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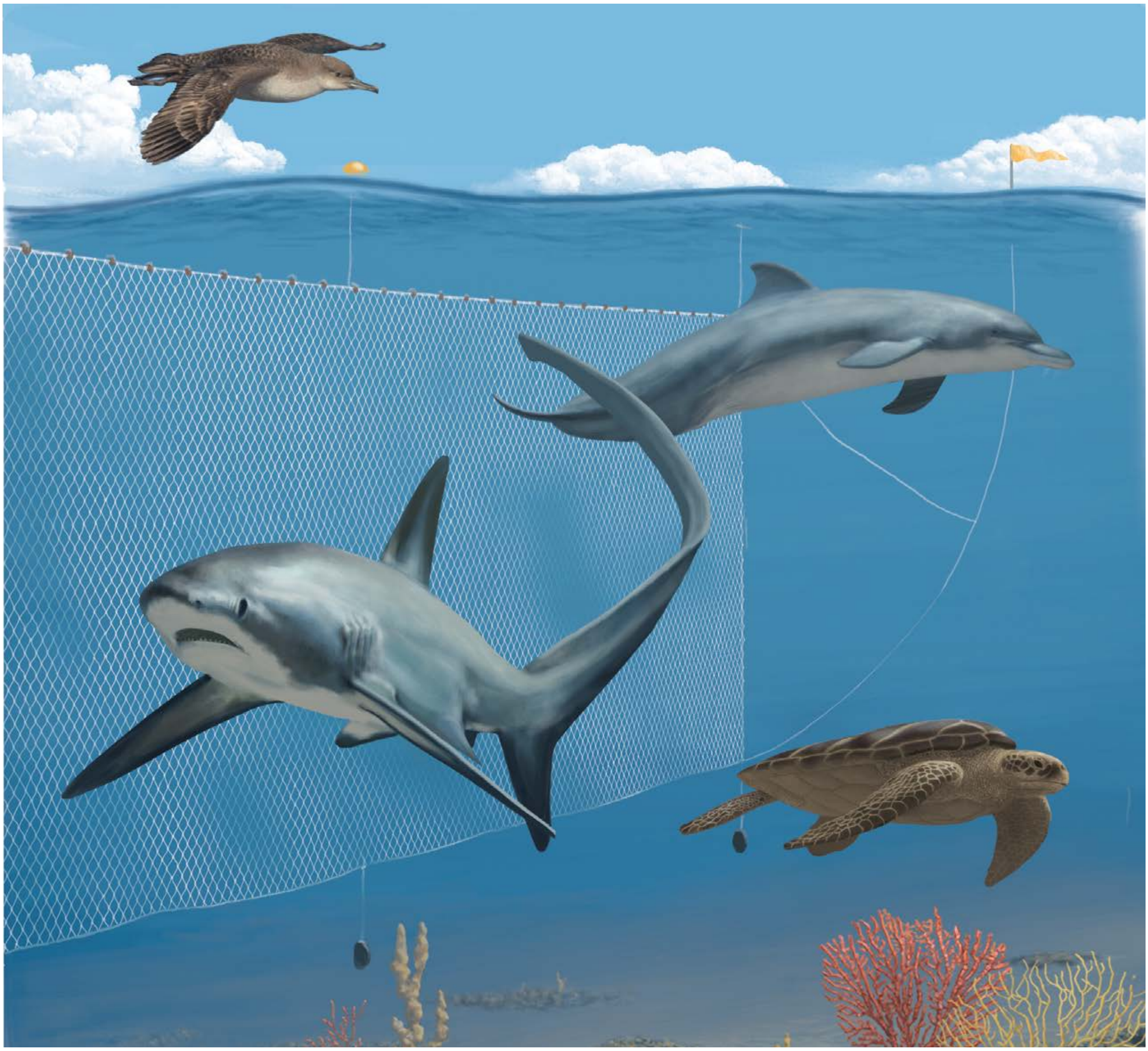
INCIDENTAL CATCH OF VULNERABLE SPECIES IN MEDITERRANEAN AND BLACK SEA FISHERIES A REVIEW



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GENERAL FISHERIES COMMISSION FOR THE MEDITERRANEAN

STUDIES AND REVIEWS 101

INCIDENTAL CATCH OF VULNERABLE SPECIES IN MEDITERRANEAN AND BLACK SEA FISHERIES
A REVIEW

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Preparation of this document

This publication was prepared in the context of the joint project "Understanding Mediterranean multi-taxa bycatch of vulnerable species and testing mitigation – a collaborative approach" (the MedBycatch project), funded by the MAVA Foundation.

The different chapters were commissioned to international experts – namely Wolf Isbert, Verónica Cortés, Jacob González-Solís (Seabirds), Alessandro Lucchetti (Sea turtles), Fabrizio Serena (Elasmobranchs), Fulvio Garibaldi (Marine mammals), Giovanni Chimienti, Gianfranco D'Onghia and Francesco Mastrototaro (Macrobenthic invertebrates) – who compiled baseline information and performed the analyses, highlighting interactions with fishing activities and vulnerable species, major bias and knowledge gaps, and proposing approaches to address challenges in data collection.

The project partners – namely the General Fisheries Commission for the Mediterranean (GFCM), the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS), the Specially Protected Areas Regional Activity Centre (SPA/RAC) of the United Nations Environment Programme/Mediterranean Action Plan (UN Environment/MAP), the International Union for Conservation of Nature – Centre for Mediterranean Cooperation (IUCN-Med), BirdLife Europe and Central Asia (BL ECA) and the Mediterranean Association to Save the Sea Turtles (MEDASSET) – arranged the peer-review process through their own pools of taxon-specific experts, alongside the members of the Scientific Committee of the MedBycatch project.

Abstract

This publication offers an overview of historical and current trends in the bycatch of five important groups of vulnerable species in the Mediterranean and the Black Sea: seabirds, sea turtles, elasmobranchs, marine mammals and macrobenthic invertebrates. Interactions between these groups and fisheries are known to occur in the context of nearly all commonly used types of fishing gear and can result in injury or death to the animals. Each chapter in this review focuses on one of the five groups of vulnerable species, describing and presenting data from surveys and studies conducted over recent decades. The chapters are further subdivided according to fishing gear and GFCM subregion (western, central and eastern Mediterranean, the Adriatic Sea and the Black Sea).

The incidental catch records included in this review are derived from a variety of approaches. Surveys completed by onboard observers, while demanding more time and resources, represent the most comprehensive and accurate of these methods. Less reliable data come from non-systematic, opportunistic data collection, such as questionnaire surveys answered by fishers. Though many geographic areas and vessel groups remain underrepresented in the available data, coverage has generally increased in recent years and insight continues to emerge on the key dynamics governing the bycatch of vulnerable species in the Mediterranean and Black Sea.

Seabird bycatch has mainly been recorded from the western Mediterranean and in longline fisheries. Bottom trawlers, on the other hand, have the greatest impact on sea turtles, especially in the northern Adriatic Sea, Tunisia, Egypt and Turkey. The vessel groups most implicated in elasmobranch bycatch vary by subregion, with longliners accounting for nearly 80 percent of incidental captures in the central Mediterranean, for example, while pelagic trawlers are responsible for an even greater majority of incidental captures in the neighbouring Adriatic Sea. Historically, marine mammals were often caught in large-mesh driftnets, but the incidental capture of these species has declined since bans on driftnets were put in place in the late 1990s. Unsurprisingly, macrobenthic invertebrates, including soft and hard corals, sponges, echinoderms and molluscs, are most affected by bottom trawls, as they are dragged across the seafloor these species inhabit.

Vulnerable species are not the only ones to come out the worse for wear from their interactions with fishing activities. Fishers also risk economic losses resulting from damage done to their nets by entrapped individuals or from the depredatory behaviour of species that feed on bait meant to lure target species. Raising awareness amongst fishers and relevant stakeholders of the threats currently facing vulnerable populations across the Mediterranean and the Black Sea, as well as their importance to local ecosystems, will help to improve relations between fisheries and these species and to ease transitions toward safer practices. New technologies that can mitigate the bycatch of vulnerable species must continue to be tested and implemented in fisheries and standardized procedures for data collection should be established to better understand the many factors influencing bycatch in the region.

Contents

Tables, figures and plates

Tables

Figures

Plates

Preface

Bycatch – a term widely used to refer to the part of catch unintentionally captured during a fishing operation in addition to target species, and consisting of discards and incidental catches of vulnerable species – is considered an important threat to the profitability and sustainability of fisheries, as well as to the conservation of the marine environment and its ecosystems. Understanding bycatch and adopting effective measures to reduce it are essential steps towards minimizing the incidental catch of vulnerable species and, more generally, conserving the marine ecosystems, as well as ensuring a sustainable fishery sector.

For the Mediterranean and the Black Sea, two semi-enclosed seas highly susceptible to human-induced stressors, the absolute numbers of the incidental catch of vulnerable species (seabirds, sea turtles, elasmobranchs, marine mammals and macrobenthic invertebrates) are not (yet) available to fishery managers. Without adequate monitoring and reliable information on incidental catch rates, the actual level and type of interactions between fishing activities and these vulnerable groups are difficult to estimate. However, in general, quantifying incidental catch rates is particularly complicated given that these captures are not systematically logged or reported, and observer programmes do not cover the entirety of a fleet, being often patchy in location and time. The result is that little is known of the scope of the problem, despite its importance.

This review aims to develop a baseline and reference for the incidental catch of vulnerable species in Mediterranean and Black Sea fisheries, with a view to supporting the identification of priorities in terms of bycatch management and environment conservation. It compiles, into one single document, the available data, including historical records on the incidental catch of vulnerable species, taken from existing literature, databases and other grey literature sources and collated in a standardized way, subdivided into GFCM vessel groups and subregions (namely, western, central and eastern Mediterranean, Adriatic Sea and Black Sea).

This work highlights that major knowledge gaps exist in most of the GFCM subregions and that available data are often flawed due to the fact that, until recently, no standardized protocol for data collection existed, thus affecting data reliability and preventing quantitative comparisons among studies, areas and temporal scales. Indeed, to date, data on the incidental catch of vulnerable species have been collected in an opportunistic way, gathered from studies covering only a small portion of the total fishing activity, resulting in important knowledge gaps for many types of fishing gear, countries and/or subregions. This analysis also brings to light the general difficulties in obtaining solid estimates on the incidental catch of vulnerable species, since the available information is subject to a number of shortcomings (lack of onboard observer programmes, problems with species identification, inadequate spatial and temporal coverage, etc.), which increase uncertainty.

In general, the incidental catch is not equal for seabirds, sea turtles, elasmobranchs, marine mammals and macrobenthic invertebrates, depending on the type of gear and area, among other factors. Seabirds are mainly bycaught in the western Mediterranean, mostly by small-scale longlines (both demersal and pelagic), in coastal zones close to important breeding sites, such as the Balearic Islands, considered a hotspot for breeding sites. For sea turtles, incidental catch estimates and associated mortality rates show great variability, not only between subregions and fishing gear, but also within the same area from one year to the next – mainly due to a lack of standardization in the frequency, temporal scale and type of data collected. As for elasmobranchs, their life cycle, associated with their low resilience to fishing pressure, are among the main reasons for the concerning observed decline of elasmobranch populations in most of the world's seas, including the Mediterranean and the Black Sea. In the region, fishing activities only sporadically target elasmobranchs, and the majority of the available data point to individuals caught as bycatch by several types of gear, sometimes in greater numbers/biomass than the target species. Sharks and rays are then subsequently either discarded at sea or retained and landed to be sold, including, regrettably, protected species. As a result of bycatch, many Mediterranean shark and ray species are locally disappearing from areas in which their presence has been historically commonly recorded. Marine mammals are incidentally caught mainly by the pelagic driftnets targeting large pelagic commercial species, such as tunas, though the related ban in the early 2000s has had positive and tangible effects, considerably reducing the incidental catch of both dolphins and whales. However, in the Black Sea, set nets deployed to catch turbot, incidentally catch the three Black Sea endemic cetacean subspecies, including the harbour porpoise (the only harbour species present in the GFCM area of application). Over the last ten years, most likely linked to the observed decline in the incidental catch of cetaceans, the number of related studies has considerably reduced, offset by research on depredation issues, which aims to quantify the importance of this other type of interaction between marine mammals and fisheries by assessing the extent of damage often caused to fishers and the related socio-economic impacts. Regarding macrobenthic invertebrates (which may form vulnerable marine ecosystems), bottom trawls represent the fishing practice with the highest impact although little is known about the bycatch of these species by set longlines and small-scale fisheries. This review confirms that, despite the scattered data available, the scale and dimension of the incidental catch of vulnerable species in the Mediterranean and the Black Sea is not negligible, especially for given species across some specific areas.

Monitoring incidental catch in fisheries as regularly as possible, through both direct observations and indirect methodologies, in line with standard protocols such as those developed by the GFCM, is essential in order to fuel management decisions and to possibly incorporate protection and/or mitigation measures in management plans and other binding instruments. Indeed, efficient monitoring and reporting of incidental catches at the regional level contributes to identifying sensitive areas, fishing gear, and seasons, as well as earmarking the level of vulnerability of the species against these factors, thus better enabling relevant stakeholders to take targeted action towards ensuring the sustainability of Mediterranean and Black Sea fisheries and preserving vulnerable populations, endemic species, as well as the ecosystems in which they live. In addition, the identification and testing of different types of mitigation measures, adapted according to the species, areas or gear (and, for the specific case of cetaceans, type of depredation), are key towards reducing interactions. Their suitability and effectiveness should be evaluated against baseline information and over time, and replicated as appropriate.

Available data can already be taken into account for conservation purposes, and the preliminary insights on the level of bycatch for some vulnerable species call for the application of precautionary approach principles. For example, the case of elasmobranchs requires specific attention, considering the current indications of the state of many shark and ray species (i.e. endangered or critically endangered), calling for an improvement and/or extension of existing management and conservation approaches (such as fishing bans in mating areas and the systematic release of live specimens), as well as the potential protection of additional species. In parallel, the launch of awareness campaigns among the fishing community should be envisaged in addition to the enforcement of monitoring, control and surveillance measures including against illegal fishing.

It is hoped that this baseline work can serve as further incentive to take bold action to reduce the incidental catch of vulnerable species and thus ensure more sustainable fisheries and healthier seas. A number of efforts are already being deployed to specifically address the issue of incidental catch –through ad hoc projects supporting data collection and bycatch mitigation and the adoption of decisions, based on existing evidence and/or the precautionary approach – but more needs to be done, in terms of data availability and reliability, to facilitate the implementation of conservation measures at the local, national, subregional and regional level.

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Abbreviations and acronyms

ACCOBAMS	Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and contiguous Atlantic area
AIS	automatic information system
BPUE	bycatch per unit effort
BRDs	bycatch reduction devices
CBD	Convention on Biological Diversity
CCL	curved carapace length
CPUE	catch per unit effort
CITES	Convention on International Trade in Endangered Species of Fauna and Flora
DCRF	Data Collection Reference Framework (GFCM)
DNA	deoxyribonucleic acid
FAD	fish aggregating device
FAO	Food and Agriculture Organization of the United Nations
GEN	gillnets and entangling nets, not specified
GFCM	General Fisheries Commission for the Mediterranean
GND	driftnet
GNS	set gillnet
GPS	global positioning system
GSA	geographical subarea (GFCM)
GTR	trammel net
IBAs	important bird areas
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
IEO	Spanish Institute of Oceanography
IUCN	International Union for Conservation of Nature
IUCN-MED	IUCN Centre for Mediterranean Cooperation
LL	longline
LLD	drifting longline
LLS	set longline
MAP	Mediterranean Action Plan
MEDASSET	Mediterranean Association to Save the Sea Turtles
MEDLEM	Mediterranean Large Elasmobranchs Monitoring
MEDITS	international bottom trawl survey in the Mediterranean
MCS	monitoring, control and surveillance
OTB	bottom otter trawl
PS	purse seine
PTM	midwater pair trawl
REM	remote electronic monitoring
ROV	remotely operated vehicle
SPA/BD Protocol	Barcelona Convention Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean
SPA/RAC	Specially Protected Areas Regional Activity Centre
SSF	small-scale fisheries
TL	total length
TM	midwater trawl
UN Environment	United Nations Environment Programme
UNEP-MAP	UN Environment/Mediterranean Action Plan
VME	vulnerable marine ecosystem
VMS	vessel monitoring system

Introduction

Data collection on the incidental catch of vulnerable species (elasmobranchs, sea turtles, marine mammals, seabirds and macrobenthic invertebrates) in the Mediterranean and the Black Sea has traditionally been carried out using varying protocols at different geographic scales. The absence of a systematic reporting of the incidental catch of vulnerable species has always made data comparison at a regional level difficult, despite national and international obligations in this regard. In fact, observations and reports tend to lack standardization and continuity and important knowledge gaps exist. Furthermore, efficient mitigation techniques for the multi-taxa bycatch of vulnerable species, as well for different fishing operations and types of gear, are yet to be developed in the region.

The joint project, "Understanding Mediterranean multi-taxa bycatch of vulnerable species and testing mitigation: a collaborative approach" (the MedBycatch project) was established with the aim to support Mediterranean countries in developing a common standardized data collection methodology and in testing appropriate mitigation solutions to be potentially replicated at the regional level, with a view to providing elements for the formulation of national/regional strategies towards the reduction of the incidental catch of vulnerable species and the sustainability of fisheries.

Among the expected outputs of the project was the creation of a knowledge base and the production of baseline information on vulnerable marine species affected by fishing activities. This regional review, reporting all published information on the incidental catch of vulnerable species in the Mediterranean and the Black Sea, represents one of the outputs of the project.

The MedBycatch project is the fruit of a partnership between the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS), the General Fisheries Commission for the Mediterranean (GFCM) of the Food and Agriculture Organization of the United Nations (FAO), the Specially Protected Areas Regional Activity Centre (SPA/RAC) of the United Nations Environment Programme/Mediterranean Action Plan (UN Environment/MAP), the International Union for Conservation of Nature – Centre for Mediterranean Cooperation (IUCN-Med), BirdLife Europe and Central Asia (BL ECA) and the Mediterranean Association to Save the Sea Turtles (MEDASSET). Funded by the MAVA Foundation, it capitalizes on the complementarities among the partners' fields of work and mandates with a view to promoting synergies as well as sharing resources and expertise.

The implementation of the MedBycatch project involves field observation programmes (on board, at landing sites), interviews and self-sampling operations, across different types of fishing gear (i.e. bottom trawls, gillnets and demersal longlines), as well as training, awareness raising, identification and testing of mitigation techniques. Although originally implemented in three Mediterranean countries (Morocco, Tunisia and Turkey), the project develops tools and builds knowledge applicable to the entire Mediterranean and Black Sea area.

The main project outputs include:

- standardized regional protocols for multi-taxa data collection, inclusive of methodological annexes for observations on board and at landing sites, as well as self-sampling and questionnaires;
- capacity-building and training activities, including for teams of national onboard observers and for fishers on self-sampling methodologies;

- data analysis on the impacts of various fleet segments on the incidental catch of vulnerable species and on the spatial and temporal distribution of incidental catch per select fleet segments;
- identification and quantitative assessment of fishing practices and fisheries leading to incidental catch (e.g. fishing areas, seasonality, vessel carrying capacity, market, etc.);
- awareness-raising initiatives on the impacts of the incidental catch of vulnerable species; and
- testing of mitigation measures, including the implementation and monitoring of possible methods and tools in select fisheries and countries.

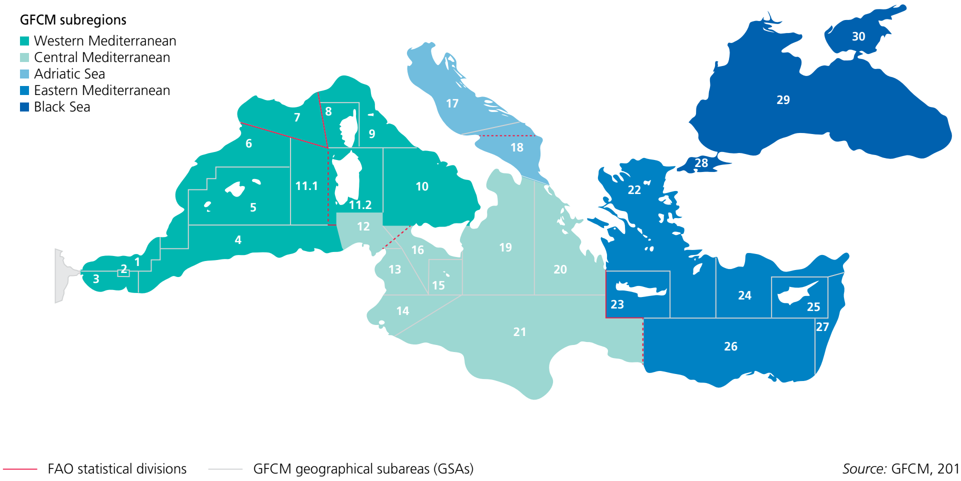
A steering committee oversees the proper and effective coordination and implementation of the project and a scientific committee provides technical feedback and advice. The scientific committee is composed of project partners, national focal points, as well as international taxon-specific experts and one fishery expert.

Methodology

This publication compiles recent data (from 2008) on the incidental catch of vulnerable species – seabirds, sea turtles, elasmobranchs, marine mammals and macrobenthic invertebrates – in the Mediterranean and the Black Sea (FAO major fishing area 37 and GFCM area of application) available in literature and scientific works, national and regional statistics, databases and other relevant sources (including grey literature and technical reports, master theses and personal communications), as well as data derived from opportunistic and irregular surveys (such as non-systematic observations on board and partly interview-based studies and self-reporting questionnaires). In each chapter, the information is grouped by GFCM subregion (Figure 1) and by vessel group (i.e. bottom trawlers, pelagic trawlers, small-scale vessels, purse seiners, tuna seiners, dredgers and longliners) as defined by the GFCM Data Collection Reference Framework. This approach enabled a comparative analysis of the different vessel groups across the western, central and eastern Mediterranean, the Adriatic Sea and the Black Sea.

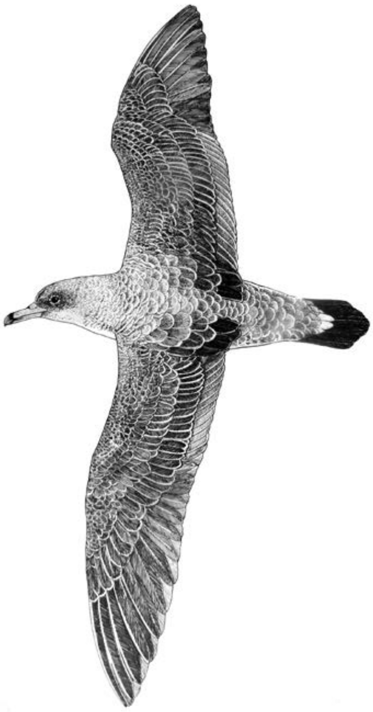
Within the chapters, as appropriate and relevant, the information is presented at the scale of smaller aggregation levels, i.e. by geographical subareas, commonly used by the GFCM as the minimal management unit. Each chapter provides a general description of the relevant group of vulnerable species, with a focus on the species inhabiting the Mediterranean and the Black Sea, followed by an overview of historical records (data published before 2008) of interactions of vulnerable species with fisheries, with tables summarizing, by vessel group, all the results from the literature cited. The chapter sections cover all vessel groups and subregions, even when no information is available (in which case "data not available" is indicated) so as to clearly show knowledge gaps. Finally, an outlook provides take-home messages and conclusions, highlighting the most impactful fishing gear for each group of vulnerable species, as well as the main challenges for a systematic collection of reliable data and future scenarios.

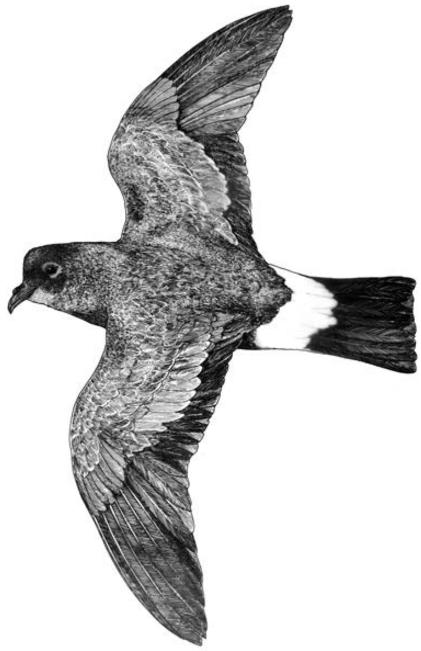
FIGURE 1
GFCM area of application, subregions and geographical subareas



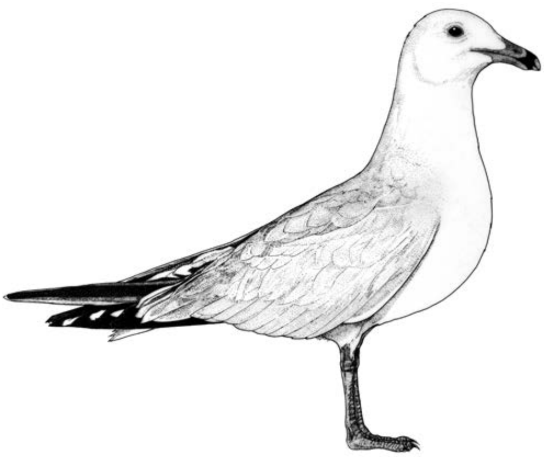
Source: GFCM, 2018.

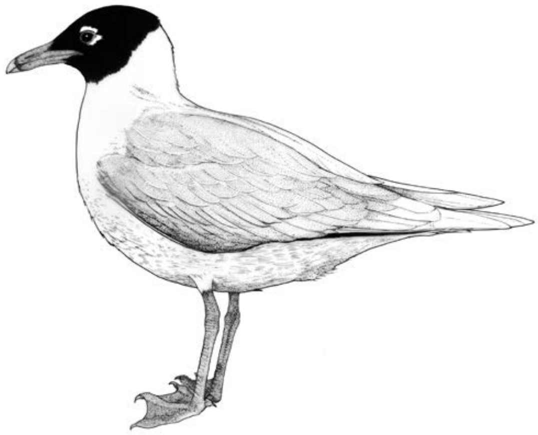
01. Northern Alboran Sea	07. Gulf of Lion	13. Gulf of Hammamet	19. Western Ionian Sea	25. Cyprus
02. Alboran island	08. Corsica	14. Gulf of Gabès	20. Eastern Ionian Sea	26. South Levant
03. Southern Alboran Sea	09. Ligurian Sea and northern Tyrrhenian Sea	15. Malta	21. Southern Ionian Sea	27. Eastern Levant Sea
04. Algeria	10. South and central Tyrrhenian Sea	16. South of Sicily	22. Aegean Sea	28. Marmara Sea
05. Balearic islands	11.1. Sardinia (west) 11.2. Sardinia (east)	17. Northern Adriatic Sea	23. Crete	29. Black Sea
06. Northern Spain	12. Northern Tunisia	18. Southern Adriatic Sea	24. North Levant Sea	30. Azov Sea





SEABIRDS





Scopoli's shearwaters (*Calonectris diomedea*) flying close to the sea surface

1. Seabirds

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Executive summary

The effects of fisheries on seabirds can be manifold: (1) overexploitation by fisheries can decrease the availability of some prey for seabirds; (2) abundant fishery discards provide a very predictable food resource for scavenging seabirds that would otherwise be unattainable; and (3) seabirds can get caught in some types of fishing gear and possibly drown while trying to snatch at bait on longlines or they can collide with warp cables during shooting and hauling (trawls) or become entangled in floating or set nets. This review focuses on the latter aspect. The incidental catch records of seabirds presented here are derived from a variety of different approaches, including monitoring programmes with onboard observers, non-systematic, opportunistic data collection, such as questionnaire surveys answered by fishers, tagging/ringing recovery programmes, personal comments from scientists, self-reporting by fishers, beach surveys or recoveries from rescue

centres. Overall, the data available on seabird bycatch in Mediterranean and Black Sea fisheries are scarce and unequally distributed, with data mainly gathered in the western Mediterranean. No records could be found for the Black Sea or from North African Mediterranean countries. About 68 percent of records originated from the western Mediterranean Sea, with only limited data available from the other GFCM subregions: eastern Mediterranean (16.7 percent), central Mediterranean (9.7 percent) and Adriatic Sea (6.5 percent). Moreover, the records from the western Mediterranean came mainly from two countries: Italy (6.9 percent), and especially Spain (63.3 percent), where the only known study involving regular data collection of seabird bycatch over a long time period (2000–to date) is conducted. Considering the overall impact of different vessel groups/fishing gear, no records of seabird bycatch were found for pelagic trawls (midwater pair trawls), tuna seiners or dredgers. In contrast, about 50 percent of the available literature and records in the Mediterranean on seabird bycatch refer to longline fisheries, followed by set nets (16.7 percent) and bottom trawls (14 percent). This dynamic is consistent with data available from other regions of the world, indicating that research effort is focused primarily on the impact of longlines and set nets. No direct link could be found between the overall fishing capacity of single countries or of GFCM subregions and their seabird bycatch. Small-scale fisheries are active close to the coasts, where breeding sites and rafting areas of several seabird species are located. Small-scale fisheries use relatively small boats, from 6 to 15 metres, so many of them measure below the length at which positioning systems are mandatory. Urgency should therefore be given to improving the methods for recording fishing effort and incidental catch, particularly in small-scale fisheries, and to understanding more precisely the factors that influence interactions between seabirds and fisheries. New technologies for tracking seabirds (global positioning system (GPS), radar detectors, portable cameras) and fishing vessels (vessel monitoring system (VMS) and automatic identification system (AIS), onboard cameras) can also provide crucial data in this regard. This knowledge is critical for developing and implementing appropriate incidental catch mitigation measures. For a seabird bycatch mitigation strategy to be effective in the long term, it should be, among other factors, practical, easy to implement and manage, safe, and cost-effective for the fishers, while also being in their interest to pursue. In particular, these considerations apply to small-scale fisheries, where proper mitigation measures can not only reduce seabird bycatch, but also help to avoid bait loss and interruptions of settings when seabirds are released, and can therefore have potential economic benefits. Finally, the achievement of these objectives can only be guaranteed through the assistance of fishers, scientists, conservationists and policy makers.

1.1 Description of the group

1.1.1 Seabirds and fisheries

Seabirds are long-lived species with late maturity and low fecundity, and therefore any impact on their adult survival rates could have severe negative consequences for the viability of their populations (Brothers, Cooper and Løkkeborg, 1999; Furness, 2003; FAO, 2016; BirdLife International, 2017a). As described above, the effects of fisheries on seabirds can be manifold:

- overexploitation by fisheries can decrease the availability of some prey for seabirds, which can result in lower survival and reproductive success in some seabird species (Crawford, 2004; Cury *et al.*, 2011; Grémillet *et al.*, 2018; Guillemette *et al.*, 2018);
- abundant fishery discards provide a very predictable food resource, in space and time, for scavenging seabirds, which would otherwise be unattainable (Furness, 2003; Arcos, Louzao and Oro, 2008), potentially creating a dependency in the birds; and

– seabirds can get caught in some types of fishing gear and possibly drown while trying to snatch at bait on longlines, or collide with warp cables during shooting and hauling (trawls), or become entangled in floating or set nets (gillnets and entangling nets; FAO, 2018a), from now on referred to as "set nets" (Anderson *et al.*, 2011; Bicknell *et al.*, 2013; Žydelis, Small and French, 2013).

Although these effects from fisheries have uneven impacts on seabirds, they are interrelated and interact in complex and unexpected ways, potentially jeopardizing seabird populations, especially at a local scale.

Several studies carried out in the northwestern Mediterranean have shown that fisheries discards, such as those from demersal trawlers and purse-seiners, can create a strong dependency in some seabird species (Oro and Ruiz, 1997; Arcos, Oro and Sol, 2001; Arcos and Oro, 2002a, 2002b). Discards have changed the diet, distribution and foraging behaviour (Oro *et al.*, 1997; Arcos, Oro and Sol, 2001; Navarro *et al.*, 2009; Cama *et al.*, 2013; Bécares *et al.*, 2015), as well as the demographic parameters, of some Mediterranean seabirds (Louzao *et al.*, 2006; Genovart *et al.*, 2016), particularly large gulls and shearwaters. For instance, it is estimated that the availability of discards influences the breeding performance of the Balearic shearwater (*Puffinus mauretanicus*) and that discards can represent up to 40 percent of its diet during the breeding season (Arcos and Oro, 2002a; Louzao *et al.*, 2006). The predictability and abundance of trawling discards are the main factors in the population increase in yellow-legged gulls (*Larus michahellis*) in the western Mediterranean; a strong population increase of a generalist species, such as the yellow-legged gull can have associated negative effects on other smaller seabird species in the same area (i.e. predate on them or their eggs and chicks) and can alter local ecosystem structure and functioning (Louzao *et al.*, 2006; Real *et al.*, 2017).

Seabirds' potential dependency on discards may also have negative long-term effects as the induced changes in the foraging strategies of several species may increase the risk of incidental catch in fishing gear (Furness, 2003; Anderson *et al.*, 2011; Bicknell *et al.*, 2013), greater intake of pollutants (Arcos *et al.*, 2002) and low-quality food (Grémillet *et al.*, 2008). For instance, in the western Mediterranean, Scopoli's shearwaters (*Calonectris diomedea*) were observed to adapt to the fishing schedules of different fleets and to their relative abundance (Bartumeus *et al.*, 2010). On days without trawling discards, birds seek alternative resources and show stronger presence around longliners, increasing their risk of bycatch on hooks (Laneri *et al.*, 2010; Báez *et al.*, 2014; Soriano-Redondo *et al.*, 2016). In the long term, the elimination of the discard practice could reduce the presence of seabirds around fishing vessels, which may also reduce the risk of fishery-induced mortality (Bicknell *et al.*, 2013). Direct interactions between seabirds and fishing gear can result in incidental lethal captures, while the fate of seabirds released alive is often unknown (Pott and Wiedenfeld, 2017). However, landing fish discards may cause seabirds to seek food elsewhere and therefore considerably increase the bycatch of seabirds in bait fisheries, such as longliners, or increase predation rates on other seabirds (Votier *et al.*, 2004). These potential knock-on effects highlight the need to urgently implement mitigation measures and monitor seabird communities, especially in European countries where the European Union landing obligation[1] (discard ban) is applied (Soriano-Redondo *et al.*, 2016).

1. Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC. Official Journal of the European 2013, L354, 22–61.

Presently, most of the information available on seabird bycatch is derived from geographical areas with highly industrialized fishery activities, such as longline fleets in the Southern Hemisphere and the North Pacific (Anderson *et al.*, 2011; Pott and Wiedenfeld, 2017), although a growing number of studies are emerging from the North Atlantic and the Baltic Sea. Seabird interactions with fishing gear have been recorded in longlines (for example, Gales, Brothers and Reid, 1998; Weimerskirch, Capdeville and Duhamel, 2000; Fangel *et al.*, 2015; Oliveira *et al.*, 2015), trawlers (for example, Sullivan, Reid and Bugoni, 2006; Croxall, 2008; Watkins, Petersen and Ryan, 2008), set nets (for example, Žydelis *et al.,* 2009; Oliveira *et al.*, 2015; Hanamseth *et al.*, 2018), purse seines (for example, Schlatter *et al.*, 2009; Suazo *et al.*, 2014; Oliveira *et al.*, 2015) and traps (Shester and Micheli, 2011; Oliveira *et al.*, 2015).

Global estimates of annual seabird mortality have been calculated for specific vessel groups, types of fishing gear and geographical areas. For instance, Anderson *et al.* (2011) estimated that bycatch mortality from longliners ranged from 160 000 to 320 000 seabirds per year. BirdLife International (2017a) judged that trawl and longline fisheries together could be responsible for the incidental catch of about 300 000 seabirds annually at a global level. Additionally, Žydelis, Small and French (2013) estimated that set nets may catch about 400 000 seabirds per year. Unfortunately, no global seabird bycatch estimates exist for other types of fishing gear. Indeed, the quantification and extent of seabird bycatch are difficult to determine, in part due to substantial spatial and temporal variations of these stochastic events, as well as the diversity of fishing strategies and gear types around the world.

In comparison to other geographical areas of the Northern Hemisphere, the Mediterranean and the Black Sea are characterized by a dearth of information on seabird bycatch (Cooper *et al.*, 2003; Anderson *et al.*, 2011; Žydelis, Small and French, 2013). This shortcoming is mainly due to the fishing fleet composition of the Mediterranean and the Black Sea, which is dominated by small-scale fisheries (about 80 percent of total fishing vessels) and to the lack of systematic onboard observer programmes on most of the fleets (Anderson *et al.*, 2011; Fric *et al.*, 2012; Tarzia *et al.*, 2017b; FAO, 2018b; Genovart *et al.*, 2018).

Although the number of studies and reports has increased slightly over the last decade, information is lacking for several types of fishing gear and their potential impacts within several GFCM subregions and geographical subareas. The main reason behind this knowledge gap is the under-reporting of small-scale fisheries, which are often difficult to monitor (BirdLife International, 2009; Anderson *et al.*, 2011; Pott and Wiedenfeld, 2017). For the Mediterranean and the Black Sea, risk assessments by the Working Group on Bycatch of Protected Species of the International Council for the Exploration of the Sea (ICES, 2013b) for set nets and longlines (both demersal and pelagic) suggested high (longlines) to very high (nets) risks for diving seabirds (i.e. foraging and pursuing prey underwater for extended periods down to depths of 20 m), and medium (nets) to very high (longlines) risks for surface seabirds (i.e. foraging mainly at the surface within the first metre of the water column (Butler, 2000). Risks for seabirds posed by pelagic and bottom trawlers were considered low to medium, especially for surface seabirds. Purse seines, dredgers and traps were judged to present a low risk of bycatch for all seabird taxa.

The 2016 report on *The State of Mediterranean and Black Sea Fisheries* (FAO, 2016) estimated an annual incidental catch rate of at least 5 100 seabirds for the Mediterranean and the Black Sea, mainly composed of shearwaters and gulls (Belda and Sánchez, 2001; Cooper *et al.*, 2003; Valeiras and Camiñas, 2003). This number likely underestimates the true value due to the aforementioned lack of onboard observer programmes for most fisheries/gear types and fisheries probably pose an even higher risk to Mediterranean seabird populations, given their comparatively low abundance in this basin.

Several authors have highlighted the need to fill knowledge gaps concerning the impact of fisheries in the Mediterranean and the Black Sea, where negative interactions with fishing activities are considered to be one of the reasons behind the decline of some seabird populations (Cooper *et al.*, 2003; Laneri *et al.*, 2010; Genovart *et al.*, 2016). Indeed, the published literature highlights that bycatch rates in some Mediterranean areas could have important consequences on seabird populations (Anderson *et al.*, 2011; Cortés and González-Solís, 2018).

A number of bycatch-susceptible seabird species in the Mediterranean are included in the "Threatened" categories of the International Union for Conservation of Nature (IUCN) Red List of Threatened Species and the Annex II of the Barcelona Convention Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol) (BirdLife International, 2009; Cortés, Arcos and González-Solís, 2017; UNEP-MAP RAC/SPA, 2018). For instance, Žydelis, Small and French (2013) indicated the high susceptibility of the Balearic (*Puffinus mauretanicus*) and the Yelkouan shearwater (*Puffinus yelkouan*) to set nets, while others highlighted the consistent incidental catch of both species, as well as Scopoli's shearwater (*Calonectris diomedea*), in pelagic and demersal longline fisheries of the western Mediterranean (García–Barcelona *et al.*, 2010; FAO, 2016; BirdLife International, 2017b; Cortés, Arcos and González-Solís, 2017). These species have relatively small populations (BirdLife International, 2009; UNEP-MAP RAC/SPA, 2013), and while bycatch is partly considered as the main driver of decline, as in the example of the Balearic shearwater (Genovart *et al.*, 2016), populations are negatively affected by other factors as well, including the decrease and degradation of available coastal habitat, introduced predators and various types of pollution.

1.1.2 Mediterranean and Black Sea seabird species

Seabird diversity and population size in the Mediterranean Sea are considered low in comparison to more eutrophic oceanic or upwelling regions (BirdLife International, 2009; Coll *et al.*, 2010; UNEP-MAP RAC/SPA, 2013). As such, Coll *et al.* (2010) listed fifteen Mediterranean species of breeding seabirds, ten of which belong to the gulls and terns (Charadriiformes), four to the shearwaters and storm petrels (Procellariiformes) and one shag species (Pelecaniformes). Three of these fifteen species are endemic: the Balearic and Yelkouan shearwaters and Audouin's gull (*Larus audouinii*), as well as two endemic subspecies, the European storm petrel (*Hydrobates pelagicus melitensis*) and the Mediterranean shag (*Phalacrocorax aristotelis desmarestii*). In addition to these, resident species of the Mediterranean seabird community are the yellow-legged gull (*Larus michahellis*), Mediterranean gull (*Larus melanocephalus*) and slender-billed gull (*Larus genei*). The terns are represented by the lesser-crested tern (*Thalassens bengalensis* (*emigrata*)), gull-billed tern (*Gelonchelidon nilotica*), sandwich tern (*Thalassens sandvicensis*), Caspian tern (*Hydroprogne caspia*), common tern (*Sterna hirundo*) and little tern (*Sternula albifrons*) (Coll *et al.*, 2010; UNEP-MAP RAC/SPA, 2013).

The Black Sea is of high importance for several seabird species, including the Mediterranean gull (*Larus melanocephalus*), 90 percent of whose world population is found in this area, the pygmy cormorant (*Microcarbo pygmaeus*) (75 percent of the world population), and the slender-billed gull (*Larus genei*) (65 percent of the world population) (Nankinov, 1996). Additionally, the Black Sea is also considered as an important congregation and foraging area for the Yelkouan shearwater outside the breeding season (Pérez-Ortega and Isfendiyaroglu, 2017).

All the above-mentioned species have been observed to interact with fishing gear, while the main breeding sites and distribution of the majority of these species are found within the Mediterranean and the Black Sea. However, available information on terns indicates that these birds are less susceptible to incidental catch events in fisheries compared to shearwaters, gulls and shags. Therefore, the focus of the following section is on shearwaters, gulls and shags.

Shearwaters and storm petrels (Procellariiformes)

Scopoli's shearwater (*Calonectris diomedea*) is classified as "Least Concern" on the IUCN Red List, but its population is considered to be decreasing (BirdLife International, 2018d), with an estimated global population ranging from 140 000 to 223 000 pairs. The species' main breeding colonies are concentrated in the western and central Mediterranean (the world's largest colony is the island of Zembra, Tunisia, followed by the island of Linosa, Italy), while the largest known colony in the eastern Mediterranean is in the Strofades archipelago (Ionian Sea, Greece) (FAO, 2016; BirdLife International, 2018d; A. Vulcano, personal communication, 2019).

The Balearic shearwater (*Puffinus mauretanicus*) breeds exclusively in the Balearic Islands (western Mediterranean, Spain) and is classified as "Critically Endangered" on the IUCN Red List due to rapid population declines (BirdLife International, 2018a). Owing to the alarming situation of this species, its Species Action Plan was updated to cover its complete distribution range in order to halt the negative population trend (Arcos, 2011). However, while in previous years, estimates of the Balearic shearwater ranged from 3 000 to 4 500 pairs (Arcos *et al.*, 2012), a more recent estimate based on counts at sea indicated an overall population of 25 000 birds (i.e around 5 000 breeding pairs) (Genovart *et al.*, 2016; Arcos *et al.*, 2017). Thus, the estimate of the breeding population size ranges between 3 000–7 000 pairs, though, in general, such an optimistic estimate should be considered with caution (BirdLife International, 2018a).

The Yelkouan shearwater (*Puffinus yelkouan*) is regarded as "Vulnerable" on the IUCN Red List, as it shows a decreasing population trend (BirdLife International, 2018b). Due to the alarming situation of the Yelkouan shearwater, an International Single Species Action Plan for the Conservation of the Yelkouan shearwater was adopted in May 2018, which covers the complete distribution range of *P. yelkouan*, in order to halt the negative population trend (Gaudard, 2018). Although Oppel *et al.* (2011) indicated that the magnitude and potential causes for the decline of the Yelkouan shearwater are unknown, a number of studies have demonstrated the susceptibility of shearwater species to incidental catch in fisheries (for example, Besson, 1973; Cortés, Arcos and González-Solís, 2017; Tarzia *et al.*, 2017b; Cortés, García-Barcelona and González-Solís, 2018). The species distribution covers the Mediterranean Basin and the Black Sea, with the main breeding colonies found in the western, central and eastern Mediterranean Sea, while small colonies are also found in the Black Sea. The latter area is additionally considered as an important congregation area during the non-breeding season (Oppel *et al.*, 2011; FAO, 2016; BirdLife International, 2018b; Pérez-Ortega and İsfendiyaroğlu, 2017). Bourgeois and Vidal (2008) estimate that the total population ranges between 11 400 and 54 500 breeding pairs, while Garcia Robles, Deceuinck and Micol (2016) place it at around 21 500 to 32 800 pairs. The difference between these values indicates that a strong degree of uncertainty exists; these censuses probably overestimate the actual population, which could consist of only a few thousand breeding pairs.

As the smallest seabird breeding in the region, the Mediterranean storm petrel (*Hydrobates pelagicus melitensis*) is included in Annex II of the SPA/BD protocol (UNEP-MAP RAC/SPA, 2018). In contrast to the European storm petrel (*H. pelagicus*), this endemic subspecies is still not assessed by the IUCN Red List (BirdLife International, 2018), while it is estimated that the number of breeding pairs accounts for less than a tenth of the estimated total population, with 10 000 to 16 000 breeding pairs (Lago, Austad and Metzger, 2019). The authors indicated that this subspecies is restricted to a few rat-free islands in the Mediterranean and that half of all nesting pairs are concentrated in the central Mediterranean on the Maltese islet of Filfla (5 000–8 000 pairs) (Lago, Austad and Metzger, 2019).

Gulls (Charadriiformes)
Audouin's gull (*Larus audouinii*) is listed as "Least Concern" on the IUCN Red List with a stable population trend (BirdLife International, 2020). The population of *L. audouinii* mainly breeds in the western Mediterranean (90 percent), with the Ebro Delta acting as the core breeding area over the last two decades and hosting over 67 percent of the global population (Mañosa, Oro and Ruiz, 2004; BirdLife International, 2020), though in recent years large numbers of birds have moved to breed in adjacent areas. After being considered a highly threatened species in the 1970s, the high levels of protection afforded to Audouin´s gull at its breeding sites have resulted in a significant increase in the population (Mañosa, Oro and Ruiz, 2004; BirdLife International, 2020). Currently, the global population is estimated at 60 000 to 66 000 individuals (BirdLife International, 2020). Nevertheless, although in some areas of the western Mediterranean Sea, the population has recovered from low population levels, in the eastern part of the Mediterranean, populations seem to be declining. For example, data from Cyprus indicate a decline of over 70 percent in ten years with a current population there of less than 30 breeding pairs (R. Snape, personal communication, 2019).

The yellow-legged gull (*Larus michahellis*) is listed as "Least Concern" on the IUCN Red List, with an increasing population trend (BirdLife International, 2019b). The yellow-legged gull exhibits a broad distribution pattern, resident in all of southern Europe (which includes the Mediterranean), the Black and the Caspian Sea. The European population size is estimated at 409 000 to 534 000 pairs, and currently the yellow-legged gull is not included in Annex II of the SPA/BD protocol (BirdLife International, 2019b; UNEP-MAP RAC/SPA, 2018).

Shags (Pelecaniformes)
The European shag (*Phalacrocorax aristotelis*[2]) is assessed as "Least Concern" on the IUCN Red List, though it shows a decreasing population trend (BirdLife International, 2018c). Its distribution ranges from northern Europe to northern Africa along the Atlantic coast, and it is also present across the entire Mediterranean and Black Sea area, with nesting sites in Turkey and Italy. The current global population size of the European shag is assessed to lie between 230 000 and 240 000 individuals (BirdLife International, 2018c).

The Mediterranean Sea endemic subspecies, *Phalacrocorax aristotelis desmarestii* (syn. *Gulosus aristotelis desmarestii*), is not separately assessed on the IUCN Red List, and it is listed only on the National Red List of France and Spain as "Vulnerable" and included in Annex I of the Birds Directive (Madroño, González and Atienza, 2004; National Red List, 2008; European Commission, 2016b, 2016c). It is estimated that the population size of Mediterranean shag ranges between 2 700 and 10 000 breeding pairs across the whole Mediterranean Sea, with an unknown population trend over the long term (European Commission, 2016c; European Environment Agency, 2019).

2. Also known as *Gulosus aristotelis*.

The pygmy cormorant (*Microcarbo pygmaeus*) is assessed as "Least Concern" on the IUCN Red List with an increasing population trend (BirdLife International, 2019a). Its breeding grounds range from southeastern Europe to western Central Asia, on the coasts of the Black, Caspian and Aral seas, and it winters primarily in the coastal countries of the eastern Mediterranean and the Black Sea (Barati, Javan and Sehhatisabet, 2008; BirdLife International, 2019a). The population of the pygmy cormorant is estimated at between 45 000 and 180 000 individuals and is separated into two populations, one breeding in eastern Europe and Turkey (centred on the Black Sea), the other in western Asia (centred on the Caspian Sea) (Barati, Javan and Sehhatisabet, 2008; BirdLife International, 2019a).

1.2 Historical records of interactions with fisheries

Seabirds have long been interacting with fisheries as they use, and compete for, the same productive fishing areas and resources. The expansion and growth of fishing activities over the last century has led to stronger and more complex interactions (Tudela, 2004; Arcos, Louzao and Oro, 2008). However, the issue of seabird bycatch in the Mediterranean and the Black Sea passed unrecognized for decades. The first evidence of the phenomenon was collected in the French Mediterranean in the early 1970s, when an annual mortality of Balearic/Yelkouan shearwaters was estimated at several hundred caught in set nets, shortly after the introduction of nylon materials for this type of fishing gear (Besson, 1973).

It was not until the early 2000s that the seabird bycatch issue became more apparent in the region, particularly in relation to longline fisheries (Belda and Sánchez, 2001; Sánchez and Belda, 2003; Valeiras and Camiñas, 2003; Louzao and Oro, 2004). However, there remained either information gaps from a number of countries or errors in the systematic collection of the available data, which were therefore insufficient to assess the impacts on seabird populations (Cooper *et al.*, 2003; ICES, 2008). Seabird bycatch was reported in at least six countries (France, Greece, Italy, Malta, Spain and Tunisia), but the most extensive information came from the western Mediterranean. Indeed, Spain was the only country that provided quantitative information on the mortality rates in longline fisheries (Belda and Sánchez, 2001; Cooper *et al.*, 2003). As a result, Belda and Sánchez (2001) estimated that between 650 and 2 800 birds were caught annually by drifting and set longliners operating around the Columbretes Islands (northwestern Mediterranean), where an important breeding colony of Scopoli's shearwater is found, with a higher mortality rate reported by set longlines. This estimate took into account the mortality of seven different seabird species, although Scopoli's shearwater was the most susceptible to incidental catch (66 percent of the seabird bycatch). For this species, the incidental catch observed mainly consisted of adult breeders, therefore potentially impacting 4–6 percent of the breeding population in the area (Belda and Sánchez, 2001). Moreover, it was demonstrated that seabird bycatch could also have negative effects on fishers due to bait loss and reduced catch (Sánchez and Belda, 2003). These findings highlighted that incidental catch was affecting not only the viability of Scopoli's shearwaters in the region, but also the fishing efficiency of longline fishers. At that time, night setting was proposed as the best measure to prevent seabird incidental capture and minimize economic loss for fishers (Belda and Sánchez, 2001; Sánchez and Belda, 2003).

Evidence collected from longline fisheries across the Mediterranean region showed that shearwater species were the most impacted seabirds, with Scopoli's shearwaters caught in the greatest numbers by far (Cooper *et al.*, 2003; Louzao and Oro, 2004; García-Barcelona *et al.*, 2010) and with all three shearwater species (Scopoli's, Balearic and Yelkouan) specifically affected, mainly by small-scale set longliners (Cortés, Arcos and González-Solís, 2017). In addition to Scopoli's shearwaters, France, Greece, Italy, Malta, Spain and Tunisia reported incidental catch of Balearic and Yelkouan shearwaters. For these latter two species, no accurate data on mortality rates in longlines existed, since most information available came from intermittently reported events. However, it was suspected that in the Spanish Mediterranean, species such as shearwaters were being caught on occasion in large numbers by set longlines, resulting in mass mortality events (Arcos, Louzao and Oro, 2008; Louzao *et al.*, 2011).

In general, set longlines seemed to cause the most substantial seabird bycatch, since studies carried out on drifting longliners operating in the western Mediterranean found relatively lower mortality levels (Valeiras and Camiñas, 2003; García-Barcelona *et al.*, 2010), potentially due to the larger baits and hooks used by drifting longlines. García-Barcelona *et al.* (2010) estimated an average total bycatch by drifting longliners of around 500 seabirds per year, 40 percent of which were Scopoli's shearwaters. However, the incidental catch rates by longlines varied between, for example, target species, vessels, fishing grounds and seasons.

In the case of set net fisheries, the information available is very scarce. Louzao and Oro (2004) have provided evidence of incidental catch in set nets from the Balearic Islands (Spain) particularly impacting the Mediterranean shag. Similarly, another record from the same area (the island of Cabrera, Balearic Islands) indicated an incidental catch of 28 Mediterranean shags in set nets in 1992 (Moreno Pérez, personal communication, 2019). Regarding the other fisheries of the Mediterranean and the Black Sea, no incidental catch has been documented by trawlers, purse-seiners and traps since the early 2000s. Indeed, in the case of trawlers, several studies carried out in the western Mediterranean did not find any seabird mortality in a large number of operations monitored between 1994 and 2003 (Arcos and Oro, 2002a; Abelló, Arcos and Gil de Sola, 2003; Abelló and Esteban, 2012).

1.3 Analysis of recent data from literature (2008–2018)

Overall, the data available on the bycatch of seabirds in the Mediterranean and the Black Sea are scarce, and often data are unavailable for some GFCM subregions, countries or vessel groups. No information on seabird bycatch could be found from North Africa and from many eastern Mediterranean countries. All records of incidental seabird catch in fisheries found in the literature are summarized in Tables 1 through 4, presented by fishing fleet and by GFCM subregion.

1.3.1 Bottom trawlers

Western Mediterranean

The available information shows a low probability of seabird bycatch in bottom trawlers. Questionnaires completed by Spanish fishers (450 surveys, including fishers from the Atlantic) indicated a low to very low risk of seabird bycatch in trawl fisheries from the western Mediterranean (Cama and Arcos, 2013). This risk assessment integrates the estimation of one annual event of seabird bycatch in this area with a very low number of seabird individuals affected. Genovart *et al.* (2016) recorded three incidental catch events by bottom trawlers, in which 20 Balearic shearwaters were caught during ten commercial and scientific fishing hauls (Table 1). In contrast, information from scientific hauls (120 bottom trawl hauls) (Abelló and Esteban, 2012) and observer data from 150 field trips (J.M. Arcos, personal communication, in Cama and Arcos, 2013) conducted in the western Mediterranen revealed very low (two Balearic shearwaters) or no bycatch, respectively (Table 1).

PLATE 1
Seabirds following a trawler

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TABLE 1 – Incidental catch of seabirds in bottom trawlers (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch (percent or individuals/ year)	Source of data	Fishing effort
Abelló and Esteban, 2012	2011	OTB	Western Mediterranean	Spain	*Puffinus mauretanicus*	2	-	onboard observation	~120 scientific hauls
Cama and Arcos, 2013	unspecified	OTB	Western Mediterranean	Spain	-	0	-	onboard observation	150 fishing surveys
Genovart, Oro and Tavecchia 2017	2014	OTB	Western Mediterranean	Spain	*Puffinus mauretanicus*	14	-	onboard observation	5 scientific hauls
Genovart, Oro and Tavecchia 2017	2014	OTB	Western Mediterranean	Spain	*Puffinus mauretanicus*	~6	-	self-reporting fishers	-
SEO/BirdLife, 2019	2018	OTB	Western Mediterranean	Spain	*Larus michahellis*	1	-	self-reporting fishers	521 fishing trips
ICES, 2018	2016	OTB	Adriatic Sea	-	*Phalacrocorax aristotelis desmarestii*	1	-	-	25 fishing days

Note: OTB = bottom otter trawl.

Central Mediterranean

No records of seabird bycatch could be found in the existing literature.

Adriatic Sea

One European shag caught by a bottom trawl was reported for the Adriatic Sea (ICES, 2018; Table 1). This record is based on 25 days of observation on bottom trawlers in this area (ICES, 2018). No further records were found for bottom trawls in this area.

Eastern Mediterranean

No records of seabird bycatch could be found in the existing literature.

Black Sea

No records of seabird bycatch could be found in the existing literature.

1.3.2 Small-scale fisheries

The search for records within this vessel group focused on set nets, traps and small-scale longliners (passive fishing gear). The data available for small-scale fisheries reveal that some of these types of fishing gear can have a very high impact at a local scale on certain seabird taxa. While small-scale longlines mainly affect shearwaters (see below), set net fisheries may have impacts on birds with intense diving behaviour, such as cormorants.

Western Mediterranean

Set nets

Data collected through questionnaires provided to fishers (450 surveys from the Atlantic and Mediterranean, Spain) showed that incidental catch in set nets is relatively infrequent and does not affect a large number of seabirds in the western Mediterranean (Cama and Arcos, 2013). The authors estimated that around five incidental catch events could occur annually in these fisheries in each of the Spanish locations considered (Catalonia, Valencian Community and the Balearic Islands) with one to many (>10) seabird individuals/set caught in each incident (Cama and Arcos, 2013). The overall risk for seabirds, which takes into account the number of incidents and the number of seabirds per capture, varies regionally from very low to very high (with high variation locally in Catalonia and the Valencian Community) (Cama and Arcos, 2013). For the western Mediterranean, these authors suggested that this fishing gear affects mostly shearwaters and gulls, and, to a lesser extent, cormorants/shags, alcids (puffins, guillemots, razorbills, auks, etc.) and gannets. Nevertheless, data obtained from beach surveys carried out over four months of two consecutive years along the coast of Mar Menor (Murcia, southeastern Spain), a coastal salty lagoon in the western Mediterranean, have demonstrated a high mortality rate of cormorants and grebes from set nets (Zamora Urán, 2014, 2015) (Table 2). These studies showed that high numbers of great cormorants (*Phalacrocorax carbo*) (333–439 individuals) and black-necked grebes (*Podiceps nigricollis*) (48–60 individuals) were found dead each year. This mortality was mainly associated with the presence of an average of 32 to 80 set nets per month in this area, and since both species are divers that hunt their prey underwater, they are therefore highly susceptible to being caught by this kind of fishing gear (Žydelis, Small and French, 2013). Zamora Urán (2014, 2015) also estimated that these mortality events could affect up to 30–40 percent and 4.6–5.7 percent of the local winter populations of great cormorant and of the black-necked grebe, respectively.

Small-scale longlines

Higher incidental catch rates were observed in small-scale set longliners from the Iberian Peninsula and Balearic Islands, in comparison to medium-scale longliners (Cortés, Arcos and González-Solís, 2017) (Table 2). In this study, the estimate of annual seabird bycatch from small-scale fisheries was almost twice (675 individuals/year) that of the medium-scale fleet (357 individuals/year), with an overall mortality of 81 percent. The species most affected by this fishery were shearwaters (*Puffinus* spp.) (47 individuals not distinguished); over 90 percent of the *Puffinus* spp. individuals were caught in a single setting. Another study from the Catalonian coast (northeastern Spain) analysed records from self-reporting surveys of fishers, which covered over 400 fishing trips,

TABLE 2 – Incidental catch of seabirds in small-scale fisheries (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated mortality due to bycatch (percent or individuals/ year)	Source of data	Fishing effort
Zamora Urán, 2014	Nov 2012– Feb 2013	set nets	Western Mediterranean	Spain	*Phalacrocorax carbo* *Podiceps nigricollis* *Larus michahellis*	333 48 1	– – –	stranding data	–
Zamora Urán, 2015	Nov 2013– Feb 2014	set nets	Western Mediterranean	Spain	*Phalacrocorax carbo* *Podiceps nigricollis* *Larus michahellis*	439 60 13	– – –	stranding data	–
BirdLife International, 2017b	April–June 2017	LLS, occasionally traps or set nets	Western Mediterranean	Spain	*Puffinus mauretanicus; Puffinus yelkouan; Calonectris diomedea; Larus* spp.*; Morus bassanus; Phalacrocorax* spp.	685 (405)	–	self-reporting fishers	403 fishing days
Cortés *et al.*, 2017; Cortés, pers. comm., 2019	2011–2015	LLS	Western Mediterranean	Spain	*Larus michahellis* *Puffinus mauretanicus* *Puffiunus yelkouan* *Puffinus spp.* *Calonectris diomedea* *Larus audouinii*	4(1) 8(8) 1(1) 47(5) 27(5)	675 (148–1 556)	onboard observer	117 fishing days; 113 219 hooks
Cortés *et al.*, 2017; Cortés, pers. comm., 2019	2011–2015	LLS	Western Mediterranean	Spain	*Calonectris diomedea; Puffinus mauretanicus; Puffinus yelkouan; Puffinus spp.; Larus audouinii; Morus bassanus; Larus melanocephalus; Thalassens sandvicensis*	252	–	self-reporting fishers	–
Genovart *et al.*, 2017	1992–2012	sport trolling	Western Mediterranean	Spain	*Larus audouinii*	40	0.02% (juvenile), 0.1% (adult)	opportunistic information	–
Cortés and González-Solís, unpubl. data	2013– 2015	fish traps	Western Mediterranean	Spain	*Phalacrocorax aristotelis desmarestii* *Phalacrocorax carbo*	4 1	– –	opportunistic information	–
González-Solís, unpubl. data	2018	fish traps	Western Mediterranean	Spain	*Phalacrocorax aristotelis desmarestii*	3	–	opportunistic information	–
SEO/BirdLife, 2019	2018	LLS	Western Mediterranean	Spain	*Calonectris diomedea; Phalacrocorax aristotelis; Larus michahellis; Puffinus mauretanicus; Puffinus yelkouan; Puffinus spp.; Phalacrocorax carbo; Larus melanocephalus*	36	–	self-reporting fishers	1 375 fishing trips
		set nets fishing traps	Western Mediterranean	Spain	*Phalacrocorax aristotelis* *Phalacrocorax aristotelis*	4 2	– –		
Genovart *et al.*, 2017	2005– 2013	GNS	Adriatic Sea	Croatia	*Phalacrocorax aristotelis desmarestii*	9	3.5% (juvenile)	opportunistic information	-
Karris *et al.*, 2013; G. Karris, pers. comm., 2019	2010	set nets	Eastern Mediterranean	Greece	*Phalacrocorax aristotelis desmarestii*	1	-	questionnaire to fishers (n=139)	-

Note: GNS = set gillnet; LLS = set longline. The numbers in brakets correspond to the number of individuals recovered alive in the study.

mostly conducted by small-scale longliners, carried out between April and June 2017 (BirdLife International, 2017b) (Table 2). Overall, 685 individuals caught were reported, mainly Balearic (51.8 percent), Yelkouan (43.9 percent) and Scopoli's (4 percent) shearwaters, as well as a number of gulls (16 individuals; *Larus* spp.), one shag and a gannet (*Morus bassanus*). Fortunately, almost 60 percent of the birds were released alive. These reports revealed that the highest catches occurred in unweighted gear of the small-scale longlines (5.86 seabirds/1 000 hooks) compared to weighted gear (2.99 seabirds/1 000 hooks) and medium-scale longliners (0.49 seabirds/1 000 hooks) using the *piedra-bola* system (i.e. a line with hooks hanging off it at regular intervals, which hangs near the bottom with alternating weights and buoys, as used by set longliners) (BirdLife International, 2017b; Cortés, Arcos and González-Solís, 2017).

Traps

Based on opportunistic information collection, a few incidental catch records for this subregion exist: three individuals of cormorants/shags were caught by traps in Catalonia (Spain) (Cortés and González-Solís, unpublished data) (Table 2); five individuals (four Mediterranean shags, one great cormorant) were recorded in fish traps between 2013–2015; and a further three immature specimens of the Mediterranean shag were found in traps in 2018 (González-Solís, unpublished data). In a questionnaire given to fishers, Cama and Arcos (2013) noted that traps were less frequently used in Spanish Mediterranean waters than in the Atlantic, and that the incidental catch of shags, shearwaters and gannets was highly irregular and comprised low numbers of individuals.

Central Mediterranean

Set nets

No records of seabird bycatch could be found in the existing literature.

Small-scale longlines

No records of seabird bycatch could be found in the existing literature.

Traps

No records of seabird bycatch could be found in the existing literature.

Adriatic Sea

Set nets

Only one reference could be found concerning a small-scale fishery operating in Croatia: 29 Mediterranean shags were recorded dead over eight years of sampling (nine died due to incidental catch in set nets, while 20 died due to unknown causes) (Genovart *et al.*, 2017) (Table 2). The authors inferred that set nets in Croatia were responsible for 9 percent of juvenile shag mortality and the annual probability for juveniles dying in fishing gear was estimated at 3.5 percent (Genovart *et al.*, 2017).

Small-scale longlines

No records of seabird bycatch could be found in the existing literature.

Traps

No records of seabird bycatch could be found in the existing literature.

Eastern Mediterranean

Set nets

Information available for this GFCM subregion is sourced from Greece, with no data available from other countries. Based on data from questionnaires of coastal fisheries in the Aegean and Ionian Sea, Fric *et al.* (2012) noted that Mediterranean shag (*Phalacrocorax aristotelis desmarestii*) were mainly caught by set nets, which also affected the Yelkouan shearwater (*Puffinus yelkouan*), occasionally catching high numbers of individuals. Karris *et al.* (2013) (Table 2) used questionnaires for fishers to assess and quantify the potential impact of set nets on Scopoli's (*Calonectris diomedea*) and Yelkouan shearwaters, Mediterranean shags, and Audouin's gulls (*Larus audouinii*) in the Ionian Sea (150 fishers). Based on these data, the authors estimated an incidental mortality of 1.3 Mediterranean shag individual caught by the whole fleet in this area annually. No other seabird species were observed to be caught by this fleet (Karris *et al.*, 2013). Further data from the Ionian and the Aegean Sea, obtained by questionnaires and onboard observers, suggested that an estimated 2.7–3.3 percent of the local population of the Mediterranean shag may contribute to the annual incidental catch in set nets and longline fleets from these areas (Karris, Portolou and Fric, 2015). Additionally, the authors inferred that set nets do not affect Scopoli's and Yelkouan shearwaters, or Audouin's gull, as no catch was recorded.

Small-scale longlines

Examining small-scale longliners in the Aegean and Ionian Sea revealed that this method of fishing can have impacts on seabird populations, at least at the local scale (Karris, Portolou and Fric, 2015). Based on questionnaires and onboard observations (2009–2012) in the southern Ionian Sea, the percentage share of local/regional breeding populations that may be affected annually, especially by small-scale set longliners, was estimated: Scopoli's shearwater (1.8–2.1 percent), Mediterranean shag (2.7–3.3 percent) and Audouin's gull (0.9–1.9 percent). It was also highlighted that, at the local scale, small-scale longlines can also impact Yelkouan shearwaters, though estimates are not available (Karris, Portolou and Fric, 2015; G. Karris, personal communication, 2018) (Table 2).

Black Sea

No records of seabird bycatch could be found in the existing literature.

1.3.3 Purse seiners

Western Mediterranean

Very few data are available for this fishery in the western Mediterranean. Based on questionnaires given to Spanish fishers by Cama and Arcos (2013), it was estimated that up to five events, each involving just a few seabirds (<10), can occur in purse seine fisheries annually, with variations at the local scale: an overall low to medium seabird bycatch risk was observed in purse seiner activities, with the Strait of Gibraltar exhibiting the highest risk of incidental catch. This study confirmed that incidental catch in purse seines mostly concerns shearwater species (*Puffinus* spp.) It should be also reported that around 25 dead Balearic shearwaters were found washed ashore on a beach in the western Mediterranean (Valencian Community) (Genovart, Oro and Tavecchia, 2017) (Table 3); this finding could not be clearly associated with a specific fishing gear, but the presence of dislocated wings on several of the seabirds indicates impacts from trawlers or purse seiners. Nevertheless, no incidental bycatch was recorded by fishers during an additional study conducted in Spanish Mediterranean waters (SEO/BirdLife, 2019) (Table 3).

TABLE 3 – Incidental catch of seabirds in purse seiners (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch (percent or individuals/ year)	Source of data	Fishing effort
Genovart, Oro and Tavecchia, 2017	2013	PS/OTB	Western Mediterranean	Spain	*Puffinus mauretanicus*	~ 25	-	stranding data	-
SEO/BirdLife (2019)	2018	PS	Western Mediterranean	Spain	no bycatch observed	0	-	self-reporting fishers	223 fishing trips

Note: PS = purse seine; OTB = bottom otter trawl.

Central Mediterranean
No records of seabird bycatch could be found in the existing literature.

Adriatic Sea
No records of seabird bycatch could be found in the existing literature.

Eastern Mediterranean
No records of seabird bycatch could be found in the existing literature.

Black Sea
No records of seabird bycatch could be found in the existing literature.

1.3.4 Longliners

High mortality of seabirds, particularly shearwater species, has been found to occur in some Mediterranean longline fisheries. Other seabirds, such as gulls, cormorants, skuas and terns, also contribute to this kind of bycatch. Generally, two types of longlines are used in the Mediterranean and the Black Sea: set longlines (sometimes also called bottom or demersal longlines) deployed on the sea bottom, and drifting longlines (sometimes also called surface or pelagic longlines) used in the water column at variable depths. Therefore, these two types of vessel groups are presented separately in the considerations of some GFCM subregions (i.e. in the western Mediterranean).

Western Mediterranean
Drifting longliners
The results of questionnaires compiled from Spanish fishers indicated that seabird bycatch events in the drifting longline fisheries of the western Mediterranean may occur more than five times a year, each involving a few (<10) to many (>10) individuals caught and varying locally and/or regionally (Cama and Arcos, 2013). The risk of incidental catch in drifting longlines is high to very high for the northeastern Spanish coast (Catalonia, Valencian Community) and Balearic archipelago and low in the Alborán Sea. Cama and Arcos (2013) highlighted that specifically in the Balearic Sea, 80 percent of drifting longline fishers catch seabirds incidentally more than five times a year. The species most affected by this gear is the Scopoli's shearwater (*Calonectris diomedea*), due to the large hooks used, which prevent the capture of smaller shearwater species (Cama and Arcos, 2013). However, a single event of 145 Balearic (*Puffinus mauretanicus*) and Yelkouan (*Puffinus yelkouan*) shearwater specimens (137 of which were found dead) from the Ebro Delta (northwestern Mediterranean) demonstrates the potentially high impact of set longliners (García-Barcelona *et al.*, 2016) (Table 4). Additionally, onboard observers from 2013 recorded 40 individuals of the northern gannet (*Morus bassanus*) caught during a single fishing trip by a drifting longliner

(González-Solís *et al.*, 2014). A questionnaire given during the same study (involving six fishers on drifting longliners) confirmed frequent bycatch, mainly of gannets, shearwaters and gull species; this dynamic is also partly supported by independently observed interactions of the yellow-legged gull (*Larus michahellis*), Scopoli's shearwater and *Puffinus* spp. with this kind of fishery (González-Solís *et al.*, 2014). In contrast, no seabirds were caught during onboard observations made aboard Ligurian semi-pelagic swordfish longliners, which involved 48 fishing trips between 2010 and 2013 (Garibaldi, 2015) (Table 4). In general, the present review highlights the need to obtain an overall estimate of the potential effects of drifting longlines on seabirds in Mediterranean waters.

Set longliners

The estimates of the aforementioned questionnaires revealed that seabird bycatch in set longliners in Spanish waters may occur more than five times a year, with each event involving one to many (>10) individuals caught, while varying locally and/or regionally (Cama and Arcos, 2013). The incidental catch risk for seabirds was highest locally in Catalonia and especially in the Balearic archipelago: 50 percent of set longline fishers in the Balearic Sea reported incidental catch of seabirds (mostly shearwaters and gulls) more than five times a year (Cama and Arcos, 2013). Conversely, onboard observer data from thirty fishing trips conducted in 2013 did not report any bycatch from set longliners, although frequent interactions between this fishery and several seabird species (Audouin's and yellow-legged gulls, Scopoli's shearwater) were recorded (González-Solís *et al.*, 2014). In the same study, a questionnaire (answered by 24 fishers on set longliners, including some small-scale vessels) revealed that 29 percent of fishers recorded seabird bycatch at least once annually, with reported incidents of species such as gannets, shearwaters, gulls and cormorants. Nevertheless, seabird bycatch was considered as rare or even exceptional (González-Solís *et al.*, 2014).

Observations onboard set longliners (medium-scale) off the Iberian Peninsula, carried out over a four-year study period (2011–2015), resulted in an estimated annual mortality of around 360 seabirds for the Catalonian fleet (Cortés, Arcos and González-Solís, 2017) (Table 4). Additionally, on fishing days without onboard observers during the four-year study period, fishers continued to report seabird bycatch and recorded 487 individuals: this highlights the hidden mortality when considering onboard observation only (Table 4). Nevertheless, the number and the composition of the species caught was similar to the onboard observations made in the same study, comprising the three shearwater species (Balearic, Yelkouan and Scopoli's), gulls (yellow-legged, Audouin's and black-legged kittiwake (*Rissa tridactyla*)) and the northern gannet. Further, more recent onboard observations carried out on set longliners in 2015 and 2016 in Catalonian waters recorded six seabirds (three Scopoli's shearwaters and three yellow-legged gulls) caught during 232 fishing sets with an average of 0.031 bird/1 000 hooks (BirdLife International, 2017b) (Table 4). However, the authors also indicated that, over the same period, an additional 40 individuals were caught by neighbouring vessels or on the same vessels during trips without observers.

Specific effects of drifting and set longliners on shearwater populations

Among the potential impacts of longliners on seabird population sizes, other studies analysed the effects of this fishing gear on different seabird age classes. Based on data from ringed individuals of Audouin's gull from Catalonia (data collection carried out over 20 years) and Scopoli's shearwater from the Balearic archipelago (28 years), Genovart *et al.* (2017; Table 4) estimated that 23 percent and 28 percent of total adult mortality, respectively, were caused by longline incidental catch in these areas. The authors further estimated that 3.4–6.0 percent of Scopoli's shearwater adults die in longlines in the western Mediterranean. However, the data collected cannot precisely attribute these deaths to the fishing gear type, though it is assumed that these individuals were mainly caught by small-scale demersal longliners, which are abundant in the area (Genovart *et al.*, 2017). Furthermore, dead individuals (639) of the three shearwater species (Scopoli's, Balearic and Yelkouan) caught by set and drifting longliners were recorded over 12 years by observers or fishers in the northwestern Mediterranean Sea (Cortés, García-Barcelona and González-Solís, 2018) (Table 4). The analysed data revealed a higher mortality of adults in all three species compared to subadults and immatures. In addition, the authors observed differences in the incidental catch composition (age and sex of individuals) according to the breeding period: for instance, Scopoli's shearwater males exhibited an overall higher mortality than females; when analysing the breeding periods separately, this male bias was significantly higher only during the pre-laying period; in both *Puffinus* shearwaters (i.e. Balearic and Yelkouan), male-biased mortality was observed during the pre-laying period, while mortality in females was higher in the chick-rearing period (Cortés, García-Barcelona and González-Solís, 2018). The mortality differences between the sexes were explained by different foraging behaviours during the breeding periods, which resulted in differential interactions with longliners.

Central Mediterranean

Two studies from this region applying different approaches indicated rather low seabird incidental catch in longline fisheries. While no seabirds were caught during the observations made onboard Maltese tuna longliners, covering 85 fishing days in 2008 (Burgess *et al.*, 2010) (Table 4), a second self-reporting study exhibited low incidental catch of seabirds. This latter study was carried out from May 2008 through the end of April 2010, with most trips (221) occurring between May and August, by seven Maltese fishers, covering 443 fishing trips in total (163 drifting and 280 set longlines). During this period, one Scopoli's shearwater was caught by drifting longlines, while one Scopoli's shearwater and one black-legged kittiwake were caught by set longliners. The estimated annual total seabird bycatch for both methods in this area was 52 and 94 individuals, respectively (Darmanin, Caruana and Dimech, 2010).

Adriatic Sea

No records of seabird bycatch could be found in the existing literature.

Eastern Mediterranean

Set longlines have impacts on certain seabird species in the southern Ionian Sea. Studies based on questionnaires given to fishers (150 surveys) carried out between 2009 and 2011 indicated that set longlines caught up to 351 Scopoli's shearwaters and four Mediterranean shags annually (Karris *et al.*, 2013) (Table 4). In the case of drifting longlines, annual mortality was estimated at 42 Scopoli's shearwaters and one Mediterranean shag, respectively. Additionally, these questionnaires revealed that the Yelkouan shearwater and Audouin's gull were not impacted by these types of gear. Based on data from questionnaires of longliners and other coastal fisheries in the Aegean and Ionian Sea, Fric *et al.* (2012) noted that Scopoli's and Yelkouan shearwaters and Audouin's gulls can be affected by this fishery, at least occasionally. Preliminary data from a questionnaire and from an onboard observer programme (Table 4) conducted in 2015 and 2016 in the Aegean Sea demonstrated again that longliners can have relevant impacts, especially on shearwaters and gulls (D. Sahin, unpublished data): a questionnaire given to 57 fishers revealed a high frequency of bycatch of Yelkouan and Scopoli's shearwaters (43.8 and 7 percent, respectively) and the yellow-legged gull (40.3 percent). The results also showed quite a high overall frequency for shags and cormorants combined (31.6 percent). Sahin (personal communication, 2019) assumed that the relatively high *Phalacrocorax* spp. bycatch could be associated with the type of drifting longlines used by fishers in some locations. Instead of fishing offshore, drifting longlines can be set very close to the shore, thereby increasing the risk of cormorant and shag bycatch (D. Sahin, unpublished data). The preliminary data from an onboard observer programme (mainly set longliners) carried out on 17 fishing trips indicate higher bycatch of Yelkouan shearwaters (estimate of 680 individuals/year) and lower bycatch of yellow-legged gulls (170 individuals/year) and Mediterranean shags (85 individuals/year), which partly confirmed the results obtained by the questionnaires (D. Sahin, unpublished data). In contrast, another study in the Aegean Sea on drifting longliners (onboard observers surveying 50 operations) could not detect any seabird bycatch between 2008 and 2013 (Ceyhan and Akyol, 2014; Table 4).

Black Sea
No records of seabird bycatch could be found in the existing literature.

PLATE 2
Specimens of Mediterranean shearwater caught by longlines

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1.3.5 Pelagic trawlers

Western Mediterranean
No records of seabird bycatch could be found in the existing literature.

Central Mediterranean
No records of seabird bycatch could be found in the existing literature.

Adriatic Sea
No records of seabird bycatch could be found in the existing literature.

Eastern Mediterranean
No records of seabird bycatch could be found in the existing literature.

TABLE 4 – Incidental catch of seabird in longlines (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated mortality due to bycatch (percent or individuals/ year)	Source of data	Fishing effort	Notes
C. Carboneras, pers. comm., 2008 in García-Barcelona *et al.*, 2010	May 2008	LL	Western Mediterranean	Spain	*Puffinus yelkouan*	60	-	opportunistic information	one fishing set or day (not specified)	-
González-Solís *et al.*, 2014	2013	LLD	Western Mediterranean	Spain	*Morus bassanus*	40	-	onboard observer	one fishing trip	-
González-Solís *et al.*, 2014	2013	LLS	Western Mediterranean	Spain	no bycatch observed	0	-	onboard observer	30 fishing trips	-
Garibaldi, 2015	2010–2013	LLD	Western Mediterranean	Italy	no bycatch observed	0	-	onboard observer	48 fishing trips, 32 000 hooks	-
García-Barcelona *et al.*, 2016	2015	LLD	Western Mediterranean	Spain	*Puffinus yelkouan; Puffinus mauretanicus*	145 (8 released alive); 64.6%; 35.4%	-	onboard observer	one fishing set	-
Genovart *et al.*, 2016	1985–2004 2010–2014	LL	Western Mediterranean	Spain	*Puffinus yelkouan*	16	-	opportunistic information	–	Literature, wildlife recovery centres
		LL	Western Mediterranean	Spain		5	-	opportunistic information	–	ringing of 1 344 individuals
BirdLife International, 2017b	2015–2016	LLS	Western Mediterranean	Spain	*Calonectris diomedea; Larus michahellis*	6		onboard observer	81 fishing trips, 232 settings, 195 000 hooks	–
					Calonectris diomedea; Larus michahellis	~40		seft reporting fishers		–
Cortés *et al.*, 2017; V. Cortés, pers. comm	2011–2015	LLS	Western Mediterranean	Spain	*Morus bassanus* *Puffinus mauretanicus* *Puffinus yelkouan* *Puffinus* spp. *Calonectris diomedea* *Larus audouinii* *Larus michahellis* *Rissa tridactyla*	1 5 2 3 2			–	
					Calonectris diomedea; Puffinus mauretanicus; Puffinus yelkouan; Puffinus spp.*; Larus audouinii; Morus bassanus; Larus melanocephalus; Thalassens sandvicensis*	487		self-reporting fishers		reported by fishers over 4 years of the study period

TABLE 4 (Continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated mortality due to bycatch (percent or individuals/ year)	Source of data	Fishing effort	Notes
Genovart, Oro and Tavecchia, 2017	2008		Western Mediterranean	Spain	*Puffinus mauretanicus*	12	-	opportunistic information	-	Offshore, boat transect 4 miles, birds with hooks
	2009–2015	LLS	Western Mediterranean	Spain	*Puffinus mauretanicus; Puffinus yelkouan*	>100	-	onboard observer	one fishing set	massive catch in one set during 2009–2015
	2015	LLS	Western Mediterranean	Spain	*Puffinus mauretanicus; Puffinus yelkouan*	20–30	-	opportunistic information	-	mortality reported by fishers
	2015	LL	Western Mediterranean	Spain	*Puffinus mauretanicus;*	5	-	stranding data	-	signs of neck injuries (hooks?)
	2015	LL	Western Mediterranean	Spain	*Puffinus yelkouan*	2	-	stranding data	-	signs of neck injuries (hooks?)
Genovart *et al.*, 2017	1985–2013	LL	Western Mediterranean	Spain	*Calonectris diomedea*	14	1.2% (immature), 3.4% (adult)	opportunistic information	-	3 071 individuals captured and banded
	1992–2012	LL	Western Mediterranean	Spain	*Larus audouinii*	15	34% (juvenile), 16% (immature), 2.5% (adult)	opportunistic information	-	21 679 individuals captured and banded
SEO/BirdLife, 2019	2018	LLS	Western Mediterranean	Spain	Calonectris diomedea	1	-	self-reporting fishers	833 fishing trips	-
Burgess *et al.*, 2010	April–June 2008	LLD	Central Mediterranean	Malta	no bycatch observed	0	-	onboard observer	85 fishing days, 109 155 hooks	-
Darmanin *et al.*, 2010	May 2008– April 2010	LLD	Central Mediterranean	Malta	*Calonectris diomedea*	1	52*	self-reporting fishers	163 fishing trips	-
		LLS	Central Mediterranean	Malta	*Calonectris diomedea; Rissa tridactyla*	2	94*	self-reporting fishers	280 fishing trips	-
Fric, 2013	2009–2012	LLD	Eastern Mediterranean	Greece	no bycatch observed	0	-	onboard observer	30 trips, 142 fishing days	-
Karris *et al.*, 2013; G. Karris, pers. comm.					*Calonectris diomedea;*	351	-	questionnaire to fishers (n=150)	–	bycatch rate 0.0626 birds/1 000 hooks
	2010	LLS	Eastern Mediterranean	Greece	*Phalacrocorax aristotelis desmarestii*	4	-			bycatch rate 0.00071 birds/1 000 hooks
		LLD	Eastern Mediterranean	Greece	*Calonectris diomedea*	42	-	questionnaires to fishers (n=150)	–	bycatch rate 0.06976 birds/1 000 hooks
Ceyhan and Akyol, 2014	2008–2013	LLD	Eastern Mediterranean	Turkey	no bycatch observed	0	-	onboard observer	50 fishing days	-
C. Sahin, unpublished data	2015–2016	LLS	Eastern Mediterranean	Turkey	*Puffinus yelkouan*	680	–	onboard observer	17 fishing trips	–
					Larus michahellis	170	–			
					Phalacrocorax aristotelis desmarestii	85	–			

Note: LL= Longline; LLS = set longline; LLD = drifting longline.
*estimated number of seabirds caught annually (mortality rate not specified).

1.3.6 Tuna seiners

Western Mediterranean
No records of seabird bycatch could be found in the existing literature.

Central Mediterranean
No records of seabird bycatch could be found in the existing literature.

Adriatic Sea
No records of seabird bycatch could be found in the existing literature.

Eastern Mediterranean
No records of seabird bycatch could be found in the existing literature.

1.3.7 Dredgers

Western Mediterranean
No records of seabird bycatch could be found in the existing literature.

Central Mediterranean
No records of seabird bycatch could be found in the existing literature.

Adriatic Sea
No records of seabird bycatch could be found in the existing literature.

Eastern Mediterranean
No records of seabird bycatch could be found in the existing literature.

1.4 Outlook

1.4.1 Records on the distribution of seabird bycatch

The records presented in this report are sourced from a variety of approaches, including regular monitoring programmes with onboard observers as well as non-systematic, opportunistic data collection such as questionnaire surveys with fishers, tagging/ringing-recovery programmes of seabirds, personal comments from scientists, self-reporting by fishers, beach surveys or recoveries from wildlife centres. Figures 1–3 present tallies of events involving seabirds caught accidentally by fisheries (2008–2018) grouped by GFCM subregion, country and vessel group. Each event represents the incidental catch of seabirds (from 1 to 200) during one fishing operation (Cortés, García-Barcelona and González-Solís, 2017). Studies, personal comments and reports of single events were counted equally within the same record, with the awareness that this puts a strong study bias on rare events, lending them the same weight as studies reporting regular bycatch occurrence. When a study addressed several vessel groups/gear types, it was counted for each relevant group or gear type (Figure 3).

Seabird bycatch by GFCM subregion
Overall, the data available on seabird bycatch in fisheries of the Mediterranean and the Black Sea are scarce and unequally distributed, with data mainly gathered in the western Mediterranean

(Figure 1). No records could be found for the Black Sea or from African Mediterranean countries. About 68 percent of the records found originated from the western Mediterranean Sea, with only some data available from the other GFCM Mediterranean subregions: eastern (16.7 percent), central (9.7 percent) and the Adriatic Sea (6.5 percent). More specifically, the records from the western Mediterranean Sea were sourced from Italy (6.9 percent), and especially from Spain (63.3 percent), where the only study with regular data collection of seabird bycatch over a long time period (2000–to date) could be found; this observer programme on longliners targeting large pelagic fish species is conducted by David Macías López and Salvador García-Barcelona (Spanish Institute of Oceanography (IEO), Málaga, Spain). Additionally, for this subregion, a number of other records were gathered through opportunistic data collection (for example, see Zamora Urán, 2014, 2015; Garibaldi, 2015; Genovart *et al.*, 2016, 2017), while some data were also obtained from personal onboard observations over longer timeframes during ship cruises (J.M. Arcos, personal communication, in Cama and Arcos, 2013; F. Garibaldi, personal communication, 2018; Cortés, Arcos and González-Solís, 2017) and from the recovery of banded birds (Genovart *et al.*, 2016, 2017). No published data of this kind could be found for any of the other Mediterranean subregions or for the Black Sea. For the central Mediterranean, records came from Malta only, while for the eastern subregion, information was obtained from Greece and Turkey (Figure 2). One record for the Adriatic Sea refers to Croatia, while the other could not be assigned to any country.

FIGURE 1
Number of recorded events of seabird incidental catch by GFCM subregion

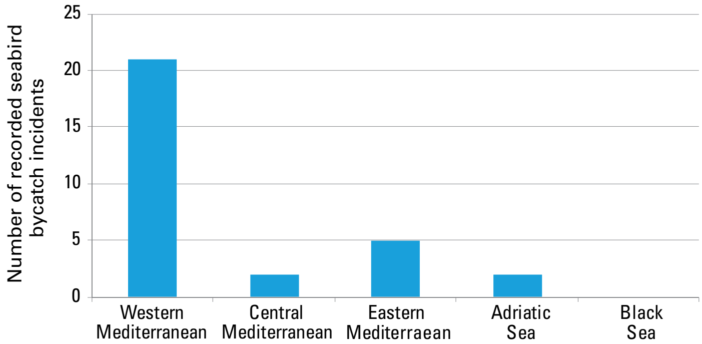


FIGURE 2
Number of recorded events of seabird incidental catch by country

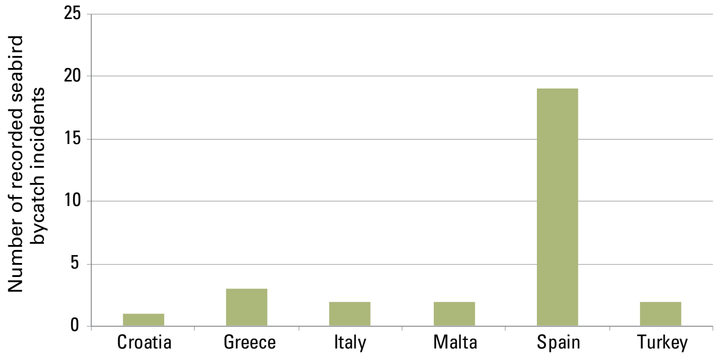
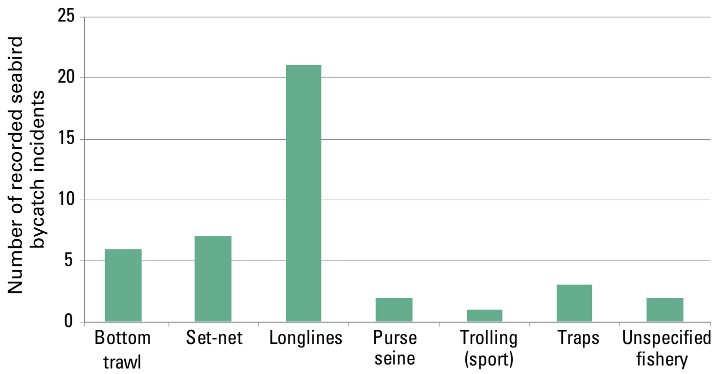


FIGURE 3
Number of recorded events of seabird incidental catch by fishing gear



This general tendency is partly in line with a data assessment performed by the United Nations Environment Programme (UNEP) on the Mediterranean quality status (UNEP-MAP, 2017). This report highlights that data for seabird distribution and abundance in the Mediterranean showed an increasing seabird diversity gradient from southeast to northwest. With the acknowledgement that some seabird species may be rare or absent in the eastern Mediterranean, this gradient was also associated with varying degrees of monitoring effort, since for many countries in the southern and eastern part of the Mediterranean, information is patchy or completely lacking; this applies to some countries of the Adriatic Sea as well (UNEP-MAP, 2017). Similarly, other authors from the eastern Mediterranean have already recognized the current dearth of information and requested more basic data on seabird population assessments and distribution patterns (for example, Zakkak, Panagiotopoulou and Halley, 2013; Turan *et al.*, 2016). The information on the distribution, feeding sites, demographic parameters and size of certain seabird populations is essential for the identification of important bird areas (IBAs), as well as for assessing the effects of fisheries on seabird populations (UNEP-MAP, 2017).

The reasons behind the observed unequal data distribution across the Mediterranean are unclear. One possible explanation could involve the relation between incidental catch numbers and fishing capacity across the GFCM area of application. According to the 2018 report on *The State of Mediterranean and Black Sea Fisheries* (FAO, 2018b), over 86 500 fishing vessels (as of 2017) are registered in the Mediterranean and the Black Sea. Even though this should be considered as an underestimate of the real fleet size, as it lacks information specifically on small-scale fleets (FAO, 2018b), it provides data on the distribution of vessels across the Mediterranean subregions and the Black Sea. According to this report, most vessels are registered in the eastern (30.6 percent) and central (26.4 percent) Mediterranean, while the vessel number is lower in the western Mediterranean (17.3 percent), the Adriatic Sea (12.3 percent) and the Black Sea (13.4 percent). Polyvalent vessels (defined as vessels using more than one gear type, either passive and/or active) represent the main share of all vessel groups over all GFCM subregions (Mediterranean Sea mean: 77.8 percent; Black Sea mean: 91.3 percent) (FAO, 2018b). Higher percentages were found for specific vessel groups in certain subregions, such as in the Adriatic Sea, where trawlers represent 15 percent of vessels, the western Mediterranean, where trawlers account for 13 percent and purse seiners/pelagic trawlers account for 11.6 percent), and the eastern Mediterranean, where "other vessel groups," including all longliners, comprise 17.7 percent of vessels) (FAO, 2018b).

Further complicating the picture, a comparison of the fishing capacities and shares of fishing vessels (percentage share of total in the Mediterranean and the Black Sea) of single countries from which records were obtained shows that Spain, with by far the most available records, exhibited a distinctly lower value than Italy, Croatia and Greece, and a slightly lower value compared to all North African Mediterranean countries (FAO, 2018b). Consequently, no direct link could be found between the overall fishing capacity of single countries or GFCM subregions and the currently available information on seabird bycatch. It is assumed that many additional aspects contribute to the observed unequal data distribution. On the one hand, financial resources of European countries may be greater compared to those of developing countries, but this difference cannot be the only reason, as a lack of data from more prosperous regions has already been indicated by several authors (for example, Anderson *et al.*, 2011; Žydelis, Small and French, 2013; Lewison *et al.*, 2014; Fangel *et al.*, 2015). Therefore, among the many aspects hampering the collection of this kind of information (for example, Fangel *et al.*, 2015), a scientific emphasis on certain regions or countries may explain some trends observed in the present data distribution.

Additionally, a current general unawareness of this problem is reflected by the very few records available indicating zero seabird bycatch (Burgess *et al.*, 2010; J.M. Arcos, personal communication, 2019 in Cama and Arcos, 2013; Fric *et al.*, 2013, Ceyhan and Akyol, 2014; Garibaldi, 2015). Considering the present shortage of seabird bycatch information, especially with regard to certain areas of the Mediterranean and the Black Sea, these kinds of "negative records" may be highly useful for obtaining greater insight into efforts taken toward tackling this issue in different areas and vessel groups. In several studies on the incidental catch of vulnerable species (marine mammals, sea turtles and elasmobranchs) in different vessel groups of the Mediterranean and the Black Sea (for example, Ceylan, Şahin and Kalayci, 2013; Tsagarakis, Palialexis and Vassilopoulou, 2014; Fortuna *et al.*, 2010; Bonanomi *et al.*, 2018), sometimes it is not clearly stated whether seabirds were even considered. Therefore, it would be highly advantageous if studies publishing data and information on incidental catch indicated whether or not seabirds were observed in bycatch.

Seabird bycatch in relation to vessel group/fishing gear

In terms of the overall impacts of vessel group/fishing gear, no records of seabird bycatch were found for pelagic trawls (midwater pair trawls), tuna seiners or dredgers. In contrast, most records referred to the longline fishery (see Figure 3). This dynamic may be due in part to the recommendation from ICES to give priority to monitoring of, and data collection from, set longline fisheries in the European Union's Mediterranean countries (ICES, 2013a). Additionally, it may also reflect the higher susceptibility of seabirds to being caught in longlines and the concern shared by scientists regarding this impact. Moreover, the longline fishery is of high importance in the Mediterranean Sea, specifically in the western part, with Spain boasting the largest longline fleet, consisting of 389 vessels (FAO, 2016) and characterized by a great diversity of longline gear and configurations for targeting different commercial fish species in coastal and offshore areas (Valeiras and Camiñas, 2003; Macías López *et al.*, 2012). Lastly, the Mediterranean is inhabited by some endemic and threatened (according to the IUCN Red List) shearwater species, for whom the western part represents an important area for breeding colonies, as well as a major feeding ground, for other seabirds as well (Cortés, Arcos and González-Solís, 2017). For instance, it hosts the entire global population of the critically endangered Balearic shearwater (*Puffinus mauretanicus*) and an important portion of the Audouin's gull (*Larus audouinii*) population. Thus, the higher fishing activity and the increased susceptibility of these seabirds to different kinds of fishing gear (for example, Cortés, Arcos and González-Solís, 2017) may have contributed to increased efforts and number of studies performed in that area.

About 50 percent of the available literature and records in the Mediterranean on seabird bycatch refer to longline fisheries, followed by set nets (16.7 percent) and bottom trawls (14.3 percent) (see Figure 3 for absolute values). This sequence is in line with data available from other regions of the world, which indicate that research effort is focused on the impacts of longlines and set nets (Žydelis *et al.*, 2009; Pott and Wiedenfeld, 2017). However, some authors have stressed that seabird bycatch represents a "multi-gear problem," with high bycatch rates recorded in trawl fisheries from the Southern Hemisphere (see Moore and Žydelis, 2008, and references therein). In contrast, the very few data available for the Mediterranean and the Black Sea, sourced from only European countries, indicate instead a low to medium risk of seabird bycatch in trawl fisheries (midwater and bottom) (ICES, 2013b). This risk estimate is based on expert opinions considering the likelihood of bycatch of certain taxa by each vessel group/fishing gear and integrates the abundance data for these taxa and the fishing effort of all gear types from countries where this information is available, i.e. mostly the Mediterranean and Black Sea countries that are part of the European Union

(ICES, 2013b). Furthermore, the available literature indicates rather low mortality of seabird populations from trawl fisheries in the Mediterranean and the Black Sea (Tudela, 2004; Ancha, 2008; Abelló and Esteban, 2012), though current information on this potential impact is scarce and more research is needed to conduct a proper assessment (Abelló and Esteban, 2012). Other types of fishing gear, such as purse seines and traps, were considered to be of rather low risk for seabirds. Nevertheless, the scarce available data presented in this review highlight again the need for more information and systematic data collection, as in other geographical areas, some severe impacts on seabirds were recorded by purse seiners and also trawlers (for example, González-Zevallos, Yorio and Caille, 2007; Waugh, MacKenzie and Fletcher, 2008; Shester and Micheli, 2011; Maree *et al.*, 2014; Suazo *et al.*, 2014; Oliveira *et al.*, 2015; Baker and Hamilton, 2016).

Longliners

Available data confirm that longliners can have a higher impact on seabirds in some coastal areas of the Mediterranean Sea. In almost all cases, when seabird bycatch was recorded, shearwater species were represented in the bycatch (see Table 4). Generally, however, the extent of seabird bycatch may differ between drifting and set longliners (for example, García-Barcelona *et al.*, 2010; Báez *et al.*, 2014). Indeed, in studies that considered both set and drifting longliners, estimates of annual seabird bycatch were always lower in the drifting than in the set longlines (Dimech *et al.*, 2009; Cama and Arcos, 2013; Karris *et al.*, 2013), which is in line with the available data at the global scale (Anderson *et al.*, 2011). In particular, seabird bycatch in small-scale set longlines is more common and results in a higher mortality rate, specifically for the three endemic shearwater species (Dimech *et al.*, 2009; Darmanin, Caruana and Dimech, 2010; FAO, 2016; Cortés, Arcos and González-Solís, 2017; Cortés and González-Solís, 2018; SEO/BirdLife, 2019). However, incidental catch events in drifting longlines usually affect high numbers of caught seabirds (>100) (Garcí-Barcelona *et al.*, 2016; Genovart, Oro and Tavecchia, 2017).

The higher seabird bycatch in small-scale set longlines compared to drifting longlines is explained by the smaller hook and bait size used, which increase the likelihood of their being swallowed by various seabird species (Cortés and González-Solís, 2018). Furthermore, studies from the western Mediterranean Sea showed that small-scale longliners exhibit higher seabird bycatch in comparison to those of the industrial fleet (BirdLife International, 2017b; Cortés, Arcos and González-Solís, 2017). Similarly, in the eastern Mediterranean, higher seabird bycatch in longline and set net fisheries was also observed on vessels fishing closer to the coast (Karris *et al.*, 2015). It has been suggested that small-scale fisheries may cause high seabird bycatch because they fish in proximity to the coast, often close to breeding colonies or rafting areas and in shallow waters (Karris *et al.*, 2015; BirdLife International, 2017b; Cortés, Arcos and González-Solís, 2017; Sánchez-Román *et al.*, 2019). However, in comparison to larger fisheries, mortality rates can generally be lower, owing to the lower setting speed of small-scale vessels, as fishers are able to stop and release hooked birds alive. Additionally, these vessels fish in shallower waters and may use longlines equipped with lighter weights and longer branch lines, which can allow birds to reach the surface and breathe, thus increasing their chances of survival (for example, BirdLife International, 2017b; Cortés, Arcos and González-Solís, 2017).

The greater research effort made on seabird bycatch due to longline fisheries (especially in the western Mediterranean) has resulted in more information being available concerning the factors and parameters influencing these incidents than for other types of fishing gear. Several studies and experiments have addressed the impacts of a number of factors on seabird bycatch, such as weather conditions, distance from the coast, gear configuration, bait type, time of day of setting, target species of the fishery, breeding or non-breeding periods (BirdLife International, 2017b; Cortés, Arcos and González-Solís, 2017; Gladics *et al.*, 2017; Cortés and González-Solís, 2018; Cortés, García-Barcelona and González-Solís, 2018), and even the presence or absence of other fisheries in the area (Laneri *et al.*, 2010; Soriano-Redondo *et al.*, 2016). These studies provide a comprehensive basis for the development of proper mitigation measures, still lacking for other types of fishing gear. Nevertheless, as already mentioned, most of the studies reported above were undertaken in the northwestern Mediterranean and coverage should be extended to other regions of the Mediterranean and the Black Sea. Clearly, further work must be carried out on gear configurations and operational practices in order to avoid seabird bycatch without compromising the ability to catch targeted fish. Additionally, more information on the survival rates of released birds is highly necessary to obtain a complete assessment of fishery-induced mortality, as well as to develop rescue protocols to maximize survival likelihood (BirdLife International, 2017b).

Small-scale fisheries

Gillnets and set nets (anchored or floating in the water column) can create a risk of entanglement when seabirds are diving for benthic prey and fish (Žydelis, Small and French, 2013). Some of the specific traits of set nets used in the Mediterranean and the Black Sea vary, mainly depending on the species targeted (pelagic or demersal), which in turn influence the season, as well as the fishing location (spatial and temporal target species availability) (Maynou, Recasens and Lombarte, 2011). Therefore, set nets are used at different distances from the coast (close to the shore or offshore), at varying depth ranges (in deeper or shallower waters), and in a variety of fishing areas (potentially overlapping with important seabird foraging or breeding areas), thereby potentially exposing seabirds to incidental catch, depending on the traits of each species (for example, foraging distances, hunting behaviour under water, diving depth) (Oppel *et al.*, 2018). Although fewer data are available for gillnets and entangling nets than for longlines, records indicate occasional impacts of these gear types on local populations of seabirds, especially on cormorants/shags and grebes, but also on shearwaters (see Table 2), notably small shearwater species (SEO/BirdLife, 2019). For diving seabirds (for example, cormorants, shags, grebes and small shearwater species), the risk of getting caught in fixed demersal set nets is higher than for surface seabirds, who exhibit a higher risk of capture in pelagic nets or longlines (for example, gulls, terns and large shearwaters). The bycatch of diving seabirds is explained by their intense diving behaviour, as well as by the strongly coastal behaviour of some species, such as cormorants and shags (Grémillet and Wilson, 1999; Bildsøe, Jensen and Vestergaard, 2008), which increases the likelihood of entanglement in coastal set nets. Regarding shearwaters, small shearwater species such as *Puffinus* spp. (notably the Balearic and Yelkouan shearwaters) may forage closer to the coast than larger species, resulting in a higher susceptibility to capture by set nets for those smaller species. Moreover, small shearwater species exhibit stronger diving behaviour than large shearwaters, such as *Calonectris* spp. (including Scopoli's shearwater), thus further increasing their risk of incidental catch. While the overall impact of set nets is assumed to be lower in the Mediterranean in comparison to other geographical areas (Žydelis, Small and French, 2013), this cannot be confirmed as data are still scarce or lacking from several subareas of the Mediterranean and the Black Sea (see Žydelis *et al.*, 2009; Žydelis, Small and French, 2013).

Regarding mitigation measures, very little and only rather general information exists for set nets, in comparison to longlines. Usually, the species and number of individuals caught by gillnets and entangling nets depend on several factors, such as location, weather conditions, water transparency, time of day, setting depth, soak time, mesh size and seabird abundance (Žydelis, Small and French, 2013). In 2016, the European Union adopted new fisheries management measures for its countries, including in the Mediterranean and the Black Sea. Although these included technical measures for static nets (such as twine thickness and mesh size) and temporal and spatial closures in certain areas, no precise mitigation measures were adopted to address seabird bycatch. Given the relatively short foraging distances from the coast of the seabirds most affected by set nets (Oppel *et al.*, 2018), some authors advised that new measures should establish a minimum distance from seabird breeding areas for the setting of static nets (Tarzia *et al.*, 2017a). Mitigation measures studied in other geographical areas, such as acoustic or visual alerts, could potentially decrease seabird bycatch under specific conditions (Bull, 2007; Mangel *et al.*, 2014; Martin and Crawford, 2015; Hanamseth *et al.*, 2018). While further studies concerning the efficacy of different mitigation measures are still necessary, it has been suggested that a combination of measures might be more effective than one single solution (Bull, 2007). Additionally, another approach likely to decrease seabird bycatch rates could be in the adjustment of setting time (for example, at dawn or dusk, or in the daytime), though this requires a comprehensive knowledge of the temporal movement and behavioural activity of seabirds (Bull, 2007), which is often lacking in the Mediterranean and the Black Sea.

1.4.2 Data collection: progress and challenges

Overall, most seabird bycatch records refer to longlines and set nets, which are often used in small-scale fisheries. However, in many geographical areas, small-scale fisheries are currently not monitored properly with regard to impacts on non-target species (Hanamseth *et al.*, 2018). Although less studied than industrial fisheries, small-scale fisheries may have negative effects on seabirds (Žydelis *et al.*, 2009; Laneri *et al.*, 2010). Furthermore, considering the scale and frequency of seabird bycatch in some areas of the Mediterranean, it is highly recommended to begin studying and understanding the nature and extent of interactions between seabirds and fisheries throughout the entire basin in a systematic way.

In fact, most of the available data on seabird bycatch are derived from opportunistic and irregular surveys, such as beach surveys, ringing-recovery programmes and non-systematic onboard observations. A relevant part of the data also comes from interview-based studies and self-reporting questionnaires, but the lack of a standardized protocol before recently (FAO, 2019) has impeded the assessment of data reliability and comparisons between studies (Moore *et al.*, 2010). Nevertheless, interviews with fishers can provide important qualitative information, especially for data-poor areas, and provide indications on the basic dynamics of seabird bycatch, such as the extent of its occurrence, the species involved and the most critical periods (Moore *et al.*, 2010; Cortés, Arcos and González-Solís, 2017). In general, alternative, and more robust, carefully designed monitoring methods (for example, standardized onboard observations and questionnaires, including for small-scale fisheries) are required to correctly estimate seabird bycatch (Žydelis *et al.*, 2009; Fangel *et al.*, 2015), despite the challenges involved with pursuing such objectives: effective onboard observer programmes are expensive, for example, and data collection is a time-demanding task, involving multiple shiptime operations over many trips (Moore and Žydelis, 2008; Žydelis *et al.*, 2009; Fangel *et al.*, 2015). Nevertheless, this approach currently seems to offer the most reliable way forward in understanding the impacts of fisheries on seabirds, as well as on other vulnerable species. The use of remote electronic monitoring by cameras – already used in some parts of the world to monitor bycatch – can be especially relevant for studies concerning small-scale fisheries, where systematic onboard observations are often not feasible (Moore *et al.*, 2010; Bartholomew *et al.*, 2018).

The current dearth of data is also due to the fact that the activities of all fishing vessels cannot be controlled systematically. Some Mediterranean fishing vessels are equipped with the satellite-based VMS, which provides data on location, course and vessel speed to fisheries authorities at regular intervals (GFCM, 2009, 2014; Burgos, Gil and Del Olmo, 2013). However, this monitoring system is only compulsory for European Union vessels above 12 m length overall and for non-European Union vessels above 15 m length overall, while smaller fishing vessels are not obliged to use this system. Similarly, these criteria also apply to the AIS, which helps to identify and monitor fishing vessels continuously (Kroodsma *et al.*, 2018).

The data presented in this review indicate that most seabird bycatch data come from small-scale fisheries (particularly longliners and set nets), which are active close to the coasts where the breeding or rafting sites of several seabird species are located. Unfortunately, small-scale fisheries use relatively small boats, from 6 to 15 m long (BirdLife International, 2017b; Cortés, Arcos and González-Solís, 2017; GFCM, 2018), many of which measure below the length requiring positioning systems. Therefore, to understand the potential impact of small-scale fisheries on seabirds, it is essential to obtain reliable information on the fishing effort of this vessel group, which entails knowing when, where and what gear they use year-round (Burgos, Gil and Del Olmo, 2013; GFCM, 2018).

In terms of regional instruments, the GFCM issued a recommendation for the development of mechanisms to record potential seabird bycatch incidences in Mediterranean fisheries and to keep them to the "lowest levels possible," specifically with regard to those species listed in the Barcelona Convention, and produced good practice guides for the handling of seabirds caught incidentally in Mediterranean drifting longline fisheries (GFCM, 2011; Tarzia *et al.*, 2017a; FAO and ACCOBAMS, 2018; FAO 2019). In addition, European Union countries can apply measures through the process detailed under Article 11 of the Common Fisheries Policy – specifically for measures related to marine protected areas (MPAs). However, no European Union country has yet proposed joint measures to tackle seabird bycatch in their MPAs through this process. The European Commission further proposed that the European Union adopt a regulation to conserve the marine environment through technical measures in 2016 (European Commission, 2016a), with the intention of applying baseline mitigation measures to all European Union longline vessels in the Mediterranean.

The above-mentioned developments reflect an increasing awareness of the issue of seabird bycatch in the Mediterranean Sea. This change also comes out of work carried out by many scientists (universities, research institutes, non-governmental organizations) in different countries (for example, Greece, Italy, Malta, Spain and Turkey) within the framework of research projects and programmes, such as the LIFE programme of the European Union (Hellenic Ornithological Society, 2012; Fundación Biodiversidad, 2014; BirdLife Malta, 2016, 2019; European Commission, 2021).

Overall, developments and technical advances in recent decades have allowed for new approaches in studying seabird–fishery interactions and identifying high-risk areas of incidental catch. The advances made in communication markets and in the miniaturization of electronics (sensors, batteries, improved memory storage) have increased exponentially the possibilities to study the biology and ecology of seabirds and other megafauna, including their physiology and behaviour, by means of satellite tracking, geolocation, GPS, accelerometers, ship radar detectors and other loggers (López-López, 2016; Hays *et al.*, 2016; Weimerskirch *et al.*, 2018). Furthermore, current technical advances allow fishery data (such as VMS and AIS) gathered on a large spatial and temporal scale to be collected and made accessible, helping to identify areas with high fishing activity and relate these dynamics to seabird movement and behaviour (for example, Sugishita, Torres and Seddon, 2015; Soriano-Redondo *et al.*, 2016; Le Bot, Grémillet and Lescroël, 2018). Similar to seabird tracking data (for example, BirdLife International, 2021), the world wide web provides data from global ship tracking (VMS/AIS) on online platforms (for example Global Fishing Watch, 2017), enabling the assessment of potential overlaps between fishing effort and the distribution of marine megafauna, even in areas where surveillance is challenging owing to logistical issues. However, despite calls for the urgent implementation of these types of monitoring systems across the entire fishing fleet, including small-scale vessels, many fishing vessels are not yet obliged to carry monitoring systems (see above), undermining the potential of these approaches. A novel approach could be the use of cameras onboard fishing vessels to record the incidental catch of vulnerable species (for example, Bartholomew *et al.*, 2018).

Research projects over the last decade (2009–2019) have led to an increasing number of studies dealing with seabird bycatch in the Mediterranean Sea (for example, Darmanin, Caruana and Dimech, 2010; Laneri *et al.*, 2010; Karris *et al.*, 2013; Báez *et al.*, 2014; Ceyhan and Akyol, 2014; Garibaldi, 2015; Genovart, Oro and Tavecchia, 2017; Cortés, García-Barcelona and González-Solís, 2018). These investigations refer not only to scientific peer-reviewed publications, but also to reports from NGOs, such as BirdLife International and their national partners (for example, BirdLife International, 2009, 2017a; SEO/BirdLife, 2014). Besides the publication of valuable scientific papers and reports related to this topic, scientists and partners within research projects/programmes have also conducted awareness campaigns with dissemination activities and materials aimed at fishers (such as cards and posters to help identify seabird species). Furthermore, they inform authorities and provide recommendations to decision makers, as well as enable concerned citizens to understand and become aware of the issue of seabird bycatch. These activities include, for instance, the recruitment and training of volunteers, the distribution of questionnaires for the general public, meetings with institutions and national authorities, and events such as exhibitions and public lectures (for example, Fric, 2013).

In particular, seabird bycatch mitigation requires increasing commitment from national authorities to take responsibility for tackling the issue, with greater awareness and involvement from the fishing community (Cortés and González-Solís, 2018). For instance, under the framework of BirdLife International, together with their national partners, experts and scientists, a European Task Force has been established in order to enhance collaboration with fishers toward improving knowledge of seabird bycatch and developing technical solutions (Tarzia *et al.*, 2017a; BirdLife International, 2017b).

The data presented in this review are often sourced from questionnaire surveys of fishers. These interviews not only provided valuable information on seabird incidental catch, but they also raised the awareness of this issue among the fishing community. Some authors have already highlighted that the systematic collection of data depends greatly on the collaboration and willingness of fishers, which is often a limiting factor (Žydelis *et al.*, 2009; Fangel *et al.*, 2015; Oliveira *et al.*, 2015). This complication is understandable considering that logbook entries and questionnaires add extra work to the fishers' schedules and are related to an issue of a "somewhat discomforting character" for them, if they are asked to report detailed information on incidental catch (Fangel *et al.*, 2015).

This dilemma has been acknowledged by most scientists who collaborate with fishers; some scientists further highlighted that an intended "seabird bycatch mitigation strategy" should be targeted among other objectives, offering practical, easy to implement and manage, safe, and cost-effective alternatives for the fishers (Maree *et al.*, 2014; Cortés and González-Solís, 2018). A practical mitigation strategy would also be in the fisher's' best interests, at least for small-scale fisheries, where proper mitigation measures can not only reduce seabird bycatch, but also prevent bait loss and interruptions in settings when birds are released (BirdLife International, 2017b; Cortés, Arcos and González-Solís, 2017). In conclusion, there is currently an urgent need to improve the methods for recording fishing effort and incidental catch, particularly in small-scale fisheries, and to understand more precisely the factors influencing interactions between seabirds and fisheries in order to develop and implement appropriate mitigation measures. Finally, the achievement of these objectives can only be guaranteed through the assistance and collaboration of fishers, scientists, conservationists and policy makers (Oliveira *et al.*, 2015).

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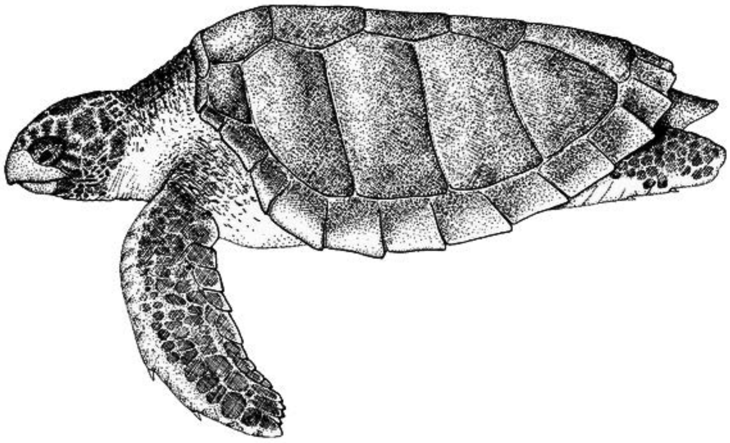
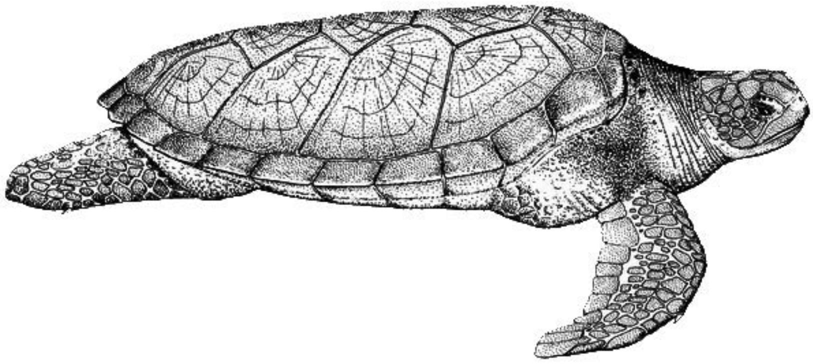
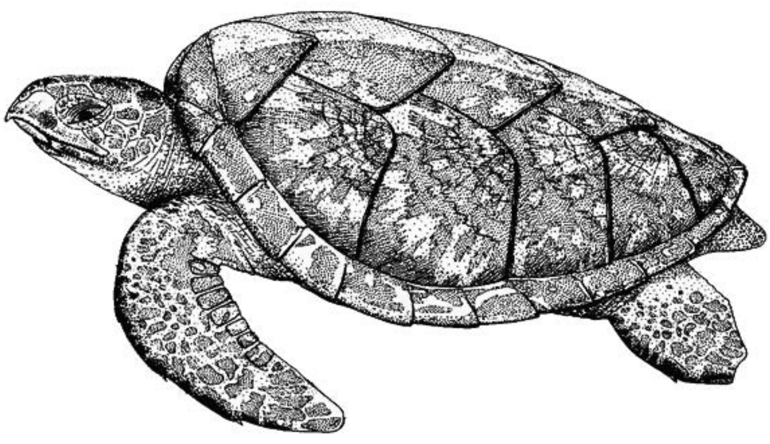


SEA TURTLES





Green sea turtles (*Chelonia mydas*)

2. Sea turtles

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Executive summary

In the Mediterranean and the Black Sea, scientific efforts over the last ten years have focused on the study of sea turtle biology, ecology and the protection of nesting sites. As a result, fairly complete information is available on sea turtles' major migratory routes, prey preferences, neritic foraging habitats, growth rates, genetic structure, and the areas hosting their main nesting sites, among other important traits and behaviours. However, some knowledge gaps still remain on key aspects of biology and ecology, particularly on interactions with sea turtles in areas of fishing activity. These gaps mainly persist because structured and standardized surveys for the observation of sea turtle bycatch have not yet been developed. The bycatch estimates presented in this review are mostly based on documents and data obtained by onboard observers and from interviews with fishers. These estimates are often biased, however, by a lack of reliable information representing the entire fleet and fishing effort, resulting in high variability between geographical areas, years and fishing gear. However, the information gathered up to now allows an outline to be drawn of the impacts of different types of fishing gear on sea turtles and of the most impacted areas. In the last ten years, bottom trawling has become the fishery with the greatest impact on sea turtles, registering around 51 000 capture events and an estimate of around 9 000 dead, largely concentrated on the continental shelves of the northern Adriatic Sea, Tunisia, Egypt and Turkey. Drifting longliners and set net fisheries are responsible for the bycatch of about 27 000 and 31 000 sea turtles, respectively, with about 5 300 and 16 000 dead, especially in the western and central Mediterranean. Set longlines catch around 12 000 sea turtles each year, causing the death of around 2 600, with the eastern and the southcentral Mediterranean the areas of main concern. The presence of sea

turtles in the Black Sea is so rare that it is not feasible to assess the impact of fishing activities, even if some specimens are occasionally found in set nets. Direct mortality rates show great variability between different types of fishing gear, but also within the same gear based on several factors: gear-related features (including mesh opening size and net slackness in passive nets, hook size and shape, branch line length in the longline, etc.); operational factors (e.g. soaking time in set nets, depth setting in the longlines, towing time in bottom trawls, etc.); environmental factors (such as sea water temperature); and ecological factors (e.g. sea turtle–fishery interactions occurring wherever fishing activities overlap with sea turtle habitats). Set nets, and especially trammel nets, appear to be responsible for the highest direct mortality rate (51 percent on average). Compared to the oldest estimates, the current figures seem to lend increased importance to bottom trawls, which could be considered the most impactful of fishing activities, while sea turtle bycatch in drifting longlines appears to be far less dramatic than depicted in the past. This shift is due to recent advanced data analysis, which considers the diversity of catch rates associated with longlines used in different areas and targeting different commercial species (such as swordfish, albacore and bluefin tuna). Moreover, the introduction of the mesopelagic longline, in early 2010, seems to have strongly reduced sea turtle bycatch in Spanish and Italian waters. In this regard, the implementation of technical solutions for reducing sea turtle bycatch in the Mediterranean is either low or non-existent. Thus, bycatch reduction devices (BRDs) should be tested more and adapted according to fishing gear, country and fishery. Apart from the negative impacts on sea turtle populations, the incidental catch of sea turtles can also cause losses in earnings through damage done to nets. Therefore, as many projects have demonstrated, collaboration with fishers is key to decrease incidental catch and reduce delayed mortality. Involving fishers and establishing permanent cooperation with them are fundamental for increasing the chances of sea turtle post-capture survival. Awareness campaigns on handling sea turtles should be further encouraged for fishers, personnel operating in the rescue centres, those involved in the protection of nesting sites and for local people who live in these coastal areas. However, this type of campaign needs to be complemented and reinforced by a binding cooperation between the fishing industry, management bodies and research institutions, whose collaboration is paramount for the protection of sea turtles.

2.1 Description of the group

The Mediterranean Sea hosts populations of three sea turtle species: the loggerhead sea turtle (*Caretta caretta*), the green sea turtle (*Chelonia mydas*) and the leatherback sea turtle (*Dermochelys coriacea*). While the loggerhead sea turtle is quite common everywhere in the Mediterranean, with important nesting sites in Greece, Libya, Turkey and Cyprus, the green sea turtle is less common and mainly inhabits the easternmost part of the Mediterranean (Turkey, Syria, Cyprus, Lebanon, Israel, Egypt, Greece and Libya), with nesting sites in Turkey, Cyprus and Syria. Some individuals of green sea turtle can be found rarely in the Adriatic Sea, in Tunisia, in Malta and in the western part of the basin. The leatherback sea turtle is rare, and although it is almost certain that the species does not nest in this basin, it is occasionally observed throughout the Mediterranean (Camiñas, 1998; Bradai and El Abed, 1998; Bradai *et al.*, 2004). The olive ridley turtle (*Lepidochelys olivacea*) is also found in the Mediterranean on rare occasions, having been reported in Spain (Revuelta *et al.*, 2015), as well as the Kemp's ridley (*L. kempii*) turtle, observed in Spain, France, Malta and Italy (Oliver and Pigno, 2005; Tomás and Raga, 2008; Insacco and Spadola, 2010; Sénégas, Sacchi and Lescure, 2016; Carreras *et al.*, 2014) and the hawksbill turtle (*Eretmochelys imbricate*), which has been reported in France, Albania, Malta, Tunisia and Spain (Mourgue, 1909; Frommhold, 1959; Groombridge, 1989; Brongersma and Carr, 1983; Mateo and Pleguezuelos, 2001; Gasc *et al.*, 2004; Bellido *et al.,* 2006;).

In the Black Sea, the loggerhead sea turtle (*Caretta caretta*) is found mostly in the western part of the basin (Nankinov, 1999), though there are no nesting beaches and observations are quite unusual (Márquez and Bauchot, 1987). Even rarer is the presence of the green sea turtle, with some sightings from the western side of the basin (Nankinov, 1999; Öztürk *et al*., 2011), and one confirmed record from the eastern side in 2016, which was incidentally caught by a gillnet targeting Atlantic bonito (Orhan *et al*., 2016). Accordingly, sea turtle bycatch seems not to be a conservation issue in the Black Sea.

Since the early 1980s, loggerhead, green and leatherback turtles have been included, among other sea turtle species, in the lists of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and on the Red List of the International Union for Conservation of Nature (IUCN), although the conservation activities of several non-governmental organizations began even earlier, in the late 1970s (Casale *et al*., 2018).

Human-induced, on-land threats to sea turtle populations are mainly associated with modifications made to the beaches hosting nesting sites. The construction of new buildings, coastal erosion and sediment changes (due, for example, to breakwater barriers, beach nourishment and beach cleaning) reduce the habitat available for nesting, thus preventing females from accessing suitable nesting sites. Furthermore, artificial lights from land can scare away females approaching the beaches and disorient hatchlings. Similarly, tourist activities can discourage females from coming ashore, with particular concern around motorboat strikes in busy waters frequented by sea turtles. In addition, the presence of other animals (such as dogs, foxes, birds and crabs) can present an issue for the survival of clutches and hatchlings. Indeed, it has been estimated that predation levels at unprotected nests can range from 38 to 80 percent of the individuals (Demetropoulos and Hadjichristophorou, 2010; Fuller *et al*., 2010). Climate change can also have negative effects on sea turtle nesting areas, causing increased storm frequency and sea level rise, heightening the risk of nest inundation (especially of those not monitored) (Varela *et al*., 2019), and can lead to a "coastal squeeze," i.e. reducing the number of beaches and amount of space available to the turtles (Casale *et al*., 2018). Moreover, rising ambient temperatures, which affect incubation temperatures, can increase female sex bias or compromise the success of nests.

So far in the Mediterranean, stranded individuals represent the best available source of information on the relative importance of different threats. The indication is that interactions with fisheries constitutes one of the main causes of sea turtle mortality in the Mediterranean Sea (Camiñas, 2004; Bjerregaard Walsh, 2018; Casale *et al*., 2018). Conversely, scientific studies on sea turtles in the Mediterranean, which began in association with conservation projects, have mainly focused on the monitoring and protection of nesting sites.

2.1.1 Loggerhead sea turtle

On a global scale, the IUCN Red List of Threatened species has listed the loggerhead sea turtle (*Caretta caretta*) as "Vulnerable," with a decreasing population trend observed (Casale and Tucker, 2017). However, according to the current IUCN Red List criteria, the status of the loggerhead sea turtle in the Mediterranean Sea has recently changed from "Endangered" to "Least Concern" (Casale, 2015). This revision is mainly due to the observation, in recent years, of a positive trend in the total number of nesting sites (used as an index of population abundance). However, using nesting females as a proxy for overall population dynamics comes with its own disadvantages and risks, as they represent only a small proportion of a sea turtle population. Moreover, the effort and methodologies in the monitoring of nests can vary within and across study sites. Thus, the "Least Concern" status should be taken with caution and considered as entirely conservation-dependent, as the current population numbers are the result of decades' worth of intense conservation efforts, especially at nesting sites (Casale and Margaritoulis, eds., 2010), and the cessation of these programmes would likely be followed by a population decrease. Due to the long sexual maturation time of these animals and the available indexes of abundance (for example, nest counts), the Mediterranean subpopulation would probably not qualify for a threatened category within five years of the cessation of conservation programmes, as prescribed for triggering the "Near Threatened" category (IUCN Standards and Petitions Committee, 2014).

The loggerhead turtle is a highly migratory species inhabiting a wide range of habitats (<200 m depth) over the course of its lifetime. After hatching, young sea turtles begin an oceanic phase in major current systems, which are important for pelagic development. Heppell *et al.* (2003) report that sea turtle populations mainly consist of juveniles of small size that never come ashore. Juvenile loggerhead sea turtles usually float on the surface, are positively buoyant and prey upon epipelagic animals. After spending 4 to 19 years in pelagic environments, loggerhead sea turtles – once they have reached around 25 cm in curved carapace length (CCL) – gather together in neritic feeding areas rich in benthic prey and grow until they reach sexual maturity at 21 to 34 years (Avens and Snover, 2013 report 10 to 39 years; UNEP/MAP SPA/RAC, 2017). When foraging on the seabed, larger juveniles and adult loggerhead sea turtles feed upon benthic animals, like crustaceans (e.g. *Liocarcinus vernalis*) and molluscs, such as bivalves (e.g. *Mytilus galloprovincialis*), gastropods (e.g. *Bolinus brandaris*) and cephalopods. In some areas, they also feed on fish discarded by fishing vessels (Tomás, Aznar and Raga, 2001). In contrast, in oceanic habitats, loggerhead sea turtles are diurnal predators, spending most of their time close to the surface. Their diet is mainly composed of gelatinous plankton, such as jellyfish and tunicates, though it is also supplemented by fish and squid.

Adults migrate to breed between foraging grounds and nesting areas. During non-breeding periods, adults reside in coastal foraging habitats, sometimes with developing juveniles. Migration for breeding occurs every 2.5 to 3 years for females, while males have shorter migration intervals.

According to Wallace *et al.* (2010), the Mediterranean Sea is frequented by loggerhead sea turtles belonging to three independent regional management units: the Mediterranean, the northwest Atlantic and the northeast Atlantic; it seems that only individuals from the Mediterranean regional management unit reproduce in the region. The loggerhead sea turtle is common throughout the Mediterranean region, with high densities recorded in the westernmost part of the Mediterranean Sea (from the Alboran Sea to the Balearic Islands), the Strait of Sicily, Ionian Sea, Gulf of Gabès in Tunisia, Adriatic Sea, and off the southeastern coast of Turkey. Juveniles from rookeries originating in the Atlantic mostly remain within the westernmost part of the Mediterranean. The average size of nesting females has been used to estimate the age at sexual maturity of loggerhead sea turtles through growth models applied to size at maturity. The mean size of males and females nesting in the Mediterranean is 80 cm (Casale *et al.*, 2005a, 2014), with an average age at sexual maturity of 25 years (Casale and Heppell, 2016). Piovano *et al.* (2011) found that loggerhead sea turtles of Mediterranean origin grew faster than their conspecifics with Atlantic origins by exploiting the richer feeding grounds in the Mediterranean Sea. In agreement with Casale and Heppell (2016), they also discovered that the age of sexual maturity for loggerhead sea turtles of Mediterranean origin is 24 years; therefore, loggerhead sea turtles nesting in the Mediterranean are smaller and younger than those nesting in the western North Atlantic. Hochscheid, Kaska and Panagopoulou (eds., 2018) reported that 8 653 to 11 638 loggerhead sea turtle clutches are documented annually at 25 major (>20 nests and >10 nests/km/yr) and 72 minor (<20 nests or <10 nests/km/yr) nesting sites. Based on an estimated clutch frequency of two nests per female annually, these figures correspond to approximately 1 822 nesting females per year. Casale *et al.* (2018) reported that most of the annual nesting sites for loggerhead sea turtles (around 96 percent of the total) are located along the coasts of Greece (more than 3 300), Turkey (around 2 800), Cyprus (around 1 360) and Libya (around 600, even if knowledge gaps exist for this country). Loggerhead sea turtle (*Caretta caretta*) nesting sites also occur in much smaller numbers annually in Lebanon (around 55) and Tunisia (around 22). In recent years, loggerhead sea turtles have been consistently exhibiting low levels of nesting activity at locations in the western (Spain, Italy, France and Malta) and eastern Mediterranean (Israel, Egypt and Syria). On average, each clutch comprises about 110 eggs and the mean hatching success ranges between 56 and 86 percent.

The duration of incubation is negatively correlated with nest temperature and varies between Mediterranean beaches, ranging from 36 (Mingozzi *et al.*, 2007) to 89 days (Margaritoulis, 2005; Margaritoulis, Rees and Riggall, 2011).

Within the Mediterranean, the distribution of the loggerhead sea turtle is driven by the basin's main circulation system, as studies based on genetics, tagging and incidental catch have demonstrated – see Casale *et al.* (2018) and references therein. Recent satellite tracking studies and data from incidental catches of loggerhead sea turtle have revealed the southern Tyrrhenian Sea to be an important area for juveniles and adults foraging on pelagic prey (Blasi and Mattei, 2017; Luschi *et al.*, 2018). Other pelagic areas observed, probably used as foraging sites, are off Algeria, in the Strait of Sicily, and in the western and central Ionian Sea. Unfortunately, similar satellite tracking data are not available for all areas, particularly for the Levantine Basin.

Neritic foraging grounds are more frequented by larger individuals. The Levantine Basin seems to provide a nursery area for loggerhead sea turtles originating from eastern rookeries, whereas sea turtles hatching in Greece and the central Mediterranean nesting areas disperse mainly througout the Ionian Sea, southcentral Mediterranean and Adriatic Sea (Casale and Mariani, 2014). These dispersal patterns are supported by high incidences of small sea turtle (<30 cm) strandings along the Ionian and Adriatic coasts of Italy and the southern coasts of Turkey. Based on simulations, dispersal into the western basin is unlikely to occur during the first six months of life. The western basin of the Mediterranean is considered less suitable, as post-hatchlings would not survive the cold-water winter temperatures. However, recent observations of sporadic nesting sites on Spanish, French, and Tuscan (North Tyrrhenian Sea) coasts suggest increasing dispersal capabilities of the loggerhead sea turtle and the colonization of new suitable habitats, indicating an adaptability to changing environments (Sénégas *et al.*, 2009; Carreras *et al.*, 2018).

A rough indication of the abundance of individuals can be provided by specimens collected as incidental catch, particularly by bottom trawlers. The highest catch rates of loggerhead sea turtles in the Mediterranean have been observed over the continental shelves off Tunisia, in the Adriatic Sea and in the easternmost part of the Levantine Basin, off Turkey, Syria and Egypt (Casale, 2011). These results are also supported by flipper tagging, stranding reports and satellite tracking (Luschi and Casale, 2014). Loggerhead sea turtles are furthermore known to frequent some neritic areas in the western Mediterranean, including Spanish waters, the Balearic Islands and, to a lesser extent, the southwestern coast of Italy. Usually loggerhead sea turtles tend to spend the winter within or near their foraging areas.

In an attempt to provide a rough calculation of the loggerhead sea turtle population living in the Mediterranean, starting from nest counts and using other available data, Casale and Heppell (2016) estimated that the loggerhead turtle population (with several assumptions) lay between 1 200 000 and 2 360 000 individuals. Importantly, the population trend, based on a temporal comparison of nesting sites, seems to be positive.

2.1.2 Green sea turtle

The green sea turtle (*Chelonia mydas*) is listed as "Endangered" in the IUCN Red List and a decreasing population trend is observed (Seminoff, 2004). Young green sea turtles leave their nesting beaches just after hatching and begin an oceanic phase, floating passively in major current systems serving as pelagic habitats for development. After a number of years in these pelagic environments, the young turtles gather in neritic areas, rich in seagrass and/or marine algae, where they forage and grow until maturity. Once they reach sexual maturity (27–50 years), they begin to make breeding migrations between foraging grounds and nesting areas. During non-breeding periods, adults inhabit coastal neritic feeding grounds that sometimes coincide with juvenile developmental habitats.

The green sea turtle is mainly concentrated in the eastern basin, particularly in the Levantine Basin, where post-hatchling green sea turtles are well distributed (Turkey, Syria, Cyprus, Lebanon, Israel and Egypt). The presence of juveniles in Greece and the central and southern Adriatic Sea, suggests that green sea turtles might be using oceanic habitats when migrating from natal sites to the Adriatic Sea. Indeed, monitoring studies show that nesting activity is increasing, reflecting an upward trend in adult female individuals.

Recent studies suggest that the Levantine Basin provides the main nursery area for green sea turtles. Turkey, Cyprus and Syria host the main nesting sites of green sea turtle, with about 1 450, 620 and 140 nests per year, respectively (Casale and Heppell, 2016; Casale *et al.*, 2018). Meanwhile, Hochscheid, Kaska and Panagopoulou (eds., 2018) reported that between 1 164 and 2 674 green sea turtle clutches are laid annually in 12 major (>20 nests and >10 nests/km) and 53 minor (<20 nests or <10 nests/km) nesting sites in Turkey, Cyprus and Israel. No updated data have come from Lebanon and Egypt, where green sea turtle nesting also occurs. An estimated clutch frequency of three nests per female per season leads to an approximate calculation of 784 nesting females per year. On average, each clutch produces 114 eggs and hatching success ranges between 70 and 77 percent, while the mean incubation duration ranges from 49 to 60 days. Females are known to revisit their natal beaches at two- to four-year intervals to lay their eggs.

Information on the neritic foraging sites of green sea turtles is scarce, but stranding reports and incidental catch data have revealed that their feeding grounds are mainly distributed along the coasts of Turkey, Cyprus, Syria, Egypt, Libya, Greece and in the southern Adriatic Sea, and that the green sea turtle begins to frequent neritic waters at smaller sizes than the loggerhead sea turtle. Stokes *et al.* (2015) found furthermore that the coastlines of Egypt and Libya host high densities of migrating green sea turtles following the nesting season, particularly in July–September, and likely also during the pre-nesting period (April–June). Therefore, Libya and Egypt can be considered as important foraging grounds for this species. Indeed, recent satellite and stable isotope analyses have similarly suggested that Egypt is a major contributor to nesting aggregations in Cyprus (Bradshaw *et al.*, 2017).

The diet of green sea turtle juveniles is similar to that of loggerhead sea turtles, while adults larger than 60 cm are primarily herbivores, feeding mainly on the seagrass *Cymodocea nodosa*, which grows in shallow and sheltered bays (Casale *et al.*, 2018). In Cyprus, green sea turtle juveniles larger than 30 cm also feed on seagrass (Cardona *et al.*, 2010).

Using similar methods for calculating loggerhead sea turtle numbers, Casale and Heppell (2016) have estimated that the green sea turtle population in the Mediterranean Sea ranges from 261 000 to 1 252 000 individuals, and importantly that the population trend overall is positive.

2.1.3 Leatherback sea turtle

The leatherback is an oceanic, deep-diving sea turtle inhabiting tropical, subtropical and subpolar seas and listed as "Vulnerable" in the IUCN Red List of Threatened Species (Wallace, Tiwari and Girondot, 2013). So far, only one comprehensive review of the available data for the leatherback sea turtle (*Dermochelys coriacea*) in the Mediterranean has been published (Casale *et al.*, 2003), while several scientific papers report the presence of this species at the local level (for example, Taškavak and Farkas, 2013; Karaa *et al.*, 2013; Bearzi *et al.*, 2015). This species is the largest sea turtle and is able to carry out extensive migrations between different feeding areas during different seasons, to and from nesting areas. Indeed, the Mediterranean pelagic feeding grounds of leatherback sea turtles are frequented by individuals from Atlantic populations. Both adults and large juveniles (>145 cm) seem to frequent the Mediterranean (Casale *et al.*, 2003), while small juveniles are limited to tropical waters and do not enter. It is worth noting that small juveniles have never been reported, suggesting that neither the Mediterranean nor the Northeast Atlantic are areas in which the Atlantic populations of this species spend time as small juveniles (Casale *et al.*, 2003). As further evidence, a distribution analysis by Eckert (2002), based on 98 small individuals (<145 cm) around the world, suggested that leatherback sea turtles do not leave tropical waters before reaching a size of about 100 cm, probably due to thermal constraints.

Reproduction in Mediterranean waters is considered absent or exceptional (Lescure, Delaugerre and Laurent, 1989). The main nesting areas of this species are concentrated in the tropical waters of Central and South America (Camiñas, 1998). Females produce multiple, i.e. between three and ten clutches of 60 to 90 eggs during the nesting season, with a migration interval of multiple years (2+) between subsequent reproductive seasons. The leatherback sea turtle seems to feed mainly on jellyfish, salps, siphonophores, and other pelagic invertebrates (Bjorndal, 1997).

Casale *et al.* (2003) collected a total of 411 individual records for the whole Mediterranean. Most of the specimens were found stranded and had probably been caught by small-scale nets, longlines or trawls. Meanwhile, Karaa *et al.* (2013) noted a total of 51 records of leatherback sea turtles in Tunisian waters (based on scientific and grey literature, including technical and scientific congress reports, as well as on unpublished/personal observations), mainly during the warm period of the year, possibly as a result of the abundance of jellyfish during that season. On the other hand, the data available may reflect the consequences of intensified human activities during the warm period of the year rather than the actual temporal distribution of the species. Similarly, Camiñas *et al.* (2018) reported that from 1999 to 2016, ten leatherback sea turtles were found in the incidental catch of the Spanish surface longline fleet in the western Mediterranean Sea. In this area, the observed incidental capture of leatherback sea turtles corresponded to 0.001 catches/1 000 hooks. Likewise, during a similar period, 32 stranded leatherback sea turtles were documented in the Alboran Sea from 1997 to 2015 (Bellido Lopez *et al.*, 2018). In contrast, only a few specimens were recorded in the eastern basin, including from Greece, Syria, Israel, Cyprus, Turkey and Egypt (Casale *et al*., 2003). It is possible that the distance from the Atlantic is only one of the factors determining the distribution of this highly vagile species in the Mediterranean (Casale *et al*., 2003).

2.2 Historical records of interactions with fisheries

In the Mediterranean Sea, sea turtles have been historically exploited by fisheries for food and trade since the late nineteenth century through the mid-1960s (Margaritoulis *et al*., 2003), especially in the Levantine Basin (Hornell, 1935; Sella, 1982). Sea turtles were fished mainly at sea, though the available information reports that sea turtles were also collected from their nesting beaches. While green sea turtles were primarily targeted, the loggerhead turtle population was impacted as well. At the beginning of the last century, the loggerhead sea turtle was considered the most abundant species (Gruvel, 1931), and Flower (1933) highlighted the importance of the loggerhead sea turtle in the so-called turtle soup. According to Sella (1982), it is estimated that from the end of the First World War to the mid-1930s, at least 30 000 sea turtles, both green and loggerhead, were caught in the eastern Levant Sea. However, it is difficult to assess the impact of sea turtle fisheries, as stated by Sella (1982) and Mendelssohn (1983), as intensive fishing was carried out not only for local consumption but also for export, mainly to the United Kingdom of Great Britain and Northern Ireland, resulting in a high exploitation of the *Chelonia* population in the eastern Mediterranean, across Cyprus, Lebanon, Egypt and Turkey (see Gruvel, 1931; Nada, 2005; Venizelos and Nada, 2000; Boura, Abdullah and Nada, 2015).

As far as other Mediterranean areas, the first records in Italy are from Faber (1883) and Stossich (1880), who reported that *Chelonia caretta* (an earlier scientific name of the loggerhead sea turtle) was quite common and even caught in the Trieste harbour, while a few specimens of green sea turtle (*Chelonia mydas*) were caught in the Adriatic Sea. The Clodia database (Università degli Studi di Padova, 2020) of the Chioggia fish market (Italy, northern Adriatic Sea) reports sea turtle landings from the Second World War through 1988, when an annual average of 0.13 tonnes of sea turtle (likely loggerheads) were sold at the market, with peaks in 1968 (0.8 tonnes) and 1972 (0.9 tonnes). Similarly, sea turtles were included on a price list of an unpublished statistical report conducted between 1895 and 1987 in Croatia (Lazar, 2010). Mingaud (1894) reported the first capture of loggerhead sea turtles in France, and Laurent *et al*. (1997) stated that some specimens observed at the Station biologique de Tamaris (Provence, France) were captured between 1920 and 1927. More recently, Di Palma (1978) documented a specialized fishery operating in the Aeolian Islands, north of Sicily (Italy) before 1980, catching about 500 to 600 sea turtles per year. Although fishing for sea turtles has been banned in Italy since 1980, the exploitation of incidentally caught sea turtles allows for the continuation of some local traditions involving the illegal sale of sea turtle shells (Argano *et al*., 1990). Additional studies revealed that green sea turtle meat was historically sold also in Malta (Gramentz, 1989), Spain (Mayol and Castello Mas, 1983), Algeria and Morocco (Laurent, 1990). Furthermore, Benhardouze *et al*. (2004) and Benhardouze *et al*. (2009) investigated the use of loggerhead turtles in northern Morocco and did not observe meat being sold in stores or markets, though some loggerhead carapaces were still sold as late as 2003 in craft shops or displayed as decoration on restaurant walls.

In Tunisia, Laurent and Lescure (1994) reported that loggerhead turtles caught by the Tunisian fishing fleet in 1990 were being sold on the market. The Port Services Agency declared that 883 sea turtles were landed in 1986, 2 122 in 1987 and 2 913 in 1988 (Laurent and Lescure, 1994;

Laurent *et al.*, 1990). Although the sale of sea turtles in Tunisian fish markets was prohibited in 1990, there has persisted a black market for local consumption (Laurent *et al.*, 1996) or for carapaces as ornaments (Bradai, 1993). Laurent *et al.* (1996) similarly reported that in Egypt, both loggerhead and green sea turtles were sold at fish markets, despite legislation prohibiting this practice. In addition, a study based on interviews with fishers in Syria in 2004 revealed the existence of a sea turtle market (Jony and Rees, 2009).

In general, direct harvesting of sea turtles for commercial purposes declined after the 1970s due to the introduction of protective legislation and trade restrictions in all Mediterranean countries. However, sea turtle incidental catch concerns began growing from 1960 to 1970, in response to the increasing industrialization of fishing practices and fishing effort.

Subsequently, at the end of the 1980s through the beginning of the 1990s, studies on sea turtle bycatch started to produce reliable data (e.g. Camiñas, 1988; Laurent, 1990; Bradai, 1992; De Metrio and Megalofonou, 1988). Indeed, incidental catch estimates reported up to the beginning of 2000 made it possible to identify the most problematic areas, though the reported data should be considered with caution, due to a lack of information from several Mediterranean subregions and of procedures for data standardization. Lewison, Freeman and Crowder (2004) have suggested that the Mediterranean is a global hotspot for interactions between longlines and loggerhead sea turtles and estimated that between 60 000 and 80 000 loggerhead sea turtles were captured by drifting longliners in 2000 alone. However, their analysis was based on the assumption of homogeneous incidental catch rates covering the entire region, which may actually differ from reality (Báez, Real and Camiñas, 2007; Camiñas *et al.*, 2006a, 2006b; Báez *et al.*, 2007).

A detailed review of data from sea turtle–fishery interactions before 2000 was carried out by Gerosa and Casale (1999), who showed that drifting longlines had the highest interaction rates with sea turtles, followed by bottom trawls and set nets. Drifting longlines targeting swordfish (*Xiphias gladius*) and albacore (*Thunnus alalunga*) appeared to be the fishing method incidentally catching the most loggerhead sea turtles – almost entirely in the western and central parts of the basin (Demetropoulos and Hadjichristophorou, 1995). In the Mediterranean Sea, only one of the three species present, the loggerhead sea turtle, was regularly noted among the incidental catch of this fishing method. Panou *et al.* (1992) reported around 35 000 loggerhead sea turtles caught annually as bycatch in the western and central Mediterranean, of which 15 000 to 20 000 specimens or more were caught each year by the Spanish fishing fleet off the Balearic Islands (Camiñas, 1988; Aguilar, Más and Pastor, 1995). Furthermore, Aguilar, Más and Pastor (1995) showed that the highest catch rate (9.8 sea turtles per boat daily) was observed in the southwestern Mediterranean in 1990. In contrast, the catch rate strongly decreased (0.16 sea turtles per boat daily), according to Panou *et al.* (1992, 1999), in the Greek waters of the Ionian Sea.

Nevertheless, in terms of mortality, non-homogeneous results have been obtained by various authors, with mortality rates ranging from 0 percent (Ogren, 1994) to 29.5 percent (Balazs and Pooley, eds., 1994). The available data indicate that 15.6 percent of captured specimens show the hook inserted in the mouth (Aguilar *et al.*, 1995); this type of hooking usually allows the the animal to survive. In general, direct mortality induced by longlines appeared to be low; this conclusion was supported by the fact that hooked loggerhead sea turtles are able to maintain enough power to raise themselves with the lines to the surface and breathe. The greatest number of sea turtles caught with drifting longlines was reported between June and August and mainly consisted of juveniles and subadults, ranging from 27 to 50 cm CCL. The catch rate with set longlines was unknown at that time, and the mortality rate was clearly related to the depth setting (one main line at a depth greater than 200 m) (Bolten, Bjorndal and Martins, 1994). Indeed, set longlines were considered responsible for a potential mortality (delayed) of about 40 percent, as hooked juveniles could not reach the surface to breathe (Casale, 2008; Casale, Freggi and Rocco, 2008; Jribi *et al.*, 2008).

Bottom trawls were considered the second most impactful of fishing gear types for sea turtle populations, in terms of number of catches per year. Loggerhead sea turtles are probably incidentally caught in bottom trawls during towing operations occurring while sea turtles forage along the bottom. Records available before 2000 showed a significant incidental catch rate in Tunisia (2 000–5 000 sea turtles caught per year; Bradai, 1992; Laurent *et al.*, 1996) and in the Adriatic Sea (2 500 sea turtles caught per year; Lazar and Tvrtkovic, 1995). Sea turtle bycatch was reported also in Egypt (Laurent *et al.*, 1996), Turkey (Laurent *et al.*, 1996) and Greece (Margaritoulis *et al.*, 1992), especially on shallower sea bottoms (Oruç, 2001; Oruç, Demirayak and Sat, 1996), although estimates were not available at that time. More recently, Casale, Laurent and De Metrio (2004) reported more than 4 200 loggerhead sea turtles caught annually in the northwestern Adriatic; Margaritoulis *et al.* (2003) recorded around 300–400 loggerhead and 200 green sea turtles captured each year in Greece; Casale *et al.* (2007) reported around 4 000 loggerhead sea turtle catches per year by Italian trawlers in the central Mediterranean; and Jribi, Bradai and Bouain (2004, 2007) recorded more than 5 000 loggerhead sea turtles caught annually in Tunisia: individuals between 50 and 70 cm CCL represented the majority of the impacted population. Fortuitously, the direct mortality rate was judged not to be very high, ranging from 0 to 10 percent (Tunisia) of capture events (Jribi, Bradai and Bouain, 2004, 2007).

Gillnets are a traditional type of fishing gear used widely across the Mediterranean and present in all coastal zones. Although poor historical data are available for this type of fishing, a high mortality rate (around 74 percent) is reported from different Mediterranean countries (for example, Argano *et al.*, 1992). Concerning trammel nets, the mortality rate records available in the literature are: 94.4 percent for the loggerhead sea turtle in Corsica, with trammel nets placed at depths of >60 m (Delaugerre, 1987), 53.7 percent in France (Laurent, 1991) and 83 percent in Croatia (Lazar, Ziza and Tvrtkovic, 2006). In contrast, lower mortality rates were found in Tunisia, at 5.2 percent (Bradai, 1993).

Beginning in the late 1970s and early 1980s, attention was focused on driftnets (local names include *spadara* and *thonaille*) targeting large pelagic fish species, due to their impacts on marine mammals, pelagic sharks and sea turtles. Indeed, by the end of the 1980s, intensive use of large driftnets in the Mediterranean had led to a marked decline in large pelagic vertebrates (i.e. sharks, cetaceans and sea turtles), as well as overexploitation of target species, for example, swordfish (Tudela, 2004). Since a very similar scenario had been described in several countries around the world, the use of driftnets raised conservation concerns on a global scale. This fishing method spread quickly in the 1980s, spurred by a desire for higher catch efficiency, which encouraged fishers, for example, to use the swordfish driftnet instead of the traditional longline technique, as it was considered more selective and less harmful for the environment. The unrestrained use and lengthening of nets (up to 60 km) began to worry various governments because of the excessive pressure put on the stocks of target species and the number of marine mammals incidentally captured (Northridge, 1991). As a result, driftnets longer than 2.5 km have been banned in European Union waters since 1992, except in some specific areas (Council of the European Union, 1992).

From 1998, all driftnets, irrespective of size, have been prohibited in European Union countries when intended for capturing highly migratory species, such as bluefin tuna, tuna-like species, swordfish, and large and medium-sized pelagic species in general (Council of the European Union, 1997; 1998; 2007), thus shifting the burden of incidental catch issues from the northern part of the Mediterranean basin to the southern part. Nonetheless, illegal drift netting by European fishing vessels continues to be reported, prompting criticism of European Union compliance with international obligations (Oceana, 2009). In 2003, the use of these nets was therefore also banned by the International Commission for the Conservation of Atlantic Tunas (ICCAT) through Recommendation [03–04] relating to Mediterranean swordfish, which was adopted in 2005 by the General Fisheries Commission for the Mediterranean (GFCM) through its Recommendation GFCM/29/2005/3 concerning selected ICCAT recommendations. Although this gear has been in use for over fifteen years, the catch data available and experts' opinions remain controversial; while it is certain that considerable incidental capture of marine mammals has occurred, the number of sea turtles caught is still little known. Data from research carried out in the Tyrrhenian Sea and the Ligurian Sea between 1990 and 1991 by Di Natale (1995) show an average bycatch per unit effort (BPUE) of 0.005 loggerheads/km of net for about 100 fishing vessels. Bănaru *et al.* (2010) reported similar values for French driftnets (0.002 loggerheads/km of net) operating illegally up to 2007–2009. Furthermore, Aguilar, Más and Pastor (1995), and Silvani, Gazo and Aguilar (1999) reported catches of a few hundred loggerhead sea turtles per year in Spain. Other data presented a much more worrying situation: De Metrio and Megalofonou (1988) estimated 16 000 loggerhead sea turtle captures seasonally by a small group of 29 vessels operating near the Ionian coast of Calabria with nets up to 12 km long, and a 20–30 percent mortality rate. In general, it is reasonable to assume that driftnets have been very dangerous when placed along the migratory routes of sea turtles moving from feeding zones to nesting areas and vice versa.

2.3 Analysis of recent data from literature (2008–2019)

Available data on sea turtle bycatch in the Mediterranean Sea have increased over time and become more reliable as monitoring programmes have expanded, along with data standardization. However, the information remains biased since it is not distributed equally over the Mediterranean and Black Sea. Moreover, the data obtained for most areas and types of fishing gear used do not come from specific monitoring surveys, adding uncertainty to the viable quantification of captures and mortality. Often, data could only be gathered opportunistically, therefore representing single incidences of sea turtle bycatch. Furthermore, Mediterranean and Black Sea fisheries are essentially multi-species- and multi-gear-oriented, while fishing fleets mostly consist of small artisanal vessels, i.e. vessels of the small-scale fisheries (SSF) sector, dispersed in small ports or along the coast. Therefore, the collection of data on incidental catch is difficult, and extrapolating the data from the few surveys conducted often comes with biases, due to the lack of reliable information representative of the entire fleet. Similarly, information from large-scale vessels in some areas can be biased due to a lack of knowledge (for example, of vessel numbers and catch composition) and the relative importance of the different vessel groups

In the last ten years, information on sea turtle bycatch collected by onboard observers has been collated with information derived from interviews with fishers and logbooks. Sea turtle incidental catch data collected by direct interviews have the potential to help develop effective conservation measures, even if their results might underestimate the true figures of sea turtle bycatch (FAO, 2019; Carruthers and Neis, 2011; Lucchetti, Vasapollo and Virgili, 2017b; Casale *et al.*, 2020).

The information gathered up until now, especially over the last ten years, does allow for an outline to be drawn of the impacts caused by the various types of fishing gear and of the most impacted areas, i.e. different types of fishing gear may induce different capture and mortality rates and affect different ecological phases of sea turtles in different areas. Sea turtle–fishery interactions occur wherever fishing activities overlap with sea turtle habitats (Lucchetti, Punzo and Virgili, 2016; Lucchetti, Vasapollo and Virgili, 2017a, 2017b). For example, the capture of loggerhead sea turtles depends on various parameters, with the most important factor being fishing effort: number of vessels, engine power, i.e. kilowatts, horsepower and gross tonnage, time at sea (e.g. hours per day, days per year), number of hooks on longlines, and so on. All these parameters are essential, though mortality rates vary and largely depend on gear type, onboard practices and the sea turtles' ability to survive forced apnoea due to the long soaking time of nets (i.e. turtles can be forcibly submerged for lengths of time greater than their average dive times, which may result in the turtles becoming comatose and eventually drowning) (Lutcavage and Lutz, 1997). Therefore, to properly understand sea turtle bycatch rates and impacts, it is necessary to determine the types of fishing gear used, the fishing effort and areas exploited, as well as the sea turtle habitats and their movement patterns.

The current review should be considered as an updated estimate of sea turtle bycatch rates in Mediterranean and Black Sea fisheries; when no recent information was available, historical data (prior to 2008) were used. However, in general, outliers (data that differ significantly from other collected observations) have not been used for the purposes of this review. In cases where multiple estimates were available for the same area and fishing gear from different bibliographic sources, the most recent fishery data were considered. For each type of fishing gear, mean mortality rates obtained for the entire Mediterranean were examined, even though this is not the best way to make estimates at the basin level, as the mortality rate depends on many factors. However, for some areas no data were available, leaving mean rates as the only way to make estimates.

Overall, it was possible to estimate sea turtle bycatch and the mortality induced by different types of fishing gear as summarized in Table 1. Nevertheless, it should be noted that data for some countries and types of fishing gear were missing, so the estimate could be biased.

As highlighted in Table 1, the differences between the data produced by Casale (2011) and the data collected up to 2018 are mainly due to Casale's inclusion of incidental catch estimates for drifting longlines. The most recent review of Mediterranean incidental catch (Casale *et al.*, 2018), estimated that over 132 000 sea turtles were caught annually, of which 44 000 might be dead.

It is useful to underline that the estimates made in previous reviews by Casale (2008; 2011), which represent an important portion of the available data, were obtained for certain areas, by expanding the same sea turtle bycatch data, i.e. BPUE, published by other authors to the fishing effort in those areas.

For the types of fishing gear described, the FAO code provided in the International Standard Statistical Classification of Fishing Gear (ISSCFG) (FAO, 2016); Nédélec and Prado, 1980) is also reported.

2.3.1 Bottom trawlers

Based on estimates made after 2008, Mediterranean bottom trawlers are considered to catch a total of around 50 000 sea turtles per year (Table 1), with a corresponding mortality rate of

TABLE 1 – Incidental catch of loggerhead sea turtles (capture events per year) and mean mortality estimates for the most important types of fishing gear in the Mediterranean Sea, by GFCM subregion

	Bottom trawl (mean mortality 18%)		Drifting longline (mean mortality 20%)		Small-scale (mean mortality 51%)		Set longline (mean mortality 23.9%)		Total	
	Bycatch	**Dead**	**Bycatch**	**Dead**	**Bycatch**	**Dead**	**Bycatch**	**Dead**	**Bycatch**	**Dead**
Adriatic Sea	18 204	3 277	1 251	250	8 908	4 543	0	0	28 363	8 070
Central Mediterranean	19 732	3 552	14 472	2 894	6 157	3 140	5 270	1 260	4 5631	10 846
Eastern Mediterranean[1]	10 430	1 877	2 210	442	13 826	7 051	6 843	1 635	33 309	11 006
Western Mediterranean	2 300	414	8 786	2 410	2 058	1 050	258	62	13 402	3 382
Western Mediterranean[2]			37 828	7 566					42 444	9 091
Total	**50 666**	**9 120**	**26 719**	**5 344**	**30 949**	**15 784**	**12 371**	**2 957**	**120 705**	**33 204**
Total[2]			**55 761**	**11 152**					**149 747**	**39 013**

Notes:

1. Loggerhead and green sea turtle data are reported together because separate information on the two species is not always available.
2. Bycatch and direct mortality estimates in grey calculated by Casale (2011) for drifting longline bycatch in Spain and Morocco.

around 18 percent. Although catch rates are high, mortality rates are regarded as being relatively low. Therefore, other fishing vessels, such as those using set nets, while they may exhibit lower catch numbers, can have an effect comparable to that of bottom trawlers in terms of the resulting mortality.

The bottom trawl has historically been recognised as the second most impactful fishing gear on sea turtle populations in terms of the number of catches per year. However, recent estimates (Lucchetti, Vasapollo and Virgili, 2017a, 2017b) obtained from Italian waters alone have suggested that the impacts of this gear are comparable or even greater than those of drifting longlines.

Bottom trawlers mainly affect sea turtles in their demersal phase, as they prefer coastal shallow waters for feeding when they are juveniles and subadults. The data available after 2008 confirm that the Gulf of Gabès, the northern and central Adriatic Sea, southern Turkey, and, to a lesser extent, Egypt and southern Sicily represent hotspots for sea turtle–bottom trawler interactions, due to the shallow waters (<100 m deep) and rich benthic communities that make these areas the most important neritic feeding habitats in the whole Mediterranean (see Table 2).

Western Mediterranean

This area of the Mediterranean generally shows a low annual level of sea turtle bycatch due to trawlers: Spain (around 200–400 individuals), France (around 25–100), Morocco (around 200), Italy (around 300) and Algeria (around 650) (Casale 2008, 2011; Alvarez de Quevedo *et al.*, 2010). An exception comes from the neritic habitat near the Valencian Community (eastern Spain; around 200–300 sea turtles; Domènech *et al.*, 2015), as this area mainly hosts oceanic foraging habitats for sea turtles. Therefore, in the western Mediterranean, drifting longlines, rather than bottom trawls, are the major concern.

Central Mediterranean

The wide central Mediterranean area is known to host oceanic and neritic habitats for loggerhead sea turtles. Around 4 000 sea turtles per year are estimated to be caught in the Strait of Sicily, mainly around the island of Lampedusa, due to the high fishing pressure from bottom trawlers in this area (Lucchetti, Vasapollo and Virgili, 2017a, 2017b; Casale *et al.*, 2007).

Jribi, Bradai and Bouain (2004, 2007) have also estimated that the annual incidental catch in bottom trawls in the Gulf of Gabès area (Tunisia) alone is around 5 500 sea turtles. Furthermore, in other Tunisian fishing grounds, about 10 000 sea turtles overall are estimated to be caught annually. Casale *et al*. (2007) have likewise confirmed the importance of this area for both juveniles and adults of loggerhead sea turtle (*Caretta caretta*). Elsewhere, more than 4 000 sea turtles per year appear to be caught in Libya (Casale, 2011), while a few catches are reported from Greece, mainly during the winter (Margaritoulis and Teneketzis, 2003).

Adriatic Sea

The northern Adriatic, with its shallow waters, flat seabed and rich benthic communities, is a major feeding habitat for sea turtles nesting in Greece, Turkey, Cyprus and Libya (Bertuccio *et al*., 2019), as well as an important fishing ground for bottom-towed fishing gear (Lucchetti and Sala, 2012). Indeed, geographical subarea 17 (i.e. the central-northern Adriatic) is frequented by over 1 000 bottom trawlers, mainly from Italy and Croatia, and to a lesser extent from Slovenia, Montenegro and Albania, while aerial surveys have made it possible to estimate the sea turtle population in the Adriatic Sea at over 70 000 turtles (Fortuna *et al*., 2011). Therefore, loggerhead sea turtle-trawler interactions are quite common. This area, due to its geomorphological characteristics, could represent a natural cul-de-sac for sea turtles, especially for those wintering in this basin, so that multiple incidental catch events (up to eight sea turtles caught hourly during towing; A. Lucchetti, personal observation, 2018) are not uncommon. Therefore, the Adriatic Sea represents a key area for the management and conservation of this species, and especially for the population nesting in Greece.

Lucchetti, Vasapollo and Virgili (2017a, 2017b) recently reported that more than 14 000 capture events may occur annually in the Adriatic Sea, involving only the Italian fishing fleet. Furthermore, Lucchetti *et al*. (2018) clearly showed that the Rapido trawl (a type of beam trawl rigged with 5–7 cm long teeth) is also heavily responsible for sea turtle bycatch and sea turtle injuries following impacts with its rigid frame and teeth. Casale, Laurent and De Metrio (2004) reported around 4 300 capture events annually in the northwestern Adriatic alone, but they also observed that incidental catch rates in the eastern part of the Adriatic Sea were 15 times higher than in the western part. Elsewhere, although incidental catch estimates available for Croatia are quite old and based on the work of Lazar and Tvrtkovic (1995), these authors estimated around 2 500 catches annually, of which around 500 came from the centre and 2 000 from the northern coastal areas of Croatia. However, this figure was obtained through interviews and therefore may be an underestimate. Around 560 sea turtles were also estimated to be caught annually by Albanian fishers, according to Casale (2011).

Eastern Mediterranean

Turkey, Greece and Egypt are considered the countries whose fisheries have the greatest impacts on sea turtles (both loggerhead and green sea turtles) in the eastern basin (Table 2), with estimates of around 3 500, 2 900 and 2 000 sea turtles caught per year, respectively. The eastern Mediterranean coast of Turkey represents an important area for sea turtle nesting and feeding (Baran and Kasparek, 1989). Oruç (2001) observed in this area that the bycatch of green sea turtles was greater than that of loggerhead sea turtles, with mostly juveniles caught (81 percent).

In Israel, Casale (2011) reported an annual incidental catch estimate of six sea turtles (calculated by applying a conservative catch rate, equal to the minimum recorded in the Mediterranean), while more recently, Levy *et al*. (2015) noted in contrast an estimate of around 1 300 sea turtles caught per year. Casale (2011) also estimated a bycatch of 107 sea turtles per year in Cyprus and of around 200 in Syria. Elsewhere, in Lebanon, bottom trawling is forbidden. In light of the available data, it is estimated that over 10 000 sea turtles per year are caught by bottom trawlers in the eastern basin.

Black Sea

Very little information is available from the Black Sea and it is not possible to make estimates. Due to the limited presence of sea turtles in Black Sea waters, incidental catch in this area is not considered a conservation problem for sea turtle populations.

Bottom trawlers overview

In general, the direct mortality induced by bottom trawls is low and sea turtles are usually released alive. Indeed, underwater videos recorded that sea turtles are still able to swim in the net after capture (TartaLife, 2013). Various studies (Table 2) report different mortality rates, and it is assumed that a reliable mortality rate of sea turtles incidentally caught in bottom trawls ranges between 10 and 20 percent.

In bottom trawls, the incidental catch of loggerhead sea turtles probably occurs during towing operations when sea turtles are foraging on the bottom. For this reason, the incidental catch, and sometimes the mortality rate, mainly depend on three operative parameters: the duration of the trawl (greater mortality when towing time is higher than one hour) (Henwood and Stunz, 1987), the intensity of the fishing effort in a certain zone (high number of vessels in a restricted area might lead to multiple catches) (Epperly, Braun and Veishlow, 1995), and water temperature (maximum time before apnoea decreases as water temperature rises, due to increasing oxygen consumption) (Lutz, Bergey and Bergey, 1989). While mortality caused by trawlers may be due partly to the physical stress exerted on the animal caught inside the net, it is mainly due to forced apnoea (Hare, 1991). Delayed mortality due to decompression sickness is a matter of further concern (García-Parraga *et al*., 2014). Thus, longer or faster-moving tows, which depend on several parameters (including the nature of the fishing area and target species), are likely responsible for higher mortality rates. In fact, the mortality rate for a towing time less than one hour may be negligible (Henwood and Stuntz, 1987; Laurent and Lescure, 1994; Lucchetti, Vasapollo and Virgili, 2017a, 2017b). Therefore, towing time could be one of the main factors affecting mortality rates, though additional factors such as seasonal differences may increase the impact, especially of bottom trawls, with mortality higher in the winter than in summer due to the cold (Gerosa and Casale, 1999; Gilman, Bianchi and Attwood, 2009; Maxwell *et al*., 2018). On the other hand, higher water temperatures associated with increased metabolic rates can dramatically reduce sea turtles' ability to survive apnoea, for example, in warm Tunisian waters (National Research Council, 1990).

Based on recent incidental catch estimates obtained by different authors (Table 2), and taking into account that the estimates may sometimes refer to partially overlapping areas, it is assumed that around 50 000 sea turtles are caught annually by Mediterranean bottom trawlers, with likely 9 000 dead:

- In the western Mediterranean, around 2 300 capture events may occur annually, with around 400 dead;

- In the central Mediterranean, about 20 000 sea turtles may be caught annually, mainly by Tunisian and Italian trawlers, with possibly 3 500 dead;
- In the Adriatic Sea, around 18 000 capture events may occur annually, with more than 3 000 dead;
- In the eastern Mediterranean, around 10 000 sea turtles may be caught annually, with about 2 000 dead.

PLATE 1
Sea turtle incidentally caught by a bottom trawler

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TABLE 2 – Incidental catch of sea turtles in bottom trawlers (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Lazar and Tvrtkovic, 1995; Lazar *et al.*, 2003	1995	OTB	Adriatic Sea	Croatia (north)	*Caretta caretta*	1 950	12.5%
Lazar and Tvrtkovic 1995; Lazar *et al.*, 2003	1995	OTB	Adriatic Sea	Croatia (centre)	*Caretta caretta*	459	12.5%
Lazar *et al.*, 2004	1990–2002	OTB	Adriatic Sea	Slovenia–Croatia	*Caretta caretta*	-	0–10%
Casale *et al.*, 2004	2004	OTB	Adriatic Sea	Italy (northwestern Adriatic)	*Caretta caretta*	4 273	9.4% (43.8% potential)
Casale, 2008	2005	OTB	Adriatic Sea	Albania	*Caretta caretta*	444	-
Lazar, 2010	-	OTB	Adriatic Sea	Croatia	*Caretta caretta*	2 500	12.5%
Casale, 2008	2008	OTB	Adriatic Sea	Italy (northwestern Adriatic)	*Caretta caretta*	5 833–49 547[2]	-
Casale, 2008	2008	OTB	Adriatic Sea	Italy (southern Adriatic–Ionian)	*Caretta caretta*	849	-
Casale, 2008	2008	OTB	Adriatic Sea	Slovenia	*Caretta caretta*	57	-
Casale, 2011	2011	OTB	Adriatic Sea	Albania	*Caretta caretta*	564	-
Casale, 2011	2011	OTB	Adriatic Sea	Italy (northwestern Adriatic)	*Caretta caretta*	5 878–49 508[2]	-
Casale, 2011	2011	OTB	Adriatic Sea	Slovenia	*Caretta caretta*	210	-
Casale, 2011	2011	OTB	Adriatic Sea	Italy (southern Adriatic–Ionian Sea)	*Caretta caretta*	316	-
Lucchetti *et al.*, 2017a	2017	OTB	Adriatic Sea	Italy (central–northwestern Adriatic)	*Caretta caretta*	14 705	15%
Laurent *et al.*, 1990	1988	OTB	Central Mediterranean	Tunisia	*Caretta caretta*	2 800–4 400	-

TABLE 2 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Bradai, 1992	1992	OTB	Central Mediterranean	Tunisia (Gulf of Gabès)	*Caretta caretta*	2 000–2 500	-
Laurent and Lescure, 1994	1994	OTB	Central Mediterranean	Tunisia	*Caretta caretta*	3 500–4 000	-
Laurent *et al*., 2001	1999–2000	OTB	Central Mediterranean	Greece (Ionian Sea)	*Caretta caretta*	0–211(±415)	0%
Margaritoulis, Politou and Laurent, 2003	2001	OTB	Central Mediterranean	Greece (Ionian Sea)	*Caretta caretta*	0–448	0%
Margaritoulis *et al*., 2003	2000	OTB	Central Mediterranean	Greece (Ionian Sea)	*Caretta caretta*	211	-
Casale *et al*., 2007	2003–2005	OTB	Central Mediterranean	Italy (Central Mediterranean)	*Caretta caretta*	4 056	-
Jribi and Bradai, 2008	2008	OTB	Central Mediterranean	Tunisia (whole continental shelf)	*Caretta caretta*	14 000	-
Casale, 2008	2008	OTB	Central Mediterranean	Tunisia (other than Gulf of Gabès)	*Caretta caretta*	5 458	-
Casale, 2008	2008	OTB	Central Mediterranean	Greece (Ionian Sea)	*Caretta caretta*	119	-
Casale, 2008	2008	OTB	Central Mediterranean	Tunisia (Gulf of Gabès)	*Caretta caretta*	5 457	-
Casale, 2008	2008	OTB	Central Mediterranean	Egypt	*Caretta caretta*	1 978	-
Casale, 2008	2008	OTB	Central Mediterranean	Libya	*Caretta caretta*	2 479	-
Casale, 2008	2008	OTB	Central Mediterranean	Italy	*Caretta caretta*	1 016–12 880[2]	-
Casale, 2008	2008	OTB	Central Mediterranean	Malta	*Caretta caretta*	8	-
Casale, 2011	2011	OTB	Central Mediterranean	Greece (Ionian Sea)	*Caretta caretta*	8	-
Casale, 2011	2011	OTB	Central Mediterranean	Libya	*Caretta caretta*	4 726	-
Casale, 2011	2011	OTB	Central Mediterranean	Italy (Lampedusa Island)	*Caretta caretta*	1 014	-
Casale, 2011	2011	OTB	Central Mediterranean	Italy (other than Lampedusa)	*Caretta caretta*	3 040–12 880[2]	-
Casale, 2011	2011	OTB	Central Mediterranean	Malta	*Caretta caretta*	4	-
Casale, 2011	2011	OTB	Central Mediterranean	Tunisia	*Caretta caretta*	10 940	-
Lucchetti *et al*., 2017a	2017	OTB	Central Mediterranean	Italy (south Sicily-Ionian Sea)	*Caretta caretta*	3 620	15%
Jribi *et al*., 2004, 2007	1992–2004	OTB	Central Mediterranean	Tunisia (Gulf of Gabès)	*Caretta caretta*	5 458	3.3%
Margaritoulis *et al*., 1992	1989–1990	OTB	Eastern Mediterranean	Greece (Lakonikos Bay)	*Caretta caretta*	38	2.6%
Margaritoulis *et al*., 1992	1989–1990	OTB	Eastern Mediterranean	Greece (Lakonikos Bay)	*Chelonia mydas*	6	-
Margaritoulis, Politou and Laurent, 2003	2001	OTB	Eastern Mediterranean	Greece (Thracian Sea)	*Caretta caretta*	0–418	0%
Laurent *et al*., 2001	1999–2000	OTB	Eastern Mediterranean	Greece (Thracian Sea)	*Caretta caretta*	133–410	0%
Margaritoulis *et al*., 2003	1999	OTB	Eastern Mediterranean	Greece (Thracian Sea)	*Caretta caretta*	410	-

TABLE 2 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Margaritoulis *et al.*, 2003	2000	OTB	Eastern Mediterranean	Greece (Thracian Sea)	*Caretta caretta*	298	-
Oruç, 2001; Oruç *et al.*, 1996	1996–1997/2001	OTB	Eastern Mediterranean	Turkey	*Caretta caretta*	43	0.3–5%
					Chelonia mydas	3	
Nada and Casale, 2008; Laurent *et al.*, 1996	1996–2008	OTB	Eastern Mediterranean	Egypt	*Caretta caretta*	1 916 (1 114–2 228)	1–10%
Casale, 2008	2008	OTB	Eastern Mediterranean	Greece (Thracian Sea)	*Caretta caretta*	2 296	-
Casale, 2008	2008	OTB	Eastern Mediterranean	Cyprus	*Caretta caretta*	150	-
Casale, 2008	2008	OTB	Eastern Mediterranean	Turkey (Aegean Sea)	*Caretta caretta*	1 143	-
Casale, 2008	2008	OTB	Eastern Mediterranean	Turkey (Levant Sea)	*Caretta caretta*	2 380	-
Nada and Casale, 2011	2007	OTB	Eastern Mediterranean	Egypt	*Caretta caretta–Chelonia mydas*	1 916 (1 114–2 228)	-
Casale, 2011	2011	OTB	Eastern Mediterranean	Cyprus	*Caretta caretta*	107	-
Casale, 2011	2011	OTB	Eastern Mediterranean	Israel	*Caretta caretta*	6	-
Casale, 2011	2011	OTB	Eastern Mediterranean	Syria	*Caretta caretta*	205	-
Casale, 2011	2011	OTB	Eastern Mediterranean	Turkey (Aegean Sea)	*Caretta caretta*	1 144	-
Casale, 2011	2011	OTB	Eastern Mediterranean	Turkey (Levant Sea)	*Caretta caretta*	2 321	-
Casale, 2011	2011	OTB	Eastern Mediterranean	Greece (Thracian Sea)	*Caretta caretta*	2 878	-
Levy *et al.*, 2015	2012	OTB	Eastern Mediterranean	Israel	*Caretta caretta–Chelonia mydas*	1 124–1 506	47.1%
Laurent, 1991; Delaugerre, 1987	1987–1991	OTB	Western Mediterranean	France	*Caretta caretta*	51	3.3–3.7%
Claro *et al.*, 2010	1991-2010	OTB	Western Mediterranean	France	*Caretta caretta*	38	<10%
Laurent, 1990	1990	OTB	Western Mediterranean	Algeria	*Caretta caretta*	284	0-10%
Carreras *et al.*, 2004	2001	OTB	Western Mediterranean	Spain (Balearic Islands)	*Caretta caretta*	13	50%
Alvarez de Quevedo *et al.*, 2006	2004–2006	OTB	Western Mediterranean	Spain	*Caretta caretta*	265	-
Alvarez de Quevedo *et al.*, 2010	2003–2004	OTB	Western Mediterranean	Spain (northeastern)	*Caretta caretta*	249 (83–515)	15.7%
Casale, 2008	2008	OTB	Western Mediterranean	Spain (north)	*Caretta caretta*	270	-
Casale, 2008	2008	OTB	Western Mediterranean	Spain (Balearic Islands)	*Caretta caretta*	13	-
Casale, 2008	2008	OTB	Western Mediterranean	Spain (south)	*Caretta caretta*	177	-
Casale, 2008	2008	OTB	Western Mediterranean	France (mainland)	*Caretta caretta*	92	-
Casale, 2008	2008	OTB	Western Mediterranean	France (Corsica)	*Caretta caretta*	27	-
Casale, 2008	2008	OTB	Western Mediterranean	Algeria	*Caretta caretta*	284	-
Casale, 2008	2008	OTB	Western Mediterranean	Italy (Tyrrhenian Sea)	*Caretta caretta*	822	-

TABLE 2 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Casale, 2011	2011	OTB	Western Mediterranean	France	*Caretta caretta*	25	-
Casale, 2011	2011	OTB	Western Mediterranean	Algeria	*Caretta caretta*	667	-
Casale, 2011	2011	OTB	Western Mediterranean	Morocco	*Caretta caretta*	199	-
Casale, 2011	2011	OTB	Western Mediterranean	Italy (Tyrrhenian Sea–Sardinia)	*Caretta caretta*	306	-
Lucchetti *et al.*, 2017a	2017	OTB	Western Mediterranean	Italy (Tyrrhenian Sea–Sardinia)	*Caretta caretta*	1 769	15%
Casale, 2011	2011	OTB	Western Mediterranean	Spain (north)	*Caretta caretta*	265	-
Casale, 2011	2011	OTB	Western Mediterranean	Spain (Balearic Islands)	*Caretta caretta*	13	-
Casale, 2011	2011	OTB	Western Mediterranean	Spain (south)	*Caretta caretta*	99	-
Domènech *et al.*, 2015	2010	OTB	Western Mediterranean	Spain	*Caretta caretta*	500	-
Domènech *et al.*, 2015	2010	OTB	Western Mediterranean	Spain (Valencia region)	*Caretta caretta*	173–304	16%
Casale, 2008	2008	OTB	Entire Mediterranean Sea	-	*Caretta caretta*	>35 000	20%
Casale, 2011	2011	OTB	Entire Mediterranean Sea	-	*Caretta caretta*	39 276	20%
Casale *et al.*, 2004; Casale, 2008; Laurent *et al.*, 1996; Lazar and Tvrtkovic, 1995; Oruç, 2001	-	OTB	Entire Mediterranean	-	*Caretta caretta*	30 000	5% (20–25% potential)
Argano, 1979	-	OTB	-	Italy	*Caretta caretta*	1 000–1 500	-
Casale *et al.* 2004, 2007; De Metrio and Casale, 2001	*	OTB	-	Italy	*Caretta caretta*	8 500	14% (57% potential)

Notes: OTB = bottom otter trawl.

In grey data collected before 2008.

1. The data reported here are derived either from direct observations or from yearly estimates. Please refer to the original paper for the methodology used to obtain the value(s).
2. Data estimated and considered as outliers.

2.3.2 Pelagic trawlers

In pelagic or midwater pair trawls, the net is rigged to operate in mid-water to capture small pelagic species, such as anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*), and, to a lesser extent, other pelagic fish, including horse mackerel (*Trachurus* spp.) and mackerel (*Scomber* spp.). During the daytime, small pelagic species form large schools close to the sea bottom; therefore, this type of gear is used during the day with the groundrope towed close to the bottom. Under these circumstances, sea turtles are likely to be incidentally caught when feeding on the bottom, as already observed for bottom trawls. Most midwater trawlers operate in pairs, with the trawl net being towed by two boats working together. Single net pelagic trawls saw use almost exclusively in France, but they have not been employed since 2007, due to the difficult economic situation (a shortage of resources and a rise in fuel prices) in the Gulf of Lion sardine fishery (Monaco and Prouzet, eds., 2014).

Western Mediterranean
No data available from the pelagic trawlers operating in this subregion (i.e. France).

Central Mediterranean
No data available for pelagic trawlers operating in this subregion.

Adriatic Sea
In the Adriatic Sea, between 150 and 2 000 sea turtles are estimated to be incidentally caught annually (around 800 sea turtles per year on average) (Table 3), with especially high numbers near the Po river mouth (geographical subarea 17, i.e. central-northern Adriatic), an area with a high

TABLE 3 – Incidental catch of sea turtles in pelagic trawlers (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Casale *et al.*, 2004 Laurent *et al.*, 2001	1999–2000	PTM	Adriatic Sea	Italy (northwest)	*Caretta caretta*	124–161	7.7% (+31% comatose)
Fortuna *et al.*, 2008	2006-2008	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	1 550	-
Casale, 2008	2008	PTM	Adriatic Sea	Italy (northwest)	*Caretta caretta*	161	-
Sala *et al.*, 2017	2007	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	1 939	6%
Sala *et al.*, 2017	2008	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	474	9%
Sala *et al.*, 2017	2009	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	1 276	5%
Sala *et al.*, 2017	2010	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	595	7%
Sala *et al.*, 2017	2011	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	395	6%
Sala *et al.*, 2017	2012	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	671	3%
Sala *et al.*, 2017	2013	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	1 414	20%
Sala *et al.*, 2017	2014	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	1 274	-
Sala *et al.*, 2017	2015	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	343	9%
Sala *et al.*, 2017	2016	PTM	Adriatic Sea	Italy (central-northwest)	*Caretta caretta*	132	-
Oruç, 2001	1996–1997	TM	Eastern Mediterranean	Turkey (southeast)	*Caretta caretta* *Chelonia mydas* *Trionyx triunguis*	71 249 389	0.3–5%

Notes:
PTM = midwater pair trawl.
TM = midwater trawl.
In grey data collected before 2008.
1. The data reported here are derived either from direct observations or from yearly estimates. Please refer to the original paper for the methodology used to obtain the value(s).

density of sea turtles feeding on abundant prey along the sea bottom. The great variability of sea turtle bycatch observed over the years is mainly due to changes in fishing effort, as vessels easily switch from pelagic to bottom trawls from one year to another.

Eastern Mediterranean
In southeastern Turkey, Oruç (2001) found that the impact of pelagic trawlers (86 percent of the incidental catch observed) was higher than that of bottom trawlers, with the greatest affect on green sea turtles (around 77 percent of the marine turtles caught). In addition, in the area between Mersin and Iskenderun, the euryhaline Nile soft-shelled turtle (*Trionyx triunguis*), which lives in freshwater and brackish habitats, can be found in the bycatch of pelagic trawlers (Oruç, 2001).

Black Sea
No pelagic trawlers operate in this subregion.

Pelagic trawlers overview
The mortality reported for this fishery is usually low (8 percent, on average) and most of the sea turtles caught are alive and healthy and usually released back into the sea immediately after capture. In the Adriatic Sea, this fishery may be responsible for around 70 events in which individuals were found dead each year. In Turkey, pelagic trawlers cause incidental catch of both sea and freshwater turtles, though with a low direct mortality rate (0–5 percent).

2.3.3 Small-scale fisheries

Most SSF in the Mediterranean use gillnets and/or trammel nets, generally called set nets. Set nets represent a problem for sea turtles mainly in coastal areas, where these types of nets are used (Lazar, Margaritoulis and Tvrtkovic, 1998, 2004; Argano *et al.* 1992). Set nets, being positioned on the sea bottom, can interact with sea turtles in the demersal phase. Therefore, these types of fishing gear have potential impacts on sea turtles if deployed at depths less than 50 m. At the same time, set nets can also be used in waters deeper than 200 m and interact with post-pelagic stage loggerheads. In this case, the likelihood of fatal decompression rises with increasing depth of gear deployment (Fahlman *et al.*, 2017).

Sea turtles can become entangled in nets when trying to feed on previously captured fish or if they do not perceive the presence of the nets at all (Suggett and Houghton, 1998). When caught, they can be forced underwater for an unsustainable period of time (Laurent, 1991; Laurent *et al.*, 1996). Drowning is the main reason behind sea turtle mortality in this fishing gear: the animals, once entangled in the net, cannot reach the surface to breathe. Therefore, the soaking time and bottom depth setting strongly influence the probability of survival: the longer the setting time, the lower the probability of survival; the deeper the net setting (up to 50 m), the lower the probability of reaching the surface to breathe. Environmental parameters may also affect sea turtle mortality: high water temperatures (such as in North African countries), associated with high metabolic rates, can strongly weaken resistance to forced immersion. Moreover, sea turtles rely extensively on visual cues, particularly when foraging (Swimmer *et al.*, 2005), due to their well-developed visual system endowed with a wide spectral range (Mäthger, Litherland and Fritsches, 2007; Southwood *et al.*, 2008). Therefore, water turbidity and the setting of nets at night negatively affect the likelihood of sea turtles seeing them. In addition, various technical parameters of set nets could strongly influence the probability of catching sea turtles; for example, the use of large mesh openings and highly slack netting could increase the risk of turtles' entanglement. Moreover, with the same mesh openings used, trammel nets are more dangerous than gillnets (Lucchetti, Vasapollo and Virgili, 2017b).

However, quantifying captures in these SSF is difficult to assess due to the high number of small boats widely distributed along Mediterranean coasts using this gear. According to GFCM (FAO, 2018), SSF account for about 80 percent of the Mediterranean fleet, with more than 74 000 vessels. Passive set nets (gillnets, trammel nets, combined nets and small driftnets) are among the principal types of fishing gear used by SSF to target a variety of demersal, benthic and pelagic species (Lucchetti *et al*., 2015). The technical and operating features of the different types of fishing gear influence the quantities of incidental catch and its composition. However, as the technical properties of fishing gear are not always documented, the incidental catch data in this review have been generically assigned to set nets.

Although information about set net–sea turtle interactions in the Mediterranean is scarce, and spatially and temporally scattered, by merging the incidental catch data obtained from different regions of the Mediterranean (Table 4), an estimate of around 31 000 sea turtles caught annually emerges. These estimates are higher than those obtained by Casale (2008, 2011). Both juvenile and adult life stages of loggerhead turtles are affected, as confirmed by biometric data, indicating that the size of sea turtles caught ranges from 21 to 80 cm carapace length (Lucchetti, Vasapollo and Virgili, 2017b; Casale *et al*., 2005a, 2005b; Echwikhi *et al*., 2010a). Larger adult green turtles are also occasionally caught in set nets off Cyprus (Snape *et al*., 2013).

Western Mediterranean

In the western Mediterranean, sea turtle bycatch in SSF seems to be lower than in the rest of the Mediterranean, with estimates of about 1 000 to 3 000 sea turtles caught per year, mainly off France and the Balearic Islands. Casale (2008, 2011) estimated that around 1 500 to 1 700 sea turtles can be caught in French Mediterranean waters each year. Nevertheless, according to recent observations (after 2008) carried out on gillnets, sampling indicates much lower values – between 300 and 500 sea turtles per year – mainly resulting from a reduction in the number of active netters (Pascual-Fernandez *et al*., 2015). Most bycatch takes place in the spring or summer and mainly involves juveniles (Oliver, 2008). Carreras, Cardona and Aguilar (2004) estimated that in 2001, around 300 sea turtles were caught in all types of set nets in the Balearic Islands. This low estimate probably follows from the fact that set nets are positioned close to the bottom, and in this area of the Mediterranean basin, sea turtles usually remain near the surface. Moreover, the depth at which these nets are set prevents the depredation activity of sea turtles.

In Morocco, Casale (2008) estimated around 1 700 captures per year, but these estimates were further revised (Casale, 2011) to around 300 sea turtles annually. No data or reliable estimates are available from Algeria or for the entire Tyrrhenian Sea.

Central Mediterranean

Considering the sea bottom characteristics in the central Mediterranean, set nets present a matter of concern for sea turtle bycatch in this basin, especially on the continental shelf of Tunisia, which is considered to be one of the main sea turtle foraging habitats in the Mediterranean. Echwikhi *et al*. (2010b) estimated that around 450 sea turtles may be caught annually in the southern part of the Gulf of Gabès alone. However, these estimates cannot be extrapolated to the entire length of the Tunisian coast, due to the unusual characteristics of this area and its fishery (for example, the types of fishing gear used and the species targeted). Casale (2011), taking into account the

BPUE calculated by Echwikhi *et al*. (2010b) in the southern Gulf of Gabès, has described a worst-case scenario, with more than 4 000 catches per year in Tunisia, and, using a similar approach, 300–350 per year in Libya.

Casale (2011) also reported around 500 captures per year in Italian waters. However, Lucchetti, Vasapollo and Virgili (2017a), based on data collected from interviews with fishers, estimated around 1 500 catches annually in the Ionian Sea and the Strait of Sicily.

In the Gulf of Gabès (Tunisia), one of the Mediterranean areas with the highest sea turtle abundance, Echwikhi *et al*. (2010b) found a mean value of 0.339 sea turtles caught per km of gillnet. Therefore, these data confirm that sea turtle bycatch rates vary greatly according to fishing areas and target species.

Adriatic Sea

In the Adriatic Sea, Italy, Croatia and Slovenia combined can catch 9 000 sea turtles per year in set nets. Lazar, Ziza and Tvrtkovic (2006) estimated an annual bycatch between 650 and 4 000 sea turtles on the eastern side of the Adriatic Sea, with a mean annual catch of around 2.8 sea turtles per vessel. Lucchetti, Vasapollo and Virgili (2017a, 2017b) estimated that the annual incidental catch per vessel in the Adriatic (Italian fleet) ranged from 1.8 (southern Adriatic) to 5.3 (at the Po River Delta), for a total of more than 5 000 sea turtles caught per year. Indeed, Lucchetti, Vasapollo and Virgili (2017b) recently found a distinct bycatch hotspot during the summer period in the central-northern Adriatic. The high abundance of sea turtles in this survey area is probably linked to the nutrient input from the Po River and its effect of increasing phytoplankton concentrations. In the area identified as a hotspot, the bycatch rate in trammel nets and gillnets (0.7 and 0.5 sea turtles per km of net, respectively) was greater than the rates found in other Mediterranean areas. In contrast, in the southern Adriatic Sea, Lucchetti, Vasapollo and Virgili (2017b) estimate that 2 000 sea turtles are caught per year.

Eastern Mediterranean

The eastern basin is a matter of concern, as it is estimated that more than 13 000 sea turtles may potentially be captured on an annual basis in set nets (Table 4), with most catches – more than 4 000 sea turtles per year – occurring along the southern coast of Turkey, another 1 000 to 4 000 per year in Cyprus, around 3 000 in Egypt, and 2 500 in Greece.

Casale (2011), on the other hand, used secondary data to estimate sea turtle bycatch in both set nets and bottom longlines, applying the original data collected by Godley *et al*. (1998) to the 2011 fishing effort statistics. By considering more recent data, the estimate for the entire basin could be as high as 16 000 sea turtles per year. Indeed, juveniles are frequently caught close to nesting areas in Greece, Turkey and Cyprus (Suggett and Houghton, 1998; Godley *et al*., 1998).

Casale (2011) applied the annual capture rate (per vessel) estimates of Godley *et al*. (1998) in Cyprus to the number of vessels registered at the time of his study and estimated that 3 600 sea turtles were captured in set nets. The mean mortality rate of 60 percent estimated by Casale (2011) was also found by Snape *et al.* (2013) to be of an appropriate order; therefore the number of sea turtle mortalities occurring annually in set nets around Cyprus is likely around 2 150. Trammel nets targeting mainly siganids (rabbitfishes), but also the Mediterranean parrotfish (*Sparisoma cretense*), *Mullus* spp. (particularly the red mullet, *M. barbatus*), *Dentex* spp. (particularly the common dentex, *D. dentex*) and *Pagellus* spp. (particularly the common pandora, *P. erythrinus*), appear to be responsible for a large proportion of these catches, because they are set close to shore in shallow waters (Snape, 2015; Snape *et al.*, 2013), with especially strong impacts on juvenile green sea turtles. Gillnets targeting bogue (*Boops boops*) and picarels *Spicara* spp. (represented in the Mediterranean by the blotched picarel, *S. maena*, and the picarel, *S. smaris*) also capture loggerhead sea turtles, although these nets are soaked for short periods and therefore result in fewer captures and fewer mortalities (Snape *et al.*, 2013). Recent incidental catch monitoring as part of the MedBycatch project (GFCM, 2021) has found that large mesh (100 mm) set nets targeting the greater amberjack (*Seriola dumerili*), frequently capture loggerhead sea turtles and inflict a high mortality rate. Additionally, some sea turtles caught in deeper waters (for example, up to 70 m) show signs of decompression sickness and die post-capture on the deck or en route to rehabilitation. Moreover, the longer average soaking time of gillnets may lead to a greater risk of decompression sickness (Fahlman *et al.*, 2017).

Black Sea

Little information is available from the Black Sea and it is not possible to make estimates. Due to the limited presence of sea turtles in Black Sea waters, incidental catch in this area is not considered an issue for the conservation of sea turtle populations.

Small-scale fisheries overview

To summarize, sea turtle mortality caused by set nets depends on several factors: gear-related features (including mesh opening size, hanging ratio, net type, vertical netting slackness and twine thickness, among others), operational factors (soaking time, depth setting), environmental factors (such as sea water temperature), as well as the dimensions of the sea turtles, since survival of larger individuals (with high duration of apnoea) is possible if the capture occurs before gear retrieval (Cambiè, 2011). Some studies (Carreras, Cardona and Aguilar, 2004; Lucchetti, Vasapollo and Virgili, 2017b) highlighted that the use of gillnets with large meshes presents a serious threat of entanglement to sea turtles; similarly, trammel nets with large meshes in their external panels cause comparable catch rates. Therefore, large mesh sizes, such as the ones used in Tunisia for demersal fish species (14-16 cm mesh size; Echwikhi *et al.*, 2010b) increase entanglement of sea turtles. Lucchetti, Vasapollo and Virgili (2017b) concluded that fishing gear should be redesigned by encouraging the use of gillnets with small meshes (less than 70 mm mesh opening) to reduce sea turtle entanglements. Moreover, the authors suggested that the use of trammel nets should be reduced, especially during the summer, while alternative and less impactful types of gear (such as fish pots) should be encouraged. In conclusion, technical solutions, including smaller mesh openings, reduced slackness, flotation devices and thin twine, could allow traditional fishing practices to survive while improving the conservation of protected species.

The direct mortality associated with these types of gear seems to be very high in comparison with that of bottom trawls (Table 4). According to the different parameters affecting survival probability (as described above), the mortality rates reported for different areas vary greatly, ranging from heights of 87 percent in Corsica (Delaugerre, 1987) and 69 percent in Sardinia and Tunisia (Cambiè, 2011; Echwikhi *et al.*, 2010b) to the low values registered in Tunisia (5.2 percent) (Bradai, 1993) and Turkey (10 percent) (Godley *et al.*, 1998). In the Adriatic Sea, recent estimates (20–30 percent) (Lucchetti, Vasapollo and Virgili, 2017a, 2017b; Virgili, Vasapollo and Lucchetti, 2018), in agreement with the values obtained in Spain (21.4 percent) (Álvarez De Quevedo, 2010), are quite low in comparison with the mortality rates found in other areas. Combining all the available data (Table 4), the mean mortality rate for the entire Mediterranean Sea is estimated at around 51 percent, taking into account the high diversity of types of fishing gear (i.e. trammel net, gillnets, entangling nets not specified) and fishing tactics (for example, depth setting and time setting, among others) in each region. By applying a flat rate (51 percent) and the rates found in the different areas, it is estimated that between 13 000 and 17 000 sea turtles die annually due to Mediterranean set nets.

PLATE 2
Sea turtle incidentally caught by a set net

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If a sea turtle survives, there may still be a delayed mortality due to injuries and necrosis after entanglement and/or release. In all studies, the delayed mortality (i.e. after turtles have been released) is unknown, although recently Snoddy and Williard (2010) suggested that, at least in North Carolina (USA), up to 30 percent of turtles that survived gillnet entanglement died after release. Moreover, differences in the habitats of adults and juveniles relative to the different types of fishing gear used might make juveniles more susceptible to gillnet and trammel net entanglement than adults. Tomás, Aznar and Raga (2001) have documented scavenging behaviour in juvenile loggerheads (i.e. foraging for fish that are discarded due to low commercial value or because they measure below the minimum legal size), which might also lead them to depredate from static fishing gear, thereby making them more vulnerable to entanglement than their adult counterparts.

Based on the incidental catch estimates obtained by different authors, and taking account that sometimes the estimates could refer to partially overlapping areas, it is roughly calculated that around 31 000 sea turtles are caught by Mediterranean set net fisheries per year:

- In the western Mediterranean Sea, around 800–2 000 capture events per year may occur, with around 500–1 000 dead;
- In the central Mediterranean, 6 000 sea turtles may be caught annually, mainly by Tunisian and Italian vessels, with possibly 2 400–3 100 dead;
- In the Adriatic Sea, around 9 000 capture events per year may occur annually, with about 3 500–4 500 dead;
- In the eastern Mediterranean, around 14 000 sea turtles per year may be caught, with around 4 800–7 000 dead; the maximum value is from Casale (2011).

TABLE 4 – Incidental catch of sea turtles in small-scale fisheries (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Lazar and Tvrtković, 2003; Lazar *et al.*, 2003	2000–2002	GEN	Adriatic Sea	Slovenia–Croatia	*Caretta caretta*	-	54.9–65.4%
Lazar *et al.*, 2004	1990–2002	GEN	Adriatic Sea	Slovenia–Croatia	*Caretta caretta*	-	62.5%
Lazar *et al.*, 2006	2006	GEN/GNS	Adriatic Sea	Slovenia–Croatia	*Caretta caretta*	658–4 038	54.9–73%
Lazar *et al.*, 2006	2006	GEN	Adriatic Sea	Slovenia	*Caretta caretta*	270	74.7%
Casale, 2008	2008	GEN	Adriatic Sea	Slovenia	*Caretta caretta*	393	-
Casale, 2011	2011	GEN	Adriatic Sea	Slovenia	*Caretta caretta*	433	-

TABLE 4 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Lucchetti *et al.*, 2017a	2017	GEN	Adriatic Sea	Italy (central-northern)	*Caretta caretta*	5 433	21–24%
Lucchetti *et al.*, 2017b	2017	GEN	Adriatic Sea	Italy (south)	*Caretta caretta*	2 818	-
Virgili *et al.*, 2018	2015–2016	GEN	Adriatic Sea	Italy	*Caretta caretta*	-	30%
White *et al.*, 2008	N/A	Stationary fish trap (*Stavnike*)	Adriatic Sea	Albania (Patoku Lagoon)	*Caretta caretta*	103	-
Laurent *et al.*, 1990	1988	GEN/LL	Central Mediterranean	Tunisia	*Caretta caretta*	800–1 650	-
Bradai, 1993	1993	GEN	Central Mediterranean	Tunisia (Gulf of Gabès)	*Caretta caretta*	920–2 000	5.2%
Casale, 2011	2011	GEN	Central Mediterranean	Tunisia	*Caretta caretta*	2 000	-
Casale, 2008	2008	GEN	Central Mediterranean	Malta	*Caretta caretta*	185	-
Casale, 2008	2008	GEN	Central Mediterranean	Libya	*Caretta caretta*	5 624	-
Casale, 2008	2008	GEN	Central Mediterranean	Tunisia	*Caretta caretta*	4 600	-
Casale, 2011 (based on Echwikhi *et al.*, 2010a, 2010b; Jribi *et al.*, 2010)	2010	GEN	Central Mediterranean	Tunisia	*Caretta caretta*	4 200	69.4%
Casale, 2011	2011	GEN	Central Mediterranean	Libya	*Caretta caretta*	322	-
Casale, 2011	2011	GEN	Central Mediterranean	Malta	*Caretta caretta*	65	-
Lucchetti *et al.*, 2017a	2017	GEN	Central Mediterranean	Italy (Ionian Sea)	*Caretta caretta*	1 095	-
Lucchetti *et al.*, 2017a	2017	GEN	Central Mediterranean	Italy (Strait of Sicily)	*Caretta caretta*	475	-
Echwikhi *et al.*, 2010b; Echwikhi *et al.*, 2011	2007–2008	GEN	Central Mediterranean	Tunisia (southeast region)	*Caretta caretta*	443	69.4%
Godley *et al.*, 1998	1995	GEN/LL	Eastern Mediterranean	Cyprus	*Caretta caretta*	684	10%
Godley *et al.*, 1998	1995	GEN/LL	Eastern Mediterranean	Turkey (southeast)	*Caretta caretta*	1 328	10%
Nada and Casale, 2011	2007	GEN	Eastern Mediterranean	Egypt	*Caretta caretta*–*Chelonia mydas*	1 763–3 526	-
Nada and Casale, 2008; Casale, 2008	2008	GEN	Eastern Mediterranean	Egypt	*Caretta caretta*	754	-
Casale, 2008	2008	GEN	Eastern Mediterranean	Turkey	*Caretta caretta*	5 000	-
Casale, 2008	2008	GEN	Eastern Mediterranean	Cyprus	*Caretta caretta*	3 300	-
Casale, 2008	2008	GEN	Eastern Mediterranean	Egypt	*Caretta caretta*	651	-
Casale, 2011	2011	GEN	Eastern Mediterranean	Greece	*Caretta caretta*	2 533	-
Casale, 2011	2011	GEN	Eastern Mediterranean	Syria	*Caretta caretta*	875	-
Casale, 2011	2011	GEN/LL	Eastern Mediterranean	Cyprus	*Caretta caretta*	3 568	-
Casale, 2011	2011	GEN	Eastern Mediterranean	Egypt	*Caretta caretta*	2 791	-
Casale, 2011	2011	GEN/LL	Eastern Mediterranean	Turkey	*Caretta caretta*	4 728	-

TABLE 4 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Levy *et al.*, 2015	2012	GEN	Eastern Mediterranean	Israel	*Caretta caretta–Chelonia mydas*	1 672	74%
Snape *et al.*, 2013	2009–2011	GEN	Eastern Mediterranean	Cyprus	*Caretta caretta–Chelonia mydas*	800–1 100	60%
Panagopoulou *et al.*, 2017	2013	GEN	Eastern Mediterranean	Greece (Crete)	*Caretta caretta*	120	-
Laurent, 1991	1990	GTR (for lobster)	Western Mediterranean	France	*Caretta caretta*	low	100%
Laurent, 1991	1990	GTR (for sole)	Western Mediterranean Sea	France	*Caretta caretta*	2[2]	53%
Laurent, 1991	1990	GTR (for mixed species)	Western Mediterranean	France	*Caretta caretta*	0.12[2]	28%
Laurent, 1991	1990	GNS	Western Mediterranean	France	*Caretta caretta*	0.8[2]	33%
Claro *et al.*, 2010	1991-2010	GEN	Western Mediterranean	France	*Caretta caretta*	44	>50%
Carreras *et al.*, 2004	2001	GTR (for lobster)	Western Mediterranean	Balearic Islands (Spain)	*Caretta caretta*	196	77.7%
Carreras *et al.*, 2004	2001	GNS (for red mullet)	Western Mediterranean	Balearic Islands (Spain)	*Caretta caretta*	low	50%
Alvarez de Quevedo *et al.*, 2006; Carreras *et al.*, 2004	2004–2006	GEN	Western Mediterranean	Spain	*Caretta caretta*	267	-
Delaugerre, 1987	1987	GEN	Western Mediterranean	Corsica (France)	*Caretta caretta*	low	87.5%
Laurent *et al.*, 1996	1987–1996	GEN	Western Mediterranean	France	*Caretta caretta*	low	28.5%
Laurent *et al.*, 1996	1987–1996	GEN	Western Mediterranean	Corsica (France)	*Caretta caretta*	low	75%
Casale, 2008	2008	GEN	Western Mediterranean	Spain (north)	*Caretta caretta*	65	-
Casale, 2008	2008	GEN	Western Mediterranean	Spain (Balearic Islands)	*Caretta caretta*	6–196	-
Casale, 2008	2008	GEN	Western Mediterranean	France	*Caretta caretta*	1 509	-
Casale, 2008	2008	GEN	Western Mediterranean	Morocco	*Caretta caretta*	1 765	-
Casale, 2011	2011	GEN	Western Mediterranean	France	*Caretta caretta*	1 676	-
Casale, 2011	2011	GEN	Western Mediterranean	Morocco	*Caretta caretta*	282	-
Cambiè, 2011	1992–2001	GEN	Western Mediterranean	Italy (central-west Sardinia)	*Caretta caretta*	92	69%
Lozano *et al.*, 2011	2008–2010	GEN	Western Mediterranean	Spain (Cabo de Gata–Níjar Marine Reserve)	*Caretta caretta*	11	-
Lucchetti *et al.*, 2017a, 2017b	2017	GEN	Western Mediterranean	Italy (Tyrrhenian Sea)	*Caretta caretta*	11 787[3]	-
Lucchetti *et al.*, 2017a, 2017b	2017	GEN	Western Mediterranean	Italy (Sardinia)	*Caretta caretta*	1 365[3]	-
Álvarez de Quevedo *et al.*, 2010	2003–2004	GEN	Western Mediterranean	Spain (northeastern)	*Caretta caretta*	67 (33–101)	21.4%

TABLE 4 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Benhardouze *et al.*, 2012	2003–2007	GND[4]	Western Mediterranean	Morocco (northwestern)	*Caretta caretta*	719	6.3%
Benhardouze *et al.*, 2012	2003–2007	GND[4]	Western Mediterranean	Morocco (northwestern)	*Dermochelys coriacea*	101	-
Argano *et al.*, 1992	1992	GEN	-	Italy	*Caretta caretta*	-	50%
Casale, 2011	2011	GEN	-	Italy	*Caretta caretta*	523	45.5%
Casale, 2008	2008	GEN	-	Italy	*Caretta caretta*	1 338	-
Casale, 2008	2008	GEN	-	Greece	*Caretta caretta*	2 694	-
Casale, 2008	2008	GEN	-	Entire Mediterranean	*Caretta caretta*	30 000	50%-60%
Casale, 2011	2011	GEN	-	Entire Mediterranean	*Caretta caretta*	22 921–31 153	60%

Notes:

GNS = set gillnet; GTR = trammel net; GEN = gillnets and entangling nets not specified; GND = driftnet; LL = longline.
In grey data collected before 2008.

1. The data reported here are derived either from direct observations or from yearly estimates. Please refer to the original paper for the methodology used to obtain the value(s).
2. Bycatch per vessel per year (obtained from interviews with fishers).
3. Data not considered for the calculation of total estimates.
4. The use of driftnets is forbidden since 2005.

2.3.4 Longliners

The main causes of mortality in longlines are injuries due to ingested hooks and branch lines and the subsequent drowning of sea turtles (Work and Balazs, 2002; Casale, 2011).

The features of hooks can be identified by various parameters, including their general shape (J-shaped or circle), dimensions (for example, total length, length diameter, gap between point and shank, shank length, width, throat and barb size), material (steel, inox), point (with barb or without), and shape of the eye (flat or twisted). In the hooking process, the most important parameters are: the overall hook width, which can be correlated with sea turtle mouth dimensions; its gap, which ensures deeper penetration of the point and better holding power over the fish; and its shape, which can influence the hooking position. The hook size and shape (J-shaped or circle) influence the probability that the hook is swallowed and of the sea turtle becoming hooked internally, which increases the chances of delayed mortality after release (Read, 2007).

Nevertheless, in addition to the hook, the branch lines can easily kill sea turtles, especially if, when ingested, they are long enough to affect intestinal peristalsis (Bjorndal, Bolten and Lagueux, 1994; Orós, Calabuig and Deniz, 2004; Di Bello, Valastro and Staffieri, 2006; Casale *et al.*, 2007). In these cases, death typically occurs after many days. Unfortunately, it is common practice for fishers to cut the branch lines from the deck while the captured sea turtle is still in the water (they save time because sea turtles are often very heavy to lift out of the water), thereby releasing most sea turtles caught with branch lines longer than 1 m (Guglielmi, Di Natale and Pelusi, 2000). The branch line can either be ingested or trap fins or other parts; in both cases, the consequences could be dangerous for the sea turtle. Therefore, it appears that hooks can cause death in the short term and branch lines over the long term (Casale *et al.*, 2007).

Moreover, the type of bait and its olfactory attraction strongly influence sea turtle bycatch in drifting longlines, with squid bait being more attractive than mackerel (Piovano *et al.*, 2004, 2005;

Rueda *et al.,* 2006). There is also evidence of released turtles being caught again on other nearby longlines (Tomás *et al.*, 2001).

Generally, two types of longlines are used in the Mediterranean Sea: set longlines (sometimes also called bottom or demersal longlines), which are deployed on the sea bottom, and drifting longlines (sometimes also called surface or pelagic longlines), which are used in the water column at variable depths. Therefore, the two corresponding types of vessel groups are presented separately in the following records.

a) Drifting longliners

Drifting longlines targeting swordfish, albacore and bluefin tuna (*Thunnus thynnus*), deployed over the continental shelf and in offshore waters, are historically considered as the main concern to sea turtles in the Mediterranean Sea, in terms of bycatch per year (Gerosa and Casale, 1999; Margaritoulis *et al.*, 2003; Deflorio *et al.*, 2005). The incidental capture of loggerhead sea turtles in their pelagic phase with longlines mainly occurs from late spring to late autumn (May–September), with most captures recorded over the summer. To summarize, Morocco, southern Spain, the Balearic Islands, the southern Ionian Sea–Strait of Sicily and the northern Ionian Sea–southern Adriatic Sea are the regions with the highest catch per unit effort using drifting longlines (for example, Casale, 2008, 2011; Echwikhi *et al.*, 2010a; Alvarez de Quevedo *et al.*, 2013; Báez *et al.*, 2014).

Western Mediterranean

The western Mediterranean, especially the area around the Balearic Islands, seems to be the most problematic area for high incidental catch rates in drifting longlines, partly due to the high concentration of Mediterranean sea turtles in the western basin, as well as of those entering from the Atlantic Ocean via Gibraltar (Camiñas and de la Serna, 1995; Argano *et al.*, 1992). Results indicate that drifting longlines for swordfish are responsible for greater incidental catch than drifting longlines for bluefin tuna and albacore (Camiñas, Valeiras and de la Serna, 2003; Báez, Real and Camiñas, 2007; Camiñas *et al.*, 2006b, 2016; Báez *et al.*, 2007, 2014b). Spain was considered to be the country with the highest number of sea turtle captures per year, with past estimates ranging from 22 000 to 35 000 sea turtles annually (Table 5). Casale (2011) reported around 35 000 captures per year, with Spain accounting for around 20 000 and Morocco for around 15 000 sea turtles, respectively. In Morocco, Laurent (1990) had previously estimated a much lower rate, at around 3 600 sea turtles per year.

However, in Spain, recent estimates made by Báez *et al.* (2018, 2019) from 2000 to 2016 indicate that the incidental catch rate could be less marked than previously calculated, with around 5 600 (3 000–9 000) sea turtles caught per year. These estimates are even lower than those found by Alvarez de Quevedo, San Félix and Cardona (2013), who reported about 10 000 catches per year. In recent years (2013–2016), bycatch estimates in this area have further decreased to around 2 400 turtles per year (Báez *et al.* (2019). The difference in these estimates could be due to the spatial overlap in fishing grounds and loggerhead distributions, the technical differences in fishery operations and in the configuration of types of fishing gear, as well as the real fishing effort, none of which were considered in the past. Báez *et al.* (2018, 2019) observed a clear decreasing trend that could also be due to the recent gradual introduction of mesopelagic or semipelagic longlines (since 2007 in Spain and since 2010 in Italy) (Camiñas, 2015; Garibaldi, 2015; Báez *et al.* 2019), which replaced, for example, the surface longline gear previously used by the main Italian fishing fleets (i.e. in the Ligurian Sea and Ionian Calabria) (Garibaldi, 2015; Cambié *et al.*, 2013). This technological innovation is particularly important because of its implications for the bycatch rates of sea turtles. The mesopelagic longline is set in deeper waters (150–200 m), usually for a longer period, and with a lower number of hooks per set, compared to a traditional surface longline. The results show that sea turtle bycatch strongly decreases and around 90 percent of the catch is composed of swordfish. Moreover, Garibaldi (2015) reported that with the mesopelagic longline, sea turtle bycatch is reduced to zero.

Nevertheless, bycatch estimates for longliners can vary highly for the same area. For example, the estimates for Morocco increased from 3 600 sea turtles per year, as estimated by Laurent (1990), to 14 800 sea turtles per year, as calculated by Casale (2011; secondary data based on Benhardouze, 2004).

Elsewhere, 2 500 to 5 000 sea turtle captures per year by longliners have been estimated to occur in the western Italian regions (Tyrrhenian Sea and Sardinia; Casale, 2008, 2011), while Algeria seems to play a smaller role overall, with around 200 to 300 catches per year; Casale (2008) confirms the estimate made by Camiñas (2004). However, estimates for the Tyrrhenian Sea should also be revised in light of the introduction of mesopelagic longlines in this area.

Thus, considering past and recent estimates for longliners, sea turtle bycatch in the western Mediterranean could range between 12 000 and 38 000 captures per year, with the highest estimates coming from Morocco and Spain, generated by Casale (2011).

Central Mediterranean

The central Mediterranean, particularly the Strait of Sicily and the Ionian Sea, connects the eastern and western basins and also borders the Adriatic Sea; therefore, this area is intensely frequented by sea turtles in the oceanic phase migrating between the basins and foraging in the area. The Ionian Sea is also frequented by small sea turtles, which probably hatched in the major nesting sites of Greece. Indeed, sea turtles caught by longlines are reported from areas close to neritic foraging grounds, such as Greece (Kapantagakis, 2001) and Tunisia (Jribi *et al.*, 2008). Moreover, catch rates suggest a high number of captures in the area by the Italian fishing fleet (Casale, Freggi and Rocco, 2007), with other fleets present in the same area, including the Maltese, Greek and Tunisian fleets (Table 5). In Malta, loggerhead sea turtles were also the most abundant non-target bycatch species (Burgess *et al.*, 2010).

More than 14 000 sea turtles can be incidentally caught annually in this area (around 11 000 sea turtles per year if the minimum values are considered), mainly in Italian (up to 6 000 sea turtles per year; Casale, 2011; Lucchetti, Vasapollo and Virgili, 2017a), Tunisian (around 1 000 sea turtles per year; Casale, 2011), Greek (around 3 300 sea turtles per year; Casale, 2011) and Libyan (around 1 410 sea turtles per year; Casale, 2011) waters.

Adriatic Sea

In the Adriatic Sea, only the southern part seems to show notable incidental catch, with around 1 000 sea turtles caught annually Fortuna *et al.*, 2008; Casale, 2011), though, in the last five years, some vessels have begun to catch swordfish, bluefin tuna and albacore in the central Adriatic during summer and autumn, meaning that the number of sea turtles caught may be higher (Lucchetti, Vasapollo and Virgili, 2017a).

Eastern Mediterranean

In the eastern basin, the use of longlines is more limited and around 2 000 sea turtles may be caught annually as bycatch, mainly by Egypt, accounting for 1 300–3 000 sea turtles per year (Casale, 2011; Nada and Casale, 2011).

Black Sea

No data are available for drifting longliners operating in the Black Sea.

Drifting longliners overview

Technical and operational factors affect sea turtle mortality in drifting longliners, including the number of hooks, hook size and shape, the use of a roller, the type of bait and materials, boat length, and the number of fishers onboard. Indeed, Camiñas *et al.* (2006a, 2006b) found that bycatch and direct mortality differed significantly according to the type of boat and gear. Albacore and bluefin tuna drifting longliners generally result in higher direct mortality of the hooked sea turtles than do swordfish longlines. This difference is probably due to the gear structure (mainly the hook size), but it could also be a result of the fishing depth or the distance from the coast (Báez *et al.*, 2007, 2011), or even the higher amount of catch, which causes the fishing gear to sink further, thereby increasing sea turtle mortality by drowning.

According to Table 5, the direct mortality induced by drifting longlines appears to be low when compared with other types of gear. However, great variability has been observed, depending on several parameters (such as area, fishing tactics, target species, depth setting, vessel and gear properties), so that mortality rates should be considered case by case, and not as a flat value. Delayed mortality is a major cause of concern because it is largely unknown and suspected to be high (National Marine Fisheries Service, 2001; Camiñas and Valeiras, 2001; Kapantagakis and Lioudakis, 2006; Lewison, Freeman and Crowder, 2004; Deflorio *et al.*, 2005). Post-release mortality depends strongly on the position of the hooks along the digestive tract, potentially attaching to, for example, the mouth, oesophagus, stomach or intestines (Camiñas and Valeiras, 2001). If the hook is swallowed in the lower oesophagus or in the stomach, the sea turtle has a very low chance of survival. Conversely, sea turtles caught with a hook in the mouth or in the upper oesophagus seem to face less life-threatening odds, though a hook in the mouth could compromise feeding performance, especially if it prevents closure of the mouth (Casale, Freggi and Rocco, 2007; Casale *et al.*, 2007). Aguilar, Más and Pastor (1995) have reported a post-release mortality of 24.4 percent, while Álvarez de Quevedo, San Felix and Cardona (2013) found a post-release mortality ranging from 31 to 38 percent within the 90 days following release.

Bàez *et al.* (2019) recently discovered that loggerhead sea turtle bycatch in the Spanish surface fleets had significantly decreased over the previous eight years as an indirect effect of the introduction of new technology and fishing strategies. Indeed, sea turtle mortality by drifting longlines can be strongly affected by the depth of the main line setting. Juvenile loggerhead sea turtles are capable of diving to depths below 200 m, though they mainly stay in the upper 30 m (Dellinger, 2000; Dellinger and Ferreira, 2005). In general, loggerhead sea turtles spend most of their time at less than 40 m and they do not dive deeper than 100 m (Polovina *et al.*, 2003; Báez *et al.*, 2019). Thus, the primary depths at which interactions with longlines occur are in the upper 20 m of the water column (Dellinger and Ferreira, 2005). In fact, several studies have confirmed the very low direct mortality rate due to shallow-set longline gear activities (Pinedo and Polacheck, 2004; Piovano, Swimmer and Giacoma, 2009; Deflorio *et al.*, 2005; Gilman *et al.*, 2006; Jribi *et al.*, 2008). Recent studies confirm that by modifying only the depth of fishing (i.e. leaving the longline at a depth inaccessible to sea turtles), the bycatch of loggerhead turtles can be reduced by up to 99.5 percent compared to surface longlines (Garibaldi, 2015; Cambiè *et al.*, 2013; Baèz *et al.*, 2019;). Therefore, shallower longlines result in lower direct mortality, while deeper longlines reduce bycatch rates.

Furthermore, sea turtle mortality seems to be correlated with setting time. For example, Camiñas *et al.* (2006) found that around 93 percent of loggerhead sea turtles were caught on the second half of the longline, i.e. the last part of the gear to be hauled back onboard. Therefore, the longer the set time, the more captured sea turtles may die. Indeed, by merging the data obtained in different areas, the mean mortality rate may be around 20 percent, i.e. ranging from 0 to 40 percent.

Based on the incidental catch estimates obtained by different authors for longlines, and considering that: a) sometimes the estimates could refer to partially overlapping areas; b) the bycatch estimates and mortality rates reported for certain areas show great variability (according to the reference year and type of longline); and c) the direct mortality and the delayed mortality are not always reported or are sometimes not clearly reported, it is calculated that between 27 000 and 56 000 sea turtles – if the estimates made for Morocco by Casale (2011) are taken into account – are caught annually by Mediterranean drifting longlines, with a direct mortality rate of around 20 percent, on average.

- The western Mediterranean is the area that raises the most concern. However, great variability in the estimates, especially regarding the Balearic Islands, prevents a clear picture of the situation from emerging. Older references indicate that around 38 000 sea turtles may be caught each year, with potentially more than 7 000 dead, while more recent estimates report about 9 000 sea turtles (and around 1 800 dead) caught in the western Mediterranean.
- In the central Mediterranean, the estimates are biased as the data from the Aegean Sea could be shared (and overlap) between the eastern and the central Mediterranean (especially for the Greek data). However, it is estimated that around 14 000 sea turtles may be caught annually, with around 2 900 dead.
- In the Adriatic Sea (mainly the southern Adriatic), around 1 200 capture events may occur annually, with around 250 dead. However, with increasing fishing effort in recent years from drifting longlines targeting swordfish, the overall rate could be higher;
- In the eastern Mediterranean, longliners are less important than in other areas, so that sea turtle bycatch is around 2 200 sea turtles annually, with about 400 dead.

TABLE 5 – Incidental catch of sea turtles in drifting longlines (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Casale, 2011; Fortuna *et al.*, 2008	2009	LLD	Adriatic Sea	Italy	*Caretta caretta*	1 025	-
Lucchetti *et al.*, 2017a	2017	LLD	Adriatic Sea	Italy (central-northern)	*Caretta caretta*	226	14%
Gramentz, 1989	1989	LLD	Central Mediterranean	Malta	*Caretta caretta*	1 000–2 000	-
Panou *et al.*, 1992	1992	LLD	Central Mediterranean	Greece (Cephalonia)	*Caretta caretta*	50	-
Panou *et al.*, 1999	1989–1995	LLD	Central Mediterranean	Greece (Ionian Sea)	*Caretta caretta*	280	-
Freggi and Casale, 2006	2001–2002	LLD	Central Mediterranean	Italy (Lampedusa Island)	*Caretta caretta*	-	33%[2]

TABLE 5 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Kapantagakis, 2001	1999–2000	LLD	Central Mediterranean	Greece (east Ionian-Aegean)	*Caretta caretta*	3 310	-
Kapantagakis, 2001	1999–2000	LLD	Central Mediterranean	Greece (east Ionian-Aegean)	*Dermochelys coriacea*	171	-
Salter, 1995	1990–1991	LLD	Central Mediterranean	Greece	*Caretta caretta*	-	15–50%
STECF, 2005	1999–2005	LLD	Central Mediterranean	Greece (Ionian Sea)	*Caretta caretta*	3 181	-
Kapantagakis and Lioudakis, 2006	1999–2000	LLD	Central Mediterranean	Greece (Aegean and south Ionian Sea)	*Caretta caretta*	1 145–5 474	4.7%
Kapantagakis and Lioudakis, 2006	1999–2000	LLD	Central Mediterranean	Greece (Aegean and south Ionian Sea)	*Dermochelys coriacea*	0–342[3]	4.7%
De Metrio *et al.*, 1983	1983	LLD	Central Mediterranean	Italy (Ionian Sea–Gulf of Taranto)	*Caretta caretta*	250–1 000	-
Deflorio *et al.*, 2005	1999–2000	LLD	Central Mediterranean	Italy (Ionian Sea)	*Caretta caretta*	1 084–4 447	0% (high potential delayed mortality)
Jribi *et al.* 2008; Echwikhi *et al.*, 2006	2004–2005	LLD	Central Mediterranean	Tunisia (southern Gulf of Gabès)	*Caretta caretta*	486	0–9%
Casale *et al.* 2007, Casale, 2008; Casale, Freggi and Rocco, 2007	2007	LLD	Central Mediterranean	Italy (Lampedusa Island)	*Caretta caretta*	2 148	>30% (potential)
Cambiè *et al.*, 2010	2007	LLD	Central Mediterranean	Italy (south Ionian)	*Caretta caretta*	500	-
Casale, 2008	2008	LLD	Central Mediterranean	Tunisia	*Caretta caretta*	1 000	-
Casale, 2008	2008	LLD	Central Mediterranean	Libya	*Caretta caretta*	1 142	-
Casale, 2008	2008	LLD	Central Mediterranean	Malta	*Caretta caretta*	2 965	-
Burgess *et al.*, 2010	2008	LLD	Central Mediterranean	Malta	*Caretta caretta*	320	-
Echwikhi *et al.*, 2010a	2008	LLD	Central Mediterranean	Tunisia (Gulf of Gabès)	*Caretta caretta*	437	12%
Casale, 2011	2011	LLD	Central Mediterranean	Malta	*Caretta caretta*	3 101	-
Casale, 2011	2011	LLD	Central Mediterranean	Libya	*Caretta caretta*	1 410	-
Casale, 2011	2011	LLD	Central Mediterranean	Italy (Ionian Sea)	*Caretta caretta*	3 553	-
Casale, 2011	2011	LLD	Central Mediterranean	Italy (central Mediterranean)	*Caretta caretta*	2 148	-
Casale, 2011	2011	LLD	Central Mediterranean	Tunisia	*Caretta caretta*	972	-
Casale, 2011	2011	LLD	Central Mediterranean	Greece (eastern Ionian-Aegean Sea)	*Caretta caretta*	3 310	-
Lucchetti *et al.*, 2017a	2017	LLD	Central Mediterranean	Italy (Strait of Sicily, around Lampedusa)	*Caretta caretta*	5 679	14%
Nada and Casale, 2011	2007	LLD	Eastern Mediterranean	Egypt	*Caretta caretta–Chelonia mydas*	2 081 (1 095–3 285)	>30%
Casale, 2011	2011	LLD	Eastern Mediterranean	Egypt	*Caretta caretta*	1 275	-

TABLE 5 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Argano and Baldari, 1983	1978	LLD	Western Mediterranean	Spain	*Caretta caretta*	650–3 750	-
Mayol *et al.*, 1988	1985	LLD	Western Mediterranean	Spain	*Caretta caretta*	17 712	-
Camiñas, 1986	1985	LLD	Western Mediterranean	Spain	*Caretta caretta*	20 326	-
Camiñas, 1988	1986–1987	LLD	Western Mediterranean	Spain	*Caretta caretta*	16 315–16 697	-
Groombridge, 1989	-	LLD	Western and Central Mediterranean	-	*Caretta caretta*	35 000	-
Màs and Garcia, 1990	1989	LLD	Western Mediterranean	Spain (eastern basin)	*Caretta caretta*	5 935–7 568	-
Laurent, 1990	1988	LLD	Western Mediterranean	Morocco	*Caretta caretta*	3 581	-
Laurent, 1990	1988	LLD	Western Mediterranean	Algeria	*Caretta caretta*	324	-
Camiñas *et al.*, 1992	1989	LLD	Western Mediterranean	Spain	*Caretta caretta*	15 339	-
Màs *et al.*, 1992	1991	LLD	Western Mediterranean	Spain	*Caretta caretta*	22 880	-
Aguilar *et al.*, 1993	1992	LLD	Western Mediterranean	Spain	*Caretta caretta*	4 363–6 620	-
Aguilar *et al.*, 1995	1990	LLD	Western Mediterranean	Spain	*Caretta caretta*	35 637	20–30%
Aguilar *et al.*, 1995	1990–1991	LLD	Western Mediterranean	Spain	*Caretta caretta*	22 225–23 637	20–30%
Camiñas, 1996	1993	LLD	Western Mediterranean	Spain	*Caretta caretta*	1 953	-
Camiñas, 1996	1994	LLD	Western Mediterranean	Spain	*Caretta caretta*	5 364	-
Camiñas, 1996	1995	LLD	Western Mediterranean	Spain	*Caretta caretta*	11 673	-
Aguilar *et al.*, 1995; Camiñas *et al.*, 2001	1988/1995/2001	LLD	Western Mediterranean	Spain (Balearic Islands)	*Caretta caretta*	15 000–18 000	0.4%–7.7% (20–30% potential)
Laurent *et al.*, 2001; Mejuto *et al.*, 2006	-	LLD	Western Mediterranean	Spain	*Caretta caretta*	2 000–20 000	-
Camiñas, 2004	2004	LLD	Western Mediterranean	Algeria	*Caretta caretta*	250	-
Carreras *et al.*, 2004	2001	LLD	Western Mediterranean	Balearic Islands (Spain)	*Caretta caretta*	-	7.7%
Benhardouze, 2004	-	-	Western Mediterranean	Morocco	-	193	-
Benhardouze, 2004	-	-	Western Mediterranean	Morocco (Tangier region)	-	206	-
Camiñas, 2005	1984	LLD	Western Mediterranean	Spain	*Caretta caretta*	17 092	-
Camiñas *et al.*, 2006a, 2006b	1999–2004	LLD	Western Mediterranean	Spain	*Caretta caretta*	-	0.5–4.2%
Casale, 2008, 2011	2008	LLD	Western Mediterranean	Morocco	*Caretta caretta*	14 822	-
Casale, 2008	2008	LLD	Western Mediterranean	Algeria	*Caretta caretta*	294	-
Casale, 2008	2008	LLD	Western Mediterranean	France	*Caretta caretta*	317	-
Casale, 2008	2008	LLD	Western Mediterranean	Spain (north, Catalonia)	*Caretta caretta*	130	-

TABLE 5 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Casale, 2008	2008	LLD	Western Mediterranean	Spain (Balearic Islands)	*Caretta caretta*	102	-
Casale, 2008	2008	LLD	Western Mediterranean	Spain (south)	*Caretta caretta*	19 008	-
Casale, 2008	2008	LLD	Western Mediterranean	Italy (Tyrrhenian Sea)	*Caretta caretta*	5 055	-
Casale, 2008	2008	LLD	Western Mediterranean	Italy (Ionian Sea)	*Caretta caretta*	3 053	-
Álvarez de Quevedo *et al.*, 2010	2003–2004	LLD	Western Mediterranean	Spain (north, Catalonia)	*Caretta caretta*	124 (49–199)	0%
Benhardouze *et al.*, 2012	2003–2007	LLD	Western Mediterranean	Morocco (Tangier region)	*Caretta caretta*	51	-
Álvarez de Quevedo *et al.*, 2013	2007–2008	LLD	Western Mediterranean	Spain	*Caretta caretta*	10 656	32–37%
Báez *et al.*, 2014b	2006–2007	LLD	Western Mediterranean	Spain	*Caretta caretta*	6 060	40%
Báez *et al.*, 2014b	1999–2012	LLD	Western Mediterranean	Spain	*Caretta caretta*	56–597	-
Báez *et al.*, 2014b	2010	LLD	Western Mediterranean	Spain	*Dermochelys coriacea*	3	-
Casale, 2011	2011	LLD	Western Mediterranean	Italy (Tyrrhenian Sea, Sardinia)	*Caretta caretta*	5 572	-
Casale, 2011	2011	LLD	Western Mediterranean	Spain	*Caretta caretta*	20 176	-
Lucchetti *et al.*, 2017a	2017	LLD	Western Mediterranean	Italy (Tyrrhenian Sea, Sardinia)	*Caretta caretta*	2 506	14%
Camiñas *et al.*, 2018	1999–2016	LLD	Western Mediterranean	Spain	*Dermochelys coriacea*	1	-
Báez *et al.*, 2018	2004–2016	LLD	Western Mediterranean	Spain	*Caretta caretta*	5 639 (2 724–9 169)	-
Báez *et al.*, 2019	2000–2016	LLD	Western Mediterranean	Spain	*Caretta caretta*	5 317–5 565	1 861–1 955[4]
Báez *et al.*, 2019	2000–2003	LLD	Western Mediterranean	Spain	*Caretta caretta*	8 800–11 800	-
Báez *et al.*, 2019	2015–2016	LLD	Western Mediterranean	Spain	*Caretta caretta*	2 375	50%–low[5]
Báez *et al.*, 2019	2000–2016	LLD (for swordfish)	Western Mediterranean	Spain	*Caretta caretta*	3 000	-
Báez *et al.*, 2019	2000–2016	LLD (for albacore)	Western Mediterranean	Spain	*Caretta caretta*	833	-
Casale, 2008	2008	LLD	-	Entire Mediterranean	*Caretta caretta*	53 347	40%
Casale, 2011	2011	LLD	-	Entire Mediterranean	*Caretta caretta*	57 371	30%
Lewison *et al.*, 2004; NMFS, 2001	2001–2004	LLD	-	Entire Mediterranean	*Caretta caretta*	60 000–80 000	17–42% (potential)

Notes: LLD = drifting longline.

In grey data collected before 2008.

1. The data reported here are derived either from direct observations or from yearly estimates. Please refer to the original paper for the methodology used to obtain the value(s).
2. This estimate considers only the effect of the hook; considering the effect of the branch line on the mortality is even higher.
3. Only one specimen of leatherback sea turtle (Dermochelys coriacea) caught; the estimate of 342 sea turtles caught is obtained by extrapolating the bycatch to the whole fleet and fishing effort.
4. Estimates in number.
5. 50% for mesopelagic longlines, low mortality for drifting longlines (50–1 000 specimens).

These figures can be worse when considering the delayed mortality (more than 30–40 percent; Casale, Freggi and Rocco, 2007; Álvarez de Quevedo, San Felix and Cardona, 2013).

b) Set longliners

Set longlines are widely used in the Mediterranean, especially in the eastern Mediterranean. Gilthead seabream (*Sparus aurata*), common dentex and pink dentex (*Dentex* spp.), common pandora, seabreams (*Diplodus* spp.), groupers (*Epinephelus* spp.) and European seabass (*Dicentrarchus labrax*) are usually the main target species of set longlines. Taking into account the dimensions of the target species, set longlines usually employ smaller hooks than do drifting longlines. Therefore, their hooks can be swallowed by sea turtles feeding on the bait or on the prey captured by the set longlines. Nevertheless, set longlines, used at depths of 200–700 m, are not usually considered an issue for interactions with sea turtles (Bolten, Bjorndal and Martins, 1994). However, this fishing method is widely used also in shallower waters, where it results in sea turtle captures, mainly of juveniles. The data collected from the scientific literature suggest that set longlines are responsible for around 12 000 captures per year (Table 6).

TABLE 6 – Incidental catch of sea turtles in set longlines (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Bradai, 1993	1993	LLS	Central Mediterranean	Tunisia (Gulf of Gabès)	*Caretta caretta*	2 000	0.5%
Casale *et al.*, 2007	2007	LLS	Central Mediterranean	Italy (Lampedusa Island)	*Caretta caretta*	257	-
Jribi *et al.*, 2008; Echwikhi *et al.*, 2006	2004–2005	LLS	Central Mediterranean	Tunisia (southern Gulf of Gabès)	*Caretta caretta*	733 (469–1090)	12.5% (33% potential)
Casale, 2008	2008	LLS	Central Mediterranean	Tunisia	*Caretta caretta*	1 000	-
Casale, 2008	2008	LLS	Central Mediterranean	Greece (Aegean Sea)	*Caretta caretta*	98	-
Casale, 2008	2008	LLS	Central Mediterranean	Malta	*Caretta caretta*	286	-
Casale, 2008	2008	LLS	Central Mediterranean	Libya	*Caretta caretta*	13 378[2]	-
Casale, 2011	2011	LLS	Central Mediterranean	Tunisia	*Caretta caretta*	1 466	-
Echwikhi *et al.*, 2012	2007–2008	LLS	Central Mediterranean	Tunisia (southern Gulf of Gabès)	*Caretta caretta*	142	43.8%
Casale, 2011	2011	LLS	Central Mediterranean	Libya	*Caretta caretta*	3 310	-
Casale, 2011	2011	LLS	Central Mediterranean	Malta	*Caretta caretta*	41	-
Nada and Casale, 2008	2008	LLS	Eastern Mediterranean	Egypt	*Caretta caretta*	2 218	>30%
Casale, 2008	2008	LLS	Eastern Mediterranean	Turkey	*Caretta caretta*	5 000	-
Casale, 2008	2008	LLS	Eastern Mediterranean	Greece	*Caretta caretta*	6 064	-
Casale, 2011	2011	LLS	Eastern Mediterranean	Greece	*Caretta caretta*	1 034	-
Casale, 2011	2011	LLS	Eastern Mediterranean	Syria	*Caretta caretta*	275	-

TABLE 6 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Casale, 2011	2011	LLS	Eastern Mediterranean	Egypt	*Caretta caretta*	806	-
Casale, 2011	2011	LLS	Eastern Mediterranean	Turkey	*Caretta caretta*	4 728	-
Levy *et al.*, 2015	2012	LLS	Eastern Mediterranean	Israel	*Caretta caretta-Chelonia mydas*	129	10%
Álvarez de Quevedo *et al.*, 2006; Carreras *et al.*, 2004	2004–2006	LLS	Western Mediterranean	Spain	*Caretta caretta*	21	-
Álvarez de Quevedo *et al.*, 2010	2003–2004	LLS	Western Mediterranean	Spain (northeastern)	*Caretta caretta*	11 (1–21)	-
Casale, 2011	2011	LLS	Western Mediterranean	France	*Caretta caretta*	22	-
Casale, 2008	2008	LLS	Western Mediterranean	Spain	*Caretta caretta*	96	-
Casale, 2008	2008	LLS	Western Mediterranean	Morocco	*Caretta caretta*	3 366	-
Casale, 2011	2011	LLS	Western Mediterranean	Morocco	*Caretta caretta*	127	-
Casale, 2008	2008	LLS	Western Mediterranean	Algeria	*Caretta caretta*	88	-
Casale, 2011	2011	LLS	Western Mediterranean	Algeria	*Caretta caretta*	98	-
Kaddouri *et al.*, 2018	2016	LLS	Western Mediterranean	Morocco (northwestern)	*Caretta caretta*	17	-
Benhardouze *et al.*, 2012	2003–2007	LLS	Western Mediterranean	Morocco (Tangier region)	*Caretta caretta*	91	16.6%
Casale, 2011	2011	LLS	-	Italy	*Caretta caretta*	471	-
Casale, 2008	2008	LLS	-	Italy	*Caretta caretta*	2 645	Potential mortality 40%
Casale, 2008	2008	LLS	-	Entire Mediterranean	*Caretta caretta*	12 000–34 000	Potential mortality 40%
Casale, 2011	2011	LLS	-	Entire Mediterranean	*Caretta caretta*	12 656	-

Notes:

LLS = set longline.

In grey data collected before 2008.

1. The data reported here are derived either from direct observations or from yearly estimates. Please refer to the original paper for the methodology used to obtain the values.
2. Estimated on the basis of values from Egypt and Tunisia.

Western Mediterranean

In the western basin, the incidental catch from set longlines seems to be less important than from drifting longlines. For example, Spain, Morocco and Algeria each appear to catch only around 100 sea turtles per year (Table 6).

Central Mediterranean

In the central Mediterranean, the data collected allow for an estimate of over 5 000 capture events per year. Tunisian set longliners, for example, seem to be responsible for around 1 000 catches annually. Indeed, Jribi *et al.* (2008) reported that the total bycatch of set longlines in Tunisian waters is higher than that of drifting longlines, due to greater fishing effort. Meanwhile, around 600 sea turtles annually can be added to this figure from Italy (Lampedusa Island), Algeria and

Malta combined (Table 6). Furthermore, Casale (2011) estimated about 3 310 captures per year from Libya alone.

Eastern Mediterranean

The eastern basin sees intensive fishing effort from set longliners, with incidental catch estimates of about 7 000 sea turtles per year, mainly in Greece (between 1 000 and 6 000), Turkey (around 5 000) and Egypt (between 800 and 2 000). In Greece, the estimates made by Casale in 2008 (6 000 sea turtles per year), based on the fishing effort at that time, have been subsequently revised downward by the same author in 2011 (to around 1 000 sea turtles per year).

Adriatic Sea

No data are available for set longliners operating in the Adriatic Sea.

Black Sea

No data are available for set longliners operating in the Black Sea.

Set longliners overview

The mortality induced by set longlines is difficult to evaluate; direct mortality seems to be low, but the studies conducted at sea turtle rescue centres show a high post-release mortality, over both the short and long term.

The mortality rate appears to be concentrated among young sea turtles, as larger specimens are often able to drag the main line, with its weights, up to the surface to breathe or even break the branch lines. According to Casale (2008), set longlines seem to be responsible for a potential (delayed) mortality of about 40 percent, though data obtained from the review lead to a lower estimate of average mortality rate – around 24 percent.

To summarize, about 12 000 sea turtles may be caught annually in the Mediterranean Sea by set longlines, with about 3 000 dead.

- Around 7 000 sea turtles caught per year (and around 1 400 dead) in the eastern basin;
- Around 5 000 sea turtles caught per year (and 1 000 dead) in the central Mediterranean;
- Around 300 sea turtles caught per year in the western basin.

2.3.5 Purse seiners

Purse seining is an important fishing technique in the Mediterranean, developed around the end of the 1950s and targeting either small fish, such as sardine and anchovy, or bluefin tuna. Information on sea turtle bycatch and mortality in purse seines is scarce, probably since these fisheries do not heavily impact sea turtles (Universitat de Barcelona, 1995). Purse seines are made of a long wall of netting framed by a floatline on top and a leadline at the bottom, which is used to surround a school of fish, both from the sides and from underneath, thereby preventing them from escape by diving downwards. Unfortunately, sea turtles may be captured while the school of fish is encircled. After the setting is completed, the net is closed by hauling in the purse line and the fish can no longer escape. The vessel begins to haul back the net by means of a mechanized power block (if there is one) or by hand, and the catch is slowly herded into the bunt (i.e. the section of the net hung to form a bag or pocket, which is hauled in last). Once most of the purse seine has been retrieved, the fish are grouped within a restricted area along one side of the vessel. Subsequently, the fish are harvested from the purse seine using a large scoop net. Fish caught by this gear remain alive within the net and are then transferred into large tanks with water and ice. Therefore, caught sea turtles are still alive in the net at the end of the hauling process, and their mortality is negligible (Sacchi, 2008).

Some authors highlighted that traditional fish aggregating devices (FADs) might present a serious threat to sea turtles (Blasi *et al.*, 2016). Fish aggregating devices are permanent, semi-permanent or temporary structures or devices used in some fisheries to concentrate schools of fish, mainly dolphinfish (*Coryphaena hippurus*), and other large pelagic fish species such as the greater amberjack. Purse seines, with and without purse lines, are generally used to catch the fish aggregated below the FAD. Blasi *et al.*, (2016) reported that loggerhead sea turtles show a strong tendency to aggregate near FADs, as these represent foraging hotspots to sea turtles. Fish aggregating devices are potentially dangerous because the turtles can become entangled in their anchoring lines of nylon, which can wrap around the sea turtles' necks, flippers and posterior limbs. Sea turtle–FAD interactions can occur at all life stages, although bycatch seems to be more frequent for smaller turtles (Blasi *et al.*, 2016).

Despite the importance of this fishery for some Mediterranean countries (Morales-Nin *et al.*, 2000; Morales-Nin 2011; Scott and Lopez, 2014; FAO CopeMed II, 2016; Sinopoli *et al.*, 2019), the indirect impacts of FADs on sea turtles have potentially been underestimated up to now and require further study.

Western Mediterranean

A few catches have been registered in the western basin (Carreras, Cardona and Aguilar, 2004), but the reported mortality was negligible (Camiñas, 1997; Sacchi, 2008). Laurent (1990) reported that around 260 sea turtles per year are caught in Algeria by purse seines targeting sardines (Table 7). Laurent (1991) reported that in France, purse seines targeting small and large pelagic species can catch from zero to five turtles per vessel per year and that turtles are always released alive.

TABLE 7 – Incidental catch of sea turtles in purse seiners (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported or estimated individuals in bycatch events[1]	Estimated mortality rate due to bycatch
Nada and Casale, 2011	2007	PS	Eastern Mediterranean	Egypt	*Caretta caretta–Chelonia mydas*	99	-
Levy *et al.*, 2015	2012	PS	Eastern Mediterranean	Israel	*Caretta caretta–Chelonia mydas*	67	0–2%
Nada and Casale, 2008	2008	PS	Eastern Mediterranean	Egypt	*Caretta caretta*	37	-
Laurent, 1990	1989	PS	Western Mediterranean	Algeria	*Caretta caretta*	262	-
Álvarez de Quevedo *et al.*, 2010	2003–2004	PS	Western Mediterranean	Spain (northeastern)	*Caretta caretta*	4 (3–5)	-
Carreras *et al.*, 2004	2001	PS	Western Mediterranean	Spain Balearic Islands	*Caretta caretta*	6	-
Universitat de Barcelona, 1995	1995	PS	Western Mediterranean	Spain	*Caretta caretta*	1.5 per vessel/ year	0%
Kaddouri *et al.*, 2018	2016	PS	Western Mediterranean	Morocco (northwestern)	*Caretta caretta*	21	-

Notes: PS = purse seine.

In grey data collected before 2008.

1. The data reported here are derived either from direct observations or from yearly estimates. Please refer to the original paper for the methodology used to obtain the values.

Central Mediterranean
No data were available for purse seiners operating in the Central Mediterranean.

Eastern Mediterranean
The collected information confirms that purse seine incidental catch could represent an issue in the eastern basin, as the Egyptian and Israeli fishing fleets each catch almost 100 sea turtles annually in purse seiners (Nada and Casale, 2011) (Table 7).

Adriatic Sea
No data were available for purse seiners operating in the Adriatic Sea.

Black Sea
No data were available for purse seiners operating in the Black Sea.

2.3.6 Tuna seiners

Western Mediterranean
No data available.

Central Mediterranean
No data available.

Eastern Mediterranean
No data available.

Adriatic Sea
No data available.

Black Sea
No data available.

2.3.7 Dredges

Western Mediterranean
A few catches (21 sea turtles per year) were reported by Álvarez de Quevedo *et al*. (2010) in whelk dredges operating in the waters off Catalonia (northeastern Spain). Dredges probably interact with sea turtles feeding along the seabed in coastal waters.

Central Mediterranean
No data available.

Eastern Mediterranean
No data available.

Adriatic Sea
No data available.

Black Sea
No data available.

2.4 Outlook

In the Mediterranean Sea, scientific efforts over the last ten years have focused on the study of sea turtle biology and ecology and the protection of their nesting sites. As a result, quite complete information is available on the areas hosting their main nesting sites, their major migratory routes (mainly detected through satellite tracking and tagged sea turtles), prey preferences, neritic foraging habitats, growth rates and genetic structure, among other aspects (see Casale *et al.*, 2018 for a review). However, knowledge gaps still remain, as highlighted in this review, on the incidental capture of sea turtles and their interactions with different types of fishing gear. This lack of information mainly persists because structured and standardized survey methods (e.g. questionnaires, observations onboard, etc.) have not been developed and/or implemented until recently (FAO, 2019). The current shortcomings can be partially justified by the fact that onboard observations are demanding in terms of the time, resources and personnel required. These challenges also explain why, in in the last ten years, surveys based on interviews with fishers are often heavily relied upon to assess incidental catch (for example, Nada and Casale, 2011; Carreras, Cardona and Aguilar, 2004; Lucchetti, Vasapollo and Virgili, 2017a; Domènech *et al.*, 2015; Levy *et al.*, 2015). Indeed, in cases of poor data availability from onboard observations – the best way to achieve the clearest picture of sea turtle bycatch – involving and interviewing fishers and stakeholders may offer an effective alternative data collection method when resources are limited (FAO, 2019). Such a method can provide data on sea turtle bycatch, which is sufficient to arrive at estimates of minimum annual incidental catch, to identify high-risk types of fishing gear/location/season combinations and to prioritize areas for further research and the introduction of management measures.

The sea turtle bycatch estimates obtained by onboard observers and interviews with fishers, while sometimes reporting great variability between geographical areas and fishing gear types, can also show similar diversity within the same area from one year to another, as well as in relation to different aspects of sea turtle life history, such as nesting intervals and migration and feeding patterns, among other factors. This is mainly due to a lack of clear knowledge of the true fishing effort, and thus incidental catch data are usually inaccurately extrapolated to the entire fleet by using a nominal rather than a real fishing effort. Moreover, the characteristics of a fishery, together with different gear properties and fishing tactics (such as fishing depth and setting time) could affect the BPUE.

Presently, few national standardized onboard observer programmes are in place and monitoring often covers only a very limited number of industrial fisheries, while information on many coastal artisanal fisheries is poor. Furthermore, some geographical areas are not yet covered for many reasons (such as for political or economic motives). This situation has led to estimates of sea turtle bycatch in some countries based on BPUE figures from neighbouring countries, which, while certainly not the ideal approach, is often the only possible one. Moreover, it is rarely accurate to extrapolate the estimated data for a type of fishing gear to the whole fleet. Indeed, within the same vessel type (e.g. drifting longliners), the type of gear or fishing strategy used, according to the target species (e.g. bluefin tuna or swordfish), can result in different bycatch rates. The case of the incidental catch (and mortality) estimates obtained for Spanish longliners, following the introduction new technology and fishing strategies in the longline fleets, is emblematic of this issue: before the 2000s, 22 000, or even 35 000, sea turtle captures per year were reported (e.g. Aguilar, Más and Pastor, 1995); however, recent estimates (Báez *et al.*, 2018, 2019) seem to paint quite a different picture, with around 3 000–9 000 catches annually until 2013, and around 3 000 more recently (2013–2016).

Thus, in order to obtain a reliable estimate of the number of incidental captures in an area, for example, in a geographical subarea, it is essential to identify:
- The real fishing effort (including the number of vessels, number of fishing days, number of hooks/nets per vessel, among many other factors);
- The BPUE for each type of fishing gear used in that area, taking account that the BPUE for the same gear could vary greatly according to gear properties, fishing tactics, target species and environmental conditions.

As mentioned above, due to a lack of standardized protocols to record sea turtle bycatch, the estimates obtained from this review should be considered as an indication of the magnitude of the issue. However, even if gaps and weaknesses do exist in the estimates gathered, it is possible to gain a perspective of the scale of the phenomenon, in relation to the most impactful fishing gear types and the different areas of the Mediterranean. Nevertheless, when data only referred generically to "turtles," it was not possible to discern incidental catch estimates at the species level.

The information collected allowed an estimate to be made of around 121 000 sea turtles potentially caught in the Mediterranean each year, with about 33 000 considered potentially dead. In the last ten years, bottom trawlers seem to represent the fishery with the greatest impact on sea turtles, responsible for around 51 000 catches and 9 000 dead (17.6 percent). Drifting longline and set net fisheries are responsible for about 27 000 and 31 000 capture events, respectively, with about 5 300 (19.6 percent) and 16 000 (51.6 percent) dead. Set longlines catch around 12 000 sea turtles each year, with around 2 600 dead (21.7 percent). Other types of fishing gear seem to have a negligible impact on sea turtles, except for midwater pair trawls in the northern Adriatic Sea and in southern Turkey, two important foraging areas for sea turtles. However, if the estimates made by Casale (2011) for Morocco (14 800 catches per year) and Spain (20 200 catches per year) are instead taken into account (without judging which of these or the previous estimates are the most accurate), the bycatch numbers in the western basin rise markedly, to around 38 000 captures and about 7 600 dead (20 percent) with drifting longlines. These estimates lead to a total bycatch (aggregating all the different types of fishing gear) of 150 000 sea turtles and 39 000 dead (26 percent). Considering the precautionary approach, the first scenario (121 000 capture events and 33 000 dead, i.e. 27.3 percent) seems to be the most reliable. The presence of sea turtles in the Black Sea is so rare that it was not feasible to assess the impact of fishing activities, even though the sea turtles recorded in this area were in fact found in set nets.

Compared to past estimates, the current figures seem to highlight the importance of sea turtle bycatch in bottom trawls, which could be considered the most impactful of types of fishing gear, especially on the continental shelves of the northern Adriatic Sea, Tunisia, Egypt, Turkey and Israel. On the other hand, the estimates made after 2008 suggest that the incidental catch in drifting longlines in the western basin (operated mainly by the Spanish fleet) could be considered less severe than was estimated in the past. What appears like an apparent reduction in sea turtle bycatch could be due to advanced data analysis, which takes into consideration the different catch rates associated with longlines used in different areas and targeting different species (such as swordfish, albacore and bluefin tuna). Moreover, the introduction of the mesopelagic longline seems to have strongly reduced sea turtle bycatch in this area. This effect was also observed in the Ligurian Sea (Italy) by Garibaldi (2015). An explanation for reduced bycatch could be that loggerhead turtles usually spend most time at less than 20 m and do not dive deeper than 70–100 m (Houghton *et al.*, 2002; Polovina *et al.*, 2003).

An analysis of the various fisheries and their interactions with sea turtles in the Mediterranean show diverse impacts, depending on species, country and gear. Based on the available data, the most important vessel groups interacting with sea turtles in all countries are pelagic and bottom trawlers (with higher interactions recorded in the northern Adriatic, Turkish Mediterranean Sea, and off Tunisia) and drifting longliners (with higher interactions recorded off Spain and Italy). In general, sea turtle bycatch in SSF is a critical issue, though difficult to assess due to the large number of small boats scattered along the Mediterranean coastline and the logistical problems involved with data collection through onboard observations.

The estimates of direct mortality rates show great variability between different fishing gears, but also within the same gear, since gear-related, operational, environmental and ecological factors (such as migratory routes) may all affect sea turtle mortality. Interactions between fishing activities and sea turtles mostly occur when fishing activities overlap with sea turtle habitats and migratory routes. Therefore, bottom trawls and set nets mainly interact with sea turtles in their neritic foraging habitats while sea turtles feed on the bottom. Moreover, in overwintering grounds, sea turtles exhibit intermittent dormancy, resting for longer periods on the seabed, in addition to reduced metabolic rates, which decrease their mobility (Broderick *et al.*, 2007; Hochscheid *et al.*, 2007). As a result, when feeding on the bottom, sea turtles are more vulnerable to any fishing gear operating on the seabed (e.g. bottom trawls). In contrast, drifting longlines mainly interact with sea turtles in the pelagic environment, when they are feeding or migrating between different basins.

The estimates of bycatch-induced mortality depend on the capacities of sea turtles to survive forced apnoea and consequent drowning. Set nets seem to be responsible for the highest mortality rates (51 percent on average), with the highest values recorded for trammel nets set in deep waters (with mortality rates greater than 80 percent). Mortality rates vary according to different types of set nets (gillnets, trammel nets, among others), gear properties (such as mesh size, hanging ratio, vertical netting slackness and netting twine thickness), operational factors (soaking time, depth setting) and environmental factors (such as sea water temperature), as well as the dimensions of sea turtles. Sea turtles may also die if released with pieces of netting tangled around their bodies, as these can be ingested or cause necrosis of the flippers (Margaritoulis, Koutsodendris and Panagopoulou, 2007). Moreover, differences in habitat use by adults and juveniles, in relation to different types of fishing gear, appears to make juveniles more susceptible to gillnet and trammel net entanglement than adults. In fact, Tomás, Aznar and Raga (2001) described juvenile loggerheads as scavengers of discards, noting that this behaviour might lead them to depredate from static fishing gear, thereby making them more vulnerable to entanglement than their adult counterparts. Furthermore, recent studies (TartaLife, 2013) have demonstrated that set nets with larger meshes (more than 70–80 mm mesh openings) are more harmful than nets with smaller meshes. Similarly, trammel nets seem to induce higher mortality rates than gillnets. Bycatch mitigation measures should be one of the priorities for set net fisheries in the eastern Mediterranean Sea (especially trammel nets in shallow waters), as most nesting occurs in this area.

The other gear types, i.e. bottom trawls, drifting and set longlines, showed similar mean direct mortality rates (18, 20 and 21 percent on average, respectively), even if within the same gear type, mortality could vary greatly according to different factors.

Towing time can be considered as the main factor influencing sea turtle mortality in bottom trawls (long towing time results in prolonged apnoea and increases the risk of injuries caused by contact with the net, the bottom or debris, including rocks and timber also caught in the net), even though environmental factors, such as water temperature, can also greatly affect survival. In general, however, direct mortality induced by bottom trawls is low and sea turtles are usually released alive.

In longlines, direct mortality observed at gear retrieval is often low, when compared with other types of fishing gear (such as set nets), but the post-release mortality is suspected to be higher (up to 40 percent; Álvarez de Quevedo, San Félix and Cardona, 2013). Báez *et al.* (2013) found that the type of longline (according to the target species and depth setting) significantly affects the bycatch rate and the size of the turtles caught: drifting longlines targeting albacore and using smaller hooks tend to capture smaller loggerheads but show the highest BPUE; conversely, surface longlines targeting bluefin tuna and traditional surface longlines targeting swordfish, both using larger hooks, tend to select for larger animals. Moreover, surface longlines targeting swordfish have the lowest BPUE. In addition, Báez *et al.* (2007) found that the probability of catching sea turtles decreases with greater distance from the coast and, to a lesser extent, with increasing depth. Thus, sea turtle bycatch in longline fisheries can be substantially reduced by restricting fishing effort within 35 nautical miles of the coast and by setting the main line deeper (i.e. at depths below which sea turtles are abundant; Garibaldi, 2015; Cambiè *et al.*, 2013).

Over the last 20 years, a number of studies have been carried out to find technical solutions to reduce sea turtle bycatch. However, the level of implementation of such measures to reduce bycatch (for example, BRDs) in the Mediterranean is either low or zero. Most of the studies have dealt with drifting longlines and have mainly focused on the effects of hook shape, hook size and type of bait in relation to sea turtle bycatch (MRAG Ltd., Lamans S.A. Management Services and AZTI-Tecnalia, 2008; Piovano, Swimmer and Giacoma, 2009). The studies carried out in the Mediterranean (for example, Piovano *et al.,* 2004, 2005; Rueda *et al.,* 2006) highlighted the positive effects of circle hooks and mackerel bait as a means to reduce sea turtle mortality and bycatch. Unfortunately, only a few studies have been carried out to reduce sea turtle bycatch in bottom trawls and set nets. The results obtained from studies using turtle excluder devices (TEDs) in bottom trawls, mainly carried out in Italy (TartaLife, 2013) and Turkey (Atabey and Taskavak, 2001), are promising and should be replicated in other areas. Similarly, experiments with visual deterrents (ultraviolet light-emitting diodes) mounted on set nets, based on the findings of Wang, Fisler and Swimmer (2010), Wang *et al.* (2013) and Ortiz *et al.* (2016), have shown positive results in Italy (TartaLife, 2013; Virgili *et al.*, 2018) and Turkey (Snape, 2014). Therefore, BRDs should be tested more and adapted according to country, fishery and subregion.

As many projects have demonstrated, such as the Project on mitigating interactions between endangered marine species and fishing activities (2015–2018) carried out by the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) and the GFCM (ACCOBAMS, 2018), the collaboration of fishers and the establishment of permanent cooperation with them is key for the conservation of sea turtles (Rueda and Sagarminaga, 2008). In this regard, the use of proper gear/devices or the right fishing tactics can decrease incidental catch. Moreover, the first operations carried out onboard by fishers following the capture of a sea turtle are fundamental in reducing delayed mortality. Thus, education/awareness campaigns for fishers and other users on handling sea turtles (for example, Gerosa and Aureggi, 2001; FAO and ACCOBAMS, 2018) should be further encouraged (i.e. including advice on keeping the sea turtles onboard and allowing them to recover before release, making sure sea turtles are warm during winter and cool during summer, cutting the branch lines as close as possible to sea turtles' mouths, delivering injured sea turtles to rescue centres, and removing hooks from sea turtle mouths when possible, etc.).

In summary, reducing sea turtle bycatch in the Mediterranean could be improved through a multidisciplinary approach that consists of:

- improving data collection regarding sea turtle bycatch and mortality (including post-release mortality) in relation to different gear types, in terms of estimates, areas and periods of interaction;
- identifying and applying suitable changes to fishing gear and practices (while considering the economic and social consequences);
- identifying reliable management policies, such as replacing some types of fishing gear, at least in certain periods, setting up (temporarily) closed areas and seasons, among others;
- awareness campaigns on correct handling procedures for fishers, for personnel operating in the rescue centres, for those involved in the protection of nesting sites and for local people who live in these coastal areas.

Therefore, a binding cooperation between the fishing industry, management bodies and research institutions is of paramount importance for protecting sea turtles.

Improving the data collection of sea turtle bycatch remains urgent. Currently, only a few national programmes for onboard observers are active. Very often, the data available cover a few industrial fisheries, while a general lack of information remains for many coastal fisheries. To remedy this situation, systematic surveys to monitor sea turtle bycatch in different fisheries should be urgently launched, particularly in order to identify the incidental catch rates and mortality rates in each area and by gear type. Effective reporting and monitoring would allow scientists and managers to develop a more complete overview of the situation and to identify priority areas for management actions. Therefore, the use of a standard sampling procedure should be encouraged (FAO, 2019). Detailed data need to be collected on fleet structure, fishing effort, fishing gear and fishing tactics, so that the incidental catch data gathered through onboard surveys can be more accurately extrapolated. Additionally, logbooks and interviews with stakeholders should guarantee a reasonable knowledge base for sea turtle bycatch. This approach can be used as a first assessment of the extent of the problem in areas where information on bycatch is scarce or it can be applied to those fisheries presenting challenges to the use of observers (e.g. small vessels that cannot host an observer onboard). However, to be effective and useful, logbooks and interviews should be conducted and compiled using a standardized system across the different countries. Thus, stakeholder involvement determines the success of these projects, not only in gathering better bycatch data more widely, but in ultimately reducing the mortality rates of incidentally caught sea turtles in the Mediterranean Sea.

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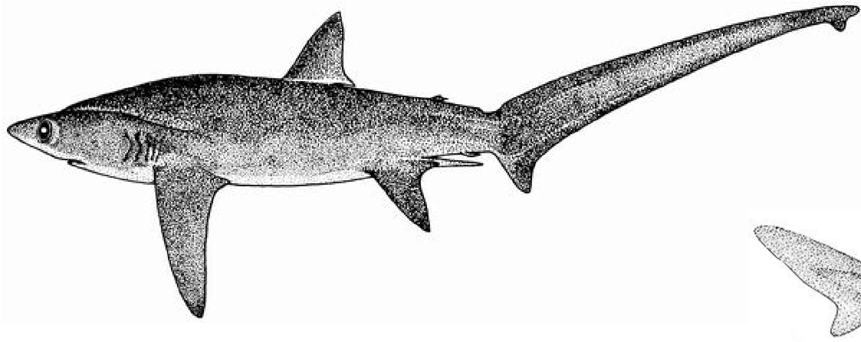
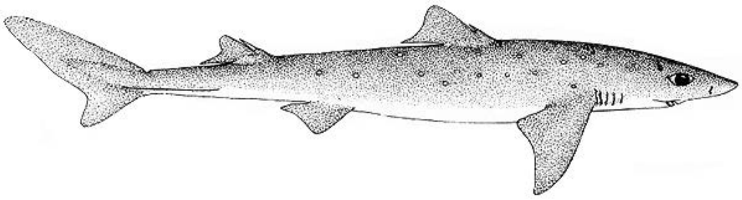
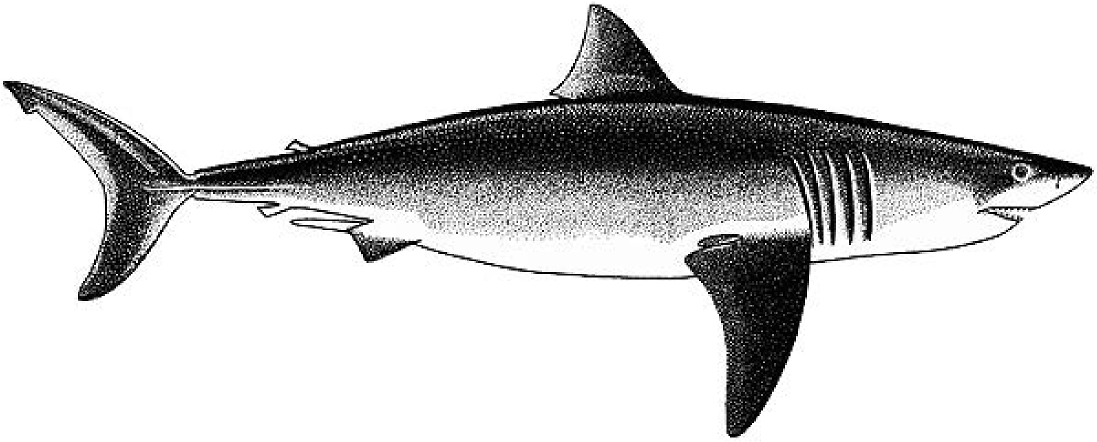
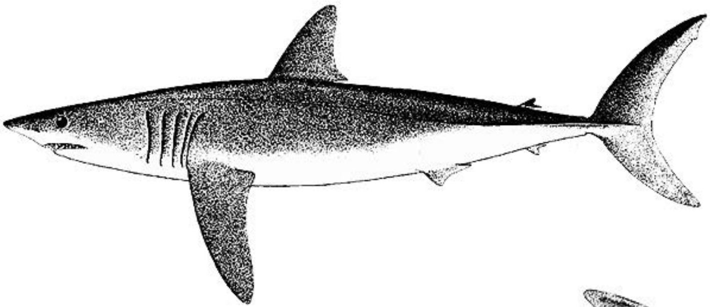
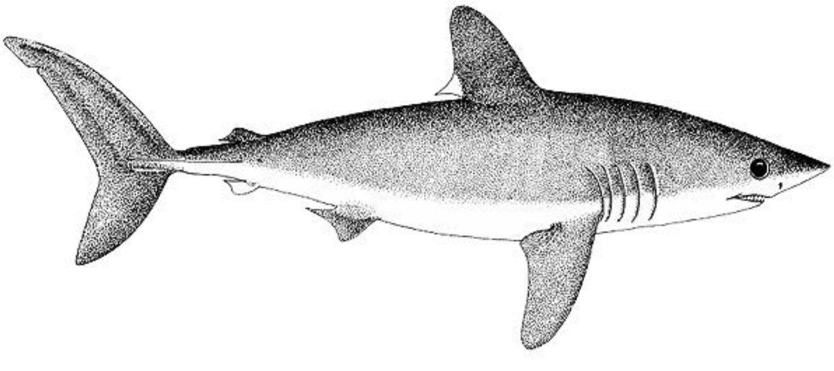


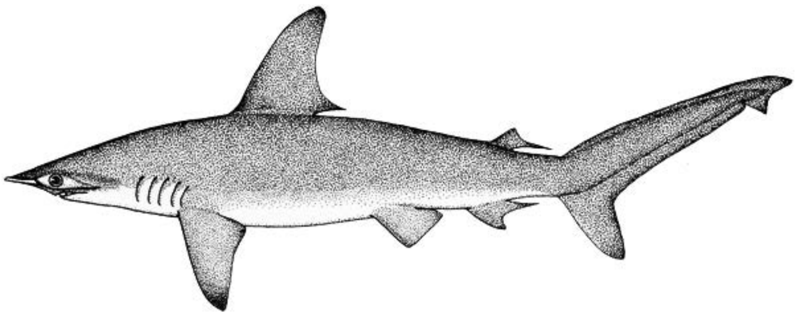


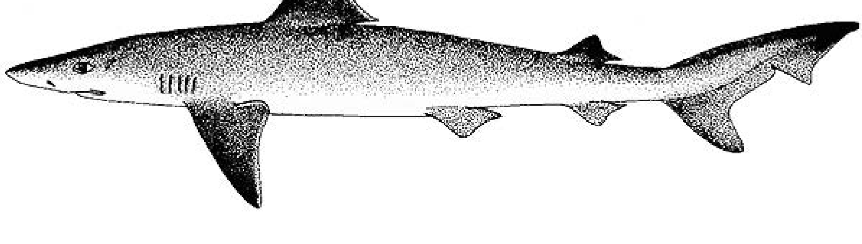


ELASMOBRANCHS









Spintail devil ray (*Mobula mobular*)

3. Elasmobranchs

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Executive summary

Mediterranean and Black Sea ecosystems contribute about seven percent of global chondrichthyan (cartilaginous fishes, including sharks, skates, rays and chimaeras) diversity, with at least 48 species of sharks and 38 species of batoids (rays and skates). As K-strategists (low population growth rates, late sexual maturity and production of relatively few offspring), chondrichthyans have low resilience to anthropogenic pressures, making them particularly vulnerable to human activities. Over a relatively short time, human pressure has caused a worrying decline in chondrichthyan populations worldwide, including in the Mediterranean and the Black Sea. At the Mediterranean level, 24 species of elasmobranchs are considered by regional conventions or regulations to require conservation efforts, such as those described by the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) and in recommendations of the European Union and the General Fisheries Commission for the Mediterranean (GFCM), among others. Currently, about 28 percent of Mediterranean and Black Sea chondrichthyan species are granted a legal protection framework.

In the Mediterranean Sea, though almost no fishing activity currently targets elasmobranchs and finning is banned by international decisions, elasmobranchs are often still caught as bycatch in many fisheries; depending on the species, individuals are either discarded or landed despite generally low market values. In any case, chondrichthyan incidental catch rates threaten to be

unsustainable for the long-term survival and conservation of some species, particularly for those assessed as "Endangered" or "Critically Endangered" in the International Union for Conservation of Nature (IUCN) Mediterranean Red List of Threatened Species (IUCN, 2021). Similarly, in the Black Sea, the piked dogfish (*Squalus acanthias*°) has been assessed as depleted by the GFCM and a recovery plan should be implemented. In order to better understand the impacts of fisheries on elasmobranchs, it is necessary to carefully monitor all fishing activities to understand the composition of the catch, including discards and species' post-capture survival rates.

Using sources such as scientific papers and reports, as well as unpublished information, it was possible to obtain baseline information regarding interactions between elasmobranchs and fishing activities in the Mediterranean and the Black Sea at the subregional scale, with a focus on the 33 conservation-priority species identified by GFCM recommendations (identified with the symbol "°" in this review). From 2008 to 2019, a total of 25 312 specimens belonging to various conservation-priority species were reported in the relevant literature from the various subregions. According to the sources gathered and analysed in this review, most conservation-priority elasmobranch bycatch comes from longliners (set and drifting together) (55 percent), followed by small-scale fisheries (18 percent), bottom trawlers (13 percent), pelagic trawlers (11 percent), and purse and tuna seiners (almost 3 percent). In particular, 78 percent of the total bycatch events involving elasmobranchs in the central Mediterranean subregion are reported from longline fisheries (set and drifting), whereas in the Adriatic Sea, the large majority of elasmobranch bycatch records are reported from pelagic trawlers (85 percent). Most bycatch records from bottom trawlers come from the eastern Mediterranean (32 percent), while the bycatch of sharks and rays in small-scale fisheries is most frequently reported from the western Mediterranean area (52 percent). Very few records could be found for the Black Sea region, probably due to the small populations of elasmobranch species in this area; however, the *S. acanthias*° is reported as a major bycatch component of Black Sea small-scale fisheries and bottom trawlers. The highest diversity of elasmobranch conservation-priority species is found in the eastern Mediterranean Sea, followed by the central Mediterranean, though the majority of bycatch records available come from the central Mediterranean; almost all records from the Adriatic Sea, meanwhile, concerned only three species.

Standard fishery measures for the recovery of bony fish are seldom effective for elasmobranch species. In fact, the best measures to ensure the conservation of shark populations are those that aim to reduce fishing mortality by avoiding fishing activities in nurseries and reproduction sites, and by releasing individuals that are still alive when caught.

One of the most difficult issues related to assessing elasmobranch bycatch is species identification. Easy tools should be provided to fishers to help them recognize Mediterranean species and distinguish protected species from commercial ones, as well as to record catches. The precautionary approach becomes very important for these species with limited data available to assess their conservation status. For this reason, it is crucial to gather information systematically from all fisheries data collection framework programmes in place and to enforce current management measures. Nevertheless, information campaigns for fishers and stakeholders are required in order to raise awareness of the current legal framework and the ecological roles played by these vulnerable animals in sustaining the health of marine ecosystems.

3.1 Description of the group

The Chondrichthyes (i.e. cartilaginous fishes, including sharks, skates, rays and chimaeras) consist of two subclasses, the Holocephali (chimaeras) and the Neoselachii (sharks and rays). Taxonomic studies considering both morpho-biometric and genetic aspects have led to increasingly improved knowledge of the different species in general. Globally, 599 shark species belong to 37 families; 818 batoid species belong to 26 families; and 57 Holocephali species belong to three families of chimaeras (The ETYFish Project, 2019; Ebert, Fowler and Compagno, 2013; Nelson, Grande and Wilson, 2016; Last *et al.*, eds, 2016; Roskov *et al.*, 2020).

Mediterranean and Black Sea ecosystems contribute about seven percent of this chondrichthyan diversity, with at least 48 species of sharks and 38 species of batoids (rays and skates); of these, only 10 species live in the Black Sea (Bilecenoğlu, Kaya and Cihangir, 2014). Up until recently, the only species of chimaera thought to be present in the Mediterranean was the rabbit fish (*Chimaera monstrosa*). However, in recent years Syrian and Egyptian researchers have found another species of chimaera, the large-eyed rabbit fish (*Hydrolagus mirabilis*), originating from the Atlantic Ocean (Serena, 2005; Hassan, 2013; Farrag, 2016; FAO, 2018a; FAO, 2018b; Serena *et al.*, 2020). Of the 48 Mediterranean shark species, about half have demersal habits, while the remaining half are considered to be free swimming in the water column. In contrast, almost all the batoids are demersal and only two species, the pelagic stingray (*Pteroplatytrygon violacea*) and the spintail devil ray (*Mobula mobular*), have pelagic habits. Some species of rays, as well as certain sharks, such as the bluntnose sixgill shark (*Hexanchus griseus*), are known to make movements by detaching themselves from the seabed relatively effortlessly in order to swim upwards in the water column (Mundy, 2005; Castro, Woodley and Brudek, 1999).

Although the chondrichthyans have maintained the same optimal evolutionary status they achieved relatively quickly more than 400 million years ago, at the global level their populations are currently threatened by two main phenomena: alterations in the marine habitat, coupled with the development of increasingly intensive and technological fisheries, and the quite recent phenomenon of finning (i.e. the act of removing fins and discarding the rest of the shark), which is of great concern for the conservation of shark populations (Ferretti and Myers, 2006; da Silva Rodrigues Filho and Bráullio de Luna Sales, 2017; Hareide *et al.*, 2007; Oliver *et al.*, 2015).

As K-strategists (low population growth rates, late sexual maturity and production of relatively few offsprings), chondrichthyans have low resilience to anthropogenic pressures, making them particularly vulnerable and limiting their recovery capacity from fishing mortality, both direct and indirect (Cavanagh and Gibson, 2007; da Silva Rodrigues Filho and Bráullio de Luna Sales, 2017; Stevens *et al.*, 2000; Ferretti *et al.*, 2010; Oliver *et al.*, 2015; Dulvy *et al.*, 2016). Over a relatively short amount of time, anthropogenic pressure has caused a worrying decline in elasmobranch populations worldwide, including in the Mediterranean basin (Coll, Navarro and Palomera, 2013; Başusta, Başusta and Özgürözbek, 2016; Bargnesi, Lucrezi and Ferretti, 2020; Myers *et al.*, 2007; Ferretti *et al.*, 2008; Heithaus *et al.*, 2008; Camhi *et al.*, 2009; Guisande *et al.*, 2013; Worm *et al.*, 2013; Barausse *et al.*, 2014; Oliver *et al.*, 2015; Dulvy *et al.*, 2014, 2016). Chondrichthyans are, in fact, considered among the most threatened marine animals worldwide; based on the last IUCN Shark Specialist Group's assessment of 1 041 species, at least 24 percent are classified as "Near Threatened" at the global level (Cavanagh and Gibson, 2007; Dulvy *et al.*, 2014, 2016; Nieto *et al.*, 2015). At the Mediterranean level, between 53 and 71 percent of elasmobranch species are at conservation, risk with many showing an elevated and deteriorating regional threat status (i.e. Mediterranean Sea) compared to their global status (Bargnesi, Lucrezi and Ferretti, 2020; Cashion, Bailly and Pauly, 2019). For example, 9 out of 16 shark species reported in domestic FAO Mediterranean landings are considered more threatened regionally than they are at the global level (Cashion, Bailly and Pauly, 2019).

Unlike other species considered vulnerable (for example, marine mammals and sea turtles) that are generally protected by various international conventions and national regulations, cartilaginous species are not totally protected, even though they often constitute important proportions of bycatch in all fisheries at the global scale. Referring to the Mediterranean and the Black Sea, current instruments in place, such as the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention), Regulation 2019/124 of 30 January 2019 of the Council of the European Union (Council of the European Union, 2019), and Recommendation GFCM/36/2012/3 on fisheries management measures for conservation of sharks and rays in the GFCM area of application, later amended by GFCM/42/2018/2 on fisheries management measures for the conservation of sharks and rays in the GFCM area of application (GFCM, 2021), consider only a few species of elasmobranchs from a conservation point of view. In particular, Recommendation GFCM/36/2012/3 on fisheries management measures for conservation of sharks and rays in the GFCM area of application and Recommendation GFCM/42/2018/2 on fisheries management measures for the conservation of sharks and rays in the GFCM area of application refer to the annexes of the Barcelona Convention Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol)[1]. They are accomplished by granting full protection to the Mediterranean elasmobranch species included in Annex II of the SPA/BD Protocol (List of endangered or threatened species) and by requesting detailed reports on any catch of species included in Annex III of the SPA/BD Protocol (List of species whose exploitation is regulated). These species are listed in Table 1A and Table 1B (also shown in Plate 1 and Plate 2), together with their assessment in the International Union for Conservation of Nature (IUCN) Mediterranean Red List of Threatened Species (IUCN, 2021). Among all the elasmobranch species cited in this review, conservation-priority species as defined by GFCM Recommendation GFCM/42/2018/2 (Table 1A, Table 1B) are marked with the symbol "°". The GFCM recommendations, *inter alia*, also ban finning practices within the GFCM area of application. However, some countries, in addition to those foreseen by the European Union and GFCM regulations, have adopted stricter specific national legislative measures. For example, Malta also identifies 24 species of elasmobranchs of national interest under strict protection, as well as an additional 14 species subject to specific management measures (Ministry for the Environment, Sustainable Development and Climate Change, 2019). Likewise, Turkey protects the sandbar shark (*Carcharhinus plumbeus*°) (Bilecenoğlu, 2008) and the piked dogfish (*Squalus acanthias*°) in the Black Sea (FAO, 2018c, 2020a; Table 2).

1. The SPA/BD Protocol is main tool in the Mediterranean for implementing the 1992 Convention on Biological Diversity (CBD) as regards the in situ sustainable management of coastal and marine biodiversity.

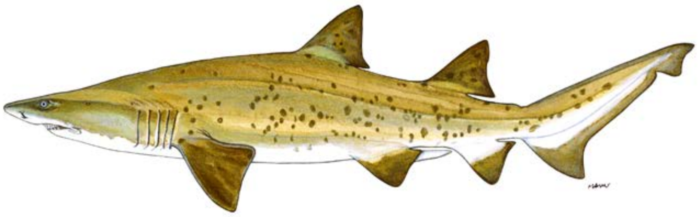
Table 1A – Species in Annex II of the SPA/BD Protocol covered by Recommendations GFCM/36/2012/3 and GFCM/42/2018/2

Annex II of the SPA/BD Protocol (List of endangered or threatened species) Fishing is prohibited in the Mediterranean and the Black Sea and the reporting of any incidental catch to the GFCM is mandatory	**IUCN Red List category[1]**	
Carcharias taurus (Rafinesque, 1810)	Critically Endangered	(Walls and Soldo, 2016)
Carcharodon carcharias (Linnaeus, 1758)	Critically Endangered	(Soldo, Bradai and Walls, 2016)
Cetorhinus maximus (Gunnerus, 1765)	Endangered	(Sims *et al.*, 2016a)
Dipturus cf. batis (Linnaeus, 1758)	Critically Endangered	(Dulvy *et al.*, 2016)
Galeorhinus galeus (Linnaeus, 1758)	Vulnerable	(McCully, Dureuil and Farrell, 2016)
Gymnura altavela (Linnaeus, 1758)	Critically Endangered	(Walls *et al.*, 2016)
Isurus oxyrinchus (Rafinesque, 1810)	Critically Endangered	(Walls and Soldo, 2016)
Lamna nasus (Bonnaterre, 1788)	Critically Endangered	(Ellis *et al.*, 2016c)
Leucoraja circularis (Couch, 1838)	Critically Endangered	(McCully *et al.*, 2016)
Leucoraja melitensis (Clark, 1926)	Critically Endangered	(Dulvy and Walls, 2015)
Mobula mobular (Bonnaterre, 1788)	Endangered[3]	(Marshall *et al.*, 2019)
Odontaspis ferox (Risso, 1810)	Critically Endangered	(Pollard *et al.*, 2016)
Oxynotus centrina (Linnaeus, 1758)	Critically Endangered	(Soldo and Guallart, 2016)
Pristis pectinata (Latham, 1794)	Critically Endangered	(Kyne, 2016a)
Pristis pristis (Linnaeus, 1758)	Critically Endangered	(Kyne, 2016b)
Rhinobatos cemiculus[2] (Geoffroy Saint-Hilaire, 1817)	Critically Endangered[3]	(Kyne and Jabado, 2019)
Rhinobatos rhinobatos (Linnaeus, 1758)	Endangered	(Bradai and Soldo, 2016)
Rostroraja alba (Lacépède, 1803)	Endangered	(Ellis, Morey and Walls, 2016)
Sphyrna lewini (Griffith and Smith, 1834)	Critically Endangered[3]	(Rigby *et al.*, 2019a)
Sphyrna mokarran (Rüppell, 1837)	Critically Endangered[3]	(Rigby *et al.*, 2019b)
Sphyrna zygaena (Linnaeus, 1758)	Critically Endangered	(Ferretti *et al.*, 2016a)
Squatina aculeata (Cuvier, 1829)	Critically Endangered	(Soldo and Bariche, 2016b)
Squatina oculata (Bonaparte, 1840)	Critically Endangered	(Ferretti *et al.*, 2016b)
Squatina squatina (Linnaeus, 1758)	Critically Endangered	(Ferretti *et al.*, 2016d)

Notes:

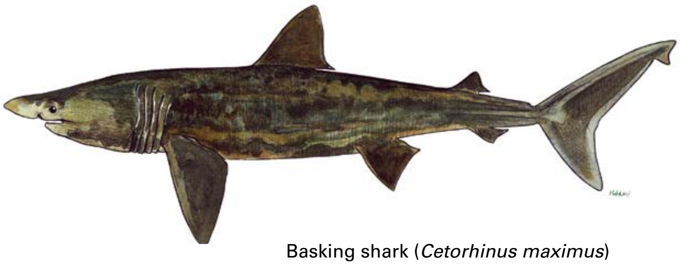
1. IUCN Red List Categories: Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW), Extinct (EX).
2. *Glaucostegus cemiculus* is the new name assigned to the species; however, the name *Rhinobatos cemiculus,* which is the one listed in Annex II of the SPA/BD Protocol, has been used in the main text of this review.
3. Species for which the Mediterranean assessment is still in progress; thus the global assessment has been reported instead.

PLATE 1
Mediterranean elasmobranach species listed in annex II of the SPA/BD Protocol

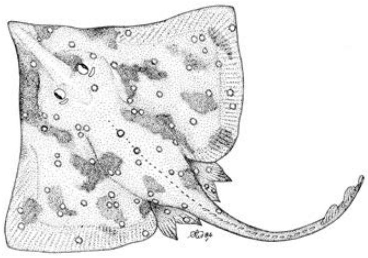


Sand tiger shark (*Carcharias taurus*)

Spiny butterfly ray
(*Gymnura altavela*)

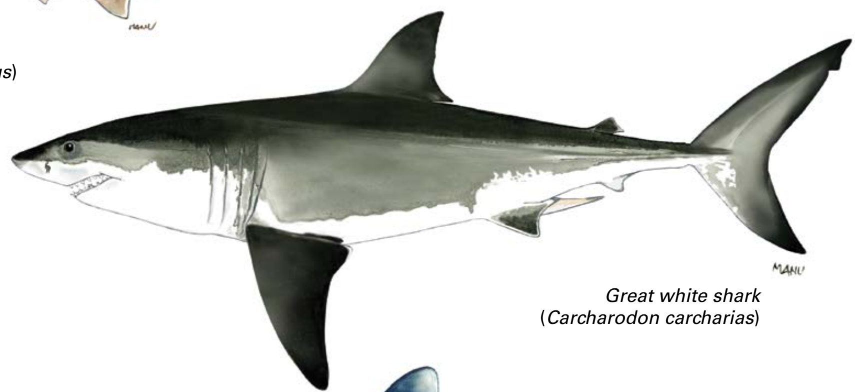


Basking shark (*Cetorhinus maximus*)



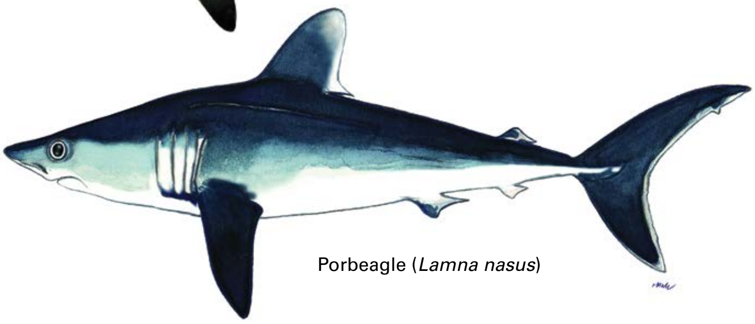
Common skate (*Dipturus cf. batis*)

Tope shark (*Galeorhinus galeus*)



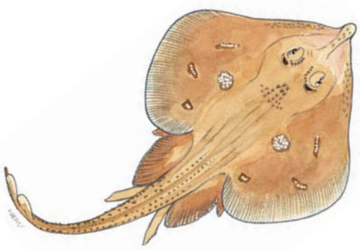
Great white shark
(*Carcharodon carcharias*)

Sandy ray (*Leucoraja circularis*)



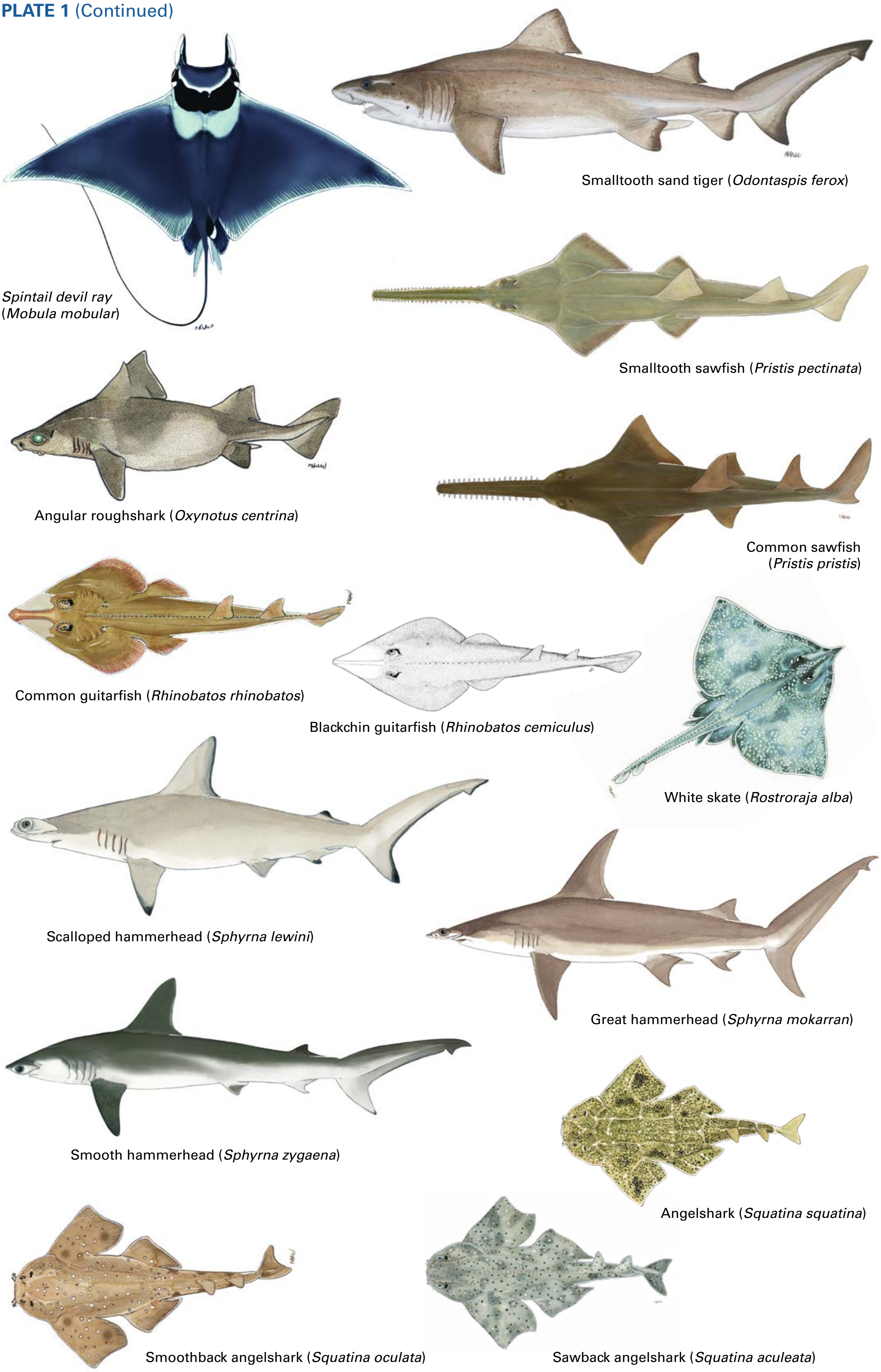
Porbeagle (*Lamna nasus*)

Shortfin mako shark (*Isurus oxyrhinchus*)



Maltese skate (*Leucoraja melitensis*)

PLATE 1 (Continued)



Spintail devil ray (*Mobula mobular*)

Smalltooth sand tiger (*Odontaspis ferox*)

Smalltooth sawfish (*Pristis pectinata*)

Angular roughshark (*Oxynotus centrina*)

Common sawfish (*Pristis pristis*)

Common guitarfish (*Rhinobatos rhinobatos*)

Blackchin guitarfish (*Rhinobatos cemiculus*)

White skate (*Rostroraja alba*)

Scalloped hammerhead (*Sphyrna lewini*)

Great hammerhead (*Sphyrna mokarran*)

Smooth hammerhead (*Sphyrna zygaena*)

Angelshark (*Squatina squatina*)

Smoothback angelshark (*Squatina oculata*)

Sawback angelshark (*Squatina aculeata*)

Table 1B – Species in Annex III of the SPA/BD Protocol covered by Recommendations GFCM/36/2012/3 and GFCM/42/2018/2

Annex III of the SPA/BD Protocol (List of species whose exploitation is regulated) Fishing of these species is allowed in the Mediterranean Sea, but the reporting of any catch to the GFCM is mandatory	**IUCN Red List category[1]**
Alopias vulpinus (Bonnaterre, 1788)	Endangered (Ellis *et al.*, 2016a)
Carcharhinus plumbeus (Nardo, 1827)	Endangered (Ferretti *et al.*, 2016c)
Centrophorus granulosus[2] (Bloch and Schneider, 1801)	Critically Endangered (Guallart *et al.*, 2016)
Heptranchias perlo (Bonnaterre, 1788)	Data Deficient (Soldo and Bariche, 2016a)
Mustelus asterias (Cloquet, 1821)	Vulnerable (Farrell *et al.*, 2016)
Mustelus mustelus (Linnaeus, 1758)	Vulnerable (Farrell and Dulvy, 2016)
Mustelus punctulatus (Risso, 1827)	Vulnerable (Dulvy, Farrell and Buscher, 2016)
Prionace glauca (Linnaeus, 1758)	Critically Endangered (Sims *et al.*, 2016b)
Squalus acanthias (Linnaeus, 1758)	Endangered (Ellis *et al.*, 2016b)

Notes:

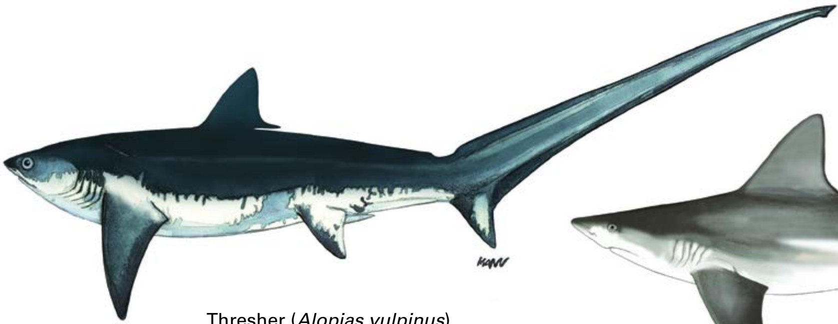
1. IUCN Red List Categories: Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW), Extinct (EX).
2. *Centrophorus* cf. *uyato* is the new name assigned to the species; however, the name *Centrophorus granulosus*, which is the one listed in Annex III of the SPA/BD Protocol, has been used in the main text of this review.

According to GFCM recommendations, about 28 percent of Mediterranean and Black Sea elasmobranch species (i.e. the 24 species of Annex II of the SPA/BD Protocol) are currently granted a legal protection framework. The remaining species, including those listed in Annex III of the SPA/BD Protocol, can be regularly fished and marketed, notwithstanding their current assessment status. For this reason, management problems can arise around the proper identification of protected versus non-protected species, especially for those management and control bodies responsible for deciding administrative sanctions.

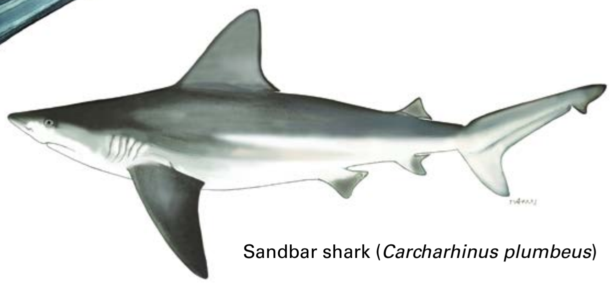
In the Mediterranean, almost no fishing activity currently targets elasmobranchs and finning has been banned by international decisions (European Parliament and Council of the European Union, 2013; GFCM, 2014a). Only sporadic fishing activities target elasmobranch species in some areas, such as in the northern Adriatic and in the Strait of Sicily, where vessels using gillnets target smooth-hound sharks (*Mustelus*° spp.) and dogfish sharks (*Squalus* spp.) (Ferretti and Myers, 2006; Bradai, Bradai and Enajjar, 2012). Nevertheless, fishing of protected guitarfishes (*Rhinobatos*° spp.) still occurs in the Gulf of Gabès (Bradai, Bradai and Enajjar, 2018; Bargnesi, Lucrezi and Ferretti, 2020; Bradai *et al.*, 2016; Marino *et al.*, 2017). In general, data on directed shark fisheries are difficult to obtain as these fisheries are often artisanal and operate in countries where regular fishery data reporting comes with greater challenges for a variety of reasons (Ferretti and Myers, 2006; Bradai, Bradai and Enajjar, 2012; Ferretti *et al.*, 2010).

Only 10 cartilaginous species are assumed to be present in the Black Sea (Bilecenoğlu, Kaya and Cihangir, 2014; Serena, 2005; FAO, 2018a, 2018b; McEachran and Capapé, 1984; Fredj and Maurin, 1987; Fischer, Schneider and Bauchot, 1987; Serena, Mancusi and Barone, 2014; Serena *et al.*, 2020), and no regular fishing activities exclusively target elasmobranchs in this area either. Some seasonal fisheries targeting piked dogfish *S. acanthias*°, however, do exist in Bulgaria (GFCM, 2011, 2016b, 2018b). In general, the most commonly caught elasmobranch species in the Black Sea, the piked dogfish (*S. acanthias*°) and the thornback ray (*Raja clavata*), are found in the incidental catch of fisheries (especially those using trawls, set nets and, more rarely, longlines) targeting turbot (*Scophthalmus maximus*), red mullet (*Mullus barbatus*) and European whiting (*Merlangius merlangus*) (Avsar, 2001; GFCM, 2016b; STECF, 2017; Sağlam and Bascinar, 2008;

PLATE 2
Mediterranean elasmobranch species listed in Annex III of the SPA/BD Protocol



Thresher (*Alopias vulpinus*)

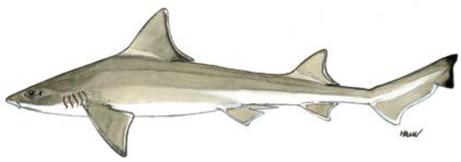


Sandbar shark (*Carcharhinus plumbeus*)

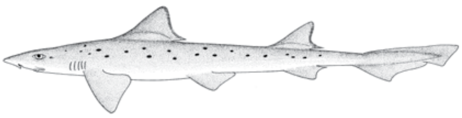
Gulper shark (*Centrophorus granulosus*)

Sharpnose sevengil shark (*Heptrachias perlo*)

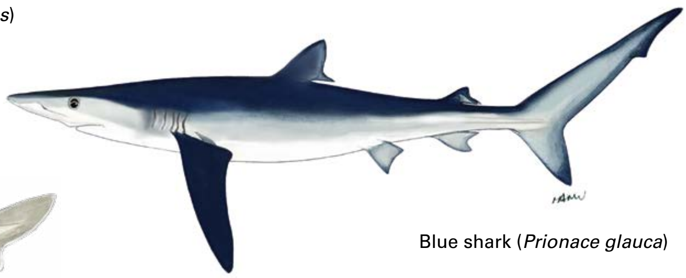
Starry smooth-hound (*Mustelus asterias*)



Smooth-hound (*Mustelus mustelus*)



Blackspotted smooth-hound (*Mustelus punctulatus*)



Blue shark (*Prionace glauca*)

Piked dogfish (*Squalus acanthias*)

Yıldız and Karakulak, 2017; Bengil and Başusta, 2018; Demirhan, Engin and Can, 2005; Ceylan, Şahin and Kalayci, 2013). Due to high bycatch rates, the *S. acanthias*° Black Sea population has been declared as depleted by the GFCM for a long time, and specific management measures have been adopted since 2015 (see GFCM, 2011, 2014b, 2016a, 2016b, 2017a, 2017b, 2018a, 2018b), though the implementation of a full recovery plan is still advised (GFCM, 2018). The different minimum landing sizes adopted by Black Sea countries for *S. acanthias*° are presented in Table 2.

Table 2 – Minimum landing size for piked dogfish (*Squalus acanthias*) in Black Sea countries

Bulgaria	Georgia	Romania	Russian Federation	Turkey	Ukraine
90 cm	85 cm*	120 cm	85 cm*	No fishing of this species is allowed	85 cm*

Notes:
Total length; *standard length (GFCM, 2017a).

Though chondrichthyans are mostly caught as bycatch in fisheries targeting more valuable resources, available evidence indicates that in the Mediterranean, they are generally declining in abundance, diversity and range, and that they are possibly faring worse than chondrichthyan populations elsewhere in the world (Ferretti and Myers, 2006; Cavanagh and Gibson, 2007; Bargnesi, Lucrezi and Ferretti, 2020; Cashion, Bailly and Pauly, 2019; Walker *et al.*, 2005; Dulvy *et al.*, 2016). A few studies (Cavanagh and Gibson, 2007; Dulvy *et al.*, 2016) have indicated that bycatch in fisheries probably presents the main threat to elasmobranch populations in the Mediterranean Sea, with all species of Mediterranean elasmobranchs potentially affected, while they show different sensitivities to other threats, such as pollution (around 30 percent threatened), habitat loss (around 30 percent), direct fisheries (around 9 percent), among others. The vulnerability of Mediterranean elasmobranch species to fishing gear is high: all species may be caught in trawlers, almost all (94 percent) in various types of nets[2] and two thirds of Mediterranean species (67 percent) by longliners (Cavanagh and Gibson, 2007).

This review attempts to compile the relevant information on interactions between fisheries and elasmobranchs available in scientific publications, reports, databases, news, *inter alia*. Bibliographic items were searched for in electronic archives, papers, and on the internet by means of key words. However, it is important to note that given the heterogeneity of elasmobranchs as a taxonomic group (including protected and unprotected species, demersal and pelagic species, commercial and non-commercial species), relevant information on elasmobranch interactions with fisheries was sometimes buried within studies whose objectives were not bycatch-related; for example, they may have focussed on catch composition of a given fleet, fish weight-length relationships, occurrence of species in a given area, molecular and deoxyribonucleic acid (DNA) analysis, and so on. The historical section of this chapter focuses on data collected up to around 2008, including anecdotal facts from the previous century, for all elasmobranch species. The section on recent data focuses on data collected between 2008 and 2019, with an emphasis on GFCM priority-conservation species as identified by Recommendation GFCM/36/2012/3 (see above); in both sections, the information collected is organized by fishing vessel group and subregion.

3.2 Historical records of interactions with fisheries

Historically, the diversity of chondrichthyans used to be high throughout the Mediterranean (Dulvy *et al.*, 2016). Human impacts (including exploitation, pollution, fisheries and habitat degradation) have caused, however, a significant reduction in species richness throughout the basin, with historic declines in elasmobranch abundance reported (Bradai, Bradai and Enajjar, 2018; Bargnesi, Lucrezi and Ferretti, 2020; Ferretti *et al.*, 2008, 2015; Fortibuoni *et al.*, 2010; Dulvy *et al.*, 2016). At present, a decreasing trend in diversity can be observed across the Mediterranean, from the eastern part to the western part (Ferretti *et al.*, 2008, 2015; Fortibuoni *et al.*, 2010; Serena *et al.*, 2020), though in the past, the presence of elasmobranchs had been considered higher in the

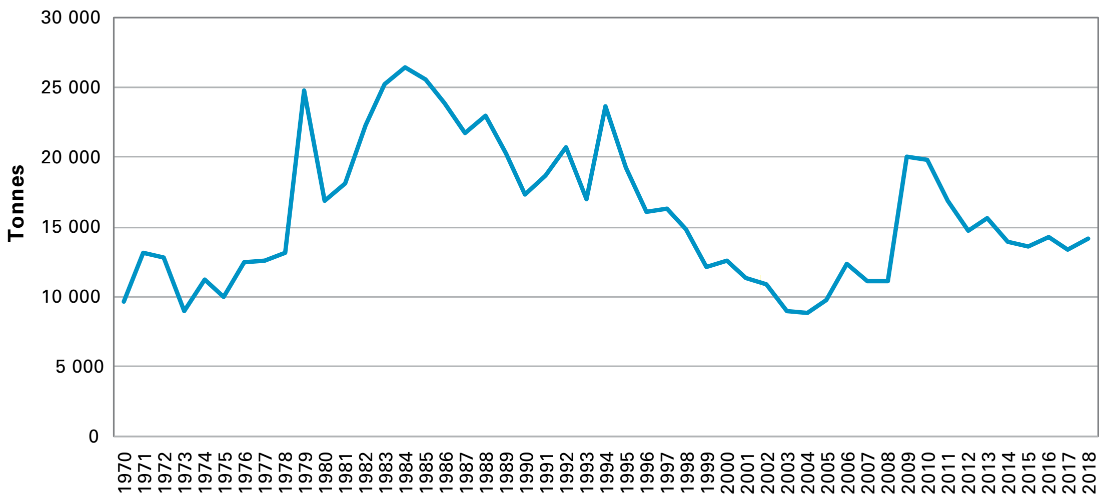
2. These include purse seines, gillnets and driftnets (use banned in 2005).

western than in the eastern Mediterranean, with peak abundances (still true) in the Strait of Sicily and along the coasts of Tunisia and Libya (Bradai, Bradai and Enajjar, 2012; Coll *et al.*, 2010).

As mentioned, in the Mediterranean Sea, elasmobranchs are mostly found in the bycatch of fisheries targeting more valuable fish and crustacean species (Vannuccini, 1999; Ferretti and Myers, 2006; Geraci *et al.*, 2017), though what are regarded as discards in more developed countries may have a certain market value in southern and eastern Mediterranean countries (Ferretti and Myers, 2006). In general, about 46 species of demersal elasmobranchs caught in trawl fisheries are commercially valuable (Ferretti and Myers, 2006).

According to FAO, beginning in the 1950s, landings of sharks and rays gradually increased, peaking in the mid-1980s before declining again by over 50 percent (Dent and Clarke, 2015; Bonanomi *et al.*, 2017). In fact, the analysis of the historical series (the last 46 years) of Mediterranean chondrichthyan landings shows that a significant decline followed the maximum of the mid-1980s, reaching a minimum at the beginning of the 2000s. After another relative maximum at the end of the first decade of the 2000s, a new decline has been observed due to the contributions of newly involved countries, such as Libya (Bradai, Bradai and Enajjar, 2018), to FAO official statistics (Figure 1). Indeed, the overall fishing capacity and effort in the Mediterranean area, before it stabilized around 2010, increased rapidly beginning in the late 1970s (Ferretti and Myers, 2006; Cavanagh and Gibson, 2007; Bell, Watson and Ye, 2017), causing overexploitation of some Mediterranean and Black Sea fish stocks (FAO, 2016, 2018c), with direct and indirect effects on elasmobranch species (Cavanagh and Gibson, 2007; Tsikliras *et al.*, 2015). These impacts included local reductions of coastal elasmobranch diversity by more than 50 percent over 50 years of fishing exploitation and the local disappearance of certain species once considered common (Ferretti and Myers, 2006; Bargnesi, Lucrezi and Ferretti, 2020; Ferretti *et al.*, 2005, 2013; Barausse *et al.*, 2014; Dulvy *et al.*, 2016; Fortibuoni *et al.*, 2016).

FIGURE 1
Historical trends in chondrichthyan landings in the Mediterranean and the Black Sea (1970–2018)



Source: FAO, 2020b.

Indeed, the situation may be even worse, as this figure reports only the official landings that reached the market and does not include all the non-desirable shark catch that was returned to the sea (i.e. discards), making it extremely difficult to quantify the actual magnitude of shark bycatch in the Mediterranean Sea (Vannuccini, 1999; Ferretti and Myers, 2006). Furthermore, data reported from scientific research showed that some of the most frequent species caught as bycatch are not even listed in official statistics. In particular, this has long been the case for the blue shark (*Prionace glauca*°) and other vulnerable species with no commercial value. The most important shark species landed in the Mediterranean, as already reported by FAO (Vannuccini, 1999), have always been *Mustelus*° spp. and the piked dogfish (*Squalus acanthias*°).

3.2.1 Bottom trawlers

Bottom trawlers have always been responsible for catching various demersal shark and ray species, and several studies, mainly focusing on discards and catch composition, have provided information on the elasmobranch species most caught in trawl nets (Bradai, Bradai and Enajjar, 2012). Given that bottom trawlers do not target sharks, the catch rate is expected to be random and non-homogeneous over time for the same gear, country and subregion (Vannuccini, 1999; Serena *et al.*, 2008; Bradai, Bradai and Enajjar, 2012, 2018; Serena *et al.*, 2009; Ramírez-Amaro *et al.*, 2018). The species accounting for the most bycatch in trawls have historically been *Mustelus*° spp. and the common stingray (*Dasyatis pastinaca*) (Vannuccini, 1999), though official statistics often only thoroughly report the former due to their higher commercial value than the latter, which is usually discarded at sea.

In the Alboran Sea, Torres *et al.* (2001) reported that bottom trawlers targeting red shrimp (*Aristeus antennatus*) caught, by biomass, more blackmouth catshark (*Galeus melastomus*) than the target red shrimp species. Twenty-one specimens of spintail devil ray (*Mobula mobular*°) were collected at the Algiers fish market between 1996 and 2001 as bycatch during trawling off the the Algerian coast (Hemida, Mehezem and Capapé, 2002). In the same area, between 1996 and 2002, sharks belonging to the genus *Carcharhinus*, *C. altimus* (41 individuals), *C. brachyurus* (17 individuals), *C. brevipinna* (2 individuals), *C. obscurus* (10 individuals) and *C. plumbeus*° (28 individuals) were caught during trawling and longliner fishing operations as bycatch at depths between 30 and 150 m (Hemida *et al.*, 2002).

In the Balearic Islands, Carbonell *et al.* (2003) analysed the catch composition of bottom trawlers and noted that the small-spotted catshark (*Scyliorhinus canicula*), the blackmouth catshark (*Galeus melastomus*) and the velvet belly (*Etmopterus spinax*), combined, represented 4.9 to 8.2 percent in weight of the total catch. In fact, small-spotted catshark catch reached proportions similar to those of the target species in the coastal fishery (targeting red and striped red mullet) and in the shelf trawl fishery (targeting European hake). In contrast, the bycatch of blackmouth catshark and velvet belly represented a small proportion of the total catch of the slope fishery targeting red shrimp (*Aristeus antennatus*).

The size range of the small-spotted catshark (*Scyliorhinus canicula*) ran between 7 and 53 cm total length (TL). Juveniles and adults were distributed throughout the whole area, although adults appeared to be more abundant in coastal zones. The length distribution of the blackmouth catshark (*Galeus melastomus*) showed a trend of size increasing with depth; the size range was between 9 and 63 cm TL. For both species, individuals smaller than 35 cm TL were usually discarded. Only 25 percent by number and 60 percent by weight of the total small-spotted catshark catch was landed. For the total blackmouth catshark catch, the corresponding percentages were 10 percent by number and 35 percent by weight.

The elasmobranch communities exploited by the bottom trawl fishery off the Balearic Islands (northwestern Mediterranean) have been analysed in different studies (for example, Massutì and Moranta, 2003; Moranta *et al*., 2008; Guijarro *et al*., 2012). From 1965 to 2009, Guijarro *et al.* (2012) identified a total of 25 elasmobranch species in the fishing grounds off the Balearic Islands; the predominant species were *Galeus melastomus, Scyliorhinus canicula* and the thornback ray (*Raja clavata*). Temporal trends and depth correlations between the shelf and the slope for the other elasmobranch species (i.e. *Hexanchus griseus, Centrophorus granulosus*°, *Dalatias licha, Centroscymnus coelolepis, Mustelus asterias*°, *M. mustelus*°, *Scyliorhinus canicula, Dipturus oxyrinchus, Leucoraja circularis*°, *L. fullonica, L. naevus, Squalus blainville, S. acanthias*°, *Torpedo marmorata, Raja asterias, R. clavata, R. miraletus, R. brachyura, R. polystigma, R. radula, Bathytoshia lata, D. pastinaca* and *Myliobatis aquila*) were also recorded.

In the Gulf of Lion, long-term changes in the diversity of elasmobranch species responsive to the evolution of the bottom trawl fishery were observed from 1994 to 2009 (Farrugio and Cebrian, 2013). The abundance of some marketable species, including small sharks such as the smooth-hound shark (*Mustelus mustelus*°), the starry smooth-hound (*Mustelus asterias*°), the nursehound (*Scyliorhinus stellaris*) and the longnose spurdog (*Squalus blainville*), had declined over that time period. Only two species of rays, *Raja clavata* and *R. asterias*, the most abundant and frequent in the area, were still being fished during the most recently surveyed years, even as *R. clavata* showed a decrease in its biomass indices, as well as a reduction in its distribution area in the Gulf of Lion. In fact, concerns about the exploitation sustainability of Rajidae populations in the Gulf of Lion were already being voiced by scientists as early as the late 1990s.

Conversely, a strong resilience to population declines of non-commercial species has been confirmed, even in cases where a low level of abundance was initially observed, such as for the three species of electric rays *Torpedo marmorata*, *T. torpedo* and *Tetronarce nobiliana* or the angular rough shark *Oxynotus centrina*°. Similarly, as a result of the impacts on other commercial species, the small-spotted catshark (*Scyliorhinus canicula*), and the blackmouth catshark (*Galeus melastomus*) became the most abundant elasmobranchs on the continental shelf and on the slope, respectively.

Furthermore, off the Languedocian coast (French Mediterranean), Capapé and Reynaud (2011) investigated the maturity and reproductive cycle of the piked dogfish (*Squalus acanthias*°); 209 specimens (110 males and 99 females) were collected from 1997 to 2005 by bottom trawling at depths between 80 and 100 m on sandy-muddy and detrital bottoms.

The occurrence, abundance and size trends of 25 demersal chondrichthyans were recorded (Marongiu *et al*., 2017) over a period of 22 years (1994–2015) as part of the MEDITS[3] dataset in geographical subarea (GSA) 11 (the sea surrounding the island of Sardinia, Italy). Temporal trends in the abundance indices were found to be stable or increasing in all depth strata (from 10 to 800 m). Almost all elasmobranch species showed stability in size structure analyses, apart from the blonde ray (*Raja brachyura*) and the longnose skate (*Dipturus oxyrinchus*), which showed increasing trends; the chondrichthyan species examined in the study area did not seem to show an alarming conservation status (Marongiu *et al*., 2017).

3. International bottom trawl survey in the Mediterranean (MEDITS survey programme).

Similarly, a long time series of elasmobranch catch rates off the Tuscan coast of Italy (northwestern Mediterranean) was studied by Ligas *et al*. (2013) in order to estimate variations in population abundance and evaluate the influence of environmental and anthropogenic factors. Trawl survey and landing data showed that elasmobranch fauna had undergone a drastic decline over 50 years and that the subsequent rebound fell far short of a recovery to historical levels; *Galeus melastomus*, *Etmopterus spinax*, *Dipturus oxyrinchus, Scyliorhinus canicula* and two skates (*Raja asterias* and *R. clavata*) were the species most commonly occurring, whereas *Squalus acanthias*°, *Mustelus*°spp. and *Squatina squatina*° had not been found in the landings analysed from 1991 to 2009.

Along the eastern coast of Algeria, Hemida and Capapé (2002) reported the capture of a single specimen of the rare bramble shark (*Echinorhinus brucus*) in bottom trawl fishing operations at depths greater than 500 m. Capapé *et al*. (2008) also analysed the biology of the rare deep-sea shark the kitefin shark (*Dalatias licha*) off the southwestern Mediterranean coast by studying individuals caught by bottom trawlers: of the 47 specimens of *D. licha* observed, eight were caught off the northern Tunisian coast between 1970 and 2007 by bottom trawlers fishing at depths between 200 and 600 m on sandy-muddy bottoms, and 39 off the Algerian coast, between 1996 and 2007, also in bottom trawls operating at similar depths and over similar sediments. The results indicated that the kitefin shark probably feeds mainly on fish, occasionally on cephalopods, reproduces in alternate years and that the breeding period occurs over the summer in this region. Furthermore, around the Algerian coasts, the small-spotted catshark (*Scyliorhinus canicula*) is caught mainly by bottom trawlers targeting other demersal fish and crustacean species – axillary seabream (*Pagellus acarne*), red mullet (*Mullus barbatus*), European hake (*Merluccius merluccius*) and deep-water pink shrimp (*Parapenaeus longirostris*). A stock assessment performed over the period 2000–2010 indicated that the small-spotted catshark was being overfished, with 42–51 cm the most exploited length class (GFCM, 2011).

In the Adriatic Sea, Jukic-Peladic *et al*. (2001) analysed the composition of trawl surveys carried out in 1948 and in 1998 to identify temporal changes in the composition of demersal fish resources after 50 years of fishing activity. A decrease in elasmobranch diversity and abundance frequency was the main change observed: life history parameters appeared to be determining factors, since small-sized species such as the small-spotted catshark (*Scyliorhinus canicula*) or the brown ray (*Raja miraletus*) were frequently collected in both surveys, while bigger shark species and most other rays disappeared or rarely turned up during the 1998 survey.

Likewise in the Adriatic Sea, Gračan *et al*. (2013, 2016) provided the first detailed information on the reproductive traits and age and growth estimates of the piked dogfish (*Squalus acanthias*°); they based their findings on 224 specimens (132 females and 92 males) collected onboard commercial bottom trawls between 2005 and 2007. In addition, Ferretti *et al*. (2013), with data obtained from trawl surveys carried out over the period 1950–2010, detected a decreasing trend in the elasmobranch community, including two species that were judged to have locally disappeared in the Adriatic Sea – the blue skate (*Dipturus cf. batis*°) and the Lusitanian cownose ray (*Rhinoptera mariginata*). According to these authors, catch rates had declined by 94 percent since 1950, and 11 species ceased being detected in some specific areas of the Mediterranean, including the white skate (*Rostroraja alba*°) and the rough skate (*Raja radula*).

In other studies, Barausse *et al*. (2014) evaluated, by integrating long-term time series of landings (1945–2012) with extensive surveys of the fish market in Chioggia, Italy, which is home to the major fishing fleet of the northern Adriatic Sea, the status of elasmobranch populations subject to direct and indirect fishing pressure in the area. The analysis of the data highlighted a dramatic decline in a variety of trawl fisheries (bottom, beam and midwater) of elasmobranch landings, particularly of skates and catsharks (*Scyliorhinus* spp.), whose catch rates were found to be 2.4 and 10.6 percent of their average 1940 levels, respectively. The authors found that the data reflected similarly large reductions in abundance and also confirmed that several species formerly present in the basin were no longer detected, now considered to have locally disappeared, e.g. the skates *Dipturus cf. batis*°, *Rostroraja alba*° and *Raja montagui* (= *R. polystigma*).

In the wide area of the Strait of Sicily, between the southern Italian region and the northern coast of Africa, elasmobranchs have been a common bycatch of bottom trawl fleets since the 1970s. A research project on demersal resources in the Strait of Sicily dating back to 1991 (Vannuccini 1999), revealed that the presence of sharks caught as bycatch was dependent on depth: 95 percent of the incidental elasmobranch catch occurred within the first 200 m, with the most common species, *Dasyatis pastinaca* and *Mustelus mustelus*°, caught between 0 and 100 m; other species (*Etmopterus spinax, Galeus melastomus*, *Scyliorhinus canicula and Scyliorhinus stellaris*) were found at depths between 200 and 700 m.

Bibliographic and scientific bottom trawl survey data gathered off the southern coast of Sicily, from 1994 to 2009 and between depths of 10 and 800 m, were also analysed by Ragonese *et al*. (2013) in order to prepare a checklist of demersal sharks and chimaeras sensitive to exploitation by fisheries. Out of the 27 previously reported demersal shark and chimaera taxa in the Mediterranean, only 20 were sampled during the surveys in the investigated area. Among the species sampled in the surveys, only two ubiquitous (*Squalus blainville* and *Scyliorhinus canicula*) and three deep-water (*Chimaera monstrosa*, *Centrophorus granulosus*° and *Galeus melastomus*) species showed a wide geographical distribution with a consistent abundance. Excluding the rare (such as *Oxynotus centrina*°) or uncommon sharks (e.g. *Squalus acanthias*°), the estimated occurrence frequencies and abundance indices revealed a possible risk of local extinction for the almost exclusively (e.g. angelshark, *Squatina*° spp.), or preferentially (e.g. nursehound, *Scyliorhinus stellaris*), neritic species.

More recently, Geraci *et al*. (2017) provided a similar overview of the demersal (sharks-chimaeras) and bottom-dwelling (batoids) data obtained during the experimental international bottom trawl survey in the Mediterranean (MEDITS) carried out from 1994 to 2013 in the Strait of Sicily (see also the Elasmostat project; Serena, ed., 2014). Overall, 37 species were recorded as captured at least once: 16 demersal species of the shark-chimaera category and 21 batoids. In particular, four shark-chimaera orders (Chimaeriformes, Hexanchiformes, Squaliformes and Carcharhiniformes) and three batoid orders (Myliobatiformes, Rajiformes and Torpediniformes) were found. In the investigated area, the analysis of the density index and the biomass index temporal evolution from 1994 to 2013 showed a slight recovery of sharks-chimaeras and a steady state for batoids.

In Tunisia, a rare and now protected species, the common guitarfish (*Rhinobatos rhinobatos*°) was recorded commonly in the bycatch of commercial bottom trawlers operating along the coast of the Gulf of Gabès between 2001 and 2005 (a total of 498 specimens were identified) (Enajjar, Bradai and Bouain, 2008). In the same area, in order to collect biological data on the longnose skate (*Dipturus oxyrinchus*), monthly sampling was conducted onboard a commercial bottom trawler in December 2006 and January 2007; a total of 561 individuals were collected at depths between 80 and 185 m (Kadri *et al*., 2014).

On a broader geographical scale, Bertrand *et al*. (2000) carried out a subregional cross-cutting study, covering the European waters of the western and central Mediterranean, the Adriatic Sea and part of the eastern Mediterranean (up to Crete, Greece). From the bottom trawl survey data obtained during spring campaigns conducted between 1994 and 1998, they identified 44 species of chondrichthyans, including 24 skates, 19 demersal sharks and 1 chimaera from 10 to 800 m in depth. Among these 44 species, only 8 species were found to occur across the entire sampled area.

In the north Aegean Sea and the central Aegean plateau (Cyclades plateau), a scientific campaign carried out on trawlers between 1991 and 1996 evaluated the presence and abundance of three elasmobranch species, *S. canicula*, *Raja montagui* (= *R. polystigma*) and the marbled electric ray, *Torpedo marmorata*, which represented 2.2, 0.08 and 0.05 percent, in numbers, of the total catch and 67, 21 and 22 percent of their total occurrence in hauls, respectively (Damalas *et al*., 2010). In a subsequent ten-year study, carried out in the central Aegean Sea and divided between two sub-periods (1995–2000 and 2003–2006), based on bottom trawl fishery datasets, a total of 30 elasmobranch species were identified, accounting for 14.3 percent of the total catch in terms of weight and 2.2 percent in terms of number. In particular, seven species alone represented almost 95 percent of the total in number (50 057 specimens collected); they consisted of four sharks and three skates: *Scyliorhinus canicula* (52.5 percent), *Galeus melastomus* (10.3 percent), *Squalus blainville* (10.0 percent), *Etmopterus spinax* (9.2 percent), *Raja clavata* (7.6 percent), *Dipturus oxyrinchus* (3.9 percent) and *Raja miraletus* (1.2 percent) (Damalas and Vassilopoulou, 2011).

Still in the Aegean Sea, Maravelias *et al*. (2012) analysed fisheries-independent scientific bottom trawl survey data for two of the most abundant cartilaginous demersal species in the Aegean Sea, the small-spotted catshark (*Scyliorhinus canicula*) and the thornback ray (*Raja clavata*), covering an 11-year sampling period from the mid-1990s through 2008. Over the studied period, these two species represented more than 70 percent (14.4 and 60.3 respectively) of the total abundance of demersal elasmobranchs caught; the findings revealed a declining trend in *R. clavata* and *S. canicula* abundance from the late 1990s until 2004. Filiz and Mater (2002) obtained a further 247 specimens of seven species (three shark species, *Scyliorhinus canicula, Mustelus mustelus*° and *Squalus acanthias*°, and four ray species, *Torpedo marmorata, Raja clavata, Raja miraletus* and *Dasyatis pastinaca*) caught by commercial fishers using bottom trawls in the North Aegean Sea between July 1999 and March 2000. Meanwhile, also in the Aegean Sea, Corsini-Foka (2009) reported the capture of a single specimen of the rare smalltooth sand tiger (*Odontaspis ferox*°) in September 2007 by bottom trawling, 1.5 nautical miles off the southern coast of Rhodes at a depth of 70 m.

Elsewhere, in the Aegean Sea, Filiz and Bilge (2004) analysed the length–weight relationships of 24 fish species caught by commercial bottom trawling in the trawl area of *Sığacık* Bay. The catch included many elasmobranch species, such as *Scyliorhinus canicula* (637 individuals), *Mustelus mustelus*° (35 individuals), *Squalus acanthias*° (32 individuals), *Torpedo marmorata* (37 individuals), *Dipturus oxyrinchus* (8 individuals), *Raja clavata* (37 individuals), *R. miraletus* (13 individuals), *Dasyatis pastinaca* (29 individuals), *Gymnura altavela*° (9 individuals) and *Myliobatis aquila* (14 individuals). In the same area, Yiğin and İşmen (2009), also analysing the length–weight relationships of elasmobranch species caught by bottom trawl fisheries, recorded 936 individuals belonging to nine different species: *Dasyatis centroura* (i.e. *Bathytoshia lata*) (8 individuals), *Gymnura altavela*° (2 individuals), *Leucoraja naevus* (1 individual), *Aetomylaeus bovinus* (1 individual), *Dipturus oxyrinchus* (179 individuals), *Rostroraja alba*° (126 individuals), *Myliobatis aquila* (66 individuals), *Dasyatis pastinaca* (71 individuals) and *Raja radula* (204 individuals).

İşmen *et al*. (2007) analysed the weight–length relationships of 63 fish species sampled by a commercial bottom trawl vessel at depths ranging from 28 to 370 m between February 2005 and April 2006 in Saros Bay, Turkey. Among these were found: *Dasyatis pastinaca* (48 individuals), *Heptranchias perlo*° (14 individuals), *Hexanchus griseus* (5 individuals), *Myliobatis aquila* (14 individuals), *Dipturus oxyrinchus* (118 individuals), *Raja clavata* (112 individuals), *R. miraletus* (30 individuals), *R. radula* (49 individuals), *Rostroraja alba*° (43 individuals), *Galeus melastomus* (93 individuals), *Scyliorhinus canicula* (1501 individuals), *Squalus blainville* (299 individuals), *Torpedo marmorata* (20 individuals) and *Mustelus mustelus*° (26 individuals).

In the Marmara Sea, from 2006 to 2007, Deniz *et al*. (2011) collected specimens of *Squalus acanthias*° (8 individuals), *S. blainville*, (18 individuals), *Mustelus mustelus*° (2 individuals), *Raja oxyrinchus* (2 individuals), *Oxynotus centrina*° (1 individual) and *Dasyatis pastinaca* (12 individuals) caught by bottom trawl and beam trawl vessels operating at depths of 30–100 m. In the same area, a total of 620 piked dogfish (*Squalus acanthias*°; 346 females and 274 males) were collected between February 2005 and September 2007 from commercial bottom trawls in order to estimate age and growth parameters (Yiğin and İşmen, 2016). In the Turkish Mediterranean Sea, Yeldan *et al*. (2013) analysed temporal changes in some Rajiformes species caught by commercial bottom trawlers along the west coast of İskenderun Bay from 2004 to 2011. Six species belonging to six different Rajiformes families were identified over the sampling period, including the common stingray (*Dasyatis pastinaca*), the spiny butterfly ray (*Gymnura altavela*°), the common guitarfish (*Rhinobatos rhinobatos*°), the rough ray (*Raja radula*), the common eagle ray (*Myliobatis aquila*) and the marbled electric ray (*Torpedo marmorata*). The only significant annual changes were found for *R. rhinobatos*°.

Further east, Golani (1986) recorded the first appearance of demersal species of sharks, at depths of 1 330–1 440 m, off the eastern Mediterranean coast of Israel among the bycatch of a commercial bottom trawler. These species included: the little sleeper shark (*Somniosus rostratus*), the gulper shark (*Centrophorus granulosus*°), the kitefin shark (*Dalatias licha*) and the blackmouth catshark (*Galeus melastomus*).

In the Black Sea, the piked dogfish (*Squalus acanthias*°) has always been one of the most heavily caught non-target species in bottom trawls. The end of the 1970s and the 1980s had a crucial impact on the *S. acanthias*°, when fishing activities conducted by Turkey and, to a lesser extent, by the Russian Federation, led to the overexploitation of *S. acanthias*° population. Turkey alone reached a maximum catch of 10 887 tonnes in 1979. The 1990s saw a continued and progressive decline in the catch of *S. acanthias*°, ultimately leading to an all-time low of around 62 tonnes in 2014. Between 1989 and 2000, Turkey's annual landings of *S. acanthias*° ranged between 4 558 and 2 390 tonnes (Shlyakhov and Daskalov, 2008), followed by a sharp decline to below 100 tonnes in 2009. Similarly, data for the Black Sea populations of thornback ray (*Raja clavata*) indicated patterns of overexploitation, with maximum landings of 3 390 tonnes and 3 078 tonnes between 1979 and 1983 (Radu and Nicolaev, 2010).

3.2.2 Small-scale fisheries

Trammel nets and gillnets, as well as longlines, are the types of gear most commonly used in Mediterranean small-scale fisheries. The nets are often used at night and the length of the set nets depends on the size of the fishing boat (Bradai, Saidi and Enajjar, 2012). Occasionally, these have been reported to catch several non-target species of sharks and rays, mostly demersal ones, such as the small-spotted catshark (*Scyliorhinus canicula*), piked dogfish (*Squalus acanthias*°), nursehound (*Scyliorhinus stellaris*), common eagle ray (*Myliobatis aquila)*, bull ray (*Aetomylaeus bovinus)*, requiem shark (*Carcharhinus* spp.) and stingray (*Dasyatis* spp.), though the pelagic tope shark (*Galeorhinus galeus*°) and the basking shark (*Cetorhinus maximus*°) have also been found (Bradai, Saidi and Enajjar 2012; Costantini *et al*., 2000; Mancusi *et al*., 2005; Morey *et al*., 2006). Concerning pelagic elasmobranch species, Mancusi *et al*. (2005) indicated that throughout the Mediterranean Sea, among the 323 records of basking sharks (*Cetorhinus maximus*°) registered since the mid-nineteenth century, 15 percent came from incidental catch in trammel nets.

In a study conducted in the Balearic Islands by Morey *et al*. (2006), trammel nets caught up to 12 species of elasmobranchs (ten sharks and two rays) representing 10 percent by abundance and 28 percent by biomass of the total catch. The most common species were the common stingray (*Dasyatis pastinaca*), rough ray (*Raja radula*) and marbled electric ray (*Torpedo marmorata*), representing 48 percent, 24 percent and 15 percent of the elasmobranch catch, respectively. The contribution of elasmobranchs to the total biomass of the catch was estimated at 11 to 25 percent, regardless of the season. The most abundant species were *Dasyatis pastinaca*, *Raja* spp., *Scyliorhinus* spp. and *Torpedo* spp. The common eagle ray (*Myliobatis aquila*) was scarce, while the sharks, namely the velvet belly (*Etmopterus spinax*), blackmouth catshark (*Galeus melastomus*) and longnose spurdog (*Squalus blainville*), were mainly encountered during the spring. An unidentified species belonging to the genus *Squatina*° has been observed only on one occasion.

Elsewhere off Corsica, a twelve-year seasonal survey (2001–2012) of the small-scale fishery (gillnets and trammel nets) targeting demersal fish and the common spiny lobster (*Palinurus elephas*) within and near the Scandola marine protected area has provided data on the catch and discards of elasmobranchs in the local artisanal fisheries. While the contribution of elasmobranchs to the total catch was estimated at 11 to 25 percent regardless of the season, their mean contribution to discards was 49 percent, reaching up to 74 percent in summer. The composition of the biomass of the elasmobranchs caught was: *Dasyatis pastinaca* (26 percent), *Raja* spp. (33 percent), *Scyliorhinus* spp. (23 percent), *Torpedo* spp. (6 percent), *Squalus blainvillei* (1 percent) and *Myliobatis aquila* (1 percent), with 10 percent remaining undefined (Le Direach *et al*., 2013).

In the Gulf of Gabès (Tunisia), gillnets targeting demersal fish also caught a conspicuous quantity of blackchin guitarfish (*Rhinobatos cemiculus*°) as bycatch, especially from April to August, with a total of 513 specimens collected from commercial gillnet and trawl catches between 2002 and 2004 (Enajjar, Bradai and Bouain, 2008, 2012). In Libyan waters, Lamboeuf (2000) reported artisanal gillnets targeting sharks, though no quantitative nor qualitative assessments are available. Meanwhile, off the Maghrebine shore (Algerian and Tunisian coasts), Capapé *et al*. (2003), in their review of the historical captures of basking sharks (*Cetorhinus maximus*°), reported the presence of four individuals in the bycatch of Tunisian gillnets, caught in 1981, 1992, 1998 and 1999, respectively, while in Algerian gillnets, three *Cetorhinus maximus*° were caught in 1998.

In the waters off Piran, Slovenia, in the summer of 2000, two juvenile basking sharks (*Cetorhinus maximus*°) were accidentally caught: a juvenile male was entrapped in special nets designed for small sharks (mainly species from the genus *Mustelus*°), while the other was caught (entangled) in a flatfish net (Lipej *et al*., 2000). Likewise, two specimens of *Cetorhinus maximus*° (2.5 m long and 2.6 m long, respectively) were also recorded as bycatch, caught by a gillnet along the coast of Israel in 1965 (Ben-Tuvia, 1971). Although the type of set net was not specified, three individuals of the same species were also caught along the Turkish coast in 1987 (Kabasakal, 2004) and 1995

(Kıdeyş, 1997). More recently, in 2001 and 2006, Kabasakal (2002, 2013) reported the capture of two individuals (6 m long and 3 m long, respectively) in a gillnet and in a stationary net in the northern Levantine basin.

In addition to *Cetorhinus maximus*°, young thresher sharks (*Alopias vulpinus*°) were reported as bycatch in trammel nets in Turkish and Tunisian coastal waters (Kabasakal, 2007; Hattour and Nakamura, 2004). In 2005, the capture of a 3.5 m-long bigeye thresher shark (*Alopias superciliosus*) by a coastal netter operating in Turkish waters was reported by Kabasakal and Karhan (2008). Furthermore, Kabasakal (2007) recorded the incidental capture of 15 individuals of *A. vulpinus*°), in gillnets and trammel nets in Turkish coastal waters over a study period covering ten years (1997 to 2007).

In another investigation, carried out in the Aegean Sea, elasmobranchs (mainly belonging to the Rajidae family) represented about 6 to 10 percent of the total weight of the small-scale catch (Stergiou, Moutopoulos and Erzini, 2002). Still in the Aegean Sea, one specimen of blackchin guitarfish (*Rhinobatos cemiculus*°) was reported in 1995 from the bycatch of set nets operating along the northeastern coast of Rhodes at depths of 40 m, while in 2006, set nets were responsible for the bycatch of two individuals of angular roughshark (*Oxynotus centrina*°) at depths of 40 m (Corsini-Foka, 2009). Elsewhere, in the northern Aegean Sea, Karakulak, Erk and Bilgin (2006) studied the length–weight relationships of 47 coastal fish species from Gökceada Island. Samples were caught at depths between 0 and 30 m by gill and trammel nets between March 2004 and February 2005; the elasmobranch species observed included *Dasyatis pastinaca* (12 individuals), *Raja radula* (25 individuals) and *Torpedo marmorata* (22 individuals).

In the same fishing grounds, Ceyhan, Hepkafadar and Tosunoglu (2010) carried out a total of 22 fishing trials with trammel nets, accompanied by local fishers, from September 2006 to May 2007 and six trials with traditional artisanal longlines in 2007, from July to August in Izmir Bay. Catch rate, catch per unit effort (CPUE), biomass ratios and size selectivity were investigated in order to analyse the smooth-hound shark (*Mustelus mustelus*°) fishery. It was noted that the catch composition and the corresponding proportions of various species were significantly different in longlines (51 individuals) than they were in trammel nets (139 individuals). While the mean CPUE of longlines was 119.2±14.3 kg per 1 000 hooks, these values for 150 mm and 170 mm trammel nets were 5.3±1.2 kg per 1 000 m of net and 12.7±3.9 kg per 1 000 m of net, respectively. During a study conducted off the northeastern Mediterranean coast of Turkey, between April 2004 and December 2005, a total of 115 common guitarfish (*Rhinobatos rhinobatos*°), 66 females and 49 males, were caught by a commercial gillnetter (44 mm mesh size) and by bottom trawlers and in a longline fishery (Başusta *et al.*, 2008).

In the Black Sea, *S. acanthias*° catch has always been reported by the coastal fisheries, including by those using static nets. The landings of *S. acanthias*° by Ukrainian small-scale fisheries from 1997 to 2007 totalled 907 tonnes (with the lowest value, of 20 tonnes, recorded in 1997 and a peak of 172 tonnes in 2003) (GFCM, 2014b).

3.2.3 Purse seiners

Purse seiners usually target large and small pelagic species. They are considered relatively selective in terms of discards/catch rates. Although little information is available in the relevant literature on the bycatch of encircling nets, it is reported that purse seiners, while targeting bluefin tuna and small pelagic species, have been responsible for the sporadic capture of pelagic sharks, such as of the shortfin mako (*Isurus oxyrinchus*°), basking shark (*Cetorhinus maximus*°) and thresher (*Alopias vulpinus*°), and of stingrays (Notarbartolo and Serena, 1988; Hattour, 2000; Fromentin and Farrugio, 2005; Bradai, Saidi & Enajjar, 2012;). Furthermore, in the central Mediterranean, over 70 percent of great white shark (*Carcharodon carcharias*°) bycatch was reported by purse seiners (Fergusson, 1996; Bradai, Saidi and Enajjar, 2012; Saidi *et al.*, 2005, 2007).

Data collected onboard commercial purse seiners in Greek waters (Aegean and Ionian seas) over 13 seasonal sampling periods from 2003 to 2008 revealed the presence of the common stingray (*Dasyatis pastinaca*) (4 individuals), spotted ray/speckled ray (*Raja montagui/polystigma*) (3+1 individuals), cuckoo ray (*Leucoraja naevus*) (1 individual), small-spotted catshark (*Scyliorhinus canicula*) (1 individual) and electric ray (*Tetronarce nobiliana*) (1 individual) in bycatch (Tsagarakis *et al.*, 2012). In the Levantine basin, according to Abudaya *et al.* (2017), the spintail devil ray (*Mobula mobular*°) has also been the target of an opportunistic purse seine (locally called *shanshula*) fishery since the early 1970s, with fishing occurring from January to April, when the animals enter coastal areas; in 2005 and 2006, 62 and 363 individuals were caught, respectively, while no catch was recorded in 2007 and 2008 (see Table 6). Elsewhere, one specimen of the spiny butterfly ray (*Gymnura altavela*°) was captured in 1999 by a purse seine operating along the northwestern coast of Rhodes (Aegean Sea), at a depth of 60 m (Corsini-Foka, 2009). The same author additionally reported the capture in Dodecanese waters of a single specimen of bull ray (*Aetomylaeus bovinus*) in 2001 and of an electric ray (*Torpedo nobiliana*) in 1998.

In the north Aegean Sea, two juvenile great white sharks *Carcharodon carcharias*° measuring 180 cm and 230 cm TL were reported as bycatch off Thásos and Kavállah, respectively (Fergusson, 1996).

In 2007, the capture of a bigeye thresher shark (*Alopias superciliosus*), measuring 450 cm TL, by a purse seiner operating in Turkish waters was documented by Kabasakal and Karhan (2008). In Turkish coastal waters, Kabasakal (20 7) also reported the incidental capture of two individuals of thresher (*Alopias vulpinus*°), caught in 1996 and 2004, respectively, by purse seiners.

3.2.4 Longliners

Several types of longlines are used in the Mediterranean basin. Depending on the species targeted, either demersal or pelagic, these are also referred to as set (bottom) longlines and drifting (surface) longlines, respectively. Drifting longlines target, according to the hook size and immersion depth, mainly swordfish (*Xiphias gladius*), albacore (*Thunnus alalunga*) and bluefin tuna (*Thunnus thynnus*). These fishing lines have always led to significant bycatch of sharks (Bradai, Saidi and Enajjar, 2012); at least 15 species of sharks (*Prionace glauca*°, *Carcharodon carcharias*°, *Isurus oxyrinchus*°, *Alopias vulpinus*°, *Galeorhinus galeus*°, *Lamna nasus*°, *Alopias superciliosus*, *Sphyrna zygaena*°, *Pteroplatytrygon violacea*, *Mobula mobular*°, *Hexanchus griseus*, *Carcharhinus plumbeus*°, *Squalus blainville*, *Mustelus mustelus*° and *Cetorhinus maximus*°) have been reported as bycatch in drifting longliners (Di Natale, 1998; Vannuccini, 1999; Garibaldi, 2006; Mejuto, Garcia-Cortés and de la Serna, 2002; Bradai, Saidi and Enajjar, 2012; Megalofonou, Dimitris and De Metrio, 2009; Filanti *et al.*, 1986; Megalofonou *et al.*, 2005; Peristeraki *et al.*, 2008). Megalofonou, Dimitris, and De Metrio (2009) reported that a total of 870 blue sharks (*Prionace glauca*°), ranging from 70 to 349 cm TL, were sampled from the swordfish longline fishery in the Mediterranean Sea over the period 1998–2003.

Indeed, studies on drifting longline fisheries targeting swordfish and tuna across the Mediterranean have shown that sharks and rays represent about 6.2 percent by number and 13.5 percent by weight of the total catch: the catch rate was highest in the Alboran Sea (34.3 percent; CPUE of 3.8 individuals per 1 000 hooks) followed by the Adriatic Sea (15.1 percent; CPUE of 1 individual per 1 000 hooks) (Megalofonou *et al.*, 2005). In general, the blue shark (*Prionace glauca*°) was the species most represented in the catch of drifting longliners, accounting for about 71 percent of the total elasmobranch catch, followed by the tope shark (*Galeorhinus galeus*°), at about 13 percent, and the shortfin mako shark (*Isurus oxyrinchus*°), at about 10 percent (Megalofonou, Damalas and Yannopoulos, 2005; Megalofonou, Dimitris and De Metrio, 2009; Megalofonou *et al.*, 2005).

The Alboran Sea represents the area of the western Mediterranean where Spanish fleets targeting swordfish with drifting longlines achieved the highest bycatch rates of pelagic sharks (between 78 percent and 92 percent of the total bycatch in weight). The most heavily caught species were, in order of increasing total weight, *P. glauca*°, *I. oxyrinchus*° and *A. vulpinus*° (UNEP-MAP-RAC/SPA, 2014; Valeiras and de la Serna, 2003; Macías, Gómez-Vivez and de la Serna, 2004; Castro *et al.*, 1999; de la Serna *et al.*, 2002; Megalofonou *et al.*, 2005). Likewise, in the Strait of Gibraltar, Buencuerpo, Rios and Moron (1998), carrying out a study on the composition of the pelagic shark catch in drifting longlines targeting swordfish, reported the presence of *Isurus oxyrinchus*° (3.4 individuals/1 000 hooks), *Prionace glauca*° (19.6 individuals/1 000 hooks), *Alopias vulpinus*° (0.01 individual/1 000 hooks), *Alopias superciliosus* (0.25 individual/1 000 hooks) and *Sphyrna zigaena*° (0.42 individual/1 000 hooks).

Along the coast of Morocco, studies have shown that shark bycatch did not exceed 3 percent of the total weight landed by drifting longliners (Srour and Abid, 2004; Bradai, Saidi and Enajjar, 2012). Regarding pelagic Batoidea, the only species reported as bycatch in drifting longlines was the common pelagic stingray (*Pteroplatytrygon violacea*) (Macías, Gómez-Vivez and de la Serna, 2004; Báez *et al.*, 2009). Over the period 1998–1999, another study examined different swordfish longliners, operating in the waters of southern Spain: sharks represented 13.5 percent of the biomass of the sampled catch, with the main species being blue shark (*P. glauca*°), shortfin mako (*I. oxyrinchus*°), common thresher shark (*Alopias vulpinus*°) and tope shark (*Galeorhinus galeus*°). As a comparison between the different study areas, sharks represented 34.3 percent, 1.7 percent and 1.4 percent of the total biomass caught in the Alboran Sea, Balearic Islands and Catalan Sea, respectively (Megalofonou *et al.*, 2005).

To understand the scale of the impact in the Alboran Sea, Báez *et al.* (2009) analysed variations in swordfish capture and total bycatch under different oceanographic and technical conditions in the artisanal longline fishery operating during the summer period. In 2004, a total of 42 650 hooks were deployed over the course of the observed fishing operations (i.e. approximately 6 percent of the hooks deployed in this area over the period). Nine different species were caught during the observation period: blue shark (*Prionace glauca*°) (60 individuals), bluefin tuna (*Thunnus thynnus*) (1 individual), common dolphinfish (*Coryphaena hippurus*) (31 individuals), common stingray (*Dasyatis pastinaca*) (1 198 individuals), loggerhead sea turtle (*Caretta caretta*) (4 individuals), shortfin mako (*Isurus oxyrinchus*°) (11 individuals), swordfish (*Xiphias glaudius*) (359 individuals), thresher shark (*Alopias vulpinus*°) (3 individuals) and tope shark (*Galeorhinus galeus*°) (1 individual). In line with previous studies, the authors observed that the bycatch (or incidental capture) per unit effort (BPUE) values in the open Mediterranean waters of Andalusia and Murcia were low in comparison to other Mediterranean areas.

In an earlier study carried out in the southern Adriatic Sea, Marano *et al*. (1988) reported that blue shark (*Prionace glauca*) landings accounted for 74.4 percent by weight and 61.2 percent by number of the total bycatch. In comparison, in the Aegean Sea, elasmobranch bycatch in set longlines represented between 6 and 19 percent of the total catch (Stergiou, Moutopoulos and Erzini, 2002).

In general, these records indicate the blue shark (*P. glauca*°) as the most common species found in the bycatch of drifting longliners, followed by the mako (*I. oxyrinchus*°) (Bradai, Saidi and Enajjar, 2012).

Set longliners are usually found to be responsible for bycatch of batoids and demersal shark species (Bradai, Saidi and Enajjar, 2012); in the Aegean Sea, several species of Rajidae (*Raja radula, R. clavata* and *R. miraletus*) accounted for 6 to 19 percent of the total catch. These rates varied according to the hook size (Stergiou, Moutopoulos and Erzini, 2002). A total of 526 longnose spurdog (*Squalus blainville*) specimens were obtained from bottom trawl and set longline catches in the eastern Mediterranean Sea from December 2004 to December 2009 in order to investigate the reproductive biology and the embryonic development of the species. The bottom trawl hauls were carried out at depths between 125 and 475 m in the Aegean Sea, while the longlines were set at depths between 350 and 480 m in the Levantine basin (Kousteni and Megalofonou, 2011).

Along the eastern coast of Rhodes in the Aegean Sea, a set longliner captured an individual of spintail devil ray (*Mobula mobular*°) at a depth of 30 m in 1995 (Corsini-Foka, 2009); in the same area, set longliners caught a specimen of kitefin shark (*Dalatias licha*) at depths of 550–750 m in 2004 and a specimen of common guitarfish (*Rhinobatos rhinobatos*°) in 2008 at a depth of 40 m (Corsini-Foka, 2009). In 2004, the same authors reported the capture of six individuals of longnosed skate (*Dipturus oxyrinchus*) at depths of 300–400 m.

By analysing data from drifting longline fisheries operating in the open waters of the southeastern Mediterranean Sea, Damalas and Megalofonou (2012) have identified a statistically significant decline in species richness, with the probability of shark occurrence reduced to its lowest levels in recent years. Blue shark (*Prionace glauca*°) was the predominant species, accounting for approximately 70 percent of all large sharks encountered. During the periods 1998–2001 and 2003–2005, researchers followed 62 Greek and two Cypriot commercial longliner fishing boats targeting swordfish or tuna and operating from 24 fishing ports. Large sharks were present in 207 out of a total 1 360 fishing sets (exerting an effort of almost a million hooks). In these sets, 249 large shark specimens were observed, belonging to at least ten species and five families: *Prionace glauca*° (170 individuals), *Isurus oxyrinchus*° (25 individuals), *Galeorhinus galeus*° (22 individuals), *Alopias vulpinus*° (13 individuals), *Carcharhinus plumbeus*° (11 individuals), *Alopias superciliosus* (2 individuals), *Carcharodon carcharias*° (1 individual), *Heptranchias perlo*° (1 individual), *Hexanchus nakamurai* (1 individual) and the first recorded sighting of a milk shark, *Rhizoprionodon acutus* (1 individual) in the region.

3.2.5 Pelagic trawlers

Concerning pelagic trawling, Capapé *et al*. (2003), in their review on the historical capture of basking sharks (*Cetorhinus maximus*°) off the Maghrebine shore (Algerian and Tunisian coasts), reported the bycatch of two specimens off Tunisia in 1976 and 1981, and of five specimens off Algeria in 2000 (4 individuals) and in 2002 (1 individual).

In Slovenian waters, Mavrič *et al*. (2004) recorded, for the first time, the presence of the pelagic stingray (*Pteroplatytrygon violacea*): nine individuals were caught by pelagic trawlers targeting anchovies and red bandfish (*Cepola macrophthalma*) between May and September 2004. In the Adriatic Sea, an investigation into cetacean bycatch (Fortuna *et al*., 2010) analysing data from sixteen independent observers monitoring a total of 3 141 hauls between 2006 and 2008 revealed important elasmobranch bycatch information. The observation coverage ranged between 0.9 and 6.3 percent of the regional fishing effort, and the study reported 15 elasmobranch species from bycatch over the survey period; among these, the following conservation-priority species were found: *Alopias vulpinus*° (13 individuals), *Carcharhinus plumbeus*° (1 individual), *Squalus acanthias*° (374 individuals), *Mustelus asterias*° (15 individuals), *M. mustelus*° (80 individuals), *M. punctulatus*° (18 individuals) and *Prionace glauca*° (1 individual). Other species also included *Scyliorhinus canicula, Aetomylaeus bovinus, Myliobatis aquila, Dasyatis pastinaca, Pteroplatytrygon violacea*, *Raja clavata, R. asterias* and *Torpedo marmorata*. According to the study, all species of shark and skate found in bycatch were marketed, including piked dogfish (*Squalus acanthias*°) and smooth-hounds (*Mustelus*°spp.), while the bull ray (*A. bovinus*), common eagle ray (*M. aquila*), pelagic stingray (*P. violacea*) and common stingray (*D. pastinaca*) were usually discarded at sea. Furthermore, in the Adriatic Sea, Lipej *et al*. (2013) reported the bycatch of 84 pelagic stingrays obtained during 50 sampling cruises carried out in the Gulf of Trieste, Italy and adjacent waters from April 2004 to October 2005. Pelagic trawling was conducted in the shallow coastal areas over muddy and muddy-detritic bottom sediments at depths from 20 to 30 m, with the large majority of specimens caught during the summer period.

From the French Mediterranean coast, Ferretti (2014) reported on the last record of a sawfish *Pristis*° sp. caught in the Mediterranean by fishing activities. It was recorded by a tuna fishing boat operating off Grau-du-Roi (Languedoc-Roussillon, France) in 1959. While there is evidence that sawfishes may occur in the Mediterranean Sea (Ferretti, 2014; Ferretti *et al*., 2015), the incidental catch from the different vessel groups is currently not documented.

3.2.6 Tuna traps

Regarding tuna traps, a few studies have reported elasmobranch bycatch in this type of disused coastal fishing gear. In particular, as tuna has always provided a primary food source for Mediterranean great white sharks (*Carcharodon carcharias*°) (Barrull and Mate, 2001; Moro *et al*., 2019), interactions between these large predators and tuna traps, once numerous in the Mediterranean, have been recorded. Likewise, Storai *et al*. (2011) have recorded a long data series of large elasmobranch bycatch in six traditional tuna traps (*tonnare*) off Sardinia (Italy) from 1990 to 2009. Over this period, 15 spintail devil ray (*Mobula mobular*°) and 27 large sharks were caught as bycatch: *M. mobular*° (15 individuals); smooth hammerhead (*Sphyrna zygaena*°) (2 individuals); blue shark (*Prionace glauca*°) (2 individuals); bluntnose sixgill shark (*Hexanchus griseus*) (3 individuals); thresher (*Alopias vulpinus*°) (11 individuals); basking shark (*Cetorhinus maximus*°) (4 individuals); great white shark (*Carcharodon carcharias*°) (2 individuals); shortfin mako (*Isurus oxyrinchus*°) (1 individual); copper shark (*Carcharhinus brachyurus*) (1 individual); and dusky shark (*Carcharhinus obscurus*) (1 individual).

At the Sidi Daoud tuna trap, off northeastern Tunisia, Hattour, Macias and de la Serna (2005) have reported that the great white shark (*C. carcharias*°), the shortfin mako (*I. oxyrinchus*°) and the thresher shark (*Alopias* spp.) accounted for the trap's elasmobranch bycatch, constituting 2.3 percent of the biomass of the total catch. Likewise, along the Libyan coast in June 2002, a great white shark *C. carcharias*° remained trapped for two days in a tuna cage containing 60 tonnes of bluefin tuna

(Galaz and De Maddalena, 2004). Finally, the Mediterranean Large Elasmobranchs Monitoring (MEDLEM) programme (see section 3.3) recorded about 70 incidental catches from 1879 to 2015, with about 68 percent of them that were white sharks (Mancusi *et al.*, 2020). Other cases of sharks trapped in tuna cages in the Mediterranean include an instance of two blue sharks (*P. glauca*°) caught in a cage between Italy and Spain in 2001 and a shortfin mako (*I. oxyrinchus*°) stuck in a cage between the Balearic Islands and Murcia, Spain in 2002 (Galaz and De Maddalena, 2004).

3.2.7 Pelagic driftnets

The bycatch of large elasmobranchs (for example, the blue shark *Prionace glauca*°, great white shark *Carcharodon carcharias*°, common thresher *Alopias vulpinus*°, shortfin mako *Isurus oxyrinchus*° and the basking shark *Cetorhinus maximus*°) has been at historically high levels in various pelagic driftnet fisheries (Vannuccini, 1999; Silvani, Gazo and Aguilar, 1999; Megalofonou, Damalas and Yannopoulos, 2005; Di Natale *et al.*, 1995; Mancusi *et al.*, 2005; Megalofonou *et al.*, 2005; Tudela *et al.*, 2005). The use of this kind of unselective fishing gear has been banned in the Mediterranean Sea, however, since 2005, so its impacts are not treated in detail in this review.

3.3 Analysis of recent data from literature (2008–2019)

In order to adequately assess elasmobranch bycatch in fisheries, it is necessary to carefully monitor all fishing activities, while at the same time examining in detail the existing information available in the scientific literature and from fisheries data. Nonetheless, unlike other vulnerable species (for example, sea turtles), elasmobranchs include numerous and very different species, of which some are protected, others are of commercial value, and yet others are discarded at sea, according to the region and the demand from local markets (see Section 3.1). In addition, sharks and rays are not commonly distinguished at the species level in fisheries, not only in the Mediterranean and Black Sea, but all over the world (Dulvy and Forrest, 2010; Stevens *et al.*, 2000); records usually report (only) the landed species as mixed sharks or *Raja* spp. or sharks nei[4], etc. Therefore, accurate records of elasmobranch bycatch are difficult to obtain from fisheries statistics, as commercial fishing data rarely differentiate between the various elasmobranch species caught. When working from the scientific literature, the task can be equally challenging, as the data on catch and bycatch of elasmobranchs are often pulled together and reported as the biomass percentage of the total catch and/or landings, while the number of specimens caught is frequently unavailable, especially for smaller demersal species. Conversely, when the number of specimens caught is indeed reported, sometimes information on the total catch of the fishing vessel group is not registered.

The following sections include data from scientific literature, reports and databases collected over the period 2008–2018, organized by fishing vessel group and subregion. Tables and graphs only include references from which information regarding the number of caught individuals of priority-conservation elasmobranch species could be extracted according to a specific fishing vessel group. Nevertheless, any interpretation of the results should be taken with caution and in consideration of the limitations listed above. Among these data sources, one important archive is the MEDLEM[5] database (Serena, Mancusi and Barone, 2014; Mancusi *et al.*, 2020), which has

4. "Not elsewhere included".

5. MEDLEM is a network of researchers involving Mediterranean and Black Sea scientists from various research institutes and voluntary associations. All the experts of this network can directly contribute to updating the database with data, including bycatch events and elasmobranch biological information collected in their countries.

been used for obtaining the most recent (2008–2019) bycatch records of elasmobranch species. The figures included in the MEDLEM database represent an underestimate of the real situation, though they still provide useful baseline information on elasmobranch species recorded in the catch of select fishing vessels, sorted by types of gear. When MEDLEM provided data that were also published in scientific literature, only the latter were cited for the purpose of this review in order to avoid duplicates of the same information.

The vessel groups considered in this review correspond to those provided by the GFCM Data Collection Reference Framework (DCRF): bottom trawlers, small-scale fisheries, purse seiners, longliners, pelagic trawlers, tuna seiners and dredgers (GFCM, 2018c). The latter category does not appear in this review, as dredgers do not impact sharks and rays in any GFCM subregion. Meanwhile, the category of tuna seiners also takes into consideration the few tuna traps left in the Mediterranean. Small-scale longliners, which are a major component of artisanal fishing fleets, have been considered as a separate category in the review of small-scale fisheries due to their relative importance.

Data are reported for the five GFCM subregions: western Mediterranean, central Mediterranean, Adriatic Sea, eastern Mediterranean and Black Sea. Among all the species of elasmobranchs cited in this review, conservation-priority species as defined by GFCM Recommendation GFCM/42/2018/2 (Table 1A, Table 1B) are marked with the symbol "°".

3.3.1 Bottom trawlers

Bottom trawling is a common multi-target fishing activity conducted throughout the Mediterranean and Black Sea, providing the highest income among all fishing sub-sectors (Tudela, 2004). Although bottom trawlers represent only about 8 percent of the Mediterranean fleet, they contribute approximately 21 percent of the landed catch, which figure emphasizes their economic importance (Bradai, Saidi and Enajjar, 2018; FAO 2018c). Almost all the shark and ray species in the region can potentially be caught by both pelagic and bottom trawlers (Cavanagh and Gibson, 2007); 62 species have been recorded in trawl catches in Greece, 62 species in Spain and 74 species in Italy (Bradai, Saidi and Enajjar, 2018).

As previously indicated, throughout the Mediterranean and Black Sea, several demersal elasmobranch species are commonly caught in bottom trawl fisheries, including the small-spotted catshark (*Scyliorhinus canicula*), the blackmouth catshark (*Galeus melastomus*), the velvet belly lanternshark (*Etmopterus spinax*), the longnose spurdog (*Squalus blainville*), smooth-hounds (*Mustelus*° spp.), the thornback ray (*Raja clavata*), the speckled ray (*Raja polystigma*), the starry ray (*Raja asterias*), the brown ray (*Raja miraletus*), among others. Pelagic species are also sometimes caught by bottom trawlers. These include the common thresher shark (*Alopias vulpinus*°), blue shark (*Prionace glauca*°), great white shark (*Carcharodon carcharias*°), shortfin mako (*Isurus oxyrinchus*°) and, occasionally, the basking shark (*Cetorhinus maximus*°). Rays, such as the common eagle ray (*Myliobatis aquila*) and the spintail devil ray (*Mobula mobular*°), are also affected (WWF, 2019; Bradai, Saidi and Enajjar, 2012, 2018; Başusta, Başusta and Özgürözbek, 2016). Unfortunately, for this fishing group, the information reported very often concerns a listing of species without an estimate of the bycatch rate by fishing effort and/or absolute numbers of caught individuals.

The data reported officially by countries to the GFCM are presented in Table 3 (FAO, 2018d, 2019).

Table 3 includes information on the incidental catch of conservation-priority sharks and batoid species from sources individually reporting the elasmobranchs caught by bottom trawlers. In this sense, Table 3 provides only an indicative overview, as some of the other studies cited below lack this information.

Western Mediterranean
In the western Mediterranean, most of the chondrichthyans are bottom-dwelling species inhabiting demersal ecosystems on the continental shelf and slope; these characteristics make them especially vulnerable to bottom trawling, which is the most important fishery in the western Mediterranean in terms of both the fishing capacity of the fleet and its catch (Cavanagh and Gibson, 2007). This fishery operates over a wide bathymetric range (50–800 m), exploiting different communities and thus gathering a large number of species in its catch, including bony fishes, decapod crustaceans, cephalopods and other invertebrates, as well as chondrichthyans, which represent an important fraction of bycatch and discards (Moranta *et al.*, 2008; Ramírez-Amaro *et al.*, 2020). A study based on fishery-independent scientific surveys evaluated the population trends of demersal chondrichthyans in the Spanish western Mediterranean and revealed that most of the sharks and batoids (i.e. *Scyliorhinus canicula, Torpedo mamorata, Raja clavata* and *Galeus melastomus*) currently forming these communities, have shown resilience to the impacts of fishing over the last two decades. These results could be explained by the evolution of the trawl fishery (i.e. a reduction of effort and a shift to deeper waters) over the last few years, combined with the greater resilience generally displayed by some species (e.g. *S. canicula*). By contrast, decreasing trends were detected only for the deep-water species *Etmopterus spinax* and *Dipturus oxyrinchus* (Ramírez-Amaro *et al.*, 2020).

In another study, Navarro *et al.* (2014), carrying out an investigation into the diet of the rare kitefin shark (*Dalatias licha*), collected a total of 36 specimens of *D. licha* between 2011 and 2013 (13 in 2011, 18 in 2012 and 5 in 2013); 32 of these were incidentally caught by the bottom trawling fleet operating in the Gulf of Lion and the Catalan Sea at depths between 350 and 550 m and between 400 and 1 200 m, respectively.

In the northwestern Mediterranean, Barría *et al.* (2015) analysed the morphological parameters of threatened chondrichthyans. All chondrichthyan specimens analysed in the study were collected from the Gulf of Lion or the Catalan Sea between September 2011 and June 2013. The samples were obtained from commercial bottom trawling vessels and from two experimental oceanographic surveys (Dos-Mares and Ecotrans projects; Spanish Government) conducted at depths ranging between 40 and 2 200 m. A total of around 811 individuals belonging to 20 species from seven families and six genera were collected. Among the elasmobranchs were found: *Etmopterus spinax* (143 individuals), *Galeus melastomus* (179 individuals), *Scyliorhinus canicula* (171 individuals), *Centrophorus granulosus*° (3 individuals), *Dalatias licha* (37 individuals), *Hexanchus griseus* (6 individuals), *Oxynotus centrina*° (3 individuals), *Dipturus oxyrinchus* (2 individuals), *Leucoraja naevus* (3 individuals), *Raja asterias* (77 individuals), *R. clavata* (8 individuals), *R. montagui* (= *R. polystigma*) (2 individuals), *R. polystigma* (3 individuals), *Centroscymnus coelolepis* (122 individuals), *Somniosus rostratus* (5 individuals), *Squalus acanthias*° (2 individuals), *Torpedo marmorata* (16 individuals), *T. nobiliana* (1 individual) and *T. torpedo* (28 individuals).

Elsewhere, around Ibiza in the Balearic Islands, Guallart, Morey and Bartolì (2019) recorded the presence of an immature female sharpnose sevengill shark (*Heptranchias perlo*°) in the bycatch of a commercial bottom trawler targeting blue and red shrimp (*Aristeus antennatus*). This sighting represented the first substantiated record of the species around the Balearic Islands (GSA 5).

In the MEDLEM database, about 20 percent of the available records of elasmobranch bycatch in bottom trawls are from the western Mediterranean, taking into consideration all species from 2008–2018. In the western Mediterranean, data mainly focus on the bluntnose sixgill shark (*Hexanchus griseus*), which accounts for 39 percent (15 individuals) of the reported bycatch of sharks and rays in bottom trawls; the records of priority-conservation species from the MEDLEM database are presented in Table 3.

Central Mediterranean

In this GFCM subregion, two of the Mediterranean's major trawler fleets (Mazara del Vallo, Italy and Sfax, Tunisia) are present. Meanwhile, the Gulf of Gabès has already been identified as a nursery and sensitive area for several Tunisian elasmobranchs, including *Carcharhinus plumbeus*°, *Mustelus mustelus*°, *Rhinobatos rhinobatos*°, *Glaucostegus cemiculus*° and *Gymnura altavela*° (Bradai, Saidi and Enajjar, 2012, 2018).

In the Gulf of Gabès (Tunisia), Hamdaoui (2009) reported, over a sampling period spanning six months in 2009, 14 species of sharks and 17 species of batoids (rays) caught by bottom trawlers, representing 64.6 percent of all elasmobranch species recorded in the area. The CPUE was estimated at 79.4 kg per trip, 7.6 kg per trawling day and 0.8 kg per haul for all elasmobranchs. As far as the contributions of the different groups, sharks represented 23.7 kg per trip, 2.5 kg per trawling day and 0.27 kg per haul, while the batoids accounted for 55.7 kg per trip, 5 kg per trawling day and 0.54 kg per haul. Fishes, cephalopods and crustaceans represented 74.2 percent, 12.3 percent and 9.4 percent, respectively, of the total landings. In comparison, the overall bycatch of elasmobranchs constituted, on average, 5.4 percent of the total landings (i.e. 1.7 percent sharks and 3.7 percent batoids) and contributed 62 percent to the national production of cartilaginous fish. The CPUE was estimated for some rare species: white skate (*Rostroraja alba*°) (0.1 specimen per landing); spiny butterfly ray (*Gymnura altavela*°) (0.05 specimen per landing); sharpnose sevengill shark (*Heptranchias perlo*°) (0.05 specimen per landing); starry smooth-hound (*Mustelus asterias*°) (0.019 specimen per landing); and great white shark (*Carcharodon carcharias*°) (0.014 specimen per landing). The conservation-priority species caught as bycatch over the sampling period are reported in Table 3.

More recently, in the Gulf of Gabès, Marouani *et al.* (2017) investigated the diet of the shortnose spurdog (*Squalus megalops*) (630 individuals) and longnose spurdog (*S. blainville*) (232 individuals) between January 2007 and May 2009. They were able to collect a large number of monthly samples of these two species from local commercial trawlers operating in the upper 70 m of the water column, thereby highlighting the impacts of these vessels on the species.

Also in the Gulf of Gabès, in the context of an experimental trawl survey carried out during the spring of 2014, 15 elasmobranch species belonging to eight families were incidentally caught, of which the brown ray (*Raja miraletus*), thornback ray (*Raja clavata*), common stingray (*Dasyatis pastinaca*), common smooth-hound (*Mustelus mustelus*°) and shortnose spurdog (*Squalus megalops*) were the most common; in the area, elasmobranch bycatch represented 12.6 percent of the total catch and the CPUE was estimated at 2.96 kg per haul (GFCM, 2014a).

In the same area, El Kamel-Moutalibi *et al.* (2014) reported four specimens of the rare sharpnose sevengill shark (*Heptranchias perlo*°) caught off the northern Tunisian coast between 2007 and 2014: two males (one juvenile and one adult) and two females (one juvenile and one adult). Of these four individuals, only two were certainly bycaught in a bottom trawl. *H. perlo*°, considered to be a rare species and probably threatened, is still present in the area.

In the MEDLEM database, about 8 percent of the available records of elasmobranch bycatch in bottom trawls are from the central Mediterranean, taking into consideration all species caught from 2008 to 2018, and mainly concern the bluntnose sixgill shark (*Hexanchus griseus*) (12 individuals). The records of priority-conservation species are presented in Table 3.

Adriatic Sea

In the Adriatic Sea, although the fishing effort by bottom trawlers has always been high, the bycatch records of large elasmobranch species in the MEDLEM database represent only 3 percent of the data: four individuals of the bluntnose sixgill shark (*Hexanchus griseus*), in addition to one individual of basking shark (*Cetorhinus maximus*°) and two of blue shark (*Prionace glauca*°).

In a recent investigation, Ćetković (2018) described the composition and abundance of shark bycatch in Montenegrin fisheries from fisheries data collected over a three-year survey (2016–2018) and recorded in onboard field observations and at the landing points of four vessel groups: drifting longliners, nets (gillnets and trammel nets) and bottom trawlers. The main goals of the research were to define which species could be found in Montenegrin landings, as well as to make a preliminary assessment of their abundance in the catch of the surveyed gear types. In the surveyed bottom trawls, the shark bycatch included 487 individuals of small-spotted catshark (*Scyliorhinus canicula*), five individuals of smooth-hound (*Mustelus mustelus*°), two individuals of longnose spurdog (*Squalus blainville*), and two individuals of angular roughshark (*Oxynotus centrina*°), all of which were released alive by the fishers.

In 2018, a female great torpedo ray (*Tetronarce nobiliana*) was captured by a commercial bottom trawler off southern Albania at a depth of 550 m. Its total body weight was 5.6 kg, while the specimen's TL and disc width were 70 cm and 50 cm, respectively (Bakiu and Troplini, 2018).

In the Italian Adriatic Sea, Bargione *et al.* (2019) investigated the life history traits, in relation to age structure and reproduction, of the piked dogfish (*Squalus acanthias*°) from mid-February 2012 to mid-July 2013 and in 2016. A total of 326 individuals were caught by bottom trawlers and analysed for the purposes of the study: catches occurred on sandy bottoms ranging from 40 to 90 m deep, at 15–50 nautical miles from the coast. According to the results obtained, the authors concluded that the reduction of *S. acanthias*° bycatch represented an urgent concern and that mitigation measures should be promptly adopted, fishers trained on how to release live sharks, and nursery/mating areas identified and closed during specific times of the year. In addition, awareness campaigns should be launched to reduce shark meat consumption, especially in the Italian Adriatic region.

Eastern Mediterranean

In the eastern Mediterranean, the vessel group using bottom trawls is not as developed as in other areas of the Mediterranean. In recent years, however, bottom trawling has increased, with direct impacts on the fishing of accessory species, such as elasmobranchs. Many studies, especially from Turkish Mediterranean waters, have been published, indicating a high diversity of elasmobranch species in this area of the Mediterranean. As recently pointed out by Kabasakal (2019) in a review of elasmobranch research in Turkish waters, until the last quarter of the twentieth century, most of the knowledge around these species was based on a limited number of anecdotal studies. Since the mid-1990s, however, a remarkable improvement has followed in the number and quality of elasmobranch-specific studies and publications, resulting in a gradual filling of the gaps in scientists' understanding of sharks and rays. Of a total 96 articles on the sharks and rays inhabiting Turkish waters published between 1968 and 2018 (Kabasakal, Karhan and Sakinan, 2017), only two elasmobranch-specific articles had been published prior to 1990, eight scientific articles were published between 1990 and 2000, and as many as 88 papers dealing with different aspects of sharks and rays have been since. The following section reports only on some of these studies, though the facts are clearly emerging to show that that the eastern Mediterranean should be considered as rich and important as the central Mediterranean Sea in terms of elasmobranch diversity and for conservation priorities.

In Egyptian Mediterranean waters, Moftah *et al.* (2011) classified sharks using morphological and DNA barcoding. Fifty-one shark specimens belonging to six families were collected from the commercial catch received at two major fish markets in Alexandria, namely the Abu Qir Fishing Centre and the Rasel-Tin Fishing Centre (Anfoushi). The fishing boats were operating in Alexandrian waters over the period of sample collection from May to November 2008. The study confirmed the presence of piked dogfish (*Squalus acanthias*°), angular roughshark (*Oxynotus centrina*°), angelshark (*Squatina squatina*°), small-spotted catshark (*Scyliorhinus canicula*), nursehound (*Scyliorhinus stellaris*), smooth-hound (*Mustelus mustelus*°), blackspotted smooth-hound (*Mustelus punctulatus*°) and bignose shark (*Carcharhinus altimus*) (Table 3). Though the study did not specify the relevant fishing vessel groups, the species composition can be linked to bottom trawlers.

In Iskenderun Bay in the northeastern Mediterranean, Yağlıoğlu *et al.* (2015) assessed the elasmobranch bycatch of a bottom trawl fishery by examining the total biomass, species composition, depth distribution, seasonal distribution and abundance of elasmobranchs in 52 commercial bottom trawls carried out between 2009 and 2010. It was estimated that elasmobranchs represented 23 percent (190.1 kg per km^2) of the total fish biomass (840.8 kg per km^2) in Iskenderun Bay; bycatch also included priority-conservation species, though absolute values were not provided. The batoids, *Dasyatis pastinaca*, *Gymnura altavela*°, *Raja clavata* and *Rhinobatos*° spp. (*R. rhinobatos*° and *R. cemiculus*°), occurred frequently and represented between 11.1 and 38.5 percent, respectively, of the total elasmobranch biomass. Other batoid species, *Dipturus oxyrinchus*, *Raja miraletus*, *Torpedo marmorata* and *Torpedo torpedo*, each represented between 0.1 and 2.8 percent of the total elasmobranch biomass. In addition, the shark species, *Mustelus mustelus*°, *Scyliorhinus stellaris*, *Scyliorhinus canicula*, *Galeus melastomus* and *Squatina squatina*°, each accounted for between 0.45 and 1.7 percent of the whole elasmobranch biomass. Single or sporadic captures were also recorded for the following shark and batoid species: the shortfin mako shark (*Isurus oxyrinchus*°), sandbar shark (*Carcharhinus plumbeus*°), bignose shark (*Carcharhinus altimus*), angular roughshark (*Oxynotus centrina*°), rough ray (*Raja radula*), Lusitanian cownose ray (*Rhinoptera marginata*) and the bull ray (*Aetomylaeus bovinus*).

Also in Iskenderun Bay, Yemisken, Dalyan and Eryilmaz (2014) analysed and compared the fish species found in the catch and discards of trawl fisheries during the fishing closure period and the fishing period, with sampling carried out from May 2010 to January 2011 on a commercial trawler. The results showed that chondrichthyan species abundance (number) represented 0.9 percent (465 individuals) of the total discarded catch, with only three species retained as commercial catch: the smooth-hound (*Mustelus mustelus*°) (1 individual); sandbar shark (*Carcharhinus plumbeus*°) (2 individuals); and blackchin guitarfish (*Rhinobatus cemiculus*°) (1 individual). Chondrichthyan species biomass (weight) represented 51 percent of the discarded catch, with the spiny butterfly ray (*Gymnura altavela*°) (203 individuals) and common stingray (*Dasyatis pastinaca*) (125 individuals) the most common species among the chondrichthyans in the study area. The discard rate of chondrichthyan species was estimated at 12.5 percent in May, 19.1 percent in August, 2.3 percent in October and 5.1 percent in January.

In the same area, in Mersin Bay, Turkey, Ergüden and Bayhan (2015) reported the first instance of an individual of the rare sawback angelshark (*Squatina aculeata*°) caught as incidental catch by bottom trawlers, in 2014. In the same area, a female specimen of the basking shark (*Cetorhinus maximus*°) (TL 245 cm; 75 kg weight) was incidentally caught by a bottom trawler at a depth of about 25 m in March 2014 (Ergüden *et al.*, 2020). Further west, in the Gulf of Antalya (Turkey), Kebapçıoğlu *et al.* (2010) analysed 30 hauls from a bottom trawl survey carried out over the summer of 2009, in order to determine the catch composition, abundance and biomass of the demersal fish stocks. A total of 84 fish species were identified, including nine elasmobranchs. The spiny butterfly ray (*Gymnura altavela*°) and common stingray (*Dasyatis pastinaca*) were among the five species with the highest biomass index values, indicating a high abundance of these species in the area.

Similarly, in the Gulf of Antalya, Özbek, Çardak and Kebapçioğlu (2016) also recorded the abundance and biomass of the spiny butterfly ray (*Gymnura altavela*°) at various depth levels and in different seasons. A total of 116 hauls were carried out between August 2009 and April 2010 at six stations and six depth levels (25, 50, 75, 100, 150 and 200 m) using a commercial bottom trawl. From 40 hauls, 172 individuals of *G. altavela*° were sampled; the frequency of occurrence was 41.7 percent at depths between 25 and 100 m but zero at 150 and 200 m. In another study conducted along the west coast of İskenderun Bay, Yeldan *et al.* (2013) analysed the temporal changes in some Rajiformes[6] species caught by commercial bottom trawlers from 2004 to 2011 (see Section 3.2); the priority-conservation species sampled from 2008 to 2011 are reported in Table 3. In the same area, two individuals of the rare angular roughshark (*Oxynotus centrina*°) were obtained from the discarded catch of commercial trawlers fishing at depths of 120 to 150 m off the Cape of Akinci (Ras al-Khanzir) on 14 May 2014 (Başusta, Turan and Başusta, 2015). According to the authors, the occurrence of a gravid female and an adult male of *O. centrina*° in the northeastern Mediterranean Sea strongly indicates the presence of a nursery and mating area. Furthermore, off Samandag, Iskenderun Bay, Kapiris *et al.* (2014) reported the rare occurrence of a starry smooth-hound (*Mustelus asterias*°), caught by a bottom trawler at a depth of 90 m. This record represents the first to be registered since the last reported catch of *M. asterias*° in the early 1980s by Gücü and Bingel (1994). In the same area (Iskenderun Bay), a single female specimen of the pelagic stingray (*Pteroplatytrygon violacea*) was incidentally caught on a sandy/muddy bottom at a depth of approximately 40 m by a commercial bottom trawler in 2016 (Ergüden *et al.*, 2018).

During a broader investigation of Turkish waters (northeastern Mediterranean), Gökçe, Saygu and Eryaşar (2016) analysed catch composition and diversity in Mersin Bay, an important fishing ground for demersal trawls. A total of 182 hauls were carried out by a commercial trawler between September 2009 and April 2013. Elasmobranchs represented 5.1 percent of the total catch in terms of CPUE (kg per hour) and 0.09 percent in terms of number per hour. Overall, twelve species of elasmobranchs were identified, including sandbar shark (*Carcharhinus plumbeus*°), nursehound (*Scyliorhinus stellaris*), smooth-hound (*Mustelus mustelus*°), common stingray (*Dasyatis pastinaca*), Tortonese's stingray (*D. tortonesei*), spiny butterfly ray (*Gymnura altavela*°), thornback ray (*Raja clavata*), brown ray (*R. miraletus*), blackchin guitarfish (*Rhinobatos rhinobatos*°),

6. Rays, sawfishes, guitarfishes, skates and stingrays.

angular roughshark (*Oxynotus centrina*°), marbled electric ray (*Torpedo marmorata*) and electric ray (*T. nobiliana*) (Table 3).

In another study conducted in the northeastern Mediterranean (Turkey), Başusta and Başusta (2019) analysed the occurrence of the longnosed skate (*Dipturus oxyrinchus*) as bycatch from commercial trawl fishing at depths of 300–410 m and 360–400 m in Antakya Bay and recorded the first record of egg capsules and juveniles of the longnosed skate in this area. In addition, Başusta (2016) also reported the occurrence of neonate and juvenile sharks of three rare species, the sharpnose sevengill shark (*Heptranchias perlo*°), sawback angelshark (*Squatina aculeata*°) and velvet belly (*Etmopterus spinax*), captured as bycatch by a commercial trawler fishing at depths between 360 and 430 m in the same area. It was the first time that two neonates of *H. perlo*°, five neonates of *E. spinax* and one juvenile of *S. aculeata* were identified in this region.

In the central Aegean Sea, Eronat and Özaydın (2014) carried out a study on the length–weight relationship parameters of 2 511 specimens of 30 cartilaginous fish species (11 sharks, 18 batoids and 1 chimaera) caught from depths of 0 to 500 m by a research vessel and a commercial trawler between 2008 and 2009 in Izmir and Sığacık Bay. During the operations, a traditional bottom trawl (48 mm mesh size in codend) and cover net were used, while hauls were limited to 30 mn and the average speed was 2.5 knots. The most abundant species were the small-spotted catshark (*Scyliorhinus canicula*) (1 210 individuals), longnose spurdog (*Squalus blainville*) (308 individuals), blackmouth catshark (*Galeus melastomus*) (235 individuals), thornback ray (*Raja clavata*) (137 individuals), common stingray (*Dasiatys pastinaca*) (78 individuals), nursehound (*Scyliorhinus stellaris*) (19 individuals) and rough ray (*R. radula*) (16 individuals); the few priority-conservation species noted as bycatch during these surveys are reported in Table 3.

Elsewhere, along the southern Aegean coast, the catch composition of a shrimp trawl fishery was analysed from December 2009 to November 2010 (Bilge *et al.*, 2014); among the elasmobranchs recorded during 68 hauls, the following species and abundances were noted: *Mustelus mustelus*° (74 individuals), *M. punctulatus*° (52 individuals), *Squalus blainville* (80 individuals), *Raja radula* (38 individuals), *R. miraletus* (62 individuals), *Torpedo marmorata* (57 individuals), *T. nobiliana* (73 individuals), *Scyliorhinus stellaris* (92 individuals) and *Scyliorhinus canicula* (144 individuals). Likewise, data collected from 11 scientific bottom trawling operations in 2009 and 2010 off the Turkish coast of the southern Aegean Sea were used to describe the distribution and abundance of chondrichthyan species (Filiz, Yapıcı and Bilge, 2018): the most abundant species were *Mustelus mustelus°, Dasyatis pastinaca, Raja miraletus and Raja radula*.

In another study, from Edremit Bay in the northern Aegean Sea, length-weight relationships were calculated for nine chondrichthyan species. (Türker, Zengin and Tünay, 2019). Samples were collected at depths ranging from 20 to 100 m at monthly sampling intervals from June 2007 to June 2009 using a commercial bottom trawler employing deep trawl nets with a 24 mm codend mesh size; tow duration was restricted to 30 mn. The 286 elasmobranchs caught consisted of *Dasyatis pastinaca* (10 individuals), *Mustelus mustelus*° (60 individuals), *Myliobatis aquila* (12 individuals), *Raja clavata* (33 individuals), *R. miraletus* (13 individuals), *R. radula* (23 individuals), *Scyliorhinus stellaris* (8 *individuals*), *S. canicula* (108 *individuals*) *Torpedo marmorata* (9 *individuals*), *Carcharodon carcharias*° (1 individual), *Cetorhinus maximus*° (1 individual), *Galeorhinus galeus*° (2 individuals), *Gymnura altavela*° (1 individual), *Leucoraja naevus* (1 individual), *Rostroraja alba*° (2 individuals) and *Squalus acanthias*° (2 individuals).

One of the first studies investigating the demography and reproductive biology of the blackmouth catshark (*Galeus melastomus*) in the eastern Mediterranean was carried out by Metochis *et al.* (2016), based on 452 individuals incidentally caught. The sampled population mainly consisted of immature catsharks (77 percent), predominantly trawled in the northwest Aegean and the Gulf of Corinth during winter and autumn. In addition, an investigation from the eastern part of the Aegean Sea by Bengil *et al.* (2019) onboard a commercial bottom trawler operating at depths between 150 and 550 m and studying the feeding habits of four elasmobranch species (carried out in 2008 and 2014) sampled a total of 2 174 specimens belonging to the velvet belly (*Etmopterus spinax*) (129 individuals), blackmouth catshark (*G. melastomus*) (441 individuals), longnose spurdog (*Squalus blainville*) (308 individuals) and small-spotted catshark (*Scyliorhinus canicula*) (1 296 individuals). The importance of this latter species, *S. canicula*, in the catch composition was recorded also during an investigation of commercial trawling operations conducted between March 2012 and May 2014 along the southeastern part of the Turkish coast, with a total of 1 150 individuals (562 females, 588 males) caught (Özcan and Başusta, 2018a).

Elsewhere, off the southern Turkish coast in Antalya Bay, Bulguroğlu *et al.* (2014) reported, in their study on elasmobranch parasites, that a thornback ray (*Raja clavata*) and an angelshark (*Squatina squatina*°) were captured by commercial trawl vessels as non-target species at a depth of 50 m in April and July 2013 as a result of low trawl mesh selectivity. The angelshark was returned to the sea after the parasites had been collected. Recently, also in Antalya Bay, Kabasakal and Bayrı (2019) reported a female specimen of the smalltooth sandtiger shark (*Odontaspis ferox*°) (4 m TL), incidentally caught in March 2019 by a commercial bottom trawler while towing at depths between 100 to 120 m.

Furthermore, along the Syrian coast, a total of 8 035 elasmobranchs, comprising 17 species belonging to 11 families, were recorded in bycatch at a main landing site between November 2014 and October 2015. The species caught by trawl nets were *Mustelus mustelus*° (418 individuals), *Galeus melastomus* and *Squalus blainville* (Alkusairy and Saad, 2018) (Table 3).

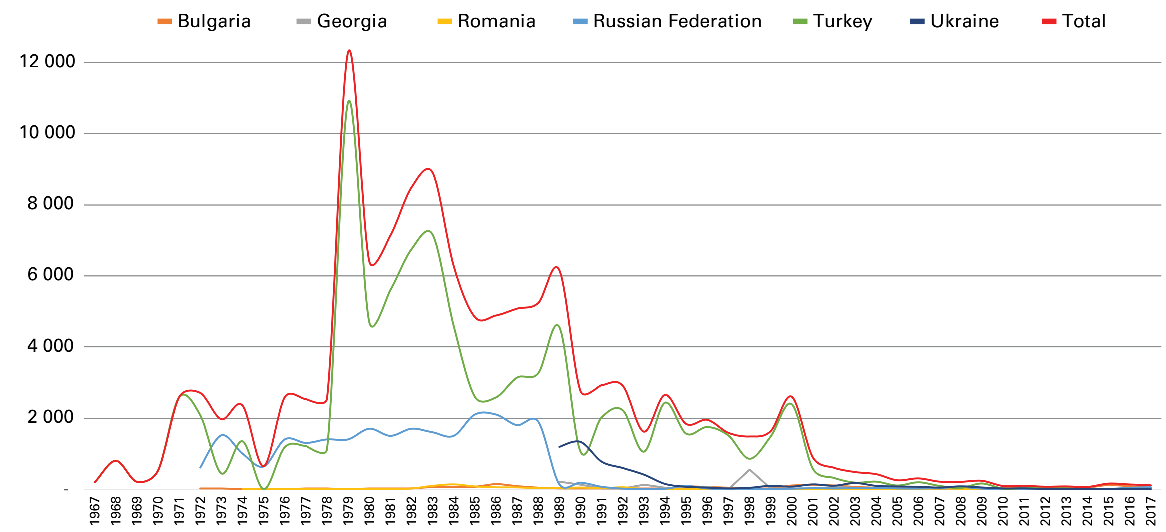
In the Marmara Sea, chondrichthyan bycatch was surveyed seasonally between October 2011 and February 2013 during 117 tows of the beam trawl fishery targeting deep-water rose shrimp (*Parapenaeus longirostris*); the bycatch per unit of effort are provided for each elasmobranch species: *Raja clavata* (0.47 kg/hour), *Raja miraletus* (0.051 kg/hour), *Dasyatis pastinaca* (0.093 kg/hour), *Scyliorhinus stellaris* (0.022 kg/hour), *Scyliorhinus canicula* (0.051 kg/hour), *Torpedo marmorata* (0.032 kg/hour), *Squalus acanthias*° (0.002 kg/hour) and *Oxynotus centrina*° (0.02 kg/hour) (İşmen *et al.*, 2013).

In the MEDLEM database, about 65 percent of the available records for elasmobranch bycatch come from bottom trawlers in the eastern Mediterranean. This high value is due, however, to a peak in bramble shark (*Echinorhinus brucus*) records (75 individuals) caught incidentally by Egyptian trawlers. The records of priority-conservation species are presented in Table 3.

Black Sea

Among the landings of small species of sharks and rays, the landings of piked dogfish (*Squalus acanthias*°) and thornback ray (*Raja clavata*) have been analysed from six countries bordering the Black Sea (Bulgaria, Georgia, Romania, Russian Federation, Turkey and Ukraine). Indeed, these two species are found in the incidental catch of the trawl fleet targeting turbot, red mullet, anchovy and whiting, among other fishes (STECF, 2017; GFCM, 2018a). Other types of fishing gear, such

FIGURE 2
Piked dogfish (*Squalus acanthias*) landings by Black Sea bottom trawlers (1967–2017)



Source: STECF, 2015; GFCM, 2018a.

as purse seines, longlines and gillnets, contribute to bycatch, but with a lower impact. Catches of *S. acanthias*° in bottom trawls have allowed for a long period of information to be analysed for this species (Figure 2) (STECF, 2015). Since 2016, Turkey has protected the piked dogfish *S. acanthias*° (STECF, 2017; GFCM, 2018a).

Due to the very low presence of *S. acanthias*° in catches in the Black Sea and a strong decrease in its biomass over recent years, the population of *S. acanthias*° is considered depleted in this subregion, and fishing mortality should be reduced by more than 90 percent (GFCM, 2018b).

Yıldız and Karakulak (2017) have estimated the discards of target and non-target species in the Black Sea from bottom trawlers (using a rhombic and 40 mm codend mesh size nets). Onboard sampling was conducted off the southwestern coast of the Black Sea in the Turkish fishing ports of Rumelifeneri and Igneada on a total of 66 hauls conducted by two commercial bottom trawlers from October 2012 to April 2013 and from October 2013 to April 2014. A total of 25 species of fish were identified, and the elasmobranchs included *Dasyatis pastinaca* (7 individuals), *Raja clavata* (157 individuals) and *Squalus acanthias*° (18 individuals).

Along the southern coast of the Black Sea, Bat *et al.* (2018) carried out a study during the fishing periods of 2013–2014 in order to evaluate certain fish agglomerations within 3 nautical miles (i.e. 4.8 km) of the coastal area in the Sinop-Inceburun Region (Turkey). Data were collected from five trawl operations at depths of 20 to 39 m at five different locations. During these surveys, 16 teleost species from 15 families, and two elasmobranch species from two families were recorded: *Raja clavata* (28 individuals) and *Dasyatis pastinaca* (2 individuals).

Among the large elasmobranchs, the MEDLEM database reports the capture of one blackchin guitarfish (*Rhinobatos cemiculus*°) and eight individuals of the bluntnose sixgill shark (*Hexanchus griseus*). Very little information about *H. griseus* is available from the Black Sea and more detailed studies on the biology of this species in this area should be carried out.

Table 3 – Incidental catch of conservation-priority elasmobranch species in bottom trawlers (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Barría *et al.* (2015)	2011–2013	OTB	Western Mediterranean	Spain/France	*Centrophorus granulosus*	III	3	Onboard observations and experimental fishing
Barría *et al.* (2015)	2011–2013	OTB	Western Mediterranean	Spain/France	*Oxynotus centrina*	II	3	Onboard observations and experimental fishing
Barría *et al.* (2015)	2011–2013	OTB	Western Mediterranean	Spain/France	*Squalus acanthias*	III	2	Onboard observations and experimental fishing
Guallart, Morey and Bartolì (2019)	2018	OTB	Western Mediterranean	Spain	*Heptranchias perlo*	III	1	Onboard observations
MEDLEM	2008–2018	OTB	Western Mediterranean	-	*Alopias* spp.	II	3	-
MEDLEM	2008–2018	OTB	Western Mediterranean	-	*Cetorhinus maximus*	II	4	-
MEDLEM	2008–2018	OTB	Western Mediterranean	-	*Galeorhinus galeus*	II	1	-
MEDLEM	2008–2018	OTB	Western Mediterranean	-	*Prionace glauca*	III	5	-
MEDLEM	2008–2018	OTB	Western Mediterranean	-	*Gymnura altavela*	II	8	-
MEDLEM	2008–2018	OTB	Western Mediterranean	-	*Rostroraja alba*	II	2	-
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Heptranchias perlo*	III	22	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Galeorhinus galeus*	II	1	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Mustelus asterias*	III	8	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	426	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Mustelus punctulatus*	III	125	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Carcharhinus plumbeus*	III	58	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Squatina aculeata*	II	7	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Squatina oculata*	II	3	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Squatina squatina*	II	2	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Carcharodon carcharias*	II	6	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Gymnura altavela*	II	19	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Rhinobatos rhinobatos*	II	192	Observation at landing sites
Hamdaoui (2009)	2009	OTB	Central Mediterranean	Tunisia	*Rhinobatos cemiculus*	II	271	Observation at landing sites
El Kamel-Moutalibi *et al.* (2014)	2014	OTB	Central Mediterranean	Tunisia	*Heptranchias perlo*	III	2	Observations at landing sites
MEDLEM	2008–2018	OTB	Central Mediterranean	-	*Carcharodon carcharias*	II	2	-
MEDLEM	2008–2018	OTB	Central Mediterranean	-	*Galeorhinus galeus*	II	1	-
MEDLEM	2008–2018	OTB	Central Mediterranean	-	*Rostroraja alba*	II	2	-
Ćetković (2018)	2016–2018	OTB	Adriatic Sea	Montenegro	*Oxynotus centrina*	II	2	Onboard and landing site observations
Ćetković (2018)	2016–2018	OTB	Adriatic Sea	Montenegro	*Mustelus mustelus*	III	5	Onboard and landing site observations

Table 3 (continued)

Bibliographic reference	**Reference years**	**Gear**	**GFCM subregion**	**Country**	**Species**	**SPA/BD Protocol Annex**	**Reported individuals in bycatch events**	**Source of data**
Bargione *et al.* (2019)	2012–2013 2016	OTB	Adriatic Sea	Italy	*Squalus acanthias*	III	326	Onboard and landing site observations
MEDLEM	2009–2018	OTB	Adriatic Sea	-	*Cetorhinus maximus*	II	1	-
MEDLEM	2009–2018	OTB	Adriatic Sea	-	*Prionace glauca*	III	2	
FAO (2018d)	2017	OTB	Adriatic Sea	Croatia	*Mustelus mustelus*	III	11	-
FAO (2018d)	2017	OTB	Adriatic Sea	Croatia	*Mustelus punctulatus*	III	2	-
FAO (2018d)	2017	OTB	Adriatic Sea	Croatia	*Squalus acanthias*	III	1	-
Kabasakal and Bayrı (2019)	2019	OTB	Eastern Mediterranean	Turkey	*Odontaspis ferox*	II	1	Landing observation
Moftah *et al.* (2011)	2008	OTB	Eastern Mediterranean	Egypt	*Mustelus mustelus*	III	8	Observations at landing sites
Moftah *et al.* (2011)	2008	OTB	Eastern Mediterranean	Egypt	*Mustelus punctulatus*	III	6	Observations at landing sites
Moftah *et al.* (2011)	2008	OTB	Eastern Mediterranean	Egypt	*Squalus acanthias*	III	5	Observations at landing sites
Moftah *et al.* (2011)	2008	OTB	Eastern Mediterranean	Egypt	*Squatina squatina*	II	3	Observations at landing sites
Moftah *et al.* (2011)	2008	OTB	Eastern Mediterranean	Egypt	*Oxynotus centrina*	II	1	Observations at landing sites
Bulguroğlu *et al.* (2014)	2013	OTB	Eastern Mediterranean	Turkey	*Squatina squatina*	II	1	Onboard observations
Eronat and Özaydın (2014)	2008–2009	OTB	Eastern Mediterranean	Turkey	*Mustelus mustelus*	III	41	Onboard observations
Eronat and Özaydın (2014)	2008–2009	OTB	Eastern Mediterranean	Turkey	*Mustelus punctulatus*	III	6	Onboard observations
Eronat and Özaydın (2014)	2008–2009	OTB	Eastern Mediterranean	Turkey	*Rostroraja alba*	II	10	Onboard observations
Eronat and Özaydın (2014)	2008–2009	OTB	Eastern Mediterranean	Turkey	*Heptranchias perlo*	III	1	Onboard observations
Eronat and Özaydın (2014)	2008–2009	OTB	Eastern Mediterranean	Turkey	*Galeorhinus galeus*	II	1	Onboard observations
Eronat and Özaydın (2014)	2008–2009	OTB	Eastern Mediterranean	Turkey	*Oxynotus centrina*	II	2	Onboard observations
Eronat and Özaydın (2014)	2008–2009	OTB	Eastern Mediterranean	Turkey	*Dipturus cf. batis*	II	2	Onboard observations
Eronat and Özaydın (2014)	2008–2009	OTB	Eastern Mediterranean	Turkey	*Gymnura altavela*	II	4	Onboard observations
Türker, Zengin and Tünay (2019)	2007-2009	OTB	Eastern Mediterranean	Turkey	*Mustelus mustelus*	III	60	Onboard observations
Türker, Zengin and Tünay (2019)	2007–2009	OTB	Eastern Mediterranean	Turkey	*Carcharodon carcharias*	II	1	Onboard observations
Türker, Zengin and Tünay (2019)	2007–2009	OTB	Eastern Mediterranean	Turkey	*Cetorhinus maximus*	II	1	Onboard observations
Türker, Zengin and Tünay (2019)	2007–2009	OTB	Eastern Mediterranean	Turkey	*Galeorhinus galeus*	II	2	Onboard observations
Türker, Zengin and Tünay (2019)	2007–2009	OTB	Eastern Mediterranean	Turkey	*Gymnura altavela*	II	1	Onboard observations
Türker, Zengin and Tünay (2019)	2007–2009	OTB	Eastern Mediterranean	Turkey	*Rostroraja alba*	II	2	Onboard observations
Türker, Zengin and Tünay (2019)	2007–2009	OTB	Eastern Mediterranean	Turkey	*Squalus acanthias*	III	2	Onboard observations
Başusta (2016)	2015	OTB	Eastern Mediterranean	Turkey	*Squatina aculeata*	II	1	Onboard observations
Başusta (2016)	2015	OTB	Eastern Mediterranean	Turkey	*Heptranchias perlo*	III	2	Onboard observations
Yemisken, Dalyan and Eryilmaz (2014)	2010	OTB	Eastern Mediterranean	Turkey	*Mustelus mustelus*	III	1	Onboard observations

Table 3 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Yemisken, Dalyan and Eryilmaz (2014)	2010	OTB	Eastern Mediterranean	Turkey	*Carcharhinus plumbeus*	III	2	Onboard observations
Yemisken, Dalyan and Eryilmaz (2014)	2010	OTB	Eastern Mediterranean	Turkey	*Rhinobatos cemiculus*	II	1	Onboard observations
Yemisken, Dalyan and Eryilmaz (2014)	2010	OTB	Eastern Mediterranean	Turkey	*Gymnura altavela*	II	203	Onboard observations
Özbek, Çardak and Kebapçioğlu (2016)	2009–2010	OTB	Eastern Mediterranean	Turkey	*Gymnura altavela*	II	172	Onboard observations
Gökçe, Saygu and Eryaşar (2016)	2009–2013	OTB	Eastern Mediterranean	Turkey	*Gymnura altavela*	II	26	Onboard observations
Gökçe, Saygu and Eryaşar (2016)	2009–2013	OTB	Eastern Mediterranean	Turkey	*Carcharhinus plumbeus*	III	1	Onboard observations
Gökçe, Saygu and Eryaşar (2016)	2009–2013	OTB	Eastern Mediterranean	Turkey	*Mustelus mustelus*	III	16	Onboard observations
Gökçe, Saygu and Eryaşar (2016)	2009–2013	OTB	Eastern Mediterranean	Turkey	*Rhinobatos rhinobatos*	II	160	Onboard observations
Gökçe, Saygu and Eryaşar (2016)	2009–2013	OTB	Eastern Mediterranean	Turkey	*Oxynotus centrina*	II	1	Onboard observations
Yeldan *et al.* (2013)	2008–2011	OTB	Eastern Mediterranean	Turkey	*Gymnura altavela*	II	56	Onboard observations
Yeldan *et al.* (2013)	2008–2011	OTB	Eastern Mediterranean	Turkey	*Rhinobatos rhinobatos*	II	62	Onboard observations
Ergüden and Bayhan (2015)	2014	OTB	Eastern Mediterranean	Turkey	*Squatina aculeata*	II	1	-
Başusta, Turan and Başusta (2015)	2014	OTB	Eastern Mediterranean	Turkey	*Oxynotus centrina*	II	2	-
Kapiris *et al.* (2014)	2014	OTB	Eastern Mediterranean	Turkey	*Mustelus asterias*	III	1	-
Bilge *et al.* (2014)	2009–2010	OTB	Eastern Mediterranean	Turkey	*Mustelus mustelus*	III	74	Onboard observations
Bilge *et al.* (2014)	2009–2010	OTB	Eastern Mediterranean	Turkey	*Mustelus punctulatus*	III	52	Onboard observations
Ergüden *et al.* (2020)	2014	OTB	Eastern Mediterranean	Turkey	*Cetorhinus maximus*	II	1	Landing observations
Alkusairy and Saad (2018)	2014–2015	OTB	Eastern Mediterranean	Syrian Arab Republic	*Mustelus mustelus*	III	418	Landing observations
MEDLEM	2009–2018	OTB	Eastern Mediterranean	-	*Alopias* spp.	II	1	-
MEDLEM	2009–2018	OTB	Eastern Mediterranean	-	*Carcharodon carcharias*	II	1	-
MEDLEM	2009–2018	OTB	Eastern Mediterranean	-	*Squatina aculeata*	II	4	-
MEDLEM	2009–2018	OTB	Eastern Mediterranean	-	*Rostroraja alba*	II	33	-
FAO (2018d)	2017	OTB	Eastern Mediterranean	Greece	*Mustelus mustelus*	III	3	-
FAO (2018d)	2017	OTB	Eastern Mediterranean	Greece	*Squalus acanthias*	III	9	-
FAO (2019)	2018	OTB	Eastern Mediterranean	Greece	*Squalus acanthias*	III	224	-
FAO (2019)	2018	OTB	Eastern Mediterranean	Greece	*Mustelus mustelus*	III	13	-
FAO (2019)	2018	OTB	Eastern Mediterranean	Greece	*Leucoraja melitensis*	II	1	-
FAO (2019)	2018	OTB	Eastern Mediterranean	Greece	*Centrophorus granulosus*	III	1	-
Yıldız and Karakulak (2017)	2012–2014	OTB	Black Sea	Turkey	*Squalus acanthias*	III	18	Onboard observations
MEDLEM	2009–2018	OTB	Black Sea	-	*Rhinobatos cemiculus*	II	1	-

Note: OTB = bottom otter trawl.

3.3.2 Small-scale fisheries

Fishing with artisanal gear is common throughout the Mediterranean and the Black Sea. Small-scale fisheries account for more than 80 percent of the Mediterranean and Black Sea fleet and probably represent the most complex vessel group, including many types of fishing gear – mostly static nets (e.g. trammel nets and gillnets), traps and longlines (both set and drifting) – and characterized by a variety of fishing grounds, seasons and target species (FAO, 2018c, 2020a). The Mediterranean and Black Sea elasmobranch species are largely coastal and benthic; some inhabit the continental shelf, making them vulnerable to small-scale fishing activities concentrated mainly along the coast (Bradai, Saidi and Enajjar, 2012; Le Direach *et al.*, 2013).

Across the whole Mediterranean, small-scale fishing gear is occasionally used to target sharks (Bradai, Saidi and Enajjar, 2012; Murua *et al.*, eds, 2013). These fisheries operate mainly on the basis of the seasonal abundance of elasmobranch species, meaning that the catch composition by species varies regionally (Ceyhan, Hepkafadar and Tosunoglu 2010; Echwikhi *et al.*, 2013). Furthermore, in some coastal communities, sharks provide a subsistence fishery between more profitable fishing seasons for teleosts, molluscs and crustaceans (Echwikhi *et al.*, 2013). Bradai, Saidi and Enajjar (2012) report limited use of gillnets targeting elasmobranch species such as *Mustelus*°spp. and *Squalus* spp. in the northern Adriatic Sea and *Mustelus*°spp., sandbar sharks (*Carcharhinus plumbeus*°) and *Rhinobatos*° spp. in the Gulf of Gabès. Stingrays and skates were the most captured species in the Balearic Islands, Corsica and the Aegean Sea. However, in general, few studies have been undertaken to assess the impacts of these fisheries on elasmobranchs.

The data reported officially by countries to the GFCM are presented in Table 4 (FAO, 2017, 2018d, 2019).

Data gathered in the MEDLEM database indicate that the elasmobranchs most frequently caught incidentally by small-scale fisheries are demersal species, notably *Mustelus*°spp. and batoids (i.e. rays, skates and their relatives), though occasionally some large pelagic elasmobranchs, such as *Carcharhinus* spp., basking sharks (*Cetorhinus maximus*°), thresher sharks (*Alopias* spp.), spintail devil ray (*Mobula mobular*°) and blue sharks (*Prionace glauca*°) are caught, as well as the great white shark (*Carcharodon carcharias*°).

Table 4 includes information on the incidental catch of conservation-priority shark and batoid species from sources individually reporting the elasmobranchs caught by small-scale fisheries. In this sense, Table 4 provides only an indicative overview, as some of the other studies cited below lack this information.

Western Mediterranean

Along the eastern Spanish coast, off the Valencian Community, Chaumel *et al.* (2018) carried out a survey from January to December 2017 on 63 sets laid by 14 vessels, gathering data through a combination of onboard observations and sampling at three harbours in order to analyse the bycatch in trammel nets. All the species caught were demersal species, totalling 424 batoid specimens belonging to five families: Torpedinidae, Rajidae, Myliobatidae, Dasyatidae and Gymnuridae, with the most common being common torpedo (*Torpedo torpedo*) (108 individuals, 25.5 percent), marbled electric ray (*Torpedo marmorata*) (101 individuals, 25.8 percent), rough ray (*Raja radula*) (67 individuals, 15.8 percent) and common stingray (*Dasyatis pastinaca*) (22 individuals, 5.2 percent).

In another study, conducted off western Corsica (France), a twelve-year seasonal survey (from 2001 to 2012) of the artisanal fishery provided data on the catch and discards of elasmobranchs in gillnets and trammel nets (Le Direach *et al.*, 2013). Among the elasmobranchs, the most frequently discarded species were *Scyliorhinus canicula* and *S. stellaris*, followed by *Dasyatis pastinaca* and *Torpedo* spp. The occurrence of *Myliobatis aquila* and *Squalus blainville* was rare, and these species were mainly encountered in the spring. An unidentified species belonging to the genus *Squatina*° was also observed only on one occasion.

Along the Algerian coast, a one-year (May 2013 to April 2014) investigation monitoring 1 330 fishing trips and 1 613 fishing operations (mainly gillnets and trammel nets) across 16 fishing grounds recorded the following species in bycatch: *Squalus acanthias*° (1 135 tonnes), *Scyliorhinus canicula* (750 tonnes) and *Torpedo* spp. (75 tonnes) (Boubekri *et al.*, 2018).

In the MEDLEM database, 14 percent of the records note small-scale fisheries bycatch in the western Mediterranean Sea. Among these, 45 percent of the records describe four large pelagic shark species, including common thresher shark (*Alopias vulpinus*°) and basking shark (*Cetorhinus maximus*° (Table 4), while bycatch of the common stingray (*Dasyatis pasticata*) alone represents 33 percent of the records.

Central Mediterranean

Along the Tunisian coast in recent years, sandbar sharks (*Carcharhinus plumbeus*°) and blackchin guitarfish (*Rhinobatos cemiculus*°) have become the object of directed artisanal fisheries using a special gillnet (stretched mesh size of 240–340 mm) locally known as a *kallabia*. Sandbar sharks (*Carcharhinus plumbeus*°) are targeted from April through June, and the guitarfishes *Rhinobatos*° spp. throughout the summer months (Echwikhi *et al.*, 2013). The study reported that over 45 fishing trips (conducted from April to June of 2007 and 2008), *R. cemiculus*° (4.6 individuals/km^2 of net per day) and the smooth-hound *Mustelus mustelus*° (2.2 individuals/km^2 of net per day) were the most important species. In comparison, the blackspotted smooth-hound *Mustelus punctulatus*° (0.7 individuals/km^2 of net per day), the common guitarfish *R. rhinobatos*° (0.6 individuals/km^2 of net per day) and the rough ray *Raja radula* (0.6 individuals/km^2 of net per day) presented lower values. Though the size composition of the catch varied by species, mature, mainly gravid, females were usually abundant.

Another study, conducted off the southern Tunisian coast, evaluated the potential impacts of the trammel net fishery on elasmobranchs (Saidi, Enajjar and Bradai, 2016). Data were based on 191 shrimp trammel net sets (40 mm stretched mesh size), conducted throughout May, June and July of 2009, onboard artisanal boats associated with the ports of Sfax, Mahres, Gabés and Zarat and targeting shrimps at depths ranging from 5 to 40 m. Five species of small coastal elasmobranchs, *Mustelus mustelus*° (706 individuals), *Mustelus punctulatus*° (117 individuals), *Dasyatis pastinaca* (54 individuals), *Dasyatis marmorata* (1 individual) and *Torpedo torpedo* (35 individuals), and two large coastal shark species, *Carcharhinus plumbeus*° (11 individuals) and *Carcharhinus brevipinna* (2 individuals), were recorded as bycatch in this fishery. Smooth-hound sharks *Mustelus*° spp. (*Mustelus mustelus*° – 3.7 individuals per trip, 1.2 individuals/1 000 m of net per day – and *M. punctulatus* – 0.6 individual per trip) were by far the most important (88.9 percent of the total elasmobranch catch), reflecting their abundance in the area. For the other species, CPUE varied between 0.2 and 0.003 individual per 1 000 m of net per day. Additionally, about 50 percent of the skates (*Torpedo torpedo* and *Dasyatis pastinaca*) were mature, while there was a high density of neonates and small juvenile *M. mustelus*° in the Sfax zone, suggesting that these nearshore waters provide nursery grounds for smooth-hound sharks *Mustelus*° spp.

Along the coast of Sicily (central Mediterranean Sea), Tiralongo, Messina and Lombardo (2018) recently evaluated elasmobranch discards in the trammel net fishery targeting the common cuttlefish (*Sepia officinalis*). In 2017, during the peak *S. officinalis* fishing season (February–May), four batoid species (*Raja radula*, *Dasyatis pastinaca*, *Torpedo marmorata* and *Torpedo torpedo*) accounted for the total elasmobranch catch over the 16 survey days. In another study by the same authors, off the southeast coast of Sicily (Ionian Sea), a total of 164 specimens of *T. torpedo* were collected from fishers using trammel nets between March and May 2019 (Tiralongo, Messina and Lombardo, 2020).

The MEDLEM data on small-scale fisheries bycatch in the central Mediterranean represent 72 percent of the archive; these largely describe the demersal species *Mustelus mustelus*° and *M. punctulatus*° (74 percent combined), while the pelagic species include *Prionace glauca*° (7 percent) and *Mobula mobular*° (7 percent) (Table 4).

Adriatic Sea

Few studies report elasmobranch bycatch in small-scale fisheries in this subregion, though captures of large pelagic species are occasionally reported.

In the central Adriatic, in July 2010 and August 2011, two porbeagle sharks (*Lamna nasus*°), a rare species in the Adriatic Sea, were caught by small-scale fishing vessels using gillnets in the area of the Jabuka/Pomo Pit (Scacco *et al.*, 2012). Within the CIESM forum "In Search of Rare Shark Species," Soldo, Briand and Rassoulzadegan (2014) reported the capture of a specimen of bluntnose sixgill shark (*Hexanchus griseus*) in 2009 and two thresher sharks (*Alopias vulpinus*°) in 2012, in Croatian gillnets. More recently, Keramidas *et al.* (2019) reported that in September 2018, an individual of *L. nasus*° was incidentally caught and landed by a small-scale fisher using drifting longlines with sardines as bait. The specimen was captured near Čiovo Island, in the Split Channel, at a depth of 60 m. The total length was approximately 80 cm and the weight around 7 kg. The authors also referred to a specimen of porbeagle shark (*Lamna nasus*°) reported for the first time in Slovenian waters as bycatch in 2016 (Lipej *et al.*, 2016), but no information on the fishing gear was available.

Furthermore, in the Adriatic Sea, Pranovi *et al.* (2016) assessed the role played by artisanal fisheries in providing an important source of employment and income to many coastal communities, as well as a major cultural and traditional identity factor at the regional level. The study analysed a wide range of data collected from 2012 to 2014 in the Veneto region (Italy) from small-scale vessels fishing with trammel nets, gillnets, pots and traps. Among other aspects, the artisanal fleet in question appeared to show very low bycatch and discard rates, while the commercial catch in gillnets and trammel nets included smooth-hounds (*Mustelus mustelus*°).

In a recent study on Montenegrin fisheries, Ćetković (2018) presented data on the composition and abundance of shark bycatch from 2016 to 2018, gathered through observations made onboard and at landing sites, as well as from interviews with fishers. The bycatch of *Prionace glauca*° (7 individuals), *Carcharhinus plumbeus*° (1 individual) and *Mustelus mustelus*° (1 individual) in set gillnets targeting medium-sized pelagic fish such as bonitos (*Sarda sarda*), amberjacks (*Seriola* *dumerili*) and false albacores (*Euthynnus alletteratus*) in Montenegro is reported. Such nets are described as being usually much taller than others, often above 7 or 8 m in height. In addition, the study showed that trammel net bycatch included *Scyliorhinus canicula* (5 individuals) and *Hexanchus griseus* (1 individual).

In southern Albania, in 2017, a bigeyed sixgill shark (*Hexanchus nakamurai*) was landed by a professional fishing vessel. The shark (230 cm TL) was accidentally caught in a gillnet set at a depth of 550 m (Save Our Seas, 2018).

MEDLEM data on small-scale fisheries bycatch in the Adriatic Sea represent only 2 percent of the archive; the data include records of the bycatch of ten basking sharks (*Cetorhinus maximus*°).

Eastern Mediterranean

As part of a study undertaken along the Lebanese coast in 2013, 225 specimens of cartilaginous fish (i.e. 11 shark and 14 batoid species), caught by three types of artisanal fishing gear (gillnets, trammel nets and longlines), were collected during experimental fishing, observations at landing sites and onboard observations (Lteif *et al*., 2015). The majority of the sharks sampled were represented by *Centrophorus granulosus*°, *Galeus melastomus, Squalus blainville, Mustelus mustelus*° and *Carcharhinus obscurus*, while the majority of the batoids consisted of *Rhinobatos rhinobatos*°, *Rhinobatos cemiculus*°, *Torpedo marmorata, Tetronarce nobiliana, Raja miraletus* and *Raja clavata* (Table 4). These cartilaginous fish specimens were caught at depths ranging from 10 to 600 m; the gear responsible for the greatest catch was longlines, followed by trammel nets, while gillnets accounted for the least. 66.7 percent of all individuals were observed at depths less than 150 m, 18.2 percent from 150 to 400 m, and 10.6 percent from 450 to 600 m.

In the same Lebanese study, Lteif *et al*. (2015) also recorded that demersal species, such as *Raja clavata¸ Raja miraletus, Torpedo marmorata* and *Tetronarce nobiliana*, were principally caught by trammel nets, whereas *Rhinobatos rhinobatos*° and *Rhinobatos cemiculus*° were only caught by longlines, while species such as *Squatina oculata*°, *Squatina aculeata*°, *Mustelus mustelus*° and *Isurus oxyrincus*° were only caught by gillnets (Table 4). Additionally, the batoid species *Rhinobatos rhinobatos*° and *Rhinobatos cemiculus*°, the shark species *Hexanchus griseus* and sharks from the family Carcharhinidae were shown to be of commercial importance in some of the ports (i.e. Tripoli in northern Lebanon, and Sidon in southern Lebanon). In another study off the Lebanese coast, Lteif *et al*. (2016a) reported the capture of 235 elasmobranch specimens from December 2012 to October 2014 by small-scale vessels using long lines, trammel nets and gillnets: *Centrophorus uyato*° (38 individuals), *Squalus blainville* (11 individuals), *Galeus melastomus* (14 individuals), *Rhinobatos rhinobatos*° (70 individuals), *R. cemiculus*° (31 individuals), *Raja clavata* (19 individuals), *Raja miraletus* (30 individuals) and *Torpedo marmorata* (22 individuals).

An investigation from Syrian waters of the Levantine basin indicated that noteworthy elasmobranch incidental catch was occurring there as well. Alkusairy and Saad (2018), in their review of shark bycatch and composition in Syrian fisheries carried out between 2014 and 2016, reported *Carcharhinus plumbeus*° (1 135 individuals) and *Heptranchias perlo*° (267 individuals) as bycatch of "nets-longlines" and "trawls-nets," each of the two groups representing an aggregation of the corresponding types of gear (Table 4). In addition, off Raas Albassit, in northern Syria, Ali *et al*. (2012) reported the capture of a female basking shark (*Cetorhinus maximus*°) in April 2012 in gillnets stretching from the beach 150 m out to sea, at a depth of approximately 10 m. Similarly, according to a report published on a local news website (in May 2013), another 4 m-long *Cetorhinus maximus*°

was caught by an unspecified set net off Famagusta harbour (Cyprus, eastern Mediterranean Sea) (LGC News, 2013).

In Mersin Bay (Turkey), in 2011, a study was carried out to evaluate the effects on discard reduction of rigging prawn trammel nets with a guarding net (Gökçe, Saygu and Eryaşar, 2016). Over a total of 15 fishing trips using both the commercial net and the alternative experimental net, the capture of the common guitarfish (*Rhinobatos rhinobatos*°) (55 individuals) and eagle ray (*Myliobatis aquila*) (3 individuals) were also recorded. Likewise, on the Turkish coast, Kabasakal (2013) recorded the capture of a basking shark (*Cetorhinus maximus*°) measuring 2.3 m TL in a gillnet. Indeed, all basking sharks *C. maximus*° recorded off the Turkish coast, as well as some noted off Syrian and Israeli coasts, have been caught in shallow coastal waters by gillnets. In one case, in the northeast Aegean Sea, an adult male *C. maximus*°, around 10 m TL, was incidentally caught in a set net by local fishers (Kabasakal, 2009).

Additionally, in the northern Aegean Sea in 2008, a new-born great white shark (*Carcharodon carcharias*°), 125.5 cm TL, was captured by a commercial gillnetter (Kabasakal and Özgür Gedikoğlu, 2008). In 2016, a female great white shark *C. carcharias*° became entangled in a coastal stationary net in the Bay of Edremit (northeastern Aegean Sea). The total length of the shark was 175 cm. In 2018, another female *C. carcharias*° was captured by a coastal stationary netter, off the İzmir coast (central Aegean Sea) (Kabasakal, Bayrı and Ataç, 2018). In another study in the Aegean Sea, Akyol and Ceyhan (2012) investigated a traditional pelagic gillnet fishery[7] targeting swordfish based out of the ports of Sivrice and Sığacık, near Izmir, from June 2008 to August 2010. A total of 12 species belonging to nine families were caught. Four vulnerable species, the loggerhead sea turtle (*Caretta caretta*), the pelagic stingray (*Pteroplatytrygon violacea*) (9 individuals), the spintail devil ray (*Mobula mobular*°) (2 individuals) and one sunfish (*Mola mola*), were thrown back into the sea, while the others were retained for their commercial value. Furthermore, Kabasakal and Bilecenoğlu (2014) reported the bycatch of two individuals of the rare bramble shark (*Echinorhinus brucus*) by commercial gillnetters in Turkey: the first was a female of 220 cm TL and 300 kg weight, caught in the Marmara Sea at a depth of 300 m in 2010; the second individual was also a female of 200 cm TL and 140 kg in weight, but it was caught in the Aegean Sea, in 2013. Also in the Aegean Sea, along the coast south of Athens, two basking sharks *Cetorhinus maximus*° (both over 7 m TL and weighing roughly 2 000 kg) were caught incidentally by an unspecified set net in 2009 (Shark Alliance, 2009).

Elsewhere in the Aegean Sea, Kabasakal, Dalyan and Yurtsever (2011) reported the bycatch of two individuals of the rare bigeye thresher shark (*Alopias superciliosus*) in a stationary net set at a depth of nearly 100 m (off the coast of Sivrice in 2006) and in a trammel net (inner mesh 30 mm, outer mesh 120 mm) on a mixed bottom of sand and pebbles at a depth of 110 m (off the coast of Fethiye in 2011). The first was a male of 400 cm TL, while the second was a female of 450 cm TL and weighing 300 kg. In the coastal waters of Edremit Bay (Turkey), Kabasakal (2010) reported that two individuals of blue shark (*Prionace glauca*°) were caught by trammel nets in 2008 and 2009; the individuals were females – one juvenile and one adult – of 98 cm and 3 kg, and 350 cm and 100 kg, respectively. In April 2013, two specimens of the blackchin guitarfish (*Rhinobatos*

7. The Europeant Union, the GFCM and the International Commission for the Conservation of Atlantic Tunas (ICCAT) enforced, in 2005, recommendations prohibiting the use of driftnets in the Mediterranean. In 2006, driftnetting was also banned in Turkey. As a result, pelagic gillnetting tended to decrease. However, the Turkish fisheries authority and ICCAT gave limited permission for traditional pelagic gillnetting in Turkish seas until July 2011, when this fleet stopped its activity (Akyol and Ceyhan 2012).

cemiculus°) were captured by trammel nets (between 60 and 72 mm mesh size) in İzmir Bay at a depth of between 6 and 8 m on a sandy bottom (Akyol and Capapé, 2014).

A recent paper by Ergenler, Turan and Turan (2019) reported the capture of a male specimen of the sawback angelshark (*Squatina aculeata*°) in a trammel net at a depth of 47 m on 19 February 2019, off the coast of Konacık, Iskenderun Bay. The specimen was 117 cm TL and 3.69 kg in total weight. In addition, in the waters off northern Cyprus, Akbora *et al.* (2019) reported the bycatch of a rare smalltooth sand tiger shark (*Odontaspis ferox*°) at a depth of 41 m in a coastal fishery (the fishing gear is not reported in the study) targeting the greater amberjack (*Seriola dumerili*).

In the MEDLEM database, records of elasmobranch bycatch in the eastern Mediterranean by small-scale fisheries account for 12 percent of the total records for this vessel group. Most of the records refer to the angelshark (*Squatina squatina*°) (41 percent) and to the spintail devil ray (*Mobula mobular*°) (17 percent) (Table 4). Other rare elasmobranch species reported in the MEDLEM database are the copper shark (*Carcharhinus brachyurus*) (2 individuals) and dusky shark (*C. obscurus*) (2 individuals).

Black Sea

As for the bottom trawlers, small-scale fisheries in the Black Sea capture piked dogfish (*Squalus acanthias*°) and thornback ray (*Raja clavata*) above all else, and, more rarely, the common stingray (*Dasyatis pastinaca*) as bycatch (GFCM, 2018a; Filiz and Togulga, 2002; Düzgüneş *et al.*, 2006). In Ukrainian and Romanian waters, *S. acanthias*° is caught mainly in the spring and autumn by small-scale fisheries (gillnets and set longlines) (STECF, 2017; GFCM, 2018a). The total landings of *S. acanthias*° in Ukranian small-scale fisheries from 2008 to 2012 were 79.1 tonnes (2008), 46.5 tonnes (2009), 26.6 tonnes (2010), 30.5 tonnes (2011), 8.5 tonnes (2012) (191.2 tonnes in total) (GFCM, 2014b).

Table 4 – Incidental catch of conservation-priority elasmobranch species in small-scale fisheries (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Alopias vulpinus*	III	26	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Alopias superciliosus*[1]	III	1	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Carcharhinus plumbeus*	III	2	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Carcharodon carcharias*	II	3	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Cetorhinus maximus*	II	25	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Galeorhinus galeus*	II	3	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Isurus oxyrinchus*	II	18	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Lamna nasus*	II	3	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Odontaspis ferox*	II	1	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Prionace glauca*	III	25	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Sphyrna zygaena*	II	2	-

Table 4 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Gymnura altavela*	II	3	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Mobula mobular*	II	18	-
MEDLEM	2008–2019	Set net	Western Mediterranean	-	*Rostroraja alba*	II	2	-
FAO (2019)	2018	GTR	Western Mediterranean	France	*Squalus acanthias*	III	1	-
FAO (2019)	2018	GNS	Western Mediterranean	France	*Squatina squatina*	II	1	-
FAO (2019)	2018	GTR	Western Mediterranean	France	*Squatina squatina*	II	5	-
Echwikhi *et al.* (2013)	2007–2008	GNS	Central Mediterranean	Tunisia	*Rhinobatos cemiculus*	II	313	-
Echwikhi *et al.* (2013)	2007–2008	GNS	Central Mediterranean	Tunisia	*Rhinobatos rhinobatos*	II	41	-
Echwikhi *et al.* (2013)	2007–2008	GNS	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	151	-
Echwikhi *et al.* (2013)	2007–2008	GNS	Central Mediterranean	Tunisia	*Mustelus punctulatus*	III	48	-
Echwikhi *et al.* (2013)	2007–2008	GNS	Central Mediterranean	Tunisia	*Carcharhinus plumbeus*	III	27	-
Saidi, Enajjar and Bradai (2016)	2009	GTR	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	706	Onboard observations
Saidi, Enajjar and Bradai (2016)	2009	GTR	Central Mediterranean	Tunisia	*Mustelus punctulatus*	III	117	Onboard observations
Saidi, Enajjar and Bradai (2016)	2009	GTR	Central Mediterranean	Tunisia	*Carcharhinus plumbeus*	III	11	Onboard observations
FAO (2019)	2019	Set net	Central Mediterranean	Tunisia	*Alopias vulpinus*	III	2	-
FAO (2018d)	2017	GTR	Central Mediterranean	Tunisia	*Carcharodon carcharias*	II	1	-
FAO (2019)	2019	GNS	Central Mediterranean	Tunisia	*Cetorhinus maximus*	II	1	-
FAO (2019)	2019	Set net	Central Mediterranean	Tunisia	*Isurus oxyrinchus*	II	1	-
FAO (2019)	2019	GNS	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	11	-
FAO (2019)	2019	GNS	Central Mediterranean	Tunisia	*Rhinobatos rhinobatos*	II	2	-
FAO (2019)	2019	Set net	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	1	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Alopias vulpinus*	III	4	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Alopias superciliosus*[1]	III	2	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Carcharhinus plumbeus*	III	18	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Carcharodon carcharias*	II	2	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Cetorhinus maximus*	II	7	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Isurus oxyrinchus*	II	5	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Mustelus mustelus*	III	706	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Mustelus punctulatus*	III	117	-

Table 4 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Prionace glauca*	III	81	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Squatina aculeata*	II	1	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Squatina squatina*	II	2	-
MEDLEM	2008–2019	Set net	Central Mediterranean	-	*Mobula mobular*	II	73	-
Scacco *et al.* (2012)	2010–2011	GNS	Adriatic Sea	Italy	*Lamna nasus*	II	2	Onboard observations
Soldo, Briand and Rassoulzadegan (2014)	2012	GNS	Adriatic Sea	Croatia	*Alopias vulpinus*	III	2	-
Keramidas *et al.* (2019)	2018	LL	Adriatic Sea	Croatia	*Lamna nasus*	II	1	Interviews with fishers
Ćetković (2018)	2016–2018	GNS	Adriatic Sea	Montenegro	*Prionace glauca*	III	7	Onboard observations, observations at landing sites, interviews with fishers
Ćetković (2018)	2016–2018	GNS	Adriatic Sea	Montenegro	*Carcharhinus plumbeus*	III	1	Onboard observations, observations at landing sites, interviews with fishers
Ćetković (2018)	2016–2018	GNS	Adriatic Sea	Montenegro	*Mustelus mustelus*	III	1	Onboard observations, observations at landing sites, interviews with fishers
MEDLEM	2008–2019	Set net	Adriatic Sea	-	*Alopias vulpinus*	III	5	-
MEDLEM	2008–2019	Set net	Adriatic Sea	-	*Alopias superciliosus*[1]	III	1	-
MEDLEM	2008–2019	Set net	Adriatic Sea	-	*Carcharhinus plumbeus*	III	2	-
MEDLEM	2008–2019	Set net	Adriatic Sea	-	*Cetorhinus maximus*	III	10	-
MEDLEM	2008–2019	Set net	Adriatic Sea	-	*Isurus oxyrinchus*	II	1	-
MEDLEM	2008–2019	Set net	Adriatic Sea	-	*Lamna nasus*	II	1	-
MEDLEM	2008–2019	Set net	Adriatic Sea	-	*Prionace glauca*	III	1	-
MEDLEM	2008–2019	Set net	Adriatic Sea	-	*Mobula mobular*	II	1	-
Ali *et al.* (2012)	2012	GNS	Eastern Mediterranean	Syria	*Cetorhinus maximus*	III	1	Survey at sea
LGC News (2013)	2013	Set net	Eastern Mediterranean	Cyprus	Cetorhinus maximus	II	1	-
Akbora *et al.* (2019)	2018	-	Eastern Mediterranean	Cyprus	Odontaspis ferox	II	1	Landing observation
Lteif *et al.* (2015)	2013	LL	Eastern Mediterranean	Lebanon	*Centrophorus granulosus*	III	18	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	GTR	Eastern Mediterranean	Lebanon	*Centrophorus granulosus*	III	12	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	GTR	Eastern Mediterranean	Lebanon	*Heptranchias perlo*	III	3	Experimental fishing, observations at landing sites, and onboard observations

Table 4 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Lteif *et al.* (2015)	2013	LL	Eastern Mediterranean	Lebanon	*Heptranchias perlo*	III	1	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	GNS	Eastern Mediterranean	Lebanon	*Heptranchias perlo*	III	1	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	GNS	Eastern Mediterranean	Lebanon	*Isurus oxyrinchus*	II	1	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	GNS	Eastern Mediterranean	Lebanon	*Mustelus mustelus*	III	1	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	LL	Eastern Mediterranean	Lebanon	*Rhinobatos cemiculus*	II	21	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	LL	Eastern Mediterranean	Lebanon	*Rhinobatos rhinobatos*	II	43	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	GNS	Eastern Mediterranean	Lebanon	*Squatina aculeata*	II	1	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2015)	2013	GNS	Eastern Mediterranean	Lebanon	*Squatina oculata*	II	1	Experimental fishing, observations at landing sites, and onboard observations
Lteif *et al.* (2016a)	2012–2014	Set nets/ LL	Eastern Mediterranean	Lebanon	*Rhinobatos cemiculus*	II	31	Observations at landing sites
Lteif *et al.* (2016b)	2012–2014	Set nets/ LL	Eastern Mediterranean	Lebanon	*Rhinobatos rhinobatos*	II	70	Observations at landing sites
Akyol and Capapè (2014)	2013	GTR	Eastern Mediterranean	Turkey	Rhinobatos cemiculus	II	2	Observations at landing sites
Alkusairy and Saad (2018)	2014–2016	OTB/Set nets	Eastern Mediterranean	Syrian Arab Republic	*Heptranchias perlo*	III	267	Observations at landing sites
Alkusairy and Saad (2018)	2014–2016	Set nets/ LL	Eastern Mediterranean	Syrian Arab Republic	*Carcharhinus plumbeus*	III	1 135	Observations at landing sites
Akyol and Ceyhan (2012)	2008–2010	Pelagic gillnet	Eastern Mediterranean	Turkey	*Mobula mobular*	II	2	Onboard observations
Kabasakal, Dalyan and Yurtsever (2011)	2011	GTR	Eastern Mediterranean	Turkey	*Alopias superciliosus*[1]	-	2	-
Kabasakal (2009)	2009	Set net	Eastern Mediterranean	Turkey	*Cetorhinus maximus*	II	1	Landing observation
Kabasakal (2010)	2008–2009	GTR	Eastern Mediterranean	Turkey	*Prionace glauca*	III	2	Landing observations
Kabasakal (2013)	2012	GNS	Eastern Mediterranean	Turkey	*Cetorhinus maximus*	II	1	Landing observation
Shark Alliance (2009)	2009	-	Eastern Mediterranean	Greece	*Cetorhinus maximus*	II	2	Landing observations
Kabasakal and Özgür Gedikoğlu (2008)	2008	GNS	Eastern Mediterranean	Turkey	*Carcharodon carcharias*	II	1	Landing observation
Gökçe *et al.* (2016)	2011	GTR	Eastern Mediterranean	Turkey	*Rhinobatos rhinobatos*	II	55	Catch observation
Kabasakal, Bayrı and Ataç (2018)	2016	Set net	Eastern Mediterranean	Turkey	*Carcharodon carcharias*	II	1	Landing observation

Table 4 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Kabasakal, Bayrı and Ataç (2018)	2018	Set net	Eastern Mediterranean	Turkey	*Carcharodon carcharias*	II	1	Landing observation
Ergenler, Turan and Turan (2019)	2019	GTR	Eastern Mediterranean	Turkey	*Squatina aculeata*	II	1	-
FAO (2018d)	2017	GTR	Eastern Mediterranean	Greece	*Centrophorus granulosus*	III	13	-
FAO (2017)	2016	Set net	Eastern Mediterranean	Cyprus	*Galeorhinus galeus*	II	1	-
FAO (2018d)	2017	GTR	Eastern Mediterranean	Greece	*Mustelus mustelus*	III	1	-
FAO (2018d)	2017	GTR	Eastern Mediterranean	Cyprus	*Isurus oxyrinchus*	II	1	-
FAO (2019)	2018	GTR	Eastern Mediterranean	Greece	*Mustelus mustelus*	III	2	-
FAO (2018d)	2017	Set net	Eastern Mediterranean	Cyprus	*Rhinobatos rhinobatos*	II	1	-
FAO (2018d)	2017	GTR	Eastern Mediterranean	Greece	*Squalus acanthias*	III	40	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Alopias vulpinus*	III	9	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Alopias superciliosus*[1]	-	6	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Carcharhinus plumbeus*	III	25	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Carcharodon carcharias*	II	6	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Cetorhinus maximus*	II	11	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Isurus oxyrinchus*	II	8	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Odontaspis ferox*	II	1	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Prionace glauca*	III	2	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Squatina aculeata*	II	1	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Squatina squatina*	II	79	-
MEDLEM	2008–2019	Set net	Eastern Mediterranean	-	*Mobula mobular*	II	34	-

Notes:

GNS = set gillnet; GTR = trammel net; LL = longline.

1. *Alopias superciliosus* is not listed in Annex II or III of SPA/DB Protocol, but due to its morphological similarity to *A. vulpinus*°, bycatch events reported for this species were included in the table.

3.3.3 Purse seiners

Interactions between elasmobranchs and purse seiners appear to be limited, compared to other types of fishing gear, across the entire Mediterranean and Black Sea region. Purse seines are usually used to target schools of small (anchovies and sardines) and large pelagic fish (tuna and tuna-like species). However, during the detection of schools of fish and encircling operations, non-target species, mainly large predators (e.g. sharks and dolphins) may be attracted by high fish density and retained within the net (Bonanomi *et al.*, 2017).

The data reported officially by countries to the GFCM are presented in Table 5 (FAO, 2018d, 2019).

Table 5 includes information on the incidental catch of conservation-priority shark and batoid species from sources individually reporting the elasmobranchs caught by purse seiners.

Western Mediterranean
The MEDLEM database on purse seine bycatch in the western Mediterranean report two individuals of thresher shark (*Alopias vulpinus*°).

Central Mediterranean
In the central Mediterranean, the only recent data available regard the Tunisian coast, where purse seiner bycatch, from 2017 and 2019, records *Mobula mobular*° (10 individuals), *Carcharodon carcharias*° (2 individuals) and *Alopias vulpinus*° (3 individuals) (FAO, 2018d, 2019).

Adriatic Sea
Soldo, Briand and Rassoulzadegan (2014) reported the capture of a thresher shark (*Alopias vulpinus*°) (250 cm, 75 kg) in 2011 and a bluntnose sixgill shark (*Hexanchus griseus*) (4.5 m, 500 kg) in 2013 by Croatian purse seiners.

Eastern Mediterranean
There are reports of a fishery targeting spintail devil ray (*Mobula mobular*°) in specific locations of this subregion, where this species is opportunistically fished by local *shanshula* (purse seines) (Abudaya *et al*., 2017). Boats ranging from 4.5 to 21 m in length, operate over a very short seasonal window to supplement the tuna fisheries. A total of 304 *M. mobular*° (over 90 percent males) were landed and recorded from 2014 to 2016, most of which were mature and appeared to be reproductively active (i.e. over 90 percent of the males had sperm-filled claspers). In 2013, the highest number of specimens landed (370) was recorded. The evidence suggests that this fishing activity probably occurs during the reproductive period of the species and points to the importance of the Levantine basin as a mating ground for *M. mobular*°, thus providing critical insights for management and conservation. According to Abudaya *et al*. (2017), the meat from *M. mobular*° is exclusively sold at local markets for consumption. It was also reported that all fishers interviewed in Gaza were unaware of the “Endangered” status of *M. mobular*° and the Mediterranean-wide protection of this species.

Kabasakal, Dalyan and Yurtsever (2011) reported the bycatch of a bigeye thresher shark (*Alopias superciliosus*°), a female of 250 cm TL weighing 65 kg, by a commercial purse seine on 2 July 2011, off the coast of Silivri in the northern Marmara Sea. Ergüden, Gurlek and Turan (2013) also reported the bycatch of a young shortfin mako shark (*Isurus oxyrinchus*°) in a purse seine from Iskenderun Bay, Turkey, in 2010. Likewise, a young male specimen of *I. oxyrinchus*°, 69.8 cm TL and 2.2 kg total weight, was caught by a purse seine boat in March 2010, at a depth of 54 m off the coast of Samandag, south of Iskenderun Bay (Bilecenoğlu *et al*., 2013). In 2014, a single male thresher (*Alopias vulpinus*°), measuring 392 cm TL and weighing about 180 kg, was incidentally captured by a purse seiner operating in Iskenderun Bay (Ergüden, Gurlek and Turan, 2015). In the same year, an individual of bluntnose sixgill shark (*Hexanchus griseus*) was captured as bycatch in a commercial purse seine fishery at a depth of 60 to 70 m in Iskenderun Bay (Başusta and Başusta, 2015). Furthermore, a total of 94 bull rays (*Aetomylaeus bovinus*) (approximately 50 percent females and 50 percent males, ranging from 29.5 to 129.2 cm disc width and weighing 0.27 to

33.6 kg), were collected as bycatch by commercial fishers using trawls and purse seines between September 2010 and December 2012, in Mersin and Iskenderun Bays (Başusta and Aslan, 2018).

More recently, Kabasakal, Bayrı and Ataç (2018) reported a male great white shark (*Carcharodon carcharias*°) measuring 200 cm TL and weighing 60 kg, captured by a commercial purse-seiner off the Didim coast (central Aegean Sea) in June, 2017.

The MEDLEM database on purse seine bycatch in the eastern Mediterranean reports four records: one individual of *Alopias vulpinus*°, one of *Carcharodon carcharias*°, one of *Isurus oxyrinchus*° and one of the rare smooth hammerhead (*Sphyrna zygaena*°).

Black Sea

Purse seiners operating in the Black Sea target mainly anchovy (*Engraulis encrasicolus*), sprat (*Sprattus sprattus*), horse mackerel (*Trachurus* spp.) and bonito (*Sarda sarda*). Between 2009 and 2010, a discard monitoring programme (Şahin, Ceylan and Kalaycı 2015), carried out monthly onboard commercial purse seiners operating along the southeastern coast of the Black Sea in Turkey, recorded the presence of *Squalus acanthias*°, *Dasyatis pastinaca* and *Raja clavata* in the catch composition, though these represented only 0.0003, 0.003 and 0.009 percent of the catch, respectively. All the elasmobranch bycatch was discarded at sea.

The MEDLEM database on purse seine bycatch in the Black Sea includes records of two individuals of *Alopias vulpinus*°, one of *A. superciliosus*, two *Hexanchus griseus*, and one of *Gymnura altavela*°.

Table 5 – Incidental catch of conservation-priority elasmobranch species in purse seiners (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
MEDLEM	2008–2019	PS	Western Mediterranean	-	*Alopias vulpinus*	III	2	-
FAO (2018d)	2017	PS	Central Mediterranean	Tunisia	*Carcharodon carcharias*	II	1	-
FAO (2019)	2019	PS	Central Mediterranean	Tunisia	*Mobula molar*	II	10	-
FAO (2019)	2019	PS	Central Mediterranean	Tunisia	*Carcharodon carcharias*	II	1	-
FAO (2019)	2019	PS	Central Mediterranean	Tunisia	*Alopias vulpinus*	III	3	-
Soldo, Briand and Rassoulzadegan (2014)	2011	PS	Adriatic Sea	Croatia	*Alopias vulpinus*	III	1	-
Abudaya *et al.* (2017)	2009	PS	Eastern Mediterranean	Palestine Territories	*Mobula mobular*	II	7	Landing survey and interviews with fishers
Abudaya *et al.* (2017)	2013	PS	Eastern Mediterranean	Palestine Territories	*Mobula mobular*	II	370	Landing survey and interviews with fishers
Abudaya *et al.* (2017)	2014	PS	Eastern Mediterranean	Palestine Territories	*Mobula mobular*	II	30	Landing survey and interviews with fishers
Abudaya *et al.* (2017)	2015	PS	Eastern Mediterranean	Palestine Territories	*Mobula mobular*	II	85	Landing survey and interviews with fishers
Abudaya *et al.* (2017)	2016	PS	Eastern Mediterranean	Palestine Territories	*Mobula mobular*	II	160	Landing survey and interviews with fishers
Kabasakal, Dalyan and Yurtsever (2011)	2011	PS	Eastern Mediterranean	Turkey	*Alopias superciliosus*[1]	III	1	-
Bilecenoğlu *et al.* (2013)	2010	PS	Eastern Mediterranean	Turkey	*Isurus oxyrinchus*	II	1	Catch data

Table 5 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Ergüden, Gurlek and Turan (2013)	2010	PS	Eastern Mediterranean	Turkey	*Isurus oxyrinchus*	II	1	-
Ergüden, Gurlek and Turan (2015)	2014	PS	Eastern Mediterranean	Turkey	*Alopias vulpinus*	III	1	Catch data
Kabasakal, Bayrı and Ataç (2018)	2017	PS	Eastern Mediterranean	Turkey	*Carcharodon carcharias*	III	1	Landing observation
MEDLEM	2008–2019	PS	Eastern Mediterranean	-	*Alopias vulpinus*	III	1	-
MEDLEM	2008–2019	PS	Eastern Mediterranean	-	*Carcharodon carcharias*	II	1	-
MEDLEM	2008–2019	PS	Eastern Mediterranean	-	*Isurus oxyrinchus*	II	1	-
MEDLEM	2008–2019	PS	Eastern Mediterranean	-	*Sphyrna zygaena*	II	1	-
MEDLEM	2008–2019	PS	Black Sea	-	*Alopias vulpinus*	III	2	-
MEDLEM	2008–2019	PS	Black Sea	-	*Alopias superciliosus*[1]	III	1	-
MEDLEM	2008–2019	PS	Black Sea	-	*Gymnura altavela*	II	1	-

Notes: PS = purse seine.

1. *Alopias superciliosus* is not listed in Annex II or III of SPA/DB Protocol, but due to its morphological similarity to *A. vulpinus*°, bycatch events reported for this species were included in the table.

3.3.4 Longliners

Generally, two types of longlines are used in the Mediterranean Sea: drifting longlines (sometimes also called surface or pelagic longlines), used in the water column at variable depths, and set longlines (sometimes also called bottom or demersal longlines), deployed on the sea bottom.

Drifting longliners in the Mediterranean and the Black Sea target, according to hook size and immersion depth, swordfish (*Xiphias gladius*), albacore (*Thunnus alalunga*) and bluefin tuna (*Thunnus thynnus*), and can incidentally capture different species of pelagic sharks (e.g. *Prionace glauca*°, *Isurus oxyrinchus*°, *Alopias vulpinus*°, *Galeorhinus galeus*°, *Lamna nasus*°, *Alopias superciliosus, Sphyrna zygaena*°, *Hexanchus griseus, Carcharhinus plumbeus*° and *Cetorhinus maximus*°). These species often end up representing relevant fractions of the total caught biomass; the importance of sharks in terms of catch composition varies according to the type of longline and the area (Gabr and El-Haweet, 2012; Ceyhan and Akyol, 2014; Bradai, Saidi and Enajjar, 2012; Echwikhi, Saidi and Bradai, 2014; Soldo, Briand and Rassoulzadegan, 2014; Murua *et al.*, eds, 2013). However, in all areas studied, the blue shark (*P. glauca*°) seems to be the species most represented in the catch, followed by the shortfin mako (*I. oxyrinchus*°) (Bradai, Saidi and Enajjar, 2012, 2018; Murua *et al.*, eds, 2013).

The bycatch of set longliners, targeting mainly demersal fish species (*Dentex dentex, Epinephelus* spp., *Pagellus* spp., *Merluccius merluccius,* etc.), consists mainly of batoids and demersal elasmobranch species (*Squalus blainville, Mustelus*° spp. *Carcharhinus plumbeus*°, *Torpedo* spp., *Raja radula, R. clavata and R. miraletus,* as well as guitarfish of the genus *Rhinobatos*°) (Bradai, Saidi and Enajjar, 2012, 2018; Bradai *et al.*, 2016).

The data reported officially by countries to the GFCM are presented in Table 6 (FAO, 2017, 2018d, 2019)

PLATE 3
A great white shark with a longline hook in its mouth

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Table 6 includes information on the incidental catch of conservation-priority shark and batoid species from sources individually reporting the elasmobranchs caught by longliners. As such, Table 6 provides only an indicative overview, as some of the other studies cited below lack this information.

Western Mediterranean

Biton-Porsmoguer and Lloret (2018) carried out a study between 2012 and 2016 on the Spanish longline fleets operating in certain areas of the Spanish Mediterranean (e.g. Andalusia, the Balearic Islands, Valencia, Murcia and Catalonia) and reported an increasing fishing impact on blue sharks (*Prionace glauca*°). During this period, the landings of *Prionace glauca*° in the Spanish Mediterranean ports totalled, on average, more than 58 tonnes per year. Meanwhile, the size of the fishing fleet involved in the Spanish Mediterranean remained stable over the investigated period (74 boats in 2012 and 73 in 2016).

Previously, Báez *et al*. (2016) reported that the bycatch of elasmobranchs from the Spanish drifting longline fleet consisted almost entirely of the pelagic stingray (*Pteroplatytrygon violacea*). Between 2000 and 2013, 3 007 longline fishing operations were monitored and 57 574 individuals of pelagic stingray recorded as bycatch. Two gear types were involved in 96 percent of the pelagic stingray bycatch observed: traditional surface longlines targeting swordfish and surface drifting longlines targeting albacore. The authors noted that despite these high bycatch numbers and the fact that the species largely dominates the drifting longline bycatch in several areas, *P. violacea* is not considered an endangered species ("Least Concern" in the IUCN Red List).

De Loyola Fernández *et al*. (2017) reported captures of the rare kitefin shark (*Dalatias licha*) (49 individuals) and the little sleeper shark (*Somniosus rostratus*) (24 individuals) over a four-year period from 2009 to 2013 in the bycatch of the commercial drifting longline fishery targeting tuna and swordfish in the Spanish Mediterranean Sea. Lanteri, Castellano and Garibaldi (2017) also reported the bycatch of a female bigeye thresher shark (*Alopias superciliosus*) in the northwestern Mediterranean Sea (Ligurian Sea, Italy) by the mesopelagic swordfish longline fishery. However, only the head was recovered, probably due to predatory/scavenging activity of other shark species. The importance of this record owes to the rarity of the species in the Mediterranean Sea and, more specifically, in Italian waters.

The MEDLEM archive does not provide specifications on type of longline (set vs drifting). However, in the western Mediterranean, the blue shark (*P. glauca*°) and the shortfin mako (*I. oxyrinchus*°) are the most reported bycatch species in longlines, accounting for 42 and 27 percent of the records, respectively. Other conservation-priority species reported in the MEDLEM database were *Alopias vulpinus*° (7 individuals), *Carcharhinus plumbeus*° (1 individual), *Carcharodon carcharias*° (1 individual) and *Gymnura altavela*° (4 individuals). Regarding non-conservation-priority species, the MEDLEM database also reports the bycatch of a *Carcharhinus obscurus* and four individuals of *Hexanchus griseus*.

Central Mediterranean

Longline fisheries targeting sharks are reported from Tunisia and Libya. Declines in swordfish catch in the area have led drifting longliners to shift towards targeting elasmobranchs, particularly the sandbar shark (*Carcharhinus plumbeus*°) (Bradai, Saidi and Enajjar, 2012, 2018; Echwikhi, Saidi and Bradai, 2014; Bradai *et al*., 2016).

Along the Tunisian coast, *C. plumbeus*° is fished by commercial longliners from July to October. During 2007–2008, 48 sets of commercial drifting longlines (corresponding to 35 950 hooks deployed) were observed (Echwikhi, Saidi and Bradai, 2014; Bradai, Saidi and Enajjar, 2018). A total of 581 elasmobranchs were caught. The sandbar shark *C. plumbeus*° (around 15.2 individuals per1 000 hooks), was the species most represented in the bycatch, accounting for 94.2 percent of the number of elasmobranchs catch. The spinner shark *Carcharhinus brevipinna* (3.8 percent) and the pelagic ray *Pteroplatytrygon violacea* (2.1 percent) comprised minor components of the drifting longliner catch (Echwikhi, Saidi and Bradai, 2014) (Table 6).

In the same study, the bycatch composition of the set longlines was also analysed, with a total of 392 elasmobranch specimens recorded over 38 bottom longline sets (48 020 hooks deployed). Among the catch of elasmobranch species, the blackchin guitarfish (*Rhinobatos cemiculus*°) was the most abundant (31.4 percent), followed by *C. plumbeus*° (21.2 percent), the smooth-hound (*Mustelus mustelus*°) (15.8 percent) and the blackspotted smooth-hound (*M. punctulatus*°), at 13.5 percent (Echwikhi, Saidi and Bradai, 2014) (Table 6). *Rhinobatos rhinobatos*° (11.2 percent), *Raja radula* (4.1 percent) and *Carcharhinus brevipinna* (2.1 percent) represented minor components of the elasmobranch catch composition.

A new survey of set and drifting longline fisheries targeting groupers and swordfish was carried out in the Gulf of Gabès in 2016 and 2017 in order to evaluate the elasmobranch catch of two consecutive fishing seasons (July–September of 2016 and 2017) (Bradai *et al*., 2016; Enajjar *et al*., 2018). In the set longline fishery, the elasmobranchs represented about 50 percent of the total catch (batoids – 25.6 percent; sharks – 24.5 percent) (Bradai *et al*., 2016; Enajjar *et al*., 2018). Among the batoids, *Rhinobatos cemiculus*° (0.84 individuals/1 000 *h*ooks) was the species caught most frequently. The other species in this group consisted of *Dasyatis* spp. (0.39 individual/1 000 hooks), round fantail stingray (*Taeniurops grabatus*) (0.2 individual/1 000hooks) *Aetomylaeus bovinus* (0.13 *individual*/1 000 hooks), *Raja radula* (0.03 individual/1 000 hooks), *R. clavata* (0.31 *individual*/1 000 hooks), *R. miraletus* (0.01 *individual*/1 000 *hooks*), *Gymnura altavela*° (0.03 individual/1 000 hooks). Sharks were also represented by a variety of species, *Carcharhinus plumbeus*° (0.43 individual/1 000 hooks), *C. brevipinna* (0.02 individual/1 000 hooks), *Squalus megalops* (0.72 individual/1 000 hooks), *Heptranchias perlo*° (0.11 individual/1 000 hooks), *Mustelus punctulatus*° (0.08 individual/1 000 hooks), *Scyliorhinus canicula* (0.05 individual/1 000 hooks) and *Carcharodon carcharias*° (0.003 individual/1 000 hooks). *M. mustelus*° was the shark species caught most frequently (around 0.86 individual/1 000 hooks) (Table 6).

Over the same period (i.e. July–September of 2016 and 2017), the catch composition of drifting longlines, mainly targeting swordfish, was investigated, (Bradai *et al*., 2016; Enajjar *et al*., 2018). In the drifting longline fishery, elasmobranchs represented almost 92 percent of the total catch (batoids 2.2 percent, sharks 89.6 percent); 96 sets were examined, and *Carcharhinus plumbeus*° came out to be the species corresponding to the highest percentage in terms of both the catch composition (82.5 percent of the total catch) and catch rates (8.79 individuals/1 000 hooks). Other elasmobranch species included *C. brevipinna* (0.20 individual/1 000 hooks), *Isurus oxyrinchus*° (0.48 individual/1 000 hooks), *Pteroplatytrygon violacea* (0.09 individual/1 000 hooks), *Mustelus*

mustelus° (0.11 individual/1 000 hooks), *Rhinobatos cemiculus*° (0.03 individual/1 000 hooks), *Aetomylaeus bovinus* (0.02 individual/1 000 hooks), *Taeniurops grabatus* (0.09 individual/1 000 hooks) and *Raja clavata* (0.03 individual/1 000 hooks) (Bradai *et al*., 2016; Enajjar *et al*., 2018).

The above results were confirmed by Saidi *et al*. (2019), who investigated in depth the status of shark populations exploited by the shark drifting longline fishery in the Gulf of Gabès, comparing the respective species compositions and catch rates of different survey periods. They based their findings off of catch data from 48 longlines set and analysed over the first period of 2007–2008 by Echwikhi, Saidi and Bradai (2014) and from 96 longlines set and analysed over the second period of 2016–2017 (Bradai *et al*., 2016; Enajjar *et al*., 2018). In both periods, elasmobranch species dominated the catch, corresponding to 94 percent (2016–2017) and 99.3 percent (2007–2008) of the number of specimens (Table 6). The sandbar shark (*Carcharhinus plumbeus*°) was the predominant species in the total catch (more than 84 percent of all species caught) during both periods. Over the second period of the study (2016–2017), three other species of sharks, *Isurus oxyrinchus*° (4.6 percent of total catch), *C. brevipinna* (1.9 percent) and *Mustelus mustelus*° (1.07 percent), were also relatively common. Among the batoids, the pelagic stingray (*P. violacea*) was the most numerous, accounting for 0.9 percent in number, while other species such as *Rhinobatos cemiculus*° (0.25 percent), *Aetomylaeus bovinus* (0.16 percent) and *Taeniurops grabatus* (0.82 percent) represented a minor component. In addition, size distribution analyses revealed that the fishery may be operating opportunistically in mating and nursery areas, with impacts on the main species during most of their life stages.

In Maltese waters, Murua *et al*. (2013) reported the mean size and sample size for four species caught by drifting longlines in GSA 15 between 2008 and 2011: *Prionace glauca*°, *Galeorhinus galeus*°, *Lamna nasus*° and *Alopias* spp. (Table 6).

In southern Italy, Cambiè *et al*. (2013) analysed the bycatch species composition of surface longlines and mid-water longlines targeting swordfish during the summers of 2007, 2010 and 2011 (surface longlines) and the summers of 2010 and 2011 (mid-water longlines). They found, among the elasmobranch bycatch, specimens of *Pteroplatytrygon violacea* (around 8 percent of total catch composition in number) and *Prionace glauca*° (around 2 percent of total catch composition in number), though absolute numbers were not reported in the study.

It is worth highlighting that Tobuni *et al*. (2016) documented, for the first time, the presence of a tiger shark (*Galeocerdo cuvier*) in the Mediterranean Sea: two individuals were accidentally caught by a drifting longline targeting swordfish in Libyan waters.

In the MEDLEM database for the central Mediterranean, the blue shark (*Prionace glauca*°) is by far the most commonly bycaught species (60 percent) (see Table 6 for the other conservation-priority species). Regarding other species, the MEDLEM database also reports the bycatch of four individuals of *Carcharhinus obscurus*, one *Hexanchus griseus* and 78 *Pteroplatytrygon violacea*.

Adriatic Sea

Recently, Ćetković (2018) presented data on the composition and abundance of shark bycatch in Montenegrin fisheries, collected between 2016 and 2018 through observations made onboard and at landing sites, as well as from interviews with fishers. In the catch composition of drifting longliners targeting swordfish and tuna, the presence of *Prionace glauca*° (17 individuals), *Isurus oxyrinchus*° (5 individuals) and *Alopias vulpinus*° (1 individual) was recorded.

In the MEDLEM database, only a few specimens are reported from the Adriatic Sea and they consist of only conservation-priority species.

It is worth mentioning the ongoing WWF SafeSharks project (WWF, 2021) that began in 2018, carried out along the Apulian Adriatic coast in southern Italy. The project aims to provide important information on bycatch in the long-established Monopoli longline swordfish fishery (about 26 boats); preliminary analysis indicates that the fishery captures large elasmobranchs, including blue sharks *Prionace glauca*°, thresher sharks *Alopias* spp., spintail devil ray *Mobula mobular*° and shortfin mako *Isurus oxyrinchus*° sharks, on a daily basis. However, the fishers release almost all caught specimens back into the sea still alive, only retaining a few large individuals for sale. Preliminary data for the fishing period of 2019 (August through October) indicate that 65 individuals of *Prionace glauca*° were caught over 34 fishing days by the local longline swordfish fishery (WWF, 2021, unpublished data).

Eastern Mediterranean

Along the Syrian coast, a total of 114 spiny butterfly rays (*Gymnura altavela*°) were caught from July 2010 through March 2013, either in trawls or set longlines operating on sandy and rocky bottoms, at depths ranging from 5 to 60 m (Alkusairy *et al.*, 2014), though the data do not specify which gear was responsible for each catch. Similarly, Alkusairy and Saad (2018), in their review of shark bycatch and its composition in Syrian fisheries carried out between 2014 and 2016, reported the sandbar shark (*Carcharhinus plumbeus*°) (1 135 individuals) as bycatch in nets–longlines (Table 6) and the gulper shark (*Centrophorus granulosus*°) (360 individuals) as bycatch in trawl–longlines. The study also recorded shark species diversity and the presence of possible nurseries along the Syrian coast.

Between December 2012 and January 2014, 67 individuals of the common guitarfish (*Rhinobatos rhinobatos*°) were caught in coastal Lebanese waters at depths ranging from 10 to 110 m by set longliners based out of different ports (Lteif *et al.*, 2016b).

In Egypt, Gabr and El-Haweet (2012) conducted a survey of the drifting longline fishery during the albacore (*Thunnus alalunga*) fishing season between June and July of 2010. The composition of the discards included between five and ten pelagic stingrays (*Pteroplatytrygon violacea*) per fishing day per boat. Additionally, in Egyptian waters, a single bigeye thresher shark (*Alopias superciliosus*) was caught in June 2015 by a drifting longline (Farrag, 2017).

In Antalya (Turkey), Gokoglu reported the bycatch of a single individual of each of *Alopias vulpinus*° and *A. superciliosus* in 2014 from the drifting longline fishery targeting swordfish (Soldo, Briand and Rassoulzadegan, 2014).

Likewise, a survey carried out by Ceyhan and Akyol (2014) in Turkish waters along the Aegean coast, monitoring 50 surveyed operations of swordfish longlines during the fishing seasons from 2008 to 2013, assessed the percentage contribution, in terms of total biomass, of cartilaginous fish. The target swordfish accounted for the highest share of the catch both in number (78.6 percent) and in biomass (73.3 percent). Nevertheless, the biomass ratio of cartilaginous fish came to around 18 percent and included specimens of *Prionace glauca*° (4 individuals), *Isurus oxyrinchus*° (4 individuals), *Alopias vulpinus*° (3 individuals) *Carcharhinus plumbeus*° (2 individuals) and *Mobula mobular*° (2 individuals) (Table 6). The authors reported that one specimen of each of *P. glauca*° and *M. mobular*° was released alive, while the rest were retained due to their commercial value.

In the northern Aegean Sea, in 2008, it was also reported that a new-born great white shark (*Carcharodon carcharias*°) (145 cm TL) was captured by a set longliner (Kabasakal and Özgür Gedikoğlu, 2008). Elsewhere, in the southern Aegean Sea (Turkish coast), a single specimen of blackchin guitarfish (*Rhinobatos cemiculus*°) (925 mm TL) was caught in 2015 by a set longline on a sandy bottom at a depth of approximately 20 m (Filiz *et al.*, 2016).

In a more recent fishing experiment conducted on set longlines by Gönülal (2017) from March to August 2016, at depths of between 500 and 900 m in the northern Turkish Aegean Sea, the presence of different elasmobranch species was recorded: *Alopias vulpinus*° (1 individual), *Dalatias licha* (4 individuals), *Dipturus oxyrinchus* (2 individuals), *Hexanchus griseus* (3 individuals), *Pteroplatytrygon violacea* (1 individuals), *Etmopterus spinax* (12 individuals), *Prionace glauca*° (6 individuals), *Mustelus mustelus*° (11 individuals), *Galeus melastomus* (39 individuals) and *Scyliorhinus stellaris* (28 individuals).

Özcan and Başusta (2018b), in their study on the age, growth and reproduction of the smooth-hound (*Mustelus mustelus*°) inhabiting the Gulf of Iskenderun, in the northeastern Mediterranean, reported that between March 2012 and October 2015, a total of 155 *M. mustelus*° were caught in gillnets and set longlines.

In Cyprus in 2015, Kleitou *et al.* (2017) observed two longlines targeting swordfish (*Xiphias gladius*) over a total of six fishing days along the island's territorial waters. During this short period, the longlines caught 10 individuals of bigeye thresher shark (*Alopias superciliosus*). These captures not only confirmed the presence of this species in the area, but clearly showed, for the first time such a large abundance of *A. superciliosus* captured in the eastern Mediterranean basin by such a low fishing effort. Additional bycatch records of *A. superciliosus* (2 individuals) were recorded again in 2016 (Kleitou *et al.*, 2017).

In the MEDLEM database, for the eastern Mediterranean, 67 bycatch records are reported and mostly include conservation-priority species (Table 6), as well as *Carcharhinus brevipinna* (1 individual), *Pteroplatytrygon violacea* (10 individuals) and *Hexanchus griseus* (10 individuals).

Black Sea

Based on an FAO report (2018d), the bycatch composition of longlines operating in the Black Sea region is composed exclusively of the piked dogfish (*Squalus acanthias*°).

Table 6 – Incidental catch of conservation-priority elasmobranch species in longlines (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Lanteri, Castellano and Garibaldi (2017)	2015	LLD	Western Mediterranean	Italy	*Alopias superciliosus*[1]	-	1	Landing observation
FAO (2019)	2017	LLD	Western Mediterranean	Algeria	*Prionace glauca*	III	1	-
FAO (2019)	2018	LLD	Western Mediterranean	France	*Isurus oxyrinchus*	II	1	-
MEDLEM	2008–2019	LL	Western Mediterranean	-	*Alopias vulpinus*	III	7	-
MEDLEM	2008–2019	LL	Western Mediterranean	-	*Alopias superciliosus*[1]	-	1	-
MEDLEM	2008–2019	LL	Western Mediterranean	-	*Carcharhinus plumbeus*	III	1	-

Table 6 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
MEDLEM	2008–2019	LL	Western Mediterranean	-	*Carcharodon carcharias*	II	1	-
MEDLEM	2008–2019	LL	Western Mediterranean	-	*Cetorhinus maximus*	II	1	-
MEDLEM	2008–2019	LL	Western Mediterranean	-	*Isurus oxyrinchus*	II	17	-
MEDLEM	2008–2019	LL	Western Mediterranean	-	*Prionace glauca*	III	27	-
MEDLEM	2008–2019	LL	Western Mediterranean	-	*Gymnura altavela*	II	4	-
FAO (2018d)	2017	LLD	Central Mediterranean	Tunisia	*Carcharhinus plumbeus*	III	84	-
FAO (2018d)	2017	LLD	Central Mediterranean	Tunisia	*Isurus oxyrinchus*	II	19	-
FAO (2018d)	2017	LLD	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	2	-
FAO (2019)	2019	LLD	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	8	-
FAO (2019)	2019	LLD	Central Mediterranean	Tunisia	*Prionace glauca*	III	1	-
Echwikhi, Saidi and Bradai (2014)	2007–2008	LLS	Central Mediterranean	Tunisia	*Rhinobatos cemiculus*	II	123	Onboard observations
Echwikhi, Saidi and Bradai (2014)	2007–2008	LLS	Central Mediterranean	Tunisia	*Rhinobatos rhinobatos*	II	44	Onboard observations
Echwikhi, Saidi and Bradai (2014)	2007–2008	LLD	Central Mediterranean	Tunisia	*Carcharhinus plumbeus*	III	547	Onboard observations
Echwikhi, Saidi and Bradai (2014)	2007–2008	LLS	Central Mediterranean	Tunisia	*Mustelus punctulatus*	III	53	Onboard observations
Echwikhi, Saidi and Bradai (2014)	2007–2008	LLS	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	62	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLS	Central Mediterranean	Tunisia	*Carcharhinus plumbeus*	III	1 132[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLD	Central Mediterranean	Tunisia	*Carcharhinus plumbeus*	III	3 795[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLD	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	48[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLS	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	2 265[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLS	Central Mediterranean	Tunisia	*Mustelus punctulatus*	III	218[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLS	Central Mediterranean	Tunisia	*Heptranchias perlo*	III	299[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLS	Central Mediterranean	Tunisia	*Carcharodon carcharias*	II	8[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLS	Central Mediterranean	Tunisia	*Rhinobatos cemiculus*	II	2 216[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLD	Central Mediterranean	Tunisia	*Rhinobatos cemiculus*	II	11[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLS	Central Mediterranean	Tunisia	*Gymnura altavela*	II	81[2]	Onboard observations
Bradai *et al.* (2016)	2016–2017	LLD	Central Mediterranean	Tunisia	*Isurus oxyrinchus*	II	208[2]	Onboard observations
Saidi *et al.* (2019)	2016–2017	LLD	Central Mediterranean	Tunisia	*Isurus oxyrinchus*	II	56	Onboard observations
Saidi *et al.* (2019)	2016–2017	LLD	Central Mediterranean	Tunisia	*Mustelus mustelus*	III	13	Onboard observations
Saidi *et al.* (2019)	2016–2017	LLD	Central Mediterranean	Tunisia	*Carcharhinus plumbeus*	III	1 024	Onboard observations
Murua *et al.*, eds (2013)	2008–2011	LLD	Central Mediterranean	Malta	*Prionace glauca*	III	240	-
Murua *et al.*, eds (2013)	2008–2011	LLD	Central Mediterranean	Malta	*Galeorhinus galeus*	II	4	-

Table 6 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Murua *et al.*, eds (2013)	2008–2011	LLD	Central Mediterranean	Malta	*Lamna nasus*	II	59	-
Murua *et al.*, eds (2013)	2008–2011	LLD	Central Mediterranean	Malta	*Alopias* spp.	-	14	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Alopias vulpinus*	III	4	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Carcharodon carcharias*	II	1	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Galeorhinus galeus*	II	19	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Isurus oxyrinchus*	II	8	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Lamna nasus*	II	2	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Mustelus mustelus*	III	1	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Mustelus punctulatus*	III	1	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Prionace glauca*	III	206	-
MEDLEM	2008–2019	LL	Central Mediterranean	-	*Mobula mobular*	II	18	-
Ćetković (2018)	2016–2018	LLD	Adriatic Sea	Montenegro	*Prionace glauca*	III	17	Onboard observations, observations at landing sites, interviews with fishers
Ćetković (2018)	2016–2018	LLD	Adriatic Sea	Montenegro	*Isurus oxyrinchus*	II	5	Onboard observations, observations at landing sites, interviews with fishers
Ćetković (2018)	2016–2018	LLD	Adriatic Sea	Montenegro	*Alopias vulpinus*	III	1	Onboard observations, observations at landing sites, interviews with fishers
MEDLEM	2008–2019	LL	Adriatic Sea	-	*Alopias vulpinus*	III	1	-
MEDLEM	2008–2019	LL	Adriatic Sea	-	*Isurus oxyrinchus*	II	1	-
MEDLEM	2008–2019	LL	Adriatic Sea	-	*Prionace glauca*	III	3	-
WWF, 2021 (unpublished data)	2019	LLD	Adriatic Sea	Italy	*Prionace glauca*	III	65	Onboard observations and fisher's logbook records
Alkusairy *et al.* (2014)	2010–2013	LL/OTB	Eastern Mediterranean	Syria	*Gymnura altavela*	II	114	Observations at landing sites
Alkusairy and Saad (2018)	2014–2015	LL/OTB	Eastern Mediterranean	Syrian Arab Republic	*Centrophorus granulosus*	III	360	-
Lteif *et al.* (2016b)	2012–2014	LLS	Eastern Mediterranean	Lebanon	*Rhinobatos rhinobatos*	II	67	Observations at landing sites
Farrag (2017)	2015	LLD	Eastern Mediterranean	Egypt	*Alopias superciliosus*[1]	n/a	1	Catch composition analysis
Gokoglu *in* Soldo, Briand and Rassoulzadegan (2014)	2014	LLD	Eastern Mediterranean	Turkey	*Alopias supercilious*[1]	-	1	-
Gokoglu *in* Soldo, Briand and Rassoulzadegan (2014)	2014	LLD	Eastern Mediterranean	Turkey	*Alopias vulpinus*	III	1	-
Filiz *et al.* (2016)	2015	LL	Eastern Mediterranean	Turkey	*Rhinobatos cemiculus*	II	1	Observations at landing sites
Kabasakal and Özgür Gedikoğlu, 2008	2008	LLS	Eastern Mediterranean	Turkey	*Carcharodon carcharias*	II	1	Landing observation
Ceyhan and Akyol (2014)	2008–2013	LLD	Eastern Mediterranean	Turkey	*Alopias vulpinus*	III	3	Onboard observations

Table 6 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Ceyhan and Akyol (2014)	2008–2013	LLD	Eastern Mediterranean	Turkey	*Carcharhinus plumbeus*	III	2	Onboard observations
Ceyhan and Akyol (2014)	2008–2013	LLD	Eastern Mediterranean	Turkey	*Mobula mobular*	II	2	Onboard observations
Ceyhan and Akyol (2014)	2008–2013	LLD	Eastern Mediterranean	Turkey	*Prionace glauca*	III	4	Onboard observations
Ceyhan and Akyol (2014)	2008–2013	LLD	Eastern Mediterranean	Turkey	*Isurus oxyrinchus*	II	4	Onboard observations
Gönülal (2017)	2016	LLS	Eastern Mediterranean	Turkey	*Alopias vulpinus*	III	1	Experimental fishing
Gönülal (2017)	2016	LLS	Eastern Mediterranean	Turkey	*Prionace glauca*	III	6	Experimental fishing
Gönülal (2017)	2016	LLS	Eastern Mediterranean	Turkey	*Mustelus mustelus*	III	11	Experimental fishing
Özcan and Başusta (2018b)	2012–2015	LLD/ GNS	Eastern Mediterranean	Turkey	*Mustelus mustelus*	III	155	-
Kleitou *et al.* (2017)	2015–2016	LLD	Eastern Mediterranean	Cyprus	*Alopias superciliosus*[1]	-	12	Onboard observations
FAO (2019)	2018	LLD	Eastern Mediterranean	Cyprus	*Prionace glauca*	III	10	
FAO (2018d)	2017	LLD	Eastern Mediterranean	Cyprus	*Prionace glauca*	III	6	
FAO (2017)	2016	LLD	Eastern Mediterranean	Cyprus	*Prionace glauca*	III	1	
FAO (2017)	2016	LLD	Eastern Mediterranean	Cyprus	*Isurus oxyrinchus*	II	2	
FAO (2019)	2018	LL	Eastern Mediterranean	Greece	*Mustelus mustelus*	III	2	
FAO (2019)	2018	LL	Eastern Mediterranean	Greece	*Rostroraja alba*	II	1	
FAO (2018d)	2017	LL	Eastern Mediterranean	Greece	*Mustelus mustelus*	III	4	
FAO (2018d)	2017	LL	Eastern Mediterranean	Greece	*Squalus acanthias*	III	45	
FAO (2019)	2018	LL	Eastern Mediterranean	Greece	*Squalus acanthias*	III	8	
MEDLEM	2018–2019	LL	Eastern Mediterranean	-	*Alopias vulpinus*	III	30	-
MEDLEM	2018–2019	LL	Eastern Mediterranean	-	*A. superciliosus*[1]	-	26	-
MEDLEM	2018–2019	LL	Eastern Mediterranean	-	*Carcharhinus plumbeus*	III	2	-
MEDLEM	2018–2019	LL	Eastern Mediterranean	-	*Carcharodon carcharias*	II	1	-
MEDLEM	2018–2019	LL	Eastern Mediterranean	-	*Isurus oxyrinchus*	II	7	-
MEDLEM	2018–2019	LL	Eastern Mediterranean	-	*Prionace glauca*	III	5	-
MEDLEM	2018–2019	LL	Eastern Mediterranean	-	*Mobula mobular*	II	1	-

Notes:

LL = longline; LLS = set longline; LLD = drifting longline.

1. *Alopias superciliosus* is not listed in Annex II or III of SPA/DB Protocol, but due to its morphological similarity to *A. vulpinus*°, bycatch events reported for this species were included in the table.
2. Bycatch estimate referring to one fishing season of all set and drifting longline fisheries operating in the Gulf of Gabès, Tunisia.

3.3.5 Pelagic trawlers

Pelagic trawlers using large openings to target small pelagic fish (anchovies and sardines) operate almost exclusively in the Adriatic Sea and can incidentally catch pelagic sharks. Table 7 includes information on the incidental catch of conservation-priority shark and batoid species from sources individually reporting the elasmobranchs caught by pelagic trawlers. The data reported officially by countries to the GFCM are presented in Table 7 (FAO, 2018d)

Western Mediterranean

Some pelagic trawlers used to operate in the western Mediterranean, mainly in the Gulf of Lion (Farrugio and Cebrian, 2013).

In the MEDLEM database, the bycatch of 11 specimens belonging to four priority-conservation species is reported (Table 7).

Central Mediterranean

In the MEDLEM database, the bycatch of nine specimens belonging to three priority-conservation species is reported (Table 7).

Adriatic Sea

As mentioned, this type of fishing technique is mainly used in the Adriatic Sea. The largest fleet of pelagic trawlers is based in Italy, where they are commonly called *volanti* and are licensed to operate in pairs. Twin boats, usually of an overall length (LOA) greater than 18 m and nominal power between 150 and 900 kW mainly operate in the open sea, trawling a net around 150 m long, with a mouth opening of 15–18 m in width and 6–10 m in height and targeting anchovies, sardines and mackerel (Fortuna *et al*., 2010).

A long bycatch monitoring programme in Italian pelagic trawlers, operating mainly in the northern central Adriatic, has provided the opportunity to collect information over a ten-year period (2006–2015) (Fortuna *et al*., 2010; La Mesa *et al*., 2016; Bonanomi *et al*., 2018); qualified observers onboard 57 pelagic trawlers monitored all fishing operations and collected bycatch data for protected species (e.g. cetaceans) and species of conservation concern (e.g. elasmobranchs). While Fortuna *et al*. (2010) focused their study on cetacean bycatch, though they also collected information on bycatch of other vulnerable species over a three-year period (see Section 1.3), Bonanomi *et al*. (2018) assessed the impacts of the pelagic trawl fishery on four species of elasmobranchs: the common smooth-hound (*Mustelus mustelus*°), piked dogfish (*Squalus acanthias*°), common eagle ray (*Myliobatis aquila*) and pelagic stingray (*Pteroplatytrygon violacea*) by examining the incidental catch recorded in a longer data series (i.e. from 2006 to 2015). In fact, these species had already been initially identified by Fortuna *et al*. (2010) as the most impacted by pelagic trawlers in the Adriatic Sea.

According to Bonanomi *et al*. (2018), the *S. acanthias*° was the species of elasmobranch with the highest bycatch (2 160 individuals of *S. acanthias*° were caught, with an average frequency of 0.061 per fishing haul), followed by the common eagle ray (1 880 individuals *M. aquila*; average frequency of 0.054 per fishing haul), the common smooth-hound (833 *Mustelus mustelus*° individuals; average frequency 0.027), and the pelagic stingray (555 *P. violacea* individuals; average frequency 0.033). It was shown that depth, season and fishing area strongly influenced the bycatch of the above-mentioned species. Additionally, the presence of a nursery area identified in the northern Adriatic was probably a major factor affecting the bycatch of the *M. mustelus*° and *S. acanthias*°. The study also revealed that demersal elasmobranchs were caught by pelagic/midwater trawlers when these vessels operated in relatively shallow waters (<50 m). Table 7 reports the bycatch of the two priority-conservation species recorded from 2008 to 2015.

Analysing the same fishing data for the period 2006–2013, La Mesa *et al*. (2016) assessed the effects of spatiotemporal, environmental and operational factors on the catch of two myliobatids, the common eagle ray (*Myliobatis aquila*) and the bull ray (*Aetomylaeus bovinus*), by midwater trawlers operating in the north central Adriatic Sea. The proportion of positive hauls (i.e. hauls in which rays were caught) was 5.8 percent for common eagle rays and 1.3 percent for bull rays, corresponding to a total of 1 857 and 215 individuals, respectively. The major occurrences of common eagle rays and bull rays in the northern Adriatic Sea were observed between late spring and early autumn. During winter, a southward shift in the catch was recorded for both species. In accordance with a significant effect noted for depth, common eagle rays were more likely to be caught in hauls conducted at depths between 10 and 60 m. The CPUEs of common eagle rays and bull rays declined significantly with haul duration and net vertical opening.

In the MEDLEM database, besides the data already mentioned above, the bycatch of *Carcharodon carcharias*° and *Mobula mobular*° are also reported for this vessel group in the Adriatic Sea (Table 7).

Eastern Mediterranean

A single individual of each of *Alopias superciliosus* and *Echinorhinus brucus* is reported as bycatch of pelagic trawlers in the eastern Mediterranean in the MEDLEM database.

Black Sea

No data available.

Table 7 – Incidental catch of conservation-priority elasmobranch species in pelagic trawlers (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
MEDLEM	2008–2019	PTM	Western Mediterranean	-	*Alopias vulpinus*	III	6	-
MEDLEM	2008–2019	PTM	Western Mediterranean	-	*Cetorhinus maximus*	II	2	-
MEDLEM	2008–2019	PTM	Western Mediterranean	-	*Galeorhinus galeus*	II	1	-
MEDLEM	2008–2019	PTM	Western Mediterranean	-	*Prionace glauca*	III	2	-
FAO (2018d)	2017	PTM	Western Mediterranean	Algeria	*Alopias vulpinus*	III	1	
MEDLEM	2008–2019	PTM	Central Mediterranean	-	*Alopias vulpinus*	III	1	-
MEDLEM	2008–2019	PTM	Central Mediterranean	-	*Isurus oxyrinchus*	II	1	-
MEDLEM	2008–2019	PTM	Central Mediterranean	-	*Prionace glauca*	III	7	-
Bonanomi *et al.* (2018)	2008–2015	PTM	Adriatic Sea	Italy	*Squalus acanthias*	III	2 068	Onboard observations
Bonanomi *et al.* (2018)	2008–2015	PTM	Adriatic Sea	Italy	*Mustelus mustelus*	III	758	Onboard observations
MEDLEM	2008–2019	PTM	Adriatic Sea	-	*Carcharodon carcharias*	II	1	-
MEDLEM	2008–2019	PTM	Adriatic Sea	-	*Mobula mobular*	II	1	-
MEDLEM	2008–2019	PTM	Eastern Mediterranean	-	*Alopias superciliosus*[1]	-	1	-

Notes: PTM = midwater pair trawl.

1. *Alopias superciliosus* is not listed in Annex II or III of SPA/DB Protocol, but due to its morphological similarity to *A. vulpinus*°, bycatch events reported for this species were included in the table.

3.3.6 Tuna seiners

This vessel group includes the large pelagic seiners and the few coastal tuna traps that remain active in the Mediterranean Sea (Storai *et al.*, 2011). Hall and Roman (2013) have provided a global review of the bycatch of the tuna purse seine fisheries. The major fishing grounds in which these types of vessels operate, with mostly the same fishing techniques and gear, are the eastern and western Pacific, the eastern Atlantic, and the western Indian Ocean; little information was provided for the Mediterranean and the Black Sea.

The data reported officially by countries to the GFCM are presented in Table 8 (FAO, 2018d). In the same table data coming from tuna trap bycatch records available in the MEDLEM archive are also reported. It is noteworthy that besides the conservation-priority species, rare large pelagic sharks have been recorded: the copper shark (*Carcharhinus brachyurus*¸1 individual) and the dusky shark (*C. obscurus*, 1 individual) in the western Mediterranean, and the silky shark (*C. falciformis*, 1 individual) in the eastern Mediterranean.

Western Mediterranean

In 2015, news (Romagnoni, 2011) reported of five bycatch events of thresher sharks (*Alopias* spp.) in tuna fishing traps operating in the waters off Camogli (Ligurian Sea, Italy). According to the source, prior to the bycatch event that occurred in February 2015, other sharks had been caught in April and May 2008, June 2009, and April 2010.

Central Mediterranean

No data available.

Adriatic Sea

No data available.

Eastern Mediterranean

No data available.

Black Sea

No data available.

Table 8 – Incidental catch of conservation-priority elasmobranch species in tuna seiners (data from literature 2008–2019)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	SPA/BD Protocol Annex	Reported individuals in bycatch events	Source of data
Romagnoni, 2011	2008–2015	-	Western Mediterranean	Italy	*Alopias* spp.	-	5	-
FAO (2018d)	2017	-	Eastern Mediterranean	Cyprus	*Prionace glauca*	III	5	-
MEDLEM	2008–2019	-	Western Mediterranean	-	*Alopias vulpinus*	III	10	-
MEDLEM	2008–2019	-	Western Mediterranean	-	*Carcharodon carcharias*	II	1	-
MEDLEM	2008–2019	-	Western Mediterranean	-	*Isurus oxyrinchus*	II	2	-
MEDLEM	2008–2019	-	Western Mediterranean	-	*Prionace glauca*	III	3	-
MEDLEM	2008–2019	-	Western Mediterranean	-	*Sphyrna zygaena*	II	1	-
MEDLEM	2008–2019	-	Western Mediterranean	-	*Mobula mobular*	II	1	-
MEDLEM	2008–2019	-	Central Mediterranean	-	*Alopias vulpinus*	III	1	-
MEDLEM	2008–2019	-	Central Mediterranean	-	*Alopias superciliosus*[1]	-	2	
MEDLEM	2008–2019	-	Central Mediterranean	-	*Carcharodon carcharias*	II	1	-
MEDLEM	2008–2019	-	Adriatic Sea	-	*Alopias vulpinus*	III	1	-
MEDLEM	2008–2019	-	Eastern Mediterranean	-	*Alopias superciliosus*[1]	-	1	-

Notes:

1. *Alopias superciliosus* is not listed in Annex II or III of SPA/DB Protocol, but due to its morphological similarity to *A. vulpinus*°, bycatch events reported for this species were included in the table.

3.3.7 Dredgers

No data available for this vessel group; these fisheries do not overlap with elasmobranch species.

3.4 Outlook

3.4.1 Results

Data on the bycatch of conservation-priority elasmobranch species in Mediterranean and Black Sea fisheries collected from around 2008 to the present from scientific literature, FAO reports and ad hoc archives (i.e. MEDLEM database, see Mancusi *et al.*, 2020) have been analysed to obtain qualitative evaluations by vessel group and subregion, as presented in Section 3.3.

Focus is given to the conservation-priority species included in Annex II (24 species) and Annex III (9 species) of the SPA/BD Protocol and considered in Recommendations GFCM/36/2012/3 and GFCM/42/2018/2 (see Table 1). From 2013, according to these regional recommendations, a high level of protection from fishing activities shall be granted to the elasmobranch species listed in Annex II of the SPA/BD Protocol (List of endangered or threatened species). These species must be released live and unharmed, to the extent possible, and cannot be retained onboard, transhipped, landed, transferred, stored, sold, displayed or offered for sale. Species listed in Annex III of the SPA/BD Protocol (List of species whose exploitation is regulated) can be commercialized but detailed reporting of any catch must be reported.

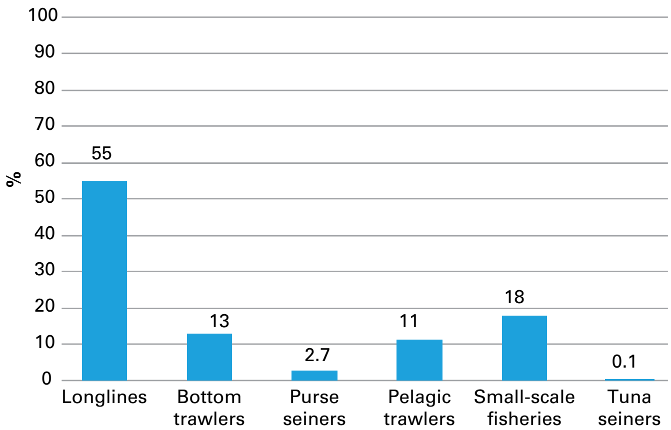
It is worth noting that the geographical and historical coverage of the data analysed varies greatly and that only studies reporting individual values of elasmobranch bycatch were considered. Therefore, the data presented in this review are likely to underestimate the real values and the actual frequency of elasmobranch incidental catch in the Mediterranean and the Black Sea. However, this analysis could represent an important starting point for management considerations.

According to the data compiled, most of the reported conservation-priority elasmobranch bycatch comes from longliners (set and drifting considered together) (55 percent), followed by small-scale fisheries (18 percent), bottom trawlers (13 percent), pelagic trawlers (11 percent), purse seiners and tuna seiners (nearly 3 percent together) (Figure 3).

Small-scale fisheries are characterized by polyvalent gear vessels that may also operate with small longlines in coastal areas and, therefore, some of the bycatch records reported here under "Longlines" actually come from small-scale polyvalent vessels. In fact, in the Mediterranean and Black Sea, elasmobranch species are mainly coastal and benthic (around 80 percent of the species), making them vulnerable to fishing activities operating along the coasts (Bradai, Saidi and Enajjar, 2018).

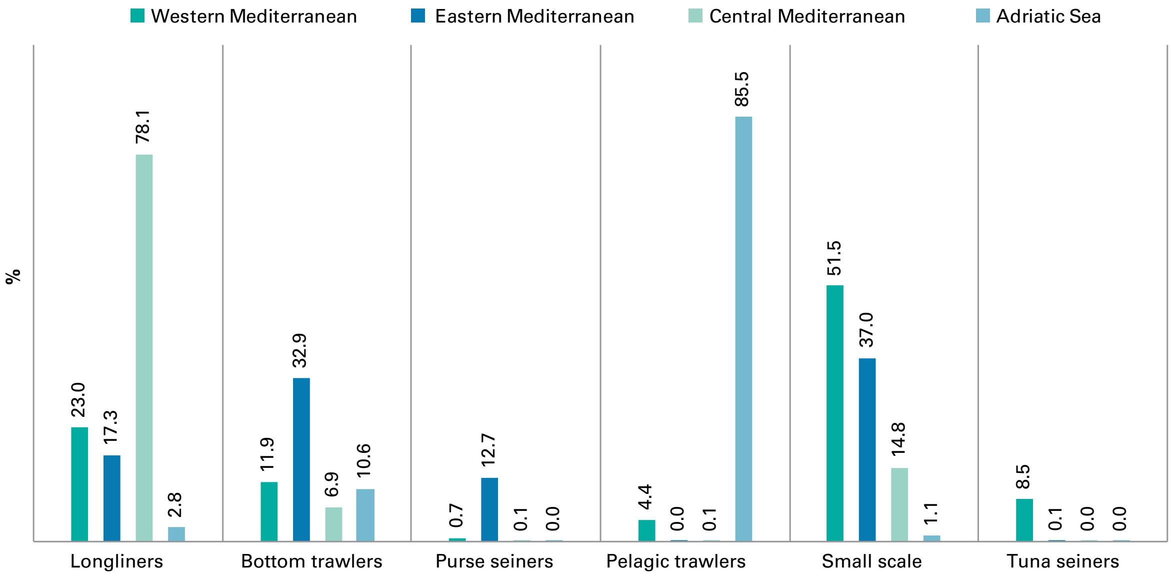
Quite different sets of impacts from the different vessel categories emerge when considering the various GFCM subregions (Figure 4). Most of the

FIGURE 3
Reported incidental catch of elasmobranchs by fishing vessel group in the Mediterranean and the Black Sea (data from literature 2008–2019)



Number of individuals = 25 312

FIGURE 4
Reported incidental catch of elasmobranchs by fishing vessel group by Mediterranean subregion (data from literature 2008–2019)



Note:
number of individuals = 270 western Mediterranean; 16 520 central Mediterranean; 3 309 Adriatic Sea; 5 190 eastern Mediterranean

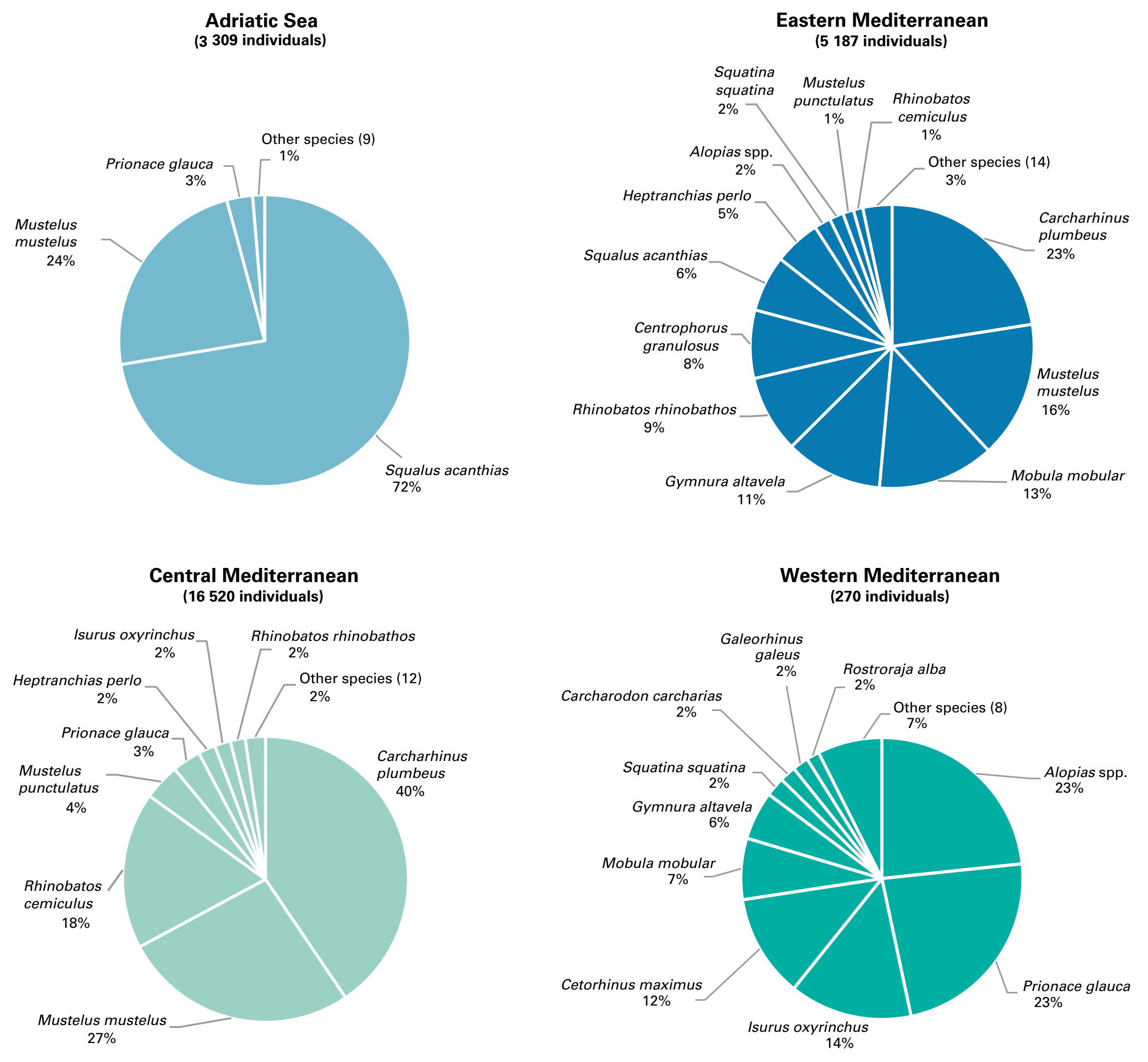
records from the Adriatic Sea come from pelagic trawlers, though it is worth noting that a specific multi-year observation campaign has been in place since 2006. Therefore, the data from this area probably reflect the extent and focuses of survey coverage, as well as the fact that, at the regional level, pelagic trawlers almost exclusively operate in the Adriatic subregion. Similarly, though traditional coastal purse seiners still used in the Levantine Sea are occasionally responsible for elasmobranch bycatch (see Table 5), elasmobranch bycatch in purse seines is rarely reported.

In the central Mediterranean, longliners are by far the most relevant fishing gear in terms of reported bycatch of conservation-priority elasmobranch species, with the absolute highest number of available records. In the eastern Mediterranean, elasmobranch bycatch is mostly reported from small-scale fisheries using a variety of set nets; bottom trawlers also seem to catch a considerable diversity of conservation-priority elasmobranch species in this subregion (see Table 3). In the western Mediterranean, most of the reported records come from small-scale fisheries, followed by longliners and bottom trawlers. It is interesting to note that almost all records of elasmobranch bycatch in tuna seiners, including tuna traps (i.e. a traditional type of gear that has almost disappeared from the Mediterranean basin), are reported from the western Mediterranean; the few remaining tuna traps are nevertheless able to incidentally catch large pelagic species of elasmobranchs (see Table 8).

Very few individual records of conservation-priority elasmobranch species could be found for the Black Sea (23 individuals), with these records coming largely from bottom trawlers (82 percent), followed by purse seiners (17.4 percent). No individual bycatch records from the other vessel groups could be found for this subregion, though small-scale fisheries targeting coastal fish such as turbot are known to incidentally catch the piked dogfish (*Squalus acanthias*°).

Regarding the conservation-priority species reported, notwithstanding differences in absolute numbers, the highest number of species reported as bycatch comes from the eastern Mediterranean (27 species), followed by the central (21 species) and the western Mediterranean (19 species), the Adriatic (13 species) and the Black Sea (4 species) (Figure 5). However, the large gap in reported individuals between the central Mediterranean Sea and the other subregions offers further evidence that the biomass of conservation-priority elasmobranch populations is still highest in the central Mediterranean, assuming that bycatch rates reflect the relative abundance of elasmobranchs, as well as the focus of scientific research. In accordance with these observations are the relevant contributions made to this review by recent studies on the incidental bycatch of elasmobranch species in the central (Tunisia) and in the eastern (Turkey) Mediterranean Sea (see for example, Kabasakal, 2019). These studies helped to expand the data pool from the historical overview (see Section 3.2) which includes data collected up to 2008–2009 mostly coming from studies carried out in the western Mediterranean and the Adriatic Sea and mainly in European countries.

FIGURE 5
Reported elasmobranch conservation-priority species by Mediterranean subregion (data from literature 2008–2019)



N.B. *Alopias vulpinus* and *A. superciliosus* records are pulled together as *Alopias* spp.

In the western Mediterranean, the five most reported species are all large pelagic elasmobranchs (around 80 percent of the records), and among the ten species most reported, eight are listed in Annex II of the SPA/BD Protocol. However, the pool of available data is scarce when compared to those of the other subregions (only 270 individuals), and most of the records come from the MEDLEM archive, as few relevant data could be found scientific literature. Nonetheless, the variety of species noted could reflect high elasmobranch diversity in the subregion (Bradai, Saidi and Enajjar, 2012; Coll *et al*., 2010; Serena *et al*., 2020).

In the central Mediterranean, the subregion with the highest number of records (16 520 individuals), the most common species reported as bycatch – mainly by Tunisian fisheries – are the sandbar shark *Carcharhinus plumbeus*° and the smooth-hound shark *Mustelus*°spp. (around 67 percent of the total records); both species are listed in Annex III of the SPA/BD Protocol. In the Adriatic Sea, despite the considerable number of records analysed (3 309 individuals), elasmobranch diversity seems to be lower than in the other subregions, with three species (listed in Annex III of the SPA/DB Protocol) accounting for around 98 percent of the reported bycatch events. The piked dogfish (*Squalus acanthias*°) is by far the most commonly reported conservation-priority species. This finding is in line with previous studies that already highlighted the impoverishment of elasmobranch populations in the Adriatic Sea, from both a quantitative and qualitative perspective (see Jukic-Peladic *et al*., 2001; Ferretti *et al*., 2013; Barausse *et al*., 2014).

From the records analysed in the eastern Mediterranean, (5 190 individuals), the largest variety of species was found, with no peaks corresponding to any single one; this balance appears to be matched by the contributions of the different vessel groups in the subregion (Figure 4), as no fishing gear clearly prevails in terms of elasmobranch bycatch. This result could be due to the relatively high abundance and diversity of species that are still commonly found as bycatch in a variety of fishing gear in this subregion. Indeed, the eastern Mediterranean represents the subregion in which industrial fisheries have developed the least and in which the artisanal nature of fishing activities remains important. In addition, many studies in the eastern Mediterranean, especially from Turkish and Syrian coastal waters, reported the occurrence of shark and ray mating grounds and nurseries for many conservation-priority elasmobranch species, including those with pelagic habits.

In the Black Sea, the paucity of published studies reporting absolute values of elasmobranch species incidentally caught in fisheries stands out (only 23 individuals reported in total). However, it is well known and reported that the piked dogfish (*Squalus acanthias*°, Annex III of the SPA/BD Protocol) and the thornback ray (*Raja clavata*, not listed) comprise regular bycatch components of Black Sea small-scale vessels and bottom trawlers (see GFCM, 2016b, 2018a, 2018b; STECF, 2017; Demirhan, Engin and Can 2005; Ceylan, Şahin and Kalayci, 2013). Most of the data regarding the bycatch of these two species in Black Sea fisheries are often reported in tonnes and, therefore, could not be compared and used in this review. Due to its high bycatch rate, the piked dogfish *S. acanthias*° population in the Black Sea has been declared as depleted by the GFCM for a long time, and specific management measures were adopted in 2015, though the implementation of a full recovery plan is still advised (GFCM, 2018a, 2018b).

The data compiled and presented here also provide useful information on the recent (and reported) occurrence of rare elasmobranch species, as well as species reported to be locally extinct in specific areas. For example, incidental catch records of angel-sharks belonging to the genus *Squatina*° were found in the western, central and eastern Mediterranean, but not in the Adriatic

Sea. Of the three species of hammerhead sharks (*Sphyrna*° spp.) listed in Annex II of the SPA/BD Protocol, only four individuals of the smooth hammerhead (*Sphyrna zygaena*°) could be found as bycatch records (in the eastern and western Mediterranean). In addition, up to 46 individuals of the rare white skate (*Rostroraja alba*°) were reported as bycatch in eastern Mediterranean fisheries. Furthermore, only a few individuals of the demersal elasmobranchs the blue skate (*Dipturus cf. batis*°) (2 individuals), Maltese ray (*Leucoraja melitensis*°) (1 individual) and smalltooth sand tiger (*Odontaspis ferox*°) (3 individuals) were found in the various sources used for this review.

No recent bycatch records were found for the following Annex II species: sand tiger shark (*Carcharias taurus*°), sandy ray (*Leucoraja circularis*°), scalloped hammerhead (*Sphyrna lewini*°) great hammerhead (*S. mokarran*°), and the smalltooth (*Pristis pectinata*°) and common (*P. pristis*°) sawfish, which can be considered extinct in the Mediterranean Sea (Ferretti *et al.*, 2015; Serena *et al.*, 2020). However, in general, unreported data do not necessarily imply that certain species are not present and caught in a particular area. Therefore, while, in general, presence data can be considered valid, the same cannot be said of absence data, as it cannot be stated with certainty that these reflect the actual absence of a species from the area considered. On the other hand, bycatch records of rare elasmobranch species not included in Annex II and III of the SPA/BD Protocol, such as the bramble shark (*Echinorhinus brucus*), kitefin shark (*Dalatias licha*), copper shark (*Carcharhinus brachyurus*), dusky shark (*C. obscurus*), silky shark (*C. falciformis*), little sleeper shark (*Somniosus rostratus*) and tiger shark (*Galeocerdo cuvier*), were also found.

3.4.2 Future scenarios

The observed decline in elasmobranchs is of great concern across almost all the seas of the world, including the Mediterranean and the Black Sea (da Silva Rodrigues Filho and Bráullio de Luna Sales, 2017; Gallucci, McFarlane and Bargmann, eds, 2009; Coll, Navarro and Palomera, 2013; Başusta, Başusta and Özgürözbek, 2016; Bargnesi, Lucrezi and Ferretti, 2020; Myers *et al.*, 2007; Ferretti *et al.*, 2008; Heithaus *et al.*, 2008; Camhi *et al.*, 2009; Guisande *et al.*, 2013; Worm *et al.*, 2013; Barausse *et al.*, 2014; Dulvy *et al.*, 2014; Oliver *et al.*, 2015; Gordon *et al.*, 2017, 2019). The low resilience that elasmobranch species show with respect to human pressure (e.g. habitat loss, pollution, fisheries activities) due to their biological traits (such as late sexual maturity, production of few offspring, among other factors), as well as their vulnerability to incidental capture, which can occur at any growth stage, must be considered by fishery managers in order for effective solutions to be implemented to decrease elasmobranch fishing mortality (Cavanagh and Gibson, 2007; da Silva Rodrigues Filho and Bráullio de Luna Sales, 2017; Bargnesi, Lucrezi and Ferretti, 2020; Stevens *et al.*, 2000; Ferretti *et al.*, 2010; Oliver *et al.*, 2015; Dulvy *et al.*, 2016). The common management measures employed for bony fish have been shown to be ineffective, as the biological and morphological characteristics of cartilaginous fish populations cause them to be more markedly and rapidly impacted by fishing activity. For example, increases in the selectivity of fishing gear, based on the type of bony fish targeted, seldom have positive effects on elasmobranchs.

The data presented in this review highlight the need to implement, at the regional and national level, management and conservation measures aiming to avoid the incidental catch of elasmobranchs, including not only protected species with low or no commercial value, but also those that can be commercialized. Indeed, implementation of these measures is required to comply with the existing regional regulations/recommendations aimed at decreasing elasmobranch bycatch events in Mediterranean and Black Sea fisheries, especially those of protected species. Critical aspects concern the quality of data collection, reporting and fishing statistics with regard to those species that can be commercialized, as the majority of the currently landed elasmobranchs are recorded at the level of family or species group, with most countries unable to record the catch at the species level (GFCM, 2012; Bradai, Saidi and Enajjar, 2012; Coll, Navarro and Palomera, 2013; Dulvy *et al.*, 2014). As for other groups of vulnerable species, systematic onboard data collection on the bycatch of elasmobranch species should be ensured for all Mediterranean and Black Sea countries. Furthermore, for all vessel groups considered, regional, easy-to-use tools should be developed for fishers to record elasmobranch incidental catch. For example, the implementation and correct use of electronic logbooks onboard could contribute in a decisive manner toward this end. One of the issues related to assessing large sharks lies in species identification and knowledge of their conservation status. Simple tools should be provided for fishers to recognize protected species, enabling them to release captured specimens still alive, in order to contribute to the conservation of elasmobranch populations, as well as to avoid disciplinary sanctions.

In terms of fisheries management, the enforcement of relevant regulations is never an easy task, as reliable, basic information in relation to exploitable versus non-exploitable resources is always required. Complications arise particularly in consideration of the exploitation of elasmobranch species. In fact, some shark and ray species are included in several international legal instruments aimed at their protection (i.e. they are found in the annexes of various conventions, such as the Barcelona Convention (see Table 1), which is used as a reference both in the European regulations and GFCM recommendations), as well as for other charismatic large marine species like marine mammals, sea turtles and seabirds. On the other hand, elasmobranch species not included in the Barcelona Convention, yet sometimes assessed as regionally "Endangered" or "Critically Endangered" by the IUCN Red List (2016), can still be caught and commercialized (although for those listed in Annex III of the SPA/DB Protocol, special reporting should be undertaken). This scenario can create misunderstandings when it comes to distinguishing protected versus non-protected species, all of which may "look" the same. Such ambiguity can create further uncertainty or even errors in the assignment of a species to a particular (protection) category, thus leading to difficulties in the enforcement of the regulations among final users and administrations. In addition, a lack of general awareness of the current legislation could prevent effective implementation at the national level. For example, in many of the recent studies analysed in this review that concluded by invoking protection for selected "Endangered" or "Critically Endangered" species, no mention was made to the current regional protection framework already granted to the same elasmobranch species, listed in Annex II of the SPA/BD Protocol.

In general, all these difficulties of communication with final users, management and regulation enforcement can favour, especially in the case of elasmobranch bycatch, illegal, unreported and unregulated (IUU) fishing, which represents one of the most serious threats to the sustainability of fisheries. Different forms of IUU fishing can directly and indirectly affect elasmobranch species, particularly through the capture of protected shark and ray species, and include the use of banned types of fishing gear, fishing within restricted or closed areas (e.g. no-take zones or within three nautical miles of the coast or at depths of 50m or less) and fishing with towed gear beyond a depth of 1 000 m.

In conclusion, the management models considered to record and reduce the impact on elasmobranchs should not differ substantially from those procedures applied to other vulnerable species, such as marine mammals, sea turtles and seabirds, for which the highest levels of protection and conservation are expected. Potentially useful conservation measures for maintaining elasmobranch populations are already known and include fishing bans in nurseries and breeding/ mating areas, as well as the release of all live specimens at sea, when the fishing gear allows, as in the case of longliners, for which post-capture survival rates have been found to be high (Bradai *et al.*, 2016). The implementation of the precautionary approach is of special importance for elasmobranch species for whom data are limited and assessments of conservation status are often categorized as "Endangered," "Critically Endangered,"' or even "Data Deficient" in the IUCN Red List (IUCN, 2021 and Table 1b). It is therefore imperative to gather information from all the fisheries data collection framework programmes in place and to build a cooperative network of stakeholders, from local fishers and research scientists to national and international organizations. Only through collaboration and clear communication between these different groups with different interests from all the countries bordering the Mediterranean and Black Sea, can the decline of elasmobranch populations be reversed.

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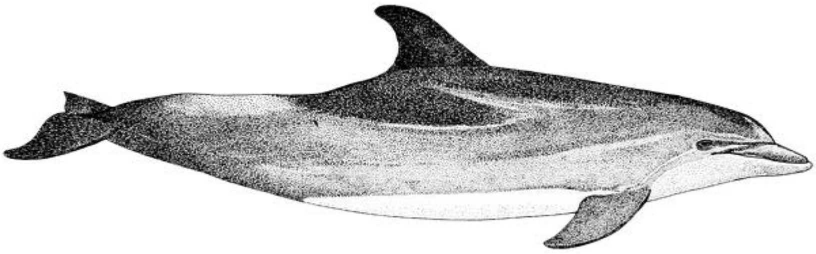
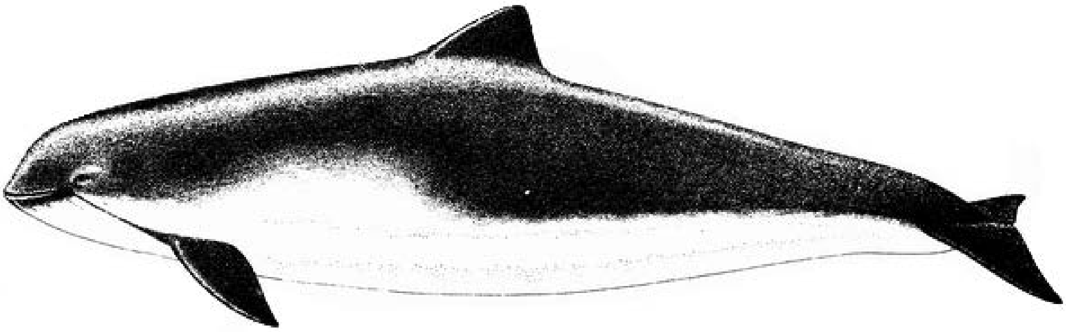
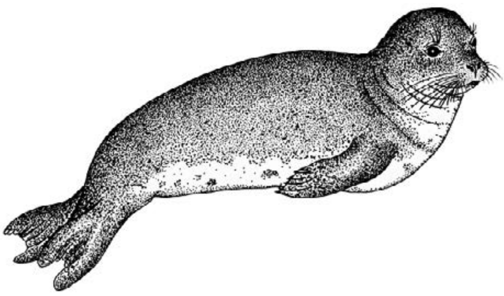
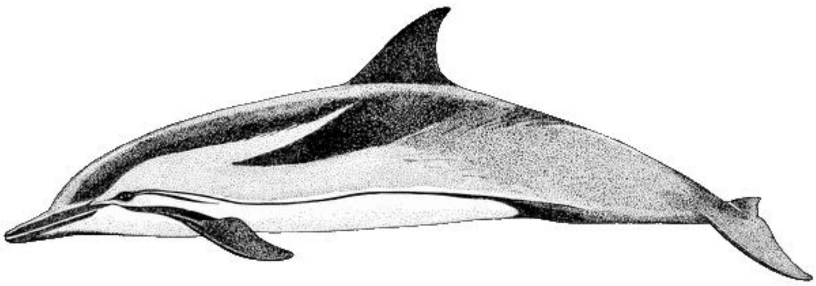


MARINE MAMMALS







Bottlenose dolphins (*Tursiops truncatus*)

4. Marine mammals

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Executive summary

The marine mammal species inhabiting the Mediterranean and the Black Sea belong to two different infraorders of the class Mammalia: Pinnipedia and Cetacea. At present, 18 different cetacean species and three subspecies have been sighted in the Mediterranean and Black Sea. The Mediterranean monk seal (*Monachus monachus*) is the only pinniped species inhabiting the Mediterranean region. Interactions between monk seals and fishers are well documented and described in literature and have always been of great conservation concern, especially in the past. In the Mediterranean, interactions between monk seals and fishing activities often lead to economic consequences for the fishers, such as damage done to fishing gear (for example, holes and ruptures) and loss of catch. Conversely, monk seals may remain entangled themselves when interacting with fisheries. Entrapment of monk seals in fishing gear has been reported from all areas of the species' distribution. The majority of interactions between monk seals and fisheries have been found to occur in coastal areas and especially involve small-scale fisheries using trammel nets, gillnets and longlines and whose activities overlap with Mediterranean monk seal habitats and target the same resources. Indeed, entanglement in gillnets and trammel nets has historically presented a major threat to the species in the absence of adequate management measures. Over recent years, reports on the mortality of Mediterranean monk seals due to fisheries are scarce, following the implementation of protection policies (for example, marine protected areas and closure to fisheries in those areas where monk seals occur) that have significantly helped to reduce the incidence of interactions with fisheries. Signs of population recovery, albeit minimal, have been recognized.

Interactions between cetaceans and different types of fishing gear (for example, trammel nets, gillnets and small-scale set longlines) have long represented a profound concern. Some cetacean species, mainly those inhabiting coastal areas, are attracted to fisheries, which offer them concentrations of "easy food" that can save them profitable energy. In the Mediterranean Sea, large-mesh driftnets targeting sizeable pelagic species, such as swordfish or tunas, represent the main sources of concern. Based on the high incidental catch rates and very high mortality rates of individuals entangled, researchers worldwide have arrived at a consensus around the severe impacts of these nets – resulting from their low selectivity – on cetacean populations, including large species. The intense use of drifting nets began in the Mediterranean in the mid-1980s. It was estimated during the late 1980s and early 1990s, which period corresponds to the peak of driftnet fishery activity, that up to 10 000 cetaceans were incidentally caught each year across the whole Mediterranean. An international moratorium on the use of driftnets to capture large pelagic species anywhere in the Mediterranean or Black Sea was issued in the early 2000s. Since about 2010, the number of new records and publications concerning surveys or studies of cetacean bycatch in different types of fishing gear, especially in the Mediterranean Sea, has drastically reduced. Formerly, at least up until the late 1990s, most cetacean bycatch occurred in large-mesh driftnets; in fact, once large driftnets were dismissed, cetacean bycatch considerably decreased, and currently concerns only sporadically medium-small cetacean species, such as the bottlenose dolphin (*Tursiops truncatus*) and the common dolphin (*Delphinus delphis*).

In contrast, depredation seems to be increasing compared to a few decades ago, now involving different and larger species of dolphins. Depredation can become a conservation issue if it results in an increased probability of bycatch or if it causes fishers to take retaliatory measures against marine mammals. It is therefore clear that the different types of interactions and the probability of entanglement depend on the characteristics of the fishing gear, such as mesh size, yarn strength, depth of deployment and fishing strategies, among other aspects. However, entanglements due to depredation are generally scarce. Recent information on cetacean bycatch has emerged from the Black Sea, where incidental catch of the three cetacean species endemic to the region continues in the context of the Black Sea coastal turbot bottom net fisheries. The high incidental catch mainly involves the Black Sea harbour porpoise (*Phocoena phocoena relicta*), which generally lives in coastal habitats and is impacted much more than the other cetacean species. From a technical point of view, this differential impact is probably due to a combination of both the size of the mesh used in the gillnets and/or trammel nets and the size of the Black Sea harbour porpoise, which is the smallest of the three cetacean species in the Black Sea.

Overall, though it has always been difficult to make reliable estimates of incidental catch, the literature and datasets analysed in this review indicate that in recent years (at least since 2008), the incidental catch of cetaceans in Mediterranean fisheries is decreasing with respect to the past. However, interactions (i.e. incidental catch and/or depredation) between marine mammals and fishing activities still occur, and in some areas (for example, Black Sea), still need to be carefully addressed in order to better understand and prevent any kind of conflict. Solid and standardized monitoring programmes would facilitate the application of emergency measures in areas where negative interactions continue to occur.

4.1 Description of the group

The marine mammal species inhabiting the Mediterranean and the Black Sea belong to two different infraorders of the class Mammalia: Pinnipedia and Cetacea. Taking into account the great differences between these two groups, in terms of life traits, behaviour, interactions with fishers and different types of fishing gear, as well as, most importantly, incidental catch, they will be treated separately in each of the following sections.

4.1.1 Pinnipeds

Pinnipeds (*Pinnipedia*), commonly known as seals, are represented in the area by a single species, the Mediterranean monk seal, *Monachus monachus* (Hermann, 1779). Historically, this species was widely distributed all over the Mediterranean and the Black Sea, and its range extended into North Atlantic waters as well, from northern Morocco to northern Mauritania (Cabo Blanco), through the Canary Islands, Madeira Islands and the Azores (Israëls, 1992; Cebrian, 1998a; Ronald and Healey, 1976, 1982; Johnson and Lavigne, 1999; Brasseur, Reijnders and Verriopoulos, 1997; Johnson *et al.*, 2006). Over centuries, however, monk seals have disappeared from the majority of their range (Cebrian, 1998a, 2005, 2007). The Mediterranean seal population has faced the most severe contraction and fragmentation, beginning at the middle of the last century, as a result of several interrelated factors, such as pollution, human-induced death (e.g. incidental entrapment in fishing gear) and loss of habitat, mainly due to coastal urban development and mass tourism (Johnson and Lavigne, 1998).

Previous records indicate that *M. monachus* was widely distributed across the entire Black Sea area, along the coasts of the Russian Federation, Ukraine, Romania, Bulgaria and Turkey (Boulva, 1979). Some studies carried out since the 1960s have revealed that, beginning after the Second World War, the species' presence was progressively eradicated from the northern part of the basin and that subsequently, its distributional range was left concentrated only along the central Black Sea coast of Turkey (Mursaloğlu, 1964; Öztürk, 1994; Kıraç and Savaş, 1996; Sergeant *et al.*, 1978; Berkes *et al.*, 1979). Dobrovolov and Yoneva (1996) reported some sightings of monk seals along the southern Bulgarian coast, where Spiridonov and Spassov (1998) reported the presence of only two or three individuals. The survey carried out by Güçlüsoy *et al.* (2004) over the period 1994–1998 demonstrated that while 120 seal sightings were reported by interviews with fishers along the entire Turkish coast of the Black Sea, these sightings corresponded to a monk seal population of only two to three individuals surviving along the central coast of the Black Sea. Nowadays, though some individuals can still be found in the Marmara Sea (Inanmaz, Degirmenci and Gücü, 2014), *M. monachus* can be considered no longer present in the Black Sea (Kiraç, 2001).

With regard to the whole Mediterranean, the monk seal population as estimated by means of fieldwork (e.g. observations, questionnaires, etc.) was reported towards the end of the twentieth century as totalling a minimum of around 700 individuals, with the largest subpopulation found in Greece (around 235–300 seals) (Cebrian, 1998a).

Regular reproduction within the Mediterranean Sea is thought to persist currently only in a few breeding areas off Greece, and in parts of Turkey and Cyprus. As a whole, the eastern Mediterranean population is estimated to consist of about 350 mature individuals (Karamanlidis *et al.*, 2015). The most important assemblage, of 85 to 120 individuals, is found in the Cyclades Islands of Greece (southern Aegean Sea), where active reproduction and at least 24 yearly births have been verified across 30 caves (Cebrian, 1998a). Important populations were also identified in the northern part of the Sporades Islands (>35 seals) and at Zakynthos Island (15–22 seals) (Cebrian, 1998a, 2008). A review of the abundance and distribution of the monk seal population was prepared by Notarbartolo di Sciara and Kotomatas (2016) as an update to the work of Notarbartolo di Sciara *et al.* (2009); they reported important breeding concentrations of monk seals in Greek waters: Gyaros Island (65–70 individuals); northern Sporades Islands (>50 individuals); Kimolos and Polyaigos Islands (<50 individuals); North Karpathos and Saria Islands (>20 individuals); Ionian Islands: Kefalonia, Lefkada, Ithaca and Zakynthos (about 20 individuals). Monk seals in Turkish Mediterranean waters are scattered from the Dardanelles to the border with Syria, with three main breeding concentrations known: in the northern Aegean (35 individuals), southern Aegean (<30 individuals) and on the Mediterranean coast (>40 individuals). In Cyprus, a small population of 3–17 individuals was judged to exist in 2006–2007 and evidence remains that pupping still occurs, even if the contribution from Cyprus is now minimal (<10 individuals) (Notarbartolo di Sciara and Kotomatas, 2016).

Between 2009 and 2016, 66 monk seal records were reported along the coast of Israel; while most sightings may refer to a single individual, there is evidence that at least two seals were present (Scheinin *et al.*, 2011; Bundone *et al.*, 2016).

Vagrant individuals have been episodically sighted elsewhere in the Mediterranean, suggesting a possible return to some of their formerly inhabited areas, such as Albania, Croatia, Egypt, Israel, Italy, Lebanon, Libya (particularly Cyrenaica), Spain and Syria (Cebrian, 1995, 2005; Monachus Guardian, 2010, 2012; Mo, 2011; Huber, 2014; Notarbartolo di Sciara and Kotomatas, 2016; Alfaghi *et al.*, 2013; Gomerčić *et al.*, 2011).

Outside the Mediterranean Sea, other subpopulations still exist in the Atlantic Ocean, around Cabo Blanco (over 360 individuals) and the Madeira Islands (Portugal) (less than 50 individuals) (Fundación CBD Habitat, 2020; Karamanlidis *et al.*, 2015). Conservation measures introduced over the last 30 years have helped to curb population decline, and there is evidence of recent small increases in these monitored subpopulations.

PLATE 1
Mediterranean monk seal (*Monachus monachus*)

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4.1.2 Cetaceans

Cetaceans (infraorder: Cetacea), namely whales, dolphins and porpoises, are represented in the Mediterranean Sea by at least 21 species (12 of which occur regularly, while the other eight only do occasionally) and three subspecies, endemic to the Black Sea: the Black Sea common dolphin (*Delphinus delphis ponticus*) (Barabasch-Nikiforov, 1935), the Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*) (Barabash-Nikiforov, 1940) and the Black Sea harbour porpoise (*Phocoena phocoena relicta*) (Abel, 1905) (Table 1). The status of conservation and the range of size and distribution of the different cetacean populations in the Mediterranean and the Black Sea vary greatly, depending on the species and areas. To a greater or lesser extent, all cetacean species may interact with different fishing gears and fishing activities. For this reason, assessing the abundance and distribution of the different species is essential in order to better understand and evaluate the relative importance of various kinds of interactions with fishing activities and the impacts of incidental catch (Notarbartolo di Sciara, Podestà and Curry, 2016).

The striped dolphin (*Stenella coeruleoalba*) is the most abundant and widespread cetacean species in the whole Mediterranean basin, though it is generally more abundant in the western Mediterranean. In the past, and more recently, population estimates have been calculated in several areas using different methods (for example, through vessel and aerial surveys). Numbers show a high variability, from a few thousand in limited local populations to more than a hundred thousand at the basin scale (Aguilar, 2000; Forcada and Hammond, 1998; Forcada, Notarbartolo di Sciara and Fabbri, 1995a; Forcada *et al.*, 1994; Gómez de Segura *et al.*, 2006: Fortuna *et al.*, 2007; Panigada *et al.*, 2011, 2017; Laran *et al.*, 2017; Benmessaoud *et al.*, 2018).

The common bottlenose dolphin (*Tursiops truncatus*) is the most common species in coastal and neritic areas and, for this reason, is considered the species that interacts the most with small-scale fishing activities. Studies have been carried out on several populations along the Mediterranean coasts of Spain, Italy, Greece, Croatia (Bearzi, Fortuna and Reeves, 2009) and Tunisia (Benmessaoud *et al.*, 2018). The same phenomenon applies to the Black Sea subspecies, the Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*).

The common dolphin (*Delphinus delphis*) has shown a steep decline in its abundance and distribution in the Mediterranean basin over the last hundred years due to the impacts of human activities – not only of fisheries, but also of pollution and habitat loss (Bearzi *et al.*, 2003, 2005). Currently, the most abundant populations occur in the Greek Ionian Sea, the Alboran Sea and off the northern coast of Africa.

Population estimates for all other cetacean species present in the Mediterranean are much more difficult to calculate and results are less reliable. However, these abundances are certainly lower than those of the species described above; for example, the estimate for the fin whale

PLATE 2
Black Sea dolphins

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Black Sea common dolphin (*Delphinus delphis ponticus*)

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Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*)

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Black Sea harbour porpoise (*Phocoena phocoena relicta*)

Table 1 – Cetacean species in the Mediterranean and the Black Sea

Common name	Scientific name
Striped dolphin	*Stenella coeruleoalba* (Meyen, 1833)
Common bottlenose dolphin Black Sea bottlenose dolphin	*Tursiops truncatus* (Montagu, 1821) *Tursiops truncatus ponticus**
Common dolphin Black Sea common dolphin	*Delphinus delphis* (Linnaeus, 1758) *Delphinus delphis ponticus**
Black Sea harbour porpoise	*Phocoena phocoena relicta**
Risso's dolphin	*Grampus griseus* (G. Cuvier, 1812)
Rough-toothed dolphin	*Steno bredanensis* (Cuvier in Lesson, 1828)
Long-finned pilot whale	*Globicephala melas* (Traill, 1809)
Cuvier's beaked whale	*Ziphius cavirostris* (Cuvier, 1823)
Killer whale	*Orcinus orca* (Linnaeus, 1758)
Sperm whale	*Physeter macrocephalus* (Linnaeus, 1758)
Fin whale	*Balaenoptera physalus* (Linnaeus, 1758)
False killer whale	*Pseudorca crassidens* (Owen, 1846)
Common minke whale	*Balaenoptera acutorostrata* (Lacépède, 1804)
Humpback whale	*Megaptera novaeangliae* (Borowski, 1781)
Indian Ocean humpback dolphin	*Sousa plumbea* (Cuvier, 1829)
Sei whale	*Balaenoptera borealis* (Lesson, 1828)
North Atlantic right whale	*Eubalaena glacialis* (P.L.S. Müller, 1776)
Dwarf sperm whale	*Kogia sima* (Owen, 1866)
Northern bottlenose whale	*Hyperoodon ampullatus* (Forster, 1770)
Blainville's beaked whale	*Mesoplodon densirostris* (Blainville, 1817)
Gervais' beaked whale	*Mesoplodon europaeus* (Gervais, 1855)

Notes:
In grey, species recorded only occasionally (modified from Pace, Tizzi and Mussi, 2015).
*Endemic subspecies of the Black Sea.

(*Balaenoptera physalus*) comes to around one thousand individuals, the majority of which are found in the western Mediterranean (Panigada *et al.*, 2017), though seasonal variation and different estimates were reported by Laran *et al.* (2017). For all the other cetacean species, no estimates are available at the basin scale, only at the local level. A few hundred individuals have been estimated for each of the following species: Risso's dolphin (*Grampus griseus*), Cuvier's beaked whale (*Ziphius cavirostris*), long-finned pilot whale (*Globicephala melas*), false killer whale (*Pseudorca crassidens*) and sperm whale (*Physeter macrocephalus*) (Notarbartolo, Podestà and Curry, 2016). Finally, two other species occur unexpectedly at opposite sides of the Mediterranean: a small population of killer whales (*Orcinus orca*) – less than 40 individuals (Esteban *et al.*, 2016) – inhabits the area of the Strait of Gibraltar, while the elusive rough-toothed dolphin (*Steno bredanensis*) is present in the easternmost part of the Mediterranean, though its abundance is unknown (Kerem *et al.*, 2016).

In the Black Sea, human activities have strongly impacted the populations of the three cetacean subspecies inhabiting the basin. After the ban on direct hunting, several studies were carried out, mainly within the last 20 years, aimed at estimating cetacean abundance in the area by means of vessel and aerial surveys (Dede (cited in IWC, 2004); Krivokhizhin, 2009; Komakhidze and Goradze, 2005; Sokolov, Yashkin and Yukhov, 1997; Birkun *et al.*, 2002, 2003, 2004; Krivokhizhin *et al.*, 2006; Paiu *et al.*, 2019). The most recent estimates for population abundance of the three subspecies, based on surveys carried out along the western coasts of the basin, come to around 60 000 individuals for the Black Sea common dolphin (*Delphinus delphis ponticus*), 26 000 for the Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*) and 29 000 for the Black Sea harbour porpoise (*Phocena phocena relicta*) (Birkun *et al.*, 2014).

In general, both the diversity and abundance of cetaceans are higher in the western Mediterranean basin. Interactions with fisheries, including incidental catch, depend on the habitat use, behaviour, size and abundance of the cetacean species involved. Similarly, each type of fishing gear represents a potential site of entanglement/entrapment, depending on the fishing gear characteristics (net mesh size, hook type), structure, surface area and time of displacement at sea, as well as fishing areas and strategies.

4.2 Historical records of interactions with fisheries

4.2.1 Pinnipeds

Interactions between Mediterranean monk seals (*Monachus monachus*) and fishers, fishing boats and fishing gear are well documented and described in the relevant literature and are of great conservation concern (Cebrian, 1998a, 2005, 2008; Güçlüsoy, 2008; Güçlüsoy and Savas, 2003; Karamanlidis *et al.*, 2008; Hale *et al.*, 2011). In the Mediterranean, interactions between monk seals as well as other marine mammals (see Section 4.3) with fishing activities often lead to economic consequences for the fishers, such as damage to fishing gear (for example, holes and ruptures), loss of catch, or depredation (Schultze-Westrum, 1976; Boulva, 1979; Berkes, 1982; Cebrian, 1998a; Ronald and Healey, 1974; Marchessaux and Duguy, 1977; Cebrian and Anagnostopoulou, 1995; Cebrian, Anagnostopoulou and Anagnostopoulou, 1995; Berkes *et al.*, 1979; Ríos *et al.*, 2017). The typical damage caused by seals consists of holes about 20 to 30 cm in diameter (Marchessaux and Duguy, 1977) and a characteristic triangular three-hole pattern, corresponding to the animal's mouth and fore-flippers (Goedicke, 1981; Johnson, 1988). On the other hand, when interacting with fisheries, monk seals may remain entangled themselves (Avellá, 1986; Harwood, 1987; Cebrian, 1998a; Öztürk, 1998b; Ronald and Duguy, 1979; Avellá and González, 1989; Cebrian and Vlachoutsikou, 1992; Öztürk and Dede, 1995; Panou, Jacobs and Panos, 1993; Berkes *et al.*, 1979). Incidental entanglement, coupled with increasing fishing effort and the introduction of new materials for fishing gear, has been considered one of the major problems facing monk seals in different Mediterranean areas (Öztürk, 1998a; Cebrian, 2005; Johnson and Lavigne, 1998, 1999; Cebrian, Anagnostopoulou and Anagnostopoulou, 1995; Androukaki *et al.*, 1999).

Entrapment of monk seals in fishing gear has been reported from all areas of the species' distribution. Although analysis of historical records shows that seals can be injured by many types of fishing gear, they appear to be most vulnerable to passive gear (i.e. stationary nets set on the bottom) and abandoned nets (i.e. the ghost fishing effect) (Tudela, 2004). The majority of interactions between monk seals and fisheries have been found to occur in coastal areas and especially involve small-scale fisheries using trammel nets, gillnets, longlines or traps, whose activities overlap with *M. monachus* habitats and target the same resources. Entanglements have been historically recorded on baited hooks in the Danube Delta (Schnapp, Hellwing and Chizelea, 1962), on tuna nets near Cassis, in southeastern France, in the 1930s and 1940s (Cheylan, 1974; Sergeant *et al.*, 1978), in trammel nets in the Bay of Tunis (Ben Othman, Mokhtar and Quignard, 1971) and in coastal gillnets in Greece (Northridge, 1984). Some authors have described other types of fishing gear as being responsible for entanglement including trawl nets and purse seines (Brusina, 1889; Harwood, 1987; Israëls, 1992; Cebrian, 1998a; Cebrian and Vlachoutsikou, 1992; Kiraç and Savas, 1996; Johnson and Karamanlidis, 2000; Panou, Beudels and Harwood, 1987; Panou, Jacobs and Panos, 1993; Güçlüsoy, Johnson and Karamanlidis, 2002), though these gear types have not been considered to present a problem for monk seals (Cebrian, 1998a; Cebrian and Vlachoutsikou, 1994). Young monk seals have also been reported as bycatch of *lampara* fisheries (a kind of purse seiner) and are considered more vulnerable, as they are worse equipped to escape from entrapment than adult specimens (Panou, Beudels and Harwood, 1987).

In the western Mediterranean, the incidental catch of monk seals in trammel nets has been recorded commonly in Italy since the 1940s (Di Natale and Notarbartolo di Sciara, 1990), while captures were noted occasionally from coastal gillnets in Morocco (Maigret, 1990) and in Algeria (Di Natale and Notarbartolo di Sciara, 1990); eight specimens died in Algeria between 1987 and 1990 due to interactions with humans (Boutiba, 1996). A similar scenario was observed for the small colony of monk seals inhabiting a cave on Gorgona Island (Tyrrhenian Sea, Italy): eight individuals perished due to entanglement in the nets of a local fisher during the 1980s (Guarrera, 1999).

However, an analysis of historical data on the causes of death for monk seals in the eastern Mediterranean and along the North African coast from 1970 to 2000 reveals that entanglements in fisheries have progressively declined. Indeed, Ronald and Healey (1974), basing their findings on interviews with fishers conducted during 1971 and 1972 (Kos, Greece), estimated that only up to four seals were caught annually in local nets, dead or alive; some years later, Jacobs and Panou (1988) reported that only eight of 34 animals died due to incidental capture in nets in the Ionian Sea, while the other 26 died from undetermined causes.

A differential vulnerability to entanglement in nets has been suggested for adult and young monk seals in the Cilician basin, off Turkey (Yediler and Gücü, 1997). It was observed that both trammel and gill nets were not strong enough to trap adults, whereas some pups were found entangled in these types of fishing nets over a five-year period. Cebrian, Anagnostopoulou and Anagnostopoulou (1995) also reported several records of pups drowned in trammel nets in the Cyclades. Indeed, pups foraging together with their mothers likely learn to eat fish from nets, thus becoming vulnerable to entanglement (Cebrian, 1995, 1998a). Kiraç and Savas (1996), and Yediler and Gücü (1997) furthermore reported a total of 13 seal deaths between 1965 and 1994 in Mediterranean and Black Sea Turkish waters.

Interviews with fishers revealed that, with very few exceptions, seals were considered to represent competition for fishers themselves. Goedicke (1981) made an attempt to ascertain fishers' attitudes towards seals and to determine the extent of net damage and loss of fish attributable to seals. Estimates of net damage ranged between USD 215 and 380 annually per boat. Cebrian (1998a) considered that, due to the weakness and methodological mistakes in data collection from fishers' interviews, unreliable conclusions had been drawn in some cases regarding the interpretation of seal–fisheries interactions, thus exaggerating interactions with nets. This situation results from fishers tending to report every time they suffer damage to their nets, but not doing so when many fishing trips are carried out without incident. In fact, onboard observations confirmed that most net damage was due to other causes, especially contact and entanglement of the gear along the sea bottom.

An additional investigation to determine the extent of net damage caused by monk seals was made by Panou, Jacobs and Panos (1993). During a survey around the islands of Kefalonia, Ithaca and Lefkada in the Greek part of the Ionian Sea, they noted that out of 1 864 fishing trips monitored over the survey period, only 136 instances (7.3 percent) of reported damage were clearly caused by monk seals. Inshore trammel nets suffered the highest frequency of seal-related damages, followed by offshore trammel nets and gillnets. Conversely, set longlines sustained the least damage, possibly because of the fine nylon lines used. Moreover, they reported, from interviews and literature, 34 cases of seal mortality between 1963 and 1987. Analysis of long-term field monitoring data in the southern Ionian Sea has also shown that monk seal interactions with static nets became much less frequent as nets were placed further away from an occupied cave. Indeed, net damage dropped to very low levels at distances along the coast greater than five nautical miles from seal caves, and all the way to insignificance at distances more than ten nautical miles from seal caves (Cebrian, 2008). Regarding seasonality, lower levels of interaction between seals and nets have been observed in the spring in the southern Ionian Sea (Cebrian, 1998b, 2008), which is probably related to monk seals fasting during this peak period of moulting and the consequent reduction in fish predation. In contrast, damage done by dolphins in the same area showed no seasonal difference.

Cebrian (1995) indicated that damage done by seals to fish traps was common in the past in Croatia, while damage to nets was reported as rare in the Adriatic when a monk seal population was still present there.

Androukaki *et al.* (1999) reported the results of a survey carried out in Greece between 1991 and 1995. Over this period, 59 dead monk seals were examined (25 by necropsy and 34 by different methods), while other information was added for 20 cases of dead seal strandings between 1985 and 1990. Considering all 79 cases, the most frequent cause of death (32 percent) was interactions with fisheries, followed by natural causes (16 percent) and other unspecified accidents (13.9 percent); however, for 30 individuals (38 percent) the cause of death could not be determined. In the same paper, an extensive review of the relevant literature was carried out, in which the authors critically revised the cause of death for 182 monk seals in Greek waters in previous years, prior to 1985. The results showed that interactions with fishing activities represented the cause of death in 65 percent of these cases (118 individuals).

Entrapment in fishing nets has also been implicated in the death of a monk seal pup in the Foça Specially Protected Area, located at the northeastern entrance of Izmir Bay, Turkey and in its immediate vicinity in February 1997 and of an adult seal found at Kaş in southwestern Turkey in 1999 (Johnson, ed., 1999; Güçlüsoy *et al.*, 2004).

The entanglement of seals in set fishing gear appeared to represent a constant issue for *M. monarchus* in all the studied regions, except the Black Sea and Marmara Sea (Güçlüsoy *et al.*, 2004). As stated already, the monk seal is probably almost extinct in the Black Sea, though occasional sightings have been recorded over the past 25 years along the central coast of Turkey and Bulgaria and some recent records exist from the Marmara Sea. Only Schnapp, Hellwing and Chizelea (1962) have reported some old cases of incidental catch of monk seals by longlines along the Bulgarian coast.

Entanglement in gillnets and trammel nets has historically been a major threat to *M. monachus* in the absence of related management measures, especially in certain areas with more robust populations, where drowning in nets surpassed 37.5 percent of the mortality records (see Table 5), as in the Cyclades, which are surrounded by shallow waters (Cebrian, Anagnostopoulou and Anagnostopoulou, 1995) and the eastern Aegean (Öztürk, 1998a).

4.2.2 Cetaceans

Though no whaling activities have regularly targeted large cetaceans in the Mediterranean Sea, except over limited periods in certain places (Cabrera, 1925; Sanpera and Aguilar, 1992; Aguilar and Borrell, 2007; Bernal-Casasola *et al.*, 2016), small cetaceans (as well as monk seals) have been caught for a variety of reasons in the past (Cebrian, 1998a; Bearzi, 2002; Bearzi, Holcer and Notarbartolo di Sciara, 2004; Androukaki *et al.*, 2006; Birkun *et al.*, 2014; Karamanlidis *et al.*, 2015), including for: museum collections and research (Richard, 1936); military target practice (Minà Palumbo, 1868; Cornalia, 1872; Parona, 1896, 1908; Anonymous, 1903; Cagnolaro, 1977; Littardi, Rosso and Wurtz, 2004); and hunting by fishers who perceived these animals as direct competitors (Lepri, 1914; Borri, 1927a, 1928b; Brunelli, 1932; Bolognari, 1949; Tamino, 1953; Cyrus, 1969; Avellà, 1979; Poggi, 1986; Öztürk, 1998a, 2007; Kiraç and Savaş, 1996; Dede, Tonay and Öztürk, 2015; Androukaki *et al.,* 1999; Notarbartolo di Sciara *et al.*, 2003; Danyer *et al.* 2013a).

In addition, interactions between cetaceans and different types of fishing gear (e.g. trammel nets, gillnets and small-scale set longlines) have long represented a profound concern. Some cetacean species, mainly those inhabiting the coastal areas, are attracted to fisheries, which offer them concentrations of "easy food," saving them profitable energy. This type of interaction (i.e. depredation, see Section 4.4), in addition to catch removal, can cause significant damage to set nets (such as holes and breakages) and generate economic losses for fishers.

As for the monk seal, information on the incidental catch of cetaceans in fishing gear in the Mediterranean used to be only anecdotally collected; beginning in the 1960s and 1970s, however, interest developed from a statistical point of view. Indeed, concerns about marine mammal conservation led to the implementation of scientific studies in this field, including more precise record-keeping, interviews with fishers, surveys and direct observations at sea, and assessments of the causes of stranding.

In the Black Sea, the regular recording of incidental catch began in the former Soviet Union in 1968 and lasted until 1993, during which period information on cetacean bycatch was partly collected in all the other countries of the Black Sea as well. Set nets targeting Black Sea turbot (*Scophthalmus maximus*) and piked dogfish (*Squalus acanthias*) were found to cause the greatest bycatch impacts on Black Sea cetaceans.

In the Mediterranean Sea, large mesh driftnets targeting sizeable pelagic species, such as swordfish (*Xiphias gladius*) or albacore tuna (*Thunnus alalonga*), represented the main sources of concern. Worldwide, researchers arrived at a consensus on the severe impacts of these nets on cetacean populations, including large species, based on the high incidental catch rates and very high mortality rates of individuals entangled. The intense use of drifting gillnets began in the Mediterranean in the mid-1980s (Di Natale, 1990a, 1990b, 1990c, 1990d, 1990e) and was introduced widely in Algeria, France, Greece, Malta, Morocco, Spain and Turkey (Di Natale and Notarbartolo di Sciara, 1994; Silvani, Gazo and Aguilar, 1999). As a result, the number of vessels rapidly expanded to over 1 000 by 1990 (IWC, 1994); for example, the Italian driftnet fleet was reported to be the biggest in the Mediterranean, increasing by 57 percent between 1987 and 1990, with up to about 700 boats. One of the main issues with driftnets targeting large pelagic fish species involves the nets' low selectivity, given that swordfish represented nearly 50 percent in weight of the Italian driftnet catch, but only 18 percent by number (Di Natale, 1996). Moreover, very few specimens of marine mammals caught were able to be disentangled and released alive;

furthermore, adults of the larger species (for example, sperm whales and pilot whales), though often still alive when the net was retrieved, were generally set adrift for days before death (Mussi *et al.*, 2004).

It was estimated at the end of the 1980s and beginning of the 1990s, which period corresponds to the peak of driftnet fishery activity, that a total of over 8 000 cetaceans were incidentally caught each year from Italian seas and up to 10 000 cetaceans across the whole Mediterranean (Di Natale 1990a, 1990b, 1990c, 1990d, 1990e, 1992; Notarbartolo di Sciara, 1990; IWC, 1994; UNEP and IUCN, 1994; Cagnolaro and Notarbartolo di Sciara, 1992; Di Natale and Notarbartolo di Sciara, 1994; Forcada and Hammond, 1998; Silvani, Gazo and Aguilar, 1999). Of these, the striped dolphin (*Stenella coeruleoalba*) was the most impacted species by number, though the effects were more severe on larger species, such as the sperm whale (*Physeter macrocephalus*) and the long-finned pilot whale (*Globicephala melas*), taking into account their population dynamics and abundance. In 1992, the United Nations General Assembly established an international moratorium prohibiting driftnets longer than 2.5 km. Moreover, a prohibition on catching certain pelagic fish species was introduced by the European Union for all its Member States' vessels on 1 January 2002. Afterwards, Recommendation GFCM/29/2005/3 prohibiting the use of driftnets for fisheries of large pelagic species adopted by the General Fisheries Commission for the Mediterranean (GFCM) (GFCM, 2021) and Resolution A/3.1 related to the use of driftnets adopted by the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) (ACCOBAMS, 2021) introduced a prohibition on the use of driftnets of any length to capture large pelagic species anywhere in the Mediterranean or Black Sea. Despite these bans and recommendations, together with some programmes put in place in different countries addressing drifting gear replacement, driftnet fisheries continued operations for several years afterwards in certain Mediterranean areas (Cornax, 2009). Given the historical importance of this activity, and in order to paint a better picture of the importance of driftnets in cetacean bycatch in the Mediterranean, the main data collected from the relevant literature are presented in Table 2.

Table 2 – Incidental catch of cetaceans in pelagic driftnets

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Di Natale and Mangano, 1981	-	GND	Western Mediterranean	Italy	*Balaenoptera acutorostrata*	4	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GND	Western Mediterranean	France	*Balaenoptera acutorostrata*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GND	Western Mediterranean	France	*Stenella coeruleoalba*	4	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GND	Western Mediterranean	Italy	*Tursiops truncatus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GND	Western Mediterranean	Spain	*Tursiops truncatus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GND	Western Mediterranean	Italy	*Grampus griseus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GND	Western Mediterranean	Italy	*Physeter macrocephalus*	16	-	-	-
Di Natale and Mangano, 1983b	1978–1982	GND	Western Mediterranean	Italy	*Physeter macrocephalus*	20	-	-	-

Table 2 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Notarbartolo di Sciara, 1990	1986–1988	GND	Western Mediterranean	Italy	*Stenella coeruleoalba*	68	-	-	-
Notarbartolo di Sciara, 1990	1987–1988	GND	Western Mediterranean	Italy	*Physeter macrocephalus*	24	-	-	-
Notarbartolo di Sciara, 1990	1988–1988	GND	Western Mediterranean	Italy	*Tursiops truncatus*	13	-	-	-
Notarbartolo di Sciara, 1990	1988–1989	GND	Western Mediterranean	Italy	*Globicephala melas*	10	-	-	-
Notarbartolo di Sciara, 1990	1988–1990	GND	Western Mediterranean	Italy	*Grampus griseus*	5	-	-	-
Notarbartolo di Sciara, 1990	1988–1991	GND	Western Mediterranean	Italy	*Ziphius cavirostris*	2	-	-	-
Notarbartolo di Sciara, 1990	1988–1991	GND	Western Mediterranean	Italy	Unidentified	28	-	-	-
Podestà and Magnaghi, 1989	1988	GND	Western Mediterranean	Italy (Ligurian Sea)	*Stenella coeruleoalba*	18	-	-	-
Podestà and Magnaghi, 1989	1988	GND	Western Mediterranean	Italy (Ligurian Sea)	*Globicephala melas*	4 + 5[2]	-	-	-
Podestà and Magnaghi, 1989	1988	GND	Western Mediterranean	Italy (Ligurian Sea)	*Physeter macrocephalus*	3[2]	-	-	-
Podestà and Magnaghi, 1989	1988	GND	Western Mediterranean	Italy (Ligurian Sea)	*Grampus griseus*	2	-	-	-
Podestà and Magnaghi, 1989	1988	GND	Western Mediterranean	Italy (Ligurian Sea)	*Balaenoptera physalus*	1	-	-	-
Podestà and Magnaghi, 1989	1988	GND	Western Mediterranean	Italy (Ligurian Sea)	Unidentified	4	-	-	-
Reeves and Notarbartolo di Sciara, eds., 2006	1986–2000	GND	Western Mediterranean	Italy	*Physeter macrocephalus*	64	-	-	-
Silvani *et al.*, 1999	1992	GND	Western Mediterranean	Spain	*Delphinus delphis*	6	-	-	13 sets/6
Silvani *et al.*, 1999	1993	GND	Western Mediterranean	Spain	*Delphinus delphis*	6	-	-	27 sets/6
Silvani *et al.*, 1999	1993	GND	Western Mediterranean	Spain	*Stenella coeruleoalba*	5	-	-	27 sets/5
Silvani *et al.*, 1999	1994	GND	Western Mediterranean	Spain	*Stenella coeruleoalba*	15	-	-	54 sets/15
Silvani *et al.*, 1999	1994	GND	Western Mediterranean	Spain	*Delphinus delphis*	15	-	-	54 sets/15
Silvani *et al.*, 1999	1993	GND	Western Mediterranean	Spain	*Stenella coeruleoalba* *Delphinus delphis*	-	366/year	0.1/km	81 sets
Silvani *et al.*, 1999	1994	GND	Western Mediterranean	Spain	*Stenella coeruleoalba* *Delphinus delphis*	-	289/year	0.1/km	81 sets
Di Natale *et al.*, 1992; Di Natale, 1995	1990–1992	GND	Western Mediterranean	Italy	*Stenella coeruleoalba*	12 + 1[2]	-	0.015/km	100 trips/13
Di Natale *et al.*, 1992; Di Natale, 1995	1990–1992	GND	Western Mediterranean	Italy	*Globicephala melas*	1	-	-	100 trips/1

Table 2 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Di Natale *et al.*, 1992; Di Natale, 1995	1990–1992	GND	Western Mediterranean	Italy	*Ziphius cavirostris*	1[2]	-	-	100 trips/1
Di Natale, 1995	1990–1991	GND	Western Mediterranean	Italy	*Stenella coeruleoalba*	-	2 512/year	-	100 trips
Di Natale, 1995	1990–1991	GND	Western Mediterranean	Italy	*Globicephala melas*	-	234/year	-	100 trips
Di Natale, 1995	1992–1991	GND	Western Mediterranean	Italy	*Grampus griseus*	-	146/year	-	100 trips
Di Natale, 1995	1991–1993	GND	Western Mediterranean	Italy	*Tursiops truncatus*	-	65/year	-	100 trips
Di Natale, 1995	1991–1994	GND	Western Mediterranean	Italy	*Physeter macrocephalus*	-	18/year	-	100 trips
Di Natale, 1995	1991–1995	GND	Western Mediterranean	Italy	*Ziphius cavirostris*	-	4/year	-	100 trips
Di Natale, 1995	1991–1996	GND	Western Mediterranean	Italy	*Balaenoptera physalus*	-	2/year	-	100 trips
University of Barcelona, 1995	1993–1994	GND	Western Mediterranean	Spain	*Physeter macrocephalus*	9 + 3[2]	-	-	-
Làzaro and Martin, 1999	-	GND	Western Mediterranean	Spain	*Physeter macrocephalus*	15	-	-	-
Mussi *et al.*, 2004	2004	GND	Western Mediterranean	Italy	*Physeter macrocephalus*	5[2]	-	-	-
Reeves and Notarbartolo di Sciara, eds., 2006	1971–2004	GND	Western Mediterranean	Italy, France, Spain	*Physeter macrocephalus*	229	-	-	-
Tudela *et al.*, 2005	2002–2003	GND	Western Mediterranean	Morocco (Alboran Sea)	*Stenella coeruleoalba*	128	-	0.06/km	369 sets/128
Tudela *et al.*, 2005	2002–2003	GND	Western Mediterranean	Morocco (Alboran Sea)	*Delphinus delphis*	108	-	0.06/km	369 sets/108
Tudela *et al.*, 2005	2002–2003	GND	Western Mediterranean	Morocco (Alboran Sea)	*Stenella coeruleoalba* *Delphinus delphis*	-	3 110–4 184/year	-	369 sets
Tudela *et al.*, 2005	2003–2003	GND	Western Mediterranean	Strait of Gibraltar	*Stenella coeruleoalba* *Delphinus delphis*	-	11 189–15 127/ year	-	369 sets
Bănaru *et al.*, 2010	2000–2003	GND	Western Mediterranean	France	*Stenella coeruleoalba*	58	326/year (in 2000)	-	329 sets/58
Bănaru *et al.*, 2010	2000–2003	GND	Western Mediterranean	France	*Globicephala melas*	1	-	-	329 sets/1
David *et al.*, 2010	2002–2006	GND	Western Mediterranean	France	*Stenella coeruleoalba*	100	81–250/ year	0.034/km	459 sets/100
David *et al.*, 2010	2002–2006	GND	Western Mediterranean	France	*Globicephala melas*	2	-	-	460 sets/2
David *et al.*, 2010	2002–2006	GND	Western Mediterranean	France	*Grampus griseus*	1	-	-	461 sets/1
David *et al.*, 2010	2002–2006	GND	Western Mediterranean	France	*Delphinus delphis*	1	-	-	462 sets/1
David *et al.*, 2010	2004–2005	GND	Western Mediterranean	France	*Physeter macrocephalus*	1 + 3[2]	-	-	463 sets/4
Panou and Tselentis, 1989	1989	GND	Central Mediterranean	Greece	*Ziphius cavirostris*	1[2]	-	-	-
Bradai and Ghorbel, 1998	1995	GND	Central Mediterranean	Tunisia	*Balaenoptera acutorostrata*	1	-	-	-

Table 2 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Bradai and Bouain, 1994	-	GND	Central Mediterranean	Tunisia	*Megaptera novaeangliae*	1	-	-	-
Öztürk *et al.*, 2001	1999–2000	GND	Eastern Mediterranean	Turkey (Aegean Sea)	*Stenella coeruleoalba*	13	-	-	-
Öztürk *et al.*, 2001	1999–2000	GND	Eastern Mediterranean	Turkey (Aegean Sea)	*Delphinus delphis*	4	-	-	-
Öztürk *et al.*, 2001	1999–2000	GND	Eastern Mediterranean	Turkey (Aegean Sea)	*Grampus griseus*	2	-	-	-
Akyol *et al.*, 2005	2002	GND	Eastern Mediterranean	Turkey (Aegean Sea)	*Delphinus delphis*	18 + 5[2]	-	-	-
Öztürk and Dede, 2002	2002	GND	Eastern Mediterranean	Turkey (Aegean Sea)	*Physeter macrocephalus*	1[2]	-	-	-
Akyol and Cehyan, 2012[1]	2010–2011	GND	Eastern Mediterranean	Turkey (Aegean Sea)	*Stenella coeruleoalba*	2 + 5[2]	-	-	-

Notes: GND = driftnet.

In grey data collected before 2008.

1. The European Union, the GFCM and ICCAT enforced regulations prohibiting the use of driftnets in the Mediterranean. Afterwards, driftnetting in Turkey was banned in 2006 and, as a result, pelagic gillnetting tended to decrease. However, the Turkish fisheries authority and ICCAT gave limited permission for traditional pelagic gillnetting in Turkish waters until July 2011, when this fleet stopped its activity (Akyol and Ceyhan, 2012).
2. Number of individuals released alive.

In contrast, bottom trawls and midwater pair trawls appeared to present fewer risks to cetaceans (Northridge, 1984, 1991; Reeves, Read and Notarbartolo di Sciara, eds., 2001). From old records, Duguy *et al.* (1983a, 1983b) reported the incidental capture of one striped dolphin (*Stenella coeruleoalba*) and four common bottlenose dolphins (*Tursiops truncatus*) by trawlers in France, and of two short-beaked common dolphins (*Delphinus delphis*), three sperm whales (*Physeter macrocephalus*) and a few fin whales (*Balaenoptera physalus*) by trawlers in Italy, over a long period. Di Natale and Mangano (1983b) provided details for 448 sperm whales stranded in the central Mediterranean between 1978 and 1982; 25 specimens of *Physeter macrocephalus* were also captured incidentally by fishing activities, including three by trawlers, probably corresponding to the same individuals reported by Duguy *et al.* (1983a, 1983b). Much of the rare incidental catch of cetaceans in trawling nets resulted from depredation, particularly in cases involving the common bottlenose dolphin (*Tursiops truncatus*), which can be attracted by fish discards or by the concentration of food available in the trawl net mouth or codend (Bearzi, 2002). Di Natale and Mangano (1981, 1982) and Di Natale (1989) reported some incidental catch of common bottlenose dolphins in Italian waters up to the end of the 1980s, while Consiglio *et al.* (1992) found no evidence of incidental catch of *T. truncatus* in Sardinia.

In the area around the Balearic Islands, Silvani, Raich and Aguilar (1992) reported, based on information collected from fishers in 1991, the death of one common bottlenose dolphin incidentally caught by a trawler over the period 1989–1991. Massuti (unpublished data) monitored 460 commercial trawling trips off Majorca between 2001 and 2004 and did not report any dolphin bycatch despite the presence of several specimens (mainly *Tursiops truncatus*) swimming near the trawler during observations. In the same area, Gonzalvo *et al.* (2008) observed a high rate of interactions between trawlers and bottlenose dolphins, probably due to the easily available discarded fish or access to fish from the net. As a result, during direct onboard observations of 79 trawling operations conducted between May 2004 and May 2005, though 55 interactions were observed, no incidental catch was recorded, nor was any incidental catch reported in interviews with more than 50 fishers. Elsewhere, in Tunisian waters, only two cases of dolphin bycatch by bottom trawlers were reported: one striped dolphin in 1988 (Bradai, 2000) and one bottlenose dolphin in 2004 (Bradai *et al.*, 2010).

Generally, the risk of incidentally capturing cetaceans within trawl nets has been very low across the Mediterranean; the only exception was recorded along the coast of Israel, where high mortality rates in bottom trawl nets were reported. In this area, out of 67 common bottlenose dolphins (*Tursiops truncatus*) found dead, stranded or adrift, between 1993 and 2004, 26 (39 percent) were incidentally caught in trawl nets (Goffman, Kerem and Spanier, 1995; Feingold *et al.*, 2005; Kent *et al.*, 2005). In the western Mediterranean, fishing activities carried out with midwater pair trawls, targeting small pelagic fish, has resulted in the bycatch of small cetaceans and, occasionally, of fin whales (*Balaenoptera physalus*) or killer whales (*Orcinus orca*) (Sacchi, 2008). However, the impacts of these fisheries remain relatively low compared to those of similar fisheries in the Atlantic region, given the small number of vessels involved in this activity and its low temporal and spatial coverage (i.e. limited fishing grounds and reduced duration of fishing operations).

In the Black Sea, before the 1990s, three Black Sea common dolphins (*Delphinus delphis ponticus*) were incidentally caught by pelagic trawlers targeting anchovy in Georgian territorial waters (BLASDOL, 1999), while two Black Sea common dolphins were recorded as bycatch in November 1995 in Ukrainian territorial waters from pelagic trawling operations for sprat (Birkun, 2002). A more detailed study undertaken in Ukraine in 2006 revealed some incidental catch of both Black Sea harbour porpoises (*Phocoena phocoena relicta*) and Black Sea common dolphins. Birkun *et al.* (2014) reported some data from surveys carried out on pelagic trawlers in 2006: over the course of 54 onboard observations in Bulgaria, no cetacean bycatch was recorded; meanwhile in Ukraine, over the course of 14 observations, the incidental catch of 18 common dolphins and two Black Sea harbour porpoises was reported. No cetacean catch has ever been reported in literature from the trawl fishery in Romanian coastal waters or from beam trawlers operating in Bulgaria and Eastern Turkey.

As far as small-scale fisheries, most vessels in the Mediterranean and Black Sea use set nets (for example, trammel nets and gillnets), representing over 80 percent of the whole fleet operating in the basin (FAO, 2018). Indeed, set nets are widely used along all coasts and are the main site of interactions between cetaceans and fishing gear. Information on incidental catch in this type of fishing gear suggests that set nets cause low mortality in coastal cetacean species, though the high number of sets deployed every day, paired with a scarcity of scientific data or surveys, make it difficult to assess past and current impacts on cetaceans.

Cetacean incidental catch in set nets has been reported from coastal waters throughout the Mediterranean and the Black Sea, both formerly and presently (Díaz López, 2006; Di Natale and Notarbartolo di Sciara, 1994; Brotons, Grau and Rendell, 2008; Birkun *et al.*, 2014). In the past, records of incidental catch described entanglements of sperm whales (*Physeter macrocephalus*), Risso's dolphins (*Grampus griseus*), common dolphins (*Delphinus delphis*) and bottlenose dolphins (*Tursiops truncatus*) in small-scale fixed nets (i.e. gillnets and trammel nets) in Italy, France and

Spain. Anecdotal information concerning four striped dolphins (*Stenella coeruleoalba*), three common dolphins, five bottlenose dolphins, six Risso's dolphins, two minke whales (*Balaenoptera acutorostrata*) and one sperm whale entangled in fixed nets was reported (Di Natale, 1983a, 1983b, 1983c; Di Natale and Mangano, 1983a, 1983b, 1983c; Duguy *et al.* 1983a, 1983b). Furthermore, Duguy and Cyrus (1973) reported the incidental catch of two rough-toothed dolphins (*Steno bredanensis*) along the French Mediterranean coast (1970–72), the first off Granier, near Aigues-Mortes and the second near Toulon. In addition, Duguy (1985, 1986, 1987, 1989) provided further information on cetacean bycatch from the French Mediterranean stranding records.

Around the Balearic Islands, interactions between coastal fisheries and the local bottlenose dolphin (*Tursiops truncatus*) population have been reported for decades, but the frequency of interactions has increased since 1990. Based on information collected from fishers in 1991, Silvani, Raich and Aguilar (1992) reported the death of 13 dolphins incidentally caught in gillnets between 1989 and 1991. In order to evaluate the impact of these interactions, involving mainly bottlenose dolphins in the Balearic Islands, 1 040 fishing trips were monitored by observers onboard nine different vessels between January 2001 and April 2003 (Brotons, Grau and Rendell, 2008; Brotons *et al.*, 2008). Although 139 instances of depredation by dolphins were reported, no incidental catch was recorded.

The common bottlenose dolphin (*Tursiops truncatus*) was regularly found throughout the year along the northern coast of Sardinia (Italy); the increasing use of bottom-set nets (mainly trammel nets) in coastal areas and the presence of fish farms led to a rise in interactions between bottlenose dolphins and human activities at sea (Díaz López, 2005; Díaz López, Marini and Polo, 2004). Two studies were carried out to evaluate the level of interaction between dolphins and bottom-set net fisheries in Sardinia. The first one was undertaken within the boundaries of the Gulf of Asinara marine protected area in 2002, northwest of Sardinia, by means of onboard observers; 88 fishing observations were conducted between October 1999 and October 2001, over the course of 24 different fishing days. However, although bottlenose dolphins were recorded interacting with fishing operations on 29 occasions out of 88, no incidental catch was observed (Lauriano *et al.*, 2004). The second study was carried out along the northeast coast of Sardinia between October 1999 and December 2004, combining direct onboard observations with interviews of fishers (Díaz López, 2006). A total of 744 interviews were carried out, covering about 20 percent of the local fleet; they reported that 2 556 days saw at least some gillnet damage caused by interactions with bottlenose dolphins, i.e. 68.7 percent of the total fishing days. Over 3 720 days of observations, three dolphins (one adult and two immature individuals) were captured (0.29 dolphin per year). Two of the entrapped dolphins were dead, but an immature dolphin was able to be rescued from the net and released alive. No other marine mammal bycatch was recorded. Combining the collected data with the fishing effort of the entire fleet in the area (30 boats) over the five-year period, and assuming a constant probability of incidental catch, the total estimated number of bottlenose dolphins caught annually in gillnets along the northeastern coast of Sardinia would be 1.47 (0.98 immatures, 0.49 adults) (Díaz López, 2006).

In the central and eastern Mediterranean, though no published data based on fishery surveys exist for cetacean bycatch, incidental captures in bottom-set nets have been reported on an anecdotal basis (Di Natale and Notarbartolo di Sciara, 1994). In Tunisia, a bottlenose dolphin entangled in November 1980 in a trammel net, north of Tunis, and a striped dolphin (*Stenella coeruleoalba*) caught in a trammel net were reported by Ktari-Chakroun (1981) and Bradai (1991), respectively. A fin whale (*Balaenoptera physalus*), 9.88 m long, was also incidentally caught in a gillnet in the region of Sfax in August 2008 (Karaa *et al.*, 2012). Among the records of strandings in Tunisian waters, there are signs of interactions between bottlenose dolphins and fishing nets (Attia El Hili *et al.*, 2010).

In the Levant Sea, Kerem *et al.* (2012), in a review of cetacean strandings along the Israeli coast between 1993 and 2009, reported the incidental catch in gillnets of three rough-toothed dolphins (*Steno bredanensis*), two striped dolphins (*Stenella coeruleoalba*) and two common minke whale (*Balaenoptera acutorostrata*) calves. Generally, the death of a stranded dolphin is attributed to incidental catch when, on external examination, clear indications of entanglement are found, such as pieces of net still present around the body or the caudal fin, or impressions left by the net mesh on the skin. In some cases, death may be due to larynx strangulation during depredation rather than to entanglement. Gomerčić *et al.* (2009) noted that out of 120 dead stranded common bottlenose dolphins (*Tursiops truncatus*) found along the Croatian coast of the Adriatic Sea from 1990 through the beginning of 2008, 12 (10 percent) showed signs of larynx strangulation by gillnet parts, though only in a few cases were the causes of death identifiable through external examination alone. Therefore, cetacean mortality due to interactions with different kinds of small-scale fishing gear may be underestimated.

In the Black Sea, bottom gillnets targeting Black Sea turbot (*Scophthalmus maximums*) and piked dogfish (*Squalus acanthias*) were responsible for the large majority of known cetacean bycatch. The scientific literature available over the past 60 years reveals that the direct impact of set nets used in Black Sea fisheries mainly affects the Black Sea harbour porpoise (*Phocoena phocoena relicta*). The information on cetacean bycatch in Ukraine, Russia and Georgia was for a long time available only in strictly confidential internal annual reports or published in brief papers. Artov, Pavlov and Zhuravleva (1994), and Pavlov, Artov and Zhuravleva (1996) reported, between 1968 and 1993, the incidental catch of 1 695 Black Sea harbour porpoises (*Phocoena phocoena relicta*), 287 Black Sea common dolphins (*Delphinus delphis ponticus*) and 104 Black Sea bottlenose dolphins (*Tursiops truncatus ponticus*). Cetacean bycatch in set net fisheries was also monitored in Romania from 1984 to 1990 (Vasiliu and Dima, 1990), and from 2002 to 2006 (Radu, Anton and Radu, 2006). Overall, the surveys recorded an incidental catch of 2 991 cetaceans: 2 545 Black Sea harbour porpoises (85.1 percent), 326 Black Sea common dolphins (10.9 percent) and 120 Black Sea bottlenose dolphins (4.0 percent). Furthermore, a comprehensive investigation was carried out for two years (from February 1997 to January 1999) simultaneously in Bulgaria, Georgia and Ukraine (BLASDOL, 1999; Birkun *et al.*, 2002, 2009, 2014). In addition, studies undertaken between 1993 and 2003 provided data on the Turkish Black Sea coast (Tonay and Öz, 1999; Tonay and Öztürk, 2003; Öztürk, Öztürk and IWC, 2004). Ghost fishing, involving the capture of fish in abandoned gillnets, was found to be another issue affecting cetacean populations along the Romanian coast. Radu, Anton and Radu (2006) reported that 20 Black Sea harbour porpoises were caught in a set of 40 km-long abandoned turbot nets in 2005, estimating an incidental catch of about 50 cetaceans per 100 km of net (i.e. 0.5 individuals per km). Considering the quantity of ghost nets that are abandoned each year, the number of cetaceans incidentally entangled in these nets could be higher. The absolute numbers of annual population loss due to incidental catch have not been estimated for each Black Sea country; the only relevant figure comes from Öztürk, Öztürk and Dede (1999), who made an estimate of 2 000–3 000 harbour porpoises (*Phocoena phocoena relicta*) and 200–300 Black Sea bottlenose dolphins (*Tursiops truncatus ponticus*) incidentally caught in Turkey every year. Details of the different species by time period, country and fishing gear are reported in Table 3.

Drifting longlines are mainly used in the Mediterranean to target swordfish (*Xiphias gladius*), bluefin tuna (*Thunnus thynnus*), albacore (*Thunnus alalunga*) and other pelagic species (Di Natale, 1990a, 1990d). There are very few examples of interactions between cetaceans and this type of gear: in the majority of cases, individuals were released still alive, as long as no particular conditions or injuries were present. However, older data on the incidental capture and entanglement of striped dolphins (*Stenella coeruleoalba*), false killer whales (*Pseudorca crassidens*), Risso's dolphins (*Grampus griseus*), fin whales (*Balaenoptera physalus*) and sperm whales (*Physeter macrocephalus*) caught by surface longlines in Italian and Spanish waters have been reported (Di Natale and Mangano, 1983a, 1983b; Duguy *et al*., 1983b).

Di Natale and Mangano (1983b) gave details on 25 sperm whales, one of whom was caught by a pelagic longline, captured by Italian boats between 1978 and 1982. Di Natale (1989) also refers to the capture of two specimens of Risso's dolphin (*Grampus griseus*) and a Cuvier's beaked whale (*Ziphius cavirostris*) caught by a longline. Furthermore, Garibaldi (2015) reported another case of dolphin bycatch from the period 1990–2009; over the course of 187 fishing operations (employing around 98 000 hooks) of the professional swordfish fishery using surface longlines in the Ligurian Sea, the only cetacean bycatch he observed directly onboard involved a juvenile striped dolphin (*Stenella coeruleoalba*), which was caught on October 1990 and released still alive. In addition, Mussi *et al*. (1998), reporting on data collected between 1991 and 1995, noted a decomposed sperm whale (*Physeter macrocephalus*) found entangled in an abandoned drifting longline in the southern Tyrrhenian Sea.

Over the same period (1990–1995), it was estimated that between 12 and 32 cetaceans were incidentally caught annually by the Spanish pelagic longline fleet operating in the Mediterranean. This bycatch mainly consisted of common dolphins (*Delphinus delphis*), striped dolphins (*Stenella coeruleoalba*) and pilot whales (*Globicephala melas*) (University of Barcelona, 1995). Taking into account that the majority of cetaceans were able to be released still alive and estimating an at-vessel mortality rate of 10 percent, one to three individuals are likely to be caught dead yearly.

During a survey carried out between 1999 and 2000, Camiñas and Valeiras (2001) described bycatch rates of cetaceans in Spanish Mediterranean longline fisheries. Over the course of 291 longline sets observed in 1999 and 507 longline sets in 2000, three species of cetaceans were entangled in fishing lines: striped dolphin (*Stenella coeruleoalba*), with three and four specimens caught respectively in 1999 and 2000; Risso's dolphin (*Grampus griseus*) with seven specimens in 2000; and beaked whale (Ziphiidae), one of whom was caught in 2000, though the species was not identified.

The activity of more widespread purse seine fleets targeting small pelagic fish in the Mediterranean does not seem to have led to high incidental catch rates, even if high numbers of interactions with cetaceans were observed, especially with coastal dolphins, such as bottlenose dolphins (*Tursiops truncatus*), common dolphins (*Delphinus delphis*) and Risso's dolphins (*Grampus griseus*). Some old instances of incidental catch were reported along the coasts of southern Spain, southern Italy and northern Africa (Tudela, 2004; Aguilar *et al.*, 1991; Zahri *et al.*, 2007). In contrast, a report by the University of Barcelona (1995) described exceptionally high dolphin bycatch in the Alboran Sea at the beginning of the 1990s, though the majority of those caught were released alive, with an estimated annual mortality of 300 dolphins, mainly common dolphins (*Delphinus delphis*). This impact could partially explain the decline of the common dolphin populations along the Spanish Mediterranean coast and northern Africa. Moreover, the impact on other species, such as striped dolphins (*Stenella coeruleoalba*), was estimated at 100 individuals caught/dead per year (University of Barcelona, 1995). In Tunisian waters, only two cases were reported: a bottlenose dolphin (*Tursiops truncatus*) caught by a purse seiner in October 1991 (Bradai, 1991) and an unidentified 8.5 m-long whale captured by a purse seiner from La Skhira in the Gulf of Gabès in September 1992 (Bradai and Ghorbel, 1998).

In the Black Sea, purse seine fisheries targeting small pelagics, such as Black Sea anchovies (particularly *Engraulis encrasicolus ponticus* and, to a lesser extent, *E. encrasicolus maeticus*), Black Sea sprats, pilchards, shads, bonitos and other small fish, are intensely active in Turkey, with a few boats also present in Ukraine. Despite this high activity, cetacean bycatch in purse seine fisheries has been rarely reported in the Black Sea area and records are scattered. Data reported by Birkun *et al.* (2014) and referring to 2006 revealed some cases of cetacean bycatch in Ukrainian waters: over the course of eight fishing observations, two Black Sea common dolphins (*Delphinus delphis ponticus*) and three Black Sea harbour porpoises (*Phocoena phocoena relicta*) were caught, while in Turkish Black Sea waters, 63 out of 194 direct onboard observations involved Black Sea common dolphins and 45 involved Black Sea harbour porpoises.

In Mediterranean waters, cetaceans are generally not caught by purse seiners targeting bluefin tuna (Table 3). However, a handful of records in the relevant literature refer to occasional bycatch in different Mediterranean regions; nevertheless, fishers themselves have also reported catching pilot whales (*Globicephala melaena*) and other small cetacean species sporadically (Di Natale, 1990d). Additionally, Duguy *et al.* (1983a, 1983b) reported the capture of three striped dolphins (*Stenella coeruleoalba*) in French waters before the 1980s; during the same period, Di Natale (1983a) described the incidental catch of 21 striped dolphins in two separate incidents in the Ligurian Sea, both involving tuna purse seine nets. In the same area, Magnaghi and Podestà (1987) observed directly onboard the incidental capture of eight striped dolphins off Sanremo (northwestern Italy) in 1986. Furthermore, within the framework of the Regional Observer Programme for Bluefin Tuna

Table 3 – Incidental catch of cetaceans in purse seiners

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Duguy *et al.*, 1983a, 1983b	-	PS (for bluefin tuna)	Western Mediterranean	France	*Stenella coeruleoalba*	3	-	-	-
Di Natale, 1983a	-	PS (for bluefin tuna)	Western Mediterranean	Italy (Ligurian Sea)	*Stenella coeruleoalba*	21	-	-	-
Magnaghi and Podestà, 1987	1986	PS (for bluefin tuna)	Western Mediterranean	Italy (Ligurian Sea)	*Stenella coeruleoalba*	8	-	-	-
Fromentin and Farrugio, 2005	2003	PS (for bluefin tuna)	Western Mediterranean	France	*Stenella coeruleoalba*	3	-	-	-
University of Barcelona, 1995	1990–1994	PS	Western Mediterranean	Spain	*Delphinus delphis*	-	300/year	-	-
University of Barcelona, 1995	1990–1994	PS	Western Mediterranean	Spain	*Stenella coeruleoalba*	-	100/year	-	-
Bradai, 1991	1991	PS	Central Mediterranean	Tunisia	*Tursiops truncatus*	1	-	-	-
Bradai and Ghorbel, 1998	1992	PS	Central Mediterranean	Tunisia	*Megaptera novaeangliae*	1	-	-	-

Table 3 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Birkun *et al.*, 2014	2006	PS	Black Sea	Ukraine	*Delphinus delphis ponticus*	2	-	1	2/2
Birkun *et al.*, 2014	2006	PS	Black Sea	Ukraine	*Phocoena phocoena relicta*	3	-	0.8	4/3
Birkun *et al.*, 2014	2006	PS	Black Sea	Ukraine	*Tursiops truncatus ponticus*	0	-	-	2/0
Birkun *et al.*, 2014	2006	PS	Black Sea	Turkey	*Delphinus delphis ponticus*	63	-	0.7	91/63
Birkun *et al.*, 2014	2006	PS	Black Sea	Turkey	*Phocoena phocoena relicta*	45	-	1.2	37/45
Birkun *et al.*, 2014	2006	PS	Black Sea	Turkey	*Tursiops truncatus ponticus*	0	-	-	64/0

Notes: PS = purse seine.
In grey, data collected before 2008.

of the International Commission for the Conservation of Atlantic Tunas (ICCAT), three striped dolphins were caught in 2003 over the course of 190 fishing day trips on a French purse seiner operating in the Gulf of Lion (Fromentin and Farrugio, 2005).

Other types of fishing gear were responsible for the incidental catch of cetaceans in a very limited number of cases (Table 4). Traditional tuna traps targeting large bluefin tuna during their spawning migrations can sometimes trap cetaceans as well: on 18 June 1946, a minke whale (*Balaenoptera acutorostrata*) was caught in the small tuna trap of Camogli, near Genoa, in the Ligurian Sea (Cattaneo and Bava, 2009), and another specimen of minke whale was found in the tuna trap of Sidi-Daoud in 1976 (Ktari-Chakroun, 1980). Di Natale and Mangano (1983a) likewise refer to the capture of a killer whale (*Orcinus orca*) in a tuna trap in Sicily.

Table 4 – Incidental catch of cetaceans in various types of fishing gear

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Cattaneo and Bava, 2009	1946	Tuna trap	Western Mediterranean	Italy	*Balaenoptera acutorostrata*	1	-	-	-
Ktari-Chakroun, 1980	1976	Tuna trap	Central Mediterranean	Tunisia	*Balaenoptera acutorostrata*	1	-	-	-
Di Natale and Mangano, 1983a	1983	Tuna trap	Western Mediterranean	Italy	*Orcinus orca*	1	-	-	-
Vasiliu and Dima, 1990	1988	Pound net	Black Sea	Romania	*Delphinus delphis ponticus*	8	-	-	-
Birkun *et al.*, 2014	2006	Pound net	Black Sea	Turkey	*Delphinus delphis ponticus*	5	-	-	-

Note:
In grey, data collected before 2008.

In the Black Sea, the entrapments of a number of cetaceans were attributed to pound nets, small traps targeting mixed pelagic and demersal fish. A group of eight Black Sea common dolphins (*Delphinus delphis ponticus*) entered pound nets installed by the Romanian Marine Research Institute in July 1988 (Vasiliu and Dima, 1990), while another case involving five Black Sea common dolphins in Turkey was reported by Birkun *et al.* (2014).

Interactions between handline fisheries and cetaceans were further recorded in some Mediterranean and Black Sea areas. Mussi *et al.* (1998) also reported the results of a five-year field survey conducted in Italian waters in the southern Tyrrhenian Sea, where the local cetaceans, i.e. striped dolphins (*Stenella coeruleoalba*), Risso's dolphins (*Grampus griseus*), long-finned pilot whales (*Globicephala melas*) and sperm whales (*Physeter macrocephalus*), were observed taking advantage of the handline squid fishery by depredating the squids that were attracted to the lights. However, cetacean bycatch was reported neither here nor in a survey carried out in Bulgarian waters, perhaps due to the short soaking time involved (Birkun *et al.*, 2014).

4.3 Analysis of recent data from literature (2008–2019)

4.3.1 Pinnipeds

Over the last years, reports on the mortality of Mediterranean monk seals (*Monachus monachus*) due to fisheries are scarce.

Only a few papers have been published as comprehensive reviews of the causes of death, based on different methods (such as interviews, direct observations and necropsies) and covering extended periods. For example, Danyer *et al.* (2018) have provided a brief summary of the details of the individuals found dead along the coast of Turkey; over the period 1994–2014, 32 entanglements and 49 directly human-induced deaths were reported in the relevant literature (Öztürk, 2007; Güçlüsoy *et al.,* 2004; Danyer *et al.,* 2013a, 2013b, 2014). Danyer *et al.* (2018) also updated the information on monk seal deaths recorded along the Mediterranean Turkish coast to include

Table 5 – Incidental catch of Mediterranean monk seal in various types of fishing gear

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Number of dead individuals recorded	Direct human-induced deaths	Individuals found entangled in fishing gear	Reported individuals in bycatch events (%)	Individuals with unidentified causes of death
Županović, 1966	1907–1908	Tuna trap	Adriatic Sea	Croatia	*Monachus monachus*	2	0	2	100%	-
Županović, 1966	1886–1928	Tuna trap	Adriatic Sea	Croatia	*Monachus monachus*	15	15	0	0	-
Ronald and Healey, 1974	1900–1930	Tuna trap	Western Mediterranean	Spain (Balearic Islands)	*Monachus monachus*	26	19	7	26.9%	-
Avellà, 1979	1900–1970	-	Western Mediterranean	Spain (Balearic Islands)	*Monachus monachus*	50	26	24	48%	-
Guarrera, 1999	1980s	GNS	-	Italy (Tuscany)	*Monachus monachus*	8	0	8	100%	-
Boutiba, 1996	1987–1990	GNS	Western Mediterranean	Algeria	*Monachus monachus*	8	0	8	100%	-
Ronald and Healey, 1974	1971–1972	GNS	Eastern Mediterranean	Greece (Kos)	*Monachus monachus*	0	0	4/year	0	-
Jacobs and Panou, 1988	1980–1982	GNS	Central Mediterranean	Greece (Ionian Sea)	*Monachus monachus*	34	26	7	20.6%	-

Table 5 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Number of dead individuals recorded	Direct human-induced deaths	Individuals found entangled in fishing gear	Reported individuals in bycatch events (%)	Individuals with unidentified causes of death
Jacobs and Panou, 1988	1980–1982	LLS	Central Mediterranean	Greece (Ionian Sea)	*Monachus monachus*	34	26	1	2.9%	-
Avellà, 1987	1980s	-	Western and central Mediterranean	Tunisia, Algeria, Morocco	*Monachus monachus*	40	11	6	15%	23
Berkes *et al.*, 1979	1960s–1970s	-	Eastern Mediterranean	Turkey (Aegean Sea)	*Monachus monachus*	25	19	6	24%	-
Cebrian, 1993	1988–1990	GNS	Eastern Mediterranean	Greece (Halkidiki)	*Monachus monachus*	16	11	3	18.8%	2
Cebrian and Anagnostopoulou, 1992	1988–1992	-	Eastern Mediterranean	Greece (South Aegean Sea)	*Monachus monachus*	37	28	5	13.5%	4
Kiraç and Savaş, 1996; Yediler and Gücü, 1997	1965–1994	GNS	Eastern Mediterranean and Black Sea	Turkey (Med. and Black Sea)	*Monachus monachus*	13	11	2	15.4%	-
Cebrian *et al.*, 1990	1990	GNS	Eastern Mediterranean	Greece (Santorini)	*Monachus monachus*	1	0	1	0	-
Cebrian *et al.*, 1995	1986–1994	GNS	Eastern Mediterranean	Greece (Cyclades)	*Monachus monachus*	16	4	6	37.5%	6
Cebrian *et al.*, 1995	Before 1986	GNS	Eastern Mediterranean	Greece (Cyclades)	*Monachus monachus*	5	5	0	0	-
Cebrian and Vlachoutsikou, 1994	1988–1993	GNS	Central Mediterranean	Greece (southern Ionian Sea)	*Monachus monachus*	8	6	1	12.5%	1
Cebrian, 1998a	1987–1994	GNS	Eastern and central Mediterranean	Greece	*Monachus monachus*	61	34	11	18%	16
Panou *et al.*, 1993	1963–1987	GNS	Central Mediterranean	Greece (Ionian Sea)	*Monachus monachus*	34	21	8	23.5%	5
Panou *et al.*, 1993	before 1963	GNS	Central Mediterranean	Greece (Ionian Sea)	*Monachus monachus*	13	10	3	23.1%	-
Dede *et al.*, 2015	1986–1996	GNS/ LLS	Eastern Mediterranean	Turkey (Aegean Sea and Mediterranean coast)	*Monachus monachus*	24	12	6	25%	6
Öztürk, 1998a	1986–1996	GNS	Eastern Mediterranean	Turkey (Aegean Sea)	*Monachus monachus*	13	5	5	38.5%	3
Androukaki *et al.*, 1999	1985–1995	-	Eastern Mediterranean	Greece	*Monachus monachus*	79	25	11	13.9%	43
Androukaki *et al.*, 2006	up to 1995	-	Eastern Mediterranean	Greece	*Monachus monachus*	182	118	27	14.8%	37
Johnson, ed., 1999; Güçlüsoy *et al.*, 2004	1997 and 1999	GNS	Eastern Mediterranean	Turkey	*Monachus monachus*	2	0	2	0	-
Veryeri *et al.*, 2001, 2003	-	GNS	Eastern Mediterranean	Turkey (Aegean Sea)	*Monachus monachus*	7	0	7	0	-
Androukaki *et al.*, 2006	1986–2005	-	Eastern Mediterranean	Greece	*Monachus monachus*	203	37	12	6%	154
Karamanlidis *et al.*, 2008	1991–2007	-	Eastern Mediterranean	Greece	*Monachus monachus*	96	15	7	7.3%	74
Danyer *et al.*, 2018	1994–2014	-	Eastern Mediterranean	Turkey	*Monachus monachus*	81	49	32	39.5%	-
Danyer *et al.*, 2018	2012–2018	-	Eastern Mediterranean	Turkey	*Monachus monachus*	18	2	0	0	16

Notes: GNS = set gillnet; LLS = set longline.
In grey, data collected before 2008.

those occurring between 2012 and 2018. Out of 18 dead seals, five died due to natural causes, two in human-induced deaths, while for the other 11, it was not possible to determine the cause. A summary of the records available in the relevant literature is reported in Table 5.

Androukaki *et al*. (2006) published a complete review of the causes of death in the monk seal population in Greece between 1986 and 2005. Based on information and data collected from 203 stranded animals (full necropsies were performed on 86 specimens), death was attributed most commonly to various natural explanations (45 percent), followed by human-induced death (around 20 percent) and accidental death (8 percent); unknown causes of death were recorded for the remaining 27 percent of the cases. The results were also analysed dividing the period into two intervals (1986–1995 and 1996–2005) but no important differences were found in the patterns of mortality between them.

Another review of the Mediterranean monk seal data in Greek waters was undertaken by Karamanlidis *et al.* (2008), obtaining results similar to those of Androukaki *et al*. (2006). The research was carried out based on three different sources: a literature review, data on incidental catch collected through questionnaires and data from necropsies. The interviews registered the entanglement of 13 seals in fishing gear, 11 in gillnets and two in longlines. The two individuals caught by longlines were released still alive, as well as two seals entangled in gillnets. From 1991 to 2007, 200 dead monk seals were reported, and in 96 cases, full necropsies were performed. Natural causes, human-induced death, and entanglement corresponded to 41 percent (39 cases), 16 percent (15 cases) and 7 percent (7 cases) of the 96 seals examined, respectively, while the cause of death could not be determined for the remaining 36 percent (35 cases). Entanglement appeared to affect mainly sub-adult individuals (46 percent); in contrast, the most frequently recorded causes of mortality in adults and pups were human-induced death (50 percent) and natural causes (93 percent), respectively. In addition, incidental entanglement in fishing gear was determined to be the cause of death for seven female sub-adults found in Zakynthos (n = 2), Naxos, Samos, Evoia (n = 2) and Lavrio. Overall, the most frequently recorded cause of death, throughout the study period, was found to be non-human-induced. However, this finding is not consistent with what the authors noted when considering the different age classes: pups died mainly due to natural causes, whereas sub-adults and adults died due to interactions with fishing activities (for example, entanglement in fishing gear).

Veryeri, Güçlüsoy and Savas (2001) and Veryeri, Nurlu and Erdem (2003) stressed the large impact of nets on pups and juveniles, describing at least seven cases of entanglement clearly leading to death from the Turkish Aegean coast.

4.3.2 Cetaceans

Since about 2010, the number of new records and publications concerning surveys or studies of cetacean bycatch in different types of fishing gear has drastically reduced. Formerly, at least up until the late 1990s, most cetacean bycatch occurred in large-mesh driftnets; once these were banned, cetacean bycatch – and consequently mortality – in fishing gear dropped. Currently, large-mesh driftnets are officially banned from all countries in the GFCM area of application, though some anecdotal information and evidence (e.g. cetacean strandings showing typical signs of entanglement in large driftnets, images and videos on social networks, or news from online sources) occasionally surface, meaning that this activity may still be illegally practiced in some areas.

In particular, recent information on cetacean bycatch has emerged from the Black Sea, where incidental catch of the three cetacean species endemic to the region continues in the context of the Black Sea turbot bottom net fisheries. An update on the most recent studies available in the literature, examined according to vessel group and area, here follows.

4.3.2.1 Bottom trawlers

Bottom trawlers are widely distributed across the Mediterranean and the Black Sea (FAO, 2018, 2020) and have been historically considered as only a minor threat to cetaceans, even if a high number of interactions have been reported in recent years (Pace, Tizzi and Mussi, 2015). Based on the available data, incidental catch in trawl fisheries appears to be relatively uncommon in most Mediterranean areas (Table 6); only a few instances of incidental catch have been reported in the past, from the Mediterranean coast of Israel (Goffman, Kerem and Spanier, 1995; Kent *et al.*, 2005).

Table 6 – Incidental catch of cetaceans in bottom trawlers and midwater pair trawlers

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Duguy *et al.*, 1983a, 1983b	-	OTB	Western Mediterranean	France	*Stenella coeruleoalba*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	OTB	Western Mediterranean	Italy	*Delphinus delphis*	2	-	-	-
Duguy *et al.*, 1983a, 1983b	-	OTB	Western Mediterranean	France	*Tursiops truncatus*	4	-	-	-
Duguy *et al.*, 1983a, 1983b	-	OTB	Western Mediterranean	Italy	*Physeter macrocephalus*	3[1]	-	-	-
Di Natale and Mangano, 1983b	-	OTB	Western Mediterranean	Italy	*Physeter macrocephalus*	3[1]	-	-	-
Silvani *et al.*, 1992	1989–1991	OTB	Western Mediterranean	Spain (Balearic Islands)	unidentified dolphin	1	-	-	-
Massuti (unpublished data)	2001–2004	OTB	Western Mediterranean	Spain (Balearic Islands)	-	0	-	-	-
Gonzalvo *et al.*, 2008	2004–2005	OTB	Western Mediterranean	Spain (Balearic Islands)	-	0	-	-	79 sets/55
Bradai, 2000	1988	OTB	Central Mediterranean	Tunisia	*Stenella coeruleoalba*	1	-	-	-
Bradai *et al.*, 2010	2004	OTB	Central Mediterranean	Tunisia	*Tursiops truncatus*	1	-	-	-
Goffman *et al.*, 1995; Feingold *et al.*, 2005; Kent *et al.*, 2005	1993–2004	OTB	Eastern Mediterranean	Israel	*Tursiops truncatus*	26	-	-	-
Fortuna *et al.*, 2010a	2006–2008	PTM	Adriatic Sea	Italy (Adriatic Sea)	*Tursiops truncatus*	2 + 1[2]	22[3]	-	3 141 hauls/609
Fortuna *et al.*, 2010b	2009–2010	PTM	Adriatic Sea and Central Mediterranean	Italy	*Tursiops truncatus*	0[4]	-	-	2 254 hauls/-
Fortuna *et al.*, 2012	2011–2012	PTM	Adriatic Sea	Italy (Adriatic Sea)	*Tursiops truncatus*	3	72 (2001)	0.001	2 735 hauls/604
Morizur *et al.*, 2012a	2010	PTM	Western Mediterranean	France (Gulf of Lion)	*Stenella coeruleoalba*	4	-	-	-
Morizur *et al.*, 2012b	2011	PTM	Western Mediterranean	France (Gulf of Lion)	*Stenella coeruleoalba*	1	-	-	-

Table 6 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Morizur *et al.*, 2014	2012	PTM	Western Mediterranean	France (Gulf of Lion)	*Tursiops truncatus*	1	-	-	-
Sala *et al.*, 2013	2012–2013	PTM	Adriatic Sea	Italy (Adriatic Sea)	*Tursiops truncatus*	0[5]	-	-	144 hauls/31
Sala *et al.*, 2014	2013–2014	PTM	Adriatic Sea	Italy (Adriatic Sea)	-	0	-	-	202 hauls/49
Sala *et al.*, 2016	2015–2016	PTM	Adriatic Sea	Italy (Adriatic Sea)	*Tursiops truncatus*	1	2	0.002	1 797/587
Sala *et al*, 2018	2016-2017	PTM	Adriatic Sea and Central Mediterranean	Italy	*Tursiops truncatus*	3	-	0.05	1 571/438
BLASDOL, 1999	1997–1999	PTM	Black Sea	Georgia	*Delphinus delphis ponticus*	3	-	-	-
Birkun, 2002	1995	PTM	Black Sea	Ukraine	*Delphinus delphis ponticus*	2	-	-	-
Birkun *et al.*, 2014	2006	PTM	Black Sea	Ukraine	*Delphinus delphis ponticus*	18	68	1.8	14/18
Birkun *et al.*, 2014	2006	PTM	Black Sea	Ukraine	*Phocoena phocoena relicta*	2	25	0.5	14/2

Notes: OTB = bottom otter trawl; PTM = midwater pair trawl.

In grey data collected before 2008.
1. Same specimens probably.
2. Number of individuals released alive.
3. Value obtained from unreliable statistics.
4. Five specimens reported by fishers from other vessels not involved in the survey.
5. One specimen reported by fishers from other vessels not involved in the survey.

Western Mediterranean
No recent data are available from bottom trawlers operating in this subregion.

Central Mediterranean
No recent data are available from bottom trawlers operating in this subregion.

Adriatic Sea
No recent data are available from bottom trawlers operating in this subregion.

Eastern Mediterranean
No recent data are available from bottom trawlers operating in this subregion.

Black Sea
No recent data are available from bottom trawlers operating in this subregion.

4.3.2.2 Pelagic trawlers
Activity of pelagic trawlers, mainly targeting small pelagic fish such as anchovies (*Engraulis encrasicolus*), sardines (*Sardina pilchardus*), mackerel (*Scomber* spp.) and horse mackerel (*Trachurus* spp.), is not evenly distributed across the Mediterranean and the Black Sea. This fishery is active only in France and Italy for the western Mediterranean, in Tunisia and Malta for the central Mediterranean, in Montenegro and Italy for the Adriatic and in Turkey for the eastern Mediterranean and the Black Sea (Bulgaria, Ukraine, Romania and Georgia) (FAO, 2016; Birkun *et al.*, 2014).

Western Mediterranean

In the Gulf of Lion, in 2010, four striped dolphins (*Stenella coeruleoalba*) were caught by pelagic trawlers (Morizur *et al.*, 2012a, 2012b). In 2011, only one bottlenose dolphin (*Tursiops truncatus)* was incidentally caught by a pelagic trawler over the course of 200 days of fishing and 700 pelagic trawl operations, and a striped dolphin was also captured over 50 days of fishing activity and 150 pelagic trawling operations (Morizur *et al.*, 2012a, 2012b) (Table 6).

Central Mediterranean

No recent data are available for pelagic trawlers operating in this subregion.

Adriatic Sea

Pelagic trawlers targeting anchovies and sardines are active in Italian waters, mainly in the Adriatic Sea. Beginning in 2006, a project (Fortuna *et al.*, 2010b) was carried out to monitor the possible non-commercial incidental catch, including of protected species, occurring during pelagic trawling activities in the Adriatic Sea; pingers were used to test the influence of acoustic deterrent devices on the behaviour of cetaceans and other protected species, such as sea turtles. Between 2006 and 2008, the fishing operations of a subset of 27 fishing vessels (out of about 69 operating in the area) were monitored over 24 months (for a total of 745 successful fishing trips and 3 141 hauls); 609 groups of bottlenose dolphins (*Tursiops truncatus*) were sighted close to the nets, with dolphins present at over 30 percent of the hauls and often interacting with the fishing operations. Nevertheless, only three bottlenose dolphins were caught, one of which, entangled in the net by its caudal fin, was immediately released still alive. On the basis of these data, an estimate of the total annual incidental catch was considered statistically unreliable by Fortuna *et al.* (2010a). After this start, the survey was extended year by year and was carried out continuously until 2019 following the same sampling scheme: the results of the different extensions are summarized and reported in Table 6.

During the 2009–2010 survey, carried out also in Sicilian waters, 528 fishing days were monitored (2 254 hauls) and no cetacean bycatch was observed, though fishers reported the incidental catch of five bottlenose dolphins in the Adriatic by boats not involved in the monitoring programme (Fortuna *et al.*, 2010b). In 2011–2012, a total of 658 fishing days were monitored by onboard observers for a total effort of 2 735 hauls. Over the course of the survey, 604 interactions with bottlenose dolphins (*Tursiops truncatus*) were observed and the bycatch of three specimens was recorded. On the basis of these data, the estimated annual number of dolphins captured as bycatch for 2011 was estimated at 72; considering the entire period 2006–2011, a total estimate of 35 dolphins per year was calculated (Fortuna *et al.*, 2012). From May 2012 to May 2013, a less extensive survey was carried out (Sala *et al.*, 2013), monitoring the fishing activity of 15 boats in the central Adriatic Sea; onboard observers monitored 35 fishing days and 144 fishing operations. Over the course of the entire survey, 31 interactions with bottlenose dolphins (*Tursiops truncatus*) were recorded, but no incidental catch occurred; during the same period, the incidental catch of a bottlenose dolphin was reported by fishers in one of the 15 boats monitored without onboard observers.

In 2013–2014, 53 fishing days were monitored (202 hauls) and 49 interactions between fishing vessels and bottlenose dolphins were observed, though none involved any incidental catch (Sala *et al.*, 2014). Subsequently, another survey was carried out over the period from February 2015 to February 2016. Overall, 464 fishing trips were monitored for a total of 1 797 hauls; out of 587 bottlenose dolphin individuals interacting with fishing operations, only one incidental catch was recorded, for an estimated catch rate of 0.002, corresponding to two expected catches per year (Sala *et al.*, 2018). The last available report of this project is referred to in the 2016–2017 survey. Overall, 397 fishing days (1 571 hauls) were monitored by onboard observers and 438 interactions between fishing boats and dolphins were observed; the bycatch of three bottlenose dolphins was recorded, but no estimate of the total annual bycatch was calculated.

Eastern Mediterranean

No recent data are available for pelagic trawlers operating in this subregion.

Black Sea

No recent data are available for pelagic trawlers operating in this subregion.

4.3.2.3 Small-scale fisheries

Small-scale fisheries represent more than 80 percent of the Mediterranean and Black Sea fleets as a whole (FAO, 2018, 2020). Passive bottom-set nets are widely used along all the coasts of the Mediterranean and the Black Sea, targeting several demersal species, including red mullet (*Mullus surmuletus*), common cuttlefish (*Sepia officinalis*), European hake (*Merluccius merluccius*), European spiny lobster (*Palinurus elephas*) and other commercially valuable species. According to the available data, passive bottom-set nets may represent the most common site of interactions between cetaceans and fishing gear. However, further analysis of the same data indicates low mortality of coastal cetacean species interacting with these types of gear across the whole Mediterranean. The many small boats docking in numerous ports, together with the multiple sets each deploys nearly every day and the scarcity of scientific data or surveys, make it difficult to assess and compare the past and current impacts of small-scale fisheries on coastal cetaceans.

Western Mediterranean

In the western Mediterranean Sea, only two surveys have been carried out recently to monitor interactions between cetaceans and small-scale fishing activities. The first one was dedicated to set nets hauled by coastal vessels in Corsica between March and September of 2011; over 164 days at sea, no cetacean bycatch was recorded (Morizur, Gaudou and Dermaneche, 2014; Morizur *et al.*, 2012a, 2012b). Another study was undertaken on a particular type of small-scale fishing gear, the so-called small-scale driftnet. These nets are traditional legal driftnets, with a small mesh size and moderate total length, that mainly target pelagic schooling species, such as anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), mackerel (*Scomber* spp.), horse mackerel (*Trachurus* spp.) and saddled seabream (*Oblada melanura*). In the past, their use was widespread all over the Mediterranean and presented no major environmental concern; in fact, no entanglement of cetaceans has ever been reported. In 2013, a project investigating the past and present activities of these small-scale fisheries collected data in 15 Italian fishing ports, where 98 vessels (plus two in Slovenia) were identified as using nine different types of small-scale driftnets. The project was based on interviews, direct measurements of the characteristics of the nets, and onboard observations. The findings generally indicated a high selectivity of these nets toward a well-defined range of small and medium pelagic species, and no incidental catch or interactions with cetaceans were recorded (Lucchetti *et al.*, 2017).

Central Mediterranean

Some recent data on cetacean bycatch were collected from an analysis of cetacean strandings occurring along the northern coast of Tunisia. Following necropsies, Attia El Hili *et al.* (2010) found that at least four out of seven bottlenose dolphins stranded over the period 2006–2008 died due to possible interactions with fisheries: two specimens in 2006 were found with their tails amputated, as well as one in 2007, while another specimen in 2008 showed the remains of a net in its mouth and/or around the epiglottis. More recently, using the same methodology, data collected from 2007 to 2017 revealed that at least five out of 25 stranded bottlenose dolphins showed the remains of fishing nets in their mouths, suggesting death by asphyxia following net ingestion during depredation activity (Attia El Hili *et al.*, 2018).

Adriatic Sea

No recent data are available for small-scale fisheries operating in this subregion.

Eastern Mediterranean

No recent data are available for small-scale fisheries operating in this subregion.

Black Sea

The most common types of fishing gear in the Black Sea are gillnets and trammel nets, used to catch Black Sea turbot (*Scophthalmus maximus*) and other demersal fish. The use of these types of gear is generally seasonal, depending on the target species, country and fishing grounds. Given the high level of cetacean incidental catch recorded in the past for these types of gear, several studies have been carried out over the last 10 to 15 years, involving more or less all the countries around the basin, in order to evaluate the impact of these fisheries on cetacean populations; for instance, it is reported that bottom-set gillnets caused 98 percent of cetacean bycatch in the northeastern Black Sea (Birkun and Krivokhizhin, 2011). In Ukraine, following the BLASDOL survey (BLASDOL, 1999), onboard observations were carried out yearly, between 2006 and 2009, monitoring 4 769 bottom-set gillnets (deploying a total of 354.1 km) targeting Black Sea turbot and piked dogfish. During these periods, the incidental catch of 515 Black Sea harbour porpoises (*Phocoena phocoena relicta*) and five Black Sea bottlenose dolphins (*Tursiops truncatus ponticus*) was recorded (Birkun and Krivokhizhin, 2011). Furthermore, Birkun *et al.* (2014) reported the results of various small surveys conducted along the Ukrainian coast (involving 543 vessels deploying 760 865 km of nets) and estimated an annual bycatch of 1 539 Black Sea harbour porpoises and 1 211 Black Sea bottlenose dolphins.

A more recent paper (Vishnyakova and Gol'din, 2015) described the results of an analysis carried out on Black Sea harbour porpoise (*Phocoena phocoena relicta*) strandings along the Azov Sea coastline between 1993 and 2013. Out of the 633 specimens examined, around 93 individuals (14.7 percent) showed evidence of incidental capture in fishing gear. In addition, direct monitoring onboard fishing vessels (covering 88.4 km of the central part of the Bulgarian coast) reported bycatch of 19 Black Sea harbour porpoises and two Black Sea bottlenose dolphins between April 2010 and July 2011 (Mihaylov, 2011). A monitoring survey, undertaken with the cooperation of 812 gillnet fishers (targeting Black Sea turbot), allowed Birkun *et al.* (2014) to calculate that at least 945 662 km of nets were annually deployed in Bulgarian waters and to estimate an annual incidental catch of 3 016 Black Sea harbour porpoises and 1 895 Black Sea bottlenose dolphins, resulting in respective catch per unit effort (CPUE) of 0.22 and 0.02. Since 2002, several surveys on cetacean bycatch and strandings have been regularly carried out along the Romanian coast. Radu and Anton (2014) reported that from 2002 to 2011, 129 Black Sea harbour porpoises and two Black Sea bottlenose dolphins were incidentally caught in fishing gear (i.e. gillnets, pound nets and pelagic trawls) used in Romanian fisheries. Moreover, the same authors reported that in 150 gillnets (with an average length of 60 m), the bycatch of Black Sea harbour porpoises totalled about seven individuals (CPUE 0.8/1 km).

In Romania, Anton, Cândea and Paiu, (2012) reported the results of a survey carried out in 2010 and 2011 along the Romanian Danube delta. The main cause of death was asphyxia for the majority of the 80 stranded cetaceans (73 Black Sea harbour porpoises, five Black Sea bottlenose dolphins and two Black Sea common dolphins) and was linked to incidental capture in gillnets or other fishing gear. The high vulnerability of the Black Sea harbour porpoise was confirmed by direct observations made onboard, which reported the bycatch of 54 Black Sea harbour porpoises (Anton, Cândea and Paiu, 2012). Furthermore, Radu and Anton (2014) recorded, from 2002 to 2011, 483 stranded cetaceans, comprising 259 Black Sea harbour porpoises, 20 Black Sea common dolphins, 44 Black Sea bottlenose and 160 unidentified dolphins; the presence of net marks and scars on their bodies indicated that more than 95 percent of these cetaceans had died due to being incidentally caught in gillnets or other fishing gear.

In their review on the state of knowledge of Black Sea cetaceans, Birkun *et al.* (2014) recorded, while observing some trips between 2002 and 2011, the incidental capture of 52 Black Sea harbour porpoises, with a high CPUE of 10.4/km. In addition, other data were obtained by interviews with fishers: 56 responses from 165 boats led to a bycatch estimate of 208 Black Sea harbour porpoises and one of zero for the other dolphin species. The authors estimate a potential bycatch of 2.71 porpoises per boat annually, assuming that responses were not biased (Birkun *et al.*, 2014).

One of the most recent studies on cetacean bycatch in Turkish Black Sea waters was published by Tonay (2016); over the course of two seasons (from April to July 2007 and from April to September 2008), a fishing vessel using trammel nets targeting Black Sea turbot (*Scophthalmus maximus*) was monitored on 629 and 584 fishing trips in 2007 and 2008, respectively. A total of 24 Black Sea harbour porpoises and one Black Sea bottlenose dolphin were recorded as bycatch (13 in 2007, 12 in 2008). Based on these results, the author estimated an incidental catch rate (number of specimens per km of fishing gear) of 0.18 for Black Sea harbour porpoises and 0.01 for Black Sea bottlenose dolphins in 2007, and 0.19 for Black Sea harbour porpoises in 2008. According to these data, and assuming that the incidental catch rate and the net and fishing characteristics are similar along the whole Turkish Black Sea coast, it could be estimated that around 2 011 (SE ± 742) Black Sea harbour porpoises were caught in 2007 and 2 294 (SE ± 806) in 2008, while 168 Black Sea bottlenose dolphins were caught (SE ± 156) in 2007.

Meanwhile, in another investigation, Bilgin, Kose and Yesilcicek (2018) concentrated their research effort along the Turkish coast in the southeastern Black Sea. They conducted surveys monthly between March 2010 and September 2011, monitoring 136 gillnet operations targeting Black Sea turbot. Seventy-one Black Sea harbour porpoises and four Black Sea common dolphins were incidentally caught over the study period. CPUE values were estimated as 0.09 ± 0.028 individuals per km daily in 2010 and 0.15 ± 0.032 individuals per km daily in 2011 for Black Sea harbour porpoises (CPUE 0.13 ± 0.023 individuals per km daily for the two years combined); for the Black Sea common dolphin, the CPUE figure was calculated as < 0.003 individuals per km daily for 2010 and 2011, as well as for both years combined. The authors remarked on the high seasonality of the incidental catch rate, especially of Black Sea harbour porpoises, given that they were caught mostly between April and June, both in 2010 and in 2011, with the highest CPUE value – of 0.26 individuals per km daily – occurring in April 2011.

The historical and recent data on cetacean bycatch in small-scale fisheries are summarized in Table 7.

Table 7 – Incidental catch of cetaceans in small-scale fisheries

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year[1]	Fishing operations/ Number of interactions recorded
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	France	*Stenella coeruleoalba*	4	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	France	*Delphinus delphis*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	Spain	*Delphinus delphis*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	Italy	*Delphinus delphis*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	Spain	*Tursiops truncatus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	France	*Tursiops truncatus*	4	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	Italy	*Grampus griseus*	2	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	France	*Grampus griseus*	4	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	Italy	*Physeter macrocephalus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	GN	Western Mediterranean	France	*Balaenoptera acutorostrata*	2	-	-	-
Granier, 1970	-	GN	Western Mediterranean	France	*Steno bredanensis*	1	-	-	-
Duguy and Cyrus, 1973	-	GN	Western Mediterranean	France	*Steno bredanensis*	1	-	-	-
Silvani *et al.*, 1992	1989–1991	GN	Western Mediterranean	Spain (Balearic Islands)	various species of dolphins	13	-	-	-
Brotons *et al.*, 2008, Brotons, Grau and Rendell, 2008	2001–2003	GN	Western Mediterranean	Spain (Balearic Islands)	-	0	-	-	1 040/139
Lauriano *et al.*, 2004	1999–2001	GN	Western Mediterranean	Italy (Sardinia)	-	0	-	-	88/29
Díaz López, 2006	1999–2004	GN	Western Mediterranean	Italy (Sardinia)	*Tursiops truncatus*	2 + 1[2]	-	1.47/year	3 720/2 556
Ktari-Chakroun, 1981	1980	GN	Central Mediterranean	Tunisia	*Tursiops truncatus*	1	-	-	-
Bradai, 1991	-	GN	Central Mediterranean	Tunisia	*Stenella coeruleoalba*	1	-	-	-
Karaa *et al.*, 2012	2008	GN	Central Mediterranean	Tunisia	*Balaenoptera physalus*	1	-	-	-
Karaa *et al.*, 2012	1937–2009	GN	Central Mediterranean	Tunisia	*Tursiops truncatus*	25	-	-	-
Gomerčić *et al.*, 2009	1990–2008	GN	Adriatic Sea	Croatia	*Tursiops truncatus*	12	-	-	-
Morizur *et al.*, 2012b; Morizur *et al.*, 2014	2011	GN	Western Mediterranean	France (Corsica)	-	0	-	-	164 hauls/0
Kerem *et al.*, 2012	1993–2009	GN	Eastern Mediterranean	Israel	*Stenella coeruleoalba*	2	-	-	-
Kerem *et al.*, 2012	1993–2009	GN	Eastern Mediterranean	Israel	*Steno bredanensis*	3	-	-	-
Kerem *et al.*, 2012	1993–2009	GN	Eastern Mediterranean	Israel	*Balaenoptera acutorostrata*	2	-	-	-
Attia El Hili *et al.*, 2010	2006–2008	GN/GTR	Central Mediterranean	Tunisia	*Tursiops truncatus*	4	-	-	-
Attia El Hili *et al.*, 2018	2007–2017	GN/GTR	Central Mediterranean	Tunisia	*Tursiops truncatus*	5	-	-	-

Table 7 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year[1]	Fishing operations/ Number of interactions recorded
Artov *et al.*, 1994; Pavlov *et al.*, 1996	1968–1993	GN	Black Sea	Russian Federation, Ukraine	*Phocoena phocoena relicta*	1 685	-	0.009/0.12	-
Artov *et al.*, 1994; Pavlov *et al.*, 1996	1968–1993	GN	Black Sea	Russian Federation, Ukraine	*Delphinus delphis ponticus*	297	-	0.009/0.12	-
Artov *et al.*, 1994; Pavlov *et al.*, 1996	1968–1993	GN	Black Sea	Russian Federation, Ukraine	*Tursiops truncatus ponticus*	104	-	0.009/0.12	-
Vasiliu and Dima, 1990	1984–1990	GN	Black Sea	Romania	*Phocoena phocoena relicta*	541	-	-	-
Vasiliu and Dima, 1990	1984–1990	GN	Black Sea	Romania	*Delphinus delphis ponticus*	22	-	-	-
Vasiliu and Dima, 1990	1984–1990	GN	Black Sea	Romania	*Tursiops truncatus ponticus*	3	-	-	-
Radu *et al.*, 2006	2002–2006	GN	Black Sea	Romania	*Phocoena phocoena relicta*	46	-	0.5	-
Radu *et al.*, 2006	2002–2006	GN	Black Sea	Romania	*Delphinus delphis ponticus*	3	-	-	-
Radu *et al.*, 2006	2002–2006	GN	Black Sea	Romania	*Tursiops truncatus ponticus*	2	-	-	-
Radu *et al.*, 2006	2005–2006	GN	Black Sea	Romania	*Phocoena phocoena relicta*	20	-	0.5	40 km/20
Öztürk *et al.*, 1999	1993–1997	GN	Black Sea	Turkey	*Phocoena phocoena relicta*	62	-	-	-
Öztürk *et al.*, 1999	1993–1997	GN	Black Sea	Turkey	*Delphinus delphis ponticus*	0	-	-	-
Öztürk *et al.*, 1999	1993–1997	GN	Black Sea	Turkey	*Tursiops truncatus ponticus*	1	-	-	-
Tonay and Öz, 1999	1999	GN/GTR	Black Sea	Turkey	*Phocoena phocoena relicta*	28	-	-	-
Tonay and Öz, 1999	1999	GN/GTR	Black Sea	Turkey	*Delphinus delphis ponticus*	0	-	-	-
Tonay and Öz, 1999	1999	GN/GTR	Black Sea	Turkey	*Tursiops truncatus ponticus*	0	-	-	-
Tonay and Öztürk, 2003	2002–2003	GN/GTR	Black Sea	Turkey	*Phocoena phocoena relicta*	40	-	-	875 nets (i.e. 94.5 km)/40
Tonay and Öztürk, 2003	2002–2003	GN/GTR	Black Sea	Turkey	*Delphinus delphis ponticus*	1	-	-	875 nets (i.e. 94.5 km)/1
Tonay and Öztürk, 2003	2002–2003	GN/GTR	Black Sea	Turkey	*Tursiops truncatus ponticus*	1	-	-	875 nets (i.e. 94.5 km)/1
BLASDOL, 1999	1997–1999	GN	Black Sea	Bulgaria	*Phocoena phocoena relicta*	13	-	-	-
BLASDOL, 1999	1997–1999	GN	Black Sea	Bulgaria	*Delphinus delphis ponticus*	0	-	-	-
BLASDOL, 1999	1997–1999	GN	Black Sea	Bulgaria	*Tursiops truncatus ponticus*	1	-	-	-
BLASDOL, 1999	1997–1999	GN	Black Sea	Georgia	*Phocoena phocoena relicta*	7	-	-	-
BLASDOL, 1999	1997–1999	GN	Black Sea	Georgia	*Delphinus delphis ponticus*	3	-	-	-
BLASDOL, 1999	1997–1999	GN	Black Sea	Georgia	*Tursiops truncatus ponticus*	1	-	-	-
BLASDOL, 1999	1997–1999	GN	Black Sea	Russian Federation/ Ukraine	*Phocoena phocoena relicta*	123	-	-	-
BLASDOL, 1999	1997–1999	GN	Black Sea	Russian Federation/ Ukraine	*Delphinus delphis ponticus*	0	-	-	-

Table 7 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year[1]	Fishing operations/ Number of interactions recorded
BLASDOL, 1999	1997–1999	GN	Black Sea	Russian Federation/ Ukraine	*Tursiops truncatus ponticus*	7	-	-	-
Mihaylov, 2011	2010–2011	GN	Black Sea	Bulgaria	*Phocoena phocoena relicta*	19	-	0.22	88.4 km/19
Mihaylov, 2011	2010–2011	GN	Black Sea	Bulgaria	*Tursiops truncatus ponticus*	2	-	0.02	88.4 km/2
Birkun *et al.*, 2014	-	GN	Black Sea	Bulgaria	*Phocoena phocoena relicta*	-	3 016	-	-
Birkun *et al.*, 2014	-	GN	Black Sea	Bulgaria	*Tursiops truncatus ponticus*	0	1 895	-	-
Birkun and Krivokhizhin, 2011	2006–2009	GTR	Black Sea	Russian Federation/ Ukraine	*Phocoena phocoena relicta*	355	-	1.42	250 km/355
Birkun and Krivokhizhin, 2011	2006–2009	GTR	Black Sea	Russian Federation/ Ukraine	*Tursiops truncatus ponticus*	5	-	0.02	250 km/5
Birkun and Krivokhizhin, 2011	2006–2009	GN	Black Sea	Russian Federation/ Ukraine	*Phocoena phocoena relicta*	159	-	1.51	104 km/159
Birkun and Krivokhizhin, 2011	2006–2009	GN	Black Sea	Russian Federation/ Ukraine	*Tursiops truncatus ponticus*	0	-	-	-
Birkun *et al.*, 2014	-	GN	Black Sea	Russian Federation/ Ukraine	*Phocoena phocoena relicta*	-	1 539	-	-
Birkun *et al.*, 2014	-	GN	Black Sea	Russian Federation/ Ukraine	*Tursiops truncatus ponticus*	-	1 211	-	-
Birkun *et al.*, 2014	2006–2009	GN	Black Sea	Russian Federation/ Ukraine	*Delphinus delphis ponticus*	2	-	0.09	23 km/2
Birkun *et al.*, 2014	2006–2009	GN	Black Sea	Russian Federation/ Ukraine	*Delphinus delphis ponticus*	29	-	0.95	31 km/29.5
Birkun *et al.*, 2014	2006–2009	GN	Black Sea	Russian Federation/ Ukraine	*Phocoena phocoena relicta*	2	-	1.0	2 km/2
Birkun *et al.*, 2014	2006–2009	GN	Black Sea	Russian Federation/ Ukraine	*Phocoena phocoena relicta*	0	-	-	18 km/0
Birkun *et al.*, 2014	2006–2009	GN	Black Sea	Russian Federation/ Ukraine	*Phocoena phocoena relicta*	68	-	2.8	24 km/68
Birkun *et al.*, 2014	2006–2009	GN	Black Sea	Russian Federation/ Ukraine	*Delphinus delphis ponticus*	81	-	2.4	34 km/81.5
Anton *et al.*, 2012	2010–2011	GN	Black Sea	Romania	*Phocoena phocoena relicta*	54	-	-	-
Radu and Anton, 2014	2002–2011	GN	Black Sea	Romania	*Phocoena phocoena relicta*	129	-	-	-
Radu and Anton, 2014	2002–2011	GN	Black Sea	Romania	*Tursiops truncatus ponticus*	2	-	-	-
Birkun *et al.*, 2014	2002–2011	GN	Black Sea	Romania	*Phocoena phocoena relicta*	52	-	10.4	5 sets/52
Birkun *et al.*, 2014	-	GN	Black Sea	Romania	*Phocoena phocoena relicta*	-	320	-	-
Gönener and Bilgin, 2009	March–April 2006	GTR	Black Sea	Turkey	*Phocoena phocoena relicta*	92	-	4.14	22 km of nets/92

Table 7 (continued)

Bibliographic reference	Reference years	Gear	GFCM subregion	Country	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year[1]	Fishing operations/ Number of interactions recorded
Gönener and Bilgin, 2009	March–April 2006	GTR	Black Sea	Turkey	*Phocoena phocoena relicta*	2	-	0.01	22 km/2
Birkun *et al.*, 2014	-	GN	Black Sea	Turkey	*Phocoena phocoena relicta*	-	6 477	-	-
Birkun *et al.*, 2014	-	GN	Black Sea	Turkey	*Tursiops truncatus ponticus & Delphinus delphis ponticus*	-	4 500	-	--
Tonay, 2016	2007–2008	GTR	Black Sea	Turkey	*Phocoena phocoena relicta*	24	1 269–3 100	0.18	130 km/24
Tonay, 2016	2007–2008	GTR	Black Sea	Turkey	*Tursiops truncatus ponticus*	1	12–324	0.01	130 km/1
Bilgin *et al.*, 2018	2010–2011	GN	Black Sea	Turkey	*Phocoena phocoena relicta*	71	-	0.13	136 nets/71
Bilgin *et al.*, 2018	2010–2011	GN	Black Sea	Turkey	*Delphinus delphis ponticus*	4	-	< 0.003	136 nets/4
Vishnyakova and Gol'din, 2015	1993–2013	-	Black Sea	Russian Federation/ Ukraine	*Phocoena phocoena relicta*	93	-	-	

Notes:
GN = gillnet not specified; GTR = trammel net
In grey, data collected before 2008.
1. n/year or CPUE=n/km nets
2. Number of individuals released alive.

4.3.2.4 Longliners

Generally, two types of longlines are used in the Mediterranean Sea: drifting longlines (sometimes also called surface or pelagic longlines) used in the water column at variable depths and set longlines (sometimes also called bottom or demersal longlines) deployed on the sea bottom.

a) Drifting longlines

Drifting longlines are one of the most widespread types of fishing gear globally, as well as in the Mediterranean, where they target mainly swordfish (*Xiphias gladius*), albacore (*Thunnus alalunga*), bluefin tuna (*Thunnus thynnus*) and some smaller tunas. They can be deployed on the continental shelf or in offshore waters at different depths (i.e. from the surface down to 600 m) and can reach 55 km in length, comprising up to 2 000–3 000 hooks. Depending on the target species, the hook size and shape can vary, ranging from 4 to 7 cm or more. In the past, the impact on cetaceans was low: only some cases were recorded, scattered across the Mediterranean and the Black Sea (Table 8).

Western Mediterranean

Between 2000 and 2009, an extensive survey was carried out in Spanish waters to assess the interactions between drifting longliners and cetaceans; 2 587 fishing sets were observed and a gross total of 5 398 297 hooks were monitored (Macías López *et al.*, 2012). Over this period, only in 52 cases (around 2 percent of the total fishing operations) were cetacean interactions recorded; these resulted in the capture of 57 individuals. The cetaceans belonged to four species: 33 Risso's dolphins (*Grampus griseus*), eight striped dolphins (*Stenella coeruleoalba*), six common dolphins (*Delphinus delphis*) and four long-finned pilot whales (*Globicephala melas*), plus six unidentified dolphins. Overall, 82 percent of the dolphins were released alive. The study showed significant differences in the numbers of dolphins caught, according to the type of bait, the size of the hook, the soaking time (i.e. the time during which the fishing gear is actively in the water), the type of longline (i.e. traditional surface longline, Japanese longline, the American type longline with light sources to attract fish, the mesopelagic longline) and the depth of deployment (Table 8).

Central Mediterranean

No recent data are available for drifting longliners operating in this subregion.

Adriatic Sea

No recent data are available for drifting longliners operating in this subregion.

Eastern Mediterranean

No recent data are available for drifting longliners operating in this subregion.

Black Sea

No recent data are available for drifting longliners operating in this subregion.

b) Set longlines

Set longlines are not considered as a threat to cetaceans.

Western Mediterranean

No recent data are available for set longliners operating in this subregion.

Central Mediterranean

Bradai *et al*. (2018, unpublished data) report the entanglement of two bottlenose dolphins in Tunisia, both of which were released alive (Table 8).

Adriatic Sea

No recent data are available for set longliners operating in this subregion.

Eastern Mediterranean

No recent data are available for set longliners operating in this subregion.

Black Sea

No recent data are available for set longliners operating in this subregion.

4.3.2.5 Tuna seiners

Dolphins are rarely caught in purse seines targeting bluefin tuna and the impact of this type of fishery on cetaceans can be considered negligible (see Table 3).

Western Mediterranean

No recent data are available for tuna seiners operating in this subregion.

Central Mediterranean

No recent data are available for tuna seiners operating in this subregion.

Eastern Mediterranean

No recent data are available for tuna seiners operating in this subregion.

Table 8 – Incidental catch and estimated mortality rates of cetaceans in drifting longlines

Bibliographic reference	Reference years	Gear	Country	GFCM subregion	Species	Reported individuals in bycatch events	Estimated bycatch events	Mortality rate/year	Fishing operations/ Number of interactions recorded
Di Natale and Mangano, 1983b	1978–1982	LLD	Italy	Western Mediterranean	*Physeter macrocephalus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	LLD	France	Western Mediterranean	*Stenella coeruleoalba*	4	-	-	-
Duguy *et al.*, 1983a, 1983b	-	LLD	Spain	Western Mediterranean	*Tursiops truncatus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	LLD	Italy	Western Mediterranean	*Tursiops truncatus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	LLD	Italy	Western Mediterranean	*Grampus griseus*	1	-	-	-
Duguy *et al.*, 1983a, 1983b	-	LLD	Italy	Western Mediterranean	*Physeter macrocephalus*	16	-	-	-
Di Natale, 1989	-	LLD	Italy	Western Mediterranean	*Grampus griseus*	1	-	-	-
Di Natale, 1989	-	LLD	Italy	Western Mediterranean	*Ziphius cavirostris*	1	-	-	-
Garibaldi, 2015	1990	LLD	Italy	Western Mediterranean	*Stenella coeruleoalba*	1*	-	-	-
Mussi *et al.*, 1998	1991–1995	LLD	Italy	Western Mediterranean	*Physeter macrocephalus*	1	-	-	-
University of Barcelona, 1995	1991–1995	LLD	Spain	Western Mediterranean	all species	-	13–32	10%	-
Camiñas and Valeiras, 2001	1999	LLD	Spain	Western Mediterranean	all species	3	-	-	-
Camiñas and Valeiras, 2001	2000	LLD	Spain	Western Mediterranean	all species	12	-	-	-
Macías López *et al.*, 2012	2000–2009	LLD (for albacore)	Spain	Western Mediterranean	*Delphinus delphis*	1	-	0.002/1 000 hooks	-
Macías López *et al.*, 2012	2000–2009	LLD (for swordfish)	Spain	Western Mediterranean	*Delphinus delphis*	5	-	0.0015	-
Macías López *et al.*, 2012	2000–2009	LLD (for albacore)	Spain	Western Mediterranean	*Stenella coeruleoalba*	2	-	0.004	-
Macías López *et al.*, 2012	2000–2009	LLD (for swordfish)	Spain	Western Mediterranean	*Stenella coeruleoalba*	5	-	0.0016	-
Macías López *et al.*, 2012	2000–2009	LLD (for swordfish)	Spain	Western Mediterranean	*Stenella coeruleoalba*	1	-	0.003	-
Macías López *et al.*, 2012	2000-2009	LLD (for swordfish)	Spain	Western Mediterranean	*Globicephala melas*	2	-	0.0038	-
Macías López *et al.*, 2012	2000–2009	LLD (for swordfish)	Spain	W Mediterranean	*Globicephala melas*	2	-	0.0006	-
Macías López *et al.*, 2012	2000-2009	LLD (for swordfish)	Spain	Western Mediterranean	*Grampus griseus*	14	-	0.0246	-
Macías López *et al.*, 2012	2000–2009	LLD (for swordfish)	Spain	Western Mediterranean	*Grampus griseus*	10	-	0.0028	-
Macías López *et al.*, 2012	2000–2009	LLD (for swordfish)	Spain	Western Mediterranean	*Grampus griseus*	5	-	0.0087	-
Macías López *et al.*, 2012	2000–2009	LLD (for swordfish)	Spain	Western Mediterranean	*Grampus griseus*	4	-	0.012	-
Macías López *et al.*, 2012	2000–2009	LLD	Spain	Western Mediterranean	unidentified	6		-	-
Macías López *et al.*, 2012	2000–2009	LLD	Spain	Western Mediterranean	all species	47 + 10[1]	-	22% - 0.011/1 000 hooks	2 877 sets/52
Bradai *et al.*, unpublished data	2018	LLD (for swordfish)	Tunisia	Central Mediterranean	*Tursiops truncatus*	2	-	-	-

Notes: LLD = drifting longline.

In grey, data collected before 2008.

1. Number of individuals released alive.

Adriatic Sea

No recent data are available for tuna seiners operating in this subregion.

Black Sea

No recent data are available for tuna seiners operating in this subregion.

4.3.2.6 Dredges

Western Mediterranean

No recent data are available for dredges operating in this subregion.

Central Mediterranean

No recent data are available for dredges operating in this subregion.

Eastern Mediterranean

No recent data are available for dredges operating in this subregion.

Adriatic Sea

No recent data are available for dredges operating in this subregion.

Black Sea

No recent data are available for dredges operating in this subregion.

4.4 Depredation

Interactions between marine mammals and fisheries have a double effect: while marine mammals can be trapped by nets and hooks (incidental catch), they can also hurt fishers (depredation) in several ways. From a socio-economic perspective, marine mammal interactions with fisheries may have negative effects, including damage to fishing gear, reductions in catch size or quality, as well as loss of fishers' time, money or even gear. A number of studies have been carried out in the past on this issue, mainly involving the common bottlenose dolphin in many areas of the Mediterranean Sea (Díaz López, 2006; Cebrian, 2008; Mitra, Koutrakis and Milani, 2001; Fossa, Lammers and Orsi Relini, 2011; Pace, Tizzi and Mussi, 2015; Lauriano *et al.*, 2004; Pennino *et al.*, 2015; Benmessaoud *et al.*, 2018), but also on monk seals (Schultze-Westrum, 1976; Boulva, 1979; Berkes, 1982; Cebrian, 2008; Güçlüsoy, 2008; Ronald and Healy, 1974; Marchessaux and Duguy, 1977; Berkes *et al.*, 1979; Ríos *et al.*, 2017). Likewise, bottlenose dolphins also interact with fish farms at sea (Díaz López, 2006, 2017; Díaz López and Methion, 2017; Bearzi, Quondam and Politi, 2001; Piroddi, Bearzi and Christensen, 2011), sometimes resulting in incidental catch (Díaz López and Shirai, 2007).

Indeed, fishers have always viewed marine mammals as competitors for the same resources; furthermore, depredation by some species (such as monk seals and bottlenose dolphins) has always been the subject of complaints from fishers. In some cases, however, it appears that cetacean interactions with fishing activities, rather than having had only negative consequences, actually allowed for an increase in catch and fishing yields (CPUE), with the cetaceans incidentally foraging cooperatively with fishers (Benmessaoud *et al.*, 2018).

Depredation seems to be increasing in comparison to a few decades ago, involving different and larger species, such as sperm whales (Hanselman, Pyber and Peterson, 2018) and killer whales (Towers *et al.*, 2018). In the Mediterranean, one of the most notable cases is linked to the depredation by killer whales of the bluefin tuna small-scale fishery in the Strait of Gibraltar (de Stephanis, Cornulier and Verborgh, 2008; Guinet *et al.*, 2007; Esteban *et al.*, 2014, 2016). It is clear that the different types of interactions and the possibility of entanglement depend on the characteristics of the fishing gear, such as mesh size, yarn strength, depth of deployment and fishing strategies, among other aspects. However, entanglements due to depredation are generally scarce. The behaviour of depredation and the relative capacity to recognize and distinguish noises produced by the different phases of fishing activities (haulers, depth sounders, engines and so on) can be learned and passed down from generation to generation in cetacean populations (Díaz López, Bunke and Shirai, 2008; Pace, Pulcini and Triossi, 2011).

It is not easy to assess the actual damage, especially depending on the species and gear in question. Some attempts to estimate the damage and economic loss dealt by marine mammals, for example, Mediterranean monk seals (*Monachus monachus*), to fishers have been made in the past (see Goedicke, 1981). However, Cebrian (2008) remarked that seal damage reported by fishers in small-scale fisheries has generally been overreported, potentially distorting calculation values. Meanwhile, besides possibly overestimated damage to nets, monitoring of coastal fishing activities in Greek waters with important seal populations has revealed that monk seals may take an average of as little as 1 kg of fish from nets monthly per animal (Cebrian, 2008). More recently, however, Ríos *et al*. (2017) estimated possible economic loss due to depredation by monk seals in Greece at EUR 2 230 per fisher annually.

The cost of catch loss and net damage caused by common bottlenose dolphins (*Tursiops truncatus*) in the Balearic Islands between 2001 and 2003 was estimated as 6.5 percent of the total catch value and the annual loss as 3.4 percent of the total catch by weight (Brotons, Grau and Rendell, 2008). Another study conducted in the Balearic Islands between September and October of 2001 estimated the total economic damage caused by bottlenose dolphins as EUR 1 094 per trammel boat (Gazo, Gonzalvo and Aguilar, 2008). In addition, Lauriano *et al.* (2004) carried out an investigation in northeastern Sardinia and estimated that the catch loss from 1999 to 2001 came to about EUR 1 170 per trammel boat per fishing season, based on direct observations.

It is more difficult to quantify the damage done to other fishing activities, such as purse seiners targeting small pelagics. These fisheries are based on the concentration of fish, often in strictly coastal waters, and therefore also greatly attract marine mammals, especially cetaceans, often lured by the easy capture of their favourite prey, which allows them to save energy in the search for food in the process. The resulting arrival of the cetaceans disaggregates the schools of small pelagics, leading to delays, as well as losses of catch, for the fishers. Unpublished studies carried out in Morocco reported an annual economic loss due to bottlenose dolphins (*Tursiops truncatus*) in the purse seine fishery as high as 36 percent, with an annual loss per boat owner varying between 9 and 19 percent (Zahri *et al.*, 2004). More recently, Benmessaoud *et al*. (2018) estimated EUR 364 per month as the average costs of repairing nets damaged by dolphins in the area of Kelibia, Tunisia.

The situation for trawlers remains different. Interactions involving bottom trawlers frequently occur in the Mediterranean, as in other parts of the world, with the main species involved being the common bottlenose dolphin (Fertl and Leatherwood, 1997; Silvani, Raich and Aguilar, 1992;

Goffman, Kerem and Spanier, 1995; Trites, Christensen and Pauly, 1997; Consiglio *et al*., 1992; Mussi *et al*., 1998; Pace *et al*., 1999; Bearzi *et al*., 2008; Gonzalvo *et al*., 2008). Indeed, foraging behind bottom trawlers provides cetaceans with an efficient strategy to save time and energy (Fertl and Leatherwood, 1997). Generally, cetaceans, such as bottlenose dolphins, feed on the fish that come out of the nets or on discards rejected by fishers at sea and therefore rarely cause any real physical damage. Only a few cases were reported of individuals catching prey fish in front of the mouth of the trawling net, thereby capitalizing on the higher fish concentrations. Under these circumstances, in addition to possibly doing economic damage to the fishers, such types of behaviour are dangerous for the dolphins themselves, potentially leading to capture or entanglement (Goffman *et al*., 1995; Kent *et al*., 2005).

4.5 Outlook

Marine mammals have always had a conflictual relationship with fishing activities/fishers, to a greater or lesser degree depending on the historical period, the type of fishing gear and species involved and socio-economic factors. Nevertheless, the literature and datasets analysed in this review indicate that in recent years (since 2008), the incidental catch of cetaceans in Mediterranean fisheries has begun to decrease with respect to past levels, i.e. when bycatch of marine mammals in pelagic driftnets was relevant, as well as of other groups of large marine vertebrate species. The use of these nets was banned in 2005 and since then, only a few studies have reported the bycatch of marine mammals from other fisheries in the Mediterranean Sea.

Generally, the types of fishing gear responsible for the most interactions with marine mammals are those used by small-scale fisheries in coastal areas, including bottom-set gillnets and trammel nets targeting several demersal species, such as red mullet (*Mullus surmuletus*), common cuttlefish (*Sepia officinalis*), and other neritic fish and cephalopod species in the Mediterranean Sea, and bottom-set gillnets for Black Sea turbot (*Scophthalmus maximus*). The marine mammal species most impacted in the Mediterranean are the Mediterranean monk seal (*Monachus monachus*), common bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*) and harbour porpoise (*Phocoena phocoena*), along with three highly vulnerable species endemic to the Black Sea, the Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*), the Black Sea common dolphin (*Delphinus delphis ponticus)* and the Black Sea harbour porpoise (*Phocoena phocoena relicta)* (Birkun, 2002; Reeves, McClellan and Werner, 2013; Birkun *et al*., 2014).

The Mediterranean monk seal (*Monachus monachus*), given its biological and physiological characteristics, has always been extremely vulnerable to human activities; this species has seen its distribution area and population size dramatically drop since the last century. Its populations still present in the Mediterranean have now been reduced to a few hundred individuals, and it has been considered extinct in the Black Sea for over 20 years (Güçlüsoy *et al*., 2004). Though historically, the main cause of death was related to direct interactions with humans, in more recent years, habitat disturbance and loss due to the expansion of human activities, including tourism, have been the main causes of death affecting monk seals, rather than incidental catch in coastal fisheries. Though it may not always be easy to understand the real causes of death, monk seal bycatch seems to have an impact primarily on calves and juveniles, rather than on adults (Androukaki *et al.* 1999, 2006). Currently, signs of population recovery, albeit minimal, have been offered by some authors; these positive trends are probably due to the protection policies implemented and above all to a better relationship between fishers and monk seals (Notarbartolo di Sciara and Kotomatas, 2016).

Considering cetacean bycatch in the Mediterranean basin from a strictly numerical point of view, mortality due to fishing reached high numbers only in large-mesh driftnets targeting large pelagic fish (Di Natale, 1989, 1995; Notarbartolo di Sciara, 1990; IWC, 1994; Di Natale and Notarbartolo di Sciara, 1994; Forcada and Hammond, 1998; Reeves and Notarbartolo di Sciara, eds., 2006; Tudela *et al.*, 2005). In fact, once large driftnets were banned and subsequently dismissed, cetacean bycatch considerably decreased, currently concerning only sporadically medium-small cetacean species, such as the bottlenose dolphin and the common dolphin.

PLATE 3
Common dolphin (*Delphinus delphis*)

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The situation in the Black Sea is quite different, as the coastal fisheries targeting Black Sea turbot still have an impact on the endemic cetacean populations (Birkun, 2002; Birkun *et al.*, 2014). The high levels of incidental catch mainly involve Black Sea harbour porpoises (*Phocoena phocoena relicta*), which generally live in coastal habitats and are impacted much more than the other cetacean species. From a technical point of view, this differential impact is probably due to a combination of both the size of the mesh used in the gillnets and/or trammel nets and the size of the Black Sea harbour porpoise, which is the smallest of the three cetacean species in the Black Sea (Birkun, 2002; Birkun *et al.*, 2014).

In general, however, it has always been difficult to make reliable estimates of total cetacean incidental catch. One of the main problems is that the methods used by researchers in different countries are not standardized, making it extremely difficult to compare the results obtained (Di Natale, 1995; Silvani *et al.*, 1999; Tudela *et al.*, 2005). Moreover, the parameters that should always be taken into account are numerous and difficult to evaluate; in order to make estimates more reliable, it is necessary to assume that observations made during surveys at sea (the best approach) are applicable to the entire fleet or vessel group throughout the year and during all seasons. The number of vessels involved in a certain fishery and the fishing effort (based on days at sea, kilometres of nets, number of hauls and number of hooks, among other criteria) should be considered, as well as cetacean behaviour (for example, time, area and species involved) and environmental parameters. Nevertheless, it is likewise complicated to obtain good estimates of the total incidental catch, even when surveys are carried out at sea. Moreover, collecting data in the field unfortunately consumes large amounts of time and money.

An example of the potential difficulties involved with this kind of approach comes from analysing gillnets targeting turbot (*Scophthalmus maximus*) in the Black Sea. This fishery has always impacted the local cetacean populations. Many estimates have been made in the past, some of which are more reliable than others. Based on surveys, onboard observations and interviews with fishers, Birkun *et al.* (2014) estimated the total effort of the turbot set net fishery in the Black Sea by country and the corresponding total cetacean bycatch for the Black Sea harbour porpoise (*Phocoena phocoena relicta*), as well as a combined figure for the other two endemic dolphin species, the Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*) and the Black Sea common dolphin

Table 9 – Estimated number of vessels, fishing effort, stated catch rate and potential total incidental catch of cetaceans from the fishers' survey for the turbot gillnet fishery

Country	Number of vessels	Number of trips	Number of hauls	Km of net hauled	Km days of effort	Stated porpoise[1] bycatch per vessel/year	Stated dolphin[2] bycatch per vessel/year	Potential porpoise[1] bycatch per year	Potential dolphin[2] bycatch per year
Ukraine	543	16 154	96 926	760 865	3 660 110	2.83	2.23	1 539	1 211
Romania	118	2 931	12 777	95824	716 058	2.71	0	320	0
Bulgaria	812	8 088	76 263	945 662	13 398 754	3.71	2.33	3 016	1 895
Turkey	1 119	7 553	26 856	306 158	3 348 608	5.79	4.02	6 477	4 500
Total	**2 592**	**34 726**	**212 821**	**2 108 510**	**21 123 528**			**11 351**	**7 606**

Source: modified from Birkun *et al.* (2014).

Notes:

1. Black Sea harbour porpoise (*Phocoena phocoena relicta*).
2. Could refers to both Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*) and Black Sea common dolphin (D*elphinus delphis ponticus*).

Table 10 – Indicative incidental catch of vulnerable species in other types of fishing gear in the Black Sea

Gear	Country	Number of vessels	Porpoise bycatch rate per vessel	Dolphin bycatch rate per vessel	Estimated porpoise bycatch per year	Estimated dolphin bycatch per year
Gillnets	Ukraine	474	0.25	2.27	119	1 076
Gillnets	Turkey	3 148	3.11	1.62	9 799	5 104
Purse seine	Ukraine	21	1.15	1	24	21
Purse seine	Turkey	395	2.71	0.56	1 070	220
Pelagic trawl	Ukraine	49	0.50	1.38	25	68
Total					**11 037**	**6 489**

Source: modified from Birkun *et al.* (2014).

(*Delphinus delphis ponticus*). The same procedure was carried out for the other types of fishing gear used in the Black Sea as well; the results are reported in Table 9 and Table 10 and clearly show the difference between stated and potential bycatch in the Black Sea in relation to fishing effort.

Considering the incredibly high levels of incidental catch they came up with, the authors themselves cast some doubt on the reliability of these estimates, which, in some cases, even exceeded the actual abundance of the entire population of the species. They concluded that the main problems are linked to difficulties in obtaining robust estimates of incidental catch rates, which can then be extrapolated to produce a better estimate for the whole fleet. Indeed, it appears likely that the observations reported must have been far from representative of the overall fishing activities. In order to provide more accurate data, these types of errors can be corrected only by a higher coverage of monitoring activities.

PLATE 4
Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*)

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Over the last two decades, as made clear by this review, studies on incidental catch have considerably declined, while research on direct interactions (i.e. depredation) between marine mammals and fishing gear is increasing, often with the aim of quantifying its importance and, when possible, assessing the damage inflicted on fishers from an economic point of view (Díaz López, 2006; Radu, Anton and Dumitrache, 2008; Quero *et al.*, 2000; Bearzi *et al.*, 2008; Bradai *et al.*, 2010; Pennino *et al.*, 2015; Ríos *et al.*, 2017; Revuelta *et al.*, 2018).

However, it clearly remains very difficult to reduce interactions between marine mammals and fishing activities. A positive sign seems to come from the recent decreases in bycatch and lethal interactions, which depend on increased awareness of fishers and reductions in fishing effort, especially in the number of boats in some areas (FAO, 2016, 2018, 2020), as well as on the introduction of protection and mitigation measures. These measures can vary, depending on the types of fishing gear and strategies employed and the marine mammals involved. In order to reduce cetacean and monk seal bycatch (and mortality) and economic damage to fishers, controls could be implemented to limit fishing effort (i.e. closures at certain times and in specific areas) or to modify the different types of fishing gear and strategies used by fishers (i.e. gear designed to minimize bycatch, the introduction of devices able to prevent unwanted catch, such as grids for trawlers, and changes in fishing behaviour). Awareness campaigns should be implemented for fishers and all stakeholders involved in fishery activities, highlighting the important value of marine mammals in terms of natural cycles, biodiversity conservation, ecotourism, etc.

Acoustic deterrent devices are one of the most widespread measures used in attempt to mitigate interactions between marine mammals and fishing gear. Pingers (i.e. devices that transmit short, high-pitched signals) have been tested in a large variety of situations all over the world, but sometimes offer contradictory results. For example, pingers can function as a "dinner bell" for cetaceans (Bordino *et al.* 2002), who become rapidly habituated to the initial avoidance response (Imbert *et al.*, 2002, 2007). While in the GFCM area of application, it seems they could have a positive effect on reducing the bycatch of Black Sea harbour porpoises (*Phocoena phocoena relicta*) in the Black Sea turbot gillnet fishery (Gönener and Bilgin, 2009; Zaharieva, Spasova and Gavrilov, 2016), other areas showed different results. In the Adriatic Sea, pingers were used consistently from 2006 to 2018 during surveys carried out on midwater pair trawlers (Fortuna *et al.*, 2010a, 2010b). The objective was to test the effects of different types of acoustic deterrent devices on the behaviour of cetaceans and assess their real efficacy as a mitigation measure for this fishing activity. The first results seemed encouraging, but statistical analysis of the entire project revealed that the pinger influence on dolphin behaviour was not significant, highlighting a gradual reduction of the effects over time (De Carlo *et al.*, 2012; Sala *et al.*, 2018). Other studies provide good evidence for the effectiveness of pingers in reducing the incidental catch of some cetacean species (Gazo, Gonzalvo and Aguilar, 2008; Brotons *et al.*, 2008; Dawson *et al.*, 2013), but a definitive answer for achieving effective mitigation overall is still lacking (Zahri *et al.*, 2007; Buscaino *et al.*, 2009).

In conclusion, further studies are required to improve the collection of reliable data on fishing effort, fishing gear and fishing strategies, covering, to the greatest extent possible, all the coastal fisheries of the whole Mediterranean and the Black Sea region. Moreover, the standardization of survey methods and observer sampling protocols should be considered one of the top priorities in order to obtain robust estimates of marine mammal bycatch rates, of which so much remains unknown.

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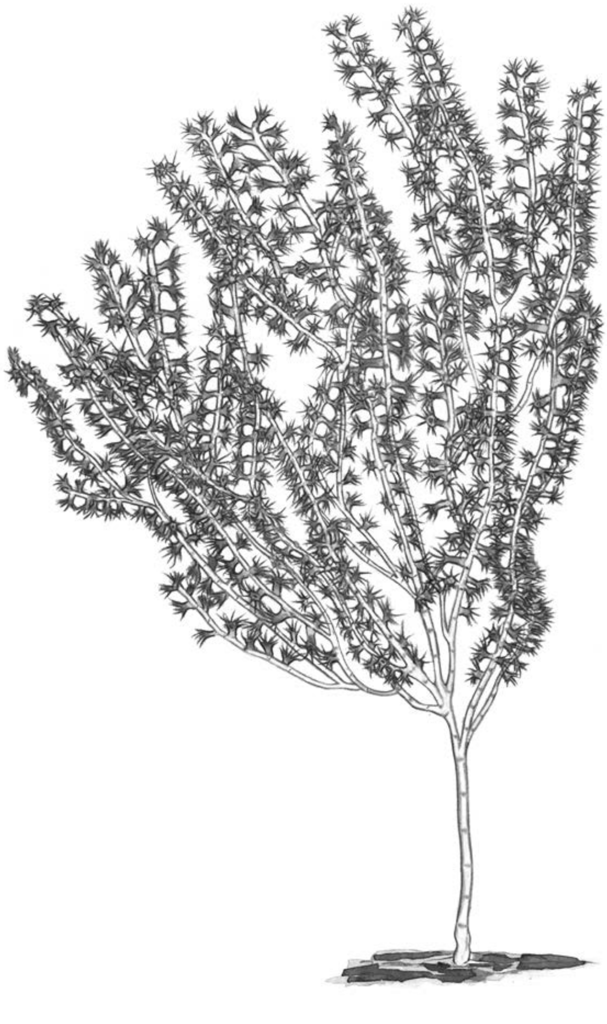
MACROBENTHIC INVERTEBRATES



The black coral (*Antipathella subpinnata*)

5. Macrobenthic invertebrates

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Executive summary

Macrobenthic invertebrates such as soft and hard corals, sponges, echinoderms, molluscs and other benthic organisms contribute to forming structured habitats that may constitute the so-called vulnerable marine ecosystems (VMEs). This review describes VMEs and their macrobenthic indicator taxa currently known in the Mediterranean Sea, and provides an overview of available information on the bycatch of these taxa from fishery-dependent and fishery-independent surveys. It presents a detailed analysis of available information on the incidental catch of VME indicator taxa at the lowest possible taxonomic level, by sub-basin and bottom-contact fishing gear (such as bottom trawlers set longliners and gillnets, as well as pot and traps generally used in small-scale fisheries). Nonetheless, bycatch data from commercial fisheries are often scarce or only refer to a few specific areas. In this respect, independent scientific surveys can provide insights into the bycatch of VME indicator taxa. Bottom trawls represent the most impactful fishing practice to VMEs. On the other hand, the extent of bycatch from set longlines and small-scale fisheries is almost unknown. For example, the use of a VME encounter protocol for deep-sea fisheries using bottom-contact gear, as well as fishery monitoring protocols based on onboard observers, could provide new information on the distribution of VME indicators in most of the Mediterranean areas not covered by scientific surveys. This would assist in identifying VME hotspot or priority areas for the implementation of conservation measures (such as fishery closure).

5.1 Vulnerable marine ecosystems

A wide variety of macro- and megabenthic species (0.5–20 mm and >20 mm, respectively) are present in the Mediterranean Sea. They can display an aggregative behaviour and constitute populations and communities which play a significant structural role in providing essential three-dimensional habitats for fish and invertebrate communities, acting as habitat formers, from the shallow to the deep-sea (e.g. Caddy, 2007; Bo *et al.*, 2011; Freiwald *et al.*, 2009; Buhl-Mortensen *et al.*, 2010; D'Onghia *et al.*, 2010, 2011; Bo *et al.*, 2012; Aguilar *et al.*, 2013; Chimienti *et al.*, 2019a). The biogenic habitats resulting from this aggregation host a rich fauna, including endangered and protected species as well as fish and crustacean species of high commercial value (D'Onghia, Sion and Capezzuto, 2019; Mastrototaro *et al.*, 2010, 2017; D'Onghia *et al.*, 2012, 2017; Rueda *et al.*, 2019; Sion *et al.*, 2019).

Because of the high abundance of commercial species, often with large-sized specimens, inhabiting them, these benthic habitats are usually targeted by commercial fisheries (Bo, Canese and Bavestrello, 2014; Bo *et al.*, 2014a; Cau *et al.*, 2017c; D'Onghia, 2019). However, they are particularly sensitive to certain types of bottom-contact fishing gear used in some fisheries, as well as to other human activities impacting the seabed. According to FAO (2009), vulnerable marine ecosystems (VMEs) are groups of species, communities, or habitats that may be vulnerable to impacts from fishing activities. Their vulnerability is linked to their likelihood of experiencing substantial alterations from short-term or chronic disturbances, as well as to their eventual recovery possibilities. Thus, a marine ecosystem is classified as vulnerable based on its uniqueness or rarity, its functional significance, its fragility (both physical and functional), its structural complexity and the life-history traits of the species that make its recovery difficult (for example, slow growth rate, late age of maturity, low or unpredictable recruitment and long-life expectancy).

Deep-sea ecosystems more generally present these traits and may hence be particularly vulnerable to the impacts of fishing gear (Danovaro *et al.*, 2010; Ramirez-Llodra *et al.*, 2011). Deep-sea fisheries, which make use of gear that comes into contact with the seafloor to catch benthic or demersal species, can affect the marine environment damaging VMEs and causing negative effects, known as significant adverse impacts. Several resolutions adopted by the United Nations General Assembly, namely Resolution 59/25 in 2004 (UNGA, 2004), Resolution 61/105 in 2006 (UNGA, 2006) and Resolution 64/72 in 2009 (UNGA, 2009), called upon regional fisheries management organizations to take urgent action to protect VMEs from significant adverse impacts in areas beyond national jurisdiction. Significant adverse impacts occur when the ecosystem function is impaired and the long-term natural productivity is degraded on more than a temporary basis, compromising the long-term integrity and function of VMEs as structurally complex communities and habitats.

Temporary impacts are those that are limited in duration and allow an ecosystem to recover over an acceptable time span. Ecosystem recovery is case-by-case dependent, but impacts are generally not considered temporary if the recovery takes more than 5 to 20 years, depending on the specific features of the populations and ecosystems (FAO, 2009). Moreover, impacts should be evaluated individually, in combination and cumulatively. Vulnerable marine ecosystems develop under specific topographical, hydrophysical and geological conditions, such as seamounts and volcanic ridges, canyons and trenches, steep slopes, submarine relief structures (for example, slumped blocks, ridges and cobble fields), cold seeps (including pockmarks, mud volcanoes, sediment under reducing conditions, anoxic pools and methanogenic hard bottoms), as well as hydrothermal vents, collectively referred to as VME indicator features (FAO, 2009). In association with these features, several benthic species or groups of species can settle and live, representing a signal of VME occurrence, and are thus called VME indicator species or taxa.

The General Fisheries Commission for the Mediterranean (GFCM) defined Mediterranean VME indicator taxa, habitats and features (GFCM, 2017, 2018b). Vulnerable marine ecosystem indicator taxa include soft and hard corals, sponges, echinoderms, molluscs and other benthic organisms (Table 1, Table 2), most of which are included in relevant lists of protected species, such as the International Union for the Conservation of Nature (IUCN) Red List (IUCN, 2021). Nevertheless, no broad consensus exists about the depth range for the occurrence of VMEs or for restricting deep-sea fishery practices. Conventionally, from an ecological point of view, the deep sea is considered to be over 200 m depth and beyond the shelf break (Thistle, 2003), and the deep Mediterranean is regarded as roughly coinciding with the aphotic zone, from 150–200 m depth, where the direct influence of the sunlight is almost absent and the bathyal zone, as defined by Pérès and Picard (1964), generally begins. The mesophotic seabed of the so-called twilight zone (from 50 to 150–200 m depth), often targeted by fisheries, can host important and fragile animal communities too, and generally fits the definition of VMEs (Bo, Canese and Bavestrello, 2014; Cerrano *et al.*, 2010; Bo *et al.*, 2014a, 2015; Cau *et al.*, 2017c; Chimienti *et al.*, 2020b). In fact, in the North Atlantic, the ecological impacts on seabed communities are considered comparable to ocurring on shallower ecosystems (Clark and Koslow, 2007; Hall–Spencer, Allain and Fosså, 2002; Clark, Althaus and Schlacher, 2016; Gage *et al.*, 2005; Waller *et al.*, 2007), and this might also be the case at a global scale (Clark and Rowden, 2009; Koslow *et al.*, 2001; Althaus *et al.*, 2009). From a fishery management perspective, the concept of deep sea is linked to the occurrence of deep-sea fisheries (FAO, 2009), which in many regions of the world operate in areas beyond national jurisdiction, i.e. from the continental slope to depths of thousands metres. In light of this, the significant adverse impact on VMEs has been mostly associated with deep-sea fisheries in the international context.

Due to the oceanographic conditions characterizing the Black Sea (Özsoy and Ünlüata, 1997), no VME indicators are likely to occur in this basin below 200 m depth, though some fragile communities can occur in shallower waters. For instance, a rare garden of the gorgonian *Spinimuricea klavereni* was found in the Marmara Sea, which connects with the Black Sea (Figure 1), where unquantified trammel net fishing activities were reported (Topçu and Öztürk, 2016). However, no VME indicator taxa were reported in the invertebrate bycatch from commercial trawling along the Turkish coast in the southern Black Sea (Kasapoglu and Duzgunes, 2017), or from the shrimp beam trawl fishery in the Marmara Sea (Zengin and Akyol, 2009). Moreover, there are no data available on the incidental catch of VME indicator taxa from longline and small-scale fisheries in the Black Sea; therefore the following sections focus on the Mediterranean Sea.

BOX 1. Definitions

Alcyonacea: corals (Phylum: Cnidaria; Class: Anthozoa; Subclass: Octocorallia) that do not produce calcium carbonate skeletons, but only minute, thorny skeletal elements called sclerites. They include the so-called gorgonians.

Antipatharians: also known as black corals, an order of coral (Phylum: Cnidaria; Class: Anthozoa; Subclass: Hexacorallia) characterized by a black skeleton and an arborescent shape.

Aphotic zone: the portion of the seabed where there is very little or no sunlight. It is formally defined as the depths beyond which less than 1 percent of sunlight penetrates. In the Mediterranean Sea, it indicatively starts below 200 m depth and includes the bathyal zone.

Bathyal and abyssal zones: the portion of the seabed where the light is absent and plants and algae cannot live. In the oceans, the bathyal zone is followed by the abyssal zone, where the water temperature is less than 4°C. In the Mediterranean Sea, the bathyal zone indicatively starts below 200 m depth and has a temperature between 12.5 and 14.5°C, depending on the different locations in the basin.

Byssus: a bundle of protein filaments secreted by many species of bivalves that function to attach the mollusc to the substrate.

Cold seep: an area of the ocean floor, sometimes also called cold vent, where hydrogen sulphide, methane and other hydrocarbon-rich fluid seepage occurs, often in the form of a brine pool.

Deep-sea fisheries: Deep-sea fisheries are those that operate at great depths (up to 1 600 m). Deep-sea fisheries in the Mediterranean Sea are defined as: i) all fishing vessels above 15 m length overall (LOA) using bottom contact fishing gear to fish for giant red shrimp (*Aristaeomorpha foliacea*), blue and red shrimp (*Aristeus antennatus*) or golden shrimp (*Plesionika martia*); and ii) all fishing vessels above 15 m LOA using bottom contact gear (bottom trawls, longlines, gillnets and pots and traps) at depths deeper than 300 m or on offshore seamounts (FAO, 2020).

Ecosystem engineer: any organism that creates, significantly modifies, maintains or destroys a habitat.

Emergent fauna: an aggregation of individuals or colonies of benthic animal species that develop above the seabed, enhancing the three-dimensionality of the environment.

Epibiosis: any relationship between two organisms in which one lives on the other. Epibionts can usually settle on a coral when the latter is stressed, injured or dead.

Encounters and encounter rules: an encounter with vulnerable marine ecosystem (VME) indicator taxa is defined as any catch of VME indicator taxa by any deep-sea fishery. Encounter rules stipulate that, following an encounter, the captain of the vessel shall report the encounter to the flag State, completing an ad hoc form and providing the following information: i) the position of the vessel; ii) the fishing characteristics of the vessel; and iii) the groups of VME indicator taxa encountered and the best estimates of their live weight. Encounter rules were endorsed by the GFCM in 2018, and GFCM contracting parties and cooperating non-contracting parties are encouraged to use them when implementing measures to prevent significant adverse impacts of deep-sea fisheries on VMEs (Resolution GFCM/43/2019/6 on the establishment of a set of measures to protect vulnerable marine ecosystems formed by cnidarian (coral) communities in the Mediterranean Sea) (FAO, 2020).

BOX 1. (Continued)

Essential fish habitat: Habitats identified as essential to satisfying the ecological and biological requirements of critical life history stages of exploited fish (used as a collective term to include molluscs, crustaceans and any other aquatic animal that is harvested) species. These habitats may require special protection to improve the status of the stocks and secure their long-term sustainability (FAO, 2020).

Exploratory deep-sea bottom fishing protocols: exploratory (or new) deep-sea bottom fishing occurs during the initial development phase of a deep-sea fishery when it begins to either operate in areas that have not previously been fished or to fish again in familiar areas after significant changes in gear or effort. Exploratory deep-sea bottom fishing protocols are established to ensure that exploratory or new deep-sea fishing activities are only allowed to grow at a rate consistent with the knowledge and management of that fishery and while always respecting existing VMEs. Thus, vessels undertaking exploratory (or new) deep-sea bottom fishing shall be required to follow the exploratory deep-sea bottom fishing protocol, providing information on: i) the start and end points of each tow or set; ii) the fishing characteristics of the vessel, including the gear used; iii) the geographical subarea and the statistical grid where the exploratory deep-sea fishing occurred; iv) catch, bycatch, discards and fishing effort; and v) VME indicator taxa (if any) through the VME encounter protocol. These protocols were endorsed by the GFCM in 2018, and GFCM contracting parties and cooperating non-contracting parties are encouraged to use them when implementing measures to prevent significant adverse impacts of deep-sea fisheries on vulnerable marine ecosystems (Resolution GFCM/43/2019/6 on the establishment of a set of measures to protect vulnerable marine ecosystems formed by cnidarian (coral) communities in the Mediterranean Sea) (FAO, 2020).

Fishery-dependent surveys: surveys carried out as part of commercial fishing activities.

Fishery-independent surveys: surveys not carried out as part of commercial fishing but, for example, through ad hoc fishing campaigns or scientific/experimental surveys.

Mesophotic zone: also known as the circalittoral zone or twilight zone, the portion of the seabed from the limit of seagrass present to the limit of algae present (loss of net productivity at the level of irradiance <1 percent). In the Mediterranean Sea, it indicatively ranges between 50 and 200 m depth.

Methanogenic hard bottom: the production of methane from the seafloor which sometimes form a hard crust.

Osculum, oscula: an excretory structure in the living sponge, represented by a large opening through which the current of water exits after passing through the atrial cavity (spongocoel).

Precious corals: a term collectively describing the species of corals (species belonging to the Phylum Cnidaria with a skeleton made of calcium carbonate or limestone) whose skeletal axis is used as a gemstone to make ornaments and jewelry (FAO, 2020).

Pockmarks: circular to ellipsoid shallow craters on soft muddy sea floors, formed by sub-sea-floor fluid expulsion. The diameter of pockmarks can range from a few metres to >300 m. They can be locally very abundant, forming pockmark fields.

Table 1 – Vulnerable marine ecosystem indicator features, habitats and taxa present in the Mediterranean Sea

Mediterranean VME indicator features		
Seamounts and volcanic ridges		
Canyons and trenches		
Steep slopes		
Submarine relief structures (e.g. slumped blocks, ridges and cobble fields)		
Cold seeps (pockmarks, mud volcanoes, sediment under reducing conditions, anoxic pools and methanogenetic hard bottoms)		
Hydrothermal vents		
Mediterranean VME indicator habitats		
Cold-water coral reefs		
Coral gardens		Hard-bottom coral gardens
		Soft-bottom coral gardens
Sea pen fields		
Deep-sea sponge aggregations		"Ostur" sponge aggregations
		Hard-bottom sponge gardens
		Glass sponge communities
		Soft-bottom sponge gardens
Tube-dwelling anemone patches		
Crinoid fields		
Oyster reefs and other giant bivalves		
Seep and vent communities		
Other dense emergent fauna		
Mediterranean VME indicator taxa		
Phylum	**Class**	**Subclass (order)**
Cnidaria	Anthozoa	Hexacorallia (Antipatharia, Scleractinia)
		Octocorallia (Alcyonacea, Pennatulacea)
		Ceriantharia
	Hydrozoa	Hydroidolina
Porifera	Demospongiae	
	Hexactinellida	Amphidiscophora
		Hexasterophora
Bryozoa	Gymnolaemata	
	Stenolaemata	
Echinodermata	Crinoidea	Articulata
Mollusca	Bivalvia	Gryphaeidae (*Neopycnodonte cochlear, N. zibrowii*)
		Heterodonta* (Lucinoida) (e.g. *Lucinoma kazani*)
		Pteriomorphia* (Mytiloida) (e.g. *Idas modiolaeformis*)
Annelida*	Polychaeta	Sedentaria (Canalipalpata) (e.g. *Lamellibrachia anaximandri, Siboglinum* spp.)
Arthropoda*	Malacostraca	Eumalacostraca (Amphipoda) (e.g. *Haploops* spp.)

* Only chemosynthetic species indicating the presence of a cold seep or hydrothermal vent are considered.

Source: GFCM, 2018b.

Table 2 – Examples of families, genera and species included in vulnerable marine ecosystem indicator taxa, and main references

VME indicator habitat	Family	Genus/species	Author	References
Cold-water coral reefs (section 5.1.1)	Order Scleractinia			
	Caryophylliidae	*Desmophyllum dianthus*	(Esper, 1794)	Tursi *et al.*, 2004; Taviani *et al.*, 2005, 2017; Freiwald *et al.*, 2009, 2011; Mastrototaro *et al.*, 2010; Angeletti *et al.*, 2014, 2020; D'Onghia *et al.*, 2015a; Chimienti, Angeletti and Mastrototaro, 2018; Chimienti *et al.*, 2019a
	Caryophylliidae	*Lophelia pertusa* (*Desmophyllum pertusum*)	(Linnaeus, 1758)	Tursi *et al.*, 2004; Taviani *et al.*, 2005, 2017; Schembri *et al.*, 2007; Freiwald *et al.*, 2009, 2011; Orejas *et al.*, 2009; Mastrototaro *et al.*, 2010; Gori *et al.*, 2013; Angeletti *et al.*, 2014, 2020; Fabri *et al.*, 2014; Addamo *et al.*, 2015; Chimienti, Angeletti and Mastrototaro, 2018; Chimienti *et al.*, 2019a
	Dendrophylliidae	*Dendrophyllia cornigera*	(Lamarck, 1816)	Tursi *et al.*, 2004; Orejas *et al.*, 2009; Mastrototaro *et al.*, 2010; Salomidi *et al.*, 2010; Gori *et al.*, 2013, 2014; Bo *et al.*, 2014a; D'Onghia *et al.*, 2016; Lastras *et al.*, 2016; Chimienti *et al.*, 2019a; Enrichetti *et al.*, 2019; Giusti *et al.*, 2019; Moccia *et al.*, 2021
	Scleractinia	*Madrepora oculata*	(Linnaeus, 1758)	Tunesi and Diviacco, 1997; Tursi *et al.*, 2004; Taviani *et al.*, 2005, 2017; Schembri *et al.*, 2007; Freiwald *et al.*, 2009, 2011; Orejas *et al.*, 2009; Mastrototaro *et al.*, 2010; Lo Iacono *et al.*, 2012; Gori *et al.*, 2013; Angeletti *et al.*, 2014, 2020; Fabri *et al.*, 2014; D'Onghia *et al.*, 2015a, 2016; Lastras *et al.*, 2016; Fanelli *et al.*, 2017; Chimienti, Angeletti and Mastrototaro, 2018; Chimienti *et al.*, 2019a
	Order Anthoathecata			
	Stylasteridae	*Errina aspera***	(Linnaeus, 1767)	Giacobbe, 2001; Álvarez–Pérez *et al.*, 2005; Giacobbe *et al.*, 2007; Salvati *et al.*, 2010; Chimienti *et al.*, 2019a
Mesophotic stony coral communities (section 5.1.2)	Order Scleractinia			
	Caryophylliidae	*Phyllangia americana mouchezii*	(Lacaze-Duthiers, 1897)	Zibrowius, 1980; Corriero *et al.*, 2019
	Caryophylliidae	*Polycyathus muellerae*	(Abel, 1959)	Zibrowius, 1980; Corriero *et al.*, 2019
	Dendrophylliidae	*Dendrophyllia ramea**	(Linnaeus, 1758)	Zibrowius, 1980; Ocaña *et al.*, 2000; Sánchez *et al.*, 2004; Salomidi *et al.*, 2010; Orejas *et al.*, 2017
Coral gardens (section 5.1.3)	**Hard-bottom coral gardens (section 5.1.3.1)**			
	Order Antipatharia			
	Antipathidae	*Antipathes dichotoma*	(Pallas, 1766)	Mastrototaro *et al.*, 2010; Bo *et al.*, 2011, 2014c, 2020b; Mytilineou *et al.*, 2014; Cau *et al.*, 2015; Chimienti *et al.*, 2019a ; Moccia *et al.*, 2021
	Leiopathidae	*Leiopathes glaberrima*	(Esper, 1788)	Deidun *et al.*, 2010, 2015; Mastrototaro *et al.*, 2010; Angeletti *et al.*, 2014; Mytilineou *et al.*, 2014; Bo *et al.*, 2015; Cau *et al.*, 2015; Ingrassia *et al.*, 2016; Massi *et al.*, 2018; Chimienti *et al.*, 2019a; Moccia *et al.*, 2021
	Myriopathidae	*Antipathella subpinnata*	(Ellis and Solander, 1786)	Bo *et al.*, 2008, 2009, 2012, 2014c; Cau *et al.*, 2015; Deidun *et al.*, 2015; Enrichetti *et al.*, 2019; Chimienti *et al.*, 2020b ; Moccia *et al.*, 2021
	Schizopathidae	*Parantipathes larix*	(Esper, 1788)	Bo *et al.*, 2012, 2014b; Cau *et al.*, 2015; Ingrassia *et al.*, 2016; Chimienti *et al.*, 2019a ; Moccia *et al.*, 2021

Table 2 (continued)

VME indicator habitat	Family	Genus/species	Author	References
	Order Alcyonacea			
	Acanthogorgiidae	*Acanthogorgia hirsuta*	(Gray, 1857)	Tursi *et al.*, 2004; Mastrototaro *et al.*, 2010; Bo *et al.*, 2012, 2014a; Moccia *et al.*, 2021
	Alcyoniidae	*Alcyonium acaule**	(Marion, 1878)	Ambroso *et al.*, 2013a; Fiorillo *et al.*, 2013
	Alcyoniidae	*Alcyonium coralloides*	(Pallas, 1766)	Groot and Weinberg, 1982; Quintanilla *et al.*, 2013
	Coralliidae	*Corallium rubrum*	(Linnaeus, 1758)	Rossi *et al.*, 2008; Deidun *et al.*, 2010; Santangelo and Bramanti, 2010; Costantini *et al.*, 2011; Bramanti *et al.*, 2013; Bavestrello *et al.*, 2014; Cau *et al.*, 2015; Knittweis *et al.*, 2016; Lastras *et al.*, 2016; Giusti *et al.*, 2019; Ferrigno *et al.*, 2020; Moccia *et al.*, 2021
	Dendrobrachiidae	*Dendrobrachia bonsai*	(López-González and Cunha, 2010)	López-González and Cunha, 2010; Sartoretto, 2012; Bo *et al.*, 2020b
	Ellisellidae	*Ellisella paraplexauroides*	(Stiasny, 1936)	Angiolillo *et al.*, 2012; Maldonado *et al.*, 2013; Grinyó *et al.*, 2016
	Ellisellidae	*Viminella flagellum*	(Johnson, 1843)	Giusti *et al.*, 2012; Lo Iacono *et al.*, 2012; Bo *et al.*, 2014a; Cau *et al.*, 2015, 2017c; Deidun *et al.*, 2015; Chimienti *et al.*, 2019a; Moccia *et al.*, 2021
	Gorgoniidae	*Eunicella cavolini*	(Koch, 1887)	Russo, 1985; Weinbauer and Velimirov, 1996a, 1996b; Cau *et al.*, 2015; Sini *et al.*, 2015; Enrichetti *et al.*, 2019; Giusti *et al.*, 2019; Moccia *et al.*, 2021
Coral gardens (section 5.1.3)	Gorgoniidae	*Eunicella singularis**	(Esper, 1791)	Skoufas *et al.*, 2000; Coma *et al.*, 2006; Gori *et al.*, 2007, 2011a, 2011b, 2012; Ribes *et al.*, 2007; Linares *et al.*, 2008; Ferrier–Pagès *et al.*, 2009;
	Gorgoniidae	*Eunicella verrucosa*	(Pallas, 1766)	Coz *et al.*, 2012; Bo *et al.*, 2014a; Enrichetti *et al.*, 2019; Giusti *et al.*, 2019; Chimienti, 2020
	Gorgoniidae	*Leptogorgia sarmentosa**	(Esper, 1789)	Mistri, 1995; Rossi and Gili, 2009; Gori *et al.*, 2011a
	Isididae	*Chelidonisis aurantiaca*	(Studer, 1890)	Bo *et al.*, 2020b
	Nidaliidae	*Chironephthya mediterranea*	(López-González, Grinyó and Gili, 2015)	López-González *et al.*, 2015
	Nidaliidae	*Nidalia studeri**	(Koch, 1891)	López-González *et al.*, 2012
	Plexauridae	*Bebryce mollis*	(Philippi, 1842)	Mastrototaro *et al.*, 2010; Bo *et al.*, 2012; Grinyó *et al.*, 2016; Moccia *et al.*, 2021
	Plexauridae	*Muriceides lepida*	(Carpine & Grasshoff, 1975)	Bo *et al.*, 2020a, 2020b
	Plexauridae	*Paramuricea clavata*	(Risso, 1826)	Bavestrello *et al.*, 1997; Cerrano *et al.*, 2005; Linares *et al.*, 2008; Linares and Doak, 2010; Gori *et al.*, 2011a; Mokhtar-Jamai *et al.*, 2011; Bo *et al.*, 2014a; Ponti *et al.*, 2018; Enrichetti *et al.*, 2019; Giusti *et al.*, 2019; Moccia *et al.*, 2021
	Plexauridae	*Paramuricea macrospina*	(Koch, 1882)	Mastrototaro *et al.*, 2010; Bo *et al.*, 2011, 2012; Angeletti *et al.*, 2014; Grinyó *et al.*, 2016; Enrichetti *et al.*, 2019
	Plexauridae	*Placogorgia coronata**	(Carpine and Grasshoff, 1975)	Cartes *et al.*, 2009; Enrichetti *et al.*, 2018
	Plexauridae	*Spinimuricea klavereni**	(Carpine and Grasshoff, 1975)	Vafidis *et al.*, 1994; Bo *et al.*, 2012; Topçu and Öztürk, 2013, 2015, 2016
	Plexauridae	*Swiftia dubia*	(Thomson, 1929)	Mastrototaro *et al.*, 2010; Mytilineou *et al.*, 2014; Grinyó *et al.*, 2016
	Plexauridae	*Villogorgia bebrycoides**	(Koch, 1887)	Bo *et al.*, 2012, 2014a, 2020a

Table 2 (continued)

VME indicator habitat	Family	Genus/species	Author	References
Coral gardens (section 5.1.3)	Primnoidae	*Callogorgia verticillata*	(Pallas, 1766)	Tursi *et al.*, 2004; Mastrototaro *et al.*, 2010; Pardo *et al.*, 2011; Bo *et al.*, 2012, 2014a, 2015, 2020a; Lo Iacono *et al.*, 2012; Angeletti *et al.*, 2014; Fabri *et al.*, 2014; Cau *et al.*, 2015, 2017c; Deidun *et al.*, 2015; Chimienti *et al.*, 2019a, 2020b; Moccia *et al.*, 2021
	Soft-bottom coral gardens (section 5.1.3.2)			
	Order Alcyonacea			
	Alcyoniidae	*Alcyonium palmatum**	(Pallas, 1766)	Ambroso *et al.*, 2013b; Enrichetti *et al.*, 2019
	Isididae	*Isidella elongata*	(Esper, 1788)	D'Onghia *et al.*, 2003; Maynou and Cartes, 2012; Bo *et al.*, 2014a, 2015; Fabri *et al.*, 2014; Mytilineou *et al.*, 2014; Pierdomenico *et al.*, 2016; Mastrototaro *et al.*, 2017; Chimienti *et al.*, 2019a; Gerovasileiou *et al.*, 2019; Carbonara *et al.*, 2020
Sea pen fields (section 5.1.4)	Order Pennatulacea			
	Funiculinidae	*Funiculina quadrangularis*	(Pallas, 1766)	Ocaña *et al.*, 2000; Tunesi *et al.*, 2001; Freiwald *et al.*, 2009; Porporato *et al.*, 2009; Pardo *et al.*, 2011; Bo *et al.*, 2012; Aguilar *et al.*, 2013; Cartes *et al.*, 2013; Fabri *et al.*, 2014; Pierdomenico *et al.*, 2016; Bastari *et al.*, 2018; Chimienti *et al.*, 2019a
	Kophobelemnidae	*Kophobelemnon stelliferum*	(Müller, 1776)	Gili *et al.*, 1987; Hebbeln *et al.*, 2009; Pardo *et al.*, 2011; Bo *et al.*, 2012; Mastrototaro *et al.*, 2013; Fabri *et al.*, 2014; Pierdomenico *et al.*, 2016; Chimienti *et al.*, 2019a
	Pennatulidae	*Pennatula phosphorea*	(Linnaeus, 1758)	Mytilineou *et al.*, 2014; Mastrototaro *et al.*, 2017
	Pennatulidae	*Pennatula rubra*	(Ellis, 1761)	Chimienti, Angeletti and Mastrototaro, 2018; Chimienti *et al.*, 2015, 2018; Enrichetti *et al.*, 2019
	Pennatulidae	*Pteroeides spinosum*	(Ellis, 1764)	Porporato *et al.*, 2011, 2012, 2014
	Veretillidae	*Veretillum cynomorium*	(Pallas, 1766)	
	Virguatiidae	*Virgularia mirabilis*	(Müller, 1776)	Ambroso *et al.*, 2013a; Deidun *et al.*, 2015
Deep-sea sponge aggregations (section 5.1.5)	**"Ostur" sponge aggregations (section 5.1.5.1)**			
	Order Tetractinellida			
	Geodiidae	*Geodia barretti**	(Bowerbank, 1858)	Cárdenas *et al.*, 2013
	Geodiidae	*Geodia conchilega**	(Schmidt, 1862)	Vacelet, 1961; Pulitzer-Finali, 1972, 1983; Saritas, 1973; Corriero *et al.*, 2000; Ben Mustapha *et al.*, 2003; Voultsiadou, 2005; Cárdenas *et al.*, 2013
	Geodiidae	*Geodia nodastrella**	(Carter, 1876)	Longo *et al.*, 2005
	Hard-bottom sponge gardens (section 5.1.5.2)			
	Order Dictyoceratida			
	Dysideidae	*Dysidea* spp.		Vacelet, 1959; Corriero *et al.*, 1997
	Irciniidae	*Sarcotragus foetidus*	(Schmidt, 1862)	Enrichetti *et al.*, 2020
	Order Haplosclerida			
	Chalinidae	*Haliclona* spp.		Bertolino *et al.*, 2013; Grenier *et al.*, 2018
	Petrosiidae	*Petrosia (Petrosia) ficiformis*	(Poiret, 1789)	Bertolino *et al.*, 2013; Grenier *et al.*, 2018

Table 2 (continued)

VME indicator habitat	Family	Genus/species	Author	References
Deep-sea sponge aggregations (section 5.1.5)	Order Poecilosclerida			
	Cladorhizidae	*Lycopodina hypogea**	(Vacelet and Boury-Esnault, 1996)	Vacelet and Boury-Esnault, 1996; Aguilar *et al.*, 2011; Fourt *et al.*, 2017; Grenier *et al.*, 2018
	Microcionidae	*Antho (Antho) dichotoma*	(Linnaeus, 1767)	Boury-Esnault *et al.*, 1994
	Order Suberitida			
	Halichondriidae	*Topsentia* spp.		Bertolino *et al.*, 2013; Grenier *et al.*, 2018
	Suberitidae	*Suberites* spp.*		Pansini and Musso, 1991; Bertolino *et al.*, 2013; Grenier *et al.*, 2018
	Order Tetractinellida			
	Axinellidae	*Phakellia hirondellei*	(Topsent, 1890)	Boury-Esnault *et al.*, 1994; Grenier *et al.*, 2018
	Axinellidae	*Phakellia robusta**	(Bowerbank, 1866)	Topsent, 1925; Maldonado, 1992; Boury-Esnault *et al.*, 1994; Calcinai *et al.*, 2013; de la Torriente *et al.*, 2014; D'Onghia *et al.*, 2015a; Grenier *et al.*, 2018
	Axinellidae	*Phakellia ventilabrum**	(Linnaeus, 1767)	Maldonado, 1992; Lo Iacono *et al.*, 2012; de la Torriente *et al.*, 2014
	Axinellidae	*Axinella* spp.		Enrichetti *et al.*, 2020
	Azoricidae	*Leiodermatium lynceus**	(Schmidt, 1870)	Boury-Esnault *et al.*, 1994; Magnino *et al.*, 1999; Longo *et al.*, 2005; Grenier *et al.*, 2018
	Azoricidae	*Leiodermatium pfeifferae**	(Carter, 1873)	Maldonado *et al.*, 2015; Bo *et al.*, 2020a
	Pachastrellidae	*Pachastrella monilifera*	(Schmidt, 1868)	Pulitzer-Finali, 1983; Maldonado, 1992; Longo *et al.*, 2005; Voultsiadou, 2005; Mastrototaro *et al.*, 2010; Bo *et al.*, 2012; Calcinai *et al.*, 2013; Angeletti *et al.*, 2014; D'Onghia *et al.*, 2015a; Grenier *et al.*, 2018; Moccia *et al.*, 2021
	Vulcanellidae	*Poecillastra compressa*	(Bowerbank, 1866)	Vacelet, 1976; Pansini, 1987a, 1987b; Boury-Esnault *et al.*, 1994; Longo *et al.*, 2005; Voultsiadou, 2005; Mastrototaro *et al.*, 2010; Bo *et al.*, 2012; Calcinai *et al.*, 2013; Angeletti *et al.*, 2014; D'Onghia *et al.*, 2015a; Fourt *et al.*, 2017; Grenier *et al.*, 2018; Moccia *et al.*, 2021
	Vulcanellidae	*Vulcanella gracilis*	(Sollas, 1888)	Calcinai *et al.*, 2013; Grenier *et al.*, 2018
	Soft-bottom sponge gardens (section 5.1.5.3)			
	Order Poecilosclerida			
	Cladorhizidae	*Cladorhiza abyssicola**	(Sars, 1872)	Boury-Esnault *et al.*, 1994; Fourt *et al.*, 2017; Mastrototaro *et al.*, 2017
	Order Suberitida			
	Stylocordylidae	*Stylocordyla pellita*	(Topsent, 1904)	Zibrowius and Taviani, 2005; Maldonado *et al.*, 2015; Fourt *et al.*, 2017; Grenier *et al.*, 2018; Bo *et al.*, 2020a
	Suberitidae	*Rhizaxinella* spp.		Pansini and Musso, 1991; Ilan *et al.*, 2003; Bertolino *et al.*, 2013; Grenier *et al.*, 2018
	Order Tetractinellida			
	Theneidae	*Thenea muricata*	(Bowerbank, 1858)	Sarà, 1958; Vacelet, 1969; Pansini, 1987b; Uriz and Rosell, 1990; Pansini and Musso, 1991; Ben Mustapha *et al.*, 2003; Voultsiadou, 2005; de la Torriente *et al.*, 2014; Fourt *et al.*, 2014, 2017; Evans *et al.*, 2016; Mastrototaro *et al.*, 2017; Grenier *et al.*, 2018

Table 2 (continued)

VME indicator habitat	Family	Genus/species	Author	References
Deep-sea sponge aggregations (section 5.1.5)	**Glass sponge communities (section 5.1.5.4)**			
	Order Amphidiscosida			
	Pheronematidae	*Pheronema carpenteri*	(Thomson, 1869)	Rice *et al.*, 1990; Barthel *et al.*, 1996; Boury-Esnault *et al.*, 2015; Grenier *et al.*, 2018
	Order Lyssacinosida			
	Rossellidae	*Asconema setubalense*	(Kent, 1870)	Aguilar *et al.*, 2011, 2013; Sitjà and Maldonado, 2014; Boury-Esnault *et al.*, 2015; Maldonado *et al.*, 2017
Tube-dwelling anemone patches (section 5.1.6)	Order Spirularia			
	Cerianthidae	*Cerianthus membranaceus*	(Gmelin, 1791)	Aguilar *et al.*, 2008; Lastras *et al.*, 2016
	Order Penicillaria			
	Arachnactidae	*Arachnanthus* spp.		Aguilar *et al.*, 2014
Crinoid fields (section 5.1.7)	Order Comatulida			
	Antedonidae	*Leptometra phalangium**	(Müller, 1841)	Laborel *et al.*, 1961; Vaissière and Carpine, 1964; Reyss and Soyer, 1965; Bourcier and Zibrowius, 1973; Kallianotis *et al.*, 2000; Smith *et al.*, 2000; Colloca *et al.*, 2004; Abelló and Sola, 2006; Fanelli *et al.*, 2007; Marin *et al.*, 2011a, 2011b; Pardo *et al.*, 2011; Gofas *et al.*, 2014
Oyster reefs and other giant bivalves (section 5.1.8)	Order Ostreida			
	Gryphaeidae	*Neopycnodonte cochlear**	(Poli, 1795)	de la Torriente *et al.*, 2014; Fabri *et al.*, 2014; Angeletti and Taviani, 2020; Cardone *et al.*, 2020
	Gryphaeidae	*Neopycnodonte zibrowii*	(Gofas, Salas and Taviani, 2009)	Beuck *et al.*, 2016; Taviani *et al.*, 2017, 2019
	Pinnidae	*Atrina fragilis*	(Pennant, 1777)	Zenetos, 1997; Alliani and Meloni, 1999; Šimunović *et al.*, 2001; Hiscock and Jones, 2004; Casellato and Stefanon, 2008; Papoutsi and Galinou-Mitsoudi, 2010; Pubill *et al.*, 2011; Fryganiotis *et al.*, 2013
Seep and vent communities (section 5.1.9)	**Polychaetes**			
	Order Sabellida			
	Siboglinidae	*Lamellibrachia* spp.		Olu–LeRoy *et al.*, 2004; Hughes and Crawford, 2008; Bayon *et al.*, 2009; Gambi *et al.*, 2011; Southward *et al.*, 2011; Taviani *et al.*, 2013
Other dense emergent fauna (section 5.1.10)	**Actinians**			
	Order Actiniaria			
	Hormathiidae	*Actinauge richardi*	(Marion, 1882)	Marano *et al.*, 1989; D'Onghia *et al.*, 2003
	Hydrozoans			
	Order Leptothecata			
	Aglaopheniidae	*Lytocarpia myriophyllum*	(Linnaeus, 1758)	Rossi, 1950; Di Camillo *et al.*, 2013; Cerrano *et al.*, 2015; Fourt *et al.*, 2017; Enrichetti *et al.*, 2019
	Brachiopods			
	Order Terebratulida			
	Terebratulidae	*Gryphus vitreus*	(Born, 1778)	Boullier *et al.*, 1986; Emig, 1989, 1997; Logan *et al.*, 2002; Taviani *et al.*, 2011; Gerovasileiou and Bailly, 2016

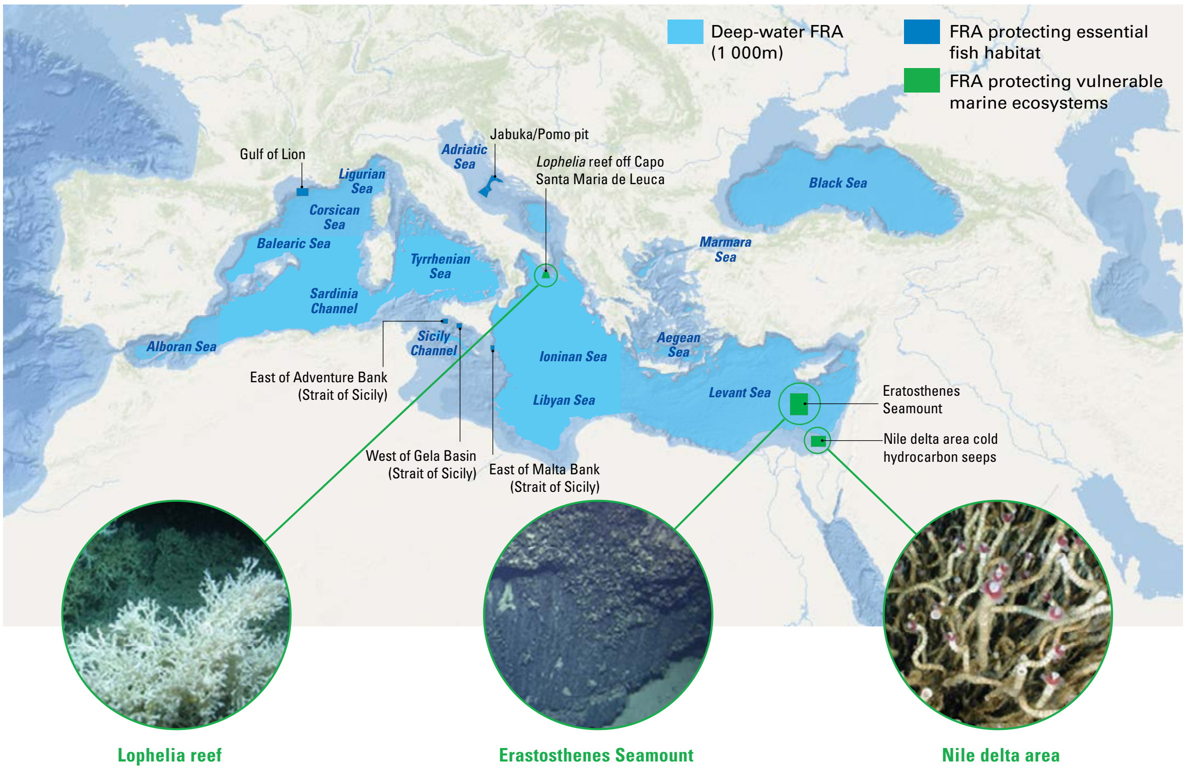
Table 2 (continued)

VME indicator habitat	Family	Genus/species	Author	References
	Bryozoans			
	Order Cheilostomatida			
Other dense emergent fauna (section 5.1.10)	Adeonidae	*Adeonella* spp.		Casoli *et al.*, 2020
	Bitectiporidae	*Pentapora* spp.		Enrichetti *et al.*, 2019; Casoli *et al.*, 2020
	Bugulidae	*Kinetoskias* spp.		Harmelin and d'Hondt, 1993; Aguilar *et al.*, 2013; Maldonado *et al.*, 2015; Mastrototaro *et al.*, 2017
	Celleporidae	*Celleporina* spp.		
	Celleporidae	*Turbicellepora* spp.		
	Myriaporidae	*Myriapora* spp.		Casoli *et al.*, 2020
	Phidoloporidae	*Reteporella* spp.		Casoli *et al.*, 2020
	Smittinidae	*Smittina* sp.		Casoli *et al.*, 2020
	Order Cyclostomatida			
	Horneridae	*Hornera* spp.		

* plasticity in the occupation of both hard bottoms or soft detritic bottoms.

** not a true coral, but a hydrocoral that may form reef-like structures.

FIGURE 1
GFCM Fisheries restricted areas for the conservation of fishery resources and marine habitats



Source: FAO, 2020.

5.1.1 Cold-water coral reefs

Cold-water coral reefs or frameworks are marine bioconstructions structuring important habitats of the deep Mediterranean Sea (Ingrosso *et al*., 2018; Chimienti *et al*., 2018c), identified as biodiversity hotspots (Mastrototaro *et al*., 2010; Watling *et al*., 2011) of considerable ecological and economic value (Foley, van Rensburg and Armstrong, 2010; Capezzuto *et al*., 2018a). These habitats are mainly composed of the so-called white corals, namely the colonial species *Madrepora oculata* and *Lophelia pertusa* (currently renamed as *Desmophyllum pertusum*), as well as the solitary coral *Desmophyllum dianthus*. These species have a broad frame-building ability, being able to deposit calcium carbonate and build up durable biogenic substrata. In particular, the branched stony corals *M.oculata* and *L. pertusa* can create large bioconstructions (Plate 1), facilitating the formation of true deep-sea coral frameworks, while *D. dianthus* is a pseudo-colonial bank-building coral which can reach high local densities in the Mediterranean Sea, often in association with colonial corals (Freiwald *et al*., 2009; Roberts *et al*., 2009; Gori *et al*., 2013; Angeletti *et al*., 2014; Lo Iacono *et al*., 2014; Chimienti *et al*., 2018c, 2019a).

D'Onghia (2019) described the role of cold-water coral as shelter, feeding and life-history critical habitats for fish species in the Mediterranean Sea and in world oceans. Cold-water coral habitats provide a suitable ground for larval settlement and juvenile growth of benthic species and represent an important spawning and nursery area for vagile fauna, acting as essential fish habitat for several commercial and non-commercial fish and invertebrate species (D'Onghia, Sion and Capezzuto, 2019; Fabri *et al*., 2014; D'Onghia *et al*., 2015a, 2015b, 2016; Cau *et al*., 2017b; Capezzuto *et al*., 2018b, 2019; Sion *et al*., 2019). For instance, D'Onghia *et al*. (2010) reported that a cold-water coral habitat in the central-eastern Mediterranean hosted large densities of reproducing fish individuals, such as the blackbelly rosefish (*Helicolenus dactylopterus*) and the blackspot seabream (*Pagellus bogaraveo*). In addition, cold-water corals act as nursery areas for the deep-water shark, the velvet belly lanternshark (*Etmopterus spinax*) and some important commercial fish species such as the European hake (*Merluccius merluccius*).

Other stony corals can occur in cold-water coral reefs, though their presence is not usually predominant. For instance, the yellow coral *Dendrophyllia cornigera* can occur with relatively high colony density on flat or gently sloping hard bottoms (Plate 1), as well as on flat muddy bottoms without any consistent anchorage, forming *D. cornigera* beds that significantly contribute to the three-dimensionality of the seabed (Bo *et al*., 2014a; Enrichetti *et al*., 2019; Chimienti *et al*., 2019a). Solitary corals such as *Stenocyathus vermiformis*, *Javania cailleti*, *Anomocora fecunda* and cup-corals belonging to the genus *Caryophyllia* (especially *C. calveri*) can also be present in cold-water coral reefs, although they have not been reported so far with a relevant aggregative behaviour, and their role in the bioconstruction is minimal (Ocaña *et al*., 2000). In addition, the hydrocoral *Errina aspera* can be considered among the Mediterranean habitat-formers due to its branched calcareous skeleton. Currently, this species is found in the Strait of Messina, at 80–230 m depth (Giacobbe, 2001; Giacobbe *et al*., 2007), where it forms monospecific stands showing high densities similar to deep-sea coral reefs or frameworks (Salvati *et al*., 2010). The Strait of Messina's population was the only one found so far in the Mediterranean Sea but other large populations of *E. aspera* probably occur deeper in the basin, as is the case in the Strait of Gibraltar (Álvarez-Pérez *et al*., 2005; Chimienti *et al*., 2019a).

5.1.2 Mesophotic stony coral communities

Some mesophotic stony corals do not belong to the so-called cold-water corals, but they can also structure communities and bioconstructions comparable to reefs, and similarly fit the definition of VME. This is the case of the scleractinians *Phyllangia americana mouchezii* and *Polycyathus muellerae* that were observed forming mesophotic coral reefs along the Adriatic coast of Apulia, in southern Italy, with mixed bioconstructions involving, among others, the bivalve *Neopycnodonte cochlear* and serpulids (Corriero *et al*., 2019). Although these formations are assimilated to animal-dominated coralligenous bioconstructions (Ingrosso *et al*., 2018), they represent unique habitats of the mesophotic zone, whose role is likely to be comparable to the cold-water coral reefs present in deeper waters. Similarly, the pink coral *Dendrophyllia ramea* (Plate 1), mainly found in isolated colonies on the hard and sedimentary bottoms of the Mediterranean Sea (Zibrowius, 1980; Sánchez, Demestre and Martin, 2004; Ocaña *et al*., 2000; Salomidi *et al*., 2010), can occasionally form patches of up to four or six colonies per square metre (Orejas *et al*., 2017, 2019).

5.1.3 Coral gardens

Arborescent corals belonging to the subclasses Hexacorallia and Octocorallia can form large aggregations of colonies known as coral facies (as defined by Pérès and Picard, 1964), coral meadows, coral forests or coral gardens, due to their analogy with land habitats structured by plants. These coral aggregations can be monospecific or they can be present as mixed coral communities (Chimienti *et al*., 2019a).

Coral gardens can develop on hard or soft substrata, depending on the habitat-forming species. Some species settle directly on rocky bottoms or use a small hard substratum for their settlement, thus also developing their presence on detritic bottoms, on soft substrata containing shells, coral rubble and pebbles or on small rocky scattered substrata. For this reason, though categorized as hard-bottom coral gardens (Table 2), these species can be also collected during trawling operations on muddy, sandy or coarse detritic bottoms.

5.1.3.1 Hard-bottom coral gardens

The typical garden-forming anthozoans on hard bottoms belonging to the orders Antipatharia and Alcyonacea. Antipatharians are present in the Mediterranean Sea with four main species, namely *Antipathes dichotoma*, *Parantipathes larix*, *Leiopathes glaberrima* and *Antipathella subpinnata* (Plate 1), all of them forming monospecific or multispecific forests (e.g. Bo, Bavestrello and Canese, 2011; Bo, Canese and Bavestrello, 2014b; Bo *et al*., 2012, 2015; Cau *et al*., 2017b; Chimienti *et al*., 2019a, 2020b). Several fish species are often associated with these antipatharians (e.g. Mytilineou *et al*., 2014; Bo *et al*., 2015; Chimienti *et al*., 2020b). Two other species may also occur in the basin, despite information on their presence being unclear: *Antipathella wollastoni*, an Atlantic species reported only in shallow waters close to the Strait of Gibraltar (Ocaña, Opresko and Brito, 2007) and likely to be present solely in the Alboran Sea, and *Antipathes fragilis*, considered taxonomically doubtful since it was found only once, when it was described, and the holotype was subsequently lost.

Alcyonaceans are present on Mediterranean Sea hard bottoms with several species, covering a wide bathymetric range. Typical garden-forming species in the bathyal zone are the whip-like gorgonian *Viminella flagellum* (Plate 1) and the fan-shaped gorgonian *Callogorgia verticillata*, both of them known to form large gardens from 100–500 m and 150–1 000 m depth, respectively (Chimienti *et al*., 2019a). Other bathyal gorgonian species can locally contribute to structuring coral gardens, such as *Villogorgia bebrycoides*, which may occasionally form monospecific populations, and *Bebryce mollis*, which does not form extensive monospecific gardens but is often present in mixed gorgonian communities (Bo *et al.*, 2012). Furthermore, *Dendrobrachia bonsai* and *Swiftia dubia* (also synonymised with *S. pallida*; Plate 1) are characterized by small colonies that can be locally abundant (Sartoretto, 2012; Grinyó *et al.*, 2016). Together with these strictly bathyal species, other hard-bottom alcyonaceans can form large colonial aggregations from shallow to deep waters, such as *Acanthogorgia hirsuta*, *Paramuricea macrospina*, *Placogorgia coronata*, as well as the precious red coral *Corallium rubrum*.

Shallower alcyonacean species, mainly present above 200 m depth, meet the criteria for VME indicator taxa, based on traits related to their functional significance, fragility, as well as to the life histories of component species with a slow recovery to disturbance, and thus are vulnerable to fishing practices. This is the case, for example, of the gardens formed by the gorgonians *Paramuricea clavata* (Plate 1), *Ellisella paraplexauroides*, *Leptogorgia sarmentosa* and *Eunicella* spp. (*E. cavolini*, *E. singularis* and *E. verrucosa*), sometimes mixed with the ectoparasitic Zoantharia *Savaglia savalia*. These gardens can host a large variety of species, playing an important ecological role, and therefore represent true VMEs in shallow waters (Gori *et al.*, 2007, 2011b, 2017; Linares *et al.*, 2008; Cerrano *et al.*, 2010; Linares and Doak, 2010; Ponti *et al.*, 2018). Nevertheless, in the case of *L. sarmentosa*, despite its tolerance for high-sedimentation environments and ability to appear even in harbours (e.g. Betti *et al.*, 2018), its role as an ecosystem engineer on trawlable grounds should be considered, as well as for the other gorgonian gardens.

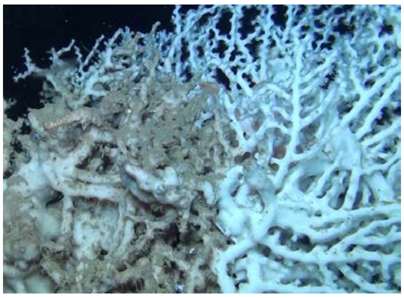
Another coastal species worth noting is *Spinimuricea klavereni*, a rare Mediterranean endemic anthozoan, whose unique large population was found in the northeastern Marmara Sea, and which requires proper protection from the impact of fishing (Topçu and Öztürk, 2016). Hard-bottom soft corals representing VME indicator species also include the nidaliids *Chironephthya mediterranea* and *Nidalia studeri*, as well as the alcyoniids *Alcyonium acaule* and *Alcyonium coralloides*. These last two species can locally form large patches on rocky bottoms and, occasionally, on detritic bottoms characterized by shells or pebbles. The alcyoniid *Alcyonium palmatum* was included for the purpose of this review within the soft-bottom alcyonacean category because it mainly dwells on more or less detritic soft substrata, even though it can be present on hard bottoms (Ambroso *et al.*, 2013b).

5.1.3.2 Soft-bottom coral gardens

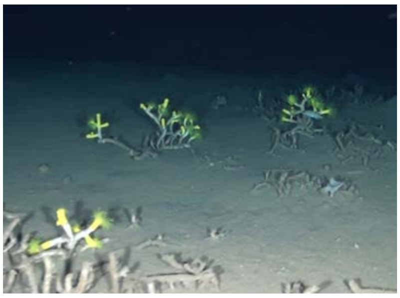
On soft bottoms, true coral gardens can be structured by the alcyonaceans *Isidella elongata* and *A. palmatum*. The dead man's fingers, *A. palmatum*, can colonize both hard and soft bottoms, although it forms large aggregations, typically on bathyal soft bottoms (Ambroso *et al.*, 2013b). The bamboo- coral, *I. elongata* (Plate 1), forms dense gardens on bathyal compact mud between 110 and 1 600 m depth, on a relatively flat or gently inclined seabed (Chimienti *et al.*, 2019a). This candelabrum-shaped gorgonian is highly sensitive to fishing pressure, with high fragility and low recovery rates (Mastrototaro *et al.*, 2017; Carbonara *et al.*, 2020). Despite being very common in the past (Carpine, 1970), the presence of *I. elongata* gardens is essentially limited to areas where trawling does not occur due to: particular seabed features, such as large cold-water coral reefs nearby or sloping soft bottoms (Hebbeln *et al.*, 2009; Fabri *et al.*, 2014); fishing bans as a result of the presence of submarine cables (Mastrototaro *et al.*, 2017); and depths over 1 000 m representing deep refuges (up to 1 656 m depth), such as for the population of *I. elongata* along the Catalan coast (Maynou and Cartes, 2012). Moreover, where trawling occasionally occurs in certain coastal areas, for example on the upper slope of the eastern Ionian Sea (D'Onghia *et al.*, 2003) and along the

PLATE 1
Examples of corals representing vulnerable marine ecosystem indicator taxa

Cold-water coral reefs


©Giovanni Chimienti

White coral
(*Madrepora oculata*)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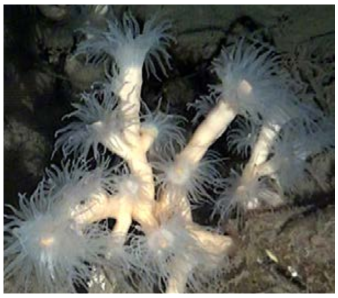
Yellow coral
(*Dendrophyllia cornigera*)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Pink coral
(*Dendrophyllia ramea*)

Hard-bottom coral gardens


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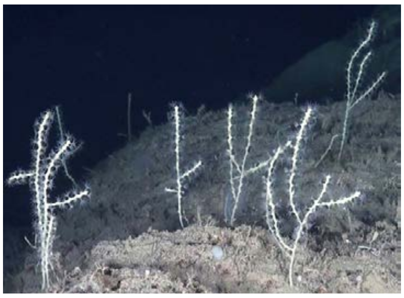
Black coral
(*Antipathella subpinnata*)


©Giovanni Chimienti

Red gorgonian
(*Paramuricea clavata*)


©Oceana

Northern sea fan
(*Swiftia dubia*)


©Oceana

Whip gorgonian
(*Viminella flagellum*)


©Oceana

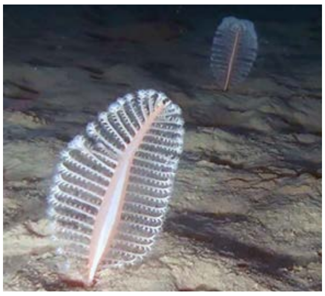
V. flagellum on a detritic bottom

Soft-bottom coral gardens


©Oceana

Bamboo coral (*Isidella elongata*)

Sea pen fields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Red sea pen (*Pennatula rubra*)

southwest Sardinian coast (Bo *et al.*, 2015), *I. elongata* can be present in shallow refuges (i.e. around 100 m depth). The overlapping of *I. elongata* hotspots with nursery and spawning areas of the deep-water red and blue shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus* and the blackmouth catshark *Galeus melastomus* was investigated in the central Mediterranean (Carbonara *et al.*, 2020).

5.1.4 Sea pen fields

Pennatulaceans, commonly known as sea pens, are colonial octocorals characterized by a more or less distinct feather-like appearance; they are adapted to live on muddy, sandy or detritic bottoms, which can be subject to bottom-contact fishing activities. These soft corals can form dense aggregations, called sea pen fields, structuring the environment and attracting vagile fauna (Pardo *et al.*, 2011; Baillon *et al.*, 2012; Mastrototaro *et al.*, 2013; Chimienti *et al.*, 2018). In the Mediterranean Sea, the sea pens *Pennatula rubra* (Plate 1), *Pteroeides spinosum* and *Veretillum cynomorium* were found to form monospecific fields on the continental shelf (Chimienti, Tursi and Mastrototaro, 2018; Porporato *et al.*, 2014; Chimienti *et al.*, 2019b). Other species like *Pennatula phosphorea* and *Virgularia mirabilis* can occur from shallow to deep seabed, often in mixed aggregations with other soft-bottom anthozoans, while *Funiculina quadrangularis* and *Kophobelemnon stelliferum*, which are true deep-sea pennatulaceans, can form dense fields in the deep muddy bottoms of the Mediterranean Sea (Freiwald *et al.*, 2009; Mastrototaro *et al.*, 2013). It is assumed that other sea pens, namely *Cavernualria pusilla, Crassophyllum thessalonicae* and *Protoptilum carpenteri*, can form fields too, but only a few scattered occurrences were recorded in the basin, thus suggesting that these species are rare (Sezgin and Yüksek, 2015; Fryganiotis *et al.*, 2011; Mastrototaro *et al.*, 2015).

5.1.5 Deep-sea sponge aggregations

Deep-sea sponge aggregations have been identified as potential VMEs under the United Nations General Assembly Resolution 61/105 of 2006 (UNGA, 2006) and by FAO (2009); in addition, they are listed as “Threatened and/or declining species and habitats” by the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) (OSPAR, 2008). The ecological importance of deep-sea sponge aggregations, rich associated community and sensitivity to human pressures have been widely documented, and the United Nations Environment Programme (UNEP) has called for international engagement in mapping and modelling deep-sea sponge distribution to preserve these habitats (Hogg *et al.*, 2010). Deep-sea sponge aggregations developing under certain geological, hydrological and biological conditions and forming a three-dimensional habitat are known as sponge beds, sponge fields, sponge grounds, sponge associations, “ostur” and sponge reefs (Hogg *et al.*, 2010). In literature, all these terms are used either as synonyms or in reference to particular species and features, which makes their use rather confusing. However, Mediterranean sponge-dominated habitats can be broadly distinguished as: 1) “ostur” sponge aggregations; 2) hard-bottom sponge gardens; 3) soft-bottom sponge gardens; and 4) glass sponge communities.

These habitats can be structured by one or more species, with different morphologies influencing the structure and composition of the associated community (Beazley *et al.*, 2013). Sponge communities can also be found in association with cold-water corals, structuring a mixed coral-sponge habitat (e.g. Mastrototaro *et al.*, 2010; Angeletti *et al.*, 2014; D’Onghia *et al.*, 2015a).

Table 2 reports the Mediterranean VME indicator habitats structured by sponges and the main VME indicator sponge taxa, with a non-exhaustive list of species and genera. In fact, due to the complex taxonomic identification of many sponge species, data are often only available for higher systematic levels, such as family or order.

5.1.5.1 "Ostur" sponge aggregations

"Ostur" sponge habitats were first described off the Faroe Islands, between the North Atlantic and the Norwegian Sea, where fishers defined the large aggregations of massive sponges as "ostur", which literally means cheese bottom and refers to the size, form and consistency of these sponges as well as the smell of broken specimens (Klitgaard and Tendal, 2001). Ostur-type sponge aggregations in the Mediterranean Sea are mainly built up by species of the genus *Geodia* (Table 2). These massive, hard sponges can have a variety of shapes, from irregular to convoluted masses, with young specimens, usually sub-spherical. They settle on gravel, pebbles or other small hard substrata, incorporating gravel into their cortex in order to anchor more strongly to the seafloor and to resist faster current speeds (Klitgaard and Tendal, 2001). "Ostur" sponge aggregations typically develop on gravelly or detritic bathyal bottoms, where the sponges grow to include the hard substratum in their body on which they originally settled.

5.1.5.2 Hard-bottom sponge gardens

The deep hard bottoms of the Mediterranean Sea can host complex sponge-dominated habitats, mainly structured by Demospongiae belonging to the orders Dictyoceratida, Haplosclerida, Poecilosclerida, Suberitida and Tetractinellida (Table 2). This latter order usually includes larger species such as the stalked, fan-shaped sponges of the genus *Phakellia*, the lamellate rock sponges *Leiodermatium lynceus* and *L. pfeifferae*, or the laterally-flat white and orange sponges *Pachastrella monilifera* and *Poecillastra compressa* both displaying an extensive distribution in the Mediterranean Sea, reaching densities of up to ten individuals per square metre, and forming mixed communities with the cold-water corals *Madrepora oculata* and *Lophelia pertusa* in several areas of the Mediterranean (Longo, Mastrototaro and Corriero, 2005; Bo *et al.*, 2012; Calcinai *et al.*, 2013; Angeletti *et al.*, 2014; Maldonado *et al.*, 2017). On mesophotic bottoms, Demospongiae belonging to the genus *Haliclona* can form extensive sponge gardens on rocky habitats (Plate 2), thus acting as habitat formers. Moreover, other species such as *Sarcotragus foetidus*, *Spongia lamella* and *Axinella polypoides* are known to form sponge aggregations on flat, patchy and highly silted hardgrounds between 40 and 70 m depth (Enrichetti *et al.*, 2020).

Some of the taxa included in this VME indicator habitat can settle on small rocks or pebbles, and thrive not only on rocky bottoms but also on mixed substrata.

5.1.5.3 Soft-bottom sponge gardens

On Mediterranean soft bottoms, the presence of sponge aggregations is limited to a few species. Sponge-based VME indicator taxa are broadly represented by the carnivorous pine-tree sponge *Cladorhiza abyssicola*, the lollipop sponges *Stylocordyla pellita* and *Rhizaxinella* spp. (mainly *R. pyrifera*), and the globular sponge *Thenea muricata*. In particular, *S. pellita* has a smooth and flexible stalk and is often attached to small hard substrata by means of a rounded disc, while *R. pyrifera* has an occasionally knobbed or branched rigid stalk and a branching root-like structure to settle on soft sediment and detritic bottoms, including mud volcanoes (Olu-Le Roy *et al.*, 2004). The globular sponge *T. muricata* is anchored to muddy bottoms by means of its rooting structures, and can form as a result monospecific or mixed communities with other sponges, as well as with the bamboo-coral *Isidella elongata* and/or sea pens (de la Torriente *et al.*, 2014; Fourt *et al.*, 2014; Evans *et al.*, 2016; Mastrototaro *et al.*, 2017).

5.1.5.4 Glass sponge communities

Hexactinellids, also known as glass sponges, represent a predominantly deep-sea group, with only nine representatives in the Mediterranean Sea. Among them, two main species are known to form sponge aggregations. The barrel-shaped *Pheronema carpenteri* lives on soft or mixed deep bottoms, where it is anchored by rooting tufts of long spicules. It is also known as the bird's nest sponge due to its hairy surface, forming an intricate network of spicules, and its globular/subcylindrical shape with a wide and deep atrial cavity and a large apical osculum. This species forms extensive populations from the south of Iceland to the western Mediterranean, forming aggregations of up to six individuals per square metre with a wet weight biomass of 1.1 kg per square metre (Rice, Thurston and New, 1990; Barthel *et al*., 1996; Boury-Esnault *et al*., 2015). The second species is the large funnel-shaped *Asconema setubalense*, living mainly on deep gravel and stones, as well as on soft or mixed substrata (Plate 2). It is called the felt vase sponge due to its thin fiberglass-like wall, folding outwards at the top. This species was documented as forming aggregations of up to five individuals per square metre in the Alboran Sea, although details of its distribution, biomass and population densities are still unknown (Aguilar *et al*., 2013; Boury-Esnault *et al*., 2015; Maldonado *et al*., 2017).

5.1.6 Tube-dwelling anemone patches

Tube anemones or cerianthids can reach high densities on both detritic and muddy bottoms. *Cerianthus membranaceus* is the most common and widespread species known so far in the Mediterranean Sea, with populations of many colonies forming cerianthid patches, often on sloping soft bottoms or around canyons (Aguilar, Torriente and Garcia, 2008; Lastras *et al*., 2016). Species belonging to the genus *Arachnanthus* can form groups of thousands of individuals, even though they tend to be slightly separated from each other (Marin *et al*., 2011a; Aguilar *et al*., 2014).

5.1.7 Crinoid fields

The crinoid *Leptometra phalangium* forms extensive crinoid fields, playing an important role in the structuring of soft bottoms (Plate 2). These fields develop particularly along shelf-break and canyon-head areas under bottom currents, where *L. phalangium* can reach a density of 50 individuals per square metre (Vaissière and Carpine, 1964; Reyss and Soyer, 1965; Bourcier and Zibrowius, 1973; Fanelli, Colloca and Ardizzone, 2007; Laborel *et al*., 1961; Kallianotis *et al*., 2000; Gofas *et al*., 2014). Despite being a vagile species, *L. phalangium* can form habitats hosting a rich associated community and supporting high abundances of recruits and juveniles of important commercial species, such as the European hake (*Merluccius merluccius*), the greater forkbeard (*Phycis blennoides*), and the deep-water rose shrimp (*Parapenaeus longirostris*) (Ordines and Massutí, 2009; Colloca *et al*., 2004). In fact, the fields of *L. phalangium* represent an indicator of highly productive areas, particularly along the Mediterranean shelf break (Colloca *et al*., 2004), where this species can be present not only on muddy bottoms, but also on hard bottoms and cold-water coral frameworks (Pardo *et al*., 2011). Occasionally, the crinoid *Antedon mediterranea* can also reach high densities and form crinoid fields in coastal waters.

5.1.8 Oyster reefs and other giant bivalves

Oysters belonging to the Gryphaeidae family, such as *Neopycnodonte cochlear* and *Neopycnodonte zibrowii*, can grow with their valves cemented onto each other, forming durable aggregations known as oyster reefs. These bioconstructions contribute to significantly increasing the habitat heterogeneity and biodiversity. In particular, *N. cochlear* reefs (Plate 2) can develop in both mesophotic and aphotic zones, from the circalittoral to the bathyal zone (Pérès and Picard, 1964), on both hard and soft detritic bottoms (de la Torriente *et al.*, 2014; Fabri *et al.*, 2014; Angeletti and Taviani, 2020; Cardone *et al.*, 2020). In contrast, *N. zibrowii* develops mainly on the deep seabed, on rocky bottoms from 350 m to more than 1 000 m depth, in locations where escarpments, seamounts and canyons are present and where it was found to reach a density of around 20 individuals per square metre (Beuck *et al.*, 2016; Taviani *et al.*, 2019).

In addition, species of the genus *Atrina* have the narrow half of their shells anchored in the sediment by means of a byssus, with a large part of the fragile shell protruding from the sea floor, making them highly vulnerable to damage by bottom trawls. The fan mussel, *Atrina fragilis*, is present on sandy and detritic bottoms throughout the basin (Zenetos, 1997; Alliani and Meloni, 1999; Hiscock and Jones, 2004; Casellato and Stefanon, 2008; Papoutsi and Galinou-Mitsoudi, 2010; Šimunović *et al.*, 2001; Pubill *et al.*, 2011). In a few areas, this species can form more or less extended patches of specimens, generally from 30 to 100 m depth and, occasionally, down to 600 m depth (Poutiers, 1987; Fryganiotis, Antoniadou and Chintiroglou, 2013; Šimunović *et al.*, 2001). Although there is very little information available, the rare congeneric comb pen shell, *Atrina pectinata,* can probably play a similar role on the circalittoral and bathyal seabed.

5.1.9 Seep and vent communities

Assemblages of certain bivalve species belonging to the families Lucinidae (e.g. *Lucinoma kazani*, *Loripes orbiculatus* and *Myrtea spinifera*), Mytilidae (e.g. *Idas modiolaeformis*), Thyasiriidae (e.g. *Thyasira flexuosa*) and Vesicomyidae (e.g. *Isorropodon perplexum*), and of polychaetes belonging to the genera *Lamellibrachia* and *Siboglinum* can develop in areas rich in sulphur and methane (Taviani, 2014), such as the Eratosthenes Seamount in the Levant Sea (Figure 1). These chemosynthetic taxa live in association with archaean communities and microbial mats (Pachiadaki and Kormas, 2013; Pachiadaki *et al.*, 2010; Brissac *et al.*, 2011; Giovannelli *et al.*, 2016), usually indicating the presence of cold seeps, hydrothermal vents or other reducing environments (Taviani, 2014), but they can also be present sometimes on wrecks with an unclear energy source for the obligate symbiotic bacteria (Hughes and Crawford, 2008; Gambi, Schulze and Amato, 2011; Dando *et al.*, 1992). These communities occur down to more than 3 000 m in depth, in proximity of submarine volcanic apparatuses, pockmark fields, fluid seepage areas and mud volcanoes (Southward, Andersen and Hourdez, 2011; Olu-Le Roy *et al.*, 2004; Dupré *et al.*, 2007; Hilário *et al.*, 2011; Taviani *et al.*, 2013) (Plate 2). Furthermore, seep and vent communities host peculiar associated species, such as the ghost shrimps of the genus *Calliax*, thus representing an important source of primary production in the deep sea (Taviani *et al.*, 2013).

5.1.10 Other dense emergent fauna

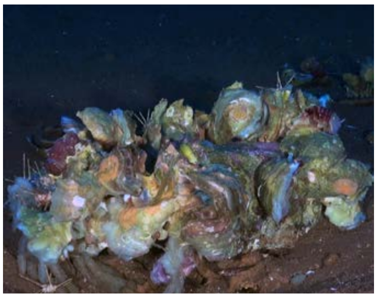
Other animal species form dense aggregations in the mesophotic and aphotic zones of the Mediterranean Sea, acting as habitat-formers, and are particularly sensitive to bottom fishing pressures. This is the case, for example, of the mud sea anemone *Actinauge richardi*, which can occur in abundant populations on bathyal bottom sediments throughout the basin. This sea anemone has a typically invaginated base, forming a rounded cavity, which encloses a ball of mud or sand for anchoring onto soft bottoms, though it is also able to adhere to solid substrata such as rocks, pebbles and even plastic litter.

PLATE 2
Examples of vulnerable marine ecosystem habitats


©Oceana
Haliclona sp. sponge garden


©Oceana
Asconema setubalense sponge garden


©Oceana
Leptometra phalangium crinoid field


©Oceana
Neopycnodonte cochlear oyster reef


©Oceana
Cold seep on muddy seabed


©Ocean Exploration Trust
Siboglinids (*Lamellibrachia anaximandri*) in a hydrothermal area

Another example, the leptomedusan hydroid *Lytocarpia myriophyllum*, can form dense aggregations of up to seven colonies per square metre on muddy detritic bottoms, often rich in biogenic mineral detritus and characterized by a high terrigenous supply (Rossi, 1950; Di Camillo *et al.*, 2013; Cerrano *et al.*, 2015; Enrichetti *et al.*, 2019). The populations of *L. myriophyllum* act as habitat-formers by enhancing the complexity of the seabed and hosting a rich associated fauna, but remain highly vulnerable to trawling activities.

In addition, the brachiopod *Gryphus vitreus* can form large facies (Pérès and Picard, 1964) on soft bottoms, mainly on the continental slope, where the species can reach up to 800 individuals per square metre on sandy mud with bottom currents (Emig, 1989, 1997; Boullier *et al.*, 1986).

Erect bryozoans can usually form mixed aggregations with other benthic species, including cold-water corals. Nevertheless, some species can comprise true bryozoan beds on both hard or soft bottoms in deep Mediterranean areas, such as escarpments, seamounts and pockmark fields (Bellan-Santini *et al.*, eds., 2002; Aguilar *et al.*, 2010; de la Torriente *et al.*, 2014; Enrichetti *et al.*, 2019). These beds are ecologically relevant in providing a substratum for epizoans and refuge for several organisms, including ophiuroids and small fish (Smith *et al.*, 2001). On hard bottoms and/or on gravelly sedimentary bottoms, bryozoan communities include the branched genera *Adeonella*, *Hornera*, *Myriapora*, *Pentapora* and *Reteporella*, as well as the massive genera *Celleporina* and *Turbicellepora*, while on muddy bottoms the stalked genus *Kinetoskias* was found to be locally abundant (Harmelin and D'Hondt, 1993; Aguilar *et al.*, 2013; Maldonado *et al.*, 2015; Mastrototaro *et al.*, 2017; Enrichetti *et al.*, 2019). Erect byozoans can reach high densities and form important benthic communities at mesophotic depth, similar to coralligenous bioconstructions (Casoli *et al.*, 2020).

5.2 Incidental catch of vulnerable marine ecosystem indicator taxa

Bycatch is the part of the catch that is unintentionally caught during a fishing operation in addition to the target species. It refers to the catch of other commercial species that are landed, commercial species that cannot be landed (for instance, undersized or damaged individuals), non-commercial species, as well as the incidental catch of endangered, vulnerable or rare species (for example, sea turtles, shark, marine mammals and seabirds) (FAO, 2020). Discard is the part of the catch that is not retained onboard and is instead returned to the sea, dead or alive. It can include target species or any other species (both commercial and non-commercial) that has been discarded at sea (GFCM, 2018a). Vulnerable marine ecosystem indicator taxa can represent a relevant part of the catch, but information from fishery-dependent surveys is lacking and, to date, their overall contribution to bycatch in the Mediterranean and Black Sea is not clear yet.

Some information can be gathered from observer programmes of fishing activities (Sánchez, Demestre and Martin, 2004; D'Onghia *et al.*, 2017), as well as from fishery-independent surveys, such as experimental fishing campaigns aimed at assessing demersal resources (Bertrand *et al.*, 2002). Although the scale of bycatch is not exhaustively understood and is mostly unquantified, the physical damage and the mortality it causes can be observed, in addition to the loss of fishing gear entangled on rocks or on benthic organisms. The impact of demersal fishing on VMEs has been recognized as a major environmental concern, causing not only the direct removal of species, but also several secondary effects, such as tissue abrasion and consequent vulnerability to epibiosis, damage due to resuspension of the sediments and the interruption of reproduction in stressed or injured species (Hinz, 2017; Clark, Althaus and Schlacher, 2016; Bavestrello *et al.*, 1997; Hogg *et al.*, 2010; Bo *et al.*, 2014a; Cau *et al.*, 2017a; D'Onghia *et al.*, 2017; Gori *et al.*, 2017). In fact, visual techniques such as remotely operated vehicles (ROVs) and towed cameras allow documenting the physical impact of fisheries on VMEs, though it cannot be comprehensively quantified yet. In addition, derelict fishing gear, from set nets to set longlines, is particularly common on bioconstructions, seamounts, banks, mounds and canyons in both the Mediterranean Sea and the North Atlantic Ocean, representing on average 34 percent of the total benthic litter (Pham *et al.*, 2014b).

5.2.1 Bottom trawlers

Bottom trawls are commonly used throughout the Mediterranean and routinely remove most of the benthic fauna, resulting in declines of faunal biodiversity, cover and abundance. However, the incidental catch of VME indicator taxa is difficult to assess as data are lacking, since commercial vessels do not report the bycatch of benthic invertebrates. Quantitative data from scientific surveys are rarely available in the literature (e.g. D'Onghia *et al.*, 2003; Carbonara *et al.*, 2020), since they are often observed as unquantified catch, but not reported. Despite a lack of bycatch data, trawling impacts are nevertheless well documented as a result of experimental trawl fishing operations and ROV surveys.

Soft-bottom coral gardens and sea pen fields have been historically impacted by trawl fishing, as higher coral densities support higher abundance and biomass of crustacean species. In fact, some commercially important species such as the deep-water red shrimps *Aristeus antennatus*, *Aristaeomorpha foliacea* and *Plesionika martia* reach their maximum abundance in the bamboo-coral (*Isidella elongata*) gardens, while the Norway lobster (*Nephrops norvegicus*) and the deep-water rose shrimp (*Parapenaeus longirostris*) usually coexist with fields of the sea pen *Funiculina quadrangularis* (Pérès, 1967; Pérès and Picard, 1964; Cartes *et al*., 2004; Maynou *et al*., 2006).

Western Mediterranean

Bycatch from commercial trawling on the northern Alboran Sea continental shelf and slope includes the soft coral *Alcyonium palmatum* and the sea pen *Pennatula rubra*, with retrieved quantities of 0.07 ± 0.02 and 0.1 ± 0.04 kg per hour of trawling (Abad *et al*., 2007). In addition, Gofas *et al*. (2014) observed the sea pen *Kophobelemnon stelliferum* and the sponge *Thenea muricata* being caught, together with many specimens of the crinoid *Leptometra phalangium*, during a single experimental beam trawl in the Alboran Sea.

Cnidaria, including the VME indicator species *Alcyonium palmatum*, represent 1.6 percent by mass of the total catch from commercial otter trawling off the Catalan coast, characterized by high fishing intensity (Sánchez *et al*., 2007). Similarly, Gili, Ros and Pagès (1987) reported a long list of anthozoans, including many VME indicator species collected from trawling grounds in the same area. In particular, *A. palmatum* and the sea pen *Veretillum cynomorium* are notably common in the trawl catch of this area, together with isolated or few colonies of stony corals (*Dendrophyllia ramea*, *Caryophyllia smithii*, *Madrepora oculata*), gorgonians (*Eunicella* spp., *Leptogorgia sarmentosa*, *Isidella elongata*), antipatharians (*Parantipathes larix*) and sea pens (*Pteroeides spinosum*, *Cavernularia pusilla*, *Virgularia mirabilis*, *Pennatula phosphorea*, *Funiculina quadrangularis* and *Kophobelemnon stelliferum*).

Based on four scientific trawl surveys carried out between 1985 and 2008, Maynou and Cartes (2012) reported in the northwestern Mediterranean the collection of many colonies of *Isidella elongata*, together with the cold-water coral *Desmophyllum dianthus*, the sea pen *Funiculina quadrangularis* and the brachiopod *Gryphus vitreus*. In addition to providing data about the distribution of *I. elongata* gardens and the relevant number of fish and invertebrate species associated with this habitat, the authors highlighted the impacts of bottom trawls on this VME. In particular, they reported 97.63 ± 73.83 kg per square kilometre of *I. elongata* being collected along the continental margin of the Iberian Peninsula, with a maximum of 28 kg (1 292 kg per square kilometre) in a single haul at 626 m depth. Crustacean species richness, abundance and biomass positively correlated with the density of *I. elongata*, especially in the case of the blue and red shrimp *Aristeus antennatus* and the golden shrimp *Plesionika martia* (Maynou and Cartes, 2012). Further evidence was provided by the high density of trawl tracks, which demonstrated that the continental margin along the Catalan coast is intensely fished down to 900 m depth (Company, Ramirez-Llodra and Sardà, 2012). Indeed, observers onboard commercial trawlers on the continental shelf and platform along the same coast were able to detect a relevant commercial discard, including, among others, the stony corals *Dendrophyllia ramea* (0.19 kg per hour) and *Dendrophyllia cornigera* (0.25 kg per hour), the sea pens *Pteroeides spinosum* (0.17 kg per hour) and *Veretillum cynomorium* (0.5 kg per hour), as well as the crinoid *Leptometra phalangium* (0.06 kg per hour) (Sánchez, Demestre and Martin, 2004).

Experimental trawling in the Balearic basin indicated a large amount of incidental catch of corals, such as *Isidella elongata, Desmophyllum dianthus, Paramuricea macrospina, Placogorgia coronata and Funiculina quadrangularis*, and sponges, including *Thenea muricata* (Cartes *et al*., 2009). Among the VME indicator taxa, Massutì and Reñones (2005) reported the bycatch of the soft coral *Alcyonium palmatum*, sea pens and the brachiopod *Gryphus vitreus* during experimental trawling around the Balearic archipelago. Although such bycatch was not quantified, the authors highlighted the negative effects of trawling which can lead to the removal of soft-bottom habitat formers and cause consequent changes in the benthic community of the area, as mentioned by Gili, Ros and Pagès (1987).

In the Gulf of Lion canyon system, Madurell *et al.* (2012) highlighted that the areas where little trawling occurs coincide with areas of high ecological interest featuring VMEs, thus indicating the impact of trawling on benthic habitats (Gili *et al.*, 2011). Elsewhere, Relini, Peirano and Tunesi (1986) reported the bamboo-coral *Isidella elongata* as a common element of the commercial trawling bycatch in the Ligurian Sea together with several other VME indicator species, while Fusco (1967) identified cold-water coral reefs off Punta Mesco, also in the Ligurian Sea, based on the catch from trawling. In the same basin, the gorgonian *Placogorgia coronata* often occurred among the discards of the bottom trawl fishery targeting red shrimps, with an average estimated catch rate of about 18 live colonies per year per fisher (Enrichetti *et al.*, 2018). In addition, Arena and Li Greci (1973) reported historical records of living colonies of the black coral *Leiopathes glaberrima* collected during trawling operations in the Sardinia Channel and the Tyrrhenian Sea, as well as along the coast of Sicily. Furthermore, through observers onboard commercial vessels in the northern Tyrrhenian Sea, Sartor, Sbrana and Reale (2003) reported the presence of the soft coral *Alcyonium palmatum* and the red sea pen *Pennatula rubra* as a common fraction of the bycatch, although catches were less than 0.1 kg per hour.

In the Sardinia Sea, Carbonara *et al.* (2020) reported the occurrence of *Isidella elongata* in 2 percent of the trawl hauls carried out between 200 and 800 m depth, indicating the overall rarity of this species.

In the central Tyrrhenian Sea, the same authors reported the presence of *Isidella elongata* in 30 percent of the trawl hauls (Carbonara *et al.*, 2020). Regarding the crinoid *Leptometra phalangium*, Fanelli, Colloca and Ardizzone (2007) estimated a density of 12–15 individuals per square metre collected during experimental bottom trawls, while Colloca *et al.* (2004) observed that about 300 kg of this species (around 200 000 individuals) can be collected during one hour of bottom trawls, which represents the only quantitative information available concerning the heavy impact of trawling on crinoid fields.

Remotely operated vehicle surveys in the western Mediterranean (for example, the Alboran Sea, Balearic Islands and Gulf of Lion) highlighted how soft-bottom anthozoans such as *Isidella elongata* and sea pens are present with high densities in areas where trawling is not carried out, while they are hardly present or totally absent where trawl marks are more evident (Chimienti *et al.*, 2019a). In particular, *I. elongata* seems to be still present in a few areas, with dense aggregations thriving in places more or less accidentally protected from fishing pressure. This is the case, for example, of the populations found in shallow-water inaccessible refuges (e.g. Bo *et al.*, 2015), in deep-water refuges greater than 1 000 m depth (e.g. Maynou and Cartes, 2012), on sloping soft bottoms where trawling is difficult (e.g. Fabri *et al.*, 2014) or where the presence of submarine cables does not allow fishing activities (e.g. Mastrototaro *et al.*, 2017). Like *I. elongata*, sea pen fields remain only in areas where the fishing pressure is generally low, whereas they have disappeared from areas where they were formerly found due to trawling (Hebbeln *et al.*, 2009; Bo *et al.*, 2012; Fabri *et al.*, 2014; Mastrototaro *et al.*, 2015, 2017; Chimienti *et al.*, 2019a). Lost trawling nets were also documented in the Gulf of Saint Eufemia (southern Tyrrhenian Sea), impacting some hard-bottom coral gardens and sponge aggregations (Bertolino *et al.*, 2013).

Central Mediterranean

Incidental trawl catch in the central Mediterranean revealed the presence of true cold-water coral reefs, such as the coral communities of Santa Maria di Leuca in the northern Ionian Sea and South Malta in the Strait of Sicily (Chimienti, Angeletti and Mastrototaro, 2018; Tursi *et al.*, 2004; Schembri *et al*., 2007; Mastrototaro *et al*., 2010). This suggests that, occasionally, trawls can directly impact cold-water coral reefs and other hard-bottom VMEs due to trawling operations that should not have been carried out in these areas (e.g. by positioning errors or trying to exploit new areas). In addition, the presence of stony corals is generally known to the local fishers, who experience gear damage and losses, although they often fish close to these areas with the aim to obtain greater catch and larger specimens. In fact, side-scan sonar and underwater video images show the characteristic seabed scars of otter trawls ploughing through the coral banks (D'Onghia *et al*., 2010, 2017).

Except for occasional trawling on hard bottoms, trawling in the central Mediterranean mostly impact detritic- and muddy-bottom VMEs. Based on scientific trawl survey data, Lauria *et al*. (2017) modelled the presence of the bamboo coral *Isidella elongata* in the Strait of Sicily, and found a negative linear relationship with fishing effort, suggesting a rapid decline of *I. elongata* abundance as fishing activity increased, until its disappearance due to intense trawling. Along the Tunisian coast, Azouz (1972) also highlighted the close relationship between red shrimps and *I. elongata*, with the latter usually collected as unquantified bycatch. Recent experimental trawl fishing operations highlighted the presence of *I. elongata* in 6 percent of the trawl hauls carried out in the Ionian Sea (Carbonara *et al*., 2020). Likewise, off Malta, Terribile *et al*. (2016) reported that during experimental trawling, several VME indicator taxa were caught, including sponges, anthozoans and crinoids. Among the corals, the presence of *Lophelia pertusa* and *I. elongata* was noted, although both were identified with low densities (0.1 and 1.1 colonies per square kilometre, respectively), while *Funiculina quadrangularis* was particularly abundant in the trawling catch, with 324 colonies collected per square kilometre (Terribile *et al*., 2016). Despite being sensitive to trawling impacts, *F. quadrangularis* populations seem to be generally more resilient and present nevertheless in areas exploited by trawl fisheries, although they do not reach high densities (Lauria *et al*., 2017).

The bycatch of sea pen fields in the central Mediterranean may include *Kophobelemnon stelliferum*, whose large population was sampled with fishing gear towed off Santa Maria di Leuca in the northern Ionian Sea (Mastrototaro *et al*., 2013), confirming the vulnerability of this species. Moreover, an estimated bycatch of the red sea pen *Pennatula rubra*, with up to 9 492 colonies per square kilometre, was reported from scientific trawl surveys off the Calabrian coast in the Ionian Sea, where this species showed a mean density of 0.7 ± 0.1 colonies per square metre (Chimienti, Bo and Mastrototaro, 2018; Chimienti *et al*., 2015). Furthermore, in the northern Ionian Sea, D'Onghia *et al*. (2003) reported, among the benthic catch from scientific trawl surveys, the stony corals *Caryophyllia smithii* and *Desmophyllum dianthus*, the sea pens *F. quadrangularis*, *K. stelliferum* and *P. rubra*, the bamboo-coral *I. elongata* and the brachiopod *Gryphus vitreus*, all with very low densities (0.1–0.5 specimens per hour). Remotely operated vehicle explorations off Santa Maria di Leuca (Ionian Sea) enabled recent trawling traces, such as trawl door scars and lost nets, to be observed both inside and outside the fisheries restricted area (FRA) established by the GFCM in 2006 to protect these habitats from bottom trawlers, providing evidence of fishing activities occurring in the FRA (Savini *et al*., 2014; D'Onghia *et al*., 2017).

Adriatic Sea

Past scientific trawl surveys along the Italian coast of the southern Adriatic Sea revealed the bamboo coral *Isidella elongata*, sea pens and sponges as common bycatch, together with consistent amounts of the sea anemone *Actinauge richardi*, the soft coral *Alcyonium palmatum*, the crinoid *Leptometra phalangium* and the brachiopod *Gryphus vitreus* (Marano, Ungaro and Vaccarella, 1989; D'Onghia *et al*., 2003). An extensive *I. elongata* garden was collected in the same basin during a scientific trawl survey off Otranto, with large amounts of colonies sampled (Spedicato *et al.*, 2017). In the southern Adriatic, Carbonara *et al.* (2020) reported the occurrence of *I. elongata* in 23 percent of the trawl hauls. Two large fields of the sea pen *Funiculina quadrangularis* and one of the crinoid *L. phalangium* were also sampled along the Adriatic coast of Apulia during a scientific trawl survey (Spedicato *et al.*, 2017), even though no quantitative information is available to date.

On the opposite side of the Adriatic Sea, along the continental shelf and slope off Montenegro, Petović *et al.* (2016) reported the catch of some VME indicator taxa during scientific trawl surveys aiming to assess demersal resources. In particular, the soft coral *Alcyonium palmatum* was mostly caught at shallow depths, with 96 colonies per square kilometre and 0.6 kg per square kilometre within 50 m depth, 34 colonies per square kilometre and 0.6 kg per square kilometre at 50–100 m depth, and 36 colonies per square kilometre with 0.2 kg per square kilometre at 100–200 m depth. In contrast, at 200–500 m depth, the occurrence of *A. palmatum* as bycatch was only five colonies per square kilometre and 0.02 kg per square kilometre.

Petović *et al.* (2016) also documented sea pens, with *Pennatula rubra* mainly caught within 100 m depth, with 80–96 colonies per square kilometre and 0.8–0.9 kg per square kilometre; *Pteroeides spinosum* caught at 50–100 m and 500–800 m depth with 0.3 and 0.1 kg per square kilometre, respectively, and a density of 11 colonies per square kilometre; and *Funiculina quadrangularis* caught at 200–500 m depth with five colonies per square kilometre and 1.3 kg per square kilometre. In addition, the hydrozoan *Lytocarpia myriophyllum* was also reported in the catch within 50 m depth (96 colonies per square kilometre and 1.3 kg per square kilometre) and at 50–100 m depth (23 colonies per square kilometre and 0.05 kg per square kilometre).

It has been estimated that the phylum Cnidaria, including the VME indicator species *Alcyonium acaule* and *Alcyonium palmatum*, and the sea pen *Virgularia mirabilis*, represents 0.2 percent of the total catch from the commercial otter trawl fishery in the central Adriatic grounds, which are characterized by high fishing intensity (Sánchez *et al.*, 2007). In addition, in the northern Adriatic Sea, trawl survey bycatch data identified vulnerable sea pen fields and reefs of the bivalve *Neopycnodonte cochlear* in the in the Pomo/Jabuka Pit FRA (GFCM, 2017) (Figure 1). The rare giant bivalve *Atrina fragilis* was also reported as a dominant component of commercial "rapido" trawl bycatch in some areas of the northern Adriatic Sea, with most of the individuals being highly damaged by this fishing practice (Pranovi *et al.*, 2001).

Eastern Mediterranean

Reef-forming cold-water corals such as *Madrepora oculata*, *Lophelia pertusa* and *Desmophyllum dianthus* were reported as occasional catch during scientific trawling in the northern Aegean Sea (Vafidis, Koukouras and Voultsiadou-Koukoura, 1997), while some *Isidella elongata* colonies were collected from experimental trawl surveys in the eastern Mediterranean (Gerovasileiou *et al.*, 2019). Elsewhere, in the Levant Sea, the incidental catch of the phosphorescent sea pen *Pennatula phosphorea* was recorded during scientific trawl surveys along the Turkish coast (Gücü, 2012).

During experimental beam trawl surveys along the northern coast of Crete (Aegean Sea), a marked reduction of the crinoid *Leptometra phalangium* was observed in trawled areas, associated with a decrease in the richness, abundance and biomass of benthic species (Smith, Papadopoulou and Diliberto, 2000), confirming the impact of commercial trawling on the crinoid fields present in the area. Likewise, in the Gulf of Thermaikos (Aegean Sea), a great variety of VME indicator taxa were reported as discards from commercial otter trawling (Voultsiadou *et al.*, 2011). In particular, Demospongiae species (i.e. the most diverse class of sponges) were caught in 5–38 percent of the commercial hauls, depending on the sponge species. Alcyonaceans and sea pens represented common components of discards, with a high collection frequency for certain species, such as *Alcyonium palmatum* (100 percent), *Pennatula rubra* (95 percent), *Pteroeides spinosum* (29 percent), *Veretillum cynomorium* (29 percent) and *Funiculina quadrangularis* (5 percent).

Bivalves belonging to the genus *Atrina* also were found to be part of the bycatch from commercial otter trawling in the Aegean Sea, and thus considered endangered, mainly due to habitat degradation and intensive bottom trawling (Fryganiotis, Antoniadou and Chintiroglou, 2013). In fact, *Atrina pectinata* was present in 81 percent of the otter trawling hauls carried out in the Gulf of Thermaikos (Voultsiadou *et al.*, 2011). Commercial otter trawling resulted in 0.03–0.22 individuals of *A. fragilis* per square metre caught in the routinely trawled areas, while experimental trawl surveys in a comparable area of the Gulf of Thermaikos, where trawling is prohibited, revealed a catch of 4.60–6.27 individuals of *A. fragilis* per square metre (Fryganiotis, Antoniadou and Chintiroglou, 2013). Finally, the cylinder tube anemone *Cerianthus membranaceus*, a large, tube-dwelling anemone, was also caught as bycatch in 5 percent of the trawl hauls in the area (Voultsiadou *et al.*, 2011).

5.2.2 Set longliners

Set longlines are widely used in the Mediterranean Sea to catch, among others, dentex (*Dentex* spp.), seabreams (*Diplodus* spp., *Pagellus* spp.) and groupers (*Epinephelus* spp.). This gear can also be used in areas of complex bottom topography and not accessible to trawling, to catch the Atlantic wreckfish (*Polyprion americanus*), the greater forkbeard (*Phycis blennoides*), the blackbelly rosefish (*Helicolenus dactylopterus*) and the blackspot seabream (*Pagellus bogaraveo*) (D'Onghia *et al.*, 2010, 2012, 2016; Sion *et al.*, 2019). Set longlines can sweep the seabed (when the gear is hauled up) and, in the process, they can catch benthic species (Welsford and Kilpatrick, 2008; Hogg *et al.*, 2010; Sampaio *et al.*, 2012; Mytilineou *et al.*, 2014). Intensive longline fishing, while having much less impact compared to bottom trawling (Pham *et al.*, 2014a), may over time cause significant adverse impacts to VMEs (Ragnarsson *et al.*, 2017). Indeed, benthic VME indicator taxa can often be damaged or caught by demersal lines and hooks, resulting in a substantial bycatch (D'Onghia *et al.*, 2012). Longlines can also cause mechanical injuries to benthic species when drifting on the sea floor, leading to the accumulation of debris on the sea bottom due to lost gear, thus altering habitats (e.g. Hinz, 2017; Company, Ramirez-Llodra and Sardà, 2012; Reed *et al.*, 2005; Orejas *et al.*, 2009; Bo *et al.*, 2014a).

Western Mediterranean

No data are available for longline incidental catch of VME indicator taxa in the western Mediterranean. However, some lost longlines were documented by means of ROV as laying on cold-water coral reefs and on the gardens of the fan-shaped gorgonian *Callogorgia verticillata* in the Gulf of Lion, as well as on the singular lithistid demosponge (*Leiodermatium pfeifferae)* formations occurring in the Balearic Sea, thus confirming the presence of non-quantified impacts on VMEs (Fabri *et al.*, 2014; Maldonado *et al.*, 2015). In the same area, Orejas *et al.* (2009) recorded approximately 200 lost longlines in the Cap de Creus cold-water coral community, representing 0.06–0.22 longlines per square metre, demonstrating a positive correlation between the occurrence of lost fishing gear and cold-water corals.

In the Ligurian Sea, injury by longlines is the major cause of mortality for the red gorgonian *Paramuricea clavata* and the yellow gorgonian *Eunicella cavolini* (Bavestrello *et al.*, 1997; Betti *et al.*, 2020). Similarly, the dominant type of debris observed in the Ligurian and Tyrrhenian Sea (79 and 62.5 percent, respectively) is represented by lost longlines, which become entangled in the hard-bottom gardens of the black coral *Antipathella subpinnata* and the gorgonians *P. clavata*, *Paramuricea macrospina*, *Eunicella cavolini*, *Corallium rubrum*, *Viminella flagellum* and *Callogorgia verticillata* (Angiolillo *et al*., 2015; Bo *et al*., 2020b; Ferrigno *et al*., 2020). Furthermore, Bo *et al*. (2014a) reported longlines as being the most widespread derelict gear found on hard bottom coral gardens in the Tyrrhenian Sea, and in fact, they were present in almost 100 percent of the video frames analysed from four of the five different localities studied. In particular, at Mantice Shoal and Santa Lucia Bank (northern Tyrrhenian Sea), these authors reported 32 and 17 m of lines per 100 square metres, respectively.

In the Vedove Shoal (central Tyrrhenian Sea), although longlines were present in fewer video frames (35 percent), there was an estimated density of 70 m of lines per 100 square metres of sea floor (Bo *et al*., 2014a). Likewise, in the southern Tyrrhenian Sea, unquantified longlines were recorded as being entangled in colonies of the gorgonians *Bebryce mollis*, *Callogorgia verticillata*, *Eunicella cavolini* and *Paramuricea clavata* in the Gulf of Saint Eufemia, and were observed in 4–10 percent of the analysed images (Bo *et al*., 2012), while about 28 m of lines per 100 square metres were documented on the Marco Bank (Bo *et al*., 2014a). In this last location, longlines were entangled on about 29 ± 6 percent and 32 ± 3 percent of the colonies of the black coral *Leiopathes glaberrima* and the whorled tree coral *C. verticillata*, respectively, while all the observed colonies of *C. verticillata* with entangled lines had lost the flabellate shape typical of healthy specimens and had broken branches (Bo *et al*., 2014b). Elsewhere, low fishing impacts were reported for the hard-bottom coral gardens in southwestern Sardinia, where Bo *et al*. (2015) observed lost longlines in 2.2 percent of the video frames, mostly impacting *C. verticillata* and *L. glaberrima* colonies.

Central Mediterranean

Stony corals (*Desmophyllum dianthus*), black corals (*Antipathes dichotoma*, *Leiopathes glaberrima*), alcyonaceans (*Isidella elongata*, *Swiftia dubia*, *Villogorgia bebrycoides*) and sea pens (*Pennatula phosphorea*) were among the benthic bycatch observed during experimental longline surveys targeting fish assemblages off the southwestern coast of Kefalonia Island in the Ionian Sea (Mytilineou *et al*., 2014). Living colonies of these VME indicator taxa were reported as occurring in most longline sets (72 percent) with 2–4 species per longline, and with a variable abundance. Mytilineou *et al*. (2014) estimated that about 100 and 130 living colonies of black corals and *I. elongata*, respectively, were caught by each fishing boat every year in the eastern Ionian Sea, representing the most common coral bycatch. In contrast, a lower occurrence (55 percent), though a similar number of coral species (four), were reported by D'Onghia *et al*. (2012) as being caught by longlines in the northern Ionian Sea, probably due to the dominant presence of stony corals forming robust cold-water coral reefs, likely to be more resistant to hook removal than coral forests. As such, these results represent one of the few indications of the potential impact of set longlines on VMEs. Furthermore, the incidental catch of the corals *Madrepora oculata*, *Lophelia pertusa*, *Dendrophyllia cornigera* and *L. glaberrima* was documented from the commercial longline fisheries in the northwestern Ionian Sea through an ad hoc interview campaign amongst fishers (D'Onghia *et al*., 2016). Moreover, ROV exploration both inside and outside the Lophelia Reef FRA (Santa Maria di Leuca) provided images of lost fishing lines entangled on the seabed or on the coral colonies (Freiwald *et al*., 2009; Savini *et al*., 2014; D'Onghia *et al*., 2017).

Adriatic Sea

No quantitative information about longline incidental catch of VME indicator taxa in the Adriatic Sea is available. However, D'Onghia *et al*. (2016) reported the presence of the corals *Madrepora* *oculata*, *Lophelia pertusa* and *Leiopathes glaberrima* in the bycatch from commercial longline fishers in the southern Adriatic Sea (data gathered through ad hoc interviews among fishers). Moreover, 0.03 items per square metre (15 longlines over 600 square metre) were reported within a forest of *Callogorgia verticillata* in Montenegrin waters (Chimienti *et al.*, 2020a), and 0.12 items per square metre (39 longlines over 320 square metre) within a forest of *Antipathella subpinnata* at the Tremiti Islands marine protected area (Chimienti *et al.*, 2020b).

Eastern Mediterranean

No data are available for the longline incidental catch of VME indicator taxa in the eastern Mediterranean. However, the incidental catch of the bamboo-coral *Isidella elongata* by bottom longlines was reported in the literature (Mytilineou *et al.*, 2014; Gerovasileiou *et al.*, 2019), indicating the vulnerability of this species to this type of fishing gear.

5.2.3 Small-scale fisheries

Small-scale fisheries were generally assumed to have a low or negligible discard rate, comprising around 3.7 percent of total catch on the global scale (Kelleher, 2005). However, some studies suggest that a wide variation in bycatch rates may exist, with some small-scale fisheries showing levels of bycatch that could potentially wipe out some populations of marine megafauna, such as seabirds, sharks and turtles (e.g. Voges, 2005; Peckham *et al.*, 2007). In the Mediterranean Sea, demersal small-scale fisheries could also have a significant impact on megabenthic communities considering the large number of vessels involved, accounting for 83 percent of the fishing fleet in the basin (FAO, 2018, 2020). Small-scale fisheries employ a wide variety of bottom-contact fishing gear, including gillnets, baited traps and pots, which can be deployed from shallow to deep waters and varying in the way they interact with marine ecosystems (Morgan and Chuenpagdee, 2003; Shester and Micheli, 2011). For instance, dragging traps on the seafloor causes damage to the benthic species significantly more frequently than crushing, particularly on corals (Shester and Micheli, 2011). Furthermore, gillnets and trammel nets can easily remain entangled on the hard bottoms and on the VME indicator taxa, thus damaging these habitats and/or remaining abandoned on the seabed.

The issues of incidental catch and impacts of small-scale fisheries have been hardly addressed worldwide (Breen, 1989; ICES, 1995; Quandt, 1999; Stephan, Peuser and Fonseca, 2000; Erzini *et al.*, 1997; Appeldoorn *et al.*, 2000; Eno *et al.*, 2001), and the consequences, including in the Mediterranean Sea, remain difficult to quantify.

Western Mediterranean

No data are available concerning the incidental catch of VME indicator taxa by small-scale fisheries in the western Mediterranean. Nevertheless, as an example, lost gillnets and severe tissue abrasion due to small-scale fisheries were observed in the rare and vulnerable candelabrum coral *Ellisella paraplexauroides* garden in the Alboran Sea (Maldonado *et al.*, 2013), where about half of the colonies (44.6 percent) originally growing in certain areas were dead, and about 82 percent of the surviving colonies showed substantial signs of injury (e.g. broken branches, tissue abrasion, intense epibiosis).

In the Gulf of Lion canyon system (Figure 1), Madurell *et al.* (2012) noted that the best preserved benthic communities coincided with the least overlap of artisanal fishing. In some canyons of the western Ligurian Sea, derelict fishing nets from small-scale fisheries represented 57 percent of the anthropogenic objects present on the seafloor (Giusti *et al.*, 2019). Lost gillnets were also observed in the Tyrrhenian Sea, where Bo *et al.* (2014a) reported 8 and 0.5 square metres of nets per 100 square metres on the sea floor at Mantice Shoal and Santa Lucia Bank, respectively, and they were recorded in 3 percent on average of the analysed images on the hard-bottom coral gardens in the Gulf of Saint Eufemia (Bo *et al.*, 2012). Indeed, nets and pots are among the most common debris impacting hard-bottom coral gardens in the Tyrrhenian Sea, representing 24.4 percent and 2.1 percent of the total debris, respectively (Angiolillo *et al.*, 2015). Furthermore, the canyons along the upper Sardinian slope were shown to be major repositories for derelict fishing gear, mainly from small-scale fisheries (Cau *et al.*, 2017a). Derelict nets and other small-scale fishing gear were documented as common within a population of *Corallium rubrum* in the Tyrrhenian Sea (Ferrigno *et al.*, 2020).

Central Mediterranean

No data are available concerning the incidental catch of VME indicator taxa by small-scale fisheries in the central Mediterranean.

Adriatic Sea

No data are available concerning the incidental catch of VME indicator taxa by small-scale fisheries in the Adriatic Sea. A few nets (possibly gillnets or trammel nets) were observed entangled within an *Antipathella subpinnata* forest at the Tremiti Islands, with 0.02 items per square metre (Chimienti *et al.*, 2020b).

Eastern Mediterranean

No quantitative data are available concerning the incidental catch of VME indicator taxa by small-scale fisheries in the eastern Mediterranean. However, in the Gulf of Thermaikos (Aegean Sea), the bycatch of Demospongiae species was reported to be frequent, representing 14–43 percent of the discards from fishing hauls in small-scale fisheries, depending on the sponge species (Voultsiadou *et al.*, 2011). Part of the bycatch was also represented by the soft corals *Alcyonium palmatum* and *Veretillum cynomorium*, which were collected in 29 percent and 14 percent of the hauls, respectively. Likewise, bivalves belonging to the genus *Atrina* can occasionally be harvested or occur as bycatch in small-scale fisheries in the Aegean Sea (Poutiers, 1987). In the western Aegean Sea, Gökçe and Metin (2007) also conducted an observer-based survey on the commercial prawn trammel net fishery in Izmir Bay, Turkey. Based on data from three fishing boats, these authors reported a low bycatch rate of benthic species. The only VME indicator species recorded was *V. cynomorium*, collected in about 18 percent of the hauls, with one or two colonies each.

5.3 Outlook

5.3.1 Interactions between fisheries and VMEs

Bottom trawling represents the fishing practice with the highest impact on VMEs (Rogers, 1999; Maynou and Cartes, 2012; Probert, McKnight and Grove, 1997; Eigaard, Bastardie and Hintzen, 2017; Murillo *et al.*, 2011; Puig *et al.*, 2012). Its role in the degradation of VMEs is both direct, by scraping the seabed, resuspending the sediments and destroying habitat-formers, and indirect, by inducing long-term changes in the benthic community, reducing habitat complexity and affecting ecosystem functioning (Jones, 1992; Roberts, 2002; Hinz, 2017; Jennings and Kaiser, 1998; Watling and Norse, 1998; Maynou and Cartes, 2012; Colloca *et al.*, 2004; Gray *et al.*, 2006). Although bycatch data from commercial fisheries are lacking, scientific trawl surveys can provide an insight into understanding the bycatch of VME indicator taxa (e.g. Gili, Murillo and Ros, 1989; Chimienti, Bo and Mastrototaro, 2018; Petović *et al.*, 2016; Terribile *et al.*, 2016).

Despite the fact that quantification remains unclear for the incidental catch of VME indicator taxa, there is sufficient scientific evidence linking trawling practices to the impacts and particular environmental changes caused, suggesting that the higher the frequency of trawling, the greater the likelihood of permanent changes. In fact, considering the slow growth rate of many VME indicator taxa, the recovery of these fragile habitats may take decades or centuries after direct and indirect damage inflicted on them by bottom trawlers (e.g. Jones, 1992; Hinz, 2017; Fosså, Mortensen and Furevik, 2002; Bo *et al.*, 2015), thus resulting in long-term changes in the environment.

In general, hard bottom VMEs such as cold-water coral reefs and coral gardens are not directly affected by the mechanical impacts of trawling, although recent fishing technologies enable trawling to be carried out very close to them. However, together with occasional incidental catch, hard-bottom VMEs can be damaged by the resuspension of sediment and other indirect effects caused by trawling. In contrast, soft-bottom VMEs are more sensitive to trawling pressures due to the direct destruction of the habitat, particularly for fragile organisms (such as the bamboo-coral *Isidella elongata*, the sea pens *Funiculina quadrangularis* and *Kophobelemnon stelliferum*, the crinoid *Leptometra phalangium* and the fan-mussel *Atrina fragilis*). Moreover, the three-dimensionality and consistency of the body also play a significant role in the catchability of VME indicator taxa. For instance, the catch efficiency of trawling on sponge-based communities (for example, "ostur" sponge aggregations, soft-bottom sponge gardens and glass sponge communities) can easily reach 100 percent, while the efficiency on sea pen fields can be about 3–10 percent, depending on the pennatulacean species (Chimienti, Bo and Mastrototaro, 2018; Kenchington *et al.*, 2011).

Although the efficiency of fishing gear can be low, incidental mortality can be very high. In fact, as clearly shown, higher soft coral concentrations are generally located in areas characterized by low or no fishing activity (Heifetz, Stone and Shotwell, 2009; Murillo *et al.*, 2010, 2018). In particular, comparative studies found significantly lower densities of sea pens and alcyonaceans in areas of high trawling intensity (Engel and Kvitek, 1998; Hixon and Tissot, 2007), indicating an inability to recover after frequent fishing pressure. Because of its slender structure and peculiar aggregative behaviour, the tall sea pen *Funiculina quadrangularis* is often present as bycatch, although in declining abundance (Arena and Li Greci, 1973; Relini, Peirano and Tunesi, 1986; Colloca *et al.*, 2003; Voultsiadou *et al.*, 2011; Bastari *et al.*, 2018), and the formerly common *F. quadrangularis* fields have almost completely disappeared from many Mediterranean areas due to trawling (D'Onghia *et al.*, 2003; Sardà *et al.*, 2004; Chimienti *et al.*, 2019a). Data from other sea pen species in trawling discard are variable and are overall unquantified (Massutì and Reñones, 2005; Chimienti, Maiorano and Mastrototaro, 2015; Chimienti, Bo and Mastrototaro, 2018; Abad *et al.*, 2007; Bastari *et al.*, 2018).

Information about the incidental catch of VME indicator taxa by longlines is very scarce, and the impacts caused by longlines are difficult to detect, since they can be easily masked by natural events or disturbances created by other fishing gear types (Heifetz, Stone and Shotwell, 2009). As for bottom trawls, the mortality can be higher than the catchability because benthic species damaged by set longlines may not be removed from the seabed or may be simply lost in the water column during hauling operations (Welsford and Kilpatrick, 2008; Edinger *et al.*, 2007). Thus, the amount of VME indicator taxa bycatch may be a poor indicator of the actual magnitude of the damage caused by longlines, hence underestimating the scale of impacts on VMEs, while data to accurately estimate the spatial overlap between longline fishing effort and VMEs are generally lacking (Ragnarsson *et al.*, 2017).

Remotely operated vehicle surveys have provided clear information about the high-impact potential of set longlines on VMEs, based on findings of entangled longlines on arborescent habitat-formers, mainly corals, both on hard and soft bottoms (Bo *et al.*, 2012, 2014a, 2014c, 2015; Deidun *et al.*, 2015; Fanelli *et al.*, 2017). The frequency of coral bycatch can vary depending on the density of colonies, as well as their three-dimensional structure and resistance to anchoring. In general, antipatharians and the bamboo-coral *Isidella elongata* show the highest catchability, due to a highly branched structure. Moreover, *I. elongata* has a weak anchoring apparatus, while large antipatharians are often collected with part of the small rocks or the biogenic substratum they are settled on. Other alcyonaceans and stony corals display a lower catchability, probably due to their anchoring on hard bottoms, even though entanglement may cause the loss of longlines to occur more frequently (Bo *et al.*, 2014a; Cau *et al.*, 2017a). Finally, sea pens are broadly less affected because of their soft consistency. No data are available about the catchability of other VME indicator taxa, but their presence as part of longline bycatch is likely to be limited to the branched or morphologically complex species.

The extent of VME indicator taxa bycatch from small-scale fisheries in the Mediterranean Sea is almost unknown. However, the effects of these fishing activities are clear, since they can remove or severely damage (for example, through the breakage of branches and tissue abrasion) corals, sponges and other VME indicator taxa. Other indirect effects of the different types of fishing gear include increased vulnerability to epibiosis, parasitism and predation, especially for corals damaged and detached from the seafloor, as well as the interruption of reproduction in injured corals due to a reallocation of energy reserves for tissue repair and regeneration (e.g. Mortensen *et al.*, 2005). However, a small amount of information is available on the response of VME indicator taxa to specific fishing activities (Bo *et al.*, 2014a; Kaiser *et al.*, 2018) and quantitative data on their commercial bycatch from small-scale fisheries are scarce and limited to a few areas (e.g. Gökçe and Metin, 2007).

There are few data available on the effects of trapping and potting in deep waters, but the fact that these types of equipment are larger and heavier compared to those used in inshore waters suggests that they may have greater impacts. If deployed on VMEs, they are likely to cause physical damage during setting and retrieval when dragged over the seafloor. Therefore, it is reasonable to assume that a certain, though still unquantified, bycatch of VME indicator taxa likely occurs. For instance, Troffe *et al.* (2005) found that prawn traps had a 0–5 percent efficiency in catching whip-like sea pens at two bays on Clio Channel, southcentral coast of British Columbia, Canada, while in the offshore area, Risk, MacAllister and Behnken (1998) reported that a pot fishery caused damage to hard-bottom alcyonaceans of the genus *Primnoa*.

Considering gillnets, despite a lack of data about incidental catch, evidence provided by visual surveys clearly revealed the high impact on VMEs, notably lost nets and extensive damage of benthic communities (e.g. Bo *et al.*, 2012, 2014a). Although the effects of gillnets are mostly visible at shallower depths in comparison to trawl nets and set longlines, they may still play an important role in the bycatch and impact on mesophotic VMEs, such as hard-bottom coral gardens structured by black corals and alcyonaceans. For instance, Shester and Micheli (2011) found that the overall damage by gillnets caused by the removal of arborescent corals can be comparable to that of bottom trawls in certain areas of Baja California, Mexico. Thus, the ecological impacts of small-scale fisheries can be severe and even comparable to those of large-scale industrial fisheries on the basis of catch per unit effort (Shester and Micheli, 2011).

5.3.2 Future scenarios

Combining commercial fishery, scientific surveys and fisher interview data represents a key step to understand the extent of the incidental catch of VME indicator taxa, and consequently the conservation of VMEs likely to occur in fished areas. In order to obtain a comprehensive estimate of the scale of fishing impacts on VMEs, commercial bycatch data, integrated with results from experimental fishing surveys, as well as with ROV imaging, are necessary. Soft-bottom VMEs are mainly affected by bottom trawls, and only secondarily by set longlines and small-scale fisheries. In contrast, lost longlines and gear from small-scale fisheries represent the majority of the marine litter recorded in the proximity of rocky sea bottoms, confirming the impact of these fishing practices on hard-bottom VMEs.

The precautionary approach for managing demersal fisheries with respect to VMEs should be adopted, including a VME encounter protocol for bottom-contact fisheries aimed at avoiding the risk of significant adverse impacts. Management measures to protect VMEs from bottom-contact fishing gear include commercial fishery monitoring protocols through onboard observers, vessel monitoring systems data, assessment of commercial bycatch rates, scientific surveys and the closure of strategic areas (Hourigan, 2009; Aguilar, Perry and López, 2017; Thompson *et al.*, 2016). The presence of trained observers onboard commercial fishing vessels is crucial to understanding the scale of incidental catch of VME indicator taxa by fishing fleets, since fishing gear and practices on commercial fishing vessels sometimes differ from experimental fishing surveys. This solution could also offer an additional means to control the catch quotas of sensitive benthic species. For example, observers onboard fishing boats targeting the precious red coral *Corallium rubrum* along western Sardinia reported the occurrence of undersized colonies, underestimated weight catches on the logbooks, as well as amounts of harvested corals above the limits imposed by the local regulations (Carugati *et al.*, 2020).

Effective fishing closures represent useful spatial management measures to prevent the bycatch of VME indicator taxa by commercial bottom fishing and thus mitigate adverse impacts on marine ecosystems. In order to ensure the conservation of VMEs, appropriate fishery policy mechanisms are required; they should involve stakeholders and include a credible system for monitoring, control and surveillance. Urgent action is needed to protect VME indicators, particularly the last living gardens of the bamboo-coral *Isidella elongata*, considered to be common until fifty years ago, but now critically endangered due to decades of commercial trawling (Mastrototaro *et al.*, 2017; Chimienti *et al.*, 2019a). This very important VME indicator species was classified as “Critically Endangered” in the IUCN Red List of Threatened Species (IUCN, 2021), which is the maximum risk category before extinction (Otero *et al.*, 2017), thus representing a conservation priority for the entire basin. While there is a need to gather more information from commercial and scientific fishing surveys, literature data already provide useful insights to identify strategic areas for the conservation of *I. elongata* and many other vulnerable benthic species.

An increasing amount of information exists about VME occurrences throughout the Mediterranean basin, based on non-destructive visual surveys, but the eastern basin and the Black Sea are certainly less covered by scientific studies. Involving fishers in the collection of data on macrobenthic invertebrate bycatch could represent an appropriate solution to help to fill knowledge gaps regarding the incidental catch of VME indicator taxa. The implementation of data collection programmes onboard commercial vessels would also provide a useful means to quantify the magnitude of fishing impacts on VMEs. Until such solutions are put in place, the adoption of the precautionary approach is necessary to preserve vulnerable habitats and species.

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Glossary

Active vessel: In terms of its operational status, a vessel is considered active when it executes at least one fishing operation during the reference year in the GFCM area of application.

Bathyal and abyssal zones: The portion of the seabed where light is absent and the life of plants and algae is impossible. In the oceans, it is followed by the abyssal zone, in which the water temperature is below 4°C. In the Mediterranean Sea, it indicatively starts below 200 m depth and has a temperature of between 12.5°C and 14.5°C, according to different locations of the basin.

Beam trawling: A fishing practice using a net attached to a steel beam and dragged along the sea bottom behind a towing vessel. The mouth of the net is held open by the beam which is attached to two solid metal plates called shoes, welded to the ends of the beam.

Biomass index: The weight of fish per square kilometre (kg/km^2).

Bycatch: The part of the catch that is unintentionally captured during a fishing operation in addition to the target species. It may refer to the catch of other commercial species that are landed, commercial species that cannot be landed (e.g. undersized, damaged individuals), non-commercial species, as well as to the incidental catch of endangered, vulnerable or rare species (e.g. sea turtles, sharks, marine mammals, seabirds).

Catch: The amount of marine biological resources that are caught by fishing gear and reach the deck of the fishing vessel. This includes individuals of the target species, which are usually kept onboard and retained, as well as bycatch, which refers to species with or without commercial value that are not targeted by the fishery.

Density index: The number of fish per square kilometre (n/km^2).

Depredation: An interaction between marine animals (e.g. cetaceans, seabirds, sea turtles, sharks and rays) with different types of fishing gear considered to be a source of food. Depredatory behaviour can have consequences on fisheries through the removal of bait or caught fish from hooks, nets or traps, thereby reducing commercial catches (i.e. income) or damage done to fishing gear. Depredation can also impact animals, who can suffer mortality and injuries from these interactions. Impacts caused by damages to fishing gear and the loss of catches can lead to hostile dynamics between fishers and those groups of species.

Discard: The part of the catch that is not retained onboard and is returned to sea, dead or alive. It may include target species or any other species (both commercial and non-commercial) discarded at sea.

Epipelagic species: Species living in the upper portion of both the neritic and oceanic waters, where photosynthesis occurs.

Fishing operation: Any single action carried out during a fishing trip, whether or not a catch was made; this includes, *inter alia*, towing a trawl net, setting a line and hauling pots and traps.

Fishing trip: In the simplest cases, a fishing vessel leaves the port, goes to the fishing grounds, fishes for a certain time and returns to the port where its catch is landed. The combination of these events is called a "fishing trip". Generally, in the Mediterranean and the Black Sea, a 24-hour period (i.e. a fishing day), irrespective of the calendar day, is often used as a unit of time. During a fishing trip, a fishing vessel may carry out different fishing operations.

Fishing vessel: Any vessel used or intended to be used for the commercial exploitation of marine living resources.

Fleet segment: A group of fishing vessels of the same size category and using the same gear type for more than 50 percent of their time at sea over the course of a year.

Hanging ratio: The ratio between the length of the headrope and the length of the netting. This term can describe the horizontal slackness of a set net.

Incidental catch or accidental catch: Non-target species captured during their attempts to take bait or other species already caught by fishing gear or taken simply through proximity to the fishing gear. See bycatch.

Landing: The part of the catch that is retained onboard and brought ashore.

Mesopelagic longlines: Longlines that are set in deeper waters (150–200 m), usually for a longer period, and have a lower number of hooks per set, compared with a traditional surface longline.

Mesophotic zone: Also known as circalittoral zone or twilight zone, the mesophotic zone is the portion of the seabed from the final limit of the presence of seagrass to the initial limit of the presence of algae (loss of net productivity at level of irradiance <1 percent). In the Mediterranean Sea, it indicatively ranges between 50 and 200 m depth.

Neritic zone: A shallow marine environment generally corresponding to the continental shelf, characterized by relatively abundant nutrients and biologic activity due to its proximity to land

Non-indigenous species: Any species introduced – either intentionally or unintentionally – outside its natural past or present distribution. These species are also known as exotic or alien species. Their establishment can modify ecosystems, biodiversity and fishing behaviour, and can have (negative and/or positive) social and economic impacts.

Otter trawling: A fishing practice using a large net dragged along the sea bottom behind a towing vessel. The mouth of the net is held open by two large otter boards (also known as doors) which are attached to either side of the net and drag on the seabed before the net.

Semipelagic longline: The main line of a semipelagic longline is positioned at a depth of 150 m or more, while the main line of a surface longline targeting swordfish is usually set at a depth less than 100 m.

Soaking time: The time during which the fishing gear is actively in the water.

Total length: The length of a fish measured from the tip of the snout to the tip of the longer lobe of the caudal fin, usually measured with the lobes compressed along the midline. It is a straight-line measure, i.e. not measured over the curve of the body.

Vessel group: Fishing vessels, regardless of their size, using the same gear for more than 50 percent of their time at sea over the course of a year.

Vulnerable marine ecosystem (VME): A marine ecosystem that has the characteristics referred to in paragraph 42 and elaborated in the annex of the FAO *International Guidelines for the Management of Deep-Sea Fisheries in the High Seas* (FAO, 2009). Vulnerable marine ecosystems (VMEs) include groups of species, communities, or habitats that may be vulnerable to impacts from fishing activities.

Vulnerable species: A taxon is considered vulnerable when facing a high risk of extinction in the wild in the medium-term future. For the purpose of this document, the lists of seabirds, sea turtles, marine mammals and shark species included in Appendix II (endangered or threatened species) and Appendix III (species whose exploitation is regulated) of the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (the Barcelona Convention), together with elasmobranch species included in the IUCN Red List of Threatened Species, and macrobenthic invertebrate species pertaining to VMEs have been used.

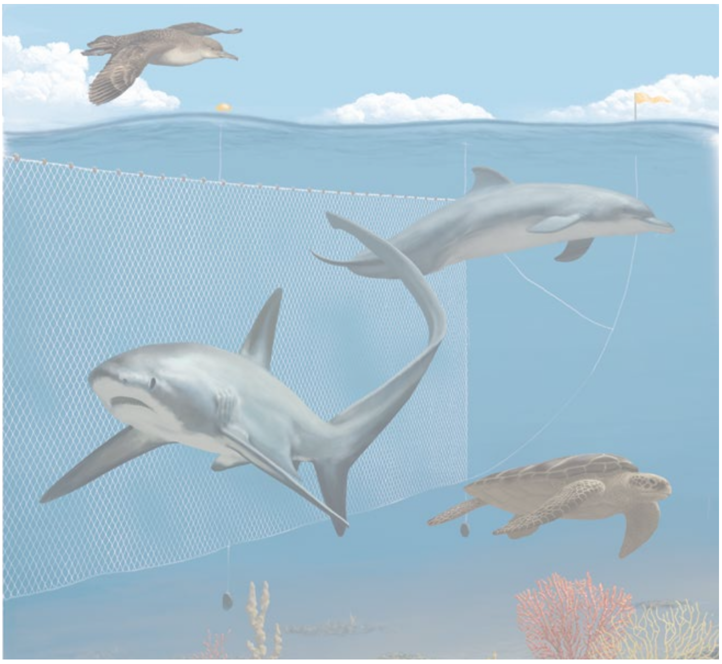
INCIDENTAL CATCH OF VULNERABLE SPECIES IN MEDITERRANEAN AND BLACK SEA FISHERIES A REVIEW

Bycatch – a term widely used to refer to part of the catch unintentionally caught during a fishing operation, in addition to target species, and consisting of the discards and incidental catch of vulnerable species – is considered one of the most important threats to the profitability and sustainability of fisheries, as well as to the conservation of the marine environment and ecosystems. Understanding the bycatch issue and adopting effective measures in order to reduce bycatch rates are essential steps towards minimizing the impacts on vulnerable species and ensuring both a sustainable fisheries sector and healthy seas.

In the Mediterranean and the Black Sea, the incidental catch of vulnerable species – namely seabirds, sea turtles, elasmobranchs, marine mammals and macrobenthic invertebrates – represents one of several challenges for the industrial, semi-industrial and small-scale fisheries that coexist in the region, as well as for the diverse and sensitive ecosystems impacted. Typically, data on this issue have been collected in an opportunistic manner and in ways that make comparisons difficult. The annual absolute values of incidental catch of vulnerable species are not available: studies cover only a small portion of the total fishing activity and often present important knowledge gaps for many types of fishing gear, countries and/or subregions, as well as on temporal scales, for example, to establish reliable baselines. The result is that little is known of the scope of the problem, despite incidental catch being a significant pressure on the populations of vulnerable species, as well as a concern for fishers.

This regional review is an attempt to compile, in one single document, all available data and historical records on the incidental catch of vulnerable species in the Mediterranean and Black Sea fisheries, obtained from existing literature, databases and other grey sources, and collated in a standardized and comparable way. The main objective is to provide comprehensive baseline information, earmark the main data gaps, as well as identify the most impacting types of fishing gear by taxonomic group.

This work is a reminder of the importance of standardized data collection and the need to have baseline information in order to support decision-making in the identification of appropriate bycatch mitigation techniques, thus enabling analysis of their effectiveness and comparison over time and space, as well as facilitating the implementation of relevant conservation and/or management measures at the national, subregional and regional levels.



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