

Article

An Annotated Checklist and the Conservation Status of Chondrichthyans in the Adriatic

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Abstract: Although there is a high number of publications listing fish species in the Adriatic, only a few have focused on chondrichthyans, while their conservation status has been investigated even less. Thus, this paper aims to provide an updated and annotated checklist of the chondrichthyans occurring in the Adriatic waters with their presence and conservation status. Each species is evaluated against the criteria defined in IUCN (International Union for Conservation of Nature) Red List Categories and Criteria and according to the guidelines for national and regional level assessments. In total, 60 chondrichthyan species from 27 families and 42 genera are listed. The list contains 33 species of sharks, 26 species of rays and one chimera. Assessment of the conservation status reveals that three species are now considered Regionally Extinct (namely *Squatina oculata*, *Pristis pectinata* and *Rhinobatos rhinobatos*). A total of 21 species are assessed as Critically Endangered, 8 are Endangered and 10 are Vulnerable. Of the remaining species, six are Near Threatened and the same number of species are Least Concern and Data Deficient. Considering that the principal driver of chondrichthyan decline and regional extinction is overfishing, it is recommended that the Adriatic countries adopt the same management measures and strengthen their coordination.

Keywords: checklist; chondrichthyans; Adriatic; conservation status



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1. Introduction

The average primary production of the Mediterranean Sea is much lower than commonly observed in most oceanic areas, but the exception is the Adriatic Sea, especially its northern area, due to an extraordinary concentration of medium nutrients coming from the rivers' run-off [1]. Oceanographic properties of the Adriatic Sea are determined by several topographic characteristics. The northern Adriatic Sea is a shallow shelf, while the open south and central Adriatic are characterized by two pits: the Jabuka Pit (maximum depth 270 m) and the South Adriatic Pit (maximum depth 1233 m) [2].

Marine biodiversity in the Adriatic Sea is attributed to its geological history, limited by its present bathymetric, hydrographic, and climatic characteristics and influenced by present geographical connectivity and anthropogenic processes [3].

The Adriatic Sea can be considered as a well-studied Mediterranean area considering that a systematic study of the Adriatic ichthyofauna began in the first quarter of the 19th century, which resulted in a high number of publications listing fish species. However, only a few focused on chondrichthyans [2,4], a class that includes sharks, skates, rays and chimeras. Furthermore, their conservation status has rarely been investigated [5,6], although chondrichthyans are by far the most endangered group of marine fish in the Mediterranean Sea [7]. The recent IUCN (International Union for Conservation of Nature) Red List demonstrated the vulnerability of chondrichthyans and the general lack of data as from more than half of the species assessed, 39 out of 73 species are considered regionally threatened (Critically Endangered, Endangered or Vulnerable), while 13 species are considered Data Deficient [7]. Consequently, the level of threat may be even worse given that the

same integrated effects of unsustainable fishing, pollution and habitat destruction are also affecting all data deficient species. The result is that more than 71% of chondrichthyans in the Mediterranean Sea may be threatened and are subjected to an elevated risk of extinction. Therefore, the Mediterranean is considered as a world priority region for conservation action for chondrichthyans and a range of fishery management measures for protection are currently granted to chondrichthyan fish species under various regional and international conventions that are also applied in the Adriatic Sea. However, on the other hand, generally, a limited number of species are considered and only a few countries have developed their own national legislation focused on chondrichthyans.

In the Mediterranean Sea, including the Adriatic, 24 species of chondrichthyans are protected under recommendation GFCM/36/2012/3 (later amended to GFCM/42/2018/2) of the General Fisheries Commission of the Mediterranean (GFCM). This recommendation is aimed at protecting those species of sharks and rays that are listed in Annex II of the Protocol of the Barcelona Convention on specially protected areas and biological diversity in the Mediterranean. Under this binding rule for all GFCM member countries, these species cannot be “retained on board, transhipped, landed, transferred, stored, sold or displayed or offered for sale”, but rather, “they must be released unharmed and alive to the extent possible”, and States must guarantee “high protection against fishing activities”.

These GFCM recommendations have been implemented into several European Union regulations, particularly Regulation (EU) 2015/2102 and are thus binding for the EU countries of the Adriatic Sea (Croatia, Italy and Slovenia). Perhaps an even higher level of protection is given to the species listed in Annex I of Regulation (EU) 2019/1241 as it is prohibited for EU vessels to fish for, retain on board, transship, land, store, sell, display or offer for sale these species for all EU waters. However, most of these regulations are limited to commercial fisheries while their application to recreational fisheries, which also have a high impact on chondrichthyans, particularly large pelagic species, is dubious. Croatia is the only Adriatic country that has produced national legislation related to the chondrichthyans and strictly protected species status has been given to 23 species of sharks and rays. Strictly protected species status is the highest level of protection in Croatia and any harm toward listed species is regulated by the Criminal Code of Croatia [8] and offenders may be punished by imprisonment.

Most of the chondrichthyan species are not target species in the Adriatic Sea but they are caught mainly as bycatch by longlines and other fishing gear used in tuna, small pelagic fish and sword fisheries. Smaller chondrichthyans are also often the bycatch of trawls and other bottom fishing gear. In some areas seasonally, mainly during the spring, houndsharks (Triakidae) are targeted with gillnets, but only a few fishermen are involved in this fishery.

This paper aims to provide an updated and annotated checklist of the chondrichthyans occurring in the Adriatic waters and for the first time present an assessment of their presence and conservation status. Given the increasing conservation and exploitation concerns about the biodiversity of the Adriatic and the considerable taxonomic changes that have taken place at the species and higher taxa levels, this paper provides a current baseline of knowledge on chondrichthyans in the Adriatic Sea and establishes the foundation for the future research on the sharks, rays and chimeras in this area.

2. Materials and Methods

It is usually considered that in the south the Adriatic Sea is separated from the Ionian Sea by the 72 km wide Strait of Otranto. However, the exact border between the Adriatic and the Ionian Sea has been reported differently by various studies. Thus, for the purpose of this study, the border between the Adriatic and the Ionian Sea follows the International Hydrographic Organization [9] which established that the whole Albanian waters belong solely to the Adriatic Sea.

A systematic literature review (Table S1) that included peer-reviewed publications, reports and personal and biodiversity databases (published until May 2022), was conducted,

starting from the last lists [2,4]. Species names, orders and families are arranged according to Eschmeyer's Catalog of Fishes [10,11].

The occurrence of a species in the Adriatic Sea was indicated following these criteria: Rare—when recorded after a long period of time (decades); Occasional—recorded every few years; Common—recorded several single records on a yearly basis; Abundant—multiple records in catches (or seen) every year; Questionable/Not Confirmed—when a record needs confirmation.

The conservation status of each species followed the IUCN Red List of Threatened Species' categories. During the assessments, all available information on a species' taxonomy, distribution, population status, habitat and ecology, major threats, use and trade and conservation measures were considered. The IUCN Red List Categories defines the extinction risk of species assessed and divides species into nine categories and in descending order of threat, the categories are as follows [12]: Extinct (EX): "no reasonable doubt that the last individual has died"; Extinct in the Wild (EW): a species "is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range"; Critically Endangered (CR): a species "is facing an extremely high risk of extinction in the wild"; Endangered (EN): a species "is facing a very high risk of extinction in the wild"; Vulnerable (VU): a species "is facing a high risk of extinction in the wild"; Near Threatened (NT): a species "not qualify for CR, EN or VU now, but is close to qualifying for or is likely to qualify for a threatened category in the near future"; Least Concern (LC): species do not qualify for CR, EN, VU, or NT; and Data Deficient (DD): species for which there is "inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status". A DD is not a category of threat but indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate [12]. Hence, following the guidelines for the application of IUCN Red List Criteria at regional and national levels [13] the Regionally Extinct (RE) category is used and combined with EW category for species "when there is no reasonable doubt that the last individual potentially capable of reproduction within the region has died or has disappeared from the wild in the region, or when, if it is a former visiting taxon, the last individual has died or disappeared in the wild from the region".

In order to determine the relative extinction risk of a regional population, each species is evaluated against the criteria defined in IUCN Red List Categories and Criteria: Version 3.1 [12] and according to the guidelines for national and regional level assessments [13].

3. Results

A total of 60 chondrichthyan species from 27 families and 42 genera were included in the new checklist representing species that are permanently living in the Adriatic Sea, those occasionally entering, as well as the species that were recorded previously but are now considered regionally extinct. The list contains 33 species of sharks, 26 species of rays and one chimera. Overall, 33 species were considered as rare, 8 species as occasional, 15 species as common and only 4 as abundant in the Adriatic Sea (Figure 1). Considering sharks and rays separately, rare presence was established equally for both groups as 16 sharks and 16 rays were assessed as rare.

Assessment of the conservation status revealed that three species previously recorded in the Adriatic Sea are now considered as Extinct in Wild or Regionally Extinct (namely *Squatina oculata* Bonaparte, 1840, *Pristis pectinata* Latham, 1794 and *Rhinobatos rhinobatos* (Linnaeus, 1758)). Hence, 21 species were assessed as Critically Endangered, 8 were Endangered and 10 were Vulnerable. Of the remaining species, six were Near Threatened and the same number of species were of Least Concern and Data Deficient (Figure 2).

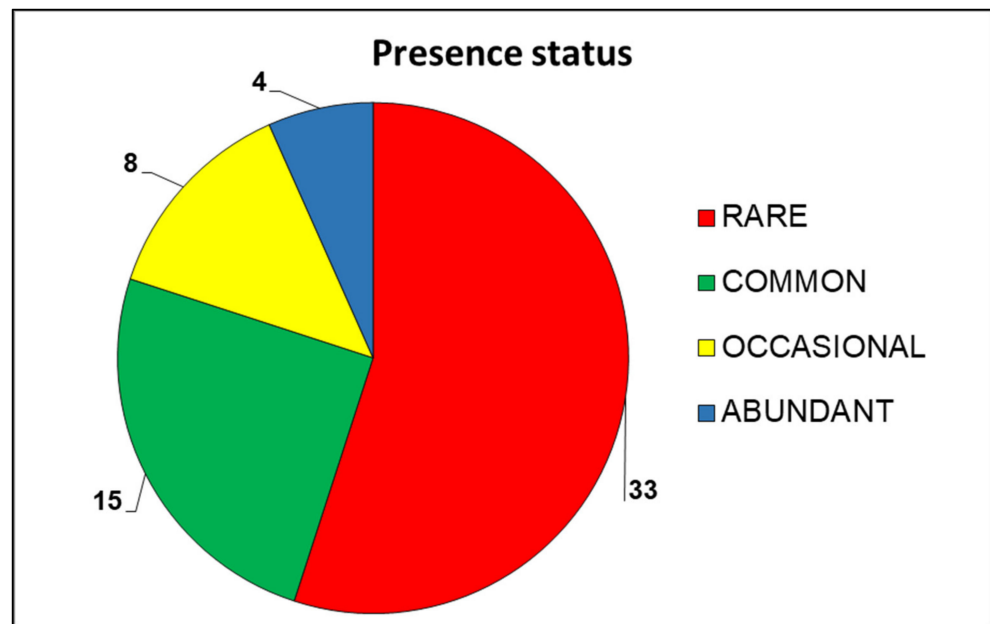


Figure 1. The division of Adriatic chondrichthyans according to their presence.

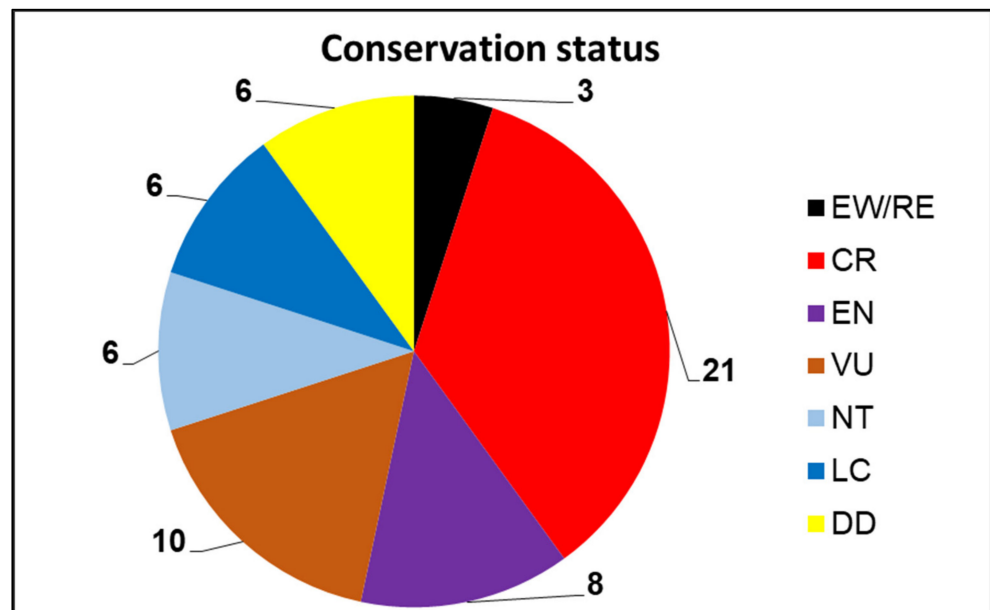


Figure 2. The division of Adriatic chondrichthyans according to their conservation status. Legend: EW = extinct in the wild, RE = regionally extinct, CR = critically endangered, EN = endangered, VU = vulnerable, NT = near threatened, LC = least concern and DD = data deficient.

3.1. Annotated Checklist

CLASS: ELASMOBRANCHII
 ORDER: HEXANCHIFORMES
 HEXANCHIDAE
Heptranchias Rafinesque, 1810

1. *Heptranchias perlo* (Bonnaterre, 1788), Sharpnose sevengill shark

Up to date, only a few records of *H. perlo* have been reported in the Adriatic Sea. Four of them are dated more than seventy years ago [2], while only two specimens were recorded in recent years, one in the Albanian waters [14] and the second in the Adriatic northernmost part in Slovenian waters [15]. This species is strictly protected in Croatia.

Presence: Rare.
 Conservation status: Data Deficient.
Hexanchus Rafinesque, 1810

2. *Hexanchus griseus* (Bonnaterre, 1788), Bluntnose sixgill shark

Lipej et al. [2] considered this species to be quite common in the central and especially southern part of the Adriatic Sea, while less common in the shallower Northern Adriatic. In recent years, although a drastic decrease in large (and other) shark species across the whole Mediterranean Sea has been reported, it seems that the bluntnose sixgill shark does not follow this trend. Based on more than 100 documented records, the bluntnose sixgill shark is considered as a common Adriatic species as it is still regularly reported in the Adriatic Sea [16]. As a large and deeper water species, perhaps it is less vulnerable to fishing activities. The existence of the Adriatic population is very likely. Strictly protected species in Croatia.

Presence: Common
 Conservation status: Least Concern.

3. *Hexanchus nakamurai* Teng, 1962, Bigeyed sixgill shark

The bigeyed sixgill shark was recently reported for the first time at the southern tip of the Adriatic Sea [17].

Presence: Rare.
 Conservation status: Data Deficient.
 ORDER: LAMNIFORMES
 CARCHARIIDAE
Carcharias Rafinesque, 1810

4. *Carcharias taurus* Rafinesque, 1810, Sand tiger shark

The last record of the sand tiger shark in the Adriatic Sea originates from 1999 when a large specimen was caught near the island of Molat in eastern central Adriatic [2]. Strictly protected species in Croatia.

Presence: Rare.
 Conservation status: Critically Endangered A2bcd + C2(i)(ii).
 ODONTASPIDIDAE
Odontaspis Agassiz, 1838

5. *Odontaspis ferox* (Risso, 1810), Smalltooth sand tiger

After several decades without any records, recently, in 2021, a female specimen was reported in the Albanian waters of the Vlore Bay [18]. Strictly protected species in Croatia.

Presence: Rare.
 Conservation status: Critically Endangered A2bcd + C2a(i)(ii) + D.
 ALOPIIDAE
Alopias Rafinesque, 1810

6. *Alopias superciliosus* Lowe, 1841, Bigeye thresher

Recently listed as an Adriatic species as several records have been reported from the southern Adriatic Sea [19,20].

Presence: Rare.
 Conservation status: Data Deficient.

7. *Alopias vulpinus* (Bonnaterre, 1788), Thresher shark

Barausse et al. [21] considered the thresher shark and other large-sized sharks largely depleted even before 1945 in the western part of the northern Adriatic Sea due to intensive exploitation. The main cause of the decline of common thresher sharks in the northern Adriatic Sea was related to commercial target and bycatch fisheries based on landings data [22]. The majority of the caught sharks were juveniles (approximately 90%) and many of them weighed less than 10 kg. The capture of juvenile specimens was recorded in

Slovenian waters as well [23]; thus, the northern Adriatic area is considered the breeding area of the Adriatic population. In Italy, the thresher shark has markedly decreased in abundance and is considered Critically Endangered [24]. Considered as common in the eastern Adriatic and caught, as bycatch, in purse seines and by tuna longlines. Big game fishermen regularly targeted this species, but a rapid decline of the thresher shark in their catches was reported during the first decade of the 21st century [5]. Strictly protected species in Croatia.

Presence: Common.

Conservation status: Endangered A2bd.

CETORHINIDAE

Cetorhinus Blainville, 1816

8. *Cetorhinus maximus* (Gunnerus, 1765), Basking shark

Since the first published record in the early 19th century occurrence of the basking shark in the Adriatic Sea was frequently documented [25–27]. In fact, contrary to the case of other large sharks whose records were reduced, the occurrence of basking sharks in the Adriatic Sea has increased in the last two decades, especially in the Northern Adriatic where the majority of the records are reported [28]. Soldo et al. [28] compared the increase and fluctuation in the occurrence of basking sharks with key physical properties of the Adriatic water (temperature and salinity at different sea depths) but found no evident pattern. However, a strong correlation was found in regard to changes in zooplankton populations, particularly *Calanus helgolandicus*, which is a basking shark major prey. Hence, it was observed that large specimens arrived in the Adriatic Sea during the winter season and left shortly after the beginning of the spring while young-of-the-year sharks appeared on the surface later in summer [28]. Such a pattern has generally continued since then. Basking sharks arriving in the Adriatic are considered as visitors from a wider Mediterranean population. Listed in Annex I of Regulation (EU) 2019/1241 and strictly protected species in Croatia.

Presence: Occasional.

Conservation status: Critically Endangered D.

LAMNIDAE

Carcharodon Smith, 1838

9. *Carcharodon carcharias* (Linnaeus, 1758), Great white shark

Soldo and Jardas [25,26] reported the historical records of the great white shark since 1868 until 2000 and associated its presence in coastal waters of the eastern Adriatic Sea with a high abundance of tunas in those waters during the 19th century and the first half of 20th century, which were their major prey. The start of intensive tuna fishing in open waters of the Adriatic Sea, especially during the 1970s, caused the disappearance of tuna in coastal waters of the eastern Adriatic, and as a consequence, the disappearance of the great white shark in the records from the last decades of the 20th century. Soldo and Jardas [25,26] also suggested that future records of the great white shark in the Adriatic Sea would be related to the abundance and migratory routes of tuna which was supported by a later record of a female caught in tuna purse seine 15 Nm southwest off Jabuka island [29]. Since then, a few new records have been recorded. Great white sharks recorded in the Adriatic are considered as part of the Mediterranean population. Listed in Annex I of Regulation (EU) 2019/1241 and strictly protected species in Croatia.

Presence: Rare.

Conservation status: Critically Endangered A2d + D.

Isurus Rafinesque, 1810

10. *Isurus oxyrinchus* Rafinesque, 1810, Shortfin mako

Shortfin mako has been reported in more than fifty cases in the Adriatic Sea; however, the majority of reports are dated before 1900 [25]. After 1972, for several decades no records of this species were reported, but in recent years smaller specimens have occasionally been

recorded in southern Adriatic offshore Montenegro and Albania. The records of the shortfin mako in the Adriatic belong to the Mediterranean population. Strictly protected species in Croatia.

Presence: Rare.

Conservation status: Critically Endangered A2bd+ C2a(i)(ii).

Lamna Cuvier, 1816

11. *Lamna nasus* (Bonnaterre, 1788), Porbeagle

At least 33 documented records exist on the presence of the porbeagle in the Adriatic Sea [30], and there is evidence of additional unpublished sightings. The catch of some juvenile specimens suggests the possible reproduction of this lamnoid shark in the Adriatic Sea [5]. However, it is most likely that the Adriatic porbeagles are part of the Mediterranean population. Strictly protected species in Croatia.

Presence: Occasional.

Conservation status: Critically Endangered A2bd.

ORDER: CARCHARHINIFORMES

SCYLORHINIDAE

Scyliorhinus Blainville, 1816

12. *Scyliorhinus canicula* (Linnaeus, 1758), Lesser spotted dogfish

Usual bycatch in bottom trawls and gillnets. Present everywhere in high numbers in the Adriatic Sea but considered rare in the Gulf of Trieste. There is an Adriatic population.

Presence: Abundant.

Conservation status: Near Threatened.

13. *Scyliorhinus stellaris* (Linnaeus, 1758), Nursehound

Usual bycatch in coastal fishing gear. Present everywhere in high numbers in the Adriatic Sea but considered rare in the Gulf of Trieste. There is an Adriatic population of the nursehound.

Presence: Abundant.

Conservation status: Near Threatened.

PENTANCHIDAE

Galeus Rafinesque, 1810

14. *Galeus melastomus* Rafinesque, 1810, Blackmouth catshark

The blackmouth catshark is considered common in the deepwater habitats of the southern Adriatic Sea [4,31] which is supported by recent research [14]. Most likely there is an Adriatic population of this species.

Presence: Common.

Conservation status: Least Concern.

15. *Galeus atlanticus* (Vaillant, 1888), Atlantic sawtail cat shark

Recently listed as an Adriatic species based on a verified single record reported from the southern Adriatic [14].

Presence: Rare.

Conservation status: Data Deficient.

TRIAKIDAE

Mustelus Linck, 1790

16. *Mustelus asterias* Cloquet, 1819, Starry smooth-hound

Common in the southern and central while rare in the northern Adriatic Sea. Usual bycatch in trawl and other bottom fishing gear. An Adriatic population exists.

Presence: Common.

Conservation status: Vulnerable A2bd.

17. *Mustelus mustelus* (Linnaeus, 1758), Smooth-hound

Common in the Adriatic Sea. In northern areas during the spring season, they are targeted by gillnets with a mesh size range of 120 to 150 mm. Largest Adriatic population amongst smooth-hounds.

Presence: Abundant.

Conservation status: Vulnerable A2bd.

18. *Mustelus punctulatus* Risso, 1827, Blackspotted smooth-hound

Common in the Adriatic Sea, but less abundant than *M. mustelus*. In northern areas during the spring season, they are targeted by gillnets with a mesh size range of 120 to 150 mm together with smooth-hound. There is an Adriatic population.

Presence: Common.

Conservation status: Vulnerable A4d.

Galeorhinus Blainville, 1816

19. *Galeorhinus galeus* (Linnaeus, 1758), Tope shark

Occasionally recorded in the Adriatic Sea. It is a relatively larger species but due to the specific habitat preferences under the high impact of fisheries. Strictly protected species in Croatia. It is unclear if there is an Adriatic population or all the tope sharks in the Adriatic are part of a wider, probably Mediterranean, population.

Presence: Occasional.

Conservation status: Endangered A2bd + C1.

CARCHARHINIDAE

Carcharhinus Blainville, 1816

20. *Carcharhinus plumbeus* (Nardo, 1827), Sandbar shark

This species might be less rare in the Adriatic Sea than the occasionally reported records suggest. The evidence of the presence of the sandbar shark in the Adriatic Sea is mainly based on the records of neonates and juvenile specimens, especially in the northern Adriatic Sea [32–35] which has led some authors to the conclusion that it may serve as a nursery area [5]. Consequently, a small Adriatic population probably exists. Strictly protected species in Croatia.

Presence: Occasional.

Conservation status: Endangered A4d + C2b.

Prionace Cantor, 1849

21. *Prionace glauca* (Linnaeus, 1758), Blue shark

The most common species of all large sharks in the Adriatic Sea. However, at the beginning of the 21st century fishers practicing big game fishing noted that blue sharks, previously the target species in that fishery, significantly declined, which was also supported by further research [36]. Soldo [5] suggested, based on the records of many neonates and pregnant females, that the Zadar archipelago in the eastern central Adriatic is a nursery area, but small juveniles are also found in the Northern Adriatic. It is still unclear if there is only a single Mediterranean population of the blue sharks or if there are smaller regional populations, including the Adriatic one. Strictly protected species in Croatia.

Presence: Common.

Conservation status: Critically Endangered A2bd.

Rhizoprionodon Whitley, 1929

22. *Rhizoprionodon acutus* (Rüppell, 1837), Milk shark

Bakui [37] reported on a female individual milk shark, caught in the waters off Orikum (Radhime) in Albanian waters and so far, it is the only documented Adriatic record of the milk shark.

Presence: Rare.

Conservation status: Data Deficient.

SPHYRNIDAE

Sphyrna Rafinesque, 1810

23. *Sphyrna zygaena* (Linnaeus, 1758), Smooth hammerhead

Soldo and Jardas [25] reported more records of the smooth hammerhead from 19th century than from 20th century. Most of the records were from the southern and central Adriatic Sea. Since then, only a few records have been recorded and they are all from the open waters of the southern Adriatic. Considering the highly migratory behavior of the *S. zygaena*, all the records in the Adriatic are probably part of the Mediterranean population. Strictly protected species in Croatia.

Presence: Rare.

Conservation status: Critically Endangered A2bd + C1.

ORDER: SQUALIFORMES

DALATIIDAE

Dalatias Rafinesque, 1810

24. *Dalatias licha* (Bonnaterre, 1788), Kitefin shark

The kitefin shark is present only in the deepwater habitats of the southern Adriatic Sea [31,38]. There is probably an Adriatic population.

Presence: Rare.

Conservation status: Vulnerable A3d + 4d.

ETMOPTERIDAE

Etmopterus Rafinesque, 1810

25. *Etmopterus spinax* (Linnaeus, 1758), Velvet belly

Considered as very rare in the Adriatic Sea, but Bello [4] reported it as more common in the bathyal grounds of the southern Adriatic which is supported by recent data [14]. The spatial population boundaries of the velvet belly inhabiting the Adriatic are unknown.

Presence: Rare.

Conservation status: Least Concern.

SOMNIOSIDAE

Somniosus Lesueur, 1818

26. *Somniosus rostratus* (Risso, 1827), Little sleeper shark

Previously not considered as an Adriatic species but recently recorded with the baited lander in deep waters of the southern Adriatic Sea [39].

Presence: Rare.

Conservation status: Data Deficient.

OXYNOTIDAE

Oxynotus Rafinesque, 1810

27. *Oxynotus centrina* (Linnaeus, 1758), Angular roughshark

Angular roughshark is considered more common than rarely published records indicate. Based on a record of small pups found in the island of Brač channel area, Soldo [5] suggested the eastern central coastal area as a possible nursery area. Whether angular roughsharks in the Adriatic belong to the regional population or the Mediterranean one it is still unknown. Strictly protected species in Croatia.

Presence: Occasional.

Conservation status: Critically Endangered A2bd.

CENTROPHORIDAE

Centrophorus Müller and Henle, 1841

28. *Centrophorus uyato* (Rafinesque, 1810), Little gulper shark

The species from the genus *Centrophorus* in the Adriatic Sea has usually been reported as *Centrophorus granulosus* (Bloch and Schneider, 1801). However, Serena et al. [40] noted that the validity of *C. granulosus* vs. *Centrophorus uyato* (Rafinesque, 1810) is still debated among taxonomists and considered *Centrophorus* cf. *uyato* as the valid species in the Mediterranean Sea. The most recent studies confirmed that the species living in the

Mediterranean should be considered as *C. uyato* [41,42]. In the Adriatic Sea, it is considered that the species lives only in southern deeper waters which was confirmed by recent research [14,39]. Taking the aforementioned into account, the exact boundaries of the little gulper shark are unclear.

Presence: Rare.

Conservation status: Critically Endangered A4b.

SQUALIDAE

Squalus Linnaeus, 1758

29. *Squalus acanthias* Linnaeus, 1758, Picked dogfish

During most of the 20th century the picked dogfish was considered as abundant in the Adriatic Sea [43], but later it faced a drastic decline in its abundance [44]. It can be presumed that the Adriatic population differs from others in the Mediterranean.

Presence: Common.

Conservation status: Endangered A2bd.

30. *Squalus blainville* (Risso, 1827), Longnose spurdog

Considered a relatively common species, but only in the central and especially in the southern Adriatic Sea [43]. However, during the last decades, significant declines in abundance have been observed [44]. Similar to the *S. acanthias* case, there is an Adriatic population of *S. blainville*.

Presence: Common.

Conservation status: Endangered A2bd.

ORDER: ECHINORHINIFORMES

ECHINORHINIDAE

Echinorhinus Blainville, 1816

31. *Echinorhinus brucus* (Bonnaterre, 1788), Bramble shark

Considered very rare as to date only a few records have been reported in the Adriatic Sea. No recent records are available on this species. Consequently, it can be presumed that the bramble shark is now regionally extinct in the Adriatic Sea but considering its preference for deeper waters from where not much data are available, this hypothesis needs further confirmation.

Presence: Rare.

Conservation status: Critically Endangered A2bcd.

ORDER: SQUATINIFORMES

SQUATINIDAE

Squatina Duméril, 1805

32. *Squatina oculata* Bonaparte, 1840, Smoothback angelshark

Brusina [45] wrote that during the 19th century in the Gulf of Trieste and Dalmatia the *S. oculata* was rarer than *Squatina squatina*. Since no records have been reported for at least 5 decades, it is considered that the smoothback angelshark is regionally extinct from the Adriatic Sea. Strictly protected species in Croatia.

Presence: Rare.

Conservation status: Extinct in wild/Regionally extinct.

33. *Squatina squatina* (Linnaeus, 1758), Angelshark

S. squatina used to be a common shark species and was abundantly caught in the Adriatic Sea during the 19th century according to Brusina [45]. In Croatia, angel sharks were historically targeted as one of the large mesh size gillnets was named *sklatara* upon the Croatian name for the angelshark—*sklat*. Such considerations were pointed out also by Fortibuoni et al. [44] who reported that according to naturalists' accounts and historical documents, in the 19th and early 20th centuries the species in the Northern Adriatic Sea was so abundant to sustain targeted fisheries, and large quantities of *S. squatina* were sold in the main fish markets, but in the 1960s the species collapsed and became economically

extinct. Soldo [5] considered both Adriatic angelshark species as very rare and critically endangered within the entire Adriatic area. Only recently *S. squatina* specimens reappeared in the catches of fishermen, as pointed out by different sources [46–48]. Considering the ecological characteristics of this species, the existence of the Adriatic population is presumed. Listed in Annex I of Regulation (EU) 2019/1241 and strictly protected species in Croatia.

Presence: Occasional.

Conservation status: Critically Endangered A2bcd.

ORDER: TORPEDINIFORMES

TORPEDINIDAE

Tetronarce Gill, 1862

34. *Tetronarce nobiliana* (Bonaparte, 1835), Electric ray

Not many records of the electric ray have been reported in the Adriatic Sea and those which have been reported are mainly related to juveniles from its central and southern parts. Population boundaries of the electric ray in the Adriatic are unknown.

Presence: Rare.

Conservation status: Vulnerable A2bcd.

Torpedo Duméril, 1805

35. *Torpedo marmorata* Risso, 1810, Marbled electric ray

Present in the Adriatic Sea mainly on its eastern side, in channels and at the open sea, while the species faced a severe decline on the western side [31]. There is an existing Adriatic population with a known breeding area in the Northern Adriatic.

Presence: Common.

Conservation status: Near Threatened.

36. *Torpedo torpedo* (Linnaeus, 1758), Common torpedo

Occasionally reported from central and southern Adriatic Sea. Thus, the population boundaries of the Adriatic specimens are unknown.

Presence: Occasional.

Conservation status: Near Threatened.

RHINOBATIDAE

Rhinobatos Linck, 1790

37. *Rhinobatos rhinobatos* (Linnaeus, 1758), Common guitarfish

Listed as the Adriatic species by many regional lists of fishes. However, no records have been reported for many decades; thus, considered regionally extinct for the Adriatic Sea. Strictly protected species in Croatia.

Presence: Rare.

Conservation status: Extinct in wild/Regionally extinct.

ORDER: RHINOPRISTIFORMES

PRISTIDAE

Pristis Linck, 1790

38. *Pristis pectinata* Latham, 1794, Smalltooth sawfish

Listed as an Adriatic species based solely on a record of the rostrum engraved by the name *Issa 1902*, which is the Latin name for the Croatian island Vis. Several rostrums are exhibited at the Natural History Museum in Zagreb but without any data on origin [49]. Consequently, the smalltooth sawfish is considered regionally extinct species in the Adriatic Sea. Listed in Annex I of Regulation (EU) 2019/1241 and strictly protected species in Croatia.

Presence: Rare.

Conservation status: Extinct in Wild/Regionally Extinct.

ORDER: RAJIFORMES

RAJIDAE

Dipturus Rafinesque, 181039. *Dipturus* cf. *batis* (Linnaeus, 1758), Blue skate

Rarely reported and mainly from the eastern side of the Adriatic Sea. However, it has to be noted that Serena et al. [40] suggested that the current status and taxonomy of *D. batis* as a valid species for the Mediterranean Sea still needs clarification as recent studies have tended to separate the common skate *D. batis* species-complex into two nominal species, the blue skate (temporarily called *Dipturus* cf. *flossada* [Risso, 1826]) and the flapper skate (*Dipturus* cf. *intermedia* [Parnell, 1837]). Serena et al. [40] also observed that although those studies included the Mediterranean Sea in the distribution range of both species, they did not provide any indication about their spatio-temporal distribution. Thus, future studies should investigate whether the species is currently present in the area but should also verify the documentation about the specimens recorded in the past. Strictly protected species in Croatia.

Presence: Rare.

Conservation status: Critically Endangered A2bcd.

40. *Dipturus nidarosiensis* (Storm, 1881), Norwegian skate

Norwegian skate was only recently reported in the Adriatic Sea by Carbonara et al. [50] based on six specimens collected in the area around the pit of Bari. However, this batoid species was recorded even earlier in 2008 by Isajlović et al. [51]. Population boundaries of the Norwegian skate occurring in the Adriatic are unknown.

Presence: Rare.

Conservation status: Critically Endangered A2bcd.

41. *Dipturus oxyrinchus* (Linnaeus, 1758), Longnosed skate

According to Jardas [31] *D. oxyrinchus* is present mainly in the central and southern Adriatic Sea. Strictly protected species in Croatia. To which population the specimens found in the Adriatic belong is unknown.

Presence: Rare.

Conservation status: Critically Endangered A2bcd.

Leucoraja Malm, 1877

42. *Leucoraja circularis* (Couch, 1838), Sandy ray

Considered rare and present only in the southern Adriatic Sea at the edge of the continental shelf and slope [31]. Thus, the boundaries of the population are unknown.

Presence: Rare.

Conservation status: Critically Endangered A2bcd.

43. *Leucoraja fullonica* (Linnaeus, 1758), Shagreen ray

Considered as very rare with only one confirmed record from the central eastern Adriatic Sea. Hence, it is so rare in the whole Mediterranean that Serena et al. [40] suggested that the current presence of this species in the Mediterranean needs confirmation.

Presence: Rare.

Conservation status: Critically Endangered A2bcd.

Raja Linnaeus, 1758

44. *Raja asterias* Delaroche, 1809, Mediterranean starry ray

Common in the Adriatic Sea, but more abundant on the western side than the eastern. There is an existing Adriatic population.

Presence: Common.

Conservation status: Near Threatened.

45. *Raja clavata* Linnaeus, 1758, Thornback ray

The thornback ray was considered to be an abundant batoid in the Adriatic Sea. However, comparing recent population status (1996–2006) with historical data (1948–1949)

revealed that the thornback ray Adriatic population has experienced a significant decline as a result of the high fishing intensity to which the species has been exposed [52].

Presence: Common.

Conservation status: Endangered A2abcd.

46. *Raja miraletus* Linnaeus, 1758, Brown ray

Widely distributed and abundant in bottom trawl catches [53]. Probably the largest Adriatic population amongst all the species from the Rajidae family.

Presence: Abundant.

Conservation status: Least Concern.

47. *Raja montagui* Fowler, 1910, Spotted ray

Considered common, especially in the open sea area of the eastern central and southern Adriatic Sea [31]. Existing Adriatic population.

Presence: Common.

Conservation status: Least Concern.

48. *Raja polystigma* Regan, 1923, Speckled ray

Considered rare as only a few records exist from the central and southern Adriatic Sea [31]. However, it has to be noted that Serena et al. [40] suggested a possible confusion in discrimination between *R. montagui* and *R. polystigma*, so further investigation on the presence of these two species is needed.

Presence: Rare.

Conservation status: Near Threatened.

49. *Raja radula* Delaroche, 1809, Rough ray

Rare species with few records found in central and northern Adriatic Sea.

Presence: Rare.

Conservation status: Endangered A4bcd.

50. *Raja undulata* Lacepède, 1802, Undulate ray

Rare species found only in the deep waters of the southern Adriatic Sea. The population boundaries of this species in the Adriatic are unknown.

Presence: Rare.

Conservation status: Vulnerable A4bcd.

Rostroraja Hulley, 1972

51. *Rostroraja alba* (Lacepède, 1803), White skate

Rare, but found in open sea areas of the whole Adriatic Sea. The exact population boundaries of the white skate in the Adriatic are unknown.

Presence: Rare.

Conservation status: Endangered A2bd.

ORDER: MYLIOBATIFORMES

DASYATIDAE

Bathytoshia Whitley, 1933

52. *Bathytoshia lata* (Garman, 1880), Brown stingray

Rarely reported in the central and southern Adriatic Sea, while mainly on its eastern side [54]. In 2017, a large female of 210 cm disc width and more than 200 kg weight was caught near the island of Glavat in Croatian south Adriatic. The size and population boundaries of *B. lata* in the Adriatic are unknown.

Presence: Rare.

Conservation status: Vulnerable A2bd.

Dasyatis Rafinesque, 1810

53. *Dasyatis pastinaca* (Linnaeus, 1758), Common stingray

Occasionally found throughout the Adriatic Sea, mainly in channel areas of the eastern side [31], but recent reports from citizen science suggest that it could be more common than previously considered. Consequently, the existence of a small Adriatic population can be presumed. Strictly protected species in Croatia.

Presence: Occasional.

Conservation status: Vulnerable A2cd.

Pteroplatytrygon Fowler, 1910

54. *Pteroplatytrygon violacea* (Bonaparte, 1832), Pelagic stingray

Rarely officially reported probably because of habitat preferences where not much fishing gear is used but considered to be fairly common as observed by some studies [36], especially those performed in the northern Adriatic Sea where juveniles are often found [55]. Thus, the existence of the Adriatic population of unknown size can be presumed.

Presence: Common.

Conservation status: Least Concern.

GYMNURIDAE

Gymnura van Hasselt, 1823

55. *Gymnura altavela* (Linnaeus, 1758), Spiny butterfly ray

The spiny butterfly ray is considered as a very rare batoid species in the Adriatic Sea. This species was more frequently caught in the 19th century as pointed out by Dulčić et al. [54]. The last available record originates from November 2000 when a male was caught by a bottom trawl near Crkvice (Pelješac peninsula) [54]. Strictly protected species in Croatia.

Presence: Rare.

Conservation status: Critically Endangered A2bd.

MYLIOBATIDAE

Aetomylaeus Garman, 1908

56. *Aetomylaeus bovinus* (Geoffroy Saint-Hilaire, 1817), Bull ray

Records exist from the central and southern Adriatic, but also the northern Adriatic Sea where occasional captures of large gravid females occurred [56]. Although consequently the northern Adriatic can be presumed as the breeding area, it is still unclear if it is of the Adriatic or wider Mediterranean population.

Presence: Rare.

Conservation status: Critically Endangered A2cd.

Myliobatis Cuvier, 1816

57. *Myliobatis aquila* (Linnaeus, 1758), Common eagle ray

Common species and widely distributed in the whole Adriatic Sea. In the Northern Adriatic juveniles are often recorded. There is an Adriatic population.

Presence: Common.

Conservation status: Vulnerable A2bd.

RHINOPTERIDAE

Rhinoptera Cuvier, 1829

58. *Rhinoptera marginata* (Geoffroy Saint-Hilaire, 1817), Lusitanian cownose ray

Very rare in the Adriatic Sea. No recent published data about its occurrence.

Presence: Rare.

Conservation status: Critically Endangered A2bcd.

MOBULIDAE

Mobula Rafinesque, 1810

59. *Mobula mobular* (Bonnaterre, 1788), Devil fish

The devil fish rarely approach coastal areas in the Adriatic Sea, which makes the assessment of the status of the species rather difficult. However, it seems that the devil fish, which was previously considered as a very rare species in the Adriatic Sea, is probably much more abundant than expected. New estimates calculated by Fortuna et al. [57] pointed out that at least 1595 giant devil fish are occurring in central-southern Adriatic. Therefore, it can be presumed that there is an Adriatic population of the devil fish but such a presumption still needs further investigation considering the highly migratory behavior of this species. Listed in Annex I of Regulation (EU) 2019/1241 and strictly protected species in Croatia.

Presence: Rare.

Conservation status: Critically Endangered A2d.

CLASS: HOLOCEPHALI

ORDER: CHIMAERIFORMES

CHIMAERIDAE

Chimaera Linnaeus, 1758

60. *Chimaera monstrosa* Linnaeus, 1758, Rabbit fish

Records only from deeper waters of central and particularly southern Adriatic Sea. It is unclear if there is an Adriatic population of the rabbit fish.

Presence: Rare.

Conservation status: Vulnerable A2d.

3.2. Questionable/Not Confirmed Species

The questionable species are mentioned in some lists of the Adriatic fishes but excluded from this list due to the lack of any reliable data.

Carcharhinus brachyurus (Günther, 1870), Copper shark

The presence of *C. brachyurus* in the Mediterranean Sea has been confirmed in different areas [40], but it was considered as the Adriatic species only by Garrick [58] who mentioned a specimen caught close to the locality of Constantinople near Trieste. However, although Constantinople is probably Iustinopolis, which is the ancient name of the town of Koper in Slovenia (rather close to Trieste), no clear evidence of this species is available. Thus, Lipej et al. [2] considered this species as a doubtful one and excluded it from the list of Adriatic chondrichthyans.

Carcharhinus longimanus (Poey, 1861), Oceanic whitetip shark

Milišić [59] included the species on the list of Adriatic fishes, but also observed that its presence in these waters is doubtful. Lipej et al. [2] excluded the oceanic whitetip shark from the Adriatic list.

Carcharhinus melanopterus (Quoy and Gaimard, 1824), Blacktip reef shark

Mentioned in the Albanian list of fishes by Rakaj [60] without any specific data. Serena et al. [40] noted that *C. melanopterus* is a species with an Indo-Pacific origin, likely entering the Mediterranean Sea via the Suez Canal and if this species is confirmed in the Mediterranean Sea, its presence is likely limited to the Levantine basin. Considering no data on the origin of the record for Adriatic Sea exist, the blacktip reef shark is excluded from this list.

Sphyrna tudes (Valenciennes, 1822), Smalleye hammerhead

Kolombatović [61] determined and reported several young specimens of the smalleye hammerhead. His observations served as the basis for all succeeding lists of the Adriatic sharks that included *S. tudes*. However, Lipej et al. [2] considered *S. tudes* as a doubtful species in the Adriatic Sea and, consequently, it was not listed as the Adriatic species. Ebert et al. [62] suggested that *S. tudes* occurred only along the South American Atlantic coasts. However, Tortonese [63] described *S. tudes* specimen, which was confirmed by Serena [64]

who observed the specimen preserved at the Calci Museum of Natural History (University of Pisa, Italy), with catalog number 2347. Serena et al. [40] revealed that this specimen was bought by Tortonese at the Livorno (Italy) fish market but the origin of the specimen is unclear as it remained unknown if the individual was caught within Mediterranean waters. Thus, Serena et al. [40] concluded that *S. tudes* remains a doubtful inhabitant of the Mediterranean.

Squatina aculeata Cuvier, 1829, Sawback angelshark

Mentioned only by Rakaj [60] without any specific data, thus excluded from this list.

4. Discussion

Taking into account the number of flora and fauna endemics, the Adriatic Sea stands out as a special biogeographical unit of the Mediterranean as the endemic species present in the flora of the central Adriatic make up 64 taxa or 12.1% of its content [2]. When it comes to fishes, the recently updated list of Adriatic fishes consists of 444 fishes in the Adriatic Sea [65] which is 58.5% of the fish species reported for the Mediterranean [66]. A similar result has been reported in the case of chondrichthyans as Serena et al. [40] stated that 60% of the Mediterranean chondrichthyans are recorded in the Adriatic Sea. On the one hand, that percentage is low compared to other Mediterranean regions as the highest number of Mediterranean chondrichthyans has been reported in the western area (84%) followed by the central Mediterranean Sea (81%) and the eastern Mediterranean Sea (78%) while only the Black Sea, with only 13% of the species represented, has a lower number [40]. On the other hand, the Adriatic Sea is considered the main Mediterranean biodiversity hotspot for chondrichthyans in terms of the diversity score [67] although it has to be noted that the diversity score is weighed by the surface of each sector; thus, this result derives mainly due to the relatively small area of the Adriatic Sea.

Nowadays, changes in marine biodiversity throughout the Mediterranean Sea and also in the Adriatic Sea, as well, are often reported. The main factors are related to the increasing arrival of alien fishes and species related to the process of meridionalisation, otherwise defined as the northward spreading of southern thermophilous species [68]. Due to such phenomena, the number of species in the Adriatic Sea may even increase in the nearby future. Actually, recently some new shark species were reported in the Adriatic Sea which could be related to the increasing water warming. In addition, some additional alien sharks are expected to arrive in the Adriatic Sea through the Suez Canal or the Strait of Gibraltar.

The 60 species in our work represent 68% of the recorded species in the Mediterranean Sea, which in turn is higher than that reported by Serena et al. [40] and it is probably due to new species records in the Adriatic Sea. This means that the Adriatic Sea is an even more significant Mediterranean biodiversity hotspot in terms of the diversity score than previously considered, but, from the conservation point of view, it is also the area of the Mediterranean where the chondrichthyans are at the highest level of threat. An assessment of the conservation status of the Adriatic species revealed that 70% (42 out of 60) are regionally threatened, including three species that are now considered as Regionally extinct (Figure 2), which is significantly higher than in other areas of the Mediterranean. The principal driver of the chondrichthyan decline and the regional extinction of some species is certainly human impact, particularly overfishing [5–7,44,53,69]. One of the problems related to the fisheries is the different legislation between countries bordering the Adriatic Sea (EU countries Croatia, Italy and Slovenia vs. Albania, Bosnia and Herzegovina and Montenegro) which makes conservation measures inefficient. Hence, even within EU countries that share the same common legislation, the absence of nationally implemented measures is noticeable.

Unfortunately, either bycatch or target fisheries on chondrichthyans have had a very low priority for management in the Mediterranean Sea because catch volumes and values were assumed to be low. Consequently, species of greater economic interest, mainly

teleost species, have received higher management priority. Although on the global and the Mediterranean level the situation is slowly changing due to increasing concern about chondrichthyan conservation, the efforts are not followed by the efficiency of management due to the lack of reliable data needed for fishery managers to make reliable stock assessments [6]. Hence, in most cases, when some kind of management of chondrichthyan species exists, the used techniques and enforcement measures are insufficient to ensure the long-term proper status of those species and their populations. Moreover, assessment models, that are usually applied, are based on teleost fisheries, making such models inadequate for chondrichthyan populations. Subsequently, for the most of chondrichthyan species, the absence of usually required and conventional stock assessment data results in the absence and/or postponing of applying measures for their conservation [6].

A particular problem is with a group of demersal chondrichthyans (e.g., all three species listed as Regionally Extinct are part of this group) which are under the high impact of various unselective fishing gear, especially bottom trawl. Even if those species will be protected by various legislation, that will not prevent the species from being caught, especially those that inhabit the inshore area where the fishing effort is the highest and where a broad range of various unselective bottom fishing gear is used in the small-scale and large-scale fisheries. Thus, the ultimate conservation issue is, after the implementation of existing conservation measures into national legislations, to identify and map the critical habitats of these species. These habitats can be relatively small, thus avoiding the conflict with fisheries interests, but effective if the use of the bottom fishing gear will be restricted only to the highly selective gear.

Another issue is with the large pelagic chondrichthyans which inhabit offshore pelagic areas. On the one hand, they are less impacted by the fisheries than demersal species, as driftnets are banned, pelagic longlines are not heavily used in the Adriatic Sea, while the fishing intensity in the open sea pelagic zone is relatively low compared to coastal bottom fisheries. However, it has to be pointed out that the level of impact of some activities that are practiced in that area is still unknown, e.g., the impact of the recreational fisheries. On the other hand, this group mainly comprises species with particular life history characteristics (late age at maturity, slow population growth, long generation time, low maximum rates of population increase etc.) which gives them reduced resilience to fishing, compared to smaller species [69]. Hence, they are also mainly highly migratory species that are migrating across boundaries and as such represent the classic case for involving international cooperation. These transboundary species have an increased risk of overexploitation as management measures and levels of protection are different among Adriatic states.

Even in cases when countries are motivated to implement co-management measures, a lack of scientific data to support the management is evident. Hence, the development of effective co-management measures for transboundary species can be severely hindered by the different institutional capacities of the Adriatic countries. Thus, after establishing, implementing and enforcing general conservation measures into national legislations, the main goals of conservation should be to strengthen the coordination of Adriatic countries and increase the data collection and scientific studies, particularly those focusing on determining critical habitats that would need additional management measures for securing reliable protection of the chondrichthyans in the Adriatic Sea.

5. Conclusions

The new list of the Adriatic chondrichthyans comprises 60 species (33 sharks, 26 rays and one chimera) that represent 68.2% of species recorded in the Mediterranean. Since the last published list of sharks [2] five new species have been recorded, all from the southern Adriatic Sea, which is similar to the trend observed with bony fishes [67,68]. Consequently, in the Mediterranean Sea, the chondrichthyan diversity hotspot in the Adriatic Sea is higher than previously considered. However, it is also the area of the Mediterranean where the chondrichthyans are at the highest level of threat, as an assessment of the

conservation status of the Adriatic species revealed that 70% of species are regionally threatened, including three Regionally Extinct species. Assessing their presence status revealed that 33 species are rare, 8 species are occasional, 15 species are common while only 4 chondrichthyans in the Adriatic Sea are still abundant.

Considering that the principal driver of chondrichthyan decline and regional extinction is overfishing, it is essential that the Adriatic countries adopt the same management measures. Hence, efforts should be increased to identify critical habitats of the chondrichthyans as proper management measures enforced in mating areas and spawning and nursery grounds are essential for their protection and restoration.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/fishes7050245/s1>, Table S1: The complete list of the references used during the research.

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