10. Mediterranean Sea

FAO Major Fishing Area 37

SUMMARY

The Mediterranean is made up of a series of deep basins mostly exceeding 3 000 m in depth, and narrow continental shelves around much of the coastline. This chapter confines itself to fisheries on those species that occur mainly below 400 m depth. The fisheries in the Mediterranean are dominated by smaller vessels that stay relatively close to the coast, but owing to the particular topography these can still be bottom fishing in deep waters. Many of the countries also have fleets of larger vessels capable of trawling down to several hundred metres. It is very difficult to fit the Mediterranean into the context of the other areas considered in this review, where high seas fisheries are typically distinct from the smaller inshore fisheries. In addition, the collection and reporting of catch statistics for many of the fleets is less complete than for many other regions, and it is certainly not separated in a manner that allows us to determine a distinct deepwater catch.

European hake is the only finfish to be targeted regularly and predominately deeper than 400 m, though catches of other commercial fish species occur as well. Two species of deepwater red shrimp are caught almost exclusively below 400 m: the blue and red shrimp and the giant red shrimp. The deepwater rose shrimp is fished at shallower depths, though a proportion will be below 400 m. There is also considerable reporting at higher taxonomic levels and about half of the shrimp catches are reported in this way. Many of these are likely to be deepwater red shrimps. An estimate of the catches of deepwater species in 2016 is around 20 000 tonnes of finfish, mostly European hake, and about 25 000 tonnes of shrimp, mostly deepwater rose shrimp and blue and red shrimp. A further catch of unidentified Natantian decapod shrimp and other shrimp species amounts to an additional 12 290 tonnes, but much of this and some of the above hake catches are likely to come from shallower waters (Table 10.1).

TABLE 10.1
Deepwater bottom fisheries catch (tonnes) in the Mediterranean in 2016

Gear	Principal grounds	Principal flag states	Target species	2016 catch
Bottom trawl, Longlines	Widely distributed at 100–c.700 m	Italy, Spain, Greece, Tunisia	European hake	19 736
Bottom trawl	Balearic area at 400–800 m	Algeria, Spain, Italy	blue and red shrimp	2 738
Bottom trawl	Widely distributed at 300–500 m	Italy, Tunisia, Algeria	deep-water rose shrimp	19 847
Bottom trawl	Sardinia area at 400–700 m	Italy	giant red shrimp	2 631
Bottom trawl	Widely distributed at 50–700 m	Egypt, Italy, Turkey, Greece	other "red" shrimp and unidentified shrimp	12 290
Total				57 242

Source: GFCM, 2018a, 2018b.

SCOPE OF THIS CHAPTER

This review is concerned with fisheries in the international waters of the high seas, which for the main oceans focuses on waters outside of national jurisdictions and more than 200 nautical miles from land. The situation is less clear in the Mediterranean. In the previous review, Bensch *et al.* (2009) limited the scope of the Mediterranean chapter to the bottom fisheries operating primarily below 400 m depth; the same approach is adopted here. The primary focus is therefore on trawl fisheries for deep-living shrimps and for various fisheries on European hake, although an overview of other fisheries that operate extensively below 400 m depth is included. The catches provided in this chapter are mainly for the stock over its entire depth range, as it is not possibly nor particularly useful to arbitrarily split the catches by depth. Blue and red shrimp, giant red shrimp and deepwater rose shrimp are fished mainly below 400 m, though European hake can be fished at 100 m depth or less and the shallow water catch is substantial.

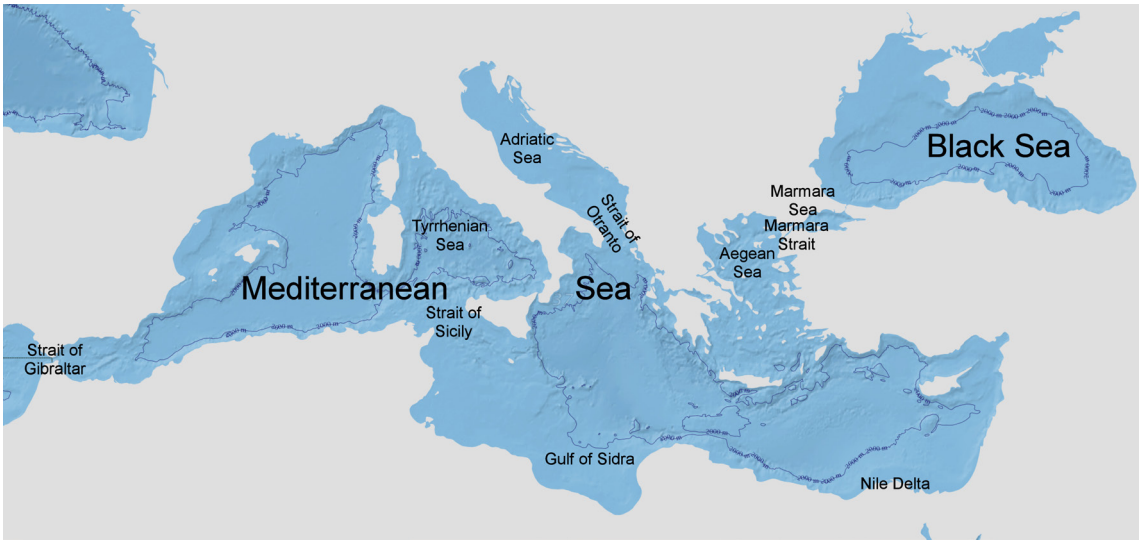
GEOGRAPHIC DESCRIPTION

The Mediterranean is the smallest region recognized by this review (Figure 10.1). It comprises of a series of deep basins, mostly exceeding 3 000 m depth, and continental shelves that vary greatly in width. The region's only natural connection with outside waters is the Strait of Gibraltar: 14 km wide, with a sill depth of about 300 m. A similar, though less extreme, restriction in the Strait of Sicily divides the deep basins of the western and central Mediterranean. Since 1869, the Suez Canal has provided a connection between the eastern basin and the richer ecosystems of the Red Sea, through which various invasive species have passed – the "Lessepsian migrants". While of concern shallower depths closer to the surface, these do not appear to have had any effect on the deep ecosystems of the Mediterranean. Due to the geographic features described above, the Mediterranean is considered the largest semi-enclosed sea in the world, and water interchange through the Strait of Gibraltar and through the Suez Canal, as well as water interchange with the Black Sea through the Marmara straits, together with internal water dynamics inside the Mediterranean water, drive oceanographic conditions in the Mediterranean.

Water circulation in the Mediterranean is driven by evaporation, especially in the extreme east, producing the warm, hypersaline Levantine Intermediate Water (LIW), which circulates around much of the Mediterranean at subsurface depths. The formation of deep water is complex and variable, inter-annually as well as in space, but everywhere involves winter cooling and mixing of the Intermediate Water. As a consequence, the deep basins are flooded with highly saline (> 38.4‰), warm (> 12°C) waters (Sardà *et al.*, 2004a; Tanhua *et al.*, 2013) – a marked divergence from those at similar depths in the rest of the World Ocean.

The main fishable areas at the deeper depths comparable to the other regions in this review are at 400–2 000 m (Table 10.2), though fishing with towed dredges and trawl nets has been prohibited deeper than 1 000 m in the Mediterranean since 2005 (Recommendation GFCM/29/2005/1). Such depths are found in the Mediterranean as a very narrow belt around the deeper basins, including the one in the southern Adriatic. There are broader extents at such depths in only a few areas: east of the Nile delta; in the Gulf of Sidra; in the Alboran Sea; around Ibiza (in the Balearic Islands) and off the adjacent coastline of Valencia; in the Strait of Otranto; in various parts of the Aegean and off Cyprus. The only extensive areas with depths of 400–1 000 m, however, lie among the shallows of the Strait of Sicily. While those potentially deep fishing grounds in the Mediterranean are limited, they total 356 000 km^2, which is more than the combined area of high sea shallower than 2 000 m in the northwest and the southwest Atlantic – two regions which dominate the worlds high sea bottom fisheries.

FIGURE 10.1
Map of the Mediterranean and Black Sea



2 000 m isobath (GEBCO).
Source: FAO VME Database, Mercator projection.

TABLE 10.2
Area statistics for the Mediterranean

Geographical area	Surface area (km²)
Total sea in the region	2 997 000
Area shallower than 400 m	676 000
Area shallower than 1 000 m	1 032 000
Area shallower than 2 000 m	1 480 000
Area deeper than 2 000 m	1 517 000

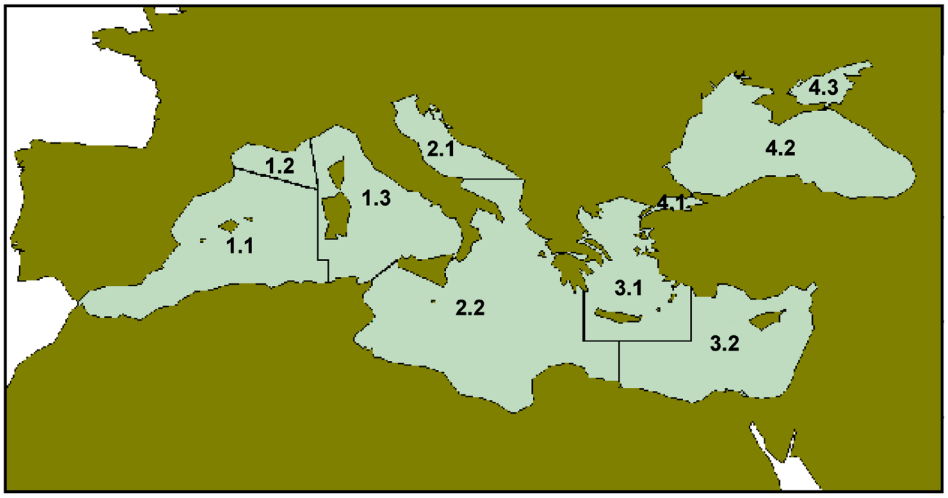
The Mediterranean and the Black Sea (FAO Major Fishing Area 37) are divided into western, central and eastern subareas, each of which is further subdivided into divisions (Figure 10.2). For the purposes of catch reporting to GFCM and FAO, Mediterranean and Black Sea countries use geographical subareas (GSAs) as the main management units (Figure 10.3).

ECOSYSTEMS AND RESOURCE SPECIES

The complex physical and chemical oceanography of the Mediterranean has recently been summarized by Tanhua *et al.* (2013). Importantly, evaporation exceeds precipitation, and the resulting difference in volume is made up primarily by a net inflow through the Strait of Gibraltar, though also through a small net supply from the Black Sea and a similar volume from river and groundwater discharges. Atlantic water from the Strait of Gibraltar forms the surface layer, circulating anticlockwise around the western basin with important eddies; some passes through the Strait of Sicily, then circulates around the eastern basin.

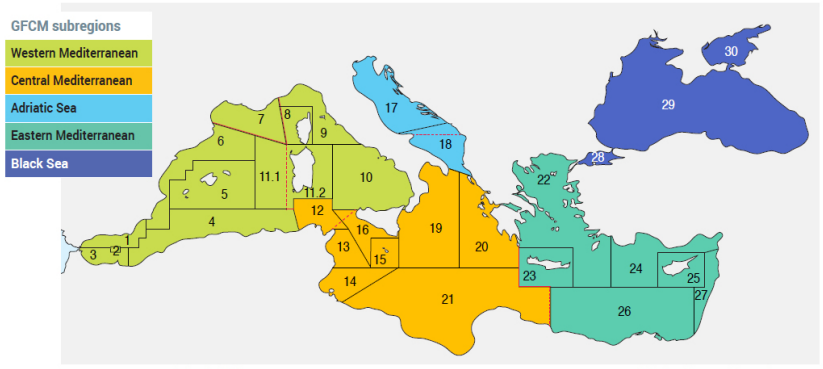
At the 400–1 000 m depths of the Mediterranean's deep fisheries, the eastern basin has temperatures around 14–15 °C and salinities of nearly 39‰, while the western basin has 13–14 °C and 38.5‰. Even the deepest parts of the Mediterranean have bottom temperatures of nearly 13 °C in the west and 14 °C in the east. Concentrations of plant nutrients in the surface layer are low everywhere but especially in the east, making the Mediterranean an oligotrophic system – indeed, some claim the eastern basin is among

FIGURE 10.2
Mediterranean and Black Sea showing subareas and divisions in FAO Major Fishing Area 37



Western Mediterranean subarea (37.1): Balearic (37.1.1), Gulf of Lions (37.1.2), Sardinia (37.1.3) divisions; Central Mediterranean subarea (37.2): Adriatic (37.2.1), Ionian (37.2.2) divisions; Eastern Mediterranean subarea (37.3): Aegean (37.3.1), Levant (37.3.2); Black Sea (37.4): Marmara Sea (37.4.1), Black Sea (37.4.2), Azov Sea (37.4.3) divisions. Note that the major fishing area prefix "37" has been omitted from the labels on the figure.
Source: redrawn from http://www.fao.org/gfcm/data/maps/gsas

FIGURE 10.3
GFCM area of application, subregions and geographical subareas



GFCM GSAs

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 Gabes	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

Source: GFCM website, http://www.fao.org/gfcm/about/area-of-application/en/

the most oligotrophic areas of the World Ocean. Despite the restrictions on water flow amongst the deep basins, water turnover is sufficient that oxygen concentrations are not limiting to marine life in any of the major basins (Tanhua *et al.*, 2013).

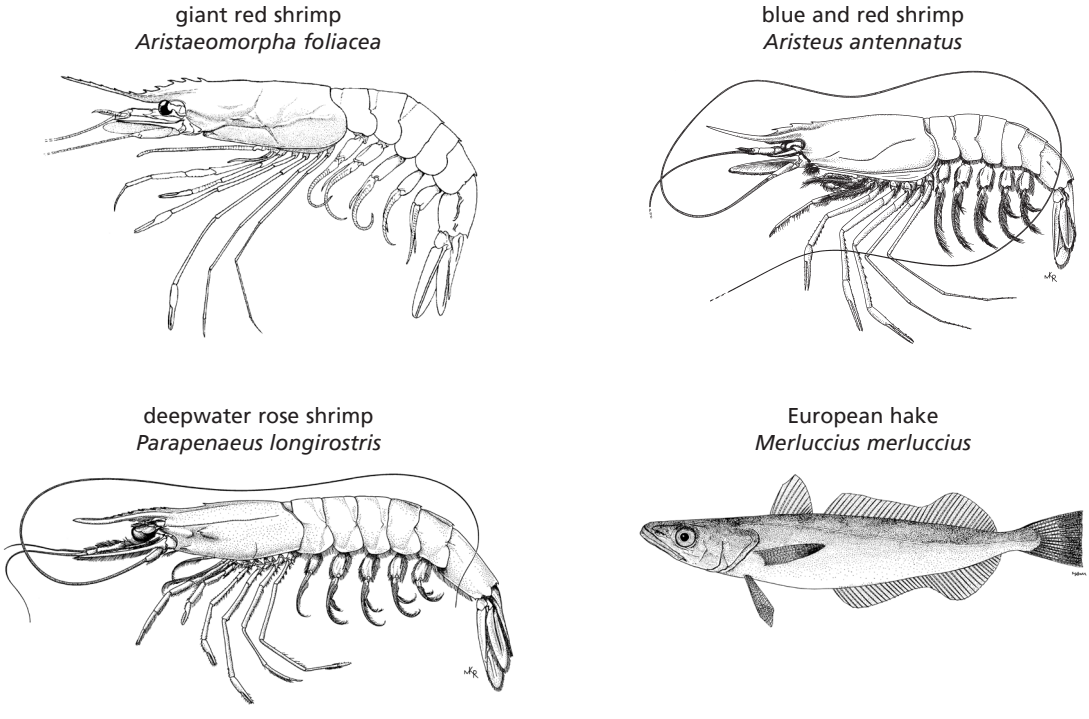
Sardà *et al.* (2004a, 2009) have summarized knowledge of the Mediterranean's deepwater and seabed ecosystems. The principal feature is low productivity, not only because of the oligotrophic surface waters but also because the high temperatures at

depth encourage mid-water consumption of such organic material as would otherwise sink to the seabed. The isolation of the basins, the high temperatures, low productivity and former periods of hypoxia led to a major loss in deep-living diversity following the Pleistocene, especially in the eastern basin. The biomass of the benthos is also low. However, the shorter-lived species are highly responsive to variations in supply of material from lesser depths, which can be seasonal but also episodic "cataclysmic" perturbations arising from unusual combinations of meteorological drivers at the surface.

The very different oceanographic processes in the Mediterranean, and the ecosystems which result from them, lead to biomass densities at depth that are at least an order of magnitude lower than those in the Atlantic. They also lead to a dominance of decapod shrimps, rather than fish, which is more pronounced further to the east (Cartes *et al.*, 2004; Sardà *et al.*, 2009).

As mentioned before, the principal deepwater fisheries are primarily supported by just three species: European hake, blue and red shrimp, and giant red shrimp (GFCM, 2016a, 2018a; Figure 10.4). This is in addition to Norway lobster, deepwater rose shrimp (primarily fished above 400 m depth) and "red" shrimp of the genus *Plesionika* (especially golden shrimp and soldier striped shrimp caught mainly below 400 m) though reported catches of these are usually under 100 tonnes per year. On the Strait of Sicily grounds, for example, deepwater rose shrimp is most abundant at 270–480 m, Norway lobster at 300–550 m, giant red shrimp at 550–650 m, blue and red shrimp at 600–700 m and various *Plesionika* sp. at 280–650 m (Spanò *et al.*, 2013). Shrimp classification – particularly for the purposes of catch recording – is by species and by two higher taxonomical groups: Natantian decapods nei and Aristeid shrimps nei (Table 10.3; GFCM, 2018a). It is likely that there is significant confusion over the recording of these shrimp species.

FIGURE 10.4
Principal deepwater demersal resource species of the Mediterranean



Source: Food and Agriculture Organization of the United Nations, Original Scientific Illustrations Archive.

TABLE 10.3
Classification of Natantian[1] decapods caught in the deep waters of the Mediterranean

Classification	Blue and red shrimp	Giant red shrimp	Deepwater rose shrimp	"Red" shrimp: Golden shrimp and striped soldier shrimp
Order	Decapoda	Decapoda	Decapoda	Decapoda
Suborder	Dendrobranchiata	Dendrobranchiata	Dendrobranchiata	Pleocyemata
Family	Aristeidae	Aristeidae	Penaeidae	Pandalidae
Genus species	*Aristeus antennatus*	*Aristaeomorpha foliacea*	*Parapenaeus longirostris*	*Plesionika martia* and *Plesionika edwarsii*

[1] Natantia is an "unaccepted" suborder of decapod crustacea and include shrimps, prawns and boxer shrimps. It is still used as an official classification in the FAO STATLANT catch recording system (FAO, 2019b) (source for classification: WORMS, 2018).

The blue and red shrimp and the giant red shrimp are the most important commercial species of Aristeidae in the Mediterranean (Rinelli *et al.*, 2013). They inhabit muddy bottoms of the upper and middle slope, with the highest abundance of both species occurring between 600 and 800 m depth, where they often co-exist (Rinelli *et al.*, 2013). In the Mediterranean, the deepest occurrence of giant red shrimp is 1 100 m (Politou *et al.*, 2004) and 3 300 m for blue and red shrimp (Sarda *et al.*, 2004b). The two species have an antagonistic longitudinal gradient in distribution, with blue and red shrimp more abundant in the western Mediterranean and presenting decreasing densities eastwards, while the giant red shrimp is more abundant in the eastern Mediterranean with decreasing densities westwards (Politou *et al.*, 2004; Sarda *et al.*, 2004b; Rinelli *et al.*, 2013).

Blue and red shrimp is the most important deep resource in the western basin and in the western Ionian Sea, where it is mostly fished at 400–1 000 m depth between late winter and early summer, when the mature females form seasonal aggregations at fishable depths. The fishery continues later into the year, when it takes a mixture of sizes, ages and sexes. Blue and red shrimp have a maximum life expectancy of about five years. They appear able to sustain intensive fishing, perhaps because of their high turnover rate combined with the effective protection of the proportion of the population that lives below the fished depths: scattered at low density in these areas, males equal or exceed the abundance of females (Sardà *et al.*, 2003, 2004a, 2004b, 2009). Blue and red shrimp also occur in the eastern basin and the Strait of Sicily but the principal deep resource there is the giant red shrimp (Sardà *et al.*, 2004a, 2009). They are particularly abundant at depths of 600–800 m. Males and females appear to live to three and six years of age, respectively. Comparing the biological characteristics of the two species, including maximum depth, vertical distribution, recruitment depth and size at maturity, Politou *et al.* (2004) suggested that giant red shrimp is more vulnerable to overfishing than blue and red shrimp.

Various populations of European hake form a principal groundfish resource throughout the Mediterranean. They are isolated from the populations in the Atlantic and partially separated between the western and eastern basins. In the west, they are found from near shore to almost 1 000 m depth but are unusual below 500 m (Oliver and Massutí, 1995).

MANAGEMENT OF HIGH SEA BOTTOM FISHERIES

General Fisheries Commission for the Mediterranean (GFCM)

The General Fisheries Commission for the Mediterranean (GFCM) was established in 1949, pursuant to Article XIV of the FAO Constitution through an Agreement, which entered into force in 1952. The Agreement was amended in 1963, 1976, 1997 and 2014, the third of which changed the "Council" into a "Commission", while the fourth aimed, *inter alia*, to enhance sub-regional cooperation, ensure Member States' compliance with binding recommendations and long-term sustainability

of ecosystems, fisheries and aquaculture. The main objective of GFCM is to promote the sustainable use, development, conservation, rational management and best utilization of living marine resources, as well as the sustainable development of aquaculture. The commission's responsibilities not only include keeping the fisheries and the living resources of the region under review, but also considering the economic and social aspects of the fishing industry, while formulating and recommending appropriate management measures, encouraging and coordinating research, promoting programmes for marine and brackish water aquaculture, and the assembly and publication of information.

The GFCM area of application encompasses all marine waters of the Mediterranean and the Black Sea. It therefore includes, among other areas, the Adriatic and Aegean seas, as well as the Sea of Marmara. For statistical purposes, the area of application has been subdivided into geographical subareas (GSAs; Figure 10.3). The commission's mandate covers all fisheries except those for large pelagic species.

GFCM is made up of 24 contracting parties, comprising 22 coastal states, Japan (as a distant-water fishing nation) and the EU. Georgia and Ukraine became cooperating non-contracting parties in 2015, followed by Bosnia and Herzegovina in 2016, the Republic of Moldova in 2017, and Jordan in 2018. GFCM operates in four official languages: Arabic, English, French and Spanish.

The commission meets annually, when it has the authority to adopt binding recommendations for fisheries conservation and management in its area of application – though members can opt out through objection procedures. GFCM implements its policies and activities during intersessional periods through its technical committees, their subcommittees and working groups, and with the assistance of its Secretariat. The committees comprise the Scientific Advisory Committee on Fisheries (SAC), the Scientific Advisory Committee on Aquaculture (CAQ), the Compliance Committee (CoC) and the Committee of Administration and Finance (CAF). The SAC, composed of individuals accredited by the contracting parties, is charged with providing independent advice on the technical and scientific bases for decisions concerning fisheries conservation and management, including their biological, social and economic aspects. Of particular relevance to this review, its subsidiary bodies include a Working Group on Stock Assessment of Demersal Species (WGSAD).

Since 2015, in order to further its objectives, GFCM has transitioned away from the former thematic approach, towards a subregional approach. Subregional committees have been established for the western Mediterranean, central Mediterranean, Adriatic Sea and eastern Mediterranean, in addition to the Working Group on the Black Sea established in 2012.

More recently, GFCM adopted a 2017–2020 strategy to ensure the sustainability of fisheries, which is intended to reverse an "alarming trend in the status of commercially exploited stocks" (Resolution GFCM/40/2016/2).

The commission has a suite of management measures also applicable to deep-sea bottom fishing, which are adopted through recommendations, resolutions and other decisions (Table 10.4; GFCM, 2017a).

With respect to specific recommendations addressing deep-sea fisheries, in 2005 Recommendation GFCM/29/2005/118 prohibited the use of towed dredges and trawl nets at depths greater than 1 000 m. The preamble to this recommendation notes that it is a precautionary measure mainly for the protection of fish stocks and to halt the expansion of fisheries into deeper waters when the stock status is unknown. In 2004, the SAC also made reference to the protection of vulnerable habitats, issuing advice to:

> *refrain expanding deep-water fishing operations beyond the limit of 1 000 m, in view of scientific considerations on the presence both of unmapped sensitive habitats (deep-water coral banks, sea vents, sea mounts, etc.), and of the fragile nature of deep-water fish assemblages as well as the presence of juveniles of different crustacean species at such depths.*
>
> **(GFCM, 2004, paragraph 80)**

This precautionary decision addresses both the management of deep-sea bottom fisheries and the protection of deep-sea benthic ecosystems. The area below 1 000 m covers a little over 1 700 000 km² (about 59 percent of the Mediterranean; c.f. Table 10.2).

More recently, specific recommendations on deepwater fishing were adopted for demersal fisheries of the Strait of Sicily and for deep-sea red shrimp fisheries in the central and eastern Mediterranean. In 2015, minimum standards were set for bottom trawling fisheries of demersal stocks in the Strait of Sicily (Recommendation GFCM/39/2015/2) and in 2016 a multi-annual management plan was established (Recommendation GFCM/40/2016/4, later repealed by Recommendation GFCM/42/2018/5) with the following objectives:

- to apply the precautionary approach;
- to bring exploitation rates of European hake and deepwater rose shrimp to levels consistent with maximum sustainable yield by 2020;
- to protect nursery areas;
- to reduce discarding;
- to adjust fishing capacity to match the reduced fishing mortality; and
- to achieve economic viability without overexploiting the resources.

Specific measures include:

- minimum sizes for European hake (20 cm total length; later extended region-wide) and deepwater rose shrimp (20 mm carapace length);
- special authorization requirements for vessels engaged in bottom fishing in the Strait;
- a VMS requirement;
- the establishment of three Fisheries Restricted Areas (FRA) to protect nursery grounds from trawling year-round; and
- a three-month seasonal closure of waters between the coast and the 200 m contour in the Gulf of Gabès.

The management plan also sets target fishing mortality rates for deepwater rose shrimp and European hake.

In 2018, two recommendations were adopted with a view to establishing multi-annual deepwater management plans for sustainable trawl fisheries targeting giant red shrimp and blue and red shrimp in the central (GSAs 19, 20 and 21; Recommendation GFCM/42/2018/4) and eastern Mediterranean (GSAs 24, 25, 26 and 27; Recommendation GFCM/42/2018/3). The objective of these two recommendations, virtually identical in their content, is to maintain fishing mortality for giant red shrimp and blue and red shrimp within agreed precautionary reference points and thus achieve/maintain fishing mortality at MSY. The recommendations are consistent with the precautionary approach, establishing transitional measures to be applied until the adoption of permanent measures, envisaged for 2020. During this transitional phase it is expected that the status of the two stocks will be regularly assessed and, if not possible, that fishing fleet capacity or fishing effort be maintained at the authorized levels exerted during the 2014–2017 period. Those contracting parties and cooperating non-contracting parties (CPCs) with developed fisheries are expected to provide lists of authorized vessels with an indication of their historical fishing effort. Among other things, they are also obliged to have VMS on board (or any other geopositioning system, if greater than 10 m length overall) and provide detailed reports on their fishing activities (operating days, operating area, total catch, discards), in order to enable the creation of maps of fishing grounds using VMS data by the end of 2020. CPCs with no fishery are not permitted to submit fleet development plans to the GFCM for consideration.

In addition to these decisions, in 2018 the commission endorsed specific protocols for the protection of vulnerable marine ecosystems (VMEs) in the GFCM area of application. These protocols include: a definition of Mediterranean deep-sea fisheries, a VME encounter reporting protocol (and associated list of Mediterranean

TABLE 10.4
Decisions adopted by GFCM relevant to deepwater bottom fisheries

Year	Decision	Summary
Gear restrictions, size limits, effort restrictions		
2005 2009	REC.CM-GFCM/29/2005/1 REC.CM-GFCM/33/2009/2	A minimum mesh size for trawl net codends has been set at 40 mm square- or 50 mm diamond mesh
2006	REC.CM-GFCM/30/2006/1	Developing management of fishing effort in the bottom trawl fisheries for, among others, European hake, "red shrimp" and Norway lobster, in specified areas
2012	OTH-GFCM/36/2012/1	Guidelines for multi-annual management plans
2016	REC.CM-GFCM/40/2016/5	Minimum fish size for European hake has been set at 20 cm total length
Area-based measures		
2005	REC.CM-GFCM/29/2005/1	Prohibition of towed dredges and trawl nets below 1 000 m depth
2006–2017	REC.CM-GFCM/30/2006/3 REC.CM-GFCM/33/2009/1 REC.MCS-GFCM/40/2016/4 REC.CM-GFCM/41/2017/3	Fisheries restricted areas for protection of vulnerable ecosystems and fish stocks
2015	REC.CM-GFCM/39/2015/2	Specific measures were adopted for the demersal fisheries of the Strait of Sicily
2016	REC.CM-GFCM/40/2016/4	Strait of Sicily multi-annual management plan
2017	REC. CM-GFCM/41/2017/3	Fisheries restricted area in the Jabuka/Pomo Pit in the Adriatic Sea
Bycatch control		
2011–2013	REC.CM-GFCM/35/2011/5 REC.CM-GFCM/35/2011/4 REC.CM-GFCM/35/2011/3 REC.CM-GFCM/36/2012/2 REC.CM-GFCM/37/2013/2	Reduce the potential for impacts on monk seals, cetaceans, sea turtles, and seabirds
2012	REC.CM-GFCM/36/2012/3	Prevent shark finning, skinning or beheading, and capture of certain shark species
Data collection, monitoring and enforcement		
1995–2017	RES-GFCM/21/1995/2 REC.MSC--GFCM/35/2011/1 REC.DIR-GFCM/41/2017/6	Data reporting Logbook
2005 2017	RES-GFCM/29/2005/2 REC.MCS-GFCM/41/2017/8	Foundations for a control and enforcement scheme Joint inspections schemes for Strait of Sicily
2016	REC.MCS-GFCM/40/2016/1	Port state measures to combat IUU fishing
2009	REC.MCS-GFCM/33/2009/6 REC.DIR-GFCM/33/2009/5	Fleet register
2009	REC.MCS-GFCM/33/2009/7 RES-GFCM/38/2014/1	VMS
2009	REC.MCS-GFCM/33/2009/8	IUU vessels list
2011	REC.MCS-GFCM/35/2011/1	Logbooks
2013	REC.MCS-GFCM/34/2010/2 RES-GFCM/37/2013/2	Guidelines for fishing capacity controls
2013	OTH-GFCM/37/2013/1	Developing interim subregional measures
2014 2017	OTH-GFCM/38/2014/1 REC.MCS-GFCM/41/2017/7	Roadmap to Combat IUU fishing in the Mediterranean Regional plan of action for the fight against IUU fishing

Source: http://www.fao.org/gfcm/decisions/en/

VME Indicators), provisions for the Mapping of existing deep-sea fishing areas and an Exploratory deep-sea bottom fishing reporting protocol in the GFCM area of application. Nonetheless, at the time of writing, no formal decision (i.e. Resolution or Recommendation) has been taken by the commission (GFCM, 2019).

Other multilateral agencies

While GFCM is the sole regional fisheries management organization (RFMO) managing fisheries in the Mediterranean and the Black Sea, multiple other bodies have mandates relating to the marine environment in the region, a number of which have Memoranda of Understanding with GFCM (Álvarez *et al*., 2016). Of these, the Mediterranean Action Plan (MAP) is worthy of note, as the first Regional Seas Programme adopted, in 1975, under the umbrella of the UN Environment Programme. The MAP was originally focused on protecting coastal waters from primarily land-based pollution. It was followed the next year by the Convention for the Protection of the Mediterranean against Pollution (the "Barcelona Convention"). In 1995, 21 states and the European Union adopted both a new Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (also dubbed the "Barcelona Convention"), which came into force in 2004, in addition to a new Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean (considered MAP Phase II). The Coordinating Unit for MAP serves as the secretariat for the Convention.

Beyond pollution prevention, MAP now covers the safeguarding of natural and cultural resources, the management of coastal areas and the integration of environment and development. The convention has an accompanying Specially Protected Areas and Biodiversity Protocol, under which there is a programme and "roadmap" for MPAs, a plan for conservation of sharks and rays, a plan for the conservation of habitats on seamounts and in submarine canyons, for the conservation of structure-forming benthos and for the conservation of chemosynthetic systems – all of which could impinge on management of deepwater bottom fisheries. Six Regional Activity Centres are responsible for the implementation of the respective parts of MAP, of which the Specially Protected Areas Regional Activity Centre (SPA/RAC) is concerned with the Specially Protected Areas and Biodiversity Protocol. In 2010 it generated a list of 13 priority open-sea areas for conservation, relevant to the impacts of fishing (de Juan and Lleonart, 2010a). Three of those correspond to GFCM Fisheries Restricted Areas and a fourth to the commission's closure of the seabed deeper than 1 000 m to all towed gears.

In 2012, GFCM and UNEP/MAP entered into a Memorandum of Understanding which commits the two organizations to cooperating in the advancement of their respective mandates, including in the arena of marine spatial planning. While the objectives of the two organizations have much in common – including the application of the ecosystem approach to fisheries – the memorandum also gives attention to mitigating cumulative risks arising from reduced access to space affected by multiple and conflicting uses.

DESCRIPTION OF BOTTOM FISHERIES

The Mediterranean, overall, lacks the large monospecific resources found in the outer oceans. Most fisheries in the region are mixed-species, often using small boats and fishing close to land. There are approximately 86 000 boats, with about 250 000 fishers working in the Mediterranean and Black Sea fisheries, but 84 percent of the boats belong to the "small-scale" sector and are under 12 m overall length (FAO, 2019a). There are about 6 200 trawlers (with 34 000 fishers), of which 2 219 are 12–24 m length overall; only 701 are longer than 24 m. Annual landings of wild-caught fish from the Mediterranean (excluding the Black Sea) increased until 1994, reaching

1 087 000 tonnes, but then declined irregularly to 850 000 tonnes (valued at about USD 2.4 billion at first sale) by 2016. Most of the catch comprised small pelagic species. However, the trawlers used in bottom fishing were responsible for 46 percent of landed value overall (GFCM, 2018a).

The deep fisheries are a minor subset, with various gears being worked from generally small boats taking a mixture of species, although larger trawlers are relatively more important than they are in shallower fishing. It is the presence of deep water close to the coast and the dense human populations of coastal, seafood-consuming communities that have made such deep fishing viable, even in the low-productivity Mediterranean. No comprehensive catalogue of the fisheries operating deeper than 400 m in the Mediterranean has been prepared, though it is clear that trawling for the two species of "red shrimp" predominates, while European hake is the principal target finfish.

During the 1930s, an existing shrimp trawl fishery, taking shallow-dwelling species in the Ligurian Sea expanded beyond the 400 m isobath and exploited both giant red shrimp and blue and red shrimp. Similar fishing emerged off the Catalan coast of Spain and around the Balearics in the 1940s, with fishing depths there reaching 700 m. During the 1980s, there was further expansion down to 1 000 m (Sardà *et al.*, 2004a). Other deep shrimp fisheries emerged subsequently around the Mediterranean, as much by local development as by dissemination from the western basin. The deepwater red shrimp fishery in the eastern–central Mediterranean has been developing since the 1960s when the Italian fleet of Mazara del Vallo began fishing predominantly for giant red shrimp in the Strait of Sicily. The progressive decrease in the catch rate of this species in these traditional fishing grounds, and the absence of deep trawling in the eastern Mediterranean, has from the early 2000s driven some boats to fish around Crete and Cyprus, as well as off the Turkish coast (Garofalo *et al.*, 2007; Vitale *et al.*, 2013).

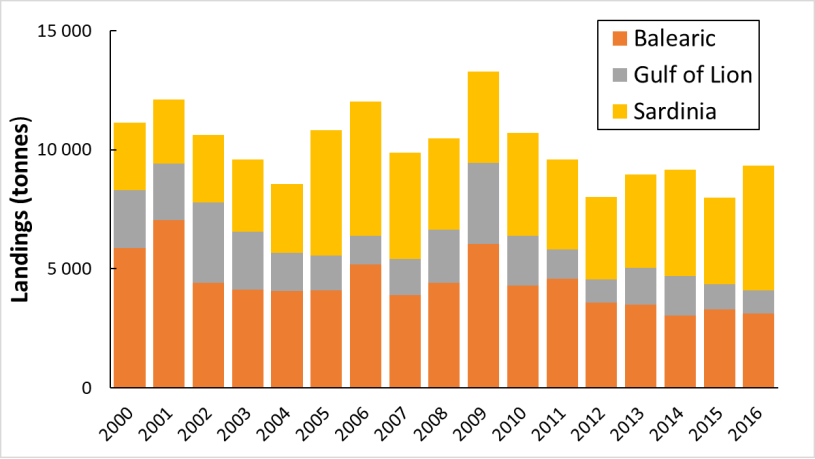
In contrast to the shrimp fisheries, the mixed-species trawl fisheries that took the majority of European hake was largely active in waters shallower than 300 m – where most of the European hake were juveniles – until the 1990s. Along with some deeper trawling, there were various longline fisheries that targeted adult European hake, including a directed fishery in the northern parts of the western basin. The mainlines were fitted with alternating weights and floats so that spans of the gear were off-bottom. Such longlines were set at depths as great as 700 m, particularly in the canyons of the Gulf of Lion and off the Spanish coast. There was also some gillnetting for European hake in the western basin and trammel netting in the east. Catches in the severely oligotrophic waters of the latter basin were very much lower than those in the west, and almost all of them came from the Aegean, where phytoplankton benefit from higher nutrient levels in the Black Sea outflow (Oliver and Massutí, 1995; Papaconstantinou and Stergiou, 1995).

Western Mediterranean

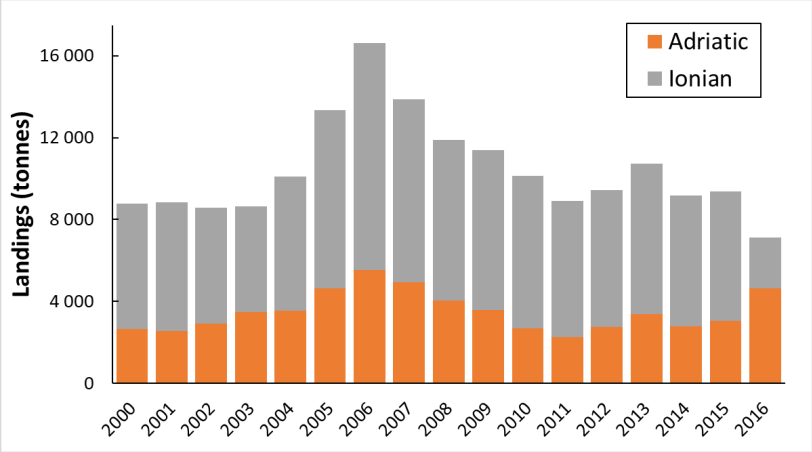
Overall, reported catches of European hake appear to be stable in the western Mediterranean, with slight increases around Sardinia being compensated by decreases in the Balearics, and an average for the subarea of 10 134 tonnes during the 2000–2016 period (Figure 10.5a). Percentages from the Balearic, Gulf of Lion, and Sardinia division were 43 percent, 18 percent and 38 percent respectively; the differences can largely be accounted for by the size of the division. It is not known what proportion comes from waters deeper than 400 m.

Shrimp catches are much harder to determine, primarily because they have mainly been reported either by species name or under one of the two shrimp groupings of Aristeidae and Natantia. The former group includes only the deepwater giant red shrimp and the blue and red shrimp, whereas the latter includes all shrimp. Catches from the

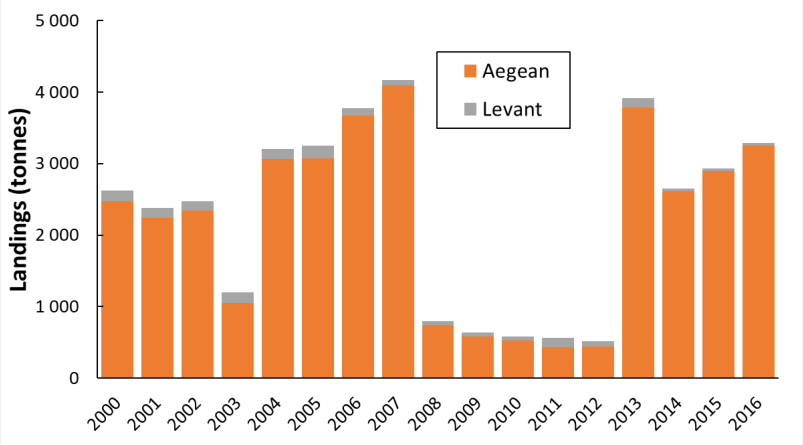
FIGURE 10.5
Reported catches of European hake in: (a) western, (b) central, and (c) eastern Mediterranean subareas, by FAO division in 2000–2016



(a)



(b)



(c)

Source: GFCM, 2018a.

Balearic and Gulf of Lion include high proportions of blue and red shrimp, whereas the Sardinia division is almost entirely made up of the shallow-dwelling deepwater rose shrimp. The total reported catches have remained reasonably stable, with occasional highs and lows. Overall average reported catches for the blue and red shrimp and the giant red shrimp are around 2 000 tonnes and 30 tonnes respectively, and these would all have come from below 400 m. Unidentified Natantian shrimp averaged 900 tonnes for the same 2000–2016 period, but it is not whether these are mainly deepwater rose shrimp and/or other species caught from shallower areas (Figure 10.6).

In the northern Alboran Sea (GSA 01), there is trawling for European hake on seamounts, at depths down to 800 m (de Juan and Lleonart, 2010b). In 2016, the European hake fishery was exploited by 110 small trawlers averaging 35 GRT (91 percent of landings), plus some longlines (3 percent of landings) and gillnets and trammel nets (6 percent of landings). In 2016, combined landings amounted to 185 tonnes, the lowest since the time series began in 2003, but landings increased to 288 tonnes in 2017 (GFCM, 2015, 2017b, 2018c). GSA 01 is also trawled for blue and red shrimp, with average landings of 136 tonnes per year for 2015–2017 (GFCM, 2018c).

The deepwater fishery around Alboran Island (GSA 02) for blue and red shrimp is targeted by the largest vessels of the deepwater trawl fleet operating on the middle slope, with trips lasting four to five days. The fishery is very weather-dependent with an average of 15 vessels in total and 47 tonnes landed annually during 2015–2017 (GFCM, 2018c).

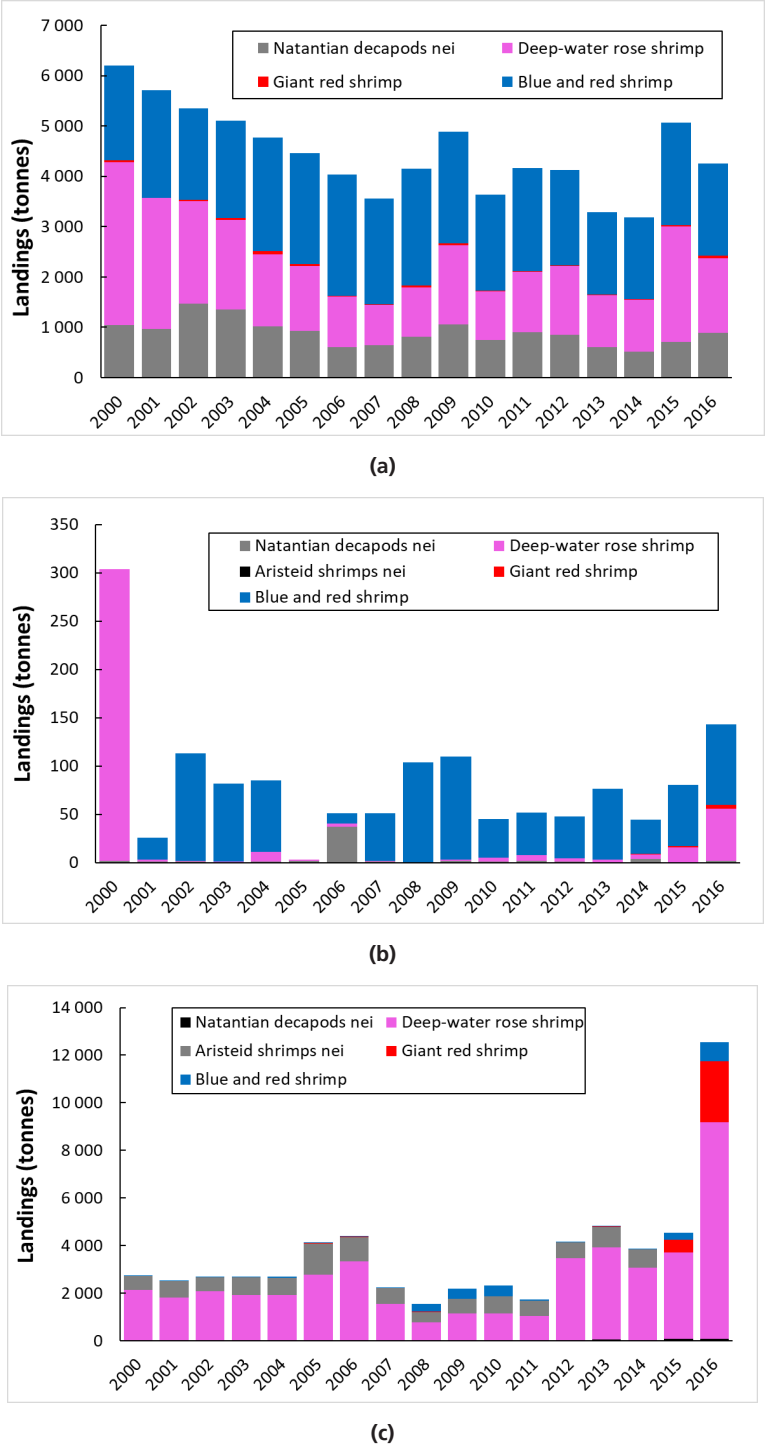
The finfish trawling fleet in the southern Alboran Sea (GSA 03) in 2016 comprised 72 vessels, targeting various species including European hake. The mean annual European hake production for 2015–2017 was 117 tonnes (GFCM, 2017b, 2018c). The Algerian shrimp fishery began working below 400 m on the continental slope in 1999, targeting blue and red shrimp, though the fishing had not exceeded 530 m depth by 2006. It took only a few tens of tonnes annually (Mouffok *et al*., 2008).

The trawl fishery off Algeria (GSA 04) is on the shallow shelf and slope at depths of 100–200 m and, though it catches European hake, is beyond the scope of this review. Small-scale fishers in this area also use gillnets and trammel nets.

Deep trawling continues around the Balearics (GSA 05), where there are four recognized fisheries at shallow-shelf and deep-shelf depths, on the upper slope and the middle slope. European hake is the principal target of a mixed-species finfish fishery on the deep shelf (80–250 m). Annual European hake landings from the GSA vary between 50 tonnes and 190 tonnes, all taken by trawling (GFCM, 2018c). The upper-slope fishery operates at 350–600 m, targeting Norway lobster, with large European hake, megrim, anglerfish and blue whiting as important bycatch species. The mid-slope fishery (600–750 m) targets blue and red shrimp (GFCM, 2018c). The deep fishery works from late winter to early summer, targeting the schools of blue and red shrimp which form on the continental slope at that time of year (Sardà *et al*., 2004a).

The fishery targeting European hake off Spain (GSA 06) is one of the largest in the Mediterranean and prosecuted by trawlers (which take 91 percent of landings) and by small-scale fishers using longlines (6 percent of landings) and gillnets and trammel nets (3 percent of landings). There are some 1 000 boats taking part in this fishery, with landings of 1 810 tonnes of European hake in 2016 – a decline when set against the average of 3 004 tonnes for 2002–2016. In 2016, there were 437 trawlers that landed 1 719 tonnes of European hake (GFCM, 2017b, 2018c). However, much of this fishery is likely to be in shallower waters and really outside of the scope of this review. Approximately 200 trawlers work off the Spanish coast, north of the Alboran Sea (GSA 06). Some target deepwater rose shrimp, with annual landings

FIGURE 10.6
Reported catches of shrimp from the western Mediterranean in the FAO divisions: (a) Balearic, (b) Gulf of Lion, and (c) Sardinia in 2000–2016



Source: GFCM, 2018a.

of around 100–150 tonnes (GFCM, 2015, 2017b, 2018c). However, blue and red shrimp are the most valuable, comprising only 3 percent of Catalonian landings by volume but 21 percent by value, sometimes reaching prices of EUR 200/kg. Annual landings of this species are highly variable, driven by the cascades of dense water

from the Gulf of Lion, but those taken by Catalonian trawlers have amounted to 500–700 tonnes annually in recent years (Gorelli *et al.*, 2016).

The Gulf of Lion (GSA 07) is more productive at depth. A complex network of trawl, gillnet and longline fisheries by some 250 Spanish and French vessels work the continental slope, fishing mostly above 400 m depth but with some deeper effort – including fixed gears fished down to 1 200 m. The principal target is European hake but a variety of species is harvested, including deep-living forms such as monkfish, European conger, megrim, horned octopus and blue whiting. Annual European hake landings averaged 1 914 tonnes over 1998–2016, but were only 1 057 tonnes in 2016, of which 74 percent was taken by the French trawling fleet (de Juan and Lleonart, 2010a, 2010b; GFCM, 2017b). Catches of blue and red shrimp from this division are modest at 50–100 tonnes per year.

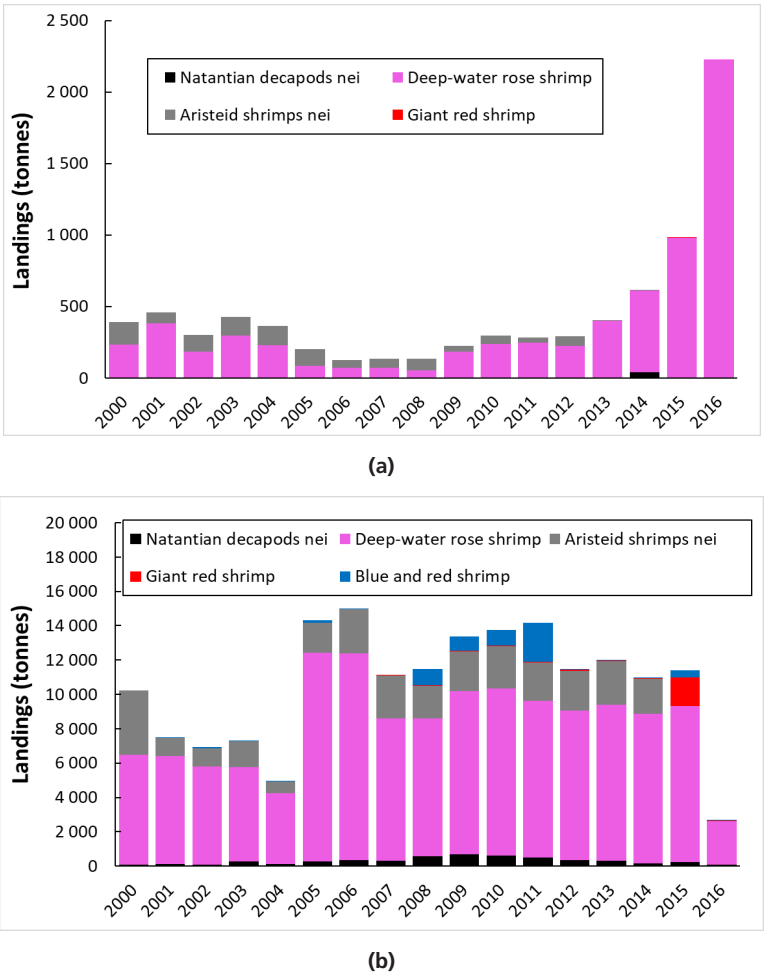
The deepwater shrimp resources in the Ligurian Sea and the northern Tyrrhenian Sea (GSA 09) declined in the late 1970s, after nearly half a century of exploitation. Blue and red shrimp soon recovered but by the end of the twentieth century the giant red shrimp, fished throughout its depth range, had not (Sardà *et al.* 2004a). Deepwater rose shrimp continue to be fished at lesser depths (150–350 m), as a component of a mixed-species trawl fishery that also targets European hake, horned octopus, Norway lobster and "red shrimp" down to 650 m – though catches also include a wide variety of other species that make a substantial contribution to overall landed value. European hake are also exploited by artisanal vessels using particularly gillnets that take almost half of the total catch (Sartor *et al.*, 2003; GFCM, 2015, 2017b).

Central Mediterranean

Reported catches of European hake in the central Mediterranean during 2000–2016 peaked around 2006 and have declined by some 50 percent in the large Ionian division (Figure 10.5b), whereas catches in the Adriatic have been more stable. Average catches during this period were 6 400 tonnes and 3 500 tonnes respectively, though again it is not known how much of this was from shallower waters. Reported catches of the deepwater blue and red shrimp and giant red shrimp have been very low, only reaching significant levels in 2008–2011 and 2015, with catches of around 800–2 200 tonnes per year. Catches of unidentified shrimp of around 2 000 tonnes per year have been reported, but this could be any species from shallow to deep waters (Figure 10.7).

The largest of the deep fisheries are those in the Strait of Sicily (GSA 12, 13, 14, 15 & 16), where giant red shrimp are especially prominent. Indeed, early in this century, the greatest combined landings of "red shrimp" were made in Bizerte, Tunisia and Mazara, Sicily (Sardà *et al.*, 2004a). Deepwater rose shrimp are also harvested in the area, mostly above 400 m depth but with some taken as deep as 600 m. The Italian fleet operating in the Strait comprises mostly small (under 12 m length), coastal trawlers making one- or two-day trips but also some "distant" trawlers of over 24 m length, which make trips of up to four weeks. Both fleets fish at varied depths, often on the same trip, exploiting deepwater rose shrimp, giant red shrimp, Norway lobster and European hake, as well as shallower-dwelling resources, changing target species as their relative availability permits. The Tunisian fleet mostly works off its northern coast (GSA 12), landing at Bizerte and Kelibia. There are also Maltese and Libyan fleets operating in the area (Sardà *et al.*, 2004a). European hake is an important bycatch for the shrimp trawlers but also a target for longliners and gillnetters, with landings by all fleets averaging more than 3 000 tonnes annually for 2007–2016. Other species taken include rosefish, greater forkbeard and monkfish (GFCM, 2017b).

FIGURE 10.7
Reported catches of shrimp from the central Mediterranean in the FAO divisions: (a) Adriatic, and (b) Ionian in 2000–2016



Source: GFCM, 2018a.

The western Ionian Sea (GSA 19) is likewise fished for shrimp, Norway lobster and European hake by a fleet of more than 200 small Italian trawlers, alongside their fishing for other species at lesser depths. Both giant red shrimp and blue and red shrimp are important. There is also some small-scale longlining targeting European hake, rosefish, greater forkbeard and bluntnose sixgill shark, among other species (Sardà *et al.*, 2004a; GFCM, 2017b).

Greek trawling in the eastern Ionian Sea (GSA 20) does not usually extend below 500 m depth. Target species there include European hake, blue whiting, monkfish, blackspot (=red) seabream and others. There is some longlining at greater depths for European hake and wreckfish, while Italian trawlers work there at 400–800 m for "red shrimp", Norway lobster, European hake, blue whiting and others (Sardà *et al.*, 2004a).

Adriatic Sea

Most of the fishing in the Adriatic is necessarily shallower than 400 m but the European hake fishery there extends down to 800 m depth in the one deep basin (in GSA 18). Deepwater rose shrimp are taken in the same area at depths of 50–500 m, while Norway lobster is targeted at 50–400 m, particularly in the Jabuka/Pomo pit.

Bycatch includes horned octopus, monkfish and megrim. Most of the catch is taken by Italian and Croatian trawlers but there are also fleets from Albania and Montenegro, while some boats use longlines, gillnets or trammel nets (GFCM, 2017b).

Eastern Mediterranean

The eastern Mediterranean comprises of the Aegean and Levant divisions, though reported catches in the latter have been very low for both European hake and shrimp. Recent reported catches of European hake in the Aegean for 2000–2016 have been variable, ranging from around 500 tonnes to 3 500 tonnes, with both good years and poor years (Figure 10.5c). Catches of shrimp in both divisions have been in the order of 1 500–3 000 tonnes in the Aegean and 400–12 000 tonnes in the Levant, though they are almost only reported at the lowest taxonomic level, and those reported to species are mainly deepwater rose shrimp (Figure 10.8).

In the Aegean (GSA 22) Greek fishermen use longlines, gillnets and trammel nets to target European hake (at depths down to 700 m) but also blackspot (=red) seabream (fished on rocky banks at 200–600 m depth) and wreckfish (at 300–1 000 m, usually on steep slopes). The bottom trawl fishery shifts its activity between shallow and deep grounds. In the 1990s it rarely operated below 500 m while targeting Norway lobster, European hake, megrim, monkfish, deep-water rose shrimp and shrimps of the genus *Plesionika*. After 2000 the fishery took to working deeper, down to 800 m, in late spring, taking giant red shrimp, blue and red shrimp, rosefish and others. In the 1990s, a longline fishery for bluntnose sixgill shark operated in the Aegean, at depths of 600–1 500 m (Mytilineou and Machias, 2007). It is unclear whether it has persisted, but it was the deepest fishing in the Mediterranean and among the deepest anywhere.

Apart from some European hake fishing off the Levant (Bensch *et al*., 2009), deep fisheries did not develop in the Levantine Sea (GSA 24, 25, 26 and 27) before the present decade (de Juan and Lleonart, 2010a). Shrimp trawling has since expanded into those waters, mainly by Italian and Egyptian fleets.

Landings of European hake from the Mediterranean, as reported to FAO, totalled 19 700 tonnes in 2016 – but much of that was caught above 400 m depth. The principal flag state involved was Italy, with reported landings of 8 700 tonnes. Greece, Tunisia, Spain and France also reported substantial landings, totalling 7 900 tonnes between them. The distribution of the European hake fisheries has been broadly consistent over the recent past, though overall regional landings have declined from a peak of over 52 000 tonnes in both 1994 and 1995, as Italian landings have declined from 38 000 tonnes.

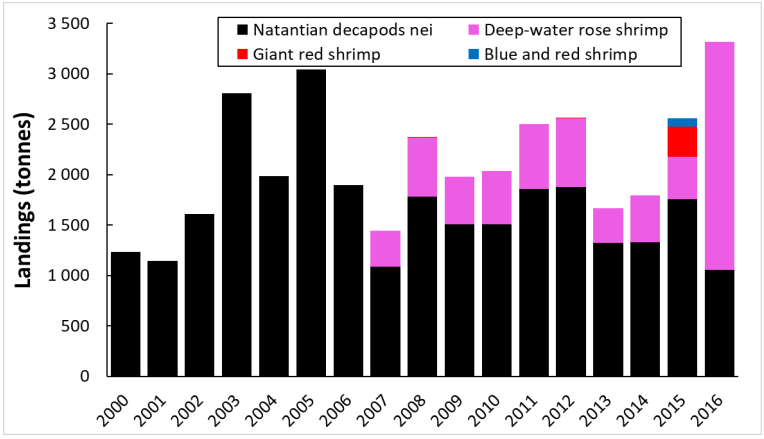
Equivalent information on the deep shrimp fisheries is not available, as much of the catch is reported to FAO merely as "Natantian decapods", without distinguishing between the deep and shallow species. Region-wide reported shrimp landings totalled 37 506 tonnes in 2016, of which 19 847 tonnes were identified as deepwater rose shrimp, with a further 12 290 tonnes as natantian decapods (much of it undoubtedly taken above 400 m depth). The majority of these were caught by Italian, Tunisian or Turkish trawlers. Only 2 738 tonnes of blue and red shrimp (most reported by Algeria and Spain) and 2 631 tonnes of giant red shrimp were identified to species level in the reports to FAO.

IMPACTS ON RESOURCES AND ECOSYSTEMS

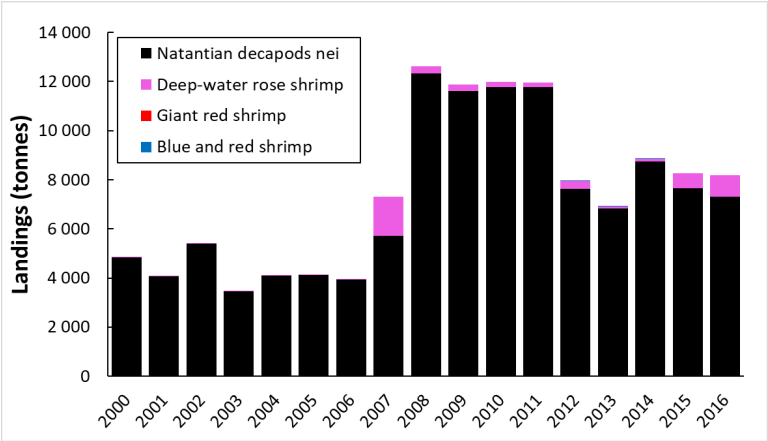
Target resources

Current scientific advice on the status of deep resources is only available for European hake and three "red shrimp" species, and then only for certain GSA areas. The advice indicates that nearly all of the species stocks included in this review for which an assessment exists are suffering overexploitation from excessive

FIGURE 10.8
Reported catches of shrimp from the eastern Mediterranean in the FAO divisions: (a) Aegean, and (b) Levant in 2000–2016



(a)



(b)

Source: GFCM, 2018a.

fishing mortality. In general, there has been a general increase in fishing mortality for these species over the last five or so years. There is an urgent need to revert the trend and implement strategies to reduce fishing effort and fishing mortality (Table 10.5).

The recent scientific advice is not directly comparable with that summarized by Bensch *et al.* (2009), since assessment approaches and the reference points used in reporting the assessment results have both changed. However, widespread over-exploitation and a need to cut fishing effort was also evident in 2006.

In addition to the advice provided by the GFCM, Gorelli *et al.* (2016) have attempted an assessment of the blue and red shrimp resource exploited by Catalonian trawlers in GSA 06, though it required a significant – and questionable – reconstruction of missing or erroneous data. They found a sharp fall in their estimated catches and catch rates during the late 1960s, when fishing effort was still minimal, followed by a general slow decline in catch rates through a period of rapidly increasing catch and effort, until 2000. Catch rate appears to have increased since the severe 2005 and 2006 cascade events, as effort either stabilized or declined. It is unclear to what degree those trends in estimated catch rate since 1970 track changes in resource biomass. Cartes *et al.* (2011) reported that giant red shrimp

TABLE 10.5
Scientific advice on the status of the principal Mediterranean deep sea stocks (reported by species and by year)

European hake			
Years	**GSA**	**Stock status**	**Scientific advice**
2016–2018	01 & 03	In overexploitation with low biomass	Reduce fishing mortality
2012–2015	01	In overexploitation with relatively intermediate-to-low biomass	Reduce fishing mortality
2018	04	In overexploitation with low biomass	Reduce fishing mortality
2012–2018	05	In overexploitation with high (2013), intermediate (2014–2016) to low (2017–2018) biomass	Reduce fishing mortality
2012–2018	06	In overexploitation with intermediate (2014–2016) to low (2017–2018) biomass	Reduce fishing mortality
2012–2018	07	In overexploitation with low (2012–2014, 2016–2018) to intermediate (2015) biomass	Reduce fishing mortality
2018	09–11	In overexploitation with low biomass	Reduce fishing mortality
2015–2017	09	In overexploitation with intermediate (2015) low (2016–2017) biomass	Reduce fishing mortality
2012–2018	12–16	In overexploitation with low (2012–2013, 2017–2018), intermediate (2016) to high (2014–2015) biomass	Reduce fishing mortality
2016–2018	17–18	In overexploitation with low biomass	Reduce fishing mortality
2012–2015	18	In overexploitation with intermediate (2013, 2015), to low (2014, 2016–2018) biomass	Reduce fishing mortality
2017	22	In overexploitation with low biomass	Reduce fishing mortality

Blue and red shrimp			
Years	**GSA**	**Stock status**	**Scientific advice**
2014–2018	01	In overexploitation with intermediate biomass	Reduce fishing mortality
2018	02	In overexploitation with low biomass	Reduce fishing mortality
2012–2018	05	In overexploitation with low (2012–2013, 2015–2017) and high (2014) biomass	Reduce fishing mortality
2012–2018	06	In overexploitation with low (2016, 2018), intermediate (2012) and high (2014, 2017) biomass	Reduce fishing mortality
2016–2017	9	In overexploitation with low biomass	Reduce fishing mortality

Giant red shrimp			
Years	**GSA**	**Stock status**	**Scientific advice**
2018	09–11	In overexploitation with low biomass	Reduce fishing mortality
2017–2016	09	In overexploitation with intermediate (2016) to low (2017) biomass	Reduce (2017) or no increase in (2016) fishing mortality
2014	19	In overexploitation with high biomass	Reduce fishing mortality

Deep-water rose shrimp			
Years	**GSA**	**Stock status**	**Scientific advice**
2018	01	In overexploitation with high biomass	Reduce fishing mortality
2012, 2018	01 & 03–04	In overexploitation with low (2012) biomass	Reduce fishing mortality
2013, 2017–2018	05	In overexploitation with intermediate (2013, 2017) high (2018) biomass	Reduce fishing mortality
2012–2013, 2015, 2017–2018	06	In overexploitation with intermediate (2013, 2015) to high (2017–2018) biomass	Reduce fishing mortality
2018	09–11	In overexploitation with high biomass	Reduce fishing mortality
2015–2017	09	In overexploitation with high biomass (2017), or sustainably exploited (2015) with high biomass (2016)	Not to increase fishing mortality (2015–2017)
2012–2018	12–16	In overexploitation with low (2016), intermediate (2015, 2017) or high (2014, 2018) biomass	Reduce fishing mortality (2012–2018) and catches of undersized shrimps (2013, 2018)
2017	17–18	Sustainably exploited, with high biomass	Maintain the current level of fishing mortality
2012–2015	18	In overexploitation with intermediate (2015) to low (2014) biomass	Reduce fishing mortality
2016	19	In overexploitation with high biomass	Reduce fishing mortality

Source: GFCM, 2012, 2014a*, 2014b, 2105, 2016b, 2017b, 2018c; * recorded as 2013 in table.

disappeared from the Catalan basin in the 1960s, likely due to a synergistic effect between change in deepwater masses (i.e. increase in water temperature) which reduced the availability of the red shrimps' prey, and fishing pressure, thereby causing an overall drop in the species.

Other ecosystem components

Much has been written about the potential impacts of deep-sea fisheries in the Mediterranean on ecosystem components other than their target species (e.g. Tudela, 2004; de Juan and Lleonart, 2010a; Álvarez *et al*., 2016). However, these contentions have relied on extrapolations from other ocean regions, or from shallow waters within the region; until recently there had been very little direct study of impacts of the deep sea fisheries of the Mediterranean (on this subject, compare Palanques *et al*., 2006; Martín *et al*., 2008; Dimech *et al*., 2012; Puig *et al*., 2012 and subsequent publications stemming from that work; as well as Pusceddu *et al*., 2014, and Almeida *et al*., 2016). The deep fisheries of the region are too incompletely known for the magnitudes of impacts to be judged effectively by inter-regional comparisons.

Impacts on sensitive deep sea habitats including VMEs no doubt occur, as well as on other species taken as bycatch, but their extent and severity are still unknown. To prevent and manage these potential impacts, in 2018 GFCM endorsed a list of VME indicators (features, habitats and taxa), as well as a suite of technical measures addressing the management of deep-sea fisheries proposed by their SAC within its area of competence. Member States are encouraged to apply their own control measures. Nevertheless, GFCM has been using FRA designation as a multipurpose spatial management tool to restrict fishing activities in order to protect sensitive deep-sea habitats, such as VMEs and essential fish habitats since 2005 (EFH; FAO, 2019a). Up to 2018, eight delimited FRAs have been established to protect EFHs and/or VMEs from the significant adverse impact of certain fishing activities.

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