

Article

# Filling the Gap and Improving Conservation: How IUCN Red Lists and Historical Scientific Data Can Shed More Light on Threatened Sharks in the Italian Seas

Francesco Luigi Leonetti <sup>1,2</sup>, Emilio Sperone <sup>1</sup> , Andrea Travaglini <sup>3</sup>, Angelo R. Mojetta <sup>4</sup>, Marco Signore <sup>3</sup>, Peter N. Psomadakis <sup>5</sup>, Thaya M. Dinkel <sup>2</sup> and Massimiliano Bottaro <sup>2,\*</sup>

- <sup>1</sup> Department of Biology, Ecology and Earth Sciences (DiBEST), University of Calabria, 87036 Arcavacata di Rende (CS), Italy; francescoluigi.leonetti@szn.it (F.L.L.); emilio.sperone@unical.it (E.S.)
- <sup>2</sup> Department of Integrative Marine Ecology (EMI), Stazione Zoologica Anton Dohrn, Italian National Institute for Marine Biology, Ecology and Biotechnology, Villa Comunale, 80121 Naples, Italy; thaya.dinkel@szn.it
- <sup>3</sup> Darwin Dohrn Museum (DaDoM), Stazione Zoologica Anton Dohrn, Italian National Institute for Marine Biology, Ecology and Biotechnology, Villa Comunale, 80121 Naples, Italy; andrea.travaglini@szn.it (A.T.); marco.signore@szn.it (M.S.)
- <sup>4</sup> Institute for Marine Studies (ISM), c/o Aquarium and Civic Hydrobiological Station of Milan, Viale Gadio, 2 20121 Milan, Italy; amojetta@tin.it
- <sup>5</sup> Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy; peter.psomadakis@gmail.com
- \* Correspondence: massimiliano.bottaro@szn.it; Tel.: +39-081-5833-280

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**Abstract:** Chondrichthyans are one of the most threatened marine taxa worldwide. This is also the case in the Mediterranean Sea, which is considered an extinction hotspot for rays and sharks. The central position of the Italian peninsula makes it an ideal location for studying the status and changes of this sea. There is a lack of biological, ecological and historical data when assessing shark populations, which is also highlighted in the Red List of Threatened Species compiled by the International Union for the Conservation of Nature (IUCN). Historical data can provide important information to better understand how chondrichthyan populations have changed over time. This study aims to provide a clearer understanding of the changes in distribution and abundance of eight shark species in the Italian seas that are currently classified as at risk of extinction by the IUCN. In this respect, a bibliographic review was conducted on items from the 19th century to the first half of the 20th century, focusing on the selected species. The results show that all sharks were considered common until the beginning of the 20th century but have declined since, with a clear negative trend, mainly in the past 70 years. The strong local decline has been attributed to overexploitation, bycatch, habitat loss, depletion of prey items and environmental pollution. Furthermore, historical data also allow us to avoid the issue of a ‘shifting baseline’, in which contemporary abundances are assumed to be “normal”. Using historical data to further our knowledge of the marine environment is becoming increasingly common, and is fundamental in understanding human impact and evaluating mitigation measures to manage and conserve marine species and environments.

**Keywords:** biodiversity; chondrichthyans; conservation; fishing; historical ecology; Mediterranean Sea

## 1. Introduction

Chondrichthyes represents one of the most threatened marine taxa worldwide [1], and its species are highly susceptible to anthropogenic pressure, both in coastal and offshore environments [2,3].

In particular, the main factor affecting these vulnerable organisms is bycatch (incidental catch), which needs to be reduced to correctly manage and conserve cartilaginous fishes [4]. However, assessing and managing chondrichthyan populations is problematic, due to the limited nature of information on their biology and fisheries [5,6]. The absence of historical information about the population of cartilaginous fishes also makes it easy to fall prey to “shifting baseline syndrome,” in which one assumes that current conditions of resources are the standard, without taking into account their history of exploitation [7,8]. Furthermore, the few available long term studies are little more than snapshots, reflecting the vulnerability of the species under the fishing conditions they were subjected to when the data were collected [9].

This lack of data is also highlighted in the List of Threatened Species (the Red List) of the International Union for the Conservation of Nature (IUCN). The Red List represents a comprehensive resource on the global status of biodiversity, and over the last decades it has become a broad and important tool for conservation, policy making and management. According to the IUCN, the Mediterranean Sea is one of the three areas in the world where the biodiversity of sharks and rays is most seriously threatened, with more than 40% of the assessed chondrichthyan species considered to be “endangered” (EN) or “critically endangered” (CR) [10]. Although the Mediterranean Sea represents a biodiversity hot spot [11], it also presents relevant geopolitical limits for the development of common and effective strategies of management and conservation of fisheries resources and natural heritage [12]. In this respect, the Italian peninsula is the core of the basin—it is placed on the natural border between the western and eastern sectors and it encompasses both the northern and southern sectors, functioning as a sort of “natural benchmark” of the general status and the changes in the Mediterranean Sea [13] and playing a potentially important role in the development of regional common initiatives for the management and protection of marine biodiversity [14,15].

Historical ecology developed as an organized research approach in the middle of the twentieth century [16]. It intersects strongly with environmental history, ecological anthropology, historical geography and paleoecology, with researchers from all disciplines contributing to the understanding of putative pristine environments and the anthropogenic changes they undergo [16–18]. Originally designed for landscape research, this scientific approach has been recently applied to the marine environment as well, focusing particularly on fishery resources [19–22]. From this point of view, even though the Mediterranean Sea is commonly regarded as the cradle of Western civilization [11], historical changes in its marine realm are less well understood [23,24], and historical research on cartilaginous fishes remains very limited and fragmented [25–30].

Considering the IUCN Red List of cartilaginous fishes in Italian waters [31], in this study we aim to provide novel scientific historical information from the last 250 years concerning the most threatened shark species, in order to contribute to a clearer understanding of their distribution before the modern fishery age, as well as the abundance and status of these chondrichthyans along the Italian peninsula, which is a key area for the marine biodiversity of the Mediterranean.

## 2. Materials and Methods

We selected ten shark species based on their risk of extinction from the Italian seas (Figure 1), according to the IUCN Red List of cartilaginous fishes in Italian waters [31]. In particular, we selected all species classified as critically endangered (CR), endangered (EN) and vulnerable (VU) shark species (Table 1).



**Figure 1.** Study area.

**Table 1.** List of threatened sharks in Italian seas considered in this study, based on the International Union for the Conservation of Nature (IUCN) Red List.

Species	Common Name	Italian IUCN Red List (2012)	Mediterranean IUCN Red List (2016)
<i>Squalus acanthias</i>	spiny dogfish	CR	EN
<i>Squatina aculeata</i>	sawback angel shark	CR	CR
<i>Squatina oculata</i>	smoothback angel shark	CR	CR
<i>Squatina squatina</i>	angel shark	CR	CR
<i>Alopias vulpinus</i>	common thresher shark	CR	EN
<i>Mustelus asterias</i>	starry smoothhound	EN	VU
<i>Mustelus mustelus</i>	common smoothhound	EN	VU
<i>Mustelus punctulatus</i>	blackspotted smoothhound	EN	VU
<i>Prionace glauca</i>	blue shark	VU	CR
<i>Galeorhinus galeus</i>	tope shark	CR	VU

The research was conducted by analyzing scientific documents, research reports, papers and books on natural history from the 19th century through to the first half of the 20th century. Bibliographic items were researched via electronic archives (e.g., Google Scholar, ISI web of knowledge, national and/or local libraries) and through general web searches, using a combination of scientific, local and vernacular names of cartilaginous fishes in the different Italian maritime districts (Ligurian Sea, Tyrrhenian Sea, Ionian Sea and Adriatic Sea (Figure 1)). When available, records for the same species and time period were compared to ensure similar trends were observed. The records were classified by type, with a

brief description for each item. All records were arranged in chronological order, by species, by citation and by geographical area.

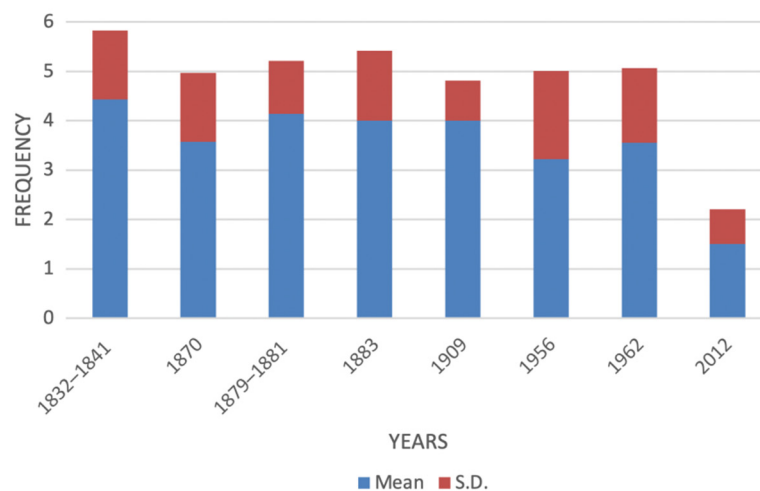
All items were analyzed to ensure the inclusion of geographical information about fish abundance and interactions with humans. Particular attention was given to the frequency and abundance reported for the different species. This information was usually described in the historical bibliographic references using quantitative adjectives like “rare”, “frequent”, “common”, etc. In order to parameterize the information, a progressive number system from one to six was associated with the quantitative terms, as summarized in Table 2. The categories considered by the IUCN (CR, EN, VU) were also parameterized in the same way (Table 2). The records are then discussed from both historical and ecological points of view, through comparison with the current status of Mediterranean chondrichthyans.

**Table 2.** Parameterization of the semiquantitative values of abundance recorded in the considered scientific references.

Reported Frequency/IUCN Category	Very Rare/CR	Rare/EN	Uncommon/VU	Frequent/NT	Common/LC	Very Common/LC
Assigned value	1	2	3	4	5	6

### 3. Results

We found scientific bibliographic references to eight of the ten selected shark species, with a temporal range from 1832 to 1962 (Table 3). All references were reported by scientists. The frequencies of species recorded in the different references over time are summarized in Figure 2. Based on the available information, semi-quantitative trends of abundance for the different species were assessed.



**Figure 2.** Frequency of species recorded in the different references.

*Squalus acanthias* was considered common along the Italian coast during the entire 19th century until the beginning of 1900 (Figure 3). Nevertheless, in the first decades after the Second World War (WWII) this species was considered uncommon, whereas today *S. acanthias* has been evaluated as very rare in the Italian seas and is listed as critically endangered (CR).

*Squatina oculata* was considered uncommon until the end of the 19th century when it was more commonly recorded (Figure 4). In the first decades after WWII it became rare again. Today, *S. oculata* is evaluated as very rare in the Italian seas and is listed as critically endangered (CR).

**Table 3.** References covering the selected shark species, with details on temporal range and related maritime sectors.

Historical Periods, Related Maritime Sectors and References									
Species	Common name	1832–1841, Italian Seas [32]	1870, Adriatic Sea [33]	1879–1881, Sicilian Seas [34]	1883, Adriatic Sea [35]	1909, Central Thyrrhenian Sea [36]	1956, Italian Seas [37]	1962, Italian Seas [38]	2012, Italian Seas [31]
<i>Squalus acanthias</i>	spiny dogfish	5	5	5	5	5	3	3	1
<i>Squatina aculeata</i>	sawback angel shark	na	na	na	na	na	1	2	1
<i>Squatina oculata</i>	smoothback angel shark	3	3	5	5	4	1	2	1
<i>Squatina squatina</i>	angel shark	5	5	3	5	na	1	2	1
<i>Alopias vulpinus</i>	common thresher shark	2	2	3	2	na	4	4	1
<i>Mustelus asterias</i>	starry smoothhound	5	5	5	5	na	5	5	2
<i>Mustelus mustelus</i>	common smoothhound	6	3	3	3	na	5	6	2
<i>Mustelus punctulatus</i>	blackspotted smoothhound	na	na	na	na	na	na	na	2
<i>Prionace glauca</i>	blue shark	na	3	na	2	4	4	5	3
<i>Galeorhinus galeus</i>	tope shark	5	2	5	5	3	5	3	1

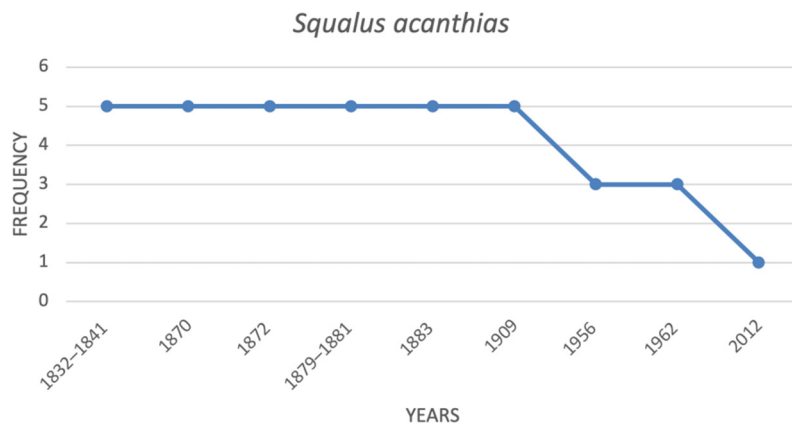


Figure 3. Temporal trend of *Squalus acanthias*.

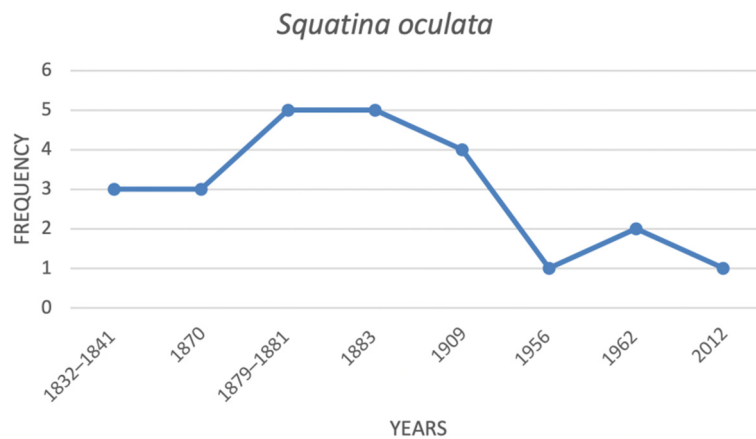


Figure 4. Temporal trend of *Squatina oculata*.

*Squatina squatina* was considered frequent along the Italian coast during the entire 19th century (Figure 5). Its populations seem to have collapsed during the first decades of the 20th century, and it became very rare from the 1940s onwards. *S. squatina* is currently listed as critically endangered (CR).

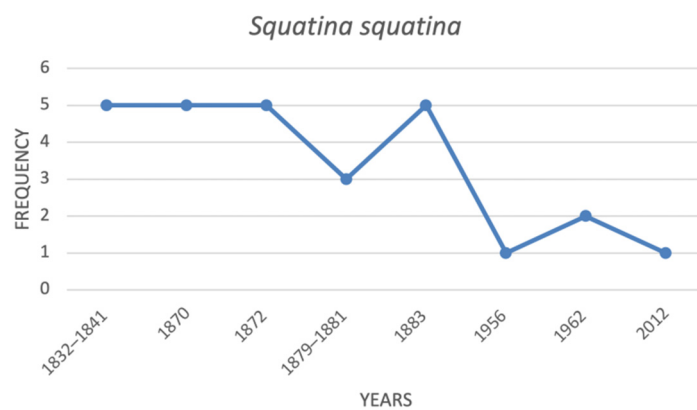


Figure 5. Temporal trend of *Squatina squatina*.

*Alopias vulpinus* was usually considered rare or uncommon in the Italian seas from the 19th century until the first decade after the end of WWII (Figure 6). In recent years *A. vulpinus* has been rarely recorded and is now listed as critically endangered (CR).

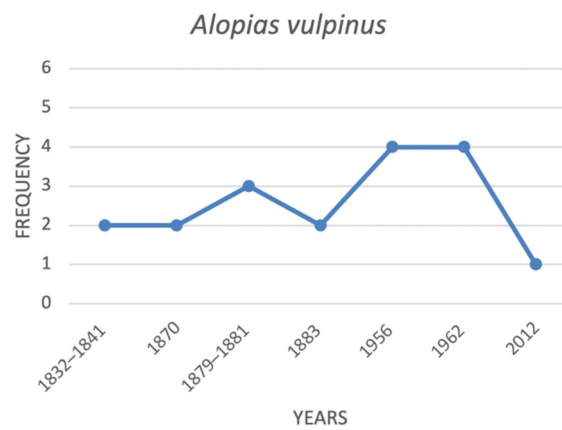


Figure 6. Temporal trend of *Alopias vulpinus*.

*Mustelus asterias* was considered very common in the Italian waters from the beginning of the 19th century until the 1950s (Figure 7). In the past 70 years, *M. asterias* has become rare and is now listed as endangered (EN).

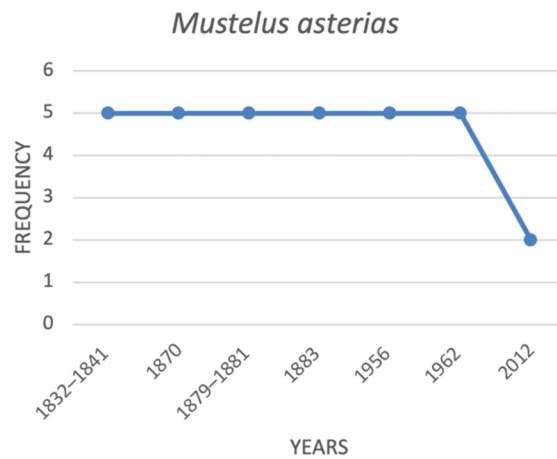


Figure 7. Temporal trend of *Mustelus asterias*.

*Mustelus mustelus* was considered very common at the beginning of the 19th century in the Italian waters, but its numbers decreased during the rest of the century (Figure 8). After WWII, *M. mustelus* was again considered very common. In the last 70 years it has been considered rare and is now listed as endangered (EN).

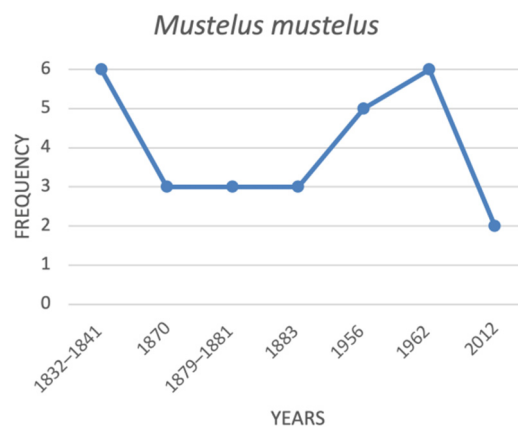
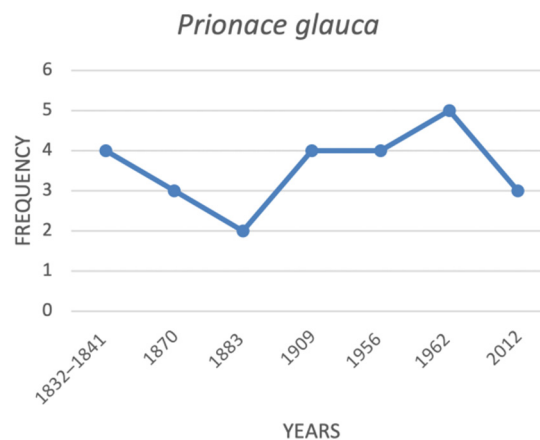


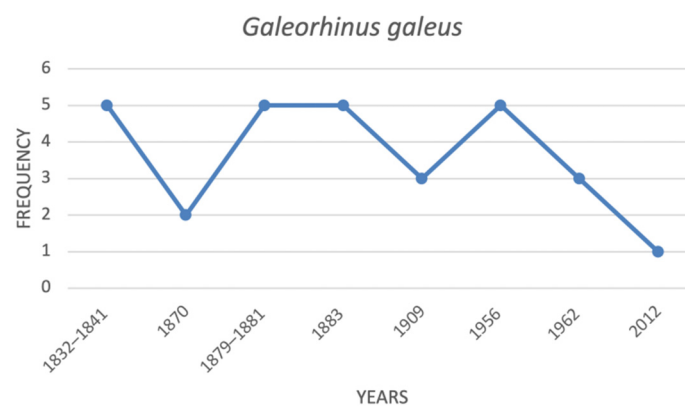
Figure 8. Temporal trend of *Mustelus mustelus*.

*Prionace glauca* was considered uncommon during the 19th century, although records indicated that it became more frequent from the beginning of the 20th century until the end of WWII (Figure 9). In the last 70 years this species has been considered rare and has been listed as vulnerable (VU).



**Figure 9.** Temporal trend of *Prionace glauca*.

*Galeorhinus galeus* was considered common in Italian waters at the beginning of the 19th century. In 1870, records described it as rare. Thereafter, it was considered common again until the beginning of the 20th century. After WWII, *G. galeus* was again considered very common, but it has since been cited as less and less common and is currently classified as critically endangered (CR) in Italian waters (Figure 10).



**Figure 10.** Temporal trend of *Galeorhinus galeus*.

#### 4. Discussion

Even though applying historical ecology to marine environments has become more common in the last two decades [18,39,40], global studies focusing on cartilaginous fishes have been limited [41–46]. This lack of information is strongly evident for the Mediterranean Sea, [18,28–30,47–49]. Considering Italian waters, historical knowledge of cartilaginous fishes is not only limited, but is also fragmented. The available information does not apply to the entire peninsula, but rather, applies only for single local maritime districts. It therefore corresponds to observed variations in local abundances. Furthermore, research has been focused on a relatively recent temporal range, usually the last 70 years [27,50–52], and larger time windows are rarely considered [53], although sharks have been a common fisheries resource for a much longer period, as can be inferred from the vernacular names correctly attributed to individual species of sharks and the existence of specific fishing gear for such prey [54]. Starting from the IUCN Red List of the Italian cartilaginous fishes [31], the present study considered for the first time all the different threatened species of sharks along the Italian coasts,



aiming to contribute to the construction of the first local baseline for these endangered vertebrates. Similarly to other marine megafauna, Chondrichthyans show a general worldwide decline [26] and, specifically, the selected species present significant negative trends, mainly in the last 70 years. Our results therefore highlight a reduction in abundance and species recorded.

#### 4.1. Historical Trends of the Threatened Shark Species in the Italian Seas

Reviewing the scientific literature, the present study reveals that the spiny dogfish, *Squalus acanthias*, was considered very common in the Italian waters until the beginning of the 20th century, after which this species started to decrease rapidly. Ever since, *Squalus acanthias* have become extremely rare along the Italian peninsula, especially in the last 60 years. Similar situations were described in other maritime sectors, such as the northeastern Pacific and in the Atlantic Ocean [54–58]. This worldwide reduction has been caused by overexploitation [59], as well as habitat degradation and loss due to coastal development and pollution [60]. In some countries, the fishing of *S. acanthias* has been successfully managed, like in US waters [61], where local stocks were considered to be rebuilt in 2010 [62]. Similar initiatives may also be developed at the Italian level—in recent years, more studies focused on biological and ecological data related to this species have been carried out, providing preliminary information that is useful for its management [63–65]. Concerning the angel sharks of the genus *Squatina*, our research on the historical scientific literature confirmed their almost complete disappearance in Italy during the last century despite their regular occurrence until the early 1900s. This is in accordance with [66], who reported that angel sharks were common in the entire Mediterranean basin in the past, but are now detected only along the African and Middle East coasts, in the Aegean Sea and in Turkish waters. Indeed, these benthic cartilaginous fishes are actually confined to the less developed coastal areas of the Mediterranean. This is also the case in Italian waters, where the very rare modern records of angel sharks have been reported in the southern regions only [67–69], while in the northern regions these elasmobranchs have now disappeared [52]. Mediterranean angel sharks commonly inhabit the soft bottoms of very shallow coastal areas [70], where they are highly susceptible to trawlers and gillnets, as well as habitat degradation due to heavy human activity in coastal areas [52,66]. Currently, an international initiative to develop a Mediterranean action plan to protect and recover angel shark populations [71] has been started, based on recent and interesting citizen scientific research on these elasmobranchs [72]. These kinds of studies can be important in promoting international cooperation, which is fundamental for the conservation of threatened marine species like *Squatina* spp. Furthermore, they can play a fundamental role in expanding knowledge when combined with research into historical scientific bibliographic references like those reported in the present paper.

*Alopias vulpinus*, the thresher shark, is a typical pelagic shark, living in an offshore marine environment, and is rarely observed near the coastline [73]. In the Mediterranean, this species may be captured as by-catch in pelagic fisheries, mainly by longliners [74,75], but also during pair trawling fishing operations [64], as well as in offshore recreational fisheries [76]. In Italian waters, the uncommon detection of thresher sharks from the 19th century to the end of WWII can be related to the scarce chance of observing this high seas species in typical coastal fishing operations. Offshore pelagic fisheries require powerful engines to reach offshore fishing grounds, which were developed only during the past century [77]. In Italy, in particular, until the early 20th century, fishing was mainly practiced close to the coastline from boats powered by sails or oars, whereas motor fishing vessels were extremely rare [78,79]. On the contrary, after the forced stoppage due to WWII, the Italian fishing fleet underwent a technological change, mainly due to the development of powerful diesel engines, which caused a rapid increase and expansion of fishing efforts, which included pelagic fisheries [80]. The exploitation by the Italian fishery fleet of novel and pristine fishing grounds, like offshore pelagic environments, during the 1950s could be linked to the enhanced frequency of capture of *A. vulpinus* reported in the analyzed scientific literature. In the same way, the rapid decline in records of this species in the last 70 years may be connected to overexploitation of pelagic marine resources, including medium and small fishes, like mackerels, anchovies and sardines, which happen to be common preys of

*A. vulpinus* [81–83], but which are also one of the most important pelagic fishery resources in the Mediterranean Sea, where their capture numbers have decreased since the 1970s [49,83,84]. This may influence the upper trophic level, as was recently hypothesised for the thresher shark [85].

Our results highlight that the common smooth-hound, *Mustelus mustelus*, is very sensitive to fishing pressure in Italian waters. It nevertheless shows remarkable resilience, as also reported in other maritime sectors [86]. There is a perception of a decrease in the frequency of observations of this species in the local historical scientific literature that corresponds to regular and continuous fishing pressure during the 19th century and the last 70 years. This observation is in line with a recent study on a century of fishery data on sharks of the genus *Mustelus* in the Mediterranean Sea, demonstrating the collapse of these marine vertebrates that occurred primarily in the last decades [28]. On the contrary, the recorded numbers of *M. mustelus* increased when the fishing effort partially or completely stopped during WWII and in the first years after the war. Similar trends were reported by D’Ancona for the Adriatic Sea [87,88] and have been recently confirmed for the entire Mediterranean basin by Colloca et al. [28]. The dramatic collapse of *M. mustelus* and congeneric species in the Mediterranean basin and along the Italian coasts can be attributed mainly to the impact of direct fishing pressure [28], although it is also possible to relate it to the overfishing of its most common preys, which has also happened recently in the Mediterranean basin [89].

The blue shark, *Prionace glauca*, is one of the most wide-ranging shark species, found throughout all oceans [90,91]. It is considered to be one global population, with little or no differentiation within and between ocean basins [92–96]. Despite spending most of its life in pelagic environments, this species can also be found in coastal waters [70], a factor that might explain the occurrence of blue sharks during the 19th century and in the first decades of the 20th century in coastal Italian waters, when the Italian fishing effort was mainly concentrated close to the coastline [78,79]. With this exception, our study highlights that the historical trend of the blue shark is very similar to that of the thresher shark, *A. vulpinus*. Both species offer moderate resilience to fishing pressure [97,98]. The increase of recorded numbers of blue sharks during the 1950s can be related to the exploitation by the Italian fishery fleet of novel and pristine fishing grounds. As with the thresher shark, the rapid decline in the recorded numbers of *P. glauca* in the last decades may be connected to the over-exploitation of pelagic marine resources in the Mediterranean [99]. However, it can also be related to the degradation of the marine environments, as recent studies have demonstrated that blue sharks are strongly threatened by the presence of chemical pollution [100] and plastic debris [101].

The tope shark, *Galeorhinus galeus*, is a bento-pelagic species that shows a mainly coastal distribution, being found on the continental shelf and the upper slopes [70,102], while also being found offshore due to its extensive migrations [103]. Its coastal distribution allowed scientists to observe it at the beginning of the 19th century until the first decades of the 20th century, when Italian fishing effort was concentrated on the coastline [78,79]. During this period it was considered a rather common species [53,104] with some exceptions [33,36] which may be attributed to temporary and/or local low densities. Its gross decline started at the end of WWII, which was probably induced by the expansion of commercial fisheries and the advancement in fisheries technologies in Italian waters, resulting in higher fishing pressure on this species. Its decline in the past 70 years is in accordance with bottom trawl surveys from 1994 to 2009 [102,105], and other literature, in which it now appears to be locally extinct in the Tyrrhenian Sea [102,106] and is rarely captured in the Strait of Sicily [74,102].

#### 4.2. Increasing Historical Knowledge to Improve Current Conservation

The heavy worldwide anthropization that occurred over the last two centuries has radically changed the structure and functioning of all ecosystems, including oceanic ecosystems [107]. Understanding historical ecological conditions is the first fundamental step in evaluating mitigation measures to best manage and conserve the marine environment [108]. Historical data provide essential information to better understand the recent human footprint on marine ecosystems and can be used not only to assess more accurately the baselines for different species, but also to develop management

and conservation plans [26]. The present study provides new historical insights regarding the most threatened sharks according to the IUCN [31] present in Italian seas, a key area of one of the most anthropized maritime sectors [11]. The strong local decline of these predators in the last 200 years is evident, and can be attributed to different anthropic factors, such as bycatch, coastal habitat loss and environmental pollution. Considering all the cartilaginous fishes of Italian waters, it is worth noting that this scenario could be extended to many other species, as up to 52% of the Italian chondrichthyans are locally listed as data deficient (DD) by the IUCN, including many iconic species such as the great white shark and hammerhead sharks. Some studies have highlighted a general decline in the Mediterranean basin for some of the sharks included in this IUCN category [47,109], but the magnitude of reduction for most of the DD-designated species remains unknown, given the lack of quantitative evidence of historical abundance and distribution. Using historical data to understand how population abundances have changed over the years can further provide important information when assessing the vulnerability of sharks to climate change stressors. Ecological risk assessments (ERAs) are frequently used to estimate the influence of human actions on natural biological systems and processes [110,111], and can then be considered in integrated risk assessments for climate change. ERAs show particular effectiveness in the case of data-poor fishes, including elasmobranchs, which are often captured as bycatch in fisheries [112,113]. Understanding if a species has been considered rare over a long time or has only recently been considered rare due to overexploitation and anthropic effects is an interesting factor to consider when assessing the risk of different changes upon species. This is because rare chondrichthyans may have reduced phenotypic variations and are therefore more susceptible to changes [113]. From this point of view, improved monitoring of sightings and statistical analysis of the results of threatened and DD sharks in Italian seas—along with enhanced efforts in searching and analyzing historical data—are essential in order to increase our understanding of these important and vulnerable marine organisms [46]. At the same time, a precautionary approach should be taken by marine stakeholders to reduce the current anthropic impact on chondrichthyans. This can be achieved through the use and distribution of bycatch reduction devices, the implementation of good fishing practices, the release of still-living accidentally caught specimens and eliminating the production of new marine litter.

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