG.A.P. is the internationally recognized standard for farm production. Main core product is the result of years of intensive research and collaboration with industry experts, producers and retailers around the globe. The aim is safe and sustainable agricultural production to benefit farmers, retailers and consumers throughout the world.

GLOBALG.A.P. Certification covers;

- Food safety and traceability
- Environment (including biodiversity)
- Workers' health, safety and welfare
- Animal welfare
- Includes Integrated Crop Management (ICM), Integrated Pest Control (IPC), Quality Management System (QMS), and Hazard Analysis and Critical Control Points (HACCP)

GLOBALG.A.P. standards demand, among other things, greater efficiency in production. It improves business performance and reduces waste of vital resources. It also requires a general approach to farming that builds in best practices for generations to come.

It covers more than 100 control points relating to the management of animal welfare, including aspects such as staff training in animal welfare, predator control, biosecurity, transport and slaughter. While the inspection procedure does not include direct assessment of fish welfare (i.e. examination of fish), this certification provides a reasonable level of assurance of finfish welfare.

GLOBALG.A.P. Certificate, also known as the Integrated Farm Assurance Standard (IFA), covers Good Agricultural Practices for agriculture, aquaculture, livestock and horticulture production. It also covers additional aspects of the food production and supply chain such as Chain of Custody and Compound Feed Manufacturing.

The IFA standard was revised through an extensive stakeholder involvement and consultation process and V5 was published in July 2015 with one-year conversion period. This means that the V5 became obligatory in 2016.

GLOBALG.A.P. IFA Standard V5 is built on a system of modules that enables producers to get certified for several sub-scopes in one audit. It consists of;

- **General Regulations:** These map out the criteria for successful Control Points and Compliance (CPCC) implementation as well as set guidelines for the verification and the regulation of the standard.
- **Control Points and Compliance Criteria (CPCC):** These clearly define the requirements for achieving the quality standard required by GLOBALG.A.P.

The CPCC is also modular-based consisting of;

- **The All Farm Base Module:** This is the foundation of all standards, and consists of all the requirements that all producers must first comply with to gain certification.
- **The Scope Module:** This defines clear criteria based on the different food production sectors. GLOBALG.A.P. covers 3 scopes. These are: (i) Crops, (ii) Livestock and (iii) Aquaculture.
- **The Sub-scope Module:** These CPCC cover all the requirements for a particular product or different aspect of the food production and supply chain.

To get certified, producers must comply with all the CPCC relevant for their sub-scope. For example, a seabream producer must comply with the All Farm Base CPCC, the Aquaculture Base Standard CPCC and Finfish CPCC to receive a GLOBAL G.A.P. IFA Finfish Standard Certificate.

GLOBAL G.A.P. also provides checklists for each module to help producers better prepare their farms and make the necessary changes before a certification body inspector performs an audit or inspection.

Certification Options;

- Option 1 (Single producer with or without an optional Quality Management System)
- Option 2 (Multiple producers with a mandatory Quality Management System)

GLOBALG.A.P. Standards applicable for each stage;

- Compound Feed Manufacturing (CFM) for feed company
- Integrated Farm Assurance (IFA) for hatchery, farm, post-harvest includes GRASP (GRASP risk assessment on social practices)
- Chain of Custody (for processing company "when legal entity different than the farm")

It is also other important requirement that the full production chain (feed, seedling, farming, chain of custody) shall be verified in GLOBALG.A.P. Aquaculture Certification system (Anonymous 2019k).

Farms require to implement criteria related to key sustainability areas. These are: (i) Food safety (in compliance with GFSI requirements at farm level), (ii) Environment (includes Protected Areas criteria and a compulsory Environmental (Biodiversity inclusive) Impact Assessment and Management Plan), (iii) Traceability (from broodstock, seedlings and feed used at the aquaculture farming activities. Batch wise identification of stock and feed used), (iv) Workers welfare (compulsory assessment on social practices; living conditions, workers health and occupational safety), (v) Animal welfare (specific to farmed fish species, including cohabitant species, e.g. cleaner fish) (Anonymous 2019k).

GLOBALG.A.P. aquaculture certification follows the 4 pillars in coordination with FAO Technical Guidelines on Aquaculture Certification. These are (Anonymous 2019k): (i) Food Safety (recognized by the Global Food Safety Initiative (GFSI)), (ii) Animal Health and Welfare (covers the OIE Aquatic Animal Health Code Requirements (OIE World Organization for Animal Health)), (iii) Environmental Integrity (recognized by the Global Seafood Sustainability Initiative (GSSI)), (iv) Socio Economic Aspects.

GlobalG.A.P. Aquaculture Certification Control Points together with All Modules have shown indicated below (Table 4).

BRCGS certification

While (Brand and Consumer Protection Organization (BRCGS) is a leading brand and consumer protection organization, it also operates a program of global schemes designed to protect brands and consumers covering food and non-food through risk-based process and system evaluation.

Table 4. GlobalG.A.P. aquaculture certification control points together with all modules (Anonymous 2019k)

GLOBALG.A.P. aquaculture certification version 5		
All Farm Module	**Aquaculture Module**	**Grasp**
	Finfish, Crustaceans, Molluscs	*GLOBALG.A.P. Risk Assessment On Social Practice*
AF.1 Site History and Site Management	AB.1 Site Management	Employees Representative
AF.2 Record Keeping and Internal Self-Assessment/Internal Inspection	AB.2 Reproduction	Complaint Procedure
AF.3 Hygiene	AB.3 Chemical Compounds	Self-Declaration on Good Social Practices
AF.4 Workers' Health, Safety and Welfare	AB.4 Occupational Health and Safety	Access to National Labor Regulations
AF.5 Subcontractors	AB.5 Fish Welfare, Management and Husbandry (at all points of the production chain)	Working Contracts
AF.6 Waste and Pollution Management, Recycling and Re-Use	AB.6 Sampling and Testing	Payslips
AF.7 Conservation	AB.7 Feed Management	Wages
AF.8 Complaints	AB.8 Pest Control	Non Employment of Minors
AF.9 Recall/Withdrawal Procedure	AB.9 Environmental and Biodiversity Management	Access to Compulsory School Education
AF.10 Food Defense (Not Applicable for F&O)	AB.10 Water Usage and Disposal	Time Recording System
AF.11 GLOBALG.A.P. Status	AB.11 Harvesting & Post-Harvest Operations	Working Hours & Breaks
AF.12 Logo Use	AB.12 Holding and Crowding Operations	Additional Social Benefits
AF.13 Traceability and Segregation	AB.13 Slaughter Activities	
AF.14 Mass Balance	AB.14 Depuration	
AF.15 Food Safety Policy Declaration	AB.15 Post Harvest – Mass Balance - Traceability	
AF.16 Food Fraud Mitigation	AB.16 Social Criteria	
Annex AF.1. Guideline Risk Assessment – General		
Annex AF.2. Guideline Risk Assessment–Site Management		

The Global Standard for Food Safety (GSFS) is developed by food industry experts from retailers, manufacturers and food service organizations to ensure it is rigorous and detailed, yet easy to understand. First published in 1998, the Food Safety Standard is now in its eighth issue and is well-established globally. It has evolved with input from many leading global specifiers. It provides a framework to manage product safety, integrity, legality and quality, and the operational controls for these criteria in the food and food ingredient manufacturing, processing and packing industry.

The Standard focuses on;

- encouraging development of product safety culture
- expanding the requirements for environmental monitoring to reflect the increasing importance of this technique
- encouraging sites to further develop systems for security and food defence
- adding clarity to the requirements for high-risk, high-care and ambient high-care production risk zones
- providing greater clarity for sites manufacturing pet food
- ensuring global applicability and bench-marking to the Global Food Safety Initiative (GFSI) (BRCGS 2019).

IFS certification

International Featured Standards (IFS) are uniform food, product and service standards. They ensure that IFS-certified companies produce a product or provide a service that complies with customer specifications, while continually working on process improvements. IFS were founded in 2003 under the name International Food Standard. It has expanded its range by six further standards and operates globally. IFS aims to ensure comparability and transparency for the consumer throughout the entire supply chain, and to reduce costs for suppliers and retailers. The IFS Food standard is a GFSI recognized standard that has been developed to ensure that the food safety and quality requirements (product specifications, customer focus, etc.), as well as applicable regulatory requirements in the products' country of destination are complied with (IFS 2019).

OIC/SMIIC Halal certification

When we look at the current situation from the Halal Certification of View, it may be easily seen that many different halal standards exist in the world and certification according to those halal standards are applied in concentration to basic economic principle as the removal of technical barriers to trade among countries while Muslim Countries using halal food standards are expected to share and transfer their experience which may result as a great synergy through Islamic Countries. There is a need for common halal standard in order to ensure trust and safety both through the value creation chain and for the consumers focused on the entire food chain and not merely on parts of it such as production. SMIIC addresses to standardization, conformity assessment and accreditation aspects of Halal both in terms of religious and technical perspectives. There are OIC/SMIIC Halal Standards which provides a comprehensive solution for conformity assessment and the accreditation of Halal. SMIIC standards are based on Islamic rules and principles as well as the standards of global organizations.

OIC/SMIIC standards refer to ISO/IEC and Codex standards and they are in line with international standards. SMIIC is about to finalize the establishment of accreditation mechanism enabling a the trustworthy certification system that is based on intergovernmental accreditation so that halal products can move freely on global scale based on OIC/SMIIC standards and related reference documents (SMIIC 2019).

Kosher certification

"Kosher" is a term used to describe food that complies with the strict dietary standards of traditional Jewish law. The English word "kosher" is derived from the Hebrew root "kashér," which means to be pure, proper, or suitable for consumption. The laws that provide the foundation for a kosher dietary pattern are collectively referred to as kashrut and are found within the Torah, the Jewish book of sacred texts. Instructions for practical application of these laws are passed down through oral tradition. Because of complex modern food production practices, ensuring that the foods you're eating are kosher can be very challenging. That's why systems are in place for certifying specific food products. Foods certified kosher feature a label on their packaging indicating that they've met all of the necessary requirements. There are dozens of different kosher labels, many of which come from different certifying organizations. If a food is certified for Passover, this will be indicated in a separate label. The labels may also indicate if a food is dairy, meat, or par eve. If you're trying to adhere to kosher dietary guidelines, it's best to choose only foods with these labels in order to avoid accidentally eating something non-kosher (Healthline 2019).

Good Agricultural Practices (GAP)

There are some important control points to be considered by the companies that will be producing under GAP in aquaculture. These are (Yılmaz *et al.* 2017): (i) Aquaculture facility must be operated in accordance with all relevant laws. (ii) Hatcheries shall be able to demonstrate that the broodstock is obtained through a breeding program. Wild caught broodstock is not used for production except for genetic improvements. (iii) The origin of eggs and broodstock must be known and recorded. (iv) Quality egg or fry should be used, used variables should be clean from virus and resistant to diseases and pests. (v) It should be possible to prove that the fish in farm are not transgenic fish. (vi) All diseases seen in the facility must be recorded. (vii) Maximum densities shall not be exceeded. Stocking data must be recorded. (viii) Feed must be suitable for the species farmed. Documentation of the used feed must demonstrate its application. (ix) The content of the feeds given to the fish must be clearly stated and certified. (x) Batches of feed from feed manufacturer must be traceable. (xi) It should be a product and safety information card for all chemicals in the facility. (xii) Drugs approved by the relevant competent authorities should be used in the facility. (xiii) There must be documentation that the entire production period of the fish is made by GAP approved company. (xiv) All kinds of wastes in the farm should be collected and transported to the dedicated location. (xv) Facilities must provide cleaning and hygiene conditions. (xvi) Environmental impacts assessment and risk assessment must be done. (xvii) The biodiversity plan must be included in the Biodiversity Risk Assessment. (xviii) An effective predator control plan must be in place. Documented anti predator methods must be in place.

Best Aquaculture Practices (BAP)

It is a set of standards established by the Global Aquaculture Alliance for the development and quality of seafood production. BAP includes standards for environmental, social responsibility, animal welfare and aquaculture facilities. BAP program has developed standards for hatchery, feed mill, farm and processing plant. It has become valid for almost all production systems, including shellfish. The new standards also include seabass, seabream and trout, which are very much produced. Before applying to the BAP program for farms, processing plants, hatcheries and feed facilities, it must meet the requirements of the standard. Subsequently, an application for certification audit can be made during the certification process. The first BAP certification step can be taken in the following steps: (i) Standard should be provided according to the type of fish. (ii) Production facility and documents should be brought into conformity with the standard within the framework of BAP standard. (iii) Pre-inspection can be done optionally. (iv) Audit planning, (v) Elimination of nonconformities, if any, (vi) BAP Certificate output confirmation (Anonymous 2019j).

Organic aquaculture

Organic aquaculture is an integrated system representation where production is realized at optimum level without endangering stability of ecosystem including benthic organisms, seaweeds, hydrophytes, living things cultured and humans in general. In particular, organic aquaculture standards prohibits usage of antibiotics, herbicides and genetically modified organisms and allows as a last resort application of parasitic substances for treatment purposes under veterinary supervision (Anonymous 2019c).

Traceability

Traceability is identified as the ability to track a product from its origin to the consumer through all stages of the supply chain. Today, the vast majority of developed countries need the traceability of food products for import and food safety issues. This approach also raises the traceability process. In addition, as a result of increased public awareness on food safety, consumers want to have more knowledge about the foods they would like to buy. Such trend enforces governments to take initiatives to monitor sensitive foodstuff like meats, dairy products, fruits, vegetables, crops and seafood by traceability systems (Tolon 2017).

Traceability in marine aquaculture is a valuable tool for stock management, reliable statistics, avoiding illegal fishing, seafood safety, sustainability and efficient control on production. Whole information on the catch, production and processing of fish throughout the supply chain should be recorded and communicated to the related institutions and consumer to ensure the safety of seafood (Dillon and Derrick 2004). However, such large information needs a well-established infrastructure to collect, organize and disseminate the data. Traceability systems with sophisticated technological infrastructure have been put into practice by many developed and developing countries in recent years. Turkey is one of these countries that implemented computer-based tracing through traceability systems since 2007 (Tolon 2017).

GFSI certification

Global Food Safety Initiative (GFSI) recognition offers a passport to the global market, both for the recognized CPOs (certification program owners) and the companies that they certify. In order to be recognized by GFSI, CPOs must verify that they meet the Benchmarking Requirements, one of the world's most widely-accepted benchmark documents for food safety programs.

The GFSI Benchmarking Requirements were first created in 2001 by a group of retailers motivated by the necessity of harmonizing food safety standards across the global supply chain. These requirements are frequently updated with input from food safety experts around the world to keep up to date with food safety trends. They do not constitute a food safety standard in their own right, nor can food businesses be audited or certified against them. For these roles, we rely on the recognized CPOs.

To learn more about the CPOs that have earned GFSI recognition, the Recognized CPO Module below indicated below;

- **BRC Global Standards**
  BRC Food Safety Version 8
  BRC Packaging and Packaging Materials Version 5
  BRC Storage and Distribution Version 3
  BRC Agents and Brokers Version 2
- **IFS – International Featured Standards**
  IFS Food Version 6.1
  IFS Logistics Version 2.2
  IFS PACSecure 1.1
- **FSSC 22000**

- **SQF**
  SQF Food Safety Code for primary production version 8
  SQF Food Safety Code for manufacturing
  SQF Food Safety Code for storage and distribution version 8
- **PrimusGFS Standard**
  PrimusGFS Standard Version 3
- **Global Aquaculture Alliance Seafood**
  Seafood Processing Standard Issue 5.0
- **GLOBALG.A.P.**
  GLOBALG.A.P. Integrated Farm Assurance Standard
- **Global Red Meat Standard**
  Global Red Meat Standard Version 6
- **CanadaGAP**
  CanadaGAP Version 7.1
- **Japan GAP Foundation**
  ASIAGAP Control Points and Compliance Criteria for Farms, Fruits and Vegetables Version 2, Tea Version 2, Grains Version 2
- **Japan Food Safety Management Association**
  JFS-C Standard Version 2.3

The economic framework of certification systems

In this part of the study, certification costs, consumer expectations, barriers to market access and motivations are tried to be explained in detail. Compliance with different regulations and voluntary standards would probably beat a path significant costs for seafood producers and exporters. Is the question to be asked? Who will bear these costs? The costs of certification by the Marine Stewardship Council (MSC), for example, range from USD 2000 to USD 20000 for a pre-assessment, and from USD 10000 to USD 500000 for a full assessment and certification, depending on the type of fishery. The average audit cost for Friend of the Sea (FOS) certification USD 5800 for wild capture and USD 3500 for aquaculture (Macfadyen and Huntington 2007; FOS 2017).

The costs of pre-assessment, fishery assessment and periodic re-assessment are typically paid by producers (Macfadyen and Huntington 2007). Certified fisheries undergo annual audits and make improvements accordingly, and are re-assessed every five years (Peacey 2001). For many fisheries, especially small-scale fisheries, certification is dependent on governments and other funding sources such as NGOs, charitable funds and retailers (Tsantiris *et al.* 2018).

In some regional ecolabelling schemes, governments help to reduce overall fishery certification costs in order to promote sustainable local fisheries. For example, The Government of Viet Nam, ensured funds to support most of the VietGAP pre-assessment procedures in 2012; the certification costs of VietGAP will hence be much lower than the previous standards (Nabeshima *et al.* 2015).

There is also criticism that government funding is generally biased in favour of industrial-scale concerns, but not small-scale fisheries: large fishing vessels, for example, are built by heavy industry companies that enjoy substantial funding, whereas small-scale boat construction usually favours local craftsmanship but receives little public financing (Jacquet and Pauly 2008).

Approaches to price premiums and producer revenues varied among the standards studied. Some initiatives such as the farm assurance program that translates consumer requirements into good agricultural practice (GLOBALGAP) actually aim to avoid premiums throughout the value chain with a view to supporting producers by reducing input costs through bulk purchasing and improving quality management (Potts *et al.* 2016).

Turkey has also made payments to support Good Agricultural Practices in aquaculture. The latest Regulation on this was published in 2019 (Anonymous 2019a). And also support for System Certification Consultancy is given by Agriculture and Rural Development Support Institution in Turkey, within the framework of sub-measure 103, “Investments in Physical Assets Concerning Processing and Marketing of Agricultural and Fishery Products” in IPARD (Investment for Pre-Accession Assistance Rural Development) Program. These supports are summarized as follows (Anonymous 2019b): (i) TS-EN-ISO 9001 Quality Management System, (ii) TS-EN-ISO 14001 Environmental Management System, (iii) TS 18001 Occupational Health and Safety Management System, (iv) TS EN ISO 22000 Food Safety Management System, (v) GMP document, (vi) GHP document, (vii) CE document.

Management systems and certification applications in marine fish farming in Turkey

In Turkey, before focusing on aquaculture certification systems, traceability will be useful to mention briefly. Traceability in food law 178 of the European Union in 2002 defines "monitoring of the production of food, feed and animals used for consumption in the processing and distribution stages" (Anonymous 2002). Marine fish farming industry in Turkey incorporates, HACCP, ISO 22000:2005 Food Safety, FSSC 22000, BRC, IFS, GlobalG.A.P., ASC, BAP and Organic Certification to such processes and quality management system has been fully integrated.

However, Article 18 of the European Union's Food Act 178 of 2002 stipulates the requirements for the establishment and labeling of the traceability system and traceability in food safety and related standards such as ISO 22000: 2005, BRC, IFS, GLOBALGAP, ASC, BAP, FSSC 22000. ISO 22005: 2007 aims at establishing a traceability system in the food chain: supporting food safety and quality, meeting consumer needs and desires accurately, identifying product history and origin, facilitating verification, informing relevant stakeholders and consumers, limiting damage (Anonymous 2007).

Traceability is now supported by legal regulations around the world. No. 5179 Production of Food in Turkey, Consumption and has supervised the provisions of the Decree Law on the Amendment to the Law on the Acceptance in all business related to food in Article 16 stipulated the establishment of a traceability system. As of 11/06/2010, the Law No. 5996 required the labelling of foods placed on the market to contain the necessary information in order to facilitate traceability. In this context, the existing legislation in Turkey, necessitates a step forward and backward traceability (Oral 2009).

Turkey is one of the countries to develop computer-based monitoring systems for fishing and aquaculture production. In this context, electronic information systems and infrastructure have been developed since 2007 (Cebeci 2014). As a matter of fact, in order to ensure traceability of fisheries products from source to consumer, traceability practices have been initiated by using information technologies for fisheries and aquaculture. Currently, the Fisheries Marketing Standards and Fisheries Registration System and the production information of all fisheries enterprises are recorded electronically by the Ministry of Agriculture and Forestry and the General Directorate of Fisheries. Fisheries enterprises are obliged to enter the Fisheries Registration System for insurance, credit support, obtaining good agricultural certification and other legal procedures. Pursuant to the decision of the Council of Ministers numbered 2008/13489 published in the Official Gazette dated April 15, 2008 and numbered 26848; producers engaged in aquaculture are paid a premium to support aquaculture provided that they are registered to the Aquaculture Registration System (Çavdar 2009).

With the Fisheries Registration System, the traceability of information such as all life stages, weight, length, quantity and type of the products from the egg is provided. The system fills an important gap in the monitoring of aquaculture activities by registering the geographical location of the production sites by geographical coordinates and complying with national legislation until the harvested fish is processed. At present, registration for all aquaculture production has not yet been completed, but information entry into the system continues intensively. In particular, large enterprises have achieved significant success in this regard (Yılmaz and Yılmaz 2017).

Mol *et al*. (2014) explored that, seafood processing firms in Turkey generally appreciated the importance of HACCP system and this system has been working without any problem in a remarkable part (80.6%) of respondent firms. It was determined that inadequacy of employee education was the main barrier of HACCP implementation in Turkish seafood processing firms. Unpredictable raw material availability, price of raw material, defective audit policy of the government, lack of information transfer from the universities, excessive bureaucracy, difficulty of employee education, excessive use of glazing and additives by rivals, tax rates, ignorance of the inspectors, difficulty to getting credits were the factors, complicating productivity. This study defined that there are major barriers of HACCP implementation, and difficulties in maintaining hygiene and sanitation. These are: (i) Education of employees is not sufficient; (ii) Cleaning agents are expensive, (iii) Prevention of extrinsic contamination; (iv) Prevention of cross contamination is difficult; (v) Wooden fish boxes are still in use, (vi) Microbial quality of food ingredients is low. This study recommends Turkish government to make provisions for distortions in credit market and provide convenience to get credits. The excessive use of glazing and food additives must be strictly controlled to avoid unfair competition. Informing the processing firms about the available supports and opportunities of foreign trade, and facilitating to access supports must be the other tasks of the government.

Food safety and quality systems in fish processing farms and seabream-seabass breeding facilities in İzmir province in 2013-2014 were examined by Tuzlu (2015). In this thesis, HACCP system in 10 fish processing plants and GLOBAL GAP system in 32 fish farms were studied for food safety and quality systems (A table). According to the study, aquaculture must be handled with care and kept under control in the period from aquaculture to processing. Marine fish products are among the perishable food products. Therefore, fish farming establishments use the GLOBALGAP system to ensure food safety in order to obtain a safe product. GLOBAL GAP system ensures a safe and healthy raw material (seabream and seabass). Processing plants processing seabream and seabass from aquaculture have GLOBALGAP certificate, they use HACCP system and other food safety systems (ISO 22000, BRC, IFS) in their facilities to process raw materials safely. As a result of the study, it is concluded that the use of GLOBALGAP is a good method to ensure food safety in aquaculture. It is seen that the aquaculture processing plants studied have developed their applications and infrastructures in order to ensure food safety and adapted to today's requirements. Processing plants were generally observed to operate in accordance with the criteria related to food safety. The majority of managers of seafood processing plants have adopted the importance of food safety systems. They are aware of the contribution of the practices carried out to ensure / maintain food safety to product quality and company reputation. Fish farms that have been trained in seabream and seabass have made significant progress with their modern technologies. The network cages they use are of world standards in terms of construction material. At the same time, there is an increase in cage dimensions depending on the production capacity. Although automatic feeding systems provide feed savings, the size of biological pollution is greatly reduced. Thanks to the camera systems placed in the net cages, the lives of the fish are monitored and measures can be taken to eliminate the possible problems as soon as possible. These improvements in fish farms are also of great importance in ensuring food safety. Fish farms mostly focus on the following practices in providing food safety. These include the use of feeds containing nutrients equivalent to natural feeds, the use of hormones and antibiotics for growth and disease prevention, and the lack of stress on fish stocks in nets. In addition, fish stocks are continuously controlled by the Fisheries and Fisheries Branch of the Ministry of Agriculture and Forestry in terms of heavy metals and additives and residues. They do not pose a risk. As a result of the work used for food safety in fish farms it was concluded that GLOBALGAP system is a good method. However, some points need to be improved (Anonymous 2019d; 2019e; 2019f; 2019g; 2019h; 2019i).

Atayeter (2013) stated that if the establishments also have ISO 9001 Quality Management System or ISO 22000 Food Safety Management Systems are integrated, the food safety, efficiency and quality increase, environmental and occupational health and safety issues will be enabled efficiently. Since many of the items are in common with IFS and BRC standards, the system installation works can be completed easily and quickly.

When the sector is compared with worldwide organic aquaculture established in 1994, 6 aquaculture plants located in Rize province has been provided with entrepreneur certificate in February 2010 and started organic salmon (*Salmo salar*) production under supervision of control and certification entity in Turkey. Total project capacity of above 6 aquaculture plants is 456 tons/year (Çavdar 2011). Organic farming activities were first applied in Black Sea region due to virginity of its water resources and nature and inability to realize intense agricultural operations as an outcome of geographical drawbacks. It is expected that organic farming activities shall be disseminated in close regions and then, all country through which our organic aquaculture figure shall accomplish striking increases. with the development of organic aquaculture, it is expected that species having limited with rainbow trout and Black Sea trout shall also show increasing acceleration.

Tolon (2017) analyzed traceability infrastructure in Turkey. He declared that in food safety issues, traceability that would let consumers to monitor seafood from catch to dish, could not be fully implemented yet. Current legislations are enforcing only one step forward and backward traceability. The draft regulation called "Market Standards in Fishery and Consumer Information", prepared in 2006 and still waiting to be adopted by Turkish Parliament (MoFAL 1995). The study pointed out those current regulations would ensure that information about the purchased seafood will be transferred to the final consumer with a label, informative product package or a commercial document accompanying with the product which would provide the traceability. Consumer will be instructed about the size, weight, freshness, catch zone and type (catch or aquaculture) of seafood through the labels of the products. The implementation of Fishing Vessel Tracking System (BAGIS) will provide traceability of seafood to the consumers through integrated interfaces (Tolon 2017).

According to the literature surveys, no other scientific sources for certification practices in aquaculture have been found. Therefore, the following findings are given from the internet based on web address reviews in detail.

We have mentioned before GLOBALG.A.P. Standards applicable for each stage as Compound Feed Manufacturing (CFM) for feed company.

The Compound Feed Manufacturing production locations where the feed is sourced from (whether internal or external), shall be certified with the: i) GLOBALG.A.P. CFM Standard or ii) A standard that has been successfully benchmarked with the GLOBALG.A.P. CFM Standard or iii) An ISO/IEC 17065 or ISO/IEC 17021: accredited feed safety scheme. This requirement also applies for hatcheries. For compound feed recognized through option iii), a letter from the feed supplier stating compliance against section 15 of the GLOBALG.A.P. Compound Feed Manufacturing - CFM Standard, under section Responsible use of natural resources shall be in place. For option i), the CFM production locations shall be registered in the GLOBALG.A.P. Database (by the time of the producer's first audit) with a GLOBALG.A.P. Number that will link it to the aquaculture producer. For options ii) and iii) registration of supplier name and accredited scheme used replaces the GGN in the GLOBALG.A.P. Database. (*) ISO/IEC 17065 (same as EN 45011): General requirements for (certification) bodies operating product certification system. ISO/IEC 17021 (former EN 45012): Conformity assessment – Requirements for bodies providing audit and certification of management systems (GLOBALG.A.P. IFA Standard Requirement (AB.7.1.2.)

So, in Turkey approximately 14 feed farms have Globalgap CFM (Compound Feed Manufacturing) Certificates: Camli Yem Besicilik Sanayi ve Ticaret A.S., Kılıç Deniz Urunleri Ithalat Ihracat ve Ticaret A.S. Feed Plant, Agromey Gida Ve Yem Sanayi ve Tic. A.S., Skretting Yem Uretim Ticaret A.S., Lezita Balik A.Ş., Ozpekler Insaat Taahhut Dayanıklı Tüketim Malları Su Urünleri San ve Tic Ltd Sti, Gumusdoga Su Ürünleri İthalat İhracat A.Ş., Ugurlu Balik Uretim San Ve TiC AS, Noordzee Su Urunleri Ihr. San. Ve Tic. A.S., Sursan Su Urunleri San ve Tic AS, Nektar Yem ve Yem Katkı Maddeleri Gıda Hayvancılık San. Ve Tic. Ltd. Şti, BioMar-Sagun Yem Sanayi Ticaret Anonim Sirketi, Turkuaz Marin Deniz Ürünleri A.S., Normfeed Su Urunleri Yem San. Tic. A.S. (Anonymous 2019k; 2019l; 2019m; 2019n; 2019o).

Conclusions

It can be stated that certification systems have developed sufficiently in the worldwide marine aquaculture. Especially in recent years, certification practices in aquaculture have shown significant improvements. Turkey exports trend in the aquaculture industry grows, certification and quality assurance systems are expected to develop further applications. Especially in medium and large enterprises, it can be stated that these certification systems are highly developed. The methods of meeting the costs of this certification system sustainably should be investigated. In this regard, new approaches should be developed for all stakeholders in the sector. On the other hand, it is expected that the benefit obtaining these certification systems will surely exceed this cost. In the future studies, it is considered carrying out studies that reveal the costs and benefits that can be obtained according to the differences of the certification systems in question will be useful.

References

Anonymous (2002) Regulation No: 178/2002 of the European Parliament and the Council of 28 January 2002 laying down procedures in matter of food safety. Official Journal of the European Communities No: L 31, 01.02.2002, pp. 1-24.

Anonymous (2007) ISO 22005:2007 Traceability in the feed and food chain-General principles and basic requirements for system design and implementation. Available at: https://www.iso.org/obp/ui/#iso:std:36297:en (accessed 11 Aug. 2019).

Anonymous (2019a) Regulation on Payment of Support for Good Agricultural Practices in Aquaculture. Regulation No: 2019/11. 10 February 2019 and 30682 Numbered of T.C. Official Newspaper (in Turkish).

Anonymous (2019b) Available at: https://www.tkdk.gov.tr/AltTedbir/processing-and-marketing-of-fishery-products-6 (accessed 10 Aug. 2019).

Anonymous (2019c) Available at: http://www. techstreet.com/products/1831710. (accessed 05 June 2019).

Anonymous (2019d) Available at: http://www.ilknak.com/certifications.html (accessed 16 Sep 2019).

Anonymous (2019e) Available at: http://www.ilknak.com/traceability.html (accessed 16 Sep 2019).

Anonymous (2019f) Available at: http://www.yasar.com.tr/en/companies-and-sector-activities/detail/Camli-Yem-ve-Besicilik/122/194/0 (accessed 16 Sep 2019).

Anonymous (2019g) Available at: https://www.kilicseafood.com/certificados (accessed 16 Sep 2019).

Anonymous (2019h) Available at: https://www.worldfishing.net/news101/fish-farming/asc-certification-for-bass-and-bream-farms (accessed 16 Sep 2019).

Anonymous (2019i) Available at: http://www.akuvatur.com/assets/ akv_corporate.pdf (accessed 16 Sep 2019).

Anonymous (2019j) Available at: http://www.eurocert.com.tr/iyi-su-urunleri-uygulamalari-bap.aspx (accessed 16 Sep 2019).

Anonymous (2019k) Available at: https://database.globalgap.org/ globalgap/search/SearchMain.faces/ (accessed 25 Oct 2019).

Anonymous (2019l) Available at: http://asc.force.com/Certificates/ (accessed 25 Oct 2019).

Anonymous (2019m) Available at: http://www.ozpekler.com.tr/ index.php?icerik=97 (accessed 25 Oct 2019).

Anonymous (2019n) Available at: http://luckyfish.co/responsibility (accessed 25 Oct 2019).

Anonymous (2019o) Available at: http://www.lezitabalik.com.tr/uretim_kalitesi (accessed 25 Oct 2019).

Atayeter, S. (2013) BRC and IFS standards for the seafood processing industry.. Available at: https://www.researchgate.net/publication/ 296193114_Su_Urunleri_Isleme_Sektoru_Acisindan_BRC_ve_IFS_Standardlari/link/56d2f45508ae85c8234c5ceb/download (accessed 10 Sep. 2019) (in Turkish).

Auld, G. (2014) Constructing private governance: the rise and corporate social responsibility in creating a seussian world of seafood sustainability. *Fish Fish* 1-9.

Bergleiter, S. (2008) Organic Aquaculture. In: The World of Organic Agriculture: Statistics and Emerging Trends 2008, (eds., Willer, H., Yussefi-Menzler, M., Sorenson, N.). International Federation of Organic Agriculture Movements (IFOAM) Bonn, Germany and Research Institute of Organic Agriculture (FiBL), Frick, Switzerland, pp. 83-88.

BRCGS. (2019) Available at: www.brcgs.com/brcgs/food-safety (accessed 25 Oct 2019).

Cebeci, Z. (2014) Information Technologies Based Traceability Systems for Traditional Foods. 4th Traditional Foods Symposium, 17-19 April 2014, Adana, 29-34. Available at: http://traglor.cu.edu.tr/objects/objectFile/Ifunuwaz-6122014-38.pdf (accessed 20 Aug. 2019) (in Turkish).

Çavdar, Y. (2009) Financial supports in aquaculture. Yunus Araştırma Bülteni, 9(1): 13. Available at: http://aquast.org/uploads/pdf_233.pdf (accessed on 20 Aug. 2019) (in Turkish).

Çavdar, Y. (2011) Turkey in the light of current legislation organic aquaculture breeding. *Dolphin Research Bulletin* 1: 2-7.

Dillon, M., Derrick, S. (2004) A guide to traceability within the fish industry. 2004: Sippo/Eurofish. 78.

FAO (2016) The state of world fisheries and aquaculture 2016: Contributing to food Security and nutrition for all. Rome. Available at http://www.fao.org/3/a-i5555e.pdf (accessed 11 Aug. 2019).

FAO (2019) Available at: www.fao.org (accessed 02 Sep. 2019).

FOS (2017) Friend of the Sea (FOS) Frequently Asked Questions [online]. Milan. Available at: www.friendofthesea.org/faq.asp. (accessed 20 July 2019).

Franz, N. (2005) Overview of Organic Markets: An Opportunity for Aquaculture Products, GRP Vol. 77 FAO/GLOBEFISH, Rome, Italy.

FSSC 22000 (2019) Available at: https://techni-k.co.uk/FSSC22000 (accessed 01 Sep. 2019).

Healthline (2019) Available at: https://www.healthline.com/nutrition/what-is-kosher (accessed 03 Sep. 2019).

IFS (2019) Available at: https://www.ifs-certification.com/index.php/en/ifs (accessed 25 Oct 2019).

ISO/IEC. (2004) Standardization and related activities — General vocabulary. ISO/IEC GUIDE 2:2004(E/F/R)', Eight Edition 2008, Switzerland.

ISO (2019) Available at: https://committee.iso.org/home/tc34sc17 (accessed 02 Sep. 2019).

Jacquet, J., Pauly, D. (2008) Funding priorities: Big barriers to small-scale fisheries. *Conservation Biology* 22(4): 832-835.

Jonell, M., Tlusty, M., Troel, M., Rönnbàck, P. (2019) Certifying Farmed Seafood. In: Certifying Farmed Seafood, (eds., Vogt, M.), Routledge, London, pp. 157-178.

Konefal, J. (2013) Environmental movements, market-based approaches, and neoliberalization: A case study of the sustainable seafood movement. *Organ Environ* 26: 336-352.

Lee, D. (2008) Aquaculture certification. In: Seafood Ecolabelling: Principles and Practice, (eds. Ward, T., Phillips, B.), Wiley-Blackwell, Singapore, pp. 106-133.

Macfadyen, G., Huntington, T. (2007) Potential Costs and Benefits of Fisheries Certification for Countries in The Asia-Pacific Region. FAO RAP Publication, Bangkok, Thailand. 36 pp.

MoFAL. (1995) Turkish Fisheries Legislation. 1995, Ministry of Food, Agriculture and Livestock. Ankara.

Mol, S., Erdogan, B.E., Ulusoy, S. (2014) Survey into the characteristics, working conditions and deficiencies of Turkish seafood processing firms. *Turkish Journal of Fisheries and Aquatic Sciences* 14: 705-712.

Nabeshima, K., Machida, E., Vu, H.N., Suzuki, A. (2015) Emergence of Asian GAPs and its relationship to Global G.A.P. Institute of Developing Economics, Japan.

OECD (2011) Fisheries and Aquaculture Certification, OECD Publishing. Available at: http://dx.doi.org/10.1787/9789264119680-en (accessed 20 Aug. 2019).

Oral, E. (2009) Traceability of Agricultural Products by Food Safety Information System. Unpublished Master's Thesis. Hacettepe University, Department of Food Engineering, Ankara (in Turkish).

Peacey, J. (2001) The Marine Stewardship Council Fisheries Certification Program: Progress and Challenges. Proceedings of the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade, Corvallis, Oregon, United States of America.

Potts, J., Wilkings, A., Lynch, M., MacFatridge, S. (2016) State of Sustainability Initiatives Review: Standards and the Blue Economy. IISD, Winnipeg, Manitoba.

Steering Committee of the State-of-Knowledge Assessment of Standards and Certification (2012) Toward Sustainability: The Roles and Limitations of Certification.

SMIIC (2019) Available at: https://www.smiic.org/en/faq (accessed 01 Sep. 2019).

Tsantiris, K., Zheng, L., Chomo, V. (2018) Seafood Certification and Developing Countries: Focus on Asia. FAO Fisheries and Aquaculture Circular No. 1157. Available at: http://www.fao.org/3/i8018en/I8018EN.pdf (accessed 10 Sep. 2019).

Tolon, M.T. (2017) Overview of fisheries traceability infrastructure in Turkey. *American Journal of Engineering Research* 6(9): 281-287.

Tuzlu, G.C. (2015) Food Safety Applications of Aquaculture Products Companies in Izmir Province. Unpublished Master's Thesis. Dokuz Eylül University, Department of Marine Sciences and Technology, İzmir (in Turkish).

UNCTAD/WTO (2002) Information Retrieval on Standards, Technical Regulations and Conformity Assessment Procedures. Export Quality, Bulletin No. 72. International Trade Centre. Geneva.

World Trade Organization (1997) Agreement on Technical Barriers to Trade. Available at: https://www.wto.org/english/tratop_e/tbt_e/tbt_e.htm (accessed 01 Sep 2019).

Yılmaz, S., Ersoy, N., Gümüş, E., Aydın, B. (2017) Good agricultural practices in Turkish aquaculture. *Acta Aquatica Turcica* 13(2): 231-238.

Yılmaz, S., Yılmaz, İ. (2017) The importance of traceability of fisheries for marketing. *Nevsehir Journal of Science and Technology* 6(Special Issue): 233-242.

Impact of sex-disaggregated data collection on employment of women in aquaculture sector

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The earliest data on sex-disaggregated employment belongs to Japan, in 1970, and since then FAO Member Countries have been gradually improving their reports in this aspect (FAO 2018).

According to the 2018 Worldfish official statistics, the number of people involved (part-time, full-time or occasionally) in the primary capture fisheries (40.3 million) and aquaculture (19.3 million) in 2016 was recorded to be 59.6 million; It is estimated that almost 14% of these were women compared to an average of 15.2% throughout the reporting period 2009–2016. The difference may be in part attributed to insufficient sex-disaggregated reporting.

Although according to Monfort (2015), the workforce in the primary and secondary workforce in both sectors are distributed evenly between men and women, the statistics data recorded by FAO does not include secondary sector of member nations. In order to fully understand and appreciate the presence of women in the fisheries sector, a more detailed data collection must be employed, including service and post-harvest data. (FAO 2018).

The collection of sex-disaggregated employment data from FAO Member Countries makes it more possible for the decision makers to focus on decisions concerning gender issues in the sector (Biswas 2017).

In the fishery and aquaculture sectors, employment-based sex-disaggregated reporting differs among countries and regions (Table 1). Also in some of the regions and countries, reported data cannot be regarded as sex-disaggregated since they were either men or not at all specified, thus it is not possible to know if women are employed in those locations. Some countries which had formerly reported sex-disaggregated data also turned to providing unspecified information. In such situations, FAO relied on their own estimations (FAO 2018).

The Common fisheries policy solely depends on the indicators of the European employment statistics. These, however, are insufficient in terms of providing the required data especially in terms of gender. However, with the commitee's decision 210/93/EU in 2008, member states are now obliged to provide gender-based employment data for aquaculture and processing sectors; whereas the catching sector was not given this advantage; since in the current datasets, the information is recorded only if such employment is declared and paid for. There are also quite a lot of questions about the accuracy of these figures. Also, apart from women who have declared and remunerable jobs, many, including wives, daughters, sisters, are still 'invisible'. This invisible group has a crucial role in both family fishing and the aquaculture sector; such as doing paperwork, repairing nets, cleaning vessels, direct sales and processing. They are seldomly paid and their existence is unknown to society as the efforts of the European Union to recognise their contribution has only recently been successful. They are mostly ignored in both national and European statistics. (EPCF 2013).

Table 1. Report by region on sex-disaggregated employment in aquaculture sector, 2016.

	Women		**Man**		**Unspecified**	
Region	**No. ('000)**	**%**	**No. ('000)**	**%**	**No. ('000)**	**%**
Africa	33.1	11	211.8	70	58.6	19
Latin America Caribbean	29.3	8	229.8	60	122.3	32
North America		0		0	9.3	100
Asia	2 764.3	15	14 068.5	76	1 645.5	9
Europe	16.7	18	56.7	62	17.5	19
Oceania	1.5	19	5.2	68	1.0	13

This process experienced by other countries of the world has similar reflections in Turkey as well. Turkey is a lucky country to have natural and artificial water resources appropriate for aquaculture production. As it is a profitable investment and thanks to the support given by the state, Aquaculture Sector has gone through a rapid development and held 43% (253,4 thousand tons) of the annual production in 2017 in Turkey. This production accounts for a monetary value of 3,2 billion Turkish Lira. Its share in the gross domestic agricultural product is around 3%. The gradual increase of the population and the growing awareness of healthy nutrition increased the consumption of aquaculture products. With this increased demand, in order to meet the need for healthy animal protein, aquaculture has been one of the fastest growing sectors in food industry. The state has been providing substantial monetary support to aquaculture since 2003. The sector was given a support payment of 1,2 billion Turkish Lira between 2003 and 2017. According to the sector data of 2017, 30% of the fish consumed by Europe is provided by Turkey. Aquaculture export increased by 16% in 2017 reaching 794 million dollars (CUAP 2017).

In Turkey's Agriculture Strategy Rural Development framework, 50% of the investment is provided by the state, aiming at supporting small and medium enterprises in order to maintain the integration of agricultural production and agriculture based industry, improving the infrastructure of agricultural marketing, enhancing food safety, creating alternative sources of income in rural areas, increasing the activities of the current rural development works and storing, processing, packing and packaging agricultural products (including aquaculture products) to establish a certain capacity in the rural society (CUAP 2018; ARDSI 2019).

The support given to aquaculture has brought along a substantial increase in employment as well. The rate of employment increase in aquaculture is higher than the rate of world population increase and the rate of employment increase in other sub-sectors in agriculture (FAO 2010; Yeşilayer *et al*. 2013). Aquaculture sector has attracted attention with the rapid increasing trend it has attained in production capacity and employment level particularly over the last 30 years (Seki and Akbulut 2015). This is a clear indicator that aquaculture sector can be benefitted as an effective political means especially in the fight against unemployment.

According to the data of 2019, there are 2015 aquaculture companies in Turkey (GDFA 2019). 30% of these companies are located in the Aegean Region, 20% in the Black Sea Region, 16% in the Eastern Anatolia Region, 16% in the Mediterranean Region and 4% in the Southern Anatolia Region. The numbers of companies by cities are presented in Figure 1.

Figure 1. The numbers of aquaculture companies by cities (GDFA 2019)

The sector provides approximately 25000 individuals with employment (Çobanoğlu *et al.* 2015; CUAP 2017). The number of engineers employed by the enterprises despite the lack of legal obligation -although not known exactly- is estimated around 1000. It is known that the number of employees working particularly at large maritime enterprises is known to exceed 30. Aquaculture sector consists of the hatcheries for larval production (Figure 2), enterprises where fry and portion fish and other aquatic animals are grown-out facilities, and institutions and organizations offering services in feed manufacturing and fish health (Yavuzcan *et al.* 2010).

Another issue to be dealt with concerning the sustainability of aquaculture production is the contribution of women in the workforce. Unfortunately, no study or source of information has been found regarding the issue. Sex-disaggregated statistics are insufficient. Only production statistics have been used in sector analysis and strategy development. Workforce compositions, workforce competencies and the requirements of the employees working at enterprises composing the aquaculture sector have been neglected. Today, approaches regarding the number and qualifications/competencies of the personnel employed by the enterprises are based solely on estimations (Yavuzcan *et al.* 2010). No information has been covered concerning the issue in the annual workshops organized by the Central Union of Aquaculture Producers so far (CUAP 2011; 2012; 2015; 2016; 2017 and 2018). Women are present in all areas of the sector in aquaculture. Working areas of the women in aquaculture sector range according to the capacity and size of the enterprise (pers.com. N. Şimsek). Women employees are preferred more particularly in packing, processing and hatchery units (pers.com. B. Yazıcıoğlu). However, a database should be set up for the effort of women and men in aquaculture sector; a regular, systematic type of statistics should be collected, research should be conducted to make women's effort in the sector visible.

The inability to know women effort and women workforce in aquaculture clearly (absence of gender-based data record in enterprises) causes difficulties in research and information production concerning the sustainability of the sector. One of the indicators of development of the sector is the number of women employees in the enterprises. Women are shareholders who are not at the forefront but have significant effect on the development of aquaculture sector. Increasing the participation and employment of women in the labour market in the aquaculture sector and strengthening their position in the labour market can make development faster as well as enabling sectoral growth to attain a balanced structure. As also proven by international experience (EPCF 2013; FAO 2016; 2018), as long as economic equality is achieved between women and men, poverty will decrease and an increase will occur in the sector's gross domestic product.

There are two institutions collecting gender-based data in the field. One is the Turkish Statistical Institute (TurkStat) and the other one is the Turkish Employment Agency (TEA). In both institutions, data pertaining to aquaculture sector are collected and brought together with the data from other fields (agricultural, forestry etc.). The data are shared with the public as "Skilled workers in agricultural, forestry and fishery sectors "and "Employment by branch of economic activity/Agriculture, forestry and fishing (Tables 1, 2 and 3). According to TurkStat (2019), the number of women working as Skilled workers in agricultural, forestry and fishery sectors is 1 532 000, it is reported to be 5 313 by TEA (2018). It is seen that three sets of data presented in Table 2, 3 and 4 do not support each other. Statistical sex-disaggregated data collection pertaining to the sector at the national level is not sufficient.

Figure 2. Women working in hatchery (Photo: Dr. D. Çoban, 2019)

Table 2. Statistics on skilled workers in agricultural, forestry and fishery sectors (TurkStat 2019).

Skilled workers in agricultural, forestry and fishery sectors (Thousand people)		
Year	**Male**	**Female**
2012	2799	2107
2013	2790	2027
2014	2574	1750
2015	2557	1679
2016	2504	1540
2017	2568	1585
2018	2574	1532

Table 3. Employment by branch of economic activity (Agriculture, forestry and fishing) (TurkStat 2019)

Agriculture, forestry and fishing (Thousand people)		
Year	**Male**	**Female**
2014	2937	2533
2015	2956	2527
2016	2920	2384
2017	2993	2471
2018	2943	2353

Table 4. Number of Employees by Occupational Groups and Gender (Skilled workers in agricultural, forestry and fishery sectors) (TEA 2018)

Skilled workers in agricultural, forestry and fishery sectors	
Male	34554
Female	5313

Why is it important to collect sex-disaggregated data?

Collecting sex-disaggregated data is critical to generate responses at sectoral level (education, health, decision-making mechanisms level). It helps conducting policy production and planning processes in a healthy way. Sex-disaggregated data collection prioritizes problems and facilitates policy development processes. As employee problems in the sector vary, it provides developing tools to deal with them. It also helps to develop and put the understanding of gender responsive budgeting into action in the sector. Budgeting is a policy tool. It is preparing the budget so as to improve women's status and achieve equality of gender, which is the process of making each and every policy by considering its effects on women and men. Revealing the degree of efficiency of the policies developed is only possible with data (Şener and Demirdirek 2014).

1. The gender of data is not neutral. Gender-blind approaches fail to recognize the difference of experience between men and women and assume that both experience the same problem and/or event and are affected by those problems in the same way. Gender-blind approaches also suppose that the ways of self-expression of men and women are similar. However, roles attributed to women and men, their life practices and surviving strategies make their ways of expression different as well.

2. Making women visible in all areas is critical in terms of equality. Especially taking the household as the main examination unit in the TurkStat statistics make women invisible and causes them to

be melted within the household. Gender-responsive data is significant in terms of making women visible.

3. Considering public policies are for everyone, it is a common understanding that they affect women and men equally and public policies aim all citizens in general. However, gender-responsive data become functional over the assumption that each policy has and might have different effects on women and men. Public policies in taxing, social security and social services influence women and men in different ways and this difference can be visible through collecting gender-responsive data.

4. It is another illusion that women and men benefit from public services equally. Women and men have different levels of accessing these services. Considering that most of the resources are held by men in all areas, it is possible to understand how this difference comes out.

National employment strategy was drafted on 8 February 2012. This draft strategy includes the issues of strengthening education and employment relationship, maintaining secured workforce flexibility, increasing employment for disadvantaged groups and enhancing employment and social protection relationship. National employment strategy aims to reduce unemployment to the level of 5% by 2023 while increasing women employment rate to 50%. In this regard, regulations have been made that can affect women's employment in the sector (CEOWM 2013).

The most detailed regulations concerning the issue and intended to achieve equality for women in working life are included by the Labour Law and the concerning legislation (Taş and Akyol 2015).

1982 Principle of Equality Before the Law: According to Paragraph 1 of Article 10 of 1982 Constitution (Law no. 2709, Official Gazette 09.11.1982, P. 17863) regulating equality, "everyone is equal before the law without distinction as to language, race, color of skin, sex, political opinion, philosophical belief, religion and sect, or any such grounds". In 2004, an addition was made to Article 10 with the Law number 5170 stating "Men and women have equal rights. The State has the obligation to ensure that this equality exists in practice."

Labour Law No 4857 Principle of Equal Treatment dictates that "no discrimination based on language, race, sex, political opinion, philosophical belief, religion and sex or similar reasons is permissible in the employment relationship (art. 5/1). Application of special protective provisions due to the employee's gender shall not justify paying him (her) a lower wage (art. 5/3-5). In the case of gender-based discrimination in the execution or termination of the employment relationship, the employee may demand compensation up his (her) four months' wages plus other claims of which he (she) has been deprived. Article 31 of the Trade Unions Act no 2821 is reserved. (art. 5/6). The Prime Ministry Circular No. 2010/14 on "Increasing Women's Employment and Promotion of Equality in Opportunities" was published in the Official Gazette and entered into force on 25th May 2010 brings a series of precautions to ensure equality of opportunities between women and men and to achieve gender mainstreaming. The precautions included by the Circular are closely related with the principle of equal treatment decreed by Article 5 of the Labour Law and to the implementation of this principle.

Labour Law No 4857 Prohibition of Recruitment Underground and Underwater: Pursuant to the Article 72 of the Labour Law, Boys under the age of eighteen, and women, irrespective of their age, must not be employed underground or underwater work such as mines, cable-laying, sewer or tunnel construction.

Labour Law No 4857 Women at Night Work: Regulation on recruiting women employees on night shifts lays the procedures and principles concerning employment of women who have exceeded the age of eighteen on night shifts. Women employees cannot be made to work for longer than 7.5 hours on night shifts (art. 5).

In accordance with the Regulation on the Employment Conditions of Pregnant or Nursing Women, Nursing Rooms and Nurseries based on the Directive on Measures to Encourage Improvements in the Safety and Health at Work of Pregnant Workers and Workers Who Have Recently Given Birth or are Breastfeeding (92/85/EEC), women employees cannot be forced to work on night shifts during the period starting from the date their pregnancy is approved by a physician until delivery.

Labour Law No 4857 Maternity (Nursing) Leave: Pursuant to Article 74 of the Labour Law, female employees must not be engaged in work for a total period of sixteen weeks; eight weeks before confinement and eight weeks after confinement.

Labour Law No 4857 Extension of Maternity Leave: According to the Labour Law, If the female employee so wishes, she shall be granted an unpaid leave of up to six months after the expiry of the sixteen weeks (art. 74).

Labour Law No 4857 Nursing Leave: Female employees shall be allowed a total of one and a half hour nursing leave in order to enable them to feed their children below the age of one. The employee shall decide herself at what times and in how many instalments she will use this leave. The length of the nursing leave shall be treated as part of the daily working time. (art. 74/ last paragraph).

Labour Law No 4857 Sexual Harassment at the Workplace: If the employer is found guilty of any speech or action constituting an offense against the honour or reputation of the employee or a member of the employee’s family, or if he harasses the employee sexually, the employee is entitled to break the contract immediately (art. 24/IIb). Although our Labour Law No 4857 mentions psychological harassment at the workplace, this case is evaluated within the scope of “the employer’s obligation to protect the worker” or “occupational health and safety”. The conditions covered by the Articles 24/II and 25/II of the Labour Act titled “situations violating morals and goodwill” giving the employee the right to immediately break the employment contract are not limited; therefore, psychological harassment at the workplace can be treated among such conditions as “sexual harassment” or “bullying” or “any speech or action constituting an offense against the honour or reputation”.

“Prime Ministry Circular on Acting in Accordance with the Principle of Equality in Recruitment” related to prevention of gender discrimination in employment was enacted on 22nd January 2004 upon being published in the Official Gazette numbered 25347. In the directive dated 25th May 2006 and numbered 9644, the Turkish Employment Agency declared that employers in the private sector shall not apply gender discrimination in recruitment announcements unless required by biological conditions or reasons related to the nature of the work.

Prime Ministry Circular on Increasing Women’s Employment and Achieving Equality of Opportunities require that "Women’s socio-economic conditions must be strengthened, equality must be achieved between men and women in social life, women’s employment should be increased in order to reach sustainable economic growth and social development aims and ensuring the opportunity of equal pay for equal work” and contains several moves including the establishment of the “National Institute for Observing and Coordinating Women’s Employment”. Article 5 of the Labour Law numbered 4857 requires that inclusion of inspection reports on whether the provisions related to gender equality are followed or not. Moreover, it is stated that gradual incentive system was brought in 2008 in order to increase female employment, and insurance premiums for all women aged 18 and over were covered by the Unemployment Insurance Fund in a 5-year span: 100% in the first year and 80%, 60%, 40% and 20% respectively in the following years. Reporting that approximately 43 thousand women benefited from this incentive, it is also stated that a new incentive package was enacted instead of this incentive system which expired in 2010. Thus, upon the regulation made with the Law no 6111, all of the insurance premium on the employer’s share will be covered by the Unemployment Insurance Fund for a period of 24 months in the event of employing women aged 18 and over. This period can be extended to 36 months if the woman receives occupational training, to 48 months if she gets a certificate of occupational competency. As for those registered to the Turkish Employment Agency, an additional period of 6 months is added to these periods.

Despite the regulations intended for facilitating women's entrance into the labour market in aquaculture sector, the rate of female employment is still lower than that of males' (TurkStat 2019; TEA 2018). The labour market in fisheries is separated as "women's work" and "men's work" (Murat 2017). The society perceives aquaculture sector as "men's work". Therefore, women hold the same perception as well (Göncüoğlu and Ünal 2011). On the other hand, another reason for the low rate of female employment in aquaculture enterprises is the absence of a safe and healthy working environment for employees (Tatar *et al*. 2018).

Women's share of the workforce is slow and problematic in aquaculture compared with other sectors. In addition, the fact that a great majority of mid-level and senior managers are still males indicates that aquaculture sector has not yet been able to break vertical segregation which is also known as "glass ceiling". There is only one female general director in the enterprises in aquaculture sector (pers.com. U.R. Birkol). The factors that limit women's presence in the aquaculture workforce can be the cultural conditions of the society, women's educational status, women's marital status, women's age factor, shadow employment and unpaid family labour and wage rates (pers.com. N. Şimsek).

For the development of a country, considering the importance of individual capital, it is necessary to increase the share allocated for educating women who can meet the workforce needs particularly in aquaculture sector (Göncüoğlu-Bodur 2018). In this respect, the organized structure of the sector and faculties of aquaculture assume big responsibilities. Workforce profiles of the women working in aquaculture in Turkey should be revealed, their problems should be detected and expectations and demands be presented; and mechanisms that can support women in the sector should be put into effect in this parallel. Including women into aquaculture sector should be taken as the primary step, first the contribution of the invisible woman into the sector must be made visible and inequalities of opportunity be eliminated. Approaching the issue in a holistic manner with the cooperation of all the sub-sectors in aquaculture (Dalkıran and Tan 2018) will contribute to enhancing the sustainability of the sector and developing sectoral planning.

References

ARDSI (2019) Agriculture and Rural Development Support Institution. IPARD-Instrument for Pre-accession Assistance for Rural Development Program (2014-2020). Available at: https://www.tkdk.gov.tr/Content/File/Ipard/IPARDII_Programme-Ingilizce3Call.pdf (accessed 24 May 2019).

Biswas, N. (2017) Towards gender-equitable small-scale fisheries governance and development – a handbook, in support of the implementation of the Voluntary Guidelines for Securing Sustainable Small Scale Fisheries in the Context of Food Security and Poverty Eradication. Rome.

CEOWM (2013) The Committee on Equality of Opportunity for Women and Men. Women Employment In All Areas And Solutıon Proposals Commission Report, Publish no: 12, 212p. Available at: https://www.tbmm.gov.tr/komisyon/kefe/docs/komisyon_raporu_2014_1.pdf (accessed 1 July 2019).

CUAP (2011) Central Union of Aquaculture Producers. 1. Aquaculture Workshop. Central Union of Aquaculture Producers, 9-11 July, Antalya, 82 p. Available at: http://suymerbir.org.tr/calistay/1-calistay/ (accessed 1 July 2019).

CUAP (2012) Central Union of Aquaculture Producers. 2. Aquaculture Workshop. Central Union of Aquaculture Producers, 9-11 July, Antalya, 106 p. Available at: http://suymerbir.org.tr/calistay/2-calistay/ (accessed 1 July 2019).

CUAP (2015) Central Union of Aquaculture Producers. 3. Aquaculture Workshop. Central Union of Aquaculture Producers, 25-27 July, Antalya, 86 p. Available at: http://suymerbir.org.tr/calistay/3-calistay/ (accessed 1 July 2019).

CUAP (2016) Central Union of Aquaculture Producers. 4 Aquaculture Workshop. Central Union of Aquaculture Producers, 25-27 July, Antalya, 77 p. Available at: http://suymerbir.org.tr/calistay/4-calistay/ (accessed 1 July 2019).

CUAP (2017) Central Union of Aquaculture Producers. 5. Aquaculture Workshop. Central Union of Aquaculture Producers, 24-26 July, Antalya, 108 p. Available at: http://suymerbir.org.tr/calistay/5-calistay/ (accessed 1 July 2019).

CUAP (2018) Central Union of Aquaculture Producers. 6. Aquaculture Workshop. Central Union of Aquaculture Producers, 23-25 July, Antalya, 141 p. Available at: http://suymerbir.org.tr/calistay/6-calistay/ (accessed 1 July 2019).

Çobanoğlu, F., Çoban, D., Yıldırım, Ş., Kırım, B., Tunalıoğlu, R., Cankurt, M. (2015) Risk resources and management strategies in the earthen pond fish farming in the Milas region (Muğla-Turkey). *Ege J Fish Aqua Sci* 32(2): 89-97.

Dalkıran, G., Tan, F.Z. (2018) The perspectives of academicians on competitiveness level of Turkish aquaculture sector. *Karabuk University Journal of Institute of Social Sciences* 8(2): 485-514.

EPCF (European Parliament’s Committee on Fisheries) (2013) Women in Fisheries: a European Perspective, Directorate-General for Internal Policies Policy Department B: Structural and Cohesion Policies. Available at: http://www.europarl.europa.eu/studies (accessed 12 May 2019).

FAO (Food and Agriculture Organization of the United Nations) (2010) The State of World Fisheries and Aquaculture 2010. Available at: http://www.fao.org/3/a-i1820e.pdf (accessed 04 May 2019).

FAO (Food and Agriculture Organization of the United Nations) (2016) Promoting gender equality and women's empowerment in fisheries and aquaculture: I6623EN/1/12.16. Available at http://www.fao.org/3/a-i6623e.pdf (accessed 04 May 2019).

FAO (Food and Agriculture Organization of the United Nations) (2018) The State of World Fisheries and Aquaculture 2018 - Meeting the Sustainable Development Goals. Available at http://www.fao.org/publications/sofia/en/ (accessed 15 May 2019).

GDFA (General Directorate of Fisheries and Aquaculture) (2019) Aquaculture Firms List. Available at: https://www.tarimorman.gov.tr/BSGM/Belgeler/Icerikler/Su%20%C3%9Cr%C3%BCnleri%20Yeti%C5%9Ftiricili%C4%9Fi/Su-Urunleri-Tesisleri-2019.pdf (accessed 04 May 2019).

Göncüoğlu, H., Ünal, V. (2011) Fisherwomen in the Turkish fishery, southern Aegean Sea. *Journal of Applied Ichthyology* 27: 1013-1018.

Göncüoğlu-Bodur, H. (2018) Education of Adults in Fisheries: Fisherwomen. International Agriculture, Environment and Health Congress / 26-28 October 2018, Aydın 42pp. (with Turkish abstract).

Monfort, M.C. (2015) The role of women in the seafood industry. Globefish Research Programme, Vol. 119. Rome, FAO.

Murat, G. (2017) Gender discrimination in working life within the context of sustainable development 2030 agenda. *Karadeniz Technical University Journal of Social Sciences* 7(13): 7-39.

Seki, İ., Akbulut, M. (2015) The analysis of the determinants of efficiency and productivity of firms in fisheries industry in TR22 region. *Turkish Journal of Agricultural Economics* 21(1): 1-6.

Şener, Ü., Demirdirek, H. (2014) Gender Responsive Data Study. Economic Policy Research Foundation of Turkey. Available at: https://www.tepav.org.tr/upload/files/haber/13990334117.TCDV_Toplumsal_Cinsiyete_Duyarli_Veri_Calismasi_Egitimi.pdf (accessed 04 May 2019).

Taş, Y.H., Akyol, Y. (2015) Turkey's workıng life, legal advantages and their reflections provided for women. *Journal of Turkish Labour Movement and Struggle: Hak-Is Confederation Labour and Society* 4(9): 136-155.

Tatar, V., Adalı, R.M., Özer, B.M. (2018) Evaluation of work in the fishing sector for occupational health and safety. *The Journal of Academic Social Science* 6(74): 513-526.

TEA (2018) Turkish Employment Agency. Activity report-2018. 164 p. Available at: https://media.iskur.gov.tr/22554/2018-yili-turkiye-geneli-ipa-raporu.pdf (accessed 26 May 2019).

TurkStat (2019) Gender Statistics 2019. Turkish Statistical Institute. 200pp.

Yavuzcan, H., Pulatsü, S., Demir, N., Topçu, A., Doğankaya, L. (2010) Sustainable aquaculture in Turkey. Agricultural Engineering VII. Technical Congress, 11-15. January, Ankara Available at: http://www.zmo.org.tr/ resimler/ekler/ 1a94cef23357f68_ek.pdf (accessed 23 July 2019).

Yeşilayer, N., Gören, M., Kaynak, E.İ. (2013) In current situation and supporting policies point of view, comparison of aquaculture production of Turkey and European Union. *Gaziosmanpasa Journal of Scientific Research* 2: 59-75.

Overview of projected climate change impacts on aquaculture, with particular emphasis on mitigation strategy for the Turkish aquaculture sector

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Introduction

Global Climate Change is a scientifically well-established reality of the 21st Century. The elevated concentration of greenhouse gases in the atmosphere, resulting from human activities such as the burning of fossil fuels and deforestation is leading to global warming. It is well perceived that the aquatic environment will be amongst the most severely affected habitats. There is no doubt that aquaculture activities, the rising trend of the 21st Century, will also be under stress. The benefits of aquaculture are related to key factors in any agricultural food production: i) resource-use efficiency; ii) sustainable supply; iii) limited land use; iv) food security and nutrition; v) supply chain management. O'Shea *et al.* (2019) explained the contribution of aquaculture to environmentally and socially beneficial food system using the term "Blue Revolution" with reporting that "Seafood is one of the most important food sources for the world's seven billion people—for as many as three billion people, it is a key source of protein. The significant demand is projected to rise as the population adds upward of two billion more people in the next 30 years. Aquaculture is the fastest-growing form of food production and the source of half the world's seafood—and most forecasts project continued growth as the global population swells to 10 billion people by 2050. Farming seafood is one of the most environmentally efficient ways of producing animal protein, but localized environmental impacts have been a major challenge. New technologies and certain production systems now offer the opportunity to grow seafood with less environmental impact."

Direct and indirect climate change effects on the aquaculture activities are conversely a major concern for the global aquaculture industry, primarily observed as negative events and conditions induce stress, increased disease prevention, and treatment strategies, feed and raw material limitations, in and out movements of the surrounding biota, unfavourable market, and logistic conditions, etc. Nevertheless, as the worldwide proportion of contribution from aquaculture with respect to capture fisheries rapidly increases to almost 80%, and close to 90% in Turkey (Anonymous 2019a), the government of Turkey has published a national strategy in 2010 (National Climate Change Strategy 2010-2020) and a national climate change action plan (National Climate Change Action Plan 2011-2023). Both documents do not deal in detail with individual sectors, including fisheries and aquaculture. However, it identifies the projected impacts including changes in river/basin regimes, diminishing surface waters, increasing scarcity of water for use, flood, coastal erosion, degradation of the marine ecosystem, the survival of migrating species, and reduced aqua-production, all of which may impact fisheries and aquaculture. Thus, the significance of a holistic sustainability strategy that also considers climate change risks becomes more evident. Any strategy paper on mitigative actions regarding an ecosystem dependent activity needs to be based on the statement that “climate change causes and influences are global, yet related with the extreme events and conditions, the effects and mitigation/adaptation actions are local”. Similar basic approaches should also be considered the region, ecosystem, niche, sector, species, specific case, society, corporate, etc. basis. Furthermore, combined bottom-up and top-down approaches need to be considered simultaneously for a working and sustainable mitigation, resilience building, and preparedness strategy. Therefore, based on this framework, an initial assessment of a sustainable “Guidelines for a Climate Change Mitigation Strategy on the Turkish Aquaculture Activities” should be based on globally accepted data and best practices while keeping in mind the regional, sectoral, and activity-based differences. It should be noted that the term “Climate Change Mitigation” now covers all aspects of ecosystem management from data collection and assessment to validated data-based modelled projections, preventive and adaptive measures, legal and financial basis to be allocated, widespread and well-monitored policies, pinpointed penalties and incentives, a well-planned and coordinated governance methodology, comprehensive and validated guidelines, etc. Any strategy paper needs to be based on well-defined assumptions and prerequisites like the presence of satisfactory public knowledge and concern; the presence of a satisfactory sectoral knowledge and concern; the presence of a satisfactory administrative knowledge and concern, in short; a unified mental and physical acceptance of simultaneous action and commitment. Most importantly, a constructive, diversified, logic-based, well planned, well defined, implementation, and a long-term empathy focused coordination and cooperation among Science-Industry-Public-Decision and Policy Makers, is essential. Accordingly, this chapter will provide insights on a strategic framework to suggest and assure a practical view on a holistic climate change mitigation initiative to assist the formation of a key stakeholder view on the possible methodology of resistance building for the aquaculture sector under the threat of gradual climate change as well as potential threats for aquaculture production characteristics and physiological response/well-being of fish under changing environmental conditions.

Critical knowledge of climate change

A report from the World Meteorological Organization released in 2017 stated that climate change has now taken the planet into 'uncharted territory'—as evidenced by the perpetual ice melting in the arctic, rises in sea levels, frequent high temperatures, disrupted rainfall regime, drought, frequent floods, abnormal weather events, and extremely elevated carbon dioxide (CO_2) amount in the earth's atmosphere for three million years. There is a vast amount of scientific information available in the literature regarding aquatic species, environment, and ecosystem specific vulnerability assessments. In general terms, it is already confirmed that the aquatic ecosystems will be under additional stress due to climate change-induced adverse conditions: increased frequency-duration-extend-magnitude of extreme meteorological events, longer and more severe water stress periods, adverse and abrupt changes in physicochemical parameters, unforeseen and untimely biological activities and influence of alien organisms, changes in the ecosystem diversity and balance, changes in the species' population composition and eco-biology and etc. to name a few.

Some commonly identified potential negative effects of global climate change on the aquatic ecosystems can be summarized as follows;

- A poleward and outward (away from shallow shores) shift of aquatic species and ecosystems (Local/Regional/Global Ecosystem and niche - Pelagic/Demersal/Species differences)
- Changes in composition, abundance, trophic level, size, and age distribution of aquatic food web elements
- Physiological changes in most fish species (changes in fecundity, age of maturity, physical appearance, growth time and period, sex and population age ratios, preference of habitat, etc.)
- Increased vulnerability to parasites, vector-borne diseases, stress-induced gill and skin diseases, malnutrition, and food scarcity
- Shifts in primary food web elements of phyto- and zooplankton blooms in terms of timing, composition, intensity, duration, and distribution
- Increased adverse effects from parasites, bacteria, and viruses, mucosa depleting, and stress-causing factors

Similarly, although the marine and freshwater aquaculture activities need to be considered differently, some common threats can be summarized as follows;

- Out of the season, extended and more severe droughts
- Out of the season, extended and more severe heavy rains
- Irregular intensities and durations in sunny and/or shady days, ice cover, snow, and glacier thickness and extend
- Frequency, duration, extent, and impact of extreme climate events

- Extended and prolonged changes and fluctuations in the river flow rates at the sources and lakes' or groundwater levels as well as extents
- Abrupt or gradual changes in the temperature, pH, oxygen content, thermocline, vertical mixing and/or stagnation, light penetration index/turbidity, physical, chemical, and biological properties, as well as regimes of the water bodies
- Changes in the biological diversity and distribution, composition, and dominance of aquatic life
- Changes in the micro and macrophyte species, timing and extent of blooms and its distributions as well as zooplankton composition and distribution
- The occurrence of introduced species of aquatic organisms, timing and intensity of mass deaths due to physio-chemical changes, harmful chemical bleaching, increased parasite infections, viral or bacterial disease outbreaks or epidemics.

Key climate change concerns for aquaculture

Temperature rise

Human activities in relation to global warming are forecasted to cause an increase of approximately 1.0°C even 1.5°C temperature change between the years 2030 and 2050. In parallel to weather temperature rise, ocean temperatures will also increase. Based on the information released by the US National Oceanic and Atmospheric Administration (NOAA) the average global sea surface temperature – the temperature of the zone at the upper few meters of the ocean – has elevated by approximately 0.13°C per decade over the past century. The warming for the surface ocean has increased between 1971 and 2010 by 0.11ºC per decade meanwhile the highest temperature increase has been recorded in the coastal zone (IPCC 2013). Future emission scenarios by IPCC (2013) remarked that surface ocean temperatures are projected to elevate in the zone of 100 m by approximately 0.6–2.0ºC by 2100. The projections for the Mediterranean area highlight a potential rise in sea surface temperature (SST) of 1–1.5ºC in the Eastern Mediterranean, Aegean, and the Adriatic Sea from 2000 to 2050 (Miladinova *et al.* 2017).

Oxygen content

Dissolved oxygen is of significance for the aquatic systems. Alterations in dissolved oxygen concentrations have important effects on the carbon and nitrogen cycles globally. A decline in the solubility of oxygen in water is estimated under the effect of ocean warming, resulting in 15 % of the current total global oxygen loss (FAO 2018). Oxygen is the vital element in aquatic living organisms, thus decreases in oxygen solubility can affect their lives such as migration and distribution behaviour although the response of aquatic organisms to oxygen depletion is changed by their tolerance.

Extreme weather conditions

Changes in extreme events frequency are being experienced in recent years as a climate change signature. Warming temperatures have been in the first rank for future climate change projections however, increases in extreme events such as heatwaves, droughts, and floods are of potential to cause fundamental changes in aquatic ecosystems ranging from freshwater lakes to the open seas. Frequent extreme weather events such as hail, intense winter precipitation, and abnormal rainfall regimes, heatwaves, and droughts are expected to occur under the impacts of climate change. A succession of floods, droughts, and storms may affect the vulnerability of the aquaculture sector. Particularly, the risk of drought and the possibility of floods are expected to rise in the near future (Anonymous 2019 b).

Acidification

The absorption of carbon dioxide can be induced by the increase in atmospheric carbon dioxide concentrations, resulting in an increase in the partial pressure of carbon dioxide at the ocean surface and a decrease in the pH of water. The predictions indicate that the decrease in pH may occur throughout the world's oceans, with the main decrease in surface waters existing in the warmer low- and mid-latitudes (Daw *et al.* 2009).

Sea level rise

Since the late 19th century, the global mean sea level has risen by 15 to 20 cm due to ocean warming and is affected by a number of factors, including the thermal expansion of seawater, the melting of glaciers and ice sheets on land, and excessive use of groundwater. An increase in sea level may occur between 10 and 90 cm in this century (Handisyde *et al.* 2006). The projections show that the basin average Mediterranean Sea level will increase between 44 cm and 102 cm by the end of the 21st century. Higher sea levels can lead to the entrance of saline water into low-land and deltaic regions, causing harmful effects on the freshwater characteristics.

Lake level fluctuations

Extended droughts from more frequent extreme events are likely to affect the levels of lakes. Lake level decrease associated with increased water temperatures can be expected to affect oxygen regimes, redox potentials, lake stratification in the lakes and even in the rivers, as well as the metabolism and life cycles of aquatic organisms (Kundzewicz *et al.* 2007).

Freshwater sources

Freshwaters may show extreme sensitivity to climate change because their availability is climate-dependent (Woodward *et al.* 2010). It is common knowledge that approximately 98% of the water on earth contains salt and freshwater sources are very limited to only 2% of the total water resources. In the available freshwater sources, snow, and ice (almost 70%), groundwater (30%), and surface water such as lakes, rivers (less than 0.5%) exist, and less than 0.05% of total freshwater may be present in the atmosphere. The proportions of water are expected to change under climate change effects globally. It has been foreseen that polar ice melting due to global warming could result in changes in seawater characteristics although total water supply is not substantially affected. On the other hand, in the projections of the impact of climate change on freshwater resources, mean values of annual runoff associated with evapotranspiration and precipitation values should be taken into consideration. Flow regimes may show unexpected variations in the whole world under climate change impacts. Under global warming, eutrophication is predicted to be exacerbated and stratification more pronounced and eventually disruption of food webs and habitat availability and quality may occur (De Silva and Soto 2009).

Climate change forecasts for Turkey

The General Directorate of Meteorology in Turkey has issued representative scenario-Representative Concentration Pathways 8.5, indicating that average annual temperature increase has been foreseen between 2,5°C and 3,7 °C for the period of 2016-2099 throughout Turkey. In the same scenario, annual rainfall abnormality alteration is estimated between +3% and -12% although the rainfall decrease is not expected. The last report from The Intergovernmental Panel on Climate Change (IPPC 2013) emphasizes the Mediterranean as one of the most vulnerable regions in the world to the impacts of global warming. The models issued by IPCC include different scenarios of climate change cast for the Region, however, each agreed on the temperature increases. In terms of the thermal regime, the scenario for the period between 1980 and 2000 was used to predict an increase in average surface temperatures in the range of 2.2°C and 5.1 °C for the period 2080-2100. It was also forecasted that the pronounced rainfall regime may change in the Mediterranean and precipitation over lands may show variations between -4% and -27% for the same period. Rosa *et al.* (2012) reported that the Mediterranean basin is expected to change i) an increase in air temperature of between 2.2°C and 5.1°C; ii) declines in rainfall varying from 4% to 27%; iii) an increase in drought periods due to more days with high temperature exceeding 30°C, and iv) an elevation in the sea level of approximately 35 cm and saline intrusion. The Black Sea is forecasted to warm with a maximal value of 2.81 °C per century in the summer period to a minimum value of 0.51 °C per century in winter by 2100 (Shaltout and Omsted 2014) although little spatial variations are expected in terms of annual records (Cannaby *et al.* 2015). In the Black Sea, it is foreseen that the cold intermediate layer will be affected by global climate change, resulting in the change of the oxygen/anoxic boundary position (Miladinova *et al.* 2017). Inland freshwater aquaculture in Turkey is likely to be affected by climate change due to drought with the highest evaporation, drying rivers and streams, decreases in lake levels, and shortage in freshwater supply.

Key issues with climate change and fish physiology

Fish physiological interaction with water temperature

Forecasts of climate change effects on aquaculture require a sound understanding of the effects of increases in water temperature on fish metabolism and physiological adjustments associated with adaptation capacity to higher temperatures. Water temperature with its effects on the biochemical and physiological processes in fish metabolism is the most important physical factor in aquatic environments.

Fish, being poikilothermic animals, regulate their internal temperature from the ambient water temperature. However, the optimal temperature for the normal physiological state of fish growth and survival exists, varying with the age and size of the fish. The lethal limits and tolerance to extreme temperatures change by the fish species (Mazumder *et al.* 2015). In fish, temperature tolerance limits (thermal windows) and temperature indices as defined by the upper-lower lethal temperatures or critical thermal maxima (CTMax)-minima (TCMin) may provide a prediction for the response to temperature changes and the degree of specialization of fish on the specific thermal environment (Mazumder *et al.* 2015; Nyboer and Chapman 2017). The CTMax values were estimated higher for species inhabiting thermally unstable environments such as intertidal, supratidal, southern distributed species, and species having reproduction migrations in their life history due to exposure to extreme temperatures. Oppositely, lower CTMax was assessed for subtidal, demersal, and northern distributed species living in colder environments (Madeira *et al.* 2012). In explication of the CTMax the mean water temperature or thermal limits are also taken into consideration. In case CTMaxs are close to the mean water temperature that fish already live in or are similar to thermal limits further increases in water temperatures make fish more vulnerable to higher temperatures resulting from global warming. Thus, the fish species of temperate and subtropical zones are particularly sensitive to high temperatures and climate warming.

Increases in water temperatures speed up biochemical reactions in total metabolism, resulting in energy expenditure to meet increased activity, growth, development, and reproduction. On the other hand, rapid anabolism and catabolism cause higher food consumption rates in order to provide a balanced energy budget (Lafferty 2009). Metabolic performance in fishes can be expressed by aerobic scope (AS) which describes the increase in an animal's oxygen consumption from its standard to its maximal metabolic rate. Thermal increases cause reductions in aerobic scope (AS), resulting in decreases in energy to be used for being physically healthy and strong as well as other performance functions. High temperatures lead to limitations in aerobic scope, implying that unfavourable consequences on fitness-related performance characteristics such as growth and reproductive rhythm. Limited thermal plasticity in relation to the reduction in aerobic space has been revealed in tropical fish, Nile perch (Nyboer and Chapman 2017). Thus, a mismatch between the need for oxygen and the capacity of oxygen supply to tissues is the first factor to limit whole-animal tolerance to thermal extremes. The oxygen functioning aerobic metabolism and oxygen supply capacity are also involved in adaptation for the fluctuations in water temperatures. The holistic approach to oxygen- and capacity-limited thermal tolerance is necessary to predict the response of fish to climate change and warming waters (Pörtner and Farrel 2008). Along with this fact that oxygen consumption ratio and temperature quotients (Q10) may provide a suitable measurement to understand the acclimation of fish to different temperatures. Q10 is related to oxygen consumption during acclimation and the preferred temperature of fish. In a study to reveal the thermal tolerance of juvenile meagre in the acclimation to different temperatures, Q10 values were determined 1.28, 2.78, and 1.10 between 18–22°C, 22–26°C, and 26–30°C, respectively. The low Q10 value between 26 and 30°C was interpreted as thermal limitation leading to restriction of an additional increase in the standard metabolic rate of the fish. Considering the Q10 values for juvenile meagre the preferred temperature range was reported between 26 and 30°C, corresponding optimum growth (Kır *et al.* 2017). However, further increases in water temperature can compel acclimatization capacity and influence metabolic processes negatively including growth.

From the angle of sustainable and efficient aquaculture production, climate change and warming waters can easily be predicted to create additional complexities in running aquaculture systems. This high level of complexity necessarily demands the understanding of interactions among higher water temperatures, oxygen consumption capacity, and growth indices in aquaculture conditions. Although standard metabolic rate increases with elevating temperatures the increases are not endless and dependent upon other factors, particularly the capacity of oxygen use. For the economically significant species juvenile European seabass, the preferred temperatures were reported as 25 and 30°C however, standard metabolic rate tended to decline gradually after 25°C, showing the low capacity to acclimatize to changes in water temperature (Kır and Demirci 2018).

Reproduction

Alterations in thermal rhythm caused by climate change would have critical results for fish reproduction, influencing each level of the reproductive process

(Pankhurst and King 2010). The importance of these effects would be controlled by a range of factors including specific physiological tolerances, the ability for acclimation and adaptation, capacity to extend or shift ranges, and the timing of thermal restrictions regarding the reproductive cycle.

Fluctuations in temperature can affect the hypothalamo–pituitary–gonadal (HPG) axis at different steps of the hormonal cascade, manifesting in hormone synthesis and action as well as hormone structure. An increase in hormone synthesis, activity, and metabolism within the limits of physiological tolerance results in decreasing activity at the end of range under the effect of higher water temperature (Pankhurst and King 2010). The reasons for inhibitory effects of higher temperature are related to the conformational changes in proteins functioning in the reproduction process such as FSH, LH, and their receptors, steroid-synthesizing enzymes, and also changes in the form of steroid hormones. Suppressive impacts of water temperature changes in the reproduction of fish may be observed in a wide range of fish species.

In general, inhibition of reproduction tends to happen in cold temperate and sub-Arctic species at around 11-12°C, cold temperate species 18°C, temperate species at around 24°C, and tropical species at 30°C and above. For example, temperate freshwater species, rainbow trout (*Oncorhynchus mykiss*) shows reduced steroid production and fertility at 18-21°C due to thermal stress. Although the reaction against rising temperature can inhibit reproduction, the thresholds for the end effects may vary by specific thermal tolerance ranges of fish (Pankhurst *et al.* 2011). Considering the projections on climate-induced changes higher temperatures may have an impact on gametogenesis, causing inhibition of spawning.

Egg incubation

The higher levels of temperature have detrimental effects particularly on non-feeding free-living stages such as eggs, cysts, and larvae (King and Monis 2007). The egg stage is the most sensitive period in the life stages in fish to thermal changes. It is reported that the thermal tolerance range for egg incubation is within 6°C of the spawning temperature for many species (Rombough 1997). Even slight changes in temperature can decrease egg viability to a large extent, particularly for tropical species (Gagliano *et al.* 2007). Higher water temperatures shorten the incubation period of fertilized eggs irrelevant of the fish species in the stenothermal or eurythermal group, leading to a mismatch between the hatching out and convenient conditions for larval survival. In normal conditions, a harmonious sequence between the timing of spawning and embryo development in terms of thermal conditions exists, however, higher water temperatures may disrupt normal egg incubation. Thus, water resources such as oceans, seas, and rivers with higher temperatures may disarrange the hatching of eggs in a proper time (Pankhurst *et al.* 2011).

The thermal tolerance and phenotypic plasticity reactions of embryos and fry of brown trout (*Salmo trutta* L.) for different temperatures were investigated by Réalis-Doyelle *et al.* (2016), showing spectacular results. The highest survival of well-formed fry at first food intake and suitable use of energy budget were assessed at 6°C and 8°C. However, at 12°C, the survival rate declined to 0.9% for well-formed fry at first food intake and fry had almost no vitellus sac at the phase of first feeding. The increase in fry with deformity at higher temperatures were also recorded. Thus, more marked dramatic effects on early life stages of stenothermal fish species can be expected in global warming associated with climate change. Nevertheless, Mediterranean fish species such as European seabass which are considered eurythermal, appear to have thermal limits for normal embryonic and larval development. The studies on the Mediterranean species revealed that higher temperatures (20°C) during the early rearing period caused an increase in the ratio of haemal lordosis in European seabass while lower temperatures (15°C) decreased the haemal lordosis, evidencing that water temperature is one of the environmental determinants for the well-being of various life stages of fish (Sfakianakis *et al.* 2013). Similarly, the effects of higher water temperature during embryonic and larval stages of European seabass, *Dicentrarchus labrax* (L.) was the reason for the occurrence of cranial deformities at a higher ratio (Georgakopoulou *et al.* 2007).

Acclimatized windows are narrow in stenothermal species and wide in eurythermal ones, showing adaptation to climate zones. Thermal window widths change by the life stages of fish (Figure 1).

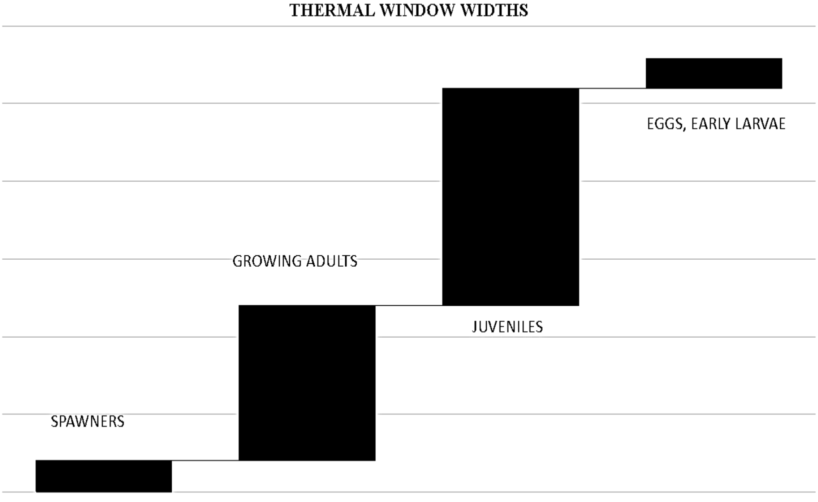

Figure 1. Aerobic thermal windows width for different life stages (adapted from Pörtner and Farrel 2008)

Acidification and fish physiology

Climate-induced ocean acidification is linked to the absorption of excess carbon dioxide by oceans which results in decreased pH of seawater. The knowledge on ocean acidification through carbon dioxide absorption is essential to evaluate the acid-base reaction of fish in climate change-induced water conditions (Daw *et al.* 2009).

It is reported that pH and carbonate presence will decrease in the Mediterranean Sea after elevated seawater pCO2, which may lead to disruption in calcification models and shell dissolution (Michaelidis *et al.* 2005a, b; Gazeau *et al.* 2007). On the other hand, it is known that low pH can cause disruption in fish physiology associated with emerging diseases resulting in high mortality rates in aquaculture and constitutes welfare problems.

Allostatic load and fish health under climate change impacts

Fish pathogens always exist in aquaculture systems, however; fish usually are able to resist them unless allostatic load gets to the level of overload. The disease is a set of interactions amongst the host (fish), the pathogen, and the environment (water). Each factor in this interaction is directly affected by climate change, eliciting modification in disease dynamics. A single factor can be potent and cause disease in aquaculture however, under climate change these factors can work synergistically, which culminated in allostatic overload associated with disease outbreaks and eventually mortality. Allostatic overload referring to the reduction in homeostatic flexibility may occur easily under climate change conditions because both altered fish metabolism and water characteristics can produce an effect greater than the sum of their individual effects. The allostatic load may give a better prediction of climate-induced changes in the long-term as it explains the consequence of repeated or prolonged stress. The disruption of fish health is related to the allostatic overload thus stress response itself may be insufficient in the evaluation of long-term effects of climate change. It has been predicted that climate change ends in altering host range, host immune response, parasite range, and virulence as well as parasite transmission rates (Marcogliese 2008). These alterations naturally increase allostatic overload, resulting in disease outbreaks and new disease dynamics.

Climate change can add complexity to the interaction of factors responsible for disease occurrence, making predictability difficult. Global warming under climate change effects is expected to change the host-pathogen relationship. Most diseases exhibit higher virulence at higher temperatures. This can also be linked with the reduced resistance of fish due to thermal stress or increased transmission potential. Alongside temperature, the effects of climate-induced changes on fish and their pathogens are also needed to be considered for the factors: i) changes in water levels and flow regimes, ii) eutrophication, iii) stratification, iv) acidification, v) ice cover decline, vi) differences in ocean currents, vii) ultra-violet (UV) light penetration, viii) runoff and ix) extreme weather conditions. Considering these factors different climate change scenarios can be developed. For example, in the warming of coastal water, shifts in host range may coincide with the introduction of new pathogens. In sea-level rise, parasites found in freshwater may decline due to the entrance of saltwater in freshwater. In the case of higher levels of UV radiation, the direct harmful effect on parasites may occur, leading to diminishing in parasites with UV-sensitive infective stages such as whirling disease and eye flukes (Marcogliese 2008). In contrast, Williamson *et al.* (2017) have demonstrated that climate change hastens to release the dissolved organic matter to inland and coastal waters because of increases in precipitation, thus declining the potential for solar UV radiation to inactivate pathogens.

Disease problem is and will be one of the most serious problems for sustainability and the future growth of aquaculture. The expected effects of climate change can be seen in pathogen diversity and disease patterns with significant economic and ecological consequences. Many aquatic pathogens can display the capacity for multiplication, recombining, and selecting fit combinations of variables in pathogenicity. An elevation in disease pressure can be projected for the future. On the other hand, it is reported that while some pathogens in aquatic environments can benefit from climate warming, the prevalence of others can decrease or remain unaffected (Karvonen *et al.* 2010). It is difficult to foresee which pathogens are going to increase or decrease in virulence and pathogenicity in future climate scenarios (Rosa *et al.* 2012). The effects of climate change on disease occurrence and pathogens in aquaculture appear uncertain to our current knowledge. Based on the climate change scenario, new disease management strategies, selective breeding with biotechnological studies and implementation to produce shellfish and fish species more tolerant of acidification and higher temperatures seem the most reasonable first steps to the adaptation to climate-induced changes.

Climate change-induced impacts on characteristics of aquaculture

Based on forecasts on global climate change the possible variations in water temperature, precipitation, ocean acidification, oxygen depletion, and higher sea levels are foreseen to have long-term impacts on the aquaculture sector. Short-term climate change impacts on aquaculture can be connected with losses of production and infrastructure problems because of extreme events such as floods, storms, and harmful algal blooms. Climate change may also have risks for fish health in the aquaculture sector, linking with the occurrence and virulence of pathogens or the susceptibility of any organisms being cultured to pathogens and infections under climate change impacts. Deterioration of water quality associated with decreasing freshwater sources may be one of the most important impacts of climate change. The physiological response of fish to climate change, affecting the aquaculture production indices would need to be evaluated for the drivers of climate-related changes. The predicted fish physiological status under climate change impacts are given in Section 3 in detail. Floods due to a changed rainfall regime may have dramatic effects on the freshwater farms, resulting in physical damages in the system and mortality of fish. Heavy storms as an extreme event can lead to stock losses in off-shore aquaculture (Rosa *et al.* 2012). It can be predicted that extreme weather events negatively affecting ecosystem functions will affect the aquaculture unavoidably. All types of aquaculture production are sensitive to the effects of extreme events in terms of both economic consequences (due to stock loss and physical harms in the systems) and undesired biological consequences (expansion of disease agents from aquaculture fish to fish in nature). The scenarios for the impact of climate change on aquaculture constitute positive effects such as an increase in areas suitable for aquaculture, increased feed conversion efficiency, and increased length of the growing season for some species. Higher temperatures have the potential to promote fish growth and increase the production capacity at a farm level. For example, some species like seabass and seabream in sea and carp and catfish in freshwater would enhance growing seasons in temperate areas. The warmer temperature would enhance fish growth rates and feed conversion ratio through increased metabolic rate. Aquaculture can be expanded into new areas as a result of the decrease in ice cover. Further, global warming may also cause higher phytoplankton diversity resulting in a positive effect on bivalve culture. The potential impacts of climate change on aquaculture are presented in Table 1.

The indirect effects of climate change on aquaculture are linked to fish meal and fish oil obtained from captured small pelagic fish. The demand for fishmeal from small pelagic fishes increased in parallel to the intensification of fish production through aquaculture, which is a limiting factor of the sustainability of the aquaculture sector. The vulnerability and availability of small pelagic fishes exposed to climate change impacts would be challenging. El Niño is a naturally occurring phenomenon characterized by the extreme temperatures of the sea surface in the central and eastern equatorial Pacific Ocean where a huge amount of small pelagic is fished and used in fish feed production. The observed changes in oceanographic data after an El Niño/Southern Oscillation (ENSO) event changed in sea-surface temperatures, changes in the vertical, thermal structure of the ocean (mainly in coastal regions), and disrupted coastal and upwelling currents. Thus, it can be predicted that the changes following ENSO could directly affect the species composition and fish stocks. Generally, that event may occur every two to seven years and last over one-year. During El Niño events, normal patterns of tropical precipitation and atmospheric circulation had seriously disrupted, inducing abnormal weather events around the world. Another potential impact of climate change is related to harmful algal blooms in fresh, marine, and brackish waters. Algal blooms negatively affect shellfish and finfish aquaculture activities due to the hazards of biotoxins accumulations in farmed shellfish which are consumed by humans (FAO 2018).

Table 1. Climate change-induced impacts on aquaculture systems and production characteristics (modified from Handisyde *et al*. 2006 and Cochrane *et al*. 2009)

Projected impacts	**Impacts on aquaculture characteristics**	**Impacts on aquaculture operational characteristics**
Higher inland and seawater temperature	Depletion in dissolved oxygen Impaired water quality Increased in infectious diseases Change in parasitic diseases Higher mortality due to harmful algal blooms Increased in fouling problems Extended growing period Increased growth rates Decreased FCR Alterations in the profile of competitor and predators Elevated primary productivity Changes in aquaculture production	Changes in aquaculture structures Changes in operation costs Enlarged area for aquaculture Increase in the range of aquatic species for raising
Sea level rise	Decrease/loss of suitable area for aquaculture Salt intrusion into freshwater sources	Damage to aquaculture structures Alteration in aquaculture zoning The decrease in freshwater sources
Wave and current action Wind velocity	Decreased food availability for shellfish Changes in water exchange Disruption in wastewater removal Uncertainty in fish availability for fish meal and fish oil	Elevated operational costs Problems in wastewater removal
Storms and floods	Salinity changes Increase in floods due to intense precipitation Expansion of disease agents by floods Loss of stock due to damaged structures	Damage to aquaculture structures Increase in operational costs Additional costs for mooring, etc
Drought	Salinity increase The decrease in water volume Increase in evaporation Deterioration in water quality Reduced freshwater supply The decline in pond level Increase in infectious diseases	The decrease in stock volume Limited aquaculture production Increase in costs to overcome the problems

Considering the aquaculture production in Turkey it can be expected that climate change would have an impact on overall Turkish aquaculture, mainly for the production in sea-cages. Marine aquaculture in Turkey, particularly off-shore production may be threatened by extreme weather conditions, such as storm surges. The challenges for inland freshwater aquaculture in Turkey can be listed as changing patterns of rainfall, drought periods, and more intense storms. Thus, Hidalgo *et al.* (2018) reported that surface warming, frequent heatwaves and a decrease in precipitation may occur probably over the Mediterranean, associated with sea-level rise. In the Black Sea, surface warming, alterations in thermohaline structure, sea-level rise, and abnormal weather events are predicted events under climate change impacts.

Specifically, to fish species cultured in Turkey, it can be perceived that climate change impacts could be beneficial for seabass and seabream or rainbow trout culture in terms of increased growth rate and better feed conversion in relation to water warming however, most impacts are likely to be adverse and occur under pressure due to other environmental factors, such as dissolved oxygen depletion, sub-optimal water quality, biofouling problems and water scarcity for freshwater species. The acclimatization capacity of the species intensively cultured would be crucial in terms of metabolic processes. Main Mediterranean species cultured; seabass and seabream at the juvenile stage may have tolerance against temperature increases, however, thermal limits for normal embryonic and larval development at earlier life stages may not be consistent with the elevated temperatures. Freshwater species; rainbow trout may exhibit different tolerance patterns from these marine fish. Reproduction in rainbow trout and subsequent egg incubation may be more severely affected by physiological processes under warming temperature, having dramatic effects on rainbow trout production. Pond aquaculture of rainbow trout is likely to be under pressure due to severe vaporization resulting from higher air temperature. Other species produced such as Black Sea trout, meagre, and bluefin tuna are likely to be affected by climate change-induced environmental conditions in relation to their thermal tolerance. The effect of global warming is expected to amplify health problems, with a higher risk of disease occurrence and mortality despite the uncertainty of pathogens causing diseases in the aquatic organisms. Thus, an increase in allostatic load on fish due to climate change impacts can predispose fish to diseases, and current cultured species in Turkey; seabass, seabream, and rainbow trout can be expected to have health problems caused by diversified disease challenges. Extreme weather conditions are of potential negative effects on all types of aquaculture, representing high risks for both marine and freshwater aquaculture in Turkey. Fluctuations in fishmeal and fish oil supply for fish feed due to a decline in raw material supplies may limit the overall carnivorous fish production. The aquaculture sector in Turkey is likely to face the challenges of fluctuations in overall aquaculture production, resulting in economic and socio-economic problems under the pressure of climate change.

Guidelines for the development of a climate change strategy to ensure a sustainable Turkish aquaculture sector

A recent observation from the UN with regards to the climate change-induced stress various culture activities will face can be summarized as; emerged impacts of climate change mean that aquaculturists need to adopt "disaster-resilient" farming practices to meet the demand of animal protein for increasing populations in the world. The United Nations declared that 91% of all disasters between 1998 and 2017 were related to floods, storms, droughts, heatwaves, and other abnormal weather events. These disastrous events have been recorded more frequently and intensely, and with harmful impacts on food security. The United Nations' Global Assessment Report 2019 (GAR 2019) underlined that overdependence on a single crop under the effects of global warming is extremely dangerous and expresses a complex risk in relation to drought in a wide range in the world. Being aware of the need for availability of relevant data, many countries, even continents, Australia, New Zealand, USA, EU, Asian and African countries, some with the assistance of international organizations, have initiated a long-term data collection program for vulnerability assessment and aquatic resilience-building plans (Anonymous 2019b). Recently, climate change is under investigation with comprehensive international projects. Two multinational EU Horizon 2020 projects (CERES 2019; ClimeFish 2019) have focused on climate change impacts on fishery and aquaculture and are worth mentioning here. These long-term projects are also relevant to the Turkish fishery and aquaculture sectors. ClimeFish Project states that "climate changes affecting aquaculture are reflected by temperature changes in both water and air, particularly surface temperatures in marine conditions and other alterations in oceanographic conditions, including currents, wind speed, and waves. Extreme weather conditions – becoming more intense and more frequent – are important effects, either as storms causing material damage or flooding of freshwater farms. Fish or shellfish will be subject to different stresses and physiological effects, affecting growth and development, which may further increase their susceptibility to diseases and infections. New and emerging diseases and parasitic infections may be potential challenges. Development work on selective breeding for more robust strains, for better temperature and disease resistance, is anticipated and already initiated. One of the biggest challenges facing the future world aquaculture industry is access to proteins, minerals, and omega 3 fatty acids. More than 85% of the world's fish stocks are already fully exploited, hence increasing the use of wild-caught fish as ingredients in the aquaculture fish feed is no longer possible. Seventy % of the ingredients in the feed fed to Atlantic salmon have already been replaced by plant sources. Climate changes could also reduce the agricultural production of soy, corn, and other ingredients that today's fish feeds rely upon, hence the industry has to search for new and sustainable resources to produce cultured fish, such as algae, in the future. The industry is in need of innovative solutions to solve this urgent challenge. Infrastructure for marine farms will be another area for investigation, particularly given the pressure to develop 'off-shore' facilities for fish, closed systems, and IMTA farming as well as species at lower trophic levels. However, lower trophic level species may be more affected by climate changes. Currently, there is evidence for the dependency on stable climate conditions for mussel settlement, growth rate, and quality (meat yield). Climate changes may affect production through differences in nutrition, frequency, and intensity of harmful algal bloom events while ocean acidification may reduce growth through reduced calcification of mussels in general. Thus, the technology for closed systems, more robust systems, systems for new species, and new operating conditions for offshore farms raise new challenges and risks, while knock-on effects will be reflected in ensuring worker safety and insurance rates. New technologies for distance management (with new ICT solutions and satellite monitoring) of farms are anticipated. A core challenge to aquaculture in this regard comes from understanding and anticipating the effects of gradual change as opposed to extreme events" (ClimeFish 2019). Similarly, the CERES project states the objectives of the project as; "CERES advances a cause-and-effect understanding of how climate change will influence Europe's most important fish and shellfish resources and the economic activities depending on them. CERES will provide tools and adaptive strategies allowing marine and inland fisheries and aquaculture sectors and their governance to prepare for adverse changes or future benefits of climate change" (CERES 2019).

The above-mentioned projects are in line with the general EU Climate Change Adaptation Strategy, where authorized multidisciplinary stakeholder participation is the key approach; "In 2013, the European Commission adopted an EU strategy on adaptation to climate change, welcomed by the EU Member States. The strategy aims to make Europe more climate-resilient. By taking a coherent approach and providing for improved coordination, it aims to enhance the preparedness and capacity of all governance levels to respond to the impacts of climate change".

The EU Adaptation Strategy focuses on three key objectives;

- "Promoting action by the Member States: The Commission encourages all Member States to adopt comprehensive adaptation strategies (currently 25 have strategies) and provides funding to help them build up their adaptation capacities and take action. It also supports adaptation in cities through the Covenant of Mayors for Climate and Energy initiative".
- "Climate-proofing' action at EU level by further promoting adaptation in key vulnerable sectors such as agriculture, fisheries, and cohesion policy, ensuring that Europe's infrastructure is made more resilient, and promoting the use of insurance against natural and man-made disasters".

- “Better informed decision-making by addressing gaps in knowledge about adaptation and further developing the European climate adaptation platform” (Climate-ADAPT 2019).

It is imperative that a sustainable national climate change strategy on aquaculture needs to take a sensitive approach with respect to specific regional, locational, administrative, spatial, economic, social, strategic, logistics, species, culture method, and technique differences and conditions. Nevertheless, there are some general guidelines that can be adjusted to the specific prevailing and projected conditions. Some examples of multiple positive effect mitigation and adaptation actions to be planned and implemented through the combined efforts of the authorities and primary stakeholders in aquaculture, both hard and soft, could be listed as follows;

- Implement environmental monitoring, indicator selection, risk assessment, early warning systems, and emergency response plans to prepare for irregular changes in the frequency, duration, and intensity of extreme weather events with projected impact on the aquatic resources and ecosystems
- Plan and implement aquatic health monitoring, indicator selection, negative impact prevention, rehabilitation, and quarantine measures
- Plan and implement fisheries, aquaculture, water resources, and aquatic ecosystems’ Climate Change adaptation and resilience-building programs and intervention measures
- Plan and implement diversification and/or integration of holistic fisheries and aquaculture activities into national sustainable development plans, spatial planning activities, and aquatic resource utilization projects
- Assess, plan and implement alternate aquatic species' utilization potentials, waste management, energy efficiency, and renewable energy alternatives, processing, storage, and marketing channels
- Integrate into the relevant legislation best practices for responsible fisheries and aquaculture principles under the ecosystem approach to cover sustainability, resilience, and socio-economically feasible and applicable food security, co-management/ participatory management practices
- Plan, procure, and implement regional and local water basin spatial/tenure planning as well as monitoring, rehabilitation and emergency measures including, but not restricted to, ecosystem and aquatic species diversity, invasive and non-native species, vector-borne diseases, re-stocking, protected areas, aeration, vertical mixing support and/or prevention, shading, artificial reefs, bathymetric deepening, landscaping, riparian vegetation, no catch areas covering breeding grounds and escape areas to deeper water,

removal of migration route obstructions, benthos rehabilitation, sediment catchment basins at input stream-entry points, etc.

- Plan and promote sustainable fishing and aquaculture facilities and activities along with required logistic, legislative, technical, economic, and structural prerequisites
- Conduct and disseminate studies and information on the vulnerability of indicative ecosystems and indigenous species, alternate culture species (based on resistance, ease of culture, marketability, etc.), polyculture, aquaponics, choice of culture systems, site selections, locations, techniques, and Good Management Practices guidelines
- Include in-laws, legislation and policies at all levels, integrated, harmonized, authorized, sustainable and Climate Change resilient aquatic resource utilization measures, guides, incentives, and mechanisms based on local, national and regional assessments, plans and practices
- Integrate into the environment, fisheries, agriculture, and water usage legislation climate change mitigation and adaptation policies. Assure that any aquatic environment-related activity and project planning, affecting primarily the fisheries, will be required to take into consideration climate change and aquatic ecosystem impact assessments and corrective/preventive measures (Ganioğlu 2016).

Consequently, the general initial short-term potential policy action recommendations could be as follows;

- Widespread administrative and technical capacity building activities (pilot projects and training; sustainable action plans; research and innovation; adaptation pathways; project evaluation cycle, project capacity, choice of species, culture method and site selection; financial and social support mechanisms; subsidies and incentives, informational guidance; legal and legislative infrastructure)
- Improvements and support to the supply chain and adequate facility requirements (feed, feed additives, and alternatives, monitoring equipment, activity integration, renovations and rehabilitations, renewable energy, closed and semi-closed system components, processing, cold chain, etc.)
- Support to academia, technical personnel, industry and fishery producer groups
- Strengthening of local, national, and regional cooperation and coordination of aquatic resources related activities.

Proposed road-map for the Turkish aquaculture sector

In light of the preceding general strategy planning framework, some possible activity focused on resilience-building initiatives in the Turkish aquaculture sector could be as follows;

- A detailed and focused guidance paper on alternative choice of species
- Selective breeding of resistant and adaptive strains, genotypes to phenotypes
- Diversified pilot projects and assessment/effect verification/validation studies
- Detailed and focused guidance papers on alternative aquaculture techniques and practices
- Detailed and focused guidance papers on alternative aquaculture environments and materials
- Well-planned risk assessment and management, monitoring, validation, evaluation, interference, mobilization, temporary shut down, correction, precaution, methodology, and protocols
- Detailed and focused guidance papers on alternative maintenance, harvest, marketing strategies
- Detailed and focused guidance papers on alternative choice of feed formulations, raw materials, and production/processing techniques of raw materials and feed additives
- Comprehensive cultured species' health and traceability programs
- Detailed ecosystem and weather information, monitoring and early warning systems
- Detailed and focused guidance papers on diversified alternative logistics.

Conclusion

It can be predicted that both marine and inland freshwater aquaculture in Turkey will be affected by climate change-induced events including surface water warming, sea-level rise, and extreme weather events. It is expected that climate change will have both negative and positive effects on aquaculture. Some aquaculture production characteristics such as food conversion and growth rates and length of the growing season may be affected positively as the higher water temperatures can improve feed conversion ratio and increase growth rates. On the other hand, negative impacts can be related to the physiological stress of fish due to environmental challenges under climate changes such as oxygen depletion in water, sea-level rise, and acidification. Thermal tolerance of fish species produced is likely to be the main criteria affecting aquaculture success. The forecast on fish health in aquaculture under the climate change impacts is uncertain because the current knowledge on potential new pathogen profiles and fish response to these pathogens under the climate change-induced changes are scarce. The interactions of fish health and pathogens associated with climate change are complex issues, leading to imperfect prediction. However, it is clear that allostatic load on fish with adaptation stress to changed environmental conditions will have significant influences on disease pictures in aquaculture. The strategy for sustainable aquaculture should be designed considering the potential positive and negative impacts of climate change on aquaculture production characteristics. Further, in order to have a multi-purpose sustainability strategy for the Turkish Aquaculture sector, especially to assure strengthened climate change resilience, preparations for cooperation and expertise centred, stakeholder and policy supported, thorough scientific analysis and assessment based, a variable term Strategic Action Plan needs to be commenced at the earliest time under the coordination of the highest authority. While a well-defined, competent, and functional stakeholder steering committee is the first step in formulating a sustainable sectoral strategy, support from policy and decision-makers is also essential. In order to secure support from policymakers, the formation of a permanent, multidisciplinary, recognized, influential, respected, financially – scientifically and administratively well equipped, globally attentive yet locally sensitive umbrella stewardship platform seems to be essential.

References

Anonymous (2019a) Fisheries statistics Available at: https://www.tarimorman.gov.tr/sgb/Belgeler/SagMenuVeriler/BSGM.pdf (accessed 01 Aug 2019).

Anonymous (2019b) Climate Change: The challenges for Agriculture. Available at: http://ec.europa.eu/agriculture/index_en.htm (accessed 11 May 2019).

Cannaby, H., Fach, B., Arkin, S., Salihoglu, B. (2015) Climatic controls on biophysical interactions in the Black Sea under present day conditions and a potential future (A1B) climate scenario. *J Marine Systems* 141: 149-166.

CERES (2019) Climate change and European Aquatic Resources. Available at: https://ceresproject.eu/ (accessed on 11 May 2019).

Climate-ADAPT (2019) Available at: https://climate-adapt.eea.europa.eu/about /c-a-strategy-2019-2021-final-jan-2019-docx.pdf (accessed 11 May 2019).

Climefish (2019) Case study fact sheets. Available at: https://climefish.eu/ (accessed 11 May 2019).

Cochrane, K., De Young, C., Soto, D., Bahri, T. (2009) Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530, Rome, FAO, 212 pp.

Daw, T., Adger, W.N., Brown, K., Badjeck, M.C. (2009) Climate change and capture fisheries: potential impacts, adaptation and mitigation. *Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge* 1: 107-150.

De Silva, S.S., Soto, D. (2009) Climate change and aquaculture: potential impacts, adaptation and mitigation. In: Climate change implications for fisheries and aquaculture: overview of current scientific knowledge (eds., Cochrane, K., De Young, C., Soto, D., Bahri, T.). FAO Fisheries and Aquaculture Technical Paper. No. 530. FAO, Rome, pp.151-212.

FAO (2018) Report of the Expert Meeting on Climate Change Implications for Mediterranean and Black Sea Fisheries. Rome, 4 to 6 December 2017. Fisheries and Aquaculture Report No. 1233. Rome, Italy.

Gagliano, M., McCormick, M.I., Meekan, M.G. (2007) Temperature induced shifts in selective pressure at a critical developmental transition. *Oecologia* 152: 219-225.

Ganioğlu, M.B. (2016) Detailed Report on Logical Framework and Background Information on Developing a Sustainable Regional Climate Change Resilience Strategy for the Inland Fisheries of the Central Asia. Available at: Academia edu.com. http://independent.academia.edu/binhanganioglu (accessed 11 May 2019).

GAR. (2019) Global Assessment Report on Disaster Risk Reduction. Available at: https://gar.unisdr.org/report-2019 (accessed 10 Aug 2019).

Gazeau, F., Quiblier, C., Jansen, J.M., Gattuso, J.P., Middelburg, J.J., Heip, C.H.R. (2007) Impact of elevated CO2 on shellfish calcification. *Geophysical Res Letters* 34: L07603.

Georgakopoulou, E., Angelopoulou, A., Kaspiris, P., Divanach, P., Koumoundouros, G. (2007) Temperature effects on cranial deformities in European sea bass, *Dicentrarchus labrax* (L.). *J Appl Ichthyol* 23(1): 99-103.

Handisyde, N.T., Ross, L.G., Badjeck, M.C., Allison, E.H. (2006) The effects of climate change on World aquaculture: a global perspective. Final Technical Report, DFID Aquaculture and Fish Genetics Research Programme, Stirling Institute of Aquaculture, Stirling, U.K., 151 pp. Available at: www.aqua.stir.ac.uk/GISAP/pdfs/Climate_full.pdf

Hidalgo, M., Mihneva, M., Vasconcellos, M., Bernal, M. (2018) Climate change impacts, vulnerabilities and adaptations: Mediterranean Sea and the Black Sea marine fisheries. In: Impacts of Climate Change on Fisheries and Aquaculture: Synthesis of Current Knowledge, Adaptation and Mitigation Options, (eds., Barrange, M., Bahri, T., Beveridge, M.C.M, Cochrane, K.L., Funge-Smith, S. Poulain, F.). FAO Fisheries and Aquaculture Technical Paper, No. 627. Rome, FAO, pp. 139-159.

IPCC. (2013) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds., Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Karvonen, A., Rintamäki, P., Jokela, J., Valtonen, E.T. (2010) Increasing water temperature and disease risks in aquatic systems: Climate change increases the risk of some, but not all, diseases. *Int J Parasitol* 40(13): 1483-1488.

Kır, M., Demirci, Ö. (2018) Thermal tolerance and standard metabolic rate of juvenile European sea bass (*Dicentrarchus labrax*, Linnaeus, 1758) acclimated to four temperatures. *J Thermal Biology* 78(March): 209-213.

Kır, M., Sunar, M.C., Altındağ, B.C. (2017) Thermal tolerance and preferred temperature range of juvenile meagre acclimated to four temperatures. *J Thermal Biology* 65(Feb): 125-129.

King, B.J., Monis, P.T. (2007) Critical processes affecting *Cryptosporidium* oocyst survival in the environment. *Parasitology* 134: 309-323.

Kundzewicz, Z.W., Mata, L.J., Arnell, N.W., Döll, P., Kabat, P., Jiménez, B., Miller, K.A., Oki, T., Sen, Z., Shiklomanov, I.A. (2007) Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (eds., Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E.), Cambridge University Press, Cambridge, UK, pp. 173-210.

Lafferty, K.D. (2009) The ecology of climate change and infectious diseases. *Ecology* 90: 888-900.

Madeira, D., Narciso, L., Cabral, H.N., Vinagre, C. (2012) Thermal tolerance and potential impacts of climate change on coastal and estuarine organisms. *J Sea Research* 70: 32-41.

Marcogliese, D.J. (2008) The impact of climate change on the parasites and infectious diseases of aquatic animals. *Revue Scientifique et Technique (International Office of Epizootics)* 27(2): 467-484.

Mazumder, S.K., De, M., Mazlan, A.G., Zaidi, C.C., Rahim, S.M., Simon, K.D. (2015) Impact of global climate change on fish growth, digestion and physiological status: Developing a hypothesis for cause and effect relationships. *J Water and Climate Change* 6(2): 200-226.

Michaelidis, B., Haas, D., Grieshaber, M.K. (2005a) Extracellular and intracellular acid-base status with regard to the energy metabolism in the oyster *Crassostrea gigas* during exposure to air. *Physiological and Biochemical Zoology* 78: 373-383.

Michaelidis, B., Ouzounis, C., Paleras, A., Pörtner, H.O. (2005b) Effects of long-term moderate hypercapnia on acid-base balance and growth rate in marine mussels *Mytilus galloprovincialis*. *Marine Ecology Progress Series* 293: 109-118.

Miladinova, S., Stips, A., Garcia-Gorriz E., Macias Moy, D. (2017) Black Sea thermohaline properties: Long-term trends and variations. *JGR Oceans* 122(7): 5624-5644.

National Climate Change Strategy 2010-2020 (2010) Republic of Turkey Ministry of Environment and Urbanization, Ankara, 26 pp.

National Climate Change Action Plan 2011-2023 (2011) Republic of Turkey Ministry of Environment and Urbanization, Ankara, 196 pp.

Nyboer, E.A., Chapman, L.J. (2017) Elevated temperature and acclimation time affect metabolic performance in the heavily exploited Nile perch of Lake Victoria. *J Experimental Biology* 220(20): 3782-3793.

O'Shea, T., Jones, R., Markham, A., Norell, E., Scott, J., Theuerkauf, S., Waters, T. (2019) Towards a Blue Revolution: Catalyzing Private Investment in Sustainable Aquaculture Production Systems. The Nature Conservancy and Encourage Capital, Arlington, Virginia, USA.

Pankhurst, A., Ned, W., Philip, L., Munday, B. (2011) Effects of climate change on fish reproduction and early life history stages. *Marine And Freshwater Research* 62: 1015-1026.

Pankhurst, N.W., King, H.R. (2010) Temperature and salmonid reproduction: implications for aquaculture. *J Fish Biology* 76: 69-85.

Pörtner, O.H., Farrell, A.P. (2008) Physiology and climate change. *Science-Perspectives* 322: 690-691

Rombough, P.J. (1997) The effects of temperature on embryonic and larval development. In: Global Warming: Implications for Freshwater and Marine Fish, (eds., Wood, C.M., McDonald, D.G.) Cambridge University Press, Cambridge, pp. 77-223.

Rosa, R., Marques, A., Nunes, M.L. (2012) Impact of climate change in Mediterranean aquaculture. *Reviews in Aquaculture* 4(3): 163-177.

Réalis-Doyelle, E., Pasquet, A., De Charleroy, D., Fontaine, P., Teletchea, F. (2016) Strong effects of temperature on the early life stages of a cold stenothermal fish species, brown trout (*Salmo trutta* L.). *PLoS ONE* 11(5): 1-17.

Sfakianakis, D.G., Papadakis, I.E., Papadaki, M., Sigelaki, I., Mylonas, C.C. (2013) Influence of rearing temperature during early life on sex differentiation, haemal lordosis and subsequent growth during the whole production cycle in European sea bass *Dicentrarchus labrax*. *Aquaculture* 412-413: 179-185.

Shaltout, M., Omstedt, A. (2014) Recent sea surface temperature trends and future scenarios for the Mediterranean Sea. *Oceanologia* 56(3): 411-443.

Williamson, C.E., Madronich, S., Lal, A., Zepp, R.G., Lucas, R.M., Overholt, E. P., Lee-Taylor, J. (2017) Climate change-induced increases in precipitation are reducing the potential for solar ultraviolet radiation to inactivate pathogens in surface waters. *Scientific Reports* 7(1): 13033-13392.

Woodward, G., Perkins, D.M., Lee, E. Brown, L.E. (2010) Climate change and freshwater ecosystems: impacts across multiple levels of organization *Phil Trans R Soc B* 365: 2093-2106

Wild fish communities associated with sea-cage fish farms in the Aegean Sea

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Introduction

Aquaculture, an ancient activity, was primarily for domestic consumption in historic times. In fact, larger farms started to appear in Northern Europe at the beginning of the 20th century (Holmer *et al*. 2008). Marine aquaculture as a part of aquaculture is practised completely or partially with human-made structures (i.e., sea-cages) in the sea (FAO 2018). The real increase in mariculture started in the early 1980s, and total mariculture production of the world reached to 28.7 Mt (36% of total aquaculture production), global production was also recorded for 598 species farmed around the world in 2016. These species include 369 finfishes, 109 molluscs, 64 crustaceans, 7 amphibians, 9 aquatic invertebrates and 40 aquatic algae (FAO 2018). Since the beginning of mariculture in the 1980s, the number of fish farms has been increasing in the Mediterranean Sea (Valle *et al.* 2007), especially in Spain, Greece and Turkey.

Mariculture in Turkey has developed considerably over the past three decades as in other Mediterranean countries. Total marine aquaculture production has increased from 35 to 172.492 mt, in 2017, and sea bass and gilthead seabream are main cultivated species with a total share of 91.6% (TUIK 2018). A total of 425 fish farms (including land ponds and hatcheries), of which 245 sea-cage farms (BSGM 2017) exist in Turkish mariculture sector and most of them are deployed in the Aegean Sea due to convenient areas for aquaculture. Muğla (southern part) and Izmir (northern part) provinces are two main mariculture centres along the Turkish Aegean Sea.

On the other hand, the concerns about the environmental impacts of aquaculture on wildlife have been realized globally. Sea-cage fish farms as a sort of ‘ecological traps’ create a new environment for wild animal populations (Barrett *et al.* 2018). The neologism, caught in an ecological trap, indicates the situation that an animal move in a relatively poor habitat to the other available habitats by choice (Robertson and Hutto 2006). Probably, the primary attractive mechanism is food availability (Barrett *et al.* 2018), second one is nutrient pollution and the others are some losses such as faeces and uneaten foods (Vita *et al.* 2004).

Aquaculture has two-way effects for fishing as negative and positive. In positive side, aquaculture provides the alternative livelihood to fisher folk with postharvest processing, marketing of the products produced by aquaculture and increased fish catch via hatchery-produced fish. On the contrary, aquaculture has negative effect on fisheries such as corruption of fragile natural habitats and sensitive ecosystems (Soto *et al*. 2012).

Pelagic fishes are known to be strongly attracted to floating structures. These floating structures are generally defined as Fish Aggregation Devices (FADs) and floating sea cages can also be assumed as a sort of FADs (Dempster and Taquet, 2004; Sanchez-Jerez *et al*. 2007). Moreover, fish aggregations beneath the sea-cages have been increasing much more by the influence of feeding, such that 2800 times more wild fish (as abundance) in immediate vicinity than in areas without farms were reported (Dempster *et al*. 2002). Around the fish farms, the most abundant families are clupeids, sparids, carangids, mugilids and pomatomids, and this aggregation affects the local ichthyofauna and fisheries. Commercially important fish species (mostly pelagics) are attracted to fish farms and they may be of interest for the local fishermen, however, the effects on stocks are poorly known (Sanchez-Jerez *et al*. 2007; Fernandez-Jover *et al*. 2008). Moreover, if the pelagic fishes aggregated to a fish farm, the predators may come to the area as a secondary attraction effect.

Some of the important issues for coastal and aquaculture management are interactions between predators and aquaculture and its consequences (Díaz López 2017). Beveridge (2001) stated that killing of reared fish, damaging of equipment and escaping of fish from cages can be caused by the predator species (i.e., fish, sea birds, turtles, mammals, squid). This is one of the principal problems at Mediterranean fish farms. However, this interaction between predators and aquaculture are complicated and the animals may react positively (attraction, A) or negatively (repulsion, R) to the fish farms. Callier *et al*. (2018) described “A” mechanisms as (i) FAD effects (i.e., biofouling communities, refuge, shelter for wild population, light and noise), (ii) farm waste effect related to feed waste and faeces, settling of fouling organisms, (iii) benthic effect related to the enhancement of organic matter abundance of benthic invertebrates attracting deposit feeders, and (iv) secondary attraction effect (i.e., predators), while “R” mechanisms were (i) husbandry practices (noise, light related to boating, cleaning), and (ii) eutrophication.

In the Mediterranean Sea, wild fish aggregations are well known around the sea-cages, especially from Spanish coasts (Dempster *et al*. 2002, 2004, 2005; Valle *et al*. 2007; Fernandez-Jover *et al*. 2008; Bacher *et al*. 2012) and Adriatic (Segvic Bubic *et al*. 2011), however, it has not been investigated throughout the eastern Mediterranean, yet. There is only a study on the fishing near sea-cage fish farms in Izmir, north-eastern Aegean Sea; however, it focused on commercially important species captured with fishing gears such as gillnet, trap, handline, spear by sea-cage farmers and artisanal fishermen (Akyol and Ertosluk 2010). As a FAD and secondary attraction effects to the mariculture, this chapter focuses on the wild fish species around the fish farms in the Aegean Sea.

Wild fish diversity around the sea-cage fish farms

A total of 42 species belonging to 24 families (Table 1) were recorded at six fish farms, where three deployed in northern Aegean Sea (NAS) and three in southern Aegean Sea (SAS). Three families, Sparidae (7 species), Carangidae (6 species) and Mugilidae (4 species) being particularly abundant around the sea-cage fish farms. Additionally, two species, monk seal (*Monachus monachus*) and swordfish (*Xiphias gladius*) were observed at the sea surface around the fish farms. In the list, four species, *Siganus luridus, Siganus rivulatus, Stephanolepis diaspros* and *Pempheris rhomboidea* in SAS were Lessepsian fish.

Totally 23 and 35 different species were determined in NAS and SAS, respectively. Total number of taxa observed per season and two areas, NAS and SAS varied between 17 and 32 with lowest taxa during winter in NAS (Figure 1). According to seasons, the most fish diversity was seen in summer, following spring, autumn and winter, respectively. Regionally, SAS shows more intensive fish diversity in all seasons, and *Boops boops* was principle fish that was observed in all seasons throughout the Aegean Sea (Figure 2).

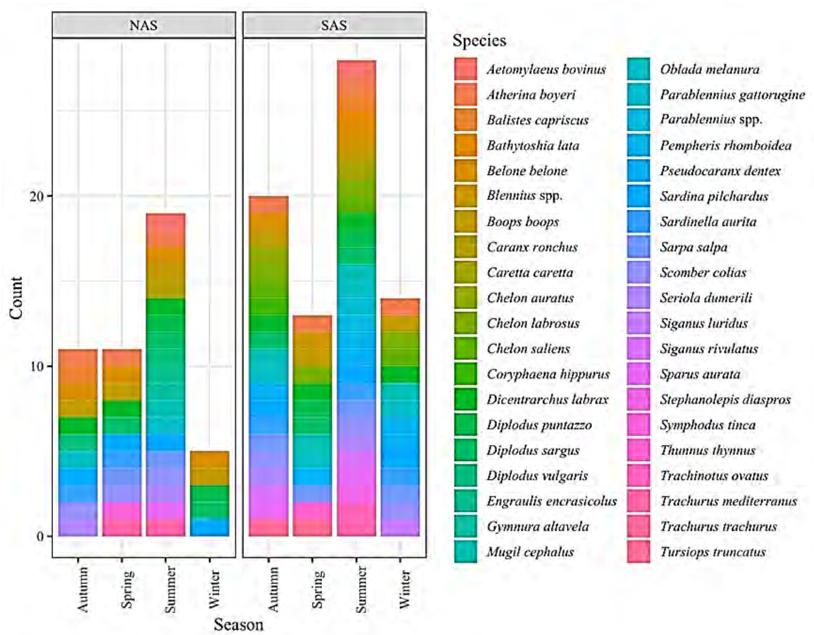

Figure 1. Total number of taxa observed at two main areas and season (NAS; Northern Aegean Sea, SAS; Southern Aegean Sea)

Table 1. Species list of the two years of sampling at different sea-cage fish farms in the Aegean Sea (*Observed at the sea surface around the fish farms) (NAS; Northern Aegean Sea, SAS; Southern Aegean Sea)

Family	Species	SAS	NAS
Atherinidae	*Atherina boyeri*	+	+
Balistidae	*Balistes capriscus*	+	+
Belonidae	*Belone belone*	+	+
Blenniidae	*Parablennius gattorugine*	+	-
	Parablennius spp.	+	-
Carangidae	*Caranx rhonchus*	-	+
	Pseudocaranx dentex	+	-
	Seriola dumerili	+	+
	Trachinotus ovatus	+	-
	Trachurus mediterraneus	+	+
	Trachurus trachurus	+	-
Centracanthidae	*Spicara smaris*	-	+
Cheloniidae	*Caretta caretta*	+	-
Clupeidae	*Sardina pilchardus*	+	+
	Sardinella aurita	+	+
Coryphaenidae	*Coryphaena hippurus*	+	-
Dasyatidae	*Bathytoshia lata*	+	-
Delphinidae	*Tursiops truncatus*	+	+
Engraulidae	*Engraulis encrasicolus*	-	+
Gymnuridae	*Gymnura altavela*	-	+
Labridae	*Symphodus tinca*	-	+
Monacanthidae	*Stephanolepis diaspros*	+	-
Moronidae	*Dicentrarchus labrax*	+	+
Mugilidae	*Chelon auratus*	+	-
	Chelon labrosus	+	-
	Chelon saliens	+	-
	Mugil cephalus	+	+
Myliobatidae	*Aetomylaeus bovinus*	+	+
Pempheridae	*Pempheris rhomboidea*	+	-
Phocidae	*Monachus monachus**	+	+
Scombridae	*Scomber colias*	+	+
	Thunnus thynnus	+	-
Siganidae	*Siganus luridus*	+	-
	Siganus rivulatus	+	-
Sparidae	*Boops boops*	+	+
	Diplodus puntazzo	+	+
	Diplodus sargus	+	+
	Diplodus vulgaris	-	+
	Oblada melanura	+	+
	Sarpa salpa	+	+
	Sparus aurata	+	+
Xiphiidae	*Xiphias gladius**	-	+

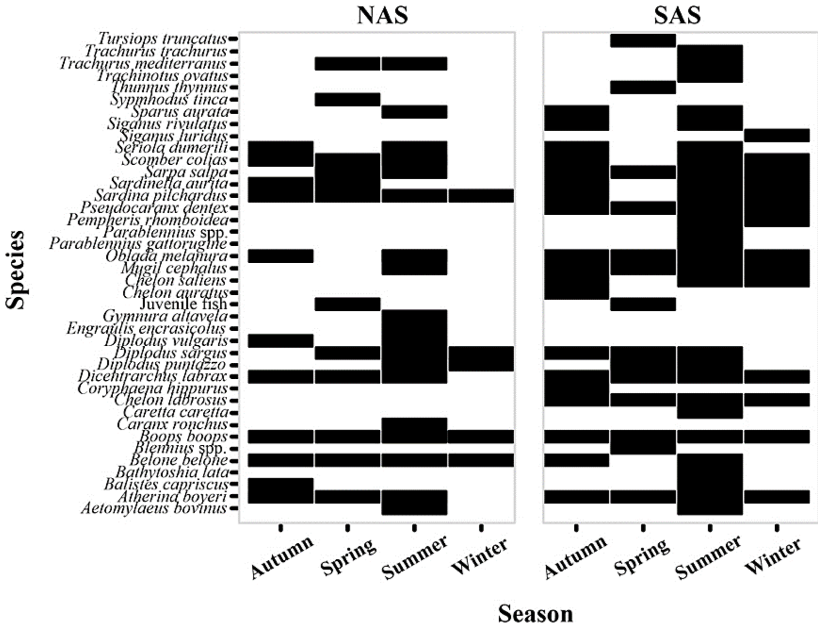

Figure 2. Seasonal distribution of wild species around the sea-cage farms in both regions (NAS; Northern Aegean Sea, SAS; Southern Aegean Sea).

Also, *Boops boops* is the most conspicuous species around the sea-cage farms in the Aegean Sea like the other countries, where mariculture is developed such as Spain, The Grand Canaries and Croatia (Dempster *et al*. 2002, 2005; Boyra *et al*. 2004; Valle *et al*. 2007; Arechavala-Lopez *et al*. 2011; Segvic-Bubic *et al*. 2011; Riera *et al*. 2014). As abundance, *B. boops* had the highest ratio with 80% among the top ten species (Figure 3).

Some interesting species around the sea-cages

Pelagic fishes around the sea-cages attract their own predators such as sea mammals (dolphins and seals), seabirds, sea turtles, stingrays and swordfishes. Besides, some Lessepsian fishes entering via the Suez Canal have been enriching the biodiversity of the Mediterranean Sea for a long time. Some of them can also be observed around the sea-cages along the Aegean Sea.

Swordfish

A swordfish (Figure 4) was observed at a depth of 50 m on April 2016 during its basking behaviour at the sea surface in Gerence Bay, İzmir, northern Aegean Sea. The occurrence of swordfish around the sea-cages is very rare phenomenon. Previously, Arechavala-Lopez *et al*. (2014) reported a swordfish for the first time at a coastal fish farm from SE Spain, western Mediterranean. Therefore, it is the second record throughout the Mediterranean.

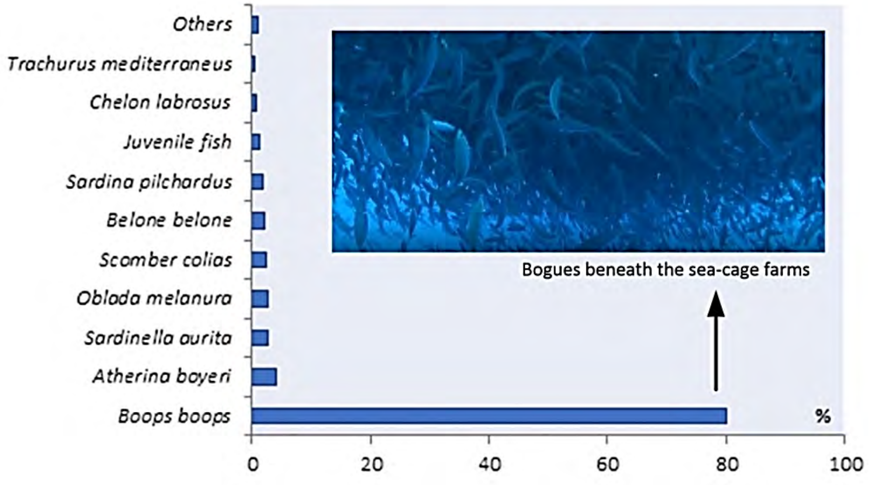

Figure 3. Abundance of top ten fish species around the sea-cage farms in the Aegean Sea

Figure 4. A swordfish, *Xiphias gladius* around the sea-cages (Photo: O. Akyol)

Dolphins

Although the dolphins (herein *Tursiops truncatus,* Figure 5) had the highest interaction rate (68.1%) with sea cage fish farms among the other predators, no attack into the sea-cages has been observed and not reported by fish farmers (Akyol *et al*. 2017). Mostly, dolphin's depredation is concerning with the gillnetters that fishing near the sea-cage farms. Whereas, Díaz López (2006) reported from a fish farm in Sardinia, Italy that bottlenose dolphins were observed damaging the nets in the form of small holes and as an opportunistic strategy, the dolphins were observed biting the nets of the cages.

Figure 5. A bottlenose dolphin, *Tursiops truncatus* around the sea-cages (Photo: T. Ceyhan)

Monk seal

The endangered Mediterranean monk seal, *Monachus monachus*, was observed at various times, especially when swimming around sea-cages in Güllük Bay and occasionally, basking on the cages. An example of this was closely photographed (Figure 6) by an aquaculture technician on 12 February 2017 in Kazıklı Cove, Güllük Bay. Gerovasileiou *et al.* (2017) reported several sightings (n=7) around four sea-cage fish farms, 3 in Güllük, and 1 in Gerence Bays between March 2016 and February 2017 along the Turkish Aegean Sea coasts. Because of the attacks on the fish in cages, the monk seal could be a big problem for the aquaculture. Güçlüsoy and Savaş (2003) reported 40 attacks on 11 fish farms in the Turkish Aegean Sea, which resulted in damage to cage nets and the escape of reared fishes.

Sea turtles

A sea turtle, *Caretta caretta*, was found and photographed while diving around the sea-cages in Kazıklı cove on 29 June 2016 (Figure 7). In addition, a sea turtle specimen was observed from the sea surface on 16 June 2017 off Göltürkbükü fish farm area, Güllük Bay. No attack to the cages has been observed during rapid visual census by SCUBA. It moved away slowly from the sea-cages due to fright from the divers. Staff of aquaculture expressed that sea turtles are usually observed in summer season beneath the sea-cages.

Figure 6. A monk seal, *Monachus monachus* on the sea-cages (Photo: M. Bilgen)

Figure 7. A loggerhead sea turtle, *Caretta caretta* around the sea-cages (Photo: F.O. Düzbastılar)

Stingrays

Aetomylaeus bovinus and *Bathytoshia lata* have been observed around the sea-cage farms. Three specimens of *A. bovinus* have been recorded on 18 July 2017 in Gerence Bay (Figure 8a). Additionally, on 15 June 2017, this species was surprisingly recorded with school of >200 individuals in Güllük Bay. Also, *B. lata*, a rare species of thorny stingrays, was recorded as a single specimen at a depth of 60 m in the Güllük Bay on 30 June 2016 (Figure 8b). Staff of aquaculture stated that stingrays can sometimes be found beneath the sea-cages.

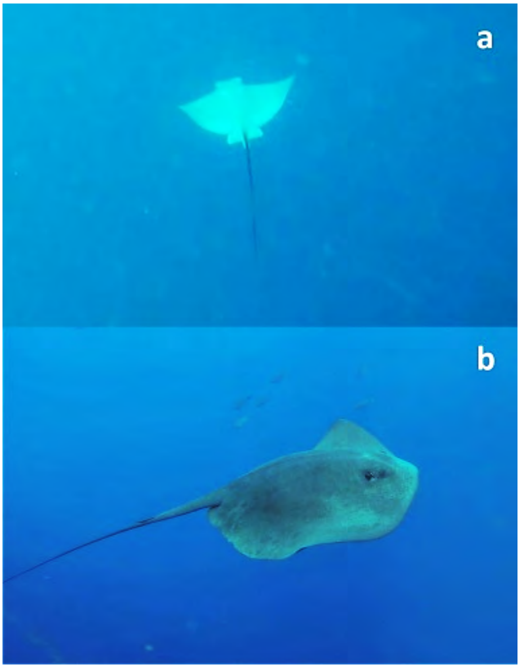

Figure 8. (a) *Aetomylaeus bovinus* and (b) *Bathytoshia lata* around the sea-cages (Photos: F.O. Düzbastılar)

Lessepsian fishes

Four species, *Siganus luridus, Siganus rivulatus, Stephanolepis diaspros* and *Pempheris rhomboidea* are observed around the sea-cage farms in southern Aegean Sea which were Red Sea immigrants (i.e., Lessepsian). These Lessepsian fish species have been recorded for the first time beneath the sea-cage farms throughout the Mediterranean. Though top three fish were expected around the sea-cages due to experience from the southern Aegean Sea, one of them, *P. rhomboidea* (Figure 9) was astonishing as a cave dependent species.

Figure 9. Lessepsian *Pempheris rhomboidea* around the sea-cages (Photo: F.O. Düzbastılar)

Seabirds

Around the sea-cage fish farms, 3 seabirds *Phalacrocorax carbo*, *Egretta alba* and *Larus michahellis* were abundantly observed (Figure 10). Cormorant, *P. carbo* from seabirds was more harmful for the sea-cage fish farms than the others. Some of the fish farms take measures against the seabirds via top covering nets (bird nets). The cage top net against seabirds are used especially during winter season when the cormorants and great white egrets enhance their population. Even, some fish farmers stated that cormorants herd sometimes reached to 1500-2000 individuals per day. Sea gulls were harmless due to being unable to grab/carry the big fish in the sea-cages. On the other hand, especially cormorants and great white egrets were being chased off intermittently with firearm via shooting into the air by sound scare.

Fish escapes

There are some reasons for fish escapes that happened by the net damages. The damages can occurred by storms, predator attacks and bites by reared fish. Monk seal and bluefish are responsible for the net damage of sea-cages in the Aegean Sea (Akyol *et al*. 2017). Especially, the increasing abundance of bluefish caused an increase in the damages of sea-cage nets especially in spring season. This net damage caused by bluefish depredation is one of the sources of significant economic losses. The recent study on bluefish attacks conducted in Spain, Italy, Malta and Turkey (Sanchez-Jerez *et al*. 2008) reported that they attacked repeatedly three times a year in Bodrum, southern Aegean Sea of Turkey. In particular, the fish farmers in southern Aegean region claimed that recently Mediterranean monk seal attacks has been increasing significantly. The attacks of monk seal to the sea-cages make them a big problem for aquaculture. Totally 40 attacks which were resulted in damage to cage nets and the escape of farmed fishes on 11 fish farms were reported by Güçlüsoy and Savaş (2003) for the Turkish Aegean Sea.

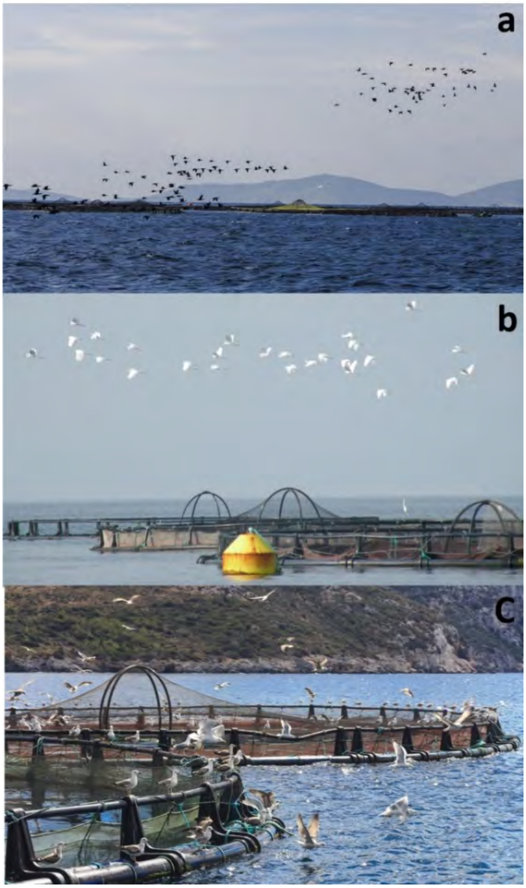

Figure 10. (a) Flocks of *Phalacrocorax carbo,* (b) *Egretta alba* and (c) *Larus michahellis* on the sea-cages (Photos: T. Ceyhan)

After the net damages caused by predator attacks, some of the escaped fish are caught easily by using gillnets of the coastal fishermen (I. Temiztepe and Ş. Kan pers. comm.). However, these escapes are undesirable events that may present unpredictable negative effects to the ecosystem (Courtenay *et al*. 2009). The main fear is that feral farmed aquatic species become established and adversely impact indigenous biodiversity (Beveridge 2001). On the other hand, disease and parasitic contaminations, gene transfer to the indigenous fish stocks are known as high possibilities. Whereas, Izquierdo-Gomez and Sanchez-Jerez (2016) stated that the important role for mitigating the genetic and competition risks occurred by escaped fish from farm could harm fishery operations. For instance, the recapturing over 60% of the biomass following a large escape event of gilthead seabream were performed by artisanal fisheries in the Mediterranean. Clavelle *et al*. (2019) suggest cooperation with local fishermen and this cooperation can serve as an early warning and monitoring system for escapes from sea-cages. Besides the visual difference between wild and reared fish, tags or fin clippings may also be used to ease identification of farmed individuals.

In conclusion, wild fishes, attracted by sea-cages are typical species of the Aegean Sea. Moreover, small scale fishermen want to catch them around the sea-cage area due to ease of finding plenty of fish like the recreational anglers. This state causes some conflicts (Akyol *et al*. 2019). The relationships between aquaculture and coastal fisheries are complex and, therefore, additional processes should be planned to balance the development of aquaculture, to regulate fishing activity and to protect the environment. All stakeholders in particular coastal fishermen must be integrated with a management plan of the Aegean Sea and the cooperation among both fishing groups should be encouraged.

Acknowledgements

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References

Akyol, O., Ceyhan, T., Düzbastılar, F.O., Özgül, A., Şen, H. (2017) Seasonal Variations of Wild Fish Assemblages Beneath the Sea-cage Fish Farms in the Aegean Sea. TUBİTAK Project (No: 114Y584) Final Report, 124 p. (in Turkish).

Akyol, O., Ertosluk, O. (2010) Fishing near sea-cage farms along the coast of the Turkish Aegean Sea. *Journal of Applied Ichthyology* 26: 11-15.

Akyol, O., Özgül, A., Şen, H., Düzbastılar, F.O., Ceyhan, T. (2019) Determining potential conflicts between small-scale fisheries and sea-cage fish farms in the Aegean Sea. *Acta Ichthyologica et Piscatoria* 49: 365-372.

Arechavala-Lopez, P., Izquierdo-Gomez, D., Sanchez-Jerez, P. (2014) First report of a swordfish (*Xiphias gladius* Linnaeus, 1758) beneath open-sea farming cages in the western Mediterranean Sea. *Mediterranean Marine Science* 15: 72-73.

Arechavala-Lopez, P., Sanchez-Jerez, P., Bayle-Sempere, J., Fernanez-Jover, D., Martinez-Rubio, L., Lopez-Jimenez, J.A., Martinez-Lopez, F.J. (2011) Direct interaction between wild fish aggregations at fish farms and fisheries activity at fishing grounds: A case study with *Boops boops*. *Aquaculture Research* 42: 996-1010.

Bacher, K., Gordoa, A., Sagué, O. 2012. Spatial and temporal extension of wild fish aggregations at *Sparus aurata* and *Thunnus thynnus* farms in the north-western Mediterranean. *Aquaculture Environment Interactions* 2: 239-252.

Barrett, L.T., Swearer, S.E., Dempster, T. (2018) Impacts of marine and freshwater aquaculture on wildlife: A global meta-analysis. *Reviews in Aquaculture* 1-23.

Beveridge, M.C.M. (2001) Aquaculture and Wildlife Interactions. In: Environmental Impact Assessment of Mediterranean Aquaculture Farms, (eds., Uriarte, A., Basurco, B.), Cahiers Options Méditerranéennes; n. 55. Zaragoza: CIHEAM, pp. 57-66.

Boyra, A., Sanchez-Jerez, P., Tuya, F., Espino, F., Haroun, R. (2004) Attraction of wild coastal fishes to an Atlantic subtropical cage fish farms, Gran Canaria, Canary Islands. *Environmental Biology of Fishes* 70: 393-401.

BSGM. (2017) Fisheries Statistics. GTHB - Balıkçılık ve Su Ürünleri Genel Müdürlüğü, Available at http://tarim.gov.tr/BSGM (accessed 03 Aug 2017).

Callier, M.D., Byron, C.J., Bengtson, D.A., Cranford, P.J., Ceross, S.F., Focken, U., Jansen, H.M., Kamermans, P., Kiessling, A., Landry, T., O'Beirn, F., Petersson, E., Rheault, R.B., Strand, O., Sundell, K., Svasand, T., Wikfors, G.H., McKindsey, C.W. (2018) Attraction and repulsion of mobile wild organisms to finfish and shellfish aquaculture: A review. *Reviews in Aquaculture* 10: 924-949.

Clavelle, T., Lester, S.E., Gentry, R., Froehlich, H.E. (2019) Interactions and management for the future of marine aquaculture and capture fisheries. *Fish and Fisheries* 20: 368-388.

Courtenay Jr., W.R., Collette, B.B., Essington, T.E., Hilborn, R., Orr, J.W., Pauly, D., Randall, J.E., Smith-Vaniz, W.F. (2009) Risks of introductions of marine fishes: Reply to Briggs. *Fisheries* 34: 181-186.

Dempster, T., Fernandez-Jover, D., Sanchez-Jerez, P., Tuya, F., Bayle-Sempere, J., Boyra, A., Haroun, R.J. (2005) Vertical variability of wild fish assemblages around sea-cage fish farms: Implications for management. *Marine Ecology Progress Series* 304: 15-29.

Dempster, T., Sanchez-Jerez, P., Bayle-Sempere, J.T., Giménez-Casalduero, F., Valle, C. (2002) Attraction of wild fish to sea-cage fish farms in the south-western Mediterranean Sea: Spatial and short term temporal variability. *Marine Ecology Progress Series* 242: 237-252.

Dempster, T., Sanchez-Jerez, P., Bayle-Sempere, J., Kingsford, M. (2004) Extensive aggregations of wild fish at coastal sea-cage farms. *Hydrobiologia* 525: 245-248.

Dempster, T., Taquet, M. (2004) Fish Aggregation Device (FAD) research: Gaps in current knowledge and future directions for ecological studies. *Reviews in Fish Biology and Fisheries* 14: 21-42.

Díaz López, B. (2006) Bottlenose dolphin (*Tursiops truncatus*) predation on a marine fin fish farm: Some underwater observations. *Aquatic Mammals* 32(3): 305-310.

Díaz López, B. (2017) Temporal variability in predator presence around a fin fish farm in the northwestern Mediterranean Sea. *Marine Ecology* 38: e12378, pp.1-13.

FAO (2018) The State of World Fisheries and Aquaculture 2018 - Meeting The Sustainable Development Goals. Rome, 210 pp..

Fernandez-Jover, D., Sanchez-Jerez, P., Bayle-Sempere, J.T., Vale, C., Demster, T. (2008) Seasonal patterns and diets of wild fish assemblages associated with Mediterranean coastal fish farms. *ICES Journal of Marine Science* 65: 1153-1160.

Gerovasileiou, V., Akel, E., Akyol, O., Alongi, G., Azevedo, F., Babali, N., Bakiu, R., Bariche, M., Bennoui, A., Castriota, L., Chintiroglou, C., Crocetta, F., Deidun, A., Galinou-Mitsoudi, S., Giovos, I., Gökoğlu, M., Golemaj, A., Hadjioannou, L., Hartingerova, J., Insacco, G., Katsanevakis, S., Kleitou, P., Korun, J., Lipej, L., Michailidis, N., Mouzai Tifoura, A., Ovalis, P., Petović, S., Piraino, S., Rızkalla, S., Rousou, M., Savva, I., Şen, H., Spinelli, A., Vougioukalou, K., Xharahi, E., Zava, B., Zenetos, A. (2017) New Mediterranean Biodiversity Records (July, 2017). *Mediterranean Marine Science* 18(2): 355-384.

Güçlüsoy, H., Savaş, Y. (2003) Interaction between monk seal, *Monachus monachus* (Hermann, 1779) and marine fish farms in the Turkish Aegean and management of the problem. *Aquaculture Research* 34: 777-783.

Holmer, M., Black, K., Duerte, C.M., Marba, N., Karakassis, I. (eds.) (2008) Aquaculture in the Ecosystem. Springer, 324 pp.

Izquierdo-Gomez, D., Sanchez-Jerez, P. (2016) Management of fish escapes from Mediterranean Sea cage aquaculture through artisanal fisheries. *Ocean & Coastal Management* 122(Suppl C): 57-63.

Riera, R., Sanchez-Jerez, P., Rodriguez, M., Monterroso, O. (2014) Artificial marine habitats favour a single fish species on a long-term scale: The dominance of *Boops boops* around off-shore fish cages. *Scientia Marina* 78: 505-510.

Robertson, B.A., Hutto, R.L. (2006) A Framework for Understanding Ecological Traps and an Evaluation of Existing Evidence. *Ecology* 87(5): 1075-1085.

Sanchez-Jerez, P., Bayle-Sempere, J., Fernandez-Jover, D., Valle, C., Dempster, T. (2007) Ecological Relationship Between Wild Fish Populations and Mediterranean Aquaculture in Floating Fish Cages. In: Impact of Mariculture on Coastal Ecosystems, Lisboa, 21-24 Feb., CIESM Workshop Monographs No.32, 86 p.

Sanchez-Jerez, P., Fernandez-Jover, D., Bayle-Sempere, J., Valle, C., Dempster, T., Tuya, F., Juanes, F. (2008) Interactions between Bluefish *Pomatomus saltatrix* (L.) and coastal sea-cage farms in the Mediterranean Sea. *Aquaculture* 282: 61-67.

Segvic Bubic, T., Grubisic, L., Ticina, V., Katavic, I. (2011) Temporal and spatial variability of pelagic wild fish assemblages around Atlantic bluefin tuna *Thunnus Thynnus* farms in the eastern Adriatic Sea. *Journal of Fish Biology* 78: 78-97.

Soto, D., White, P., Dempster, T., De Silva, S., Flores, A., Karakassis, Y., Knapp, G., Martinez, J., Miao, W., Sadovy, Y., Thorstad, E., Wiefels, R. (2012) Addressing Aquaculture-Fisheries Interactions Through the Implementation of the Ecosystem Approach to Aquaculture (EAA). In: Farming the Waters for People and Food, (eds., Subasinghe, R.P., Arthur, J.R., Bartley, D.M., De Silva, S.S., Halwart, M., Hishamunda, N., Mohan, C.V., Sorgeloos, P.), Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand, 22–25 September 2010. FAO, Rome and Network of Aquaculture Centres in Asia-Pacific (NACA), Bangkok. pp. 385-436.

TUIK (2018) Fisheries Statistics in 2017. Available at http://www.tuik.gov.tr (accessed 03 Aug 2018).

Valle, C., Bayle-Sempere, J.T., Dempster, T., Sanchez-Jerez, P., Gimenez-Casalduero, F. (2007) Temporal variability of wild fish assemblages associated with a sea-cage fish farm in the southwestern Mediterranean Sea. *Estuarine, Coastal and Shelf Science* 72: 299-307.

Vita, R., Marin, A., Madrid, J.A., Jiménez-Brinquis, B., Cesar, A., Marin-Guirao, L. (2004) Effects of wild fishes on waste exportation from a Mediterranean fish farm. *Marine Ecology Progress Series* 277: 253-261.

Marketing and economics of aquaculture in Turkey

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Today, the concept of nutrition has become more of an issue particularly in developed countries, and people are more conscious about choosing nutrients that fit better their dietary habits. Among these nutrients, fish provides essential aliments with its high protein content and multiple unsaturated fatty acids in its structure and makes a positive impact on human physiology and metabolic functions. From these aspects, fish is considered as one of the most important nutrients.

Fishery is a key sector that provides continuous input for the global economy, today and in the future, in return for a certain investment and effort. The state of yearly total fisheries production shows that there have been fluctuations in the capture production while aquaculture production has increased more and more over the years. According to the scientific research, the investments in aquaculture are expected to be expanded in the following years, the amount of aquaculture that are produced by farming is expected to be equal to the amount of capture production, and in the long term, the aquaculture sector is expected to surpass capture production by the year 2030. The given situation reveals that the importance of marines and inland waters has been increasing, and aquaculture will be one of the important industry of the future. According to the Food and Agriculture Organization of the United Nations (FAO), global fish production was reported as 171 million tons in 2016. On a country basis, global production is not distributed homogenously and Asia precedes others in the sector. In global aquaculture production, China has the leading position in both capture and aquaculture industry with 66.8 million tones and it was followed by Indonesia, India, Vietnam and the USA (FAO 2018).

China, which is the top producer of aquaculture products, is also the largest exporter of such products. China is followed by Norway, Vietnam, USA and Thailand, and Turkey made 177539 tons of export in 2018. Developed countries are responsible for 75% of total import. The USA has the first place in the import of aquaculture products with 15.2%, and Japan has second place with 103%. In 2018, Turkey made 98314 tons of import (Figure 1).

The current situation of aquaculture products in Turkey and in the world

Turkey has strategic importance due to its geographical location particularly, due to its natural water resources. The length of the coastline of Turkey is 8333 km, and the country has approximately 200 natural lakes with 8903 km², approximately 200 km of streams, 70 000 hectares of lagoon lakes and it has a 25577200 ha aquaculture production capacity in total.

Figure 1. Key exporters of aquaculture products: China, Norway, Vietnam, Thailand, USA, Others (A) and key importers of aquaculture products: USA, Japan, China, Spain, France, Others (B)

Several factors play a role in the increasing attention to aquaculture products; in other words, they play a role in the increasing emphasis on the importance of the sector. Particularly, due to several factors such global warming, decrease in the natural stocks due to the production by hunting, and increasing demand to fish and other aquaculture as a source of animal protein, which has been observed in recent years, the prominence of production by farming has become inevitable.

Aquaculture has a fundamental importance in terms of meeting the demand, having balanced and healthy nutrition, reducing the hunting stress on natural fish stocks, creating employment, ensuring opportunities for high rates of export and foreign exchange inflow, and contributing to rural development.

Based on the 2016 data, the total aquaculture production was 170 995 437 tones. Accordingly, 80 071 894 of the total production was obtained from farming and 90 923 545 tones were obtained from hunting (Table 1) (BSGM 2019).

Table 1. Global production of capture and aquaculture products (BSGM 2019) (x1000)

	Capture (Tonnes)			**Aquaculture (Tons)**			**Total**
	Marine	**Inland**	**Total**	**Marine**	**Inland**	**Total**	
2010	7782	11271	89099	22310	36790	59100	148200
2011	82623	11124	93747	23366	38698	62065	155813
2012	79179	11630	91350	24707	41948	66655	158005
2013	80899	11687	92586	35536	44686	70223	162810
2014	81564	11895	93460	26727	47104	73832	167292
2015	81179	12525	93704	27879	48761	76641	170345
2016	79288	11635	90923	28703	51368	80071	170995

In Turkey, the aquaculture sector meets the need for a high-quality protein of society and adds value to the national economy by exporting a substantial part of the production. Furthermore, we are proud of our country and the sector that the first animal product that could be exported to the European Union, which is one of the most important foreign markets, included aquaculture products, and particularly cultured fish.

The quality and standards provided by the European Union include sensitive and critical values. The exportation of our culture fish to the EU is the most important proof that in our country, cultured fish is produced by complying the required quality and standards that are suitable for human health.

Another issue to be highlighted is the fact that the cultivation and packaging facilities of the firms which export aquaculture from Turkey to the EU are controlled and approved by the EU authorities and Republic of Turkey Ministry of Ministry of Agriculture and Forestry, and published in the Official Journal of the European Union.

Table 2. Production, Export, Import and Consumption of Aquaculture Products (BSGM 2019). (The amount processed in fish flour and fish oil companies)

Years	Production (ton)	Export (ton)	Import (ton)	Consumption (ton)		Wastage (ton)	Co. Per. Capita (kg)
				Domestic	Fish Meal		
2000	582376	14533	44230	538764	71000	2309	8.0
2001	594977	18978	12971	517832	62755	8393	7.5
2002	627847	26860	22532	466289	156000	1230	6.7
2003	587715	29937	45606	470131	120000	13253	6.7
2004	644492	32804	57694	555859	105000	8523	7.8
2005	544773	37655	47676	520985	30000	3809	7.2
2006	661991	41973	53563	597738	60000	15843	8.2
2007	772323	47214	58022	604695	170000	8436	8.6
2008	646310	54526	63222	555275	95742	3989	7.8
2009	622962	54354	72686	545368	90211	5715	7.6
2010	653080	55109	80726	505059	168073	5565	6.9
2011	703545	66738	65698	468040	228709	5756	6.3
2012	644852	74007	65384	532347	94201	9682	7.1
2013	607515	101063	67530	479708	87896	6378	6.3
2014	537345	115682	77545	420361	73667	5180	5.5
2015	672241	121053	110761	479741	176138	6070	6.1
2016	588715	145469	82074	426085	93096	6139	5.4
2017	630820	156681	100444	441573	130917	2093	5.5
2018	-	177539	98314	-	-	-	-

The decrease in the hunting stocks in our waters, which is also evident in other countries, has raised the importance of aquaculture production. As reported by the Turkish Statistical Institute in the table titled 'Aquaculture Production in Turkey', while the amount of aquaculture produced by hunting has been decreased by 30% from 2000 until now, production by farming has been increased by 250%, from 79 metric tons to 276 metric tons. Another important issue is that the coverage ratio of total farming was around 13% in the same year and today it has been increased to 44% (Table 2).

Although the salmon is among the most consumed and imported sea products in the world and in Europe, the attention on seabass and seabream have been increasing year by year. Processed seabass and seabream are put on national and international markets as fresh / refrigerated fish or as a fish fillet. England, France, Spain, and Italy are the largest consumers of sea fish and they are important markets for seabass and seabream. The production made by these countries is insufficient for meeting their demands (Figure 2). The leading producers are Turkey and Greece and the countries are followed by Italy and Spain.

Figure 2. The export of aquaculture products from Turkey according to countries: Spain, Russia, Japan, Germany, England, Italy, Holland (A) and the import of aquaculture products of Turkey according to countries: China, Seychelles, Iceland, Morocco, El Salvador, Norway, Spain (B)

Seabass production

Turkey has taken over the leading role in seabass production from Greece in 2009, and the production of the country has been increasing year by year. According to the recently published data on 2020, Turkey has increased its production by 51% in 11 years, and covered 50% of the total production of 208 thousand tonnes (Table 3).

Table 3. European seabass (*D. labrax*) production (tons) (FEAP 2020 European Aquaculture Production Report)

Country	2014	2015	2016	2017	2018	2019
Turkey	74653	77000	72342	84000	75000	105000
Greece	42000	45000	46000	44000	45500	55200
Spain	17376	21324	23445	21269	22460	27335
Italy	6500	6450	6800	5600	7300	7000
Croatia	3215	4075	5310	5616	6220	6089
Cyprus	1817	1725	1442	1500	1500	5000
France	2021	1980	1928	1945	1433	2123
Total	**147982**	**157851**	**157694**	**164631**	**159869**	**208197**

Seabream production

Turkey has also taken over the leading role in seabream production from Greece, which was the top producer until 2015, and covered 42% of the total production of 199.5 thousand tones with 99 thousand tons of production. Turkey has increased the production by 44% and its growth rate has reached to 118% in the last 6 years (Table 4).

Table 4. European seabream (*S. aurata*) production (tons) (FEAP 2020 European Aquaculture Production Report)

Country	2014	2015	2016	2017	2018	2019
Turkey	41873	48000	67612	72000	83000	99000
Greece	71000	65000	59000	51000	61000	65300
Spain	16230	16231	13740	13643	14930	13521
Italy	8200	7360	7600	9000	9700	9100
Croatia	3655	4488	4101	4830	5591	6774
Cyprus	2919	3656	5136	5000	5000	2500
France	1105	1502	1671	1853	1879	2081
Total	**146053**	**147336**	**160056**	**158364**	**182181**	**199476**

Production of aquaculture products in Europe

The table shows that Norway kept the leading position in salmon production, Turkey had the second place with its seabass and seabream based production. Turkey had increased its production by 65% in the last six years and covered 10% of the total production (Figure 3).

Global fish consumption per capita per year was reported as 19.2 kg, as 24 kg in the European Union, 40 kg in Spain, 23.1 kg in Greece, 28 kg in Morocco, 11.2 kg in Egypt, 9.3 kg in Tunisia, and 7 kg in Turkey, which was far below the world average. The fish consumption per capita per year in Turkey points out the growth potential of the sector.

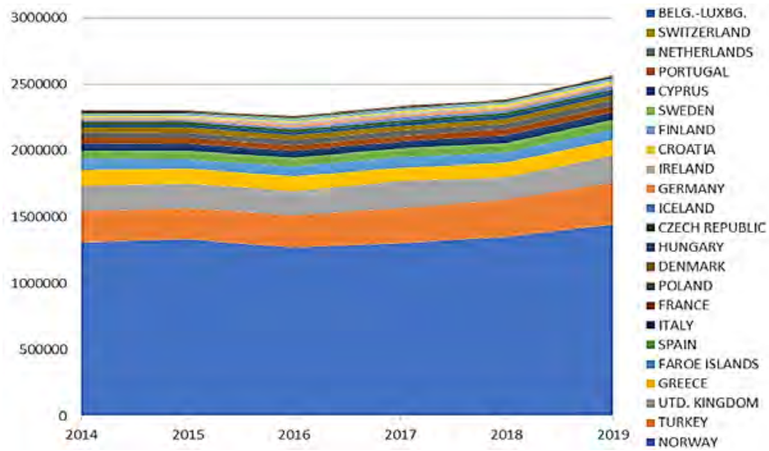

Figure 3. Total production of aquaculture products in Europe (FEAP 2020 European Aquaculture Production Report)

The fishery industry in our country provides employment opportunities for nearly 60,000 people directly, and for 300,000 people indirectly. On the other hand, only culture fishing directly provides employment for 30,000 people. The strategic location and potential of growth in domestic and foreign markets make Turkey an important power and actor in the global aquaculture market. According to the recent report published by the Turkish Statistical Institute, Turkey has achieved growth by 221% by increasing its aquaculture exports from 55,000 tons to 177,000 tons in the last 10 years. Furthermore, Turkey had increased the sum of export from 300 million dollars to approximately 950,000 million dollars and increased the foreign exchange returns by 150%. Turkey's export revenue prediction is above 1 billion dollars in 2019 (Table 5).

The most important foreign markets for aquaculture include the EU countries, Russia, Japan and the USA. The most exported products from Turkey to the EU are seabream, seabass and trout. The European countries, Spain, Italy and Greece are also the competitors of Turkey in cultured sea fish production.

Aquaculture production has an importance in terms of;

- Meeting the rapidly increasing demand,
- Balanced and healthy nutrition,
- Provision of raw material for industrial production,
- Reducing the pressure for hunting on natural fish stocks
- Creating employment,
- Providing foreign exchange inflow with high export potential,
- Contribution to rural development,
- Protection of biological diversity with efficient management of natural resources

Table 5. Turkey's Fisheries Import & Export in Turkey (BSGM 2019)

Years	Export		Import	
	Amount (ton)	Value ($)	Amount (ton)	Value ($)
2000	14533	46374937	44230	36647254
2001	18978	54487312	12971	11295373
2002	26860	96728389	22532	18754783
2003	29937	124842223	45606	32636120
2004	32804	180513989	57694	54240304
2005	37655	206039936	47676	68558341
2006	41973	233385315	53563	83409842
2007	47214	273077508	58022	96632063
2008	54526	383297348	63222	119768842
2009	54354	318063028	72686	105822852
2010	55109	312935016	80726	133829563
2011	66738	395306914	65698	173886517
2012	74006	413917190	65384	176402894
2013	101063	568207316	67530	188068388
2014	115381	675844523	77551	198273838
2015	121053	692220595	110761	250969660
2016	145469	790303664	82074	180753629
2017	156681	854731829	100444	230111248
2018	177539	952001252	98314	188951045

The common problem of all producers: Price of feed prices

One of the main unsolved problems faced by the producers in terms of financial/technical means is the increase in feed prices. In aquaculture, a substantial part of the cost consists of feed. There is a foreign-source dependence on the main inputs of the fish feed include fish flour, soybean flour, corn and gluten. Due to the given reasons, the attention should be focused on the studies on alternative raw materials for feed and protective measures should be taken for maintaining the sustainability of school hunting such as anchovy that is the raw material of fish flour and fish oil. For high-quality feed production, standardization of feed should be ensured.

Main demands of our sector

Discount in sector inputs

The main inputs of the aquaculture are feed and energy. An important part of the raw materials used for producing feed is imported and customs tariff and value-added taxes (VAT) are excised. These rates should be reduced. Furthermore, there should be special discounts and exemptions for energy provision, particularly for electric energy.

New market opportunities

For aquaculture products, which are the only animal products that we can export to the EU, new market opportunities should be created and the sector should be supported in this process. Bilateral and regional agreements should be made to benefits from neighbour counties' market potentials.

Providing insurance for workers who work at sea

The most important problem of the sector is the absence of social security provided for the workers who work at sea, and the relevant financial and non-financial problems they face. Indeed, fatal accidents occur each year. The personnel who work in the sea should be insured against remuneration.

Other predictions

- Reducing VAT rates on fish to 1%
- Building fishing ports to transport fishers
- Gathering the sector under a single roof

Alterations in customer demands

In the previous years, the demand for fresh sea products was higher in comparison to the frozen sea products, particularly in Europe. However, in recent years, more practical and easy foods are preferred due to the changing life practices to save time. Furthermore, modern freezing techniques play an important role in increasing the shelf life of the products. The length of time from the harvest of the fresh products to their delivery is considerably long, yet most of the fish are frosted with slam freezing products that provide a temperature that is far below the temperature provided by home freezers.

The opportunity to store frozen food for a long time, easy processing of frozen food, absence of limitations due to seasons, practicality, preservation of nutritional value, the adaptation to home equipment in freezing, soaking and cooking processes and the ease of use are among the factors that increase the importance of these products. The adjustability of the supply of frozen food products, based on price changes occur in the market, leads to the elasticity of the supply of these products and as a result, the revenue of the producer increases. Frozen food is an attractive field of activity for the industry given that such products have a high added value and suitable for exportation.

One of the most important factors in terms of the development of food technology or a food product is the acceptance of the consumer. Today, food producers are required to satisfy their growing number of conscious consumers. In this sense, the predictions of consumers include the ease of use, quality, and freshness, taste, safety, fair prices, complete and accurate information about the product and a package which is compatible with the product and nature.

Along with the increasing consumption and improving consciousness, global consumers shape the alterations occurring in the food sector. All preferences which have been changing due to the increase in the income of consumers, changes in the demographics and lifestyles and connections between nutrition and health contribute to the new demands of food. At the same time, technological developments that occurred in production, processing and distribution, enlargement of the large-scale retailing, alterations in product availability, and the expansion of the business the world have contributed to the rapidly changing market of food products. The changes occur in the consumption of aquaculture products also reflect the aforementioned changes. The changes in consumption patterns of consumers, changes in new technologies and business, the expanded markets and the exposure of consumers to food-based risks also create new obstacles. The strict quality control requirements of the retailing brocades, the growth of private labels and the development of marketing channels to protect value have become more fundamental in food markets (Jensen 2006).

Features of a product, predictions and the amount of consumption vary between countries. Factors such as the price of fish, importance is given to healthy nutrition, product range and level of education may vary from country to country. The given situation also shapes marketing and sales principles. Such changes have led to the emergence of new concepts in the food sector such as food security, quality, sustainability, animal welfare, and employee welfare (SEDEX).

Quality and food safety

Quality is the standard that provides the attributes which create satisfaction and contentment. It is a quantitative characteristic in terms of physical, chemical micro-biological and affective attributes. Food safety is defined by FAO-WHO Codex Alimentarius Commission of Experts as "Following requirements and taking necessary precautions in production, processing, conservation, and distribution of food to ensure the production of health and ideal food."

Quality assurance is the capacity of goods and services that are offered to fulfil the targeted features and ensure trust. The concept of quality assurance also referred as quality standardization. Quality assurance indicates eligibility check that is addressed from different perspectives such as the appropriateness of raw material and final product to the current standards, design of operating equipment, process line regulation.

In this context, quality assurance is an application that includes packaging, storage and distribution conditions which determine the shelf life of the product in the scope of the examination. The “Hazard Analysis and Critical Control Point System (HACCP)”, “Good manufacturing practice” (GMP), “Hurdle Technology (HT)” and “post-mortem microbiology implementations” (PM) are included in the implementations that ensure product safety in production, storage and marketing (Erkan *et al.* 2008).

Food security indicates the use, preparation and conservation of food in a way to minimize the rates of getting ill from food-based illnesses. Food security is a global issue that comprises different spheres of life. The principles of food security aim to prevent contamination of food and its possible consequences such as food poisoning.

These principles include;

- Proper cleaning and disinfecting of all surfaces, equipment and tools
- Provision of a high level of personal hygiene
- Proper conservation, cooling and warming of food in terms of temperature, environment and equipment
- Implementation of an effective pest control
- Having a good understanding of food allergies, food poisoning and food intolerance.

Considering these principles in the production process has key importance in terms of customer satisfaction and health. Particularly, the chain stores impose severe sanctions on the export-oriented firms. Producers who cannot meet these requirements are not included in supplier lists and their processes are controlled with annual audits.

Impacts of included in certificate of quality on the development, sales and marketing

The certificates of quality in the aquaculture products sector are addressed in terms of farms and processing and packaging facilities as the continuation of the chain. The main certificates of quality for farms include GlobalG.A.P., Friend of the Sea and Good Agricultural Practices, and BRC (British Retail Consortium), IFS (International Featured Standards) for processing and packaging facilities.

Global G.A.P. is an international certificate of good agricultural practice and it was certificated in Turkey in 2011 for the first time for seabream and seabass. The farms that were entitled to receive the certificate are evaluated in terms of different issues such as fish health, product safety, sustainability, impacts of farms on environment, accountability and social rights of the workers, and it is ensured to have a certain quality in terms of their production. The Global G.A.P. Standard requires having the same certificates in the supply chain, such as feed and seed fish. Therefore, in farms that make production with certain standards, each phase of fish production is controlled and therefore, the certificated products are highly demanded in foreign markets.

On the other hand, the certificates for product certification such as BRC and IFS are mainly based on product security. These certificates ensure that the produced fish are safe from the farm to the plate, and the production process meets the requirements. In this way, they also ensure producer firms in terms of product safety and the given situation has significance in terms of customers. The customers buy products from firms that have these certificates to reduce the control of the cost of the controls which they would make. The firms which receive these certificates that provide dual benefit can also predict potential errors that can occur in the production through risk analyses and critical control points, thus they reduce costs of production and customer complaints.

Firms that are certificated by independent third-party auditors are entitled to receive the certificate and they can use the certificate logo in their packages. In this way, the trust and demand of customers, who can see the certificates of the product increase considerably. The standards of the quality certificates are updated as a result of yearly research and new versions are provided. The firms are given a time limit to adopt the new standards. The firms that adopt the new versions are entitled to receive a new certificate.

Certificates of quality that have a key role in the supply chain of aquaculture products that are put on the market as fresh or frozen food enhance the reliability of products for customers. Customers consider certificates of quality as proof that the product was produced without damaging the environment and it was subjected to quality control in each phase of the production. Therefore, the firms that acquired these certificates use the certificates of quality as a tool of marketing.

Today, the amount of exports to Europe and America has been considerably increased and many firms operating in these countries question the existence of these certificates before making a purchase. Many firms that produce aquaculture products in our country have these certificates which are an integral part of the supply chain. At this point, the firms outscore their competitors by demanding spot checks or reaching high certificate scores.

Sustainability

Sustainability is the maintenance of functions of a community, ecosystem or a similar system until an uncertain future without disappearing due to reasons such as contamination of its main resources or overloading. On the other hand, sustainable consumption of sea products can be defined as the consumption of ‘sustainable amounts’.

The contribution of fishery and aquaculture production to the food security and nutrition is a result of the interaction between environmental, developmental, political and governmental issues. The growing global population and the need for nutrition and for meeting the increasing demand of fish creates stress on natural resources and jeopardize the sustainability of marine and inland fishery and also the aquaculture production. Thus issues related to the management of fish value chain become a topic of discussion. There are efforts towards managing this process and as a result, various organizations have been launched. The main organizations include ASC (The Aquaculture Stewardship Council) and MSC (Marine Stewardship Council). ASC (The Aquaculture Stewardship Council), is one of the most prominent aquaculture production and labelling organization which is an independent, international and non-profit organization. The main purpose of the organization is to transform aquaculture production to environmental sustainability and social responsibility by using effective market mechanisms that create value along the chain.

Marine Stewardship Council (MSC) is an organization that aims to maintain the sustainability of the fishery industry. After the approval of MSC, fishery activities are evaluated regularly. Relevant scientific knowledge improves continuously and the fishery industry is encouraged to develop new methods to protect marine resources. Recently, the export-oriented firms that produce via farming or hunting are expected to be included in these certification programs. The regulations on seabass and seabream have been recently published and the firms have started to take necessary actions to increase their sales volume and ensure customer satisfaction.

Animal welfare

Animal welfare is a definition which reflects the quality of animals' life. In a strict sense, the term includes animals' mental and physical health conditions, the status of happiness and long lifespan. In a broad sense animal welfare can be defined as "Ensuring pets', companions' exotic, laboratory and wild animals' happiness and well-being by preventing their pain and suffering during the provision of care, transportation, sheltering, slaughtering, treatment or their use in scientific research". The issue of animal welfare has become a question of debate globally since the beginning of the 1960s. With the impact of these discussions, Universal Declaration of Animal Rights was proclaimed. Until now, the organizations of the European Community and member states have made important steps towards animal welfare and many legal regulations have been put into effect. The judgments, attitudes and expectations of societies regarding animal care and welfare have been changing rapidly. Animal welfare has turned into a sensitive and political issue at the social level.

In line with these developments, many customers demand to know whether animal welfare was considered during the production phase. In terms of farming practices, the latest development is to harvest fishes via electroshock. In this way, fishes are harvested in two seconds without causing any pain and any change in their general living conditions. It is an essential requirement for many store chains in Europe, particularly in England.

Sedex

Sedex/ Smetais a non-profit organization which is dedicated to responsible and ethical work practices. Sedex is a trading community that aims to provide assistance to the development of organizations in terms of ethical trade. Participatory firms are provided an opportunity to connect to the Sedex system via a common database, participate in studies and establish contact with the members. The audit reports of the firms that were a part of the conformity auditing are also accessible for other member firms and the supply chain is created in this way.

Aquaculture production and market predictions

Production

Based on the assumptions on high demand and technological developments, the total production of aquaculture products is expected to increase during the prediction period (excluding aquatic plants) and by the year 2030, it is expected to reach 201 million tonnes.

In comparison to the year 2016, the given numbers point out to a 18% growth rate or a lower rate of annual growth rate (1.0%) compared to the rate that was observed between the years 2003-2016 (2.3%), which is equal to 30 million tons of increase. It is expected that a substantial part of this increase will stem from farming, and the total farming production will reach 109 million tonnes by increasing 37% in 2030, in comparison to 2016.

Prices

The sector is expected to enter into a 10-year period where the higher prices will be observed in terms of a nominal perspective. The factors which affect this trend include increasing population and increasing the price of meat in terms of demand, on the other hand, include the potential decrease in capture production due to the political precautions taken by China, a slowdown in aquaculture production and the cost pressure on certain vital inputs (for example: feed, energy, and crude) in terms of supply. The prices are expected to decrease slightly in terms of the "prediction period" when prices are regulated in real terms based on inflation, yet still remain high. Aquaculture production comprises a large part of the supply, therefore, it may have a strong impact on pricing for the whole sector (both production and trade).

Consumption

The production is expected to show a substantial increase and be consumption-oriented (approximately 90%). The most important factors behind this increase include increasing incomes, increasing production of aquaculture products due to urbanization and improved channels of distribution. The consumption rates are expected to increase by 20% (or 30 million tonnes more in terms of live weight) by 2030 in comparison to 2016. However, the average annual increase rate is expected to be slower (percent +1.2) in comparison to the 2003-2016 period (percent +3.0) due to decreasing production rates, high prices for aquaculture products and a slowdown in the population growth. Regarding the numbers per head, the global consumption of aquaculture products is expected to increase from 20.3 kg (2016) to 21.5 kg in 2030 (FAO 2018).

Trade

The trade of fish and aquaculture products will progress intensely. The predictions show that 31% of the total production will be traded by aquaculture production for human consumption or for non-food consumption by 2030. In terms of the amount, the trade of aquaculture products is expected to grow by 24% within the prediction period and reach to 48 million tons of live weight by 2030 (60.6 million tonnes, in the case that trade within the EU is included). China is expected to be the leading exporter of aquaculture products for human consumption with 20% of export rate and it is expected to be followed by Vietnam and Norway.

General assessment

From past to present, aquaculture products have a key role in human nutrition. However, growing population, excessive and unconscious hunting, and negative environmental factors lead to the rapid decrease of natural fish resources, also extinction of certain species. Although there are efforts to take precautions, as highlighted by experts, the natural fish stocks will not increase at the expected level and the gap that emerges with the decrease in natural fish stocks can only be filled with culture fishing. This shows that aquaculture will be an indispensable industry for the world in the near future.

Important steps have been taken in Turkey in farming systems, the transfer of fish farms in seas to open and deep waters have required the adoption of new and appropriate techniques, and accordingly, improvements have been made in cage structures and sizes, net systems and feeding systems by using technology which was above world standards.

It is accepted that the total amount of production in Turkey by hunting has reached the level of fishable stock size. The priority should be given to research studies on preserving and improving the stocks and enhancing the efforts of protection and control. Therefore, sustainable aquaculture production should be the main policy in Turkey and in the framework of this policy short, medium and long term action plans and objectives should be designed.

The research and field studies have revealed that Turkey has a large capacity for production fields suitable for aquaculture and fishing. A large part of the coasts in Turkey, particularly South Aegean and West Mediterranean coasts, remain within the specially protected environment area. The coasts have many suitable areas where there is no settlement. Macro-scale R&D studies should be conducted to benefit from these idle areas for farming and to increase their contribution to the national economy.

Besides the efficient and productive use of aquaculture facilities, studies should focus on increasing product diversity to make high value-added production. Enhancing the farming of crustaceans and mollusks in Turkey, which have relatively higher marginal revenue compared to fish, should be also emphasized in research studies. Besides aquaculture products, the studies which prioritize the production of byproducts (such as caviar, and raw material for cosmetics and medicine) should be accelerated to enhance the production and expand the market share of the sector.

References

Erkan, N., Alakavuk, D.Ü., Tosun Y.Ş. (2008) Quality assurance systems in food industry. *Journal of FisheriesSciences.com* 2(1): 88-99.

FAO (2018) The State of Food Security and Nutrition in the World 2018. Available at: http://www.fao.org/3/i9553en/i9553en.pdf (accessed 25 Sept 2019).

FEAP (2020) European Aquaculture Production Report 2014-2019: Available at: http://feap.info/wp-content/uploads/2020/10/20201007_feap-production-report-2020.pdf (accessed 25 Sept 2019).

İTO (2016) Aquaculture Sector Report Available at: http://izto.org.tr/demo_betanix/uploads/cms/yonetim.ieu.edu.tr/6414_1536313627.pdf (accessed 25 Sept 2019).

Jensen, H.H. (2006) Changes in seafood consumer preference patterns and associated changes in risk exposure. *Marine Pollution Bulletin* 53(10-12): 591-598.

BSGM (Republic of Turkey-Ministry of Agriculture and Forestry) (2019) Fishery Statistics. Available at: https://www.tarimorman.gov.tr/sgb/Belgeler/SagMenuVeriler/BSGM.pdf (accessed 25 Sept 2019).

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