CHAPTER 24

A COMPLETE OVERVIEW OF FISHERIES IN THE SEA OF MARMARA

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Abstract

This study reveals the fishing trends of important species caught in the Sea of Marmara between 1970 and 2021 using LOESS regression analyses. Out of the 24 species studied, it was found that 23 of them experienced a significant decrease in fishing quantities. Only 'deep-water rose shrimp' showed no decline and maintained a relatively stable trend. Formerly commercially important species such as bluefin tuna, swordfish, striped venus clam, and oyster were found to no longer be targeted for fishing. There has been a noticeable decline in the fishing quantities of these species, especially after the year 2000. Establishing sustainable fishing while preserving the health of the aquatic ecosystem requires effective fisheries management, which primarily relies on well-planned strategies. Therefore, it is crucial to have knowledge of parameters such as biomass, recruitment, and fishing mortality rates when developing an effective management plan. As part of the Mediterranean basin, the Sea of Marmara, where stocks are heavily exploited and rapid warming occurs, is particularly vulnerable to anthropogenic and environmental stressors, especially in recent years. Consequently, it is of utmost importance to create a specific fisheries management plan for the Sea of Marmara and adopt ecosystem-based fishing principles that aim to enhance the social, economic, and institutional aspects of fishing while ensuring its sustainability.

Keywords: Fishing fleet, pelagic species, demersal species, fisheries, Sea of Marmara

1. Introduction

The Sea of Marmara is a part of the Turkish Straits System, along with the Istanbul and Çanakkale Straits, and is an important passage between the Black Sea and the Mediterranean Sea. The surface area of the sea is 11,500 km², its volume is 3,378 km³, and it has a coastline of 927 km. Due to the influence of Black Sea water on the surface and Mediterranean water in the lower layers, it has a high potential for biodiversity. Fishing in this region has always been intense throughout history. Istanbul, one of the world's most important metropolises, being located in this region and Turkey's largest fish market being in this city, provides a great advantage in terms of marketing and further increases the importance of fishing.

In the 1930s, when the Turkish fishing industry was not developed, the total fishery production was around 25-30 thousand tons, and half or two-thirds of this amount was obtained from Istanbul and the Sea of Marmara (Üstündağ, 2010). From the 1970s onwards, thanks to some incentives provided to fishermen, such as the ease of importing fishing equipment and low-interest loans, the Turkish fishing fleet has grown (Çelikkale et al., 1992). With the development of the fleet, the European anchovy fishing in the Black Sea has shown rapid progress, and this has increased the total catch of Turkey as well. After this development in the Black Sea, the Sea of Marmara has fallen to the second place in terms of catch amounts.

In the Sea of Marmara, the average annual catch between 1970 and 1979 was 14,687 tons; however, this amount increased to 47,594 tons between 1980 and 1989, and to 56,392 tons between 1990 and 2000. The highest catch was recorded in 1999 at 83,293 tons, followed by 72,947 tons in 2001 and 71,512 tons in 2002. While there was generally an increase in catch between 1980 and 2000, it is understood that there has been a continuous decrease in these quantities since the 2000s (Figure 1). However, due to increasing fishing pressure and environmental stress factors on fish stocks in the Sea of Marmara, there has been a significant decrease in catch since the early 1990s. According to the statistics of the last two years, the catch in 2020 was 24,138 tons, and so the share of the Sea of Marmara in Turkish fishery decreased from 14% to 7% (Karakulak et al., 2023a). In 2021, with the occurrence of the mucilage event, the catch decreased further (14,400 tons), and the percentage share of the sea decreased to 4.3%. Looking at the shares of our other seas for this year, the Black Sea ranks first with 77.5%, followed by the Aegean Sea (12.57%) and the Mediterranean (5.06%). Despite this decrease over the years in the Sea of Marmara, a total of 55 commercial species (including 44 fish and 11 invertebrates) are still being fished (TURKSTAT, 2023).

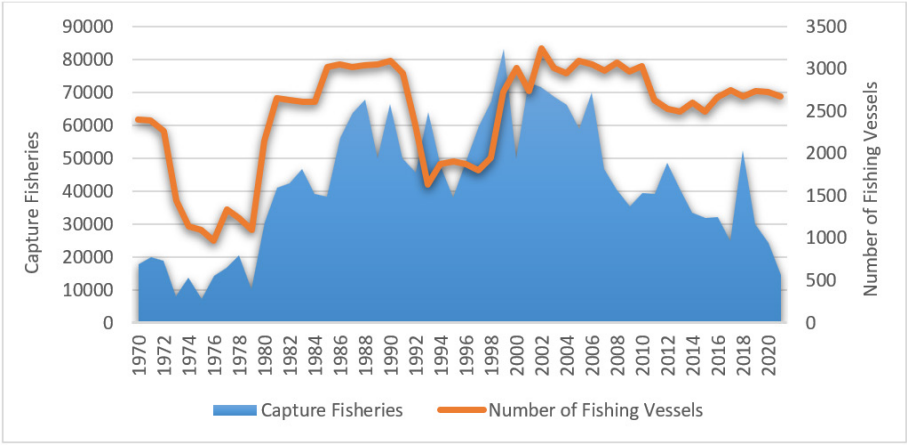


Figure 1. Capture fisheries production and the number of fishing vessels in the Sea of Marmara (TURKSTAT, 2023).

In this section, fishing activities, the structure of the fishing fleet, and fishing resources in the Sea of Marmara have been examined, and the changes and developments that have occurred from past to present have been evaluated in outline. In addition, the subject has been addressed from the perspective of fishing management, and solutions to current problems have been proposed.

2. Fishing Fleet

According to TURKSTAT (2023), of the 14,224 vessels that make up the Turkish fishing fleet, 39.56% are in the Black Sea, 19.09% in the Sea of Marmara, 29.37% in the Aegean Sea, and 11.99% in the Mediterranean. Of the total 2,240 fishing vessels that are 10 meters or longer and have an important share in our country's fisheries, 40.03% are registered in the Black Sea, 28.85% in the Sea of Marmara, 15.97% in the Aegean, and 15.16% in the Mediterranean fishing ports. When we consider the vessel distribution (with lengths of 20 meters and above) in terms of industrial fishing, we see that 49.50% of these vessels are in the Black Sea, 30.81% in the Sea of Marmara, 8.42% in the Aegean Sea, and 11.27% in the Mediterranean (Figure 2).

The number of fishing vessels operating in the Sea of Marmara varies from year to year depending on the abundance of fish. It is known that vessels fishing in the Black Sea and Aegean Sea also engage in fishing activities in the Sea of Marmara seasonally. The number of vessels in the Sea of Marmara was 1,099 in 1975 and almost tripled to 3,020 in 1985. It can be seen from Figure 1 that the number of vessels decreased between 1993-1999 (1,636-1,950 vessels) and then increased again (2,492-3,238 vessels). In 2021, the number of active fishing vessels in the Sea of Marmara was recorded as 2,676 (TURKSTAT, 2023).

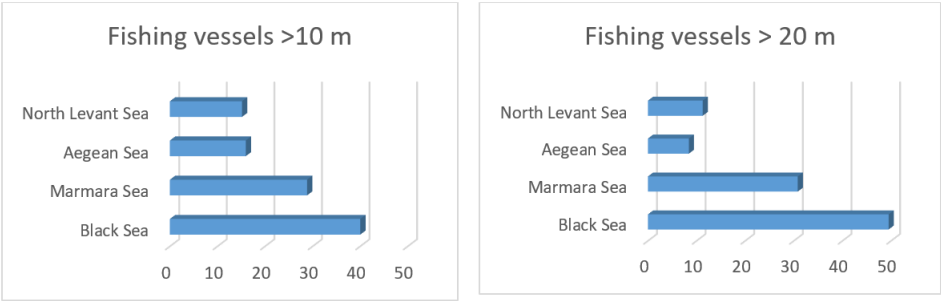


Figure 2. The distribution of the Turkish fishing fleet by vessel sizes and regions (TURKSTAT, 2023).

The fastest increase in the number of fishing vessels in Turkey occurred between 1980 and 1990. During this period of transition to a market economy, the fishing fleet of our country made significant progress both numerically and technologically thanks to recognized customs exemptions and credit support (Zengin, 2011). By 2002, however, fishing licenses were suspended by the fishing management authority to stop new boats from entering the existing fleet, and only vessel length extensions (at a rate of 20%) were allowed during this process. Nevertheless, fishing boats are currently being built in various shipyards and new ones are being added to the fleet.

When the fishing vessels in the Sea of Marmara are examined according to size groups, in the 1970s, the percentage of fishing boats under 10 meters in the fleet was recorded as 87%, those between 10-19.9 meters as 12%, and those over 20 meters as 1%. However, at the end of the 1980s, these ratios were observed as 78% for boats under 10 meters, 16% for those between 10-19.9 meters, and 6% for vessels over 20 meters. Between 2010 and 2020, the percentage of vessels over 20 meters increased to 8-9% (Table 1). As can be understood from these values, an increase in the number and size of vessels and their greater use of technology over the years can be observed.

Table 1. The distribution of vessel size in the Sea of Marmara.

	1-4,9 m	5-5,9 m	10-19,9 m	20 m>	20-29,9 m	30-49,9 m	50 m>	Toplam
1975	25	928	135	11				1099
1980	2	1813	259	74				2148
1985	10	2398	444	168				3020
1990	1	2404	505	179				3089
1995	61	1234	537	69				1901
2000	40	2161	646	159				3006

2005	4	2222	597		190	72	5	3090
2010	-	2302	493		162	70	1	3028
2015	-	1994	297		130	72	-	2493
2020	-	2084	427		133	85	1	2730
2021	-	2031	429		135	80	1	2676

Table 2. The distribution of vessel motor power (in horsepower, HP) in the Sea of Marmara.

	0	**1-9**	**10-19**	**20-50**	**51-99**	**100>**	**100-199**	**200-499**	**500>**
1975	77	624	205	128	39	26			
1980	47	1124	415	262	106	194			
1985	37	1160	664	629	132	398			
1990	24	747	752	923	203	440			
1995	64	434	255	540	254	354			
2000	-	510	630	660	327	879			
2005	4	941	427	689	346		309	219	155
2010	-	762	329	878	391		341	181	146
2015	-	765	181	629	347		215	238	118
2020	-	621	216	651	470		272	362	138
2021	-	617	211	641	405		301	344	157

When examining the fishing fleet in the Sea of Marmara in terms of motor power (Table 2), it can be seen that 23.06% of vessels have 1-9 HP, 7.88% have 10-19 HP, 23.95% have 20-49 HP, 15.13% have 50-99 HP, 11.25% have 100-199 HP, 12.86% have 200-499 HP, and 5.87% have motor power of 500 HP and above (TURKSTAT, 2023). In recent years, the desire to have faster movement capabilities at sea and the frequent occurrence of mucilage events in the Sea of Marmara has led to an increase in the number of main engines on ships (Karakulak et al., 2023b). Typically, there are two or three engines on trawl vessels in the Sea of Marmara. According to TURKSTAT (2023) statistics on fishing vessels, the highest group in terms of motor power is stated to be 500 HP and above. However, it is known that in the past 20 years, vessel motor powers have reached 3500 HP. Therefore, it can be seen that the current statistical grouping does not adequately reflect the level that vessel motor powers have reached.

When examining the fishing vessels in our sea in terms of gross tonnage (Table 3), it can be seen that 69.66% of these vessels have 1-4 GT, 9.19% have 4-5 GT, 12.67% have 10-50 GT, 3.66% have 50-99 GT, 3.44% have 100-199 GT, 1.20% have 200-499 GT, and 0.19% have gross tonnage of 500 GT and above (TURKSTAT, 2023). When looking at the distribution of gross tonnage by year, it is understood that the highest tonnage vessels joined the fleet after the 2000s.

Table 3. The distribution of vessel gross tonnage (GT) in the Sea of Marmara.

	1-4	5-9	10-50	50>	50-99	100-199	200-499	500>
1975	1013	50	36	-				
1980	1712	151	219	66				
1985	2319	266	302	133				
1995	1334	321	178	68				
2000	1822	604	375	205				
2005	1798	590	428		119	58	34	63
2010	1948	523	338		104	86	24	5
2015	1799	245	233		86	93	34	3
2020	1854	328	320		85	94	37	12
2021	1864	246	339		98	92	32	5

When examining the tonnage of fishing vessels by region, it has been determined that the highest tonnage vessels are found in the Black Sea and the Sea of Marmara, with average vessel tonnages calculated as 45±3.5 GT in the Black Sea, 40±1.8 GT in the Sea of Marmara, 27±1.4 GT in the Mediterranean, and 11±0.6 GT in the Aegean Sea (Erdoğan, 2006). Additionally, the average tonnage values calculated for vessels over 20 meters in length, which have a significant share in total production, are 160 GT for the Sea of Marmara, 150±7.9 GT for the Black Sea, 115 GT for the Aegean Sea, and 99 GT for the Mediterranean.

When the licensed vessel numbers of the provinces located on the coast of the Sea of Marmara were examined in 2022 (a total of 3,916 vessels), Istanbul was found to be in the first place with 1,747 vessels, followed by Çanakkale (746 vessels), Balıkesir (601 vessels), Bursa (250 vessels), Kocaeli (240 vessels), Tekirdağ (170 vessels) and Yalova (162 vessels) (BSGM, 2023). While small-scale fishing vessels account for 86% of those operating in the sea, industrial fishing vessels have a 14% share. This situation shows that small-scale fishing is more dominant in the Sea of Marmara.

According to TURKSTAT (2023), out of a total of 2,676 registered fishing vessels in the Marmara Region, 8.37% (224 vessels) were trawlers, 4.26% (114 vessels) were purse seiners, 0.67% (18 vessels) were carriers, and 86.70% (2,320 vessels) were small-scale vessels. Furthermore, the Sea of Marmara is a sensitive area and has been closed to trawl fishing since 1971 under the Fisheries Law No. 1380. Therefore, trawlers registered in the Marmara Region operate in the Northern Aegean or Western Black Sea for fishing. However, the use of beam trawl is allowed only for shrimp fishing, and the percentage of vessels using this fishing gear is 8.74%. The presence of pelagic species (such as anchovy, horse mackerel,

bonito, and bluefish) with high fishing yields in the Sea of Marmara and the Black Sea leads to significant investments in purse seine vessels used for commercial fishing of these species (Figure 3). Additionally, carrier vessels that transfer the retained fish to the fishing ports but do not have fishing rights also fall into this group.

Set nets play an important role in fishing in the Sea of Marmara, with 28.18% of vessels using these nets. The percentage of vessels using other fishing gear is 16.03% for gill and trammel nets, 31.05% for purse seine and hook and line, and 0.75% for beach seines (Figure 4). In fact, fishing with beach seine nets is prohibited in all Turkish seas, and in the Sea of Marmara, the use of boat seine nets ("*manyat"*) is only allowed in certain areas (Tuzla, Tavşan Island/Istanbul, and Gemlik Bay) for shrimp fishing (BSGM, 2020).

According to TURKSTAT (2023), 80.04% of fishing vessels in the Sea of Marmara are made of wood, 17.19% are made of steel, and 2.77% are made of fiber. Looking at the fishing equipment and electronic devices of these vessels, it is understood that 290 vessels have generators, 291 vessels have cold storage rooms, 110 vessels have ice machines, 1,805 vessels have echosounders, 409 vessels have sonars, 631 vessels have surface radars, 937 vessels have GPS satellites, and 586 vessels have radios.

There are a total of 7,740 fishermen engaged in commercial fishing activities in the Sea of Marmara. Of these fishermen, 33.19% are vessel owners, 3.69% are unpaid working partners, 7.84% are unpaid working household members, 24.25% are paid crew members, 28.91% are profit-sharing crew members, 0.62% are paid partners, and 1.49% are paid household members (TURKSTAT, 2023). The number of crew members working on trawlers varies between 20 and 35, depending on the vessel size. For other types of fishing activities besides trawling, the number of crew members ranges from one to four.



Figure 3. a-b) Small-scale fishing vessels operating in the Sea of Marmara (Photo: F. Saadet Karakulak; c) A boat seiner engaged in shrimp fishing (Photo: Sadettin Doğu); d) A beam trawler engaged in shrimp fishing (Photo: F. Saadet Karakulak); e-f) Purse seiners (Photo: F. Saadet Karakulak).

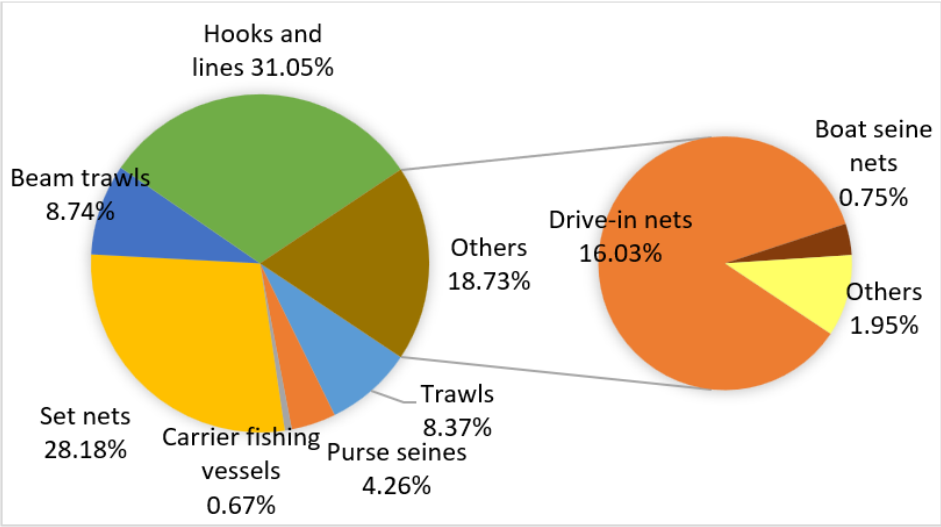


Figure 4. The distribution of fishing vessels in the Sea of Marmara based on their fishing methods.

3. Other Fishing Activities

Fishing with dalians and lift nets in the Sea of Marmara is one of the traditional fishing methods, and this activity continues today. In addition, diving and collecting by hand (using snorkeling, SCUBA, or hookah systems) for sea snails, black mussels, oysters, scallops, clams, sand clams, and sea cucumbers is also practiced.

3.1. Stationary Uncovered Pound Nets (Dalians)

Stationary uncovered pound net, which have been used in Turkey for many years, are particularly established in the Sea of Marmara, the Istanbul and Çanakkale Straits, and along the Black Sea coasts (Devedjian, 1926; Sara, 1964; Mengi, 1977). The history of dalians in the Istanbul Strait dates back to the Byzantine era (Devedjian, 1926; Sara, 1964). In the Ottoman Empire, fishing was generally carried out using dalians and beach seine nets (Doğan, 2011).

One of the leading travelers of the 17th century, Evliya Çelebi, in his travelogue, indicated that there were 300 dalians in Istanbul, with 700 fishermen working in these dalians, and that the main dalian was located at Beykoz Port (Figure 5). It is reported that swordfish and bluefin tuna were especially caught in these traps, as well as mackerel, bonito, sea bream, anchovy, goby, sardine, red mullet, scorpionfish, rockfish, silverfish, and bluefish (Dağlı and Kahraman, 2014).



Figure 5. a) Beykoz Dalian established in the Istanbul Strait (Photo: F. Saadet Karakulak); b) Fish harvest in the dalian (Photo: F. Saadet Karakulak).

In the early 1900s, it was reported that a total of 240 dalians were established in summer and winter seasons in the Istanbul Strait (52), the Sea of Marmara, the Çanakkale Strait (162), and the Western Black Sea (26) (Devedjian, 1926). The number of active fishing weirs in the Istanbul Strait decreased to 17 in 1960 (Yazıcı and Öker, 1960) and to eight in 2000 (Karakulak, 2000). The decrease in the number of dalians in the Istanbul Strait is due to the increase in sea traffic, urbanization, sea pollution, and advances in fishing technology (Bök, 1991; Karakulak, 2000). Dalians, which have been of great importance in fishing for many years, have lost their former value today. However, it is reported that four dalians (Dilburnu, Beykoz, Filburnu, and Bağlaraltı Dalians) established in the spring and summer months (March-June) continue their fishing activities in the Istanbul Strait (Yıldız and Karakulak, 2016; Biçer, 2019; Biçer et al., 2020).

3.2. Lift Nets

This fishing gear is also known as lift nets or lift dalians. In the fishing activities carried out between March and June with three lift nets set up on docks and coasts in Arnavutköy (Figure 6a), Yeniköy, and Tarabya (Figure 6b) in the Istanbul Strait, silver, mullet, and gilt-head bream are targeted (Devedjian, 1926; Yıldız et al., 2013). Additionally, in Tekirdağ, Şarköy coasts, approximately 30 lift nets are used for sea bass fishing in October-November (Figure 6c). Unlike those in Istanbul, these lift nets have a wooden hut. Moreover, in the Izmit Bay, big-scale sand smelt is caught with small lift nets operated by hand (Karakulak et al., 2019).



Figure 6. a) Two-mast lift net installed in Arnavutköy, Istanbul (Photo: F. Saadet Karakulak); b) Lift net installed in Tarabya, Istanbul (Photo: F. Saadet Karakulak); c) Lift net established in Şarköy, Tekirdağ (Photo: Tomris Deniz) d) A diving boat for sea snail fishery in the Istanbul Strait (Photo: F. Saadet Karakulak)

3.2.3. Dive Fishery: Diving is commonly used for fishing of mussels, sea snails, oysters, scallops, sand smelts, and sea cucumbers, especially since the use of dredges for fishing these species has been prohibited in the Sea of Marmara since 2000 (Öztürk et al., 2002). In the Sea of Marmara and the Istanbul Strait, diving is used to harvest veined rapa whelk (*Rapana venosa*) (Figure 6d) and black mussels (*Mytilus galloprovincialis*) in areas such as Beykoz, Poyrazköy, and Sarıyer (Öztürk et al., 2002).

4. Fisheries Resources

Local regression using "locally weighted running line smoother (LOESS)" was applied to fishing data to reveal the fishing trends of fishing resources in the Sea of Marmara between 1970 and 2021. Loess Regression is the most common method used to smoothen a volatile time series. It is a non-parametric method where least squares regression is performed in localized subsets, which makes it a suitable candidate for smoothing any numerical vector (Cleveland and Grosse, 1991; Cleveland, 1993).

Important fishing resources in the Sea of Marmara are classified into three groups: pelagic fish, demersal fish, and other aquatic products. General information about the catch amounts; fishing gear, fishing areas, and fishing times of the species in each group are presented by year.

The important fishing resources in the Sea of Marmara can be classified into three groups: pelagic, demersal, and other seafood. The average catch quantities of significant commercial species in the Sea of Marmara between 2018 and 2021 were calculated, and the proportion of each species in the total catch was determined (Figure 7). When examining these proportions, it can be observed that pelagic species account for 87.44%, demersal species for 3.74%, and other seafood for 8.82% of the total catch. Furthermore, information regarding the catch quantities of species within these groups, the fishing gears used, fishing areas, and fishing seasons is provided.

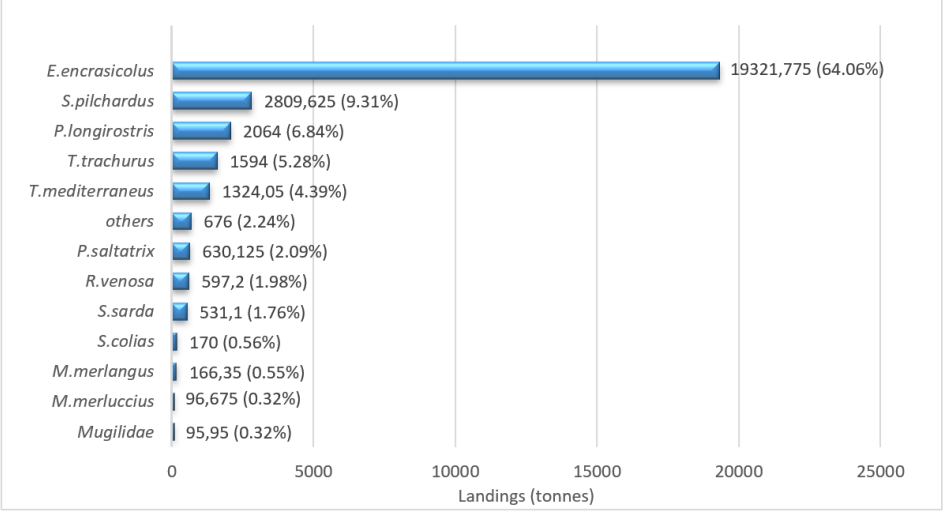


Figure 7. The commercial species in the Sea of Marmara and contribution rates of the species (average catch amount between 2018-2021).

4.1. Pelagic Fish Species

The Sea of Marmara is a region where fishing activities have been intense from past to present due to the migration route of economically valuable pelagic fish. Among the pelagic fish group, European anchovy (*Engraulis encrasicolus*), European pilchard (*Sardina pilchardus*), Atlantic horse mackerel (*Trachurus trachurus*), Mediterranean horse mackerel

(*Trachurus mediterraneus*), Atlantic bonito (*Sarda sarda*), bluefish (*Pomatamus saltatrix*), swordfish (*Xiphias gladius*), Atlantic bluefin tuna (*Thunnus thynnus*), Atlantic mackerel (*Scomber scombrus*), and Atlantic chub mackerel (*Scomber colias*) stand out. These species (except for anchovy and pilchard) migrate from the Aegean Sea to the Black Sea for reproduction in the spring months and from the Black Sea to the Aegean Sea for feeding purposes in the autumn months. It is observed that many species do not migrate in the winter months and remain in the Sea of Marmara. Fishing activities for these species intensify in the Sea of Marmara during their migration, and their fishing is carried out by both industrial and small-scale fishermen. During this process, amateur fishermen are also seen to participate in fishing activities both from the shore and with vessels.

4.1.1. European anchovy: The most caught species in the Sea of Marmara is anchovy. The annual average catch of this species between 1970 and 1996 was 8,549 tons, while this value increased to 20,364 tons between 1997 and 2021. The lowest catch amount of the species was recorded as 394 tons in 1989. In the 1980s, the invasive ctenophore, *Mnemiopsis leidyi*, entered the Black Sea with ballast water of ships and spread to neighboring seas with the effect of the current system, and it was also seen in the Sea of Marmara in the early 1990s (Shiganova, 1994; Shiganova et al., 2001). As this jellyfish species feeds on eggs and larvae of small pelagic fish, it has had a negative effect on anchovy stocks. With the entry of another jellyfish species called *Beroe ovata*, which is a predator of *M. leidyi*, into the ecosystem since 1990, it is observed that anchovy catches have started to increase. The highest catch amounts were recorded in 1999 with 36,962 tons, in 2006 with 43,238 tons, and in 2018 with 40,751 tons. According to LOESS regression, while catch amounts showed an increasing trend between 1970 and 2000, there has been a continuous decrease since the 2000s (Figure 11). The anchovy catch amount, which was 13,116 tons in 2020, decreased to 6,189 tons in 2021 due to the mucilage observed in the Sea of Marmara.

Anchovy fishing in the Sea of Marmara is mainly carried out using purse seiners (Karakulak et al., 2002). Other pelagic fish species such as horse mackerel, sardines, bonito, and bluefish are also caught with purse seiners during the fishing season (Figure 8). Anchovy fishing is also carried out with set nets and dalians. Fishing areas include the entrance of the Izmit Bay, the vicinity of the Prince Islands in Istanbul, Büyükçekmece, Silivri, Tekirdağ, Yalova/Çınarcık, Esenköy, the vicinity of Armutlu, İmralı Island, Gemlik Bay, Kurşunlu, Kapıdağ Peninsula, Bandırma, and the vicinity of Marmara Island. Purse seine fishing for anchovy continues from the beginning of September until March (Doğu, 2019). Purse seining in the Sea of Marmara falls under the seasonal fishing ban (April 15-August 31) applied for

industrial fishing (BSGM, 2020), and purse seining for anchovy is not allowed during this period. However, from July to September (Table 4), set-net fishing for anchovy is carried out in the Izmit Bay and along the Anatolian coast of Istanbul (between Moda and Küçükyalı) (Karakulak et al., 2019).

In the 2022 fishing season, a total of 283 gillnet boats ranging in length from 12 to 54 meters and with motor powers between 101 and 3122 kW were granted fishing permits for anchovy fishing in the Black Sea, the Sea of Marmara and Northern Aegean Sea (BSGM, 2023). The number of active gillnet vessels engaged in anchovy fishing in the Sea of Marmara was reported to be 112 in the 2017/2018 fishing season and 79 in the 2018/2019 season (Doğu, 2019), with variations in the number of vessels depending on changes in the catch yields of other pelagic species such as bonito and bluefish in addition to anchovy in the Sea of Marmara.

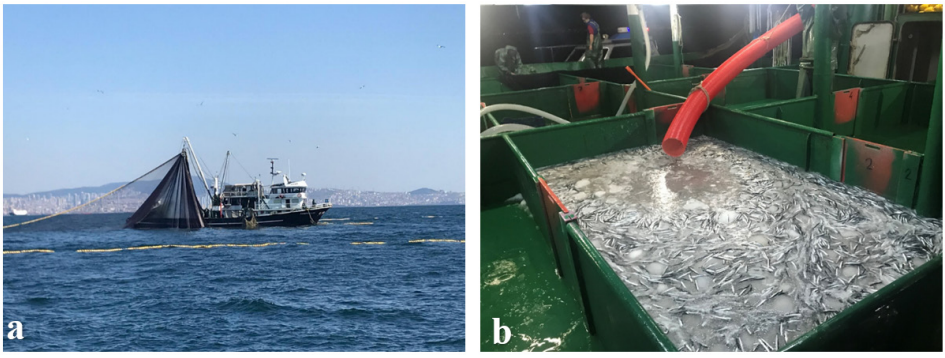


Figure 8. a) Purse seine during anchovy fishing activity in the Sea of Marmara (Photo: Sadettin Doğu); b) Taking the captured fish on deck (Photo: Sadettin Doğu).

4.1.2. Atlantic horse mackerel: The horse mackerel, which is heavily caught in the Sea of Marmara, has two different species: the Mediterranean horse mackerel (*T. mediterraneus*) and the Atlantic horse mackerel (*T. trachurus*), with annual average catches between 1970 and 1990 being 4,368 tons and 1,149 tons, respectively. The fishing of both species increased since the 1980s. However, since the comb jellyfish *M. leidyi* entered the Sea of Marmara in the 1990s, the catch of horse mackerel has begun to decline. In the 2000s, it was observed that the catch of horse mackerel started to increase again. The highest catch of horse mackerel was 10,500 tons for Mediterranean horse mackerel in 2002 and 7,514 tons for Atlantic horse mackerel in 2003. Since the peak fishing years of 2002-2003, there has been a continuous decline in the catch of horse mackerel. Between 2010 and 2021, the annual average catch of Mediterranean horse mackerel was recorded as 2,160 tons, and the Atlantic horse mackerel

was 1,717 tons. According to LOESS regression, the catch of Mediterranean horse mackerel increased between 1970 and 1985, showed fluctuations between 1985 and 2005, and has been continuously declining since 2005. On the other hand, there was an increase in the catch of Atlantic horse mackerel between 1970 and 2003, and a continuous decrease between 2004 and 2021 (Figure 11).



Figure 9. Anglers fishing for horse mackerel in the Istanbul Strait: a) Karaköy; b) Emirgan (Photo: F. Saadet Karakulak).

Horse mackerel is caught with different fishing gear (such as fishing lines, light rock fishing, set nets, purse seine nets, and dalians) (Table 4) by amateur and commercial fishermen in all regions of the Sea of Marmara and throughout the year (Figure 10) (Yıldız and Karakulak, 2010b; Akyol and Ceyhan, 2011; Biçer et al.,2020; Peksu et al., 2020).

4.1.3. European pilcard: The annual average catch of pilcard between 1970 and 1998 was 2,835 tons, while this value increased to 15,697 tons in 1999. The annual average catch of this species between 2000 and 2021 was 4,543 tons. According to the LOESS regression, while the catch showed an increasing trend between 1970 and 1999, it remained stable between 2000 and 2010 and then showed a continuous decreasing trend (Figure 11). The catch, which was 13,116 tons in 2020, decreased to 1,290 tons in 2021 due to the mucilage observed in the Sea of Marmara.

This species migrates from the Aegean Sea to the Sea of Marmara and then to the Istanbul Strait during the spring months (especially in May) for feeding. During the winter season (January-February), they return to the Aegean Sea to reproduce (Devedjian, 1926; Kocataş et al., 1990). The fishing of this species is carried out using purse seine and set nets (Karakulak et al., 2002; Akyol et al., 2009). In this fishery, purse seiners are more commonly practiced between September and October (Table 4) in the Istanbul Strait, Prince Islands, and Kurşunlu

region (Bahtiyar Menekşe, personal communication). Set nets, on the other hand, are employed between May and August in areas such as Çanakkale, Erdek Bay, Marmara Island, the Anatolian coast of Istanbul (between Moda and Küçükyalı), and Izmit Bay (Akyol et al., 2009; Yıldız and Karakulak, 2010a; Karakulak et al., 2019).

4.1.4. Bluefish: The most common fishing ground for bluefish in Turkish waters is the Western Black Sea, with the Sea of Marmara ranking second in the fishing of this species. In 2021, 77.20% of the total bluefish catch was obtained from the Western Black Sea, 14.44% from the Sea of Marmara, 5.06% from the eastern Black Sea, 2.30% from the Aegean Sea, and 1% from the Mediterranean. The annual average catch between 1970 and 2021 was 2,506 tons. The highest catch was recorded in 1982 and 2002 at 8,369 tons and 8,557 tons, respectively. According to the LOESS regression analysis, there was an increasing trend in bluefish catches between 1970 and 1985, followed by fluctuations between 1985 and 2005, and a continuous decrease after 2005 (Figure 11). The catch amount was recorded to have dropped to 838 tons in 2021.

The fishing of this species is carried out using different fishing gears by amateur and commercial fishermen. In bluefish fishery, fishing lines (mainly "*uzun olta*"), set nets, drive-in nets, purse seine nets, and dalians are used (Karakulak et al., 2002; Ceyhan and Akyol, 2005a; Ceyhan et al., 2005b; Akyol et al., 2009). In addition, it is known that this species is also caught illegally by trawlers despite the prohibition on trawling in the Sea of Marmara. Bluefish fishery is carried out in every region of the Sea of Marmara, but the most important fishing ground is the Istanbul Strait. This fishing activity in the Istanbul Strait is carried out intensively during the migration periods of the species in spring (most intense in May-June) and autumn (most intense in September-November). Most of the catch is obtained with purse seine nets between September and April (99.6% in 2013 and 98.4% in 2014) (Zengin et al., 2017). Additionally, bluefish fishery is carried out with drive-in nets between May and June throughout the Sea of Marmara, as well as with dalians in the Istanbul Strait (Table 4). There is no specific fishing ban period for this species.

4.1.5. Atlantic bonito: Fishing in Turkey was not yet developed in the 1930s, and at that time, the majority of all fishing was mainly carried out in the Sea of Marmara, primarily centered on Istanbul. Among the fish caught during those years, bonito and mackerel held an important place. In 1937, the total catch in the country was 26,000 tons, of which 18,000 tons consisted of bonito (Üstündağ, 2010).

The annual average catch of bonito between 1970 and 2021 was 1,804 tons. However, in 1982, 1983, 1993, and 2005, larger catches were made compared to other years, with catches

of 5,262 tons, 5,237 tons, 8,054 tons, and 4,878 tons, respectively. According to the LOESS regression, while the catch remained stable between 1970 and 1990, it showed a continuous decreasing trend after 1990 (Figure 11). The catch, which was 624 tons in 2020, decreased to 107 tons in 2021 due to the mucilage observed in the Sea of Marmara.

In bonito fishery, fishing lines, set nets, drive-in nets, and purse seine nets are used (Table 4). This species is intensively caught between September and December (Devedjian, 1926; Oray et al., 1997; Zengin et al., 2005; Kahraman et al., 2014). Although fishing activities are carried out in almost every region of the Sea of Marmara, the places where the species is mostly fished are the coasts of Tekirdağ, Bandırma, and the Kapıdağ Peninsula.

4.1.6. Atlantic mackerel: This species was one of the most caught species in the past in the Sea of Marmara. During its migration to the Black Sea, it was heavily caught in the dalians set up in the Istanbul Strait. In addition, it was reported that mackerel was caught using beach seine nets and drive-in nets (Devedjian, 1926). In fact, it was reported that on October 8, 1913, 520,000 individuals were caught in just three hours from a single dalian (Bülbülderesi Dalian) and sent to the Istanbul Fish Market (Devedjian, 1926). This species, which was one of the most popular fish in Istanbul in the 1960s, stopped migrating to the Black Sea after the 1970s, and its catch amount has been gradually decreasing (Pasiner, 1998).

The annual average catch of mackerel between 1970 and 1984 was 120 tons. In addition, when compared to other years, larger amounts were caught in 1985 and 1993, with catches of 948 tons and 642 tons, respectively. However, after 2010, the significant declines in catch quantities have been observed. The annual average catch between 2010 and 2021 was 51 tons. According to the LOESS regression, while the catch increased between 1970 and 1988, it showed a continuous decreasing trend after 1989 (Figure 11). On the other hand, the catch was unexpectedly recorded as 387 tons in 2017. Subsequently, the catch quantities have started to decrease again. The catch, which was 49 tons in 2020, decreased to 4,7 tons in 2021 due to the mucilage in the Sea of Marmara.

Mackerel fishery is carried out in Izmit Bay, Gemlik Bay, and around the Princes Islands between September and November (Karakulak et al, 2019), and it is also caught from the coasts of Tekirdağ between July and August using set nets (Akyol and Perçin, 2006). Besides, this species is also caught using purse seine nets in Silivri (Istanbul), Hoşgör (Tekirdağ), Imrali Island, Marmara Island, and the Çanakkale Strait between September and November (Bahtiyar Menekşe, personal communication) (Table 4).

4.1.7. Atlantic chub mackerel:

It has been reported that the fishery of chub mackerel in the Sea of Marmara is carried out using beach seine nets around the coasts of Marmara Island, Paşalimanı, Ekinlik, Kapıdağ Peninsula, Bandırma, and the Princes Islands (especially around Sedef Island and Yassıada) (Devedjian, 1926). After August 15th, this species begins to migrate from the Black Sea towards the Sea of Marmara, and then heads towards the Aegean Sea, and it returns to the Black Sea by the end of April, but does not move towards the inner parts of the Black Sea, only reaching as far as Karaburun and Kilyos (Devedjian, 1926).

The annual average catch of chub mackerel between 1970 and 1985 was 1.430 tons. When compared to other years, larger amounts were caught in 1986, 1987, 1988, and 1989, with catches of 15,600 tons, 18,190 tons, 16,500 tons, and 11,209 tons, respectively. Between 1990 and 2001, the annual average catch was 3,408 tons. This amount began to decrease after 2002, and then dropped to an average of 217 tons per year. According to LOESS regression, while there was an increase in the amount of chub mackerel caught between 1970 and 1989, it can be seen that these amounts have been continuously decreasing since 1990 (Figure 11). The catch amount, which was 473 tons in 2020, decreased to 107 tons in 2021 due to the mucilage event in the Sea of Marmara.

Nowadays, chub mackerel has been caught between September and November in the Izmit Gulf, Gemlik Gulf, and Prince Islands using fishing lines, drive-in nets, and purse seine nets (Karakulak et al., 2019). Additionally, in the Tekirdağ coast, set nets are used for catching this species during July and August (Akyol and Perçin, 2006). It has also been reported that chub mackerel is caught using purse seine nets in Marmara Ereğlisi, Tekirdağ, and around Marmara Island during September and October (Bahtiyar Menekşe, personal communication) (Table 4).

4.1.8. Atlantic bluefin tuna: Tuna fishing in the Sea of Marmara dates back to ancient times. It is known that this fish is caught especially in the dalians established in the Istanbul and Çanakkale Straits. Some ancient writers such as Homer (8th century BCE), Pliny (1st century AD), and Athenaios (2nd century AD) mention the existence of bonito and bluefin tuna fish in both the Istanbul and Çanakkale Straits. It is reported that these fish were so abundant in Byzantion (Istanbul) that they were called the “golden horn” or “horn of plenty” in the Golden Horn (Devedjian, 1926; Sara, 1964; Cuvier and Valenciennes, 1969). In addition, bronze and lead weights with tuna figures were found in the excavations conducted in the ancient city of Kyzikos, located within the borders of Balikesir (Weiss, 1990; Tekin, 2013).

It is reported that bluefin tuna begins to migrate from the Aegean Sea towards the Black Sea in April, and this migration intensifies in July, ending by the end of August. The reverse migration, on the other hand, begins in October and continues until December (Devedjian, 1926; Akyüz, 1956; Sara, 1964). It has also been reported that this species stays in the Sea of Marmara until February and March, and during some periods, the fish feeds on such species as bonito, mackerel, and horse mackerel (Üner, 1960).

Until 1950, bluefin tuna fishing in the Sea of Marmara was carried out using dalians, fishing lines, and harpoons (Devedjian, 1926; İyigüngör, 1957; Üner, 1960; Karakulak, 2004). In the 1950s, purse seine nets were introduced in bluefin tuna fishing (Akyüz, 1956; İyigüngör, 1957), and with technological developments, these nets have become a common fishing gear for bluefin tuna in later years (Karakulak, 1999; Karakulak et al., 2002).

The annual average catch of bluefin tuna between 1970 and 2007 was 159 tons. However, in 1990, 1998, 1993, and 2001, larger catches were made compared to other years, with catches of 885 tons, 677 tons, and 928 tons, respectively. According to the LOESS regression, while the catch increased between 1980 and 1998, it showed a continuous decreasing trend after 2000 (Figure 11). In recent years, these fish have only been caught for fattening in cages established in bluefin tuna farms (Karakulak, 2007). Therefore, this species has not been a target species since 2007. Bluefin tuna fishing in Turkey is carried out with purse seine nets in May and June (Figure 10a), in accordance with the recommendations of ICCAT, in fishing grounds in the Eastern Mediterranean, where the catch amount is higher (Karakulak, 2012; Karakulak and Yıldız, 2015; Karakulak et al., 2016). In addition, this species has occasionally been caught as by-catch during the anchovy and sardine fishing in the Sea of Marmara.

4.1.9. Swordfish: Swordfish fishing is currently carried out in the Aegean and Mediterranean seas. However, historical records indicate that in the past, swordfish were caught in the Sea of Marmara, particularly in the Istanbul Strait (Figure 10b). Evliyâ Çelebi, in his work *Seyahatnâme* (Book of Travels), provides detailed information about the swordfish caught in the Beykoz Dalian in the Istanbul Strait (Dağlı and Kahraman, 2014). Devedjian (1926) also mentions the swordfish fishery using drift nets in Anadoluhisarı, Kanlıca, Çubuklu, Paşabahçe, Beykoz, and Sarıyer in the Istanbul Strait. Harpoon fishing targeting swordfish in the Sea of Marmara began in 1935 (Üner, 1992) and continued until the 1970s (Alıçlı, 2010; Akyol, 2012). Demir et al. (1956) reported that swordfish were mainly caught in the spring and autumn months in the Sea of Marmara as well as in the Istanbul and Çanakkale Straits.

Baysal (1971) reported the amounts of swordfish caught in the Sea of Marmara between 1956 and 1960 as 422 tons, 84 tons, 161 tons, 189 tons, and 27 tons, respectively. According to LOESS regression, there has been a continuous decrease in the catch of this species since 1970 (Figure 11). However, when TURKSTAT (2023) data were examined, the annual average catch of swordfish in the Sea of Marmara between 1970 and 2021 was 17 tons. Yet, fishing for this species has not been carried out in the Marmara Sea for many years. It is thought that this confusion stems from some fishing vessels registered in the ports of the Sea of Marmara reporting their swordfish catch records, which they caught with harpoon in the Northern Aegean Sea during the spring months, to the fishing ports they were affiliated with.



Figure 10. a) Purse seine bluefin tuna fishing (Photo: F. Saadet Karakulak); b) Sword fishing in a dalian during the Ottoman period in the late XIX and early XX centuries (Örenç et al., 2014).

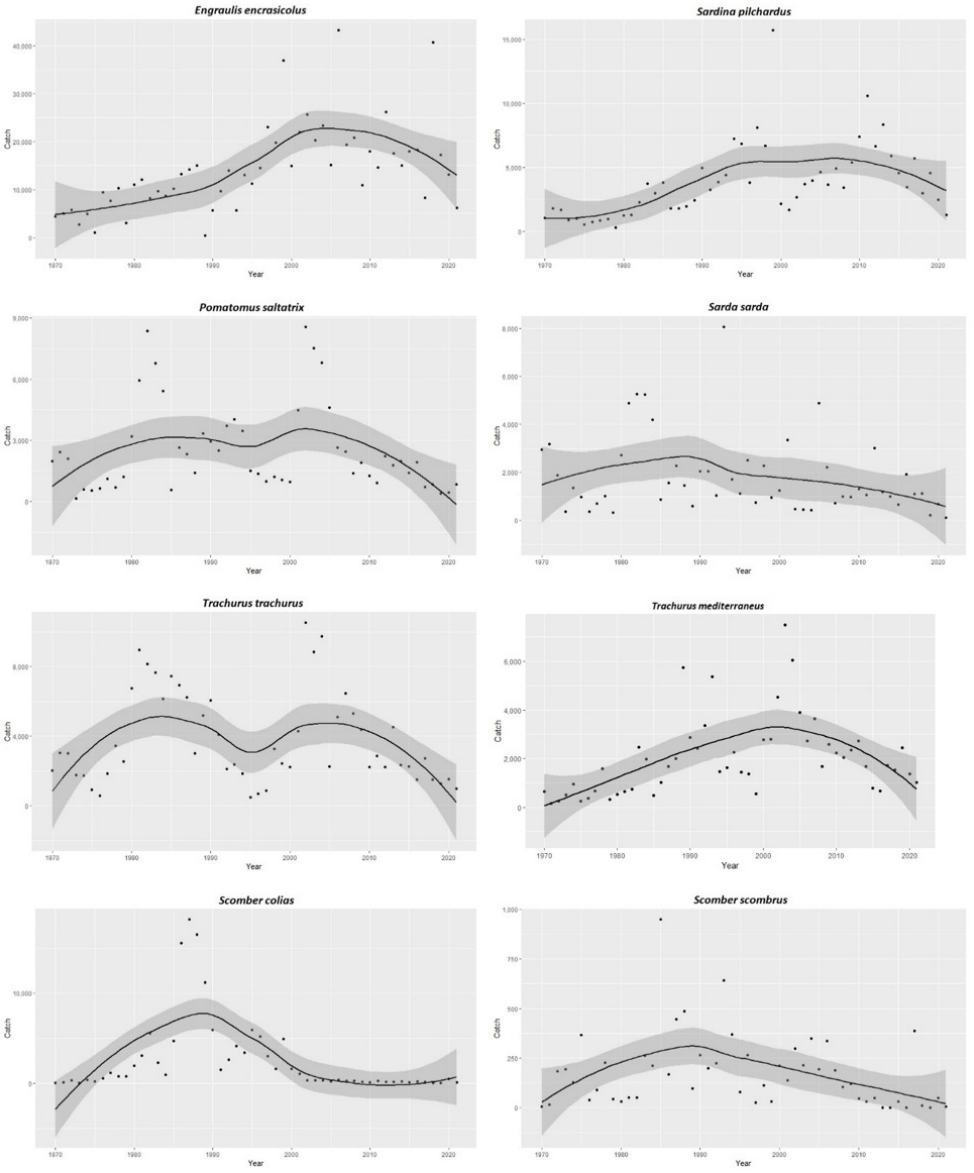


Figure 11. Catch trends of pelagic fish by years (according to LOESS regression).

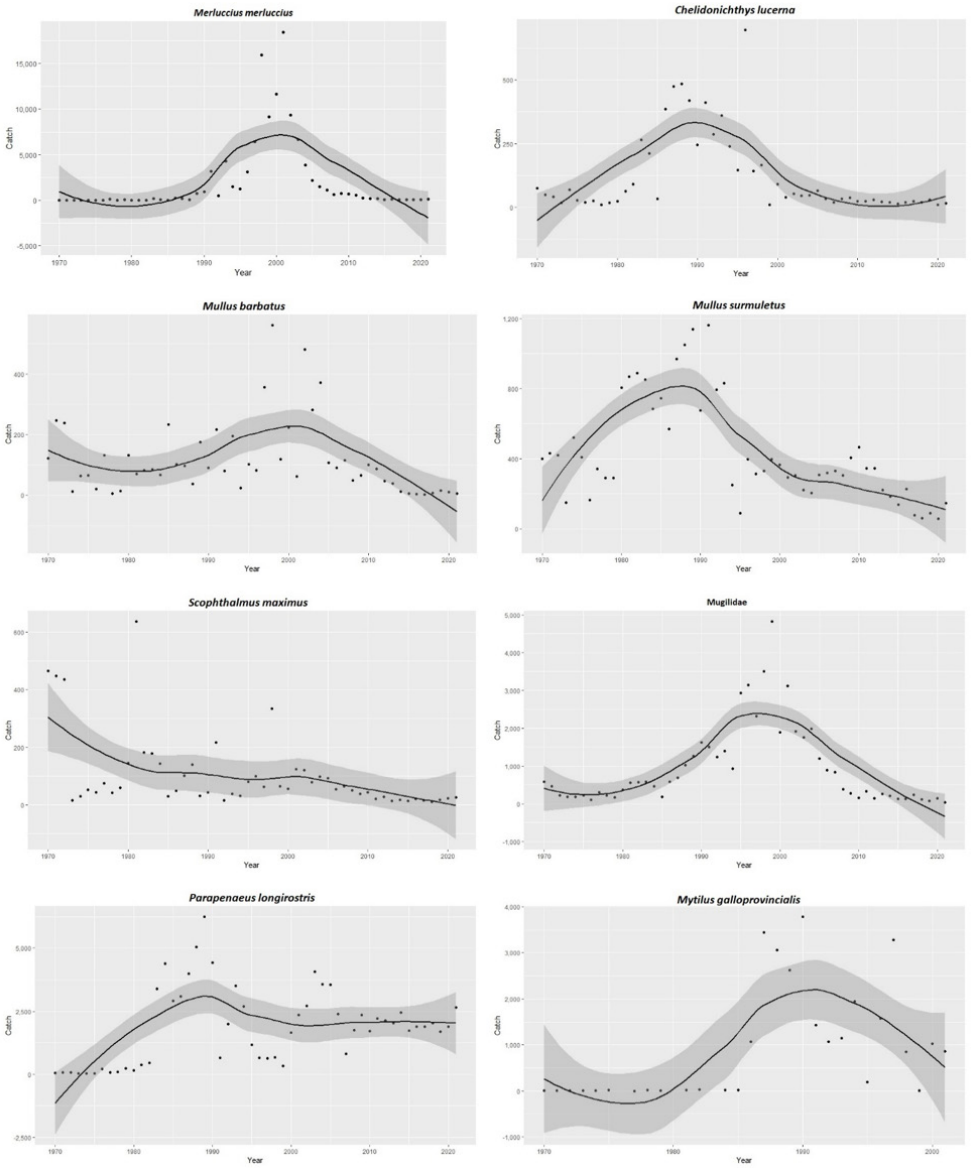


Figure 12. Catch trends of demersal fish by years (according to LOESS regression).

4.2. Demersal Fish Species

The Sea of Marmara is home to several important demersal fish species, including European hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*), striped mullet (*Mullus surmuletus*), whiting (*Merlangius merlangus*), turbot (*Scophthalmus maximus*), common

sole (*Solea solea*), flounder (*Platichthys flesus*), tub gurnard (*Chelidonchthys lucerna*), sand smelt (*Atherina* sp.), anglerfish (*Lophius piscatorius*), and mugilids (Mugilidae). Although the catch amounts of these species are less than pelagic fish, they are caught by small-scale fishermen and sold at high prices. Since the cartilaginous fishes have not been a primary target of commercial fisheries in the Sea of Marmara, and they have often been considered as spontaneous catch-opportunities, no species-specific statistics is available for most of the species. Therefore, in this chapter, we do not mention on the bycatch or targeted catches of chondrichthyans; however, this subject is discussed in another chapter of this book (see Chapter 25).

4.2.1. European hake: European hake, *Merluccius merluccius*, is one of the most important demersal fish species in the Sea of Marmara. Until 2005, the majority of its catch in Turkish waters was from the Sea of Marmara, followed by the Aegean Sea. However, since 2005, the Aegean Sea has become the primary fishing ground for this species, and its catch in the Sea of Marmara has decreased. In 2021, it was found that 81.74% of the total catch of hake was from the Aegean Sea, 14.54% from the Sea of Marmara, and 3.72% from the Mediterranean. The average annual catch between 1970 and 1990 was 137 tons, and it has increased since 1991. The highest catch was recorded in 1998 with 15,924 tons, followed by 11,662 tons in 2000 and 18,459 tons in 2001. According to the LOESS regression analysis, the catch trend showed an increasing trend between 1970 and 2001, but it has been continuously decreasing since 2002 (Figure 12). In 2021, the catch amount was 122 tons.

Fishing for *M. merluccius*, one of the most important demersal fish species in the Sea of Marmara, is mainly conducted using set nets along the northern and southern coasts of the Sea of Marmara (Deval et al., 2004; Göktürk et al., 2016; Kahraman et al., 2017a; Kahraman et al., 2017b). This fishing activity takes place between March and the end of May at depths ranging from 50 to 300 meters (Deniz et al., 2020). Additionally, this species is incidentally caught in the shrimp beam trawls and boats seine nets from September to April (Bayhan et al., 2006; Bök et al., 2011). The important fishing grounds are around Marmara Island, Silivri, Mimarsinan, Marmara Ereğlisi, Şarköy, and Çanakkale coasts (Barış Köksalan, personal communication) (Table 4).

4.2.2. Red mullet: Red mullet (*Mullus barbatus*) and striped mullet (*Mullus surmuletus*) are two demersal species that look very similar in appearance. Therefore, fishermen, with their own interests in mind, market the red mullet fish with a minimum catch size of 13 cm as the striped mullet, which has a legal catch size of 11 cm. The amount of the fish caught annually increased from an average of 104 tons between 1970 and 1996 to 307 tons between 1997 and 2004. The highest catch amounts were 561 tons in 1998, 482 tons in 2002, and 372 tons in 2004.

However, the annual catch amount decreased to an average of 45 tons between 2005 and 2021. According to LOESS regression, catch amounts increased from 1980 to 2002 but have shown a continuous decrease since 2003 (Figure 12). In 2021, the catch amount was recorded as 6 tons. Fishing for this species is conducted throughout the year, with higher activity in May and June. While fishing for red mullet was once carried out with beach seines, fish pots, and fishing lines (Devedjian, 1926), today, it is mostly done using set nets (Yıldız and Karakulak, 2010b; Akyol and Ceyhan, 2011). Due to the interaction between dolphins and nets in the Sea of Marmara, it is reported that fishermen use their set nets in a way that minimizes their impact, known as the drive-in net fishing method (Kenan Kedikli, personal communication) (Table 4).

4.2.3. Striped mullet: Fishing for the striped mullet (*Mullus surmuletus*) in the Sea of Marmara has increased since 1980. The annual catch was an average of 340 tons between 1970 and 1979, and it rose to 859 tons between 1980 and 1993. The highest catch was recorded in 1982 at 889 tons, in 1989 at 1,140 tons, and in 1991 at 1,161 tons. However, between 1994 and 2021, the average catch dropped to 256 tons per year. According to the LOESS regression, the catch showed an increasing trend from 1970 to 1991, but a continuous decrease has been observed since 1992 (Figure 12). Fishing for *M. surmuletus* can be performed in all seasons. Previously, this fish was caught using beach seines and fish pots (Devedjian, 1926; Uzer et al., 2017), but nowadays, it is mostly caught with set nets (Yıldız and Karakulak, 2010b; Karakulak et al., 2019). Similarly to the case of red mullet, fishermen use their set nets in a drive-in net fishing method to avoid dolphin interactions (Kenan Kedikli, personal communication) (Table 4).



Figure 13. a) Equipping fishing nets (Photo: F. Saadet Karakulak); b) Eskihisar/Kocaeli fishermen taking fish from the net (Photo: F. Saadet Karakulak).

4.2.4. Black Sea turbot: The annual average catch of turbot between 1970 and 1972 was 449 tons, while this value dropped to 48 tons between 1973 and 1980. Fluctuations in catch

amounts were observed in the following years. The highest catch amounts were recorded in 1981 and 1998 with 636 tons and 334 tons, respectively. According to the LOESS regression, there has been a continuous decrease in turbot catch in the Sea of Marmara between 1970 and 2021 (Figure 12). The catch amount dropped to 26 tons in 2021. Fishing for this species in the Sea of Marmara is carried out using set nets and longlines (Karakulak et al., 2019). Turbot fishing is carried out between November and April using set nets along the Anatolian coast of Istanbul (between Moda and Pendik), between Büyükçekmece and Tekirdağ (especially Silivri, Güzelce, Marmara Ereğlisi, and Kumbağ), and around the Prince Islands (Table 4). Meanwhile, longlines are used for turbot fishing between October and March in shallow and sandy areas between Bostancı, Büyükada, and Heybeliada (Akyol and Ceyhan, 2011; Yıldız and Karakulak, 2010b; Karakulak et al., 2019). However, it is explicitly stated in the regulations governing fishing that the use of longlines and trammel nets for turbot fishing is prohibited throughout all our seas, including the Sea of Marmara (BSGM, 2020).

4.2.5. Tub gurnard: There are seven species of gurnard living in the Sea of Marmara (Ünsal, 1988), but only two species (*Chelidonichthys lucerna* and *Chelidonichthys lastoviza*) are commercially fished using set nets, fishing lines, and longlines (Table 4). Tub gurnard is caught in all regions of the Sea of Marmara and the fishing season lasts from August to December (Karakulak et al., 2019). The catch of *C. lucerna* has increased since 1980 in the Sea of Marmara. The annual catch between 1970 and 1982 was an average of 41 tons, but this increased to 333 tons between 1983 and 1996. The highest catches were recorded in 1987 (475 tons), 1988 (485 tons), and 1996 (696 tons). However, the average annual catch between 1997 and 2021 decreased to 41 tons. According to the LOESS regression, there was an increasing trend in catches between 1970 and 1991, but since 1992, there has been a continuous decrease in catches (Figure 12). In 2021, the catch of *C. lucerna* decreased to 15 tons.

4.2.6. Common sole / Black Sea flounder: There are 11 species of flatfish living in the Sea of Marmara (Oral and Ünsal, 1992), and the most commercially fished species among them is the common sole (*Solea solea*). Another flatfish species caught in the Sea of Marmara is flounder (*Platichthys flesus*). Both species are caught using set nets between January and April in the Princes' Islands (Istanbul) and the Izmit Bay (Akyol and Ceyhan, 2011; Karakulak et al., 2019), and in March and April along the Tekirdağ coast (Akyol and Perçin, 2006). It is reported that the flounder is particularly heavily fished in March and April (Kenan Kedikli, Personal Communication), and it is also incidentally caught in shrimp beam trawls and boats seines (Kahraman et al., 2021). The flounder is abundant throughout the Istanbul Strait and in locations where the Strait opens into the Black Sea. While this species can be caught year-

round, its main fishing season is said to be from December to the end of January (Devedjian, 1926). However, it is also reported that it is particularly heavily fished in January and February compared to other months (Kenan Kedikli, Personal Communication) (Table 4).

Until 2007, the official statistics recorded the catch amounts for both sole and flounder together. The annual average catch amount for both species between 1970 and 2007 was 226 tons. The highest catch amounts were recorded in 1993 with 937 tons, in 1997 with 789 tons, and in 2001 with 455 tons. However, from 2007 to 2021, the annual average catch amount for sole was 87 tons, while for flounder it was 18 tons. It is clear that there has been a significant decrease in the catch amounts of both fish species compared to previous years.

4.2.7. **Mugilids (Mugilidae):** There are seven species of mugilids living in the Sea of Marmara Sea, with *Liza aurata* and *Mugil cephalus* being the most commercially caught (Bilecenoğlu et al., 2014). Mugilids are primarily fished using purse seine and drive-in nets between September and March, and set nets and fishing lines are used for catching throughout the year (Zengin et al., 2017). It is reported that these fish are intensively caught using purse seine and drive-in nets in Istanbul Strait, Bostancı, Ataköy, Silivri, Tekirdağ, Gelibolu, Kapıdağ Peninsula, and Bandırma coasts, particularly in November and December (Barış Köksalan, personal communication) (Table 4).

The annual average catch of these fish between 1970 and 1994 was 629 tons, which increased to 3,105 tons between 1995 and 2001. The highest catch was recorded in 1998 at 3,512 tons and in 1999 at 4,821 tons. However, between 2002 and 2021, the annual average catch was recorded as 563 tons. According to LOESS regression, there was an increasing trend in catch quantities between 1970 and 1999, but a continuous decrease has been observed since 2000 (Figure 12). The mugilids catch dropped to 41 tons in 2021.

4.2.8. Whiting: Fishing for whiting in Turkish waters is primarily conducted in the Black Sea, followed by the Sea of Marmara. In 2000, the Sea of Marmara accounted for 13.64% of the total whiting catch, but this percentage decreased to 2.53% in 2020 and further dropped to 1.06% in 2021. The annual average catch of whiting between 1970 and 1982 was 205 tons, which increased to 1,303 tons between 1983 and 2009. The highest catches were recorded in 1991 at 3,343 tons, in 1997 at 2,524 tons, and in 2000 at 2,455 tons. However, between 2010 and 2021, the annual average catch decreased to 443 tons. According to LOESS regression, there was an increasing trend in catch quantities between 1970 and 1995, but a continuous decrease has been observed since 1995. The whiting catch in 2021 was recorded as 110 tons.

Fishing for whiting is carried out in various regions of the Sea of Marmara, but the most intensive fishing areas for this species are in the southwest of the Sea of Marmara (Zengin et al., 2017). It is reported that whiting migrates in schools from the Black Sea to the Sea of Marmara during the winter months when strong winds occur, and they return to the Black Sea from May onwards (Pasiner, 1998). Whiting is reported to be caught year-round using bottom set nets near the Princes' Islands, in the Istanbul Strait, and along the Tekirdağ coast (Akyol and Ceyhan, 2011; Akyol and Perçin, 2006). Furthermore, it is known that this species is particularly caught using set nets and illegal trawl nets in the area between Ambarlı and Büyükçekmece during July and August (Table 4).

4.2.9. Big-scale sand smelt / Mediterranean sand smelt: In the Sea of Marmara, there are two species of sand smelt (*Atherina boyeri* and *Atherina hepsetus*) (Bilecenoğlu et al., 2014); however, *A. boyeri* is the most commercially caught species. The annual average catch of *A. boyeri* between 1970 and 1984 was 81 tons, which increased to 624 tons between 1985 and 1994. The highest catches were recorded in 1985 at 1,155 tons, in 1988 at 1,000 tons, and in 1994 at 1,034 tons. On the other hand, between 1995 and 2021, the annual average catch decreased to 91 tons. According to LOESS regression, there was an increasing trend in catch quantities between 1970 and 1988, but a continuous decrease has been observed since 1988. The catch of sand smelt in 2021 was recorded as 11 tons.

During the migration of sand smelt from the Sea of Marmara to the Black Sea, which occurs between March and June, it is reported that this species is fished in the Istanbul Strait using scoop and lift nets as well as in dalians (Pasiner, 1998; Yıldız et al., 2013; Biçer et al., 2020). Additionally, sand smelt is caught using set nets near the Princes' Islands and in the Izmit Bay from autumn to March, and around Marmara Island in February and March (Akyol et al., 2009; Akyol and Ceyhan, 2011; Karakulak et al., 2019) (Table 4).

4.2.10. Small red scorpionfish / Black scorpionfish / Red scorpionfish: In the Sea of Marmara, there are three species of scorpionfish (*Scorpaena notata*, *Scorpaena porcus*, and *Scorpaena scrofa*) (Bilecenoğlu et al., 2014), and *Scorpaena porcus* is the most commercially caught species. The annual average catch of *S. porcus* between 1970 and 1972 was 139 tons, which decreased to 16 tons between 1973 and 1985. However, the catch between 1986 and 1989, increased again to 140 tons, with the highest catches recorded in 1987 and 1988 at 150 tons. On the other hand, between 1990 and 2021, the annual average catch decreased to around 41 tons. According to LOESS regression, it can be observed that the average catch quantities showed a decrease between 1970 and 1985, an increase between 1986 and 1990, and a continuous decrease after 1990. The catch of scorpionfish in 2021 was recorded as

24.5 tons. The fishing of scorpionfish is predominantly carried out using set nets along the entire coast of the Sea of Marmara, particularly during the months of April and May (Yıldız and Karakulak, 2010b). The significant fishing areas for this species include the Istanbul and Çanakkale Straits, Marmara Island, and the Silivri coastline (Barış Köksalan, personal communication) (Table 4).

4.3. Other Species

In the Sea of Marmara, the other important commercially caught species are deep-water rose shrimp (*Parapenaeus longirostris*), Mediterranean mussel (*Mytilus galloprovincialis*), rapa whelk (*Rapana venosa*), striped venus clam (*Chamelea gallina*), and European flat oyster (*Ostrea edulis*). Additionally, some species such as common octopus, European squid, carpet shell, Mediterranean scallop, sea cucumber, edible crab, spiny lobster, and European lobster are also encountered in small quantities. In recent years, there has been a noticeable increase in the quantities of certain cephalopod species caught as bycatch in the Sea of Marmara. These species, mainly caught by small-scale fishermen, are not recorded, and therefore, not included in fisheries statistics.

4.3.1. Deep-water rose shrimp: Shrimp fishing in the Sea of Marmara has shown an increase since 1983. The average annual catch of this species was 146 tons between 1970 and 1982, but it rose to 3,382 tons in 1983. The highest catch was recorded in 1989 at 6,236 tons. The catch quantities of this species in the 1990s experienced fluctuating trends. On the other hand, the average catch quantity between 2000 and 2021 was recorded as 2,252 tons. According to LOESS regression, there was an increasing trend in catch quantities between 1970 and 1988, but a decrease was observed after 1988. Additionally, it can be observed that these quantities remained stable between 2000 and 2021 (Figure 12).



Figure 14. a) A beam trawl vessel for shrimp fishery in the Sea of Marmara (Photo: F. Saadet Karakulak); b) Separating shrimp from other fish (Photo: F. Saadet Karakulak).

Shrimp fishing in the Sea of Marmara is conducted in specific areas. In the northern part of the sea, it takes place in Istanbul (Tuzla, Yeşilköy) and Tekirdağ (Barbaros, Hoşköy, Şarköy). In the southern part, the fishing occurs in the southwest of Marmara Island, Bandırma, Erdek, Kurşunlu, and Karacabey waters as well as in the Gemlik Bay (Mudanya, Armutlu) using beam trawls and boat seines (Zengin et al., 2017) (Table 4). Fishing activities primarily take place between 50 meters and 200 meters depth during daylight hours (between 05:00 and 20:00). Boat seines are used by a limited number of fishermen in Tuzla, Tavşan Island (Istanbul), and Gemlik Bay. Shrimp fishing in the Marmara Sea is prohibited from January 1st to January 31st and from April 15th to August 31st (BSGM, 2020).

As of 2022, in the Sea of Marmara, 93% of shrimp fishing vessels use beam trawls (266 vessels), while 7% use boat seines (20 vessels). The beam trawlers range in size from 6 to 23 meters in length and have engine power between 7 and 559 kW. On the other hand, the boat seines vessels range in size from 9 to 18 meters and have engine power between 67 and 330 kW (BSGM, 2023).

4.3.2. Mediterranean mussel: It is reported that until the year 2000, mussel fishing was conducted in the northern part of the Istanbul Strait (Tarabya, Kireçburnu, Sarıyer, Rumeli Kavağı, Umuryeri, Anadolu Kavağı, and Filburnu) using approximately 24 dredging boats with lengths ranging from 6.5 to 11.10 meters and motor powers between 9 and 80 HP (Erdoğan and Bök, 2004). Since 2000, mussel fishing using dredges has been prohibited in the Sea of Marmara, Istanbul and Çanakkale Straits.

Between 1970 and 1985, the annual average mussel catch quantity was 12 tons, but in 1986, it increased to 1,068 tons. The highest catch quantity was recorded in 1987 at 3,441 tons, followed by 3,778 tons in 1990 and 9,454 tons in 2005. However, between 1998 and 2017, the average catch quantity dropped to 790 tons. This decline can be attributed mainly to the ban on dredging in mussel fishing starting from the year 2000. It is known that after 2017, mussel catch quantities are not included in fisheries statistics, but it is continued through diving (Table 4). According to LOESS regression, there was an increasing trend in catch quantities between 1980 and 1990, but after 1990, there has been a consistent decrease in these quantities (Figure 12).

4.3.3. **Rapa whelk:** After entering the Black Sea in the 1940s, the invasive species known as the rapa whelk expanded its distribution towards the Sea of Marmara. This species was reported to be present in the Istanbul Strait in 1960 and in the Sea of Marmara in 1966 (Erik, 2011). Rapana fishing started to gain importance in 1999. The average annual catch quantity

of rapana between 1999 and 2021 was recorded as 382 tons. The highest catch quantity was 681 tons in 2007, followed by 771.9 tons in 2019 and 894.6 tons in 2020. According to LOESS regression, there has been a continuous increase in catch quantities between 1999 and 2020, but in 2021, there was a decrease (247.9 tons).

The rapa whelk, which is not consumed in the domestic market, is exported mainly to the Far East as well as European Union countries such as France and Italy. Rapana fishing by diving is carried out intensively in the Istanbul Strait, around the Princes' Islands, and along the coast of Yalova, especially in summer and autumn (Table 4). In 2022, a total of 170 fishing boats, ranging from 6 to 12 meters in length and with motor powers between 7 and 358 kW, obtained permission to engage in rapa whelk fishing by diving in the Sea of Marmara (BSGM, 2023).

4.3.4. Striped venus clam: It started to gain importance from 1988 onwards and was exported to European Union countries. The catch quantity of this species was recorded as an average of 4,269 tons per year between 1988 and 1999. The highest catch quantity was 13,207 tons in 1990, followed by 11,071 tons in 1993. However, these quantities have been consistently decreasing since 1994. Finally, the catch quantity dropped to 1,028 tons in 1999. Due to excessive fishing pressure on the species, stocks were depleted, and fishing for this species was completely prohibited starting from the year 2000. According to the LOESS regression, there was a continuous increasing trend between 1970 and 1993. However, since 1994, there has been a consistent decrease.

Striped venus clam fishery has been carried out by small-scale fishermen using rakes and dredges in coastal areas (depths of 0-15 meters) in Selimpaşa, Silivri, Marmara Ereğlisi, Tekirdağ, Kumbağ, Şarköy, the Çanakkale Strait, Musakça Village, and the Gemlik Gulf between September 15th and April 15th. According to data from 1991, this fishing activity was conducted with 779 boats ranging from 5 to 10 meters in length (Patrona, 1991; Deval, 2001).

Table 4. The commercial fish species in the Sea of Marmara, fishing gears and fishing season.

Species	Fishing Gear	Fishing Season for Industrial Fisheries	Fishing Season for Small Scale Fisheries
E. encrasicolus	Purse seine, set net, dalian	September-March	July-September/set net April-June/dalian
Trachurus sp.	Purse seine, set net, dalian, fishing line	September-April	April-June/dalian All seasons/set net, fishing line
S. pilchardus	Purse seine, set net	September-October	May-August

P. saltatrix	Purse seine, drive-in net, set net, dalian, fishing line	September-April	September-April/set net, drive-in net, fishing line May-June/drive-in net, dalian, fishing line
S. sarda	Purse seine, drive-in net, set net, dalian, fishing line	September-December	September-December
S. scombrus	Purse seine, set net, fishing line	September-November	September-November July-August
S. colias	Purse seine, drive-in net, fishing line	September-October	September-November July-August
Belone belone	Boat seine, fishing line	-	All seasons
M. merluccius	Set net, beam trawl, boat seine	-	March-May/set net September-April/beam trawl, boat seine
Mullus sp.	Set net	-	All seasons
M. merlangus	Set net	-	All seasons
S. maximus	Set net	-	September-April
S. solea	Set net		January-April September-October
P. flesus	Set net		January-February
C. lucerna	Set net, longline, fishing line	-	August-December
Atherina sp.	Lift net, dalian, set net, scoop	-	February-June
Mugilidae	Purse seine, drive-in net, set net, fishing line	November-December	All seasons
Scorpaena sp.	Set net	-	April-May
Spicara sp.	Set net	-	January-February
Dicentrarchus labrax	Fishing line	-	All seasons
Diplodus vulgaris	Set net, fishing line	-	June-October/ set net January-March/fishing line
Sciena umbra	Set net, longline	-	June-July/set net May-November/longline
Dentex dentex	Longline	-	June-September
Lophius piscatorius	Set net	-	Summer / Winter
P. longirostris	beam trawl, boat seine	-	September-December February-April
M. galloprovincialis	Dive fishery	-	July-15 April
R. venosa	Dive fishery	-	Summer / Autumn
Homarus/Palinurus sp.	Set net, dive fishery	-	All seasons

4.3.5. European oyster: In the 1920s, it was reported that the best oysters were found in Istanbul, particularly in the area from Sarayburnu to Bakırköy, Yeşilköy, and Ambarlı. The

oysters caught in this region had high commercial value, and they were used for oyster fishing with dredges, with the harvested products being exported to Romania (Devedjian, 1926). In the 1990s, oyster fishing was reported to be carried out with dredges almost all parts of the Sea of Marmara (especially in Ambarlı, Mimarsinan, Silivri, Tekirdağ, Marmara Ereğlisi, Gemlik Gulf, Bandırma Gulf, and Mudanya) between September and April (Ateş and Oray, 1991). Nowadays, the fishing of this species having lost its former significance is just performed through diving (Kenan Kedikli, personal communication).

Oyster fishing in the Sea of Marmara has shown an increase since 1984. The average annual catch quantity of this species between 1984 and 2000 was approximately 760 tons. The highest catch quantity was recorded in 1989 at 1,734 tons, followed by 2,098 tons in 1990 and 1,600 tons in 1991. However, a decrease in catch quantities has been observed since 1992. According to LOESS regression, there was an increase in catch quantities between 1984 and 1994, but after 1994, there has been a consistent decrease. The most recent recorded catch was 0.2 tons in 2015.

5. Conclusion

The growth in global population over the past 60 years has led to an increased demand for seafood at a global scale. Seafood is among the most traded food products worldwide. According to the FAO's 2020 data, 34% of total seafood production is accounted for by international trade. This high demand for fisheries resources has triggered overfishing worldwide. The ratio of biologically sustainable fish stocks globally has declined from 90% in 1974 to 64.6% in 2019. Among regions where fish stocks are unsustainably exploited, the Southeast Pacific region ranks highest at 66.7%, followed by the Mediterranean and Black Sea at 63.4% (FAO, 2022). The Mediterranean and Black Sea regions have become areas where biological diversity is at risk due to increasing fishing pressure, anthropogenic stress factors, and the impact of climate change (Conides and Papaconstantinou, 2020). The Sea of Marmara (GSA28) is one of the sub-regions of the Mediterranean Basin. In this chapter, an assessment has been made regarding fishing activities, the structure of the fishing fleet, fisheries resources, and the status of fishing from the past to the present in the Sea of Marmara.

Fishing activities in the Sea of Marmara have significantly increased and reached a substantial economic size, particularly in the 1980s, with the development of the fishing fleet. The presence of abundant pelagic species such as anchovy, sardine, horse mackerel, bonito, and significant demersal species has contributed to the development and widespread use of various fishing techniques in this region (Yıldız and Karakulak, 2016). In this study, the fishing trends of important species in the Sea of Marmara between 1970 and 2021 were revealed

through LOESS regression analysis, and it was found that out of the 24 species examined, 23 have experienced a significant decrease in their catch quantities. The analysis showed that only deep-water rose shrimp catch quantities remained relatively stable without any decrease. It was revealed that formerly important commercial species in the Sea of Marmara, such as bluefin tuna, swordfish, striped venus clam, and oyster, are no longer being caught. There has been a noticeable decline in the catch quantities of species, especially after 2000. The main reasons for this decline include intense anthropogenic and industrial pressures, marine pollution, eutrophication, increasing water temperature, excessive proliferation of algae and gelatinous organisms, biodiversity loss, mucilage events, habitat losses, and particularly increased fishing pressure (Aktan et al., 2008; ÇŞİDB, TUBITAK-MAM, 2021; İşinibilir and Yılmaz, 2017; Ulman et al., 2020; İşinibilir et al., 2021a; İşinibilir et al., 2021b; Altıok et al., 2021; Salihoğlu et al., 2022).

Due to fishing activities, the imbalance in the biomass of small pelagic species, which play an important role in the trophic chain, has significant effects throughout the upper layer of the marine ecosystem (Duarte and Garcia, 2004). Gücü (2013) highlighted the increasing eutrophication in the Sea of Marmara and emphasized the need to reduce excessive fishing pressure on small pelagic species. Zengin and Mutlu (2000) estimated the maximum sustainable yield (MSY) in the Sea of Marmara to be 45,000 tons. However, when examining the 1999 TURKSTAT data, it is observed that almost twice the calculated amount (83.3 tons) was caught, and 67% of this catch consisted of small pelagic species such as anchovy, horse mackerel, and pilchard. Therefore, in order to prevent the recurrence of the recently frequent mucilage events in the Sea of Marmara, it is crucial to reduce the fishing pressure on small pelagic species.

In the Sea of Marmara, purse seiners intensively conduct fishing activities between September and December. However, some of these vessels switch to the Aegean Sea to continue fishing during the period between January and April when the catch efficiency decreases, while others choose to end the season early. Industrial fishermen, who have been earning less profit compared to previous years, have shown a tendency to fish in foreign waters. Approximately 1,000 fishing vessels (purse seiners and trawlers) including purse seiners operating in the Sea of Marmara have been reported to have started fishing off the coasts of Mauritania since 2015 and still continue these activities (Öztürk, 2018). On the other hand, small-scale fishermen in the Sea of Marmara have been forced to find secondary jobs or borrow money due to the decrease in catch efficiency. A significant portion of fishermen who have suffered economic losses in this process demand the implementation of regional

fishing management and quota systems in fisheries. The implementation of a quota system for the purse seining in the Sea of Marmara could contribute to the conservation of fish stocks. Additionally, restricting the fishing activities of purse seiners larger than 30 meters can help reduce the existing fishing pressure. Furthermore, it is necessary to provide financial support to small-scale fishermen during this process.

The fishing resources of the Mediterranean and Black Seas, which are semi-enclosed basins, have been overexploited over the years, posing ongoing threats to the biological diversity of both seas. The GFCM 2030 strategy sets forth several goals for sustainable fisheries in the Mediterranean and Black Seas. One of these goals is the promotion of healthy seas and productive fisheries. Sustainable fisheries are addressed in terms of social, economic, and environmental aspects, aiming to conserve biodiversity and ensure fishing activities are conducted at the maximum sustainable yield (MSY) level. Additionally, the GFCM 2030 Strategy emphasizes the significant role of small-scale fisheries in the region in social, economic, and cultural terms (FAO, 2021).

In 2019, approximately 82.5% of the total global fishery production was derived from biologically sustainable stocks. This indicates a positive development (+3.8%) compared to 2017, reflecting successful stock rebuilding through effective fisheries management and increased fishing yields without causing harm to the ecosystem (FAO, 2022). Establishing sustainable fisheries while preserving the health of aquatic ecosystems primarily relies on well-planned and effective fisheries management. Therefore, providing depleted stocks with the opportunity for recovery can contribute significantly to the employment, food security, and economic well-being of coastal communities.

A comprehensive assessment of stock status for species caught in the Sea of Marmara Sea has not been conducted so far. The current fisheries management primarily focuses on regulations related to time and area closures, minimum landing sizes, and fishing gear. Therefore, it is crucial to have knowledge of parameters such as biomass, stock recruitment, and fishing mortality rates to establish an effective management plan. The Sea of Marmara, a part of the Mediterranean basin, where fish stocks are heavily exploited and experiencing rapid warming, is particularly vulnerable to the negative impacts of anthropogenic and environmental stressors, especially in recent years. Consequently, it is crucial to develop a fisheries management plan specific to the Sea of Marmara and adopt ecosystem-based fisheries principles that consider the social, economic, and institutional aspects of fishing as well as the impacts of climate change.

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