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Combining official fisheries monitoring and citizen science data to create the first chondrichthyan checklist of Montenegro

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Abstract: Chondrichthyans are considered a highly threatened marine species, due both to the intense fishing pressure they have experienced in the world's Oceans over several decades, and other threats, such as habitat loss, climate change and marine pollution. A rapid decline in their populations could trigger significant negative changes in marine ecosystems, highlighting the need for improved conservation measures. This study analyzes the current state of this group in the waters of Montenegro (in the southeastern Adriatic Sea). The first national checklist is provided here, comprising of 44 species, with information on their occurrence frequencies in Montenegrin fishery catches. The dataset used consists of 1469 records obtained from 281 field samplings conducted as part of the official monitoring of commercial fisheries (DCF-DCRF) as well as 1222 records derived from citizen science. The latter contributed significantly in documenting a greater number of species, particularly those considered threatened or rare in the region, and/or overlooked by DCF-DCRF monitoring. The frequency of species in Montenegrin catches is described based on the percentage of their records in the total number of records originating from local fisheries. The obtained results indicate that only 16% of the species recorded in Montenegro are commonly present in country's catches, while 66% are either rare or not observed in local fishery. The creation of the country's first checklist might contribute to overcoming drawbacks in national legislation and protection measures, notably by reporting the presence of endangered species in national marine waters.
Keywords: Adriatic Sea; Mediterranean Sea; MECO project; sharks; elasmobranchs; opportunistic data

Sažetak: PRVI POPIS HRSKAVIČNJAČA CRNE GORE TEMELJEN NA KOMBINACIJI MONITORINGA GOSPODARSKOG RIBOLOVA I GRAĐANSKE ZNANOSTI. Hrskavičnjače se smatraju visoko ugroženim morskim vrstama zbog jakog ribolovnog pritiska kojem su izložene tijekom više desetljeća u svjetskim morima i oceanima, ali i zbog drugih negativnih utjecaja, poput gubitka staništa, klimatskih promjena i zagađenja mora. Ubrzano smanjenje njihovih populacija može pokrenuti negativne promjene u morskim ekosustavima, što dodatno naglašava potrebu za unaprjeđenjem mjera zaštite. Ovo istraživanje prikazuje analizu trenutnog stanja ove skupine organizama u crnogorskim vodama (jugoistočni Jadran). U radu je prikazan prvi popis hrskavičnjača, koji uključuje 44 vrste, s pojedinostima o učestalosti pojavljivanja u crnogorskim ulovima. Podaci se sastoje od 1469 zabilježenih nalaza u 281 terenskom istraživanju provedenom u okviru monitoringa gospodarskog ribolova (DCF-DCRF), kao i 1222 prijavljena nalaza prikupljena kroz „građansku znanost" (*citizen science*). Građanska znanost značajno je doprinijela povećanju broja zabilježenih vrsta, posebice onih koje se smatraju ugroženim ili rijetkim u regiji i koje nisu zabilježene u DCF-DCRF monitoringu. Učestalost vrsta u crnogorskim ulovima prikazana je kao udio broja njihovih nalaza u ukupnom broju nalaza hrskavičnjača u lokalnom ribolovu. Dobiveni rezultati ukazuju da je tek 16% zabilježenih vrsta uobičajeno prisutno u ulovima u Crnoj Gori, dok je 66% ili rijetko u lovinama ili potpuno odsutno. Izrada prvog nacionalnog popisa hrskavičnjača može doprinijeti rješavanju nedostataka u nacionalnom zakonodavstvu i mjerama zaštite, posebice kroz zabilježene nalaze ugroženih vrsta u nacionalnim vodama.
Ključne riječi: Jadransko more; Sredozemno more; projekt MECO; morski psi; hrskavičnjače; oportunistički podaci

INTRODUCTION

Chondrichthyans are among the most endangered vertebrate groups globally, with a third of living species facing the threat of extinction (Dulvy *et al.*, 2021). At the European level, the number of threatened chondrichthyans is equivalent to that of threatened birds, but their threat level is nearly six times greater, primarily due to the impact of fisheries, which leads to severe reductions in population (Ferretti *et al.*, 2008; Walls and Dulvy, 2021). The conservation of Mediterranean chondrichthyans faces challenges not only from the fishery

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industry itself, but also from the significant unreliability of official catch data (Cashion *et al*., 2019). The species in this group often occupy upper trophic levels, displaying K-selected life history traits characterized by slow growth, late maturity, low fecundity and long gestation periods (Stevens *et al*., 2000; Serena, 2005).

The Mediterranean is a chondrichthyan-rich area inhabited by 88 species, of which almost half are consistently recorded in the basin (Serena *et al*., 2020; Barone *et al*., 2022). The Adriatic Sea represents a sub-basin and falls within the northeastern part of the Mediterranean. The Adriatic Sea has a long history of human interaction with its environment (Fortibuoni *et al*., 2017). Over time, negative changes in various fishery resources, including chondrichthyans, have been well-documented in this region (Jukić-Peladić *et al*., 2001; Ferretti *et al*., 2013; Barausse *et al*., 2014; Follesa *et al*., 2019). The most recent regional assessment for the Adriatic Sea confirmed the presence of 60 chondrichthyan species in this sub-basin, with over half currently considered rare (Soldo and Lipej, 2022).

The coast of Montenegro is located in the south-eastern Adriatic, bordering the coasts of Croatia to the north and Albania to the south. Montenegrin waters are divided into three zones: internal waters, territorial waters and the continental shelf area (Fig. 1), while an exclusive economic zone has not been declared. The Montenegrin fishing fleet is very small compared to other fleets in the region and consists mainly of old and outdated vessels (Joksimović *et al*., 2019; Pešić *et al*., 2021). Consequently, in terms of quantity, Montenegrin landings are among the lowest of all Adriatic countries, particularly in small-scale fisheries (Matić-Skoko *et al*., 2017). Scientific research and data related specifically to chondrichthyans in Montenegro has been limited (Serena and Barone, 2008; Mancusi *et al*., 2020), although efforts have increased in recent years to improve the situation (Ćetković, 2018; Ćetković *et al*., 2022a). A national checklist has never previously been compiled, which is considered an essential tool for the effective protection of these species within a specific region (Giovos *et al*., 2022). This study utilized data obtained from official commercial fisheries monitoring (fishery-dependent) and information collected through citizen science (opportunistic data), in order to present the current state of this group in Montenegro. These two sources are based on different sampling approaches, which makes it difficult to combine the gathered data into a more complex study. On the one hand, compiling a checklist only requires the confirmed presence of a species in a specific geographic area, irrespective of the difference between the sampling strategies used. On the other hand, data from different sources can be compared informatively about parameters such as the number of recorded species and the number of recorded individuals within the same sampling period. Additionally, the current national legislation in place for the protection of chondrichthyans is discussed.

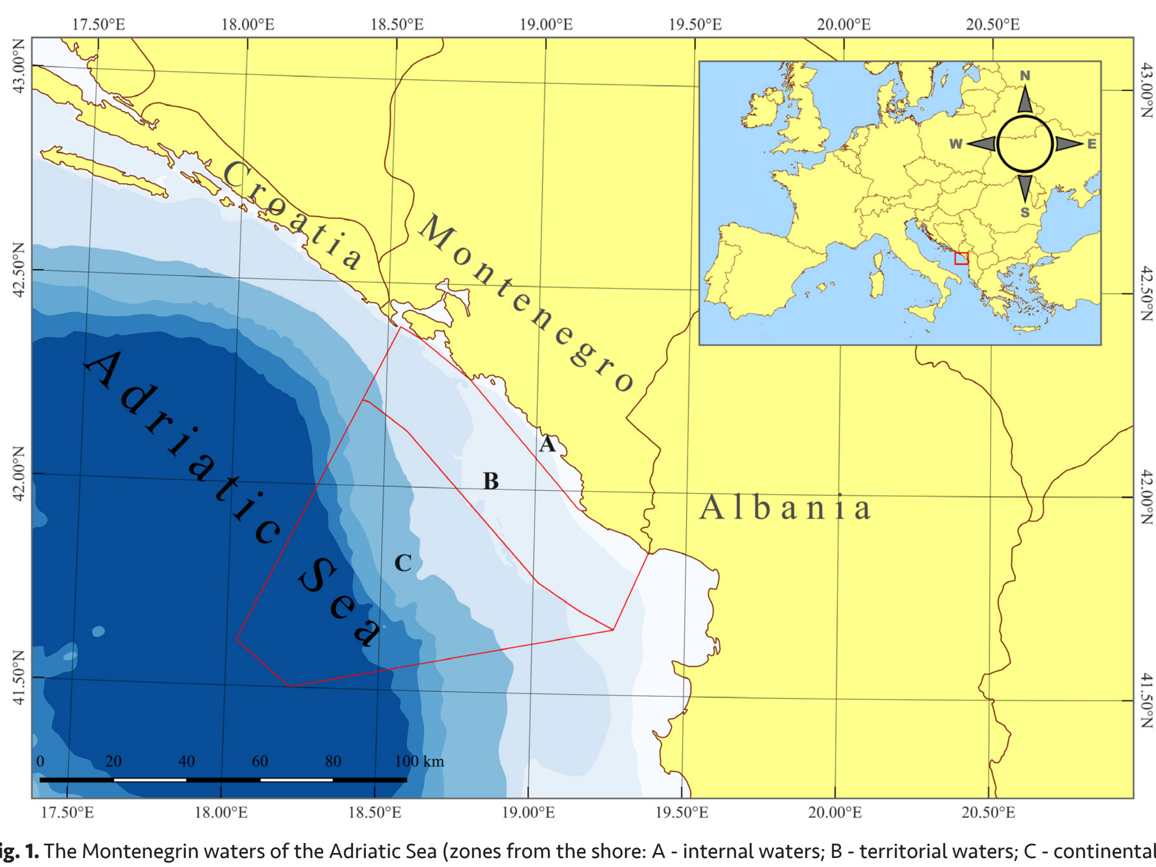

Fig. 1. The Montenegrin waters of the Adriatic Sea (zones from the shore: A - internal waters; B - territorial waters; C - continental shelf area) where the presence data of elasmobranchs were collected during this research.

MATERIALS AND METHODS

Dataset and data sources

The dataset used in this study has been compiled using two different sampling strategies:

1) The Montenegrin official monitoring program for commercial fishing (hereinafter as DCF-DCRF) implemented by the Institute of Marine Biology, and financed by the Ministry of Agriculture, Forestry and Water Management (available at: https://www.gov.me/dokumenta/2e9ee8fb-1089-423c-97c8-e6533f834b32; accessed on 18.12.2022). The monitoring program was initiated in April 2017 and involves on-board and landing samplings by trained observers across all major fleet segments.

Commonly sampled fleet segments include those that employ gillnets, trammel nets, otter bottom trawls, purse seines and beach seines, while bottom longlines were sampled to a lesser extent. Drifting longlines were not covered by the monitoring program. The samplings were carried out on a quarterly basis, and the monitoring has been implemented continuously since it started, with the exception of 2021. The number of samplings varies due to factors such as vessel inactivity, adverse weather conditions, and the availability of vessels in specific fleet segments. A total of 281 samplings were considered for analysis (Table 1). Since no chondrichthyans were recorded in either purse seines and beach seines, those catches were excluded from the analysis.

2) Two different elements of citizen science were used during the specified period in order to collect additional data from commercial fishing vessels, as well as data from sport-recreational fishing. Regarding the data sources described as reports from citizen scientists or fishermen, this part of the sampling methodology of the present study followed the usual practice of opportunistic sampling, where opportunistic records are not the direct results of scientific fishing surveys, but rather are acquired from printed or digital media, social media, or the logs of naturalists or recreational fishers (Grant *et al*., 2022; Hiddink *et al*., 2023). This includes:

- The Mediterranean Elasmobranchs Citizen Observations project (the MECO project), https://www.facebook.com/theMECOproject/; Barash *et al*., 2018). MECO engages in data collection through the creation of *Facebook* groups where interested citizens can post their observations of sharks or rays. The data is validated by expert scientists and then imported into the prepared datasheet. Montenegro has participated in this initiative since the end of 2019 and its *Facebook* group (shared with Croatia) is available at: https://www.facebook.com/groups/hrskavicnjace. Moreover, web data-mining is occasionally performed by scientists on the internet, including *Facebook*, *Instagram* and *YouTube*. The search process involved using keywords related to the topic. To make easier the search and filter the information from the web we used the following hashtags, as recommended by Kim *et al*. (2016), in Montenegrin and included general terms such as "shark" or "ray" (in Montenegrin: "ajkula", "morski pas", and "raža"). Species-specific terms referring to either single common species or terms commonly used by locals to describe multiple species were also used. Examples include: "*modrulj*", "*morska lisica*", "*morska mačka*", "*mako ajkula"*, "*pešikan"*, "*kostelj"*, "*pena"*, "*volonja"*, "*barakokula"*, "*morski golub"*, and "*viža"*.
- Reports from fishermen were another source of data, which included information on catches, observations of live animals and occasions when individuals were stranded. Fishermen often reported their observations of sharks and rays directly to the staff of the Institute of Marine Biology. The reported data, along with any available photographic or video evidence, were securely stored by the Institute. Reports without photographic proof were generally not considered valid, except in a few cases where experienced fishers had previously contributed data multiple times for the exact same species that is easily distinguished.

In the results section, data from these two subsources were grouped together under the category of "citizen science" because they are based on the same principle of citizen observations rather than data collected by scientists.

In order to accurately complete the checklist, the available scientific literature and open access databases were also accessed, following the methodology used in Giovos *et al*. (2021) and Giovos *et al*. (2022). The *Google Scholar* search engine was used to find publications dealing with chondrichthyans in Montenegrin waters in order to find records of additional species belonging to this group. The search in open access databases was limited only to species known to be present in the Adriatic Sea according to the most recent checklist produced by Soldo and Lipej (2022), but which were

Table 1. Number of official monitoring samplings considered for commercial fisheries' (DCF-DCRF) per year, since its beginning (GNS – set gillnets; GTR – trammel nets; LLS – bottom longlines; OTB – bottom otter trawl; numbers in the first column indicate vessel's length overall - LoA).

Fleet segment	2017	2018	2019	2020	2021	2022	Total
GNS < 6m	12	15	9	12	0	15	63
GNS > 6m	5	14	8	8	0	13	48
GTR < 6m	12	13	8	15	0	18	66
GTR > 6m	8	12	9	11	0	12	52
LLS < 6m	0	2	0	2	0	0	4
LLS > 6m	0	1	0	1	0	0	2
OTB < 12m	2	3	0	0	0	2	7
OTB 12m – 24m	6	14	7	4	0	5	36
OTB > 24m	3	0	0	0	0	0	3

not recorded by the data collected through the sources used in this study, including in the literature. The GBIF Global Biodiversity Information Facility (GBIF; https://www.gbif.org/) and the Ocean Biodiversity Information System (OBIS; https://obis.org/) were searched for additional information.

In addition, the datasets from Ćetković *et al*. (2022a) and from the MEDLEM database focusing on Montenegrin waters (Gallo *et al*., 2022) were included in the dataset used in this study. The MEDLEM database stores information about bycatch incidents, sightings and strandings of large elasmobranchs across the Mediterranean Sea (Mancusi *et al*., 2020). Moreover, a small number of recently published species-specific records (e.g., Nuez *et al*., 2023) from this area were also included in order to accurately analyze species frequency in the various catches. The 37 records reported in Ćetković *et al*. (2022a) were extracted from the Montenegrin DCRF reports to the General Fisheries Commission for the Mediterranean (GFCM). However, most of them originated from interviews with fishermen or their own reports, rather than the observation of specimens directly during the DCF-DCRF sampling process. Therefore, these records were classified as part of the citizen science data in this study.

Criteria for the determination of species frequency in Montenegrin catches

The total number of specimens from both the DCF-DCRF and citizen science datasets were compiled for each species to informatively show their frequency in Montenegrin catches, including data from sport-recreational fishing collected through citizen science. All other records, except those originating from fisheries, were not used. Records from the period between 2017 and 2022 were considered to be contemporary and taken into account. The frequency of species in Montenegrin catches was categorized using the percentage of the total number of individuals caught by local fishermen (n_{total}=2556) during the target period, on the following scale:

very rare – below 0.05% of the total number of records between 2017 and 2022;

rare – 0.05-0.5% of the total number of records between 2017 and 2022;

occasional – 0.5-1.5% of the total number of records between 2017 and 2022 and recorded periodically;

abundant – 1.5-15% of the total number of records between 2017 and 2022 and recorded every year;

very abundant – over 15% of the total number of records between 2017 and 2022 and recorded every year;

not present – no observations from local fishery between 2017 and 2022.

It is important to note that the aim of the presence index used here was not to estimate the relative or true abundance of these species in the ecosystem, but to provide descriptive information about their frequency in local catches. Taking into account the differences between the sampling strategies, as well as certain elements of bias affecting the data (e.g., the fact that fishermen prefer specific areas, or the fact that in the cases of opportunistic citizen science data, rare or attractive species are more likely to be reported), the dataset presented here could not be used for any estimation of the general abundance in the ecosystem. Hence, the presence index was created to describe the interaction of the various species with local fishery, and thus provide information on their frequency exclusively in the catches of Montenegro.

RESULTS

In total, records of 44 species have been confirmed in the waters of Montenegro, including 24 sharks, 19 batoids and one chimaera (Table 2). Out of these species, 17 (38.64%) were not observed in the catches of Montenegrin fishery between 2017 and 2022. Table 2 presents a comprehensive overview of all the recorded species, including those documented in the scientific literature, along with their corresponding references. Only five literature references were found which contained records of additional chondrichthyan species from Montenegrin waters, in addition to the dataset used in this study. Among those five, the reference Ikica *et al*. (2021) includes data from the "HVAR" expedition conducted in the southeastern Adriatic in 1948-1949 (Šoljan, 1977). The data available in Ikica *et al*. (2021) came from the entire waters of Montenegro, as well as a neighboring part of the waters of Croatia and Albania. However, the exact catch locations for five species (*Heptranchias perlo*, *Squatina oculata*, *Mustelus asterias*, *Dipturus* cf. *batis* and *Leucoraja circularis*) are not provided in the reference. Despite the lack of specific catch locations, these species are included in the checklist due to the relatively small size of the entire region from which the data originates.

A total of 2691 individuals were recorded, of which 1222 individuals were recorded through citizen science (CS) and 1469 individuals through DCF-DCRF (Fig. 2). Of the total, 2565 records (95.32%) were collected between 2017 and 2022, and corresponded to 27 species. The remaining 126 (4.68%) individuals were recorded through CS, either prior to 2017, or in an unknown catch/observation year. The greatest number of records comes from the analyzed catches of bottom trawlers, mostly because of the many individuals of smallspotted catshark (*Scyliorhinus canicula*) that were present in these samplings (Fig. 3). The next largest numbers come from gillnet catches and bottom longlines, respectively (Fig. 3). For about half of the gillnet records, it was not possible to determine the exact type of the net (i.e. a gillnet or a trammel net). The other types of fishing gears or observation contributed with fewer number of individuals.

Table 2. Chondrichthyan species recorded in the waters of Montenegro (*CS* - citizen science; *DCF-DCRF* – official monitoring of commercial fisheries).

FAMILY	SPECIES	SOURCE	FREQUENCY IN CATCHES (2017-2022)
SHARKS			
Hexanchidae	*Heptranchias perlo*	Ikica *et al*. (2021)	Not present
Hexanchidae	*Hexanchus griseus*	CS	Rare
Squalidae	*Squalus acanthias*	Serena and Barone (2008)	Not present
Squalidae	*Squalus blainville*	CS/DCF-DCRF	Occasional*
Centrophoridae	*Centrophorus uyato*	Serena and Barone (2008)	Not present
Etmopteridae	*Etmopterus spinax*	CS	Very rare
Oxynotidae	*Oxynotus centrina*	CS/DCF-DCRF	Rare
Squatinidae	*Squatina squatina*	CS	Not present
Squatinidae	*Squatina oculata*	Ikica *et al*. (2021)	Not present
Alopiidae	*Alopias vulpinus*	CS	Occasional
Alopiidae	*Alopias superciliosus*	Tsiamis *et al*. (2015)	Not present
Cetorhinidae	*Cetorhinus maximus*	CS	Very rare
Lamnidae	*Carcharodon carcharias*	Regner and Joksimović (1998)	Not present
Lamnidae	*Isurus oxyrinchus*	CS	Occasional
Lamnidae	*Lamna nasus*	CS	Not present
Pentanchidae	*Galeus melastomus*	CS	Very rare
Scyliorhinidae	*Scyliorhinus canicula*	CS/DCF-DCRF	Very abundant
Scyliorhinidae	*Scyliorhinus stellaris*	Serena and Barone (2008)	Not present
Triakidae	*Galeorhinus galeus*	CS	Rare
Triakidae	*Mustelus asterias*	Ikica *et al*. (2021)	Rare**
Triakidae	*Mustelus mustelus*	CS/DCF-DCRF	Abundant*
Triakidae	*Mustelus punctulatus*	CS/DCF-DCRF	Abundant*
Carcharhinidae	*Carcharhinus plumbeus*	CS	Rare
Carcharhinidae	*Prionace glauca*	CS	Abundant
BATOIDS			
FAMILY	**SPECIES**	**SOURCE**	**FREQUENCY IN CATCHES (2017-2022)**
Rajidae	*Dipturus* cf. *batis*	Ikica *et al*. (2021)	Not present
Rajidae	*Dipturus oxyrinchus*	CS	Occasional
Rajidae	*Dipturus nidarosiensis*	Carbonara *et al*. (2019)	Not present
Rajidae	*Leucoraja circularis*	Ikica *et al*. (2021)	Not present
Rajidae	*Raja asterias*	CS/DCF-DCRF	Occasional
Rajidae	*Raja clavata*	CS/DCF-DCRF	Very abundant*
Rajidae	*Raja miraletus*	CS/DCF-DCRF	Abundant
Rajidae	*Raja montagui*	Serena and Barone (2008)	Not present
Rajidae	*Raja polystigma*	CS	Very rare
Rajidae	*Rostroraja alba*	CS	Not present
Dasyatidae	*Bathytoshia lata*	CS	Rare
Dasyatidae	*Dasyatis pastinaca*	CS/DCF-DCRF	Occasional
Dasyatidae	*Pteroplatytrygon violacea*	CS	Rare
Myliobatidae	*Aetomylaeus bovinus*	CS/DCF-DCRF	Occasional
Myliobatidae	*Myliobatis aquila*	CS/DCF-DCRF	Occasional
Mobulidae	*Mobula mobular*	CS	Not present***
Torpedinidae	*Tetronarce nobiliana*	Serena and Barone (2008)	Not present
Torpedinidae	*Torpedo marmorata*	CS/DCF-DCRF	Abundant
Torpedinidae	*Torpedo torpedo*	CS	Rare
CHIMAERAS			
FAMILY	**SPECIES**	**SOURCE**	**FREQUENCY IN CATCHES (2017-2022)**
Chimaeridae	*Chimaera monstrosa*	Serena and Barone (2008)	Not present

*The four species were classified into the higher categories of frequency estimation (occasional, abundant or very abundant) as explained in the results section.
**M. *asterias* was not directly observed, however, it is currently present in very low numbers when compared to the other two *Mustelus* species, according to local fishermen.
****M. mobular* has been reported as the single free swimming individual (Ćetković *et al*., 2022a), with no reported catches.

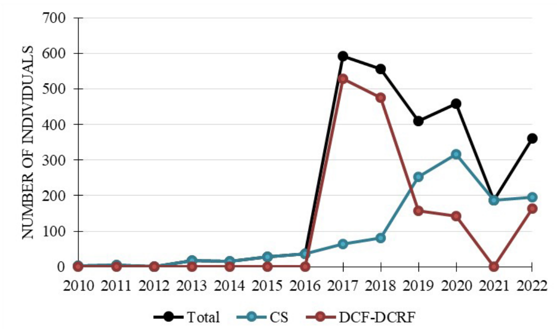

Fig. 2. The number of recorded individuals per year in the waters of Montenegro, including documented citizen science observations from 2010 onward (38 individuals for which the year is unknown or which date from the distant past are omitted) (*CS* – citizen science; *DCF-DCRF* – official monitoring of commercial fisheries).

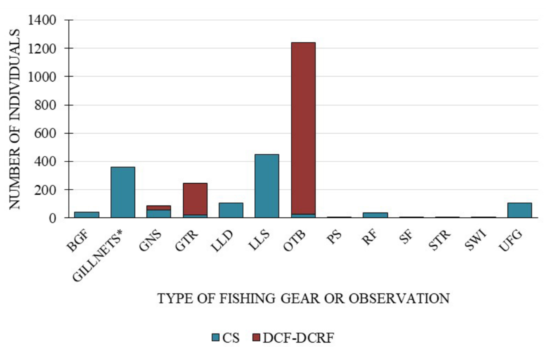

Fig. 3. The number of chondrichthyan individuals per fishing gear type or observation for the total of 2691 individuals from the waters of Montenegro. Abbreviations: *BGF* – big game fishing; *GNS* – set gillnets; *GTR* – trammel nets; *LLD* – drifting longlines; *LLS* – bottom longlines; *PS* – purse seine; *RF* – recreational fishing; *SF* – spearfishing; *STR* – stranding; *SWI* – swimming individuals; *UFG* – unknown fishing gear). *Gillnets represent lumped GNS and GTR observations from citizen science, if the set net type was not specified.

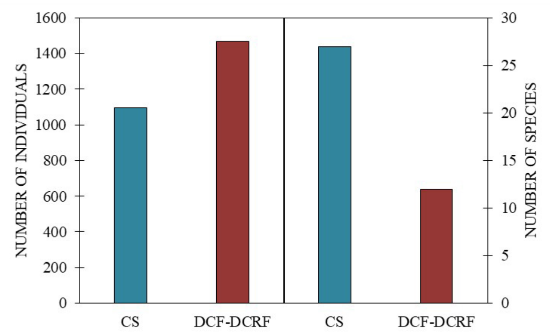

Fig. 4. The total number of recorded individuals (left) and the total number of recorded species (right) per each data source, as observed in the waters of Montenegro between 2017 and 2022.

By comparing of the two data sources by number of species and individuals recorded, it was found that citizen science has significantly contributed, providing more than double the recorded species sampled by DCF-DCRF for the same period (Fig. 4). Moreover, all the species observed in the DCF-DCRF sampling were also found in the citizen science sampling. By contrast, the DCF-DCRF sampling provided records of more individuals, mostly due to the presence of *S. canicula* as noted before. If we consider the distribution of records per source and species, DCF-DCRF significantly contributed with records of small and medium-size demersal species, usually considered locally abundant (Fig. 5). The values in Figure 5 are expressed as percentages in order to ensure a standardized representation, as the raw numbers varied significantly among species.

Considering the regional IUCN Red List assessments, 57% of the species recorded in this research are classified as threatened (in the categories Vulnerable, Endangered and Critically Endangered; Fig. 6). Accord-

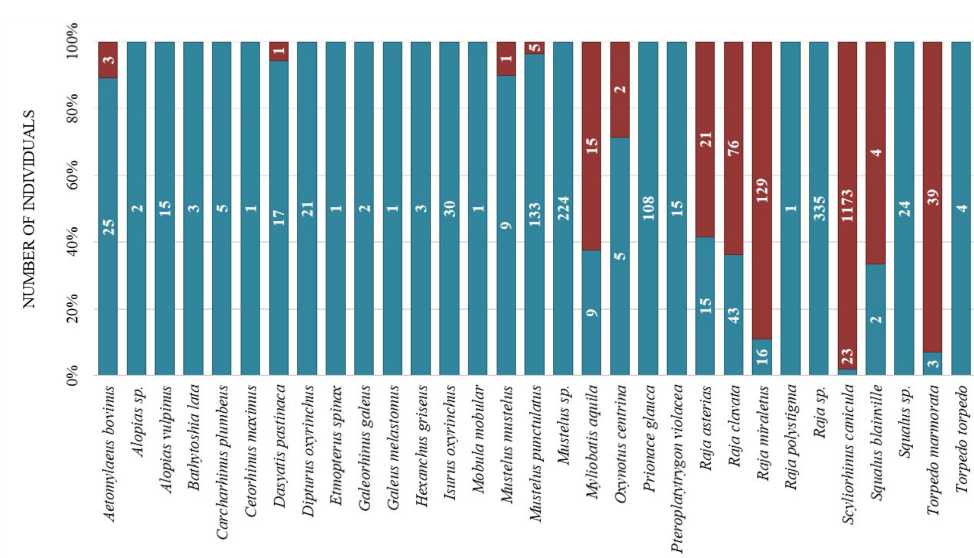

Fig. 5. The ratio between DCF-DCRF (red) and citizen science (blue) records in the total number of individuals per species in Montenegro, for the period between 2017 and 2022. The numbers inside the bars represent the raw values.

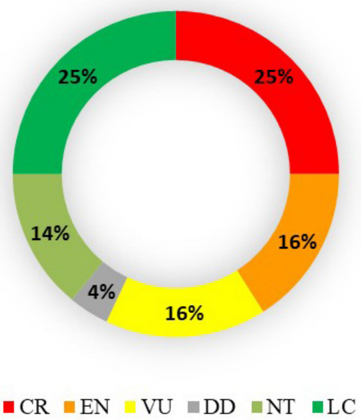

Fig. 6. Percentage of the IUCN categories for a total of 44 species confirmed as present in Montenegrin waters during this research (if the Mediterranean status was not assessed, the global status was considered instead)

ing to the here-defined criteria for estimating species frequency in local catches, 39% (17 species) were not present in local catches. Only 16% (7 species) were constantly present in the catches, while the rest were either rarely or occasionally observed (Fig. 7). For the part of the citizen science records belonging to the genus *Raja*, *Squalus* and *Mustelus*, it was not possible to determine the species, due to the minor differences between the congenerics, and as such these were kept at the genus level. However, the observed characteristics during the photo analysis strongly indicated that they belong to the most common species in the area, which were also recorded by both DCF-DCRF and citizen science, with multiple confirmed records. These characteristics included the tail banding pattern observed in individuals from the genus *Raja* (the distinctive characteristic of *Raja clavata*), as well as the absence of white marks in individuals belonging to the genus *Squalus* and *Mustelus*, which eliminates the possibility that they belonged to *Squalus acanthias* or, in the case of another genus,

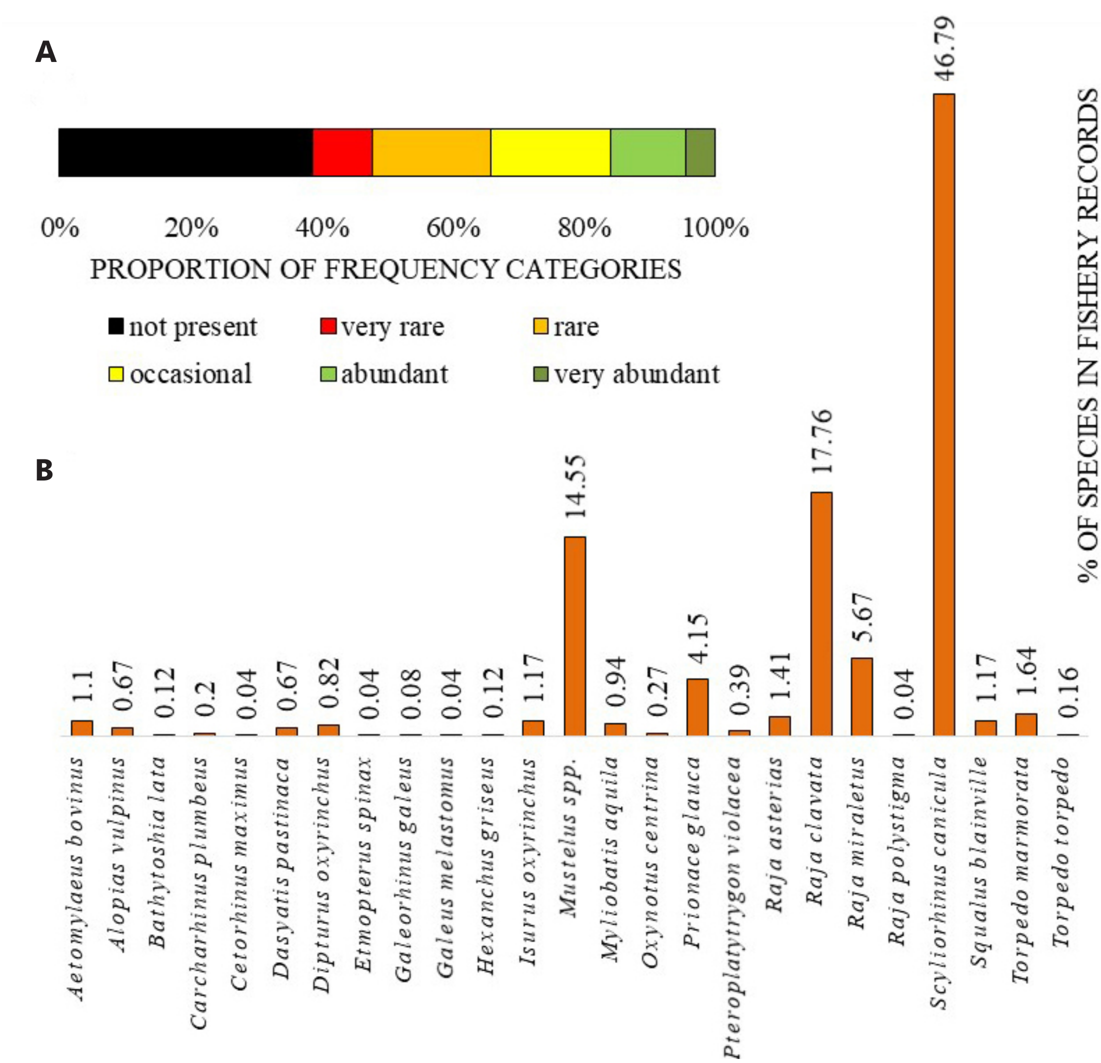

Fig. 7. Proportion of frequency categories for the 44 species listed in Table 2 (**A**) and the percentage of each species in the total number of records originating from Montenegrin fisheries, between 2017 and 2022 (**B**).

Mustelus asterias. Hence, it was assumed that they belong to the most common species within each genus, which resulted in a higher classification of the four species when estimating their frequency in Montenegrin catches (see Table 2).

DISCUSSION

The results presented here document the occurrence of 44 chondrichthyan species in Montenegrin waters, accounting for 73.34% of the total number of chondrichthyan species documented in the Adriatic Sea according to Soldo and Lipej (2022). Considering that the Montenegrin part of the Adriatic Sea represents less than 5% of its total surface area, the presence of almost three-quarters of the total Adriatic chondrichthyan species is significant. However, it is unfortunate that 17 historically present species were not recently observed in Montenegrin catches, which at least in some cases aligns with the long-term decline observed in chondrichthyan populations in the Adriatic Sea, as reported by earlier studies (Jukić-Peladić *et al*., 2001; Ferretti *et al*., 2013; Barausse *et al*., 2014; Follesa *et al*., 2019). Certain deep-sea species, considered regionally abundant, require additional data as most fishing activity in Montenegro occurs in coastal areas and down to a depth of 100 m (Joksimović *et al*., 2019). Therefore, their absence or low abundance (e.g., *G. melastomus*) in Montenegrin catches is likely associated with this fact. On the other hand, it remains unknown for others whether they have disappeared from the area, or if their abundance is so low that they could hardly be detected during this research. The results presented here indicate that only 16% of recorded species are consistently present in Montenegrin catches (i.e. in the categories abundant or very abundant; Fig. 7), while two-thirds (66%) are either rare or not present. Overfishing and the intensive exploitation have led to a drastic decline in chondrichthyan catch rates in the Adriatic Sea, with a 94% reduction observed by Ferretti *et al*. (2013). While some species have shown potential signs of recovery at the Mediterranean level due to the establishment of protection measures (e.g., *I. oxyrinchus*; Serena *et al*., 2020), it is important to note that the effective recovery of highly depleted populations, particularly of large sharks, may take decades (Frisch and Rizzari, 2019; Erguden *et al*., 2022), and such increase patterns should be carefully monitored.

As noted before, it is important to acknowledge that the estimation of species frequency in Montenegrin catches, based on the data used in this study, cannot reflect the relative or true abundance of species in the ecosystem. The presence index used here tends to show how often a species can be encountered in local fishery catches. It has been shown that Montenegro has experienced a significant worsening of taxonomic data resolution for chondrichthyans over recent decades (Cashion *et al*., 2019), as such, this information can contribute to a better understanding of the impact of local fishing practices on this group.

Furthermore, present taxonomic issues, such as the case of *D. batis*, might pose challenges in terms of assessment. This species presence is uncertain and it is currently considered as a species complex (Barone *et al*., 2022), whose presence and status in the Mediterranean need to be thoroughly clarified (Serena *et al*., 2020 and discussion therein). However, recent studies conducted in the outer European seas, outside the Mediterranean, consider it to be a valid species (e.g., Bache-Jeffreys *et al*., 2021; Delaval *et al*., 2022). Therefore, the Mediterranean records from the past should be carefully analyzed, and in this study, the records from Ikica *et al*. (2021) were listed as *D.* cf. *batis*.

Additionally, Serena and Barone (2008) originally contained records of the genus *Centrophorus* assigned to *Centrophorus granulosus*, which has been a subject of a debate for a long time (Serena *et al*., 2020). Recent research has revealed that the Mediterranean records of this genus belong to a single species, and they should be considered *C. uyato* (Bellodi *et al*., 2022; White *et al*., 2022). Hence, this study assigned the records published in Serena and Barone (2008) to *C. uyato*. These taxonomic uncertainties highlight the need for careful analysis and clarification of species taxonomies, in order to ensure the accurate assessment and understanding of their presence and distribution.

The case of Montenegro highlights the importance of integrating results from different methods rather than relying on a single source, in order to effectively monitor chondrichthyan diversity at the local level. The Montenegrin DCF-DCRF currently does not sample drifting longlines, which means that important data on the bycatch of this fishing process can only be obtained through citizen science. The biological data collected through the Montenegrin DCF-DCRF are highly valuable for abundant species, because of the greater numbers of recorded individuals (e.g., *S. canicula*). On the other hand, species that are rare or highly depleted in the region are often missed during field samplings due to their comparatively low abundance. This creates a significant opportunity for citizen science, as this approach can greatly contribute to collecting records of rare and unusual species that might otherwise go unnoticed (see Fig. 4).

Furthermore, the results presented here indicate that citizen science may be the only source of information for certain species. This data collection method can be of particular help in developing regions (e.g., Blanco-Parra *et al*., 2022; Wambiji *et al*., 2022) where chondrichthyans are often overlooked, as is the case in Montenegro. The Mediterranean-related research by Bargnesi *et al*. (2020) documents an increasing trend in the use of citizen science in studies of chondrichthyans, although the number of published papers based on this methodology remains low. Recent studies by Boldrocchi and Storai (2021) and Jambura *et al*. (2021) have demonstrated that citizen science not only supports overall chondrichthyan research but might also provide certain insights into species-specific ecology at a regional scale. In a recent study performed in Turkish waters, Kabasakal and Bilecenoğlu (2020) provided data on rare or large sharks from that region, based exclusively on data extracted from the internet and social media. Furthermore, the utility of social media films as a non-invasive and non-extractive sampling methodology for monitoring the bycatch of elasmobranch species in commercial fishing was further demonstrated in a case study performed in the northern Aegean Sea, if the obtained data is analyzed properly (Kabasakal, 2023). Although citizen science has many advantages including, for instance, being a cost-effective method, its data should be carefully considered and checked before usage, especially in a more complex research studies.

Montenegro has adopted a permanent fishing ban related to 24 species of sharks and rays, in accordance with the recommendations of the GFCM (Official Gazette of Montenegro No. 56/2009; No. 40/2011; No. 47/2015). The requirement to report incidental catches of these species and enter them into the relevant logbooks, as well as the prohibition on finning, are also currently in force. However, certain protected species have not been recorded in Montenegrin waters or even in the Adriatic Sea, while some locally present and regionally threatened species are not covered by the current protection measure. Thus, such species receive no national-level protection, even if Montenegrin waters might be important from a specific aspect, for instance, that of reproduction (e.g., *C. plumbeus*; Ćetković *et al*., 2022b). Recent global effort to map crucial habitats for chondrichthyans, the Important Shark and Ray Areas project (ISRAs; Hyde *et al*., 2022), has contributed to the identification of such areas in the Adriatic Sea, two of which are partially located within Montenegrin waters (Jabado *et al*., 2023). Fig. 6 shows that 57% of the chondrichthyans recorded in Montenegro are assessed as threatened, and the value rises to 61% if data-deficient species are included. National legislation should be more rigorous than regional measures and be adjusted to local requirements, in accordance with the spatial distribution of protected species. By establishing a comprehensive and accurate checklist serving as a foundation, the authorities can realize the presence and conservation status of the species distributed in Montenegrin waters, so as to implement specifically targeted conservation measures. Furthermore, it is essential to strengthen cooperation and overcome inconsistencies in species protection between the various countries in the region. Migratory sharks and rays, in particular, require collaborative conservation efforts that transcend national boundaries. The collaboration of the Adriatic countries through regional initiatives, such as MEDLEM or the MECO project, might provide an effective way to better understand the ecology of these species in the region. By aligning conservation strategies and fostering cooperation between neighboring countries, conservation efforts can be significantly enhanced, leading to the more effective protection of these vulnerable species.

CONCLUSIONS

The monitoring of chondrichthyans in Montenegro highlights the complementary nature of the two data collecting methods and emphasizes the importance of their combined usage in studying species diversity and distribution. The application of citizen science alongside standard fishing monitoring, can significantly contribute to the management of species through documenting the presence of rare species and spreading knowledge among fishermen. However, combining the use of fishery-dependent and citizen science data will require more complex studies that are able to harmonize these different data sources and sampling strategies. In the end, the case of Montenegro showcases that the creation of a national checklist can provide data that helps to identify the shortcomings in national protection measures, and thus contributes to the regional protection of chondrichthyans.

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