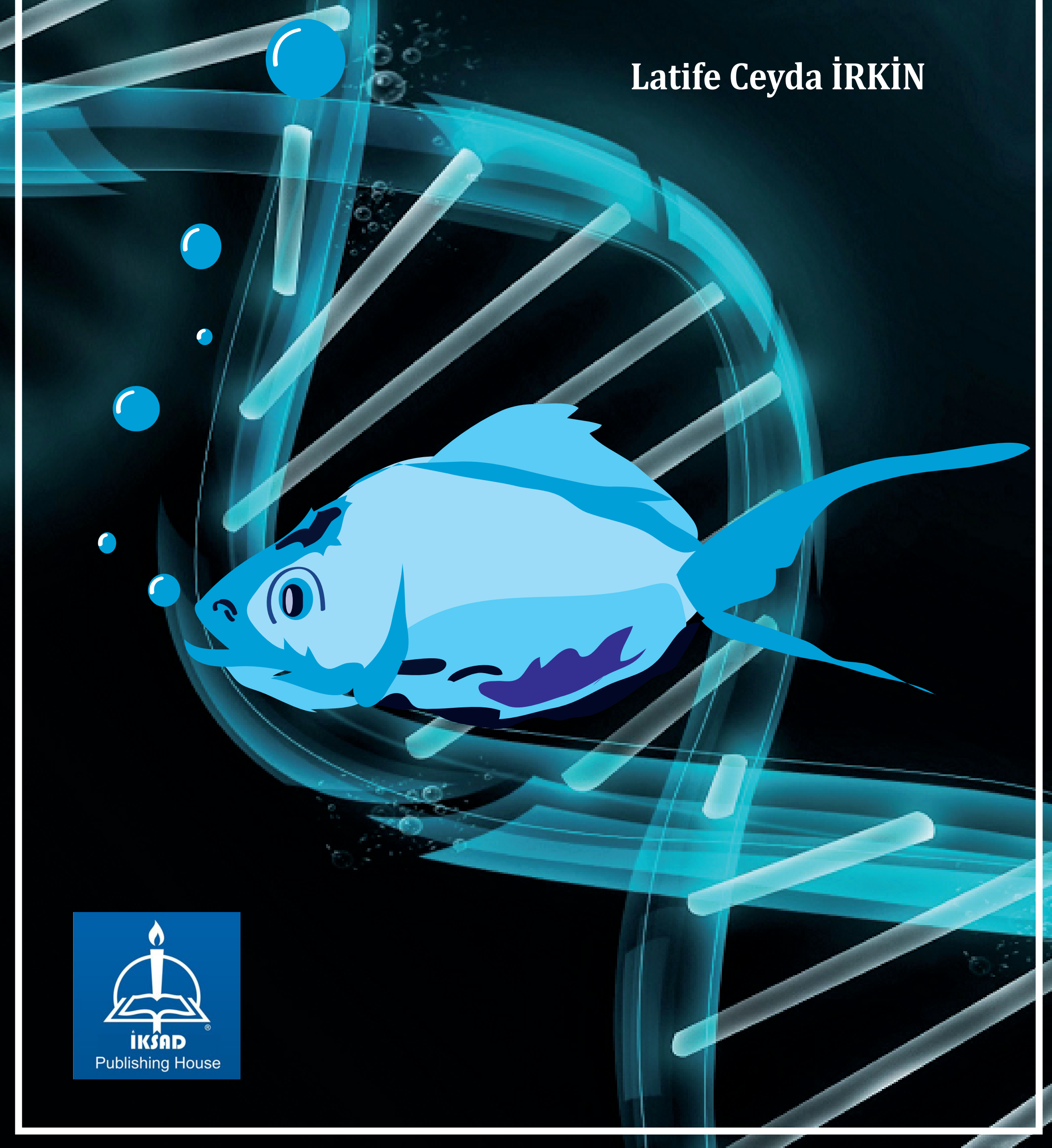
AQUACULTURE and BIOTECHNOLOGY

Latife Ceyda İRKİN



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PREFACE

The aquaculture sector has gained an important place in nutrition as it is an affordable and high quality protein source and has become a rising sector among food products, especially since the 1990s. Demand for seafood, which is an important resource in meeting people's quality protein needs, is increasing day by day. The lack of an increase in aquaculture has made aquaculture a sought-after option.

Benefiting from the latest scientific studies with educated human resources, following international developments closely and benefiting from advanced technologies of many countries are the basis of the rapid development of aquaculture in the world.

Biotechnological applications in the field of aquaculture include chromosome manipulations, sex control, gene transfer, DNA damage and cryopreservation. Biotechnological methods applied in aquaculture provide a positive effect on growth and reproduction rates in living things, and provide a negative return in the emergence of conditions such as disease and DNA damage. In the breeding environment, healthier and more productive individuals are obtained and the genes of the endangered species are taken under protection. Effective use of biotechnological methods in the field of aquaculture as well as in farm animals will contribute to the positive development of the sector and the country's economy.

In the light of these requirements, it was decided to prepare this book in order to contribute to the literature. During my studies, I owe my endless thanks to my friends Dr. Şamil ÖZTÜRK and Lecturer İlhan ÖZDEMİR, my family, who confronted all difficulties with me, who believed and supported me unconditionally in every moment of my life.

Dr. Latife Ceyda İRKİN
February, 2021, ÇANAKKALE

1. INTRODUCTION

Aquaculture is the whole of activities include the cultivation aquatic organisms, including fish, bivalves, crustaceans and aquatic plants. Aquaculture has become a growing sector fastly that has noticeably improved in recent years. Global fish production has increased rapidly especially in the last forty years, contributing significantly to the amount of fish required for the consumption of the world population. The decrease in natural stocks and the increase in interest in fishery products for healthy nutrition play an important role in the aquaculture sector to reach this position. Problems in food demand and high prices will be one of the most important problems we will face in the future. Aquaculture contains important nutrients for global food obtaining and malnutrition. Furthermore aquaculture has a key role in rural economies by creating new job areas. Therefore, to meet the increasing demand for aquaculture products in years, aquaculture production should be increased [1].

Biotechnology is a widely used method in health, agriculture, food and many other industrial fields, using living organisms and building blocks. Biotechnology, which has a great potential in terms of contribution to agricultural production, has become increasingly important in the field of aquaculture in recent years. Biotechnological applications in the aquaculture field include chromosome manipulations, sex control, gene transfer, DNA damage and cryopreservation. Biotechnology makes a significant contribution to the development of aquaculture, fisheries and the food industry. The growing aquatic products and the decline of habitats are encouraging researchers to increase the production of aquaculture and popularize aquaculture with biotechnology. Biotechnology allows scientists to define and combine the characteristics of fish and crustaceans to improve production quality. While biotechnological methods applied in aquaculture provide a positive effect on the growth and reproduction rates of organisms, they show negative effects on the occurrence of diseases and DNA damage. With biotechnology, healthier and more productive individuals are obtained in the breeding environment and the genes of the endangered species are taken under protection. Effective use of biotechnological methods in livestock as well as in the field of breeding will contribute to the positive development of the sector and the economy of countries [2].

The success and development of biotechnology, but the biology, diversity, breeding, physiology of organisms through manipulation, it may be possible when a broad research and knowledge base is available in such areas. The benefits of technological advances cannot be fulfilled independently from basic research. Biotechnological programs must be integrated into a research and must not go beyond the set program in order to be successful [3]. Today, biotechnological applications used in aquaculture are one of the most frequently used methods both in academic institutions. Biotech-based studies include a wide range of applications from microbiology to algae biotechnology, from aquaculture to aquatic diseases, from fish breeding to product development. On the other hand, priority is also given to applications related to biotechnology in the solution of the problems caused by climate change, which has made its effects felt significantly in recent years. Since aquatic and aquatic organisms are the common subject of interdisciplinary studies, they allow researchers working in different disciplines such as biotechnology and molecular-based studies to collaborate.

2. AQUACULTURE

Aquaculture is the cultivation of fish and other aquatic creatures in a controlled or semi-controlled manner for food, stockpiling, ornamental, hobby and scientific research [Çelikkale et al., 1999]. Aquaculture is growing sector and currently accounts for 50% of fish population as food. Aquaculture also means a kind of breeding process to increase production, such as breeding, feeding, protection from predators, and regular stocking. Breeding also refers to the individual or institutional ownership of the stock grown [4, 5].

Aquaculture types include fish farming, shrimp farming, oyster farming, seafood farming, algae and ornamental fish farming. FAO defines aquaculture most directly affected by climate change's impacts. Activities such as algae cultivation are part of mitigating climate change, other types of cultivation have negative effects such as nutrient pollution or disease transmission to wild species [5]. Approximately 580 aquatic organisms are representing a rich genetic diversity. Aquaculture is carried out by both producers in developing countries and multinational companies. Consuming fish is part of cultural traditions and has an excellent nutritional profile in terms of health benefits. Seafood is a very rich food source in terms of protein, vitamins, minerals, fatty acids and micronutrients. Aquatic plants such as seaweed also have an important place in the aquaculture industry in terms of their nutritional and industrial uses. Approximately eighty percent of aquaculture production consists of animals such as herbivorous, omnivorous fish and mollusks. Based on the dynamic performance of the last 30 years and production from fishing, it is inevitable that the aquaculture industry will grow day by day [1].

In the name of a sustainable aquaculture strategy, the farmers should recognize the fact that they gain a fair financial gain from the farm, ensure the equal sharing of benefits and costs, create financial competence and job opportunities, ensure that sufficient foodstuffs are accessible for individuals, manage the environment for the benefit of future generations is extremely important. The ultimate aim here is to develop the full potential of aquaculture. With the increasing income source, societies are enriched and consist of healthier individuals. Fish farms are much more diverse than terrestrial livestock farming. This is because, as there are many species to be put into production, each one has a separate characteristic structure. Some species need a seawater environment, some need fresh water, others brackish water. Although migrating fish such as salmon enter fresh water to spawn, they have to pass into sea water during juvenile and growing periods. While these conditions create a need for fresh water incubators to produce eggs from salmon, it becomes necessary to provide a marine environment for growth. Many species can adapt to different temperatures. Tropical fish are unlikely to survive unless their habitat is artificially heated. Carnivorous fish such as snakes [Anguillidae sp.] And sea bream require a large amount of animal protein in their diet. This situation differs according to omnivorous and herbivorous species. The differences that occur in the early stages of fish's life cause changes in their nutritional needs [5].

Different preferences of different species sometimes allow species to live together in the same environment [polyculture]. The opposite is the monoculture where one species is considered. Sometimes the culture medium is shared with the agricultural area [eg using rice paddies or duck ponds]. Fish farms obtain eggs from mature rootstocks during the production period. The species is then pre-grown by completing the larval stages and finally sent to the market. Alternatively, this chain can be shortened in different ways. It is possible to raise the offspring of the species that cannot be raised in the culture environment by catching from the natural environment. It is even possible for migrating fish to be made juvenile in the culture environment and released to the nature and then to be caught by taking advantage of their instinctive return. This situation is called as culture origin fishery [6].

In areas where regional conditions prevail, the diversity of fish farms varies extensively. This situation can be organized to require extensive, mesocosmic and intensive cultivation and their subcultures. Fish farming in industrial countries with a developed market economy is affected by some or all of the following. Use of suitable units at every stage of production. High stocking amount in order to obtain the product to be put on the market at the maximum rate from the established volume or the production area used. Use of scientifically formulated feed that can meet the nutritional needs of the species in pellet form High level of automation usage in operations such as feeding, grading and harvesting. Ensuring that the production is brought to the market stage by using eggs obtained from rootstock.

Undoubtedly, one of the most important problems of mass is nutrition. An average of 140,000 children are born every day around the world. It is estimated that the world population will exceed 10 billion in 2030. World aquaculture production increased rapidly after World War II and reached from 20 to 65 million tons in the 1970s. Oil crises and global economic recession that occurred in this period put a brake on this rapid increase. In the 2000s, this number reached the 130-140 million band with the increasing use of technology [hunting + aquaculture]. Approximately 30% of this figure is obtained from aquaculture. When the increase continues in this way, it is estimated that the fishery products obtained through aquaculture will be equal to the amount of fishery products obtained by hunting in 2020, and this figure will double in 2040 [7].

6% of the protein used by the world population is met from fish consumption. Total animal protein is obtained from fish at a rate of 24%. Despite the increase in the amount obtained through breeding, different reasons arise in the increase in demand from hunting stocks [8]. Due to the use of the efficiency of the natural stocks in the world at maximum capacity, the demand for obtaining fish from the natural environment cannot be retarded. Societies' understanding of the nutritional value of fishery products and having high feeding criteria for increasing population The 200-mile Exclusive Economic Zone advertisements caused restrictions on fishing, and offshore fishing has turned into an increasingly expensive economic activity. Marine pollution and intensive fishing from the environment have damaged natural stocks and some species have faced the danger of extinction. This situation made it necessary to reinforce these stocks. The increase in market prices as a result of the increase in market demand and the decrease in natural production made breeding attractive. Societies that have become accustomed to fish culture have started to demand fish not only during fishing seasons but also throughout the year. Constant demand depends on the species' habitat and natural conditions. Therefore, the production put to the market is seasonal. In farming, the lives of the living creatures and environmental factors are largely under control. Depending on all these variables, developments in biology, engineering and genetics increase the quality and quantity by solving the problems in aquaculture [9].

3. HISTORY OF AQUACULTURE

The first farmed species is known as cold-water salmon. The first salmon hatchery was established in Germany in 1741, and the breeding of this species has increased with the developing culture systems since this date. The situation indicated by the decrease in the fishing tonnages seen both in our country and on a global scale is that the natural fish stocks in our country and the seas of the world have decreased considerably. Considering the importance of fish in human nutrition and the increasing hidden protein deficit in the world; The role and importance of fish produced in fish farms and aquaculture at this point emerges [10].

The first records of aquaculture was seized in China in 2000 BC. However, in recent excavations, there are documents showing that aquaculture was first discovered by the Egyptians. BC In Ancient Egypt The figures showing people taking tilapia [*Tilapia* sp.] Fish out of the pond around 2500 BC are present in the tomb paintings, and fish drawings were found on the wall decorations [Fig. 1]. Again BC. It is known that controlled oyster [*Ostridea* sp.] Cultivation was practiced on the shores of Japan in 2000. Extensive marine farms on the other hand, for the first time in BC. It emerged in the 6th century. Species belonging to shellfish cultivation BC It was tested in Greece in the 5th century. Studies of sea bass [*Dicentrarchus labrax*], sea bream [*Sparus aurata*], mullet [*Mugil* sp.] And oyster [*Crassostrea gigas*] cultures are found in ancient Rome BC. In 475, Fan Lai presented the first information about carp [*Cyprinidae* sp.] Breeding. There are findings that the Greeks had intensive studies on oyster culture in the 100's BC. At the same time, fish farming is mentioned in the Bible. In the Roman period, aquaculture studies on the coastal area emerged. These techniques form the basis of those currently used in Italy. In the last periods of the Roman Empire, the traces of aquaculture disappeared until the breeding of freshwater fish in central Europe in the 12th century. In the middle ages, carp species stocked for consumption throughout the year are encountered in the aquatic environment around castles and monasteries. Firstly, the cultivated species depends on the salmon [*Salmonidae sp*.] found in cold waters. The first salmon hatchery was established in Germany in 1741 and the breeding of this species has increased with the developing culture systems since that date [11].

Figure 1. The ancient Egyptian people used nets to catch fish [https://www.sd81.bc.ca/aspire/?page_id=2610, Access; 02.02.2021].

The first practices of marine fish farming began in Indonesia around 1400. During this period, milk fish [*Chanos chanos*] juveniles were stocked in coastal ponds. It has continued for many years to raise this fish in the rivers that are connected to the sea in Java island, without entering the environment. Individuals consuming dense algae clusters formed in the aquatic environment continued their development. Later, the fertilization of the ponds increased the feed density in the environment and a new era began. In the following years, modern fish farming was started as a result of external feeding efforts. Even today, the methods applied years ago are still valid. In the 15th century, large-scale extensive aquaculture [valliculture] studies can be found on the Adriatic coasts. The religious ban on eating meat on Fridays has led to the development of fish farming in European culture. In the 19th century, the crustacean culture became up-to-date once again and spread in the western Mediterranean and Adriatic. Developments in marine fish farming began with the introduction of yellow tail [*Seriola quinqueradiata*] fish into breeding in Japan in the 1960s. In the later period, coral [*Pagrus major*] and tuna [*Thunnus thynnus*] breeding were discussed extensively. Modern aquaculture in fish and oysters began some 30 years ago. Many Mediterranean countries have taken part in this development. As of today, Northern Europe has made progress in salmon, and in the 1980s, Mediterranean countries introduced sea bream and sea bass farming to the economic system. Italy has become a leader in the market with its traditional valiculture methods. Aquaculture has improved significantly in many countries compared to the agricultural sector [12].

4. THE ROLE OF AQUACULTURE IN THE WORLD ECONOMY

Hunger caused by malnutrition continues to be an important global problem, especially in rural areas or developing regions [13]. Today, societies are faced with the obligation to provide food and livelihoods to a population of more than 9 billion, while struggling with population growth, the negative effects of climate change and environmental pollution. Since 2016, the record has been broken with 171 million tons, 88 percent of which is presented to consumption, with increasing aquaculture production, more accurate hunting and decreasing waste. With these production figures, it corresponds to the per capita consumption of 20,3 kg of fisheries. This is a positive approach by FAO in terms of achieving a goal without hunger and malnutrition [13].

According to FAO data; Production through fishing in the seas peaked at 86.4 million tons in 1996, and showed a relatively stable course in the following years. In recent years, the total production of marine and inland water fishing has been around 90 million tons. Aquaculture production is continuously increasing and shows the fastest growth among all food products production

[13]. World aquaculture production was 172.7 million tons in 2017; 92.5 million tons [53.6%] of this production was obtained from hunting and 80.1 million tons [46.4%] of it was obtained from aquaculture. While 80.6 million tons of hunting production in 2017 was obtained from the sea and 11.9 million tons from inland waters, 30.6 million tons of aquaculture production was obtained from the sea and 49.5 million tons from inland waters [5]. China has the largest amount of hunting production [16.6% in 2017], followed by Indonesia, India, the United States of America [USA] and the Russia. Ten countries, which hunt over two million tons, accounted for 56.8% of world hunting production in 2017 [5]. FAO fisheries statistics contain data on more than 1,680 marine species. However, 25 main species represent almost 42% of the total fishing. More than half of these species are small pelagics whose production fluctuates greatly due to environmental impacts [13].

In 2017, China [46.8 million tons], which is the country that grows most aquatic products [excluding aquatic plants and non-food products], provided 58.4% of the world's total production alone. China respectively; India, Indonesia, Vietnam and Bangladesh followed suit. The top ten producers realized 88.9% of the world aquaculture production in 2017 [5]. In 2017, 53.4 million tons of world aquaculture production was fish [66.6%], 17.4 million tons mollusks [21.7%], 8.4 million tons crustaceans [10.5%] and 0.9 million tons is composed of other aquatic organisms [1.1%]. On the other hand, the production of aquatic plants [mainly seaweed] reached 32.9 million tons in 2017, of which 31.8 million tons [96.6%] were obtained through cultivation. It is stated that the number of people directly engaged in aquaculture business worldwide is 158 million and the vast majority of them live in developing countries. It is estimated that 38 million of this number work in aquaculture and more than 120 million people live dependent on fishing activities [fishing, processing, trade]. It is assumed that 56 million of those employed in fishing-related jobs are women and mostly work in the processing sector and in small-scale fisheries trade [14].

Figure 2. International examples offer US a blueprint for aquaculture regulation in 2020 [https://foe-us.medium.com/international-examples, Access; 02.02.2021].

Aquaculture represents one of the most commercially traded products of the world food industry. Exports of fish and fishery products obtained from sea and inland waters are very important for the country's economies, especially for many countries as in island countries. Most of the world aquaculture production in 2016 [approximately 35% of live weight] was traded in international marketing channels. The value of world aquaculture exports reached 143 billion dollars in 2016 [13]. In 2016, approximately 71% of the total aquaculture imports were made by developed countries. The USA and Japan together accounted for 25% of total imports. Imports by the European Union [EU] represented 39% of the total world imports [if trade between member countries is excluded, this rate corresponds to 25% of world imports]. The EU still remains the world's largest market. China is the main exporting country, followed by Norway, Russia, Vietnam and the USA. Developing countries play an important role in these exports [Fig. 2]. The share of developing countries in total fishery exports in 2016 is approximately 53% in value and approximately 59% in quantity. The net export value of fisheries products of developing countries increased from 17 billion USD in 1996 to 25 billion USD in 2006 and 37 billion USD in 2016. These figures are also significantly higher than other agricultural products such as rice, coffee and tea [13]. Salmon and trout have become the most important traded products in terms of value since 2013 and accounted for approximately 18% of the total value of fishery products subject to international trade in 2016. The other main product groups of the exported species were shrimp species with approximately 16%, demersal fish with 10% [eg cod, haddock, etc.] and tuna with 9%. China is far ahead in both sides of foreign trade [13].

5. AQUACULTURE IN TURKEY

Seas around Turkey is part of the Mediterranean water system. But these seas differ from each other in terms of ecological, geographic, geomorphological and meteorological features. The difference between the Black Sea and the Mediterranean is more pronounced. This situation is reflected in species diversity and abundance when evaluated in terms of fisheries. Turkey's annual aquaculture production varies according to the year due to the fluctuations in fishery production, water resources between the years 2010-2018 between the years 537-704 thousand tons of aquatic products were produced. Similar to world production; Turkey's aquaculture continues to increase aquaculture production and increases the share of the total production culture. The aquaculture production in Turkey stood at 628 631 tonnes in 2018, 35.3% of the marine fish production, the 9.9% other seafood, constituted 4.8% of inland fisheries and aquaculture products 50%. While the production made by hunting was 314,094 tons, the aquaculture production was 314,537 tons [15].

Turkey Statistical Institute [TSI], according to data of the fishery products made by fishing showed fluctuations since 1989, overall the last 20 years in landings of catches of decreases, it is seen that the undulating but relatively stable trend exhibited in recent years. Turkey hunting in the hunting of seafood production in particular has a lot of important marine fish. In 2018, 90.4% of the total fishing production was obtained from the seas, and 70.7% of the total fishing was marine fish fishing. The prices of small pelagics such as anchovy, sprat, sardine, seafood such as white sand mussel, sea snail, pearl mullet, silver and silvery pond fish, which are mostly hunted in inland waters, are generally low. Depending on these species, although the amount of hunting products is higher, their value is lower than that of aquaculture products. Depending on the increase in production in aquaculture, the total value of aquaculture products increases every year. Production figures are analyzed across Turkey when the majority of anchovy fishing in marine fish species, sardine, horse mackerel, bonito and it appears to form species such as sprat. In the period after 2000, anchovy fishing has constituted a large part of the annual marine fishing production, which varies from year to year, such as 40-75% [15] [Fig. 3].

Figure 3. Fish Aquaculture In Turkey Fish Farm
[https://www.istockphoto.com/tr/foto, Access; 02.02.2021].

The fluctuation in aquaculture from year to year is due to the change in the fishing of migratory marine fish such as anchovy, sprat and bonito, which constitute the vast majority of fishing. The fishing of these fish depends on many environmental factors such as the biology of the fish and the water temperature, and the amount of catching varies from year to year. The important bottom fish in hunting; haddock, red mullet and turbot fish. Demersal fish production is much less compared to pelagic fish [15]. The production of crustaceans and mollusks is also important in seafood fishing, which is mainly composed of marine fish. In 2018, 21.8% of the total seafood fishing production was made up of the other seafood group other than fish. The species with the highest production amount in this group are white sand mussels and sea snails, both of which are caught in the Black Sea. Most hunting is done anchovies in Turkey, sprat, bonito, mackerel, whiting, all in some kind of white clams and sea snails production, some in fishing in the

Black Sea when it is taken into consideration that fished in the Black Sea, the majority seems to have a very important place. In the period after 2000, 70-80% of the total seafood fishing was provided from the Black Sea. Most of the anchovies and sea snails are caught in the Eastern Black Sea, almost all of the sprat are caught in the Sinop-Samsun region in the Eastern Black Sea, and the whole of the white sand mussels in the Western Black Sea. Particularly depending on the anchovy and sprat production amount, 57% of the amount of fish caught in the seas in 2017 and 37% in 2018 was obtained from the Eastern Black Sea. The share of the Western Black Sea in the production of other seafood other than fish was 73% in 2017 and 77% in 2018 with the effect of the production of white sand mussels. The most caught species in inland fisheries are pearl mullet and carp. While carp production has decreased in recent years, there has been an increase in the production of silverfish and especially the silvery crucian fish, which is an invasive species [15, 16].

The share of manufacturing in total aquaculture in Turkey, aquaculture production which stood at 10% in the early 2000s, in 2005 20%, up to 25% on 2010 levels by 2017 in%43,8, while in 2018 50% has reached. This development is similar to the development of aquaculture in the world. While hunting production has fluctuated from year to year, aquaculture production has increased every year after 2002. While farming was carried out in inland waters before, in recent years, aquaculture has increased rapidly. Initially, aquaculture was carried out in inland water resources in soil and concrete pools, and later in net cages in inland water and seas. Mesh cages, which can be set up in a short time, allow production in large capacities. Having more production areas than inland waters, the share of marine production has increased in recent years, reaching 66.6% in 2018 [15].

While trout is the most grown species in inland waters, sea bass and sea bream production stands out. Trout production increased after 2002 and reached 128 thousand tons in 2013. Trout production has been around 110 thousand in recent years. Sea bream production increased slightly after 2002, after a steady development period between 2005-2012, it increased again and reached the level of 76.7 thousand in 2018. Sea bass production, which has been increasing every year since 2002, was 116.9 thousand tons in 2018 [15]. Aegean Region provinces are seen to be prominent in aquaculture. 2018 year of aquaculture production 69% was provided from the Aegean Region. The provinces with the highest share in aquaculture production are respectively; Muğla [36.6%], İzmir [23.9%], Aydın [6.5%] and Elâzığ [5.7%]. Sea bream and sea bass production and therefore marine aquaculture, respectively; Muğla, İzmir and Aydın are in the first place. In trout production and therefore inland water farming, respectively; Muğla, Elâzığ and Tokat are in the first places. The fisheries sector is one of the most important sectors in Turkey's exports. Turkey's export value is increasing every year. Parallel to the developments in aquaculture production and export of aquatic products processing technology in Turkey is also seen a significant increase. In the period after 2000, the increase in exports continued, and imports, on the other hand, showed a partially fluctuating and partially stable course. In terms of quantity, imports in 2010 (80.7 thousand tons) were considerably higher than exports (55.1 thousand tons), while exports in the following years were always higher than imports. Looking at recent years in terms of monetary value; it is always seen that the export value is much higher than the import value. Fisheries exports, which was 27 thousand tons in 2002, increased to 177 thousand tons in 2018, from 97 million dollars in value to 952 million dollars. In the same period, the import of fisheries; While it was 23 thousand tons in 2002, it reached 98 thousand tons in 2018, and the monetary value of imports increased from 19 million dollars to 189 million dollars. When the export-import balance in 2018 is analyzed, it is seen that exports are 79 thousand tons more than imports and 763 million dollars more in monetary value [TUIK, 2019]. The most important export items are the bluefin tuna fish, which are caught with trout, sea bream and sea bass obtained through aquaculture, and then reared in net cages and have high commercial value. Exports are made to many countries of the world. In 2018, exports were to 81 countries, and 60% of exports were to EU countries. The most exported countries are the Netherlands, Italy and Russia [15].

6. MAIN SPECIES CULTIVATED IN AQUACULTURE

Around a hundred different species are currently farmed in aquaculture around the world. Some examples of animals farmed in aquaculture illustrate the wide variety.

5.1. Carp [*Cyprinus carpio*, Linnaeus, 1758]

C. carpio is a species originating from Asia and Eastern Europe. The Romans consumed carp. Carp farming in Europe began in the Middle Ages. Carp is a species that can easily adapt to breeding systems. It is a living thing with a wide ecological spectrum that is tolerant of water quality and temperature. It prefers slow flowing and still waters. It is an omnivorous species; feeds on zooplankton and aquatic plants. The original species is known as "scaly carp" with a large and regularly spaced array of scales [Fig. 4].

Figure 4. Carp [*Cyprinus carpio*, Linnaeus, 1758] [https://www.turbosquid.com/3d-models, Access: 27.01.2021].

Carp is mostly reproduced in hatcheries. When the larvae hatch, they are taken into shallow tanks rich in plankton. Initially, the amount of plankton, vegetation, and benthic invertebrates of the pond is sufficient to feed. Then the creatures are usually fed with coarse grain meal or feed mixes. In the autumn the ponds are cleaned and the fish are moved to a deeper pond [winter pond]. During the coldest times, their feed intake decreases considerably and their activity decreases. The following spring, the carp are transferred to summer pools. In the spring of their third year, carp are now taken into marketing pools. It feeds on food from the natural habitat, but is supplemented with grains [17].

Carp is harvested in the fall [before frost]. It is marketed according to its size. Since the carp is usually sold before Christmas, it is kept in clean, fresh water for several weeks. Thus, its taste is improved. At other times of the year, an increasing amount of carp is harvested. A mature carp can weigh up to 30 kg and measure up to one meter in length. However, the marketing size is 30 to

50 cm long and about 1,5 kg-3 kg in weight. These criteria last about three to four years in European climatic conditions. Carp can be grown in monoculture and polyculture [with other desserts such as pike, catfish or silver carp] also integrated with agricultural activities. Pools where carp are raised are important in increasing biodiversity, landscaping and flood protection. The majority of carp production is provided from farming. 80% of the world's carp production is obtained from China. Other producers are Indonesia, Vietnam, EU, Russia, Bangladesh and Brazil. The largest producers in Europe are Poland and the Czech Republic [18].

5.2. Clam [*Ruditapes decussatus*, Linnaeus, 1758/ *Ruditapes philippinarum*, Adams & Reeve, 1850]

R. decussatus, which is commonly found in Europe, is grown in the Atlantic coast and the Mediterranean Sea of France, Spain, Portugal and Ireland. *R. philippinarum*, known as Japanese clam, is found in Indian Ocean and the Pacific Ocean [Fig. 5]. This species has been known for the past 30 years along the European coastline from England to the Mediterranean. It is the most produced species in Europe and has a settled population in certain regions. Unlike some other bivalve species, this species has two separate sexes. In the spring, breeding can be carried out artificially with high temperatures and abundant food. Oysters extract organic matter and plankton from the environment by filtering them with two siphons [19, 20].

Figure 5. Clam *[Ruditapes philippinarum & Ruditapes decussatus]* *[https://www.discoverlife.org/mp, Access: 27.01.2021].*

In Europe, the vast majority of both European and Japanese oyster seeds are harvested from their natural habitat. In addition, thermal shock ovulation is also produced in hatcheries where stimulation is performed by the addition of sperm. After fertilized eggs are filtered through the net, they are kept in different containers until they become larvae. Oysters feed on microalgae until they undergo metamorphosis. European oysters can be grown in a control feeding system with microalgae. Also, they can be grown in mesh tanks on culture trays. In Italy, this species are mostly grown in wooden frame covered with plastic mesh. In Ireland it is grown in net pocket on trays around low spring tide areas. Oysters must be classified to ensure the size of species. The aim is to prevent competition for food that will cause smaller clams to grow more slowly. In order to grow European oysters, regular maintenance of the substrate is required. Algae and predators [crabs and sea stars] should be abolished and the substrate should get enough oxygen. It is essential to maintain a proper oyster population. Japanese oysters are especially grown in tidal areas protected from extreme conditions. But some oyster pools can be used to produce oysters. Before fertilization, the area should be prepared and cleaned in such a way that predators are away. Oysters are covered with a net that helps protect them from predators. A seeder that plows the nets and sows the seeds at the same time has been developed in Europe. Nets should be cleaned regularly to protect organisms from contamination, siltation, and the entry of predators. Depending on the habitat carrying capacity, oysters can reach a size of about 40mm in about two or three years. Clam seeds are wild-collected in Europe and Japan. In addition, seeds can be produced in hatcheries where ovulation is stimulated by an increase in thermal temperature, increasing the amount of sperm in the environment, or peeling. Fertilized eggs are drained and kept in different pools until the larval stage. Clams are fed with microalgae until they undergo metamorphosis. European oysters are grown in nurseries with the help of a controlled feeding system with micro algae. Another alternative mode of production is to grow in mesh containers on culture tables. In Italy, Japanese oysters are grown underwater in wooden frames covered with plastic mesh. Nurseries in Ireland consist of net bags on coffee tables around the tidal parts [21].

European clam breeding requires regular maintenance of the substrate. Mosses and predators should be removed from the environment and sufficient oxygen should be present in the substrate. It is very important to provide a suitable density. Japanese oysters are grown in areas protected from excessive wind, waves and tides. Also, ponds are used to grow oysters. Before seeding, the environment should be properly cleaned. The environment should be surrounded by a net that will help protect the oysters from predators. In Europe, a machine that drives nets and sows seeds at the same time is used. Nets should be checked and cleaned regularly to prevent siltation and the penetration of predators. Depending on the conditions of the environment, oysters grow to 40mm in about two to three years.

China provides 98% of the clam production all over the world. Other manufacturers are EU and Korea. It can be counted among the major producers from Italy, Portugal, France and Spain in Europe. Production in Italy is carried out in lagoons in the northeast Adriatic and in the Po river delta. A controlled stock management regime is used here. Trade with Europe is very limited, except for imports from South Korea to Spain and Portugal. Small-scale intra-European trade is carried out from France and Italy to Spain [22].

5.3. Mussels [*Mytilus edulis*, Linnaeus, 1758/ *Mytilus galloprovincialis*, Lamarck, 1819]

Mussels can be found in various habitats with wide tolerances [temperature and salinity] to fully submerged regions in tidal zones [Fig. 6]. They feed with phytoplankton and organic matter by constantly filtration of water. For this reason, they prefer water rich in plankton. Water quality is very important in farming. The larval period of the mussels is a mobile period that allows high fertility and wide spread. Mussels produce larvae that move by currents, usually between March and October. In less than 72 hours, the larvae become large and unable to swim. They cling to the environment and their development is provided in this way.

Figure 6. Mussels *[Mytilus edulis & Mytilus galloprovincialis]* *[https://www.discoverlife.org/mp, Access; 02.02. 2021].*

Mussel farming is the largest shellfish activity in Europe. The first farming is in France in 13th century by planting with wooden piles. Farming started with blue mussels [*M. edulis*] on the Atlantic coast, and continued with Mediterranean mussels [*M. galloprovincialis*], which were grown on the Atlantic coast and Black Sea in Spain in the following years. Two species are widely found in natural habitats. Cultivation begins with the collection of mussel seeds from the natural environment and placing them in selected rope nets. Ropes are collected and transported to sheltered growing areas on the shores between May and July. The most common cultivation methods in Europe's coastal areas are:

- Ropes [especially Spain, the Mediterranean, Ireland and England]-Mussels are attached to ropes vertically in a fixed or floating structure in water. Long ropes are used in France, Ireland and Belgium
- Piles [known as 'boats' in France]-In this method rows of wooden piles driven into the lower tidal zone is used. Three to five meters of collecting rope or pipe filled with larvae is wrapped and attached to the stake. The net is laid over the structure to prevent mussels to fall out.
- Plots [Netherlands, Ireland and UK]-Juveniles are spread out over shallow water plots in sheltered areas. The product is harvested at the end of 12 to 15 months.

Worldwide, 95% of aquaculture is mussel farming. China and Europe are the largest mussel producers, others are Chile and New Zealand. Mussels are produced locally in Europe. Chile and New Zealand supply mussels to Europe, and frozen products used in the processing industry are supplied to Europe. Intra-European trade is worth about half the demand in Europe. Exports are made from Spain, the Netherlands and Denmark. The European mussel market is divided into sections with various prices and market periods. Exports to Europe are smaller, especially to Switzerland and Russia [13, 23].

5.4. Oyster [*Ostrea edulis*, Linnaeus, 1758/ *Crassostrea gigas*, Thunberg, 1793]

Today, the indigenous flat oyster [*O. edulis*] culture is produced in limited quantities in Europe. Exploitation and diseases have caused the species became extinct. *C. gigas*, is native to Japan were carried to Europe in 1970 [Fig. 7]. Thanks to rapidly development and adaptation to various environment, Pacific coated oysters are n the most grown species worldwide nowadays, including Europe. Its population in nature began to increase in northern Europe, causing pollution in coastal areas. Oysters are hermaphroditic and they can change sex. First, a male individual is formed and then they mature as a female. Reproduction occurs depending on the temperature and salinity of the water. Before settling, the larvae are located in the pelagic areas and are dispersed by currents. They then change morphologically, assuming the juvenile forms of bivalves. Oysters feed by filtering the water.

Figure 7. Oyster *[Crassostrea gigas & Ostrea edulis]* *[https://www.liveirishshellfish.com/products/pacific-oyster-crassostrea-gigas, Access: 27.01.2021].*

Production begins with the collection of oyster larvae from the natural environment. Collectors placed at important points are used to collect the larvae. When the larvae reach a few millimeters in length, they are removed with collectors and ready to be grown. However, most larvae are obtained from hatcheries. Sea-based facilities are established for this production. As the water temperature rises, oysters begin to release their gametes. The larvae are placed in a closed circuit tank system and fed with algae as food. When the larvae are about to settle on a surface, solid substrates are placed in the tank. The method of growing oysters depends on both environmental conditions [tidal range, water depth, etc.] and traditional conditions. Oysters are produced as a "bottom culture" on the Atlantic coast of France. Oysters are placed in netted plastic bags found in coastal areas. The "bottom culture", which is made by leaving oysters on the shore or under low water, is not used much today. In Spain, unlike France, oysters are cultured with the "hanging culture", which is the way they are grown on a rope. This method is more suitable for non-tidal waters or open sea environments. Another method, 'deep water culture', consists of embankments where oysters can be placed up to ten meters deep. After approximately 18-30 months, oysters reach the desired size. Harvesting method depends on the type of culture. Cultured species are harvested by removing the bags with the help of tripods, except for the dip method. In bottom culture, the grown species are harvested using rake or dredging [if water level allows] when the tide is low. Worldwide, cultivation accounts for 97% of the total oyster production. China is the largest producer with 80% of its total production, followed by Korea, Japan, the USA and Europe. Europe is self-sufficient when it comes to oysters. Intra-Europe trade is very limited. France has the largest market share in Europe [24, 25].

5.5. Atlantic salmon [*Salmo salar*, Linnaeus, 1758]

Atlantic salmon [S. salar] is found in rivers flowing to Europe's North Atlantic coast. Anadrom is one of a kind. It spends the first few years in fresh waters and migrates to fresh waters to breed. However, they mostly live in sea water [Fig. 8]. Spawning takes place between October and January. The eggs are released into gravel beds and fertilized. Fertilization takes place in oxygen-rich waters. Most of the fish die after spawning. Larvae feed on their own reserves for four to six weeks. Later, the larvae feed on insect larvae. The babies, called "Parr", usually live in fresh water for an average of two to five years between March and June until they adapt their physiology to sea water and go through the smog process they migrate to the sea [26].

Figure 8. Atlantic salmon [*Salmo salar*] [https://www.dreamstime.com/salmo-salar-atlantic-salmon, Access: 27.01.2020].

The hatching technique for Atlantic salmon was first applied to stockpiling in the United Kingdom in the 19th century. However, in 1960, adult salmon produced in floating cages was introduced to the market for the first time in Norway. The first part of salmon farming takes place in freshwater. Propagation of Atlantic salmon is under strict control. Eggs are taken from the female individuals and fertilization takes place with the sperm taken from the male individuals. Fertilized eggs are then placed in incubation tanks. The first stage after fertilization takes four to six weeks until the larvae suck the egg sac and become parr. The second stage is taken to parr fresh water tanks [or floating cages in a lake] where the time required for smoltification is one to two years. The fry are then placed in a floating cage and released to the sea. The time required to reach market size [2-5 kg] is two years. Salmon are carnivores. They are fed with fish meal and fish oil pellets. These feeds contain additional ingredients such as vitamins, mineral salts and carotenoid pigments. Worldwide, its culture accounts for two-thirds of the total salmon production. 93% of the main species grown are Atlantic salmon. The main producers of Atlantic salmon in 2009 were Norway, Chile, EU and Canada. Only Atlantic salmon is grown in the EU. The EU imports 80% of the demand from third world countries and 20% from Norway. Imports from China are increasing day by day. Stuffed and frozen Norwegian salmon is produced in China. The main importer countries of Norwegian salmon are Sweden and Denmark. These two countries act solely based on central location and have started to re-export especially to EU markets [France, England, Germany and Poland]. This particular role of Sweden and Denmark explains why the value of intra-EU trade is as important as the value of imports. Raw material from Norway is processed and imported in Poland and Germany. This situation contributes to intra-EU trade. The export price from EU to ABY is not considerable [27].

5.6. Seabass [*Dicentrarchus labrax*, Linnaeus, 1758]

European sea bass [*D. labrax*] is found throughout the Mediterranean, Black Sea and North East Atlantic from Norway to Senegal. They can live in waters up to 100 m depth, in estuaries and in brackish waters in coastal lagoons. Young fish, especially seasonal migrations form flocks. This species feeds on crustaceans, mollusks and fish. In the Mediterranean, males reach sexual maturity in three years and females in four years. In Atlantic, this period can be listed as four and seven, respectively [Fig. 9].

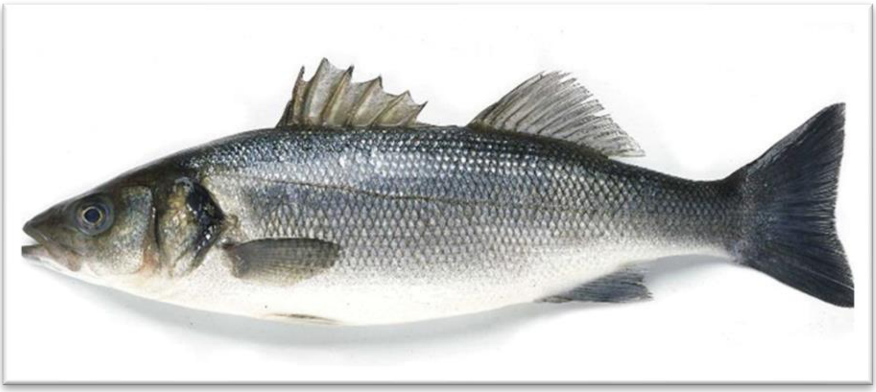

Figure 9. Seabass [*Dicentrarchus labrax*] [http://www.alphasouthsarl.com/fish, Access: 27.01.2021].

Sea bass is grown by traditional methods where fish are allowed to enter lagoons. The entry point of the fish is closed after a certain period of time, as in the "valliculture" used in Italy and "esteros" used in southern Spain, and the fish are confined inside. Imprisoned creatures are fed naturally until they are harvested. In the 1960s, Mediterranean researchers developed intensive breeding methods involving complex incubation techniques. Running a hatchery requires many technical and trained personnel. Hatcheries usually operate independently and sell the larvae to the farms. The reproduction of sea bass can be completely controlled at the facility. The fertilized eggs are collected in the spawning tank, and the hatched larvae are placed in the hatchery tanks. Then the larvae are placed in rearing tanks. After the larvae feed on the sac residues from the eggs, they first feed on micro algae and zooplankton, and a special food containing some artemia. Live feed can be produced in the hatchery. Within a month or two, the larvae begin to get used to the artificial feed and are now taken from their first food to the cutting tank. Later, the fry are transferred to the feeding unit with pellets. They can be transported to farms after two months. Mostly fish are grown in floating cages [Mediterranean and Canary Islands]. In other farms, sea bass is produced in tanks using a recirculation system that generally controls the water temperature. Some facilities use traditional extensive and semi-intensive methods. Sea bass can be harvested when it reaches a weight of 300-500 gram. This situation may take a one or two year depending on the water temperature. The main production method for *D. labrax* is aquaculture medium. More than 10% of the total sea bass production in the world consists of those grown in culture medium. The EU is the largest producer of sea bass with 80% above the second producer [Egypt]. Greece has the largest share in the EU, followed by Spain. Very little export is outside the EU. The majority of imports from third countries comes from Turkey. Importers from Turkey is Italy, Greece and the Netherlands. In Italy, imports meet local demand. However, Greece and the Netherlands prefer to export to other EU countries. Because intra-EU trade is very important for economic balance. At this point, Greece has assumed the role of the biggest exporter in Italy as the biggest importer. It is followed by England, France, Spain and Portugal [18, 28].

5.7. Seabream [*Sparus aurata*, Linnaeus, 1758]

Seabream [*S. aurata*] in culture is the only species grown in large quantities. It is widely cultivated in the Mediterranean and is found in abundant herds along the East Atlantic coast from England to the Canary Islands [Fig. 10]. It takes its name from the characteristic golden line between its eyes. It can survive under difficult conditions in the sea and up to the brackish waters of coastal lagoons. It is generally found more on rocky or sandy ground. As an exception, they can also be found in sea meadows. During the spawning period

[October-December], those who are ready to spawn migrate to deeper waters. With the arrival of spring, the offspring come to the coastal and river mouths. This species is hermaphrodite. In the first and second years of their life, they begin to develop as a male and in the second and third years as a feminine individual. They prefer mollusks, crustaceans and small fish as food [29, 30].

Figure 10. Sea bream *[Sparus aurata] [https://mare.istc.cnr.it/fisheriesv2, Access: 27.01.2021].*

Traditionally, sea bream is heavily grown in coastal lagoons and brackish waters of northern Italy ['vallicoltura'] and southern Spain ['esteros']. It has been successfully reproduced in the 1980s. Systems that provide intensive rearing [especially sea cages] have been developed. For this reason, this species has become one of the important products of aquaculture in Europe. Originally, breeding involved catching young individuals. However, most of the production today comes from the offspring obtained from technologically highly developed hatcheries with the help of qualified personnel. Hermaphroditism requires correct rootstock management. When adults are laying eggs, they prepare by controlling daylight [photo-manipulation] and temperature. Fertilization usually takes place with the female's eggs close to the surface. Fertilized eggs are transferred to the incubation tanks where they hatch within 48 hours. After three to four days, the larvae consume the egg sac and begin feeding. Before training, they are fed first with micro algae and zooplankton, then with artemia and finally with high protein feeds. In coastal lagoons, sea bream is often bred with mullet, sea bass and eel species. They grow naturally in cages or semi-closed systems where natural food is supplemented with feed. In intensive production systems, sea bream is fed with commercial feed in tanks located on land or in sea cages where the majority of its production is located [Mediterranean and Canary Islands]. Individuals who reach the market size after 18 months on average are made ready for trade. Most of the sea bream fish are obtained from aquaculture. The EU is the largest manufacturer in Turkey and is followed him. The largest producer in the EU is Greece. Spain follows Greece. Trade between the EU and third countries is very limited. On the other hand, intra-EU trade is important. Greece is the largest exporter compared to Italy, Portugal, France and Spain [31].

5.8. Sturgeon [*Acipenser baerii*, J. F. Brandt, 1869]

The species belonging to the family Acipenseridae are Siberian sturgeon, Tuna sturgeon, European, Sterlet sturgeon, Common sturgeon and Adriatic sturgeon. Many sturgeon species are threatened with extinction [Fig. 11]. Dams, whose populations cut the migration route, are decreasing day by day due to overfishing and pollution. For this reason, sturgeon farming has positive effects not only for obtaining meat and caviar, but also for restocking and preserving these species. One of the widely grown species in Europe, Siberian sturgeon [*Acipenser baerii*]. The first breeding systems in Siberia were used in the Soviet Union in the 1970s. The first samples were sent to France as part of a scientific cooperation program [32, 33].

Figure 11. Sturgeon [*Acipenser baerii*] [https://mare.istc.cnr.it/fisheriesv2, Access: 31.01.2021].

In the breeding of the Siberian sturgeon, females lay eggs throughout the year. Therefore, by controlling the water temperature, eggs can be obtained from December to May. Siberian sturgeon is raised in artificial channels, circular tanks, pools or cages. They are carnivorous creatures. They feed on feeds containing fish meal, fish oil and vegetable extracts. The average production period of sturgeon is 14 months and it is produced with an average weight of 650-700 gram. Their harvest is done with nets. Caviar production of sturgeon is quite costly. Because Females cannot produce eggs until they are seven years old. During this period, they are grown in tannins containing fresh water. In previous years, females were killed and their caviar was taken in this way. However, in recent years, techniques have been used to get caviar without killing the living creature. In this way, production becomes easier and the cost is reduced. Global sturgeon farming is carried out at very low levels due to stock depletion. Agricultural activities have outstripped fishing. Water accounts for 85% of the total production in Chinese sturgeon farming [34]. Other producers are Russia and the EU. To obtain caviar to preserve Siberian sturgeon stocks. This species is bred in Western Europe. Although statistics on caviar production are not entirely accurate, The value of caviar in sturgeon farming is over 80%. Italy and France are the main caviar producing countries. Thanks to the developments in aquaculture EU gets significant income in exporting caviar to third countries. Most of the intra-EU caviar trade is from Italy to France, Germany and UK [33, 35].

5.9. Trout [*Oncorhynchus mykiss*, Walbaum, 1792]

There are many colored spots on the skin of rainbow trout [*Oncorhynchus mykiss*]. It is one of the most important species grown in fresh water [Fig. 12]. It was brought to Europe from the Pacific coast of America at the end of the 19th century. Today it is grown in many EU countries. Rainbow trout is a species that can withstand extreme conditions. It has a wide tolerance range. It can be found in different habitats by making the transition from freshwater to salt water. But their main habitat is lakes. Reproduction occurs at temperatures below 21°C. Growth and maturation period varies according to water temperature and feeding amount. Under normal conditions, trout mature at the age of 3-4 years. They are carnivorous creatures. They should be fed with foods rich in protein. They reach 350 grams within a year and their weight reaches 3 kg at the end of two years [36].

Figure 12. Trout [*Oncorhynchus mykiss*]
[https://www.pinterest.nz/pin/329748003968395675/, Access: 31.01.2021].

Larvae have yolk sacs for feeding after hatching. They get their first food from this pouch. The pouch is sucked once and the larvae get their energy from there to swim to the surface in search of food. The fry must be fed with small pellet feeds [special feed] containing protein, vitamins and fat. Feeding is done manually to ensure a balanced diet early in the rearing. The fry are then fed with small pellets until they reach 30 grams of weight. Young fish reaching 50 g and 8-10 cm in size are transported to rearing units, either to floating cages in lakes or to tanks. These tanks, usually rectangular, are made of concrete and operate in two techniques: flow path, in the form of an open system through which river water flows from the units through a channel; or with a closed system in the form of recirculation, providing water circulation in the tanks and working with a recycling logic, or a partial recirculation system. The biggest advantage of recirculation is that the water temperature can be controlled throughout the year, thus limiting the waste going to the environment. In addition, trout farming can be done in floating cages in the sea, low salt waters of the Baltic and sheltered waters. In the Scandinavian fjords, the west coast of Scotland, and in Ireland, trout farming in seawater is done following a salmon-like diet. This explains why trout meat grown with this system is pink in color. When the fish reach its commercial weight, trout is collected by net and traded. In the year 2009 the main producers worldwide EU, Chile, Norway was ranked as Turkey and Iran. Today, almost all rainbow trout production in the EU market is provided by aquaculture. The vast majority of EU trout needs are provided locally. The main producing countries in Europe are Italy, France, Denmark, Germany and Spain. Turkey imports mainly [freshwater portion size trout] and Norway [large sea water for trout fillets] and are the main importers took place in Germany and Sweden. The EU exports trout especially from Denmark to countries such as Russia and Switzerland. In trade within the EU, this export is equal to half of the total supply. Among the permanent countries of the market, Poland, Denmark and Sweden are the main exporters; Germany and Finland are the main importers [36].

5.10. Turbot [*Psetta maxima*, Linnaeus, 1758]

Turbot [*Psetta maxima*] is a flat creature in terms of body shape with eyes located on the upper part of its body. It is quite common on the Atlantic coast of Europe, but less common in the Mediterranean [Fig. 13]. It is found at the bottom of sandy and muddy waters, which can be from shallow sections to a depth of 100 meters. It can imitate the ground color it is on very well. The spawning period is from May to July in the Atlantic and from February to April in the Mediterranean. At the end of about two months, with the increase in development, the right eye shifts to the left. This species is a carnivorous creature. Juveniles feed on mollusc and crustaceans. Adult individuals consume smaller fish and cephalopods.

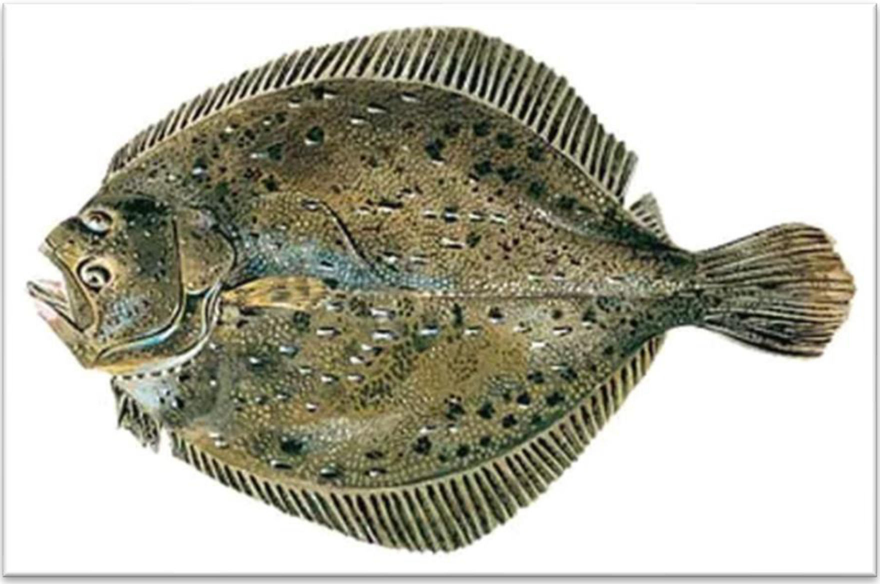

Figure 13. Turbot *[*Psetta maxima*] [Anonymous, Access: 31.01.2021].*

Turbot cultivation started in UK in the 1970s. And then France and Spain started the cultivation. Although turbot is also grown in other EU countries, Spain's Galicia region is the main producer. As with sea bream and sea bass larvae, shield larvae are also produced in technological facilities that require qualified personnel. Controlled breeding is carried out under disciplined conditions. Rootstock individuals are kept in concrete tanks, at low density, under certain light and temperature conditions, and are fed with specially formulated moist feeds. These procedures make it easier to get eggs all year round. Eggs are pelagic and are placed in incubation tanks in the time that elapses until the larvadave hatches. Larvae are grown in semi-dense systems [five larvae per liter] or dense systems [twenty to forty larvae per liter]. When their mouth structure becomes clear, they begin to intake zooplankton and artemia. Phytoplankton is also added to the tanks. Commercial artificial feeding is performed at the end of the second month. Up to 4 months of age, the offspring are fed with dry feed and weigh 5-10 grams. The juveniles are then taken into larger tanks in size so that they can reach a weight of about 100 g for the pre-fattening period. The enlargement process is carried out in circular or square-shaped tanks with a black background that can pump open circuit seawater. The upper part of the tanks is partially covered to protect living things from excessive sunlight. Individual density should be between 20-40 kg per square meter. To a small extent, this species can be produced in recirculating aquaculture systems [RAS]. It takes about 26-30 months for the fish to reach a commercial size of 1.5-2 kg [37].

Turbot cultivation has started in China with rootstock individuals imported from Europe. Before the start of production in China, turbot production was only seen in Europe. According to FAO data, China produces approximately 60,000 tons per year. EU production is around 6,000 tons per year. Within the EU, Spain is the main producer. Recently, developments have been observed in Kalkan production in Portugal. Domestic trade of shields produced in Europe is carried out from Spain to France, Italy and Portugal. This domestic trade covers half of the EU aquaculture production [38].

7. ECONOMIC PROFITS OF AQUACULTURE

Aquaculture, which is among the agricultural production activities, has shown a great development especially in recent years and is the fastest in the world. It is one of the developing sectors. Undoubtedly, for the aquaculture sector to reach this position; reduction of natural stocks and increasing demand for seafood for healthy eating plays an important role. Aquaculture in industrial countries with a developed market economy is under the influence of some or all of those mentioned [Fig. 14]. Among these, the use of units suitable for the purpose during the production phase, the amount of stocking high enough to make maximum use of the established volume or the production area used, the use of scientifically formulated feed that can meet the nutritional needs of the species, the use of high automation in operations such as feeding, classification and harvesting and using the eggs obtained to bring the species to the market stage. It has been known for a long time that seafood has an important share in human nutrition. While aquaculture production was mostly done by hunting in the past, today hunting and breeding are almost close to each other. Population growth, excessive or unconscious fishing and environmental factors have unfortunately led to a decrease in natural fish stocks and even the risk of extinction of some species. Experts also state that although natural resources are limited, some measures have been taken over time, but today the production obtained from nature through hunting cannot be increased more and that the increase in aquaculture production can be closed by aquaculture. Aquaculture is a sector that continues to grow around the world. Aquaculture production has increased 12 times worldwide with an annual average increase of 8.8% in the last 30 years [13]. It is launched by FAO as the fastest growing and continuously growing sector among all food sectors. Turkey is also in question in a similar situation. Turkey's aquaculture production showed a fluctuating exchange with hunting reputation over the years shows a steady increase in aquaculture production.

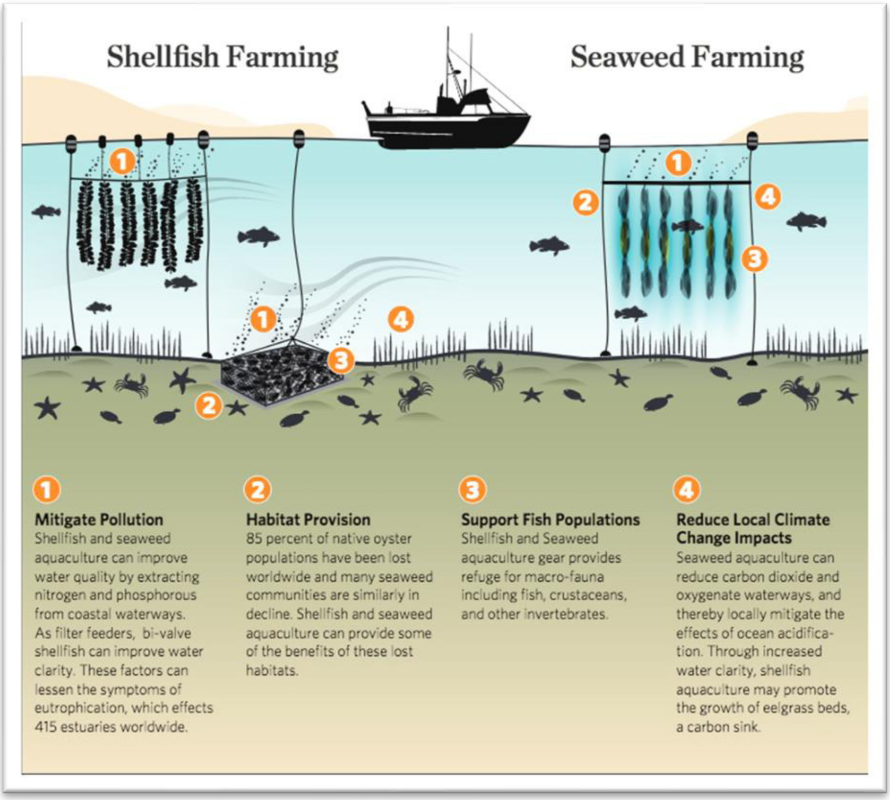

Figure 14. Positive effects of aquaculture [https://www.nature.org/en-us/what-we-do, Access; 02.02.2021].

The total production of marine and inland water fishing in the world has been at a relatively stable level, around 90 million tons in recent years; however, aquaculture production is constantly increasing. World aquaculture production was 172.7 million tons in 2017; 92.5 million tons [53.6%] of this production was obtained from hunting and 80.1 million tons [46.4%] from aquaculture [5].

According to scientific researches, it is estimated that investment in aquaculture will increase further in the coming years, the amount of aquaculture obtained through aquaculture will be equal to the amount of fishery products obtained by hunting in 2030, and in the long term, aquaculture production will surpass hunting production. The importance of the world's seas and inland waters is increasing day by day and shows aquaculture as the sector of the future. However, it is necessary to protect and planned use of water resources with environmental precautions for sustainability [1].

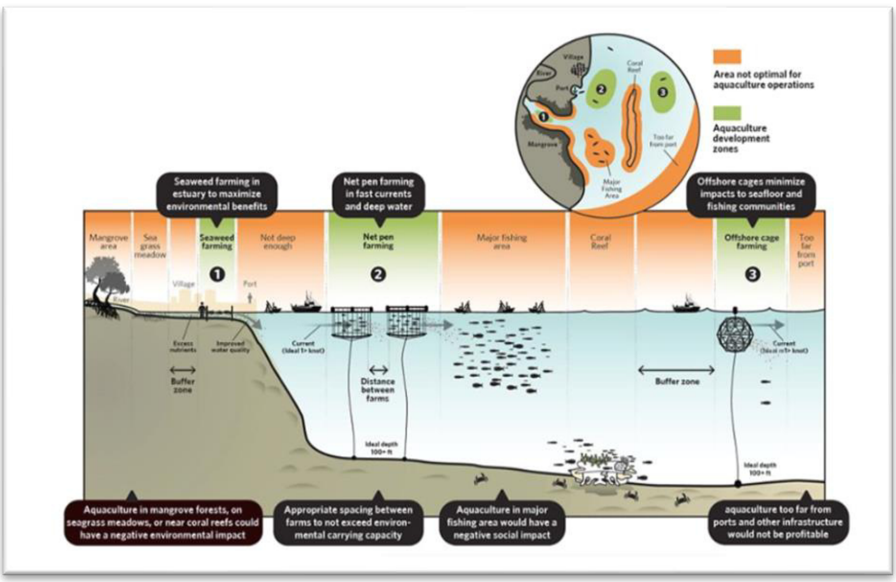

Figure 15. Stages of aquaculture [https://www.nature.org/en-us/what-we-do/our-insights/perspectives, Access; 02.02.2021].

According to the evaluations made by FAO, it is the fisheries sector of the sector that has shown the most development in the agriculture sector in the last 10 years. The main factor in the rapid increase of aquaculture is the increase in the demand for food, especially for protein-based food, primarily with the increase in the world population and also in per capita income. Considering the projection of the population of 7 billion to reach 8 billion in the next 20 years, it is inevitable that the demand for fisheries will increase. There is a huge problem in the world of fisheries resources and their management. Some of these are legal administrative control-supervision problems, and some of them are problems arising from the inability to manage the fishing fleet effectively. The increase in the digital and technological capacity of the fishing fleet in developed and developing countries has brought serious problems in the sharing of limited living resources and fishing revenues. Fisheries authorities state that sustainable production is possible if resources are managed in line with effective management plan. It is expected that aquaculture production will continue to increase in the future and its share in total production will increase. Aquaculture exports will continue to increase in parallel with the developments in aquaculture production and processing technologies. It is estimated that fishing production will be adversely affected and hunting production will not increase further due to possible reasons such as pollution of water resources, deterioration of habitats, increase in coastal areas, climate change, hunting pressure and decrease in fisheries stocks. For this reason, the basic principle of fisheries today is to continue the current production. In order to benefit from aquaculture resources effectively in the future, it is necessary to focus on measures to ensure the protection and sustainable use of resources [Fig. 15] [39].

8. THE FUTURE OF AQUACULTURE

Aquaculture is a sector that continues to grow around the world. Aquaculture production has increased almost 12 times worldwide in the last 30 years, with an annual average increase of 8.8% [13]. The aquaculture industry is introduced by the United Nations Food and Agriculture Organization [FAO] as a rapidly developing and constantly growing sector among all food sectors. In the aquaculture sector, production is carried out through hunting and aquaculture. As the emerging technologies in the world in the last century in Turkey's growing population and demand for animal products, which increased the pressure on fishery resources. As a result, the fact that fishing resources are not infinite, although they are renewable, have been faced. There is a big problem in the world of fisheries resources and their management. Some of them are legal administrative control-audit problems, some of them are caused by the inability to manage the fishing fleet effectively. The increase in the digital and technological capacity of the fishing fleet in developed and developing countries has brought serious problems in the sharing of limited living resources and fishing revenues. Fisheries authorities ensure sustainable production, if resources are managed in line with effective management plans. They state that it is possible.

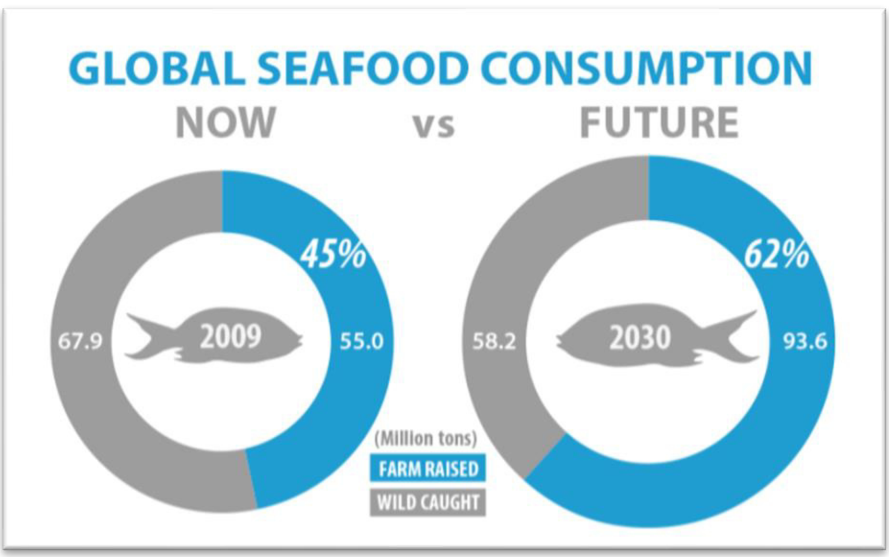

Figure 16. Future of aquaculture [https://farmerscreed.com/blog/the-future-is-in-aquaculture, Access; 02.02.2021].

Many factors such as climate change, changes in environmental factors, destruction by humans in habitats, population growth, excessive and unconscious hunting can adversely affect natural fish stocks. Although some precautions are taken against this situation, it has been adopted by the stakeholders in the sector that the production made by fishing will not increase more and that the increase in production can only be achieved by aquaculture. Undoubtedly, one of the most important problems of mass is nutrition. 6% of the protein used by the world population is met from fish consumption. Total animal protein is provided by 24% from fish. Despite the increase in the amount obtained by breeding, different reasons arise in the increase in demand from hunting stocks; Due to the use of the yield of natural stocks in the world at maximum capacity, the supply of fish from the natural environment cannot meet the demand. Marine pollution and intensive fishing from the environment have damaged natural stocks and some species have faced the danger of extinction. This situation made it necessary to reinforce these stocks. The increase in market prices as a result of the increase in market demand and the decrease in natural production made breeding attractive. Societies that have become accustomed to fish culture have started to demand fish not only during the fishing season but throughout the year. Constant demand depends on the species' habitat and natural conditions. Therefore, the production put to the market is seasonal. In farming, the lives of the living creatures and environmental factors are largely under control. Depending on all these variables, developments in biology, engineering and genetics increase the quality and quantity with each passing time by solving the problems in aquaculture [Fig. 16] [40].

In the evaluations made by the FAO, it is stated that the sector with the most development in the agriculture sector in the last 10 years is the fisheries sector.

Considering the main factors in the rapid increase in aquaculture, the increase in the world population and the per capita income also increases the demand for food, especially protein-based food. Considering the projection of the population of 7 billion to reach 8 billion in the next 20 years, it is inevitable that the demand for fisheries will increase. In the 2050s, in order to feed the increasing world population sufficiently and in a balanced way, the world food production It is stated by experts that it will need to be doubled [41].

In terms of food value, animal foods are of great importance in human nutrition. In addition to being a good source of protein, seafood contains vitamins A, D, B and K, calcium, phosphorus and many rich minerals. This situation is seen as a factor that will affect the increase of fisheries production. The high domestic and foreign trade volume of the fisheries sector and the utilization of unused water resources and bringing them into the economy are other factors that trigger the increase in fishery production in the world. Due to the limited land availability and the increasing environmental stress factors, the concern that the increasing world population will not be adequately fed in the near future is increasing. Aquaculture, which plays an important role in in nutrition, creates important opportunities in the subjects of nutrition of people, raw material supply to the industrial sector, employment, contributing to rural development, high export opportunity, more effective management of natural resources and the conservation of biological diversity. Its importance is increasing day by day [42].

9. BIOTECHNOLOGY

Using living organisms and their building blocks, biotechnology is widely used in health, agriculture, food and many other industrial fields. Biotechnology, which has a great potential in terms of contribution to agricultural production, has become increasingly important in the field of aquaculture, especially in recent years. Biotechnology covers studies that use biological systems, living organisms or parts of them to develop and create different products. With the development of genetic engineering in the 1970s, due to the possibility of making changes in the genetic material [DNA] of organisms, research in many areas such as biotechnology and human health, plant production has continued. Any technology based on living organisms or biological systems is a brief description of biotechnology. Biotechnology is a technical way of understanding and changing functions in human, animal and plant cells. Biotechnology has made significant progress in medical fields, especially in the diagnosis and treatment of various diseases. Biotechnological products, which are getting stronger day by day in the world pharmaceutical industry, were 10% in the pharmaceutical industry in the past, but now it is close to 20%. Biotechnology, cell and tissue biology culture, molecular biology, physiology, genetics, microbiology and biochemistry, as well as computer engineering, is the name given to technologies used in pharmaceutical and medical fields to develop animals, plants and microorganisms with DNA technology. However, it is thought to have an effective potential on electrical and mechanical engineering. Briefly, biotechnology is a technological method used to develop plants, animals and microorganisms with DNA technology and to obtain new materials that do not exist naturally or are not produced as much as we need [43].

Biotechnology genetic engineering methods, in which the desired products are obtained with ideal methods and techniques through living tissues and organs, are used by biotechnology as a tool. If we give examples of this technology, which is aimed at increasing human comfort today, we can list as follows:

-Use of genetic products to treat and prevent various diseases such as cancer, AIDS, leukemia, Mediterranean anemia,

-Protein production for growth retardation, infectious diseases, spinal cord repair and repair of damaged brain cells,

-Transforming bacteria in dirty water into creatures that can clean the environment,

-Transferring some special genes in a living thing to another living thing to produce more,

-Increasing the production of properties beneficial to human health such as insulin production, changing the genetic structure of cells with DNA,

-To become more durable and more efficient thanks to gene changes in plants

-Reducing the environmental impact of industrial processes such as textile paper and chemical products,

-Soil treatment, waste gas and polluted air, waste water cleaning, and the evaluation of other waste-like wastes can be given as an example of biotechnological studies [44].

At the same time, steps have been taken to develop antibiotics that fight pathogens for human health.

Biotechnology is a biotech-based method that uses cellular and biomolecular stages to produce technologies and products that help protect the quality of life and the well-being of the planet. Microorganisms have been used for over 6,000 years to produce and preserve foodstuffs such as bread and cheese. Modern biotechnology provides products and technological methods to combat diseases, reduce our damage to nature, obtain nutrients, use sufficient and clean energy, and have safer and more efficient industrial production processes.

In order to improve our planet, biotechnology uses our genetic material and the remedies inherent in nature to improve and guide our living conditions. For this reason, reducing the amount of infectious diseases, increasing the life expectancy of children, reducing serious life-threatening problems affecting human health globally, developing individual treatments to minimize health risks and negative effects of diseases, developing more sensitive methods to diagnose diseases and It is the fight against serious diseases and daily threats that emerge in parallel with today's technological developments. Microscopic plant products are used to produce biocatalysts such as enzymes, yeasts and other microbes using biological processes such as biotech, fermentation. Biotech helps feed the world by:

It regulates chemical production processes by 80% and more, lowering the temperature for cleaning clothes and providing $ 4.1 billion in savings per year, increasing production process efficiency for more than 50% savings in operating costs, to reduce the use and dependence on chemicals from petroleum;

Using biofuels to reduce greenhouse gas emissions, reducing water use and waste generation; and

With the utilization of traditional biomass waste products reaching 100%. With biotechnology, the insect resistance and herbicide tolerance of crops are increased, facilitating their use with more environmentally sustainable production practices. Biotechnology helps feed the world by: higher crop yield, reducing the use of agricultural chemicals required by crops, reduce pesticide use and use of biotech crops that allow it to reduce plowing of agricultural land, developing high nutritional value crops, to produce food free of mycotoxins and toxins, and its oil content, which will help improve cardiovascular health, allows crops to be harvested [45].

Figure 17. New scientific trends; Biotechnology [https://www.careers360.com/courses/b-tech-in-biotechnology, Access; 02.02. 2021].

10. BIOTECHONOLGY IN THE WORLD AND IN TURKEY

Biotechnology is a technology field that includes technologies and technological products developed by the use of concepts and operating rules that form the molecular basis of living organisms or living things. Traditional biotechnology, which has a history equivalent to human history, has gained a brand new meaning and importance thanks to the scientific advances made in the fields of molecular biology and genetics in the last fifty years. For this reason, biotechnology, or modern biotechnology, together with information technology, is one of the technologies expected to make the most important contribution to the welfare of humanity in the 21st century. Traditional Biotechnology and Modern Biotechnology are considered as different fields in many aspects. Traditional biotechnology is a saturated and established technology, modern biotechnology; It is a technology that is open to innovation, has unlimited potential despite its rapid growth, but is strictly dependent on basic science research and infrastructure in "molecular biology". Modern biotechnology has reached a point that can deeply affect the traditional agricultural economies of countries, especially with transgenic plants. The applications of modern biotechnology in medicine continue to grow with significant contributions in the protection of human health, which is too valuable to be measured by economic data. The second economic product group that is expected to hit the country gates in a few years will be transgenic animals. Transgenic microorganisms, on the other hand, will play an important role both as "cell factories" and in waste treatment [46].

Modern biotechnology will increase economic efficiency in animal husbandry and industrial production, while increasing foreign dependency in countries that are lagging behind in science and technology. On the other hand, modern biotechnology, in its unconscious and uncontrolled application, carries some risks in terms of environmental protection and biodiversity. Another risk that cannot be ignored is the use of modern biotechnology as a means of economic and military warfare for non-peaceful purposes. In addition, there is not enough information about the effects of genetically modified organisms [GMOs] and GMO products on human health, especially in the long term. For the aforementioned reasons, it is necessary to take urgent biosecurity measures related to modern biotechnology, make the necessary legal regulations, and more importantly, "control systems" should be put into effect in terms of following the laws. However, attitudes and measures on modern biotechnology should not be limited to legal regulations on biosafety. For the control systems required for the follow-up of legal regulations, staff who are experts in modern biotechnology and control laboratories should be established. In the long run, in terms of the welfare of the people of the country and the development of the national economy, timely investments in "modern biotechnology" would be an appropriate decision. On the other hand, in some societies and in our country, some negative reactions have started to occur against some applications of modern biotechnology. This opposition to modern biotech products is a selective opposition. For example, while there is no negative reaction to GMO products such as hepatitis B vaccine and interferons produced by recombinant DNA technology, which are used for the protection of human health and for therapeutic purposes, negative reactions are observed as well as positive reactions to herbal-derived GMO products produced with the same technology. There could be many reasons for this different attitude. One of these reasons is the suspicion about unwanted biological consequences as a result of the release of some biotechnology products to the environment. Another issue of doubt is the possibility that modern biotechnology products taken as food may harm human health. This precautionary approach to some biotech products needs to be taken seriously, preventing practices that pose a clear danger to biosecurity, and minimizing risk [47].

On the other hand, the losses that may arise from biased opposition to modern biotechnological applications and products that do not pose a risk should not be ignored. Therefore, the benefits and known and foreseeable risks of modern biotechnology should be explained to the public in a balanced and impartial manner. The informed society will thus be able to consciously make its own choice. On the other hand, it is possible for all parties interested in modern biotechnology [especially producers, scientists and consumers] to unite in middle grounds in a dialogue environment based on good intentions, unbiased and honesty. The most basic requirement for this is that discussion platforms based on accurate and complete information can be created. Although biotechnology has been a frequently mentioned concept in documents related to science and technology policies for the last thirty years in our country, a national identity and concrete accumulation has not emerged in both basic science and research and development [R&D] studies and industrial applications related to biotechnology. In parallel with this, necessary legal regulations and investments in control systems in biosecurity issues were also ignored. We believe there are two main reasons for this situation. The first and main reason is that basic science studies, which are the most indispensable condition for developing and applying modern biotechnologies, and the technical infrastructure and trained manpower required to carry out these studies are at a level that can be ignored in our country. The second reason is that national resources are not transferred to the necessary investments in this field and the limited resources transferred are used inefficiently. However, biotechnology in many ways, is a technology that can be performed for Turkey and the realization condition. There is also an attractive market for modern biotechnology products in Turkey. Modern biotechnology studies, which did not receive the necessary attention in our country, made significant progress in developed countries in the same period, and new biotechnological products were developed and marketed first in the health sector and in the last decade in the agricultural sector. Transgenic animals over the next 50 years, animals from human tissue transfer, such as use in medicine of embryonic stem cells, biosecurity and be followed strictly the bioethical terms and practices should be regulated by law, it is next to Turkey's agenda. The concept underlying this understanding, which is new for our country, is as follows: “Application without conscious research, without conscious application there can be no social welfare”. The meaning of this concept for the subject of "biotechnology and biosecurity" is as follows:

- The development of modern biotechnology is only possible with the development of research power in molecular biology and obtaining industrially applicable results.
- Modern biotechnology can only contribute to social welfare by taking biosecurity measures at every stage of the work [48].

11. USES OF BIOTECHNOLOGY IN AQUACULTURE

Aquaculture constitutes an important protein source in human nutrition in the world and in our country. However, it is known that in recent years there has been a crisis in fishery products from hunting. Especially overfishing and increasing pollution have led to a rapid decrease in aquaculture in natural resources, and the maximum amount of fishery products obtained by hunting has been fixed around 90 million tons. Many of the valuable fish species have reached the verge of extinction, while fishing productivity has declined. The population growth rate shows that in the near future, if there is no rapid and sufficient development in aquaculture production, the contribution of fishery products in human nutrition will decrease. Countries have become more important to aquaculture in order to ensure sustainability in meeting the demand of the increasing world population [49].

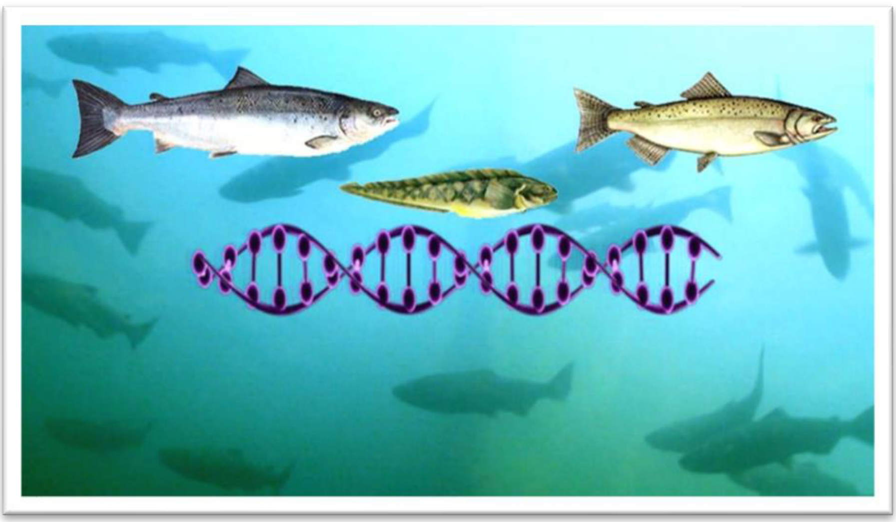

Figure 18. New trends of aquaculture: biotechnology [https://geneticliteracyproject.org/2016/11/14, Access; 02.02.2021].

The first biotechnological application in aquaculture, 1980's began with the use of synthetic growth hormones in the middle. In this first application, fish given growth hormone showed two times more weight gain than normal fish. The next application is by injecting genes into fish eggs to produce natural growth hormone. With the use of growth hormone in aquaculture, there has been a significant increase in the amount of product taken from the unit unit and a shortening in the production period.

Obtaining the desired result in aquaculture; It depends on the application of innovative management techniques, the ability to control the entire production cycle of the cultivated species, to have a good genetic structure of the rootstock individuals, to control diseases effectively and to prevent contamination, to know the optimal physiological, environmental, nutritional conditions for growth and development, to provide quality and sufficient water to the production environment. Thanks to the development and application of these factors, aquaculture has developed very well in recent years.

As in other sectors of agriculture, the aim of aquaculture is to obtain a bigger and healthier product in the shortest possible time, in the most efficient way. In achieving this result; Using better feed and growth hormones, paying attention to health conditions, reproductive technology and genetic engineering practices are used [Fig. 18] [50].

In aquaculture, biotechnology contributes to obtaining more products at many different points; It decreases the age of sexual maturation, increases the growth rate of organisms, egg production and survival rate in the larval stage. Genetic engineering; It increases the resistance of the cultured creature to diseases, the efficiency of conversion of feed into meat and the quality of meat. As it is known, epidemic diseases decrease profitability significantly in aquaculture. Long-term use of antibiotics to prevent such epidemics leads to the development of resistant bacteria in the environment and a residue problem in the product. Genetic biotechnology in the prevention of diseases, traditional selection in the development of resistant individuals and molecular biology in defining the characteristics of pathogens. At the same time, genetically developed vaccines are used to protect fish against diseases. The highly sensitive new molecular techniques developed can reveal viral, fungal and bacterial pathogens without any clinical symptoms of the disease. Biotechnology contributes to finding solutions to some environmental and technical concerns related to fish feed. Today, the protein source of fish feeds is fish meal. Intensive use of fish meal in feeds; It has some disadvantages such as being expensive, stability in the market supply, and eutrophication in the aquatic environment with the phosphorus level it contains. To eliminate these concerns about fish meal, biotechnology is being used to produce plant-based protein sources that can be used in fish feeds; wheat, canola and canola oil are used in fish feeds. Biotechnology is also used to destroy the compounds in the plant that may be harmful to fish, and enzymes that help the best use of phosphorus in feeds containing vegetable protein are produced in this way. As a result, biotechnology can meet the ever-increasing need for animal protein by realizing the change that can be described as the "blue revolution" in aquaculture. Biotechnology as the "blue revolution" in aquaculture It is in a position to meet the ever-increasing need for animal protein by making the change that can be described. Biotechnological applications in the field of aquaculture include chromosome manipulations, sex control, gene transfer, DNA damage and cryopreservation. Biotechnological methods applied in aquaculture provide a positive effect on growth and reproduction rates in living things, and provide a negative return in the emergence of conditions such as disease and DNA damage. In the breeding environment, healthier and more productive individuals are obtained and the genes of the endangered species are taken under protection [51].

Today, biotechnology is also a tool that contributes significantly to the development of aquaculture. The increase in the world population and the excessive demand for aquaculture, whose importance as a source of animal protein is increasing day by day, causes biotechnology to become widely used in the field of aquaculture. Common form of biotechnology use in aquaculture is hybridization, monosex, and genetic manipulations used to breed sterile [triploid] fish. The Monosex population has some favorable advantages in breeding: In many cultivated species, females grow faster than males and are less aggressive. For this reason, the female population is less stressed, hence healthier and more resistant to diseases. Because of these features, all female populations are preferred in the breeding of many species. However, the fact that all female populations spend most of the energy they get during sexual maturation on gonad development leads to a decrease in meat yield. Individuals are sterilized and energy is not wasted on reproductive activities. The development of cold storage [cryopreservation] technology, which is used only in male gametes among biotechnological applications, allows the gametes to be preserved for a long time. Frozen gametes provide flexibility to aquaculture breeders, especially when the breeding season is short or the male individuals are low [52].

The common use of biotechnology is hybridization, genetic manipulations used to breed single and sterile [triploid] fish. The monogamous population has some favorable advantages in breeding: In many cultivated species, females grow faster and less aggressive than males, so the female population is less stressed, hence healthier and more resistant to diseases. Due to these characteristics, all female populations are preferred in the breeding of many species. However, the gonads account for most of the energy that all female populations receive during sexual maturation. Its spending on development leads to a reduction in meat yield. Individuals can be sterilized so that energy is not wasted on reproductive activities. Biotechnological methods applied in fish culture can be divided into three headings gender control, chromosome manipulation and gene manipulation [53].

11.1. Sex control

Various techniques are used in breeding to produce single breed or sterile populations. In order to ensure unisexuality in fish; sterilization, hybridization, gynogenesis, androgenesis, polyploidy and gender transformation techniques are used [Dunham, 2004]. Sex control in fish is done by applying three different methods**.** Early sexual maturity of one or both of the sexes and its consequence; Gender control practices are carried out due to negative changes in growth, feed utilization rate, behavior, health, body and meat color [54]. A variety of techniques can be used in breeding to produce single or sterile populations. Single sex, sterilization, hybridization, gynogenesis, androgenesis, polyploidy, sex transformation can be given as examples [55]. Since embryonic development in fish occurs outside, breeders can achieve phenotypic sex by adding anabolic steroids to water or feed. In the early embryological stage, an embryo phenotypically does not have ovaries, testicles, or reproductive systems that contain both characters, and therefore neither female nor is male. During this period, the embryo contains the embryonal building blocks of the testicles and ovaries. At this stage, the embryo is called "totipotent". Because during this period, the embryo can turn into both a male and a female. A certain period of embryological development [this a chemical marker comes from one or several gene sequences, and this marker tells to which sex the totip component will transform the tissue. When this occurs, the fish becomes phenotypic female or phenotypic male. After that, it is impossible to change the phenotypic sex except for radical techniques such as surgical intervention. If the fish absorb or swallow anabolic steroids during this period, the development of totip component cells is ensured [56, 57]. Sex control in fish is done by three different methods. These are feminization, masculinization and sterilization [Fig. 19].

11.1.1. Feminization

Feminization is performed by applying 17β − Estradiol in the first feeding of the offspring. Other oestrogens [ethyl-oesradiol] are also used for feminization, but oestradiol and oestron are not a preferred steroid as they are naturally found in fish. It is reported that oestradiol is generally more effective than oestron in gender change [58]. Various oestradiol levels and application periods are used for feminization. A hormone level of 20 mg in one kg of feed is sufficient for feminizing many salmonid offspring. The most important point in all applications is that the offspring receive sufficient hormone starting from the first feeding, throughout the sexual differentiation period. This period is probably 50 days after the first feeding at 10 ° C in salmonids [59]. Johnsone et al. [1978] [60] obtained 89% female, 9% male and 2% hermaphrodite individuals as a result of feeding the rainbow trout by adding estradiol to the food. Again Johstone et al. [1979] [61] reported that they found 99% female and 1% hermaphrodite individuals in their study by adding 17-Estradiol to the feed at the rate of 20 mg kg 1 in their study on spring trout. In Salmon farming, all female populations are produced to eliminate males that die after maturation [62] [Fig. 19].

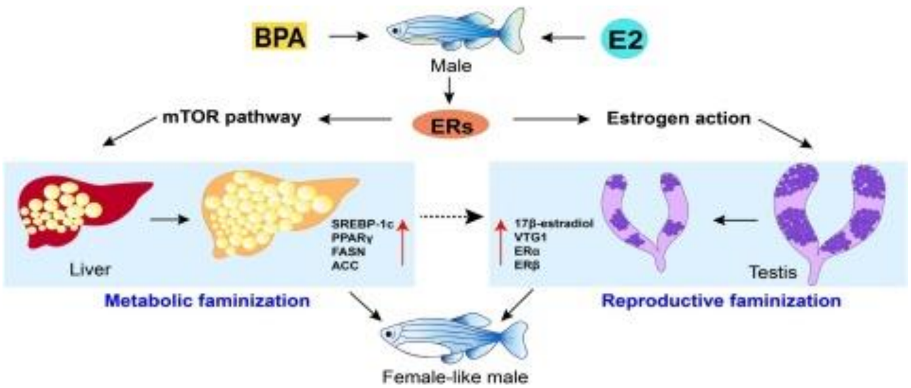

Figure 19. Sex control in fish is done by applying different methods [63].

11.1.2. Masculinization

In the indirect sex reassignment method, since functional male [XX] individuals are needed to obtain fully female individuals, androgen hormones such as 17α-methyltestosterone should be introduced into the bloodstream of fish that have hatched and have consumed the food sac. By adding this hormone to the food in certain proportions, it is possible to ensure that the fish larvae that have consumed the food sac consume this feed or to bathe the fish larvae by adding the hormone to the water [53, 64]. Progeny testing is unnecessary in rainbow trout sex-changed. Although sex-transformed male individuals [XX males] have a sperm canal, sperm retrieval from these fish should be done by cutting the testis. The color of the sexed adult fish is darker than the others. Again, the sexed fish usually has only one testis and is larger than the testes of the normal male and is able to produce sperm as much as the testes of the normal male [57].

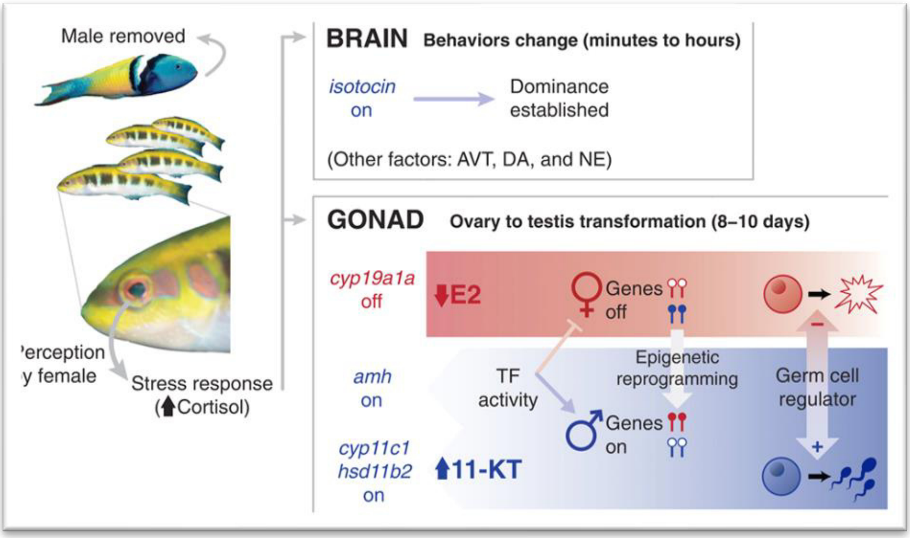

Figure 20. Masculinization [65].

11.1.3. Sterilization

Sterile fish production in aquaculture is possible by changing the chromosome numbers. It is produced by applying one of the environmental shocks to the eggs shortly after fertilization. The valid sterilization method for triploidization and radiation applications is triploidization. The purpose of sterilization is to ensure that metabolic energy is spent on growth rather than gamete development. As a result, negative effects of reproductive activity in fish on growth, survival and meat quality can be prevented [66].

11.2. Chromosome manipulations

Creatures that reproduce with males and females develop from fertilized eggs formed by the fusion of germ cells belonging to their parents. Germ cells provide the link of parents with the next generation. The most important asset of a germ cell is the chromosomes that carry heredity factors from generation to generation. Homologous chromosomes of the same shape and size, one from the mother and the other from the father, separate from each other as the gametes are formed, and each gamete goes to one of each partner. With the merger of male and female gametes, the spouses come together again and the chromosome numbers remain constant between generations [Fig. 21]. There are various manipulations performed for different purposes against meiotic and mitotic events during chromosome division. These manipulation processes; gynogenesis, androgenesis, triploidization and tetraploidization techniques. There are various environmental shocks used to alter chromosome numbers. These; temperature shock [cold or hot], hydrostatic pressure, chemicals [Colchicine], Cytochalasin B [Cytochalasin B], N_2O [Dinitrogen monoxide]. The most efficient of these methods is pressure shock [54].

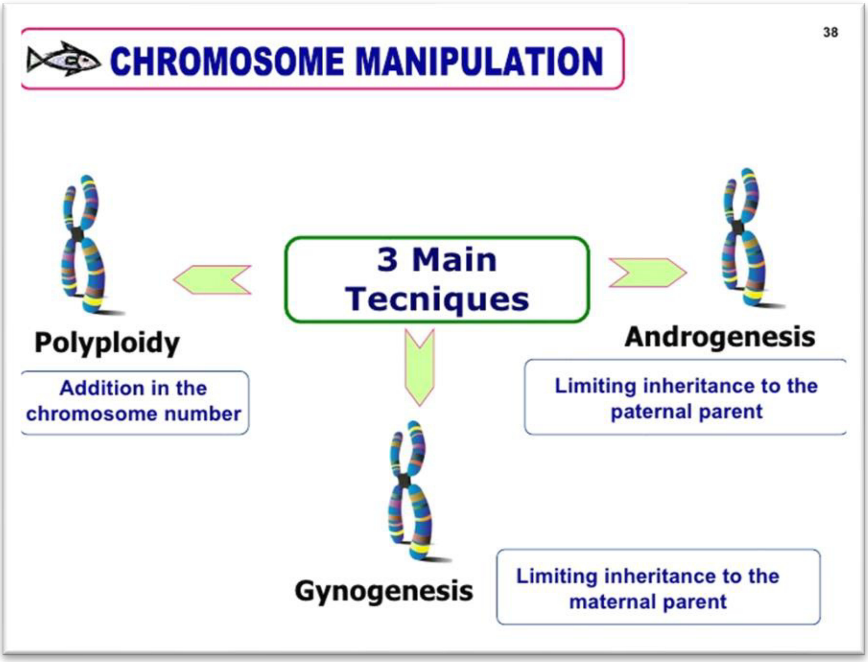

Figure 21. Chromosome manipulations [https://www.slideshare.net/shahreza51, Access; 02.02.2021]

11.2.1. Triploidization

Normal spermatozoa are the main target in the triploidization technique using to produce sterile fish. Infertility can be achieved by producing triploid by environmental shock immediately after fertilization [55]. Providing triploidy can be achieved by blocking the second meiosis division and keeping the second pole cell after fertilization [66]. Hot or cold shock, hydrostatic pressure and chemicals such as colchicine, cytochalasin B, N_2O are used in the shocking performed during triploid application. Triploids can also be produced from tetraploid and diploid coupling [54]. In aquaculture, triploid fish sometimes exhibit significantly better survival rate, growth rate and feed conversion rate than diploids. In addition, since there is no gonad development, the energy to be spent for gonad development is spent on growth [67], but these features do not show themselves until the beginning of sexual maturation. Arai and Wilkins [1987] [68] applied shocks in *Salmo trutta* at different temperatures, at different minutes after fertilization and at different times, and different triploid ratios were obtained [Fig. 22].

100% in 6 minutes shock application at 32°C 10 minutes after fertilization; In 10 minutes of shock application at 29°C at 5, 15 and 30 minutes, success was reported as 88.2%, 90.9 and 81.8, respectively [68]. Triploidization applications are used for the production of sterile individuals in salmons whose cultivation is common and offers many practical advantages for the aquaculture industry. At the same time, barren fish retain their bright silvery color and accepted as a higher quality by. Triploidization may also prevent post-breeding mortality and poor meat quality in salmon that reach sexual maturity. In addition, sterile salmons produced by triploidization are morphologically the same as diploid fish when they come to adult dye and are produced under intensive culture conditions.

Functions are normal. Research has shown that male triploid fish mature and produce gametes, but these sperms carry aneuploid chromosome complements and are far from the ability to give viable offspring. Triploid females are infertile and have a few immature bodies in their ovaries, which are mostly connective tissue egg cells are found [53].

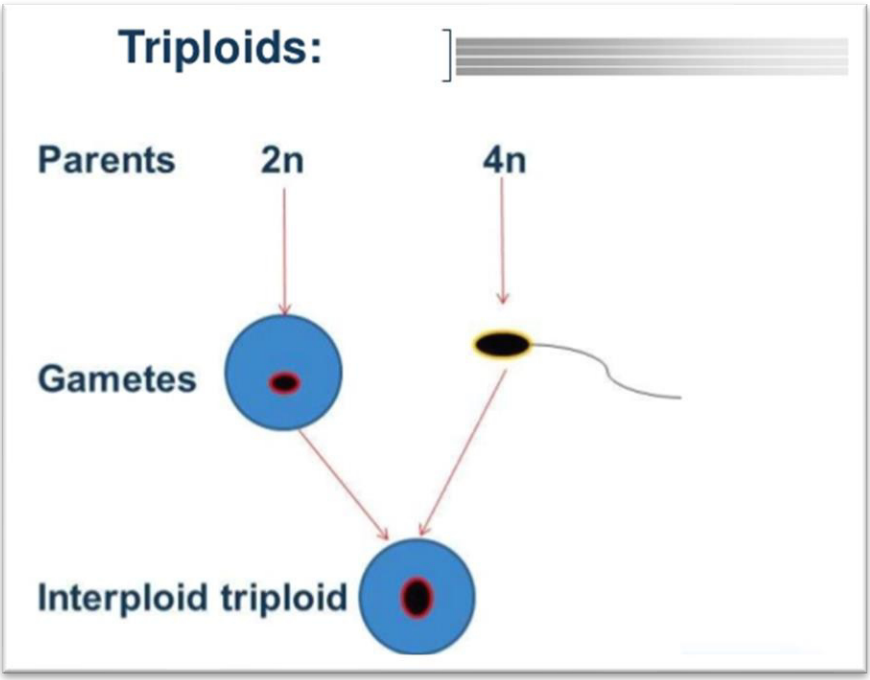

Figure 22. Triploidization [https://www.slideshare.net/masud10rana/chromosome-manupulation, Access; 02.02.2021].

There are several methods for identifying triploids:

- Determination of the chromosome number of triploids.
- The size of the cells and their nuclei [the most commonly used red blood cell that is the size of the erythrocytes].
- Investigation of erythrocyte core volume and analysis of cell density [Coulter using a counter].

- Determination of DNA content in the erythrocyte nucleus by flow cytometry.
- Using electrophoresis.
- Histological analysis of gonad tissue.

The final division of chromosomes in the egg occurs immediately after the sperm penetrate in fertilization. In this process, the polar cell in the egg is prevented from being discharged after fertilization due to the environmental shock effect. Fertilization with haploid sperm produces an egg containing three groups of chromosomes. Embryonic development begins in this egg produced. However, in such eggs, chromosomes are not evenly distributed to the poles. If the juvenile obtained from a triploid egg carries the XXX chromosome, sterile females are formed, and if they carry the XXY chromosome, male individuals that can reproduce are formed. Briefly, most of the studies on triploidy are based on the principle of sterility and better growth of triploid homogametic sex [59].

Determining triploidy levels

Chromosome numbers were examined to determine triploidy levels. With this match, chromosome preparations were made and chromosomes were stained with Giemsa.

Chromosome preparation

For chromosome preparation, the method suggested by Thorgaard and Disney [1990] [67] is applied. For this purpose, 0.1 ml of 0.1% Phytohemagglutinin M per 10g body weight of the fish was injected intramuscularly [i.m.] and left in well ventilated aquariums at 12-14°C and kept for 45 hours. At the end of this period, 0.01 ml, 0.2% of colchicine was injected from the anus of the fish weighing approximately 5 g, and kept for 4.5 hours in well-ventilated aquariums with a water temperature of 12°C. At the end of this period, the gill and anterior kidney tissues of the fish were removed and 35 minutes at 0.56% KCl at 18^{0}C. has been suspended. Treatment with freshly prepared cold Carnoy fixative [3:1 methanol: glacial acetic acid] has been. The slides washed and dried with distilled water are kept at 0^{o}C, and then taken with a pipette without any temperature loss and placed at a height of 35cm. It was distributed thoroughly on the slide.

Giemsa painting

For this purpose, Giemsa staining method suggested by Denton [1973] [69] was used. According to this; slides after chromosome release, Giemsa 5% prepared with Sorenson phosphate buffer solution [1/15M pH 6.8] at room temperature for 30 min. It has been painted.

Calculation of triploid yield

Triploid yield [TY]; calculated by the formula below.

TY = Life from fertilization to free swimming x TO [%] /100 [70].

11.2.2. Tetraploidization

The purpose of tetraploidization is fish production process with four chromosomes. Also, when tetraploid fish are crossed with diploid fish, triploid individuals can be obtained. After fertilization of a normal egg by an active spermatozoa, individuals with 4N chromosomes are obtained by shock during the first mitotoic division. The fertilization rate of diploid females by tetraploid males is lower than normal males. This is the case with the diameter of the spermatozoite. Therefore, it is more logical for tetraploid females to be fertilized by diploid males. However, tetraploid production is not easy, but tetraploid production has been achieved in rainbow trout [55].

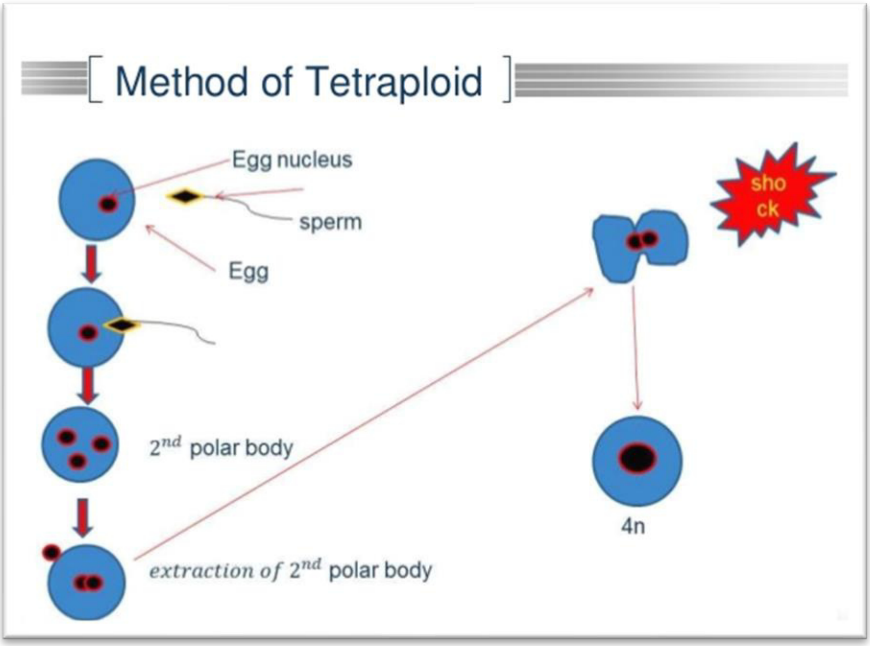

Figure 23. Tetraploidization [https://www.slideshare.net/masud10rana/chromosome-manupulation, Access; 02.02.2021].

11.2.3. Gynogenesis

Gynogenesis is a technique that allows all individuals to carry XX chromosomes, in other words, to obtain a female individual, as a result of fertilization of a normal egg with inactivated sperm. The nucleus of the male germ cell that penetrates into the egg during ginogenesis is genetically inactive in the egg plasma and the development of the embryo is controlled only by the maternal inheritance [71].

Mature eggs of the ginogenetic species do not take action to form the embryo when there are no male germ cells in the environment. Therefore, in gynogenetic reproduction, male germ cells must be found to activate mature eggs for success. The aim in ginogenesis is the production of related lines and single-sex populations. Spermatozoids whose genetic material is destroyed are used in fertilization of eggs in gynogenesis. -Rays, X-rays and ultraviolet [UV] are used to neutralize the genetic material of spermatozoids. Ultraviolet is the most preferred among these because it is cheap and useful [72]. Since the hereditary material of the sperm is destroyed, it can be used in fertilization of eggs in sperm taken from different fish species. To activate the eggs, artificial reproduction using sperm with UV radiation is required, and then physical or chemical shocks are required to restore the embryo's diploid state. These shocks prevent nuclear division by destroying the microtubules. Haploid in cases where environmental shock is not applied embryos are deformed [53].

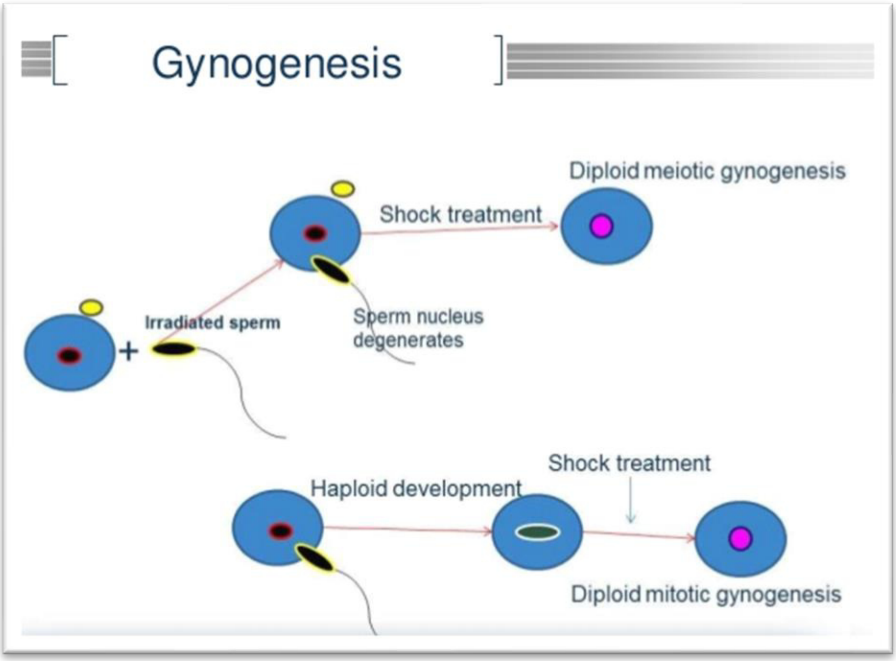

Figure 24. Gynogenesis [https://www.slideshare.net/masud10rana/chromosome-manupulation, Access; 02.02.2021].

Since the inheritance material of the sperm is destroyed, the sperm taken from different fish species can also be used for fertilization of the eggs. To activate the eggs, artificial reproduction using sperm with UV radiation is required, and then physical or chemical shocks are required to restore the embryo's diploid state. These shocks prevent nuclear division by destroying microtubules. In cases where environmental shock is not applied, haploid embryos become deformed [53].

Two different methods, mayoginogenesis and mitoginogenesis, are used in such studies.

Mayoginogenesis occurs by inhibition of the outflow of the second polar cell. The egg is fertilized by spermatozoa whose chromosome material has been eliminated. After a while, it is subjected to shock in order to prevent the emergence of the second polar cell, and thus meiotic ginogenote embryos with two sets of chromosomes are formed [73].

Mitoginogenesis produces completely homozygous progeny because it is carried out by inhibition of the first mitotic division after genome duplication. By using this breeding method, after two generations, homozygous related lines of genetically similar fish can be obtained [53].

Gynogenesis was one of the established techniques used to produce all type of female diploid offspring in aquatic organisms. Other than triploids, gynogenesis also proved as one of the methods for monosex culture for enhancing the aquaculture production. This method has been successfully applied to produce all type of female fish. UV irradiated sperms were fused with the unfertilized egg to produce gynogens larvae. Then procedure were continued by cold shock, chemical shock or pressure shock to retain the second polar body from extrude out of to induce diploid gynogens. Overall, gynogenesis was identified as successful approach and it can be applied in fishes, marine shrimps, and molluscs species such as oyster, abalone and scallops in order to produce all fe-male gynogen products which further enhance and increases the aqua-culture yield production. With improvement of the gynogenesis method will increase the hatching rate, survival rate and quality of the gynogenesis larvae in the future [74].

11.2.4. Androgenesis

Studies on induced androgenesis are carried in since 1989 with the aim of producing viable androgenetic nucleocytoplasmic hybrids. In dispermic androgenesis, the diploid status of androgenetic individuals is achieved by fusion of the chromosome sets of two spermatozoa. If the spermatozoa originate from different males, the level of heterozygosity in a given androgenetic individual will be similar to that upon usual hybridization. If the spermatozoa originate from the same male, the coefficient of inbreeding is 0.5. When developing this method, it was taken into account specific features of fishes, such as the presence of several micropyles in the egg, which allows simultaneous penetration of several spermatozoa, and physiological monospermy implying the absence of mechanisms blocking the involvement of supernumerary spermatozoa in development [75].

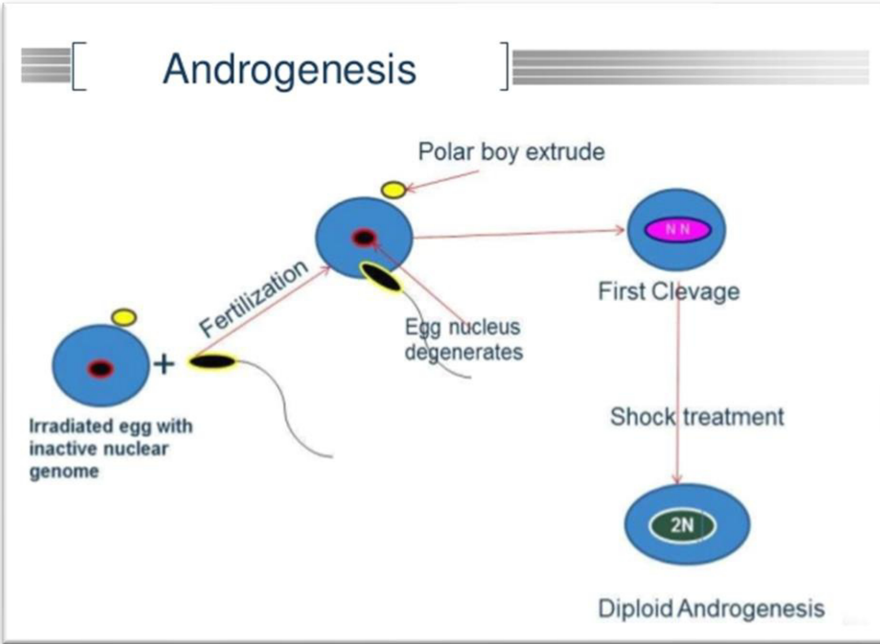

Figure 25. Androgenesis [https://www.slideshare.net/masud10rana/chromosome-manupulation, Access; 02.02.2021].

Androgenesis, unlike ginogenes, is the genetic factor of the egg. After the material is eliminated, fertilization and embryo development continues from the chromosome set of spermatozoa [76]. When the androgenetic zygote undergoes the first division, it is shocked and cell division is inhibited. Thus in individuals possesses the chromosome sets from the father [77]. In the fertilized egg, the nuclear DNA coming from the mother is successfully destroyed by ionized or ultraviolet radiation [58]. For example; trout [67], sturgeon [78], carp [79]. Since self-replicating chromosomes come from a single set of chromosomes, they are highly related and 100% homozygous. The mortality rate in such fish is high, because any mutant recessive allele is revealed [53].

11.3. Gene Manipulations

The process of transferring specific gene sequences of specific length to the structure of deoxyribonucleic acid [DNA], which is the basis of genetic material, using genetic engineering techniques, is called gene transfer [80]. Transgenic organisms are obtained by transferring a foreign gene to the genome by gene transfer techniques. Transgenic organisms are defined as those carrying a recombinant gene belonging to another organism in their genome [81].

The first experimental study showing that gene transfer can be done was carried out by Griffith in 1928. In the experimental study, it was determined that non-pathogenic pneumococcus bacteria acquired pathogenic characteristics when they were placed in the same environment with pathogenic pneumococci that were killed by heat, and the idea that genetic material transfer is possible was put forward for the first time [82]. Avery et al. [83] determined at the end of their study that DNA, which is the genetic material, can be transformed, in other words, gene transfer is possible. In addition, rapid developments in recombinant DNA technology increase the importance of gene transfer technologies day by day. Gene transfer; Microinjection is performed by viral vector technique, embryonic stem cell, cloning and electroporation methods.

Gene manipulation is a molecular technique where one or more genes are transferred from one animal to another. A gene transfer is made from one species to another to create a transgenic organism. Goal; bigger and better growing, better to feed transforming to meat, disease resistant, low oxygen level resistant individuals. For example; some fish species contain a protein that allows them to survive at the poles. When this gene is transferred to other fish, they become resistant to cold water [84]. There are two basic techniques for transferring fish genetic material. The first is microinjection; genetic material is injected into the newly fertilized egg. However, this method is quite time consuming. That's why researchers use the electroporation method. In this method, the transfer of genetic material or DNA is performed by using an electric current into fish embryos [85]. Fish are living materials that are very suitable for transgenic animal studies, because a single female fish produces thousands of indistinguishable eggs, depending on the species, the eggs have external fertilization, are tolerant of macroscopic manual intervention, standard micromanipulators are used in microinjection and the injected embryos do not require complex manipulations as required in mammals. In addition, although DNA is injected into the cytoplasm, the DNA integration rate [10-70%] in transgenic fish is quite high [86].

11.4. Spermatozoa DNA Damage

DNA, serving as the information carrier, draws attention more importantly and widely than RNA. In organisms and most phages, DNA forms a characteristic molecule. DNA, which takes an active role in heredity, is always found in the nucleus and sometimes in other parts of the cell, and forms the basis of the hereditary material in organisms [87].

Different levels of damage occur in DNA due to various internal and external reasons. The main ones of these damages in DNA are; Chromatin structure disruption, DNA bases oxidation, mismatch and suppression of tubulin polymerization, chemical change of bases, chromatin structure anomalies, DNA chain breakage, DNA-DNA, DNA-protein crosses and DNA mutations. Biotechnological methods such as cell gel electrophoresis, tunnel method, measurement of spermatozoa chromatin structure and 8-hydroxy 2-deoxyguanosine are used in order to detect these damages shaped in spermatozoa DNA [88] [Fig. 26].

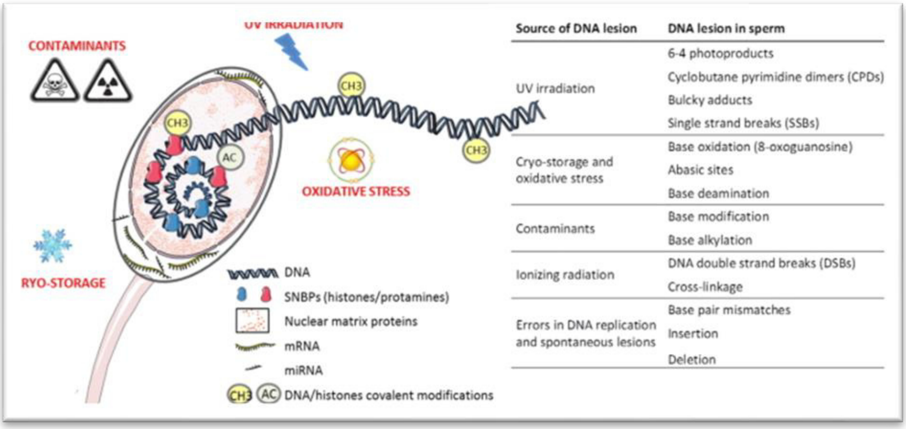

Figure 26. Differnet DNA damage of sprematozoa [Herráez, 2017].

11.5. Cryopreservation of gametes

Preservation of fish gametes is of great importance in selection programs applied in fish farming. Because the breeding of the same type of fish in the same environment and conditions throughout generations causes the loss of genes that are scarce in the current population and a decrease in heterozygosity. This decrease in genetic variation limits the potential of the existing fish stock to be used in future selection programs, which manifests itself as low survival rate, low growth rate, reduced feed conversion efficiency, increased risk of disease and increased mortality in juvenile fish [89]. Cryopreservation of tissues and cells from the 1700s It is a technique that has been applied since. Scientific and modern live cell freezing studies in the sense, in 1949 Polge and colleagues discovered the protective properties of glycerol, and the first frozen cell was spermatozoa. In this sense, cryobiology; It has increased its importance as a science that studies the freezing of cells, tissues, organs and organisms, and better understanding of the functional properties of frozen and thawed cells has led to the development of cryobiology [90, 91]. Today, the cryopreservation technique is routinely applied in preserving sperm, embryos, tissues and cells, and researchers specializing in aquaculture especially work on the freezing of fish semen [92].

Cryopreservation technique for the first time in the field of aquaculture Herring [*Clupea harengeus*] eggs in 1953. It has been applied to fertilize with frozen semen and is successfully used in many fish species today [89]. The most important purpose of cryobiology in aquaculture is to create a sperm bank or gene pool belonging to the cultured species. Since the species taken into culture have less chance to live in nature, it has become a necessity to control their genes by applying the cryopreservation process. In addition, cryopreservation process is applied in order to protect the genetic diversity of the species existing in nature. Generating a gene pool by applying cryobiological methods allows the preservation of genes and is a necessity in hybridization, genetic manipulation and stock enrichment programs [92, 93] [Fig. 26].

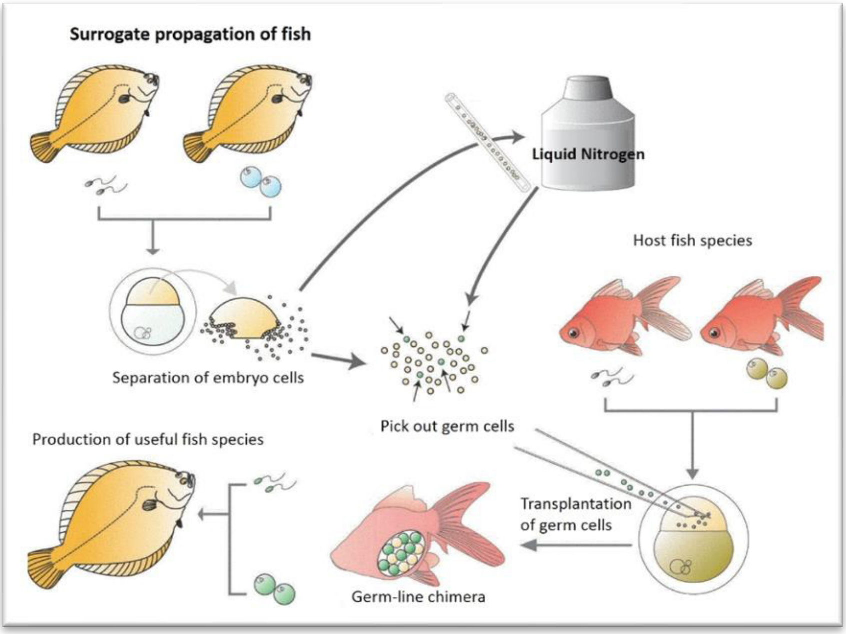

Figure 27. Cryopreservation of gametes [http://www.fsc.hokudai.ac.jp/nanae/research%20activities%20-%20english.html, Access; 02.02.2021].

11.6. Hybridization

Hybridization is the acquisition of new individuals by matching different genera and species. The main purpose of the application of this technique by fish farmers is to ensure that superior features [compliance with environmental conditions, growth, feed evaluation, disease resistance, high meat productivity, etc.] is the production of individuals in which it is brought to the fore. Commonly, offspring show better characters than their parents [94, 95]. The first studies on hybridization were mostly on Salmonids, but these species did not provide commercial advantage in terms of sedation. However, thanks to the advancing biotechnological techniques, studies on the prominent features of these species are continuing [95]. However, hybrid individuals used in breeding are not common. Inter-species hybridization studies on

Salmonids in our country, matching Alpine trout [*Salvelinus alpinus*] with brook trout [*Salmo trutta fario*] [96] and Black Sea trout [*Salmo trutta labrax*] with spring trout [Salvelinus fontinalis] [97]. The survival rate of the hybrid eggs obtained by matching the Black Sea trout with the source trout is low, and the hatching time is similar to the source trout. It was determined that the net meat yield is higher than the source trout [98] [Fig. 26].

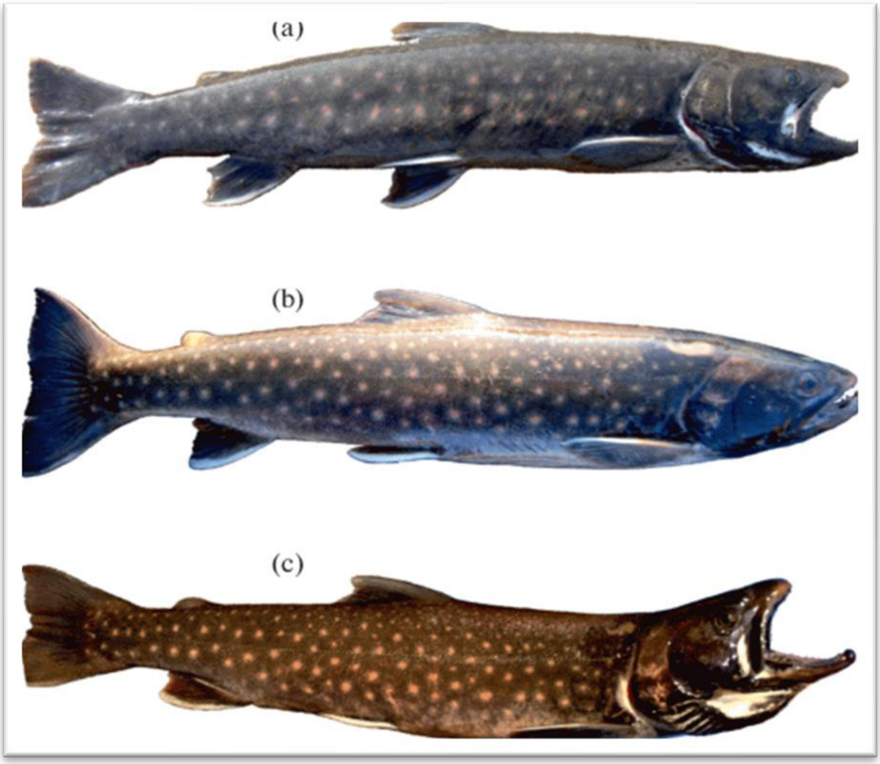

Figure 28. Hybridization in Char of the Genus Salvelinus [*Salmonidae: Salmoniformes*], [a] male, [b, c] female [98].

12. CONCLUSION AND RECOMMENDATIONS

Many factors such as climate change, changes in environmental factors, destruction by humans in natural habitats, population growth, excessive and unconscious hunting can adversely affect natural fish stocks. Although some precautions are taken against this situation, it has been adopted by the stakeholders in the sector that the production made by hunting will not increase more and that the increase in production can only be achieved by aquaculture.

Hunting production fluctuated from year to year showed Turkey aquaculture production has increased every year since 2002. This development is similar to the development of aquaculture in the world. Turkey increased from year to year the share of total fishery products in the aquaculture production in 2017 to 43.8%, in 2018 it increased to 50%. In parallel with the developments in aquaculture production and processing technologies, there is a significant increase in aquaculture exports. In the period after 2000, the increase in exports continued, and imports, on the other hand, showed a partially fluctuating and partially stable course.

Despite the current level and fluctuation of the fishing production in the waters of the country, the fact that some fishermen have been hunting in Georgia and Mauritania in recent years, and the significant increases in aquaculture production and exports are important indicators for the development of the sector. However, when the current production and foreign trade amounts are compared with the population of the country; it is seen that especially domestic consumption per capita is below the world average. Production and consumption will provide a further rise in the available potential in Turkey.

Self-sufficiency ratio and import dependency indices are used to measure the size of self-sufficiency of countries. Both of these indices measure how much of the total supply in a country is met externally through domestic production or imports. In addition to these, the exportability index can be used to show how much of the production is exported. Using these indexes together to make an overall assessment, despite several shortcomings With respect to the aquaculture industry in Turkey; Turkey in general seems to be in good condition.

The ecosystem approach to fisheries targets in Turkey, fisheries and environmental data must be provided on an ongoing basis. The amount of hunting of marine fishes in Turkey and value as an important place anchovies, sprat, small pelagics like mackerel and sardines, tuna species, swordfish, pompano and large migratory pelagics such as bluefish, mullet, mullet, pasha mullet, the whiting, baccalaureate and demersal species such as turbot and other seafood stocks such as white clam, periwinkle and shrimps should be continuously monitored using marine surveys, biological sampling and landing data.

The stocks of important fish catches in inland waters, especially pearl mullet, silver and silvery crucian fish, should be monitored routinely. Policy recommendations for sustainable management should be developed by determining the stocks of species such as eels and leeches within the scope of CITES. With the non-target fishing methods and gears used in Turkey and determining the percentage of the total amount of game hunting species research into and reduction of rejects must be performed.

In inland fisheries, studies should be carried out for hunting and fishing efforts. Breeding studies should be carried out in order to increase production efficiency in species such as trout, sea bream and sea bass, which are widely grown. Besides species widely grown in the culture of the species found naturally in the waters of Turkey, aquaculture production through the dissemination of research breeding species were cultured in conditions must be improved. Studies should be conducted to reduce the prices of feed used in breeding and to use alternative feed ingredients.

Aquaculture equipment and technologies and environmentally friendly breeding techniques should be developed. Development of domestic vaccines should be supported. Research and development studies should be carried out in the fields of expanding the processed product range, producing and marketing products with high added value.

Obtaining data on the socio-economic status of the fisheries sector and policy recommendations should be developed in the light of this information. Some physical and chemical water parameters that show the change in water resources should be continuously monitored. Researches should be conducted to protect the traditional structure of small-scale fisheries, to collect scientific data on the sector and to ensure sustainable management of the sector.

Due to the limited land availability and the increasing environmental stress factors, the concern that the increasing world population will not be adequately fed in the near future is increasing.

Aquaculture, which plays an important role in in nutrition, creates important opportunities in the subjects of nutrition of people, raw material supply to the industrial sector, employment, contributing to rural development, high export opportunity, more effective management of natural resources and the conservation of biological diversity. Its importance is increasing day by day.

Thanks to the biotechnological methods applied in aquaculture, growth and reproduction rates are increased in living things, as well as a decrease in the occurrence of diseases and DNA damage, healthier, more productive individuals with the desired characteristics can be obtained and the genes of the endangered species can be preserved for years. The effective use of modern biotechnological methods in the field of aquaculture as well as in farm animals will allow the sector to develop considerably and will make a significant contribution to the national economy.

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