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REVİEW **DERLEME**

A systematic review of age, growth and mortality studies in Mediterranean and Black Sea fishes

Akdeniz ve Karadeniz balıklarının yaş, büyüme ve ölüm çalışmalarının sistematik bir derlemesi

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Abstract: Age, growth, and mortality studies (AGMS) conducted in the Mediterranean and the Black Sea were reviewed. The main objective of this study was to find out the gaps on unstudied and less studied species. Names of the all fish species were obtained from fishbase. While the “native” and “endemic” species were taken into consideration, species “introduced”, “questionable”, “misidentified” and “error in a name” were excluded from the data set. Fishbase, semanticscholar and googlescholar were used to obtain the species related studies in June 2023. Graphs and tables were created to represent the results. Totally, 185 of 604 species have AGMS. 22 countries have investigated fish age, growth, and mortalities, and the first three countries are Türkiye, Italy, and Greece, respectively. In the Mediterranean and Black Sea, 796 AGMS were found. The top three of these families with the most species are Sparidae (177), Mullidae (87), and Mugilidae (66). Among the studied species, 86.49% of the species (160) are commercially important for fisheries, and 13.51% of the species (25) are non-commercial. 31 of the 160 species encounter existence problems. All accessible studies were used including studies’ references and it was observed that the most of the species (419) in the Mediterranean and Black Sea have no age or growth studies. This study clearly shows the gaps in AGMS in the Mediterranean and Black Sea regions.

Keywords: Mediterranean, Black Sea, scientific research, age, growth

Öz: Akdeniz ve Karadeniz'de yürütülen yaş, büyüme ve ölüm çalışmaları (AGMS) gözden geçirilmiştir. Bu çalışmanın temel amacı, üzerinde çalışılmamış ve az çalışılmış türlerdeki boşlukları ortaya çıkarmaktır. Çalışmaya dahil olan tüm balık türlerinin isimleri fishbase veri tabanından elde edilmiştir. “Yerli” ve “endemik” türler dikkate alınırken, “yabancı”, “şüpheli”, “yanlış tanımlanan” ve “isim hatası” olan türler veri setinden çıkarılmıştır. Haziran 2023'te türlerle ilgili çalışmaların elde edilmesi için Fishbase, semanticscholar ve googlescholar kullanılmıştır. Sonuçları temsil edecek grafikler ve tablolar oluşturulmuştur. Toplamda 604 türün 185'inde AGMS bulunmaktadır. Balıkların yaşı, büyümesi ve ölümleri 22 ülkede araştırıldığı tespit edilirken ve ilk üç ülke sırasıyla Türkiye, İtalya ve Yunanistan olarak belirlenmiştir. Akdeniz ve Karadeniz'de 796 AGMS yapılmıştır. En çok türün bulunduğu ilk üç familya Sparidae (177), Mullidae (87) ve Mugilidae (66) olarak belirlenmiştir. İncelenen türlerin %86,49'u (160) balıkçılık açısından ticari öneme sahip olup, %13,51'i (25) ticari değildir. 160 türden 31'i varoluş sorunlarıyla karşı karşıyadır. Çalışmaların referansları da dahil olmak üzere erişilebilir tüm çalışmalar kullanılmış ve Akdeniz ve Karadeniz'deki türlerin çoğunun (419) yaş ve büyüme çalışmalarının bulunmadığı görülmüştür. Bu çalışma Akdeniz ve Karadeniz bölgelerinde AGMS'deki boşlukları açıkça göstermektedir.

Anahtar kelimeler: Akdeniz, Karadeniz, bilimsel araştırma, yaş, büyüme

INTRODUCTION

The Mediterranean is surrounded by Asia, Europe and the Africa continents, and since ancient times, the region has numerous civilizations, cultures, and nations (Stavridis, 2017). In its history, the Mediterranean fishery also has its own tradition (Lleonart and Recasens, 1997). However, Bas et al. (1985) draw attention to the technological advances and modernization of fleets in fisheries play a role in the decline of fishery resources.

The global species richness rate is decreasing dramatically compared to past times (Barnosky et al., 2011), and marine fish species are no exception to this threat. Two basins, the Mediterranean and Black Seas (FAO area 37), have the highest percentage (62%) of stocks fished at levels that are biologically unsustainable (FAO, 2018), and one of the regions with the lowest global fisheries management index scores for management and enforcement is the Mediterranean (Hilborn et al., 2020). Anthropogenic activities (overharvesting, introduction of non-native species, pollution, habitat destruction, and human-induced climate change) have long been the underlying causes of species declines (van Treeck et al., 2020). The determination of species that are on the brink of extinction has been a major concern for scientists and environmental agencies (either governmental or private enterprises) worldwide. At the end, a number of threat categories with specified criteria identified for each have been formed to list species and place them into (IUCN, 2023). Also, the efforts to document the species prone to go extinct appear to meet around the essential idea that species that fall into high risk categories are more likely to become extinct than those in low risk categories (van Treeck et al., 2020).

The results of anthropogenic activities, for example, increasing mercury contamination, surface water acidification, and eutrophication, inhibit the growth of algae, reduce hatching success, and increase egg and larval mortality (Driscoll et al., 2001; Bergström and Jansson 2006). Adding to the above-mentioned anthropogenic activities, the complex nature of fisheries complicates the establishment of biotic resource sustainability through decreasing mortality rates and control of other fisheries measures. Unintended by-catches from flawed fishing techniques, fishing gear damaging the natural habitats of the species, and unpredictable ecological consequences of targeting one or key species within the trophic link are some of the known reasons for the complication (Caddy and Agnew, 2004). On the other hand, it is reported that there are numerous fish species that are targeted by small-scale and recreational fisheries, and about which no relevant data is present to assess their current population status (Lloret et al., 2019).

When anthropogenic activities and lack of data are considered together, the exploitation rate of fish species in the Mediterranean and Black Seas and the way this issue is being and will be assessed become even more crucial to be discussed. There are numerous assessment methods suggested to reach the goal of sustainability in fisheries (Hoggarth, 2006; Coll et al., 2013; Goetze et al., 2016; Carvalho et al., 2019). The primary goal of conventional management has been to adjust fishing effort to levels that ensure maximum sustainable yield, or the largest catch that can be taken from a stock during the course without depleting it. Maximum sustainable yield and its related biological reference points, such as stock biomass and fishing mortality rate, are key parameters used for measuring the status of a stock or fishery (Hilborn and Ovando, 2014).

The fish's biological characteristics are important values for the stock assessment studies (Najmudeen and Wilson, 2019). Growth parameters provide some indication of resource utilization and the effectiveness of management strategies. When age and growth are evaluated in combination, it may be easier to understand the relationship between population size and biomass. This understanding is the basis of modern fisheries resource allocation and management, and fisheries management should be designed based on biological data to understand the status of and manage fish stocks (Isely and Grabowski, 2007). Especially the growth parameters L_∞ (asymptotic length), K (growth coefficient and t_0 (theoretical age at zero length) are used almost in all stock assessment models. However, the studies have mostly focused on commercial species. Even if decline in fishery resources is a different topic, ecosystems should be considered as a whole. Therefore, either commercial or non-commercial species should not be considered different components of the fishery resources.

A review study indicates the gaps in a certain area and shows ways for scientists (Dhillon, 2022). Our review idea originated from Dimarchopoulou et al. (2017). The researchers put forward the available studies of Mediterranean fish with different topics. In the brainstorming phase, we thought, "Al*right, how many age, growth, and mortality studies have been conducted up to 2023?*", "*What are the details of these studies in the Mediterranean region?*" and "*Gathering information about the Mediterranean fish species could be helpful for the fisheries scientists*". Thus, this review came out to deeply learn about age and growth studies in the Mediterranean and Black Sea basins. The results obtained are thought to be very important in terms of showing neglected species in fish biology.

MATERIALS AND METHODS

The Mediterranean was separated into sub-regions by FAO (2023) as Mediterranean and Black Sea (Major Fishing Area 37); Western Mediterranean (Balearic, Gulf of Lions, Sardinia), Central Mediterranean (Adriatic, Ionian), Eastern Mediterranean (Aegean, Levant), Black Sea (Marmara Sea, Black Sea, Azov Sea).

In this study, Mediterranean fish species were determined from the Fishbase catalog (June 2023) (Froese and Pauly, 2023). The data set used in the study consisted of between 1920 and 2023. Age, growth, and natural mortality values (L_∞, k, t_0, and M) of all Mediterranean fish species in Fishbase were taken. All literature was searched for non-existing studies in Fishbase. In this process, an artificial intelligence powered research tool, semanticscholar, was used. Studies were also searched on googlescholar to keep sight of any study. The cited literature in the obtained papers was also checked.

According to the results obtained from the literature search, fish species have age, growth, and mortality studies that were conducted in the Mediterranean (from Gibraltar to the Black Sea), were selected and classified. Next, a detailed analysis was conducted to learn about the Mediterranean studies, such as regional, species-specific, number of studies, number of families, etc. Species threatened levels were also determined by the IUCN red list (IUCN, 2023).

In the visualization process, Microsoft Excel and Rstudio were used.

RESULTS

All meta-data was presented in supplementary material by separated tabs. Tabs include different statistics on all Mediterranean species, all age and growth studies on species up to June 2023, selected species for this study, study numbers by species, information on families, red list information of the species, and study information of the countries.

Mediterranean fish and overall distributions

According to Fishbase, the Mediterranean basin includes 778 fish species. In this number, 557 are "native", 135 are "introduced", 47 are "endemic", 23 species are "questionable", 14 are "misidentified" and 2 are "error in a name", or in other words "an incorrect spelling" (Figure 1). All species without native and endemic were excluded from the data set. The total number of the considered fish species in this study is 604 (native+endemic).

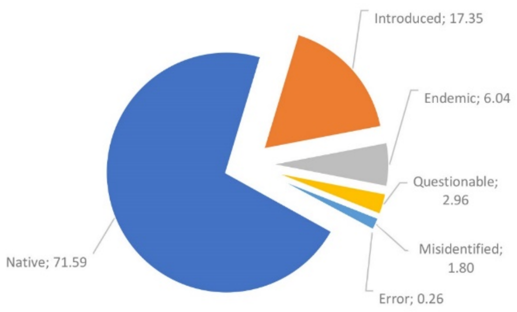

Figure 1. Distribution (%) of the total fish species in the Mediterranean (N=778)

Among the selected species, 518 are Osteichthyes (85.76%) and 86 are Chondrichthyes (14.24%).

Selected species and age, growth, and mortality studies in the Mediterranean and Black Sea

All AGMS were conducted in 22 different countries. The first three countries that have AGMS are Türkiye, Italy, and Greece, respectively (Figure 2). Fish species selected among the total of 604 species which have age, growth, and mortality studies (AGMS), and a total of 796 studies were found that belong to 185 fish species that have AGMS. In some papers, one species was studied, however, in some papers, more than one species was studied. Figure 2 was built according to species numbers in these studies.

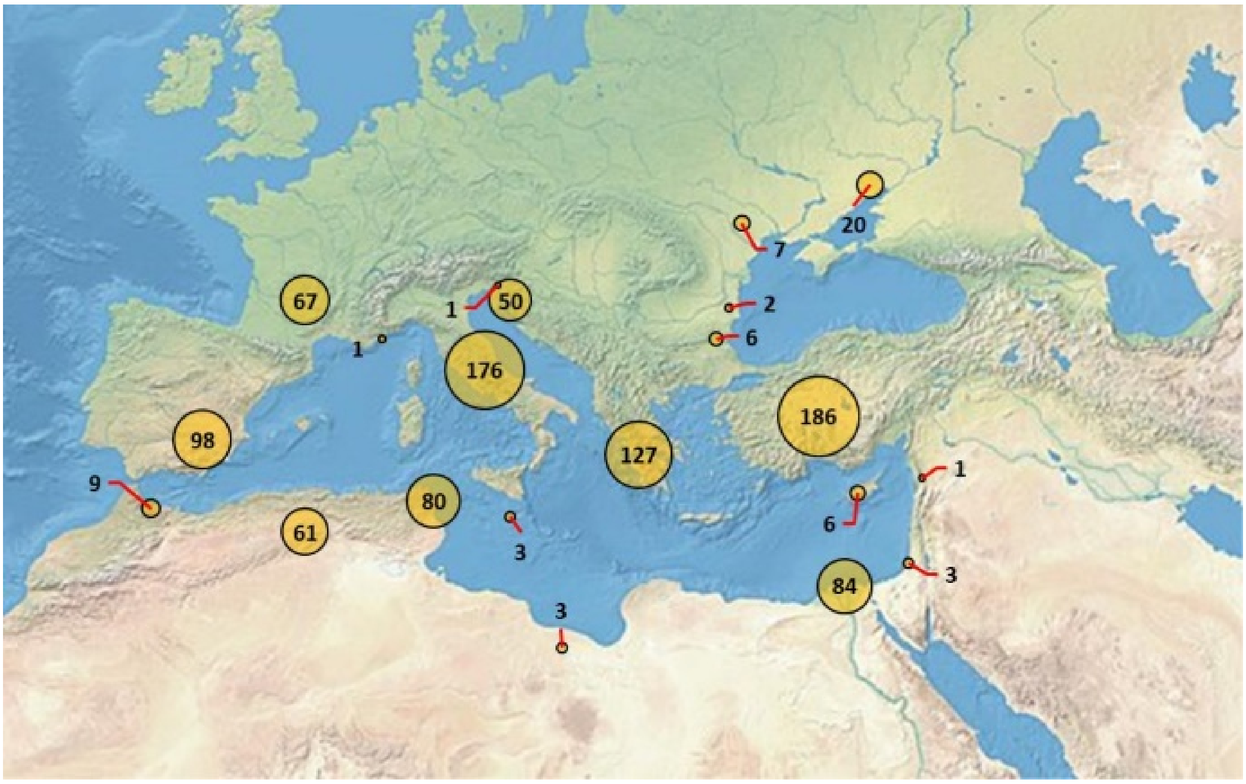

Figure 2. AGMS's distribution by countries in the Mediterranean

The number of studies had started to slightly increase by the late 1940s than a sharp increase in the 1980s (Figure 3).

The selected 185 fish species belonging to 72 families were 161 (87.03%) of Osteichthyes and 24 (12.97%) of Chondrichthyes. On the other hand, in Mediterranean age and growth studies, Osteichthyes were studied 955 times (95.79%) and Chondrichthyes were studied 39 times (3.91%).

The first 10 families and species have the most studies shown in Figure 4. The top three of these families with the most species are Sparidae (177), Mullidae (87), and Mugilidae (66), respectively. In Sparidae, the three most studied species were *Boops boops* (Linnaeus, 1758) (28), *Pagellus erythrinus* (Linnaeus, 1758) (27), and *Spicara smaris* (Linnaeus, 1758) (15) (Figure 5).

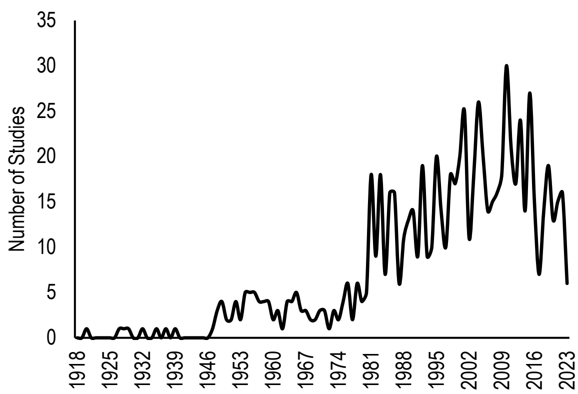

Figure 3. Number of studies by year in the Mediterranean

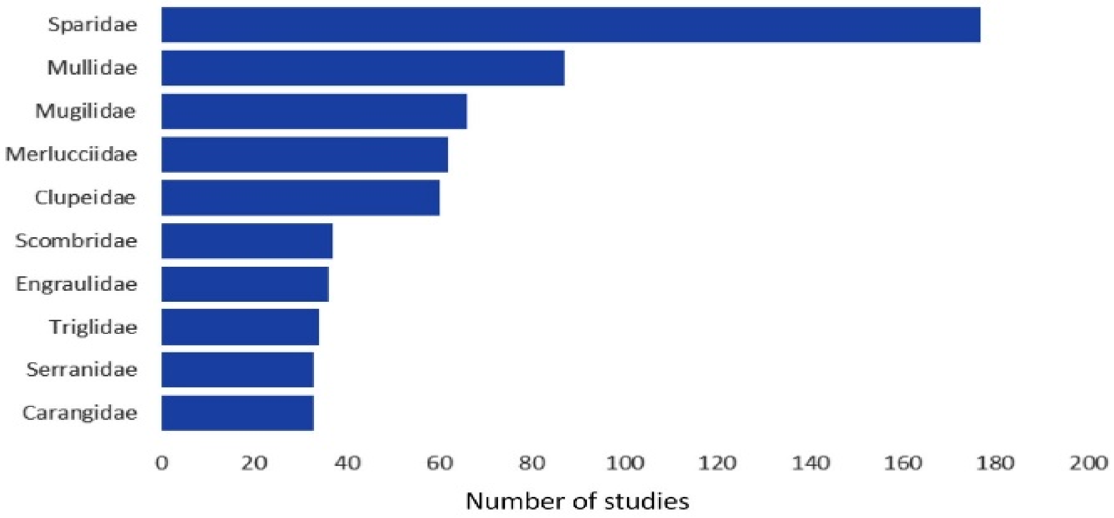

Figure 4. The 10 most studied families in the Mediterranean

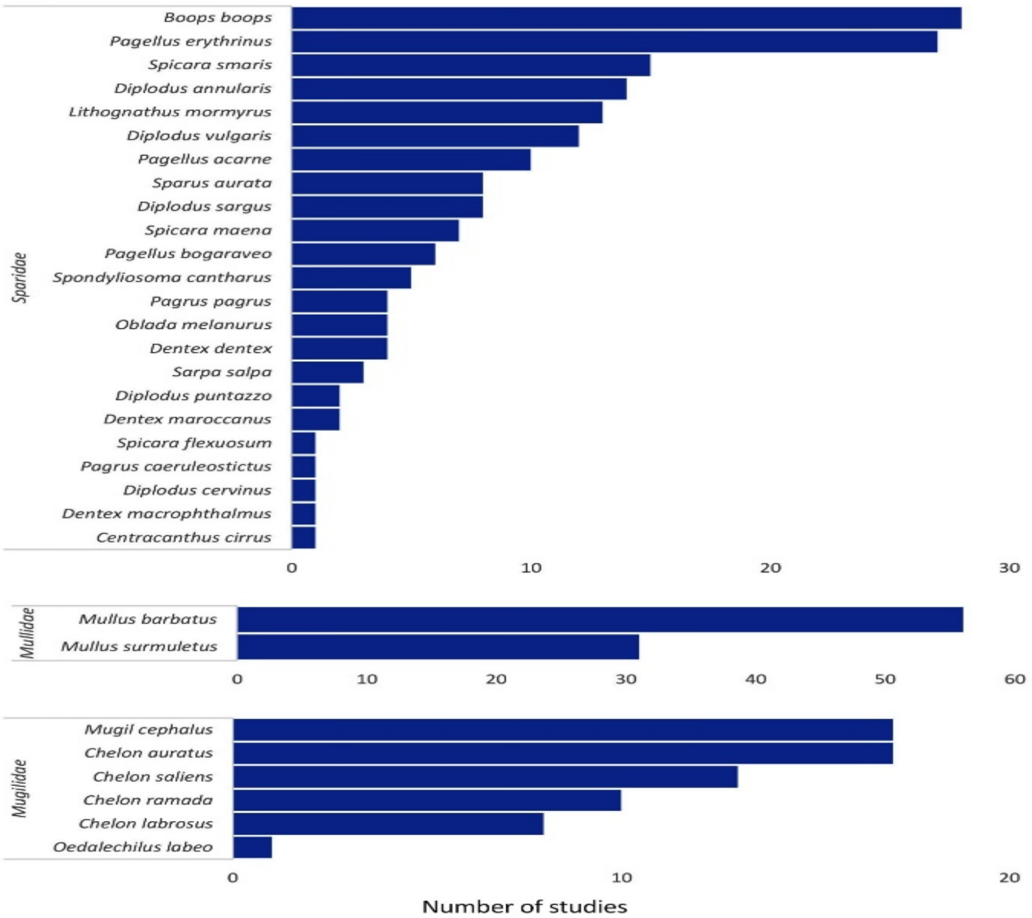

Figure 5. Species of the most studied first three families

Merluccius merluccius (Linnaeus, 1758) is the most studied species (60) among selected species (Figure 6). All species on Figure 6 are commercial for Mediterranean fisheries. On the other hand, while 86.49% of the species (160) are commercial for Mediterranean fisheries, 13.51% of the species (25) are non-commercial (Figure 7). The IUCN Red List Categories for the selected species in this study show that while a great majority of the determined species (70.81%) are in "Least Concern" status, 3.24% are in "Critically Endangered" (six species: *Anguilla Anguilla* (Linnaeus, 1758), *Rhinobatos rhinobatos* (Linnaeus, 1758), *Rhinoptera marginata* (Geoffroy Saint-Hilaire, 1817), *Acipenser stellatus* (Pallas, 1771), *Huso huso* (Linnaeus, 1758), and *Glaucostegus cemiculus* (Geoffroy Saint-Hilaire, 1817)) status (Figure 8). In 160 species that have commercial importance, 31 fish species (19.4% of 160) encounter existence problems (Table 1). 15 of the 31 species are chondrichthyes.

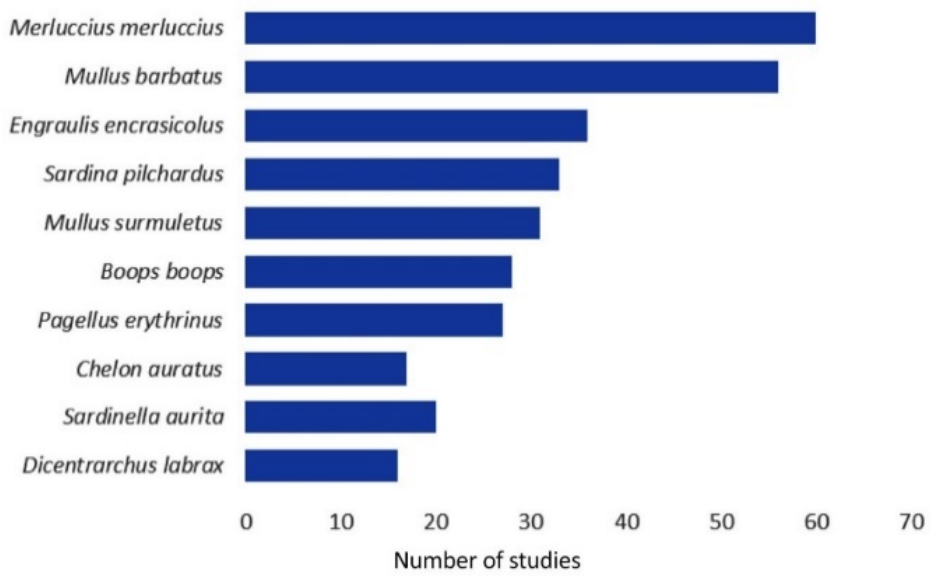

Figure 6. The 10 most studied species in the Mediterranean

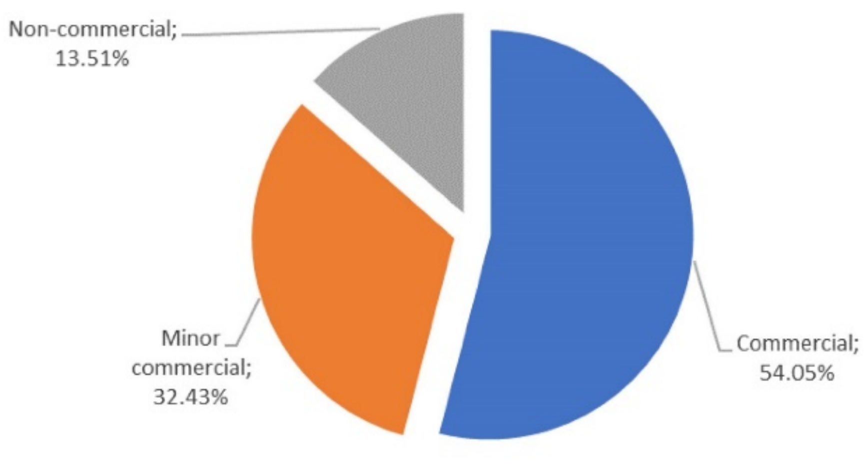

Figure 7. Commercial importance of fish for the Mediterranean fishery

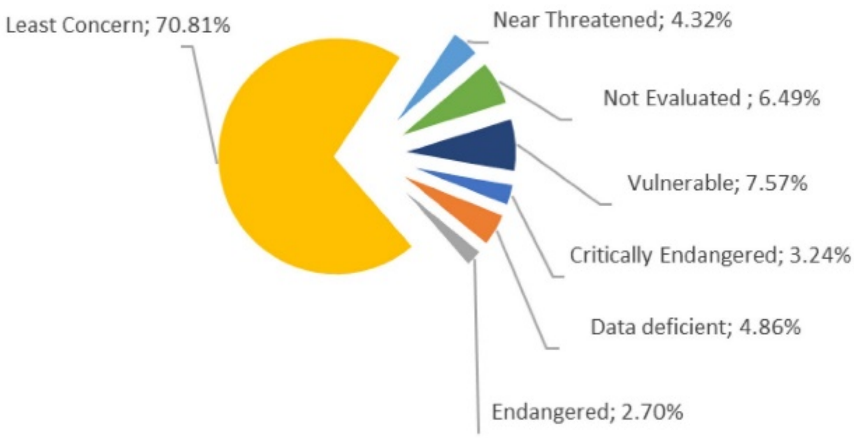

Figure 8. Fish species distributions according to the International Union for Conservation of Nature's (IUCN) Red List (N=185)

Table 1. List of the near threatened, vulnerable, endangered, critically endangered, and species by commercial importance (MC; minor commercial, C; commercial)

	Species	Commercial Importance for the Mediterranean Fishery
Near Threatened	*Dipturus oxyrinchus*	MC
	Epinephelus aeneus	C
	Pagellus bogaraveo	C
	Raja asterias	MC
	Raja brachyura	MC
	Raja clavata	C
	Sciaena umbra	C
	Xiphias gladius	C
Vulnerable	*Balistes capriscus*	C
	Dasyatis pastinaca	C
	Dentex dentex	C
	Epinephelusmarginatus	C
	Etmopterus spinax	MC
	Pomatomus saltatrix	C
	Sardinella maderensis	C
	Squalus acanthias	C
	Trachinotus ovatus	MC
	Trachurus trachurus	C
	Umbrina cirrosa	MC
	Uranoscopus scaber	MC
Endangered	*Centrophorus granulosus*	MC
	Gymnura altavela	MC
	Mustelus mustelus	C
	Raja radula	C
	Rostroraja alba	MC
Critically Endangered	*Anguilla anguilla*	C
	Acipenser stellatus	C
	Glaucostegus cemiculus	MC
	Huso huso	C
	Rhinobatos rhinobatos	C
	Rhinoptera marginata	C

DISCUSSION

The Mediterranean Sea has high species richness (Bianchi et al., 2012). The number of native and endemic species constitutes considerable amounts of total fish species in the Mediterranean (77.63% of total species). According to Cramer et al. (2018), the Mediterranean Sea water temperature is 1.4 °C above that of the late nineties. Therefore, an increase in Mediterranean temperature would lead to an increase and to a northward spread of the introduced species (Schickele et al., 2021). Thus, this phenomenon leads to an increased species number in the Mediterranean through the invasion of introduced species.

Türkiye, Italy, and Greece are big peninsulas, and all the shores of these countries are in the Mediterranean and Black Sea regions. On the other hand, France, Spain, and Morocco have shores in both the Atlantic and the Mediterranean and studies in these countries are also relatively high. However, in this study, only Mediterranean studies were collected and sorted by countries. Therefore, study numbers Türkiye, Italy, and Greece are higher than other countries in the Mediterranean and Black Sea regions.

The number of studies has increased since the 1980s. Farrugio et al. (1993) mentioned that, especially in 1980's studies, researchers tended to learn ecological parameters of the exploited populations (besides technical parameters of fishing gear) with direct methods. In addition to this, technical progress has led to an increase in the quality and efficiency of fishing gear. For example, Sardà (1998) stated that the catchability of *Nephrops norvegicus* (Linnaeus, 1758) increased with technological advances. In this finding, it can be said that an increase in the number of fisheries studies in the Mediterranean is attributed to technological advances in fisheries such as the spread of electronic devices (Ferretti, 2011) and high-power engine usage (e.g., Ünal, 2004).

Logically, the increase in fishing capacity and fishing ability has made it easier to reach the wanted species and to do the sampling process for the species.

According to the studied species numbers, most of the species are bony fish (161 species). In contrast, 24 cartilaginous fish species have been studied (24 species). Cartilaginous fish are known mostly as predators, and they are situated at high levels of the food chain. Therefore, they are rarer when compared with other fish species (Bustamante Diaz, 2014). The lesser studies in cartilaginous fish may be attributed to reaching these species is difficult and being lower abundance in catch composition (e.g., Cerim et al., 2022). Furthermore, fishing techniques may be effective in capturing cartilaginous fish species (Bengil and Başusta, 2018). In this study, the cartilaginous species mean depth ranges were min-21 m and max-821 m, and without three species, all 21 species occur at depths above 200 m. As it is known, more depth for studies needs higher fishing equipment and research vehicles (i.e., it is hard to study in deep waters). In our opinion, the most limiting factor for cartilaginous fish studies may be depth. On the other hand, most of the cartilaginous species are on the IUCN red list. This situation may be another restrictive reason for low study numbers.

Sparidae is the most studied family in the Mediterranean basin. Sparidae species are commonly found along the shores (Iwatsuki and Heemstra, 2015). Most of the Sparidae species are caught by different fishing gear. For example, *Boops boops* is captured by different fishing gear such as trawl (İlkyaz et al., 2017), purse-seine (Ceyhan and Tosunoğlu, 2022), and handline (Cerim, 2022). On the other hand, Mullidae species are captured mainly by trawl nets, besides gillnets. Furthermore, even though Mugilidae species are captured by many fishing gears, their mass capture is from traps, especially during migration (Cerim et al., 2021). Therefore, sampling of Sparidae, Mullidae, and Mugilidae species is relatively easy to compare with other species. There is a difference between “doing sampling” and “samples coming to you”. Behaviors such as being a school, being in species-specific habitats, and seasonal migration may make the sampling easy. Using these behaviors may be the reason for the aggregation of the studies in particular species.

Papaconstantinou and Farrugio (2000) separated Mediterranean fisheries into three sub-categories as; small-scale fisheries, trawling, and seining fisheries. According to FAO (2022), total 1.19 million tonnes fish were captured in the Mediterranean and Black Sea regions. *Merluccius merluccius* is a demersal species, and even though it is fished with many different fishing gears, its capture is based on trawling (Gül et al., 2019). Moreover, *Mullus barbatus* (Linnaeus, 1758) is also demersal and is mainly captured by trawls. When considered in terms of mobility or lurch, trawl vessels are relatively more stable than many other demersal fishing vessels. On the other hand, *Engraulis encrasicolus* (Linnaeus, 1758) is pelagic, and encircling nets, especially purse-seine, are used for its capture. Purse-seine catch is affected by many different environmental features, such as seasons (Pinello and Dimech, 2013), artificial lights (Tsagarakis et al., 2012), and moonlight (Tosunoğlu et al., 2021). The purse-seine and trawl ships have large horse-power engines and large decks. Therefore, purse-seine and trawl ships are appropriate environments for easy study. In our opinion, most of the species seen in Figure 6 were captured by easy fishing methods. In addition to this, species numbers are higher due to schooling. Mentioned considerations could be the reasons for the high study numbers of these species.

Totally, 86 cartilaginous fish species (sharks, rays, skates, guitarfish, angel sharks, etc.) exist in the Mediterranean basin. According to the IUCN (2023), 68 of the Mediterranean cartilaginous species are under risk (Critically Endangered- 19, Endangered- 15, Vulnerable- 20, Near Threatened- 14; total; 79.07%). Study results showed that 24 cartilaginous species have been studied in terms of age and growth. Among these studied species, 15 have commercial importance (Table 1). On the other hand, GFCM (General Fisheries Commission for the Mediterranean) statistics show that there is a decline in Chondrichthyes capture in the Mediterranean (Figure 9). Ferretti et al. (2008) mention that more than 97% of the shark catch weights have been in decline since the last 200 years, and if this situation continues like this, the extinction will be inevitable. The loss of the top predators could lead to serious ecological effects. Elasmobranchs are caught incidentally. However, by-catch and direct fisheries are not monitored in the Mediterranean (Bradai et al., 2018). Therefore, the biological parameters of cartilaginous fish stocks should be identified for both the ecological and commercial importance of the elasmobranch fishery.

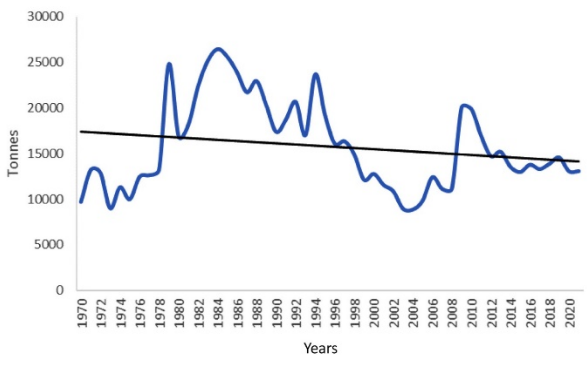

Figure 9. Cartilaginous fish catch trend in the Mediterranean (FAO-GFCM, 2023)

CONCLUSION

In conclusion, most of the species (419) in the Mediterranean have no age or growth studies. Biological identification of the fish stocks serves not only commercial sustainability but also ecological sustainability. In this sense, the construction of a reliable food web is important. Therefore, non-commercial species should also be taken into consideration in terms of age and growth studies.

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AUTHOR CONTRIBUTIONS

Hasan Cerim: Writing – original draft preparation, writing – review and editing, data curation, visualization, conceptualization, investigation. Ozan Soykan: Investigation, supervision, writing – review and editing. Sercan Yapici: Supervision, writing – review and editing. İsmail Reis: Conceptualization, data curation, visualization, original draft preparation, writing – review and editing. Özgen Yılmaz: Supervision, writing – review and editing.

CONFLICTS OF INTEREST

The authors of this article declare that they have no financial, professional or personal conflicts of interest that could have inappropriately influenced this work.

ETHICAL APPROVAL

No need for ethical approval for this study.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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