Deep-sea Atlas of the Eastern Mediterranean Sea

CURRENT KNOWLEDGE

INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE

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Deep-sea Atlas of the Eastern Mediterranean Sea

CURRENT KNOWLEDGE

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Editors:
Maria del Mar Otero, IUCN Center for Mediterranean Cooperation
Chryssi Mytilineou, Hellenic Centre for Marine Research (HCMR)

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Centre for Mediterranean Cooperation
Marie Curie 22
29590 Campanillas, Malaga, Spain
T +34 952 028430
F +34 952 028145
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Presentation/

This atlas has been developed as part of a series of publications produced by the International Union for the Conservation of Nature - Centre for Mediterranean Cooperation (IUCN-Med) to assess the current state and knowledge of Mediterranean deep-sea ecosystems and biodiversity. The development of this publication has been coordinated by IUCN-Med in close collaboration with the Hellenic Centre for Marine Research and with the financial support of the MAVA Foundation. It responds to one of the strategic actions and targets expressed in the **Conservation overview of Mediterranean deep-sea biodiversity Strategic Assessment (IUCN, 2019)** and aims to assess existing knowledge on Eastern Mediterranean deep-sea biodiversity and understand the full array of drivers that affect species and ecosystems in these environments.

The Eastern Deep Sea Atlas is the first attempt to showcase the available information on marine biodiversity for the region. It offers an opportunity to explore the relationship between biologically diverse areas and their underlying physical and chemical conditions, as well as the relationship with potential pressing factors. This atlas presents key information to promote a better understanding of important areas for biodiversity conservation and current pressures on deep-sea ecosystems to support conservation management in the region. Furthermore, the atlas assesses the occurrence and use of existing natural resources, potential negative (direct and indirect) land-sea risks and the effects of climate change on deep-sea ecosystems.

Deep-sea ecosystems include waters beyond 200 m depth and represent the world's largest biome, covering more than 65% of the earth's surface and including more than 95% of the global biosphere. Despite the vast area they cover, both pelagic and benthic deep-sea ecosystems remain widely unknown. This also applies to the Mediterranean Sea, where deep-sea habitats are estimated to form as much as 78% of the total marine surface.

The Eastern Mediterranean basin, which encompasses the areas of the Eastern Ionian, Aegean, Libyan and Levantine Seas in this volume, is a particularly sensitive area due to its geophysical position and diverse and extreme climate conditions. It is also considered one of the most oligotrophic regions of the world.

The publication has been divided into different sections that explore the ecosystem conditions, the geomorphology, biodiversity and threats facing key areas of deep-sea environments such as seamounts and canyons, as well as the role of important habitat forming species, primarily corals and sponges. Furthermore, it provides information on biodiversity, mega and meiofauna and their critical role in deep-sea ecosystems, alongside potential areas for defining essential habitats for commercial fish species. Additionally, it looks into the footprint presence of commercial fishing, which in the Mediterranean is entering deeper waters as resources in shallower areas are becoming less abundant. Finally, the atlas aims to address threats and pressures placed on deep-sea environments, including the presence of marine litter, oil and gas sourcing, cables placed along on the seafloor and marine traffic.

Collating and comparing this information obtained from different sources presented a number of challenges. Data collection across different Mediterranean countries often lacks a standardised methodology, which may complicate the diversity forms of information collected. Furthermore, there can be considerable variation regarding the extent, specificity and availability of information available.

The publication recognises the existing opportunities to improve and advance the geospatial information presented. Nonetheless, the Eastern Deep Sea Atlas provides its reader an opportunity to understand the rich biodiversity of remote deep-sea ecosystems to gain a better understanding of these environments and facilitate efforts for a comprehensive programme to ensure their conservation. As the results of further research become available and are shared, it will be possible to advance our understanding of the biodiversity and ecosystem functions as well as to assess the impacts that will help decision-makers build effective biodiversity conservation and management actions.

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Tribute to Dr. Kostas Kapiris

It ‘s been a deep great regret and sorrow to inform you that Dr. Kostas Kapiris, the chapter leader on Deep-water shrimps and Deep-sea Cetaceans and Sea turtles has unexpectedly passed way during the process of this publication. His absence was a great loss for the scientific community, and particularly for the finalization of this publication. He was an outstanding, friend, colleague, teacher, scholar, scientist, husband and father. He had a visionary spirit, and the tenacious patience required to successfully lead scientific projects. Dr. Kapiris was committed to research, and passionate to deep-water shrimps sustainability and cetaceans conservation.

Main Contributors and Affiliations /

International Union for Conservation of Nature

Maria del Mar Otero
Marthje Schüler
IUCN Centre for Mediterranean Cooperation, Spain

Ziad Samaha
IUCN Regional Office for West Asia, Lebanon

Enalia Physis Environmental Research Centre, Cyprus

Carlos Jimenez

Department of Fisheries and Marine Research, Ministry of Agriculture, Rural Development and Environment, Cyprus

Ioannis Thasitis

Institute of Marine Biological Resources and Inland Waters, Hellenic Centre for Marine Research, Greece

Chryssi Mytilineou
Aikaterini Anastasopoulou
Leila Bordbar
Dimitrios Damalas
Ioannis Dokos
Vasilis Gerovasileiou
Kostas Kapiris
Stefanos Kavadas
Evgenia Lefkaditou
Panagiota Peristeraki
Nadia Papadopoulou
Christopher J. Smith
Caterina Stamouli
Kostas Stergiou

Fisheries Research Institute, ELGO-DIMITRA, Greece

Angeliki Adamidou
Chryssa Anastasiadou
Chrysoula Gubili
Argyris Kallianiotis
Nikolaos Kamidis
Sotiris Kiparisis

University of the Aegean, Greece

Evangelia Krasakopoulou

Institute of Oceanography, Hellenic Centre for Marine Research, Greece

Dimitris Sakellariou
Paraskevi Drakopoulou
Sissy Iona
Harilaos Kontoyiannis
Chara Kyriakidou
Nikolaos Lampadariou
Isidoros Livanos
Vasiliki Loukaidi
Kyriaki Manta
Ioannis Morfis
Grigoris Rousakis
Maria Salomidi
Katerina Sevastou
Ekaterini Souvermezoglou
Konstantina Tsampouraki-Kraounaki

University of Athens, Greece

Ioannis Panagiotopoulos

University of Haifa, Israel

Yizhaq Makovsky

National Council for Scientific Research in Lebanon, National Centre for Marine Sciences, Lebanon

Myriam Lteif
Sharif Jemaa

Tishreen University, Lattakia, Syria

Malek Fares Ali

Middle East Technical University, Turkey

Ali Cemal Gücü

Al-Azhar University, Assuit, Egypt

Mahmoud M. S. Farrag

CHAPTER 1 /

Introduction

The deep-sea is the largest and unexplored environment on the planet. It is defined as the region starting below the continental shelf-slope break[1]. Thus, it is formed by a large part of the continental margin and by the deep basin proper. Another definition that applies to the deep-sea habitat relates to the definition of bathymetric zones. The *bathyal* zone includes all the continental margin, from a 200 to 3000 m depth, while the *abyssal* zone embraces most of the deep seafloor between depths of 3000 and 6000 m and the *hadal* zone below this. The deep-sea comprises a variety of different habitats, from canyons and plains of mud, to rocky seamounts, mud volcanos, chemosynthetic environments, brine lakes, pockmarks and deep-water coral frameworks, among others. Covering 65% of the Earth's surface, less than 0.0001% of the deep-sea has been explored so far, making it the least explored environment on Earth[2,3]. Recent expeditions within the framework of the Marine Life Census have documented that deep-sea biodiversity is very unevenly distributed in different oceans and ocean basins[4].

Mediterranean scientists began studying life in the deep-sea in the 19th century. The Pola expedition (1890-1893) was the first systematic oceanographic expedition followed by the Dana (1908-1910) and Thor (1921-1922) expeditions[5], while Pérès and Picard[6] provided the first detailed deep biological observations with dredges in the Eastern Mediterranean and the Greek Seas. Nevertheless, most scientific studies on Mediterranean deep-sea ecosystems have occurred during the last one or two decades. These works, through different projects and initiatives, have expanded the knowledge of its hydrodynamics, geomorphology and biodiversity. A synthetic review of the existing information on Mediterranean deep-waters and ecosystems, including a strategic plan for research, conservation, management and monitoring, has been compiled by IUCN (2019)[7] with the contribution of many experts. Most scientific studies on deep-sea ecosystems took place after the development of the deep-water fishery sector in the early decades of the 20th century[8].

The Mediterranean Sea has always been central to the economies of the coastal countries and it is known to be under intense pressure from human activities as well as experiencing a strong interest for blue growth[9,10]. It is considered a marine biodiversity hot-spot with more than 17,000 marine species known in the area and a uniquely high percentage of endemic species[11,12]. It is composed mainly by deep-sea habitats, with a mean depth of 1500 m and a maximum depth of 5267 m, found in the Calypso Deep in the Eastern Ionian Sea. First estimations indicate that its deep-sea biodiversity (excluding prokaryotes) could be composed of approximately 2805 species of which 66% are still undiscovered[13]. Deep-sea biological resources have also been investigated more extensively in the last decades, particularly for the red shrimps (*Aristaeomorpha foliacea* and *Aristeus antennatus*), since they are the main target species of deep-water fisheries. The effect of deep-water fisheries on the commercial stocks as well as on bycatch of vulnerable species and associated habitats has also been the objective of several research projects and studies.

In the Eastern Mediterranean, various research projects and studies have been carried out in the deep-sea over the last 15 years with a number of multidisciplinary collaborations (i.e. projects, cruises etc.) revealing the complex geomorphological relief of its ecosystems with diverse geological, physical and biochemical characteristics that account for a wide variety of seabed features and benthic communities (see list provided in Annex). In the next few paragraphs, we review the geography and hydrology of this deep-water environment and how it affects deep-sea biodiversity.

Eastern Mediterranean Environment

The Mediterranean is divided into the western and central-eastern basins, which are separated by the Strait of Sicily. The Eastern Mediterranean Sea, as defined here, includes the Ionian Sea east of N18°E, the Libyan and Levantine Seas and the Aegean Sea. This rather small oceanic region connects three continents: Europe to the North, Asia to the East and Africa to the South. It belongs to the most active areas on the Earth in terms of plate tectonic movements and seismicity, as it hosts the active convergent margin between Eurasia and Africa. It is also characterized by complex geomorphology, a direct result of the tectonic processes prevailing in this area.

The Eastern Mediterranean Sea consists of three main deep basins: the Ionian, Aegean, and Levantine. For the purposes of this work, the Eastern Mediterranean Sea has been divided into five regions which will be described separately (Fig. 1.2). Major geomorphological elements define the boundaries between them. The Hellenic Arc marks the boundary between the Eastern Ionian Sea (region 1) and the Libyan Sea (region 4) in the south and the Aegean Sea in the north. The south-eastern edge of the Mediterranean Ridge separates the Libyan Sea from the Levantine Sea (region 5). The Aegean Sea is divided into two regions: the North Aegean Sea (region 2) extends north of the northern margin of the shallow Cyclades Plateau; the South Aegean Sea (region 3) extends between the Cyclades Plateau to the north and the Hellenic Arc to the south.

The Eastern Mediterranean deep-sea floor includes regions characterized by complex sedimentological and structural features: continental slopes, submarine canyons and landslides, base-of-slope deposits, seamounts, cold seepages (including mud volcanoes and pockmarks), hydrothermal vents, bathyal or basin plains with abundant deposits of muds and the deep-hypersaline anoxic basins.

In the following chapters we describe in more detail the geomorphology and main geomorphic features illustrating how volcanic, tectonic, hydrothermal and sedimentary processes sculpt geomorphology in the Eastern Mediterranean deep-sea, particularly seamounts and canyons, as well as species diversity and abundance.

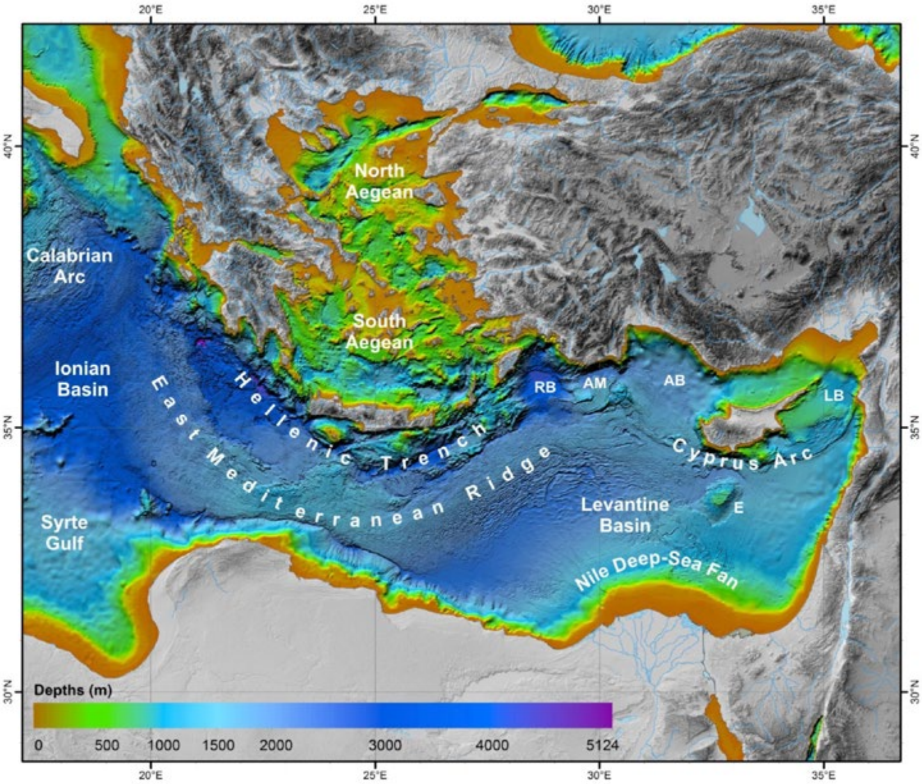

Fig. 1.1. Main geomorphological elements of the Eastern Mediterranean Sea. AB: Antalya Basin, AM: Anaximander Mountains, E: Eratosthenes Seamount, LB: Latakia Basin, RB: Rhodes Basin. Seafloor topography: “EMODNET Bathymetry” 250 m grid (2016). Land topography: SRTM90

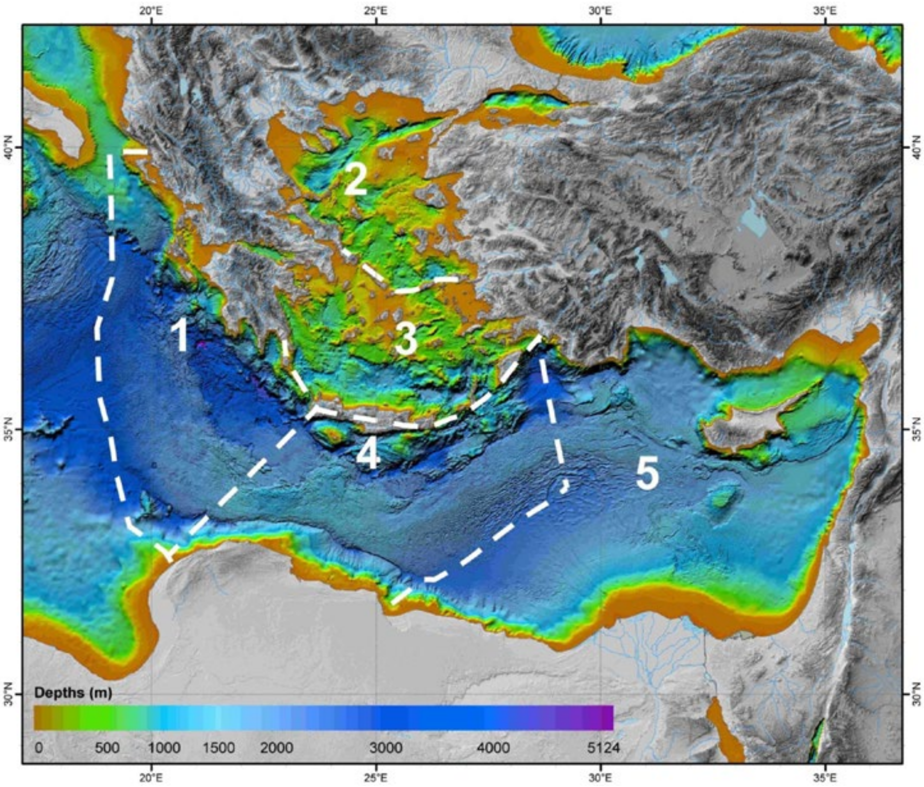

Fig. 1.2. The five regions of the Eastern Mediterranean Sea defined for the purposes of this work: Ionian Sea, 2: North Aegean Sea 3: South Aegean Sea, 4: Libyan Sea, 5: Levantine Sea. Seafloor topography: “EMODNET Bathymetry” 250 m grid (2016). Land topography: SRTM90


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HYDROGRAPHY

Kontoyiannis H. and Iona S.

The Eastern Mediterranean is known as the source region of the high-salinity intermediate water mass that spreads into the North Atlantic, after its propagation through the West Mediterranean and exit to the Atlantic through the Gibraltar Strait. In this respect, the basic physical identity of the Eastern Mediterranean is that it is a '**concentration basin'**, i.e., it receives lower salinity water from outside and then it generates and exports high-salinity water masses to the neighboring basins of the Black Sea and the Western Mediterranean.

The Eastern Mediterranean is connected to the West Mediterranean through the Strait of Sicily and to the Black Sea through the Dardanelles Strait in the North Aegean Sea (Fig. 1.3). It is also connected to the Red Sea through the Suez Canal; this connection is very small and is considered to be practically closed in view of the dynamic exchanges. In the Sicily Strait, the E. Mediterranean receives low-salinity (~37.0-37.7) **Modified Atlantic Water** (MAW) in the upper ~80 m and exports high-salinity (~38.0-38.5) Levantine Intermediate Water (LIW) in the deeper layers (~150-350 m). In the Dardanelles Strait, it similarly receives low-salinity (~26-30) Black Sea Water in the upper 20 m and exports subsurface high-salinity (~38.6-38.9) water of the North Aegean[14]. The main water masses that can be detected in the Eastern Mediterranean, apart from the MAW in the upper layer, are: 1) the **Levantine Intermediate Water (LIW)** in the approximate depth range ~150-400 m of the entire area from the Sicily Strait and the Ionian Sea to the wider area south of Crete and further to the East near Cyprus, which is considered as the source region of the LIW and 2) the **East Mediterranean Deep Water (EMDW),** at depths below ~3000 m with source region in the South Adriatic[15], apart from the period from the late 80s to the late 90s, when the source area of the EMDW was the Cretan Sea[16]. After the late 90s, the deep Cretan outflow occupies a depth layer at approximately 1500-2500 m[17].

"Specific Mediterranean sub-regions are well known for their contribution to dense water formation processes; these regions are the Levantine, the Aegean and the Adriatic for the Eastern Mediterranean, and the Gulf of Lions for the Western Mediterranean"

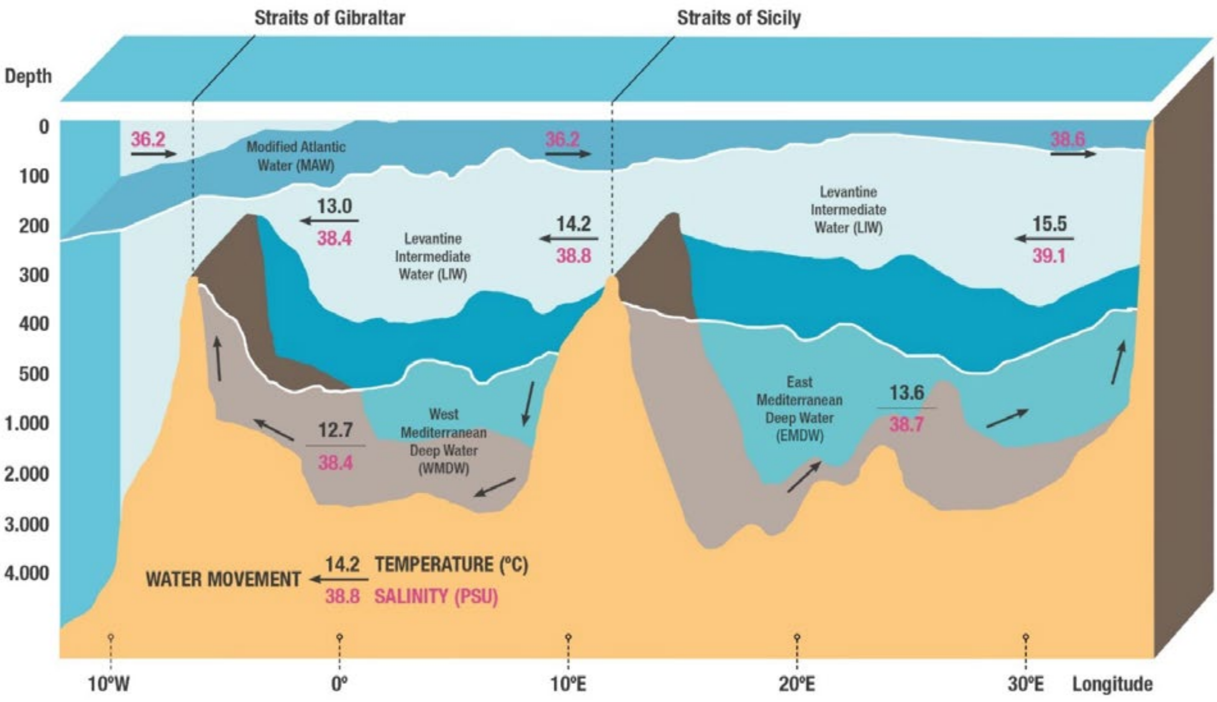


Fig. 1.3. Sea water mass circulation in the Mediterranean Sea.
Sources: Adapted from Zavattarelli, M., and Mellor, G.L., A Numerical Study[18] of the Mediterranean Sea Circulation, American Meteorological Society, 1995. GRID-Arendal.

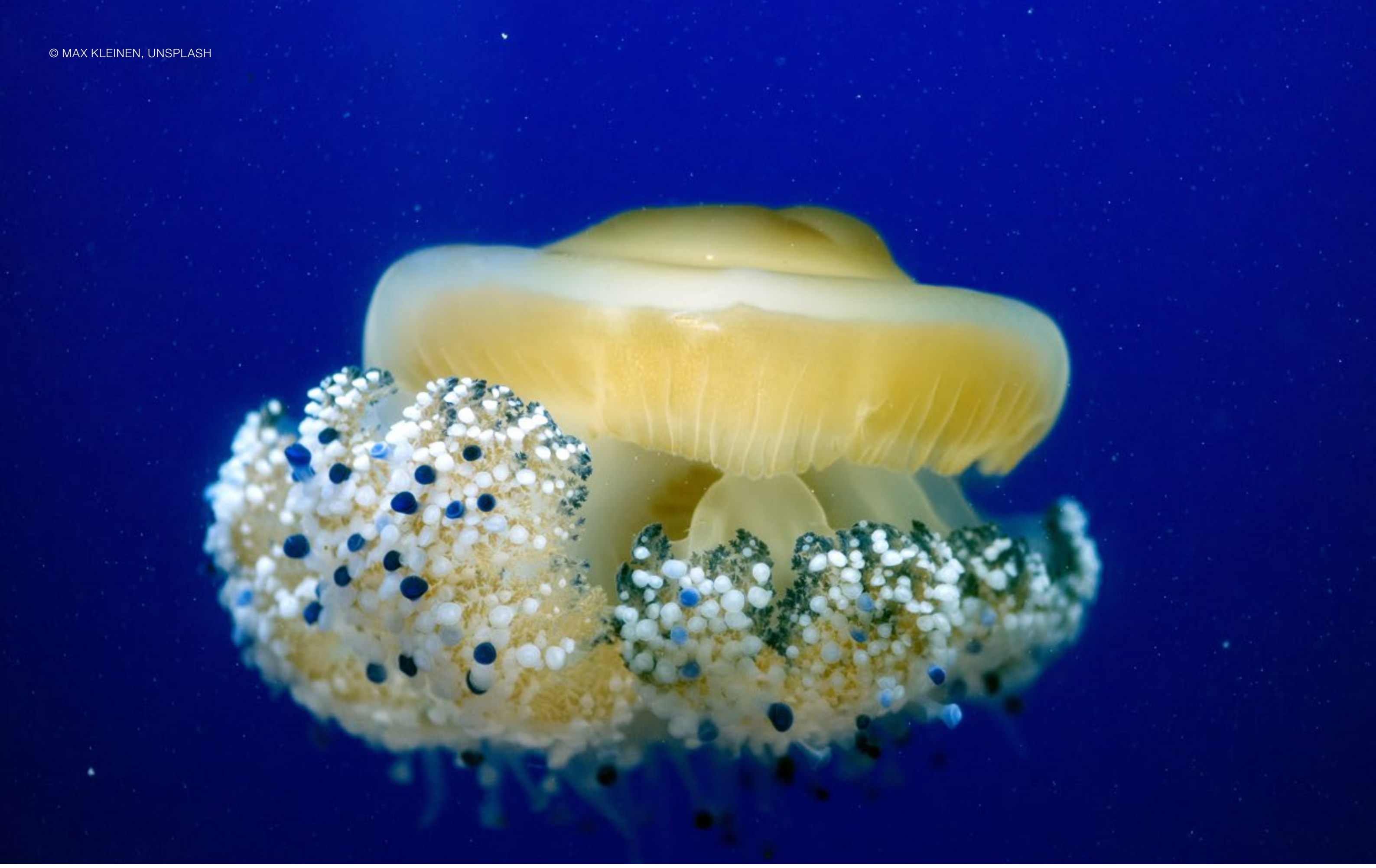
The exchange or renewal time scale of the **Levantine Intermediate Water** that is present in the entire Mediterranean is approximately ~25 years, thus, the quantity of this water produced in a specific year will exit to the Atlantic after 25 years, whereas for deep waters, this time scale is in the order of 80 to 100 years[19].

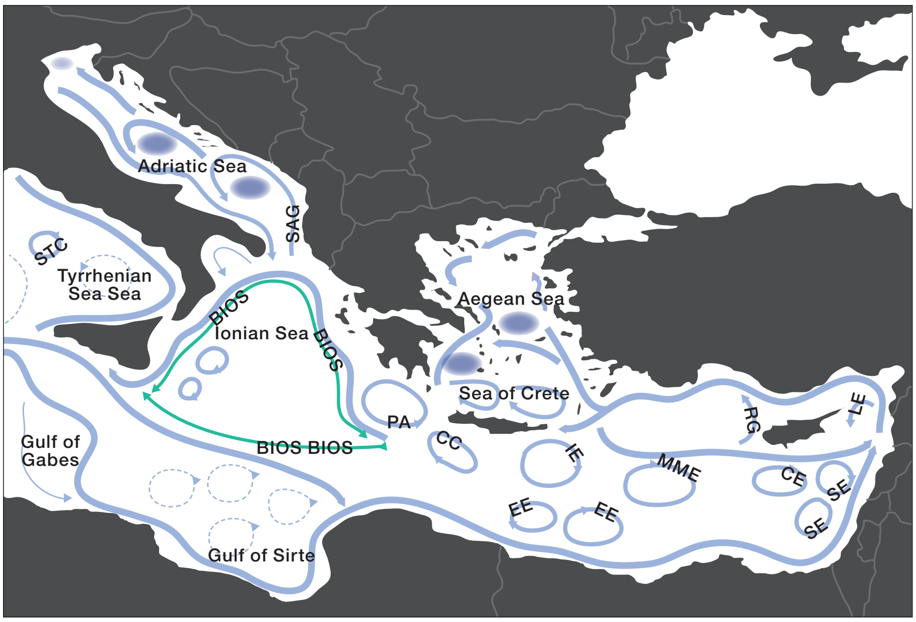
The water flow structures and the currents in the Eastern Mediterranean are characterized by different scales ranging from sub-basin, i.e., flows extending throughout most of the basin's lateral extent, to mesoscale, i.e., cyclones or anticyclones with dimensions in the order of ~100 km[20]. Most of the mesoscale water flow structures are permanent, while some of them are recurrent and show seasonal and inter-annual flow variations. Fig. 1.4 shows the most prominent circulation features of the Mediterranean basin.

The speeds of the current flows in the Eastern Mediterranean at depths greater than 2000 m are in the order of ~2-5 cm/sec with maximum values around 10 cm/sec[21,22]. Deep and near-bottom abyssal currents southeast of Crete have been observed to increase by factor ~3 in the presence of bottom trapped topographic Rossby waves generated when a mesoscale circulation structure exhibits lateral shifts over the slopped bottom at ~4000 m[22].

The high salinity of the Eastern deep-sea environment is also characterized by a seasonal pycnocline (where water density increases rapidly with depth) that is typically developed during mid-spring to mid fall and it is well-developed during late August in the layer between 30 to 80 m deep. Moreover, there is a permanent pycnocline in the open waters of the Ionian and the Levantine basins between depths of 400-600 m, below 600-700 m the density gradients are minimal[23].

Table 1.1 and Table 1.2 present typical winter and summer mean temperatures and salinities in four different subareas of the deep-Eastern Mediterranean Sea as observed for the period 2000-2015. Hence, it can be observed at a depth of 500 m where the permanent pycnocline is located that extends roughly between a depth of ~400 to 600 m[21,23]. In the areas of the south-east Ionian and south of Crete at a depth of 2000m, the deep waters are influenced by the intermediate waters of Cretan origin[21]. Observations indicated how differences in temperature or salinity between winter and summer values are insignificant below a depth of 500 m as there is not a direct seasonal influence.





Bimodal Oscillation System
Dense water formation area
Eddy
Principal
Secondary
Seasonal or instability driven

BIOS: Bimodal Oscillation System
CC: cretan cyclon
CE: cyprus eddy
EE: egyptian eddies

IA: ionian antycyclones
IE: ierapetra eddy
LE: latakia eddy
MME: mersa matruh eddy

PA: pelops antcyclon
RG: rhodes gyre
SAG: south adriatic gyre
SE: shikmona eddy
STC: south tyrrhenian cyclon

Fig. 1.4. Map of the general circulation patterns in the Mediterranean basin with a schematic of basic characteristics of the Eastern Mediterranean general circulation based on results from Robinson et al. (1991). 1: Pelops Anticyclone (recurrent), 2: Cretan Cyclone (permanent), 3: Ierapetra Anticyclone (recurrent), 4: Mersa-Matruh Anticyclone (permanent), 5: Rhodes Cyclone, MMJ: Mid-Mediterranean Jet. Areas 1) the southeast Ionian (latitude of 37° N .), 2) the Lybian Sea i.e., the area south of Crete, 3) the eastern Levantine, i.e., the area west of 30° E, 4) the south Aegean Sea, i.e., south of latitude 37.6° N . and 5) the North Aegean Sea, i.e. north of 37.6° N.

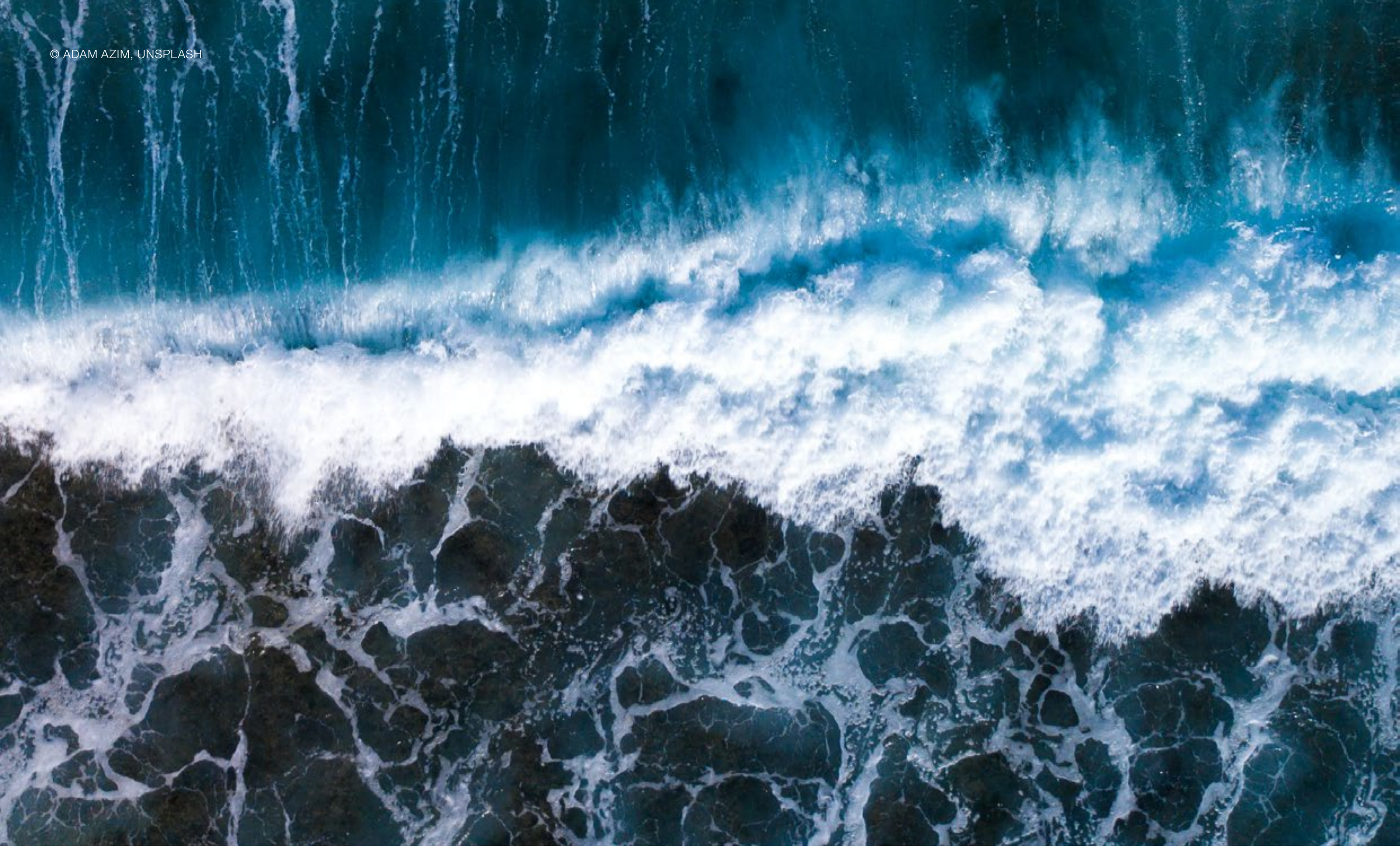


Table 1.1. Mean winter values of temperature ($T_{in\text{-}situ}$) and salinity (Sal) in different basins of the Eastern Mediterranean over the period 2000-2015 at Southeast Ionian, North Aegean, South Aegean, Libyan Sea (area south of Crete) and East Levantine Sea. Both in-situ and potential (θ) temperatures are included; values are in degrees Celsius. Dashes represent no available field data. Source References[24,25].

	EASTERN IONIAN	NORTH AEGEAN	SOUTH AEGEAN	LIBYAN SEA	EAST LEVANTINE
Depth (m)	$T_{in\text{-}situ}$ / Sal ±spatial variation	$T_{in\text{-}situ}$ / Sal ±spatial variation	$T_{in\text{-}situ}$ / Sal ±spatial variation	$T_{in\text{-}situ}$ / Sal ±spatial variation	$T_{in\text{-}situ}$ / Sal ±spatial variation
200	15.06/38.953 ± 0.2 / ± 0.012	15.87/38.994 ±0.05 /±0.022	15.75/39.104 ±0.11/ ±0.007	14.30/38.852 ±0.16/ ±0.044	15.26/38.895 ±0.2/±0.045
500	14.33/38.828 ±0.066/±0.023	14.08/38.832 ±0.185/±0.028	13.94/38.846 ±0.029/±0.010	14.22/39.023 ±0.37/±0.005	14.56/38.940 ±0.021/±0.010
1000	13.75/38.748 ±0.008/±0.004	13.27/38.820 ±0.008/±0.004	14.29/38.740 ±0.008/±0.004	13.27/39.004 ±0.34/±0.052	14.29/38.975 ±0.34/±0.052
2000	13.84/38.75	13.95/38.80	13.96/38.79	--	--
3000	13.92/38.73	--	--	--	--

Table 1.2. Mean summer values of temperature ($T_{in\text{-}situ}$) and salinity (Sal) in different basins of the Eastern Mediterranean over the period 2000-2015 at Southeast Ionian, North Aegean, South Aegean, Libyan Sea (area south of Crete) and East Levantine Sea. Both in-situ and potential (θ) temperatures are included; values are in degrees Celsius. Dashes represent no available field data.

	EASTERN IONIAN	NORTH AEGEAN	SOUTH AEGEAN	LIBYAN SEA	EAST LEVANTINE
Depth (m)	$T_{in\text{-}situ}$ / Sal ±spatial variation	$T_{in\text{-}situ}$ / Sal ±spatial variation	$T_{in\text{-}situ}$ / Sal ±spatial variation	$T_{in\text{-}situ}$ / Sal ±spatial variation	$T_{in\text{-}situ}$ / Sal ±spatial variation
200	15.13/38.945 ±0.14/±0.016	15.765/39.042 ±0.45/±0.053	15.79/39.056 ±0.35/±0.021	14.84/39.118 ±0.28/±0.031	15.20/39.081 ±0.25/±0.040
500	14.28/38.881 ±0.10/±0.010	14.17/38.856 ±0.13±/0.023	14.08/38.825 ±0.10/±0.005	14.15/39.037 ±0.25/±0.014	14.61/38.986 ±0.08/±0.007
1000	13.81/ 38.767 ±0.008/±0.004	13.81/38.762 ±0.008/±0.004	13.74/38.752 ±0.008/±0.004	13.76/38.980 ±0.34/±0.052	14.30/38.987 ±0.04/±0.033
2000	13.84/38.75	13.95/38.80	13.92/38.793	--	--
3000	13.92/38.73	--	--	--	--

CHEMISTRY

Souvermezoglou E. and Krasakopoulou E.

The Mediterranean Sea has long been known as an impoverished area with nutrient levels too low to sufficiently support a large biomass. There is a limited supply to its surface waters both from its deeper layers and from external sources (the Atlantic water inflow, riverine discharges and atmospheric input), but the principal reason of its poverty is related to its hydrology and circulation as a concentration basin. This extreme oligotrophy that makes it a concentration basin, is related to the following characteristics: i) evaporation that exceeds rainfall and river runoff, ii) nutrient-poor Atlantic surface water that flows in through the Strait of Gibraltar, iii) nutrient concentrations that are further depleted towards the East due to primary production and iv) the export of organic matter, which is transported westward by the underlying deep Mediterranean compensation current[26]. This results in depletion of nutrients as phosphate (PO_4^{3-}), nitrate (NO_3^-) and silicate (SiO_4) in the euphotic zone and thus in low primary production rates.

The **extreme low nutrient regime of the Eastern Mediterranean** has been studied extensively in recent years[27,28] and is described as one of the lowest of the world's oceans with the eastern deep Levantine representing the most oligotrophic part[27,29,57]. The surface layer totally lacks phosphate and nitrate, while containing small amounts of silicate.

The nutrient depleted water surface layer is separated from the intermediate and deep-water layers by a transitional layer of 100-200 m thick, within which the concentration of nutrients increases rapidly. The concentration of nutrients in the intermediate and deep-water layers is somewhat constant, increasing in the following order: Aegean < Ionian < Levantine (Table 1.3). The oxygen is almost saturated in the surface layer (~6mL/L in winter and ~4.8 mL/L in summer). A sharp decrease of oxygen is observed in the transition layer, while in deep waters the concentrations are around 4.2 mL/L, decreasing in the order in which the nutrients increase: Aegean > Ionian > Levantine.

The distribution of oxygen and nutrients in the Mediterranean has been affected by the presence of mesoscale cyclonic and anticyclonic gyres in the area. The most interesting features in the Eastern Mediterranean are from west to east: the large anticyclonic flow region and southwest of the Peloponnese (**Pelops gyre**), a large cyclone, namely **Cretan cyclone**, situated to the east of this anticyclone and southwest of Crete, the **Ierapetra anticyclone** and the **Rhodes cyclone**[27].

Table 1.3. Mean concentrations of oxygen (ml/L) and nutrients (μM) at three depths below the transitional layer, in different basins of the Eastern Mediterranean.

OXYGEN

Depth (m)	CRETAN SEA	NORTH AEGEAN SEA	OTRANTO STRAIT	SOUTH IONIAN SEA	CRETAN PASSAGE	NW LEVANTINE SEA
500	5.1	5.4	4.8	4.7	4.4	4.3
1000	5.3	5.2	5.4	4.3	4.2	4.2
2000	-	-	-	4.2	4.1	4.1

NUTRIENTS

Depth (m)	CRETAN SEA			NORTH AEGEAN SEA			OTRANTO STRAIT			SOUTH IONIAN SEA			CRETAN PASSAGE			NW LEVANTINE SEA		
	NO_3	PO_4	SiO_4	NO_3	PO_4	SiO_4	NO_3	PO_4	SiO_4	NO_3	PO_4	SiO_4	NO_3	PO_4	SiO_4	NO_3	PO_4	SiO_4
500	2.2	0.10	2.8	1.8	0.09	3.4	4.0	0.13	4.5	3.6	0.21	4.8	4.5	0.22	6.0	5.6	0.23	9.7
1000	1.7	0.07	1.4	2.4	0.11	4.5	2.7	0.06	3.4	4.7	0.23	8.7	4.6	0.25	9.7	5.8	0.27	11.6
2000	-	-	-	-	-	-	-	-	-	5.0	0.22	9.6	5.3	0.25	12.4	5.7	0.26	13.5

Still there are locally and temporary high planktonic biomasses in the cyclonic regions, where the nutrients ascend to the base of the euphotic surface water zone, making the phytoplankton biomass and primary production higher than in the anticyclonic regions where the layer of nutrients is situated at greater depths, limiting the nutrient input to the surface waters during the winter water mass mixing[30]. Other reasons for the relatively high production in some areas are: intensive convective water mass mixing during winter leading to vertical homogenization; the upwelling of waters from intermediate layers to the euphotic zone; and the nutrient enrichment in the river plume areas.

The Mediterranean waters, apart from their relative poverty in nutrients, are characterised by a nitrate to phosphate atomic ratio (N:P) different from that of the open ocean, in particular of the Atlantic Ocean. For the Eastern Mediterranean, the N:P ratio ranges between 20-28, which is much higher than that in the Atlantic Ocean (in conformity with the Redfield's ratio N:P = 16:1). It is interesting to note that the N:P ratio varies in different water masses of the Eastern Mediterranean. In the Eastern Ionian Sea near the Otranto Strait, the N:P ratio is estimated at 26.4, while south of 39°N it is 20.9, attributed to the different proportion of Adriatic Bottom Water (AdBW) and Levantine Intermediate Water (LIW) [31]. The N:P ratio in the Cretan Sea is estimated at about 22[32].

The N:P ratio in the water column also varies substantially with depth and it is somewhat constant below 400 m, ranging between 20 and 24. Some anomalously high values (N:P > 40) can be found at the top of the water layers of nutrients at both the Rhodes gyre and the Ierapetra anticyclone.

Dissolved oxygen concentration is an important oceanic parameter for the marine ecosystem functioning and services[33]. High concentrations of dissolved oxygen are observed in the surface water layers, particularly in coastal regions. In deep waters, oxygen gradually declines by biological respiration and is consumed by bacteria controlling organic matter decomposition. Nonetheless, climate warming is predicted to result in a further decline of the dissolved oxygen and in the intensification and expansion of low oxygen zones (LOZ) in deep layers for the following decades[33].

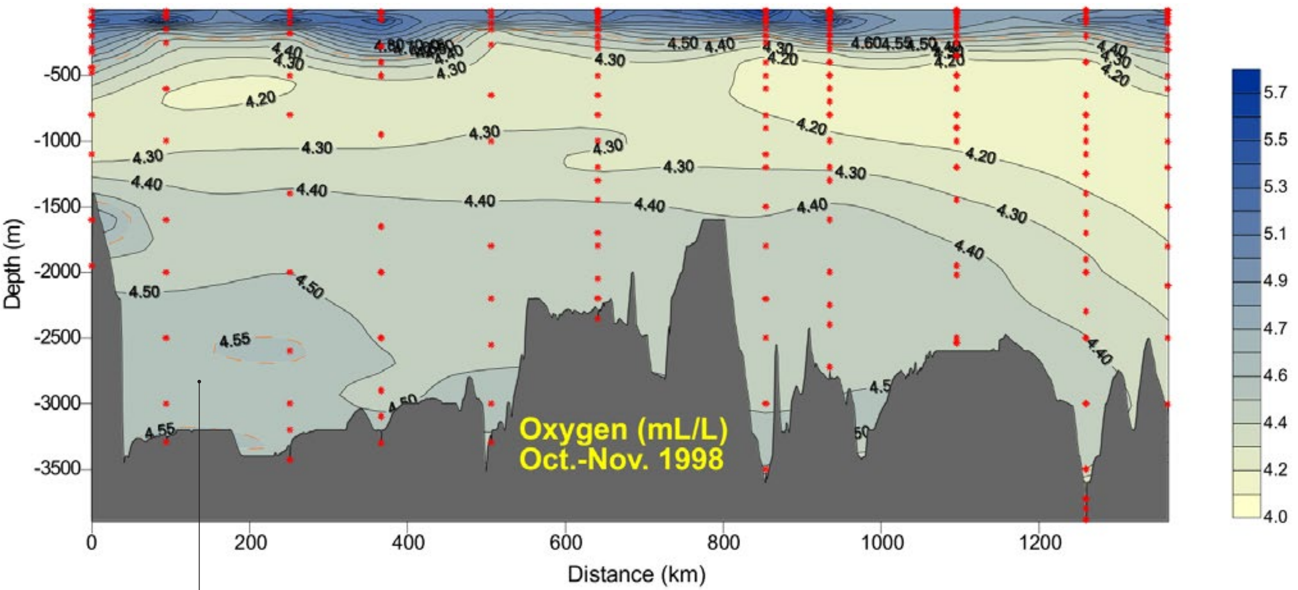
The typical Mediterranean structure of the dissolved oxygen is characterised by high oxygen concentrations for the upper and bottom water mass layers, separated by an oxygen minimum zone at intermediate layers[34].

Although an oxygen minimum zone is observed in both the Western and Eastern sub-basins, its vertical positions are different; in the Eastern Mediterranean it is between 600 and 1200 m deep and in the Western Mediterranean it is between 400 and 600 m [34].

The change in the thermohaline circulation of the Eastern Mediterranean at the end of the 1980s is known as **Eastern Mediterranean Transient (EMT).** This altered the thermohaline circulation of the Mediterranean Sea and has had a strong influence on the oxygen and nutrient concentrations in all major water masses of the Eastern Mediterranean Sea since then [58]. During the EMT event, the Aegean Sea acted as a new and more effective source of deep waters compared to the Adriatic Sea, which was commonly known as the main dense water source of the Eastern Mediterranean. Hence, waters with much higher dissolved oxygen concentration filled the deep and bottom layers of the Eastern Mediterranean. The newly formed deep waters of Aegean origin propagated through the Cretan Arc Straits and spread westward in the Ionian Sea and eastward in the Levantine Sea, following the deep depressions. Nonetheless, recent observations also indicate the presence of relatively well oxygenated and nutrient poor waters of an Adriatic origin in the Eastern Mediterranean, near the bottom in the northern Ionian Sea, providing evidence that the Adriatic Sea has once again started to form dense water (Fig. 1.5).

The **Eastern Mediterranean Transient (EMT)** event was also responsible for the advection of anomalously salty and warm Levantine Intermediate Water (LIW) through the Strait of Sicily, which in turn triggered the deep-water formation events in the Western Mediterranean during the following event known as the Western Mediterranean Transition (WMT) that occurred between 2004 and 2006[34,59].

Very few studies have been made on the long-term variability of dissolved oxygen and nutrients for specific subregions of the Mediterranean Sea and further investigations are needed to enhance the understanding of dense water formation processes and the dissolved oxygen and nutrients spatiotemporal variability as well as how they affect the ecosystems.



It shows the presence of the Eastern Mediterranean
deep-water of Adriatic origin at depths of 2000-3500 m
in the northern Ionian Sea with relatively richer
oxygen concentrations and poorer amounts
of nutrients than the overlying old Eastern deep water.

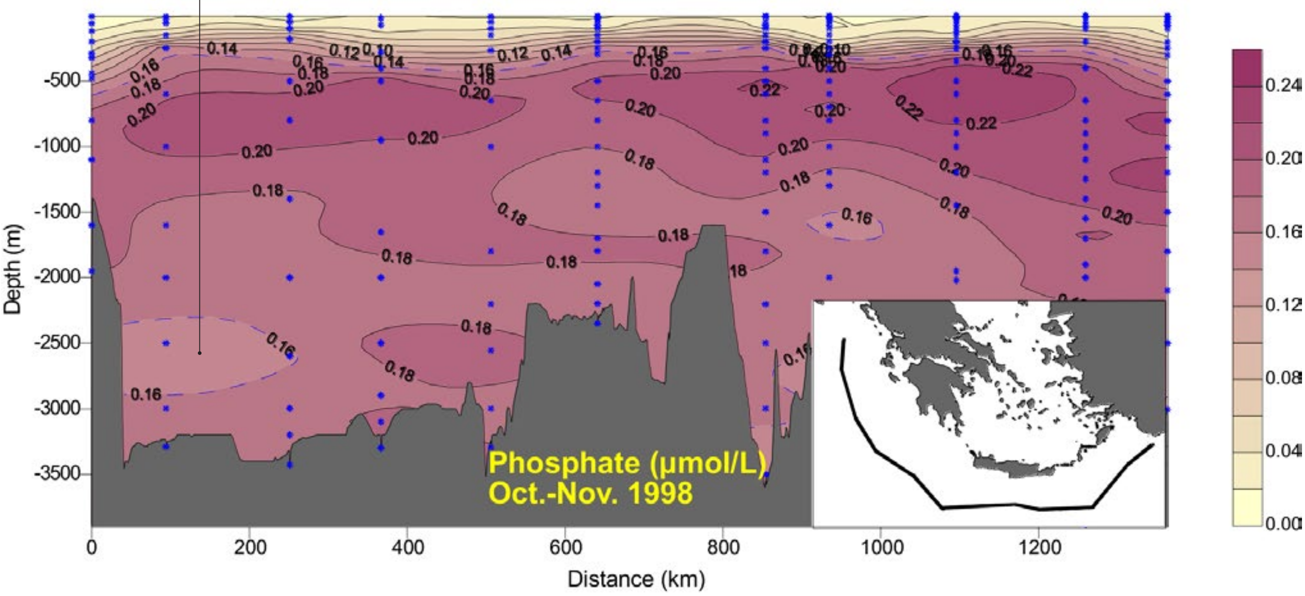


Fig. 1.5. Vertical distribution of oxygen (mL/L) and nutrients (phosphate µmol/L) along a transect from the NE Ionian – Cretan Passage – NW Levantine Sea during autumn 1998.

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BIOTIC ENVIRONMENT

Mytilineou Ch., Gerovasileiou V., Ali M., Farrag M., Stamouli C., Papadopoulou K.N., Smith C.J., Kallianiotis A., Stergiou K.I., Otero, M.

The present deep-sea fauna of the Mediterranean is characterized by a very low degree of endemism and a low diversity compared to the fauna of the adjacent Northeast Atlantic Ocean[35]. It is unique in the sense that it is relatively young, compared to the fauna of the outer Atlantic Ocean, mainly due to the Messinian salinity crisis event. As described before, the deep Eastern basin displays a number of characteristics that influence the environment for this fauna and separate it from most other deep-sea faunas in the world:

i) Extreme low nutrient regime with very low concentrations of potentially limiting organic nutrients (e.g. proteins and lipids) that sharply decline with increasing depth and distance from the coast.

ii) Low bacterial abundance with negligible inputs of primary organic matter into the deep areas. As a consequence, organic matter composed mostly of refractory compounds and "refractory" dissolved organic carbon, is thus "non-accessible" or "resistant" to rapid microbial degradation[36].

iii) Phytoplankton biomass subjected to strong grazing and thus its transport to deeper layers is kept low.

iv) Below 400 m in the Eastern basin, the water column is homothermic, with a salinity of 38.7-39.1% and a temperature of 13.5-15.0°C. It is also well oxygenated, permitting a higher decomposition rates of organic matter than in cold water areas and thus reducing the flux of organic matter to the deeper zones. Such hydrological conditions are in sharp contrast with conditions prevailing in the Atlantic with a salinity of 36.5% and a temperature decreasing gradually down to 2.5°C at 3000 m[34].

v) Generally, it is very deep, with more than 80% of the Ionian and Levantine Seas below 200 m. It is also characterized by trenches and abyssal plains around 3000 m deep.

ii) Formation of the **Intermediate Mediterranean Water** in the eastern basin (**Levantine intermediate water**) and its flows out towards the western basin limiting the vertical transport of organic matter to the deep-sea floor[26].

These conditions restrict the organic matter supply to the benthos affecting the life in deep waters and creating a decreasing abundance trend with depth, distance from the coast and food availability[13]. Despite these conditions, the deep-sea biodiversity of both Eastern and Western basins are considered similar[13] with relative isolation of deep-sea communities from the Atlantic influence and limited effect from the barriers produced by the shallow Sicily Channel between them both. This suggests that even if basin differences are evident and have to be considered, the whole Mediterranean Sea deep-sea should be considered as a wide-ranging species pool.

Throughout the continental Mediterranean slopes, a strong zonation of benthic megafauna can be observed, associated with a constant reduction in abundance, biomass and diversity, accentuated under 1200 m[1,37,38]. Below the 2600 and 2700 m isobaths, biomasses of megafauna are extremely low and population densities are reduced to minimum levels[39].

During the last 30 years, several scientific projects conducted with national, private or European funding focused more on the deep fauna of the Eastern Mediterranean providing important information. Nonetheless we still lack an approximate figure of the number of strictly deep-water species or eurybathic species (able to live at shallow and > 200 m depths) occurring in these waters. Many populations in the deep-sea are spatially fragmented, and will become more so with increasing resource exploitation.

Benthic species have complex life cycles that include a pelagic larval stage and sessile/sedentary adults and connectivity of these populations is achieved by the planktonic larval stage, and larval dispersal, which is in turn regulated by complex interactions between biological and oceanographic processes.

Some observations indicate that there is a clear and steep decline in species diversity in the Eastern Mediterranean from 1200 to 3000 m, although the presence of heterogeneous habitats can influence this biodiversity[40]. Little is known about the biodiversity of benthic prokaryotes in the deep sea. Deep Mediterranean sediments harbour an incredibly high and unique prokaryotic diversity, which is different from that described in other deep benthic environments. Significant longitudinal differences could be observed between the Western, Central, and Eastern Mediterranean, with a turnover diversity reaching 99%, indicating high regional variability[41]. In conclusion, the Mediterranean sediments can be considered to be ‘‘bacterial hotspots’’[13].

Similarly, foraminifera diversity and abundance have been found to be lower in the Eastern than in the Central and Western Mediterranean, with the lowest values in the Levantine Basin[42]. A peak in species richness has been reported between 200 m and 1000 m, below which richness decreases with depth[13]. Meiobenthos studies (focusing mostly on nematodes) also showed that the deep bottoms in the E. Mediterranean display one of the lowest meiofaunal standing stocks, which reflects the very low productivity of this area (See Chapter 5).

Studies on macrobenthos also revealed a decreasing number of taxa and density with increasing depth, that reflected the poor-nutrient status of the Eastern Mediterranean, especially in the mots eastern part[43]. The NW-SE gradient has been more or less confirmed by several studies on certain benthic groups such as decapods[44], prosobranch gastropods[45], molluscs[46], polychaetes[47] and sponges[48]. However, in trenches, like the Hellenic & Pliny Trench, hotspot abundances have been identified for macrobenthos[43]. In addition, the Aegean Sea, being the second major sea of the Eastern Mediterranean after the Levantine, does not seem to follow this general W-E declining trend.

To date, no published information exists on the presence of important fields of vulnerable deep-water sessile invertebrates in the Eastern Mediterranean, although many records of species such as the octocoral *Isidella elongata* have been reported in the Eastern Ionian and Aegean Seas[49,50], significant presence of the deep-sea sponge *Rizaxinella shikmonae* in the Levantine Sea[51] or fossils of cold water corals along the south margins of Crete, Karpathos and Rhodes Islands, suggesting the presence of important populations of frame-building corals during the Younger Dryas[52].

The most represented megafaunal groups in terms of abundance and diversity in deep Mediterranean waters are bony fishes (Actinopterygii) and decapod crustaceans[37]. This represents a major difference with the deep Atlantic seafloor[53,54] where holothurians seem to dominate[55]. Fish and crustacean species seem then to be completely adapted to bathyal conditions in the Mediterranean Sea and some studies indicated that the deepest bottoms shelter fish dominated by small-medium sized species where also some large fishes are widespread[56]. Fishing activities are worldwide recognized as producing disturbances on communities, habitat and ecosystem structure, diversity, and functioning. Fishing in deep waters, a highly sensitive ecosystem, should therefore be managed with great notion. In addition, the invasion of non-native species is a crucial factor that will continue to change the biodiversity of the Mediterranean, mainly in its Eastern basin that can spread rapidly northwards and westwards due to the warming of the Mediterranean Sea.

Overall, knowledge on the distribution of deep-sea organisms in the Mediterranean and its causes is still fragmented and systematic and molecular taxonomic revisions of a number of deep-sea fauna, including the major groups of benthic fauna, are still ongoing. Therefore, changes in the classification, as well as taxonomic revisions, are expected in the near future. •

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CHAPTER 1 /
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CHAPTER 2 /

Geomorphological Features

Sakellariou D., Drakopoulou V., Rousakis G., Livanos I., Loukaidi V., Kyriakidou Ch., Morfis I., Panagiotopoulos I., Tsampouraki-Kraounaki K., Manta K.

The Eastern Mediterranean Sea, as defined here, includes the Ionian Sea east of N18°E, the Libyan and Levantine Seas and the Aegean Sea. This rather small oceanic region connects three continents: Europe to the North, Asia to the East and Africa to the South. It belongs to the most active areas on the Earth in terms of plate tectonic movements and seismicity, as it hosts the active convergent margin between Eurasia and Africa. It is also characterized by complex geomorphology, a direct result of the tectonic processes prevailing in this area.

The **East Mediterranean Ridge** is the most striking submarine morphological feature. With a total length of roughly 1500 km and a width ranging between 200 km and 60 km, it constitutes a submarine mountain belt made of deformed sediments that have been compressed between the African plate and the Hellenic Arc [1]. The shallowest summit of the E. Mediterranean Ridge, known as Herodotus Rise or Antaeus High, is located north of Cyrenaica and reaches a water depth of less than 1250 m. The Ionian and Levantine branches of the East Mediterranean Ridge extend into water depths of approximately 3200 and 2200 m respectively. Numerous mud volcanoes occur on the Mediterranean Ridge and its relationship with active tectonic elements has been documented by several researchers[2,1].

The **Hellenic Trench** encompasses a series of deep troughs and basins surrounding the Hellenic Arc. It contains three distinct sectors: The north-western sector marks the steep escarpment and reaches more than 3000 m deep, to the western slope of Kephallinia Island. The western sector, known as the Ionian Trench or Matapan Trench, extends from the Ionian Islands to the south of Gavdos Island. It is a morphological feature characterized by small, discontinuous basins with depths exceeding 4000-5000 m and separated by shallower ridges. The Oinousses Deep (known also as Vavilov Deep), at the north-western edge of the Ionian Trench, is the deepest basin in the entire Mediterranean Sea, with maximum depths reaching 5200 m below the sea-level. The North-western slopes of the Trench are steep and irregular while the South-western slopes towards the Mediterranean Ridge are less steep. The Eastern sector is delineated by three striking features: the WSW-ENE trending Ptolemy Trench south of central Crete and the WSW-ENE to SW-NE trending Pliny and the Strabo Trenches that terminate in the 4000 m deep Rhodes Basin. Complex seafloor topography characterizes the areas between the three trenches.

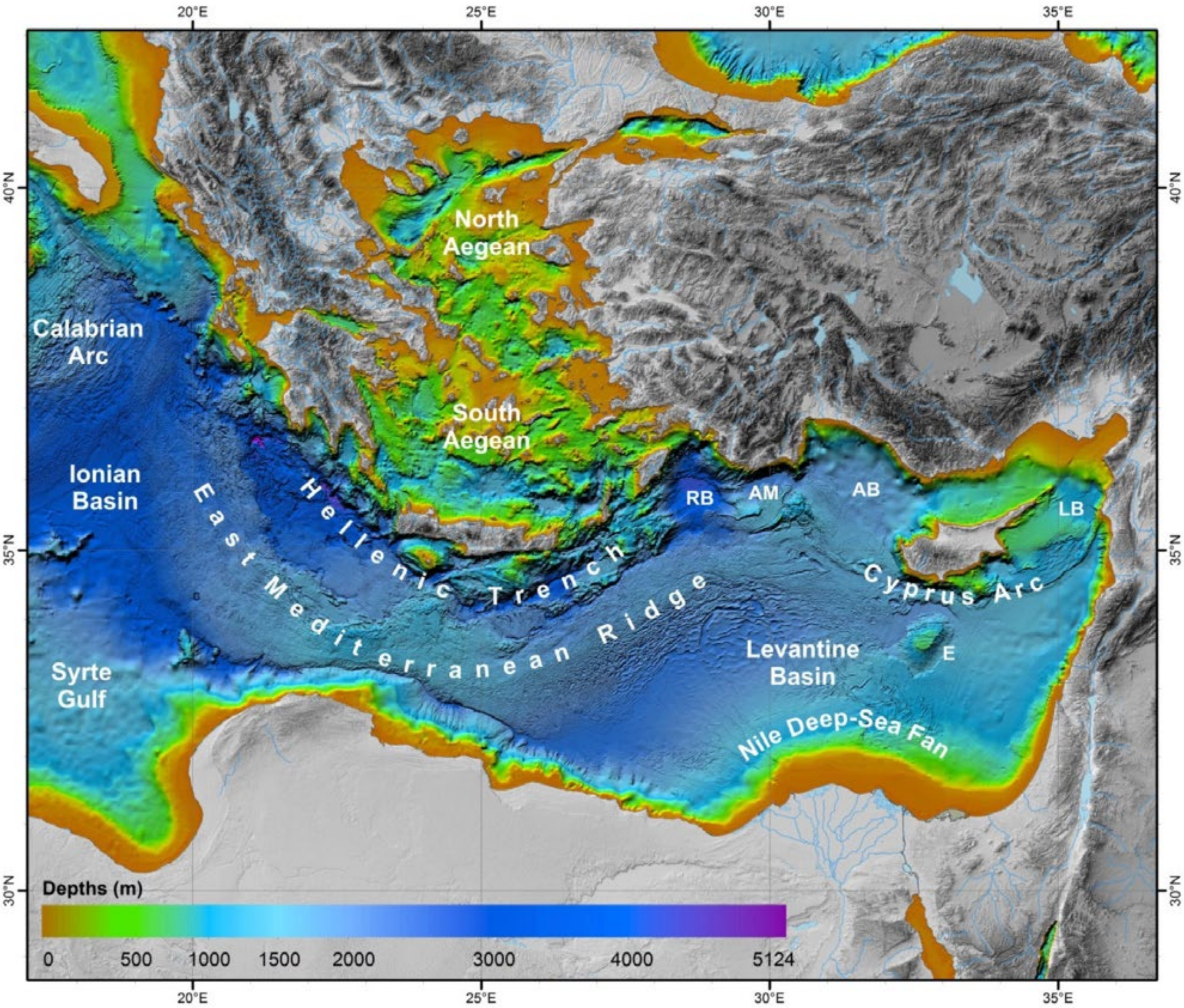

Fig. 2.1. Main geomorphological elements of the Eastern Mediterranean Sea.

AB: Antalya Basin, AM: Anaximander Mountains, E: Eratosthenes Seamount, LB: Latakia Basin, RB: Rhodes Basin.
Seafloor topography: "EMODNET Bathymetry" 250 m grid (2016). Land topography: SRTM90

The majority of the morphological basins in the **Aegean Sea** are shallower than 1000 m. Numerous, small and larger basins occur in the North Aegean Sea. The North Aegean Trough, with a 1600 m depth, is the deepest among them. Maximum depths in the South Aegean Sea, between 2000 m and 2500 m, occur only at the south-eastern edge of the Aegean. The rest of the South Aegean is characterized by variably shaped basins with bottom depths ranging between 1000 m and 2000 m, and separated from each other with shallow ridges[3].

The **Levantine Sea** constitutes the easternmost part of the Eastern Mediterranean Sea. Its northern part includes the Anaximander Mountains, the Antalya, Finike and Cilician Basins, the Cyprus Arc and the Latakia Basin and Ridge. The Eratosthenes Seamount and the Nile deep-sea fan are the most prominent morphological features of the southern part of the Levantine Sea. Mud volcanoes and other cold-seep features occur in many places along the Cyprus Arc and the Nile deep-sea fan.

We now recognize the Mediterranean deep-sea as a highly complex and heterogeneous ecosystem comprised of several different and very contrasting habitats. It contains sedimentological and structural features such as continental shelves, sea canyons, seamounts, cold seeps, brine lakes, pockmarks, active volcanic structures, hydrothermal vents, abyssal muddy plains and deep-hypersaline anoxic basins[4]. Habitat mapping and improved knowledge of these deep-sea topography features at different spatial scales is still in its infancy. Nonetheless, gathering and updating this knowledge will facilitate a better understanding of the relevance of these structures in sustaining deep-sea biodiversity as well as provide new insights for defining areas for presentation of deep-sea biodiversity and ecosystem functioning.

Following previous compilations[4,5,6], a detailed description is presented here of the geomorphological features and geological structures and environments in the Eastern Mediterranean, from scientific surveys and literature, in particular of seamounts and canyons. Seamounts and seamount-like features along with canyons have been identified and mapped on the 250 m resolution bathymetry of the Eastern Mediterranean, compiled in 2015 by IUCN[5] and thereafter in 2018 by HCMR within the framework of the EMODNET Bathymetry project (www.emodnet.eu/bathymetry). The recent advancements in swath bathymetry coverage, in particular in the Aegean Sea, and the state of the art EMODNET bathymetry along with the detailed analysis of the seafloor's relief of the Eastern Mediterranean performed during the elaboration of the present work, enriched the previous compilation by IUCN with a large number of new morphological features described or highlighted here for the first time. These new features have been named after the names of localities or archaeological sites on the nearest land or islands and/or names of mythological heroes.

In total, 47 individual or groups of positive morphological features (seamounts, knolls, mounds, ridges) are described below, grouped into five sub-areas: the Eastern Ionian Sea, North Aegean, South Aegean Sea, Libyan Sea, and the Levantine Sea.

Eastern Mediterranean Seamounts

In the Mediterranean basin, over 242 seamounts, bank rises, mounds, knolls, spurs and other kinds of sea floor elevations have been identified and described [5].

1 EASTERN IONIAN SEA

The **East Mediterranean Ridge** is the most striking submarine morphological feature of the Ionian seafloor. With a total length of roughly 1500 km and the width ranging between 200 km and 60 km, the East Ridge constitutes a submarine mountain belt made of deformed sediments that have been compressed between the African Plate and the Hellenic Arc[1]. Its shallowest summit, known as Herodotus Rise or Antaeus High, is located north of Cyrenaica and reaches a water depth of less than 1250 m. The Ionian and Levantine branches of the East Mediterranean Ridge extend into water depths of approximately 3200 and 2200 m respectively.

The western sector of the East Mediterranean Ridge starting from the latitude of the Ionian Islands to the North, displays a maximum width of about 200 km between the Backstop (NE) and the Ionian Abyssal Plain and the Gulf of Sirte (Fig. 2.2). Three different morpho-structural provinces have been recognized within this western sector[9]: an outer, south-western, folded front; an almost flat central province; and a northern area in tectonic backthrust contact with the Backstop, that is the flat inner region extending just south of the deep troughs (Matapan Trench or Ionian Trench) that run along the outer slope of the Hellenic Arc (Fig. 2.2).

Numerous mud volcanoes occur on the Mediterranean Ridge. They are located along distinct belts, in close relation with thrust faults along the Ridge and/or transcurrent faults crossing the ridge[1,2].

SEAMOUNTS and SEAMOUNT-LIKE Structures

Following the definition used by the International Hydrographic Organization (IHO, 2008/2013) and the Mediterranean Atlas of Seamounts by IUCN, the following terms are used to define morphological features:

SEAMOUNT: A distinct generally equidimensional elevation greater than 1000 m above the surrounding relief as measured from the deepest isobath that surrounds most of the feature. “Seamount” refers to seafloor elevations rising at least 100 m from the surrounding deep-seafloor. The length/width ratio is < 2 [7,8].

GUYOT: A SEAMOUNT with a comparatively smooth flat top (table mount).

KNOLL: A distinct elevation with a rounded profile less than 1000 m above the surrounding relief as measured from the deepest isobath that surrounds most of the feature.

MOUND: A distinct elevation with a rounded profile generally less than 500 m above the surrounding relief as measured from the deepest isobath that surrounds most of the feature, commonly formed by the expulsion of fluids or by coral reef development, sedimentation and (bio)erosion.

RIDGE: An elongated elevation of varying complexity, size and gradient having a length/width ratio > 2 [7,8].

EASTERN IONIAN SEA SEAMOUNTS

The seamounts in the Eastern Ionian Sea cluster in four main areas (Fig. 2.2, Fig. 2.3).

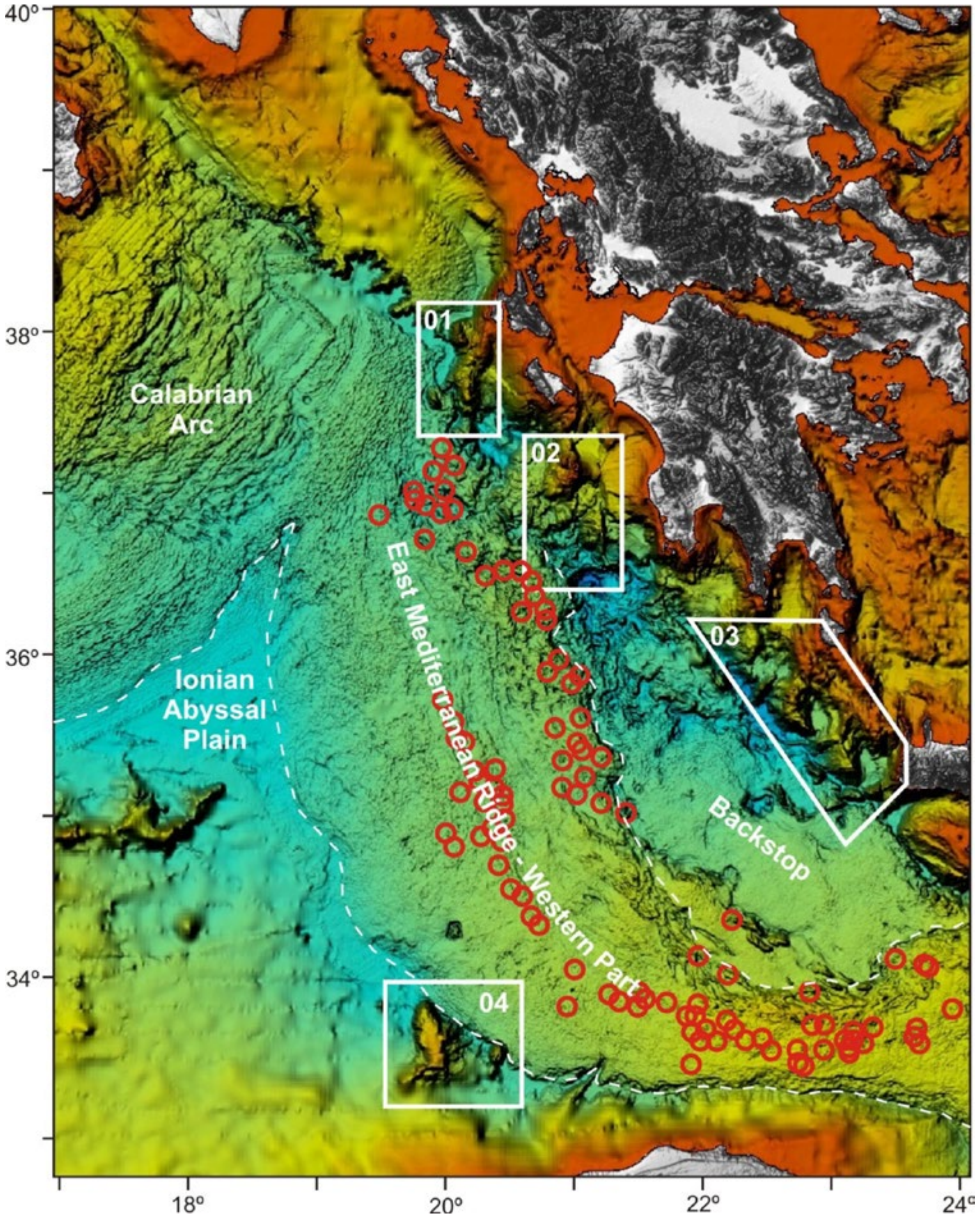

Fig. 2.2. Updated bathymetry of the Eastern Ionian Sea. Derived from GEBCO and swath bathymetry data processed at 250 m grid in the framework of EMODNET Bathymetry project (https://emodnet.eu/bathymetry;[10] and location of the seamount areas in the Eastern Ionian Sea discussed in this chapter. Red circles: mud volcanoes[11]. Boundaries between the main geodynamic and morphological elements[2].

The first area extends SSW of Kephallinia Island and includes the **Argostoli Ridge** and the **Lixouri seamount**. Their formation is controlled by the tectonic processes associated with the Kephallinia Fault. The second area extends south of Zakynthos Island and encompasses the **Strofades seamount** and the **Nestor Ridge.** The area displays complex deformation with strike-slip faults and westward thrust faults within the crust of the Peloponnese. The third area encompasses the outer (south-western) slope of the Hellenic Arc between the Southern Peloponnese and Western Crete. It is characterized by a highly complex morphology and includes a series of tectonically controlled seamounts and ridges, e.g. **Tainaron mount, Kythera mount, Avlemonas mount, Antikythera mount, Elafonissi mount and Lissos Ridge.**

The fourth area is located off the Libyan slope, southwest of the outer edge of the East Mediterranean Ridge. It includes two major seamounts, **the Herodotus** (or Cyrene) **and the Battos seamounts**. Unlike the previous ones, these seamounts belong to the crust of the African plate and have not been involved yet in the convergent tectonics which have formed the East Mediterranean Ridge.

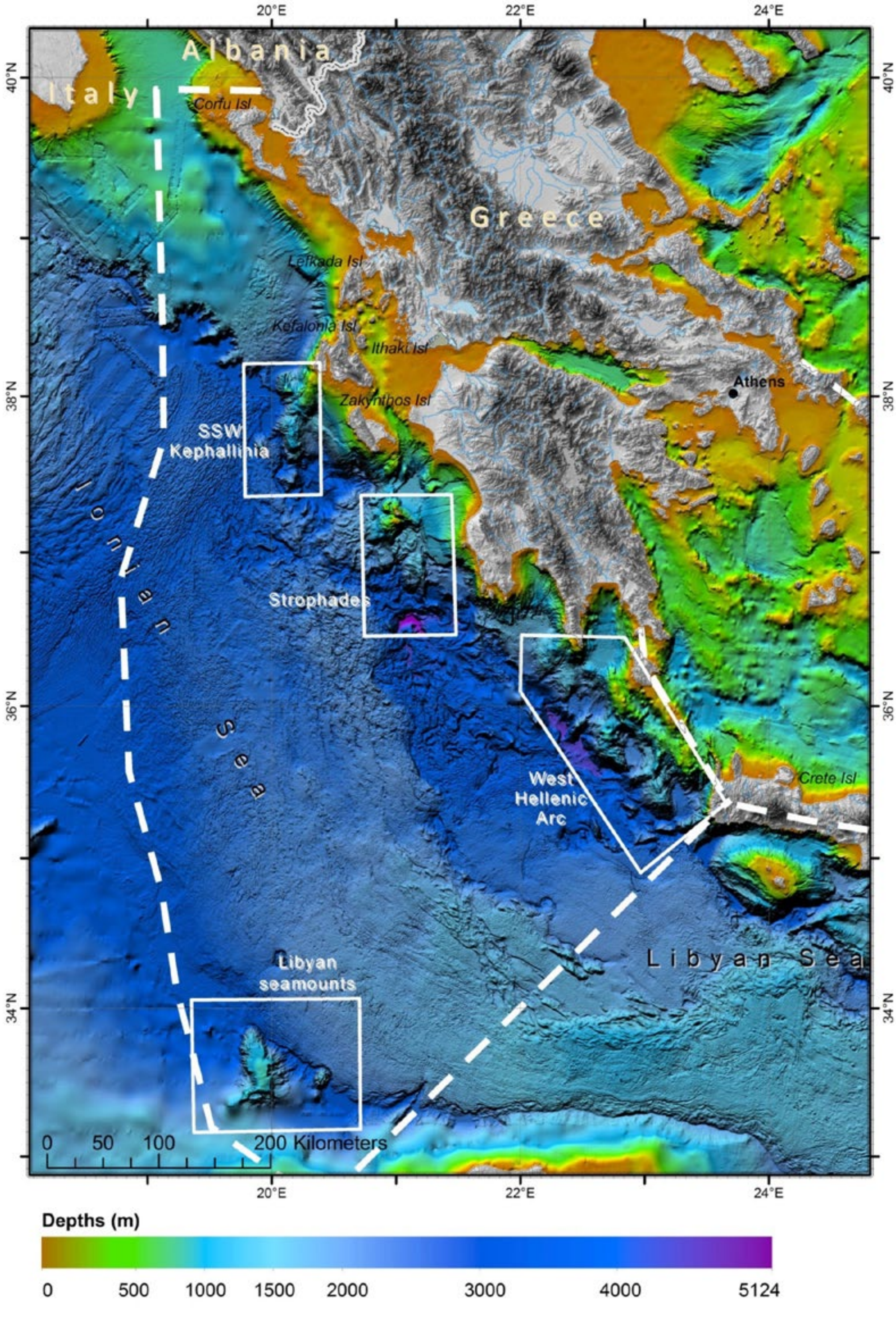

Fig. 2.3. Location of the seamount areas in the Eastern Ionian Sea.

Table 2.1. Eastern Ionian Sea Seamounts and Seamount-like structures.

			Minimum Depth / Location			Maximum Depth / Location				
Group name	Seamount	Area (km²)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Depth Range (m)	Mean Slope (deg)
	Lixouri	443.89	38.030897	20.129387	790	38.031932	20.129387	3749	2959	13.31
			38.129634	20.358007	189					
			38.032761	339	339					
SSW KEPHALLINIA SEAMOUNTS	Argostoli Ridge	2434.39	37.913355	1075	1075	37.421660	20.251946	4200	4011	8.15
			37.748851	1178	1178					
			37.748851	2473	2473					
	Strofades West	132.37	37.271126	20.918949	293	37.335140	20.895380	1860	1567	9.99
	Strofades South	620.60	37.197630	21.008511	43	37.112738	21.027366	2210	2167	8.01
STROFADES SEAMOUNTS			36.921852	21.128713	1800					
	Nestor Ridge	1122.87	36.894304	1865	1865	36.588065	21.331406	4527	2727	8.15
			36.651607	3170	3170					
			36.317694	22.422650	1237					
	Tainaron	923.86				36.032974	22.278880	3529	2292	5.62
			36.144779	1858	1858					
	Kythera mount	1005.53	36.034888	22.839822	116	36.258543	22.696051	1642	1526	6.00
	Avlemonas mount	1767.06	35.824028	22.705478	980	35.822963	22.698408	4661	3681	9.73
WEST HELLENIC ARC SEAMOUNTS			35.777947	23.127363	435					
	Lissos Ridge	2666.74	35.751909	1003	1003	35.396751	22.870461	4459	4024	7.15
			35.465125	1570	1570					
	Antikythera mounts	1439.78	35.751909	23.294703	217	35.493185	23.282919	3392	3175	7.09
	Elafonissi mount	253.75	35.222875	23.365410	994	35.151284	23.355983	3729	2735	15.28
LIBYAN SEAMOUNTS	Herodotus	3387.18	33.546465	19.940835	1003	33.877374	19.797065	4032	3029	7.57
	Battos	267.93	33.534623	20.412215	1802	33.581981	20.334438	3765	1963	14.75

SSW KEPHALLINIA SEAMOUNTS (FIG. 2.4)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Lixouri Seamount	443.89	790	3749
Argostoli Ridge	2434.39	189	4200

The area includes the **Argostoli Ridge** and the **Lixouri seamount**. The **Argostoli Ridge** is a 60 km long morphological feature at the prolongation of the Paliki Peninsula of the Western Kephallinia Island. It has developed on the footwall (eastern block) of the Kephallinia Fault and its shallowest summits occur at depths of 1200 m. The base of the western slope of the ridge reaches a depth of 3800 m while the eastern flank reaches a maximum depth of 2800 m.

The **Lixouri seamount** displays a semi-circular shape and occurs west of the Argostoli Ridge, about 23 km southwest of the nearest coast of Kephallinia Island. It is separated from the Argostoli Ridge by a 1500-1600 m deep valley which hosts the trace of the Kephallinia Fault. The summit of the Lixouri seamount is located < 800 m deep and is surrounded by the 3400-3800 m deep Kephallinia Fault Valley.

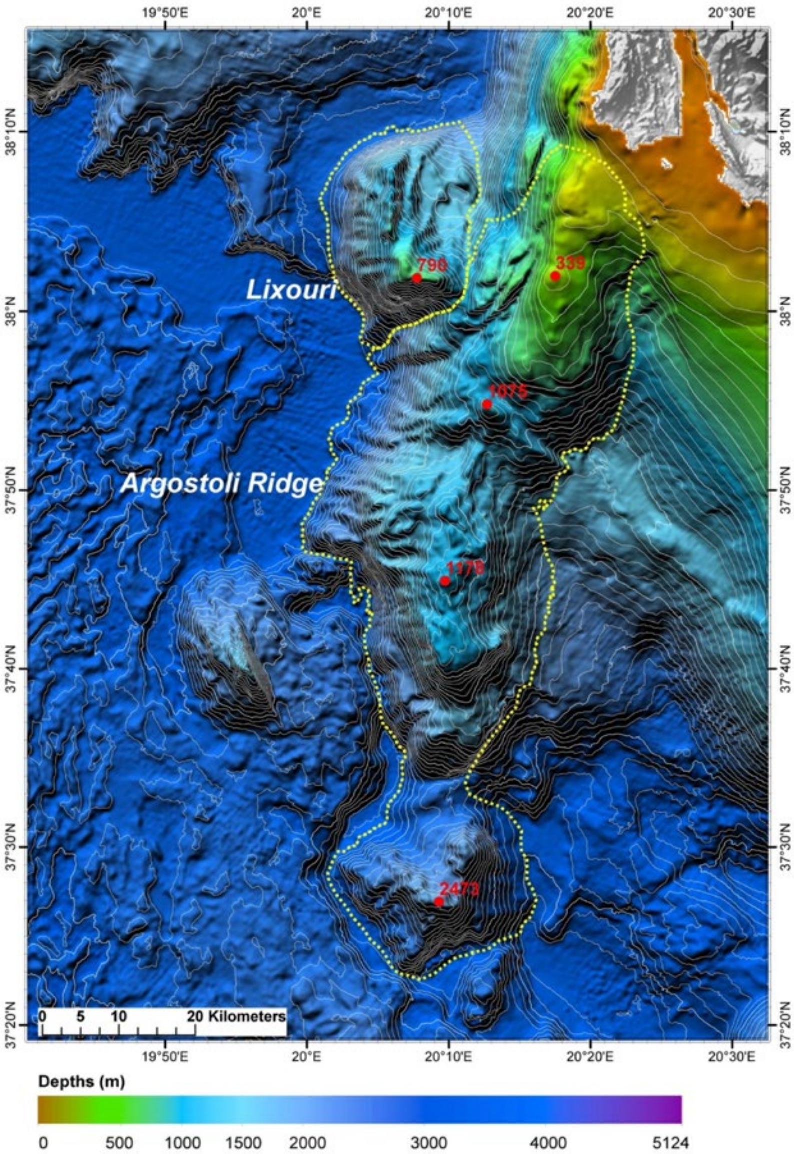

Fig. 2.4. Shaded relief map of the SSW Kephallinia seamounts area.
The outline and the tops of the observed features are indicated on the map.

STROFADES SEAMOUNTS (FIG. 2.5)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Strofades West	132.37	293	1860
Strofades South	620.60	43	2210
Nestor Ridge	1122.87	1800	4527

The two islets of Strofades, south of Zakynthos Island, mark the exposed summits of the 30 x 30 km wide, irregularly shaped seamount. It is surrounded by steep, faulted slopes with their bases lying at depths exceeding 2000 m. Next to the Strofades islets, two more shallow banks, the **Strofades South** and the **Strofades West**, with their shallowest points at 43 m and 293 m respectively, occur at about 6-7 km south and west of the islets.

Further south, the **Nestor Ridge** is a 30 km long feature which run in a N-S direction, parallel to the coastline of the SW Peloponnese. Its eastern slope is steep and linear and reaches maximum depths between 2700 m in the north and 3400 m in the south. The shallowest points of the ridge occur at the upper edge of the eastern slope and the minimum depth is roughly 1800 m. The western slope of the ridge dips more gently at depths of 3500 m. The southern tip of Nestor Ridge coincides with the NE margin of the 5200 m Oinousses Deep (North Matapan).

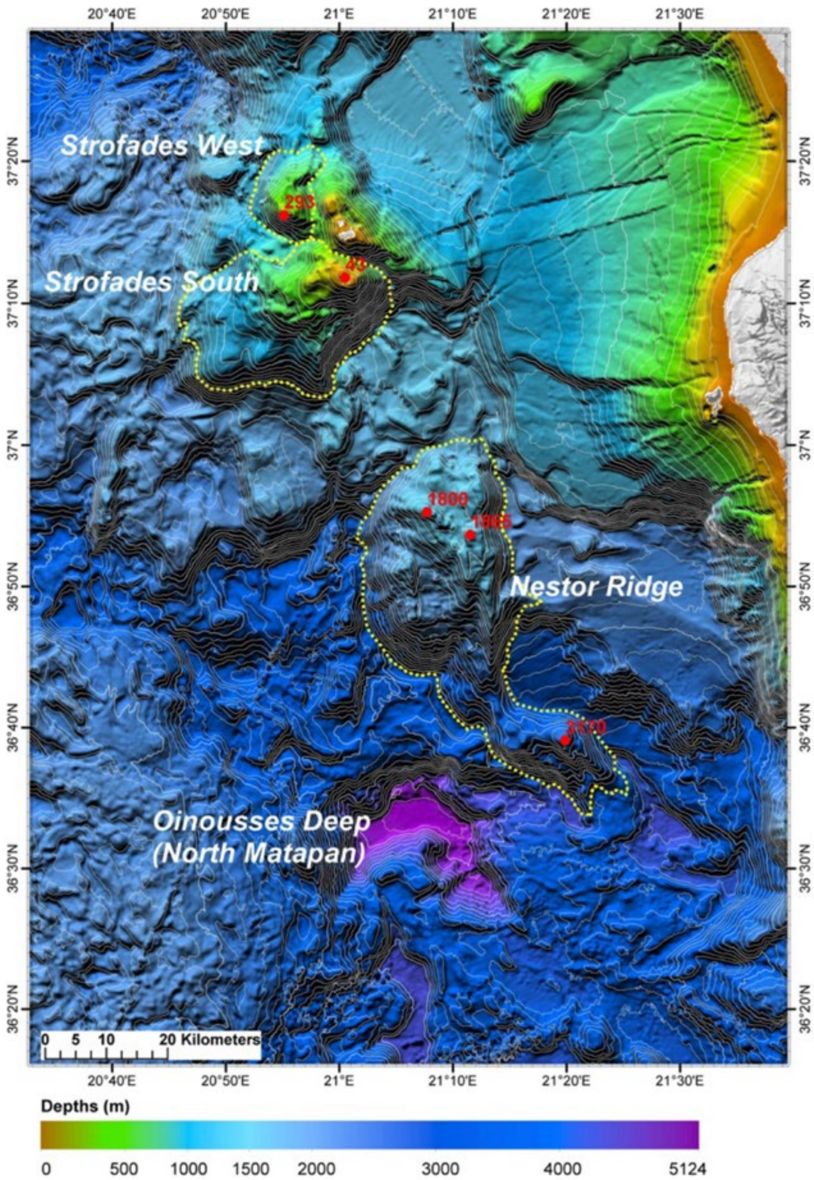

Fig. 2.5. Shaded relief map of the Strofades seamount area.
The outline and the tops of the observed features are indicated on the map.

WEST HELLENIC ARC SEAMOUNTS (FIG. 2.6)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Tainaron	923.86	1237	3529
Kythera mount	1005.53	116	1642
Avlemonas mount	1767.06	980	4661
Lissos Ridge	2666.74	435	4459
Antikythera mounts	1439.78	217	3392
Elafonissi mount	253.75	994	3729

This area encompasses the outer (south-western) slope of the Hellenic Arc between the Southern Peloponnese and Western Crete. It is characterized by highly complex morphology and includes a series of tectonically controlled seamounts and ridges, e.g. **Tainaron, Kythera, Avlemonas, Antikythera, Elafonissi seamounts** and **Lissos Ridge.**

The **Tainaron seamount** is located 27 km south of Tainaron cape, the southernmost tip of the Mani Peninsula of the Peloponnese. Its summit rises to a 1858 m depth. The mount reaches maximum depths at the bases of the western and eastern slopes exceeding 2500 m. A 4700 m deep trough, belonging to the deep basins of the Hellenic Trench, is located some 30 km south of the summit of Tainaron mount.

The **Kythera seamount** is located 16 km southwest of Kythera Island. It is a 22 km long, elongated mount with its highest summit at about a 116 m depth. It is separated from Kythera Island by a 400 m deep morphological neck. The south-western flank of the mount dips down to a small basin > 3000 m deep.

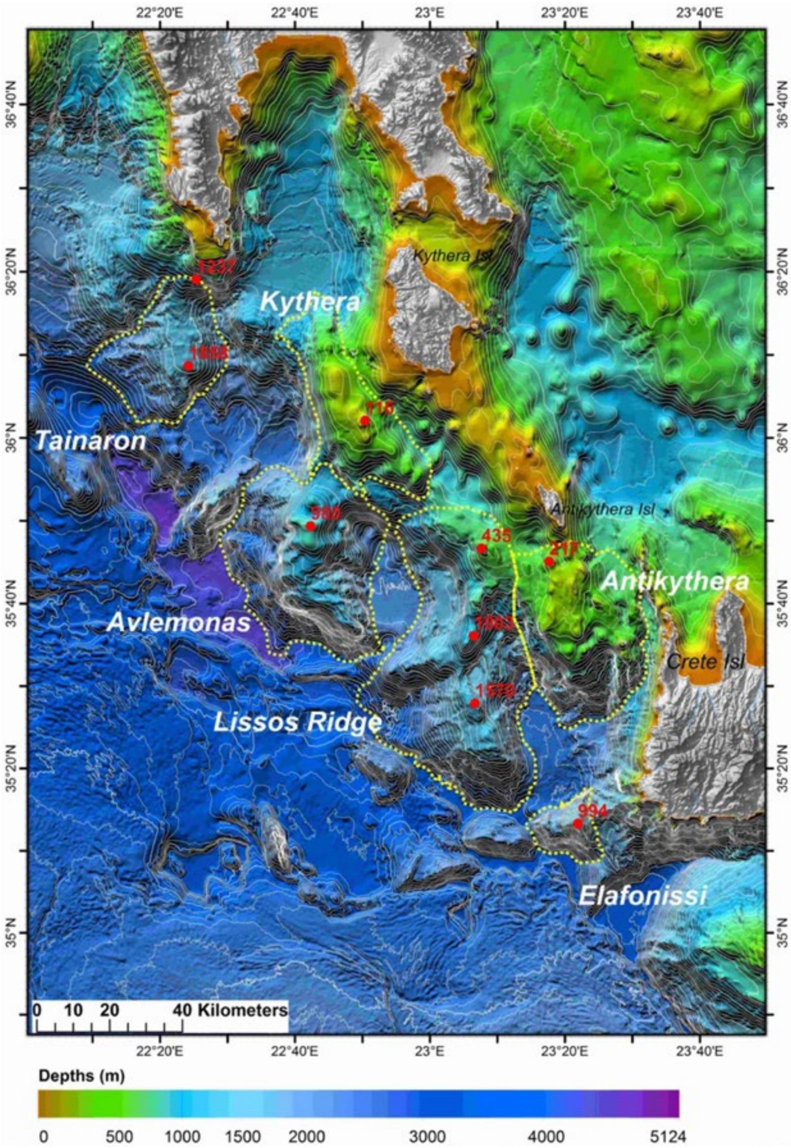

Fig. 2.6. Shaded relief map of the West Hellenic Arc seamount area. The outline and the tops of the observed features are indicated on the map.

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The **Avlemonas seamount** is separated from Kythera mount to the North by a 1500 m deep neck. The shallowest summit rises at a depth of 980 m. The NW and SE flanks of the mount dip down to > 3000 m. The south-western slope faces a 4600 m deep elongate to the basin of the Hellenic Trench.

The **Antikythera seamount** marks the underwater prolongation towards the southeast of the Kythera-Antikythera morphological ridge. It is located between Antikythera Island and the western coast of Crete. The shallow part of the mount displays very irregular, rough topography with several summits, the shallowest of which is found at a depth of 217 m.

The **Elafonissi seamount** marks the underwater prolongation of the mountainous morphology of the south-western corner of Crete. The shallowest point is found at a 994 m depth and is surrounded by steep slopes which plunge to depths of up to 3500 m or more.

Lissos Ridge is located between the Avlemonas and Antikythera mounts and has a N-S orientation. The depth of its crest increases gradually from N to S with the most prominent summits at depths of 435 m, 1003 m and 1570 m. The western, eastern and southern slopes of the ridge display high dip values.

LIBYAN SEAMOUNTS (FIG. 2.7)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Herodotus	3387.18	1003	4032
Battos	267.93	1802	3765

Two prominent seamounts occur between the south-western edge of the East Mediterranean Ridge and the continental slope of the Libyan margin. The **Herodotus** seamount is a rather irregularly shaped seamount of about 70 km. The summit displays a smooth morphology with the shallowest point at a depth of 1003 m. **Battos** seamount is a smaller, semi-circular seamount east of Herodotus with its highest point at a depth of 1802 m.

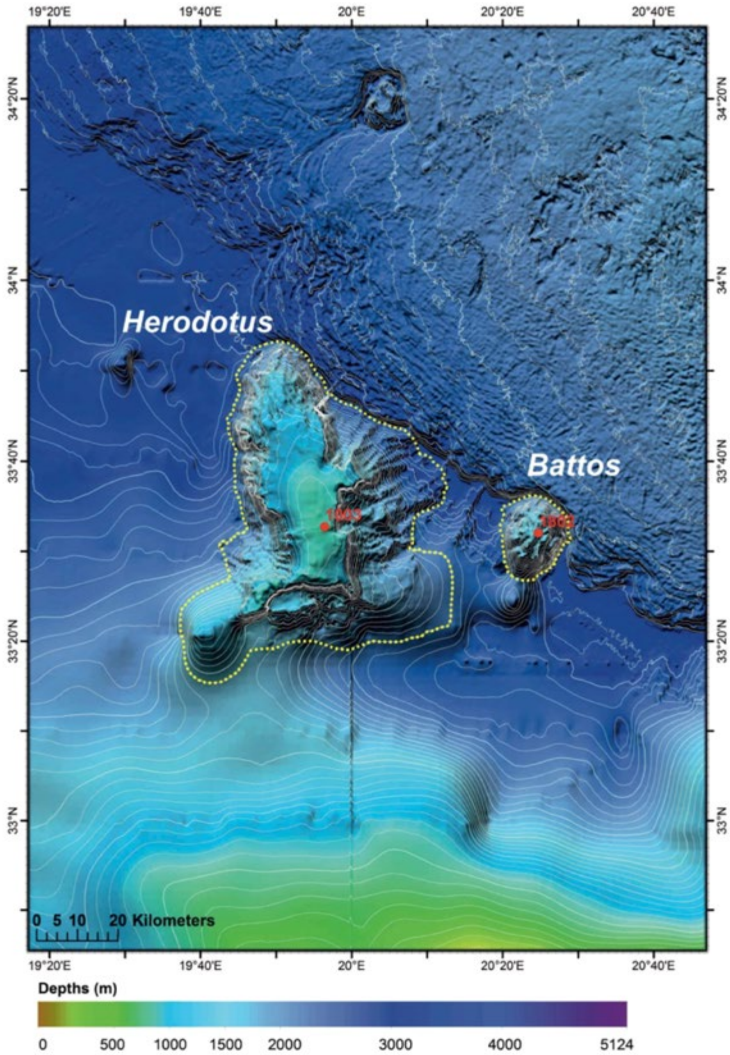

Fig. 2.7. Shaded relief map of the Libyan seamount area.
The outline and the tops of the observed features are indicated on the map.

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2

NORTH AEGEAN SEA

The North Aegean Sea includes the marine area between Northern Greece (Macedonia and Thrace) to the north, Turkey (Anatolia) to the east, Central Greece (Thessaly) to the west and the Cyclades Plateau to the south[3]. It is characterized by two **troughs**, the North Aegean Trough (NAT) and the North Skyros - Edremit Trough (NSET), as well as a series of basins and shallow banks and ridges between the latter, the Cyclades Plateau, the eastern coast of Evia and the western coast of NW Anatolia (Fig. 1.8).

The majority of the morphological basins in the **Aegean Sea** are shallower than 1000 m. The North Aegean Trough, with a depth of 1600 m, is the deepest among them. It has developed along the prolongation of the major North Anatolian Fault in the Aegean Sea and it is a 300 km long morphological feature composed of two parts with distinct morphological and structural characteristics. The western North Aegean Trough (Sporades Basin), between Pelion Peninsula and Lemnos Island, consists of a series of variably shaped basins, including the 1600 m deep Sporades Basin, separated by several high and shallower ridges, including the seamounts in the area of **NW Limnos**. The eastern North Aegean Trough (Saros Trough) extends between the north of Lemnos Island and the Saros Gulf. It consists of the 1500 m Lemnos Deep (LB), the narrow, up to a 1000 m deep basin between Samothraki and Gokceada Islands (Imbros Depression) and the 600 m deep Saros Trough which continues eastward into the Saros Gulf (SG).

The North Skyros - Edremit Trough has developed along the southern branch of the North Anatolian Fault. It is a 200 km long feature consisting of the North Skyros Basin (NSB) in the west and the Edremit Trough (EdT) and Edremit Gulf (EdG) in the east. The 1200 m deep North Skyros Basin has a base parallel to the eastern coastline of Skyros Island and its peak at 70 km[12], where it continues in the narrower and shallower Edremit Trough.

The area between the North Aegean Trough and the North Skyros - Edremit Trough constitutes a relatively flat plateau extending between a depth of 100 m and 300 m below sea-level. It includes the North Sporades Archipelago, Agios Efstratios, Limnos, Gokceada and Bokceada islands. The **North-Sporades** area is located between the North Sporades Archipelago and the Agios Efstratios Island where there are several seamounts.

Small deep basins, down to 1100 m, occur between the eastern coast of Evia, the Sporades Archipelago and Skyros Island. Skopelos Basins (SB), South Skyros Basin (SSB) and other smaller basins close to the north-eastern coast of Evia create a morphological puzzle with local depressions separated from each other by shallow ridges and mounts. The **South-Sporades** and **West-Skyros** (Fig. 2.8) areas include the most pronounced seamounts of this particular region.

The available morphology of the area, extending between the North Skyros - Edremit Trough to the north and the Cyclades Archipelago to the south[14], is made by alternating uplifted basement blocks (islands and shallow banks) and subsiding extensional depressions. The Psara Ridge separates the 700 m deep Lesvos Basin to the east from Psara Basin to the west. The **North-Skyros-Edremit-Ridge** area encompasses the seamounts on the SW-NE trending ridge along the southern margin of North Skyros - Edremit Trough, while **North-Psara** includes the seamounts north of Psara Island.

Further south, the 800 m deep Cavo Doro Basin (SE Evia Basin), north of Andros Island, is a wide depression bounded by a trending ridge which separates it from South Skyros Basin. This ridge constitutes the **Cavo-Doro-North-Ridge** area, with several shallow summits on the top. To the east, the 900 m deep North Mykonos Basin is separated from the Cavo Doro Basin by two groups of shallow banks and ridges which are included in the **South Psara** and **Andros-Tinos-North** areas.

The seamounts of the **North-Ikaria** area separate the North Mykonos Basin from the North Ikaria Basin (NIB) to the east. The latter is a 1400 m deep and wide basin bounded to the south by steep faulted slopes.

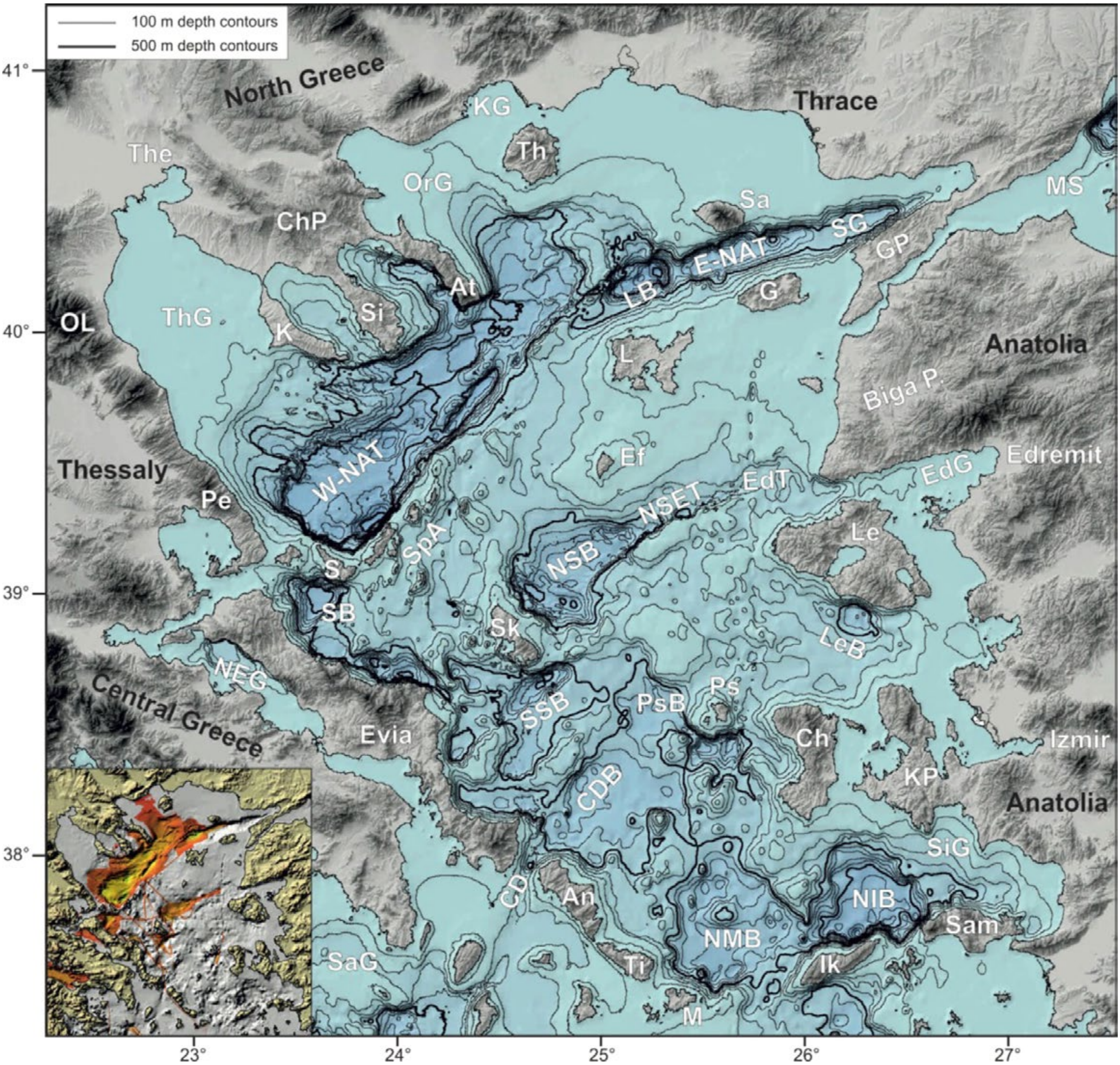

Fig. 2.8. Updated bathymetry of the North Aegean Sea.

Derived from GEBCO and swath bathymetry data processed at 250 m grid in the framework of EMODNET Bathymetry project (https://emodnet.eu/bathymetry;10,13,3). Inset map: Swath bathymetry coverage in the North Aegean. Terminology after 3.
An: Andros, At: Athos, Ch: Chios, CD: Cavo Doro strait, CDB: Cavo Doro Basin, ChP: Chalkidiki Peninsula, CG: Corinth Gulf, EdG: Edremit Gulf, EdT: Edremit Trough, Ef: Agios Efstratios, E-NAT: Eastern North Aegean Trough, G: Gokceada, GP: Gelibolu Peninsula, Ik: Ikaria, K: Kassandra, KG: Kavala Gulf, L: Lemnos, LB: Lemnos Basin, Le: Lesvos, LeB: Lesvos Basin, MS: Marmara Sea, NEG: North Evia Gulf, NIB: North Ikaria Basin, NMB: North Mykonos Basin, NSB: North Skyros Basin, NSET: North Skyros-Edremit Basin, OL: Olympos, OrG: Orfanou Gulf, Pe: Pelion, Ps: Psarra, PsB: Psarra Basin, S: Skopelos, SB: Skopelos Basin, Sa: Samothrace, SaG: Saronic Gulf, Sam: Samos, SG: Saros Gulf, Si: Sithonia, SpA: Sporades Archipelago, Sk: Skyros, SSB: South Skyros Basin, Th: Thassos, The: Thessaloniki, ThG: Thermaikos Gulf, Ti: Tinos, W-NAT: Western North Aegean Trough.

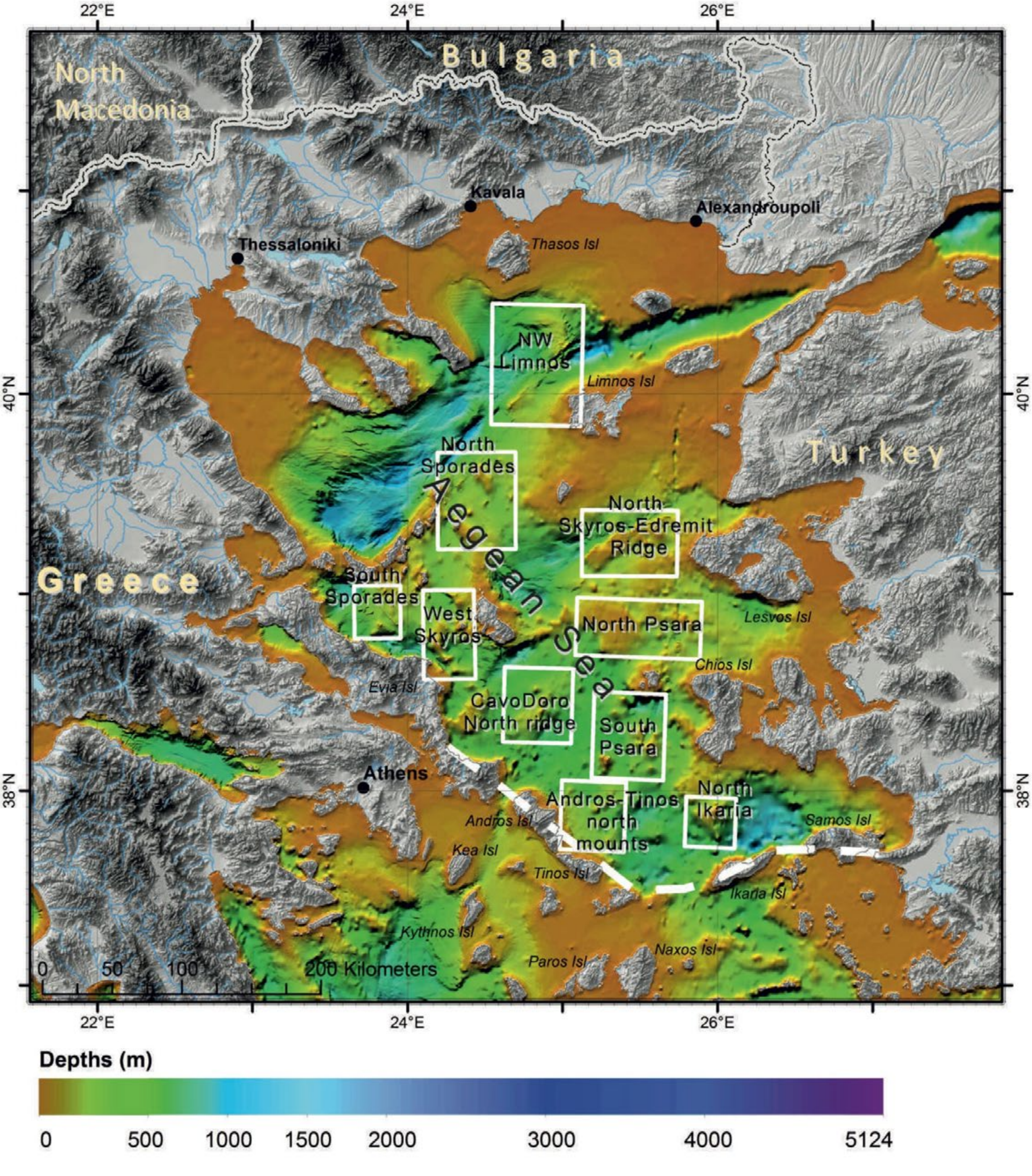

Fig. 2.9.
Location of the seamounts area in the North Aegean Sea.

Table 2.2. North Aegean Sea Seamounts and Seamount-like structures.

			Minimum Depth / Location			Maximum Depth / Location				
Group name	Seamount	Area (km²)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Depth Range (m)	Mean Slope (deg)
NW LIMNOS	Lemnos Ridge (Venus Bank)	1042.07	40.241580	25.031738	152	40.209061	24.664062	978	826	2.27
	Mourtzeflos Bank	442.84	40.138550	24.939819	258	40.225322	25.175509	1357	1099	3.41
	Myrina Bank (Aphrodite Bank)	622.04	39.946532	24.671132	160	40.009995	24.638136	922	762	2.72
NORTH SPORADES	Agios Efstratios West	295.39	39.622862	24.442513	124	39.644731	24.418944	399	275	1.89
	Psathoura East	34.49	39.549916	24.329382	221	39.529842	24.315241	373	152	2.66
	Piperi NorthEast	55.16	39.403792	24.402446	124	39.418418	24.369449	333	209	2.36
	Piperi SouthEast	221.20	39.295827	24.397732	60	39.295827	24.324668	308	248	1.74
SOUTH SPORADES	Staphylos	13.05	38.976445	23.709517	177	38.981964	23.693019	518	341	10.01
	Sarakiniko	100.69	38.842016	23.827362	172	38.799609	23.751942	508	336	2.76
	Patitiri	12.83	39.011391	23.850931	84	38.996679	23.850931	259	175	4.60
WEST SKYROS	Aloni Bank (Amfitrite)	145.96	38.958045	24.341166	117	38.994840	24.239820	505	388	2.49
	Chiliadou Bank (Ira)	480.69	38.747948	24.180897	112	38.736873	24.100763	805	693	2.75
	Kimi-1	20.27	38.611235	24.220965	57	38.620481	24.242177	462	405	5.74
	Kimi-2	177.64	38.609386	24.305813	195	38.587191	24.310527	513	318	2.47
NORTH SKYROS-EDREMIT RIDGE	Eressos Ridge	1229.70	39.308645	25.387630	83	39.196865	25.116586	895	812	2.49
	Sigri-1	108.86	39.297659	25.630390	89	39.304983	25.675171	266	177	1.51
	Sigri-2	41.53	39.253694	25.536114	58	39.240866	25.512545	281	223	2.81
	Sigri-3	27.50	39.202366	25.519616	121	39.217035	25.503118	253	132	2.28
NORTH PSARA	Psara Bank	1871.79	38.886240	25.399414	79	38.698097	25.210862	629	550	1.10
	Kalloni Bank	274.54	38.865974	25.783589	79	38.818050	25.807158	306	227	1.82
CAVO DORO NORTH RIDGE	Cavo Doro North Ridge	1736.93	38.464994	24.871469	153	38.314739	24.887967	843	690	1.68
			38.403817	24.862041	177					
			38.518712	24.826688	239					
			38.368570	24.727698	263					
SOUTH PSARA	Antipsara Bank	340.04	38.468700	25.397057	152	38.429777	25.467764	903	751	3.02
			38.401963	25.335778	239					
	Mesta Bank	802.29	38.218114	25.562040	64	38.409381	25.559683	796	732	2.67
			38.311026	25.517259	145					
			38.285022	25.595037	174					
ANDROS-TINOS NORTH	Sariza Bank	143.97	37.994638	25.043522	270	38.076659	25.060021	693	423	2.36
	Kalogeros South Ridge	451.62	37.906922	25.222647	220	37.968521	25.175509	589	369	1.62
			37.938661	25.269785	271					
			37.946127	25.307495	280					
	Panormos Bank	280.88	37.738661	25.290997	237	37.832187	25.380559	736	499	2.39
IKARIA NORTH	Pyrgi Bank	485.20	37.901320	25.995710	44	37.832187	25.866080	612	568	2.49
	Evdilos Bank	31.12	37.759247	26.002780	248	37.742404	25.995710	718	470	7.43

NORTH AEGEAN SEA SEAMOUNTS

NW LIMNOS SEAMOUNTS (FIG. 2.10)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Lemnos Ridge (Venus Bank)	1042.07	152	978
Mourtzeflos Bank	442.84	258	1357
Myrina Bank (Aphrodite Bank)	622.04	160	922

The NW Limnos seamounts occur at the junction of the two main segments of the North Anatolian Fault Zone in the Aegean: the western segment, which runs N40°E along the southern margin of the western North Aegean Trough and terminates towards NE at the Limnos Basin; similarly, the eastern segment, which runs N70°E along the eastern North Aegean Trough and dies out towards the west at the Limnos Basin. The overlapping tectonic movements at the junction of the two strike-slip fault segments creates a complicated deformation pattern with local transtension and subsidence (e.g. Limnos Basin) and local transpression and uplift (e.g. seamounts)[14,13]. The three main seamounts in this area have been formed as pressure ridges where the basement has been squeezed between faults and uplifted.

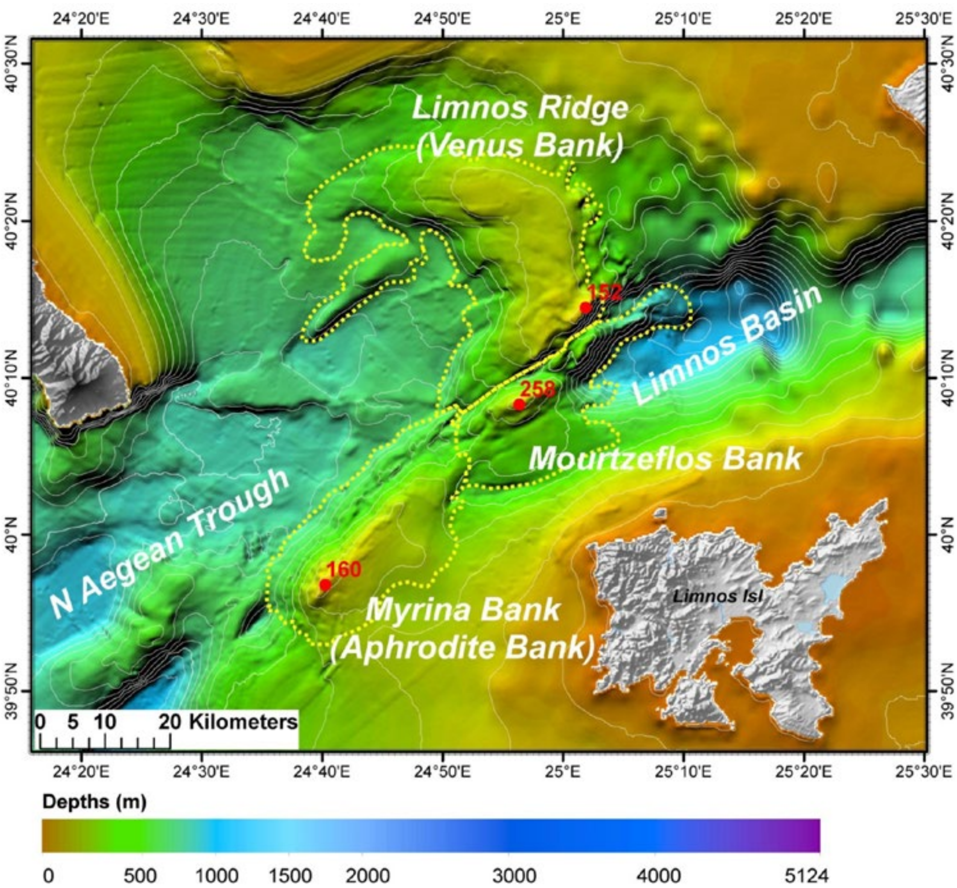

Fig. 2.10.
Shaded relief map of the NW Limnos Seamount area.

The outline and the tops of the observed features are indicated on the map.

The term **Limnos Ridge** previously named as “Venus Bank”[1], refers to the larger seamount in this area. The Limnos Ridge is a concave, 23 km long and 9 km wide ridge. It rises from a base depth of 600-700 m to a flat plateau at about 300-250 m depth. The shallowest summit, 152 m deep, occurs at the southernmost part of the ridge and is separated from the 1500 m deep Limnos Basin by a 1300 m high morphological escarpment. Despite the absence of high-resolution seismic profiles and sediment sampling data, it is believed that the rocky basement is exposed on the highest summit, while the rest of the ridge is draped by mud.

The **Mourtzeflos Bank,** proposed here, has been named after the north-western cape of Limnos island. It is a < 300 m shallow, 9 km long by 3.5 km wide, elongated bank, aligned parallel to the western segment of the North Anatolian Fault Zone. The eastern flanks dip down to the 1600 m deep Lemnos Deep, while the base of the bank in the west is at a depth of 700-800 m. The rocky basement is believed to form the shallowest parts of the bank.

The term **Myrina Bank,** previously named “Aphrodite Bank” has been renamed after the main port of Limnos Island, it occurs at the south-western prolongation of Mourtzeflos Bank. It is a < 200 m shallow, 20 km wide by 75 km long, elongated positive feature, aligned parallel to the North Anatolian Fault Zone. It rises from the 300-400 m deep neck which separates off to the south from Limnos Island. The northern flanks of Myrina Bank dip down to a depth of 900-1000 m in the North Aegean Trough. The rocky basement is believed to form the summit of the bank, while the rest of it may be covered by mud.

1 http://www.geomapapp.org/database/GEBCO/GEBCO_gazetteer.htm.
IOC-IHO GEBCO SCUFN (Sub-Committee on Undersea Feature Names) Gazetteer database.

NORTH SPORADES SEAMOUNTS (FIG. 2.11)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Agios Efstratios West	295.39	124	399
Psathoura East	34.49	221	373
Piperi NorthEast	55.16	124	333
Piperi SouthEast	221.20	60	308

A series of several mounts occurs between Psathoura-Gioura and Agios Efstratios islands. The mounts are located on a flat, 300-400 m deep plateau separating two major basins of tectonic origin: the western part of the North Aegean Trough to the north from the North Skyros Basin to the south. The four mounts described here (Fig. 2.11) are the most pronounced ones in this area. Several other smaller mount-like features can be recognized on the Sporades plateau.

The summit of **Piperi Southeast** mount rises to a depth of 60 m, while the one of the smaller **Piperi Northeast** to 124 m deep. The **Psathoura East** and the **Agios Efstratios mounts** are located on the uplifting block of the North Anatolian fault-zone. The latter is elongated in a NW-SE direction and includes the Glavki Bank. All four features are named after the nearby islands and islets Piperi, Psathoura and Agios Efstratios.

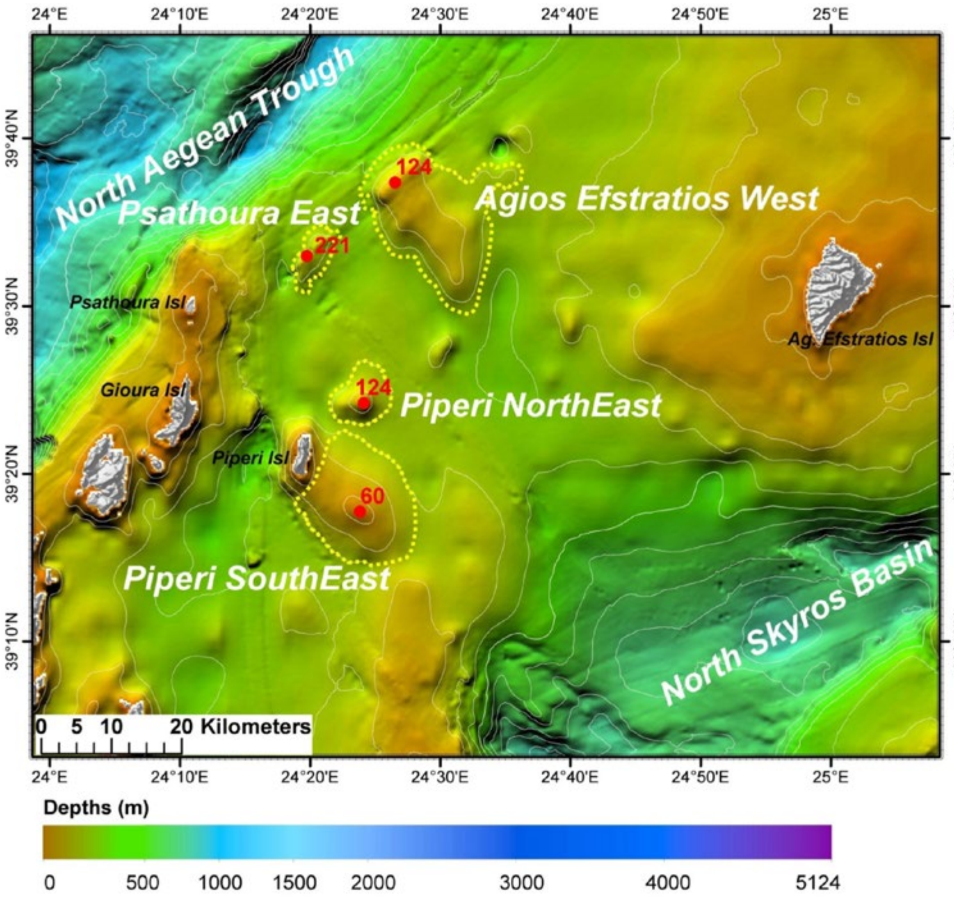

Fig. 2.11. Shaded relief map of the North Sporades area.

The outline and the tops of the observed features are indicated on the map.

SOUTH SPORADES MOUNTS (FIG. 2.12)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Staphylos	13.05	177	518
Sarakiniko	100.69	172	508
Patitiri	12.83	84	259

Further south-westwards on the Sporades plateau, a series of small and larger seamounts occurs on the seafloor between Skopelos Island and the north-eastern coast of North Evia.

Staphylos bank, with a depth of 177 m at its summit, named after a popular sandy beach on Skopelos Island. Staphylos bank marks the shallowest point on the south-eastern, steep, faulted margin of the 1000 m deep Skopelos Basin. The high relief and the steep slopes of the bank indicate that the rocky substrate outcrops on the seafloor.

Patitiri bank rises at a depth of 84 m while the depth of the surrounding seafloor varies between 150 m and 200 m. The bank is named after the main port of Alonissos Island.

Sarakiniko mount is the largest one among the mounts in this area. The depth at its summit is 172 m and is named after the nearby cape of North Evia. It has a pear-like shape, with its long axis oriented in a NE-SW direction. The base of the mount lies at roughly 300 m, however its south-eastern slope dips down to about 1000 m.

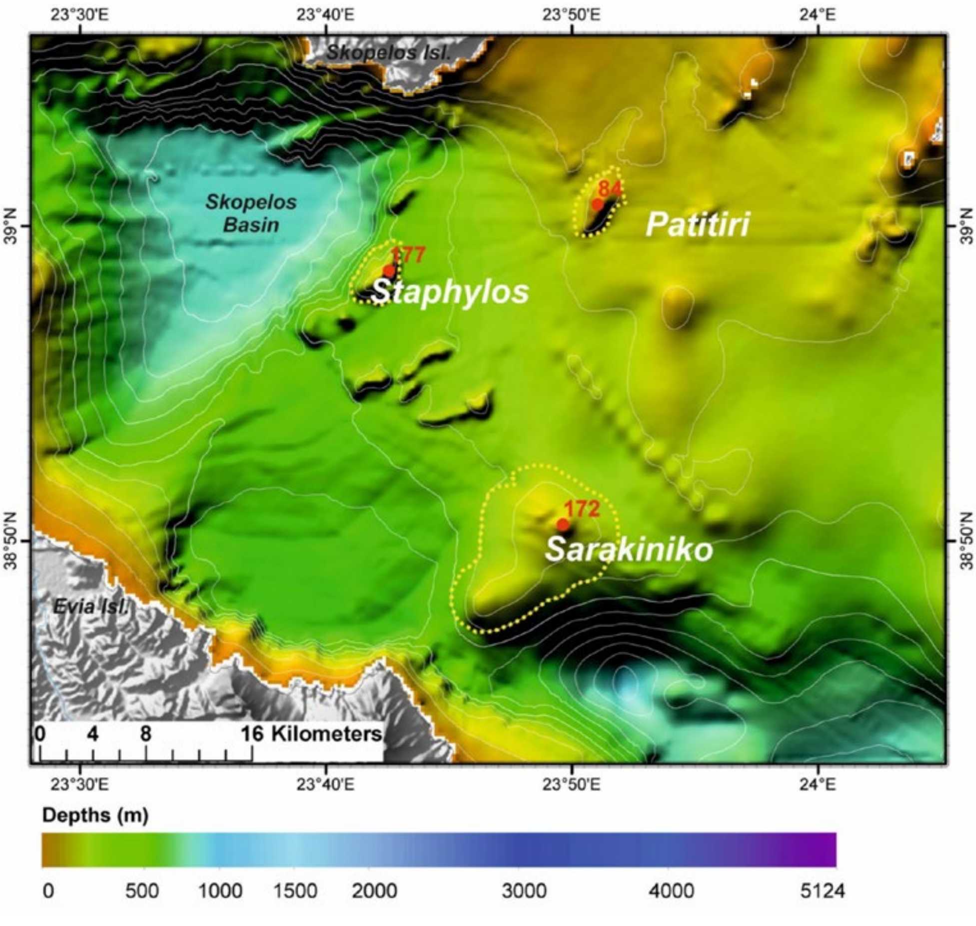

Fig. 2.12.
Shaded relief map of the South Sporades mount area.

The outline and the tops of the observed features are indicated on the map.

WEST SKYROS MOUNTS (FIG. 2.13)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Aloni Bank (Amfitrite)	145.96	117	505
Chiliadou Bank (Ira)	480.69	112	805
Kimi-1	20.27	57	462
Kimi-2	177.64	195	513

The morphology of the seafloor between Skyros Island and the coasts of Evia displays a complicated character with many shallow banks, steep slopes and NW-SE trending narrow basins and valleys.

The term **Aloni bank** is proposed here for the mound located west of the Cape Aloni, the northern tip of Skyros Island. Aloni Bank contains the “Amfitrite Bank”. Its shallowest point occurs at a depth of 117 m, while the depth of its base varies between 300 m and 500 m.

Chiliadou bank is an irregularly shaped mound with three main summits, the shallowest of which rises to a depth of 112 m and it is known as “Ira bank”. The northern flanks of the mound rise from a depth of 300-400 m. The south-western and south-eastern steep slopes dip down to > 1000 m and > 700 m respectively.

Kimi-1 and **Kimi-2** banks, with depths of 57 m and 195 m at their summits, respectively, are two mounds located east of the port of Kimi. Kimi-1 mound sits on the edge of the shelf of Evia, while Kimi-2 is separated from the latter by a 350-400 m deep morphological neck. The depth of the base of Kimi-2 is roughly 400 m.

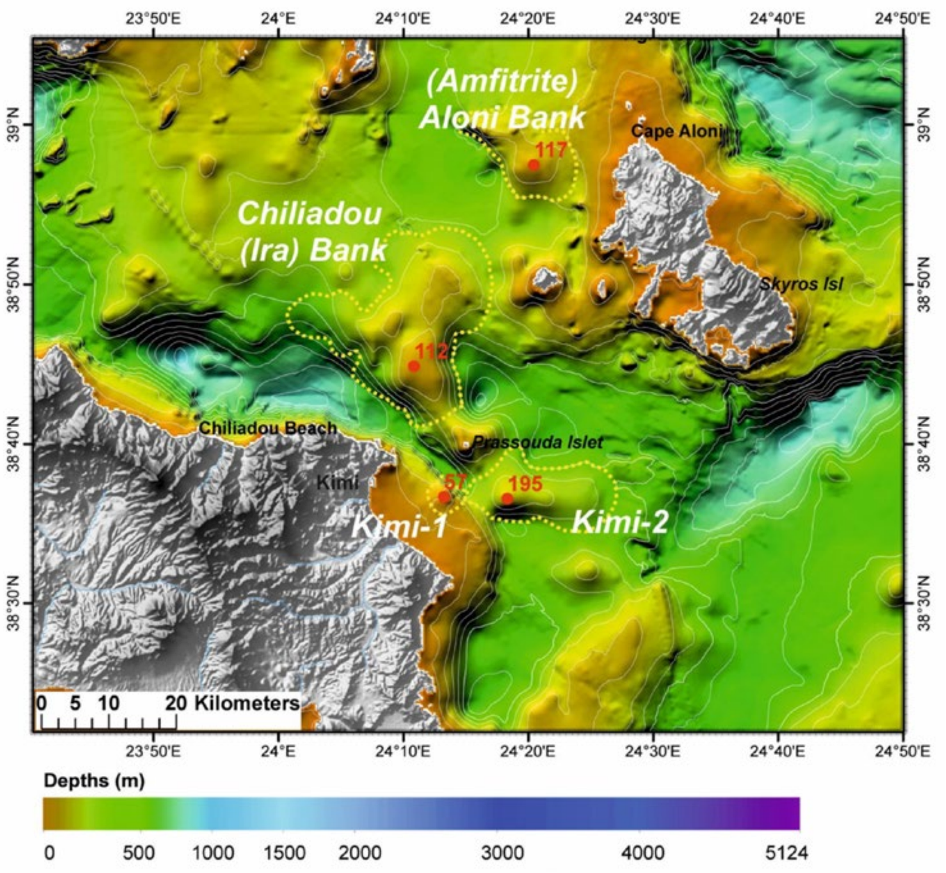

Fig. 2.13.
Shaded relief map of the West Skyros mount area.

The outline and the tops of the observed features are indicated on the map.

NORTH SKYROS-EDREMIT RIDGE (FIG. 2.14)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Eressos Ridge	1229.70	83	895
Sigri-1	108.86	89	266
Sigri-2	41.53	58	281
Sigri-3	27.50	121	253

The North Skyros-Edremit Ridge is a morphological feature running along the south-eastern margin of the North Skyros-Edremit Trough. The geological and geomorphological evolution of this area is directly associated with the tectonic activity along the southern branch of the North Anatolian Fault, which runs within the trough.

Eressos Ridge, named after the historic village of Lesvos Island, is a < 200 m deep, NE-SW elongate ridge running along the southern margin of the North-Skyros-Edremit Trough. The difference in depth between the shallow plateau of the ridge and the trough varies between 200 m at the east edge of the slope and > 700 m at the western edge. The difference in depth along the south-eastern side of the ridge does not exceed 200 m.

Three prominent mounds should be mentioned along the south-eastern side of Eressos Ridge. They are named **Sigri-1, Sigri-2** and **Sigri-3** and their tops rise below sea-level at 89m, 58 m and 121 m depth respectively. The mounts are named after Sigri, a small village on the western coast of Lesvos Island. The Sigri-1 and Sigri-2 mounds are also known as Mansell and Johnston Banks.

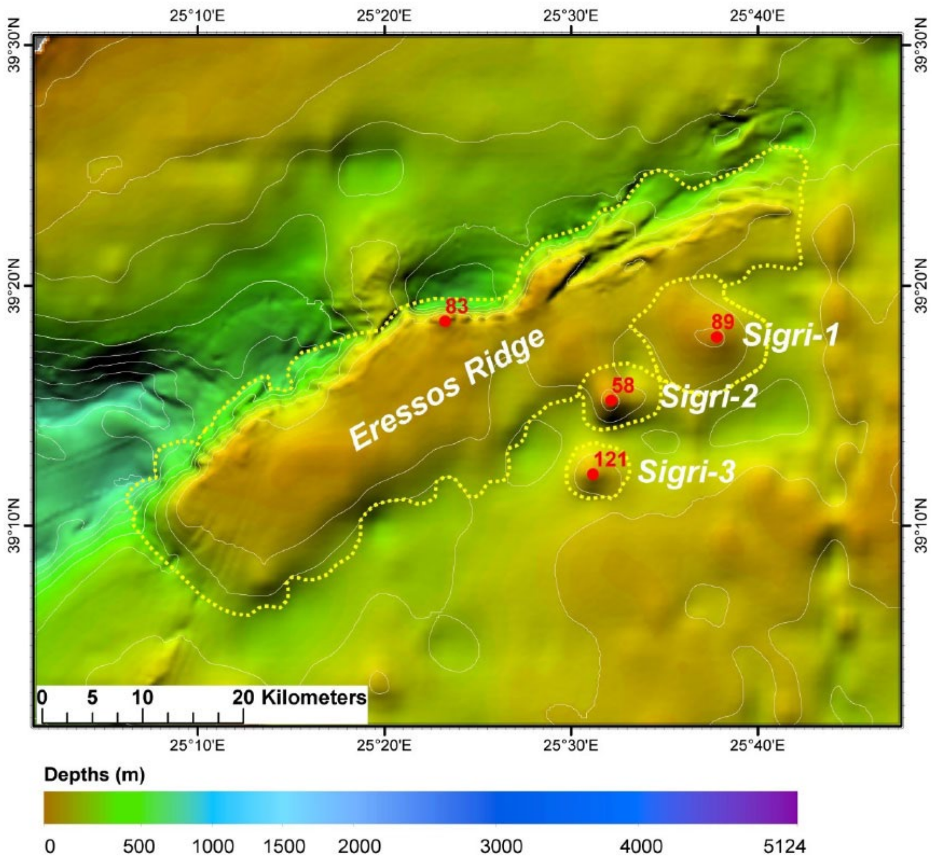

Fig. 2.14.
Shaded relief map of the North Skyros-Edremit area.

The outline and the tops of the observed features are indicated on the map.

NORTH PSARA MOUNTS (FIG. 2.15)

Feature	Total Area (km^2)	▲ Peak Depth (m)	Base Depth (m)
Psara Bank	1871.79	79	629
Kalloni Bank	274.54	79	306

Despite the lack of accurate, swath bathymetry data in the area between Lesvos Island to the North and Psara and Chios Islands to the south, the available low-resolution bathymetry indicates a very irregular and complicated seafloor relief here with many small and larger mounts (including the Brooker, Stokes and Sinaia Banks) and valley-like basins in between. The two most prominent are mounts, **Psara** and **Kalloni** Banks.

Psara Bank is named after the homonymous island and is a wide, shallow plateau with its top at 150-200 m depth and its highest summit at a depth of 79 m. The north-eastern flanks of the mount dip to roughly 300 m, while towards the south the maximum depth at the base of the slope reaches a depth of 700 m. With the exception of its highest summit, the shallow plateau displays smooth relief and is believed to be draped by sedimentary deposits.

Kalloni Bank is located opposite to the entrance of the Kalloni Gulf/Lagoon of Lesvos Island and is named after it. The summit of the mount reaches a depth of 79 m while the depth of the surrounding seafloor is 250-300 m.

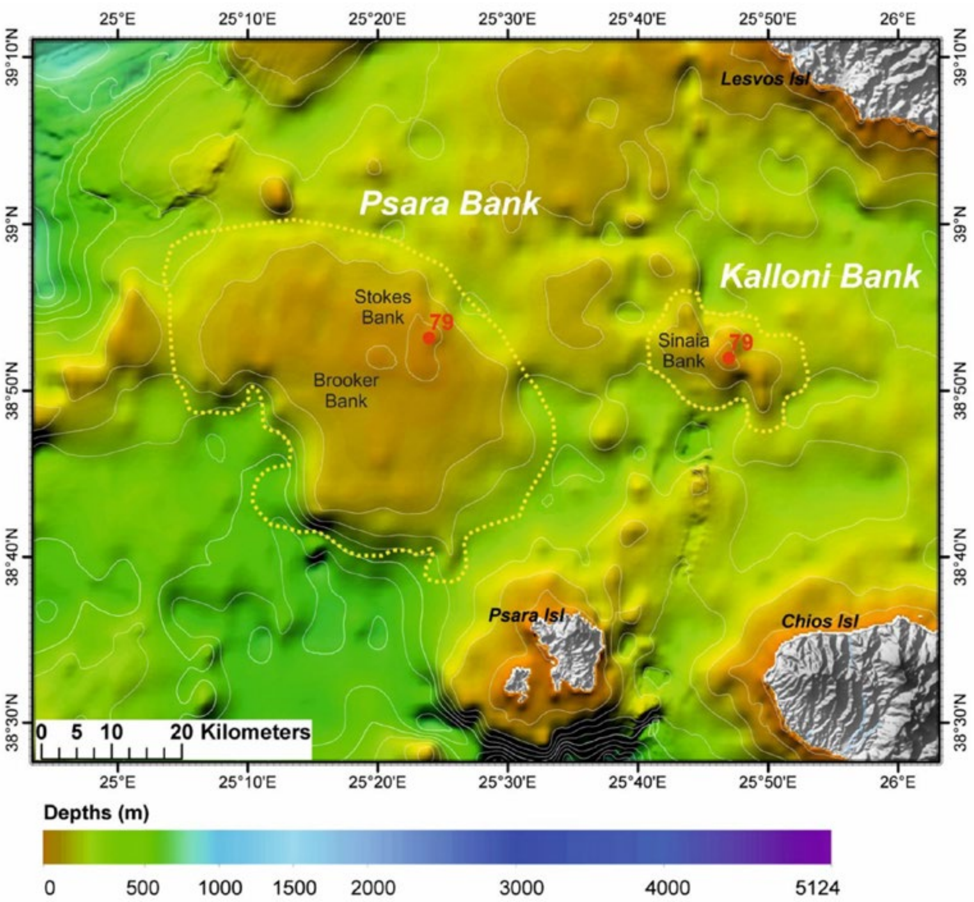

Fig. 2.15.
Shaded relief map of the North Psara mounts area.

The outline and the tops of the observed features are indicated on the map.

CAVO DORO NORTH RIDGE (FIG. 2.16)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Cavo Doro North Ridge	1736.93	153	843

It is a 40 km long, NE-SW oriented, elongated shallow ridge located to the northeast of Cavo Doro Strait. The shallow plateau of the ridge is outlined by the 300 m depth contour and the most prominent summits rise at various depths with the shallowest one at 153 m. The base of the ridge is at a depth of 600-700 m. The origin of the ridge is believed to be associated with vertical movements along a NE-SW trending fault-zone, which runs along the south-eastern flank of the ridge and continues south-westwards to the Cavo Doro strait. With the exception of the highest points (summits), the shallow ridge is believed to be covered by marine sediments of the Upper Quaternary.

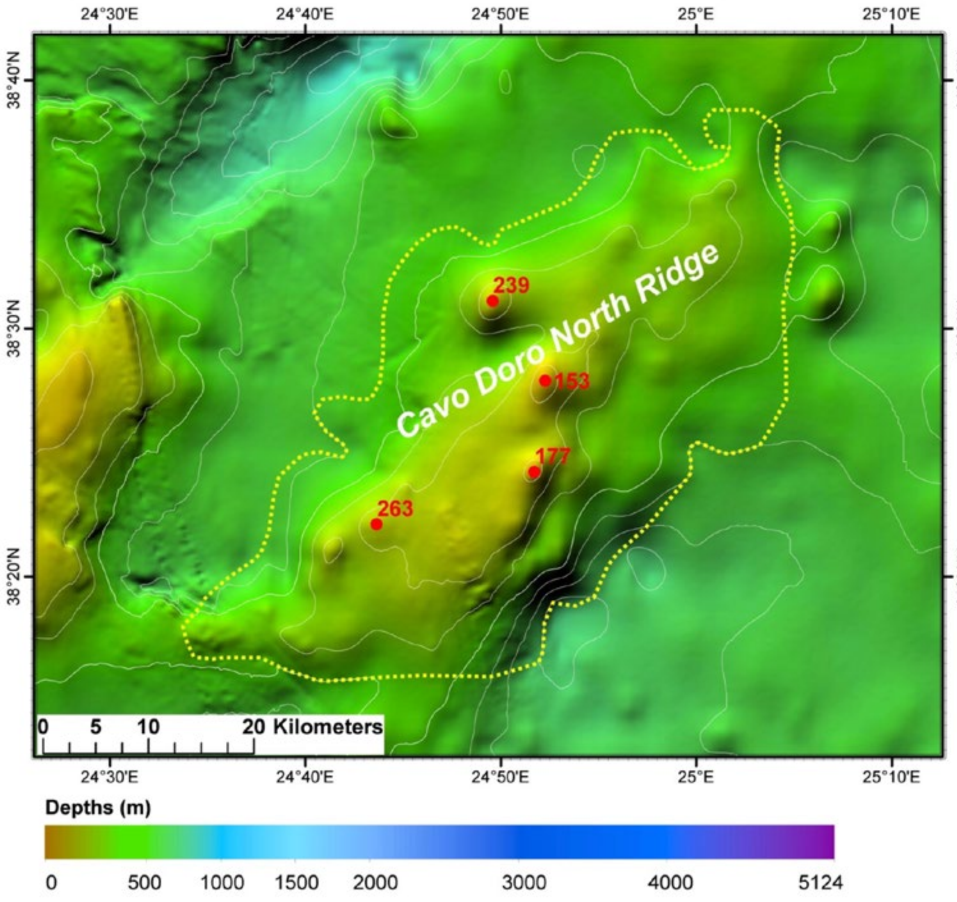

Fig. 2.16. Shaded relief map of the Cavo Doro North Ridge area.

The outline and the tops of the observed features are indicated on the map.

SOUTH PSARA MOUNTS (FIG. 2.17)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Antipsara Bank	340.04	152	903
Mesta Bank	802.29	64	796

The 600-700 m deep basin between the Cavo Doro Ridge to the West and Chios Island to the east hosts three main morphological highs. One rises above the sea-surface where the Kalogeros Islet is located. The other two mounds, the Antipsara Bank and the Mesta Bank, constitute two seamounts.

The **Antipsara Bank** displays two summits at depths of 239 m and 152 m and is named after the small island of Antipsara, southwest of Psara.

The **Mesta Bank**, is characterized by three prominent summits at depths of 64 m, 145 m and 174 m. It is named after the Medieval castle-village of Mesta on Chios Island.

Swath bathymetry and seismic profiling data are not available for the Antipsara and Mesta mounts. However, based on the sharp morphology, it is predicted that rocky substrate may be exposed on the seafloor of the shallowest points.

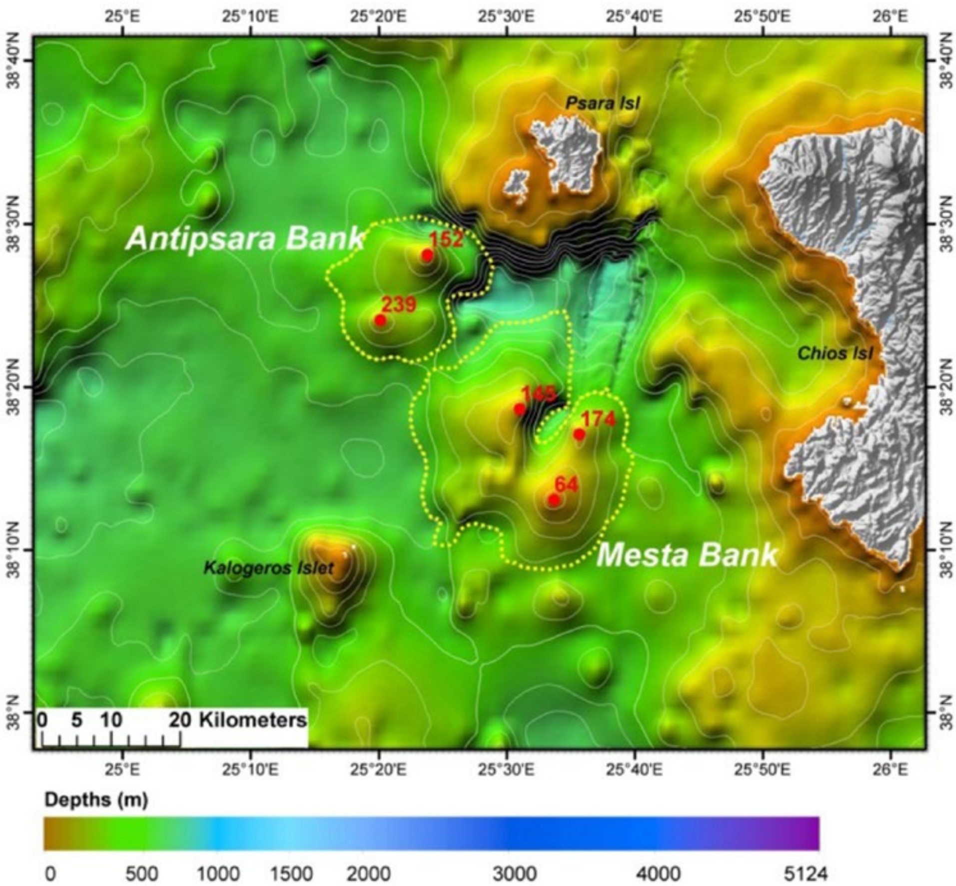

Fig. 2.17. Shaded relief map of the South Psara mounts area.

The outline and the tops of the observed features are indicated on the map.

ANDROS-TINOS NORTH MOUNTS (FIG. 2.18)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Sariza Bank	143.97	270	693
Kalogeros South Ridge	451.62	220	589
Panormos Bank	280.88	237	736

The irregular topography of the area north of the islands of Andros and Tinos displays many morphological highs rising higher than the surrounding 500-800 m deep seafloor. The most prominent and shallow seamounts highlighted here are the Sariza Bank, the Kalogeros South Ridge and the Panormos Bank.

Sariza Bank is a rather circular to elongated mound with its summit at a depth of 270 m. It is named after a water-spring on Andros Island, which has been famous since Antiquity for its quality.

Panormos Bank is a fairly circular mound with its summit rising at a depth of 237 m while the base of its eastern flank is at 800 m. It is named after the picturesque bay and village located on Tinos Island.

The **Kalogeros South Ridge** is an irregularly shaped mound with its crest running in a NE-SW direction and is outlined by the 300 m depth contour. The three shallowest points on the crest are located at depths of 220 m, 271 m and 280 m.

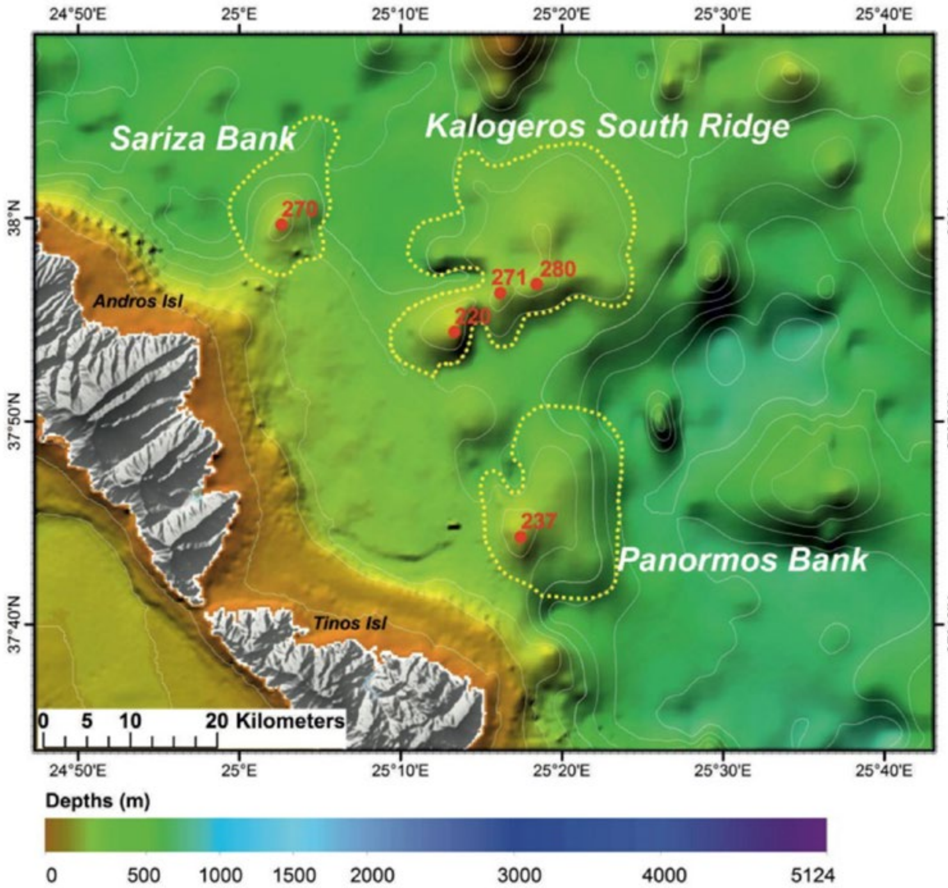

Fig. 2.18.
Shaded relief map of the Andros-Tinos North mounts area.

The outline and the tops of the observed features are indicated on the map.

IKARIA NORTH SEAMOUNT (FIG. 2.19)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Pyrgi Bank	485.20	44	612
Evdilos Bank	31.12	248	718

The western margin of the 1100 m deep North Ikaria Basin, between Ikaria Island to the South and Chios Island to the North, is marked by the presence of an irregularly shaped seamount with the shallowest summit rising at a 44 m water depth. Its name, **Pyrgi Bank**, is derived from PIRGY village on Chios Island, which is known as the "painted village" because of the unique decoration of the houses with black and white motifs in different shapes.

Evdilos Bank marks the southernmost tip of the seamount with a narrow summit at a depth of 248 m facing towards the South of the village of Evdilos on the northern coast of Ikaria Island.

The eastern flanks of the Ikaria North seamount form the > 1000 m high margin of the North Ikarian Basin. The western slopes dip down to a depth of 600-700 m.

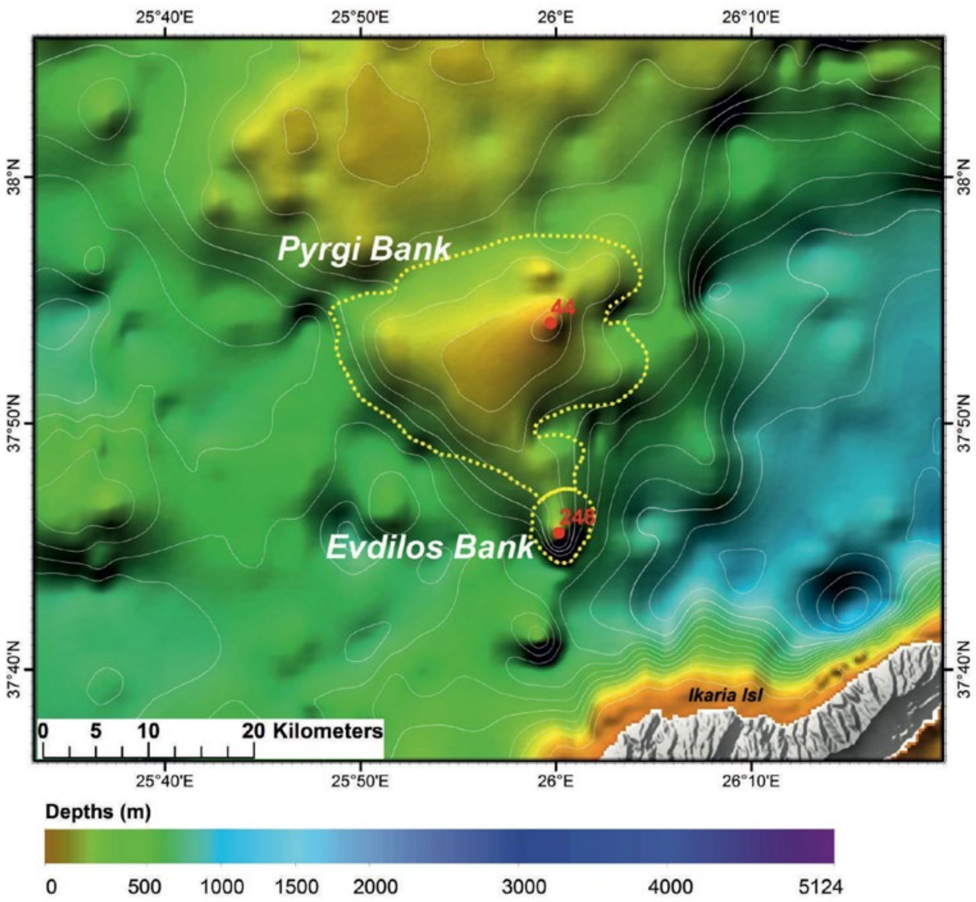

Fig. 2.19. Shaded relief map of the Ikaria North seamount area.

The outline and the tops of the observed features are indicated on the map.

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3 SOUTH AEGEAN SEA

The South Aegean Sea, as described here, includes the Cyclades Plateau to the north and extends between the western coast of Anatolia to the east, the eastern coast of the Peloponnese to the west and the Hellenic Arc (Crete, Rhodes) to the south (Fig. 2.20). Maximum depths in the South Aegean Sea, between 2000 m and 2500 m, occur only at the south-eastern edge of the Aegean. The rest of the South Aegean is characterized by variably shaped basins with bottom depths ranging between 1000 m and 2000 m, and separated from each other by shallow ridges[3].

For decades the shallow marine Cyclades Plateau (CP) has been considered as a tectonically inactive area extending from Central Greece to the west until the western coast of Anatolia to the east. Therefore, very few data are available from this area and very little is known about its offshore structure. However, a more thorough look at the updated bathymetry of the Plateau reveals some interesting geomorphological observations (Fig. 2.20). Its northern edge is marked by (i) a NW-SE running ridge consisting of the South Evia, Andros (An), Tinos (Ti) and Mykonos (M) Islands, and (ii) an ENE-WSW running ridge delineated by the Ikaria (Ik) and Samos (Sam) Islands. Both directions coincide with the major tectonic trends recognized in the Aegean Sea. The **Central Cyclades** area includes two small mounts rising from the 200-300 m deep flat seafloor between Paros, Tinos, Serifos and Sifnos Islands (Fig. 2.21).

The 500 m deep Cavo Doro strait (CD) separates South Evia from the Andros Island and extends further as a narrow, deep depression, between Kea (Ke) and the Kythnos (Ky) Islands. A similar, narrow and deep, strait separates the Serifos and Sifnos Islands and terminates in the Myrtoon Basin (MB). The **Hydra East** area highlights two mounts occurring at the western margin of the Myrtoon Basin.

The 700 m deep, South Ikaria Basin (SIB) separates the wide shelf of Anatolia from the central part of the Cyclades Plateau. Here the main morphological elements of the seafloor and of the non-volcanic islands are aligned along the two main trends of the major tectonic elements. The **South Ikaria** area includes several small and larger mounts occurring in the South Ikaria Basin.

The southern margin of the Cyclades Plateau hosts the Hellenic Volcanic Arc (Fig. 2.20). Its outward outline displays a complex morphology and coincides with the tectonically controlled margins of important basins (Myrtoon, Christiana, Heraklion and Amorgos Basins). The western sector of the South Aegean seafloor is marked by the Argolic Gulf (ArB) and Maleas (MaB) Basins, two elongated 1000-1200 m deep basins that developed along the eastern flanks of the Peloponnese and Kythera-Antikythera Ridge. A narrow ridge separates the Argolic Gulf from the composite 1100 m deep Myrtoon Basin and the Maleas from a morphologically "chaotic" area extending southwest of Milos Island (Mi). Three areas, namely **Maleas**, **Myrtoon** and **South Milos** (Fig. 2.21) highlight the complex topography and the presence of numerous shallow banks. A fourth area, namely **Antikythera-Gramvousa**, encompasses the irregular ridges and shallow summits southeast of Antikythera Island and north of the NW edge of Crete.

The south and south-eastern part of the South Aegean displays an even more complex morphology (Fig. 2.20). The entire area, encompassing the 500 m deep flat Christiana Basin (ChB) in the west and the 400-500 m deep Anydhros (AnB) and the 700 m deep Amorgos (AmB) elongated Basins in the east, hosts the volcanic group of Thera Island (Santorini). Further south, it is the almost 2000 m deep Heraklion Basin (HB). The area **Santorini** includes the submarine cones and domes associated with the Santorini volcanic province along with morphological highs of tectonic origin. The **Anafi East** and **Astypalea Ridge** areas (Fig. 2.21) include mounts and ridges developed along or within the complex Santorini-Amorgos Fault Zone.

A series of shallow ridges and narrow depressions separate the Heraklion Basin (HB) from the > 2000 m deep Kamilonissi Basin (KaB). The southeast corner of the South Aegean is marked by two deep South and North Karpathos Basins (SK and NK) more than 2500 m deep, which constitutes a negative, mirror-image, of the Karpathos and Kassos Islands landscape (Fig. 2.20). The **Syrna**, **Tilos East**, **Avgo**, **Saria East** and **East Cretan Strait** (Fig. 2.21) areas represent the individual or groups of shallow mounts developed due to tectonic processes along the margins of the major basins of the SE Aegean Sea.

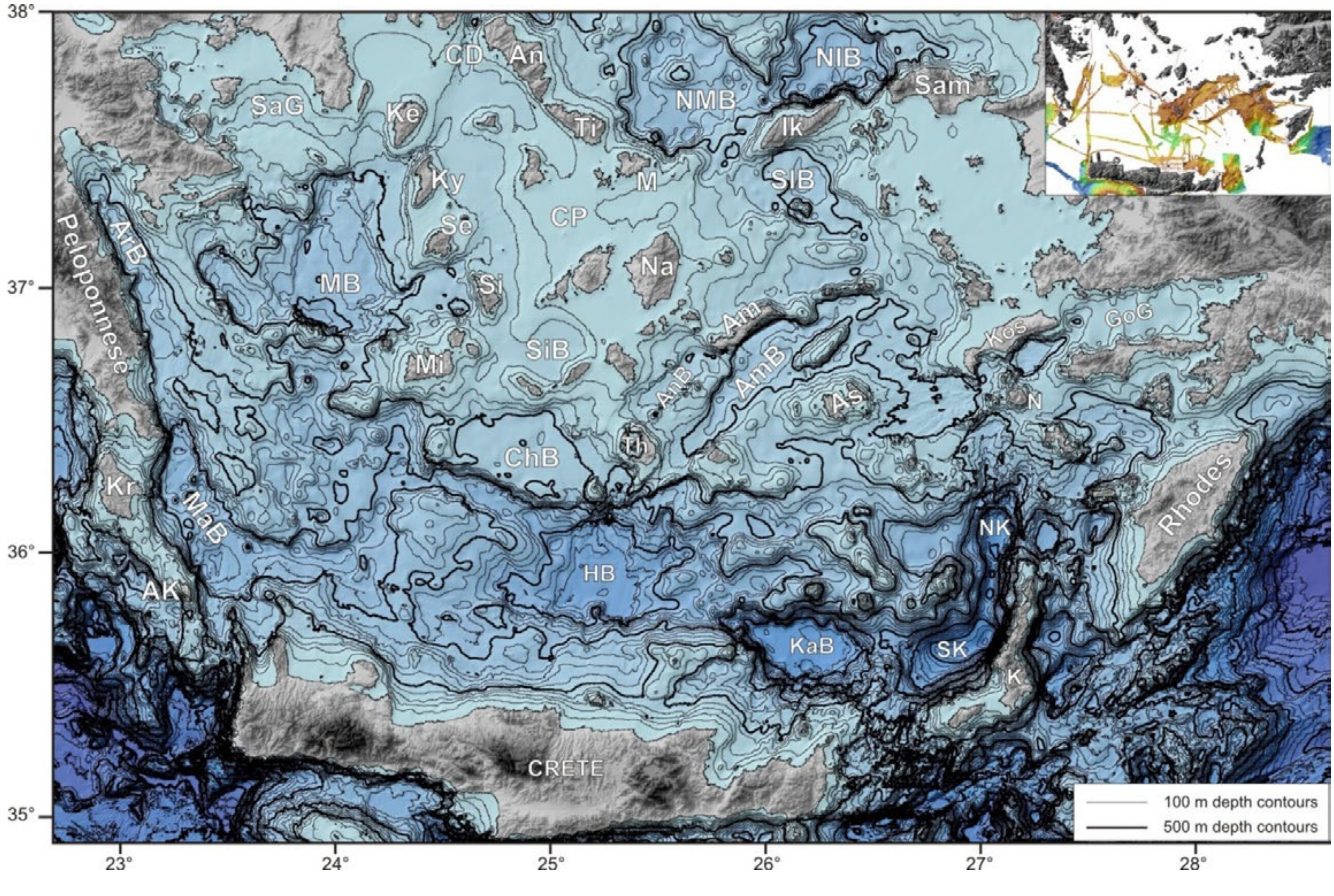

Fig. 2.20. Updated bathymetry of the South Aegean Sea.

Derived from GEBCO and swath bathymetry data processed at 250 m grid10, 3 https://emodnet.eu/bathymetry). Inset map: Swath bathymetry coverage in the South Aegean. AK: Antikythera, Am: Amorgos, AmB: Amorgos Basin, An: Andros, AnB: Anydhros Basin, ArB: Argolikos Basin, As: Astypalaea, CD: Cavo Doro Strait, ChB: Christiana Basin, CP: Cyclades Plateau, GoG: Gulf of Gokova, HB: Heraklion Basin, Ik: Ikaria, K: Karpathos, KaB: Kamilonisi Basin, Ke: Kea, Kr: Kythera, Ky: Kythnos, M: Mykonos, MaB: maleas Basin, MB: Myrtoon Basin, Mi: Milos, N: Nisyros, Na:Naxos, NIB: North Ikaria Basin, NK: North Karpathos Basin, NMB: North Mykonos Basin, SaG: Saronic Gulf, Sam: Samos, Se: Serifos, Si: Sifnos, SiB: Sikinos Basin, SIB: South Ikaria Basin, SK: South Karpathos Basin, Th: Thera, Ti: Tinos.

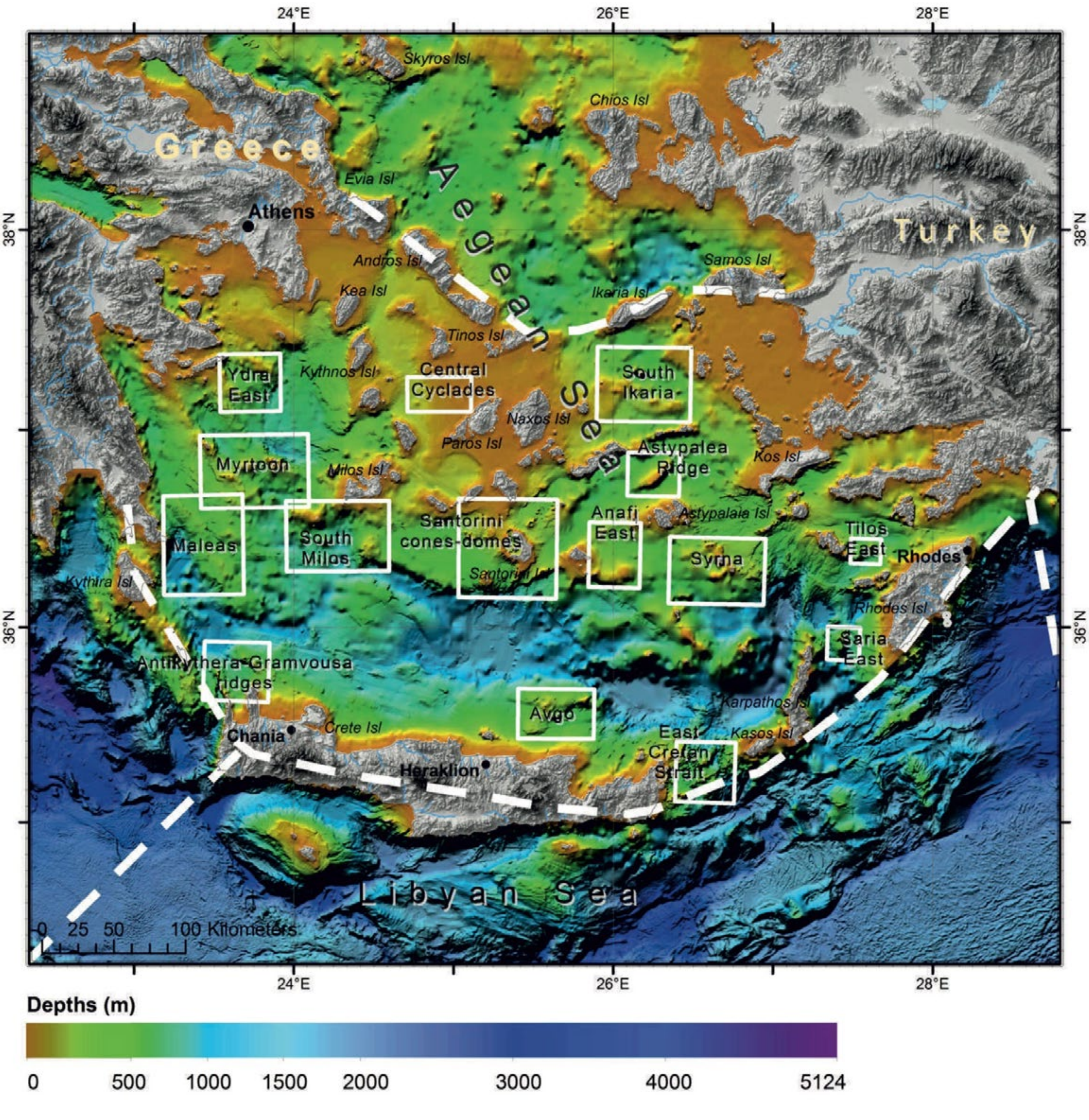

Fig. 2.21. Location of the seamount areas in the South Aegean Sea discussed in this chapter.

Table 2.3. South Aegean Sea Seamounts and Seamount-like structures.

			Minimum Depth / Location			Maximum Depth / Location				
GROUP NAME	Seamount	Area (km²)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Depth Range (m)	Mean Slope (deg)
HYDRA EAST	Hydra East	581.73	37.342668	23.751942	127	37.333258	23.942850	813	686	2.72
	Agios Nikolaos	50.58	37.165571	23.716588	346	37.176888	23.754298	711	365	3.48
CENTRAL CYCLADES	Herronissos	40.40	37.135385	24.777193	181	37.152366	24.753624	275	94	1.13
SOUTH IKARIA	Donoussa	496.85	37.195745	26.009851	63	37.274893	26.054632	406	343	1.50
			37.210827	25.920289	89					
	Ikaria twins	100.53	37.286193	26.184262	145	37.271126	26.153622	629	484	5.66
			37.303140	26.139481	218					
	Apocalypse	39.81	37.193859	26.408167	304	37.212712	26.386955	548	244	2.82
	Kinaros	253.92	37.144820	26.266753	112	37.182545	26.287965	452	340	1.67
	Levitha	224.49	37.114626	26.361029	138	37.180660	26.342174	438	300	2.24
MYRTOON SEA	Velopoula South East	80.83	36.836648	23.565747	315	36.872635	23.575174	791	476	3.33
	Karavi West	202.41	36.768416	23.563390	139	36.783584	23.499753	498	359	2.37
	Karavi South	312.46	36.645064	23.601100	299	36.711510	23.799080	691	392	2.08
			36.694429	23.766083	320					
			36.662156	23.707161	331					
	Falkonera West	246.87	36.823386	23.723659	167	36.882102	23.730730	667	500	3.16
	Ananes North	52.18	36.703919	24.034770	297	36.684938	24.020628	730	433	4.23
	Ananes West	138.07	36.652661	23.869787	370	36.681142	23.862716	931	561	3.84
MALEAS	Monemvasia Ridge	325.98	36.586165	23.346555	364	36.523415	23.297060	792	428	1.88
	Velanidia	357.86	36.477747	23.596386	308	36.593767	23.561033	633	325	1.60
	Diakofti	218.63	36.216537	23.327700	759	36.258543	23.308845	1310	551	4.45
			36.203167	23.252279	917					
			36.273812	23.337127	922					
	Cavo Malea	550.28	36.315787	23.553962	347	36.262360	23.398407	1113	766	2.38
SOUTH MILOS	Ananes	460.03	36.512001	24.126689	0.5	36.610870	23.961706	887	886.5	4.06
	Fyriplaka	540.34	36.420623	24.449584	198	36.281445	24.395375	1036	838	3.18
SANTORINI	Sikinos South	124.35	36.458710	25.111872	183	36.491070	25.010526	546	363	3.03
	Kolumbo volcanic chain	169.82	36.521513	25.472478	84	36.527220	25.488976	507	423	3.18
	Christiana East	13.85	36.252816	25.319280	336	36.243271	25.331064	683	347	7.49
	Perissa Ridge	136.34	36.273812	25.538471	178	36.210807	25.411199	1017	839	7.53
ANAPHI EAST	Anaphi East	82.58	36.487263	25.941501	176	36.500584	25.899077	400	224	2.08
	Makra East	281.38	36.268086	26.064060	78	36.224176	25.948572	413	335	2.44
ASTYPALEA RIDGE	Astypalea Ridge	412.97	36.760831	26.283251	32	36.686837	26.108841	587	555	3.93

			Minimum Depth / Location			Maximum Depth / Location				
GROUP NAME	Seamount	Area (km²)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Depth Range (m)	Mean Slope (deg)
SYRNA MOUNDS	Sofrana West	81.70	36.159220	26.419952	278	36.201257	26.422308	699	421	5.74
	Syrna West	29.37	36.355832	26.610860	176	36.352019	26.582578	374	198	2.85
	Plakida west	95.94	36.254725	26.629716	18	36.239452	26.596719	609	591	4.72
TILOS EAST MOUNDS	Antitilos	57.92	36.348206	27.520624	374	36.321509	27.506482	898	524	4.68
	Livadia	42.87	36.411099	27.619613	256	36.386329	27.621970	511	255	4.20
GRAMVOUSA	Kissamos	308.23	35.816350	23.751942	227	35.852815	23.594029	1114	887	4.67
			35.845140	23.693019	331					
	Balos Ridge	208.05	35.664550	23.570460	78	35.833625	23.485612	1000	922	6.73
SARIA EAST	Saria East	238.22	35.983184	27.454630	164	35.868164	27.454630	1096	932	6.10
EAST CRETAN STRAIT	Sidero	59.43	35.321451	26.514228	252	35.400610	26.509514	1098	846	8.76
	Fry	151.34	35.315656	26.568436	203	35.344628	26.641500	1196	993	9.53
	Palaikaston	31.99	35.232545	26.592005	253	35.201598	26.530726	646	393	8.50
	Zakros	181.92	35.178380	26.627359	105	35.149348	26.690995	1501	1396	9.46
AVGO MOUND	Avgo East	70.30	35.627997	25.828370	129	35.602978	25.771804	622	493	5.99

HYDRA EAST MOUNTS (FIG. 2.22)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Hydra East	581.73	127	813
Agios Nikolaos	50.58	346	711

The western margin of the 800-1000 m deep Myrtoon basin is dominated by morphological highs which mark the eastward, underwater prolongation of the Argolid Peninsula east of Hydra Island.

Hydra East ridge is a 20 km long, E-W oriented, irregular ridge located east of Hydra Island. The eastern flank of the ridge faces the 800 m deep seafloor of the northern Myrtoon Basin. The shallowest summit of the ridge is found at a depth of 127 m.

The small, circular **Agios Nikolaos mound** is located to the south of the Hydra East ridge. The depth of its summit is 345 m and it marks the south-eastern tip of the morphological ridge, which extends from the southern coast of Hydra Island towards the SE.

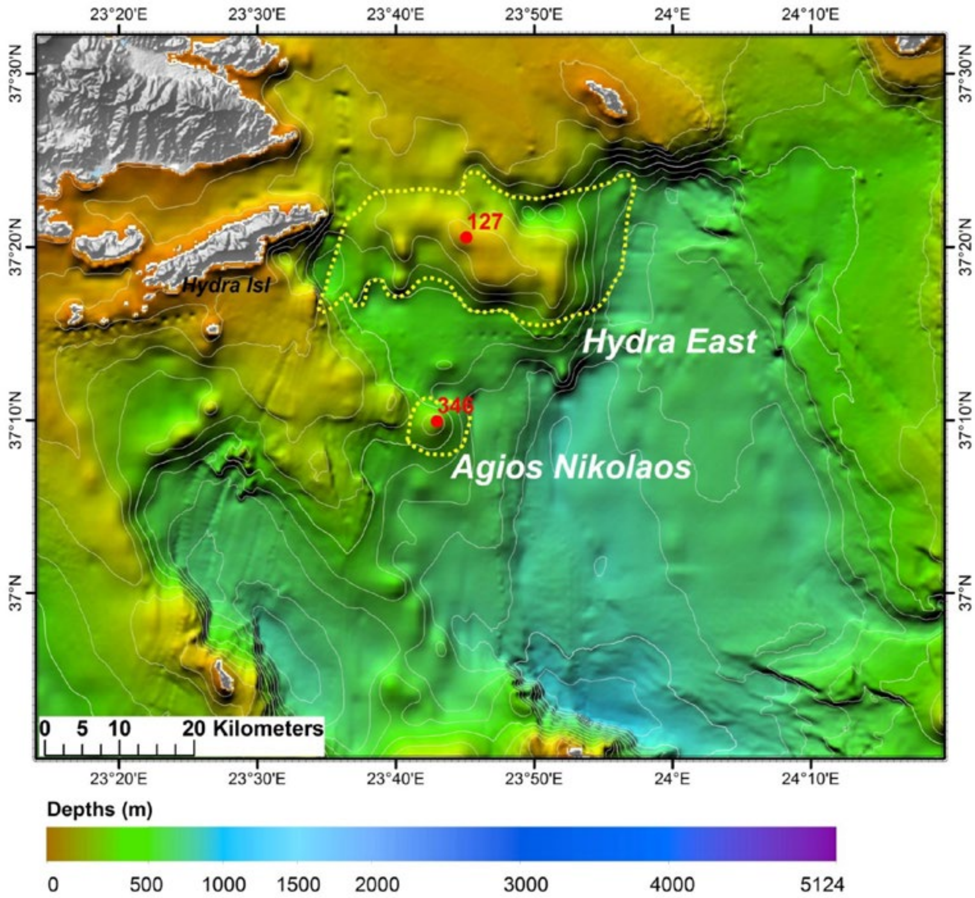

Fig. 2.22. Shaded relief map of the Hydra East mounts area.

The outline and the tops of the observed features are indicated on the map.

CENTRAL CYCLADES MOUNTS (FIG. 2.23)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Central Cyclades Mounts	40.40	181	275

The circular **Herronissos mound** with its summit at a depth of 181 m has been named after the Herronissos village and bay at the northern tip of Sifnos Island. The area of the mount has not been surveyed by means of systematic bathymetry, thus the exact shape and depth of its summit may differ from those observed.

The second, small mount shown east of Herronissos rises above the sea level forming the rocky Mermigkas Islet.

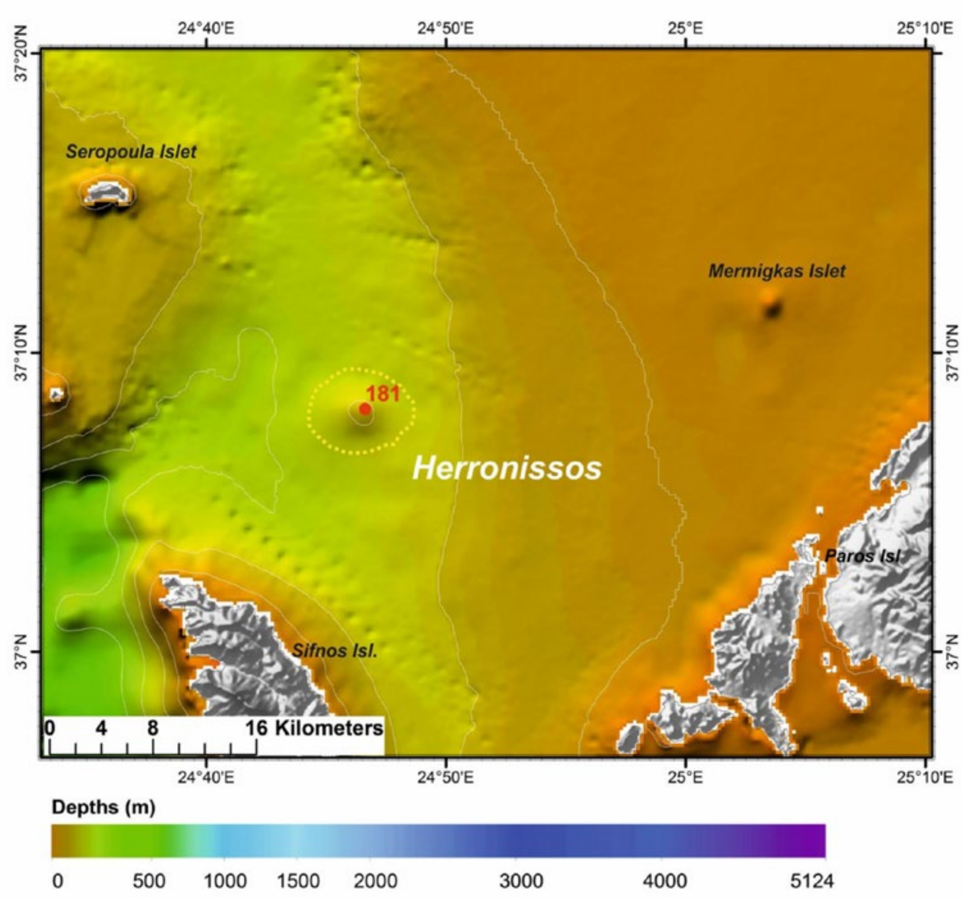

Fig. 2.23. Shaded relief map of the Central Cyclades area.

The outline and the tops of the observed features are indicated on the map.

SOUTH IKARIA MOUNDS (FIG. 2.24)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Donoussa	496.85	63	406
Ikaria twins	100.53	145/218	629
Apocalypse	39.81	304	548
Kinaros	253.92	112	452
Levitha	224.49	138	438

The South Ikaria basin, has developed in a NW-SE direction between the Central Cyclades plateau to the west, the shelf of Patmos Island to the east, the Ikaria Island to the North and the islets of Kinaros and Levitha to the South. The floor of the basin displays complicated morphology with many morphological and structural highs. The most prominent highs in this area are highlighted here.

The **Ikaria Twins** is a semi-circular mound with two summits at depths of 145 m and 218 m which rise from the surrounding, 500-600 m deep seafloor of the basin.

Apocalypse mount rises at a depth of 304 m and is named after the homonymous monastery on Patmos Island.

The **Kinaros** and **Levitha mounds** mark the two summits at depths of 112 m and 138 m of an E-W direction morphological ridge in the southern part of the South Ikaria basin.

The **Donoussa mounds** mark the shallow feature at the eastern edge of the Central Cyclades plateau, at the western margin of the South Ikaria basin. The two highest summits are located at depths of 63 m and 89 m rising from the 150-200 m deep rather flat plateau.

The entire area of the South Ikaria mounts has not been surveyed by means of systematic bathymetry, therefore the morphological characteristics described here are subject to improvement in the future.

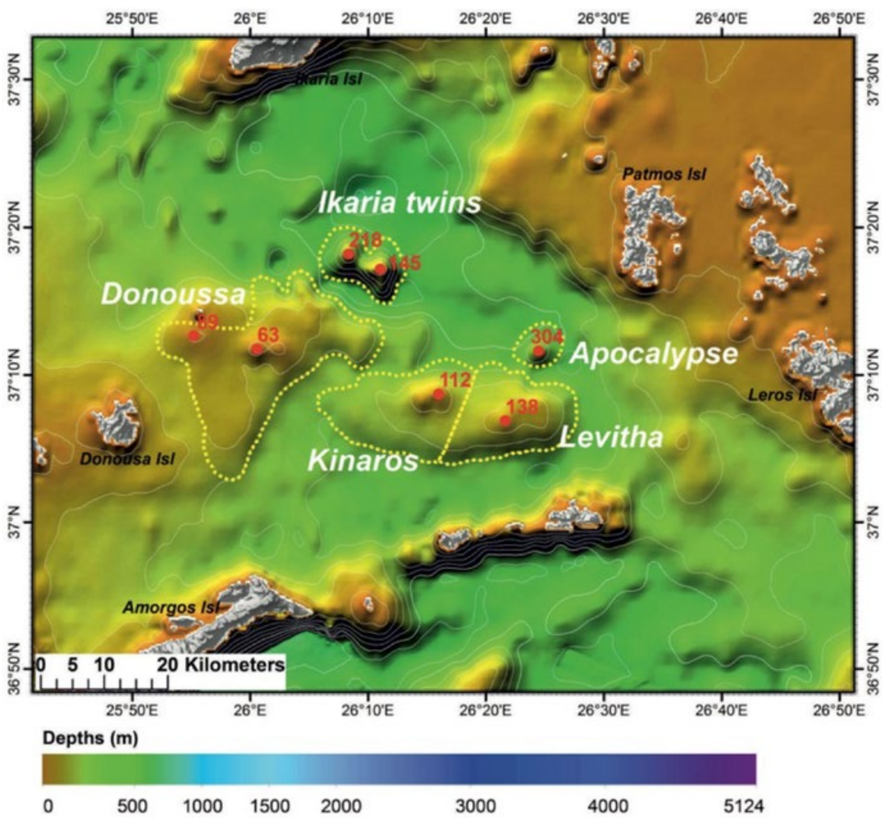

Fig. 2.24. Shaded relief map of the South Ikaria mounds area.

The outline and the tops of the observed features are indicated on the map.

MYRTOON MOUNDS (FIG. 2.25)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Velopoula South East	80.83	315	791
Karavi West	202.41	139	498
Karavi South	312.46	299	691
Falkonera West	246.87	167	667
Ananes North	52.18	297	730
Ananes West	138.07	370	931

The southern, fault controlled, steep margin of the Myrtoon Basin displays a complicated morphological structure with numerous highs and mounds, some of which rise above the sea level (Falkonera, Velopoula, Karavi islets), and are separated from each other by deeper valleys.

Falkonera West is a rather circular mound rising from a depth of 600-700 m to 167 m. It is separated from the Falkonera Islet by a 450 m deep morphological neck.

Velopoula South East is located southeast of Velopoula Islet and its summit is found at a depth of 315 m.

Karavi West is a 139 m shallow bank located west of the Karavi Islet.

Karavi South is a group of small mounds with their summits at depths of 299 m, 320 m and 331 m, located to the South and Southeast of Karavi Islet.

Ananes West and **Ananes North** are two circular mounds named after the volcanic Ananes Islets, with their shallowest points at 370 m and 297 m respectively.

The entire area of Myrtoon mounds has not been surveyed be means of systematic bathymetry, therefore the morphological characteristics described here are subject to improvement in the future.

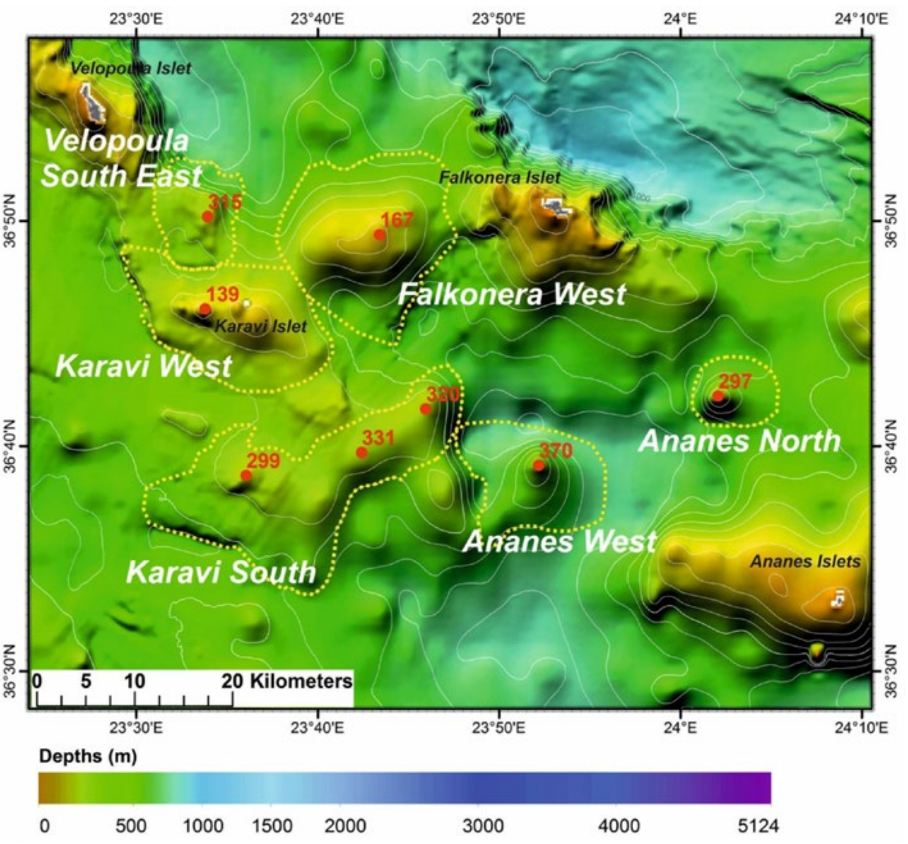

Fig. 2.25. Shaded relief map of the Myrtoon mounts area.

The outline and the tops of the observed features are indicated on the map.

MALEAS SEAMOUNTS (FIG. 2.26)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Monemvasia Ridge	325.98	364	792
Velanidia	357.86	308	633
Diakofti	218.63	759	1310
Cavo Malea	550.28	347	1113

The Maleas Basin is a NNW-SSE oriented, elongated, more than 1100 m deep basin, developed in line with and south of the Argolid Basin, along the eastern margin of the Peloponnese. The evolution of the basin is controlled by a NNW-SSE trending, predominantly extensional faults which run along both the western and the eastern margins of the basin. Towards the East, the Maleas Basin is bounded by an oriented shallow, composite ridge with the shallowest parts rising up to 200-300 m higher from the shallow plateau.

Monemvasia Ridge is a 15-20 km long elongated feature located opposite the historical castle and village of Monemvasia. The shallowest summit of the narrow crest of the ridge is found at a depth of 364 m.

Velanidia mount is located east of Monemvasia Ridge. It displays an irregular shape and rises at a depth of 308 m, roughly 200 m higher from its base. The ridge is named after the picturesque village overlooking the South Aegean Sea from the eastern flank of the mountainous Maleas Peninsula of the Peloponnese.

The **Cavo Malea ridge** is located on the southwestward prolongation of the Monemvasia ridge, with its summit rising at a depth of 347 m. It is named after Cape Maleas, the southeasternmost tip of the Peloponnese.

Diakofti mounts is a group of small mounts that rise from the more than 1200 m deep floor of the Maleas Basin, east of Kythera Island. The summits of the most prominent mounts are found at depths of 759 m, 917 m and 922 m. However, due to the lack of accurate bathymetric surveys, the precise depth of the mounts is subject to revision.

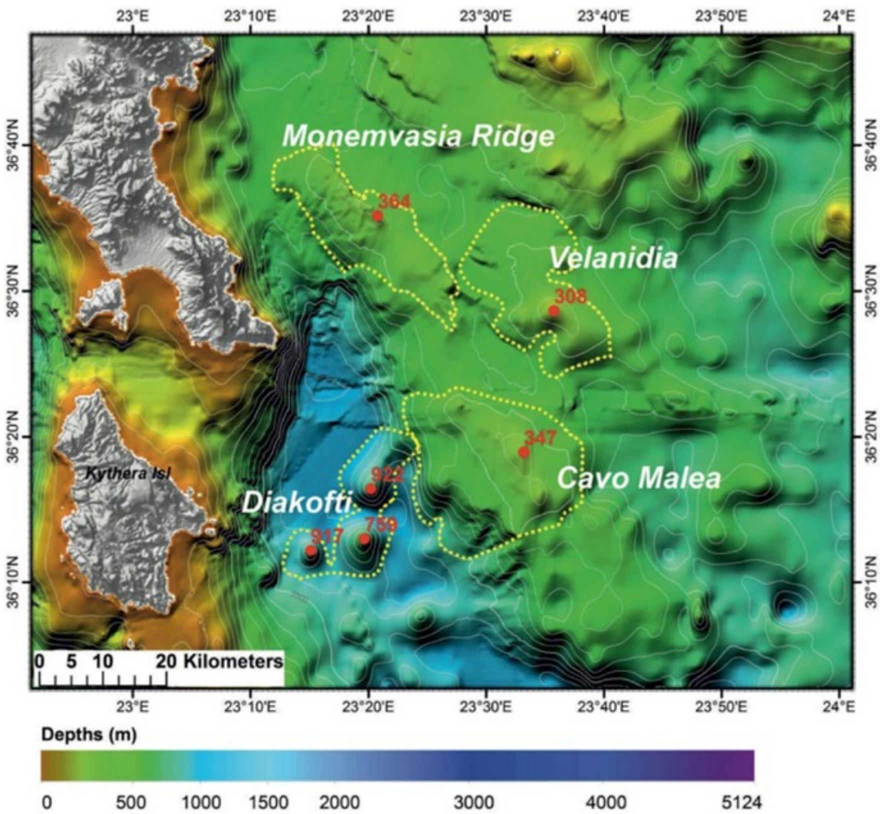

Fig. 2.26. Shaded relief map of the Maleas mounts area.

The outline and the tops of the observed features are indicated on the map.

SOUTH MILOS SEAMOUNTS (FIG. 2.27)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Ananes	460.03	0.5	887
Fyriplaka	540.34	198	1036

The **Ananes seamount** is located southwest of the volcanic Milos Island. The seamount displays several summits at depths shallower than 100 m. The highest summit rises above sea-level forming the group of small, rocky islets called Ananes, while the second highest summit is slightly submerged. Ananes Islets are formed of volcanic rocks. Thus, it is assumed that a large part of the Ananes seamount may be of volcanic origin too. The base of the seamount displays a circular shape and varies between a depth of 600 m and 800 m.

Fyriplaka seamount is located south of Milos Island. It is a circular mount with the base of the slopes located at a depth of roughly 1000 m in the West and South and at 500 m in the East. The summit of the mount rises at a depth of 198 m and is named after the spectacular volcano in Fyriplaka on Milos Island. However, marine geological surveys conducted in the area suggest a non-volcanic origin for the Fyriplaka seamount.

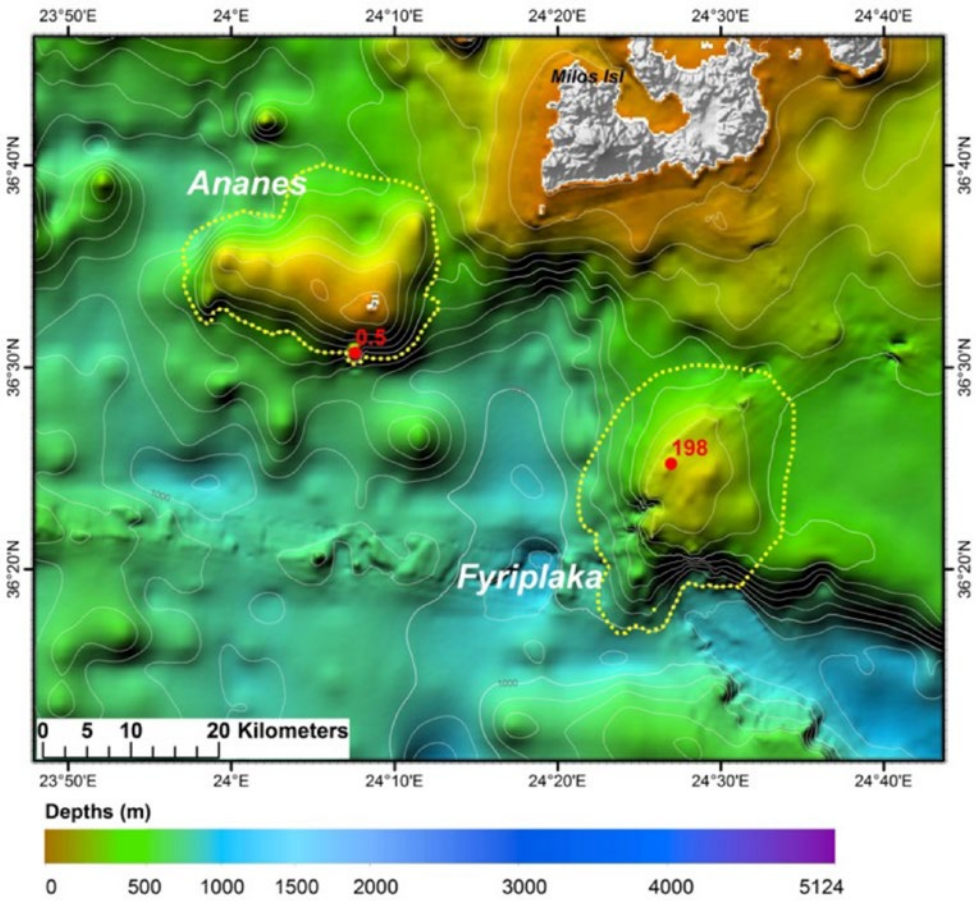

Fig. 2.27. Shaded relief map of the South Milos mounts area.

The outline and the tops of the observed features are indicated on the map.

SANTORINI MOUNTS (FIG. 2.28)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Sikinos South	124.35	183	546
Kolumbo volcanic chain	169.82	84	507
Christiana East	13.85	336	683
Perissa Ridge	136.34	178	1017

Santorini Island is world famous for its volcanic landscape and offers some of the most spectacular geomorphological and geological features of volcanic origin, including the large caldera and the steep walls surrounding it, composed of successive lava flows.

The volcanic province of Santorini includes the Christiana Islets and a large number of submarine volcanic domes. The latter are grouped here into two groups: Christiana East and the Kolumbo volcanic chain.

Christiana East is a group of small mounds, volcanic domes, located east of the Christiana Islets, with the highest summit rising at a depth of 336 m while the surrounding seafloor is at 600-700 m.

The **Kolumbo volcanic chain** is a group of more than 20 volcanic cones and domes arranged in a NE-SW direction within the 300-350 m deep, flat Anydros Basin. The most prominent feature among them is the Kolumbo submarine volcano, which erupted in 1650 and trig-

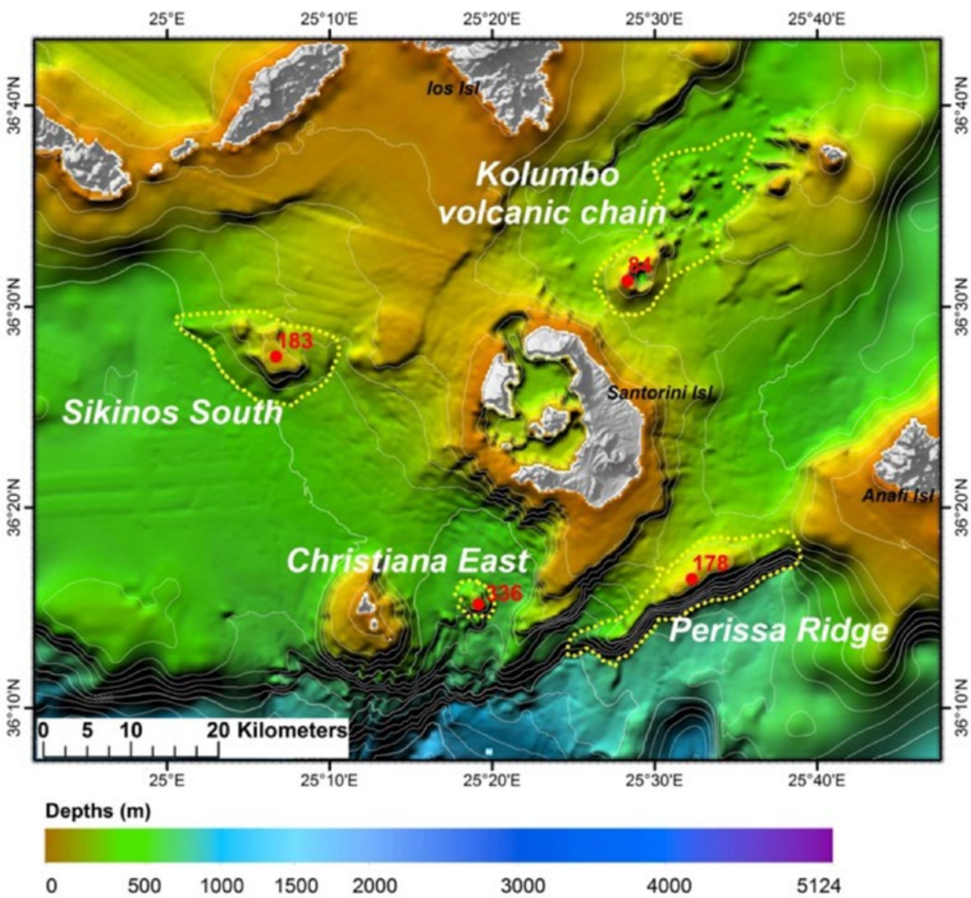

Fig. 2.28. Shaded relief map of the Santorini mounts area.

The outline and the tops of the observed features are indicated on the map.

gered a large tsunami with catastrophic impact on the nearby islands. Kolumbo displays a circular shape with a 500 m deep caldera in the centre. The rim of the submarine caldera rises at a depth of less than 100 m. The majority of the other volcanic domes of the Kolumbo chain rise several tens of metres higher than the surrounding basin's floor.

The **Sikinos South mount** is a shallow plateau (< 200 m) rising from a 300-500 m deep surrounding seafloor. Unlike the volcanic Christiana and Kolumbo domes, Sikinos South mount represents a structural high of the non-volcanic basement.

Perissa ridge is a 20 km long, NE-SW oriented narrow ridge located south of Santorini and southwest of Anafi Island. The shallowest point of the ridge rises at a depth of 178 m and is bounded both to the North and South by fault controlled steep slopes. The Perissa ridge marks a tectonically uplifted block of the non-volcanic basement of the area. It is named after Perissa beach on Santorini, which is famous for the dark coloured (black) sand and pebbles.

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ANAFI EAST MOUNTS (FIG. 2.29)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Anaphi East	82.58	176	400
Makra East	281.38	78	413

Two shallow mounts are located on the seafloor between the islands of Anafi and Astypalaea.

Anafi East is an elongated mount in a NE-SW direction which rises at a depth of 176 m. Seismic profiles acquired close to the mount suggest that the rocky basement is exposed on the seafloor at the summit of the mount.

Makra East is named after the small islet south of Anafi Island. It is an ENE-WSW elongated mount with its summit rising at a depth of 78 m. Towards the west, the mount faces an 800 m deep basin while the eastern, southern and northern bases of the mount are 300-400 m deep.

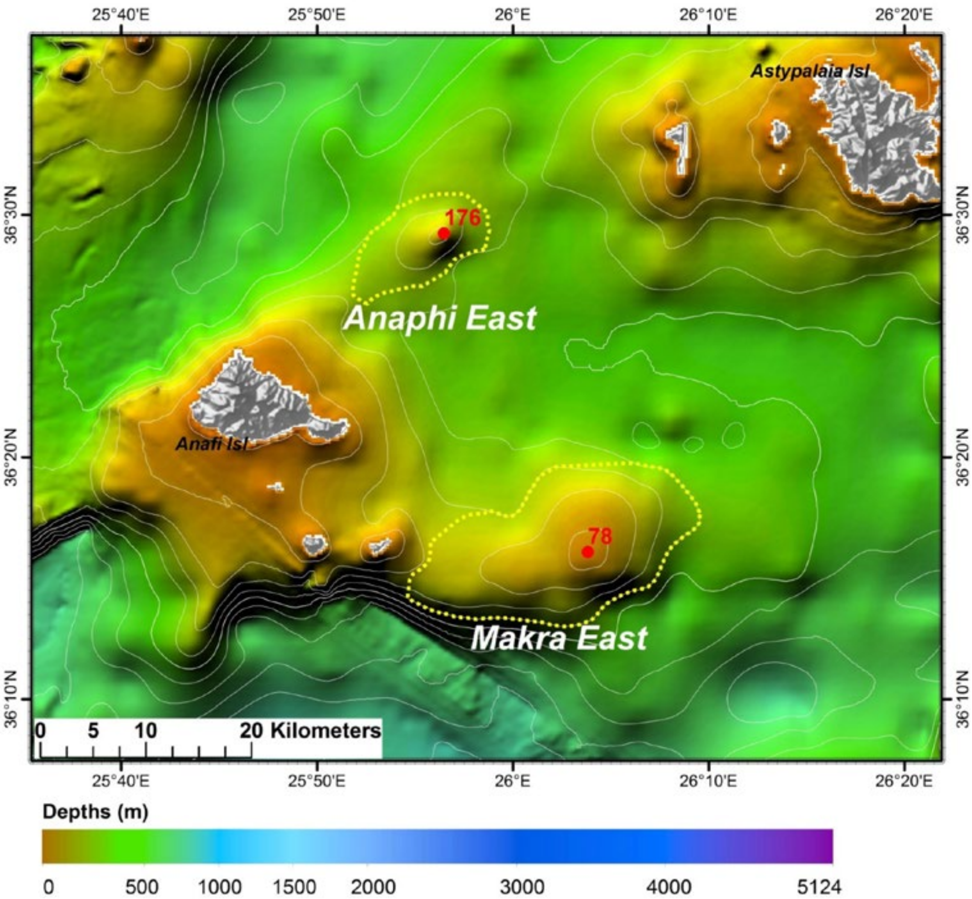


Fig. 2.29. Shaded relief map of the Anafi East mounts area.

The outline and the tops of the observed features are indicated on the map.

ASTYPALEA RIDGE (FIG. 2.30)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Astypalea Ridge	412.97	32	587

Astypalea ridge, between Amorgos Island to the North and Astypalea Island to the South, is an asymmetric morphological feature characterized by a steep south-eastern slope and a gently sloping north-western slope. The length of the ridge is roughly 30 km and its shallowest summit is found at a depth of 32 m. The depth at the base of the slopes on both sides of the ridge is roughly 600 m. Seismic profiling data indicate that the tectonically uplifted ridge is built by Plio-Quaternary sediments.

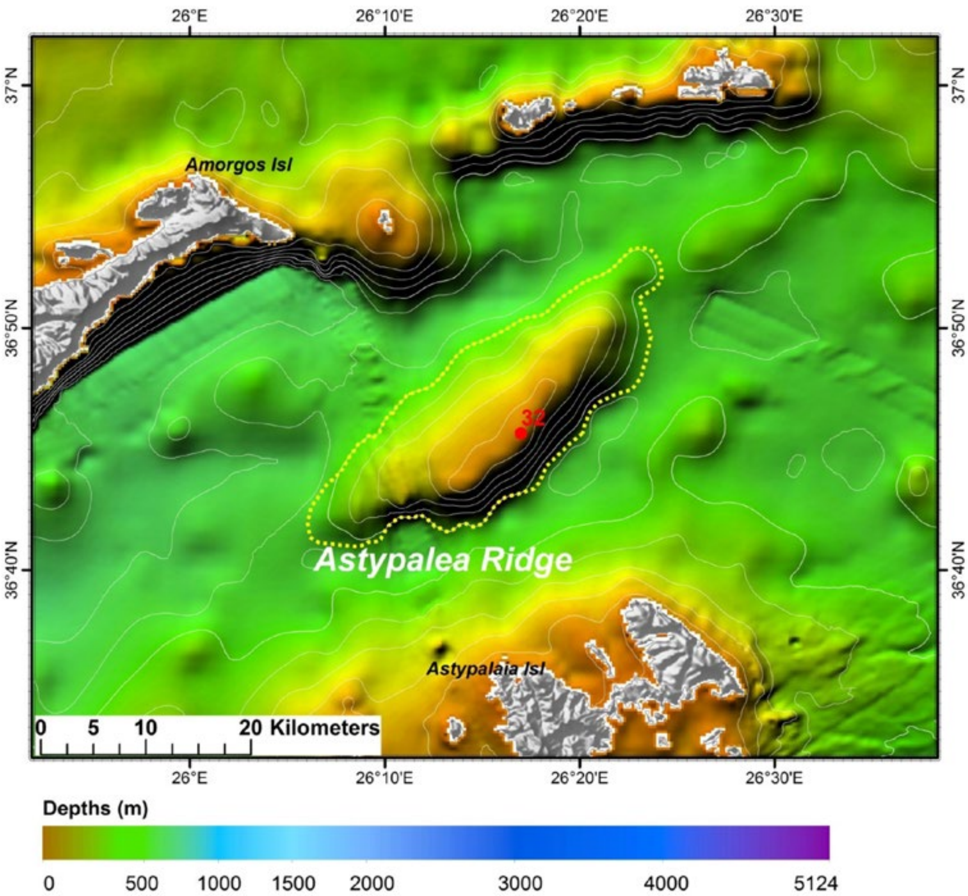


Fig. 2.30. Shaded relief map of the Astypalea ridge.

The outline and the tops of the observed features are indicated on the map.

SYRNA MOUNDS (FIG. 2.31)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Sofrana West	81.70	278	699
Syrna West	29.37	176	374
Plakida west	95.94	18	609

The seafloor of the area around the Syrna, Plakida and Sofrana islets is characterized by complicated topography with numerous morphological highs and lows and steep slopes.

Next to Syrna and Plakida islets, the **Syrna West** and **Plakida West** banks are the two shallowest summits of a composite seamount which rises from the surrounding 400-500 m deep seafloor. They rise at depths of 176 m and 18 m respectively and are composed of the rocky basement of the area.

Sofrana West is a semi-circular mound with two summits, the shallowest of which rises at a depth of 278 m.

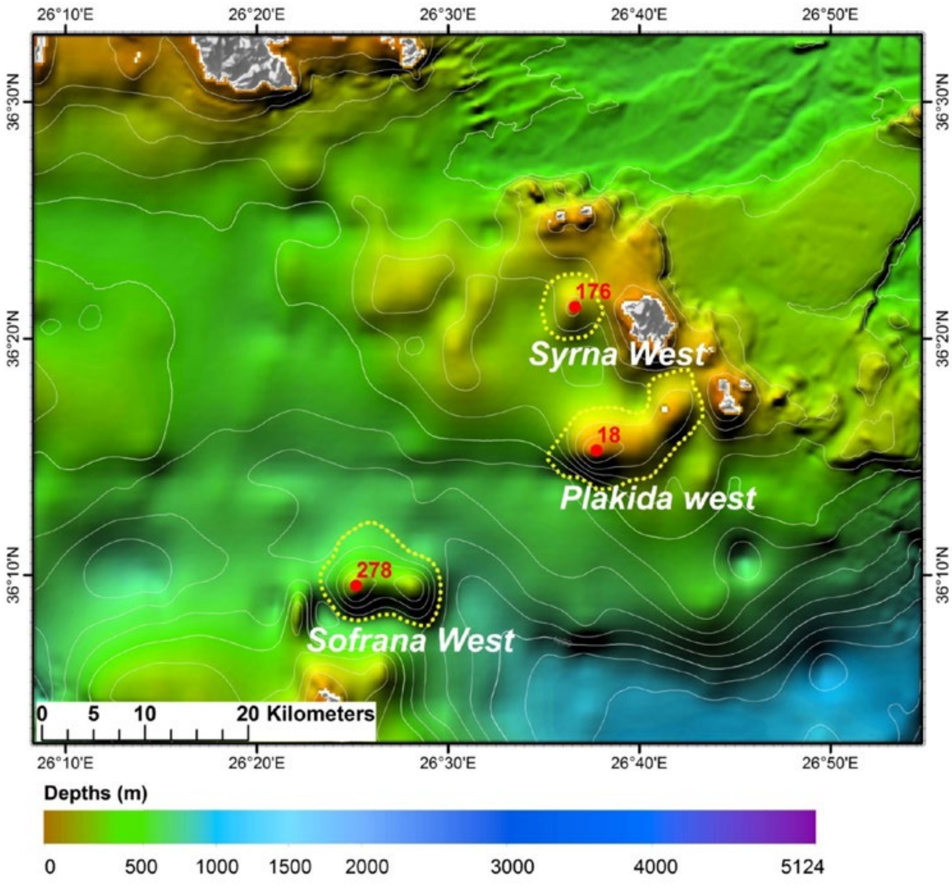


Fig. 2.31. Shaded relief map of the Syrna mounds area.

The outline and the tops of the observed features are indicated on the map.

TILOS EAST MOUNDS (FIG. 2.32)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Antitilos	57.92	374	898
Livadia	42.87	256	511

Two small mounds rise from the 600-700 m depth seafloor east of Tilos Island.

Antitilos mound has its summit at a depth of 374 m and is located east of Antitilos Islet.

Livadia mound is a circular mount with its summit at a depth of 256 m. It is named after the main village and harbour of Tilos Island.

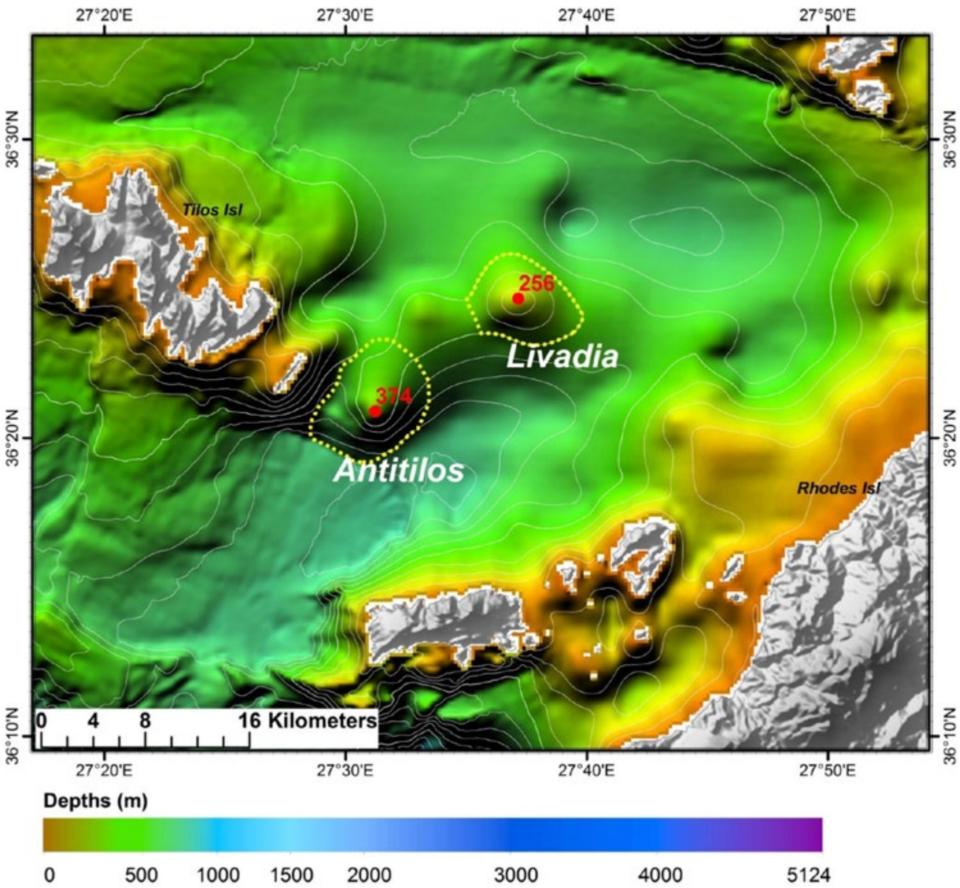


Fig. 2.32. Shaded relief map of the Tilos East mounds area.

The outline and the tops of the observed features are indicated on the map.

GRAMVOUSA RIDGES (FIG. 2.33)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Kissamos	308.23	227	1114
Balos Ridge	208.05	78	1000

The two elongated, N-S oriented, mountainous peninsulas at the north-western edge of Crete, Balos and Gramvousa, prolong northwards below the sea level forming two pronounced ridges.

Balos Ridge is located at the northward prolongation of the Balos Peninsula. It is a 20 km long ridge with steep slopes dipping down to > 1000 m. The shallowest summit of the crest of the ridge is 78 m deep and located at a short distance from the northern tip of the Balos Peninsula. Several other summits along the crest further north, rise at depths shallower than 200 m.

Kissamos Ridge is located north of the Gramvousa Peninsula and is NW-SE oriented. It is characterized by two summits, 227 m and 331 m deep, while the surrounding seafloor is > 1000 m deep.

Both ridges described here are composed of the geological basement formations occurring on nearby NW Crete.

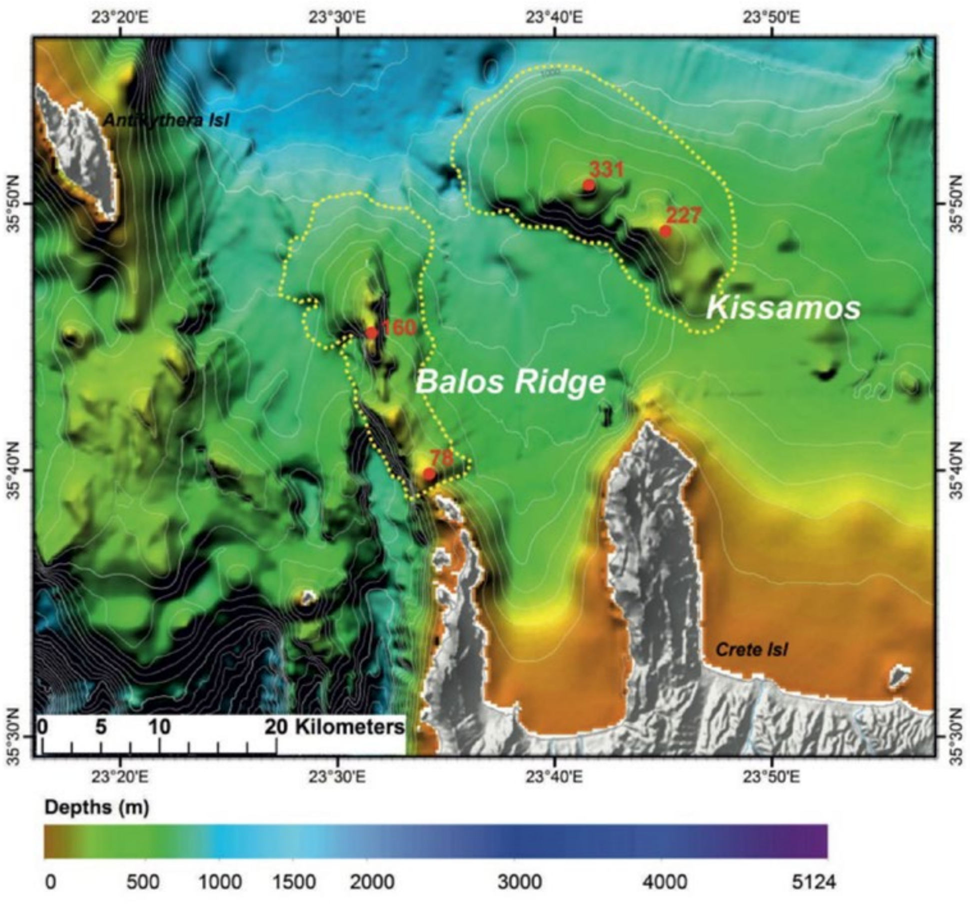


Fig. 2.33. Shaded relief map of the Gramvousa ridges area.

The outline and the tops of the observed features are indicated on the map.

AVGO EAST MOUND (FIG. 2.34)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Avgo East Mound	70.30	129	622

Avgo Islet marks the summit of an irregularly shaped morphological feature to the north of Central Crete. **Avgo East** marks the shallowest of a group of summits located at the eastern part of that feature overlooking the > 2000 m deep Kamilonissi Basin. The summit of Avgo East is at a depth of 120 m and is surrounded by steep slopes plunging to 700 m to the south and > 1500 m to the north.

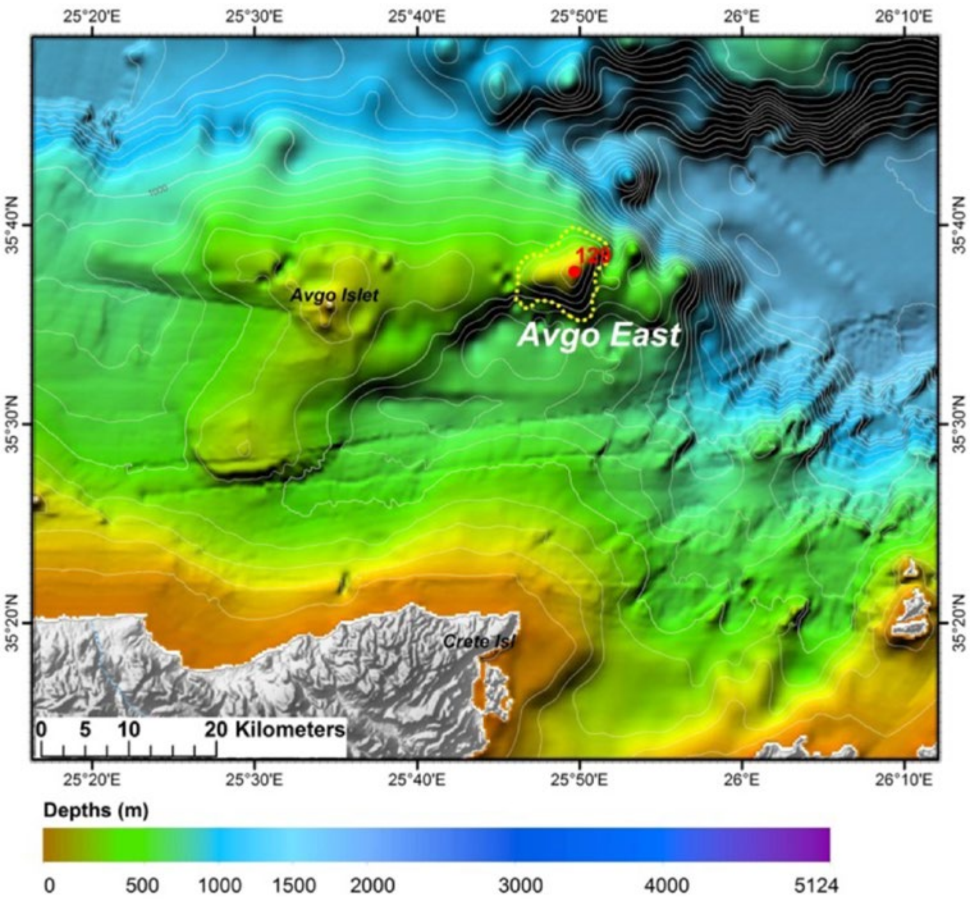


Fig. 2.34. Shaded relief map of the Avgo East mounts area.

The outline and the tops of the observed features are indicated on the map.

SARIA EAST SEAMOUNT (FIG. 2.35)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Saria East Seamount	238.22	164	1096

The seafloor between Karpathos and Rhodes displays a very complicated morphology, with local depressions and shallows, which are the result of the ongoing tectonic activity along the eastern sector of the Hellenic Arc.

Saria East is the most pronounced seamount in this area. It is located east of Saria Island and its shallowest summit rises at a depth of 164 m. Saria East mount is separated from Karpathos Island (West) and Rhodes Island (East) by two, 600-800 m deep, N-S oriented valleys.

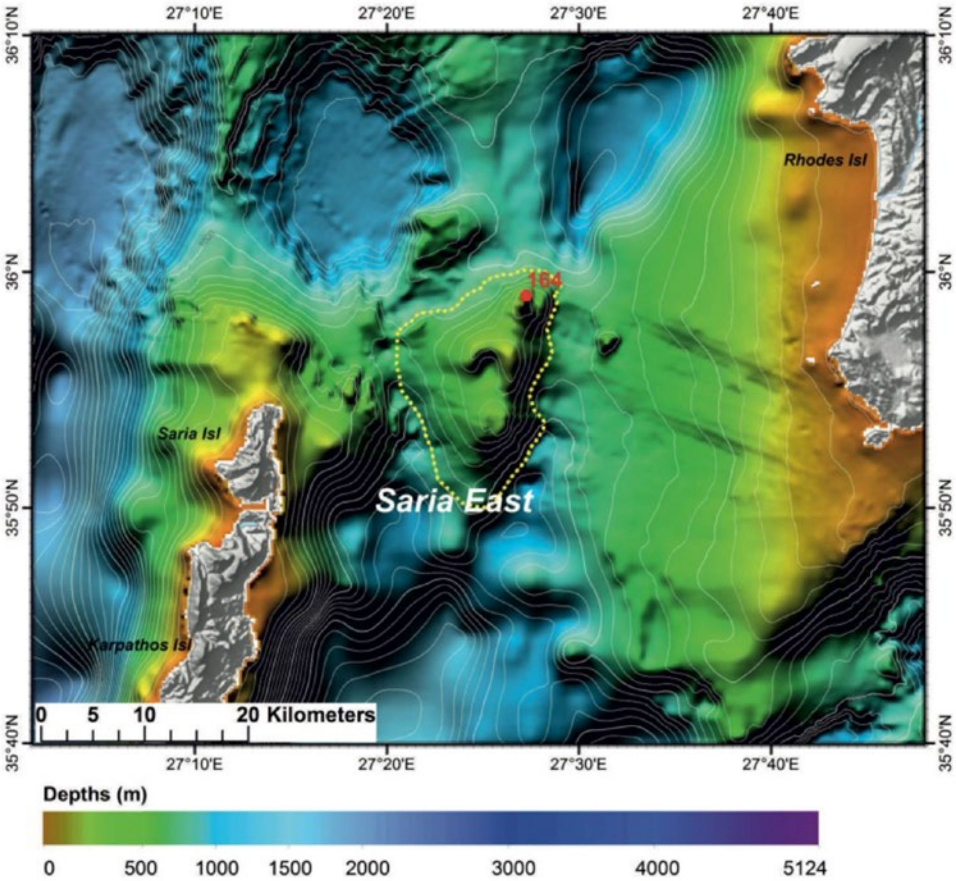


Fig. 2.35. Shaded relief map of the Saria East Seamount area.

The outline and the tops of the observed features are indicated on the map.

EAST CRETAN STRAIT MOUNTS (FIG. 2.36)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Sidero	59.43	252	1098
Fry	151.34	203	1196
Palaikaston	31.99	253	646
Zakros	181.92	105	1501

The seafloor of the East Cretan Strait, between Crete and Kassos Island is spectacular in its morphological complexity and is a result of the ongoing tectonic activity along the Hellenic Arc. It is carved and ruptured by numerous, cross-cutting faults, which create deep and narrow valleys and gorges separating small and larger mounts and ridges and creating a complex morphological pattern.

The most prominent positive morphological features of the East Cretan Strait are highlighted here. The rocky basement outcropping on Crete and Kassos Islands is believed to be exposed on the seafloor of all mounts.

Sidero and **Fry** mounts are located in the northern part of the strait. They are oriented in a NE-SW direction and overlook the > 2000 m deep South Karpathos Basin towards the NE. Their summits rise at 252 m and 203 m, respectively. Sidero mount is named after the homonymous cape at the north-eastern tip of Crete, while Fry has taken its name from the main village and port of Kassos Island.

Palaikastron mount has a central location in the strait and is oriented in a ENE-WSW direction. It rises at a depth of 253 m and is outlined by very steep slopes dipping down to a > 900 m depth. Palaikastron mount is named after the historical site on the eastern coast of Crete.

Zakros mount is the largest and shallowest one in the East Cretan Strait and is located in its southern part. Its summit is located at a depth of 105 m while its southern slopes dip down to a depth of > 3000 m, in the Pliny Trench.

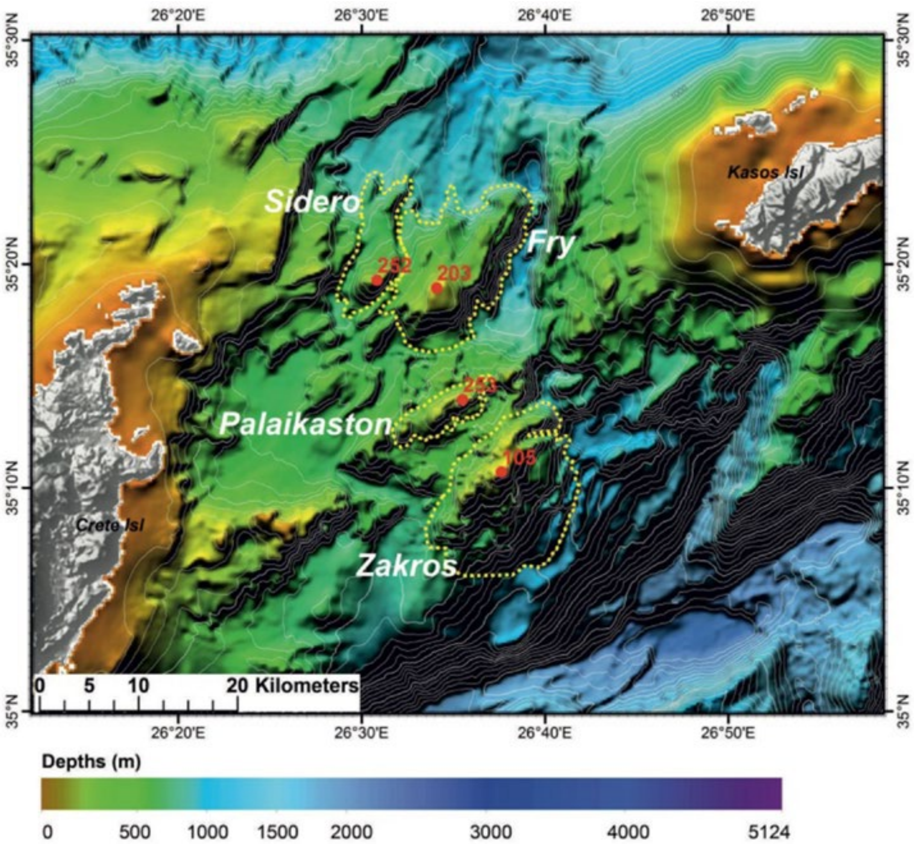


Fig. 2.36. Shaded relief map of the East Cretan Strait mounts area.

The outline and the tops of the observed features are indicated on the map.

4

LIBYAN SEA

The most pronounced geomorphological elements of the Libyan Sea are the following two (Fig. 2.37):

a) the central and eastern sectors of the Hellenic Arc and Trench, extending from off the south-western edge of Crete to the Rhodes Basin and

b) the central and eastern parts of the Mediterranean Ridge

The Hellenic Trench surrounds the outward side of the Hellenic Arc and displays two distinct sectors: The western sector, known as the Ionian Trench (IT) or Matapan Trench[15] that trends NW-SE and extends from the Ionian Islands to the south of Gavdos Island. It is a composite morphological feature characterized by small, discontinuous, NW-SE elongated or spindle-shaped basins with depths exceeding 4000-5000 m and separated by shallower ridges. The NW slopes of the Trench are steep and irregular, with N-S trending ridges advancing towards the south. The SW slopes of the Trench toward the Mediterranean Ridge are less steep. The eastern sector is delineated by three striking features: the WSW-ENE trending Ptolemy Trench south of central Crete, and the WSW-ENE to SW-NE trending Pliny and Strabo Trenches. Complex seafloor topography with shallow ridges and NW-SE trending linear deeps prevails in the areas between the Ptolemy and Pliny Trenches and between the Pliny and Strabo Trenches. The Ptolemy Trench terminates eastward at the NNE-SSW trending Ierapetra graben (depression bounded by normal faults) while the Pliny and Strabo Trenches extend up to the 4000 m deep Rhodes Basin (Fig. 2.37).

The Ptolemy (2500-3700 m) and Pliny (3700-4500 m) Trenches have developed along major transcurrent or strike-slip fault zones on the outer edge of the Aegean crust while the Strabo Trench (3000-3500 m) marks the boundary between the Aegean crust and the Mediterranean Ridge. The rugged topography of the seafloor between the three trenches is the result of the deformation of the crust due to the active tectonic processes in the area.

The majority of the observed seamounts in the Libyan Sea occur between the Ptolemy, Pliny and Strabo Trenches. The **Ptolemy Mountains** and **Chryssi** Seamounts (Fig. 2.38) are located between the Ptolemy and Pliny Trenches. The **Vai, Faistos** and **Olympos** seamounts occur between the Hellenic Arc and the Pliny Trench. The **Strabo Mountains, Knossos** and **Colossus** seamounts occur on the north-western margin of the Strabo Trench (Fig. 2.38).

The shallowest part of the Mediterranean Ridge is known as **Herodotus Rise** or Antaeus High, and is located north of Cyrenaica (Fig. 2.37). Minimum depths of the individual summits on Herodotus Rise are between 1100 and 1200 m below sea-level and increase to > 3200 m and > 2200 m towards the west and east respectively[1].

Numerous mud volcanoes occur on the Mediterranean Ridge (Fig. 2.37) and tend to cluster in groups or mud fields: The main fields of mud volcano occurrence are Pan di Zucchero, Prometheus II, Olimpi, Southern Belt and United Nations. The relationship between their occurrence and the active tectonic elements has been documented in the eastern Mediterranean Sea[2,1].

The morphological characteristics of the 9 main seamounts or groups of seamounts in the Libyan Sea are described below and in (Table 2.4).

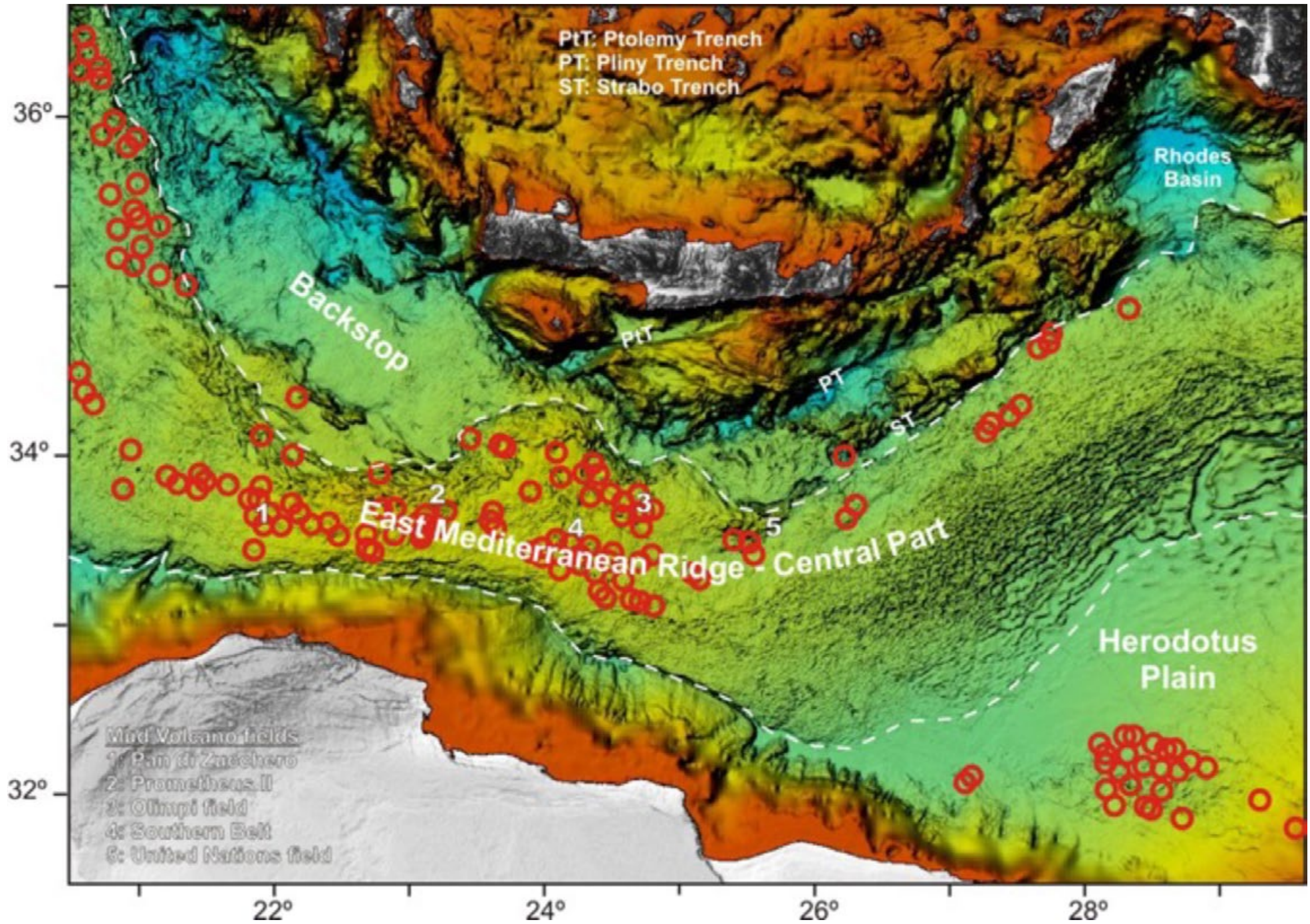


Fig. 2.37. Updated bathymetry of the Libyan Sea. Derived from GEBCO and swath bathymetry data processed at 250 m grid in the framework of EMODNET Bathymetry project (https://emodnet.eu/bathymetry). Red circles: mud volcanoes 11. GT: Gortys Trench, ST: Strabo Trench, PT: Pliny Trench, PtT: Ptolemy Trench. Mud volcano main fields: 1: Pan di Zucchero, 2: Prometheus II, 3: Olimpi, 4: Southern Belt, 5:United Nations.

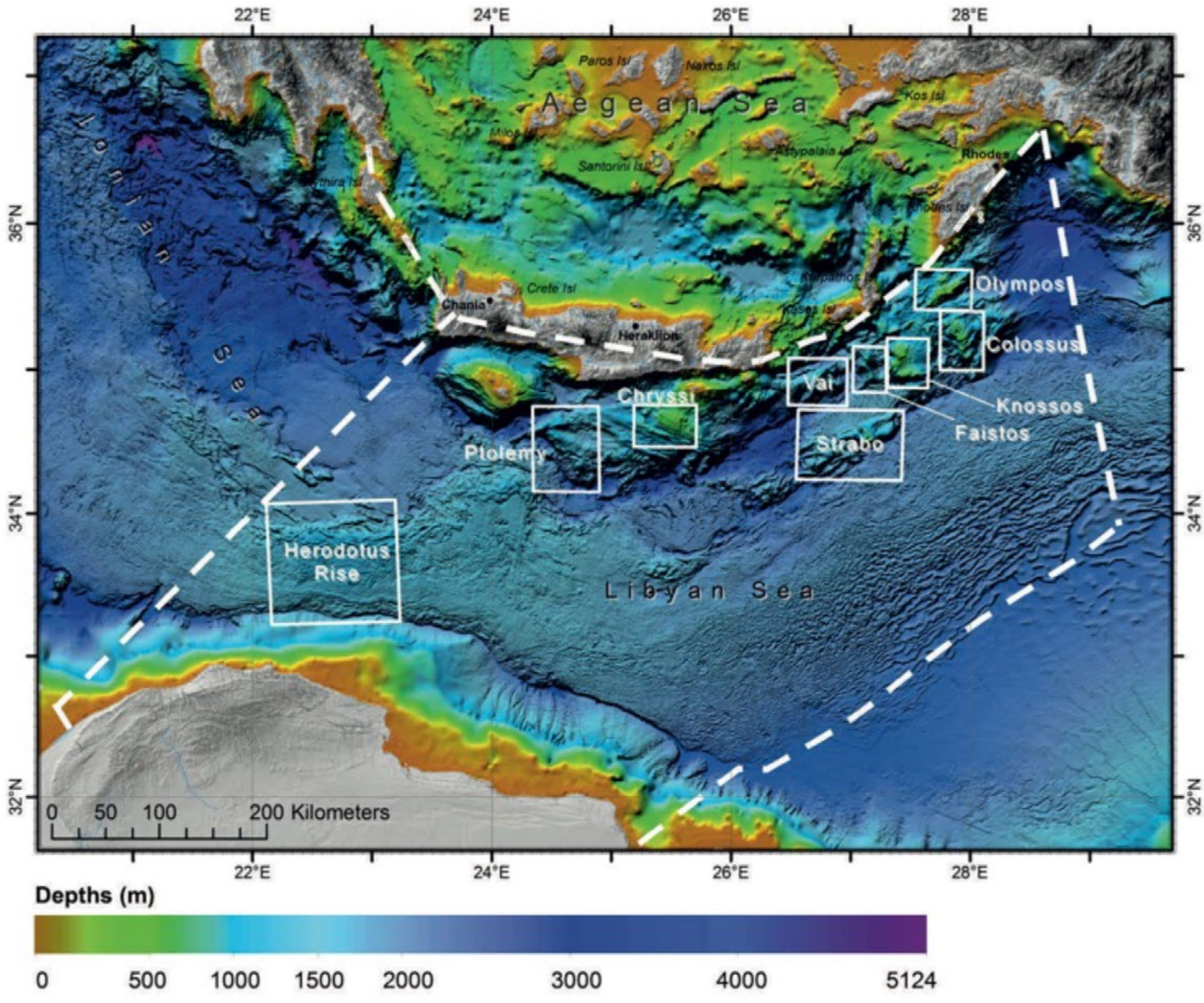


Fig. 2.38. Location of the seamount areas in the Libyan Sea discussed in this chapter.

Table 2.4. Libyan Sea Seamounts and Seamount-like structures.

			Minimum Depth / Location			Maximum Depth / Location				
Group name	Seamount	Area (km²)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Depth Range (m)	Mean Slope (deg)
HERODOTUS RISE	Herodotus Rise	10531.58	33.771151	22.714906	22.714906	33.265767	23.221639	2618	1481	3.17
			33.745559	22.917599	22.917599					
			33.773119	22.601775	22.601775					
PTOLEMY SEAMOUNTS	Ptolemy	1911.01	34.628885	24.562715	24.562715	34.673682	24.421301	3398	2352	7.63
			34.531416	24.534432	24.534432					
CHRYSSI SEAMOUNTS	Chryssi	899.35	34.665893	25.543185	25.543185	34.519712	25.455980	1310	861	3.30
			34.601605	25.302781	25.302781					
VAI SEAMOUNT	Vai	1232.07	34.934187	26.728705	26.728705	34.663946	26.535440	4036	3322	8.20
FAISTOS SEAMOUNT	Faistos	644.27	35.071878	27.143520	27.143520	35.027299	27.039816	3124	2455	10.93
			34.941950	27.178873	27.178873					
KNOSSOS SEAMOUNT	Knossos	1148.29	35.083503	27.412206	27.412206	35.013727	27.275506	2532	2144	6.14
			34.961356	27.475842	27.475842					
COLOSSUS SEAMOUNT	Colossus	1500.41	35.209336	27.944865	27.944865	35.023422	27.831734	2960	2415	6.80
			35.079628	27.966077	717					
OLYMPOS SEAMOUNT	Olympus	872.56	35.524020	27.838805	229	35.658780	28.048569	2483	2254	8.32
			35.514385	27.751600	321					
			35.616451	27.916583	894					
STRABO MOUNTAINS	Strabo	3410.42	34.504104	27.152947	729	34.183492	26.719278	3467	2738	7.47
			34.554819	27.251937	1219					
			34.525564	26.933756	1342					
			34.488493	26.789985	1467					

HERODOTUS RISE (FIG. 2.39)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Herodotus Rise	10531.58	1137, 1262, 1269	2618

Herodotus Rise or Antaeus High is the part of the Mediterranean Ridge with the shallowest depths. It is located north of Cyrenaica and close to the contact to the so-called “backstop”, a crustal slice with weak or no deformation which is believed to belong to the overriding Aegean crust.

The minimum depths of the individual summits on Herodotus Rise are between 1100 and 1200 m below the sea-level and increase to > 3200 m and > 2200 m towards the west and east respectively[1].

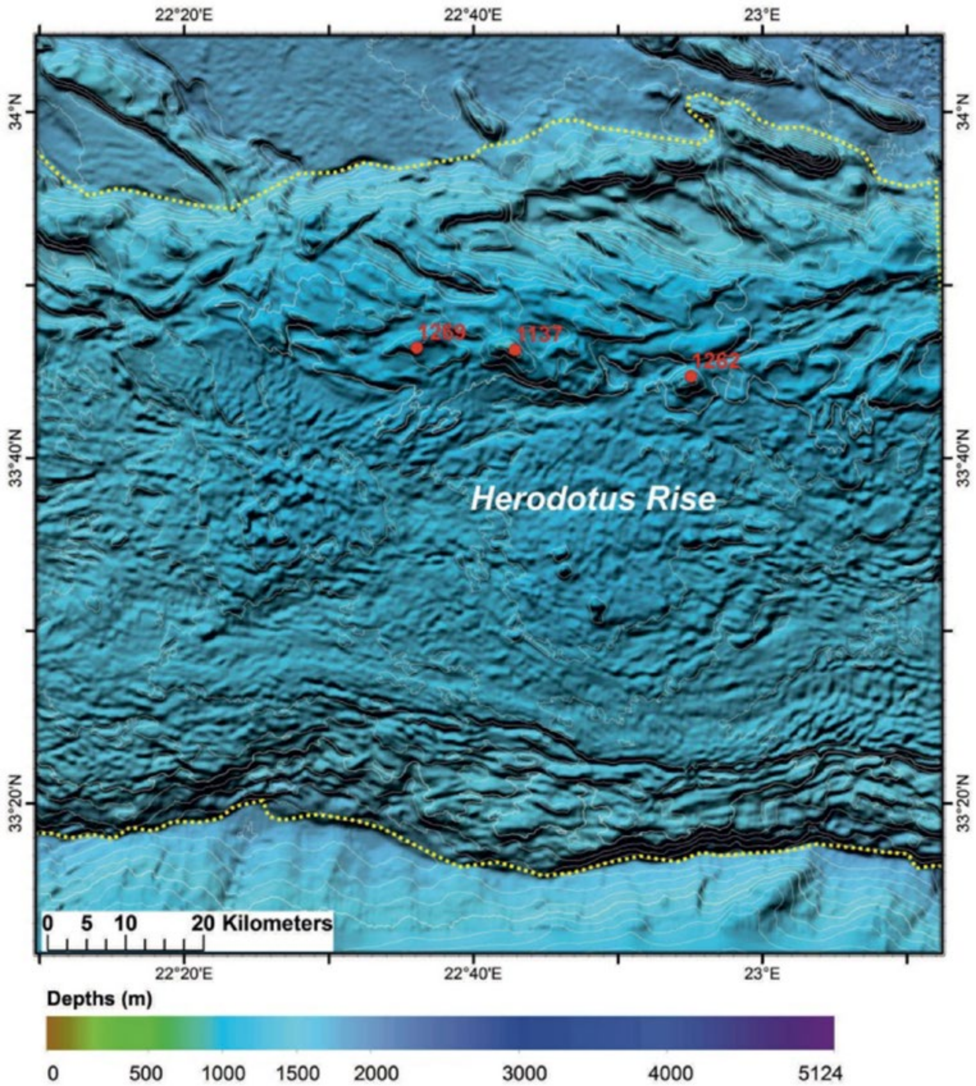


Fig. 2.39. Shaded relief map of Herodotus rise area.

The outline and the tops of the observed features are indicated on the map.

PTOLEMY SEAMOUNT (FIG. 2.40)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Ptolemy Seamount	1911.01	1046, 1117	3398

Ptolemy seamount is located on the south-western edge of the ENE-WSW trending tectonic slice which is uplifted between the Ptolemy Trench to the North and the Pliny Trench to the South. It results from the conjunction of two ridges. The first one is oriented in a ENE-WSW direction, parallel to the tectonic direction of the Ptolemy and Pliny Trenches and its shallowest summit is located at a depth of 1046 m. The second ridge runs in a NW-SE direction, parallel to the tectonic direction of the Ionian Trench. The shallowest summit of the latter is at a depth of 1117 m.

The northern and western flanks of the seamount are very steep and dip down to the > 3500 m deep basins of the Ptolemy and Ionian Trenches. The geological basement is believed to outcrop on the seafloor of both the flanks and the highest parts of the seamount.

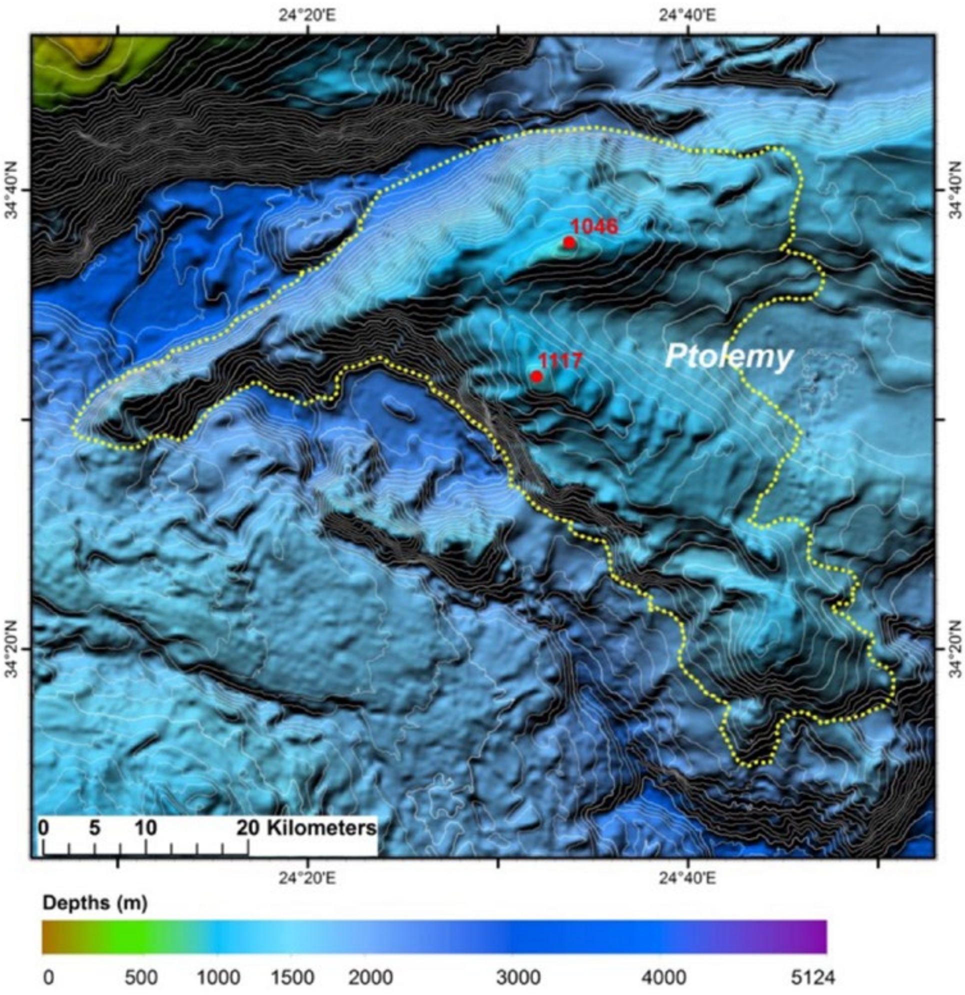


Fig. 2.40. Shaded relief map of Ptolemy Seamount area.

The outline and the tops of the observed features are indicated on the map.

CHRYSSI SEAMOUNTS (FIG. 2.41)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Chryssi Seamounts	899.35, 244.09	449, 955	1310

The Chryssi seamounts are located southwest of Chryssi Island, on the ENE-WSW trending tectonic fragment which is uplifted between the Ptolemy Trench to the North and the Pliny Trench to the South.

It is a large elliptical seamount, with its long axis trending NW-SE it is separated from Chryssi Island by an 800 m deep neck. Its shallowest summit is at a depth of 449 m while the scarps that run across the seamount in an E-W and NW-SE direction indicate enhanced tectonic activity along active faults. A high resolution seismic profiling survey in that area has shown that the gently sloping parts of the seamount are covered by Quaternary sediments.

A 25 km long, NW-SE oriented, narrow ridge is located southwest of the previous seamount and is separated from it by a 1200 m deep valley. The shallowest point of its crest rises at a depth of 955 m. Both flanks of the ridge display high dip values and are probably controlled by active faults.

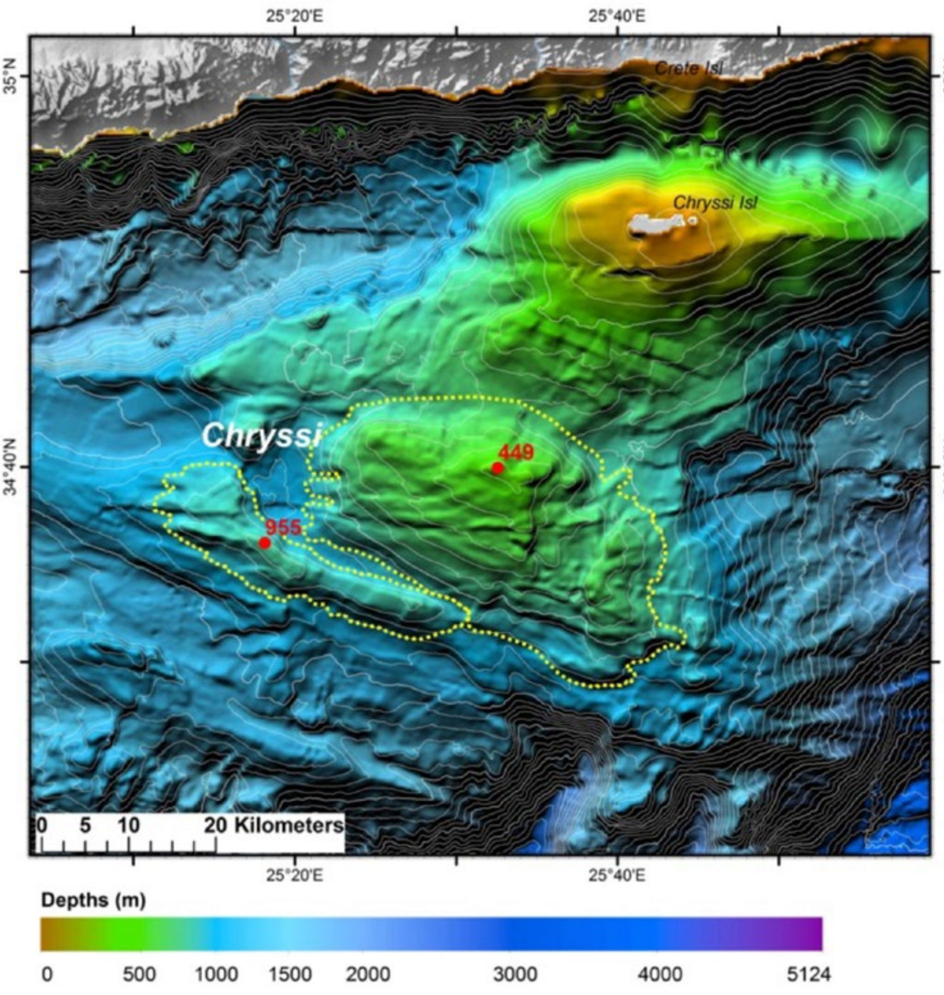


Fig. 2.41. Shaded relief map of Chryssi Seamount area.

The outline and the tops of the observed features are indicated on the map.

VAI SEAMOUNT (FIG. 2.42)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Vai Seamount	1232.07	714	4036

Vai Seamount is located between the base of the slope of the Hellenic Arc and the Pliny Trench. It displays a spindle shape with its long axis oriented in a NE-SW direction. The steep slopes of the seamount rise from a depth of > 3500 m to its summit at 714 m deep. Vai Seamount is named after the palm tree forest in Vai, a picturesque locality on the coast of Eastern Crete.

FAISTOS, KNOSSOS SEAMOUNTS (FIG. 2.42)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Faistos	644.27	669, 813	3124
Knossos	1148.29	388, 651	2532

The two seamounts, Faistos and Knossos are named after the Minoan archaeological sites of Crete. These are located between the steep slope of the Hellenic Arc and the Strabo Trench in an area where Pliny Trench fades out.

Faistos seamount rises from a depth of about 3000 m to its highest summit at 669 m. The second highest point is at a depth of 813 m.

Knossos seamount displays a dual character with two main morphological highs; the northern one rises at a depth of 388 m, and the southern one at 651 m.

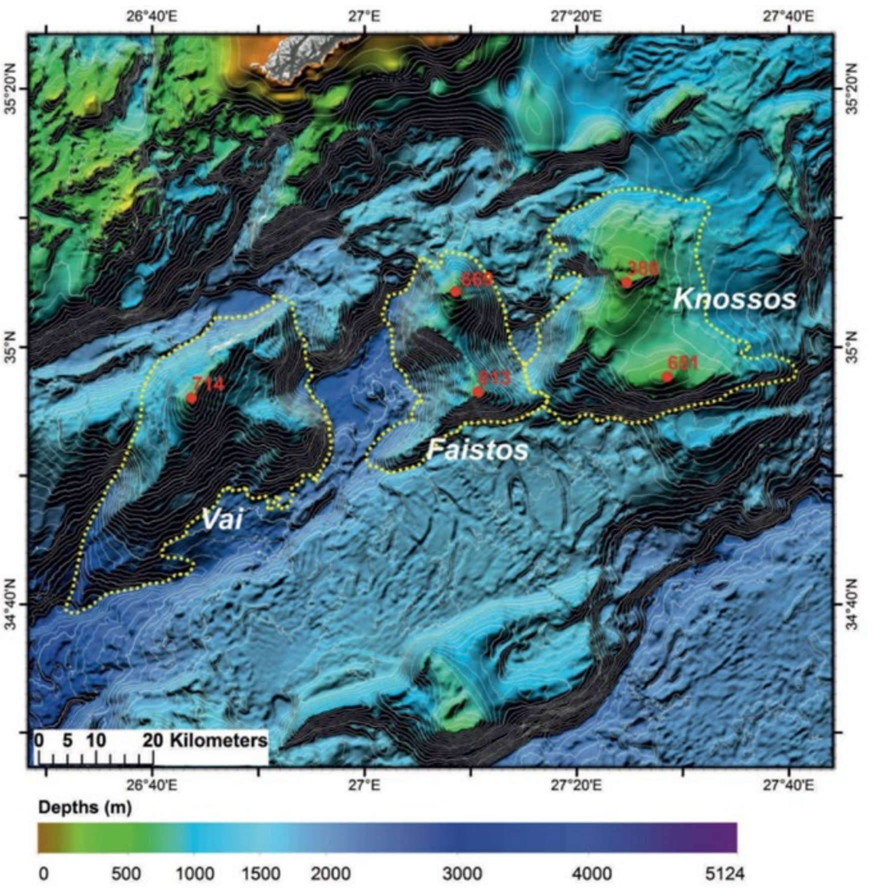


Fig. 2.42. Shaded relief map of Vai, Faistos and Knossos Seamount area.

The outline and the tops of the observed features are indicated on the map.

COLOSSUS SEAMOUNT (FIG. 2.43)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Colossus Seamount	1500.41	545	2960

Colossus Seamount is named after the famous statue of Colossus in the ancient city of Rhodes, which collapsed during a large earthquake in 227 BCE and has never been found. The base of the seamount displays an irregular shape and varies in depth between 1500 m and 2600 m. The main highest part of the seamount is aligned in a NNW-SSE direction. The depth of the crest ranges between 700 and 600 m and the two highest summits rise at 545 m and 717 m. The rugged topography of the seamount indicates that the rocky basement is exposed on the seafloor and has undergone extensive tectonic erosion.

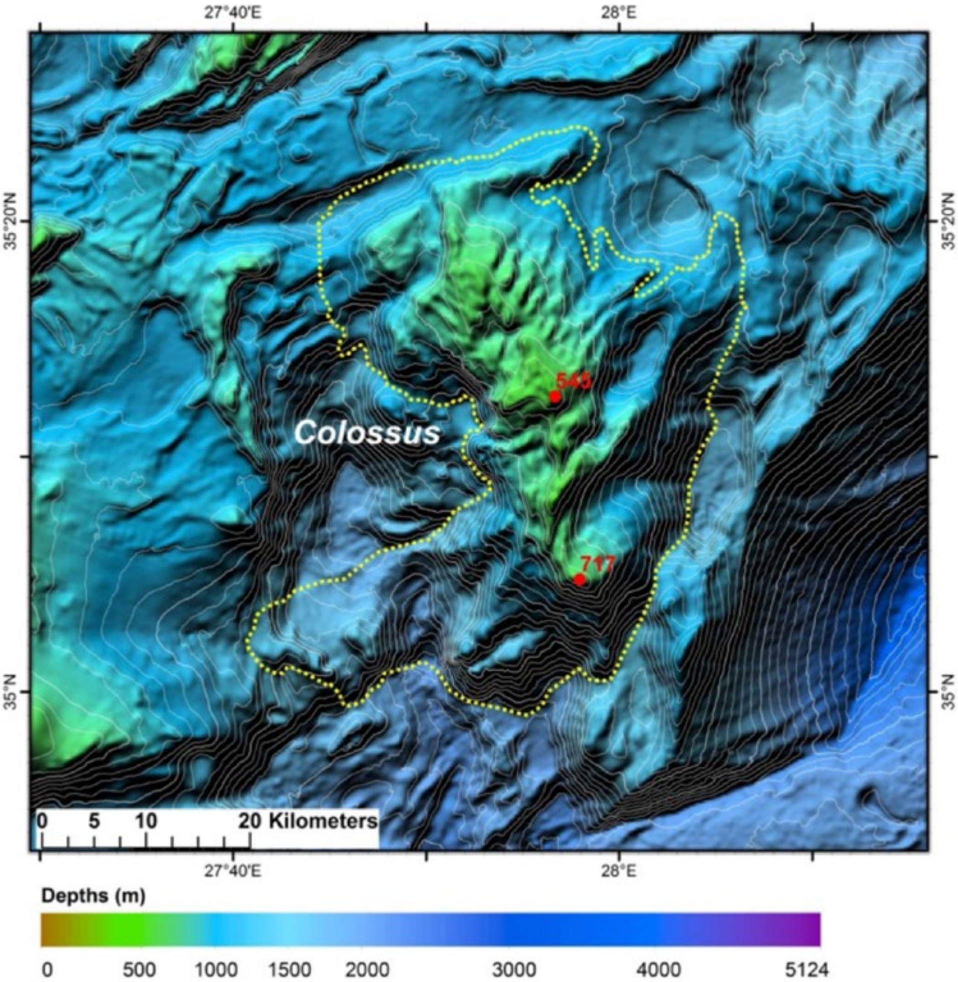


Fig. 2.43. Shaded relief map of Colossus Seamount area.

The outline and the tops of the observed features are indicated on the map.

OLYMPUS RIDGE (FIG. 2.44)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Olympus Ridge	872.56	229	2483

Olympus Ridge is a 40 km long, narrow ridge aligned in a NE-SW direction, parallel to the main tectonic direction of the eastern sector of the Hellenic Trench. It is located east of Karpathos Island and is named after the traditional village of Olympus in the northern part of the island. The two highest summits on the crest of the ridge rise at a depth of 229 m and 321 m. The south-eastern flanks of the ridge rise from a depth of 2000-2400 m. The base of the north-western slopes lies at a depth of roughly 1000-1300 m. The topography of the ridge indicates a rocky seafloor with restricted deposition of recent sediments.

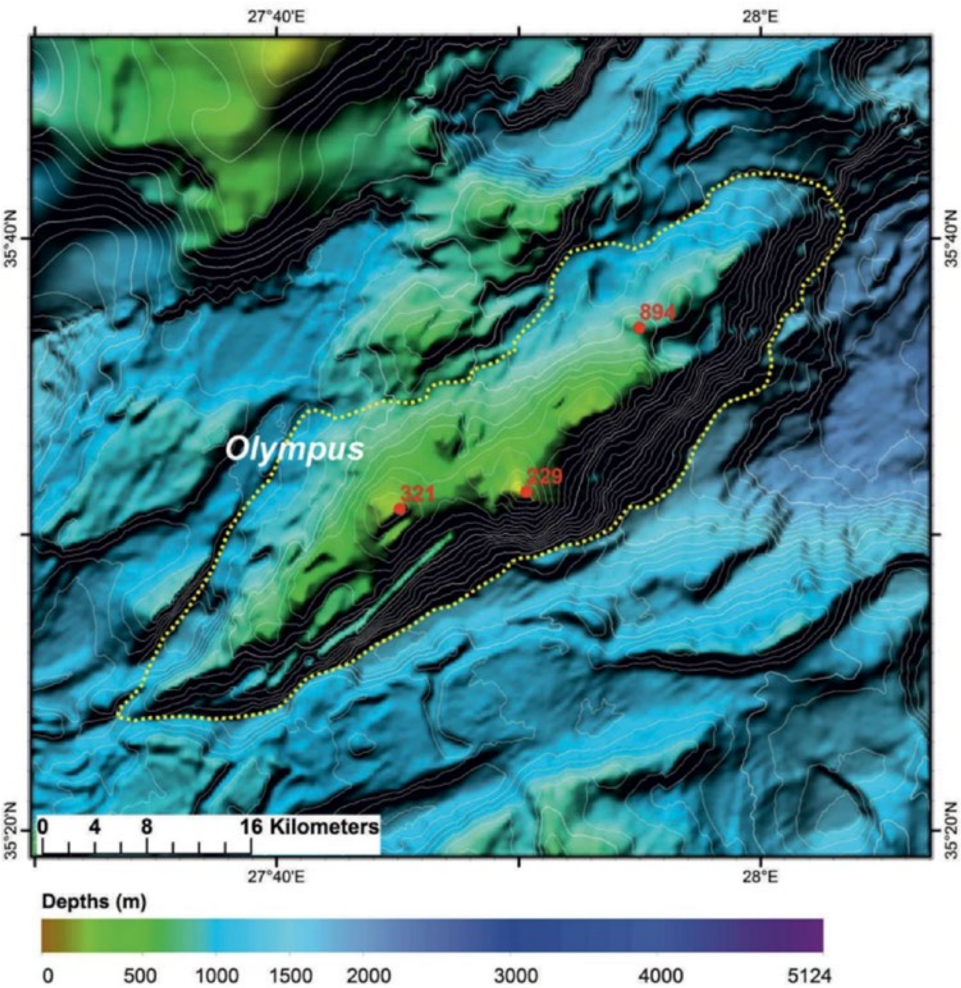


Fig. 2.44. Shaded relief map of Olympus Ridge area.

The outline and the tops of the observed features are indicated on the map.

STRABO MOUNTAINS (FIG. 2.45)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Strabo mountains	3410.42	729	3467

The **Strabo mountains** represent an elongated area along the Strabo Trench, which displays enhanced positive topography with numerous morphological highs and ridges. The shallowest point in the Strabo mountains is at a depth of 729 m. Many other highs are found at depths between 1400 and 1200 m. The south-eastern flanks of the mountains dip down to the Strabo Trench at a depth of 3000-4000 m. The north-western flanks rise from a wide, relatively smooth plateau at a depth of 2000-2200 m. It is assumed that the rocky basement is exposed at the highest points of the Strabo mountains in areas with rugged or steep topography.

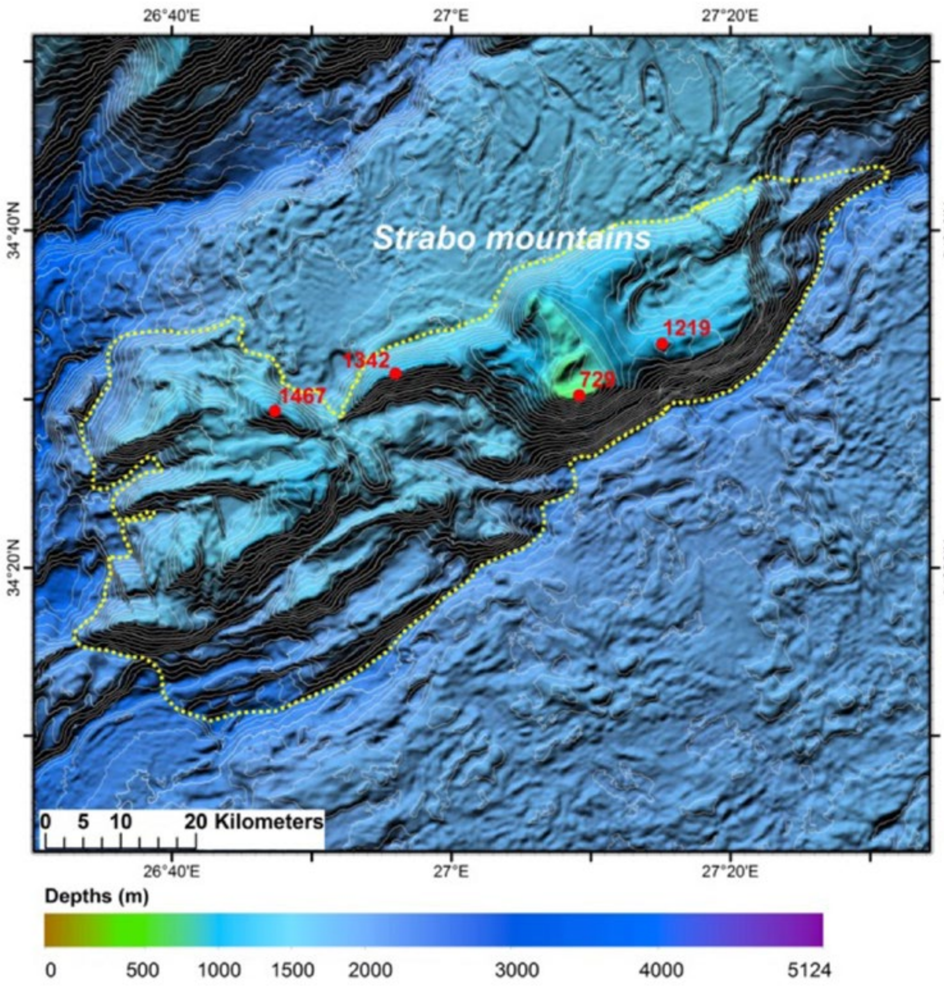
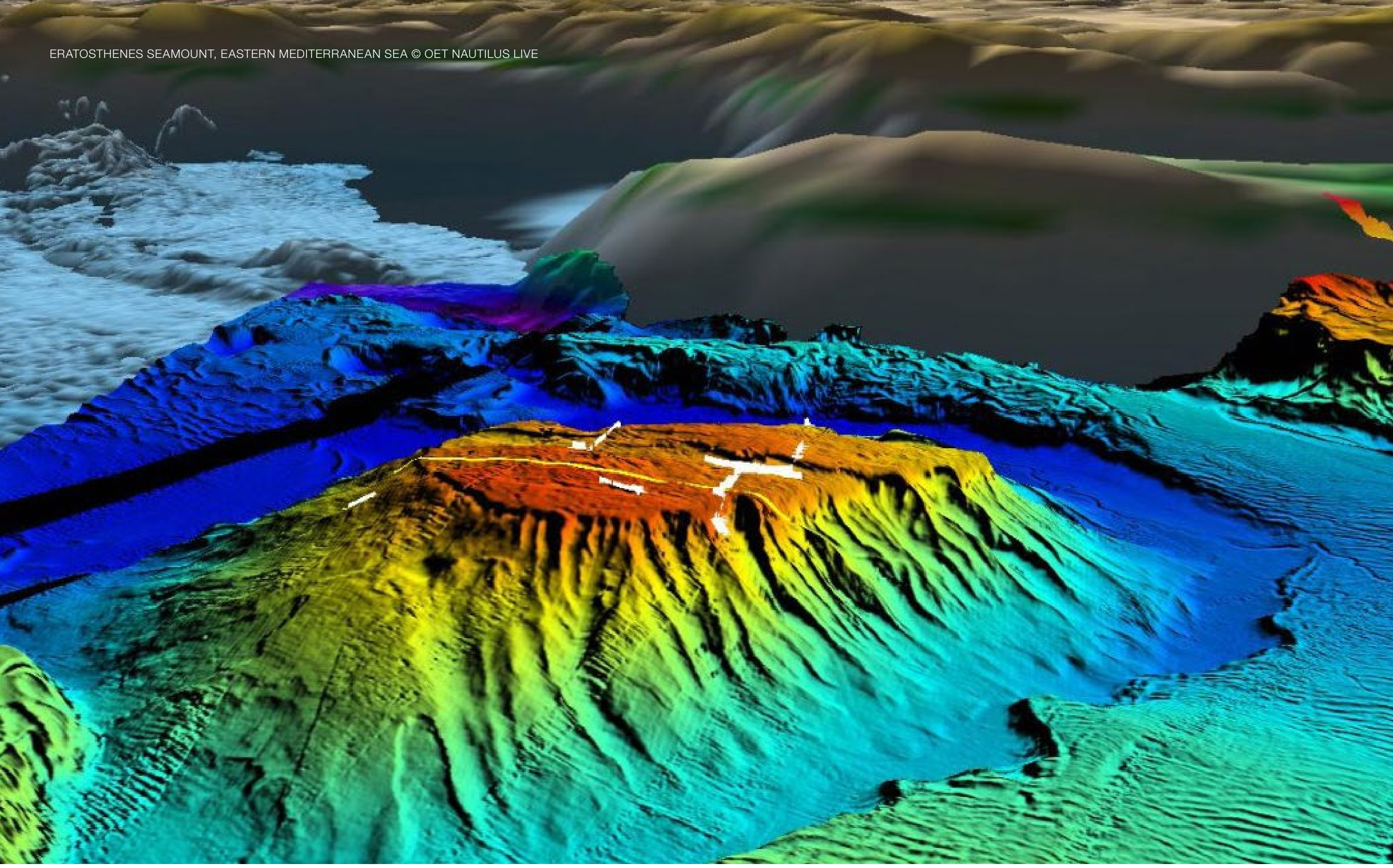


Fig. 2.45. Shaded relief map of Strabo Mountains area.

The outline and the tops of the observed features are indicated on the map.

ERATOSTHENES SEAMOUNT, EASTERN MEDITERRANEAN SEA © OET NAUTILUS LIVE



5 LEVANTINE SEA

The Eastern Mediterranean is divided by the Cyprus Arc in two, geologically and morphologically distinct areas (Fig. 2.46). The northern part includes the area between the southern coast of Turkey and the Cyprus Arc. The latter delineates the active deformation front between the African and Anatolian Plates in the Eastern Mediterranean. It extends from the Anaximander Mountains in the West over the Florence Rise and the southern margin of Cyprus to the coast of Syria near Latakia in the East. The southern part of the Eastern Mediterranean, which from the Neogene is involved in northward subduction below the Cyprus Arc, comprises two major basins, the Herodotus and Levant-Phoenician basins, with the Eratosthenes seamount located in between them.

The southern margin of the east Mediterranean is dominated by the impressive deep-sea fan of the Nile. The eastern coast of the Levantine Sea follows the trace of the N-S trending Dead Sea Fault, a major strike-slip fault which facilitates the northward motion of the Arabian plate compared to the African plate. The rate of convergence between the Eastern Mediterranean lithosphere and the Cyprus margin is **about 1 cm/yr**. Between Cyprus and the Nile Deep-sea Fan, the **Eratosthenes seamount**, the largest seamount in the Mediterranean Sea, constitutes a major, positive morphological feature rising above the seafloor of the Herodotus and Levant basins. The involvement of the continental block of the Eratosthenes seamount into the subduction zone and its incipient collision with the Cyprus margin may have also played a role in the deformation of the Cyprus Arc[16,17,18].

The majority of the seamounts described here (Fig. 2.47) are associated with the Cyprus Arc and the complex tectonic deformation along it, which is associated with the convergence of the northward moving African plate and the Anatolian continental block. **Anaximander Mountains** and **Florence Rise** are located on the western sector of the arc, while **Hecataeus** and **Cavo Greco** mounts along with the **Latakia Ridge** are located along the eastern sector of the arc. The Kas and Bilim mounts and the Rizokarpasso or Karpass Ridge are located behind the Cyprus Arc, on the overriding plate.

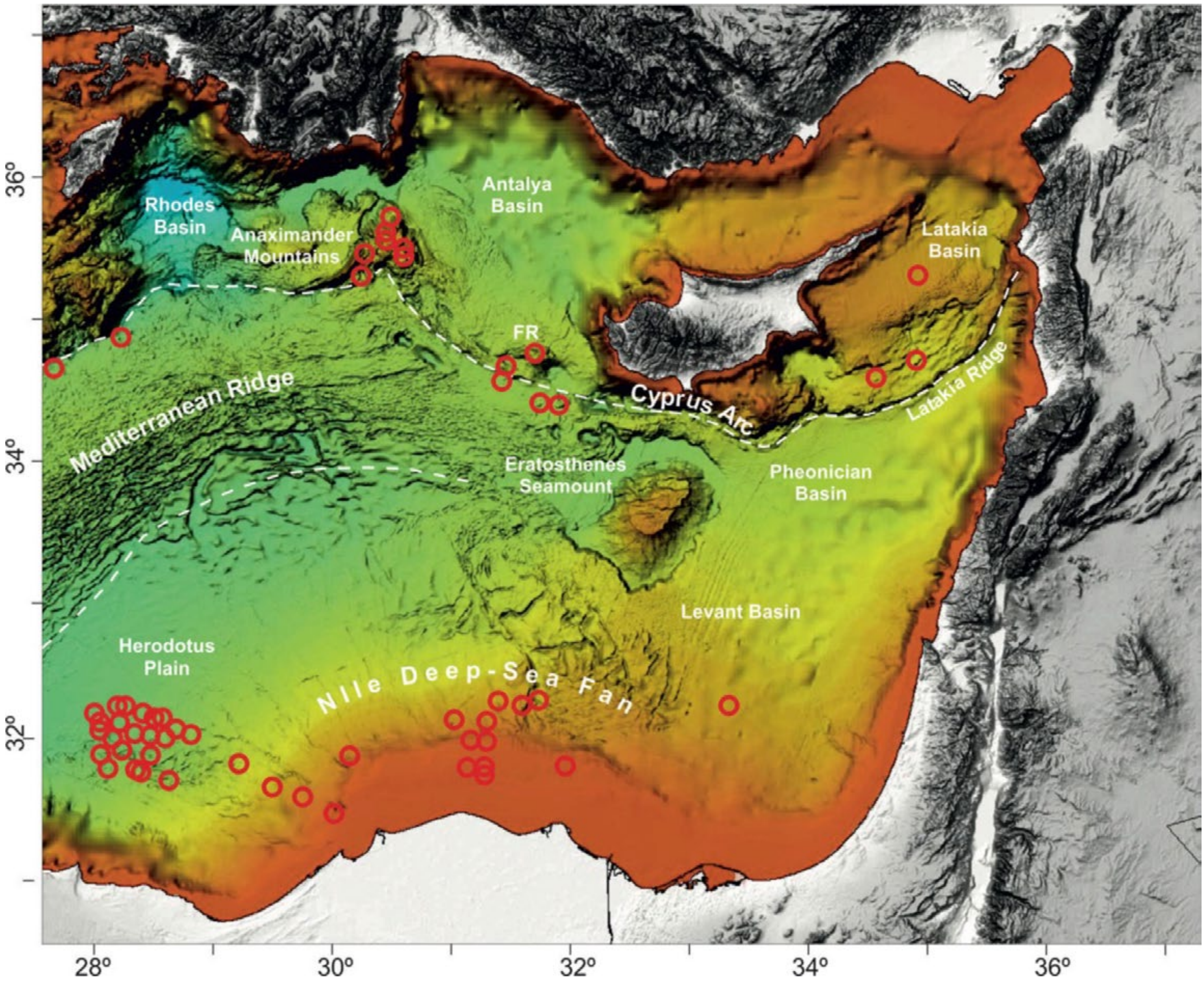


Fig. 2.46. Bathymetry of the Levantine Sea. Derived from GEBCO and swath bathymetry data processed at 250 m grid in the framework of EMODNET Bathymetry project. Red circles: mud volcanoes[11].

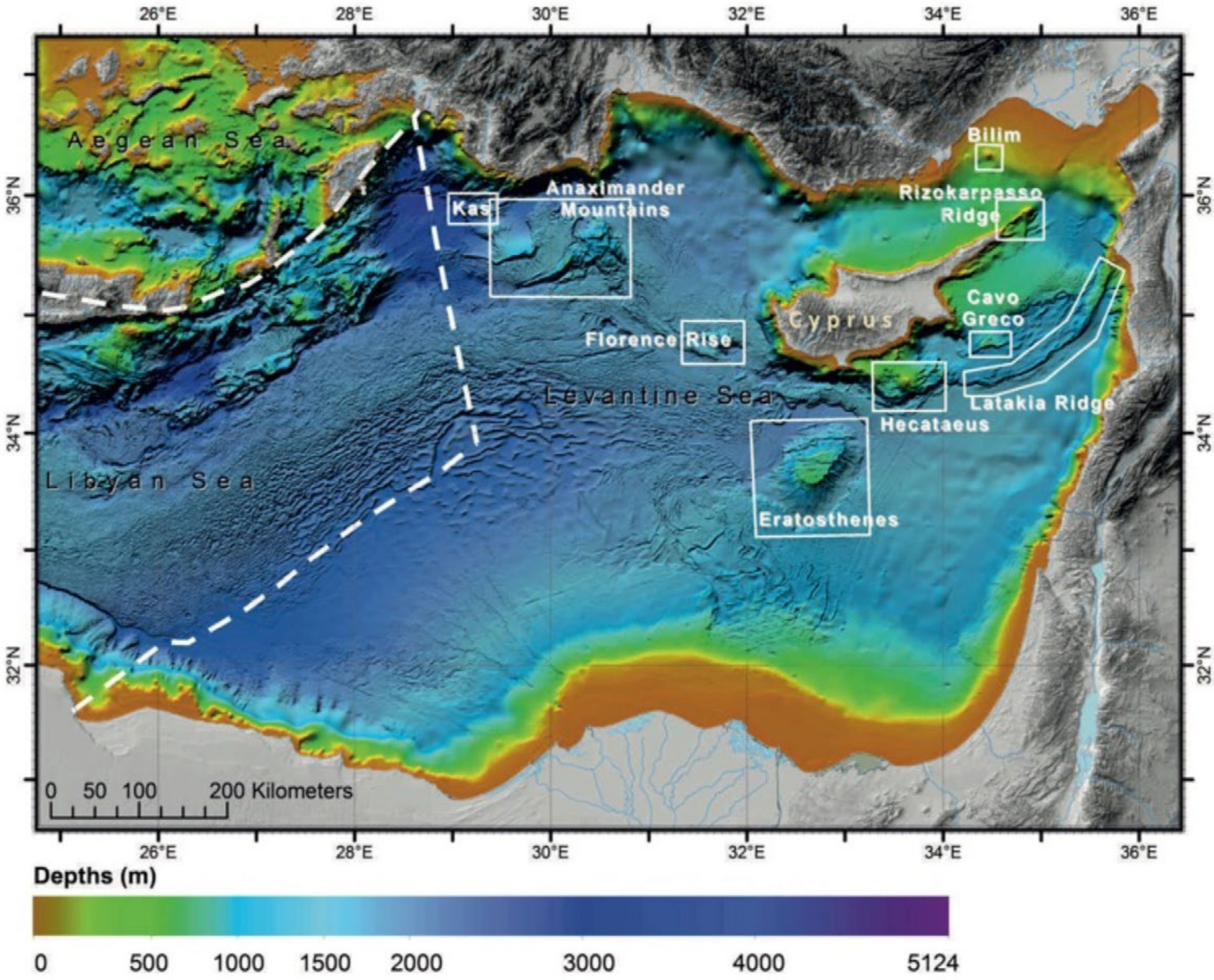


Fig. 2.47. Location of the seamounts areas in the Levantine Sea discussed in this chapter.

Table 2.5. Levantine Sea Seamounts and Seamount-like structures.

			Minimum Depth / Location			Maximum Depth / Location				
GROUP NAME	Seamount	Area (km^2)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Latitude (Dec. Deg)	Longitude (Dec. Deg)	Depth (m)	Depth Range (m)	Mean Slope (deg)
KAS SEAMOUNT	Kas	932.73	35.883510	29.295369	1950	35.977437	28.838130	4474	2524	6.42
ANAXIMANDER MOUNTAINS	Anaxagoras Mountain	1867.90	35.670320	30.518599	919	35.824028	30.377185	2610	1691	5.46
	Anaximander Ridge	597.55	35.508604	29.783247	1102	35.512458	29.111531	3123	2021	9.01
	Anaximenes Ridge	1936.46	35.427622	30.160351	678	35.249947	29.842169	3124	2446	6.94
FLORENCE RISE	Florence Rise	685.76	34.813758	31.664052	1573	34.734022	31.887958	2619	1046	4.67
BILIM SEAMOUNT	Bilim	154.22	36.332951	34.473476	39	36.300526	34.447550	355	316	2.00
HECATAEUS SEAMOUNT	Hecataeus	1791.86	34.445548	33.639134	230	34.236361	33.518932	2117	1887	4.20
CAVO GRECO SEAMOUNT	Cavo Greco	323.25	34.749586	34.442837	791	34.673682	34.324992	1554	763	4.81
RIZOKARPASSO (KARPAS) RIDGE	Rizokarpasso Ridge	522.72	35.800991	34.735092	85	35.829787	34.914217	802	717	4.53
			35.881592	34.883577	104					
LATAKIA RIDGE	Latakia Ridge	2838.92	35.412188	35.713205	153	34.396720	34.251928	2073	1920	4.10
			34.449453	34.336776	1067					
			34.665893	35.072129	1172					
ERATOSTHENES SEAMOUNT	Eratosthenes	9487.06	33.619455	32.658664	771	33.696322	32.248563	2724	1953	3.01

KAS SEAMOUNT (FIG. 2.48)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Kas seamount	932.73	1950	4474

Kas seamount is located at the base of the slopes off Kas village, on the eastern margin of the 4000 m deep Rhodes Basin. It is an E-W elongate mount with steep slopes towards the North and South. The highest summit of the seamount rises at a depth of 1950 m, roughly 1000-1500 m higher than the surrounding seafloor.

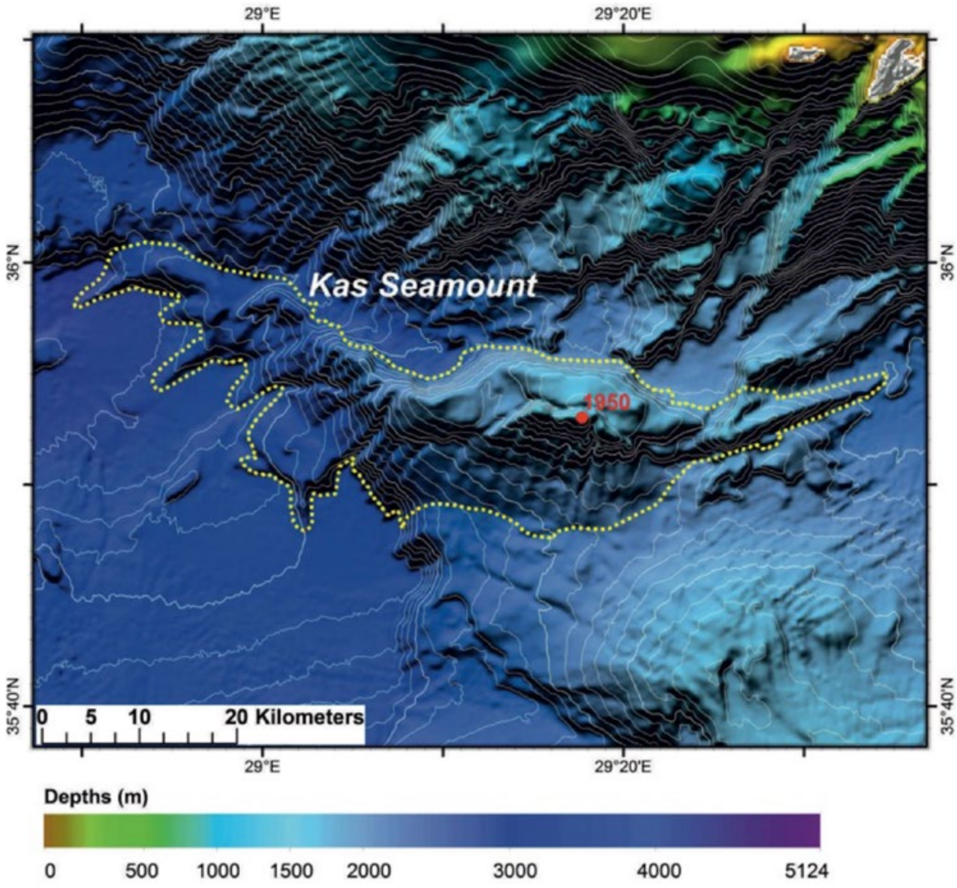


Fig. 2.48. Shaded relief map of Kas seamount area.

The outline and the tops of the observed features are indicated on the map.

ANAXIMANDER MOUNTAINS (FIG. 2.49)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Anaxagoras Mountain	1867.90	919	2610
Anaximander Ridge	597.55	1102	3123
Anaximenes Ridge	1936.46	678	3124

The **Anaximander Mountains** comprise a group of three main, positive morphological features, two ridges and one seamount, located at the junction between the Hellenic and the Cyprus Arc, east of the 4000 m Rhodes Basin. Based on their geology, they are described as large faulted and tilted continental blocks that originally were part of SW Anatolia and were detached from it and involved into complicated tectonics related to the convergence between the African plate and the Anatolian continental block[19,20,210].

Anaximander and Anaximenes Ridges can be correlated with the neritic limestone of the Bey Daglari Unit of SW Turkey[22,23], whereas the Anaxagoras SM is a continuation of the Antalya Nappes Complex[19,24,24]. The "Great Slide", an extensive multi-lobe, north and south-westward flowing mass flow unit with impressive flow structures imprinted on the morphology of the seafloor separates Anaximander Ridge to the West from Anaximenes Ridge and Anaxagoras Seamount to the east sea mounts[20,24].

Anaximander Ridge is an 80 km long, E-W oriented, narrow ridge bounded by steep slopes which rise from a minimum depth of at least 2000 m. The highest point on the crest is at a depth of 1102 m at the easternmost part of the ridge.

Anaximenes Ridge is a concave, SW-NE oriented ridge located east of Anaximander Ridge and in contact with Anaxagoras Seamount towards the north-east. With a depth of 678 m the summit of Anaximander Ridge is the shallowest point in the entire Anaximander Mountains.

Anaxagoras Seamount rises at a depth of 919 m, more than 1500 m higher than the surrounding seafloor.

Both Anaximander Ridge and Anaxagoras Seamount are characterized by many active or dormant mud volcanoes which often occur as small mounts protruding a couple of hundred metres higher than the seafloor[20,25,26]. However, the highest parts of the Anaximander Mountains are believed to be built of the geological basement of the area.

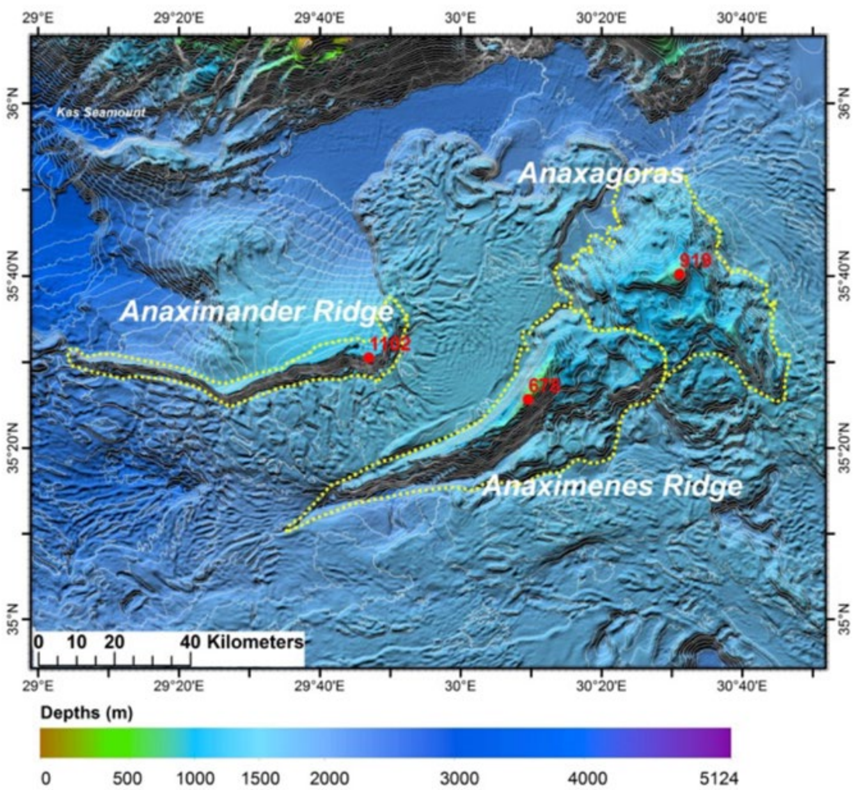


Fig. 2.49. Shaded relief map of Anaximander Mountains area.

The outline and the tops of the observed features are indicated on the map.

FLORENCE RISE (FIG. 2.50)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Florence Rise	685.76	1573	2619

The Florence Rise (or Ridge) is a submarine feature extending from the island of Cyprus in the southeast to the Anaximander Mountains in the northwest and forms the western sector of the Cyprus Arc[27,28]. It separates the deep Levantine basin to the south from the Antalya Basin to the north. The ridge is characterized by relatively low relief developed along a dextral, arc-parallel fault-zone which accommodates the oblique convergence between the African and Anatolian plates.

A marked topographic high, the **Florence Rise**, is located at a short distance west of the western coast of Cyprus. It displays an asymmetric rhomboid shape, elongated in an E-W direction, and rises from the 2200-2300 m deep seafloor to a minimum depth of 1573 m.

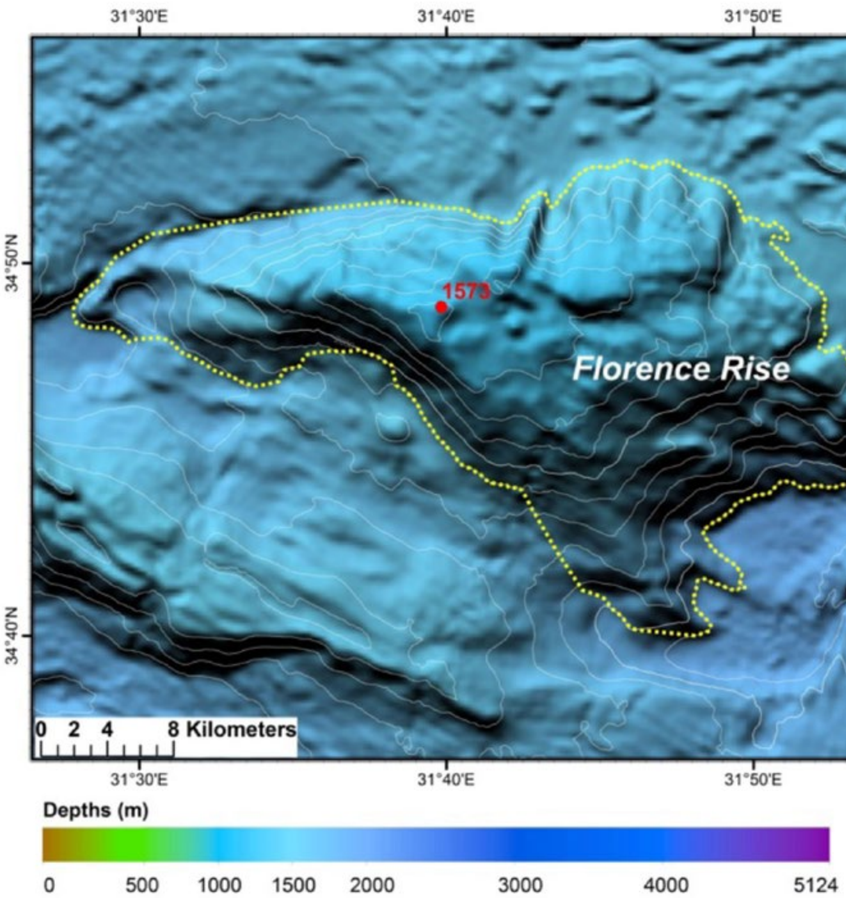


Fig. 2.50. Shaded relief map of Florence Rise area.

The outline and the tops of the observed features are indicated on the map.

BILIM BANK (FIG. 2.51)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Bilim Bank	154.22	39	355

Bilim Bank is located on the upper slope of the Mersin Gulf off SE Turkey. It displays a rather circular shape with its base at 200 m in the north and > 400 m in the south with its summit at a depth of 39 m. Precise bathymetric data are not available from the area, thus the exact shape and depth of Bilim Bank will be better defined in the future.

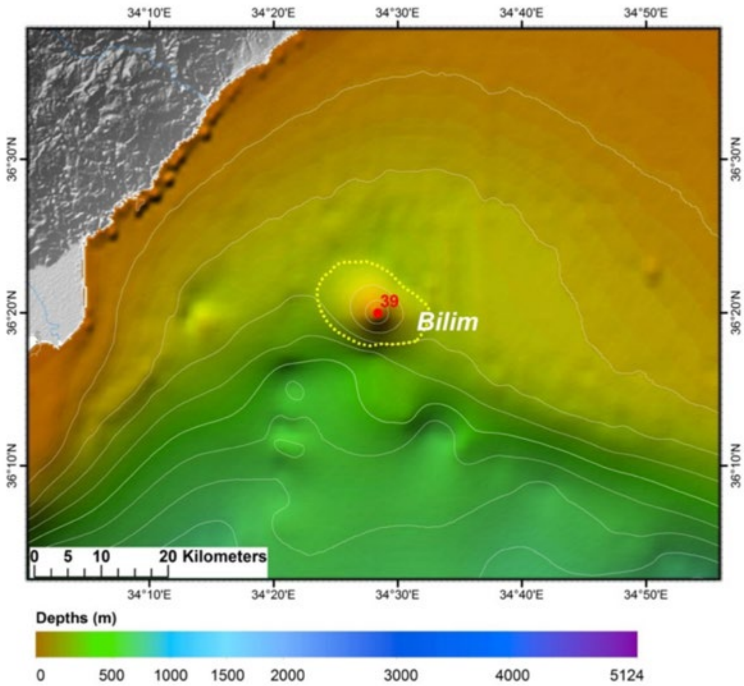


Fig. 2.51. Shaded relief map of Bilim mount area.

The outline and the tops of the observed features are indicated on the map.

HECATAEUS SEAMOUNT (FIG. 2.52)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Hecataeus Seamount	1791.86	230	2117

Hecataeus Seamount is a continental block belonging to the southern margin of Cyprus. It is located south of Larnaca and marks the shallowest underwater feature along the Cyprus Arc. It is connected with Cyprus through a 500-600 m deep, wide plateau, while its summit rises at a depth of 230 m. The southern flanks of the seamount dip steeply toward the 1800-2000 m deep Levantine Basin while the western and eastern flanks rise gently from a depth of 1000-1100 m.

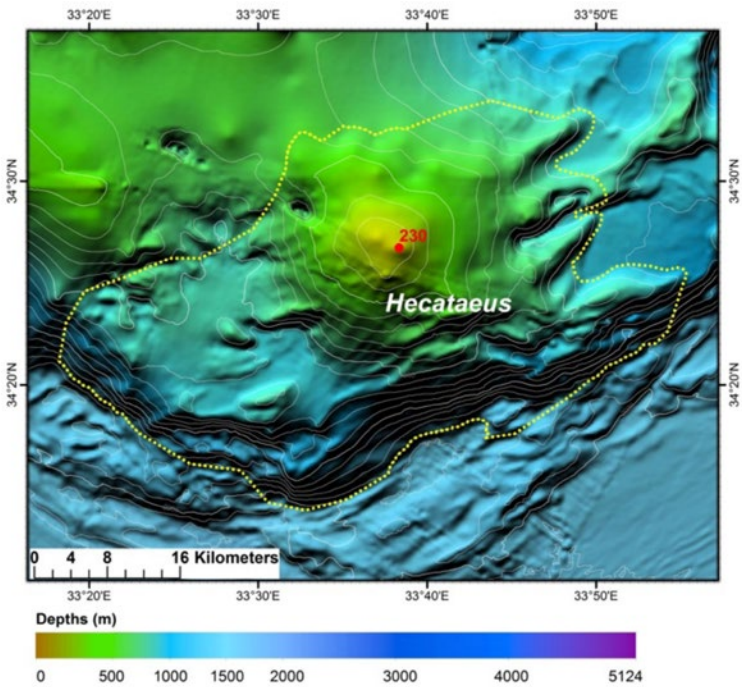


Fig. 2.52. Shaded relief map of Hecataeus seamount area.

The outline and the tops of the observed features are indicated on the map.

CAVO GRECO SEAMOUNT (FIG. 2.53)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Cavo Greco Seamount	323.25	791	1554

Cavo Greco is a triangular mount located southeast of the homonymous cape at the south-eastern tip of Cyprus. It displays asymmetric relief with steep slopes rising from a depth of around 1300 m to the 791 m shallow summit. The northern flanks dip gently to a depth of 1000 m.

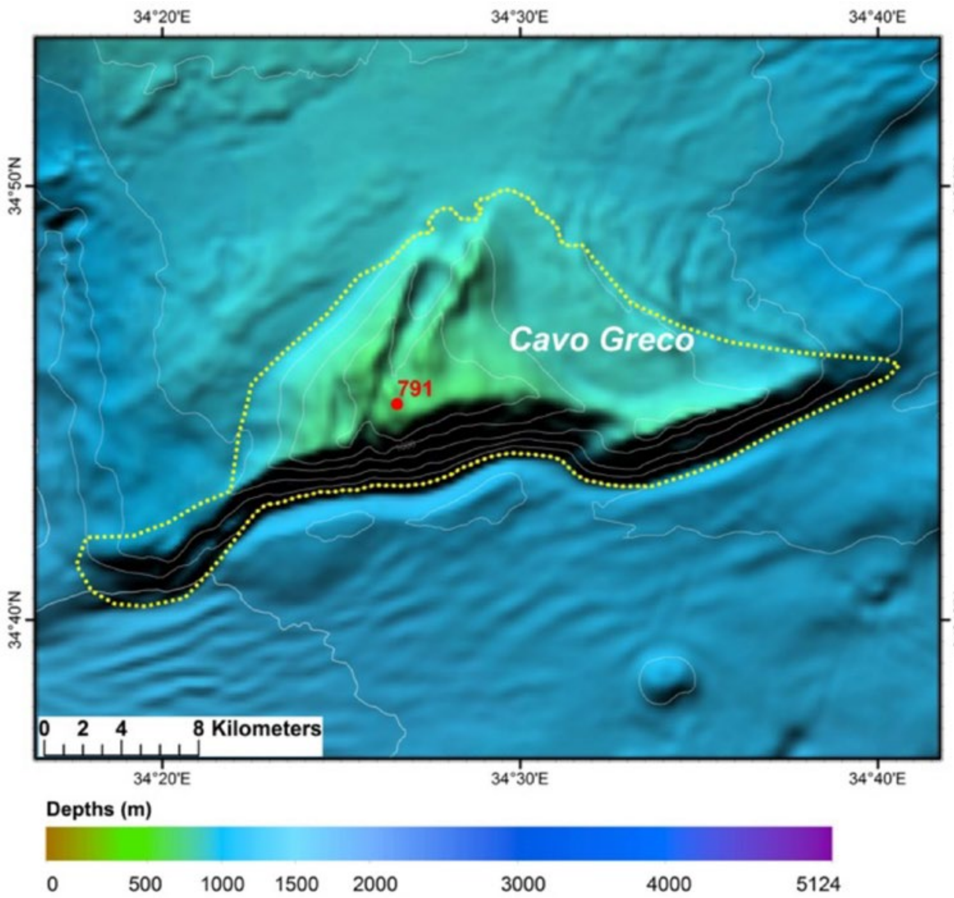


Fig. 2.53. Shaded relief map of Cavo Greco seamount area.

The outline and the tops of the observed features are indicated on the map.

RIZOKARPASSO (KARPAS) RIDGE (FIG. 2.54)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Rizokarpasso (Karpas) Ridge	522.72	85	802

Rizokarpasso or Karpas Ridge is located on the north-eastern prolongation of the Rizokarpasso Peninsula in NE Cyprus. It is a > 20 km long ridge with a narrow crest occurring at a depth of 200 m. The two shallowest points of the ridge are found at depths of 85 m and 104 m. The south-eastern and eastern flanks of the ridge rise from the 1000-1100 m deep Latakia Basin. The base of the north-western flanks lies on the 500 m deep, flat seafloor.

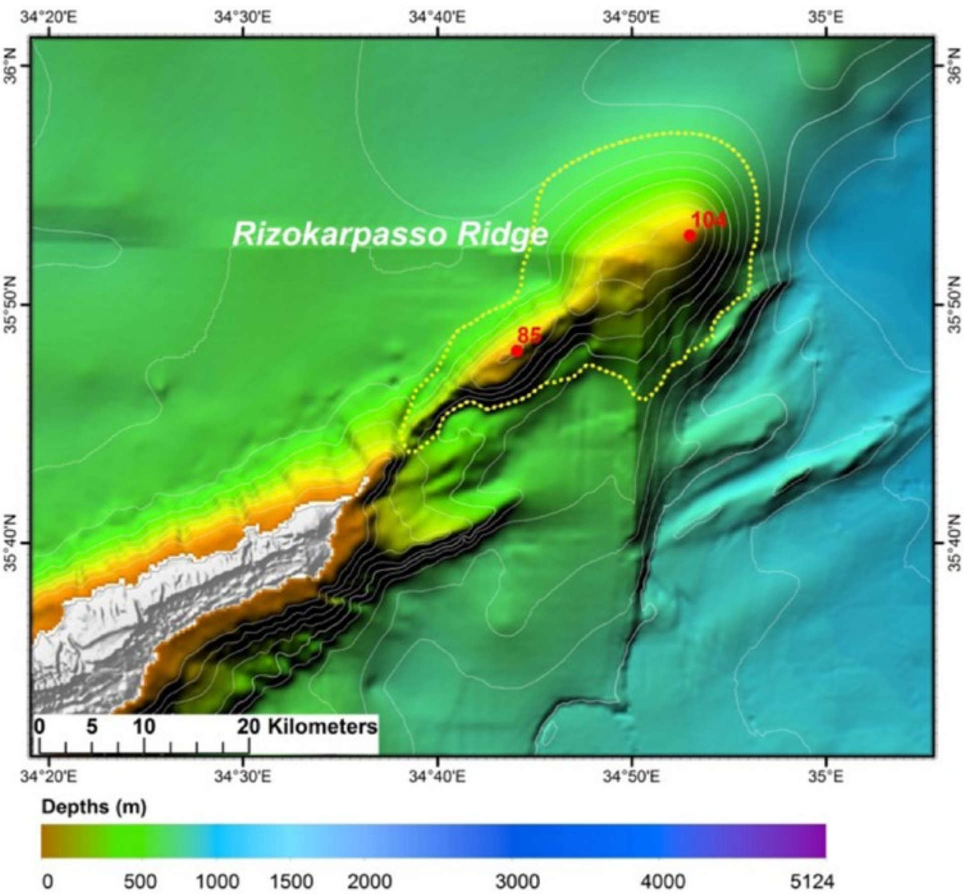


Fig. 2.54. Shaded relief map of Rizokarpasso (Karpas) ridge area.

The outline and the tops of the observed features are indicated on the map.

LATAKIA RIDGE (FIG. 2.55)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Latakia Ridge	2838.92	1067, 1172	2073

Latakia Ridge marks the eastern sector of the Cyprus Arc. It displays a concave shape and extends from the Hecataeus Seamount in the southwest to Latakia in Syria in the northeast. Latakia Ridge connects the Cyprus Arc with the sinistral East Anatolian Fault towards the northeast and represents the plate boundary with the Levantine Basin[29,30]. The north-eastern part of the ridge, off Syria, deepens gradually towards the southwest from < 100 m to > 1000 m. It forms a morphological escarpment facing southwards with the shallowest point of its crest located at depths of 1172 m and 1067 m. The latter is located at the western end of the ridge and is also described as **Hecataeus Ridge**. Its southern flank is roughly 1000 m high while the base of the northern flank dips down to a depth of 1500 m.

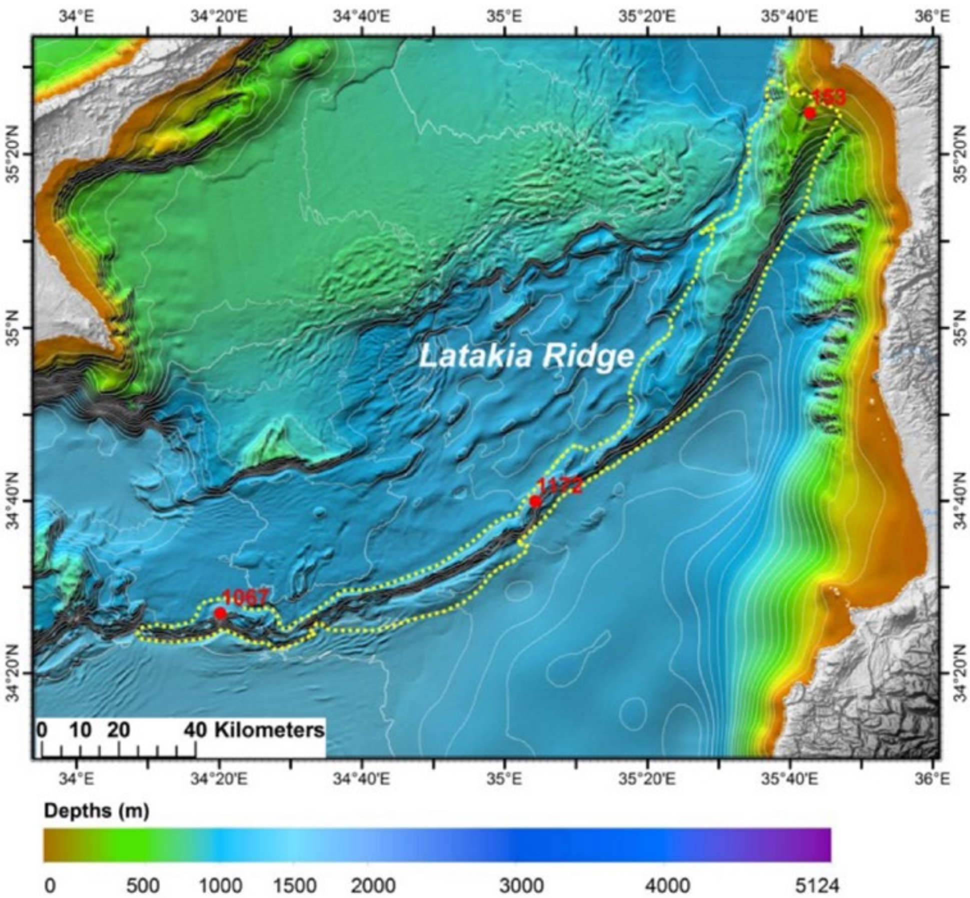


Fig. 2.55.
Shaded relief map of Latakia ridge area.

The outline and the tops of the observed features are indicated on the map.

ERATOSTHENES SEAMOUNT (FIG. 2.56)

Feature	Total Area (km²)	▲ Peak Depth (m)	Base Depth (m)
Eratosthenes Seamount	9487.06	1067, 771	2724

The Eratosthenes Seamount is an isolated, continental block hosting a Mesozoic carbonate platform. It belongs to the most extensively studied geological and geomorphological features in the Mediterranean Sea. The top of the seamount was exposed during the Messinian salinity crisis and has experienced several phases of emergence and submergence in older geologic times[31,32,33].

The Eratosthenes Seamount is a trapezoidal table mount (guyot). The base of the seamount is 102 km long in a NE-SW direction and 76 km wide in a NW-SE direction. The depth of the seamount's base increases from roughly 2000 m in the south to 2600 m in the west and north. The shallow plateau on the top extends over an area of 45 km long in a NE-SW direction and 28 km wide in a NW-SE direction with its depth ranging between roughly 800 m and 1100 m. The shallowest point on the shallow plateau is located at a depth of 771 m. The seamount is crosscut by several E-W running, normal faults which offset the flat top downwards toward the north. The faulting is associated with the progressive deformation induced by the involvement of Eratosthenes into the subduction below and incipient collision with the Cyprus Arc.

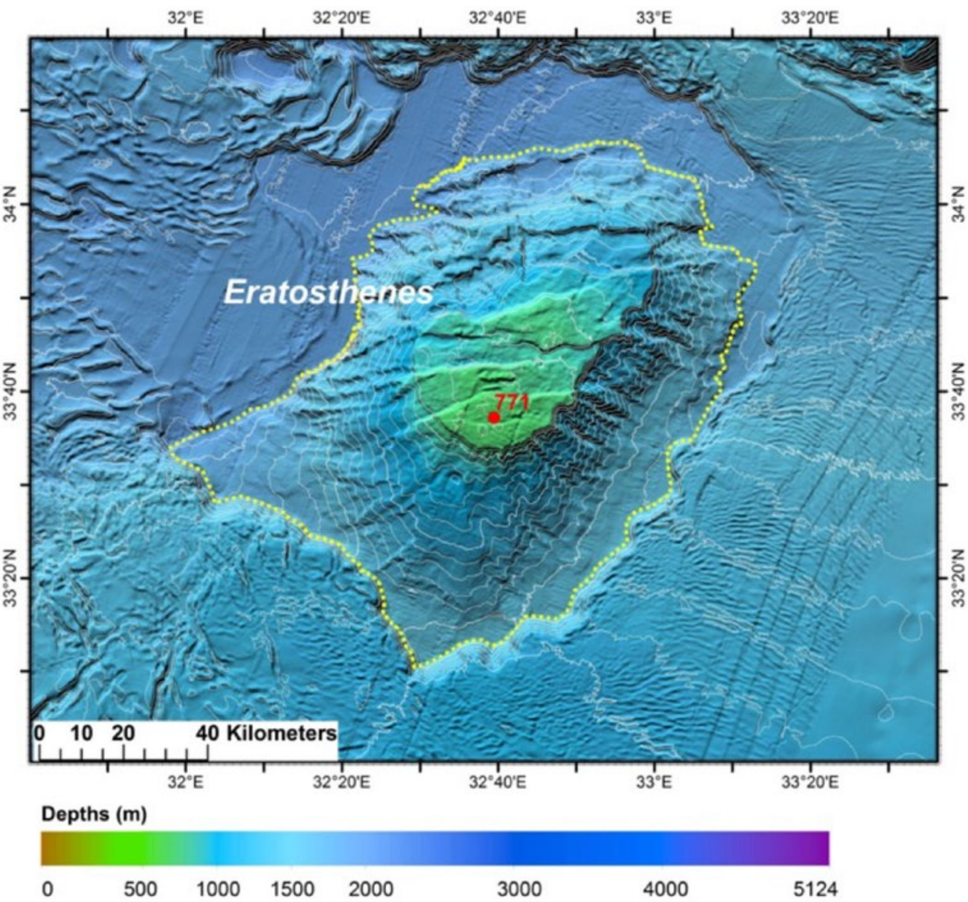


Fig. 2.56. Shaded relief map of Eratosthenes seamount area.

The outline and the tops of the observed features are indicated on the map.

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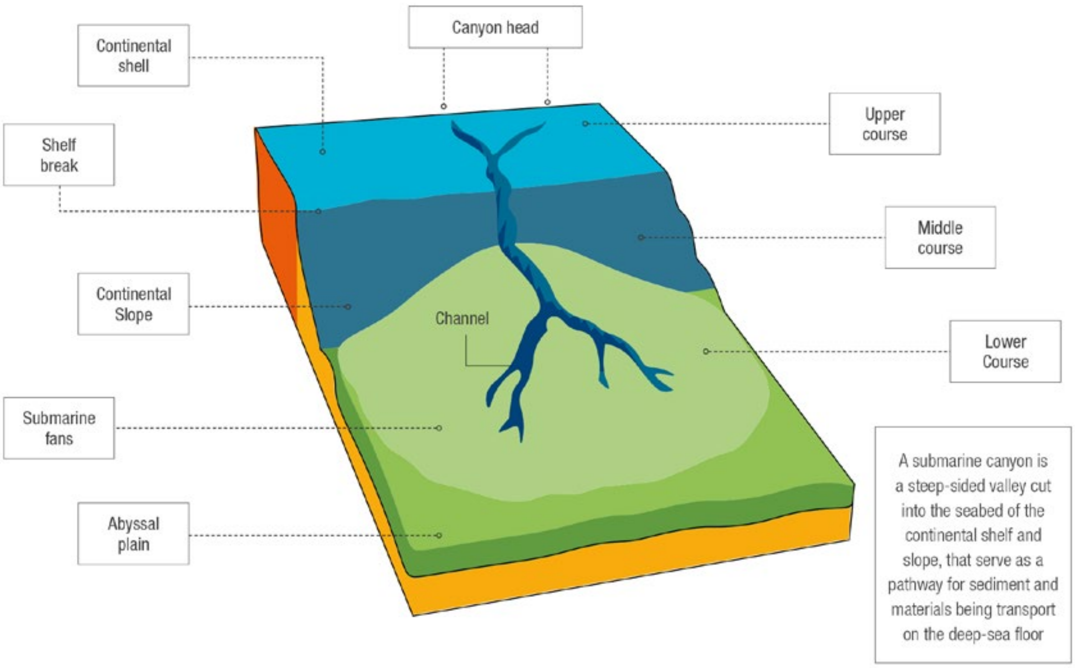
East Mediterranean Sea Canyons

A full inventory of Mediterranean submarine canyons has not yet been developed. An initial report based on the available information obtained from scientific literature indicated at least 518 large submarine canyons in the Mediterranean[34]. While a later report from IUCN described 348 submarine canyons or canyon systems from the eastern and western Mediterranean basins, of which 237 are named in scientific literature[6].

Here, a total of roughly 400 submarine canyons and gullies were identified on the seafloor of the Eastern Mediterranean. Half of them have been identified on the outer slopes of the Hellenic Arc. The total length of the identified canyons is roughly 9,000 km.



SUBMARINE CANYONS AND GULLIES SYSTEMS

Submarine canyons, gullies and thalweg are described here following these definitions[35]:

SUBMARINE CANYONS: steep-sided, V-shaped valleys with heads at or near the continental shelf edge. They extend across the continental slope and are commonly linked to numerous tributaries, similar to unglaciated river-cut canyons on land[36,37].

THALWEG: the line connecting the deepest points along the canyon (canyon axis).

SUBMARINE GULLIES: small-scale, less than 10 km long, first-order and confined channels, generally in the order of tens of metres deep and often linear in plan-view[37].

Large submarine canyons can be subdivided into three main types, in order to study their geomorphic differences between active and passive continental margins[34]:

Type 1) shelf-incising canyons having heads with a clear bathymetric connection to a major river system

Type 2) shelf-incising canyons with no clear bathymetric connection to a major river system

Type 3) blind canyons incised onto the continental slope.

1 EASTERN IONIAN SEA CANYONS

The canyons and gullies incising the margin of the Eastern Ionian are clustered into three areas: the NE Ionian margin, the Kyparisiakos Gulf margin and the Messiniakos, Lakonikos and Kythera South margin (Fig. 2.57). The canyons identified in the Corinth Gulf are also described here.

NORTH EAST IONIAN CANYONS (FIG. 2.58)

This area extends from the margin west of the Othonioi Islands to the North until the south-western margin of Kephallinia Island to the South. The steeply sloping margin of Western Greece and Ionian Islands displays two directions. The northern part, from Othonioi to Lefkas Islands, trends NW-SE. The southern part, from Lefkas to SW Kephallinia Islands, follows the major tectonic element of the Kephallinia Transform Fault and trends NNE-SSW.

The available low-resolution bathymetric data show a major, wide valley running NW-SE along the foot of the slope from Othonioi to southwest of the Paxoi Islands. **A group of submarine gullies incise the steep, eastern slope of the valley, west of the Othonioi Islands**. They develop at depths between 100 m and 1050 m. Their mean widths range from 200 m to 800 m and their length between 3 and 6.7 km. The axes of the gullies are straight. Most of them are characterized as type 3 canyons (blind canyons incised onto the continental slope). Only a couple of them belong to type 2 (shelf-incising canyons with no clear bathymetric connection to a major river system).

From the area southwest of the Paxoi Islands towards the S and SW, the former valley displays the form of a well-shaped canyon and continues as a canyon for more than 100 km. The latter follows the base of the slope, turns towards the SSW along the Kephallinia Transform Fault controlled steep margin, continues along the western, rounded base of the Lixouri Seamount and outflows at the 3800-4000 m deep basin west of Argostoli Ridge.

The margin between the main canyon and the shelf of the Ionian Islands is incised by a few dozen smaller canyons and gullies. All of them connect downwards to the main canyon. **More than 20 submarine canyons and gullies incise the continental slope west of the Paxoi Islands from depths of 250 m up to 1700 m.** They are characterized as type 3 canyons with lengths ranging between 3 km and 35 km. Their widths are from 200 m up to 1100 m and their axes are mostly straight.

More than 12 canyons and gullies incise the western slope of Lefkas Island. They belong to type 3 and their lengths range from 7.7 km up to 17 km. Their deeper edges reach depths of up to 2800 m. Their axes are mostly straight and their widths range from 400 m to 1 km.

Four Type 3 canyons occur on the margin southwest of Kephallinia Island, between the Lixouri Seamount and the Argostoli Ridge and on the western flank of Argostoli Ridge. Their lengths range from 6.5 km up to 27 km with 300 m to 600 m width and depths ranging from 700 m to 3700 m.

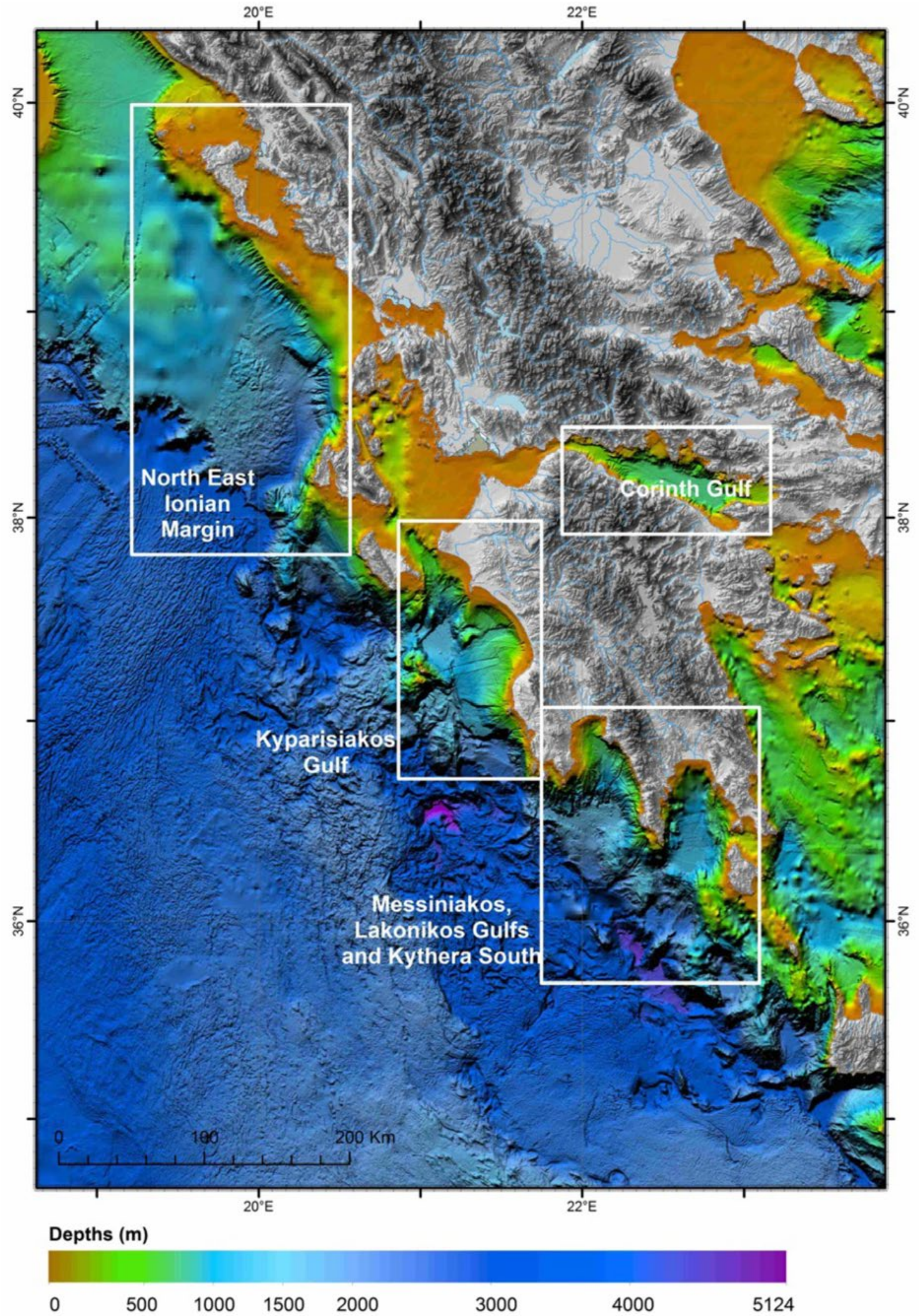


Fig. 2.57. Morphological map of the Eastern Ionian Sea with the location of the areas with submarine canyons.

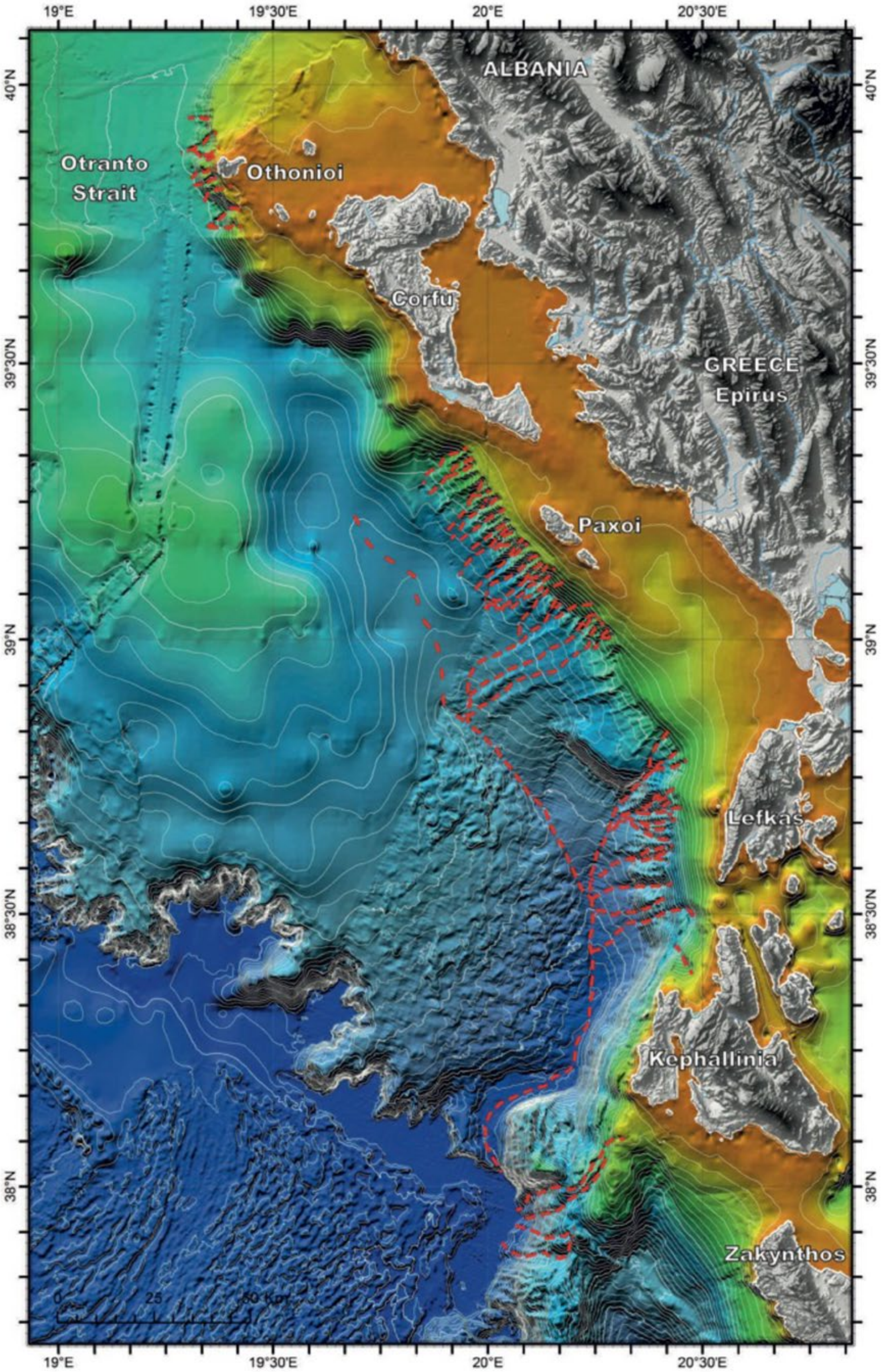


Fig. 2.58. Submarine canyons in the NE Ionian margin.

KYPARISIAKOS GULF CANYONS (FIG. 2.59)

This area extends from the strait between Zakynthos Island and Kyllene to the North all along the western Peloponnese until Pylos to the South.

The 100 km long Zakynthos Strait Canyon starts from the edge of the shelf (no connection with river – Type 2), passes through the strait of Zakynthos and outflows at a 2000 m deep plateau southwest of Katakolon. Ten smaller canyons and gullies incise the eastern wall of the canyon. Most of them start from the edge of the shelf or mid-slope, west of Katakolon, and connect at a depth with the central canyon.

Further south, **the margin of Kyparisiakos Gulf is incised by four major canyons and several gullies.** The northern canyon (**Pineios Canyon**) marks the prolongation of the **Pineios River** underwater. It is 50-55 km long and outflows at the 2000 m deep plateau mentioned above. The other three canyons start very close to the mouth of the **Neda River**. The northern one connects at a depth with the **Pineios canyon**. The other two incise the entire margin down to roughly 2000 m and merge at about 60 km southwest of the Neda mouth. From that point, one single canyon (**Neda Canyon**) continues to the south and terminates at a depth of roughly 2800-3000 m, east of Nestor Ridge.

The southern group of canyons occurs on the steep slope **west of Pylos. At least five or six canyons or gullies**, up to 15 km long, incise the steep slope starting from the edge of the shelf.

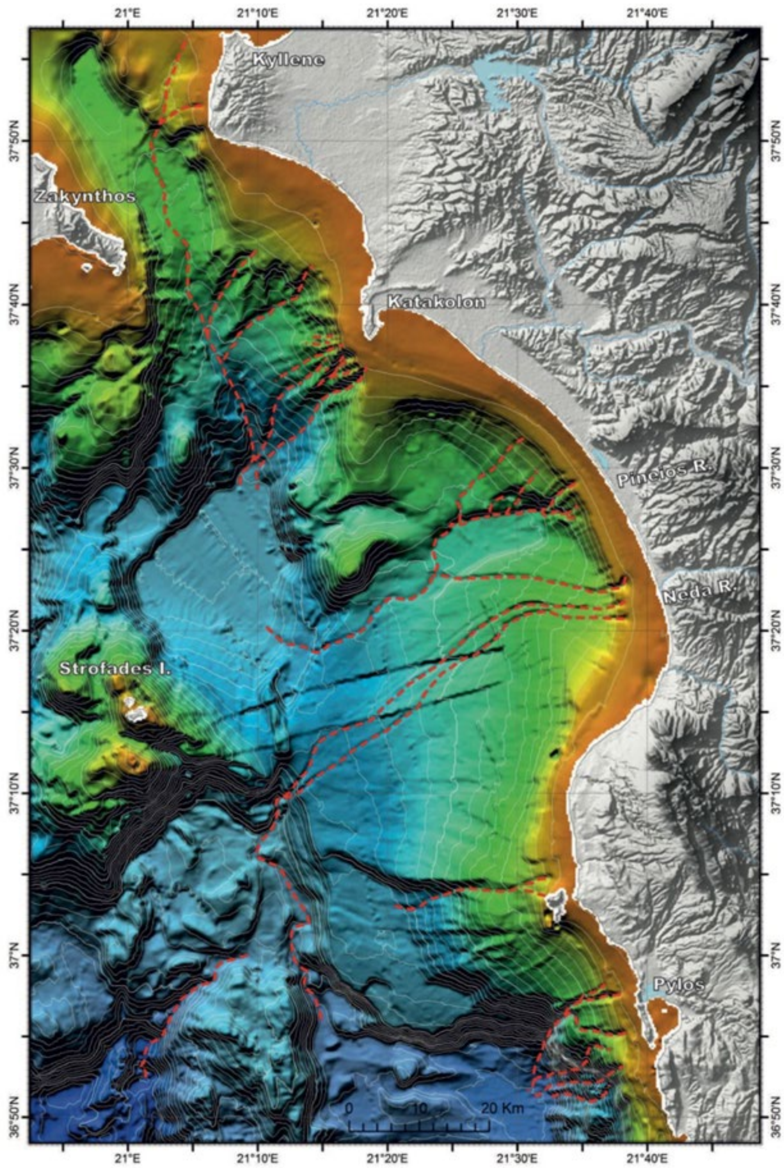


Fig. 2.59. Submarine canyons and gullies in the Kyparisiakos Gulf margin.

MESSINIAKOS-LAKONIKOS GULFS CANYONS (FIG. 2.60)

Over 40 submarine canyons and gullies incise the slope of the Messiniakos Gulf. The majority of them belong to Type 3 canyons with heads well off the shelf edge. Some of the canyons, in particular the ones which occur on the eastern slope of the Messiniakos Gulf, belong to Type 2. The length of the Messiniakos canyons ranges between 5 and 25 km and most of them terminate at a depth of around 2200-2500 m.

Two canyons begin at a depth > 200 m south of the Mani Peninsula, they merge at a depth of 2500 m and terminate at roughly 3500 m, 35-36 km away from the canyon head.

Only 2 submarine gullies have been identified in the Lakonikos Gulf. They are Type 2 canyons with lengths from 4.8 km to 10 km. Their heads are located at the shelf edge and they terminate at roughly 800 m.

One submarine canyon is recognized southwest of Kythera Island. The canyon is 12 km long and incises the eastern flank of the Avlemonas seamount. It begins at a depth of 1500 m and terminates eastwards at 3000 m.

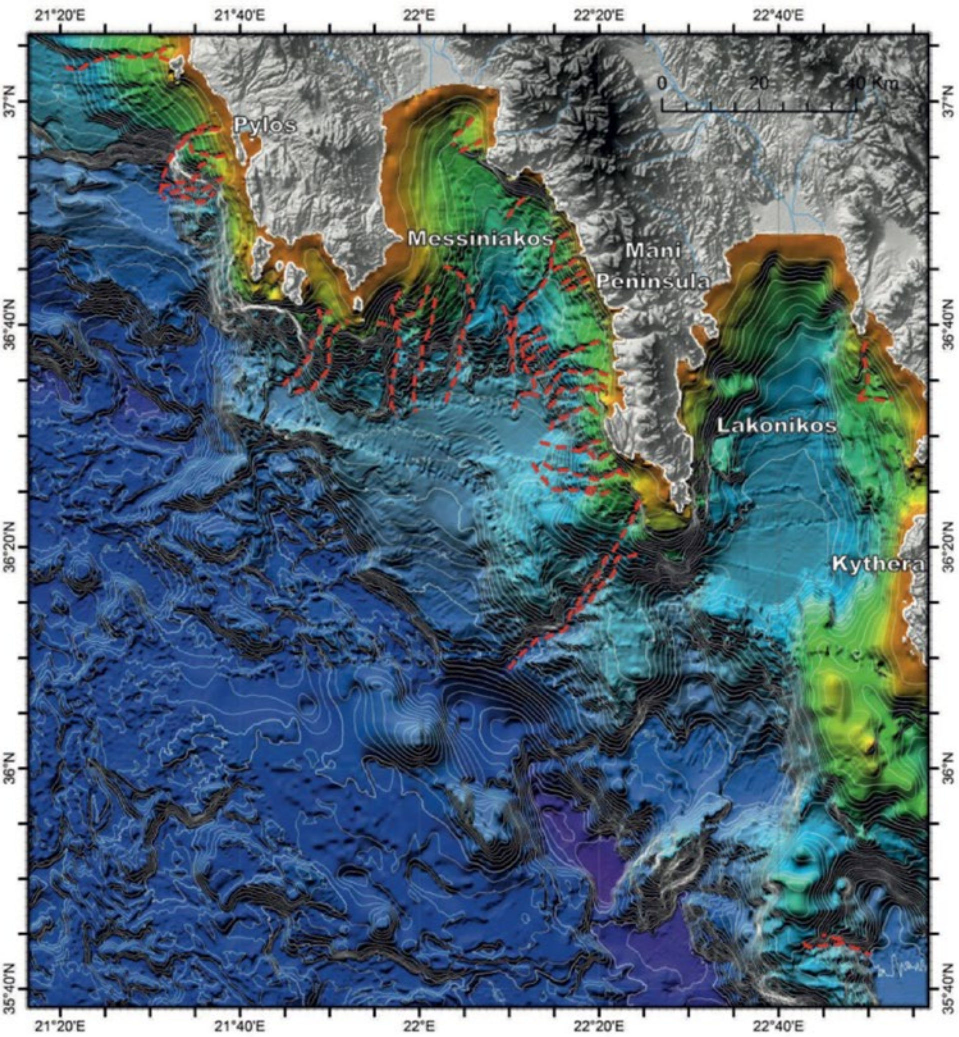


Fig. 2.60. Submarine canyons and gullies in the Messiniakos and Lakonikos Gulfs margin.

CORINTH GULF CANYONS (FIG. 2.61)

The northern and southern margins of the Gulf of Corinth are incised by numerous gullies. Only the most prominent ones have been drawn on the map (Fig. 2.61). The majority of the gullies are characterized as type 2 canyons, however some of them, in particular along the southern margin of the Gulf, do connect with rivers outflowing on the southern coast. In the western part of the Gulf they terminate at a depth of roughly 400 m. In the central part of the Gulf they terminate at the edges of the 800-850 m deep basin.

The most prominent canyon runs along the axis of the western part of the Gulf. It is 15-16 km long and connects the 400-500 m deep western basin with the 700-850 m deep basin of the central Corinth Gulf.

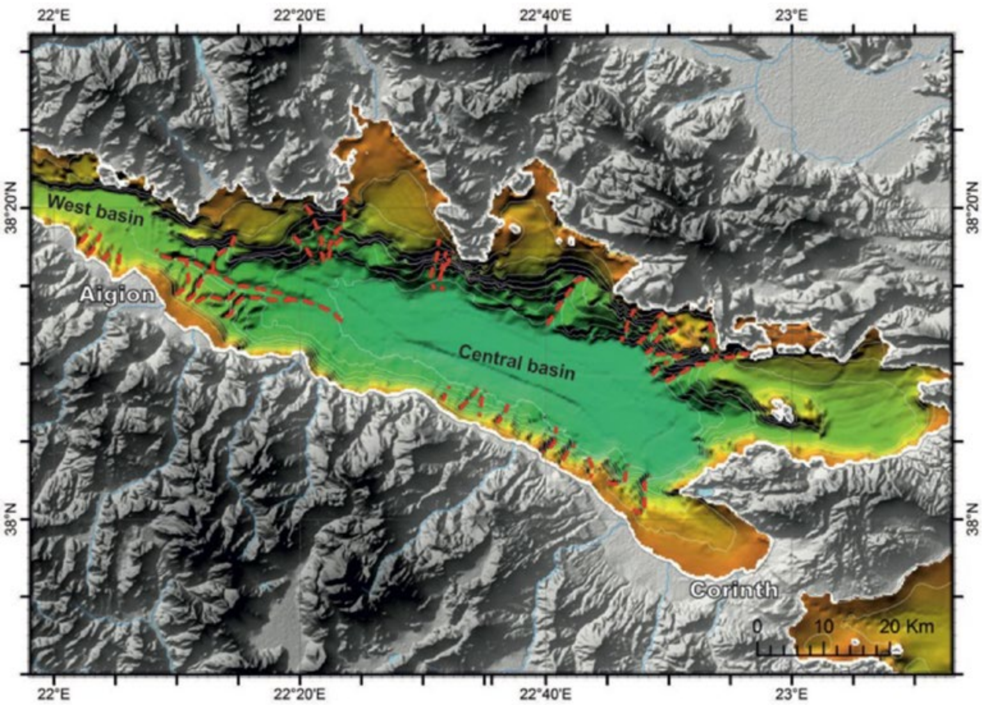


Fig. 2.61. Submarine canyons and gullies in the Corinth Gulf.

2

NORTH AEGEAN SEA CANYONS

INTRODUCTION

Submarine gullies and a few canyons have been mapped on the slopes of three basins in the North Aegean Sea: the North Aegean Trough, the Skopelos Basin and the North Evia Gulf (Fig. 2.62). With the exception of a couple of relatively long canyons on the northern slopes of the North Aegean Trough, all other canyon-like features identified in the North Aegean Sea are short gullies, which incise the steep, fault-controlled slopes.

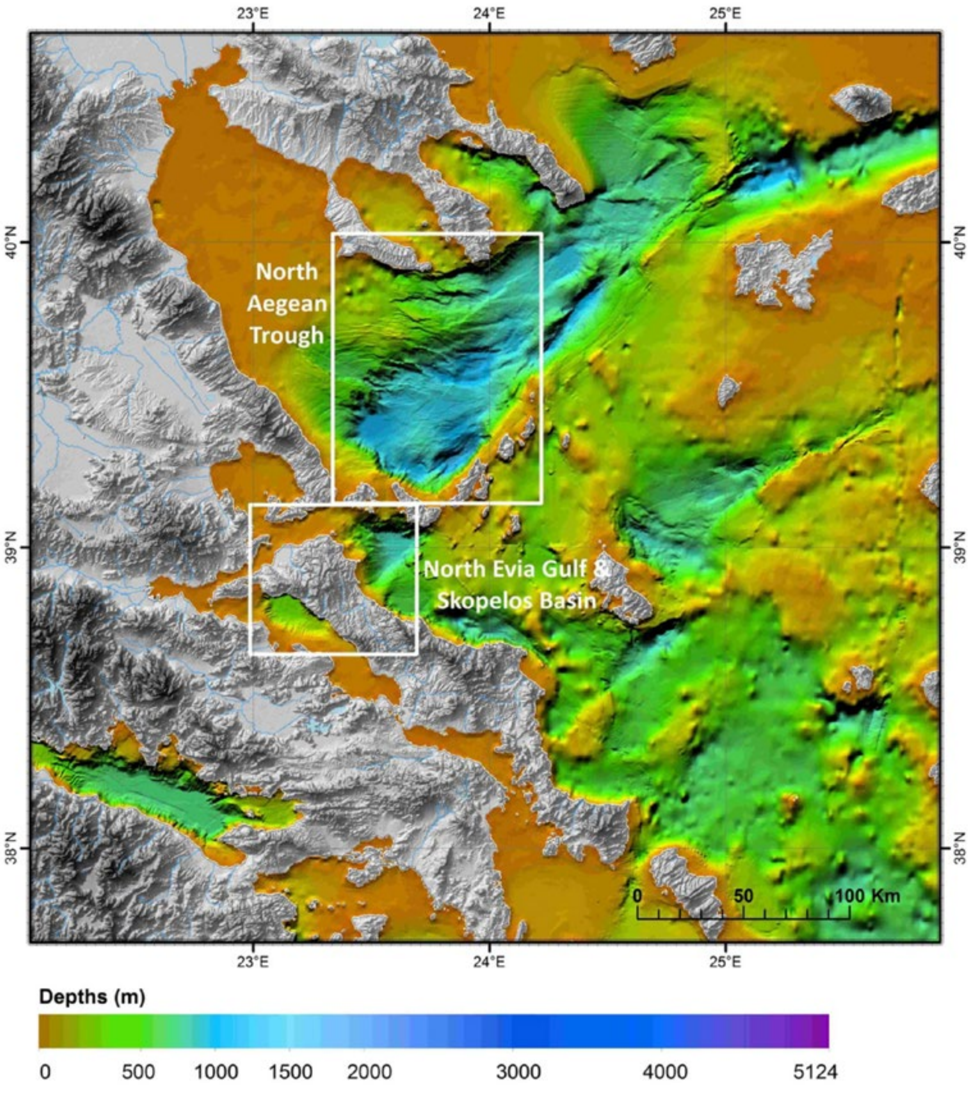


Fig. 2.62. Morphological map of the North Aegean Sea with the location of the areas with submarine canyons and gullies described here.

NORTH AEGEAN TROUGH CANYONS (FIG. 2.63)

The south-eastern margin of the North Aegean Trough displays a linear shape and is controlled by the western branch of the North Anatolian Fault. Short gullies have been identified on the westernmost part of the margin, as well as on the steep, NW-SE trending, western slope of the basin, which has developed along a major, predominantly normal to oblique fault zone.

The north-western margin of the Trough is dissected by several failure scars, associated with short gullies. **Three longer canyons occur on this margin**. They are 15-25 km long, they initiate at the upper part of the slope, at a depth of between 400-700 m and can be traced downslope and on the seafloor of the Trough, following the directions of the main tectonic lines.

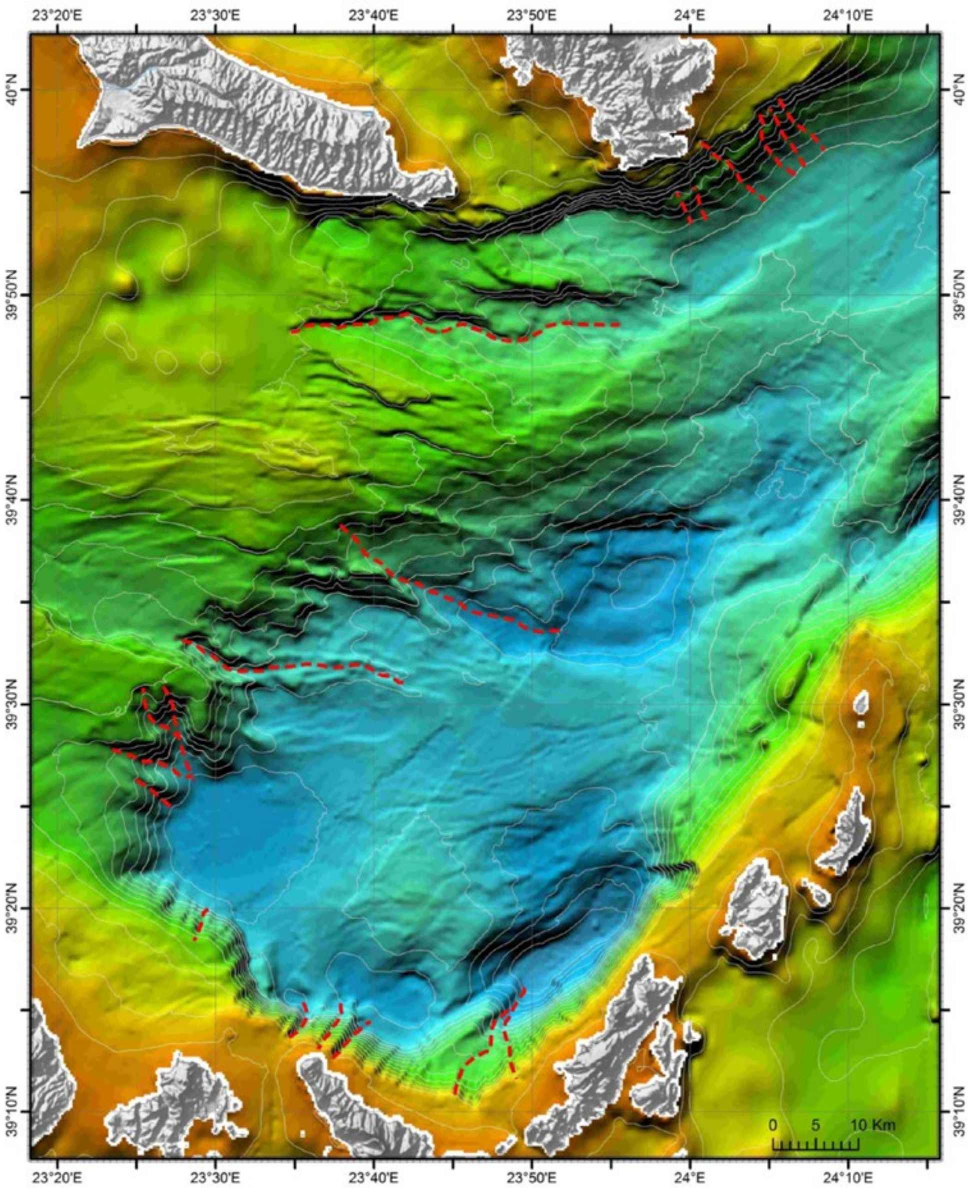


Fig. 2.63. Submarine canyons and gullies on the slopes of the North Aegean Trough.

SKOPELOS BASIN AND NORTH EVIA GULF GULLIES (FIG. 2.64)

The **Skopelos Basin** is a 1000 m deep, isolated morphological depression, surrounded by steep, fault controlled slopes. **Short gullies** incise the steep slopes of the northern margin of the basin, without any connection to any morphological feature onshore.

The 440 m deep **North Evia Gulf** basin displays an asymmetric morphological character. The north-eastern margin of the basin is very steep while the south-western one dips more gently. **Short gullies** incising the north-eastern slope probably initiate very close to the shoreline and are associated with distinct onshore valleys. The gullies which incise the south-western margin start at the edge of the shelf and show no apparent connection with any onshore river valleys.

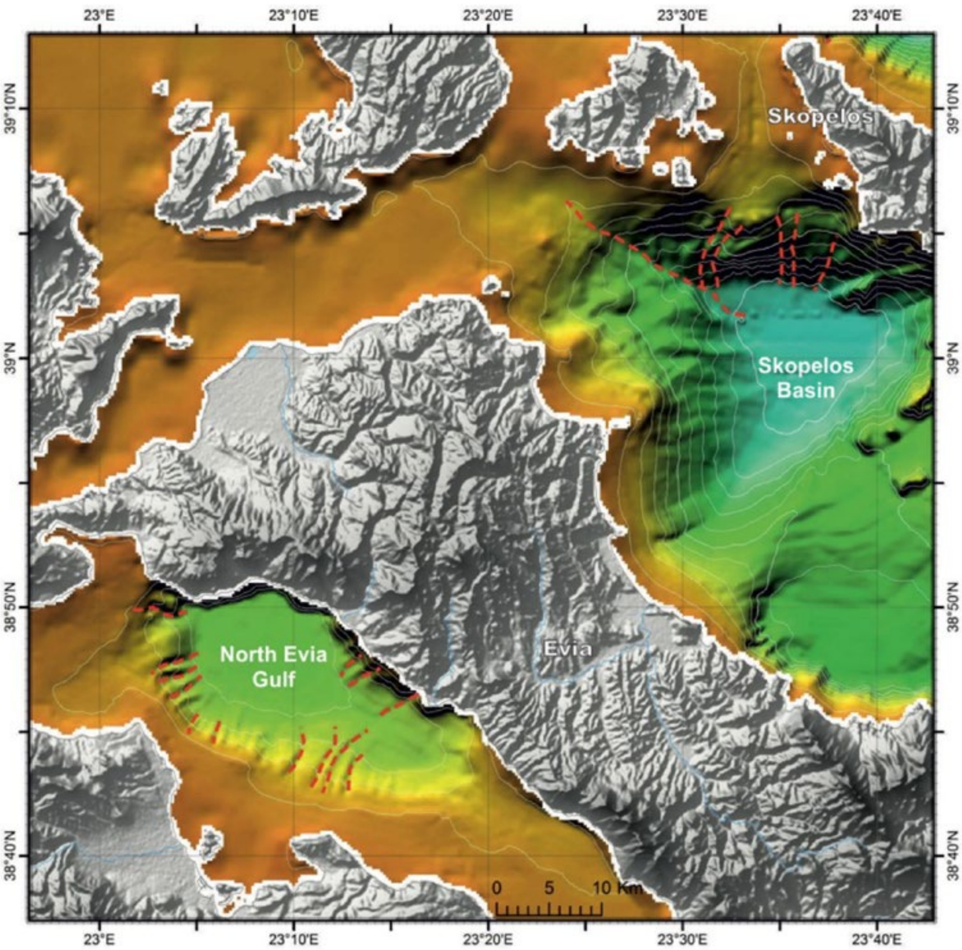


Fig. 2.64. Submarine gullies on the slopes of Skopelos Basin and the North Evia Gulf.

3 SOUTH AEGEAN SEA CANYONS

INTRODUCTION

Submarine canyons in the South Aegean Sea have been recognized in three areas: south of Serifos Island, southwest of Nisyros and Tilos Islands and south of Kassos Island. The latter is located on the Hellenic Arc (Fig. 2.65).

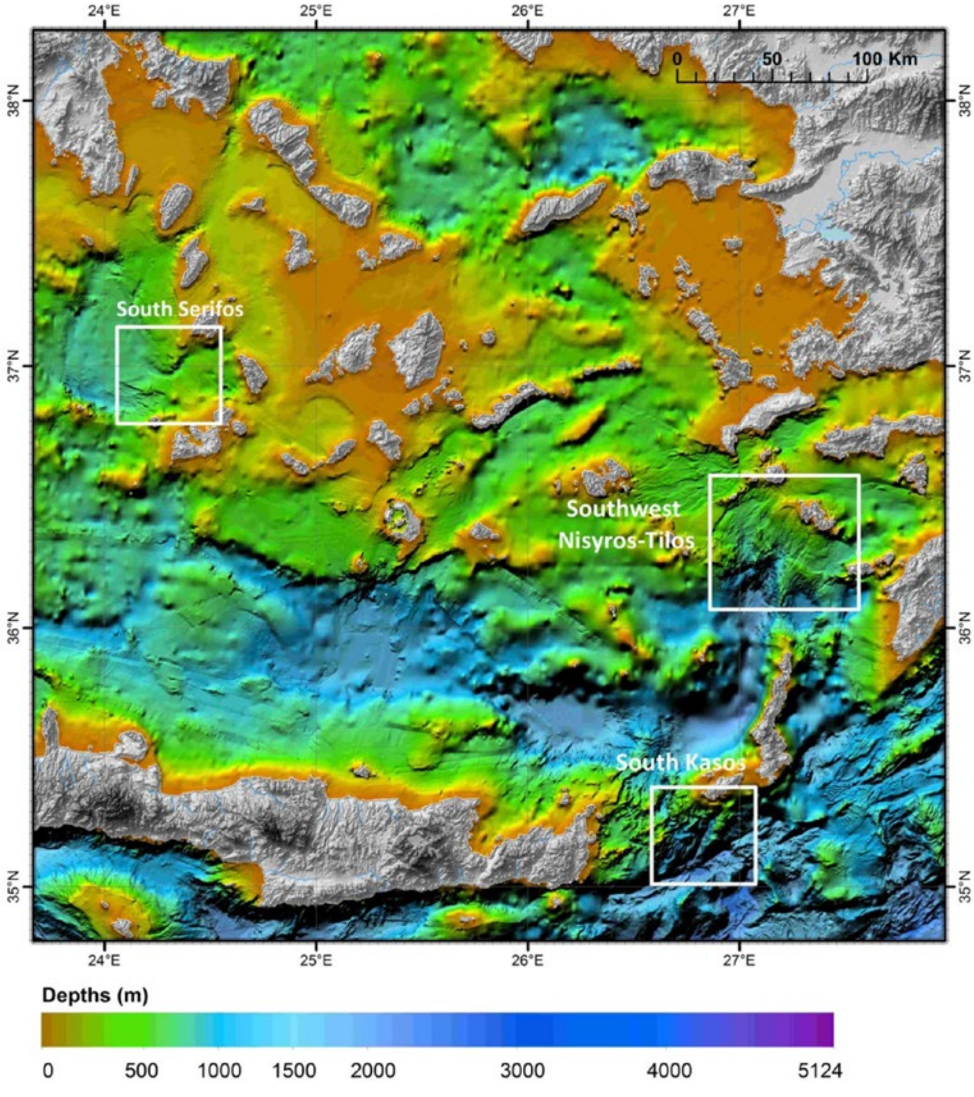


Fig. 2.65. Morphological map of the South Aegean Sea with the location of the areas with submarine canyons and gullies described here.

SOUTH SERIFOS CANYON (FIG. 2.66)

A well developed, 20-25 km long canyon has been formed along the base of the submarine slope south of Serifos Island, in the western part of the South Aegean Sea. The canyon follows the trace of a NE-SW trending fault and bends to the north before its termination in the Myrtoon Basin.

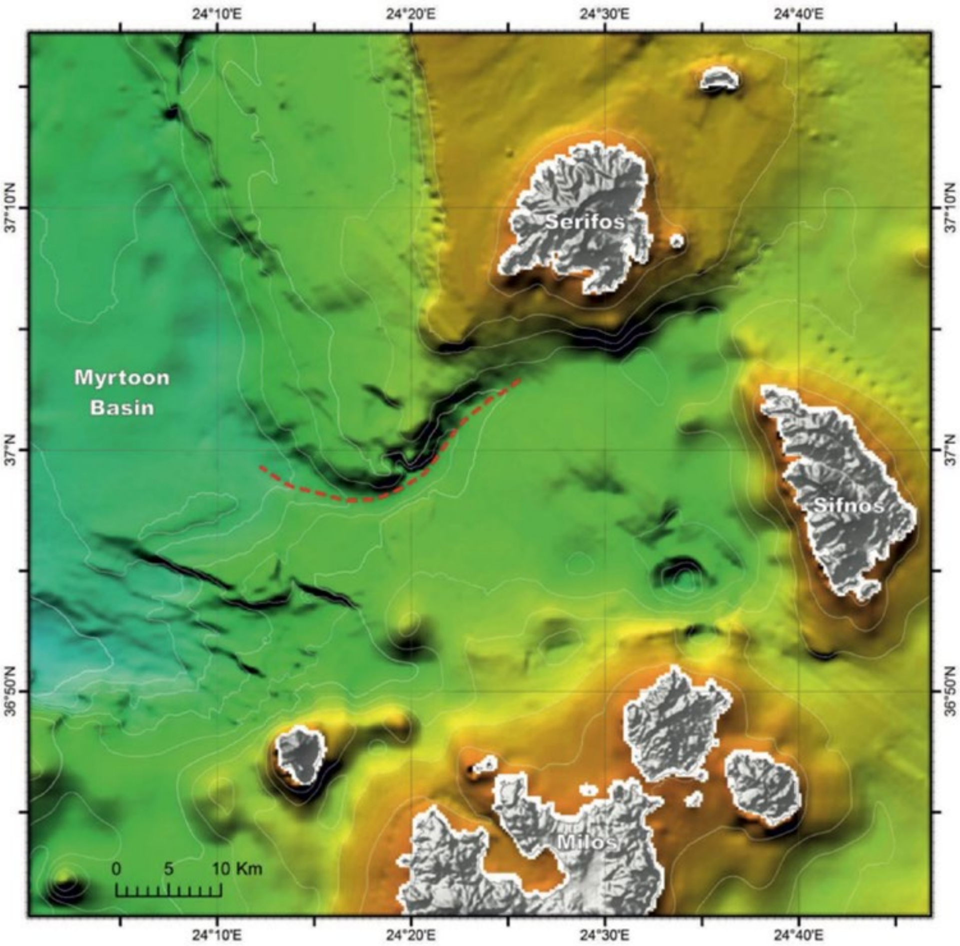


Fig. 2.66. The submarine canyon along the southern slope of Serifos Island.

SOUTHWEST NISYROS-TILOS CANYONS (FIG. 2.67)

The morphologically complex and irregular slope southwest of Nisyros and Tilos Islands, toward the > 2000 m deep North Karpathos Basin is incised by **three prominent canyons**.

The longer one, roughly 50 km long, begins south of Nisyros, at a depth of 350-400 m, runs toward the Southwest, bends to the South forming a narrow valley on the steep slope and terminates on the flat floor of the North Karpathos Basin.

Two canyons have their heads southwest of Tilos Island. They run to the southwest and merge at a depth of roughly 1000 m. The lower part of the canyon incises the steep slope and terminates in the North Karpathos Basin.

A short gully occurs south of Tilos Island and west of Chalki Island. It is < 15 km long and terminates in the flat floor of the Saria Basin.

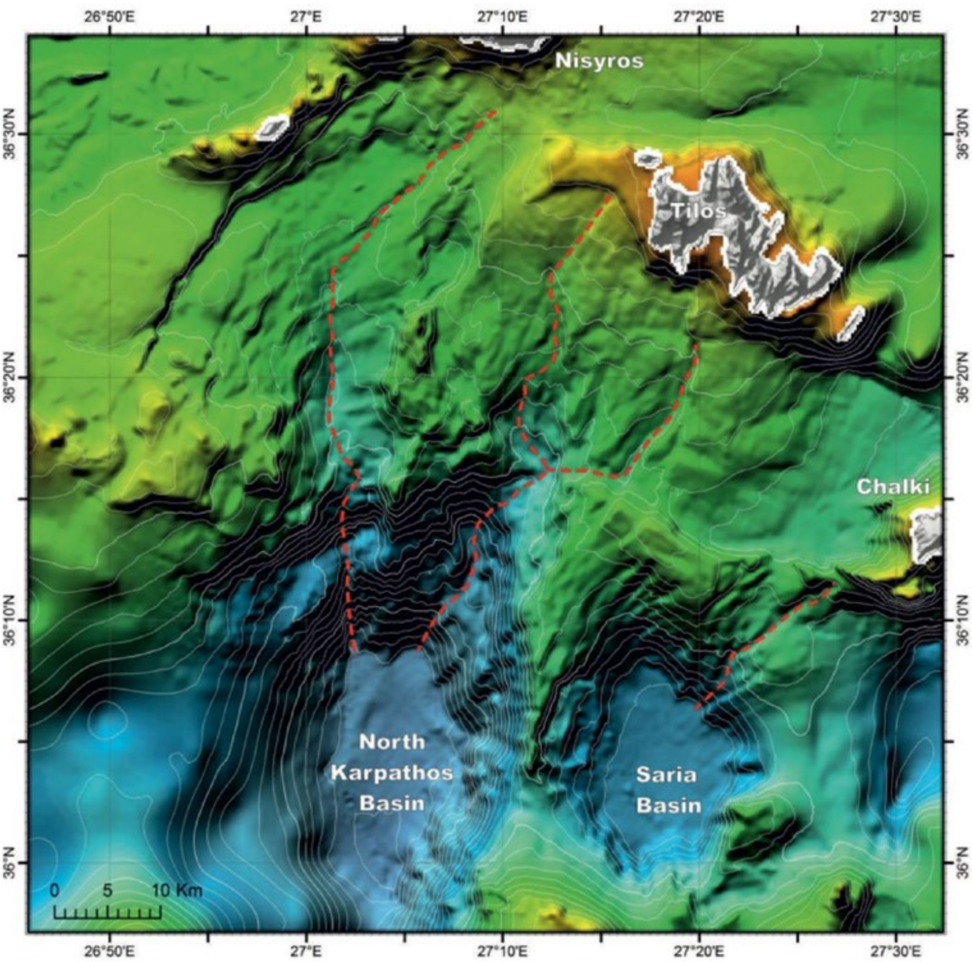


Fig. 2.67. Submarine canyons on the seafloor southwest of Nisyros and Tilos Islands.

SOUTH KASOS CANYON (FIG. 2.68)

A 30 km long canyon initiates at the upper part of the slope south of Kasos Island. It runs toward the southwest forming a V-shaped valley and terminates on the flat floor of a 3000 m deep small basin developed within the composite morphological feature of the Pliny Trough.

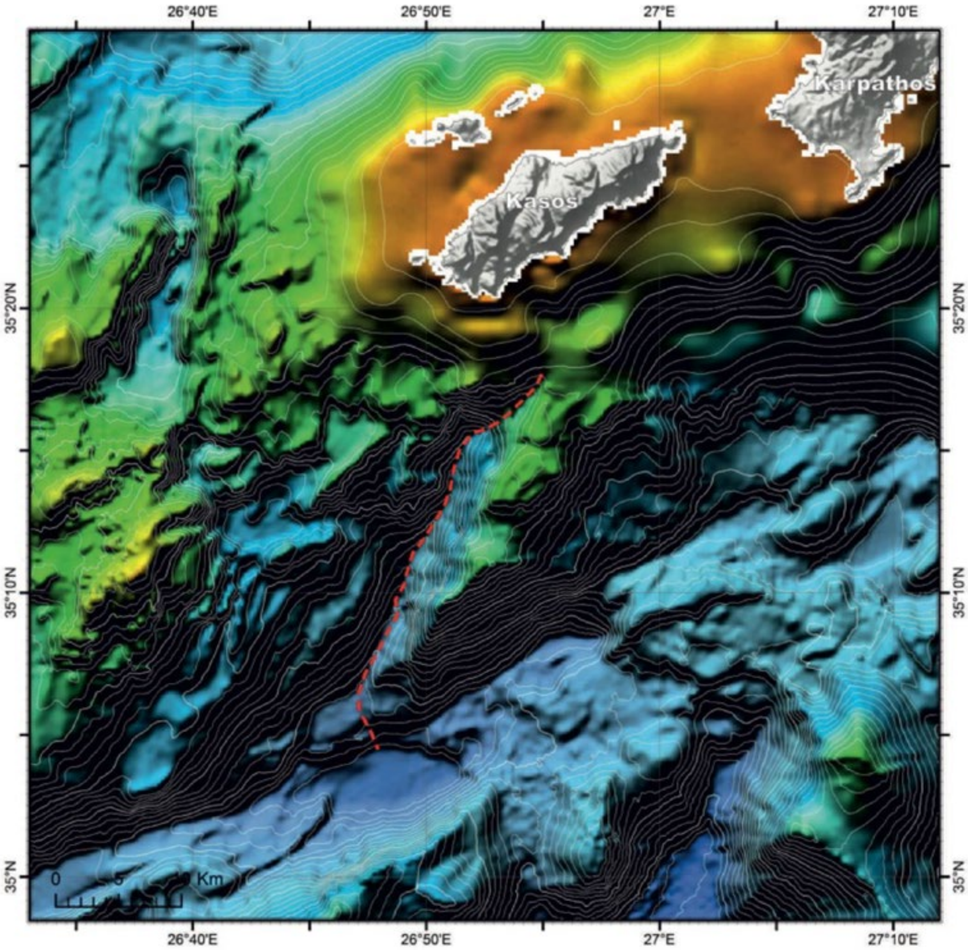
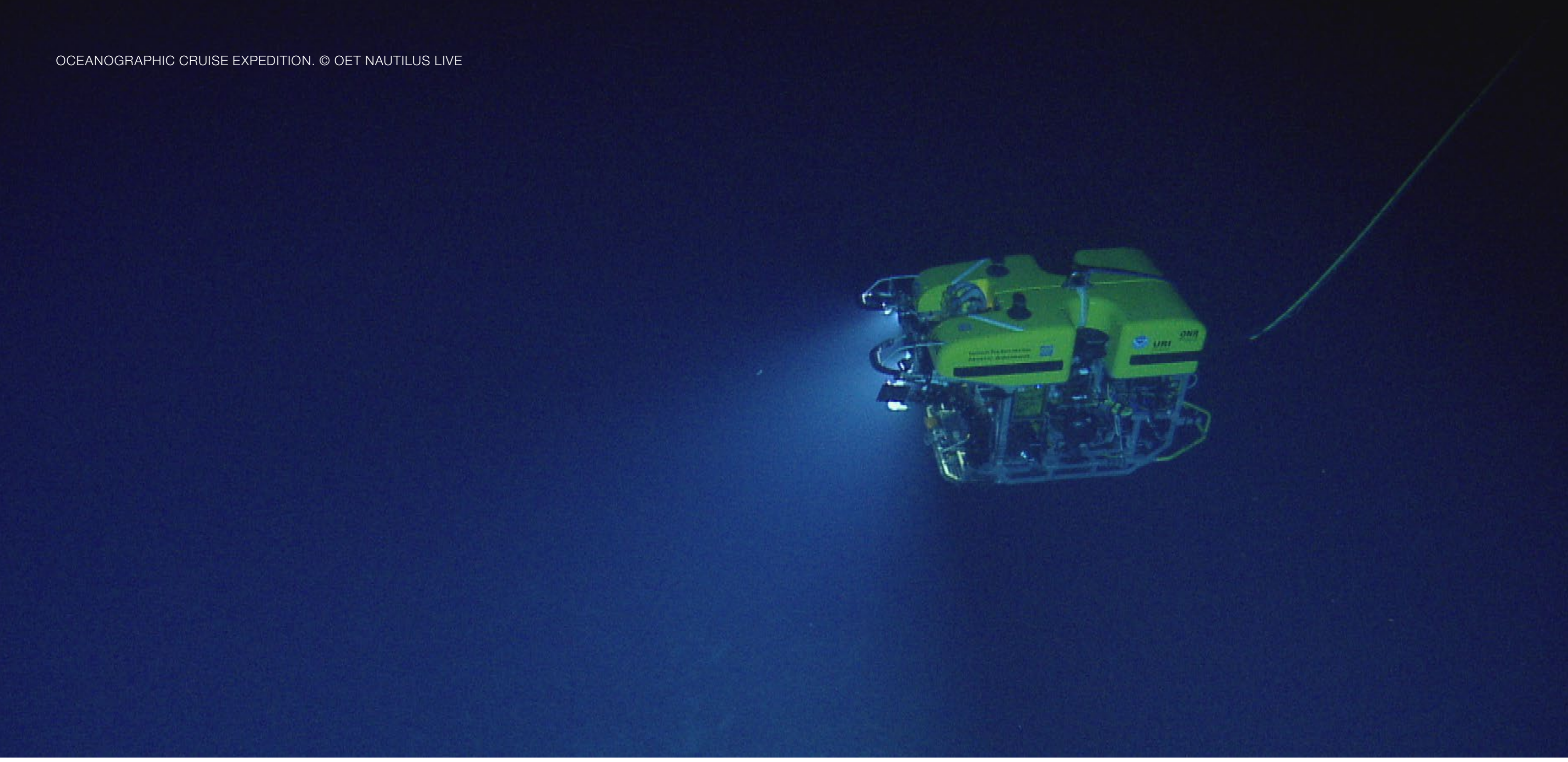


Fig. 2.68. The submarine canyon south of Kasos Island.



4 LIBYAN SEA CANYONS

The canyons and gullies incising the slopes of the Libyan Sea are clustered in two main areas (Fig. 2.69): the active margin of the Hellenic Arc and the passive margin of Libya.

The southern margin of Crete is incised by numerous gullies (Fig. 2.70). The area of the Samaria Canyon (Fig. 2.71) and east of Gavdos Island (Fig. 2.72) are described in detail. A major canyon off the south-eastern edge of Crete marks the western margin of Vai Seamount (Fig. 2.73). Long canyons and associated gullies incise the south-eastern margin of Rhodes Island (Fig. 2.74).

The canyons identified on the passive margin of Libya occur in the area of Tobruk (Fig. 2.75).

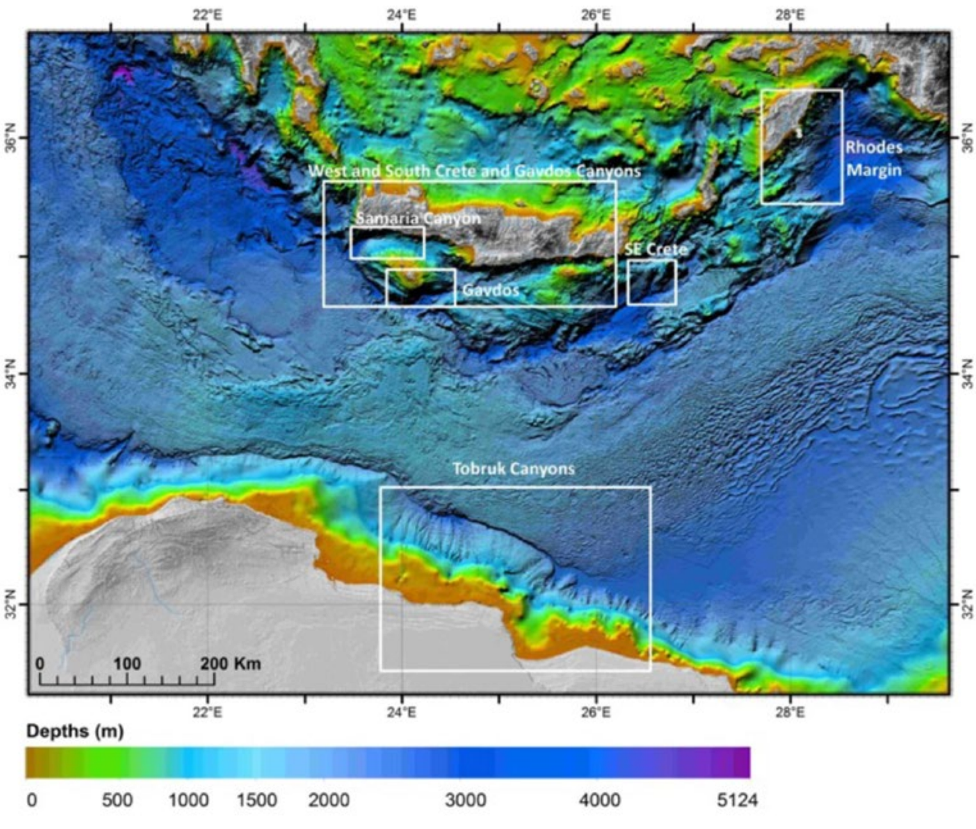


Fig. 2.69. Morphological map of the Libyan Sea with the location of the areas with submarine canyons and gullies.

SOUTH CRETE CANYONS (FIG. 2.70)

The southern, steep margin of the 250 km long Crete Island marks the spectacular morphological escarpment between the > 2000 m high mountains of the island and the > 3000 m deep marine troughs to the south. Numerous, short gullies incise the steep margin, while many of them merge with long canyons, which run along the base of the slopes.

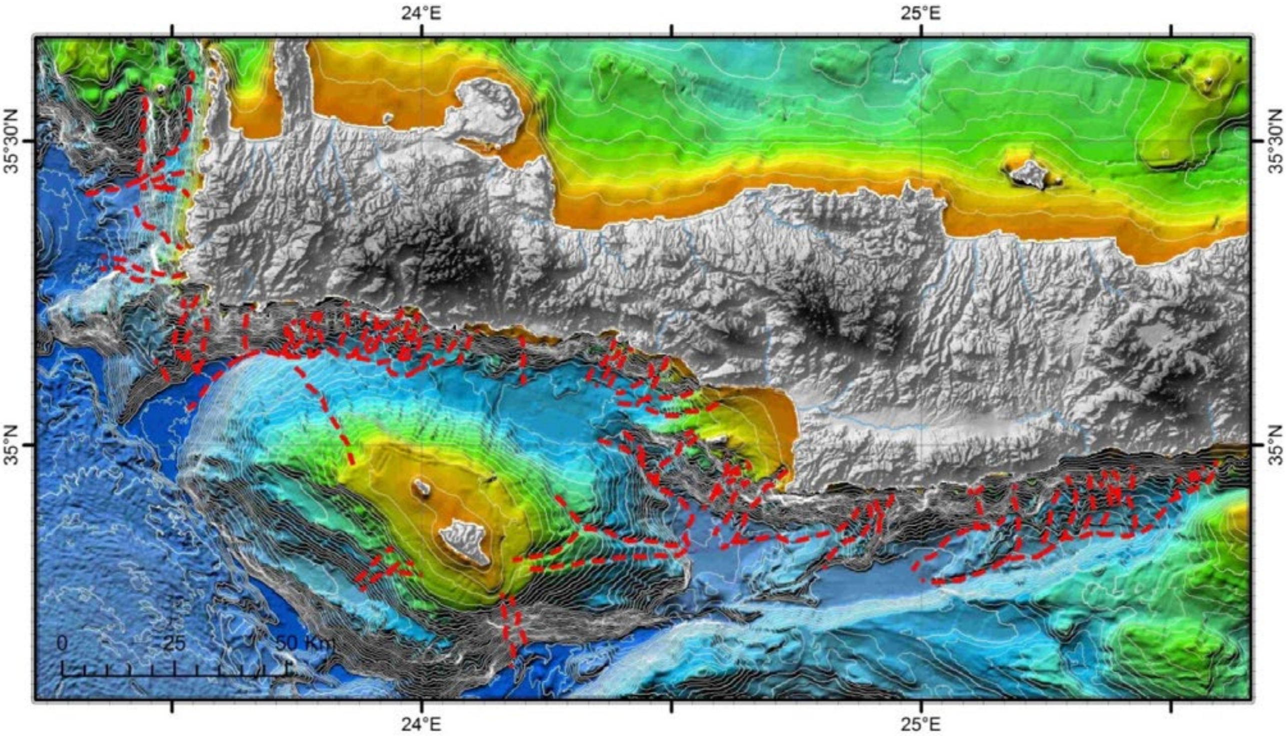


Fig. 2.70. Submarine canyons and gullies in the southern margin of Crete and on the margins of Gavdos Island.

SAMARIA CANYON (FIG. 2.71)

The Samaria Canyon is named after the Samaria Gorge, the most famous and spectacular one out of the numerous gorges which incise the southern mountainous slopes of Crete.

The total length of the **Samaria Canyon** exceeds 50 km. It originates on the steep slopes east of the Samaria Gorge, bending towards the west at the base of the slope, it runs parallel to and between the margins of West Crete and Gavdos and terminates in the Gortys Trough at a depth of roughly 3500 m. The Samaria Gorge continues offshore as one of the **dozens of gullies** which incise the steep southern margin of Crete and merge with the main Samaria Canyon.

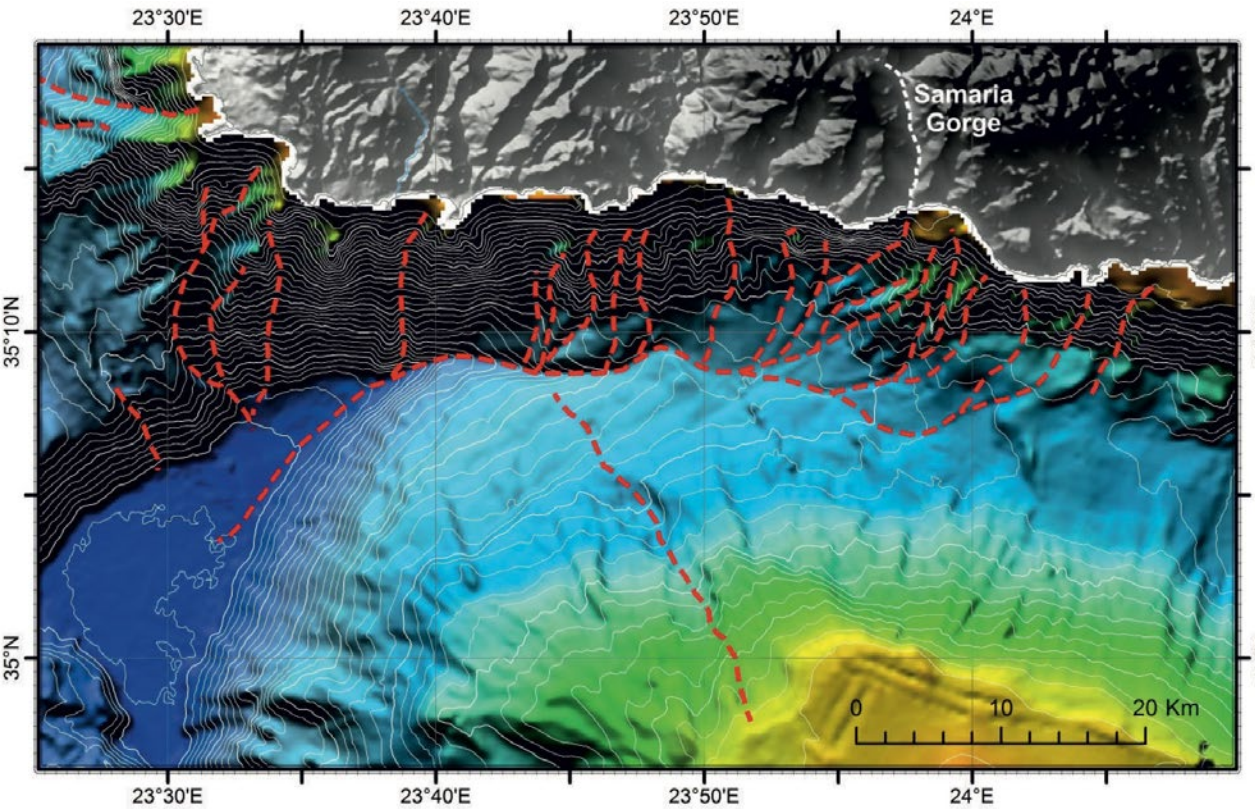


Fig. 2.71. Submarine canyons and gullies in the southern margin of Western Crete (Samaria Canyon).

GAVDOS CANYONS (FIG. 2.72)

Four short, 10-15 km long gullies have been mapped on the south-eastern and south-western slopes of Gavdos Island. **Longer and well developed canyons** occur on the eastern submarine slope of Gavdos. One of them runs between the margin of Gavdos and the one of Central Crete and drains the 1500 m deep basin between Gavdos and Western Crete towards the 3000 m deep Ptolemy Trough to the east.

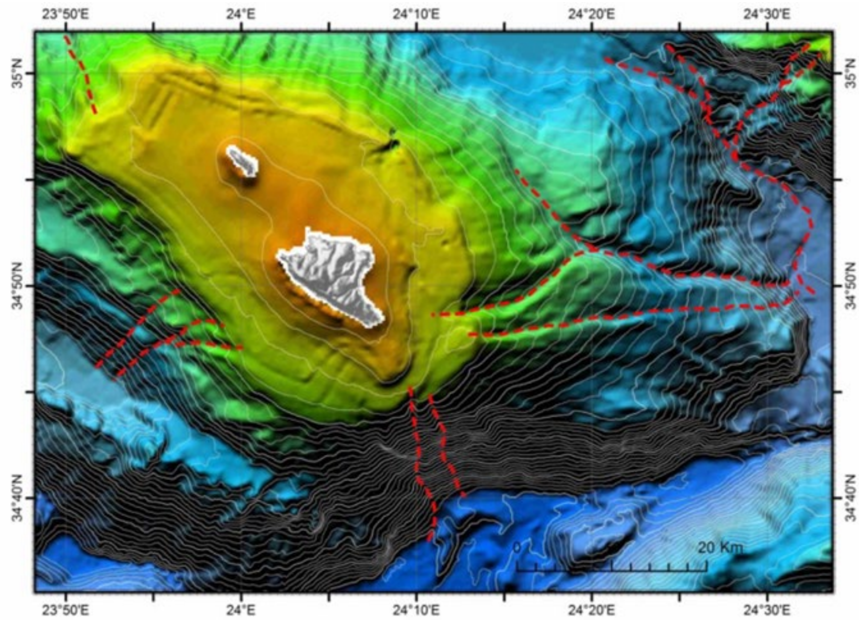


Fig. 2.72. Submarine canyons and gullies on the margins of Gavdos Island.

SE CRETE CANYON (FIG. 2.73)

A 30 km long, impressive canyon marks the western limit of Vai Seamount, located southeast of Crete. The canyon starts at a depth of 1300 m, west of the summit of Vai Seamount, and terminates at the one of the deep basins of the Pliny Trench at a depth of 3500 m.

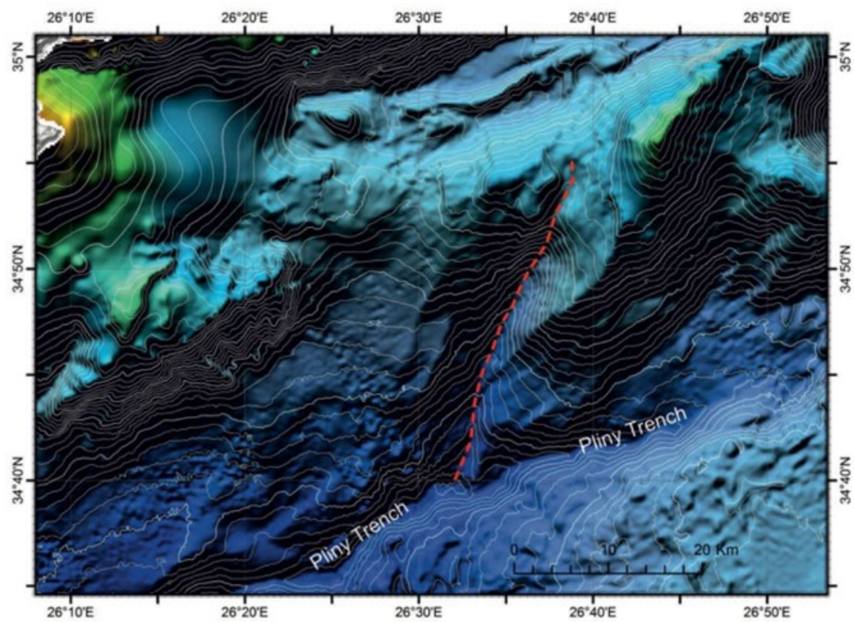


Fig. 2.73. The submarine canyon at the western limit of Vai Seamount, southeast of Crete.

RHODES MARGIN CANYONS (FIG. 2.74)

The south-eastern margin of Rhodes, toward the 4000 m deep Rhodes Basin, is incised by many canyons and gullies. Long, well developed canyons originate from the edge of the shelf or the upper slope off the northern part of the island. Short gullies occur on the slope off the southern part of Rhodes.

The longest canyon occurs south of Rhodes Island. It is a roughly 100 km long canyon, which originates from within the Pliny Trench and terminates in the Rhodes Basin towards the NE.

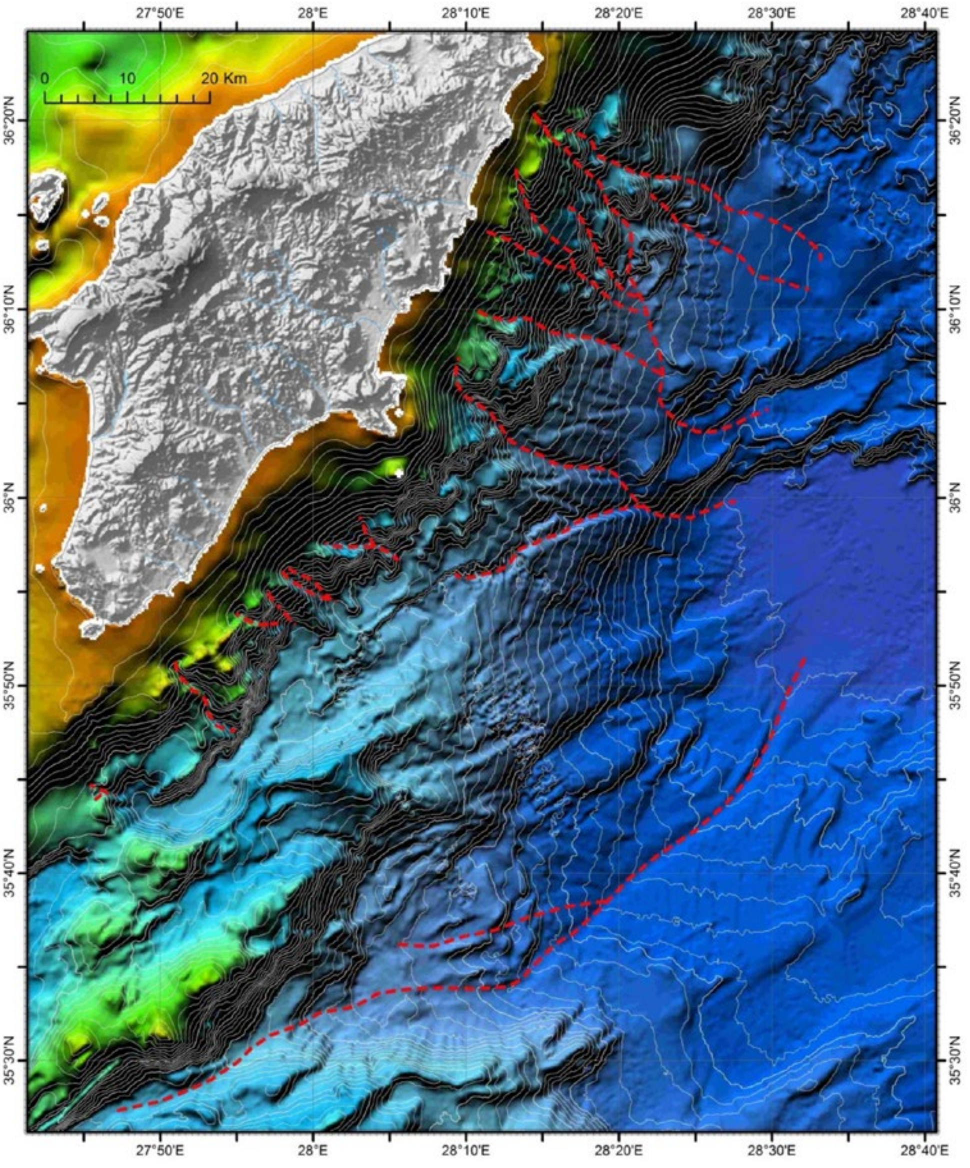


Fig. 2.74. Submarine canyons and gullies on the margins of Rhodes Island.

TOBRUK CANYONS (FIG. 2.75)

The passive margin off the coasts of Eastern Libya and Western Egypt are incised by a large number of canyons. The longest ones occur in the western part of the area, off the Libyan coast of Tobruk. Their length exceeds 30-40 km, they originate at mid-slope and terminate at the base of the passive margin, at the boundary with the deformed sediments of the Mediterranean Ridge.

The eastern canyons and gullies, off the Egyptian coast originate at the mid slope and terminate at the 3200 m deep flat Herodotus Basin.

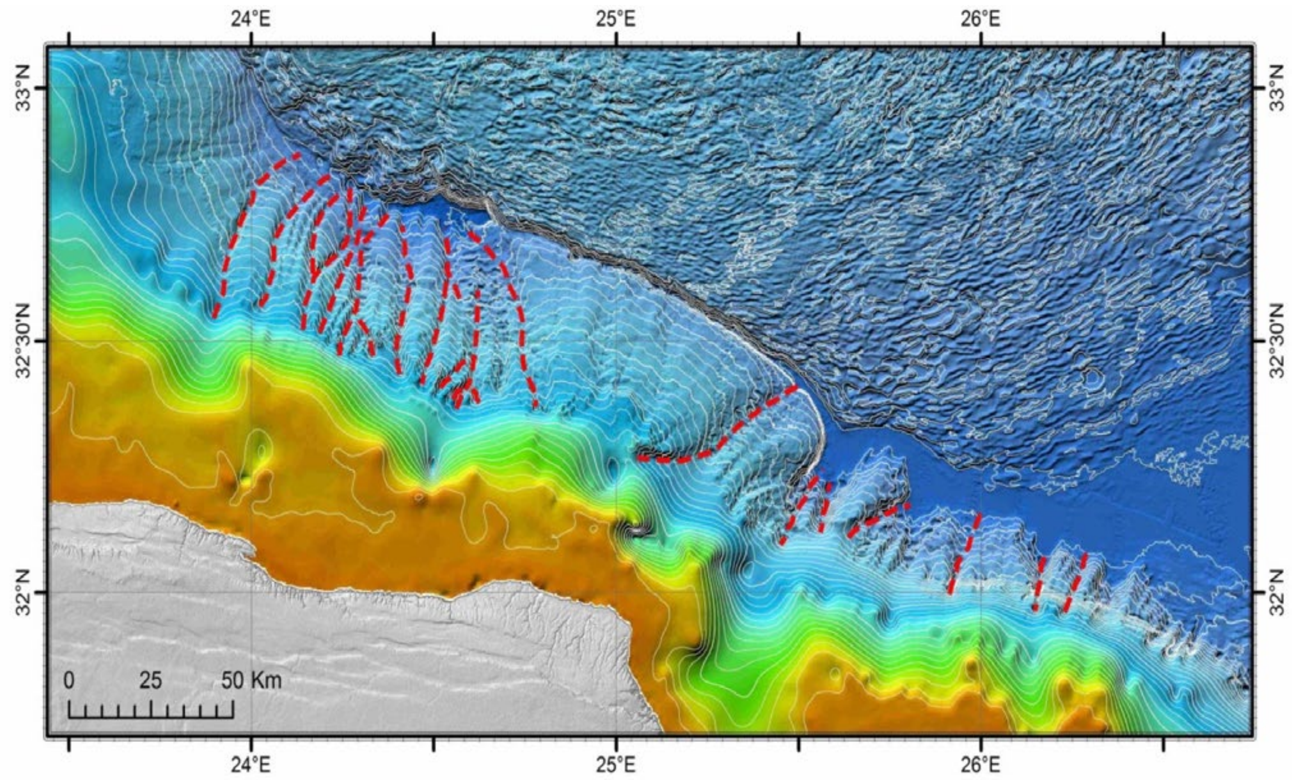


Fig. 2.75. The canyons and gullies on the margins off Tobruk (Libya).

5 LEVANTINE SEA CANYONS

Significant canyons and many gullies incise the margins and slopes of the Levantine Sea (Fig. 2.76). Five main areas are described here below: the slopes off the south-western coast of Turkey, the eastern margin of Eratosthenes Seamount, the Tartush and Haifa canyons on the eastern margin of the Levantine Sea and the western slope of the Nile deep-sea fan. Short gullies have been identified on the slopes around Cyprus, however the absence of bathymetric data with an adequate resolution does not provide enough information to describe them.

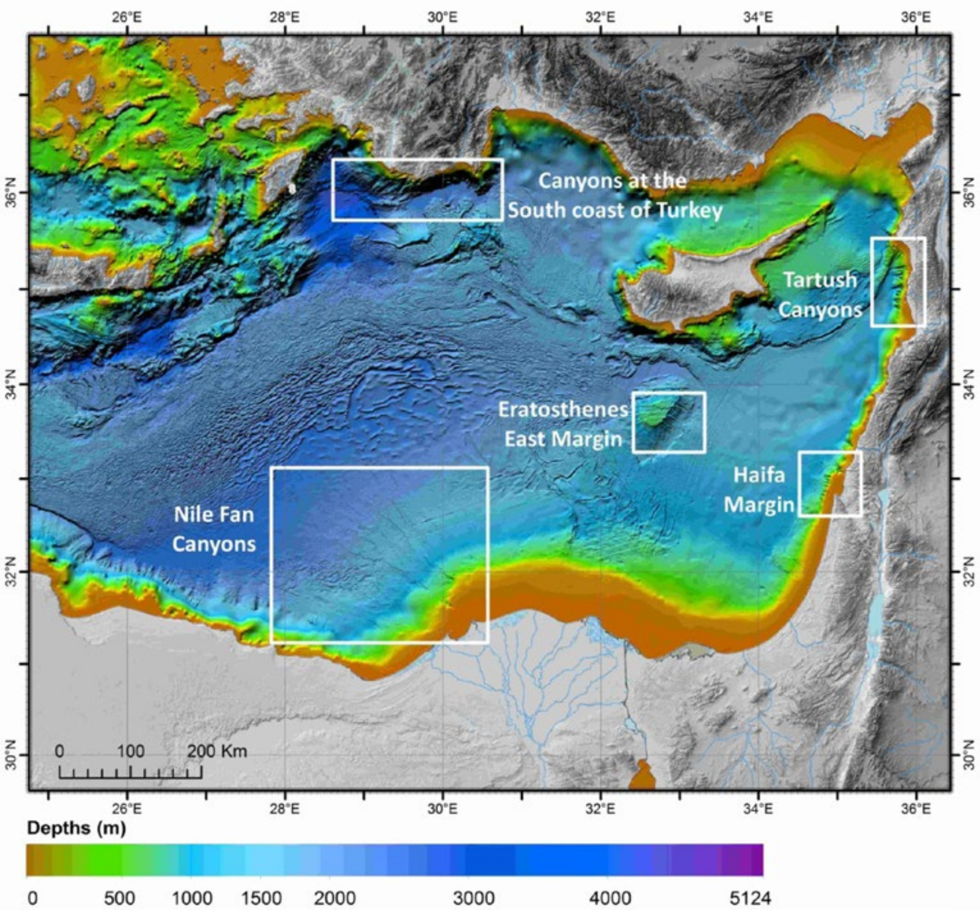


Fig. 2.76. Morphological map of the Levantine Sea with the location of the areas with submarine canyons described here.

SW TURKEY CANYONS (FIG. 2.77)

The steep slopes off South West Turkey facing the 3000 m deep Finike Basin are incised by several, short gullies, the length of which does not exceed 10-15 km. All these gullies originate either at mid slope or on the lower part of the steep slope.

Longer canyons, 30-40 km long, incise the lower parts of the slope between the coast of SW Turkey and the 4000 m deep Rhodes Basin.

All canyons and gullies in the area off the SE coast of Turkey fall into category 3 (canyons incising the continental slope).

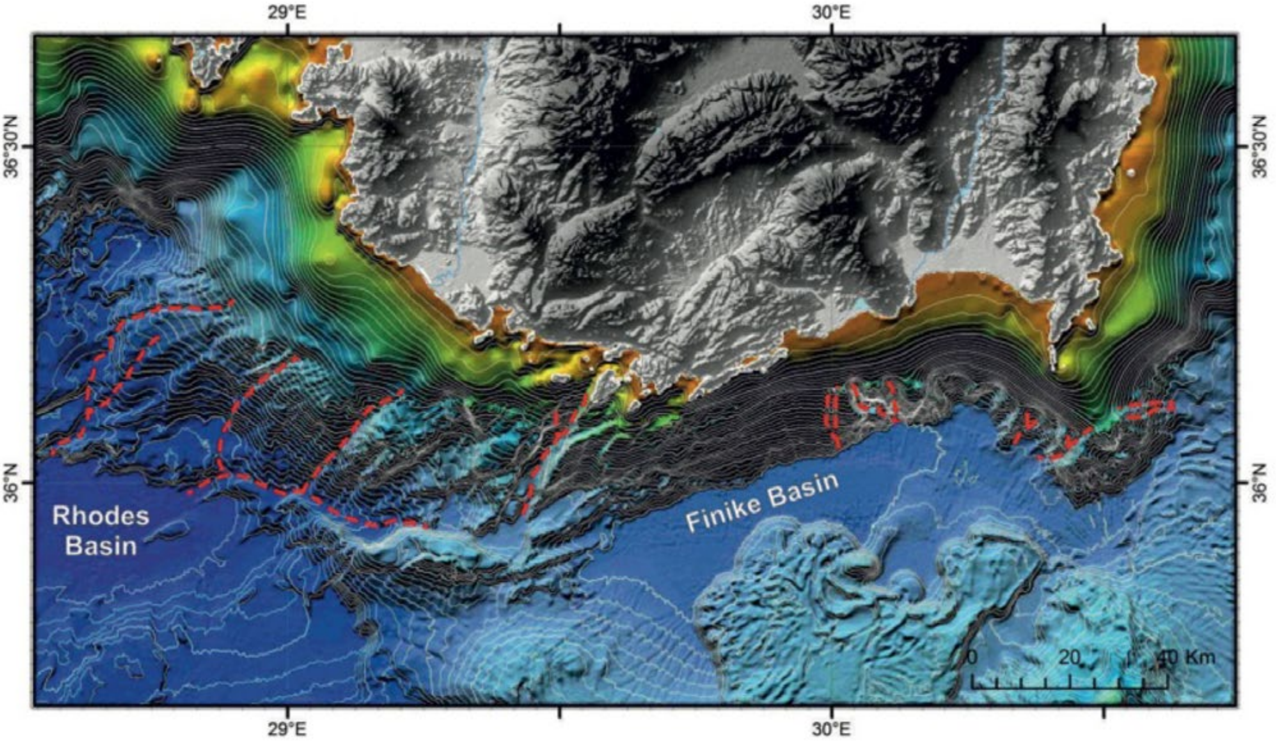


Fig. 2.77. Submarine canyons and gullies off the SE Turkey coast.

ERATOSTHENES EAST MARGIN (FIG. 2.78)

A series of 10-20 km long gullies incise the eastern margin of the Eratosthenes Seamount. They originate from the flat top of the seamount with their heads affecting the shape of its edge and they reach the 2000-2200 m deep, flat seafloor of the Levantine Basin to the East.

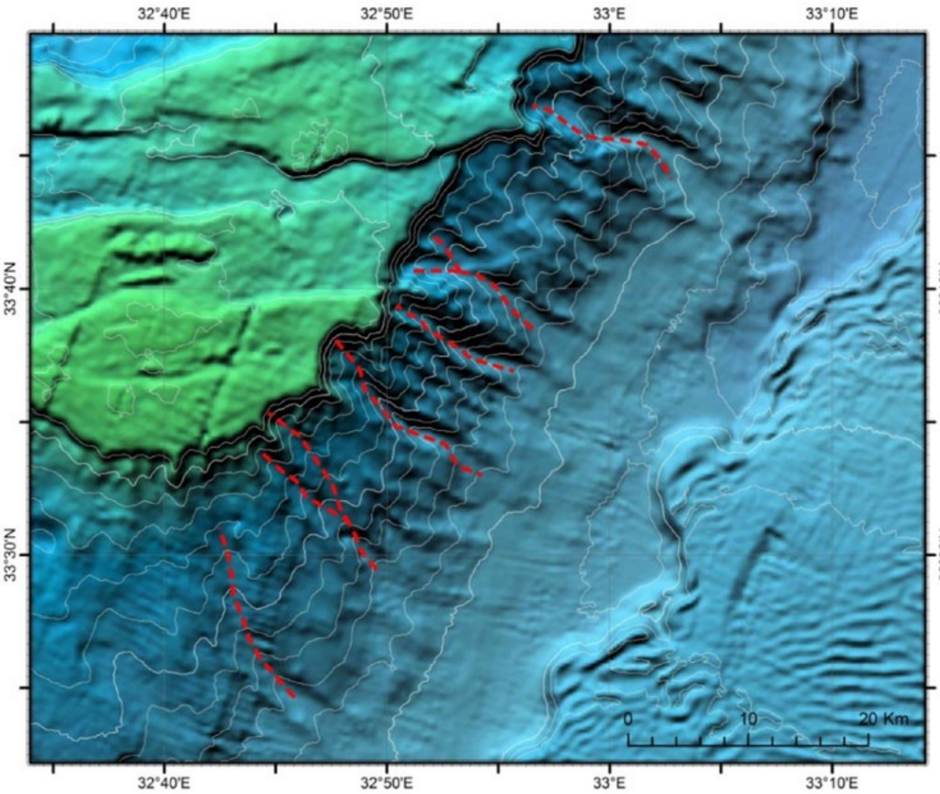


Fig. 2.78. Submarine gullies on the eastern margin of the Eratosthenes Seamount.

TARTUSH CANYONS (FIG. 2.79)

The Syrian margin, between Latakia to the North and Tartush to the South, is incised by a series of short gullies and **long canyons**. The longer canyon originates in the upper slope south of Latakia and with a SSW direction of its thalweg and a total length of roughly 55 km runs between the eastern slope of the Latakia Ridge and the Syrian margin.

Further south, the length of the canyons and gullies decreases while the steepness of the margin increases. All canyons and gullies originate from the mid slope, with no evidence of incision in the upper slope or the continental shelf.

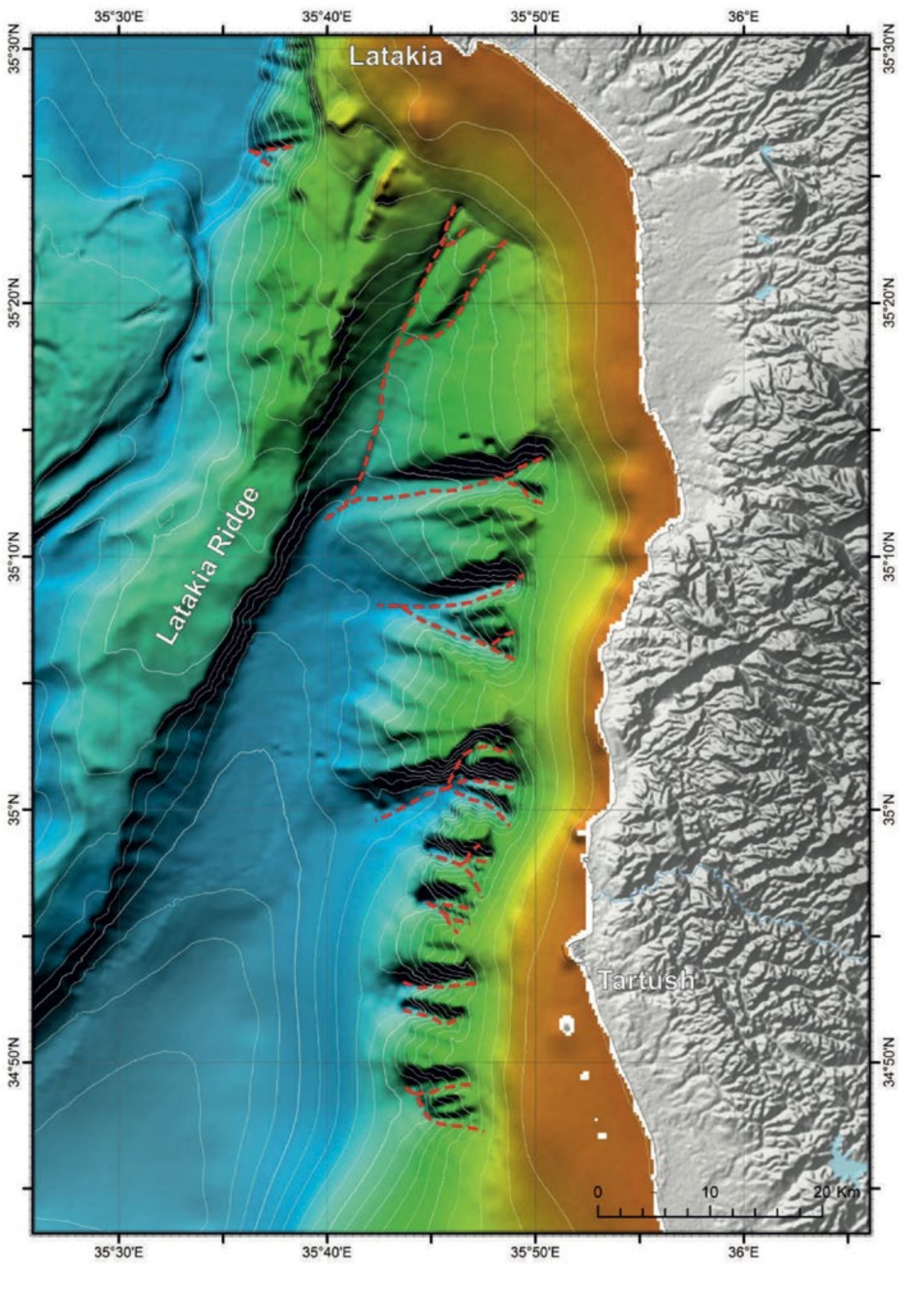


Fig. 2.79. Submarine canyons and gullies on the Syrian margin.

HAIFA CANYONS (FIG. 2.80)

The steeper part of the slope of Haifa occurs between the edge of the continental shelf and the 1000 m depth contour. This part of the slope is incised by a series of 5-10 km long gullies, which originate at the edge of the shelf and terminate at a depth of around 1000 m.

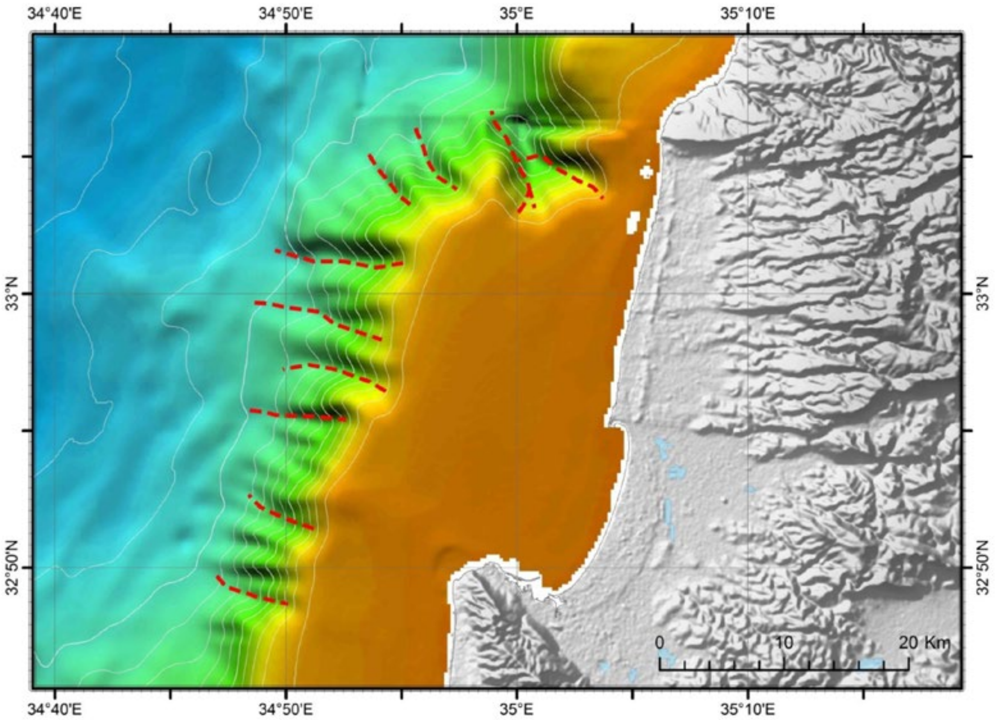


Fig. 2.80. Submarine gullies on the Haifa margin.

NILE FAN CANYONS (FIG. 2.81)

The Nile deep-sea fan is the largest deltaic body in the Mediterranean and has developed and evolved throughout the Plio-Quaternary covering the Messinian evaporate[38]. The submarine part of the delta is characterized by a 30-60 km wide continental shelf, a relatively steep upper slope between the shelf edge and the 1000-1200 m depth contour and a gentler lower slope. A detailed description of its geomorphology is provided in several references[39].

The western submarine flank of the Nile Fan is incised by **the > 100 km long Rosetta Canyon**. It begins at the shelf edge, roughly 30 km off the mouth of the Rosetta branch of the Nile River, and follows a linear path downslope toward the Northwest. At a depth of about 2000 m the Rosetta canyon branches into two meandering canyons.

Three more canyons occur on the lower slope of the western Nile deep-sea fan. They are probably relict morphological features inherited from older canyons which are no longer active[40].

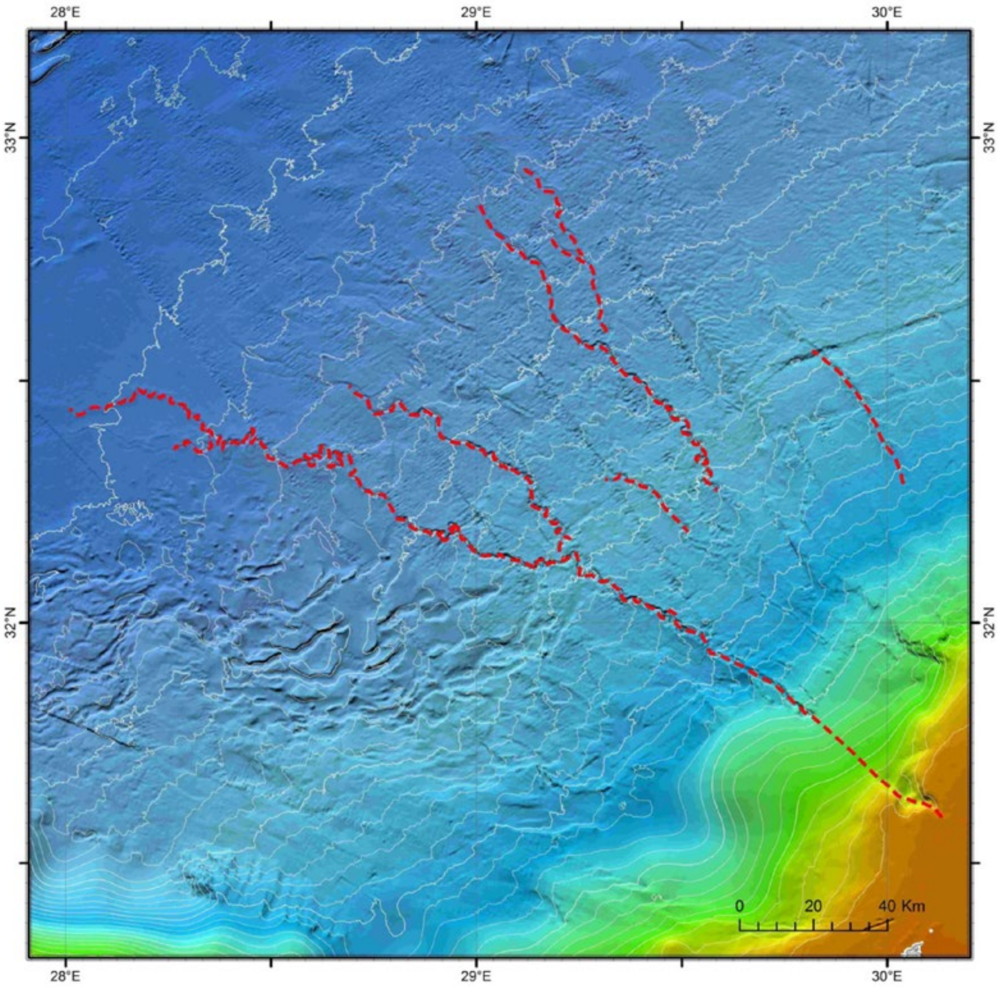


Fig. 2.81. Submarine canyons on the western Nile deep-sea fan.

CHAPTER 2 /

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CHAPTER 3 /

Deep-sea vulnerable benthic fauna

Salomidi M., Gerovasileiou* V., Stamouli C., Drakopoulou V., Otero M.M., Jimenez C., Kiparissis S., Mytilineou Ch., Papadopoulou N., Smith C.J., Thasitis I., Anastasiadou Ch., Lefkaditou E., Makovsky Y., Schüler M.*

* equal contribution

The uniqueness of the Mediterranean oceanography, local hydrography, geochemical and geomorphological settings on a relatively small scale, make its deep sea very diverse and with contrasting patterns of biodiversity. Hotspots of diversity can be found around complex topographic structures attracting a high abundance and diversity of species ; this is particularly pronounced in areas with chemical effluxes that produce a true oasis of life specialised for extreme environmental conditions[1].

Many sessile (non-moving) deep-sea animals can form important aggregations or biogenic structures with surrounding ecosystems of low resilience yet hotspots of biodiversity. These species have positive impacts on associated species richness and abundance, play a major role in organizing community structure, and have an important function in determining community stability and productivity.

The vulnerability of these communities and their ecosystem is mainly related to the life history characteristics of each species, affected by habitat loss or destruction combined with other impacts on their surrounding environment. Thus, a large number of deep benthic species or communities are endangered and included in national and international lists of threatened/protected species or as indicators for sensitive marine ecosystems. In some regions, measures are being developed to protect them, with spatial and temporal management measures through the creation of marine protected areas (MPAs), designation of fisheries restricted areas (FRAs) to protect vulnerable marine ecosystems (VME) or other non-spatial management measures (e.g. restricted oil and gas exploitation) among others.

Information about deep sea benthic invertebrate diversity and abundance in the Eastern Mediterranean Sea is scarce and, as a result, advances in management, including conservation, have been slow. To progress in this direction, this section presents the results[1] of an extensive historical literature review on deep-sea vulnerable sessile benthic fauna for the Eastern Mediterranean based on published literature (spanning from as old as 1900 to as recent as 2018), grey literature (international and national project deliverable reports) and other critically examined unpublished records (Table 3.4). The contribution of grey literature and unpublished reports or otherwise inaccessible information collated here, greatly extends the known distribution of these species and communities, as well as our understanding of the deep Eastern Mediterranean biodiversity.

In addition, the present information also provides data collected from the analysis of photographic material (on-board and laboratory) of deep-sea experimental fishing catches, collected in the framework of research projects, including MEDITS surveys (Table 3.5), in the Eastern Ionian, Aegean, and Levantine Seas, covering a time span of 24 years (1995-2018). The assembled material included mostly photos from trawl survey catches and to a lesser extent from longline catches. Additional coral sample material was also collected from longline fishing targeting blackspot seabream *Pagellus bogaraveo* at two sites in the South Aegean and Libyan Sea (off South Crete), respectively[2].

The compiled information has the potential to identify biodiversity vulnerable hotspot areas for conservation and mitigation of impacts based on the presence and aggregations of key species around the Eastern Mediterranean. Nonetheless, given the nature and time of these records, they represent highly conservative estimates of the distribution of these communities.

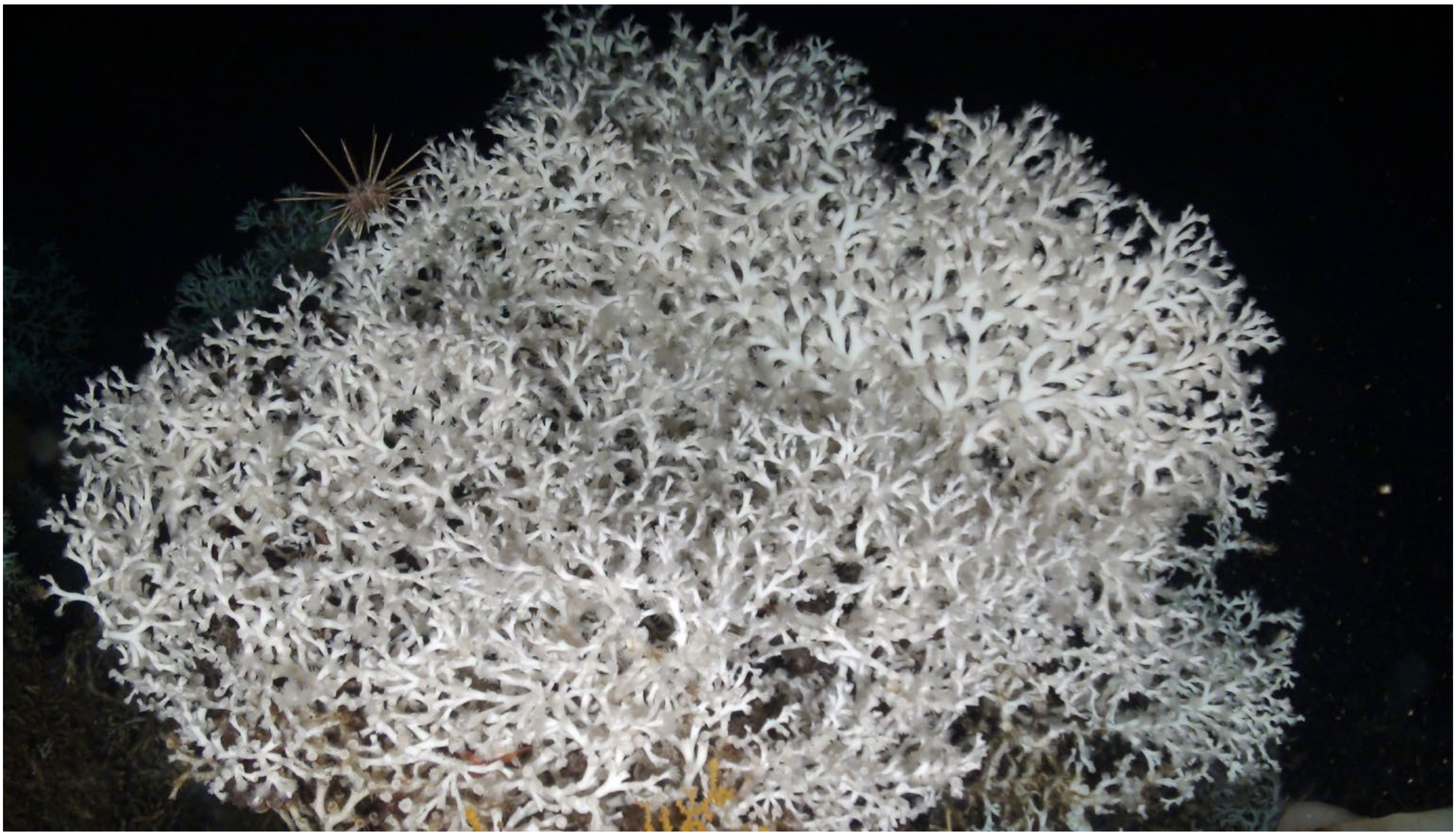
Vulnerable habitat-forming sessile fauna from literature review

The presence of vulnerable benthic invertebrates in the Eastern Mediterranean basin has been known from records as early as 1896. Much of the existing information however could be considered rather outdated, as 46% of all compiled records have been obtained earlier than the year 2000. Furthermore, the main bulk of the existing records has been collected by blind, non-selective and destructive techniques such as trawling (~70%), dredging (~13%) and other fishing gear (~7%), while less than 10% has been obtained via less impacting methodological approaches (i.e. ROVs and submersibles) which allow proper collection of important scientific information such as accurate position and depth of observation, abundance data, seabed type and state, associated biodiversity, etc.

The present literature review is focused on vulnerable habitat-forming benthic species that can form aggregations occurring in the deep sea (typically > 200 m water depth), provide structural complexity to the seabed and might contribute to habitat formation as well as have long life spans and slow growth rates. Additionally, it was further considered whether species were listed as threatened in the IUCN Red list and/or if they have been identified as being vulnerable to fishing impacts (i.e. fragility, rareness, or low turnover rates). Potential assemblages of this benthic fauna could provide an indication

> “Deep-sea biodiversity hotspots represented by habitat-forming sessile fauna such as deep-sea coral banks, gorgonian and black coral gardens, sea pen fields and sponge gardens have a high vulnerability to disturbance and a low recovery potential”

1 The data that support the findings of this analysis are available from the corresponding authors on request.



Cold-water coral *Desmophyllum pertusum.* © Oceana.

Gorgonians (*Callogorgia verticillata* and *Viminella flagellum*). © Oceana.

Sea pen *Pennatula rubra*. Oceana/IUCN/UNEP-MAP RAC-SPA Deep Sea Lebanon Project. © Oceana.

of vulnerable biodiversity hotspots, that can constitute an important component of fisheries habitats, but also contribute to the biodiversity of the marine environment.

Deep-sea biodiversity hotspots represented by habitat-forming sessile fauna such as deep-sea coral banks, gorgonian and black coral gardens, sea pen fields and sponge gardens have a high vulnerability to disturbance and a low recovery potential.

The literature review revealed a total of 38 invertebrate taxa considered as key habitat-forming sessile fauna for the Eastern Mediterranean (Table 3.1): Scleractinian coral species as indication of the potential presence of **coral reefs or banks** (the latter suggesting cases where scattered species or aggregations do not actually build up in extensive reef structure); soft coral species (e.g. gorgonians, black corals, alcyonids) indicating the potential presence of hard or soft bottom **gorgonian and black coral gardens**; sea pens indicating the potential presence of **sea pen fields**; sponges indicating the potential presence of hard or soft bottom **sponge gardens**, as well as specific assemblages of the same taxa (a bivalve mollusc, a brachiopod and a crinoid taxa species) indicating the potential presence of **other emergent fauna** fields.

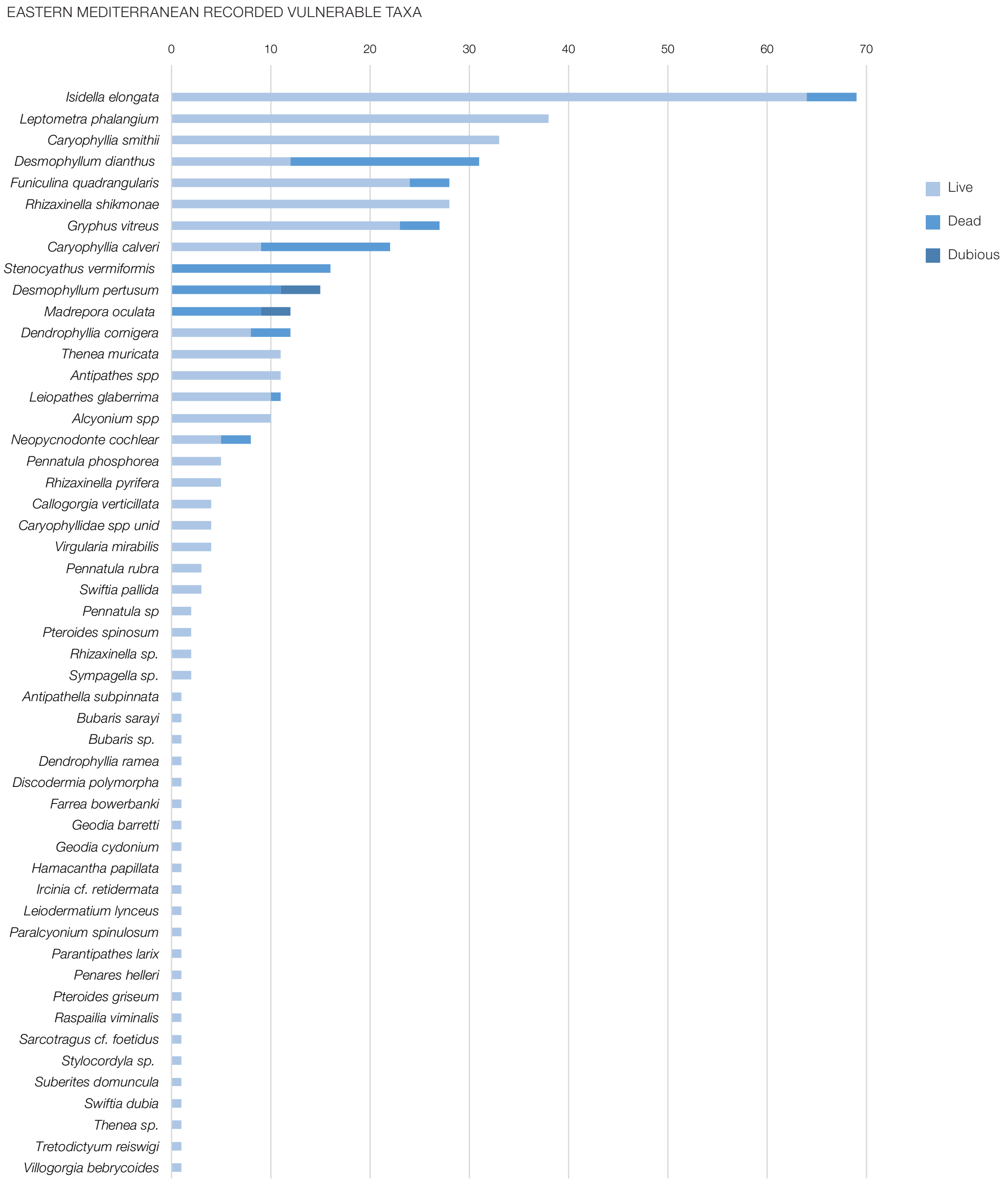
Sponges
(*Poecillastra compressa*)
on maërl seabed.
© Oceana.

Table 3.1. List of the deep-sea habitat-forming vulnerable sessile taxa based on the literature review for the Eastern Mediterranean Sea. IUCN Conservation status of species and relevant international agreements, directives and conventions with listed annexes, applicable recommendations and regulations. DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

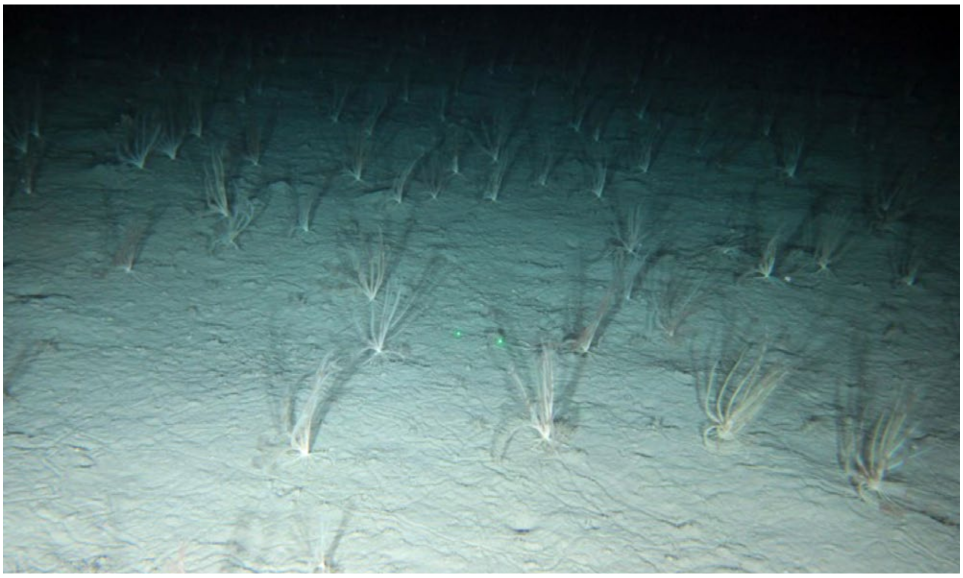
Key Habitat-Forming Vulnerable Fauna	Protection Status	IUCN Red List	Habitat Type
Madrepora oculata	CITES: II, Protocol SPA/BD (b): II, EU Regulation Trade: B	EN	Coral reefs/banks
Desmophyllum pertusum (=Lophelia pertusa)	CITES: II, Protocol SPA/BD (b): II, EU Regulation Trade: B	EN	Coral reefs/banks
Desmophyllum dianthus	CITES: II, EU Regulation Trade: B	EN	Coral reefs/banks
Caryophyllia calveri	CITES: II, EU Regulation Trade: B	DD	Coral reefs/banks
Caryophyllia smithii	CITES: II, EU Regulation Trade: B	LC	Coral reefs/banks
Dendrophyllia cornigera	CITES: II, EU Regulation Trade: B	EN	Coral reefs/banks
Stenocyathus sp.	-	DD	Coral reefs/banks
Bebryce mollis	-	DD	Coral gardens
Swiftia spp.	-	DD (*S. pallida*)	Coral gardens
Villogorgia bebrycoides	-	DD	Coral gardens
Callogorgia verticillata	Protocol SPA/BD (b): II	NT	Coral gardens
Antipathes dichotoma	CITES: II, Protocol SPA/BD (b): II, BERN: III, EU Regulation Trade: B	NT	Coral gardens
Isidella / Acanella	-	CR	Coral gardens
Leiopathes glaberrima	CITES: II, Protocol SPA/BD (b): II, BERN: III, EU Regulation Trade: B	EN	Coral gardens
Parantipathes larix	CITES: II, Protocol SPA/BD (b): II, EU Regulation Trade: B	NT	Coral gardens
Alcyonium palmatum	-	LC	Coral gardens
Paralcyonium spinulosum	-	LC	Sea pen fields
Pennatula spp.	-	VU	Sea pen fields
Pteroeides spp.	-	VU (*P. spinosum*)	Sea pen fields
Virgularia mirabilis	-		Sea pen fields
Funiculina quadrangularis	-	VU	Sea pen fields
Kophobelemnon stelliferum	-	LC	Sea pen fields
Bubaris spp.	-	-	Sponge gardens
Farrea bowerbanki	-	-	Sponge gardens
Geodia spp.	-	-	Sponge gardens
Penares spp.	-	-	Sponge gardens
Leiodermatium lynceus	-	-	Sponge gardens
Discodermia polymorpha	-	-	Sponge gardens
Sympagella sp.	-	-	Sponge gardens
Tretodictyum reiswigi	-	-	Sponge gardens
Hamacantha spp.	-	-	Sponge gardens
Thenea muricata	-	-	Sponge gardens
Stylocordyla sp.	-	-	Sponge gardens
Rhizaxinella spp.	-	-	Sponge gardens
Suberites spp.	-	-	Sponge gardens
Gryphus vitreus	-	-	Other emergent fauna
Neopycnodonte cochlear	-	-	Other emergent fauna
Leptometra phalangium	-	-	Other emergent fauna

Based on the review of the existing literature[2], and expanding the initially proposed genera into species, there are 51 deep-sea vulnerable sessile taxa (3 of them only detected in dead or dubious records) accounting for a total of 441 records across the region of which 93 are in the Eastern Ionian Sea, 76 in the North Aegean, 86 in the South Aegean, 83 in the Libyan Sea and 102 in the Levantine Sea. The bamboo coral *Isidella elongata* was recorded as the most common species (69 records) from the literature review, mostly in the Eastern Ionian but also in the North Aegean and Libyan Seas. Other deep-sea habitat-forming vulnerable taxa frequently detected include the crinoid *Leptometra phalangium* (38 records), the scleractinians *Caryophyllia smithii* (33 records) and *Desmophyllum dianthus* (31 records), the sea-pen *Funiculina quadrangularis* (28 records), the demosponge *Rhizaxinella shikmonae* (28 records) and the brachiopod *Gryphus vitreus* (27 records) (Fig. 3.1).

Fig. 3.1. Key-habitat forming sessile invertebrate taxa detected (live, dead or with dubious records) in published and grey literature between 1995-2018, and number of records per each in the Eastern Mediterranean Basin.



2 excluding the Sea of Marmara



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Crinoid beds of *Leptometra phalangium*.

Table 3.2. Minimum and maximum depth and seabed type of occurrence for the most frequently recorded species in literature sources from each sub-region.

Location	Taxa	Min Depth (m)	Max Depth (m)	Seabed Type
Eastern Ionian Sea	*Antipathes dichotoma*	516	600	Deep-sea muds
	Desmophyllum dianthus	400	968	Deep-sea muds, deep fossil coral reefs
	Isidella elongata	356	1,082	Deep-sea muds
	Leiopathes glaberrima	367	634	Deep-sea muds
North Aegean Sea	*Leptometra phalangium*	74	181	Circalittoral and deep-sea muds
	Funiculina quadrangularis	45	638	Circalittoral and deep-sea muds
	Caryophyllia smithii	74	439	Circalittoral and deep-sea muds
	Isidella elongata	150	760	Circalittoral and deep-sea muds
	Alcyonium palmatum	74	200	Circalittoral and deep-sea muds
	Gryphus vitreus	180	420	Deep-sea reefs / banks
	Desmophyllum pertusum	110	360	-
	Dendrophyllia cornigera	170	420	Deep-sea reefs / banks
	Madrepora oculata	110	360	-
	Callogorgia verticillata	60	200	Deep-sea reefs / banks
	Pennatula phosphorea	45	427	Deep-sea muds
South Aegean Sea	*Leptometra phalangium*	183	1,000	deep-sea muds
	Caryophyllia smithii	115	1,000	deep-sea muds
	Funiculina quadrangularis	51	711	deep-sea muds
	Gryphus vitreus	500	700	deep-sea muds
	Dendrophyllia cornigera	150	460	Reefs / banks
Libyan Sea	Fossil white coral reefs	284	1,208	coral framestone/rubble
	Dendrophyllia cornigera	560	620	Reefs / banks
	Gryphus vitreus	219	550	-
Levantine Sea	*Rhizaxinella shikmonae*	1,227	1,493	Deep-sea muds
	Gryphus vitreus	254	726	-
	Thenea muricata	254	620	-
	Caryophyllia calveri	301	804	-
	Desmophyllum dianthus	310	804	various
	Alcyonium spp.	138	617	-
	Funiculina quadrangularis	254	604	Deep-sea muds
	Neopycnodonte cochlear	55	179	-
	Virgularia mirabilis	66	131	-
	Leiopathes glaberrima	256	612	mixed facies
	Pennatula rubra	65	206	-

Vulnerable benthic fauna from photographic material of experimental fishing catches

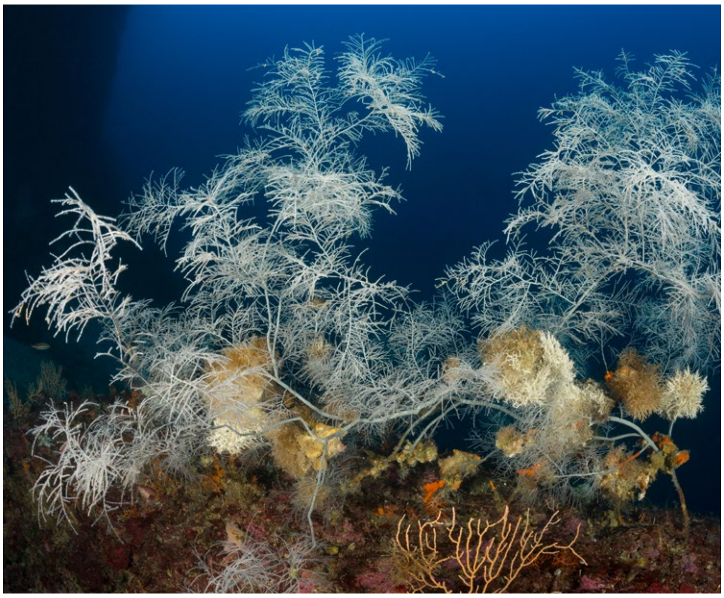
Based on the analysis of photographic material (onboard and laboratory) of experimental fishing catches, a total of 355 occurrences were recorded and identified as 33 invertebrate taxa (9 Porifera, 19 Anthozoa, 2 Mollusca, 1 Brachiopoda, and 2 Echinodermata), which include habitat-forming and other emerging benthic fauna[3] taxa that are Vulnerable Marine Ecosystem (VME) indicators for fisheries, are protected by international, EU or national legislation or are listed in the IUCN threatened categories (1 Critically Endangered, 3 Endangered, 2 Vulnerable species). Some of these taxa were identified only at higher taxonomic levels (e.g. genus, family) or as morphological categories (e.g. unidentified massive sponges), due to restrictions in taxonomic identification based on photographs. However, it should be noted that a considerable percentage of the occurrence records was obtained from old material (8% before 2000; 53% before 2010). Most of the occurrence records involved single (45%) or 2-5 individuals/colonies (36%).

“These vulnerable marine ecosystems are considered hotspots of biodiversity and ecosystem functioning in the deep sea”

Vulnerable invertebrates were reported from a depth range of 163-897 m. Sponges were found in photographic material from trawl catches from a depth range of 165-766 m; anthozoans (stony corals, soft corals, sea pens and gorgonians) were found at trawls and longlines from relatively deeper waters, specifically 270-897 m depth.

Most invertebrate occurrences were found for the Eastern Ionian (46%) and North Aegean Seas (27%), while lower numbers were found for the South Aegean (16%) and Levantine Seas (11%), possibly reflecting the lower sampling effort. Anthozoan occurrences dominated (55%), followed by sponges (14%), molluscs (12%), echinoderms (11%) and the brachiopod *Gryphus vitreus* (8%).

The critically endangered “bamboo coral” *Isidella elongata* and the vulnerable sea pen *Funiculina quadrangularis* were the most frequently recorded anthozoans (81 and 65 occurrences respectively). In several cases, these two taxa presented considerable abundances (> 10 colonies) in fishing catches from particular areas, including MEDITS stations. The sponge *Thenea muricata* along with unidentified massive sponges were the most commonly recorded sponge taxa. It should be noted that in several cases there were smaller sponges, which could hardly be identified based only on photographs.



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3 *this term refers to fauna that can develop in clusters and offers hard substrate to smaller species such as the brachiopod *Gryphus vitreus*

Parazoanthus cf. *anguicomus* covering a sponge, probably *Thenea muricata*. © Oceana.

The gastropod *Tonna galea*. Oceana/IUCN/UNEP-MAP RAC-SPA Deep Sea Lebanon Project. © Oceana.

Table 3.3. Number of georeferenced records collected as bycatch from photographic material analysis of experimental fishing surveys. (See Annex 3.1 on data sources). Gastropod records include empty shells.

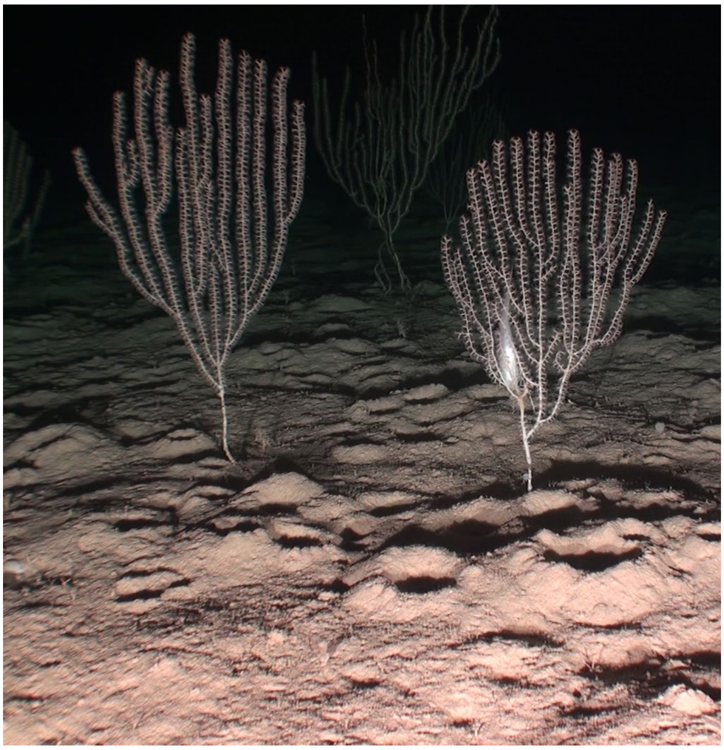
	Eastern Ionian Sea	North Aegean Sea	South Aegean Sea	Levantine Sea	Libyan Sea	Total records	Depth range (m)
Porifera (Sponges)	**9**	**11**	**22**	**8**		**50**	
Agelas oroides	1					1	499-533
Axinella cannabina		2				2	386
Dysidea avara			1			1	254-303
Geodia sp.			5			5	354-435
Leiodermatium sp. (rock sponge)	1					1	492
Sarcotragus foetidus	3		6			9	271-766
Suberites sp.		1	2			3	230-530
Thenea muricata	2	2	2	8		14	165-619
Unidentified massive sponges	2	6	6			14	165-716
Anthozoa (corals, sea pens, sea fans and anemones)	**117**	**46**	**12**	**19**		**194**	
Alcyonium acaule			1			1	270
Antipatharia spp.				3		3	256-600
Antipathes dichotoma	9					9	516-773
Antipathes sp.				2		2	612-617
Caryophyllia calveri				3		3	302
Caryophyllia sp.				4		4	256-318
Dendrophyllia cornigera	3					3	367-634
Desmophyllum dianthus	5			3		8	310-600
Elisellidae sp.	1					1	555
Funiculina quadrangularis	21	36	5	3		65	223-856
Gorgoniidae		2				2	210-292
Isididae	68	8	4		1	81	239-897
Leiopathes glaberrima	2					2	380-620
Paracyathus pulchellus	1					1	586
Pennatula sp.	2					2	519-571
Pennatulacea sp.				1		1	256
Swiftia sp.	1					1	343
Unidentified corals	3		2			5	322-740
Villogorgia sp.	1					1	499
Gastropod (Molluscs)	**13**	**11**	**12**	**5**		**41**	
Ranella olearium	1	4		1		6	428-609
Tonna galea	12	7	12	4		35	163-798
Brachiopoda (Lamp shells)						**0**	
Gryphus vitreus	18	6		6		30	223-813
Echinodermata (sea urchins, sea lillies)	**5**	**23**	**11**	**0**		**39**	
Centrostephanus longispinus	1		7			8	254-800
Crinoidea spp.	4	23	4			31	284-865
Total	**162**	**97**	**57**	**38**	**1**	**355**	

Table 3.4. Species collected as bycatch from photographic material analysis of experimental fishing surveys which are protected under relevant international agreements, directives and conventions with listed annexes, applicable recommendations, and regulations. IUCN Conservation status of species also indicated. DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Taxa	Common name	IUCN	CITES	EC 338/97	Barcelona Convention	Bern Convention	GFCM
Axinella cannabina					II	II	
Sarcotragus foetidus	Black sponge				II	II	
Antipathes dichotoma	Black coral	NT	II	B	II	III	GFCM/43/2019/6
Caryophyllia calveri	Cup coral	DD	II	B			
Dendrophyllia cornigera	Yellow tree coral	EN	II	B	II		GFCM/43/2019/6
Desmophyllum dianthus	Cockscomb cup coral	EN	II	B	II		GFCM/43/2019/6
Funiculina quadrangularis	Tall sea pen	VU					
Isidella elongata	Bamboo coral	CR			II		GFCM/43/2019/6
Leiopathes glaberrima	Smooth black coral	EN	II	B	II	III	GFCM/43/2019/6
Paracyathus pulchellus	Papillose cup coral	DD	II	B			
Pennatula sp.	Greater sea pen	VU					
Ranella olearium	Wandering triton				II	II	
Tonna galea	Giant tun				II	II	
Centrostephanus longispinus	Hatpin urchin				II	II	

1 EASTERN IONIAN SEA

The overall analysis of the number of publications dealing with deep-sea biodiversity from the Eastern Ionian Sea (93), shows the presence of 17 sessile taxa at 84 locations (Fig. 3.2). Among these, the bamboo coral *Isidella elongata* (potentially also including misidentified *Acanella* species) ranked as the most common reported species. This was followed by the black corals *Antipathes dichotoma* and *Leiopathes glaberrima* together with the coral *Desmophyllum dianthus*. The maps generated by the database most likely represent maps of research effort rather than maps of the true extent of sessile species occurrences. Although the general lack of concrete and quantitative data does not allow a coherent identification of locations of special conservation interest, the scattered occurrence of several vulnerable taxa across the Eastern Ionian Sea is well-confirmed, indicating the widespread presence of deep-sea coral gardens, but also coral banks/reefs, sponge gardens and other vulnerable emergent fauna.



EUO. © OCEANA.

The bambo coral *Isidella elongata*.

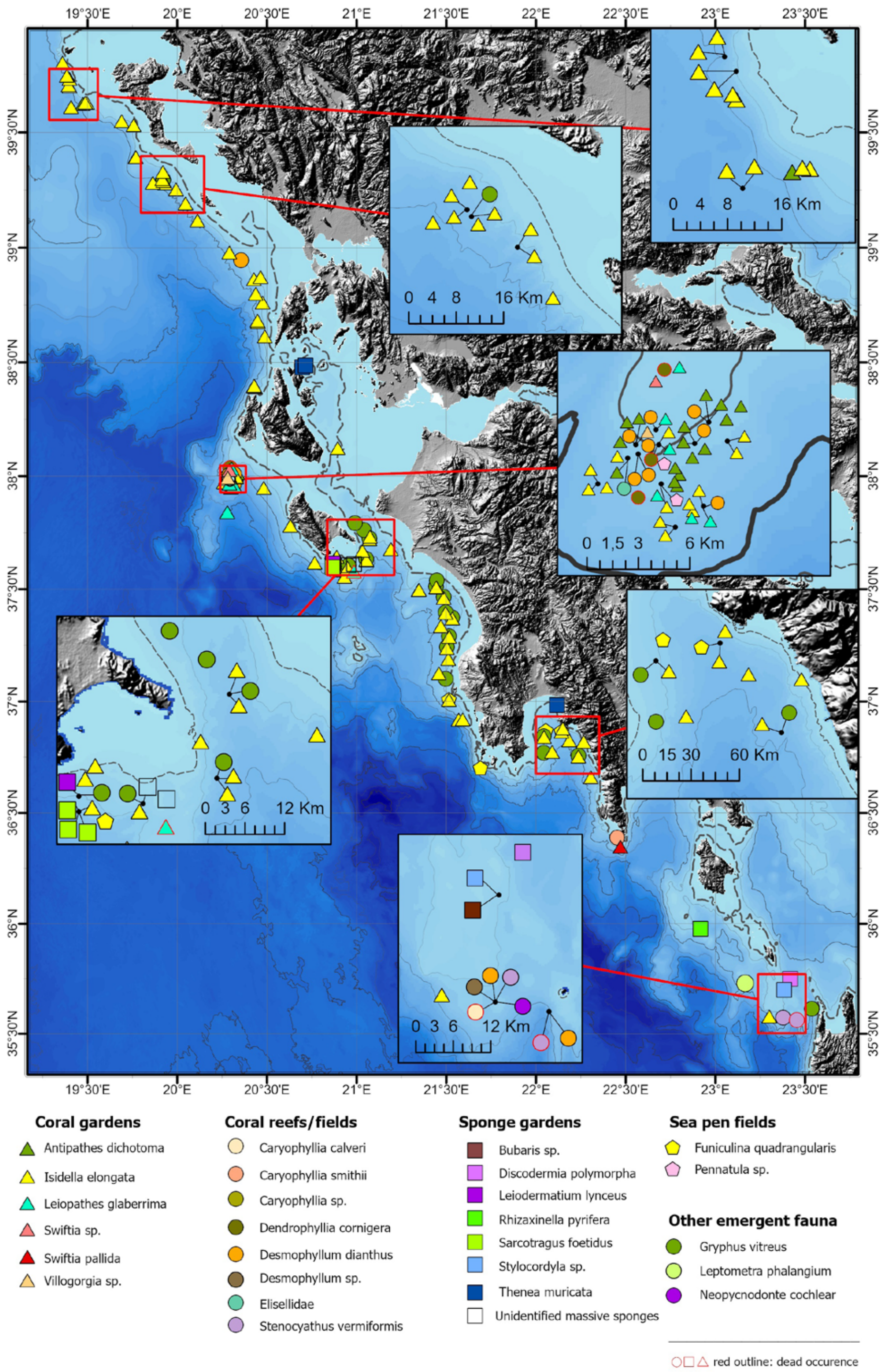


Fig. 3.2. Recorded presence of vulnerable sessile invertebrate taxa across the Eastern Ionian Sea.

The depth range and seabed type of occurrence, at least for the most frequently recorded taxa in the Eastern Ionian Sea (Table 3.2), clearly suggest that bamboo and black corals are the habitat-formers best adapted to life at these profound depths, deep-sea muds at depths between 300-1,000 m. The bamboo coral *Isidella elongata* is shown to be more or less continuous in the deep waters of the E. Ionian Sea and has a maximum recorded depth of 1,082 m, with deeper bottoms showing the highest abundances[3].

Cold-water corals such as *Madrepora oculata* are well documented in the other parts of the Mediterranean but not documented here. Only one deep-sea survey targeting potential cold-water coral reefs in the South Ionian Sea off NW Crete Island (Antikythera Strait) reported the discovery of subfossils of cold-water coral banks in the area (i.e. *Desmophyllum* - *Madrepora*)[4], with sporadic occurrences of other living corals (*D. dianthus* and Caryophyllidae). Further exploration in different types of seabeds and geomorphological formations (e.g. rock

Plate 3.1. Multiple *Desmophyllum dianthus* colonies (> 140) caught on a single longline at a depth of 531 m in the framework of CORAL-FISH project (Photo by HCMR, Greece). The species can form colonies with younger individuals growing on the skeleton of older ones and might constitute the framework-building species in coral banks.

Plate 3.2. The brachiopod *Gryphus vitreus* was caught in high numbers in six stations in the Eastern Ionian Sea (> 60 individuals/station) and one station in the Levantine Sea (> 30 individuals) (Photos by HCMR and FRI, Greece).

Plate 3.3. Multiple specimens of the sponge *Thenea muricata* from the Patraikos Gulf, Eastern Ionian Sea. The sponge is characterized by root-like structures projecting from the base, by means of which it attaches itself to soft substrate (Photo by HCMR, Greece).

Plate 3.4. Multiple *Funiculina quadrangularis* specimens (yellow circles) and crinoids from MEDITS trawl catch from a depth of 512 m off Antipsara Island, North Aegean Sea (Photo by FRI, Greece).

dredging or ROV surveys on steep continental slopes, seamounts or relief hard grounds) would have provided better insights on the potential occurrence of other key assemblage sessile species, such as these deep-sea coral banks or sponge gardens.

The present analysis of photographic material (on-board and laboratory) from deep-sea experimental fishing catches, collected in the framework of past research projects, indicated the presence of an additional 162 unreported records. The taxa with the highest number of records in this area were *Isidella elongata* (68 records at 255-897 m depth), which has a wide distribution in the deep waters of the E. Ionian Sea, as shown by the literature review, and the sea pen *Funiculina quadrangularis* (21 records from Kefalonia Island to Peloponnesus and inner Korinthiakos Gulf, at a depth range of 364-856 m) which was not reported in deep E. Ionian waters from literature sources. Notable examples of high abundance of other sessile fauna as individuals or colonies collected in experimental fishing catches also included the cold-water coral ***Desmophyllum dianthus*** (3.1) caught on a single fishing longline, the brachiopod ***G. vitreus*** (3.2) and the sponge ***Thenea muricata*** (3.3) in trawl catches.

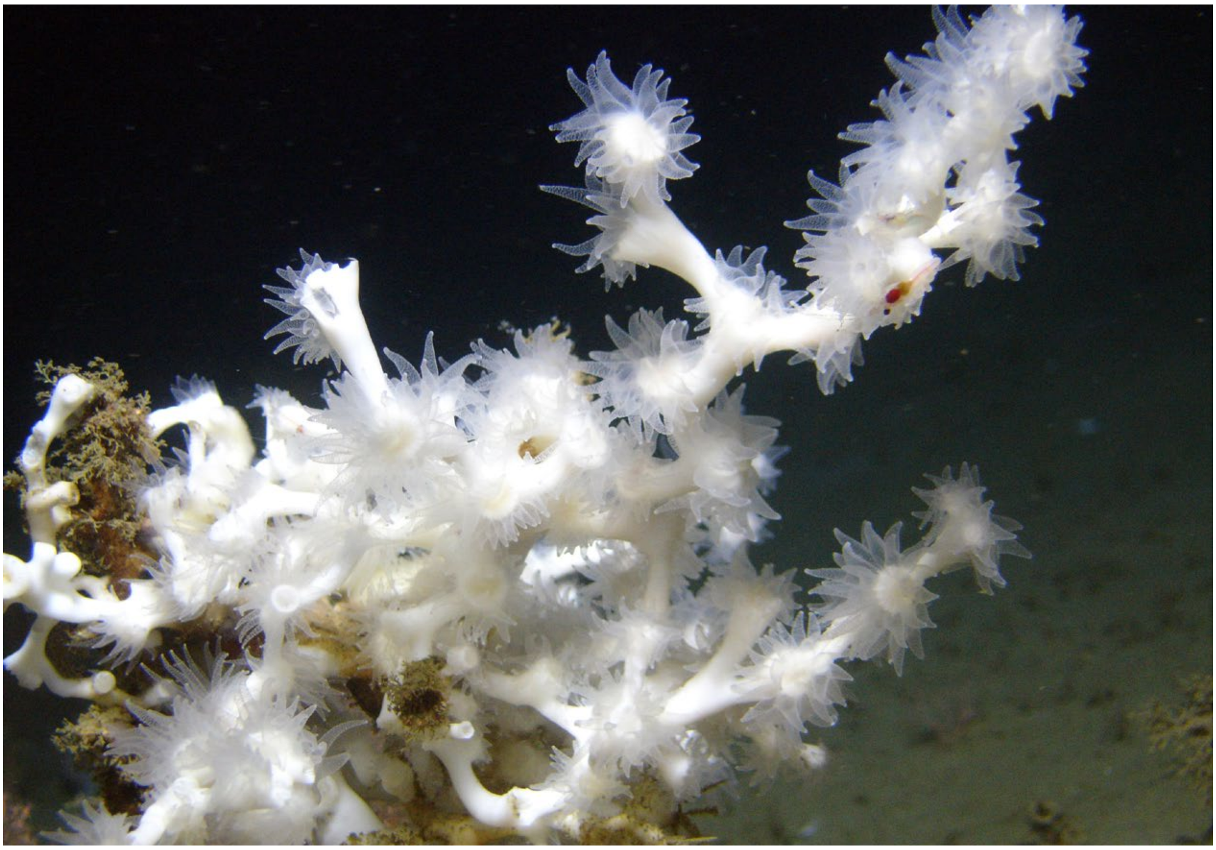
2

NORTH AEGEAN SEA

In general, the existing literature for the North Aegean Sea can be considered rather outdated, as most records (97%) are earlier than the year 2000, pointing to the general lack of more recent research efforts in the deep Aegean Sea (Table 3.4). Trawling, and less so fishing nets (bottom set gillnets and trammel nets), were the most common approach in the collection of these observations.

Data records from existing literature indicates the presence of 23 vulnerable sessile fauna, with a total of 76 records from 42 sites in the North Aegean Sea (Fig. 3.3). Among these, the most common species encounters have been the crinoid *Leptometra phalangium*, followed by the sea-pen *Funiculina quadrangularis*, the cup coral *Caryophyllia smithii* and the gorgonian *Isidella elongata*. The soft coral *Alcyonium palmatum* and the brachiopod *G. vitreus* have also been recorded in the region. Reefs or banks built by cold-water corals, and particularly by the species *Desmophyllum pertusum*[4] and *Madrepora oculata*, considered rare in the Eastern Mediterranean, appear at only a few sites (4 and 3 records respectively) from depths between 110-360 m in several areas of the North Aegean Sea. Recurrent observations through decades seem to strengthen the validity of these records.

The findings support the high biodiversity richness of this region, even if seldom studied, with deep-sea crinoid and sea pen fields, coral gardens, and other emergent fauna, at times in impressively dense aggregations.



Scleractinian coral *Lophelia pertusa*. Image courtesy of Lophelia II 2009 Deepwater Coral Expedition Reefs Rigs and Wrecks.

4 *Desmophyllum pertusum* (= *Lophelia pertusa*: Addamo et al., 2016).

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Dendrophyllia cornigera.

Aggregations of the crinoid *L. phalangium,* sometimes on very dense fields[5] have been reported in several localities characterized by muddy or detritic bottoms at depths between 74-181 m. Suspension-feeding species such as crinoids, are known to occur along the shelf break and circalittoral environments in the Mediterranean and have been suggested as an indicator of highly productive areas that can sustain large biomasses of fish and recruits[5].

Sea pen fields of *Funiculina quadrangularis* and *Pennatula phosphorea*, were also relatively commonly reported at muddy bottoms between 45-638 m. Scattered colonies of *Isidella elongata* and the soft coral *Alcyonium palmatum* occurring at depth ranges between 150-760 m and 74-200 m respectively, also indicate the potential presence of soft bottom coral gardens in this

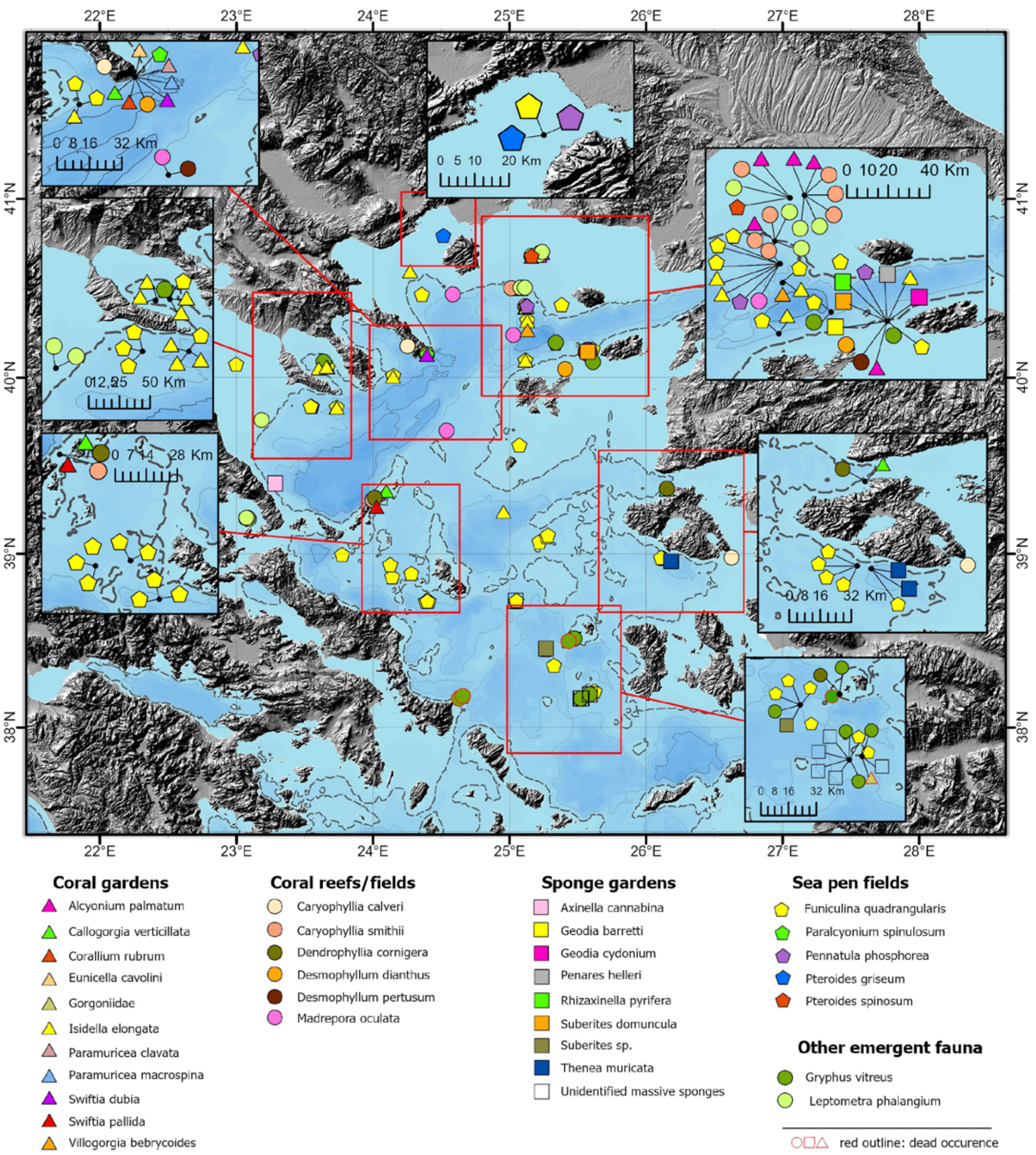
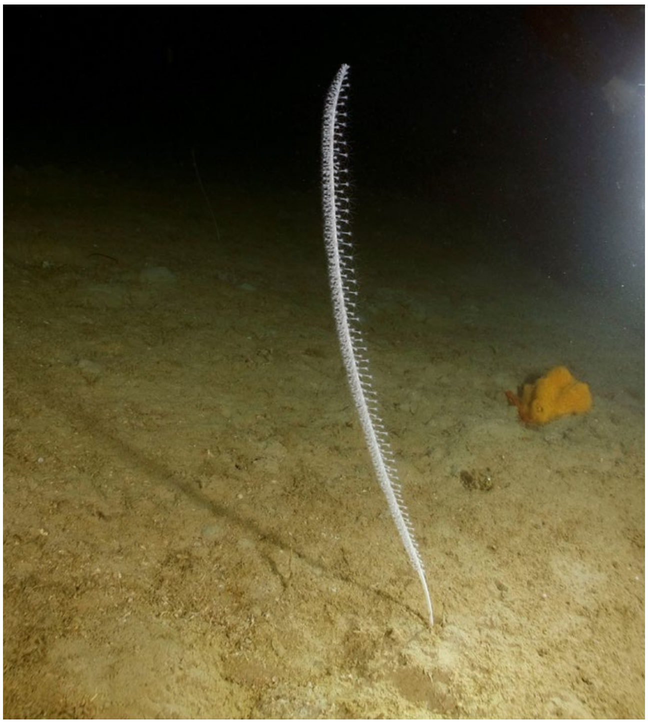


Fig. 3.3. Recorded presence of habitat-forming vulnerable sessile species across the North Aegean Sea (76 records, 42 sites).

5 Smith CJ, unp. data



Funiculina quadrangularis. © Simone Nicolini.

region. Older historical records indicate the presence of living colonies of the yellow coral *Dendrophyllia cornigera* off W. Kyra Panagia Island (Sporades Islands) and Antipsara Island, at depths of 170-420 m[6], a species that can also settle at shallower depths.
Fields or forests of other species reported the presence of the black coral *Parantipathes larix*, the sponge *Thenea muricata* or crinoid *L. phalangium*[7,8] although the reports lack information on the location and bathymetric range of the findings.

The present photographic material analysis from experimental fishing revealed a further addition of 97 records from a depth range of 210-630 m. The most common species recorded from trawl catches were the sea pen *Funiculina quadrangularis* (36) and crinoids (23). Notable examples of high numbers (more than 10) of vulnerable sessile individuals/colonies included: *Isidella elongata* (in 3 trawl catches in the Toroneos Gulf and off the Kassandra Peninsula, Chalkidiki), *F. quadrangularis* **(3.4)** (in 6 trawl catches in the centre of the N. Aegean), and crinoids (in 6 trawl catches).

SOUTH AEGEAN SEA

With some quite interesting exceptions, much of the existing knowledge (~93%) compiled for the South Aegean Sea from the literature review is rather outdated (earlier than the year 2000), and most relevant records (82%) come from observations aboard trawlers. The spatial distribution of available records (Fig. 3.4) are around the Cyclades islands and the Cretan Sea. In the Cyclades, records are random and highly scattered as they originate from variable timespans and methodological approaches, while the Cretan Sea presents more concentrated and systematic information, collected by means of experimental trawling in the frames of two HCMR research projects (CINCS and FGEII Project).

Both circalittoral and deep-sea muds of the Cretan Sea have been confirmed to host significant fields of the crinoid *Leptometra phalangium* at depths of between 51-1,000 m (up to 1,552 individuals have been reported from a single haul in the Cretan Sea), *Funiculina quadrangularis* sea-pen fields at depths of between 51-711 m, and sparse but widespread aggregations of the brachiopod *Gryphus vitreus* at depths of between 500-700 m. Along with these findings, the cup coral *Caryophyllia smithii* (115-1,000 m) is also frequently reported, suggesting that deep-sea muds in this region might host occasional mixed communities.

The new records of reef-forming *Dendrophyllia cornigera,* at the muddy crater of the Kolumbo submarine volcano (460 m) and surrounding the lower circalittoral off Serifos Island (150-200 m) further add to S. Aegean conservation interest. These locations are known to receive high pressure from artisanal fisheries using bottom gillnets, mostly targeting *Squalus* shark spp. and the blackspot seabream *Pagellus bogaraveo*[6].

The present photographic material analysis revealed a further addition of 57 records from a depth range of 163-766 m. Notable examples of high numbers of vulnerable invertebrate individuals in the examined photographs included crinoids and the sponge *Thenea muricata*. The bamboo coral *Isidella elongata* was previously unknown in the area.

6 Salomidi M, unp. data

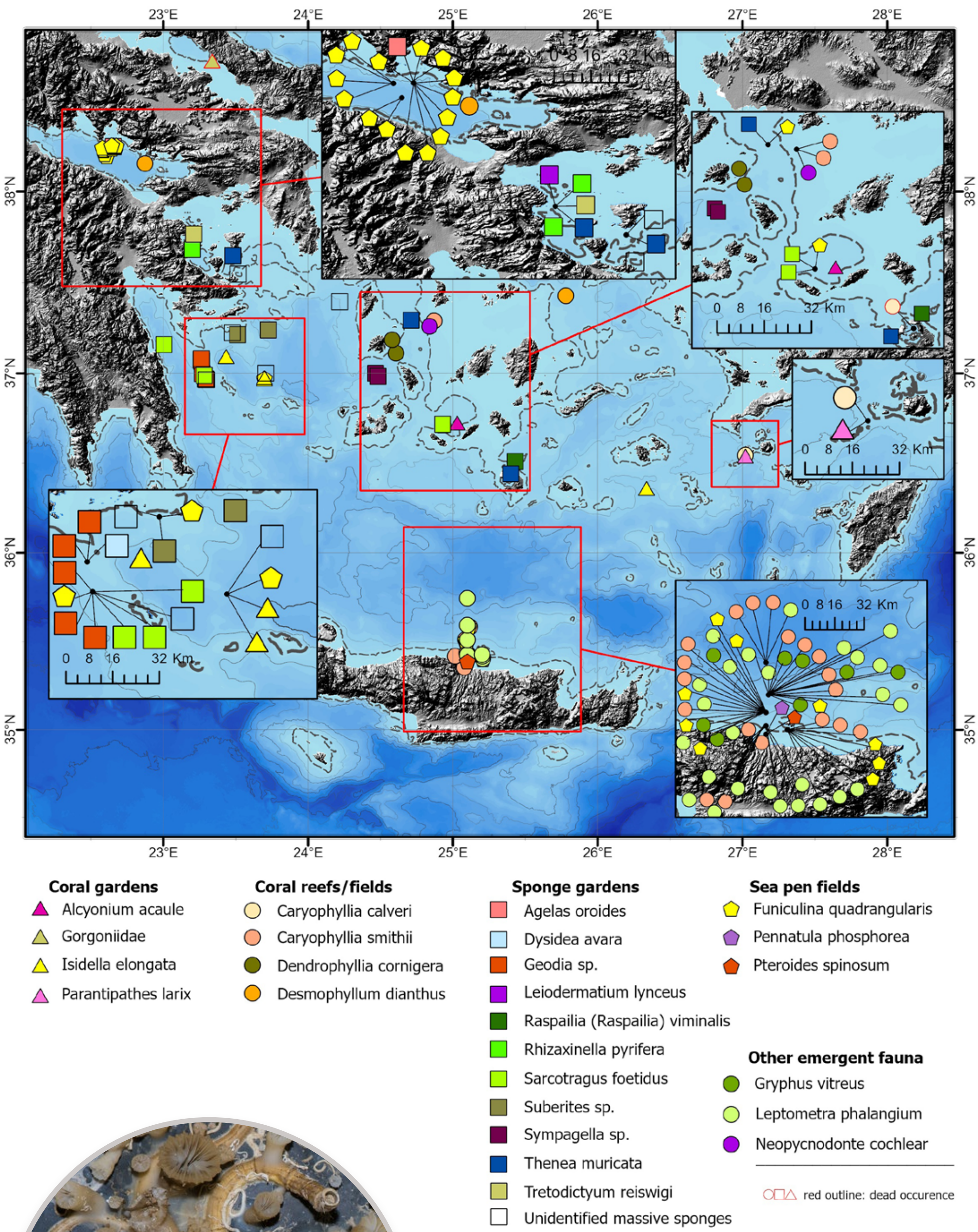


Fig. 3.4. Recorded presence of vulnerable sessile invertebrate taxa across the South Aegean Sea (86 records, 43 sites).

Desmophyllum dianthus covering the Arado WWII aircraft.

Also noteworthy for being of exceptional interest in this area is the 2013 case of a WWII aircraft wreck (sunk in 1944) accidentally raised by a trawler from a depth of ~400-500 m west off Ikaria Island, densely colonized by large individuals of *D. dianthus* and other deep reef-associated fauna (mostly serpulids)[7].

7 Salomidi & Zibrowius, unp. data

4 LIBYAN SEA

Most recorded vulnerable sessile invertebrate taxa in the Libyan Sea (88%) originate from a single research cruise that aimed particularly to explore the potential presence of cold-water coral banks along the margins south off Crete, Karpathos, and Rhodes islands, by the combined use of rock and epibenthic dredges on hard bottoms[4]. Information on deep-sea biodiversity from this region is therefore rather limited, with 15 key sessile species recorded from 34 sites (Fig. 3.5). Reef-forming species such as *Dendrophyllia cornigera* have been twice recorded alive from SE off Crete Island at depths of 520-620 m, while other cold-water corals (*Desmophyllum dianthus*, *D. pertusum, Caryophyllia calveri*, *Madrepora oculata* and *Stenocyathus vermiformis*) are so far known only in dead or subfossil aggregations.

Of special interest, a significant population of "exceptionally large specimens" of the deep demosponge *Rhizaxinella pyrifera* has been reported at 450 m depth of the Napoli Mud Volcano[9], lying approximately equidistant from Crete Island and the Libyan coast. Scattered records of other key fauna include the presence of the brachiopod *Gryphus vitreus*, the antipatharians *Antipathes* spp. and *Leiopathes glaberrima,* the gorgonian *Isidella elongata,* the sea-pen *Funiculina quadrangularis*, as well as the demosponge *Rhizaxinella pyrifera.*

The occurrence of fossil and subfossil cold water coral aggregations in the Libyan Sea has been confirmed both on land (palaeo coasts in St. Paul's Bay Limestone;[11], as well as on steep escarpments and elevations along the south margins of Crete, Karpathos and Rhodes Islands, suggesting cold-water corals forming banks and reefs might have had a wider area in previous times (12.4-12 ka cal BP)[4].

Although photographic material from fisheries catches from this area were not available, one *Isidella elongata* coral sample was caught with longlines targeting *Pagellus bogaraveo* (off South Crete), at a depth of approximately 400 m.

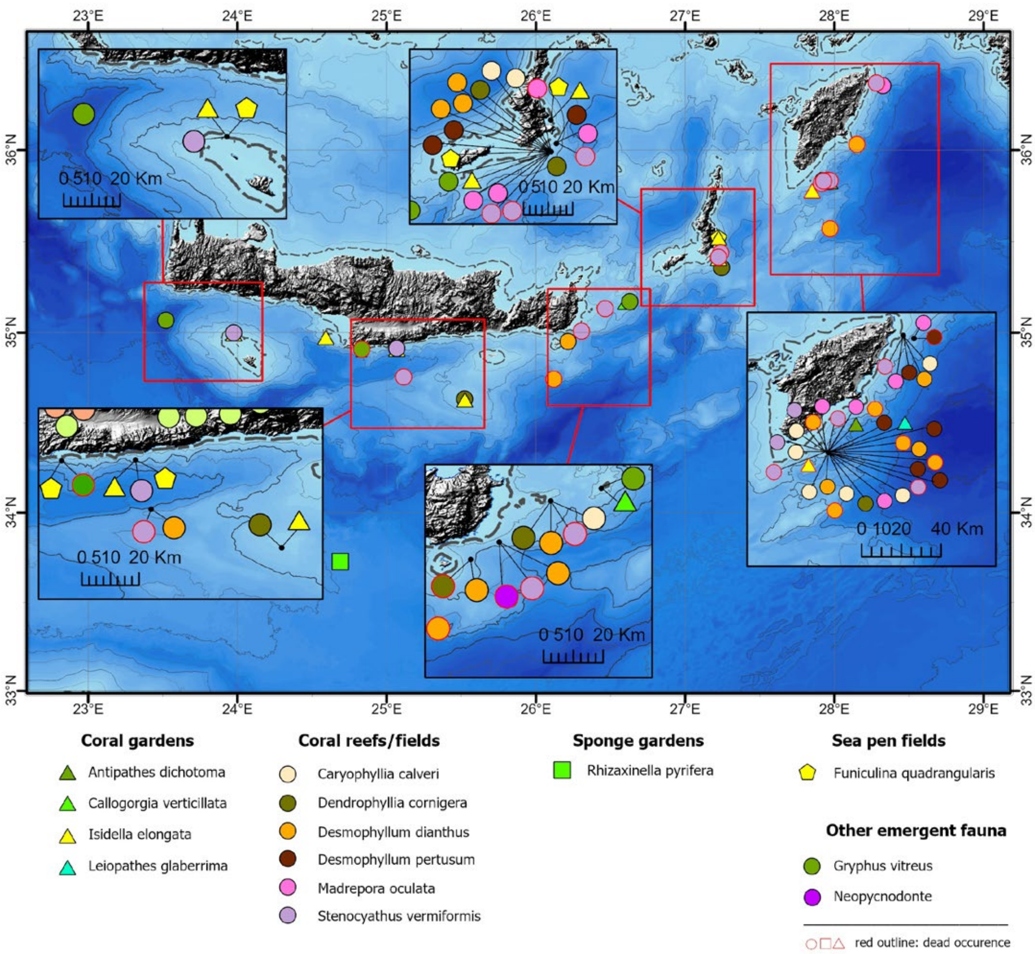


Fig. 3.5. Recorded presence of vulnerable sessile invertebrate taxa (classified under respective VME types) across the Libyan Sea (83 records, 34 sites).

5 LEVANTINE SEA

Although trawling remains the most important source of information (~70% of all compiled records), a significant part of the collected observations for the Levantine sub-region (~26%) also comes from the recent ROV deep survey off Lebanon (Deep-Sea Lebanon project, 2016) and the recent discoveries in Palmahim Disturbance on the continental margin offshore southern Israel[12].

The quantitative analysis of all historical literature reports 30 vulnerable sessile taxa within a total of 105 records from 76 sites for the Levantine Sea (Fig. 3.6). Among them, the deep-sea sponge *Rhizaxinella shikmonae* was the most commonly reported of all the habitat-forming species, followed by the brachiopod *Gryphus vitreus*, the sponge *Thenea muricata* and the corals *Caryophyllia calveri* and *Desmophyllum dianthus* (the latter however includes three dubious ones in terms of taxonomic identification). More recently, numerous colonies of the habitat-forming hydroid *Lytocarpia myriophyllum* were reported for the first time around South and North-western Cyprus (Pendaskhnos, Kolpos Epistokopis and Vailiko-Mori), often in considerable densities, at a bathymetric range of 45-619 m[10]. This feather-like hydroid is the largest hydroid of the Mediterranean Sea and its colonies can reach up to 1 m in height, organized in tufts and anchored to detritic and sandy bottoms.

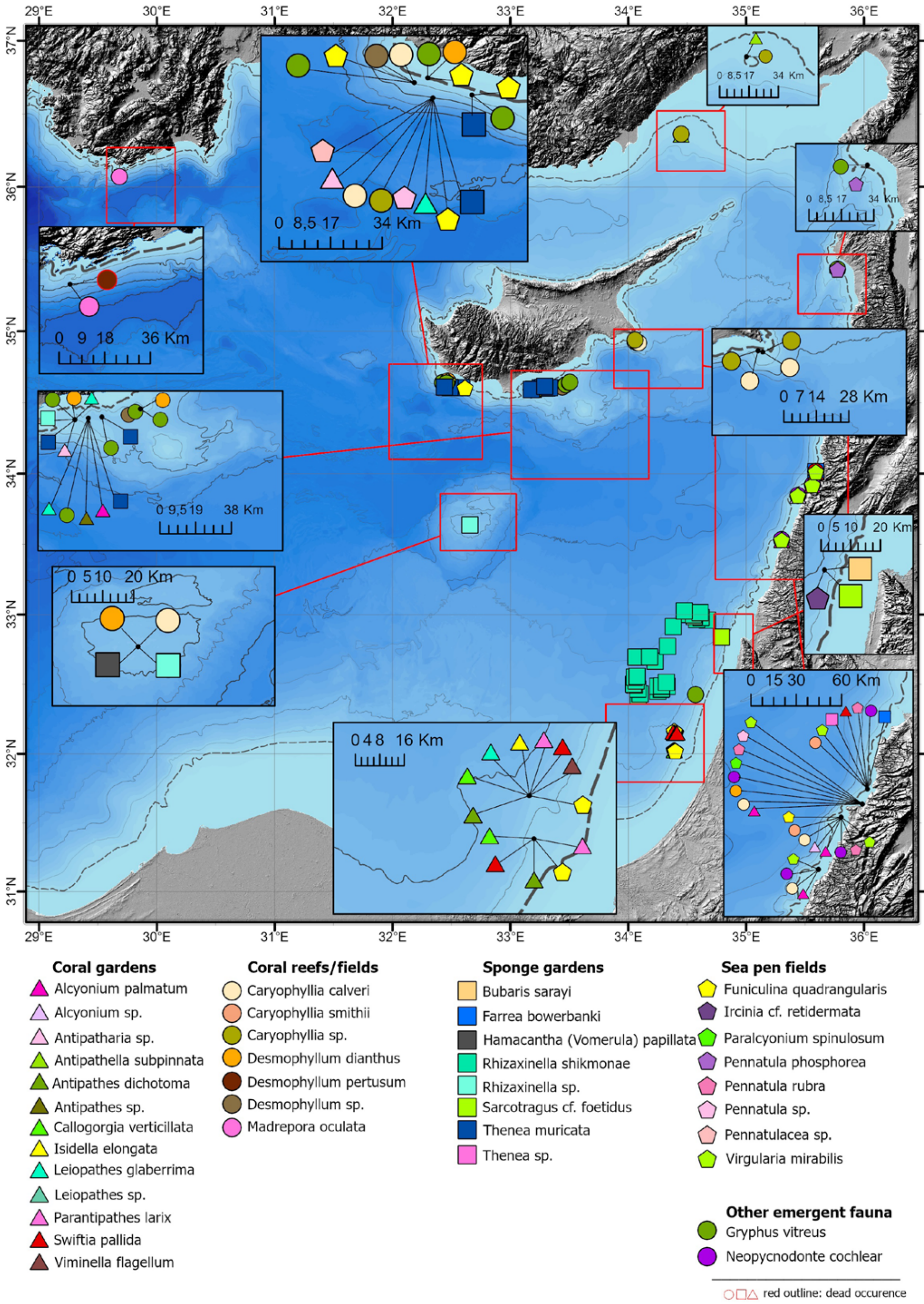
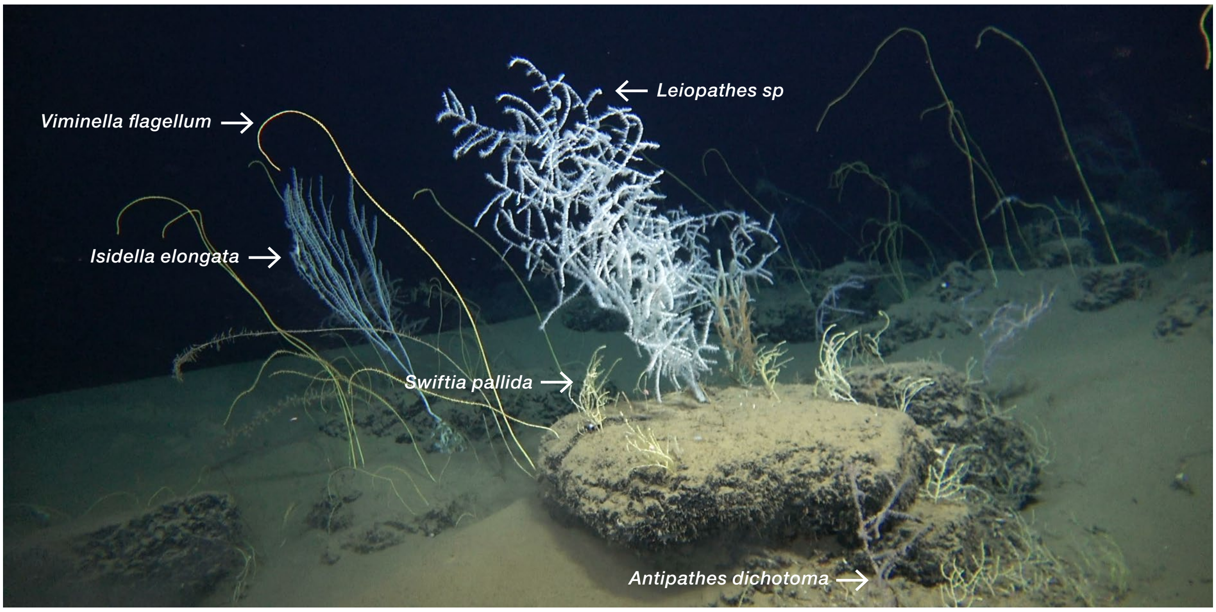


Fig. 3.6. Recorded presence of vulnerable sessile invertebrate taxa (classified under respective VME types) across the Levantine Sea (105 records, 76 sites).



Deep-sea corals gardens on on the northern face of Palmahim Disturbance (~650 m water depth). *Desmophyllum* corals were found to a maximum depth of ~1150 m. © Applied Marine Exploration Lab., Charney School of Marine Sciences, University of Haifa/ Israel Oceanographic and Limnological Research Institute.

Early expeditions to the Eratosthenes Seamount[13] have shown this area to host important communities of deep vulnerable sessile species. More recent studies from Cyprus, Israel, and Lebanon, both by experimental trawling and ROV surveys, highlight the Levantine deep muddy bottoms as important grounds for various key sessile fauna, and particularly the demosponges *Rhizaxinella shikmonae* and *Thenea muricata* (trawled from depths of between 1,227-1,493 m and 256-620 m respectively), the brachiopod *Gryphus vitreus* (254-726 m), and the sea-pen *Funiculina quadrangularis* (254-604 m). The scleractinian *Desmophyllum dianthus* has also been commonly reported from these same habitats, either as an associate of soft-bottom communities or colonizing natural or man-made fixed substrates (e.g. litter) scattered across muddy bottoms between 310-804 m.

Recent explorations have uncovered unique deep-sea communities off the Israeli shelf at the Palmahim Disturbance with the easternmost cold-water coral community in the Mediterranean. Overall, more than 7,400 coral colonies have been documented to date, including *Leiopathes*, *Antipathes dichotoma*, *Callogorgia verticilata, Viminella flagellum* and *Parantipathes larix*[12]. Of the compact mud growing upon the rock facies, both the critically endangered bamboo coral, *Isidella elongata*, and the vulnerable species of sea pen *Funiculina quadrangularis* are found in large numbers (hundreds of colonies) at the locality (Weissman et al. unpublished data).

A significant population of *Dendrophyllia ramea*, a species typically known from rocky circalittoral habitats in the Mediterranean, has been recently discovered off Protaras SE Cyprus forming a rather extensive coral

Polyps of *Dendrophylia ramea*. © Jose Elias Cabrera.

Pteroeides spinosum. © Francesco Pacienza.

field on circalittoral muds at depths of between 125-170 m[14]. Although not regarded as part of the truly deep-sea biodiversity, this finding is presented here for its exceptional interest, which highlights our thus far poor understanding of the eastern Mediterranean deep biota.

Apart from dead branches of the white corals *Madrepora oculata* and *Desmophyllum pertusum* dredged off Kastelorizo Island in 1956[15], other living coral banks of these species have not been reported from the Levantine, although unconfirmed sources do mention the presence of the cold-water coral *Desmophyllum pertusum* in deep-sea grounds of oil exploration interest[8].

Although not included in this deep-sea compilation, several sea pen colonies of *Pteroeides spinosum* collected from the shallow coastal waters (20-25 m) of the northern coast of Egypt[16] also suggest potential occurrence of deeper sea-pen fields in this area.

The present work on the photographic material from experimental fishing observations indicated the presence of 11 species (1 Porifera, 7 Anthozoa, 2 Mollusca, and 1 Brachiopoda) encountered from 38 observations. The most common species, all from trawl catches, were the brachiopod *Gryphus vitreus*, the sponge *Thenea muricata* and the sea pen *Funiculina quadrangularis* (> 50 colonies in one trawl catch off Cyprus).

CONCLUDING REMARKS

According to the literature review on existing records of habitat-forming sessile species in the Eastern Mediterranean Sea, the presence of such fauna was revealed to be widespread, diverse, and, in cases, long-known for several decades.

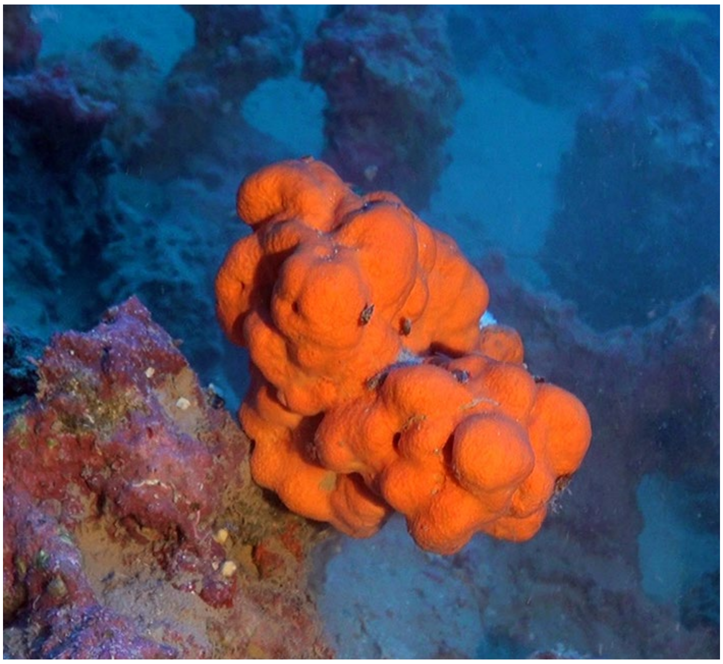
Overall, 51 key species have been recorded at depths as shallow as 33 m (i.e. in the case of *Caryophyllia smithii*) and as deep as 2,000 m (i.e. in the case of the demosponge *Rhizaxinella pyrifera*) from the period 1995-2018 across various seabed types, suggesting both the ubiquity as well as the wide natural variation in the distribution of vulnerable fauna in this area.

The historical records reveal that bamboo corals, of the family Isididae, were previously documented as being common along the continental shelf and shelf slope, particularly in the E. Ionian Sea. Other widely and commonly reported benthic invertebrate taxa with habitat-forming characteristics include the crinoid *Leptometra phalangium*, the scleractinian corals *Caryophyllia smithii, C. calveri*, *Desmophyllum dianthus* and *Dendrophyllia cornigera*, the sea-pens *Funiculina quadrangularis* and *Pennatula phosphorea,* the demosponges *Rhizaxinella* spp. and *Thenea muricata,* the brachiopod *Gryphus vitreus*, the black corals (*Antipathes* spp., *Leiopathes graberrima*) and soft corals (*Alcyonium* spp.), as well as the mollusc *Neopycnodonte cochlear*.

8 Jimenez, unp. data.

Photographic documentation from experimental fishing surveys, even when not taken under a systematic and concrete sampling scheme, also provide valuable information, extending the known distribution range of rarely reported species. Notable examples include: the critically endangered bamboo coral which was found in several locations in the N. Aegean, S. Aegean and Libyan Sea, significantly extending the known distribution of the species[2], *Funiculina quadrangularis* in the E. Ionian Sea and off Cyprus, the rock sponge *Leiodermatium* sp. which was recorded for the first time in the E. Ionian Sea (off W. Peloponnesus at 492 m), and many records of the brachiopod *Gryphus vitreus* which is rarely reported from the Eastern Mediterranean Sea[17].

Areas of high abundances were also found, more specifically: high abundances of *Isidella elongata* in the Toroneos Gulf and off Sithonia, Chalkidiki (N. Aegean Sea), several sites in the E. Ionian Sea, Antikythira Strait and South Kasos Strait off Crete Island and Palmahin Disturbance. *Funiculina quadrangularis* in central N. Aegean Sea and off south coasts of Cyprus and Israel (Palmahin Disturbance); *Gryphus vitreus* in the E. Ionian Sea. In addition, specific areas harboured multiple taxa of conservation interest: off SE Kefalonia (e.g. *Antipathes dichotoma*, *Dendrophyllia cornigera*, *Desmophyllum dianthus*, *Funiculina quadrangularis*, *Isidella elongata*, *Leiopathes glaberrima*) and the south coasts of Cyprus (e.g. *F. quadrangularis*, *D. dianthus*, *Caryophyllia* spp. and many unidentified corals). These findings indicate areas of potential conservation interest, which require further examination of their present conservation status before adequate management and protection measures are planned.



Sponge *Agelas oroides*. Oceana/IUCN/UNEP-MAP RAC-SPA Deep Sea Lebanon Project. © Oceana.

Giant oyster (*Neopycnodonte cochlear*) off Tyre coast, Lebanon. Oceana/IUCN/UNEP-MAP RAC-SPA Deep Sea Lebanon Project. © Oceana.

“

Biodiversity hotspots of habitat forming fauna were found in the Toroneos Gulf and off Sithonia, Chalkidiki, several sites in the E. Ionian Sea, Antikythira Strait and South Kasos Strait off Crete Island and Palmahin Disturbance. These historical records also show rich faunal assemblages off SE Kefalonia and the south coasts of Cyprus”

Critical information is however needed to enable a better understanding and management of deep-sea sessile communities that will help in the future to assess the distribution, status, health, and potential threats faced by these important ecosystems. Since deep-sea ecosystems, and within them vulnerable sessile communities, extend beyond national boundaries and encounter similar threats, cooperative efforts among countries could be beneficial to maximize available resources, share expertise, and exchange data to rapidly increase the scientific understanding of the communities that are created by these habitat-forming species.

- **Locating and mapping of sessile habitat-forming species.** The historical dataset shows that the bulk of the information was acquired through trawling (~70% of all records), whereby only coordinates and depth of the start (at times also the end) of them are provided. Cases also exist where an important species presence is mentioned only across very large spatial scales and depth ranges. Some data from the NE Aegean and the Levantine coasts were difficult to retrieve although are probably available in local grey literature or otherwise inaccessible sources (e.g. published in Turkish, Israeli or Arabic) and there is very limited information from the Libyan Sea.

- **Obtaining specific information on populations and their specific threats using state-of-the-art advanced underwater technologies.** This is largely due to the lack of systematic studies, and particularly ones that would allow for the collection of scientifically sound quantitative information, such as visual transects by means of ROVs or submersibles (representing 10% of the studies to date) or multiparametric deep-sea observatory platforms.

- **Obtaining information and all habitat types**. The historical literature review shows that records from reefs/banks and other hard-bottom communities hardly account for 15% of all available data, as opposed to 85% obtained from the exploration of muddy bottoms. Studies should also investigate the fauna present in different ecosystems made by a variety of geomorphological formations such as seamounts, canyons or the continental shelf-break.

- **Understanding the status and vulnerability of sessile fauna.** A significant part of the historical records (~46%) pre-date the year 2000, and the overwhelming majority (83.5%) are older than 2010. Given the vulnerability of these species, and the constantly increasing pressures – especially as the trawling industry expands in previously unexploited grounds – their persistence today can by no means be considered certain.

- **Expand the collection of information from fisheries in a systematic manner.** Information from experimental fisheries surveys (e.g. MEDITS), other scientific surveys and commercial fisheries (including photographic documentation and use of morphological groups for sponges/corals in cases where species identification is not possible) could be useful measures for getting a greater understanding of the biology and ecology of species as well as evaluating the impact of fisheries on vulnerable benthic assemblages. This approach has been recently adopted by several Mediterranean countries for the identification of by-catch sponges and corals in commercial fisheries catches, within the framework of a pan-Mediterranean project[9][18]. •

9 "Understanding Mediterranean multi-taxa 'bycatch' of vulnerable species and testing mitigation - a collaborative approach".

CHAPTER 3 /

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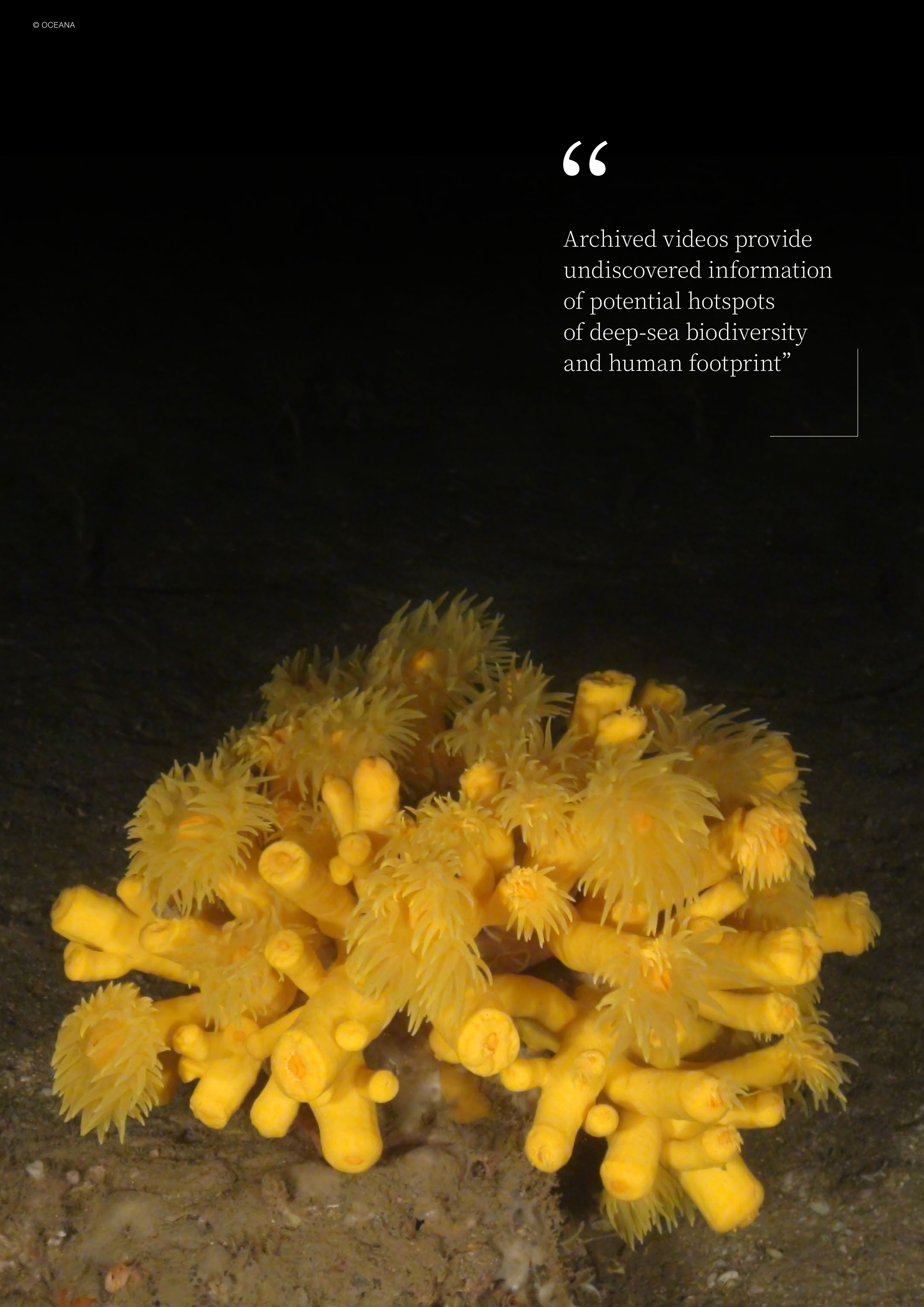
> “Archived videos provide undiscovered information of potential hotspots of deep-sea biodiversity and human footprint”



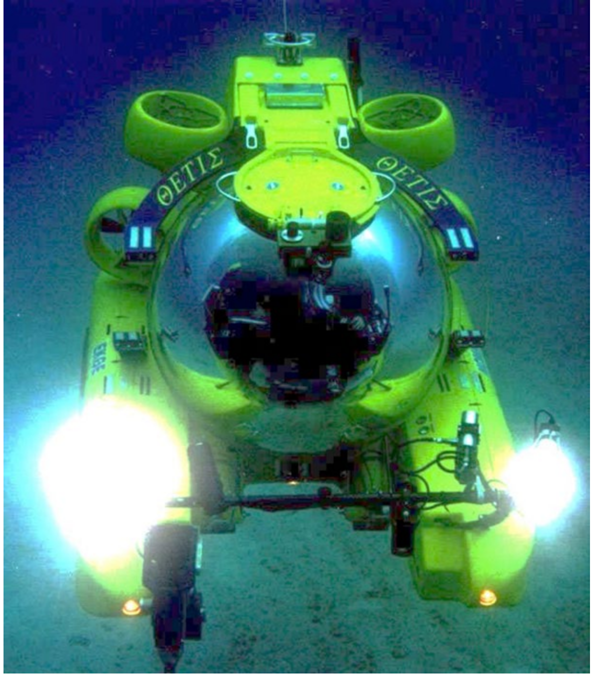
CHAPTER 4 /

Revisiting underwater surveys to uncover sites of conservation interest

Smith C.J., Gerovasileiou V., Mytilineou Ch., Jimenez C., Papadopoulou K., Salomidi M., Sakellariou D., Drakopoulou V., Otero M.

In contrast to the Western and Central Mediterranean Basin, data on deep-sea biodiversity are scarce in the Eastern Mediterranean (see Chapter 2). Visual observation has been extremely important for identification of deep-sea habitats and areas of conservation interest, directly from submersibles and indirectly from Remotely Operated Vehicles (ROVs) and other camera platforms. Where 40 years ago the availability to science of deep water imaging systems was restricted to only key institutions/organisations worldwide, there is today, much more common access to institutions' own, or shared resources. Imaging material has been produced from a variety of commercial and non-commercial sectors conducting offshore oil-and-gas explorations, geological-and-geophysical surveys, power cables and pipelines environmental impact assessments, wrecks and archaeological explorations, marine litter assessments as well as biological and oceanography campaigns. These surveys/works whilst not targeted to enhance biodiversity knowledge still have potential to deliver useful data.

By analysing existing repository data from these works, further knowledge can be acquired, and unknown spatial patterns uncovered, contributing to a more complete and comprehensive portrait of the deep ecosystem. Here, we present the results using this approach to catalogue and review video material, primarily acquired by HCMR over the last decades, from a variety of underwater mission types from different geographical areas in the Eastern Mediterranean. The aim was to further investigate areas of high interest (defined biological or geological features) previously identified (Chapters 2 & 3) and report the presence, association and distribution (geographical and depth range) of vulnerable marine fauna. Archived video material covering a 25-year period (1995-2017) was analysed to produce thematic maps for all sites observed in deep waters (> 200 m depth) with notification of sites of particular interest (biodiversity hotspots), particularly towards the presence of species already noted in Chapter 3, or other important conspicuous species (for example, some vent/seep related species).



One of the video data collection platforms, the HCMR submersible Thetis.

Video dive logs were examined, highlighting 36 distinct sites with over 250 hours of material for video analysis (Fig. 4.1 and Annex 4.1 with site metadata). The collection of information included area, date, depth range, number of dives and observation time, mission type, site description, vulnerable species (species, depths, number of observations and substrate), special features observed and anthropogenic traces[1]. Underwater video has been collected for a wide range of operations, from dedicated faunal surveys with prime usable video (constant slow speed, direction and low altitude) to target verification (on the seabed, searching and driving onto and around a target, targets being geological, archaeological, deployed equipment, lost structures) or manipulation (diving and working on a target). With different objectives, there were differences between missions in coverage and focus as well as different effort (from less than one hour to 37 hours, but 7 hours on average). Depths ranged from 200 m (the "deep sea" shallower limit) to 1,560 m (North Aegean). The usability of video was therefore highly variable and inconsistent, not allowing for the estimation of density or complete area comparisons.

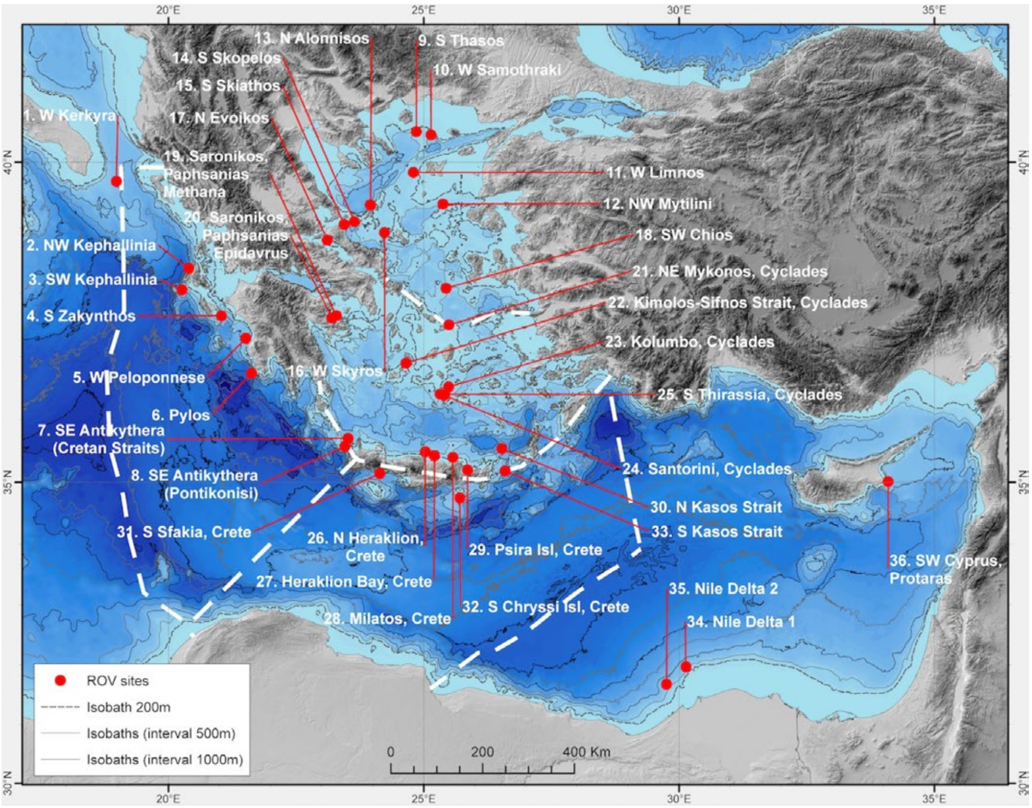


Fig. 4.1. Location of the sites examined within the different geographical areas of the Eastern Mediterranean.

1 The methodological analyses that support the findings are available from the corresponding authors upon request.

Kephalonia (in Greek also known as Kefallonia or Kephallinia), Eastern Ionian Sea. © Skaisu, Dreamstime.

Table 4.1.
Areas where sampling observations were taken for video analysis.

Eastern Ionian Sea	South Aegean Sea
1. W. Kerkyra	19. Saronikos, Paphsanias Methana
2. NW. Kephallinia	20. Saronikos, Paphsanias Epidavrus
3. W. Kephallinia	21. NE. Mykonos, Cyclades
4. S. Zakynthos	22. Kimolos-Sifnos Strait, Cyclades
5. W. Peloponnese	23. Kolumbo, Cyclades
6. Pylos	24. Santorini, Cyclades
7. SE. Antikythera (Cretan Straits)	25. S. Thirassia, Cyclades
8. SE. Antikythera (Pontikonisi)	26. N. Heraklion, Crete
	27. Heraklion Bay, Crete
North Aegean Sea	28. Milatos, Crete
9. S. Thasos	29. Psira Island, Crete
10. W. Samothraki	30. N. Kasos Strait
11. W. Limnos	
12. NW. Mytilini	**Libyan Sea**
13. N. Alonnisos	31. S. Sfakia, Crete
14. S. Skopelos	32. S. Chryssi Island, Crete
15. S. Skiathos	33. S. Kasos Strait
16. W. Skyros	
17. N. Evoikos	**Levantine Sea**
18. SW. Chios	34. Nile Delta 1
	35. Nile Delta 2
	36. SW. Cyprus, Protaras

EASTERN IONIAN SEA

1

Of the 8 areas analysed with respect to underwater video, two areas of high biological interest were identified in the Eastern Ionian Sea due to numbers of vulnerable species and relative abundance, South West of the island of Kephallinia (4.1 - 4.2) and South East Antikythera (4.3 - 4.6).

The area South West of the island of Kephallinia, located on the Argostoli ridge within the Kephallinia seamount area (see Chapter 2, Fig 1.4) was characterised on sedimentary slopes by the presence of the bamboo coral *Isidella elongata* and the seapen *Funiculina quadrangularis* whilst interspersed bedrock outcrops, stones or exposed crusts had black corals *Antipathes dichotoma,* Plexauridae gorgonian spp. and the stone coral *Desmophyllum dianthus* as well as a few colonies of the long-lived black coral *Leiopathes glaberrima*.

Cape Apolytaras South of Antikythera Island © Charalambos Andronos, Dreamstime

These species were also recorded off SE Antikythera, but in richer concentrations and also included large numbers of the whip coral *Viminella flagellum*. Antikythera had a wide range of bottom types within a relatively small area across the straits and most likely had the richest concentration of vulnerable, and predominantly filter-feeding species, from the relatively richer waters funnelled through the straits from the Aegean Sea. Across all the Eastern Ionian Sea, sponges were only notable in the SE Antikythera straits area. *Isidella elongata, Pennatula* sp. and *Funiculina quadrangularis* were the most ubiquitous vulnerable species found at most of the studied areas. In terms of geology, the straits area was also of high interest due to its high variety of seabed types and very high topography including visible seismic evidence from faulted rocks.

Here, the richest dive sites were in the area of the Antikythera seamounts (see Chapter 2, Fig 1.6). A second area of high geological interest was noted in the steep slope off Pylos off the SW Peleponese, an area that drops off into the deepest part of the Mediterranean (Matapan Trench/Calypso Deep/Oinousses Deep, approximately 5,200 m depth), characterised by rock cliffs and seismic faulting.

Anthropogenic impacts were observed at most of the sites, this included ancient items including shipwrecks and amphoras and more modern items including a range of plastics, metal and glass/ceramics. Fishing traces were also evident from parts of lost fishing gears (nets and longlines) to scrapes from recovered gears on the seabed. Lost fishing gears were evident in some places of coral occurrence.

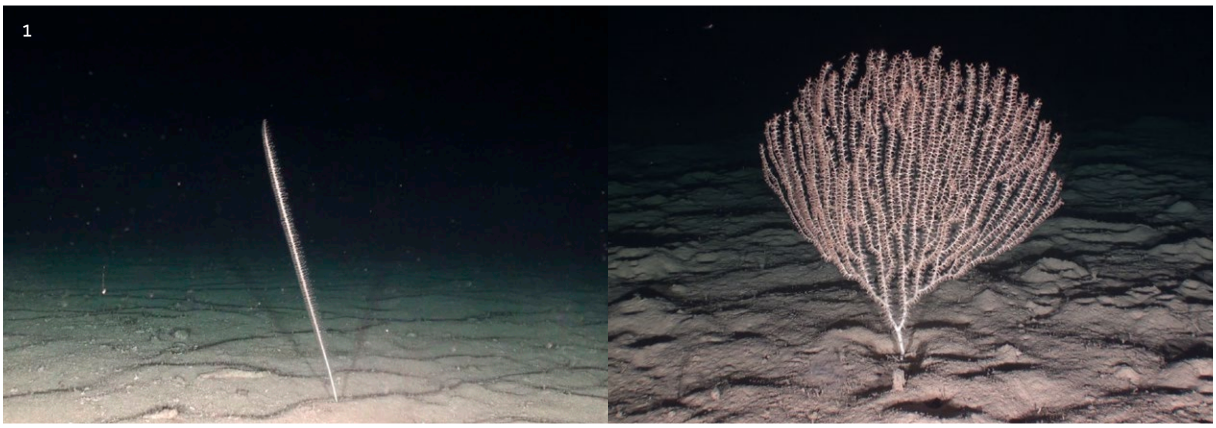


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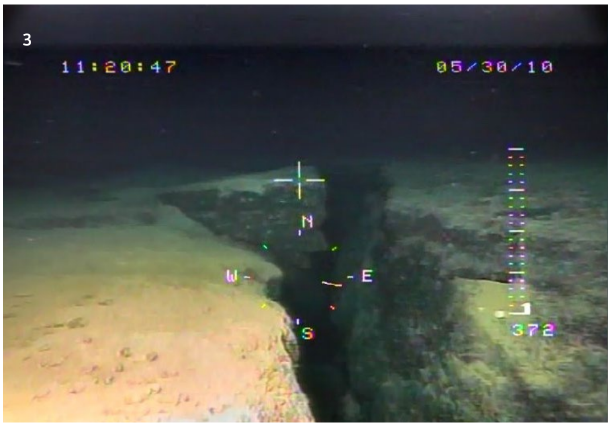
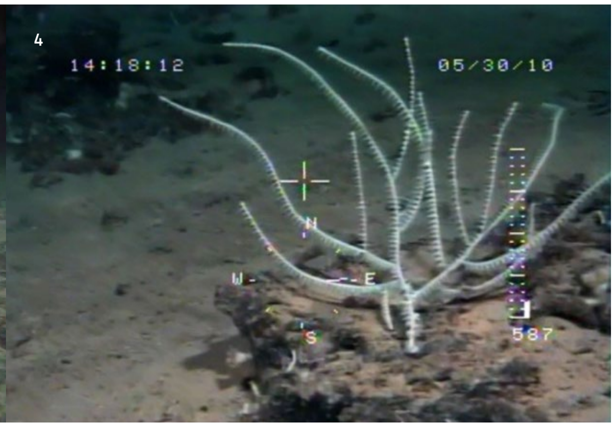
Plate 4.1. *Funiculina quadrangularis* (left) and bamboo coral *Isidella elongata* (right) as those observed in SW Kephallinia.





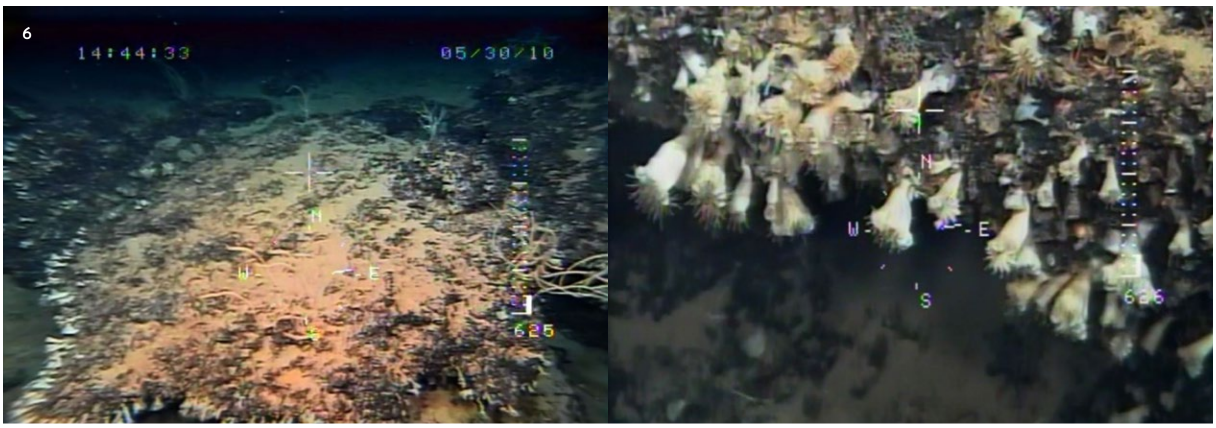


Plate 4.2. *Antipathes dichotoma* (left) and Plexauridae sp. (right) from SW Kephallinia.

Plate 4.3. Fractures on the rocky seabed of SE Antikythera.

Plate 4.4. *Antipathes dichotoma* (right) observed on hard substrates covered with a thin sediment layer from SE Antikythera.

Plate 4.5. Large sized (> 1 m high) colony of the antipatharian *Leiopathes glaberrima* (left) and zoom photo of a scleractinian (possibly *Thalamophyllia gasti*) developing on its lower branch (right) from SE Antikythera.

Plate 4.6. Dense aggregations/facies of the scleractinian *Desmophyllum dianthus* developed on the sides or under-hanging surfaces of boulders and rocks from SE Antikythera.

Peristera island, Alonnisos. © Dreamstime.

2 NORTH AEGEAN SEA

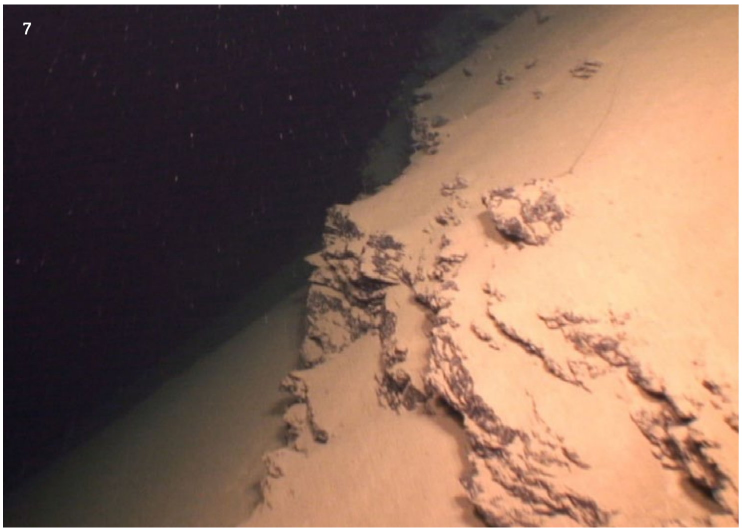
For the North Aegean, video observations have been reviewed in 10 different areas, mostly in the northern part and towards soft sedimentary areas (*Nephrops* grounds) with only few observations of hard substrates, notably in North Alonnisos and SW Chios (**4.7 - 4.9**). Of these, 2 were ROV missions, one with the submersible Jago and 7 with video sled. All the missions were science oriented with the exception of one search for airplane wreckage. Of the video sled observations 6 were during one early stock assessment survey for *Nephrops norvegicus* in Northern Aegean *Nephrops* fishing grounds during 1996. Most of the dives were therefore made on soft sedimentary grounds, and seapens were the most common group observed with *Funiculina quadrangularis* with high density at SW Chios Island and *Kophobelemnon stelliferum* with very high density (at field level) in the northern most site of South Thasos. The only observation of the critical endangered bamboo coral *Isidella elongata* was in the southern most site (SW Chios). Corals were represented in very low occurrences with exceptions of some scleractinians (*Desmophyllum dianthus* and Caryophyllidae sp.) in North Alonnisos and a few species (*Parantipathes larix*, *Callogorgia verticilata* and Caryophyllidae sp.) on low rock outcrops at SW Chios (**4.9**).

Sponges were mostly observed in the deep (950-1,500 m) Alonnisos dives, where there were significant areas of hard substrate from crusts to boulders and bedrock outcrops, a steep sedimentary slope with outcrops and evidence of landslides. Sponges observed included the glass sponge *Farrea* sp. (**4.8**), an unidentified lollipop sponge, *Phakellia* sp., *Haliclona* sp. with many encrustations of *Hamacantha falcula* and tetractinellids (e.g. *Geodia* sp. and *Pachastrella monilifera*). In addition, several individuals (> 30) of the rock sponge *Neophrissospongia* sp. were observed on rocks off SW Chios. On soft sediments, in South Skiathos a field of the sponge *Thenea muricata* was observed.

The crinoid *Leptometra phalangium* was recorded in two sites (West Limnos and North Evoikos) with very low numbers, whilst uncommonly high densities of the echiuran worm *Bonellia viridis* forming a field on soft sediments were recorded in North Evoikos Gulf. There were also high densities of the squat lobster *Munida* sp. in the same area on the sediment surface. The North Evoikos Gulf deep basin, from where the observations were made, is a relatively small basin (approximately 20 x 8 km), close to shore on the Evia Island side, with a number of steep submarine canyons leading into the basin. Two chondricthyans, the rabbitfish *Chimaera monstrosa* and the kitefin shark *Dalatias licha* were observed in the deep dives in North Alonnisos.

The most important sites were South Thasos due to the high seapen *Kophobelemnon stelliferum* abundance and SW Chios Island and the deep Alonissos site for overall abundance and diversity of corals and sponges. The deep Alonnisos dives had significant geological features ranging from hard substrate from crusts to boulders and bedrock outcrops, a steep sedimentary slope with outcrops and evidence of landslides. Two apparent broken thin "chimneys" were also observed at this site, isolated on soft sediments.

Litter including lost fishing gears were found in a number of sites, with only very low amounts recorded in the seven North Aegean sites observed by video sled from 1996. Trawl fishing marks were strongly present in some of these sites, which is unsurprising as they are commercial trawling grounds.



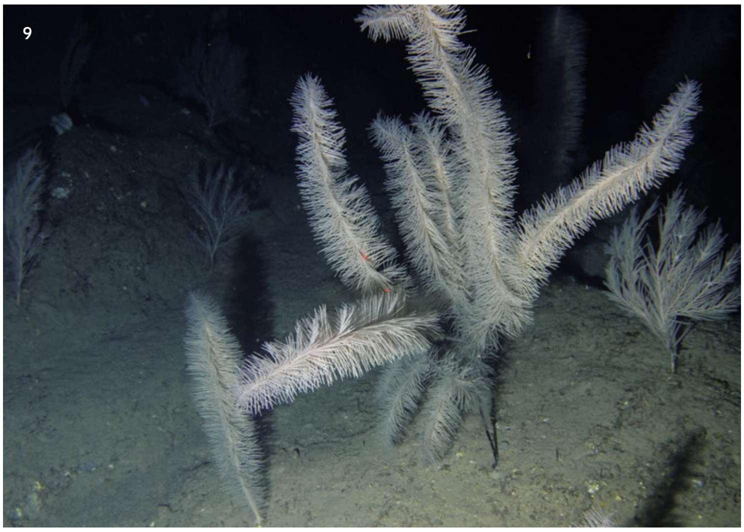


Plate 4.7. Steep sediment covered bedrock in North Alonissos.

Plate 4.8. Glass sponges *Farrea* sp. on hard substrate on outcrop reef (1560 m depth) in North Alonissos.

Plate 4.9. Rocky reef with *Callogorgia verticilata* and *Parantipathes larix* in SW Chios.

Palea Kameni island within the Santorini caldera, Cyclades Plateau, South Aegean Sea. © Maria Michelle.

3 SOUTH AEGEAN SEA

For the South Aegean, video observations have been reviewed in 12 major areas, 6 by ROV, 5 with the Jago manned submersible (from 1995) and one recently using a drop-camera system. All missions were part of scientific expeditions, either general survey concerning biology and geology or archaeological and litter searches. Three of the survey areas were related to underwater volcanoes including Paphsanias (Saronikos Gulf), Santorini and Kolumbo (Cyclades Plateau).

The volcanic areas of Paphsanias, Santorini and Kolumbo (4.10, 4.11 - 4.12, 4.13 - 4.14 respectively), presented seemingly similar environments although they may be unique in terms of species composition. They all presented a range of different habitats, whether broken rock piles, rock faces, soft sediments, with abundant sponge communities; Paphsanias: *Haliclona* sp. (4.10), *Hamacantha falcula*, *Hexadella* sp., tetractinellid sponges; Kolumbo: lollipop sponges and *Hamacantha falcula*; Santorini: lollipop sponges and *Haliclona* sp (4.12).

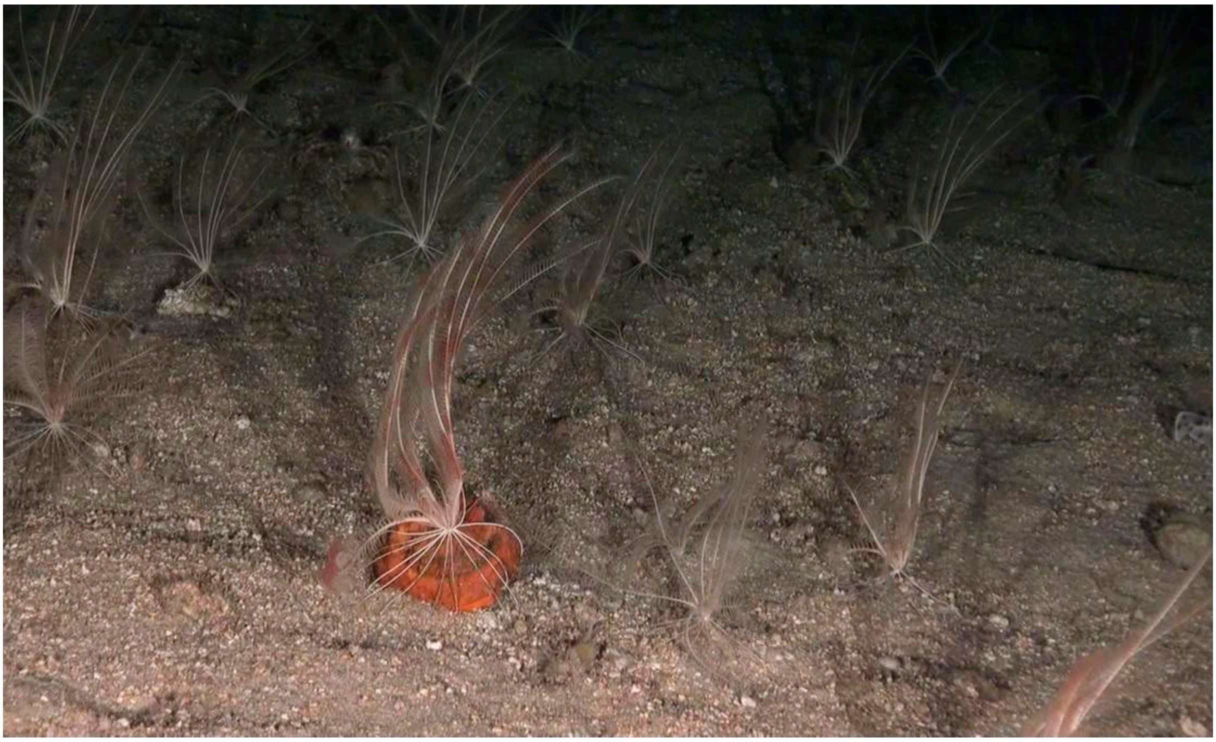
What was also notable in these volcanic areas was the fact that the habitats were characterised by mono-specific assemblages: sponges on rock faces away from active seeps/vents in all areas, and in Kolumbo, Cerianthidae (tube anemones) fields on soft sediments adjacent to seeps/vents and mono-specific ascidian facies covering boulders or inactive chimneys.

One other area that may be identified as a sponge field was the shallower (250-300 m) area of NE Mykonos with many yellow/orange massive-tubular sponges (probably *Aplysina* sp. and *Agelas oroides*, (4.15 - 4.16). The shallower seabed in the same area (140-200 m) was covered by maerl gravel with very rich sponge gardens and bryozoan colonies. Two areas of high species numbers including corals were noted at: a) Kimolos-Sifnos Strait (4.17 - 4.19); particularly on rock terraces with high numbers of lollipop sponges and the sponge taxa *Phakellia* spp./*Poecillastra compressa*, as well as the corals *Callogorgia verticillata*, *Acanthogorgia hirsuta* and both living and rubble *Dendrophyllia cornigera*; and b) North Kasos Strait; including a variety of different kinds of hard substrate, with *Antipathes dichotoma*, *Parantipathes larix*, Plexauridae, *Leiopathes glaberrima* and Caryophylliidae sp. An additional area with high coral coverage was the cliff at Psira Island, Crete with many individuals of shallower water corals *Antipathella subpinnata* and *Eunicella cavolini* (4.20).

In two areas on the north of Crete, important beds of the fragile sediment dwelling, filter feeding crinoid *Leptometra phalangium* were observed (4.21). Although the bed in Heraklion Bay was first observed in 1995, further observations have been made in the same area[1,2]. This site is adjacent to a commercial trawl lane, but protected from trawling by the local topography (slope) and extends into waters shallower than 200 m. The single observations of seapens *Funiculina quadrangularis* and *Kophobelemnon stelliferum* were near the southeastern-most area studied, the North Kasos Strait. This was also the only site in the region where *Isidella elongata* was observed (4.22).

As noted, most of the observed areas were characterised by prominent geological features, whether volcanos or areas with faults. The 3 volcanos (Paphsanias in Saronikos Gulf, Santorini and Kolumbo) had many different habitats/formations within close proximity including active venting/seeping chimneys or flowing bottom seeps across soft sedimentary seabeds, inactive chimneys, fractured rock slopes or boulder slopes and cliffs. The volcanic areas have been well described[3]. The faults were found in North Heraklion and North Kasos and were characterised by open troughs a few metres deep with rock faces and sediments in the bottom in otherwise sedimentary bottoms, and in the case of Kasos with other broken rock faces and crusts.

> “The volcanic sites of Paphsanias and Kolumbo and the Kimolos Strait had rich sponge field grounds adjacent to the seeps and vent formations, tube anemones, corals, bryozoans and occasional maerl beds”



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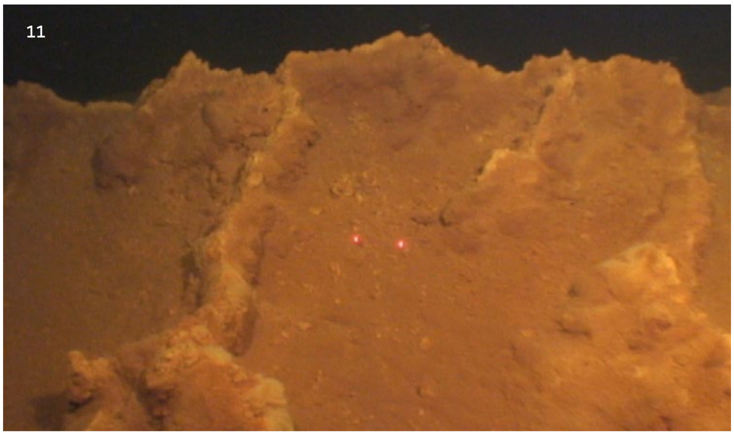
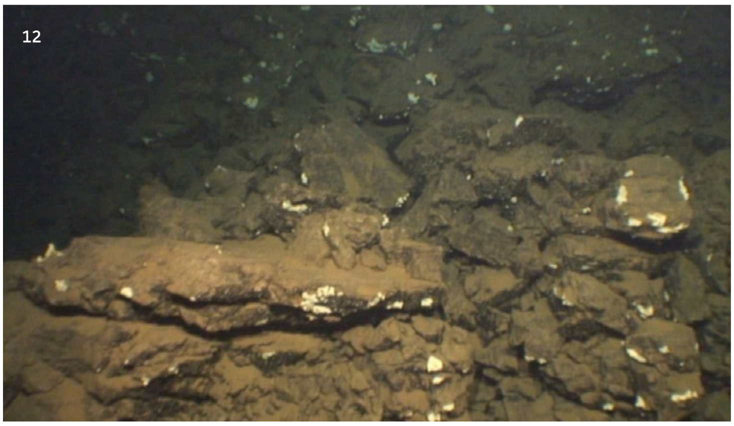
The crinoid *Leptometra phalangium* a suspension-feeding species confined in the Mediterranean to the continental shelf-break area.

View of Santorini Caldera. © Dreamstime.





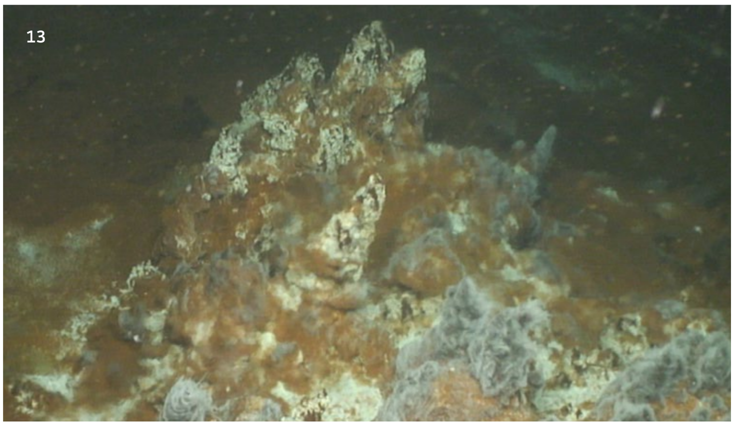


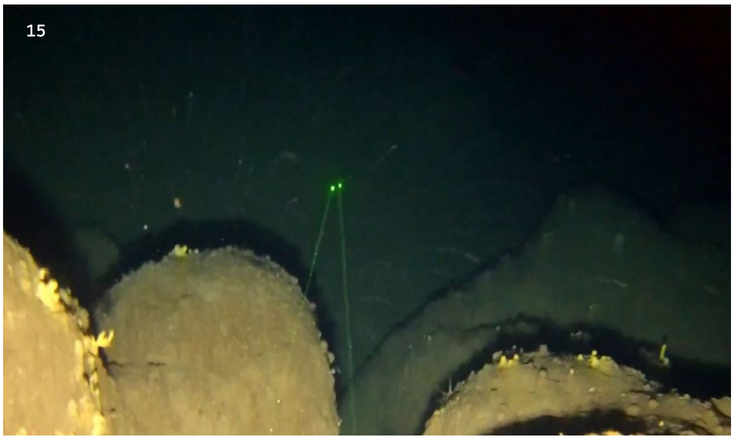
Plate 4.10. Sponges (probably *Haliclona* sp.) and the decapod *Munida* sp. were found in high numbers on rocks in the Paphsanias volcano.

Plate 4.11. Soft sediment with cemented-looking crests, possibly covered with bacteria from Santorini caldera.

Plate 4.12. Mono-specific sponge assemblages, possibly belonging to the genus *Haliclona*, on boulders and outcrops (200-295 m depth) from Santorini caldera.

Plate 4.13. Active rocky chimney with hot water seeps and gas vents, covered with bacteria from the Kolumbo volcano.

Mykonos Greece. © Fokke Baarssen, Dreamstime.



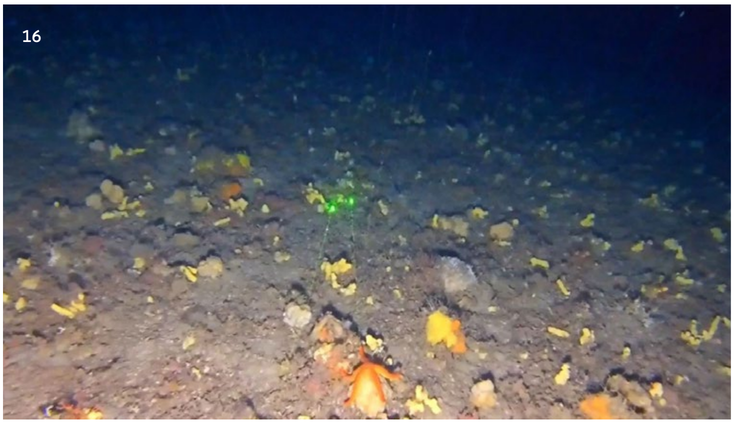


Plate 4.14. Active chimney covered with bacteria and microbial mats forming “white rivers” from the Kolumbo volcano.

Plate 4.15. Yellow and orange massive/tubular sponges (possibly *Aplysina* sp. and/or *Agelas oroides*) (approx. 250-300 m depth) on edge of rock steps and boulders from NE Mykonas.

Plate 4.16. Maerl bed with rich sponge gardens and bryozoan colonies (140-200 m depth) from NE Mykonas.

Aerial view of the south Kimolos-Sifnos Strait, Cyclades. © Jan Hamadak, Dreamstime.

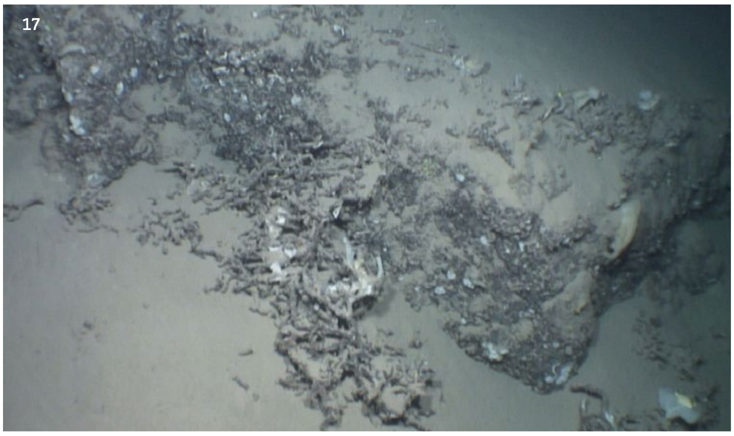


Plate 4.17. Upslope with sediment covered short (< 1 m) rough-faced bedrock terraces, partially comprised of *Dendrophyllia* coral rubble from Kimolos-Sifnos Strait.

Plate 4.18. Lollipop sponges (540-600 m depth) patch/field on soft sediment from Kimolos-Sifnos Strait.

Plate 4.19. Massive tetractinellid sponges, *Phakellia* spp./*Poecillastra compressa* individuals and the corals *Callogorgia verticillata* on *Dendrophyllia cornigera* reef terraces from Kimolos-Sifnos Strait.

Psira island, Greece. © Nerijus Juras. Dreamstime.

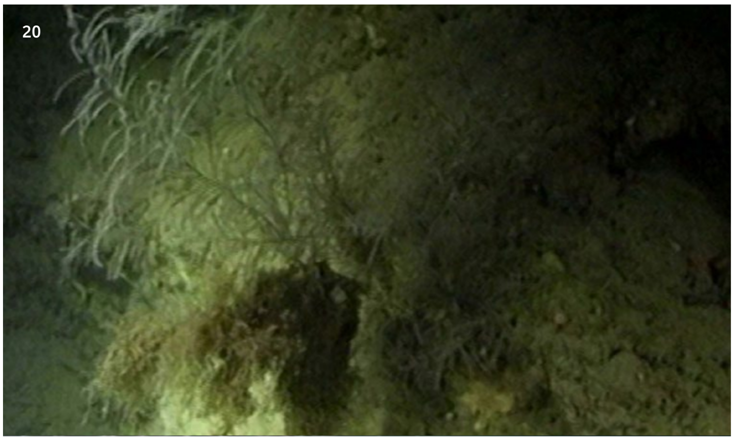


Plate 4.20. *Antipathella subpinnata* on the rock wall of Psira Island, Crete.

Plate 4.21. *Eunicella cavolini* on the rock wall of Psira Island, Crete.

Plate 4.22. *Isidella elongata* on soft substrate (right) from N. Kasos Strait.

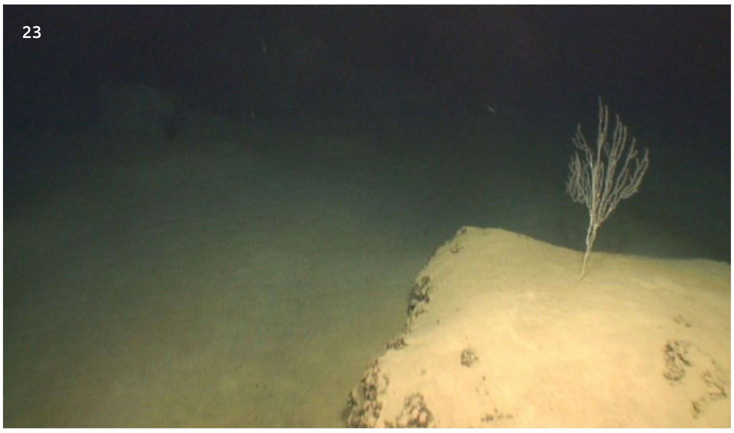
Kasos island. © Dimitris Tzortzakis, Dreamstime.

4 LIBYAN SEA

The three observation areas in the Libyan Sea were all in the area of the Hellenic Trench, off the South coast of Crete or the Crete-Kasos strait. The two easterly areas were investigated as part of archaeological expedition, whilst the westerly area was a search mission for a recent airplane wreck. All three areas were characterised by predominantly flat soft sediments, with some small patches of crusts, a few stones or small areas of low outcropping rocks (**4.23 - 4.28**). Commonly present were the corals *Funiculina quadrangularis* and *Isidella elongata* and, in the Kasos Strait, one observation on soft sediments of the seapen *Kophobelemnon stelliferum*.

There were rarer hard substrates, exposed crusts and rocks, and these were colonised by low numbers of mostly small vulnerable coral species including black corals of *Antipathes dichotoma* and *Parantipathes larix* as well as the scleractinians Caryophyllidae spp. and *Dendrophyllia cornigera,* both living and rubble, observed on the edge of hard substrates. The richest area with the highest number of species was the area South of Chyrssi Island (**4.24 - 4.26**), the main Chryssi Seamount with a total of 14 vulnerable species and notably high numbers of the seapen *Funiculina quadrangularis,* the black coral *Antipathes dichotoma,* Caryophyllidae sp., Zoantharia sp., the uncommon Corallimorpharia *Sideractis glacialis* and the brachiopod *Gryphus vitreus*. Dense aggregations of deep-shrimps *Plesionika* sp. were also observed on the occasional crusts and small outcrops in this area (**4.26**). Observations of small corals were also made on ancient litter in the form of terracotta amphora. More observations of the filter feeding vulnerable species were made in the Kasos Straits area, another important site, particularly *Funiculina quadrangularis* and *Isidella elongata* on soft sediments, which may have been due to higher water flows. However, the number of sponge observations was very low. The most striking sponge record was that of the rarely reported rock sponge *Leiodermatium* sp., which was found on fine substrate, at 450-617 m in the Kasos Strait (**4.27**). Bioturbation levels were mostly low, although large densities of wide echinoid feeding trails bulldozed on the sediment surface were observed particularly in the South Crete areas from an irregular heart urchin (probably *Spantangus purpureus*). Another monospecific hotspot was evidenced by large number of the sea urchin *Cidaris cidaris* feeding on a mammal skeleton.

A mixture of small litter items (e.g. plastic bags, bottles and cans) were observed in all sites and lost longlines were observed at the shallower two sites off South Chryssi Island and the Kasos Strait (500-600 m) (**4.27 - 4.28**) with none at the deeper South Sfakia site (950 m), with the exception of the modern airplane wreckage (metal allows and plastics). Overall the sites represented an important area for the Libyan Sea in terms of vulnerable species.



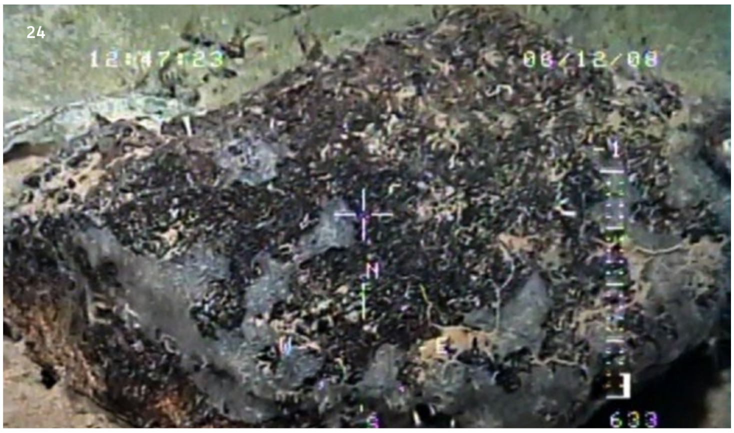


Plate 4.23. *Isidella elongata* on rock boulder covered with sediment, S. Sfakia, Crete.

Plate 4.24. Stones covered with the sponge *Hamacantha falcula*, S. Chryssi Island, Crete.

Plate 4.25. *Leiopathes glaberrima* colonies on amphora (different specimens), S. Chryssi Island, Crete.

Plate 4.26. Aggregations of shrimps *Plesionika* sp. on crust outcrops, S. Chryssi Island, Crete.

Plate 4.27. Rock sponges *Leiodermatium* sp. on fine substrate observed from the submersible, S. Kasos Strait, Crete.

Plate 4.28. Degraded *Isidella elongata* covered by plastic litter, S. Kasos Strait, Crete.


© YIANNIS ISSARIS.

Dendrophyllia ramea **is considered a rare coral in the Mediterranean Sea and with a patchy distribution.**

5 LEVANTINE SEA

ROV dives were available for examination in only three areas in the Levantine Sea and it is not possible to draw any broad conclusions about biological or geological areas of interest or distribution maps from video with such limited material available. From two close dive sites in the Nile Delta and one of the South West Coast of Cyprus, the most important biological feature from the material observed was the presence of patches and tube matrices of the siboglinid annelid *Lamellibrachia* sp. (most probably *L. anaximandri*) (**4.29**). This species has been reported before in the Levantine Sea related to seeps and vents (it is named after the Anaximander seamount), and it is highly probable that its presence is related to the geological formation on the sediments in the Nile Delta. There were no biological features of interest observed in the deeper waters of the Cyprus dive, although the coral *Dendrophyllia ramea* was observed in shallower waters (125-175 m) during the same dive transect[4].

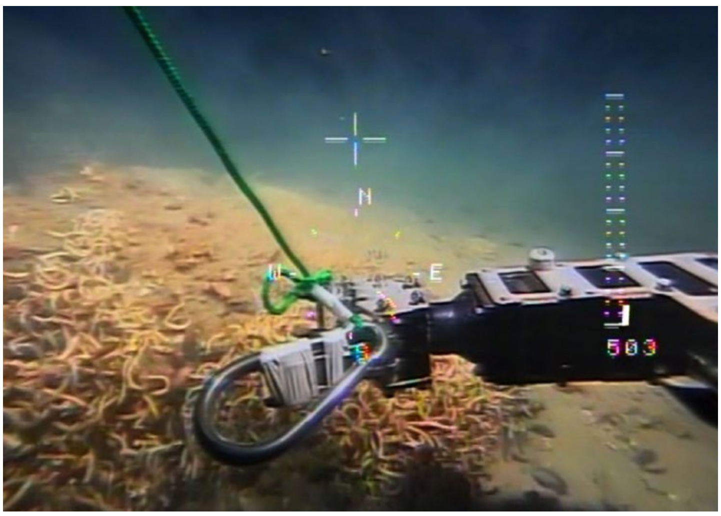


Plate 4.29.
Patches of the Siboglinidae annelid *Lamellibrachia* sp. associated with crusts or low sediment covered outcrops from the Nile Delta.

Species diversity

A total of 46 vulnerable invertebrate taxa were identified in the examined video material from 6 different phyla.

SPONGES (PORIFERA)

Sponges were recorded extending from the Eastern Ionian to the Aegean and Libyan Seas (Fig. 4.2). The bathymetric range of these occurrences was 200-1,650 m, with most taxa being found at 200-1,200 m (Fig. 4.3). Most recorded taxa of sponges belonged to the demosponge order Tetractinellida, namely *Geodia* sp., *Leiodermatium* sp., *Neophrissospongia* sp., *Poecillastra compressa*, *Thenea muricata*, tetractinellid sponges (unidentified) and probably several of the unidentified white massive sponges. The latter two taxa were the most widely distributed ones, along with lollipop sponges and the encrusting species *Hamacantha falcula* (found in 7-8 sites, each). Only two hexactinellid taxa (glass sponges) were observed, *Farrea* sp. and *Tretodictyum reiswigi*, but it is possible that the categories “white-blue sponges” and “lollipop sponges” also included some glass sponges (e.g. *Sympagella* sp.).

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Demosponge (*Geodia* sp.).

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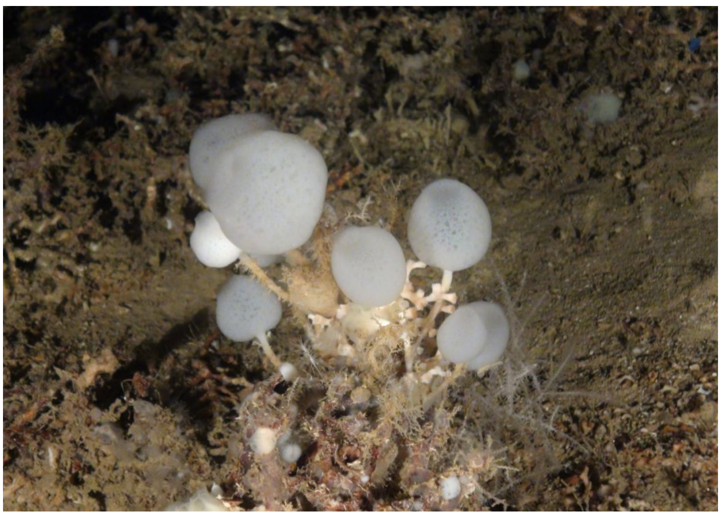
Poecillastra compressa.



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Glass sponges pedunculated (*Sympagella delauzei*).

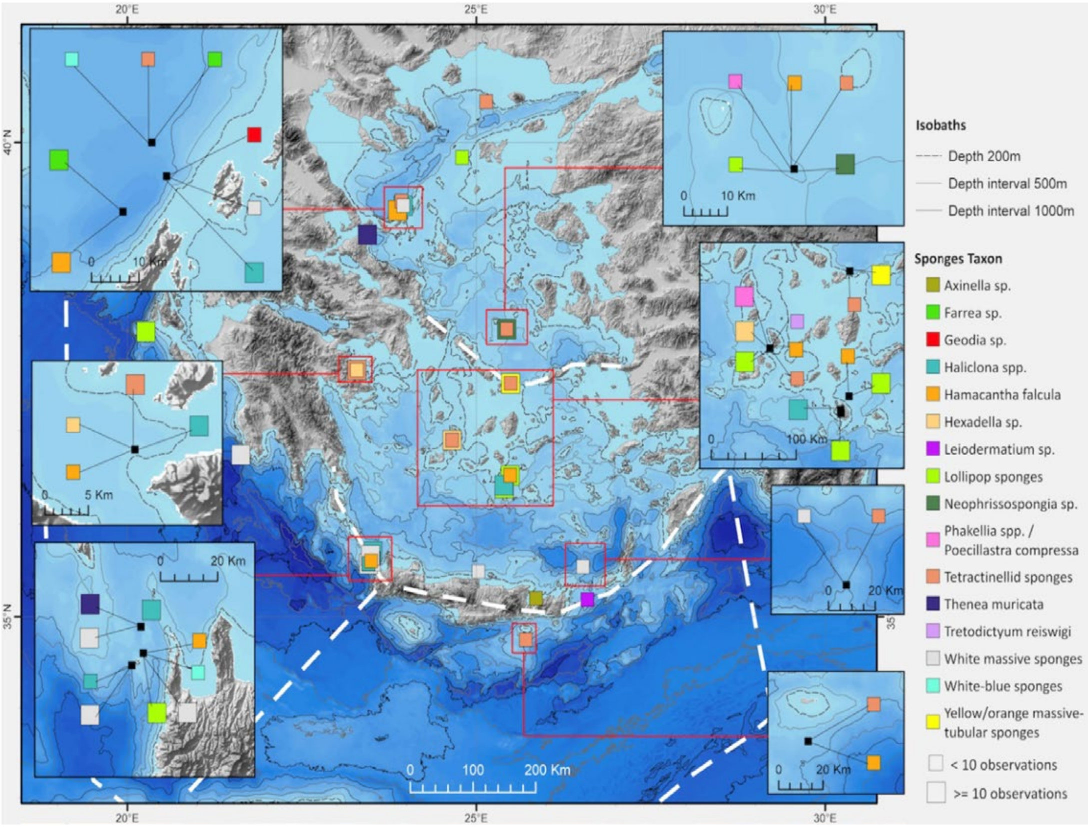


Fig. 4.2. Geographic distribution of the recorded sponge fauna. Site points are identified in Fig. 4.1.

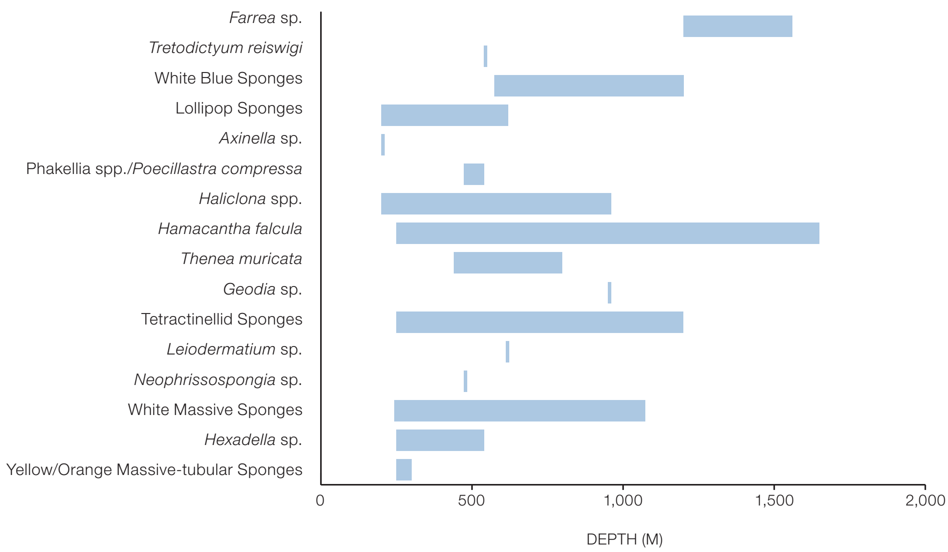


Fig. 4.3. Bathymetric distribution of the recorded sponge fauna.

ANTHOZOANS

Most recorded vulnerable taxa were anthozoans which were further categorized as “cold water corals” (CWC), which developed on both hard substrates (mostly) and fine sediments, and sea pens and anemones (7 taxa), mostly on soft substrates. Cold-water corals extend from the Eastern Ionian to the Aegean and Libyan Seas (Fig. 4.4) and were observed at a depth range of 300-500 m with Caryophyllidae reaching a maximum depth of 1,150 m (Fig. 4.5). The most widely distributed were the bamboo coral *Isidella elongata*, black corals *Antipathes dichotoma* and Plexauridae gorgonians.

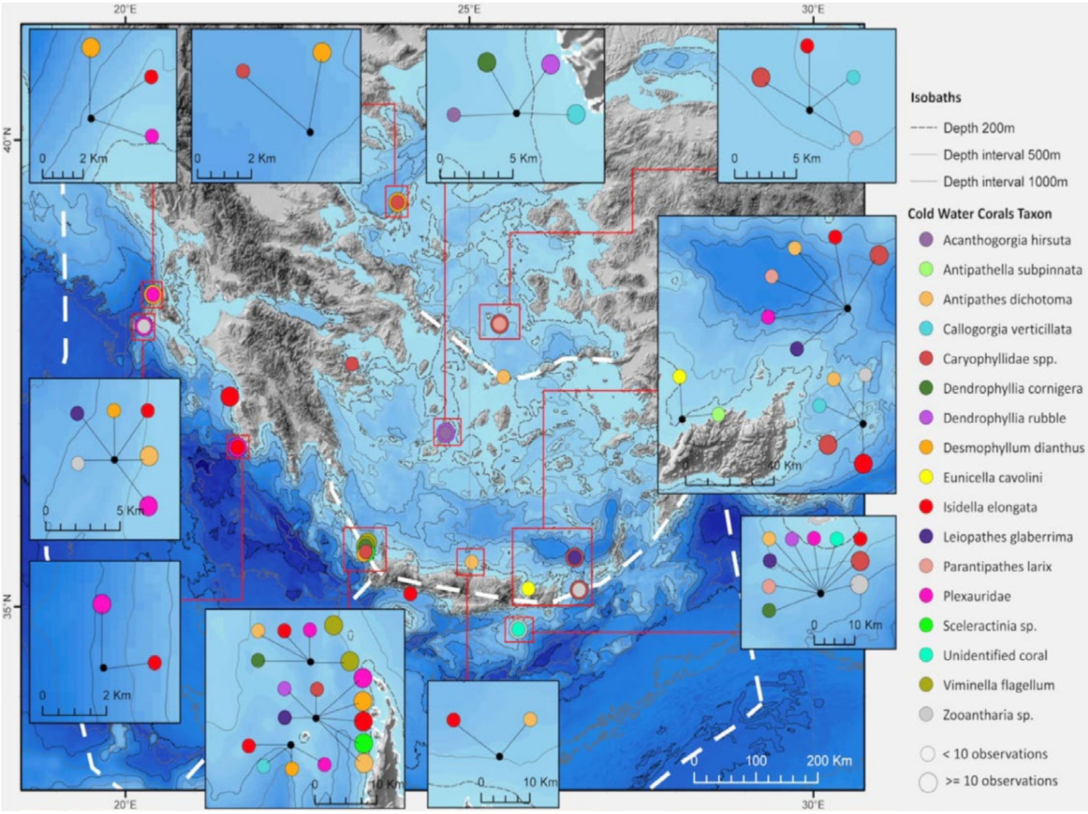


Fig. 4.4. Geographic distribution of the recorded cold water corals. Site points are identified in Fig. 4.1.

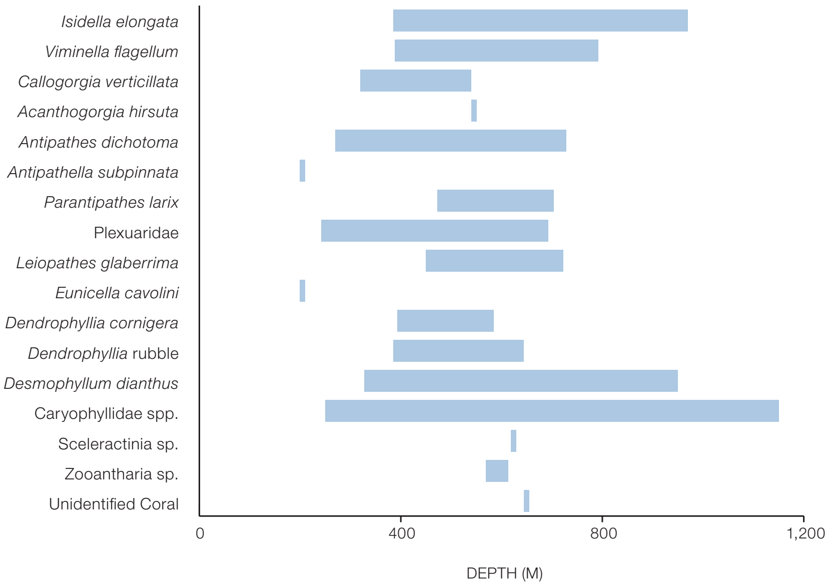


Fig. 4.5. Bathymetric distribution of the recorded cold water corals.

Most taxa of sea pens and anemones were found at 400-800 m depth, with their maximum bathymetric range being 970 m (Fig. 4.6; Fig. 4.7). The most widely distributed species was the tall vulnerable sea pen *Funiculina quadrangularis*.

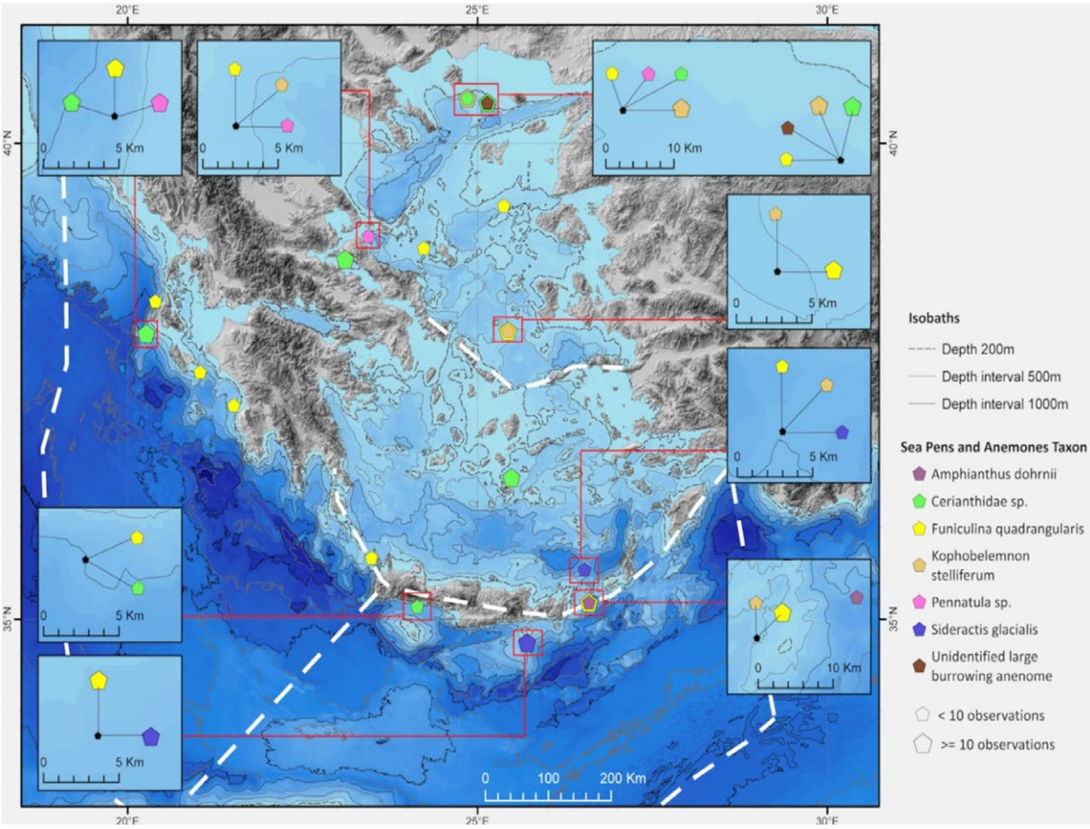


Fig. 4.6. Geographic distribution of the recorded sea pens and anemones. Site points are identified in Fig. 4.1.

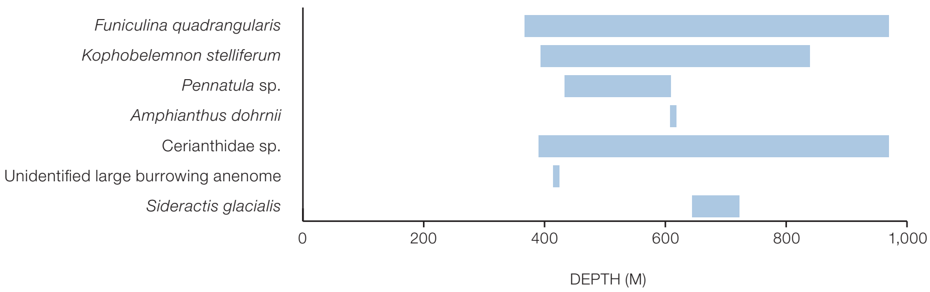
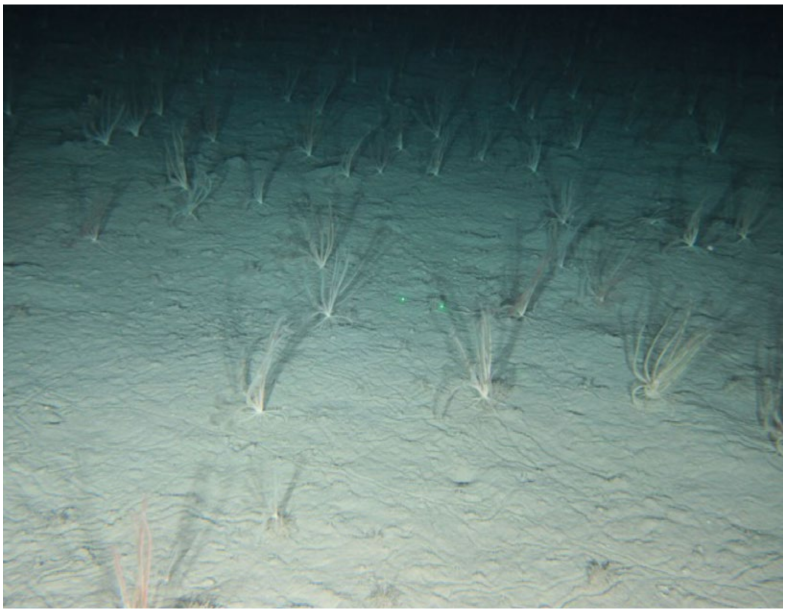


Fig. 4.7. Bathymetric distribution of the recorded sea pens and anemones.

OTHER FAUNA

Other vulnerable invertebrate taxa were found with a small number of occurrence records and limited spatial distribution (Fig. 4.8) and bathymetric range of 220-690 m (Fig. 4.9).



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Leptometra phalangium.

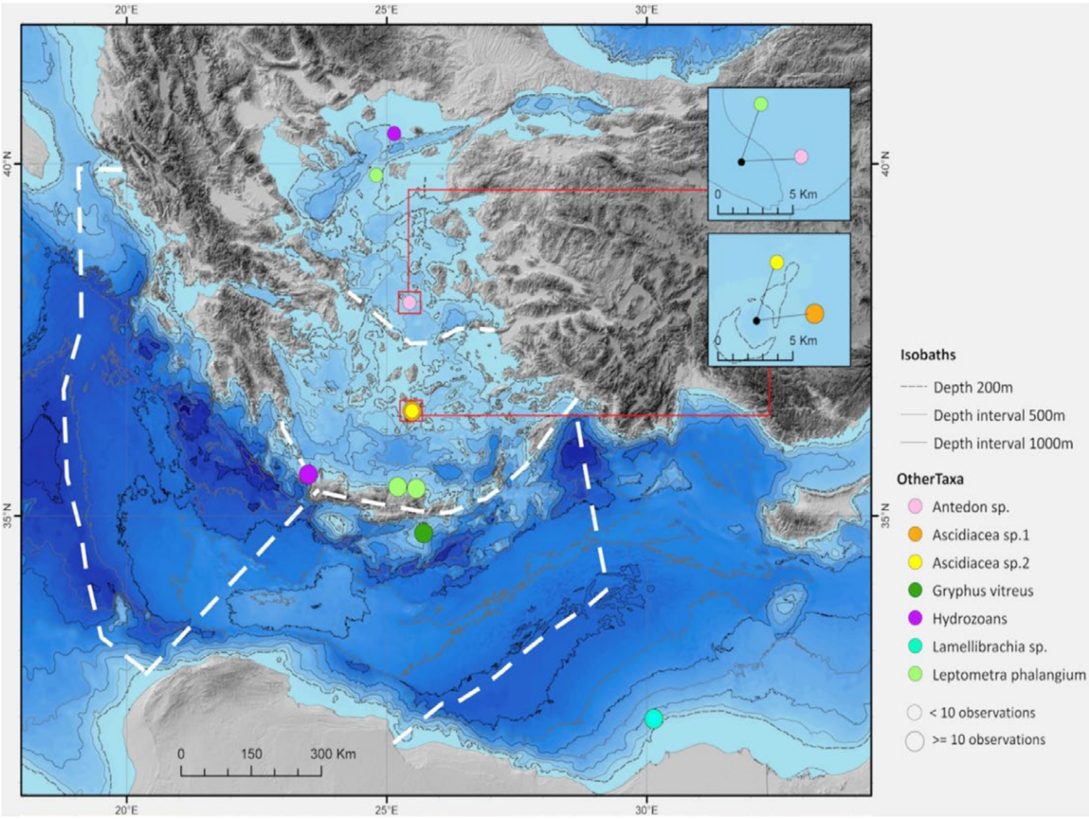

Fig. 4.8. Geographic distribution of other recorded taxa. Site points are identified in Fig. 4.1.

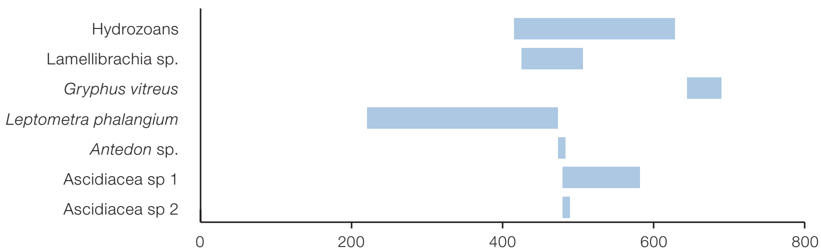

Fig. 4.9. Bathymetric distribution of other recorded taxa.

General Remarks

NEW AND RARE RECORDS

The whip-like gorgonian *Viminella flagellum*, the gorgonian *Acanthogorgia hirsuta* and the sponge *Phakellia* spp. are reported for the first time in the Eastern Mediterranean Sea and Greek waters. The glass sponges *Farrea* sp. and *Tretodictyum reiswigi* and the rock sponge *Leiodermatium* sp. are reported for the second time in the Eastern Mediterranean. The former was only recently found off Lebanon in the framework of Deep-sea Lebanon Expedition[5] while the latter two species were collected by dredging, at 207 m depth, off Epidaurus in 1968[6]. Other rare records are the rock sponge *Neophrissospongia* sp., which has been recently reported only from shallow marine caves and deep-waters of the Aegean Sea[7,8] and several anthozoan species with a restricted number of records in the Eastern Mediterranean: the actiniarians *Amphianthus dohrnii*, the corallimorpharian *Sideractis glacialis*, the black corals *Antipathella subpinnata*, *Leiopathes glaberrima* and *Parantipathes larix*, the gorgonian *Callogorgia verticillata* and the seapen *Kophobelemnon stelliferum*[5,9,10]. Other interesting records include the siboglinid annelid *Lamellibrachia* sp. (most probably *L. anaximandri*) associated to seeps and vents off Nile Delta.

In addition to the new/rare distribution records, interesting ecological habits were recorded for several taxa: *Dendrophyllia cornigera* was found to be capable to construct extensive terraced reefs, comprised mainly of coral rubble and some living colonies (540 m depth, Kimolos-Sifnos Strait, South Aegean Sea); *Desmophyllum dianthus* was found to form dense aggregations on the sides or under-hanging boulders and rocks (573-632 m, SE Antikythera, Eastern Ionian Sea); a deep record of the yellow gorgonian *Eunicella cavolini* was observed at 200 m, off Crete (Psira Island, South Aegean Sea), close to its deepest known bathymetric edge (220 m); abundant sponge assemblages, Cerianthidae fields and facies of ascidians, often mono-specific, were observed in different volcanic areas (Paphsanias, Kolumbo and Santorini volcanos, South Aegean); dense observations of the annelid *Bonellia viridis* (up to 1 m^{-2}) and numerous *Munida* sp. decapods were made in North Evoikos Gulf (442-445 m, North Aegean Sea), man-made structures (e.g. ancient and modern litter and wrecks) often provided hard substrate for the development of several taxa (e.g. sponges and corals).

These findings provide a baseline for future surveys tailored specifically towards samplings for accurate spatial and taxonomic characterization of deep water fauna at present.

Biodiversity Hotspots

There are two levels of hotspots in the Eastern Mediterranean, large-scale of geographical importance with higher levels of biodiversity or abundance potentially on a kilometre scale and those at the local level, small-scale, often oases, at the metre scale.

LARGE-SCALE HOTSPOTS

At the large area scale certain hotspots could be identified. These areas of higher species number and abundance of vulnerable species included, **two areas on either side of Crete, the SE Antikythera sites to the northwest of Crete in the Eastern Ionian Sea, the Chryssi Island and the Straits of Kasos to the SE of Crete, in the Libyan Sea, as well as the SW Kephallinia area in the Eastern Ionian Sea. In the southern part of the North Aegean Sea, there was an important site south west of the island of Chios, but also potentially in S. Thasos if the sea pen field is still present. In the South Aegean, the volcanic sites of Paphsanias and Kolumbo and the Kimolos Strait were also sites of interest.**

At this scale both geological and oceanographic phenomena are the primary reasons for higher biodiversity or abundance. The sites associated with straits on either side of Crete (bordering south eastern Ionian and south western Aegean on the one side and south eastern Aegean and north western Libyan Sea on the other) are firstly areas of higher water movement with exchange between the Aegean Sea and other surrounding seas. The Antikythera area on the western side will be more associated with nutrient richer water from the Aegean Sea (Black Sea origins), having better feeding conditions for vulnerable filter feeders. For both straits a net export of nutrients from the Cretan Sea towards the open waters of the Eastern Mediterranean through deep water outflow have

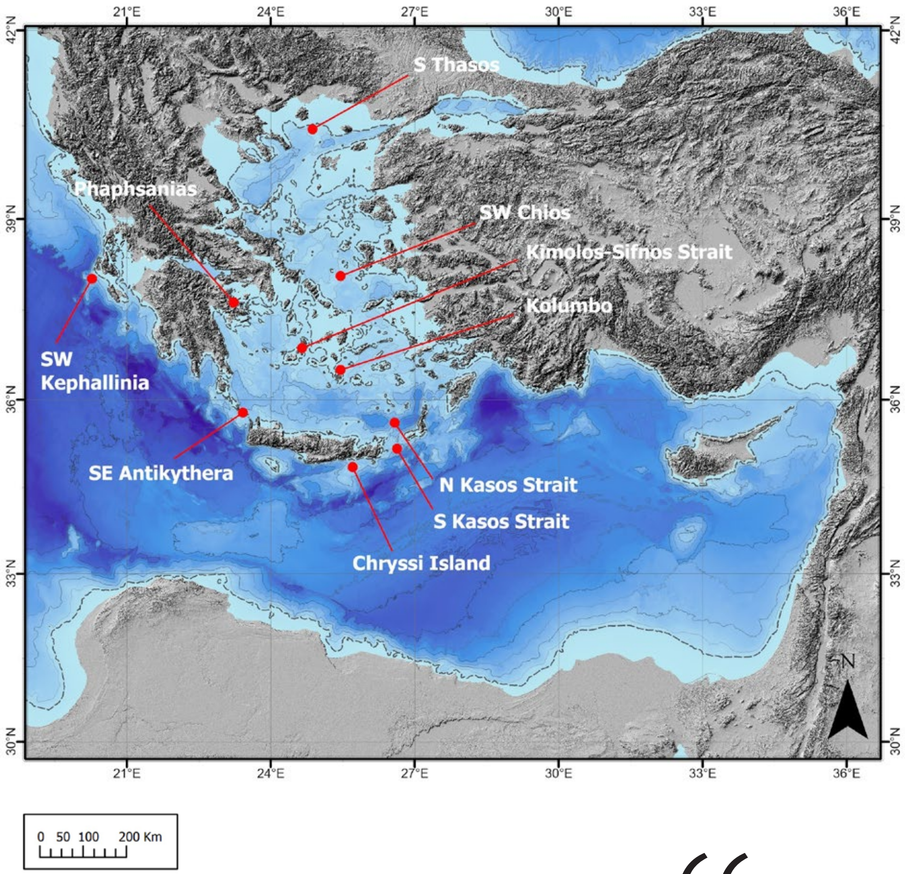

Fig. 4.10. Deep-sea hotspots of benthic biodiversity identified.

> "Hotspots of biodiversity were found at several areas on either side of Crete (SE Antikythera sites, the Chryssi Island and the Straits of Kasos), the SW Kephallinia area in the Eastern Ionian Sea, south west of the island of Chios and S. Thasos in North Aegean Sea. In the South Aegean, the volcanic sites of Paphsanias and Kolumbo and the Kimolos Strait"

been recorded[11]. Secondly these are areas of variable seabed morphology providing substrates for both soft sediment fauna (sea pens and *Isidella elongata*) and hard substrate fauna (corals and sponges). The Antikythera and areas to the south west of Crete were also associated with seamounts, which are seabed geomorphologies that are known to have high biodiversity levels[12]. The Antikythera area had the largest number of species and abundance from all the sites investigated. The Eastern Ionian Sea site investigated off SW Kephallinia is also located on a seamount and was noted for high diversity and abundance. The area also had a mix of substrates with sea pens and *Isidella* bamboo corals on soft sediments and the corals *Antipathes dichotoma,* Plexauridae spp. and *Desmophyllum dianthus* as well as a few large individuals of the longeveous black coral *Leiopathes glaberrima.* This area is approximately 130 nm south west of the highly biodiverse cold water coral province of Santa Maria di Leuca, characterised by the reef building scleractinian corals *Madrepora oculata* and *Lophelia pertusa*[13]. No living analogues to these reef systems have been located further east from Italy, which may be due to the more oligotrophic and warmer nature of the Eastern Mediterranean or lack of extensive survey effort.

In the North Aegean, the area SW of Chios was represented mostly by flat soft sediments and had large numbers of *Funiculina quadrangularis*, with a few sporadic low rock outcrops which were characterised by a covering of a diverse mixture of corals and sponges, most likely indicating higher trophic conditions which may be due to flow of more nutrient rich Black Sea water towards the south west. The geological feature of the low outcrops was the reason for the presence of the corals and sponges. This area was also the northern-most record for video observation of *Isidella elongata* in this study[10]. In the South Aegean another Strait site had high abundance and diversity between the islands of Kimolos and Sifnos, primarily associated with rock terraces amongst a sloping sedimentary seabed. An important feature amongst the predominantly sponge fauna were many small reefs of live and dead coral *Dendrophyllia cornigera*.

Both of the submerged volcanoes Paphsanias and Kolumbo are situated along the Aegean volcanic arc[3]. They both had high numbers of sponges, but Kolumbo was also characterised by high numbers of large Cerianthidae anemones on soft sediments and ascidians on rocks and old chimneys close to active areas. The volcanos provided a rich range of habitats in terms of hard substrate types, but also very soft sediments. Santorini an emergent volcano is also part of the arc located only 4 nm south west of Kolumbo, but had much lower observed species and abundance with just a few sponges recorded.

SMALL-SCALE HOTPOTS

Small-scale hotspots were found to be related specifically to small geological or anthropogenic features. Within a sedimentary area this could be represented by a single crust, stone or outcrop that was substrate for corals or sponges. Small outcrops were observed in several areas including those noted above, for example SW Kephallinia, Antikythera, SW Chios, Kimolos-Sifnos Strait, South Crete and Kasos Strait (north and south). One specific type was small metre-scale crust and rough, low outcrops south of Chryssi Island (Crete) with very high numbers of shrimp *Plesionika* sp. These features also appeared to have encrusting fauna, although not clearly identified with the exception of the coral *Dendrophyllia cornigera*. In adjacent sites within the same area, other crusts had various corals and sponges and this is one of the few sites with observations of the large coral *Leiopathes glaberrima.*

Anthropogenic traces could also provide the same type of substrate base for corals and sponges, the most common being amphora, that may have been on the seabed for one or two thousand years. In two cases an amphora was the attachment point for large specimens of the arborescent, longevous black coral *Leiopathes glaberrima.*

One last observation was made of a biomass hotspot, a mammal skeleton, possibly a dolphin with just decaying bones visible. The bones were supporting a feeding group, approximately 20 individuals, of the sea urchin *Cidaris cidaris*. Some shrimps of *Plesionika* sp. were also present, probably with respect to an “attraction point” as the skeleton appeared to be well past scavenging for flesh.

Mono-specific habitats

A feature noted in several areas was the presence of visibly mono-specific habitats with respect to filter feeding organisms. This was particularly noted in the submerged volcanos, with sponge habitats in the Paphsanias volcano (probably *Haliclona* sp.), but with many more mono-specific habitats in the Kolumbo volcano with areas of only unidentified Cerianthidae species on sediments (very large individuals), whilst different areas of hard substrate had unidentified Ascidiacea species completely covering some boulders and old chimneys and lollipop sponges on the volcano wall (also present on mud slopes leading up to the volcano wall). Why these almost exclusive habitats occur, with no mixing of species is unknown. However, the absence of taxa with calcareous skeletons (e.g. scleractinians) from volcanic areas could be possibly related to lower pH in the water close to vents/seeps.

Out-with of volcanic areas, three other species seemed to be in mono-specific habitats, the whip coral *Viminella flagellum* which was observed in a mono-specific habitat in an area of cliffs in Antikythera (this species was only recorded in the two Antikythera sites). Caryophyllidae were also observed in a number of sites in low numbers or small aggregations on small rocks or amphora, also as the only visible species present, particularly in the Libyan Sea sites of south Crete. Lastly the siboglinid annelid *Lamellibrachia* sp. was noted as the only species of interest observed in one of the Nile Delta sites.

Gaps and Recommendations

There are several notable gaps that have recommendations attached for our better understanding of biodiversity hotspots of sessile fauna in the deep waters of the Eastern Mediterranean and how they could be better covered by the use of underwater video systems, primarily ROVs. The lack of systematic and consistent coverage means that the present records are only indicative and consequently, there are important missing baselines for the natural range and densities of species, for example *Funiculina quadrangularis* or *Isidella elongata*, that might have been reduced in the last decades as trawling has spread into deeper waters particularly moving Eastwards in the Mediterranean (targeting deep-water red shrimp).

1. Coverage:
    a. There is a definite need to both extend our geographical coverage, both into areas that have not been covered before, for example, the Libyan and Levantine Seas, but also to have denser sampling scheme in those areas that might already have been covered, for example north western and eastern parts of the North Aegean.
    b. There is also a need to revisit areas as video material may have originated from 25 years ago, and with anthropogenic or natural changes, the present situation may have changed.
    c. Finally, there is a need for better depth coverage in deeper waters. Most of the observations analysed in this report were in a depth range of 400-800 m with maximum of 1,570 m. The seabed deeper than this which comprises a large area of the South Aegean and the majority of the Libyan and Levantine Seas are un-visited by underwater systems with imaging technologies.
    d. Marine industries could be used for sources of deep-water video observations. There is on-going exploration and survey for marine resources and related infrastructure. ROV's are routinely used and provisioning could be made in licensing and use to make their georeferenced video material available for study.
2. New surveys need to be undertaken and tailored specifically towards recording species and habitats.
    a. High quality imaging with neutral lighting is required, so that small details can be observed and species can be better identified.
    b. There are also requirements for quantitative imaging to assess species/population densities on the one hand and size structures on the other.
    c. Some sampling needs to be undertaken to ensure identification, morphologies and for genetic records.
3. Abundance estimates issues and confidence in the identification and assignment of biodiversity hotspots requires further research aiming to overcome problems linked to subjectivity, variable data quality and lack of consistency/ transparency in decisions behind categorisations. Habitat suitability or predictive modelling may also be used to assess where vulnerable species may occur.
4. Besides legislation for deep water trawling (ban deeper than 1,000 m), there is little protection given to deep water areas from exploitation and consequent anthropogenic impacts, e.g. activities for oil and gas exploration are moving forward into areas with little or no information on deep water habitats, whilst passive gears have no prohibitions in deep water and may target coral areas[14] and trawling is still permitted at intermediate depths where pennatulid fields or cold water corals occur. Several areas of higher diversity and abundance of vulnerable marine species have been identified. Some of these should be taken forward as sites requiring some form of protection, particularly areas SW of Kephallinia, the Cretan straits and the volcanos in the South Aegean. •

CHAPTER 4 /

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In deep-sea environments, meiofauna support an abundant and complex food web. As human pressures in these environments are increasing, these species can be used to monitor changes and play a vital role in developing conservation and monitoring programmes.”

CHAPTER 5 /

Deep-sea meiofauna diversity

Lampadariou N., Sevastou K.

The deep sea supports a very high biodiversity, composed mainly of macrofauna and meiofauna. Meiofauna is a collective name that represents one of the most diversified communities of the marine realm, including small organisms, unicellular protists and multicellular metazoans (size < 1 mm) that live in aquatic sediments (Fig.5.1). Owing to their high abundance and diversity - especially in ecosystems where other metazoans are practically absent - their effects on benthic ecosystems through bioturbation and grazing activities, and their role in stimulating microbial activity and linking prokaryotic and detrital resources to higher trophic levels, meiofaunal organisms are believed to be important contributors to deep-sea ecosystem processes and functions, including nutrient cycling and degradation of organic pollutants[1,2]. In extreme environments, such as hydrothermal vents, brines or deep-sea plains, meiofauna organisms are an important part of the communities present. The dynamic responses of different meiofauna groups (taxa), such as some foraminiferans, nematodes and copepods, may also reveal important information on how the communities respond to changes and provide a warning signal of anthropogenic impacts. Given the ongoing and future developments regarding oil exploration and pipeline installations in the deep sea, information regarding these organisms could serve as a valuable reference point regarding the prevailing environmental and ecological conditions before and after the onset of anthropogenic disturbances.

As regards the Mediterranean deep sea, substantial work has been carried out over the last three decades expanding the knowledge of meiofauna distribution patterns[3,4,5]; nevertheless, the understanding of how their community functions is still largely unknown. In the Eastern Mediterranean, deep-sea meiofauna studies have traditionally focused on basin ecosystems. More recently, studies from other habitats, such as open slopes and cold seeps, have also started to emerge, while those from canyons and seamounts are still rare.

Fig. 5.1. Some representative meiobenthic animals from the eastern Mediterranean.
(a) a harpacticoid copepod, (b) a gastrotrich, (c) the head end of a nematode and (d) a tardigrade.

Here, we present an overview summary of all the available published and unpublished information on meiofauna from different deep-sea habitats and regions in the Eastern Mediterranean. It is focused on showing the variations in abundance, community structure and diversity of meiofauna and their relation to the environmental conditions in each of the regions. The detailed analysis[1] and data are derived from a number of multidisciplinary collaborations (e.g., projects, cruises etc.), in the course of which benthic samples were collected at different depths (Table 5.1) and habitats (deep-sea basins and slopes, canyons, seamounts, brine lakes and mud volcanoes), with most of them concerning two habitats, deep-sea basins and open slopes.

1 The data that support the findings of this analysis are available from the corresponding authors on request.

Table 5.1. Overview of projects, surveys and investigated areas from canyons, seamounts, brine lakes, mud volcanoes, deep-sea basins and slopes of the eastern Mediterranean.

Area	Habitat	Project	Expedition	Research Vessel	Date	No of Stations	Depth range (m)
Ionian Sea (Area 1)	Basin	ADIOS	Cruise 2	AEGAEO	Oct-2001	9	2765-2840
		BIODEEP	Cruise 1	AEGAEO	Aug-2001	14	3078-3424
		BIOFUN	TRANS-MED	SARMIENTO DE GAMBOA	Jun-2009	3	3335-3335
		MATER	TransMediterranean	AEGAEO	Jun-1999	2	3200-3200
		REDECO	REDECO Cruise 1	AEGAEO	May-2010	3	3302-3315
	Brine	BIODEEP	Cruise 1	AEGAEO	Aug-2001	11	3179-3521
	Slope	BIOFUN	TRANS-MED	SARMIENTO DE GAMBOA	Jun-2009	2	2011-2012
		REDECO	REDECO Cruise 1	AEGAEO	May-2010	3	2960-2980
North Aegean Sea (Area 2)	Basin	MATER	MATER Cruise 1	AEGAEO	Mar-1997	2	798-805
			MATER Cruise 2	AEGAEO	Sep-1997	8	115-1300
		MITTELMEER 1997/98	METEOR 40/3	METEOR	Dec-1997	9	1244-1271
	Slope	MATER	MATER Cruise 2	AEGAEO	Sep-1997	6	145-340
			MATER Cruise 3	AEGAEO	Mar-1998	3	650-650
South Aegean Sea (Area 3)	Basin	MATER	MATER Cruise 1	AEGAEO	Mar-1997	3	914-914
			MATER Cruise 2	AEGAEO	Sep-1997	15	1190-2280
		MITTELMEER 1997/98	METEOR 40/3	METEOR	Dec-1997	5	1875-1876
	Slope	REDECO	REDECO Cruise 1	AEGAEO	May-2010	2	1049-1619
Libyan Sea (Area 4)	Basin	BIOFUN	TRANS-MED	SARMIENTO DE GAMBOA	Jun-2009	1	2845-2845
		HERMES	HERMES3 (HCMR)	AEGAEO	May-2006	4	2670-3603
		MATER	TransMediterranean	AEGAEO	Jun-1999	3	2950-3870
		MITTELMEER 1997/98	METEOR 40/3	METEOR	Dec-1997	9	4282-4392
		REDECO	REDECO Cruise 1	AEGAEO	May-2010	3	2707-3607
			REDECO Cruise 2	AEGAEO	May-2011	1	3564-3564
	Canyon	HERMES	HERMES3 (HCMR)	AEGAEO	May-2006	2	1220-2420
	Mud volcano	HERMES	MEDECO Leg 2	POURQUOI PAS ?	Nov-2007	9	1941-1943
	Slope	BIOFUN	TRANS-MED	SARMIENTO DE GAMBOA	Jun-2009	2	1204-2015
		HERMES	HERMES3 (HCMR)	AEGAEO	May-2006	6	508-1910
Levantine Sea (Area 5)	Basin	HERMES	MEDECO Leg 2	POURQUOI PAS ?	Nov-2007	1	2152-2152
		ZOOTOP	MSM 14/1	MARIA S. MERIAN	Jan-2010	1	2419-2419
	Mud volcano	HERMES	MEDECO Leg 2	POURQUOI PAS ?	Nov-2007	7	2024-2029
	Seamount	ZOOTOP	MSM 14/1	MARIA S. MERIAN	Jan-2010	12	874-2239

1 EASTERN IONIAN SEA

For the Eastern Ionian Sea, quantitative information on the abundance and biomass of meiofauna is available from three different habitats: deep-sea basins (2765-3424 m depth), open slopes (2011-2980 m depth) and the deep hypersaline anoxic basins (3179-3521 m depth) of the south-eastern and central Ionian Sea (Fig. 5.2).

The number of major meiofauna taxa reported from the Ionian Sea (Table 5.2), 17 in total, falls within the range of observations in other Mediterranean areas[4], with nematodes, copepods, polychaetes and ostracods most commonly found in all three habitats. Other meiofauna taxa have also been encountered but in low numbers; priapulids and sipunculids were only found in deep-sea basins and gastropods only in the brine lakes. In the deep-sea basins and slopes, nematodes dominated the communities ranging on average from 60 to 88%, while harpacticoid copepods and tardigrades represented on average 3-8% and 4-6% of the total abundance, respectively. However, the meiofauna community structure differed considerably in brine sediments, with different taxa, namely copepods, molluscs and ostracods dominating at various brine lakes[6].

The available studies also show that meiofaunal density in the Ionian Sea is low, which is typical throughout the Eastern Mediterranean, and tends to decrease with depth.

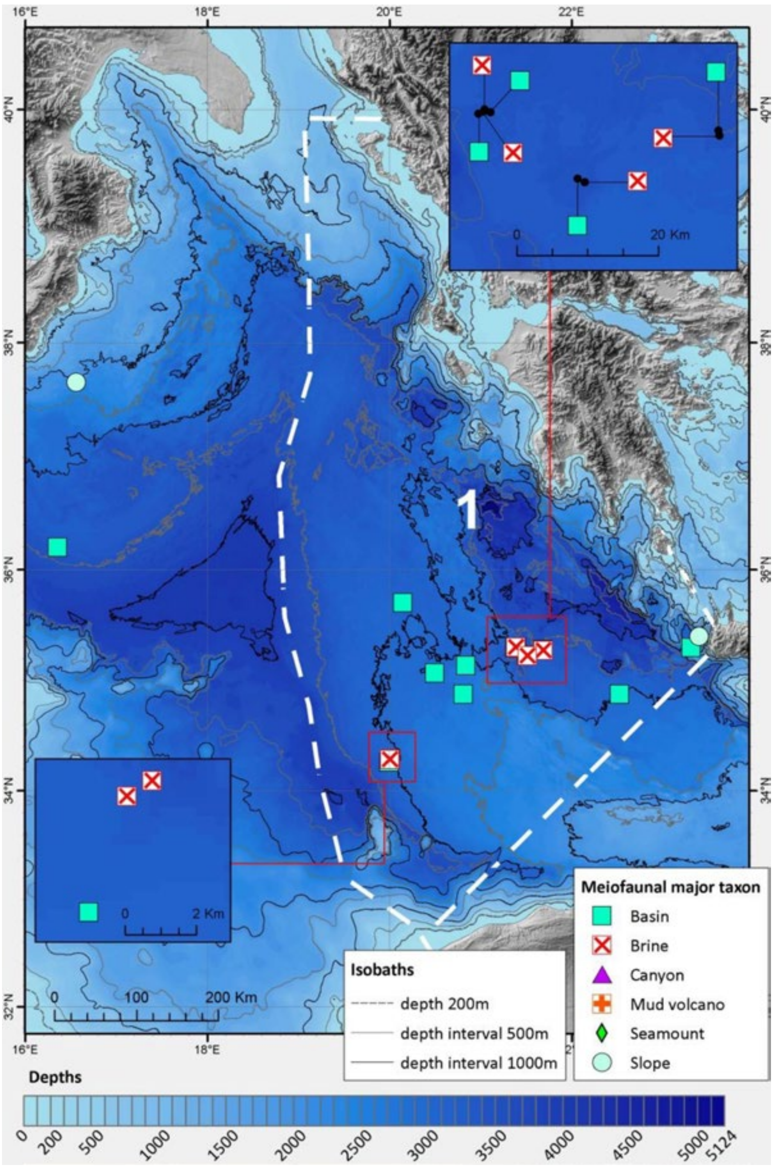

Fig. 5.2.
Map showing the locations of stations from the Ionian Sea with symbols representing different habitat types.

deep-sea basins; open slopes; Brines (deep hypersaline anoxic basins). Data campaigns from 1999 and 2010.

Table 5.2. Presence/absence data of meiofaunal taxa found at the five different areas and habitat types (Bas: Basin; Bri: Brine; Slo: Slope; MV: Mud volcano; SM: Seamount; Can: Canyon).

	Eastern Ionian Sea			Levantine Sea			Libyan Sea				North Aegean Sea		South Aegean Sea	
Taxon	**Bas**	**Bri**	**Slo**	**Bas**	**MV**	**SM**	**Bas**	**Can**	**MV**	**Slo**	**Bas**	**Slo**	**Bas**	**Slo**
Amphipoda					+	+	+				+	+		+
Annelida incertae sedis				+				+						
Aplacophora											+		+	
Bivalvia	+	+			+	+	+		+	+	+	+	+	
Caudofoveata				+	+				+					
Cnidaria						+								
Copepoda	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Crustacea		+									+		+	+
Cumacea					+						+		+	
Echinodermata							+				+			
Gastropoda		+			+						+	+		
Gastrotricha				+	+	+	+		+	+		+		+
Halacaroidea	+		+	+	+	+	+		+	+	+	+	+	+
Isopoda					+	+			+		+	+	+	+
Kinorhyncha	+		+	+	+	+	+			+	+	+	+	+
Loricifera						+	+			+				+
Mollusca							+				+		+	
Nematoda	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Nemertina							+			+	+	+	+	
Oligochaeta				+	+	+	+		+		+	+	+	
Ostracoda	+	+	+	+	+	+	+		+	+	+	+	+	+
Other	+				+	+	+	+	+	+	+	+	+	
Polychaeta	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Priapulida	+			+	+	+	+		+	+	+	+	+	
Rotifera	+		+	+	+	+	+		+	+				+
Scaphopoda											+			
Sipuncula	+			+	+	+	+		+		+	+	+	
Soft bodied	+	+					+				+		+	
Tanaidacea	+				+	+	+		+	+	+	+	+	+
Tardigrada	+		+	+		+	+	+		+	+	+	+	+
Turbellaria	+	+		+	+	+	+	+	+	+	+	+	+	

Deep-sea basins appear to be the most diverse habitat exhibiting much higher taxon richness than brines and open slopes (Fig. 5.3). In addition, brines appear to be very different from open slopes and basins in terms of community structure due to the presence in high densities of a number of taxa that have been adapted to the anoxic conditions of the brines, such as bivalve and gastropod juveniles, and which are absent from the basins and slopes.

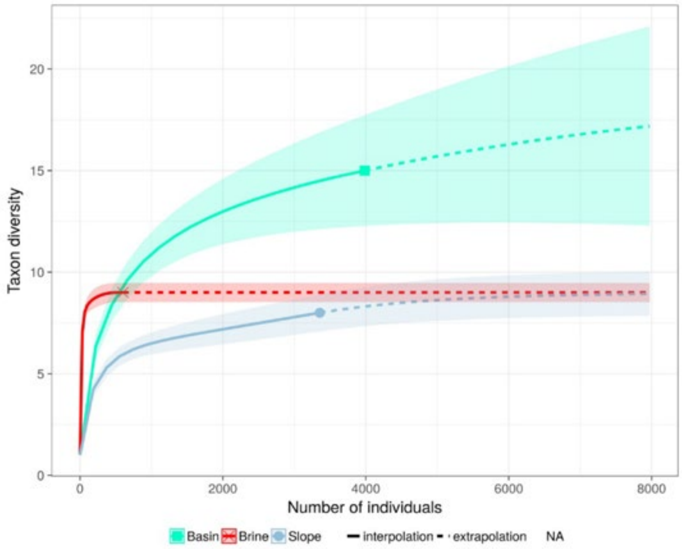

Fig. 5.3.
Comparison of meiofaunal major taxon diversity from three different habitats in the Ionian Sea.

(Solid line: actual data; dashed line: extrapolated data; colour-shaded regions: 95% confidence intervals).

2 NORTH AEGEAN SEA

For the North Aegean Sea, information on meiofauna communities is only available for two habitats: deep-sea basins (115-1271 m) and slopes (153-675 m) (Fig. 5.4).

Overall, 26 meiofaunal taxa have been encountered in all studied areas and habitats in this region. Similar to the Ionian Sea, diversity, expressed as the number of meiofauna taxa, is higher in deep-sea basins (25 taxa) as compared to slopes, (19 taxa) with gastrotrichs being the only taxon missing from the basin habitat. The difference in diversity between these two habitats high-

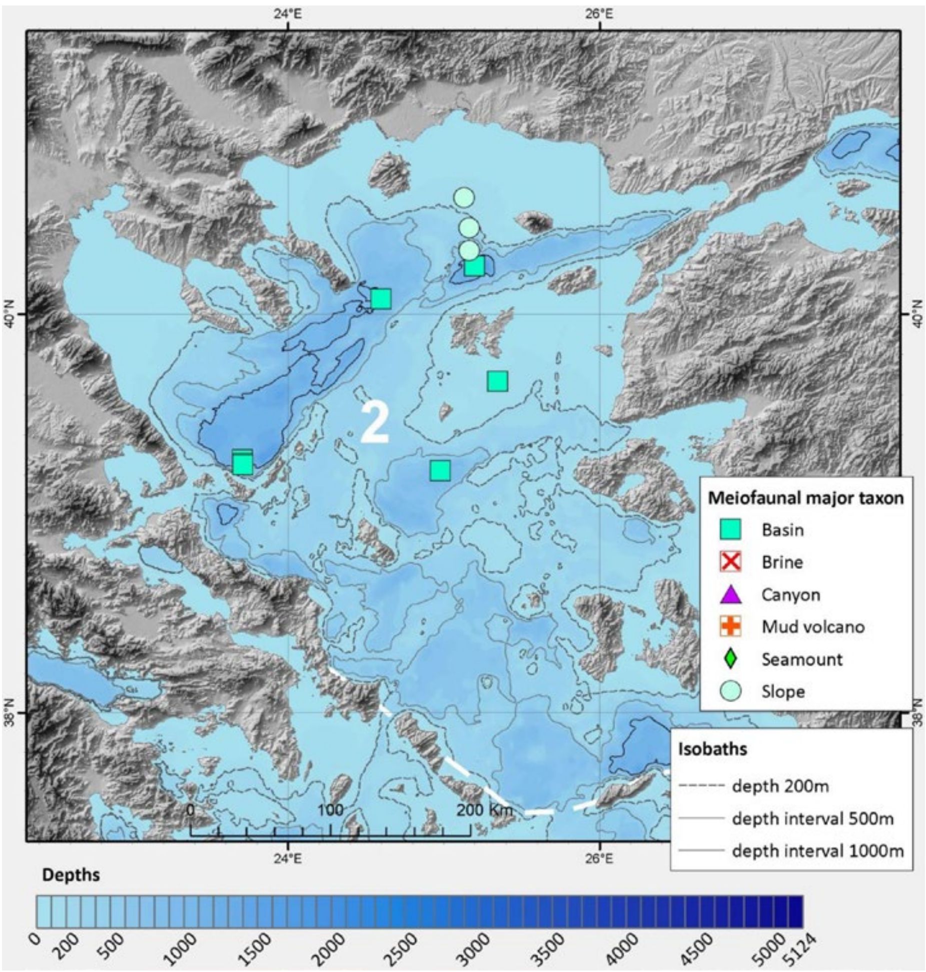

Fig. 5.4.
Map showing the locations of stations from the North Aegean Sea with symbols representing different habitat types.
deep-sea basins;
slopes. Data source from 1997.

lights the importance of each habitat for estimating global deep-sea biodiversity (Fig. 5.5).

Total metazoan meiofaunal density in the North Aegean ranged on average from 531 ind/10 cm^2 in the basin habitat to 996 ind/10 cm^2 in open slopes. These values are relatively high compared to other bathyal and abyssal areas of the Eastern Mediterranean and are directly related to the overall higher primary productivity of the North Aegean Sea, mainly due to riverine outflows and the influx of nutrient-rich Black Sea surface waters entering through the Dardanelles Straits[7]. Depth had no effect on the densities of total meiobenthos or individual groups in this area, and they remained practically constant in both habitats. This can be partly explained by the enhanced vertical flux of organic matter into the deeper parts of the basins[7].

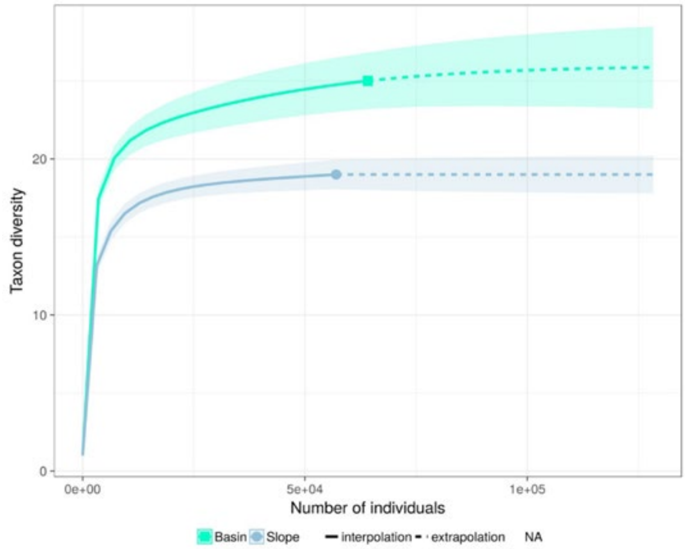

Fig. 5.5.
Comparison of meiofaunal major taxon diversity from two different habitats in the North Aegean Sea.

(Solid line: actual data; dashed line: extrapolated data; colour-shaded regions: 95% confidence intervals).

3 SOUTH AEGEAN SEA

Available studies designed to compare meiofaunal assemblages inhabiting the South Aegean Sea were only available from a few investigations in open slopes and deep-sea basins between 914-2273 m (Fig. 5.6). The community structure of meiofauna in the South Aegean Sea was similar to the north Aegean and was dominated by nematodes (73-81%) followed by harpacticoid copepods (5%). In contrast to the North Aegean, meiofaunal abundance progressively decreased with increasing water depth, from 216 ind./10 cm^2 at 914 m to 26 ind./10 cm^2 at 2273 m depth. Such a decrease in meiofaunal densities with depth is a common feature in most marine systems and has been reported in other bathymetric studies of the Mediterranean Sea[8,9,10].

The South Aegean is one of the most oligotrophic (low nutrients) regions of the Mediterranean Sea, characterised by extremely low productivity rates, high temperatures, strong summer stratification of the water column and minimal quantities of organic matter in bathyal sediments[11,12]. These, in turn, result in lower meiofaunal abundances and diversity compared to the northern region.

The number of major meiofauna taxa reported in studies from the South Aegean Sea (Table 5.2, Fig. 5.7) was 25 in total, 21 in the deep-sea basins (914-2273 m) and 14 in the open slopes (1049-1619 m). Significant differences have also been observed in terms of meiofaunal structure, either comparing different habitats or depths. Common taxa from muddy sediments such as Turbellaria or other soft bodied taxa (e.g., Gnathostomulida) as well as Nemertina, Sipuncula and Priapulida were absent from open slopes in the South Aegean (Table 5.2).

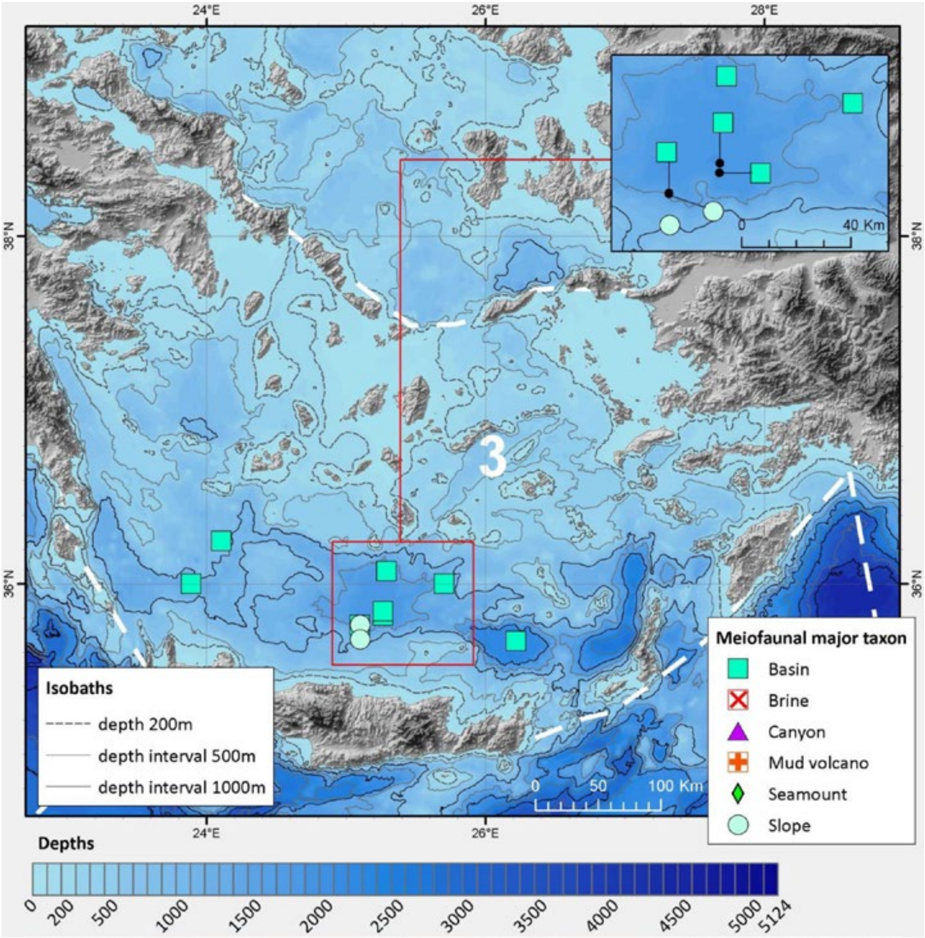

Fig. 5.6.
Map showing the locations of stations from the South Aegean Sea with symbols representing different habitat types.

deep-sea basins;
slopes.
Data from 1997 - 2010.

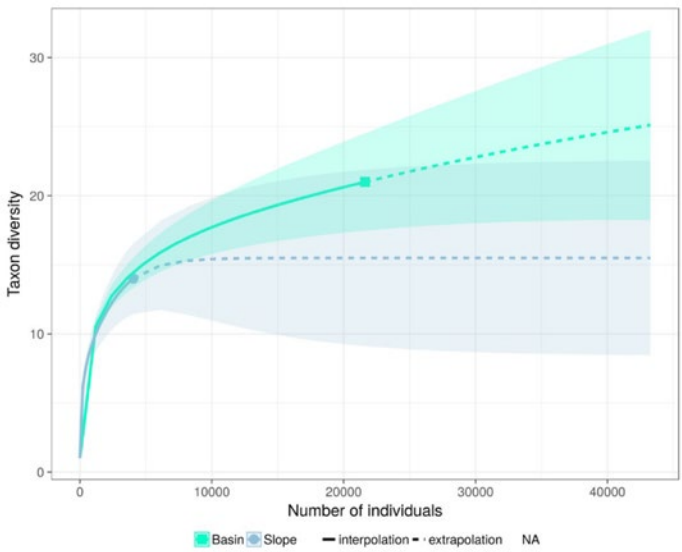

Fig. 5.7.
Comparison of meiofaunal major taxon diversity from two different habitats in the South Aegean Sea.

(Solid line: actual data; dashed line: extrapolated data; colour-shaded regions: 95% confidence intervals).

4 LIBYAN SEA

For the Libyan Sea, the available information is derived from expeditions carried out between 1997-2010 across four habitats (basins, slopes, canyons and mud volcanoes) located south of the island of Crete at depths ranging between 508-4261 m (Fig. 5.8).

The available studies suggest that meiofauna richness is greater at deep basins (2670-4261 m depth, 22 taxa). In both open slope (508-2015 m depth) and mud volcano (1941-1943 m depth) habitats, 16 taxa were encountered, whereas in the canyons (Samaria submarine canyon) at depths ranging between 1220-2420 m only 7 taxa were recorded (Fig. 5.9). The severe physical disturbance and instability of canyon systems along with the limited sampling effort in these types of habitat might explain the low diversity observed in these environments[13]. In contrast to these three habitats, mud volcanoes seem to host a remarkable abundance of rarely found meiofaunal taxa (e.g., acarians, cumaceans, tanaids and cladocerans), which are specifically associated with volcanic structures and are absent in open slope and basin sediments (Table 5.2).

Meiofauna abundance values south of Crete were highest at the Napoli mud volcano (585 ind/10 cm^2) and generally declined with water depth. This is consistent with information from other sites of similar depths in the Eastern Mediterranean, particularly deep-sea basins[4,7,14,15].

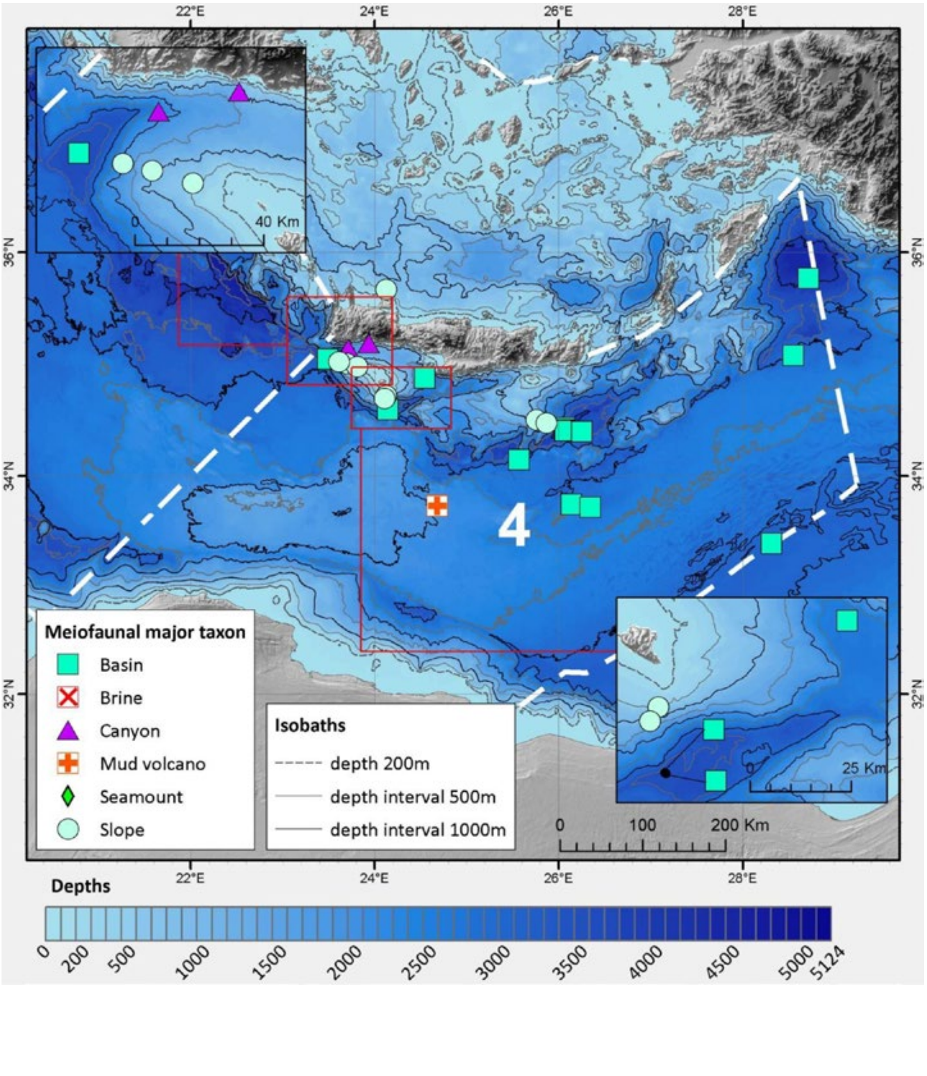

Fig. 5.8.
Map showing the locations of stations from the Libyan Sea with symbols representing different habitat types

deep-sea basins; slopes; canyons; mud volcanoes.

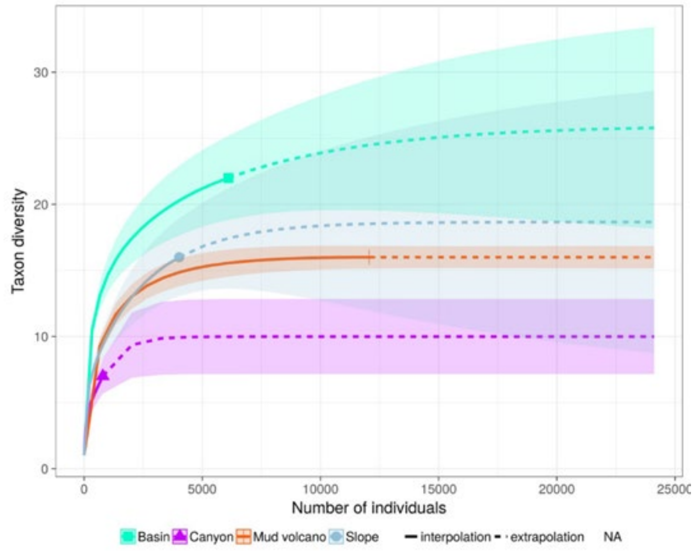

Fig. 5.9.
Comparison of meiofaunal major taxon diversity from four different habitats in the Libyan Sea.

(Solid line: actual data; dashed line: extrapolated data; colour-shaded regions: 95% confidence intervals).

5 LEVANTINE SEA

Meiofaunal abundance, community structure and biodiversity from the Levantine Sea have been investigated at depths ranging between 874-2419 m at two deep-sea sites, the Eratosthenis seamount and the Amsterdam mud volcano (Fig. 5.10).

In total, 24 taxa were encountered (Table 5.2), 15 of which were found in basin stations (2025-2419 m) surrounding the two sites, while the Eratosthenis seamount (874-2239 m) and Amsterdam mud volcano (2024-2152 m) had 20 taxa each. Despite having the same number of taxa, meiofaunal composition differed between the seamount and mud volcano, with more molluscan taxa, such as Caudofoveata and Gastropoda, found in the latter (Table 5.2).

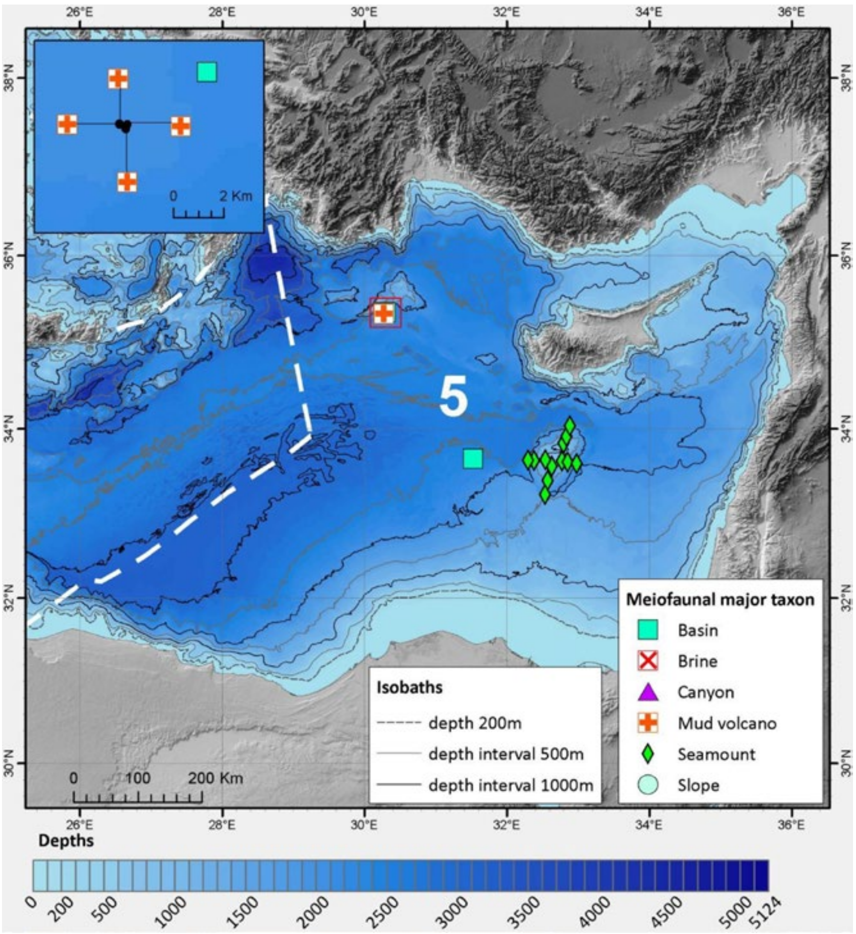

Fig. 5.10.
Map showing the locations of stations from the Levantine Sea with symbols representing different habitat types.
deep-sea basins;
seamounts;
mud volcanoes.
Data between 2007 - 2010.

The very low values of meiofaunal abundance in this area are typical for the Eastern Mediterranean deep sea. However, the values reported from the Eratosthenes Seamount are lower compared to values from other seamount areas[16]. In contrast, higher meiofaunal densities were found at the mud volcano. This observation along with the unique community structure of this habitat indicate a positive effect as a result of higher food availability or habitat complexity of these ecosystems that may provide a higher number of niches and possibly refuge from predators[17,18]. Nevertheless, diversity analysis suggests that the three habitats do not show any significant differences in taxon richness (Fig. 5.11).

Meiofaunal abundance in the Levantine Sea did not show any apparent bathymetric pattern, since densities remained practically constant, with the exception of the mud volcano stations, where values were relatively high. Densities were on average 63 ind./10 cm^2 at a depth of approximately 1000 m and remained low (approximately 38 ind./10 cm^2) at 2500 m. The mud volcano stations had on average 772 ind./10 cm^2 at a water depth of 2024 m.

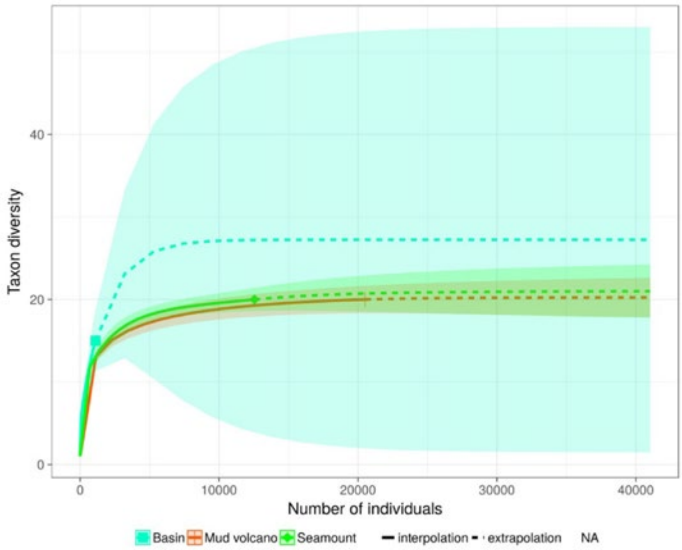

Fig. 5.11.
Comparison of meiofaunal major taxon diversity from three different habitats in the Levantine Sea. (Solid line: actual data; dashed line: extrapolated data; colour-shaded regions: 95% confidence intervals).

General Remarks

The different deep-sea habitats in the Eastern Mediterranean harbour specific meiofauna assemblages, which contribute significantly to the regional diversity and support the idea of the deep sea being a highly diverse environment making its protection highly significant for conservation. Meiofauna communities in mud volcanoes, seamounts and canyons show significant shifts in density and the relative proportions of the dominant taxa, separating them from slopes and basins. In addition, meiofauna abundance follow a general decreasing trend with depth, although some notable exceptions, such as the highly productive North Aegean Sea, exist.

Evidently, with many areas and habitats remaining still unexplored, we need more information in order to understand the unique community structure, ecosystem functioning patterns, and possible anthropogenic impacts on these very different deep-sea habitats. For the Eastern Mediterranean in particular, the focus should perhaps rely more on canyons, seamounts and cold seeps, since these environments are potential hotspots of benthic biodiversity but, so far, there have been only limited studies. •

CHAPTER 5 /
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"Half of shark
and rays species in
the Mediterranean
are threatened
with extinction"

CHAPTER 6 /

Vulnerable megafauna

Deep-sea cartilaginous fish

(Chondrichthyes: sharks, rays, skates and chimaeras)

Damalas D., Peristeraki P., Gubili C., Lteif M., Otero M., Thasitis I., Ali M., Jemaa S., Mytilineou Ch., Kavadas S, Farrag M.M.S.

Elasmobranchs, the taxonomic group comprising sharks, skates and rays, together with the chimaeras, form the chondrichthyans class. Approximately half of the known species (575 out of 1207 species), live in the deep ocean (below 200 m), yet little is known of the biology or life histories of most of these fish[1].

In the Mediterranean, a rich diversity with at least 48 species of sharks, 38 of rays and skates and two chimaeras occurs, even if some of them have to be confirmed[2]. The IUCN Red List of Threatened Species estimates that about half of elasmobranch species in the Mediterranean are threatened with extinction (i.e., assessed or estimated to be Vulnerable, Endangered, or Critically Endangered) and fishing is the principal threat causing a decline in the elasmobranch population[3] (Fig. 6.1). The level of threat may be worse because uncertainty in species status remains moderately high (17.8%) in the Mediterranean Sea. The life-history characteristics of these species such as low fecundity, slow growth and late reproductive maturity make them highly vulnerable to exploitation, and they suffer high mortality due to fishery by-catch[3,4].

Currently, the biology and ecology of deep-water sharks, rays and skates in the Mediterranean is poorly documented. A general problem in assessing populations is the lack of information on their fisheries and biology[3]. The following section provides an extensive historical literature review on these deep-sea species of the Eastern Mediterranean for both demersal and pelagic species, with information on status, spatial and depth occurrence when known. Additionally, fisheries independent data collected during MEDITS (Mediterranean Bottom Trawl Survey) surveys is provided.

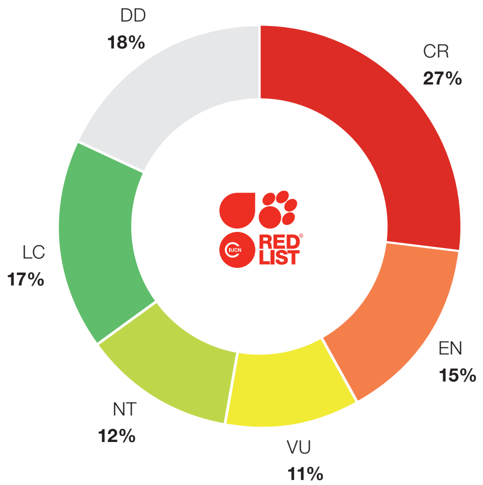

Fig. 6.1. Red List status of Mediterranean sharks, rays and skates. CR—Critically Endangered; EN—Endangered; VU—Vulnerable; NT—Near Threatened; LC—Least Concern; DD—Data Deficient

1 EASTERN IONIAN SEA

According to the most updated checklist of fishes[5], the Eastern Ionian Sea hosts at least 49 chondrichthyan species.

Demersal sharks and rays

Demersal sharks, rays and chimaeras (e.g. those living or occurring in deep-water or on the bottom of the sea) generally form small local stocks with limited and low connectivity to each other and can be highly suscebtible to trawling activities. Prior to 2002, information on these species in the Eastern Ionian Sea was scattered and mostly related to occurrence with few investigations focused on specific biological traits of certain species. Among the earliest studies, the presence of 22 elasmobranch species was reported in depths between 300 and 1,200 m during 1999-2000, with the black mouth shark *Galeus melastomus,* the small-spotted catshark *Scyliorhinus canicula* and the thornback ray *Raja clavata* exhibiting the highest abundances[6]. Later studies identified the Near Threatened longnose skate *Dipturus oxyrinchus* as the most frequently caught species in depths between 350-700 m, in contrast to the ray *Raja clavata* and the marbled electric ray, *Torpedo marmorata*, which dominated catches over the lower continental shelf between 150-350m[7]. Biological reports made through the Mediterranean Bottom Trawl Survey Programme until 2001[8], also reported the longnose spurdog *Squalus blainville* as the second most abundant fish species at depths of 200-500 m, while in the 500-800 m depth stratum, two species, the black mouth shark, *Galeus melastomus* and *S. blainville* were observed as the fourth and sixth most abundant species, respectively.

The distribution patterns of demersal elasmobranchs from the MEDITS experimental surveys conducted in the area during 2001-2014 indicated up to 19 species in the 200-800 m bathymetric zone of the Eastern Ionian Sea, including species that also occur in shallow waters. Similar to previous works, five species occur frequently in deep waters (with high frequency of occurrence > 50%), namely, *Scyliorhinus canicula, Raja clavata, Squalus spp, Galeus melastomus* and *Dipturus oxyrhinchus*, while the other species were scarcely caught (Table 6.1.) based on catches for 2008, 2014 and 2016[9]. As with other Mediterranean reports, both the black mouth shark *Galeus melastomus,* and the *Squalus* species were more abundant in the slope. In contrast, the thornback ray *Raja clavata* and the small-spotted catshark *Scyliorhinus canicula,* a species that shows a high degree of site fidelity, were more abundant in the shelf and upper slope with a higher abundance around the shelf break. Among the recorded species, the ones almost exclusively found in waters deeper than 200 m were: the longnose skate *Dipturus oxyrinchus* (54%), the velvet belly lanternshark *Etmopterus spinax* (10%), the gulper shark *Centrophorus* cf *uyato*[1] (5.8%), the sharpnose seven-gill shark *Heptranchias perlo* (3.3%), the rare angular rough shark *Oxynotus centrina* (2.5%) and the kitefin shark *Dalatias licha* (0.8%). **The results from this latest work also suggested a biomass decline for almost all demersal shark and ray species in the region with an increasing fishing effort**[9]**.** The black mouth shark *Galeus melastomus* was an exception to this general pattern, as it has not been significantly affected by fishing effort, probably because its depth preference falls outside the main depth range of bottom trawl fishing operations in the area (50-300 m depth). Overall, the explanation for these findings further suggests that the distribution of these deep-sea sharks and ray species is related to the particular topography of the Eastern Ionian Sea (narrow continental slope with steep slope) and the existing local fishing restrictions in shallow areas that result in the aggregation of over 50% of trawler fishing effort on specific shelf areas.

1 Recent findings cited gulper sharks *Centrophorus* cf. *granulosus* and *Centrophorus* cf. *uyato*[10,11] as synomys and *Centrophorus* cf. *uyato* as the valid taxonomic name for the species, as adopted in the present document.

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The blue shark *Prionace glauca* is listed as Critically Endangered in the Mediterranean since 2016. Blue Sharks are taken in large numbers in the region by both artisanal and commercial fisheries, mainly as bycatch but more recently it has also been targeted and increasingly retained as valued bycatch.

> “Over last 20 years, the number of endangered sharks such as the Bigeye thresher, Blue sharks, Mackerel sharks and Hammerhead sharks in the Eastern Ionian Sea has decreased between 73 and 99%[13]”

Table 6.1. Frequency of occurrence of the elasmobranch species caught in hauls conducted in the bathymetric zone 200-800 m of the Eastern Ionian Sea during MEDITS surveys from 2001-2014.
In red: Endangered, Vulnerable or Near Threatened species.

Species	Common name	Frequency of occurrence %
Scyliorhinus canicula	Small-spotted catshark	67,5
Raja clavata	Thornback ray	65,8
Squalus blainville	Longnose spurdog	60,8
Galeus melastomus	Blackmouth catshark	55,8
Dipturus oxyrhinchus	Longnose skate	54,2
Etmopterus spinax	Velvet belly	10
*Centrophorus cf uyato**	Gulper shark	5,8
Squalus acanthias	Picked dogfish	5,8
Heptranchias perlo	Sharpnose seven-gill shark	3,3
Raja asterias	Mediterranean starry ray	3,3
Torpedo marmorata	Marbled electric ray	3,3
Oxynotus centrina	Angular rough shark	2,5
Dasyatis pastinaca	Common stingray	1,7
Galeorhinus galeus	Tope shark	0,8
Raja montaqui	Spotted ray	0,8
Raja rondeletii	Rondelet's ray	0,8
Dalatias licha	Kitefin shark	0,8
Torpedo (Tetronarce) nobiliana	Electric ray	0,8
Torpedo torpedo	Common torpedo	0,8

**Centrophorus* cf *granulosus* has been updated to *Centrophorus* cf *uyato*[10,11]

Pelagic sharks and rays

Pelagic sharks can be distributed over large geographic areas[12] and they are regular visitors of the deep during their diurnal vertical migrations. Studies compiling time series of abundance indices from commercial and recreational fishery landings, scientific surveys, and sighting records suggested that abundance of the thresher shark *Alopias vulpinus,* the blue shark *Prionace glauca*, as well as mackerel sharks and hammerhead sharks in the Eastern Ionian Sea has decreased between 73 and 99% in the past two decades[13]. Today, all of these species are listed as Endangered and Critically Endangered in the Mediterranean[14]. Pelagic long line fishing in the Ionian Sea was ranked third, after the Alboran and Adriatic Sea in 2005, for catches of pelagic sharks, with a rate of 0.53 sharks/1,000 hooks[15]. More recently, researchers studying commercial catches in surface drifting longlines, have identified a statistically significant decline in the richness of pelagic shark species in the Ionian, with the probability of shark occurrence reducing to its lowest level in the most recent years[16].

Updated information

Based on a dataset compiled from the Hellenic Fisheries Data Collection Programme and the Fisheries Database of Hellenic Centre for Marine Research, which holds data from various projects relating to deep sea chondrichthyans, overall, 47 species of demersal and pelagic sharks, rays, skates and chimaeras were recorded during 1983-2016 in the Ionian Sea. This dataset included both experimental survey data and observations on board commercial fishing vessels. Twelve species had been exclusively reported in depths > 200 m and 14 species exclusively in depths < 200 m. Another five species had an occurrence of more than 90% in depths > 200 m, however, they are currently classified as Least Concern (*Etmopterus spinax, Galeus melastomus, Hexanchus griseus, Pteroplatytrygon violacea, Rhizoprionodon acutus*). The Endangered, Vulnerable or Near Threatened category status with an occurrence of more than 90% in depths below 200 m, are summarized in Table 6.2.

Spatial occurrence of the most vulnerable species is provided in Fig. 6.2 and Fig. 6.3.

Squalus species.

Table 6.2. Occurrence by depth for the chondrichthyan species identified during 1983-2016 in the Eastern Ionian Sea, their IUCN Red List status in the Mediterranean and percentage of occurrence in waters > 200 m. IUCN Conservation status categories: DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.
NOTE: It must be noted that for large pelagic sharks (e.g. *Prionace glauca*), the depths recorded refer to the depths of the sampling locations and not the actual depths of capture. Depth of capture was usually between 0-50 m from the surface, in the upper ocean layer.

Species	IUCN Red List Status	Min-Max depth occurrence (N)	% Occurrence > 200 m
Chimaera monstrosa	NT	225-1171 (444)	100%
Etmopterus spinax	LC	327-1171 (3620)	100%
Dalatias licha	VU	230-812 (67)	100%
*Dipturus batis***	CR	700 (1)	100%
Heptranchias perlo	DD	388-685 (19)	100%
Hexanchus griseus	LC	250-700 (7)	100%
Pteroplatytrygon violacea	LC	650-745 (2)	100%
Raja rondeleti	NE	604 (1)	100%
*Scyliorhinus stellaris***	NT	278 (7)	100%
Prionace glauca	CR	1402-4024 (11)	100%
Rhizoprionodon acutus	LC	3354 (1)	100%
*Squalus acanthias****	EN		96%
Galeus melastomus	LC		96%
Centrophorus cf *uyato**	VU		95%
*Squalus blainville****	DD		95%
Dipturus oxyrinchus	NT		92%
Scyliorhinus canicula	LC		80%
Galeorhinus galeus	VU		78%
Leucoraja circularis	CR		67%
Rhinobatos rhinobatos	EN		50%
Oxynotus centrina	CR		43%
Raja clavata	NT		34%
Raja brachyura	NT		25%

Species	IUCN Red List Status	% Occurrence > 200 m
Raja montagui	LC	20%
Raja polystigma	LC	16%
Raja asterias	NT	14%
Torpedo marmorata	LC	11%
*Dasyatis pastinaca*****	VU	4%
Tetronarce nobiliana	LC	2%
Mustelus mustelus	VU	2%
Torpedo torpedo	LC	1%
Raja miraletus	LC	1%
Dasyatis centroura	LC	0%
Gymnura altavela	VU	0%
Leucoraja melitensis	CR	0%
Leucoraja naevus	NT	0%
Mustelus asterias	VU	0%
Mustelus punctulatus	VU	0%
Myliobatis aquila	VU	0%
Pteromylaeus bovinus	CR	0%
Raja radula	EN	0%
Raja undulata	EN	0%
Rhinobatos cemiculus	EN	0%
Squatina oculata	CR	0%
Squatina squatina	CR	0%

* *Centrophorus* cf *granulosus* has been updated to *Centrophorus* cf *uyato*[10,11]
** *D. batis* and *S. stellaris* have not been reported during the last decade.
*** Perhaps two or three different species involved[17].
**** *D. pastinaca* synonym for *D. tortonesei*.

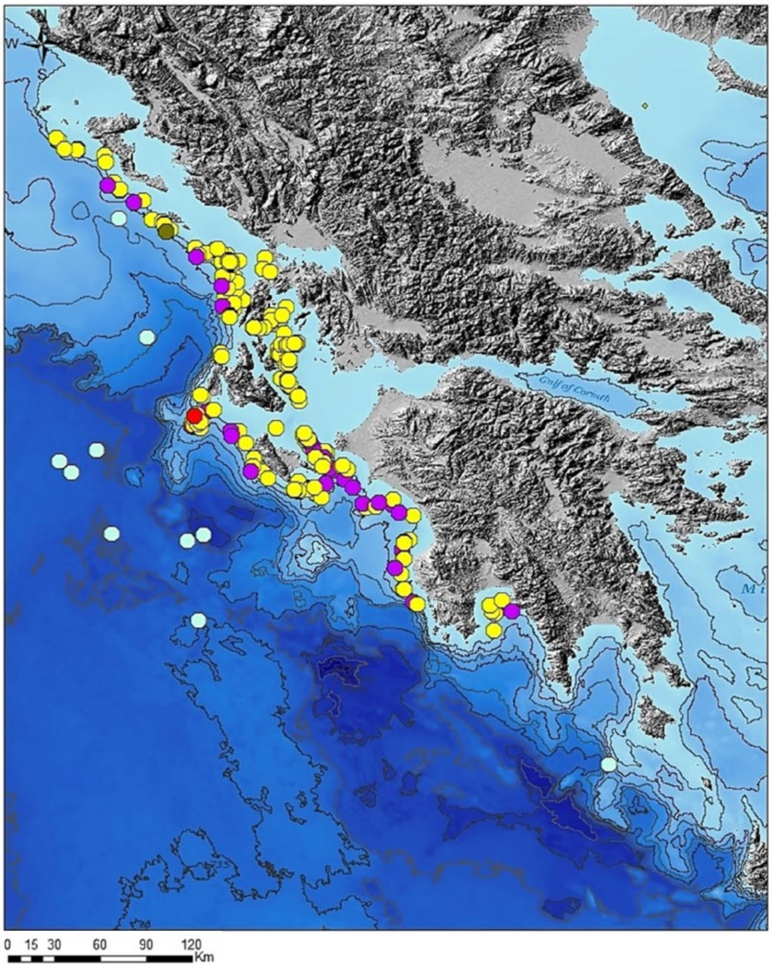

Fig. 6.2. Spatial occurrence of vulnerable chondrichthyans (*Dalatias licha* - kitefin shark, *Dipturus batis* - blue skate, *D. oxyrinchus* - longnose skate, *Prionace glauca* - blue shark, and *Scyliorhinus stellaris* - nursehound) in the E. Ionian Sea during the period 1983-2016.

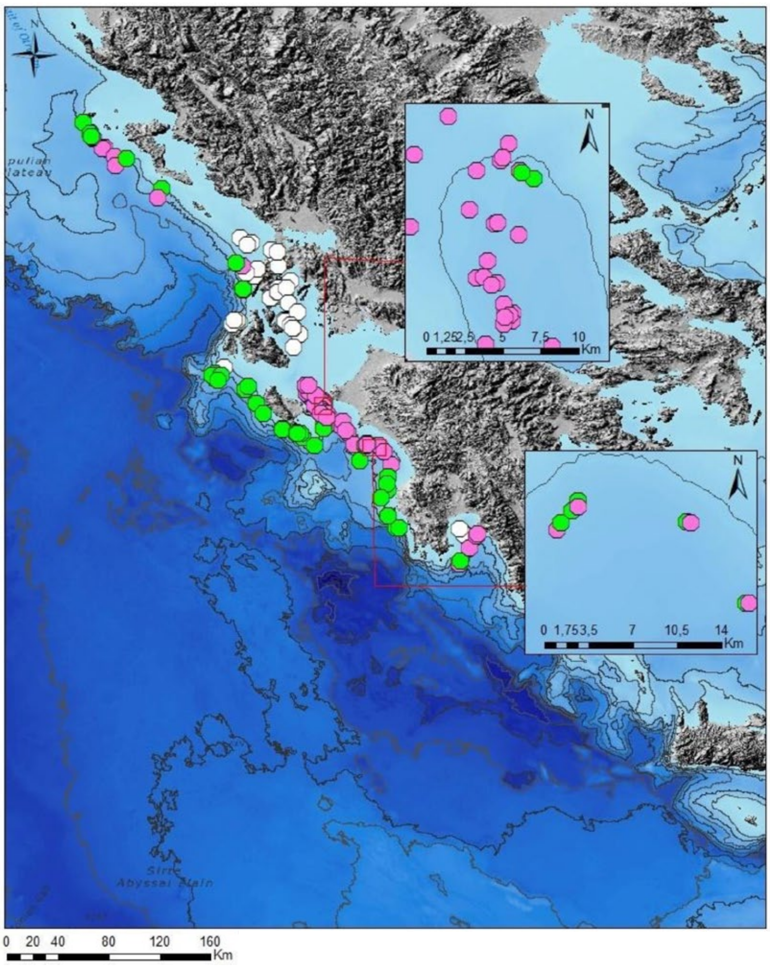

Fig. 6.3. Spatial occurrence of chondrichthyans (*Centrophorus* cf *uyato* - gulper shark, *Chimaera monstrosa* - rabbit fish, and *Squalus acanthias* - picked dogfish) in the E. Ionian Sea during the period 1983-2016.

North and South Aegean Sea

According to the most updated fish checklists[5,18,19], the Aegean Sea hosts at least 63 chondrichthyan species (Table 6.3.).

Table 6.3. Shark, skate and ray species reported in the literature for the Eastern Mediterranean and their status according to the IUCN Criteria (recordings at depths of over 200 metres are marked as "••"). IUCN Conservation status categories: DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Species	Common name	IUCN Status (Mediterranean assessment)	North Aegean	South Aegean	Aegean Sea	Ionian Sea	Levantine Sea	Libyan Sea	Reference(s)
Alopias superciliosus	Bigeye thresher shark	EN	•	••	•		•	••	[5, 19, 37, 38 ,40]
Alopias vulpinus	Thresher shark	VU	••	••	•		••	••	[5, 18, 19, 31, 32, 39, 40, 44]
Carcharias taurus	Sandtiger shark	CR	••		•		•		[18, 19, 39, 40, 44]
Carcharhinus altimus	Bignose shark	DD					•		[19, 32, 40, 44]
Carcharinus brevipinna	Spinner shark	DD			•		•		[18, 19, 39, 40, 44]
Carcharhinus falciformis	Silly shark						•		[32]
Carcharhinus limbatus	Blacktip shark	NE					•		[19, 36, 40, 44]
Carcharhinus melanopterus	Blacktip reef shark	NT					•		[39, 44]
Carcharhinus obscurus	Dusky shark	DD					•		[37, 38, 40, 41]
Carcharinus plumbeus	Sandbar shark	EN		•	•		••		[5, 18, 19, 32, 37, 38, 39, 40, 44]
Carcharodon carcharias	Great white shark	EN	•		•		•	••	[5, 18, 19, 39, 40, 44]
Centrophorus cf uyato	Gulper shark	VU	••	••	•	••	••		[5, 18, 19, 32, 37, 38, 39, 40, 41, 44]
Centrophorus moluccensis	Smallfin gulper shark	DD					••		[37, 38]
Centroscymnus coelolepis	Portuguese dogfish	LC		•					[5]
Cetorhinus maximus	Basking shark	EN	••	•	•		•		[5, 18, 19, 32, 37, 38, 40]
Chimaera monstrosa	Rabbit fish	NT	••	••	•	••	••		[5, 19, 36, 37, 38, 40, 42, 168]
Dalatias licha	Kitefin shark	VU	••	••	•	••	••		[5, 18, 19, 37, 38, 39, 40, 41]
Dasyatis centroura	Roughtail stingray	LC		••	•		•		[18, 19, 39, 40, 44]
Dasyatis chrysonota	Blue stingray	LC					•		[40]
Dasyatis marmorata	Marble stingray	DD					•		[19, 40, 41]
Dasyatis pastinaca	Common stingray	VU	••	••	•	••	••		[5, 18, 19, 36, 37, 38, 39, 40, 41, 42, 44]
Dipturus cf batis	Blue skate	CR	•	•	•	••	••		[5, 18, 19, 168]
Dipturus oxyrinchus	Longnose skate	NT	••	••	•	••	••	••	[5, 18, 19, 36, 37, 38, 39, 40, 41, 42, 44]
Echinorhinus brucus	Bramble shark	DD	••		•		••		[19, 42, 44]
Etmopterus spinax	Velvet belly	LC	••	••	•	••	••	••	[5, 18, 19, 32, 39, 40, 42, 43]
Galeocerdo cuvier	Tiger shark	DD						••	
Galeorhinus galeus	Tope shark	VU	•	••	•	••	••	••	[5, 18, 19, 39, 44]
Galeus melastomus	Blackmouth catshark	LC	••	••	•	••	••		[5, 18, 19, 36, 37, 38, 39, 40, 41, 42, 44, 168]
Gymnura altavela	Spiny butterfly ray	VU	•	•	•		••		[5, 18, 19, 36, 37, 38, 39, 40, 41, 44]
Heptranchias perlo	Sharpnose seven-gill shark	DD	••	••	•	••	••		[5, 18, 19, 36, 37, 38, 40, 41, 44]
Hexanchus griseus	Bluntnose sixgill shark	LC	••	••	•	••	••		[5, 18, 19, 36, 37, 38, 40, 41, 44]
Hexanchus nakamurai	Bigeye sixgill shark	DD		••					[5]
Himantura uarnak	Honeycomb stingray	VU					•		[19, 36, 40, 43, 44]
Hydrolagus mirabilis	Large-eyed rabbitfish	NT					••		[42, 43]
Isurus oxyrinchus	Shortfin mako	CR	•	••	•		••	••	[5, 18, 19, 36, 37, 38, 39, 40, 41]
Lamna nasus	Porbeagle	CR	•	•	•		•		[5, 18, 19, 39, 40, 44]
Leucoraja circularis	Sandy ray	CR	••	••	•	••	••		[5, 19, 43]
Leucoraja fullonica	Shagreen skate	CR	••	••	•		••		[5, 19]
Leucoraja melitensis	Maltese ray	CR	••	••					[5]
Leucoraja naevus	Cuckoo ray	NT	••	••	•		•		[5, 18, 19]
Mobula mobular	Devil fish	EN	•	•	•		•		[5, 18, 19, 32, 37, 38, 39, 40, 44]
Mustelus asterias	Starry smooth-hound	VU	••	••	•		•		[5, 18, 19, 32, 39, 40, 44]
Mustelus mustelus	Smooth hound	VU	••	••	•	••	••	••	[5, 18, 19, 36, 37, 38, 39, 40, 41, 44]
Mustelus punctulatus	Blackspotted smooth-hound	VU		••	•		•		[18, 19, 39, 44]
Myliobatis aquila	Common eagle ray	VU	••	•	•		•		[5, 18, 19, 32, 40, 44]
Odontaspis ferox	Smalltooth sandtiger shark	EN		••	•		•		[5, 18, 19, 36, 39, 40, 44]
Oxynotus centrina	Angular rough shark	CR	••	••	•	••	••	••	[5, 18, 19, 32, 37, 38, 39, 40, 44, 168]
Prionace glauca	Blue shark	CR	••	••	•	••	••	••	[5, 18, 19, 36, 39, 40, 44]
Pristis pectinata	Smalltooth sawfish	CR					•		[36, 40]
Aetomylaeus bovinus	Bull ray	CR	•	•	•		•		[5, 18, 19, 37, 38, 39, 40, 41, 44]
Pteroplatytrygon violacea	Pelagic stingray	LC		•	•	••	••		[5, 18, 19, 37, 38, 39, 40]
Raja asterias	Mediterranean starry ray	NT	••	••	•	••	••	••	[5, 18, 19, 39, 40, 42, 44]
Raja brachyura	Blonde skate	NT	••	••		••	••		[5]
Raja clavata	Thornback ray	NT	••	••	•	••	••	••	[5, 18, 19, 37, 38, 39, 40, 41, 44]
Raja miraletus	Brown ray	LC	••	••	•	••	••	••	[5, 18, 19, 36, 37, 38, 39, 40, 41, 44]
Raja montagui	Spotted ray	LC	••	••	•	••	••		[5, 18, 19, 32]
Raja polystigma	Speckled ray	LC	••	••	•	••	••		[5, 19, 18]
Raja radula	Rough ray	EN	••	•	•		•		[5, 18, 19, 37, 38, 39, 40, 44]
Raja rondeleti	Rondelet's ray	NE		••		••			
Raja undulata	Undulate ray	EN		•	•		•		[5, 19, 18]
Rhinobatos cemiculus	Blackchin guitarfish	EN		•	•		•		[5, 18, 19, 36, 37, 38, 39, 40, 41, 44]
Rhinobatos rhinobatos	Common guitarfish	EN		••	•	••	•		[5, 18, 19, 36, 37, 38, 39, 40, 41, 44]
Rhizoprionodon acutus	Milk shark	LC				••			
Rhinoptera marginata	Lusitanian cownose ray	NT			•		•		[18, 19, 39, 40, 43, 44]
Rostroraja alba	White skate	CR	••	••	•		••	••	[5, 19, 18]
Scyliorhinus canicula	Small-spotted catshark	LC	••	••	•	••	••	••	[5, 18, 19, 32, 37, 38, 39, 40, 44]
Scyliorhinus stellaris	Nursehound	NT	••	••	•	••	••		[5, 18, 19, 32, 39, 44]
Somniosus rostratus	Little sleeper shark	DD	•	•			••		[5, 37, 38]
Sphyrna mokarran	Great hammerhead	EN					•		[39, 44]
Sphyrna zygaena	Smooth hammerhead	CR		•	•		•		[5, 18, 19, 36, 39, 49, 44]
Squalus acanthias	Picked dogfish	EN	••	••	•	••	••	••	[5, 18, 19, 36, 39, 40, 44]
Squalus blainville	Longnose spurdog	DD	••	••	•	••	••		[5, 18, 19, 37, 38, 39, 40, 41, 44]
Squalus megalops	Shortnose spurdog	DD					••		[37, 38]
Squatina aculeata	Sawback angelshark	CR		••	•		••	••	[5, 18, 19, 37, 38, 40, 41, 44]
Squatina oculata	Smoothback angelshark	CR	•	••	•		•	••	[5, 18, 19, 37, 38, 39, 40, 41, 44]
Squatina squatina	Angelshark	CR	•	•	•		•		[5, 18, 19, 36, 37, 38, 39, 40, 44]
Taeniura grabata	Round stingray	DD					•		[19, 37, 38, 40, 41, 44]
Torpedo alexandrinsis	Alexandrine torpedo	NE					•		[44]
Torpedo marmorata	Marbled electric ray	LC	••	••	•	••	••		[5, 18, 19, 36, 37, 38, 39, 40, 41, 44]
Tetronarce nobiliana	Electric ray	LC	••	••	•	••	••	••	[5, 18, 19,37, 38, 39, 40, 41]
Torpedo sinuspersici	Variable torpedo ray	DD					••		[43]
Torpedo (Tetronarce) tokionis	Longtail torpedo ray	DD					••		[42]
Torpedo torpedo	Common torpedo	LC	•	••	•	••	•		[5, 18, 19, 36, 39, 40, 44]
	Total		49	59	58	32	77	20	

**Centrophorus* cf *granulosus* has been updated to *Centrophorus* cf *uyato*[10,11].

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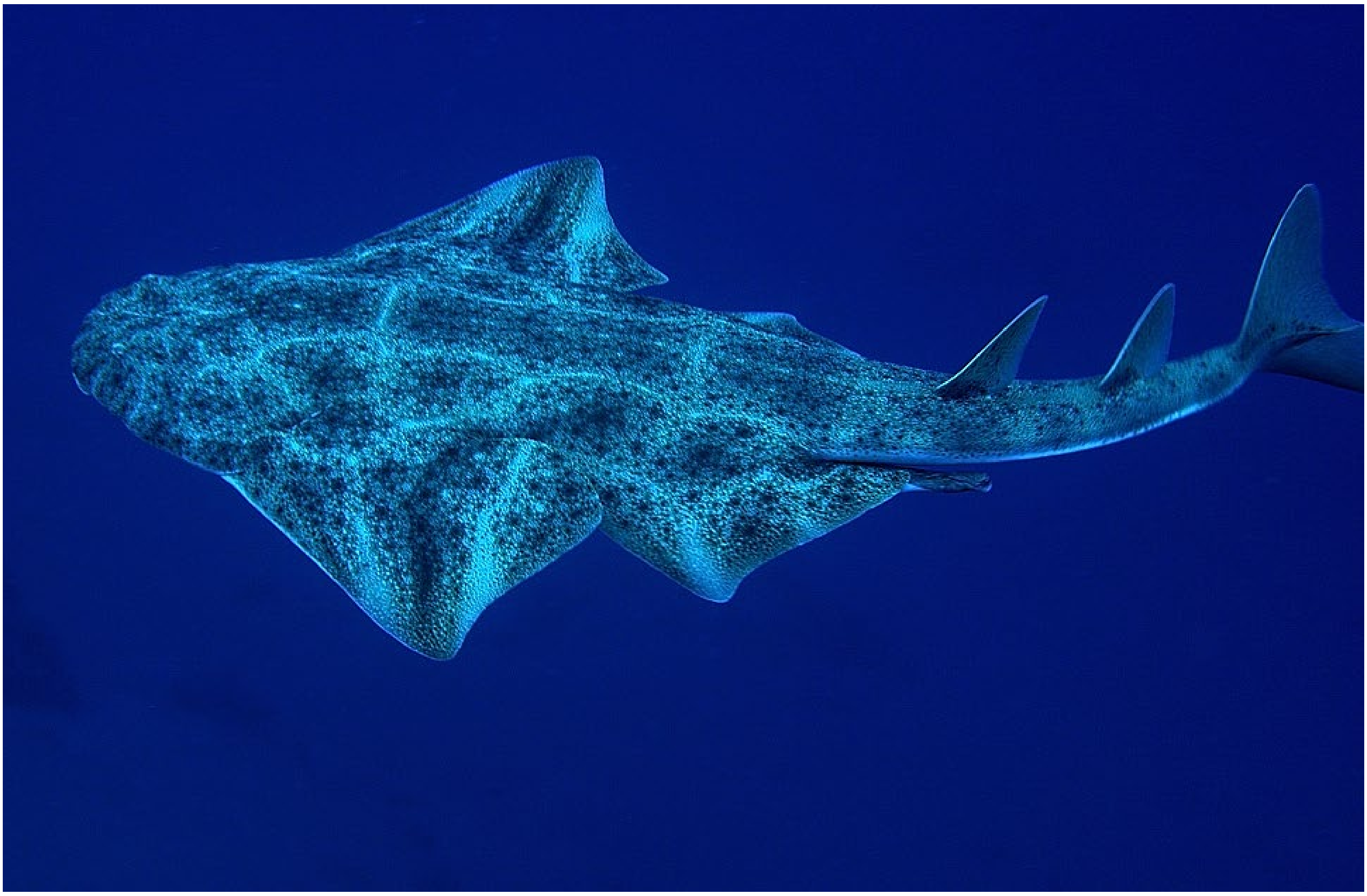


The Angelsharks (*Squatina squatina*) were formerly common throughout large areas of coastal and outer continental shelf seas in the Mediterranean and Black Seas. Their abundance have markedly declined during the past 50 years to the point where it is locally extinct from large areas and is nowadays listed as Critically Endangered in the IUCN Red list.

The deep waters of the Aegean Sea are still to be explored. There are significant gaps in present knowledge and considerable uncertainty around shark, ray and skate distribution and, moreover, their status. No specific survey has so far targeted Aegean deep-water species of this taxa and the available information presented was extracted from various studies in which chondrichthyans were reported from the Fisheries Database of the Hellenic Centre for Marine Research, MEDITS surveys and local fisheries knowledge studies[20,21].

2 NORTH AEGEAN SEA

According to the Greek National Fisheries Database, 45 sharks, rays, skates and chimaera species were reported during 1983-2016. Seven species were exclusively reported in depths of more than 200 m and 12 species were exclusively found in depths of less than 200 m. Another five species had an occurrence of more than 90% in depths more than 200 m, however, their status is considered of Least Concern (*Etmopterus spinax, Galeus melastomus, Hexanchus griseus*) or unknown because of lack of information (*Heptranchias perlo* and *Squalus blainville*). Information from all the species findings, and those from Endangered or Near Threatened species with their occurrence in depths below 200 m are summarized in Table 6.4. and their spatial occurrence in Fig. 6.4.

Additional reports from deep-trawl surveys conducted in Saros Bay (Northern Aegean Sea) in Turkey also indicated the presence of 17 elasmobranch and chimaera species in depths of more than 200 m between 2007-2008 and recent reports from Istanbul University have confirmed the presence of 12 chondrichthyans below 500 m depth[23].

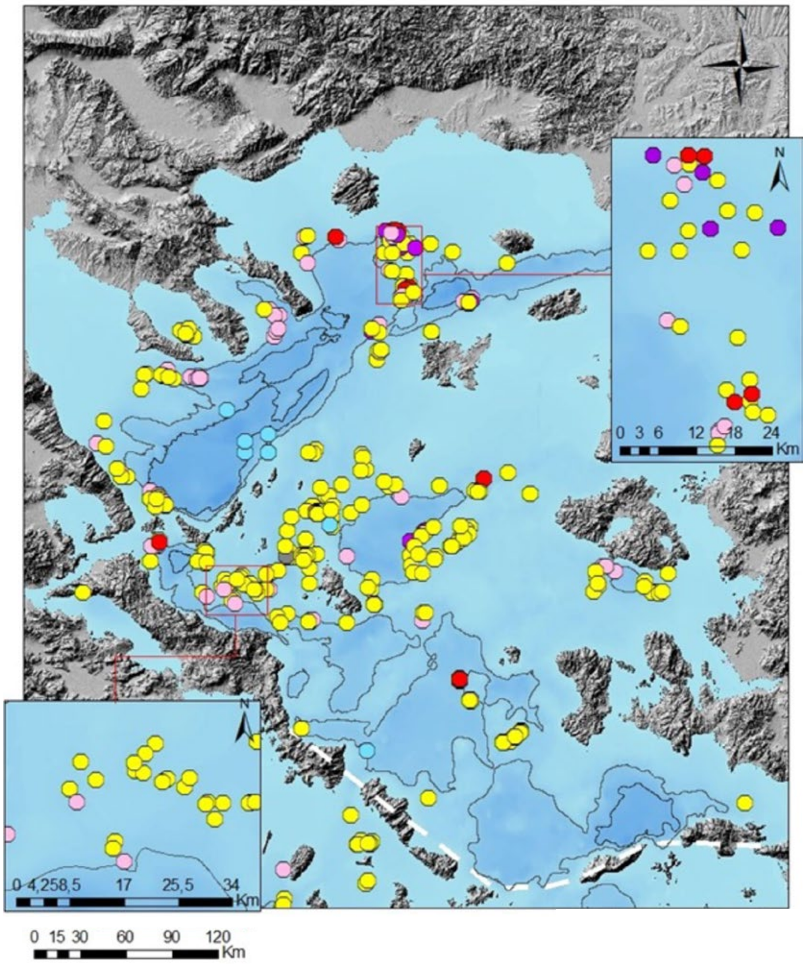
White sharks (*Carcharodon carcharias*), have also been sporadically reported (10 sightings) in the North Aegean Sea since the 1990's however there are too few records to confirm their presence in deep waters[24,25]. The conservation status was raised from Endangered to Critically Endangered in the Mediterranean Red list and genetic samples from specimens seems to indicate little or no contemporary immigration from the Atlantic Ocean[25].

Table 6.4. Occurrence by depth for the chondrichthyan species identified during 1983-2016 in the North Aegean Sea, their IUCN Red List status and percentage of occurrence in waters > 200 m. IUCN Conservation status categories: DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Species	IUCN Red List Status	Min-Max depth occurrence (N)	% Occurrence > 200 m
Centrophorus cf *uyato*	VU	518-546 (21)	100.0%
*Cetorhinus maximus****	EN	410 (1)	100.0%
Dalatias licha	VU	265-602 (719)	100.0%
*Echinorhinus brucus**	DD		100.0%
Heptranchias perlo	DD	362-548 (10)	100.0%
Hexanchus griseus	LC	291-441 (9)	100.0%
*Prionace glauca****	CR	292-1172 (8)	100.0%
Etmopterus spinax	LC		99.9%
Galeus melastomus	LC		97.5%
Chimaera monstrosa	NT		95.9%
Dipturus oxyrinchus	NT		93.7%
Scyliorhinus stellaris	NT		92.0%
*Squalus acanthias***	EN		85.5%
Rostroraja alba	CR		77.8%
Leucoraja circularis	CR		50.0%
Leucoraja melitensis	CR		50.0%
Raja asterias	NT		46.3%
Raja clavata	NT		45.6%
Scyliorhinus canicula	LC		34.4%
Leucoraja fullonica	CR		33.3%
Raja polystigma	LC		19.2%
Raja montagui	LC		13.5%
Oxynotus centrina	CR		12.9%

Species	IUCN Red List Status	% Occurrence > 200 m
Raja brachyura	NT	12.9%
Leucoraja naevus	NT	10.5%
Myliobatis aquila	VU	7.0%
Tetronarce nobiliana	LC	6.8%
Raja miraletus	LC	1.9%
Mustelus mustelus	VU	1.3%
Torpedo marmorata	LC	1.2%
Raja radula	EN	0.5%
Dasyatis pastinaca	VU	0.4%
Alopias vulpinus	VU	0.0%
Dasyatis centroura	LC	0.0%
Dipturus batis	CR	0.0%
Gymnura altavela	VU	0.0%
Mobula mobular	EN	0.0%
Mustelus asterias	VU	0.0%
Pteromylaeus bovinus	CR	0.0%
Sphyrna zygaena	CR	0.0%
Squatina oculata	CR	0.0%
Squatina squatina	CR	0.0%
Torpedo torpedo	LC	0.0%

* [26]
**Perhaps two or three different species involved[17].
***It must be noted that for large pelagic sharks, the depths recorded refer to the depths of the sampling locations and not the actual depths of capture. Depth of capture was usually between 0-50 m from the surface, in the upper ocean layer.



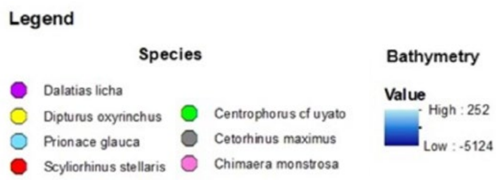


Fig. 6.4. Spatial occurrence of Endangered chondrichthyans (*Centrophorus* cf *uyato*, *Cetorhinus maximus, Chimaera monstrosa, Dalatias licha, Dipturus oxyrinchus, Prionace glauca, Scyliorhinus stellaris*) in the N. Aegean Sea during 1983-2016.

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The Bluntnose Sixgill Shark (*Hexanchus griseus*) is a benthic, littoral, and semipelagic shark occurring in deep and shelf waters down to at least 2,500 m. Young tend to be found in shallow waters often just offshore and move into successively deeper waters as they grow. The species is caught as bycatch in deepwater fisheries although there is not much report of fishing catch and landings. At present, the species is considered Least Concern in the IUCN Red list for the region.

Reports from MEDITS surveys from 2001-2014 revealed twenty-eight (28) demersal elasmobranch species found in the 200-800 m bathymetric zone of the N. Aegean Sea, with the highest concentration in depths between shelf break and the upper slope (300-500 m)[9]. Moreover, only six demersal sharks and chimaera species were found exclusively at depths deeper than 200 m in the slopes, namely, the velvet belly shark *Etmopterus spinax,* the chimaera rabbit fish *Chimaera monstrosa,* the gulper shark *Centrophorus* cf *uyato,* the not well-known sharpnose sevengill shark *Heptranchias perlo,* the vulnerable kitefish shark *Dalatias licha* and the bluntnose six-gill shark *Hexanchus griseus* (Table 6.5.). The most common species, *Raja clavata* and the small-spotted catshark *Scyliorhinus canicula* were more abundant in the shelf break, whereas *Galeus melastomus* was more abundant in the slope. Depending on the region and season, most species are marketed under generic names (e.g.'galeos, 'vatos')[20,21].

Table 6.5. Frequency of occurrence of elasmobranch species caught in the hauls conducted in the bathymetric zone 200-800 m of the North Aegean Sea during MEDITS surveys from 2001-2014.
In red: Endangered, Vulnerable or Near Threatened species.

Species	Common name	Frequency of occurrence %
Scyliorhinus canicula	Small-spotted catshark	63.1
Raja clavata	Thornback ray	50.9
Galeus melastomus	Blackmouth catshark	49.1
Dipturus oxyrinchus	Longnose skate	25.1
Squalus acanthias	Picked dogfish	20.8
Etmopterus spinax	Velvet belly	18.1
Chimaera monstrosa	Rabbit fish	16.4
Raja polystigma	Speckled ray	6.2
Squalus blainville	Longnose spurdog	4.6
Leucoraja naevus	Cuckoo ray	3.8
Raja asterias	Mediterranean starry ray	3.2
Raja miraletus	Brown ray	2.2
Heptranchias perlo	Sharpnose seven-gill shark	1.9
Raja brachyura	Blonde skate	1.9
Raja montagui	Spotted ray	1.9
Dalatias licha	Kitefin shark	1.6
Leucoraja melitensis	Maltese ray	1.6
*Centrophorus cf uyato**	Gulper shark	1.1
Hexanchus griseus	Bluntnose sixgill shark	1.1
Oxynotus centrina	Angular rough shark	1.1
Rostroraja alba	White skate	1.1
Tetronarce nobiliana	Electric ray	1.1
Leucoraja circularis	Sandy ray	0.8
Torpedo marmorata	Marbled electric ray	0.8
Mustelus mustelus	Smooth hound	0.3
Leucoraja fullonica	Shagreen skate	0.3
Raja radula	Rough ray	0.3
Scyliorhinus stellaris	Nursehound	0.3

* *Centrophorus* cf *granulosus* has been updated to *Centrophorus* cf *uyato*[10,11].

3

SOUTH AEGEAN SEA

According to the Greek National Fisheries database, 49 chondrichthyan species were reported during 1983-2016. Twelve species were exclusively reported in depths of more than 200 m and five species were exclusively found in depths of less than 200 m. The Endangered, Vulnerable or Near Threatened species with an occurrence of more than 90% in depths below 200 m, are presented in Table 6.6. with their spatial occurrence in Fig. 6.5.

Table 6.6. Occurrence by depth for the chondrichthyan species identified during 1983-2016 in the South Aegean Sea, their IUCN Red List status and percentage of occurrence in waters > 200 m. IUCN Conservation status categories: DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Species	IUCN Red List Status	Min-Max depth occurrence (N)	% Occurrence > 200 m
Alopias superciliosus	DD	496-1326 (3)	100.00%
Alopias vulpinus	VU	496-1326 (3)	100.00%
Dasyatis centroura	LC	234 (1)	100.00%
Hexanchus griseus	LC	305-366 (2)	100.00%
Hexanchus nakamurai	DD	230 (1)	100.00%
Isurus oxyrinchus	CR	524-914 (2)	100.00%
Mustelus punctulatus	VU	1-441 (1)	100.00%
Prionace glauca	CR	302-3840 (48)	100.00%
Raja rondeleti	NE	510 (1)	100.00%
Tetronarce nobiliana	LC	210-315 (4)	100.00%
Odontaspis ferox	EN	600 (1)	100.00%
Centrophorus cf uyato	VU		98.63%
Chimaera monstrosa	NT		98.26%
Galeus melastomus	LC		97.47%
*Squalus acanthias**	EN		96.41%
Dalatias licha	VU		95.65%
Galeorhinus galeus	VU		94.55%
Dipturus oxyrinchus	NT		93.12%
Squalus blainville	DD		92.48%
Squatina aculeata	CR		88.89%
Heptranchias perlo	DD		86.54%
Rhinobatos rhinobatos	EN		80.00%
Scyliorhinus canicula	LC		76.15%
Etmopterus spinax	LC		75.04%

Species	IUCN Red List Status	% Occurrence > 200 m
Scyliorhinus stellaris	NT	72.73%
Leucoraja fullonica	CR	66.67%
Raja clavata	NT	58.04%
Leucoraja circularis	CR	55.00%
Raja montagui	LC	51.01%
Squatina oculata	CR	50.00%
Oxynotus centrina	CR	40.00%
Mustelus mustelus	VU	35.58%
Raja polystigma	LC	35.35%
Leucoraja naevus	NT	32.67%
Torpedo torpedo	LC	30.43%
Raja brachyura	NT	30.00%
Rostroraja alba	CR	30.00%
Raja asterias	NT	26.17%
Torpedo marmorata	LC	19.90%
Raja miraletus	LC	15.25%
Mustelus asterias	VU	12.90%
Dasyatis pastinaca	VU	7.27%
Leucoraja melitensis	CR	1.75%
Gymnura altavela	VU	0.00%
Myliobatis aquila	VU	0.00%
Aetomylaeus bovinus	CR	0.00%
Raja radula	EN	0.00%
Raja undulata	EN	0.00%

*Perhaps two or three different species involved[17]

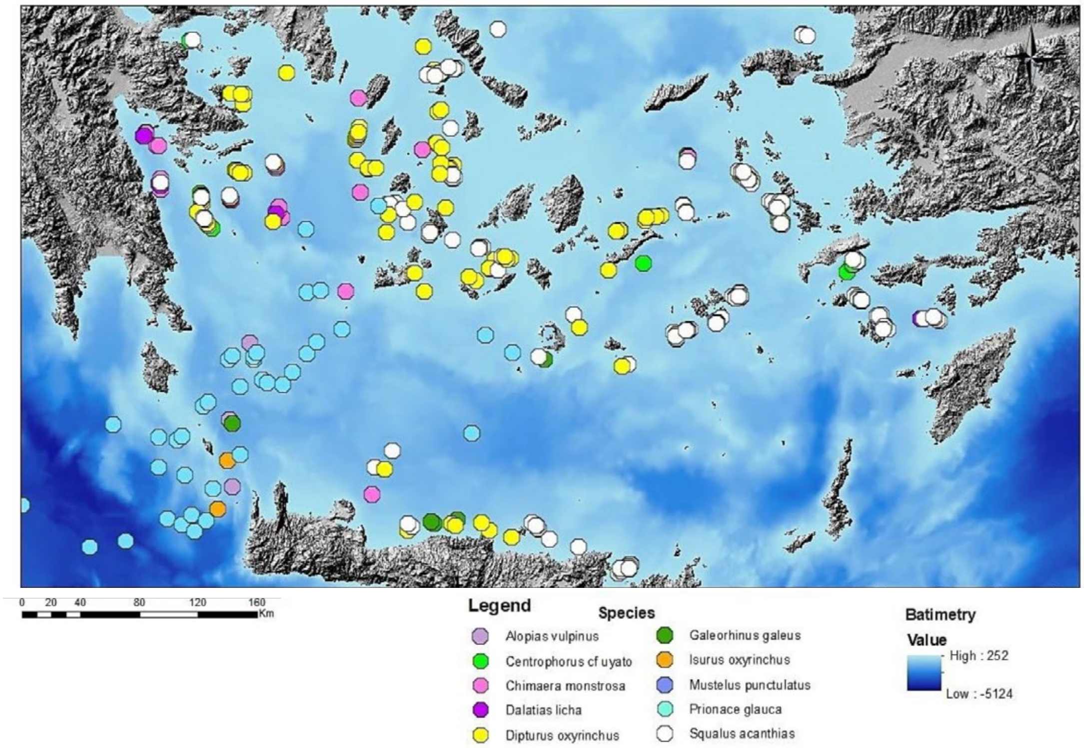

Fig. 6.5. Spatial occurrence of chondrichthyans (*Alopias vulpinus* - thresher shark, *Centrophorus* cf *uyato* - gulper shark, *Chimaera monstrosa* - rabbit fish, *Dalatias licha* - kitefin shark, *Dipturus oxyrinchus* - longnose skate, *Galeorhinus galeus* - tope shark, *Isurus oxyrinchus* - shortfin mako, *Mustelus punctulatus* - blackspotted smooth-hound, *Prionace glauca* - blue shark, and *Squalus acanthias* - picked dogfish) in the S. Aegean Sea during 1983-2016 (both experimental surveys and observations on-board commercial fishing vessels).

Fisheries independent data obtained from the MEDITS programme during 2001-2014, reported in total, twenty-nine (29) elasmobranch species in the 200-800 m bathymetric zone of the S. Aegean Sea. However, only eight species were found exclusively at depths greater than 200 m. Namely, *Etmopterus spinax, Chimaera monstrosa, Centrophorus* cf *uyato, Heptranchias perlo, Dalatias licha* together with the angelsharks (*Squatina aculeata, Squatina oculata*) and the electric ray *Tetronarce nobiliana*.

Compared to the Ionian Sea, the small-spotted catshark *Scyliorhinus canicula,* a bottom dwelling species, occurring primarily over sandy, gravel or muddy bottoms, was more abundant in the continental shelf, rather than the upper slope. Similarly, sharks of the genus *Squalus* showed a preference for deeper waters in this region, perhaps as a result of the more intense fishing pressure on the shelf in this region. The occurrence, biomass and abundance of sharks and ray species in general are also observed in higher numbers around the islands of the Eastern and central Aegean Sea (Table 6.7.).

Table 6.7. Frequency of occurrence of elasmobranch species in the bathymetric zone 200-800 m of the South Aegean Sea during MEDITS surveys from 2001-2014. In red: Endangered, Vulnerable or Near Threatened species.

Species	Common name	Frequency of occurrence %
Scyliorhinus canicula	Small-spotted catshark	78.9
Raja clavata	Thornback ray	70.5
Squalus acanthias	Picked dogfish	42.7
Galeus melastomus	Blackmouth catshark	38.7
Squalus blainville	Longnose spurdog	17.0
Dipturus oxyrinchus	Longnose skate	15.1
Etmopterus spinax	Velvet belly	12.1
Raja asterias	Mediterranean starry ray	8.8
Chimaera monstrosa	Rabbit fish	7.1
Centrophorus cf uyato	Gulper shark	6.5
Heptranchias perlo	Sharpnose seven-gill shark	3.3
Raja montagui	Spotted ray	2.7
Mustelus mustelus	Smooth hound	1.9
Oxynotus centrina	Angular rough shark	1.9
Raja polystigma	Speckled ray	1.9
Dalatias licha	Kitefin shark	1.7
Galeorhinus galeus	Tope shark	1.7
Torpedo marmorata	Marbled electric ray	1.7
Raja miraletus	Brown ray	1.5
Squatina aculeata	Sawback angelshark	1.0
Dasyatis pastinaca	Common stingray	0.8
Leucoraja naevus	Cuckoo ray	0.8
Leucoraja circularis	Sandy ray	0.6
Torpedo torpedo	Common torpedo	0.6
Leucoraja fullonica	Shagreen skate	0.4
Raja rondeleti	Rondelet's ray	0.2
Scyliorhinus stellaris	Nursehound	0.2
Squatina oculata	Smoothback angelshark	0.2
Tetronarce nobiliana	Electric ray	0.2

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The Angular Rough Shark (*Oxynotus centrina*) is a neritic and deepwater, benthic shark distributed at depths of 60–800 m. This species is taken primarily as bycatch by offshore bottom trawlers in the Mediterranean Sea and the information available indicates a suspected decline of at least 80% over last 60 years. Today is listed as Critically Endangered in the Mediterranean.

4 LIBYAN SEA

As with other biodiversity information, data from the Libyan Sea is scarce. Early studies to identify trawlable fishing grounds, conducted by the LIBFISH project[27] off the Libyan coasts during 1993 and 1994, reported the presence of smooth hound sharks *Mustelus mustelus*, dogfish *Squalus acanthias*, and several *Raja* species, exhibiting a relatively high abundance. Nonetheless, information was not available on those found at deep-waters.

A second survey[28] funded by the Libyan Marine biology Research Centre (MBRC), conducted off the Libyan coast by the Hellenic Centre for Marine Research in 2003, (Fig. 6.6) recorded eleven species at depths of more than 200 m. In general, shark, rays and skates were among the most abundant fish species encountered. Rare species listed as critically endangered such as the angular rough shark *Oxynotus centrina* or angelsharks *Squatina oculata* (38 kg/km^2) and *Squatina aculeata* (41 kg/km^2), were reported as abundant at deep-waters at that time. Other species such as the dogfish *Squalus acanthias,* the rays *Raja clavata, Raja asterias* and the longnose skate *Dipturus oxyrinchus* were also very abundant, along with other ubiquitous species such as the electric ray *Tetronarce nobiliana*. The absence of *Galeus melastomus,* a species that is very common in the Mediterranean, was also a significant finding.

More recent reviews verified the presence of 59 chondrichthyan species along the coast and deep-waters of the Libyan Sea, including a rare report of the tiger shark, *Galeocerdo cuvier*, accidentally caught by a drifting longline for swordfish off the Libyan coast, Gulf of Sirte[29,30]. Other large pelagic sharks have been cited over the deep open waters of the Libyan Sea (in order of abundance): *Prionace glauca, Isurus oxyrinchus, Alopias vulpinus, Galeorhinus galeus, Alopias superciliosus, Carcharodon carcharias.* All of the aforementioned species are categorized from Vulnerable to Critically Endangered (Fig. 6.6).

> “In Libya, some artisanal fisheries using fixed gillnets, bottom set nets and drifting longlines still target endangered and little known cartilaginous sharks such as requiem sharks , mackerel or white sharks, guitarfishes and angelsharks such as *Squatina squatina*”

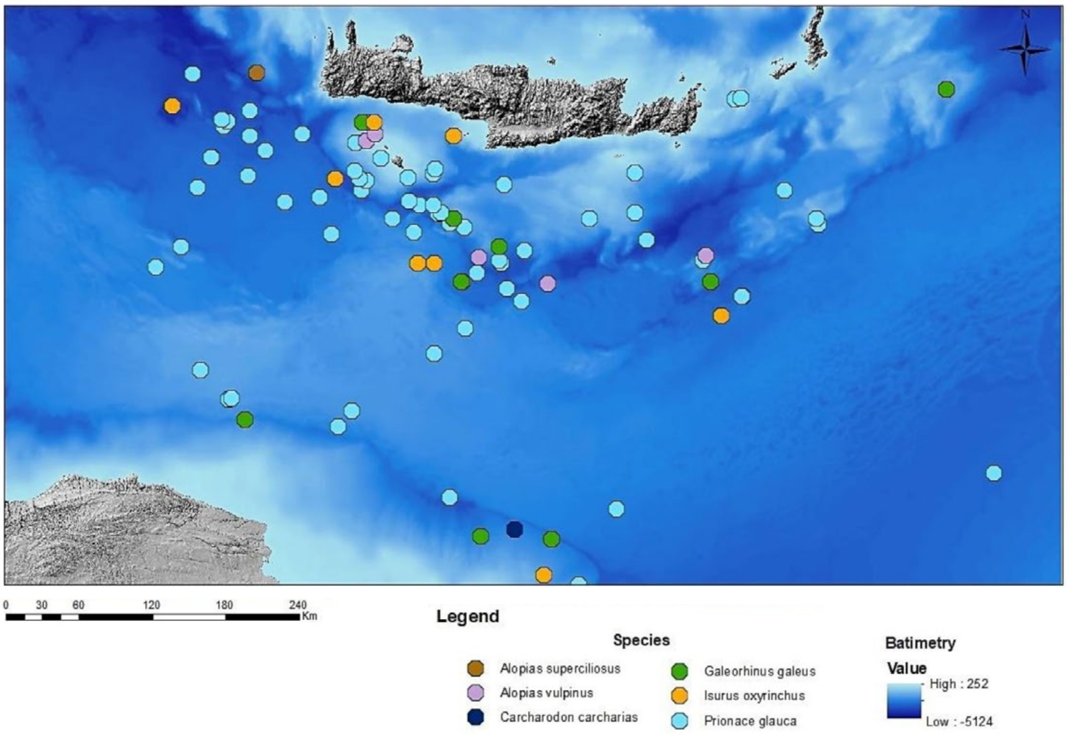
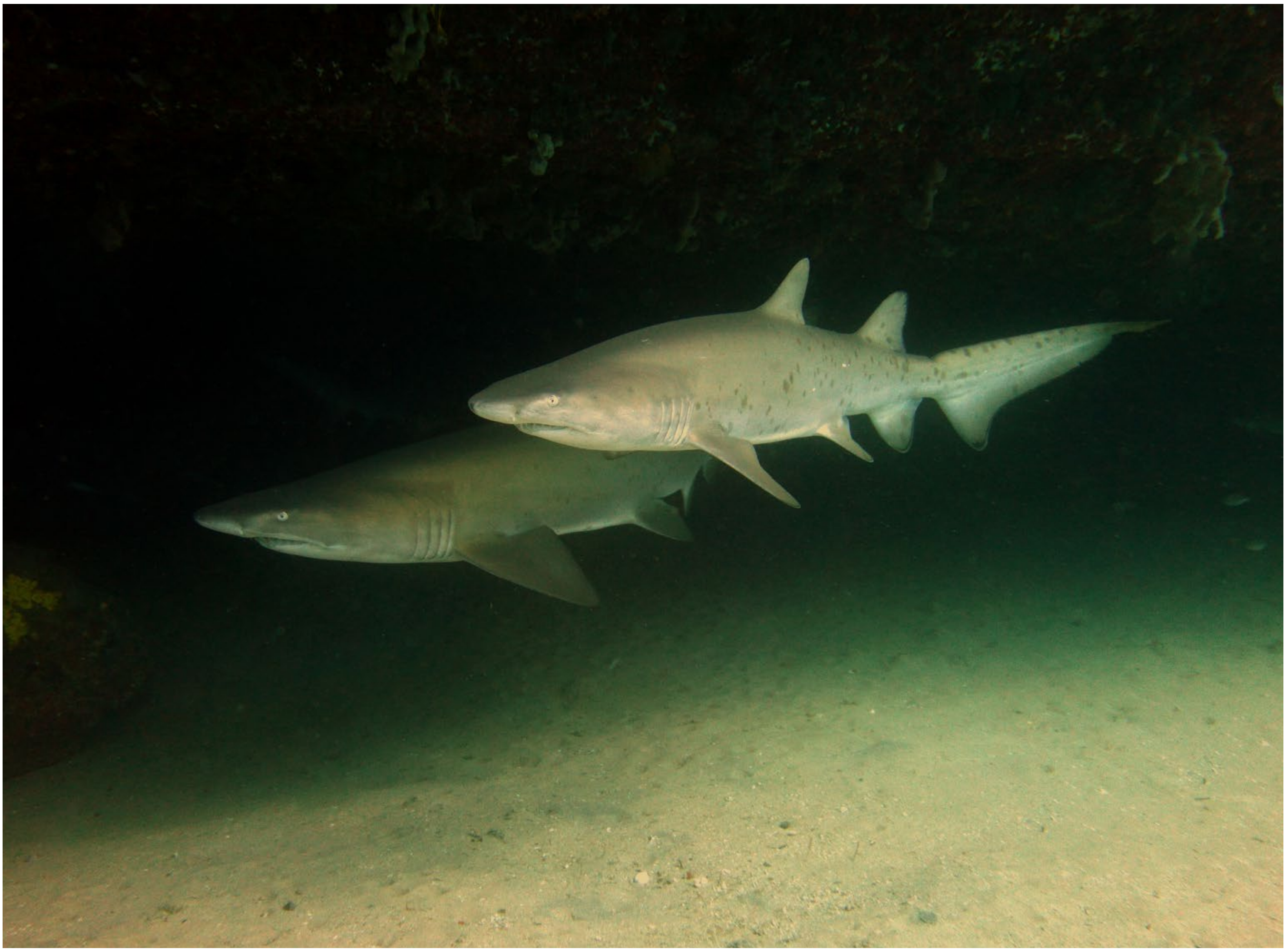


Fig. 6.6. Spatial occurrence of vulnerable large pelagic sharks (*Prionace glauca* - blue shark, *Isurus oxyrinchus* - shortfin mako, *Alopias vulpinus* - thresher shark, *Galeorhinus galeus* - tope shark, *Alopias superciliosus* - bigeye thresher shark, *Carcharodon carcharias* - great white shark) in the open waters of the Libyan Sea during 1998-2005[16].

Tiger shark © Hakbak, Dreamstime.

© Irko Van Der Heide, Dreamstime.



A pair of the critically endangered sand tiger sharks (*Carcharias taurus*) emerging from the darkness.

5 LEVANTINE SEA

The deep waters of the Levantine Sea are largely uncharted. There are significant gaps of knowledge on elasmobranchs and chimaeras in the region and information on bathymetric distribution is not provided in the majority of cases. According to the most updated fish checklists, the Levantine Sea hosts at least 78* chondrichthyan species (Table 6.8.).

Studies on deep sea fishes[2] in the Levantine has listed 11 species at depths between 800 and 2,300 m, namely: *Centrophorus* cf *uyato, Chimaera monstrosa, Dalatias licha, Etmopterus spinax, Galeus melastomus, Hexanchus griseus, Mustelus mustelus,* the little sleeper shark *Somniosus rostratus, Squalus acanthias, Squalus blainville, Oxynotus centrina* and *Torpedo marmorata*[31,32]*.* Other species such as the critically endangered Maltese skate *Leucoraja melitensis* or the Brown Stingray *Bathytoshia lata*[2], previously known as *Dasyatis centroura* are known to occur on sandy and muddy substrates down to 800m.

Off the Lebanese coast, several additional species have been found when examining offshore fishing grounds for the local artisanal fishery. Among them, *Raja montagui*, *Raja clavata* and *Raja miraletus, Dipturus oxyrinchus, Heptranchias perlo, Gymnura altavela,* and *Pteroplatytrygon violacea* were observed at depths of more than 200 m [32,33,34]. Furthermore, during the recent Deep-Sea canyon expedition along the Lebanese coast, the velvet belly lanternshark *Etmopterus spinax*, the longnose skate *Dipturus oxyrinchus* and the chimaera *Chimaera monstrosa* were reported at depths greater than 400 m (Fig. 6.7)[35].

2 According to recent taxonomic studies, all past records of Dasyatis centroura or Bathytoshia centroura should be considered as *Bathytoshia lata* (Garman, 1880) - see References[172,173].

Table 6.8. Checklist of chondrichthyans in the Levantine Sea, mentioned by country in the l literature, and their conservation status in the Mediterranean. IUCN Conservation status categories: DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Species	IUCN Status	Turkey	Cyprus	Lebanon	Syria	Israel	Egypt	Reference(s)
Aetomylaeus bovinus	CR	•	•	•	•	•	•	[18,19,34,37,38,39,40,43]
Alopias superciliosus	EN	•	•		•	•	•	[19, 37,38, 40, 165, 167]
Alopias vulpinus	VU	•	•	•		•	•	[19, 18, 31, 32,39, 40,43]
Bathytossia lata	VU	•	•					[165,171]
Carcharhinus altimus	DD	•		•		•	•	[19,32,40,43]
Carcharhinus brevipinna	NT	•	•			•	•	[18, 19,39, 40,43]
Carcharhinus falciformis	NE			•				[32]
Carcharhinus limbatus	NE	•		•		•	•	[19, 36, 40, 43]
Carcharhinus melanopterus	NT		•				•	[39,43]
Carcharhinus obscurus	DD			•	•	•		[34, 37, 38, 40]
Carcharias taurus	CR	•	•			•	•	[19, 39, 40, 43]
Carcharinus plumbeus	EN	•	•	•	•	•	•	[18,19,32,37,38,39,40,43]
Carcharodon carcharias	EN	•	•			•	•	[18,19,39,40,43]
Centrophorus cf uyato	VU	•	•	•	•	•	•	[18,19,32,34,37,38,39,40,43]
Centrophorus moluccensis	DD				•			[37, 38]
Cetorhinus maximus	EN	•	•	•	•	•		[18,19, 32, 37, 38, 40, 165]
Chimaera monstrosa	NT	•		•	•	•	•	[19, 36, 37,38, 40, 41, 164]
Dalatias licha	VU	•	•	•	•	•		[18,19,34, 37,38,39,, 40]
Dasyatis centroura	LC	•	•			•	•	[19, 39, 40, 43]
Dasyatis chrysonota	LC					•		[40]
Dasyatis marmorata	DD	•	•	•		•		[19, 34, 40, 165]
Dasyatis pastinaca	VU	•	•	•	•	•	•	[18,19,34,36,37,38,39,40,41,43]
Dipturus batis	CR	•				•		[18,19,164]
Dipturus oxyrinchus	NT	•	•	•	•	•	•	[8,19,34,36,37,38,39,40,41,43]
Echinorhinus brucus	DD	•					•	[19,41,43]
Etmopterus spinax	LC	•	•	•	•	•	•	[18,19,32,39,40,41,42]
Galeorhinus galeus	VU	•	•				•	[18,19,39,43]
Galeus melastomus	LC	•	•	•	•	•	•	[18,19,34,36,37,38,39,40,41,43,164]
Glaucostegus cemiculus	EN	•	•	•	•	•	•	[19, 34,36,37,38,39, 40, 43]
Gymnura altavela	VU	•	•	•	•	•	•	[18,19,34,36,37,38,39,40,43]
Heptranchias perlo	DD	•	•	•	•	•	•	[19,34,36,37,38,39,40,43]
Hexanchus griseus	LC	•	•	•	•	•	•	[19,34,36,37,38,39,40,43]
Himantura uarnak	VU	•		•	•	•	•	[19, 36, 40, 43,43]
Hydrolagus mirabilis	NT				•		•	[42,43]
Isurus oxyrinchus	CR	•	•	•	•	•	•	[18,19,34,36,37,38,39,40]
Lamna nasus	CR	•	•			•	•	[19, 39, 40, 43]
Leucoraja circularis	CR	•	•		•			[19, 43, 165]
Leucoraja fullonica	CR	•	•					[19, 165]
Leucoraja melitensis	CR	•						[171]
Leucoraja naevus	NT	•	•					[19, 165]
Mobula mobular	EN	•	•	•	•	•	•	[18,19,32,37,38,39,40,43]
Mustelus asterias	VU	•	•	•		•	•	[18,19,32,39,40,43]
Mustelus mustelus	VU	•	•	•	•	•	•	[18,19,34,36,37,38,39,40,43]
Mustelus punctulatus	VU	•	•				•	[18,19,39,43]
Myliobatis aquila	VU	•	•	•		•	•	[18,19,32,40,43, 165]
Odontaspis ferox	EN	•	•	•		•	•	[19, 36,39, 40, 43]
Oxynotus centrina	CR	•	•	•	•	•	•	[18,19,32,37,38,39,40,43,164]
Prionace glauca	CR	•	•	•		•	•	[18,19,36,39,40,43]
Pristis pectinata	CR			•		•		[36, 40]
Pteroplatytrygon violacea	LC	•	•	•	•	•		[19,34,37,38,39, 40]
Raja asterias	NT	•	•			•	•	[19, 39, 40, 41,43]
Raja brachyura	NT		•					[165]
Raja clavata	NT	•	•	•	•	•	•	[18,19,34,37,38, 39, 40, 43]
Raja miraletus	LC	•	•	•	•	•	•	[19, 34,36,37,38,,39, 36, 40, 43]
Raja montagui	NE		•	•				[32, 165]
Raja polystigma	LC		•					[165]
Raja radula	EN	•	•		•	•	•	[18,19,37,38,39,40,43]
Raja undulata	NT		•					[165]
Rhinobatos rhinobatos	EN	•	•	•	•	•	•	[18,19,34,36,37,38,39,40,43]
Rhinoptera marginata	DD	•	•		•	•	•	[18,19, 39,40,42,43]
Rostroraja alba			•				•	[165, 167]
Scyliorhinus canicula	LC	•	•	•	•	•	•	[18,19,32,37,38,39,40,43]
Scyliorhinus stellaris	NT	•	•	•			•	[18,19,32,39,43]
Somniosus rostratus	DD				•			[37, 38]
Sphyrna mokarran	EN		•				•	[39, 43]
Sphyrna zygaena	CR	•	•	•		•	•	[19, 36,39, 40, 43]
Squalus acanthias	EN	•	•	•		•	•	[18,19,36, 39, 40, 43]
Squalus blainvillei	DD	•	•	•	•	•	•	[18,19,34,37,38,39,40,43]
Squalus megalops	DD				•			[37, 38]
Squatina aculeata	CR	•	•	•	•	•	•	[18,19,34,37,38,40,43, 165]
Squatina oculata	CR	•	•	•	•	•	•	[18,19,34,37,38,39,40,43]
Squatina squatina	CR	•	•	•	•	•	•	[18,19,36,37,38,39,40,43]
Taeniurops grabatus	DD	•	•	•	•	•	•	[19, 34, 37,38, 40, 43, 165]
Tetronarce nobiliana	LC	•	•	•	•	•		[18,19,34,37,38,49,40]
Torpedo (Tetronarce) tokionis	DD						•	[41]
Torpedo alexandrinsis	NE						•	[43]
Torpedo marmorata	LC	•	•	•	•	•	•	[18,19,34,36,37,38,39,40,43]
Torpedo sinuspersici	DD				•			[42]
Torpedo torpedo	LC	•	•	•		•	•	[18,19,36,39,40,43]

Fifteen chondrichthyans species have been identified at depths of more than 200 m off the Syrian coast: *Centrophorus moluccensis, Centrophorus* cf *uyato, Chimaera monstrosa, Dalatias licha, Etmopterus spinax, Galeus melastomus, Heptranchias perlo, Hexanchus griseus, Hydrolagus mirabilis, Oxynotus centrina, Scyliorhinus canicula, Somniosus rostratus, Squalus blainville, Squalus megalops* and *Torpedo sinuspersici* between 2000 and 2017 (Prof. Ali Malek, *personal comm.*). Seventeen shark species landed in the port of Lattakia during the period 2014-2016; however, no depth information has been provided[44]. Five species of large pelagic sharks were also reported in the open waters off the Israeli coast, while conducting experimental fishing surveys for swordfish: *Alopias superciliosus, Carcharhinus obscurus, Carcharhinus plumbeus, Isurus oxyrinchus*, and *Prionace glauca*[45,46]. In the Palmahim Disturbance, a salient submarine slide off the continental margin in southern Israel, critical endangered species as Common Skate (*Dipturus batis*) and the Angular Rough Shark (*Oxynotus centrina)* has been recently documented near the coral gardens at a depth of 600-700 meters, and near the cold seeps at 1,150 meters [164]. This site seems to hold also the elusive *Chimera monstrosa* and an remarkable large population of blackmouth catsharks (*Galeus melastomus)*.

Twelve elasmobranch and chimaera species, at depths of more than 300 m, have been observed off the Egyptian coast: *Dasyatis pastinaca, Dipturus oxyrinchus, Raja asterias, Rostroraja alba, Tetronarce tokionis, Echinorhinus brucus, Hexanchus griseus, Galeus melastomus. Centrophorus uyato, Etmopterus spinax,* the large eye rabbitfish *Hydrolagus mirabilis* and *Chimaera monstrosa*; the last four were reported for the first time in Egyptian waters[41,166]. In the south Turkish waters, 15 chondrichthyans at depths of 200-900 m have been reported in Antalya Bay, among them: *Scyliorhinus canicula, Galeus melastomus, Squalus blainville, Etmopterus spinax, Centrophorus* cf *uyato, Heprtanchias perlo, Dalatias licha, Oxynotus centrina, Mustelus mustelus, Carcarhinus plumbeus, Raja clavata* and *Raja miraletus*[49]. In addition, 8 species were further reported at depths of 360-400 m offshore of Iskenderun Bay: *Heptranchias perlo, Squatina aculeata, Galeus melastomus, Etmopterus spinax, Oxynotus centrina, Scyliorhinus canicula, Raja clavata* and *Dipturus oxyrinchus*[48].

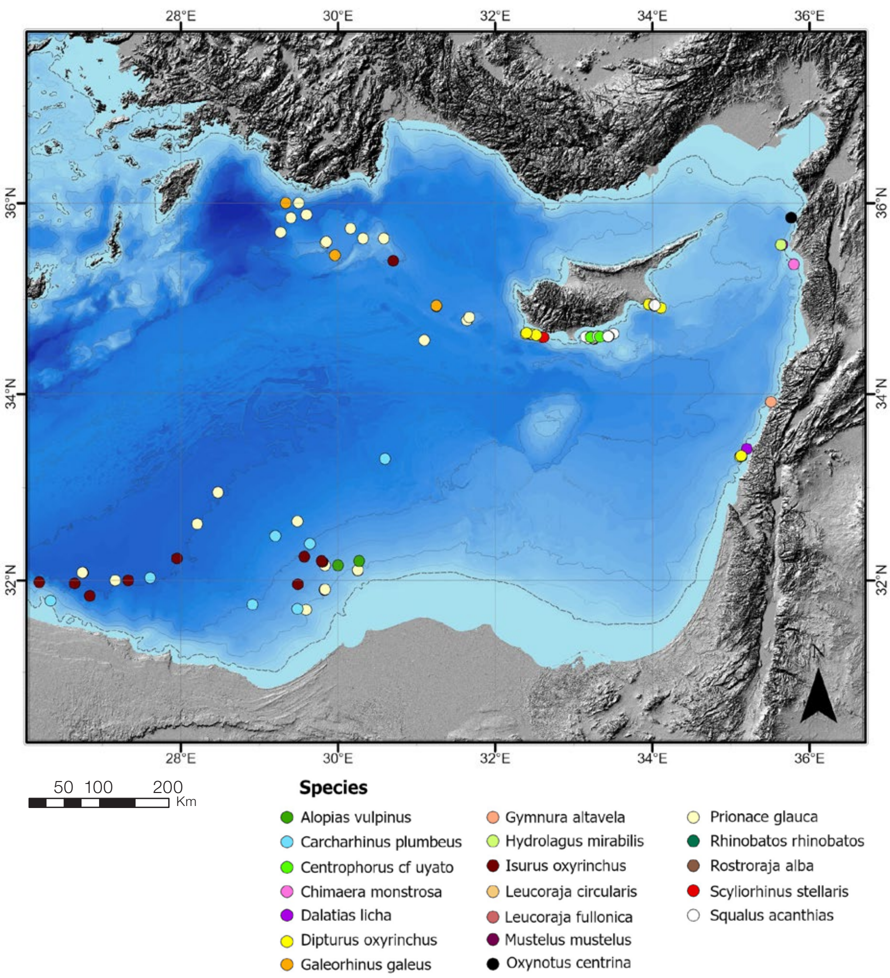


Fig. 6.7. Spatial occurrence of vulnerable chondrichthyans (*Alopias vulpinus* – thresher shark, *Carcharhinus plumbeus* – sandbar shark, *Centrophorus* cf *uyato* – gulper shark, *Chimaera monstrosa* – rabbit fish, *Dalatias licha* – kitefin shark, *Dipturus oxyrinchus* – longnose skate, *Galeorhinus galeus* – tope shark, *Gymnura altavela* – spiny butterfly ray, *Hydrolagus mirabilis* – large-eyed rabbit fish, *Isurus oxyrinchus* – shortfin mako, *Leucoraja circularis* – sandy ray, *Leucoraja fullonica* – shagreen skate, *Mustelus mustelus* – smooth hound, *Oxynotus centrina* – angular rough shark, *Prionace glauca* – blue shark, *Rhinobatos rhinobatos* – common guitarfish, *Rostroraja alba* – white skate, *Scyliorhinus stellaris* - nursehound, *Squalus acanthias* – picked dogfish) in the Levantine Sea[16,34,45,46,47,48,49].

The most comprehensive set of data comes from Cyprus, under the annual MEDITS surveys with thirteen and six species exclusively reported in depths > 200 m and depths < 200 m, respectively (Table 6.9.; Fig. 6.7). Five large pelagic shark species have been additionally reported over the deep open Cypriot waters during 1998 and 2005: the Critically Endangered species of blue shark *Prionace glauca* and shortfin mako *Isurus oxyrinchus,* the Endangered thresher shark *Alopias vulpinus,* the tope shark *Galeorhinus galeus,* with the occasional sighting of endangered sandbar shark *Carcharhinus plumbeus* ([16] – Fig. 6.7).

Table 6.9. Occurrence by depth for the chondrichthyan species identified during 2005-2017 in the Cypriot marine region (MEDITS survey), their IUCN Red List status and percentage of occurrence in waters > 200 m.

Species	IUCN Red List Status	Min-Max depth	% Occurrences > 200 m
Centrophorus cf uyato	CR	601-622 (25)	100%
Chimaera monstrosa	NT	612 (1)	100%
Etmopterus spinax	LC	525-622 (2607)	100%
Galeus melastomus	LC	525-622 (869)	100%
Heptranchias perlo	DD	570-622 (71)	100%
Hexanchus griseus	LC	578-614 (6)	100%
Leucoraja circularis	CR	612-616 (2)	100%
Leucoraja fullonica	CR	602-614(2)	100%
Mustelus mustelus	VU	254 (2)	100%
Rostroraja alba	CR	603 (1)	100%
Scyliorhinus stellaris	NT	260 (7)	100%
*Squalus acanthias**	EN	287-621 (168)	100%
Squalus blainville	DD	298-622 (59)	100%
Dipturus oxyrinchus	NT		97%
Raja brachyura	NT		89%
Scyliorhinus canicula	LC		88%

Species	IUCN Red List Status	% Occurrences > 200 m
Oxynotus centrina	CR	73%
Raja polystigma	LC	67%
Tetronarce nobiliana	LC	66%
Raja spp.		60%
Raja clavata	NT	51%
Raja asterias	NT	50%
Torpedo marmorata	LC	50%
Raja montagui	LC	43%
Dasyatis pastinaca	VU	1%
Dasyatis centroura	LC	0%
Leucoraja naevus	NT	0%
Raja miraletus	LC	0%
Raja radula	EN	0%
Raja undulata	EN	0%
Torpedo torpedo	LC	0%

*Perhaps two or three different species involved[17].

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The nursehound (*Scyliorhinus stellaris*), also known as the large-spotted dogfish, is a medium-large catshark found at depths of less than 5 metres to ~400 m in the Mediterranean. It is taken as bycatch in bottom trawl, gill net, and longline gears, and targeted by artisanal fisheries for local consumption. At present, it is listed as Near Threatened given the evidences of declines in different areas and its patchy distribution.

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The Common Blue Skate (*Dipturus batis*) is a Global Critically Endangered species once abundant from shallow shelf and continental slope areas as deep as 600m. More efforts are needed in clarifying the current status and taxonomy of this species in the Mediterranean.

STATUS OF THREATENED CHONDRICHTHYAN SPECIES IN THE DEEP WATERS OF THE EASTERN MEDITERRANEAN

The present analysis shows that at least 61 cartilaginous species have been reported at depths of over 200 metres in the Eastern Mediterranean Sea (Table 6.10.). The South Aegean (43) and the Levantine (41) were the areas with the highest number of species observed, in contrast to the Libyan Sea (19). It is more likely that the uneven research effort exerted in each area has biased these estimates.

Table 6.10. Summarised list of sharks, skates and rays species reported at depths of over 200 metres in the Eastern Mediterranean. IUCN Conservation status categories: DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Species	IUCN Status	Eastern Ionian	N. Aegean	S. Aegean	Libyan Sea	Levantine
Alopias superciliosus	EN			•	•	
Alopias vulpinus	VU		•	•	•	•
Bathytosia lata	VU					•
Carcharias taurus	CR		•			
Carcharinus plumbeus	EN					•
Carcharodon carcharias	EN				•	
Centrophorus cf uyato	DD	•	•	•		•
Centrophorus moluccensis	DD					•
Cetorhinus maximus	EN		•			
Chimaera monstrosa	NT	•	•	•		•
Dalatias licha	VU	•	•	•		•
Dasyatis centroura	LC			•		
Dasyatis pastinaca	VU	•	•	•		•
Dipturus batis	CR	•				•
Dipturus oxyrinchus	NT	•	•	•	•	•
Echinorhinus brucus	DD		•			•
Etmopterus spinax	LC	•	•	•		•
Galeocerdo cuvier	DD				•	
Galeorhinus galeus	VU	•		•	•	•
Galeus melastomus	LC	•	•	•		•
Gymnura altavela	VU					•
Heptranchias perlo	DD	•	•	•		•
Hexanchus griseus	LC	•	•	•		•
Hexanchus nakamurai	DD			•		
Hydrolagus mirabilis	NT					•
Isurus oxyrinchus	CR			•	•	•
Leucoraja circularis	CR	•	•	•		•
Leucoraja fullonica	CR		•	•		•
Leucoraja melitensis	CR		•	•		•
Leucoraja naevus	NT		•	•		
Mustelus asterias	VU		•	•		
Mustelus mustelus	VU	•	•	•	•	•
Mustelus punctulatus	VU			•		
Myliobatis aquila	VU		•			
Odontaspis ferox	EN			•		
Oxynotus centrina	CR	•	•	•	•	•
Prionace glauca	CR	•	•	•	•	•
Pteroplatytrygon violacea	LC	•				•
Raja asterias	NT	•	•	•	•	•
Raja brachyura	NT	•	•	•		•
Raja clavata	NT	•	•	•	•	•
Raja miraletus	LC	•	•	•	•	•
Raja montagui	LC	•	•	•		•
Raja polystigma	LC	•	•	•		•
Raja radula	EN		•			
Raja rondeleti	EN	•		•		
Rhinobatos rhinobatos	EN	•		•		
Rhizoprionodon acutus	LC	•				
Rostroraja alba	CR		•	•	•	•
Scyliorhinus canicula	LC	•	•	•	•	•
Scyliorhinus stellaris	NT	•	•	•		•
Somniosus rostratus	DD					•
Squalus acanthias	EN	•	•	•	•	•
Squalus blainvillei	DD	•	•	•		•
Squalus megalops	DD					•
Squatina aculeata	CR			•	•	•
Squatina oculata	CR			•	•	
Torpedo marmorata	LC	•	•	•		•
Tetronarce nobiliana	LC	•	•	•	•	•
Torpedo sinuspersici	DD					•
Tetronarce tokionis	DD					•
Torpedo torpedo	LC	•		•		
Total		32	36	43	19	44

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> “Bycatch, the unintentional capture of non-targeted species during fishing operations, is considered as one of the most important factor in causing the decline of marine species worldwide, including vulnerable shark and ray species in the Mediterranean[4,50]”

From the 61 chondrichthyan species reported in the E. Mediterranean at > 200 m depth, 36 are of conservation concern and listed as Critically Endangered, Endangered, Vulnerable or Near Threatened. Present knowledge indicates that the Libyan Sea seems to have the highest percentage (79%) of vulnerable deep-water species of sharks, rays and chimaeras, with the Ionian Sea exhibiting the lowest values (50%) (Table 6.11.).

Table 6.11. Percentage of vulnerable chondrichthyan species reported at depths of over 200 metres, by study area, in the Eastern Mediterranean Sea (IUCN Red List Mediterranean status).

Area	% of vulnerable species
Libyan Sea	78.9
N. Aegean Sea	63.9
S. Aegean Sea	62.8
Levantine	53.7
Eastern Ionian Sea	50.0
Total	**59.0**

Today, a number of shark and ray species have been declared protected (i.e. cannot be kept on board, transferred, landed, stored, sold or in display) according to various international (EU Regulation 2102 (2015), GFCM/44/2021/16[3], GFCM/42/2018/2[4], ICCAT, Barcelona SP/BD Protocol) or national regulations (e.g. Greek National Ministry Directive 4531/2016 and Central Hunting Commission of Turkey 2019-2020 Resolutions).

Data has increased over time and has become more reliable as monitoring programmes (including on-board observers, interviews with fishers and logbooks) increase, along with data standardization. However, the current available information is still biased since efforts have been unequal over the Eastern Mediterranean Sea. For a few pelagic shark species, the Eastern Mediterranean region has been suggested to have some breeding or nursery grounds at shallow areas within the continental shelf (the great white shark *Carcharodon carcharias*[51] and the sandbar shark *Carcharhinus plumbeus*[52]). Additionally, research with underwater remotely operated vehicles on deep-water cold seep sites has provided proof of nursery areas at deep sites such as those of the blackmouth catshark (*Galeus melastomus*) egg-cases found between tubeworms or lying on the nearby ground of the North Alex Mud Volcano (depth 500 m – West Nile Delta, Egypt[53]) and Palmahim Disturbance off Israel coast close to deep brine pools and brine seeps.

3 Recommendation GFCM/44/2021/16 on additional conservation and mitigation measures for the conservation of elasmobranchs in the Mediterranean Sea

4 Recommendation GFCM/42/2018/2 on fisheries management measures for the conservation of sharks and rays in the GFCM area of application, amending Recommendation GFCM/36/2012/3

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Deep-sea cetaceans and sea turtles

Kapiris K., Otero M, Christidis G., Thasitis I., Gücü A.C., Lteif M., Ali M., Farrag, M.M.S., Dokos J., Kavadas S., Schüler M.

> “Among the cetacean species regularly encountered, the sperm whale, Cuvier’ s beaked whale and long-finned pilot whale are deep-diving species, that due to the short surface period and long dive time, make difficult their observation at sea”

Despite being a small part of the world’s oceans, the Mediterranean Sea hosts a diverse marine mammal fauna, with a total of 28 different species known to occur, or to have occurred, in the region. Species currently recognised as regular in these waters are the Mediterranean monk seal (*Monachus monachus*) and 11 cetaceans (fin whale, *Balaenoptera physalus*; sperm whale, *Physeter macrocephalus*; Cuvier’s beaked whale, *Ziphius cavirostris*; short-beaked common dolphin, *Delphinus delphis*; long-finned pilot whale, *Globicephala melas*; Risso’s dolphin, *Grampus griseus*; killer whale, *Orcinus orca*; striped dolphin, *Stenella coeruleoalba*; rough-toothed dolphin, *Steno bredanensis*; common bottlenose dolphin, *Tursiops truncatus;* harbour porpoise, *Phocoena phocoena* relicta) that have been adapted well to the region’s environmental conditions, but their coexistence with human is problematic[54].

Other cetacean species that can occur in the Eastern Mediterranean waters are the rough-toothed dolphin (*Steno bredanensis*), considered only an occasional species and found primarily in the eastern part[55,56]; the endangered Black Sea harbor porpoise, *Phocoena phocoena relicta* that has been increasingly sighted in recent years in the North Aegean Sea[57] and the Indian Ocean humpback dolphin, *Sousa plumbea* a shallow-water non-native dolphin, with recent observations in Greek waters[58].

Risso’s dolphins also inhabit deep waters, common between 400 and 1,000 metres depth close to the continental slope and platform or associated to offshore archipelagos[59]. Other cetaceans are mainly found in waters shallower than 200 m depths or they display occasional or less common presence in offshore deep-waters.

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The preferred habitat of Risso’s Dolphins in the Mediterranean is continental slope waters with steep relief. The decline of abundance in part of its range, smaller area of distribution with their site fidelity categorised the species for the first time as Endangered in 2021.

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Sperm whales continue to be listed as Endangered species in the Mediterranean in 2021. Available data sources suggest that there are still fewer than 2500 mature individuals in the Mediterranean subpopulation and their decline is still ongoing from multiple threats, particularly with the increasing maritime traffic.

The Cuvier's beaked whale, *Ziphius cavirostris*, is frequently associated with high slope habitats with preference for submarine canyons and escarpments[60,61]. It is known to occurs at water depths exceeding 500–1,000 m, with a distinctive preference for depths of 1,000 m[62] and preys on various species of squids[63]. Much of the knowledge of its presence and distribution comes from stranding data but occasional sightings at sea are also reported. They occur mostly in small groups of 2 to 7, but are not uncommonly seen alone. Recently, it has been estimated that the Mediterranean subpopulation of Cuvier´s beaked whales is of approximately 3,700 individuals occurring in few, relatively high density areas. The Alboran Sea, the Hellenic Trench, the Southern Adriatic Sea, the Ligurian Sea and the Tyrrhenian Sea were indicated as high-density areas for the species.

Several reports pointed out that Cuvier's beaked whales are particularly affected by high-intensity military sonar and seismic surveying activities, due to the formation of air bubbles in their body which produce chronic and acute damage in their tissues resulting finally in their stranding[64,65,66]. The conservation status of the species in the Mediterranean has recently passed from Data Deficient to Vulnerable, thus showing the urgent need to address further conservation measures and address the gaps in knowledge on its bio-ecological features, suitable habitat and threats at local or wider scale.

The sperm whale, *Physeter macrocephalus*, is a truly cosmopolitan species, whose distribution is thought to be more extensive than that of any other marine mammal. Sperm whales swim in deep waters down to depths of 3,219 m, apparently limited only by the time it takes to swim down and back to the surface. Their distribution depend upon season and sexual/social status, however they are most likely to be found in waters inhabited by squid - at least 1,000 m deep - and with cold-water upwellings. The Mediterranean subpopulation of the sperm whales is genetically distinct from the Atlantic one and it contains fewer than 2,500 mature individuals with a continuing decline in numbers of mature individuals[5]. Sperm whales are thought to roam widely across the Mediterranean and pass between the Eastern and the Western Mediterranean deep water basins[67]. At present, they are classified as Endangered in the IUCN Red List in the Mediterranean due to a number of threats that can result in direct mortality. Among the most important ones are ship strikes, debris ingestion, illegal fishing using drift nets and noise disturbance (particularly related to intense maritime traffic, seismic surveys for oil and gas exploration and military sonar activities). Six **Im-**

5 https://www.iucnredlist.org/

portant Marine Mammal Areas (IMMAs)[6] have been designated in the Mediterranean for their importance to Sperm Whales: the Alborán Corridor and Alborán Deep, the Campanian and Pontino Archipelago, the Hellenic Trench, the Balearic Islands Shelf and Slope, and the North West Mediterranean Sea, Slope and Canyon System (Fig. 6.8). In addition, other potential sites have been identified in the Northern Sporades, the Shelf of the Gulf of Lion, the Strait of Gibraltar and Gulf of Cadiz, the waters of Ischia and Ventotene, and the Western Ligurian Sea and Genoa Canyon IMMAs.

The Long-finned Pilot Whale (*Globicephala melas*) is a predominantly offshore cetacean with a preference for deep waters of the continental shelf and slopes, generally deeper than 500 m[68,69]. They are found almost exclusively in the western basin[70] and no information exists about its possible presence in the Eastern basin.
The Risso's dolphin, *Grampus griseus,* is considered a regular inhabitant of the Mediterranean, although scarcer in the Eastern basin probably due to the paucity of regional surveys[71,72]. It inhabits waters between 300 and 1,500 metres deep, which are close to the continental slope and platform or associated to offshore archipelagos[59,73]. There are different Mediterranean studies suggesting that the species shows preferences for waters above the continental slope, especially those areas with steep slopes and submarine canyons[74,75,76]. Although, the mean depth for this species varies between 700 and 1,280 metres with a peak at 1,000 metres, it has also been spotted in waters from 400 to 1,700 metres deep and in coastal waters where their abundance is estimated to be decreasing[7]. In the Mediterranean Sea, Risso's Dolphins are genetically differentiated from those in the Eastern Atlantic[77]. The principal known threats for the populations in the Mediterranean that may be causing declines for the species include bycatch in offshore gillnets, pelagic longlines, and other fishing gear. Other likely reasons for the estimated declines might be attributed to environmental variability effects (habitat degradation or climate change effects) combined with the impact of fishery on prey availability as well as higher impact of maritime traffic in more coastal areas that force the species to move in more pelagic areas[78]. Based on the estimated decline in the number of individuals at a local scale and the decrease in the area of occupancy the species is currently classified as Vulnerable in the IUCN listing for this species.

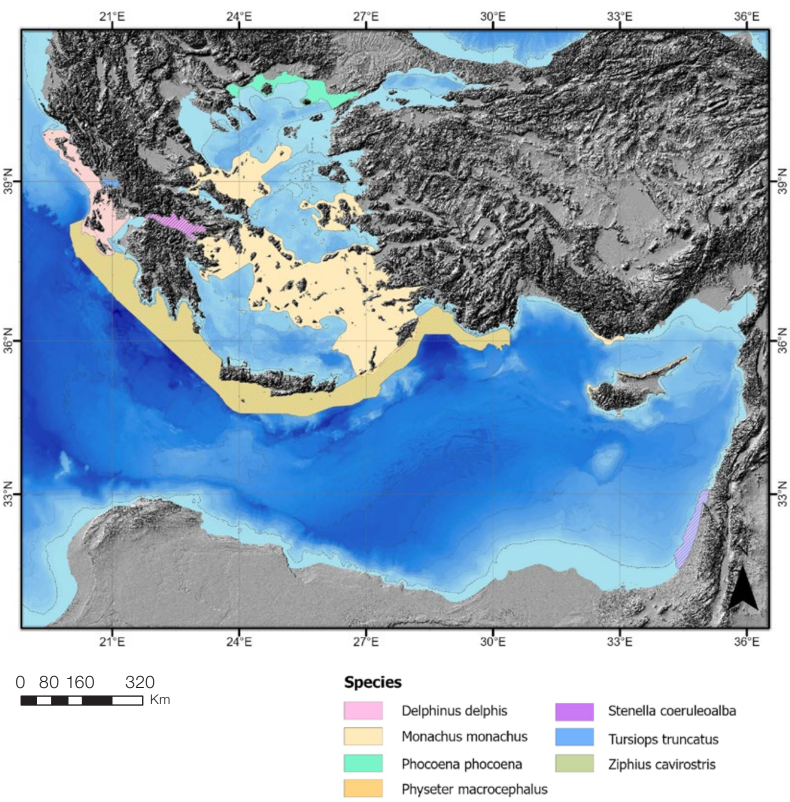

Fig. 6.8. Important Marine Mammal Areas (IMMAs) indicating the respective species for designation (*Delphinus delphis* – common dolphin, *Monachus monachus* – Mediterranean monk seal, *Phocoena phocoena* – harbour porpoise, *Physeter macrocephalus* – sperm whale, *Stenella coerueoalba* – striped dolphin, *Tursiops truncatus* – Atlantic bottlenose dolphin, *Ziphius cavirostris* – Cuvier's beaked whale).

6 https://www.marinemammalhabitat.org/immas/
7 https://www.iucnredlist.org/

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Until recently, entanglement in pelagic driftnets had been the principal threat to sperm whales. Entanglements have decreased in recent years, but this source of mortality is ongoing.

Other benthopelagic and deeper cetacean divers shows only an occasional presence in the Eastern Mediterranean. The strandings of the fin whale *Balaenoptera physalus* are very rare and only few individuals of this species had been reported in the Eastern Mediterranean such as in Greek waters[79]. The humpback whale, *Megaptera novaeangliae* and the common minke whale, *B. acutorostrata*, are considered rare visitors to the Mediterranean, with less than a one sighting or stranded record per species, per year[80]. The false killer whale (*Pseudorca crassidens*) is a cosmopolitan species of the open sea, but it is very rare along the European and Mediterranean coasts[71].

Records on fishing interactions 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[4]. Present knowledge indicates that 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 and few records shows incidental bycatch with deep cetacean divers. Drifting longline has been reported to bycatch some individuals of long-finned pilot whales, *Globicephala melas* and Risso's dolphins, *Grampus griseus* as well as one sperm whale *Physeter microcephalus* in the Western Mediterranean[81,82].

The relationships between marine mammals and plastic pollution is not well studied in the Eastern Mediterranean until now, although macroplastic debris (> 5 mm) were found in the stomachs of different cetaceans from four species (harbour porpoise, Risso's dolphin, Cuvier's beaked whale and sperm whale) with the highest frequency of occurrence in sperm whales (60%) stranded in Greece[83].

Sea turtles

Out of the seven species of sea turtles currently inhabiting the world's oceans, only two of them breed in the region: loggerheads (*Caretta caretta*) and green (*Chelonia mydas*). There are also occasional records of leatherbacks (*Dermochelys coriacea*), olive and Kemp's ridleys (*Lepidochelys olivacea* and *Lepidochelys kempii*)[84].

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Green sea turtle *Chelonia mydas* are a global endangered species that have undergone a large population decrease over the past half century.

From them, only the leatherback turtle is considered a deep-water diver, as can dive for as long as an hour to depths as much as 1,000 m. Although leatherback turtles mainly inhabit the Atlantic and Pacific Oceans, occasionally enter the Mediterranean Sea, and most of the sightings had been made from the western part of the Mediterranean and the North Africa coast[85,86]. 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, adults and large juveniles (> 145 cm), from Atlantic populations. Nesting of this species is absent or exceptional in the Mediterranean[87], therefore, the leatherback turtles found in the region are likely to be of Atlantic origin[88].

Leatherback turtles (*Dermochelys coriacea*) are globally threatened and classed as Vulnerable in the IUCN Red List of threatened species due to anthropogenic impacts on populations worldwide[89]. This is mainly due to egg poaching on nesting beaches in other areas outside the Mediterranean[90], bycatch from longline fisheries[91,92] and drift-netting[93].

It is being estimated that around 121,000 sea turtles, mostly loggerheads and green turtles, are potentially caught in the Mediterranean each year, with about 33,000 considered potentially dead[4]. According to this Mediterranean review, in the last ten years, bottom trawlers seem to represent the fishery with the greatest impact on sea turtles (17.6%) followed by drifting longline and set net fisheries while other types of fishing gear might have a localised impact when overlap with important foraging areas for sea turtles (as in Egypt, Turkey and Israel). Reported cases of bycatch of leatherbacks (*Dermochelys coriacea*) are rare[4] and ultimately the bycatch-induced mortality will depend on the capacities of sea turtles to survive.

Information on the diving behaviour of leatherbacks at non-breeding grounds is limited, derived from satellite tracking or animal-borne cameras, and most of the information is from post nesting females[94]. However, the lack of information regarding the population size and demographic characteristics of leatherback turtles in the whole Mediterranean basin impedes our understanding how the anthropogenic impact affects the status of this species in the area.

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The leatherback turtle (*Dermochelys coriacea*), is considered a deep-water diver, globally threatened and classed as Vulnerable in the IUCN Red List.

Few records are available from the Eastern Mediterranean, including specimens caught by drift nets, trammel nets, bottom trawl, coastal fisheries and unknown fishing gears off Greek[95], Syrian[96], Israeli[97], Cypriot, Egyptian[86] and Turkish waters[4,98]).

DATA INFORMATION

The following section provides a brief review on the presence records of deep-sea cetaceans and sea turtles of the Eastern Mediterranean, with information on status, spatial and depth occurrence when known. Knowledge on the distribution of all these deep-water diving species is mainly referred to the western Mediterranean region and there is a limited and fragmented information on their distribution in the Eastern Mediterranean. Most of this knowledge originates from acoustic surveys, sporadic sightings and stranding data.

Stranding data (including injured and dead cetaceans, marine turtles and other marine mammals) were obtained mainly through the national stranding networks when established, such as by the Hellenic Centre for Marine Research in collaboration with the Port Police authorities (Kapiris, *unpubl. data).* This network provides information to various recipients (ministries, research centres and NGOs) from data collected during mainly the period 2011-2016, and occasionally also the previous years. The database includes data concerning the species identification, geographical area of findings, body characteristics, cause of mortality according to the Port Authorities data and photos.

Observational information comes from sightings during aerial and photo-identification surveys, some regular monitoring efforts, and the basin-wide acoustic and block surveys carried out in 2018 as part of the ACCOBAMS Survey Initiative[99] (ASI)[8]. Other data gathered in the present work are coming from the bibliographic resources (papers, press and reports) and from personal communication with the relevant Authorities and scientists from some countries.

Available data on sea turtle and cetacean bycatch in the Mediterranean Sea has recently reviewed and provided a first indication where fishing activities overlap with sea turtle and cetacean habitats[4]. Nevertheless, data for some countries and types of fishing gear are missing and recent initiatives are complementing the gaps in several countries as Turkey and Cyprus.[9]

EASTERN IONIAN SEA

The Ionian is characterized by significant upwellings that guarantee the regular sightings of six species: striped dolphin (*Stenella coeruleoalba*), common bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*), Cuvier's beaked whale (*Ziphius cavirostris*), sperm whale (*Physeter macrocephalus*) and Risso's dolphin (*Grampus griseus*). In the Eastern Ionian, up to eleven cetacean species have been identified to occur and seven of them are found in deep and offshore waters (Fig. 6.9). including the rough-toothed dolphin (*Steno bredanensis*) a species to be part of a relict population that detached from the Atlantic population[56]. Other two species, the harbour porpoise (*Phocoena phocoena*) and the fin whale (*Balaenoptera physalus*), have been recorded locally in all seasons. One sighting of humpback whale (*Megaptera novaeangliae*) has been reported in the inner Ionian and one stranding in the south part of Corfu Island because of entanglement in fishing gear[100]. A dubious record of beaked whale (*Mesoplodon densirostris*) is also available for the E. Ionian Sea. The Gulf of Corinth also holds a isolated Striped Dolphin (*Stenella coeruleoalba*) subpopulation and a Short-beaked common dolphin (*Delphinus delphis*) subpopulation confined in this semi-enclosed bay with no evidence of individuals crossing the narrow Strait of Rion which connects the Gulf to open Ionian Sea waters. These supopulations are listed endangered and critically endangered, respectively. In the Gulf of Ambracia, another isolated population of *Tursiops truncatus* of less than 175 individuals is listed as critically endangered as a result of the increasingly degraded condition of the Gulf's water quality.

Sperm whales sightings and strandings have been recorded North-West Zakynthos Island[101] and West Peloponnisos coasts[102] along the North-West Hellenic Trench. According to various studies, a small and quite discrete sperm whale population unit is found in the Hellenic Trench that ranges from the Ionian Sea to the South Cretan Sea. The Hellenic Trench is a key area (IMMA) for sperm whales in Eastern Mediterranean Sea and possibly constitutes the most important habitat in this basin. Mass strandings of sperm whales are extremely rare in the Mediterranean Sea[103] and are also infrequent reported along the eastern Ionian coast, probably cause

8 https://accobams.org/main-activites/accobams-survey-initiative-2/accobams-survey-initiative/
9 MAVA Medbycatch and Cyprus bycatch project.

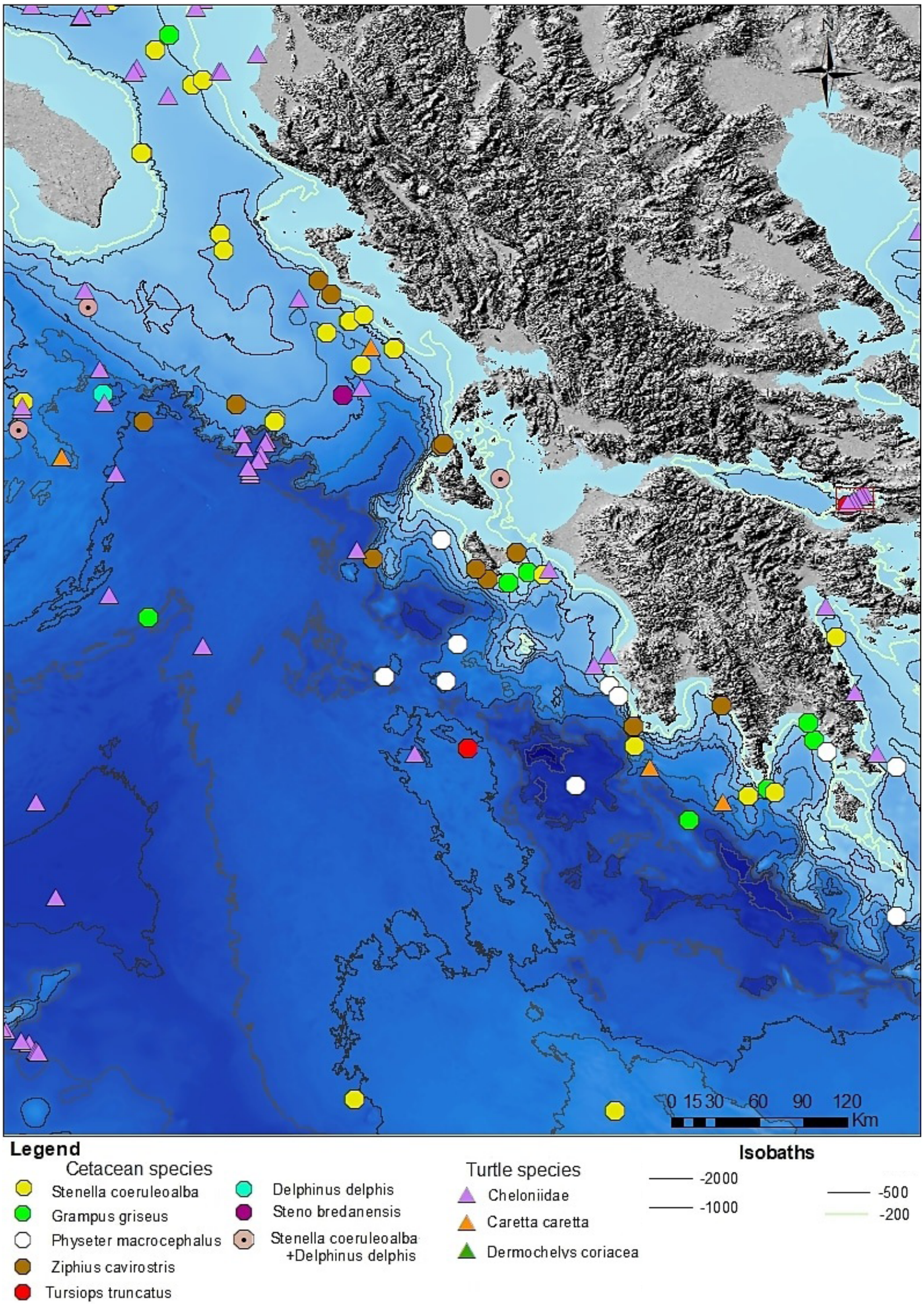

Fig. 6.9. Sightings of cetaceans and sea turtles in the Ionian Sea in offshore waters deeper than 200m. Data: ACCOBAMS Survey Initiative

by the deep seafloor morphology and wide abyssal plain that can limit risks of death. Causes of the strandings are often difficult to determine, but starvation and morbilliviruses have both been implicated in some events.

In the period 1991-2008, 1,352 strandings of deep-water cetaceans had been reported from all the Eastern Ionian Sea with eighty-two of them were Cuvier's beaked whales, while nineteen were sperm whales[100]. During the same period, 72 strandings of Cuvier's beaked whale have been recorded along the Greek Ionian and Aegean coasts, showing a mean value of 7.2 ind./year and representing the 10.7% of the total cetaceans strandings, with 37 individuals recorded in the area of E. Ionian Sea[79]. Most of the dead Cuvier's beaked whales are thought to be related to the military exercises of the Italian Navy using the military sonar, which occurred in the Ionian Sea over this

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Recent data provide a better significantly better understanding of the status of the Mediterranean sub-population of Striped Dolphin (*Stenella coeruleoalba*) and in 2021 is listed as Least Concern in the IUCN Red list. Striped Dolphins in the Gulf of Corinth are considered a geographically and genetically isolated population composed circa of 1,331 individuals and listed as Endangered.

period[10]. According to unofficial information, the local and apparently small Ionian population unit of Cuvier's beaked whales has suffered three stranding events in the past (plus one in east Sicily earlier) coinciding in time and space with the use of military exercises. However, the exact mortality reason of the dead Cuvier's beaked whales has never been documented.

Previous reports pointed out that the mass stranding event of Cuvier's beaked whale in Kyparisiakos Gulf in 1996, consisting of 14 animals (and reported later 16), was the first case reported in the Mediterranean Sea that was identified as being correlated in both space and time with sonar activities[104,105,106,107]. Two more mass strandings in October 1997, totalled 12 animals of Cuvier's beaked whale, took place in the same area (approximately 34 nm apart) and in the same time frame (within four days)[108]. The strandings of this species are more numerous in the Ionian Sea, than in other areas of the E. Mediterranean providing evidence of large aggregation of the species in this Sea[109]. These observations have made the Northern Ionian Sea be ranked as an area hosting preferential habitats of Cuvier's Beaked whales, implying also the need for protection of this area, at least in what it concerns military surveys.

Over the period from 2011 to 2016, a number of strandings of the cetaceans Cuvier's beaked whale (*Ziphius cavirostris*), sperm whale (*Physeter macrocephalus*) and Risso's dolphin (*Grampus griseus*) and leatherback turtle (*Dermochelys coriacea*), have been reported from the geographical area of the Eastern Ionian Sea. It has been noted here that no strandings of the above species has been reported in 2015 and none for Risso's dolphin (Fig. 6.10). This random incident cannot be attributed to certain specific causes.

Strandings have been reported from different areas of the Eastern Ionian Sea with most Cuvier's beaked whale carcasses have been found in the western and eastern coast of Corfu Island, while those of sperm whales are distributed along all the E. Ionian coasts; in Corfu (mainly in 2011), Lefkas, Paxi Islands and the south coasts of Peloponnese (Fig. 6.11).

Leatherbacks have been reported from the Ionian and the Aegean Seas, including coastal areas[110]. Overall, the species is considered very rare and sporadic in the E. Ionian while important nesting grounds of the logger-

10 http://www.pelagosinstitute.gr/gr/erevnitika_programmata/zifioi.html

head sea turtle *Caretta caretta* exist and observations of sea turtles are common[84]. In the past, leatherbacks have been reported from both regions with few strandings occasionally occurring as those reported in Korinthiakos Gulf in 2013 and in Kefallinia Island in 2016 (Fig. 6.11). Stranding events occur throughout the year with the lowest frequency occurring in spring and summer. According to the information provided by the local Port Authorities, approximately 36% of the events were attributed to unknown causes while 13.6% were human-related (fishery activity, boat strike, deliberate killing). Reference reports of bycatch are few related to drifting longline during surveys conducted during 1999-2000 and an estimated mortality rate of 4.7%[111].


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Fishing bycatch of a leatherback turtle (*Dermochelys coriacea*).

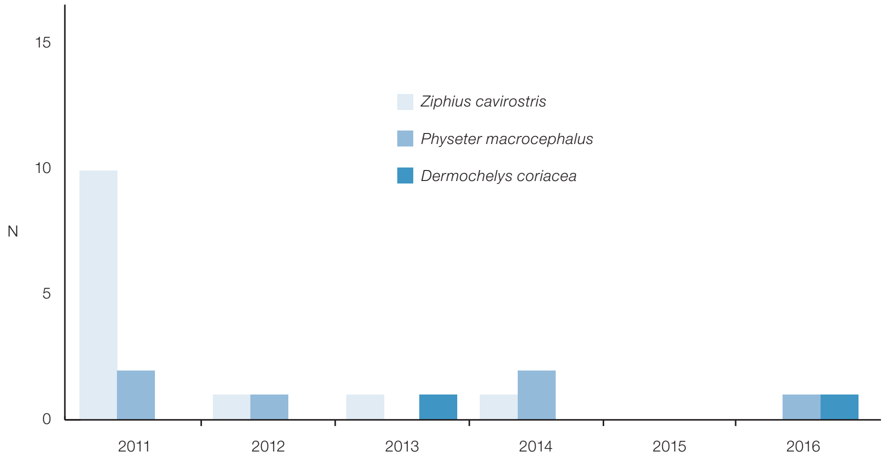

Fig. 6.10. Number of stranded Cuvier's beaked whale, *Ziphius cavirostris*, sperm whale, *Physeter macrocephalus* and Leatherback turtle, *Dermochelys coriacea* in the E. Ionian Sea during the period 2011-2016. Data source: HCMR Data base.

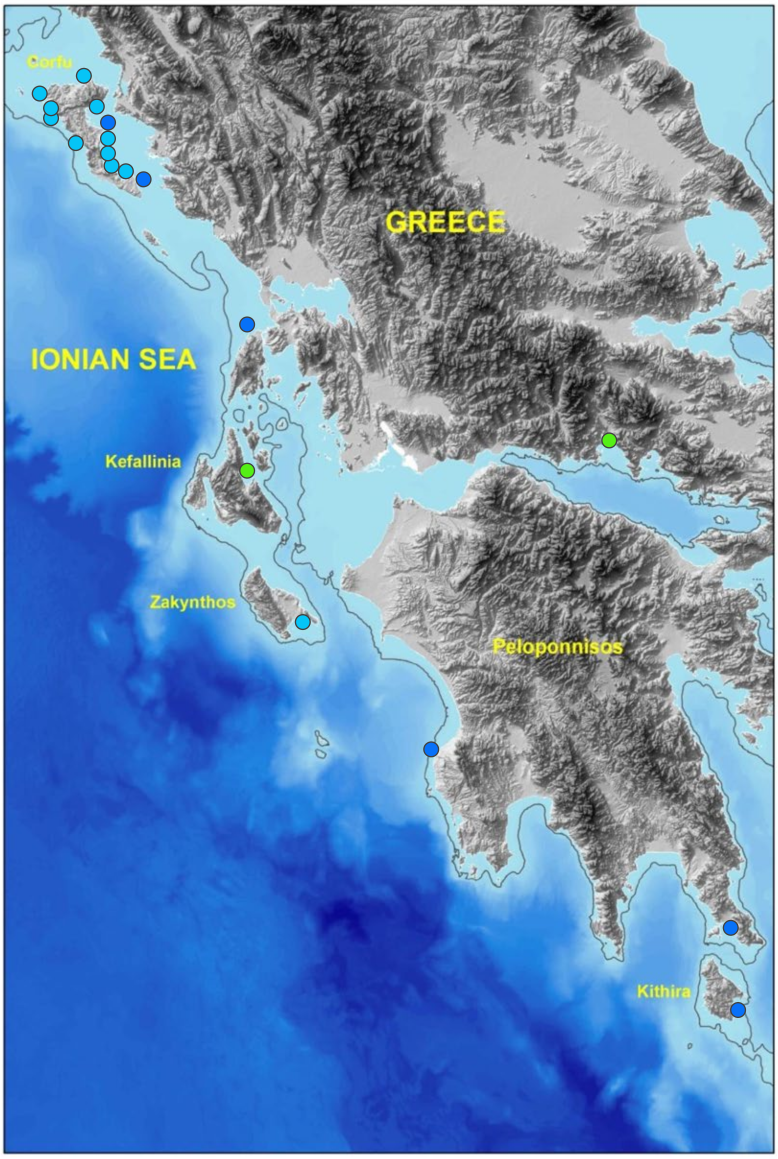

Fig. 6.11. Strandings areas of Cuvier's beaked whale, *Ziphius cavirostris* (light blue), sperm whale, *Physeter macrocephalus* (dark blue) and Leatherback turtle, *Dermochelys coriacea* (green) in the E. Ionian Sea during the period 2011-2016.

2 NORTH AEGEAN SEA

The North Aegean Sea has been stated as one of the most important areas for cetacean species in the Mediterranean. Northern Sporades, Chios and Turkish waters were identified as Important Marine Mammal Habitat due to its importance for the Mediterranean Monk Seals and Thracian Sea is delineated as an IMMA for the presence of harbor porpoises. Several Cetacean Critical Habitats (CCH) has been identified in the waters surrounding the northern Sporades, the northern Aegean Sea and the Turkish Straits system[11].

The presence of several deep-water cetaceans in the offshore waters of the North Aegean Sea is also documented by several studies involving opportunistic sighting reports, stranding records, fishing reports and hydrophone sound recordings[112,113] (Fig. 6.12). Despite the relevance of the entire region, there is only a handful of dedicated survey efforts existing in the area, with none of them consisting of a year-round effort and quantitative data on encounter rates and relative abundance, as well as distribution analyses of cetacean species for this region are still missing[100,113,114].

Sperm whales in offshore waters have been recently observed in northern Skopelos (between N. Skopelos, Sporades, and the Chalkidi peninsula) and Northern Mykonos basin as well as in the Ikaria Basin[113,115] (Fig. 6.12). The presence and distribution of the sperm whales is highly depended on prey availability, which is found at depths of 500-1,000 m[116,117], but individuals around these basins have been found as deep as 3,600m[115]. The proximity of these sites to main core habitats such as the Hellenic Trench as well as the presence of canyons and small and larger seamounts has been suggested as reasons for their presence on these waters.

Cuvier's beaked whales (*Ziphius cavirostris*) are often found in association with the sea canyons and steep escarpments. In the North Aegean region, their presence has been confirmed with acoustic surveys and field observations in the western North Aegean Through Canyons, northern Sporades to north of Lemnos Island, the Edremit Trough north of Lesbos and in the North Ikarian Basin[99,103,115,118]. The geomorphology of the North Ikarian Basin with its steep slope has been suggested to provide a suitable habitat for these whales to prey representing an important area for this rarely observed whale.

Risso's dolphin´s typical habitat is open waters offshore of North Aegean Sea and it is often found along the continental shelf and slopes as also confirmed by sightings observed off Chalkidi peninsula, the Skopelos basin and the Saronic Gulf[99]. Other no common deep-diving species such as striped dolphins and bottlenose dolphins are reported from the area. Striped dolphins are known to inhabit offshore waters from Aegean Sea and have been sighted in different locations, sometimes overlapping with the areas with common dolphins. Bottlenose dolphins are also commonly encountered along the continental shelf and in deeper waters in this region and it is known that several coastal waters in the North Aegean such as of the Gulf of Kavala, North Thassos and Foça, are important bottlenose dolphin habitats[112,119].

For the period 2011-2016, very few individuals of stranded Cuvier's beaked whale*,* sperm whales and Risso's dolphins had been found in the N. Aegean Sea (Fig. 6.13, Fig. 6.14 & Fig. 6.15). Few individuals of Cuvier's beaked whales were found stranded in Sporades and Lesvos Islands, a number higher that in previous periods 1991-2001 in the same area[79] (Fig. 6.13). Stranded Cuvier's beaked whales have also been reported off the Turkish coasts in the past[120] and in 2016, multiple strandings of another beacked whale, *Mesoplodon mirus,* were reported in Gökova Gulf and Seferihisar (southern part of the North Aegean)[121].

A small number of strandings of sperm whale are reported from the southern part of the North Aegean, north of Ikaria Island and east of Andros Island and Gokceada in the Eastern North Aegean Trough (Fig. 6.13 & 6.15). Strandings of Risso's dolphin have been found in Chalkidiki Peninsula, Gelibolu and Edremit (Fig. 6.16). According to the information provided by some local Port Authorities, approximately 88% of the events were attributed to unknown causes, while 12.5% were human-related (fishery activity) or from injuries.

11 https://accobams.org/conservations-action/protected-areas/

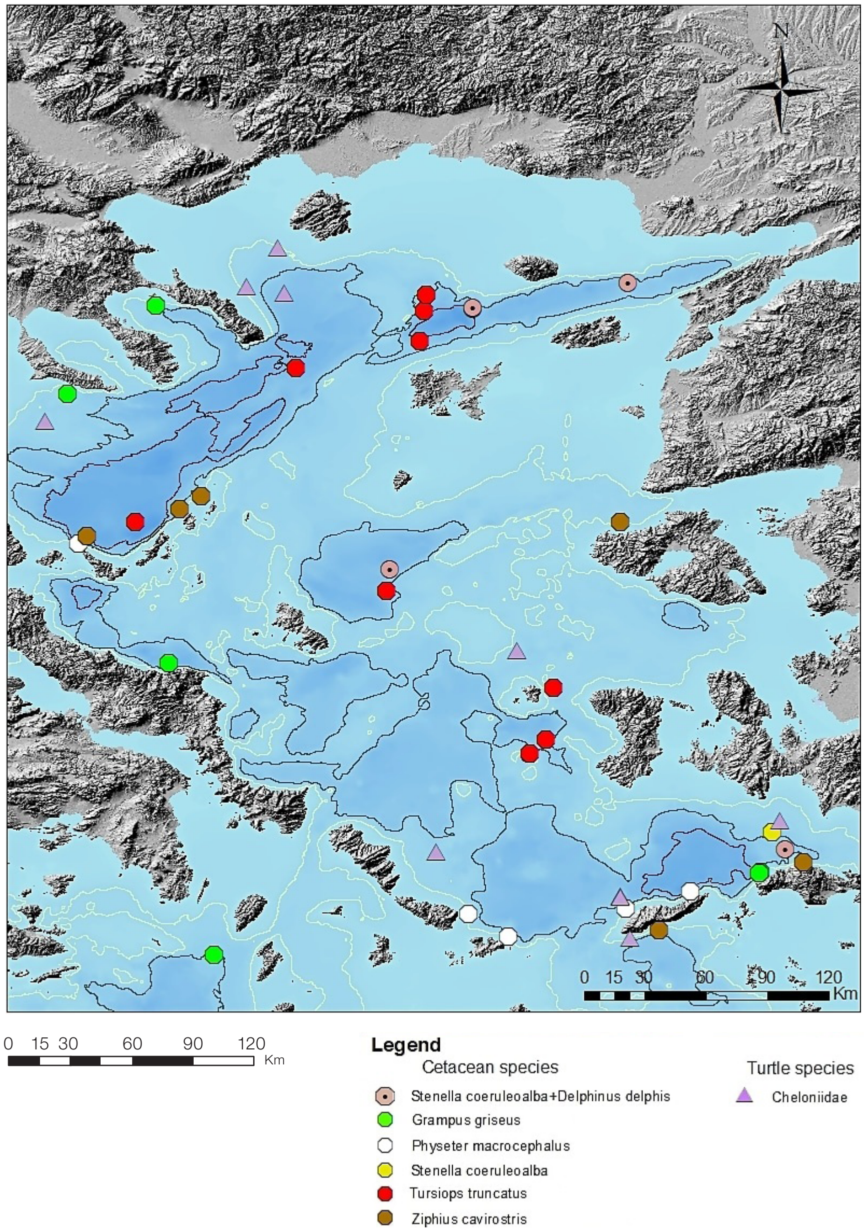

Fig. 6.12. Sightings of cetaceans and sea turtles in the North Aegean Sea in offshore waters deeper than 200 m during the Accobams survey in 2018.

In contrast to cetaceans, almost all stranded leatherbacks turtles reported in the North Aegean Sea, were recorded from Thermaikos, Pagasitikos and N. Evoikos Gulfs, Edremit Bay and Izmir Bay (Fig. 6.17). As in previous records from the area, it is worth noting that most strandings of this species were found in closed gulfs and several of them entangled in fishing gears[98,122,123]. The common occurrence of leatherback in the North Aegean Sea cannot be attributed to breeding reasons since regular nesting of the species in the Mediterranean is not known.

Is worth noting that the ambient noise levels in the Aegean Sea are highest where shipping thorough fares are geographically constrained by the complex network of islands. **Some of the noisiest areas correspond with sperm whale and beaked whale habitats**[113].

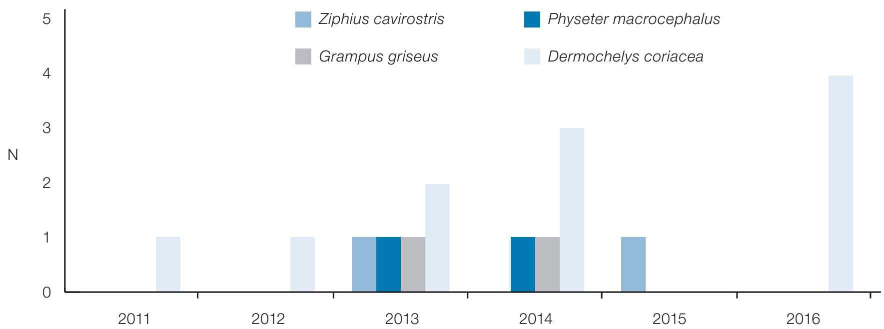

Fig. 6.13. Number of stranded Cuvier's beaked whale, *Ziphius cavirostris*, sperm whale, *Physeter macrocephalus,* Risso's dolphin, *Grampus griseus* and Leatherback turtle, *Dermochelys coriacea* in the North Aegean Sea during the period 2011-2016.

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Often associated with steep slope habitats, submarine canyons and escarpments, the population of Cuvier's beaked whales, *Ziphius cavirostris* contains fewer than 10,000 mature individuals across the Mediterranean. Given its continue decline is considered as Vulnerable for the region.

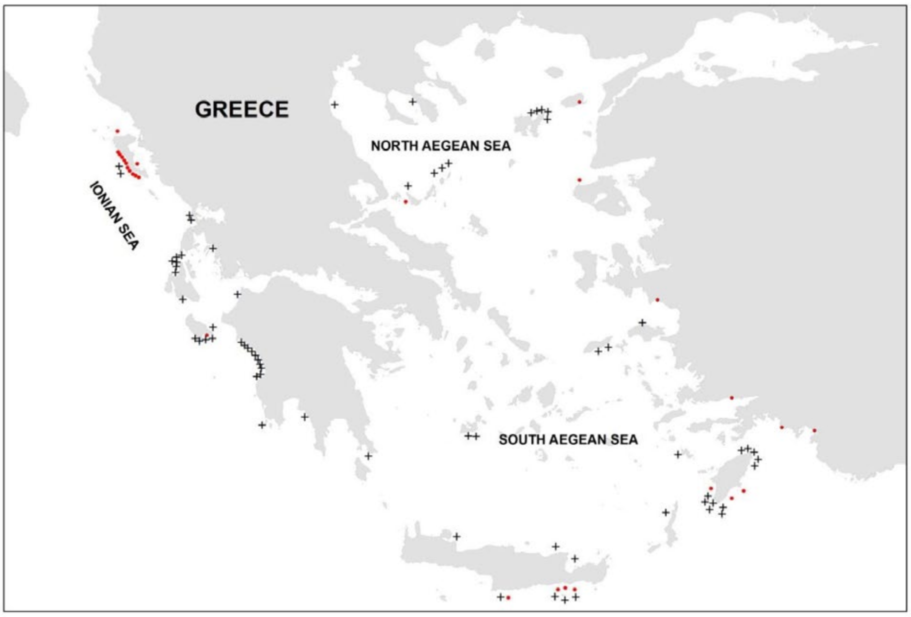

Fig. 6.14. Strandings areas of Cuvier's beaked whale in the Ionian, North and South Aegean Seas during 2011-2016 (red circles) (HCMR data). Data from [79] collected in 1991-2001 are also shown (black crosses). Source: HCMR Database and Öztürk et al (2016)[170].

Fig. 6.15. Strandings areas of sperm whale in the E. Ionian, North and South Aegean Seas during 2011-2016 (red circles). Data from [79] collected in 1991-2001 are also shown (black crosses). Source: HCMR Database and Öztürk et al (2016)[170].

Fig. 6.16. Strandings areas of Risso's dolphin, *Grampus griseus*, in the E. Ionian, North and South Aegean Seas during the period 2011-2016 (red circles) (HCMR dataand Öztürk et al (2016)[170]). Data from [79] collected during the period 1991-2001 are also shown (black crosses).

Fig. 6.17. Strandings areas of Leatherback turtle, *Dermochelys coriacea,* in the Ionian, North and South Aegean Seas during the period 2011-2016 (red circles) (HCMR data). Data from [95] collected during the period 1991-2001 are also shown (black crosses).

3

SOUTH AEGEAN SEA

In the South Aegean Sea, six species of cetaceans are known to be present year-round: striped dolphin (*Stenella coeruleoalba*), common bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*), Cuvier's beaked whale (*Ziphius cavirostris*), sperm whale (*Physeter macrocephalus*) and Risso's dolphin (*Grampus griseus*).

The Cyclades in the Central Aegean as well as the islands of Samos and Ikaria further north, have recently been listed as Important Marine Mammal Area (IMMA[12]) for the occurrence of Mediterranean monk seal and different species of cetaceans, including the common dolphin[59]. The Northern Dodecanese Archipelagos is designated as an area of interest for determining as a future candidate IMMA and designated as a Cetacean Critical Area.

Encounters with sperm whales in this region are reported surrounding the Maleas basin and South of Milos, South of Karpathos basin and southern Rhode Island towards the Levantine Sea. These observations might relate to sperm whales passing shallower waters around the Cyclades islands while traveling among underwater reliefs.

Here, the presence of Cuvier´s beaked whales has been confirmed with acoustic surveys[113] and through sightings by different surveys. Observations included their presence along the steep depressions at South Milos Island, west and northwest of Karpathos Island and in the North Cretan Sea)[13][118]. During the 2018 Accobams ASI programme, Cuvier's beaked whale were encountered in the south of Rhode Islands, South of Kasos and Nisyros, the later probably associated to the Nisyros-Tylos canyons (Fig. 6.18).

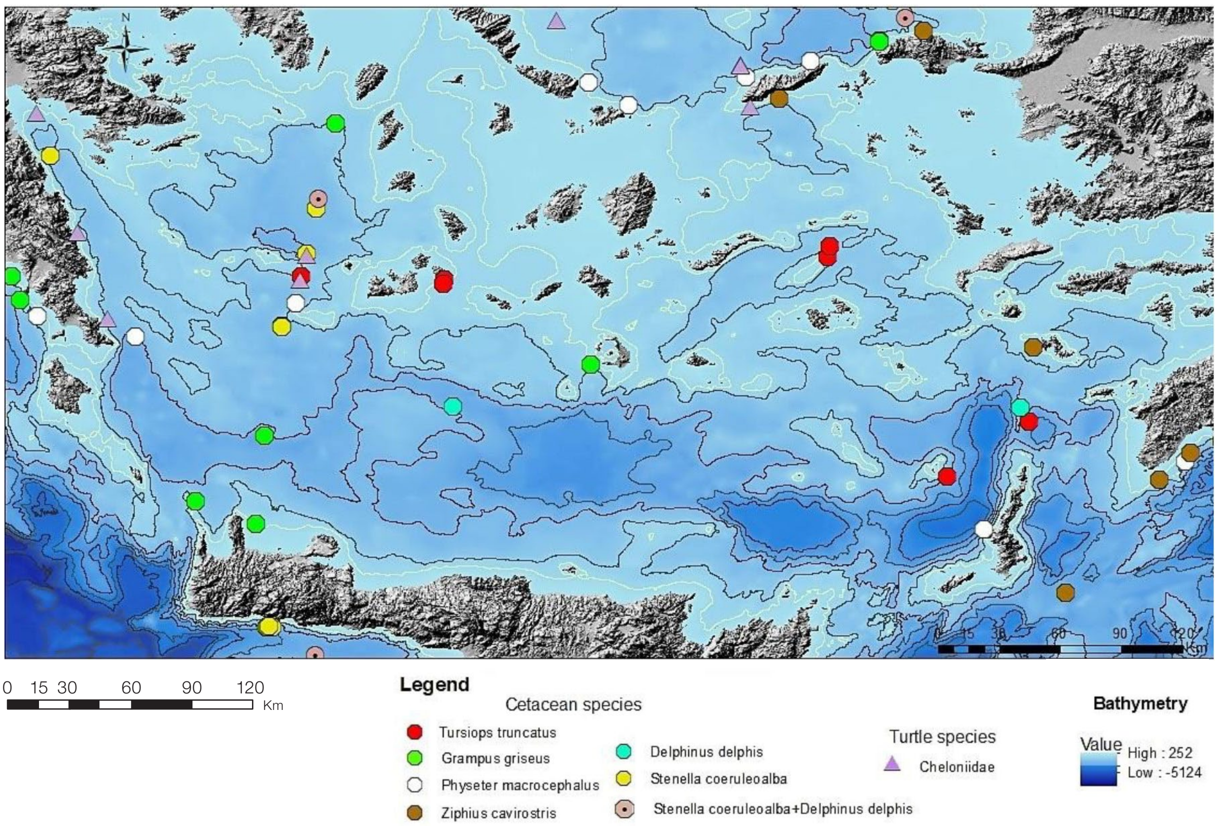

Fig. 6.18. Sightings of cetaceans and sea turtles in the South Aegean Sea in offshore waters deeper than 200 m during the Accobams survey in 2018.

12 https://www.marinemammalhabitat.org/

13 Pelagos Cetacean Research Institute, unpublished data. http://www.pelagosinstitute.gr/

Kokkari Samos Island. © Dreamstime.

In the South Aegean Sea, Risso´s dolphins are known to be relatively common from the Myrtoan Sea South (between the Cyclades and the Peloponnesos) to North-Western Crete as well as the North Aegean (Northern Sporades and Chalkidi Peninsula). There have been occasional sightings of other deep-water cetaceans such as the sighting of humpback whale (*Megaptera novaeangliae*) in Argolikos Gulf[100].

Resident species such as striped dolphins are known to be common in different offshore areas, where the water depth is greater than 500 m and less abundance at shallower areas. Common dolphins are present in both the neritic and pelagic waters of the Aegean Sea and the abundance estimates surrounding the waters south of Samos Island seems to indicate the importance of this area as a suitable habitat for the species[124,125]. Bottlenose dolphins in the other hand, occur mostly in coastal waters although they can be occasionally observed offshore including between South of Samos Island and Northern Dodecanese.

Regarding observations through stranding reports for the period 2011-2016, single stranding events had been reported for all the deep-water species every year less in 2012. Mortality events were attributed to unknown causes, while few individuals of Cuvier's beaked whale, Risso's dolphins and leatherback sea turtles were found stranded on the shore alive according to the information provided by local Port Authorities (Kapiris per.comm.).

The majority of the strandings of sperm whales over the last 30 years were found in the northern part of the S. Aegean or the southern part of North Aegean, close to North Mykonos and Ikaria Islands (Fig. 6.15). Cuvier's beaked whale strandings have been found only in Rhodes Islands as well as in the Cretan Sea, south of Ikaria Island, south of Milos Island, and Gokova Gulf; but less frequent than those observed in the Ionian Sea[79,126] (Fig. 6.14). Strandings are believed to be mostly related to military activities which have taken place in the Aegean region over the same periods. The majority of the Risso's dolphins strandings were found in S. Peloponnese and in Cyclades Islands, confirming observational distribution (Fig. 6.16).

Very limited is the occurrence of the stranded leatherbacks turtles in the S. Aegean Sea although they were more numerous than in the North Aegean Sea, with few reports in the Cretan Sea and Saronikos Gulf (Fig. 6.17).

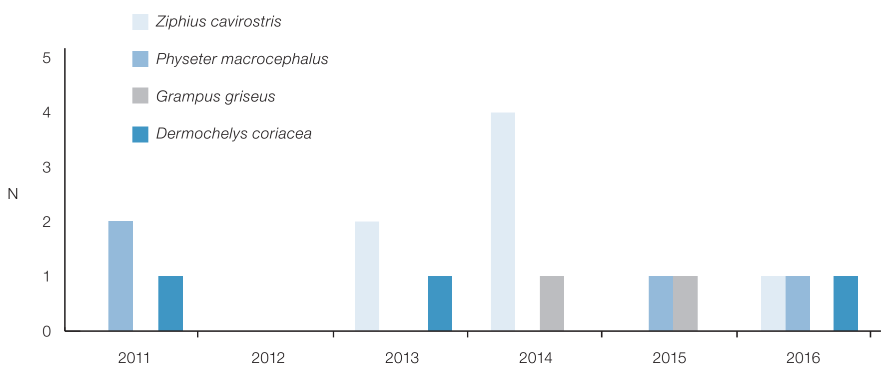

Fig. 6.19. Number of stranded *Ziphius cavirostris, Physeter macrocephalus, Grampus griseus* and *Dermochelys coriacea* in the S. Aegean Sea, during the period 2011-2016 (HCMR data).

4

LIBYAN SEA

Data from cetaceans in Libyan Sea are scarce and knowledge very uneven distributed. Its northern part, SW of Crete is part of the Hellenic Trench that runs from the Ionian Sea to the South Cretan Sea. This area is believed to be the core habitat of the Eastern Mediterranean sperm whale sub-population[127]. Population density of sperm whales in this area suggest that distribution is highly concentrated within a limited area, particularly along the 1,000 m depth contour, with lower number of individuals in both shallower and deeper waters[127]. Long-term studies along the SW of Crete have suggested that this is a consistent area of high concentrations of sperm whales where ship strike mortalities are known to have occurred (see Chapter 9, Fig. 6.20). The area is suggested as a focus for further investigation to ensure sufficient data are gathered to determine whether minor routing changes to shipping could achieve a significant risk reduction[128].

Cuvier's beaked whales have also been observed all along the Hellenic Trench, from northwestern Corfu to east Rhodos Island. The areas with the highest number of sightings are south of Crete and west to Lefkada[14, 99,118] (Fig. 6.22), coinciding with important density hotspots predicted by modelling data particularly close to the Plenny trench and off Libyan coasts of Kyrinian Peninsula[99]. A relatively increased number of Cuvier's beaked whale strandings have been found in the south part of Crete Island, during different periods, 2011-2016 (HCMR data) and 1991-2001[79] (Fig. 6.14) confirming also these observations.

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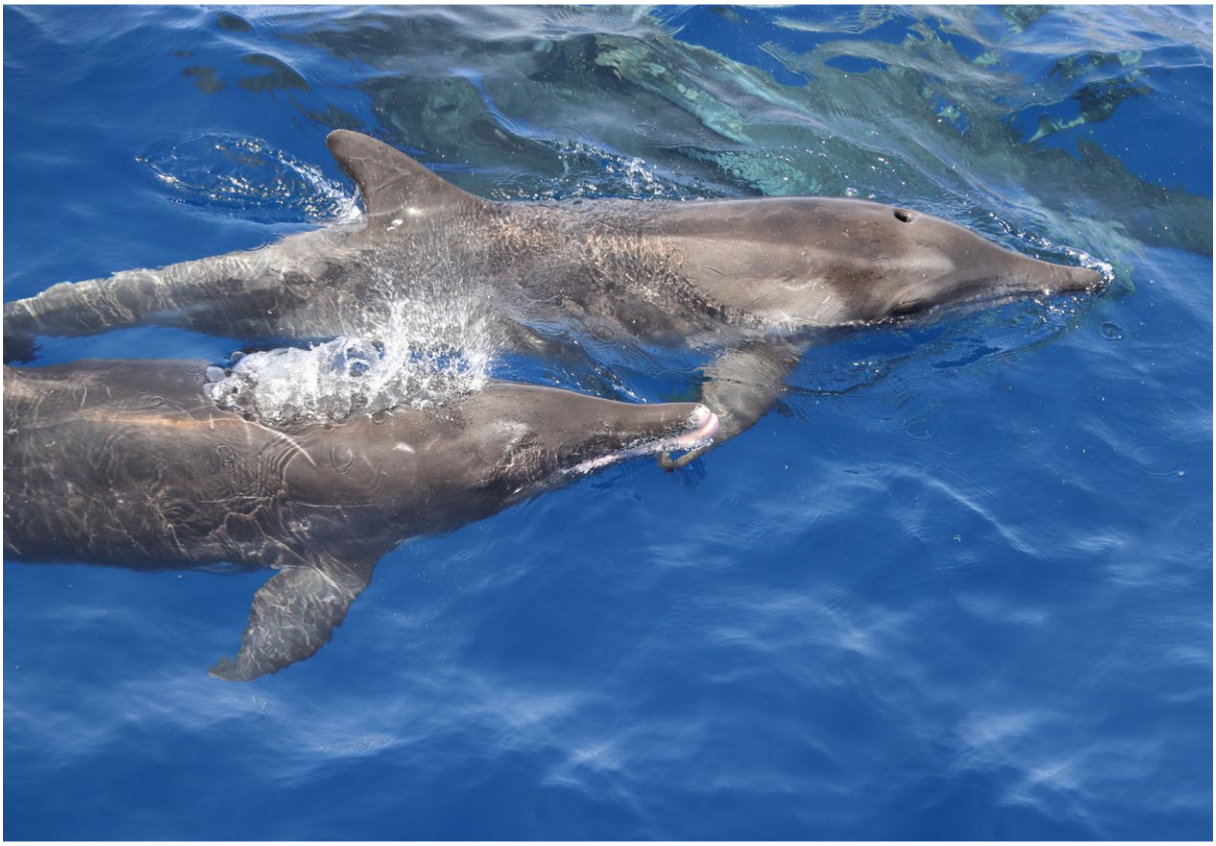

The Rough-toothed Dolphin, *Steno bredanensis*, is an mid-oceanic species sighted as deep as 1,880 m in the Mediterranean. Even when residing in deep water, Rough-toothed Dolphins are considered to be surface feeders and prefers warm waters (> 22 degrees C) which during winter are restricted to the south-eastern corner of the Levant Basin, a region into which the population may retreat during the winter months.

14 Pelagos Cetacean Research Institute, unpublished data. http://www.pelagosinstitute.gr/

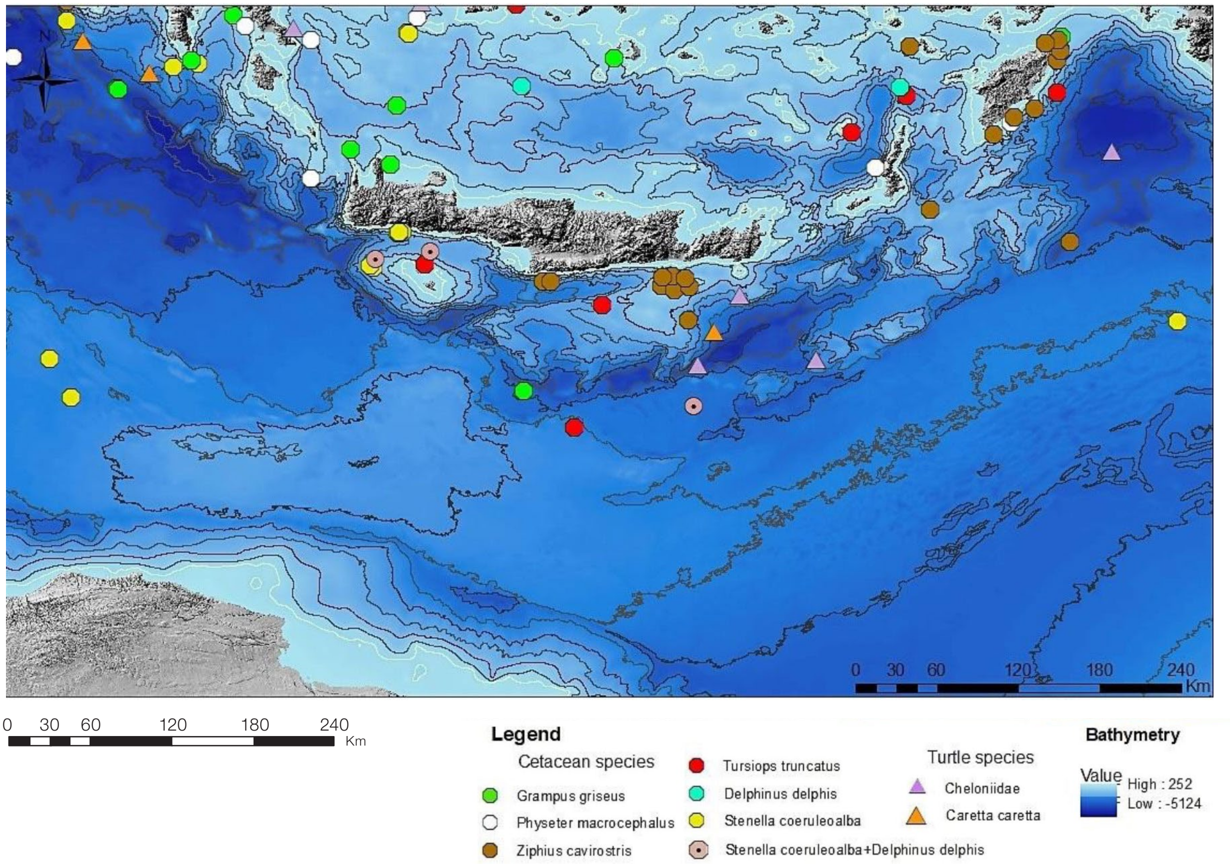

Fig. 6.20. Sightings of cetaceans and sea turtles in the South Aegean Sea in offshore waters deeper than 200 m during the Accobams survey in 2018.

Cetaceans in southern Libyan waters include sperm whales, striped dolphins and rough-toothed dolphin although cetacean studies in this subregion have been very few[99,129]. The animals are commonly regarded as "special" animals in the Libyan culture and as such, they are generally respected by fishermen and other people. Dolphins are believed to be rarely killed, even when they cause damage to fishing gear or when they reduce the catches[130]. Two recent encounters of sperm whales off Libya coast have been recently reported during the 2018 ASI cetacean observation programme[99] and several detections were also made of beaked whales near the Herodotus seamount.

The occurrence of cetacean bycatch in fishing gears along these waters in general is poorly documented but it seems to occur infrequently, possibly with purse seining, illegal pelagic drift netting use and midwater trawling. Strandings information of sperm whales are few and confirm the suggestion that the area appears to be used intermittently by this species. They are known reports in Derna (Eastern Libya) and in Ben Jawed (in the Gulf of Sirte) (Ben Amer, pers. comm[131]) while no strandings of Cuvier's beaked whales are known from this coast[61] and very limited published records of stranded Risso's dolphin are known in these waters[130].

Stranding events of the leatherback sea turtle are known to occur occasionally.

© Dreamstime.

Encounters with sperm whales are reported in Fethiye on the south-western coast of Turkey.

5 LEVANTINE SEA

The Levantine Sea is home to several species of marine mammals and few that have not been reported from the western basin. Despite the lower relative abundances, the region is perhaps disproportionately important on some marine mammals considering the relatively unique assemblage of species including monk seal (*Monachus monachus*), the rough-toothed dolphin (*Steno bredanensis*), the Risso's dolphin (*Grampus griseus*) and the presence of false killer whales (*Pseudorca crassidens*) [99,113]. Among the occasional visitors could be considered the fin whale (*Balaenoptera physalus*) and the leatherback turtle reported in occasional sightings and strandings in the area[129].

Limited information is available on sperm whales strandings and sightings. Encounters with sperm whales are reported between Rhodes Island and Fethiye on the south-western coast of Turkey (in 4,485 m depth), Rhodes Basin (off E. Rhodos Island)[113], Antalya especially in the Finike Basin and Antalya Bay[132,133] and the coasts of Lebanon, Egypt and Syria[99,134,169]. Seasonally, most of these sightings are during spring and summer months (March-August 81%). Groups of sperm whales, including calves, have also been encountered off south Cyprus Island, as reported off Larnaca Marina in 2012[113,135] and in 2016 and 2017[136]. These surveys confirmed the presence of sperm whales in waters deeper than 500 m, with 83% observed in waters over 1,000 m deep. Other species such as the striped dolphins, Risso's, rough-toothed dolphins and common bottlenose dolphins had also been recorded in this region[99].

Single stranding events of sperm whales occur occasionally across this region. In Cyprus, strandings of sperm whales have been found along the south and western side as those in Fontana Amoroza in Akamas peninsula[15]. These detections are especially noteworthy as they confirmed the occurrence of sperm whales in an area where records are rare. Stranded individuals had also been found on the western Egyptian coast of Matrouh Province (in 2016[137]), off Beirut, Lebanon (coordinates unavailable) and on the Israeli coasts[134,135,138].

15 Source: 2004 Ioannis Thasitis, per.comm, March 2018; DFMR, 2017. Whales & Dolphins of Cyprus: Summary of 2016 & 2017 Research Surveys.

Live sightings of Cuvier's beaked whales in northern Levantine waters are extremely rare. Previous to 2015, only two visual and seven acoustic reports were reported of the species from the northern Levantine Sea, over the Anaximander Seamounts off Kastellorizo Island and over the Adana Trough as well as one off Ashdod, Israel[113,135,139]. More recent observations, suggested that the area specifically between the Anaximander Seamounts, Antalya Canyon, and the Adana Trough, could be an area of importance for the distribution of Cuvier's beaked whales and that the species is regular in the area[126,140] (Fig. 6.21). Cuvier's beaked whales had also been detected acoustically off South-West Cyprus[136], and among coastal waters of Egypt and Libya in 2018[99,169].

"The northeastern corner of the Levantine Basin and Eratosthenes seamount are considered a potential hotspot area for Risso´s dolphins, found above submarine canyons and seamounts"

Strandings of Cuvier's beaked whale in this region are very few and sporadic. The majority of the strandings have been reported from the Eastern Levantine coasts (Fig. 6.21;[140]), with some recent reports in Yakacik, Gazipasa, south Turkey coast (2016); Catalkoy, north Cyprus (2017) and Camyuva, Antalya (2017). Single strandings of Cuvier's beaked whales have also been reported from Cyprus in the past[107] at Akamas area, between Lara and Cape Arnaouti (2001); Agios Ermogenis Beach, Kourio (2002) (Ioannis Thasitis, pers.comm, 2018); and Agios Epiktitos (Catalkoy, 2017) in Kyrenia after apparently becoming tangled in a fishing net. In Israel shores, seven single male individuals of Cuvier's beaked whale have been stranded in 1993-2009 between March and July, none of them further south than Tel Aviv[135]. The frequency of these strandings have been made some researchers to propose that Cuvier's beaked whale within the Levantine Sea might be as regular as in the Western Mediterranean Sea[135].

There are a few sightings and stranding records of Risso's dolphins from the Levantine Sea with several records from Turkey[141], Cyprus[136] and Israel off Haifa[135,142,143,144]. Risso's dolphins encounters with several individuals and small groups had been also reported in Syrian and Egypt coastal waters during the 2018 surveys[99,169] and the species maybe present off Lebanon as other Levantine areas where research effort has been low or nil.

Presence of Risso's dolphins have been recorded with acoustics (associated with *S. coeruleoalba* individuals) in a depth of more than 2,000 m offshore over Anaximander mountains[132] and the south-eastern region of Cyprus at more tan 1,000 m depth[136]. Even though there is no evidence for reproduction in the area, the species is considered among the regulars of the Levantine Basin[135] and **the northeastern corner of the Levantine Basin and Eratosthenes seamount is considered a potential regional hotspot area for these cetaceans**[135].

Records of single strandings of Risso's dolphins are from Turkey - as bycatch of the swordfish fishery in the Fethiye region[145]; Cyprus - in Faros Beach, Pervolia (2010) and Fontana Amoroza, Akamas (2010; Ioannis Thasitis, pers. comm, March 2018); Libya[130], Lebanon[146], Israel[135,147] and none in Syria[148] or Egypt[136,137].

As in the Western Mediterranean, it has been reported that the species **frequent waters above submarine canyons and seamounts**[149].

Regarding the leatherback sea turtles, local fishers report that they occasionally encounter them during fishing operations in different areas[97,150]. There have been a few records of incidental catches of leatherbacks in Cypriot waters, mainly on long lines and trammel nets[151], commercial trawlers off Israel[97], in Libyan waters in Tripoli, near to Palm Island (2006), trammel nets in Syria close to Jableh town[96] as well as confirmed cases around Turkish waters with some individuals tagged and released into the sea (Mersin Bay;[151,152]). Leatherback turtles frequent Egyptian waters, though this is the rarest among the sea turtles species occurring in the area[153,154]. Sporadic occurrences of leatherback sea turtle of up to two observations/year regularly, are recorded in Israeli waters and several publications refer to the presence of marine turtles in Syrian waters, namely south of Lattakia[155,156,157].

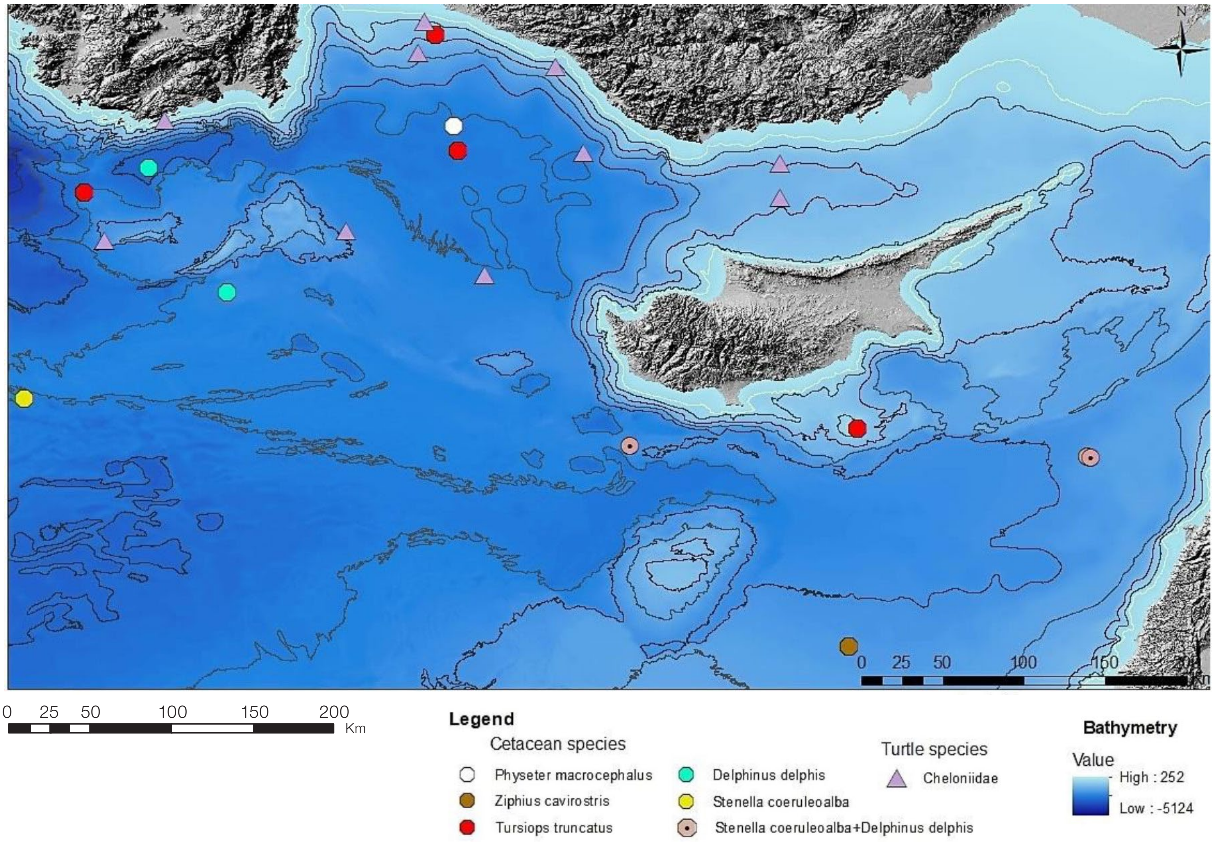

Fig. 6.21. Sightings of cetaceans and sea turtles in the Levantine offshore waters deeper than 200 m.

Stranded records are few around this coast, including in the southeastern Turkey Anamur-Bozyazı Highway, Adana and Balıkesir[125,161,165].

GENERAL CONSIDERATIONS

The present work present a brief summary on deep-water cetacean and sea turtle populations in the E. Mediterranean Sea to identify gaps and weaknesses in our present knowledge, particularly on their spatial distribution. Without information such as species composition, size and distribution of deep-water cetacean and sea turtle populations and habitats is difficult to develop effective conservation measures. Cetaceans and sea turtles travel across borders as migratory species and both regional and global efforts, are needed to study, monitor, manage and protect these animals. The available information seems to clearly indicate that in the eastern Mediterranean. Generally, information on the cetacean species occurring in and off the Syrian, Lebanon and Egypt waters is extremely scarce and limited to a handful of stranding and sighting records.

A number of Marine Protected Areas (MPAs) of different types, sizes and purposes have been established in several Mediterranean countries including in the Eastern Mediterranean, but specific measures for cetacean conservation are rarely included in their management plans. Moreover, several cetacean species are known or suspected to make long-range movements, and their presence may vary on a seasonal or annual basis. In these cases, the present MPAs in the Eastern Mediterranean may not represent the most effective conservation strategy to protect these deep-diving cetaceans, although they can help to protect ecologically important portions of their range.

In the eastern basin, sperm whales are predictably present along the Hellenic Trench (from the Ionian Sea to the South Cretan Sea), south of Rhodes Island and along the Turkish coast as far as the western part of Antalya Bay. They are also present off west and south Cyprus, and in the Aegean Sea, north of the Cyclades

"Further studies are necessary to complete the information needed to address conservation actions of these charismatic species that frequent deep-sea environments"

Islands and in the Ikaria basin. The Rhodes Basin has been recognised as an important region for sperm whales in a recent review[133] and has been proposed by some authors as a High Sea Marine Protected Area in part due to its importance for sperm whales[162]. Findings presented here lend credence to the notion that the Rhodes Basin is ecologically important for sperm whales, perhaps linked to the concentration of nutrients by the quasi-permanent Rhodes Gyre, making it the most productive area of the eastern basin with the largest phytoplankton biomass[163]. Sperm whales were also detected on several separate occasions in the Ikaria Basin, a region where sperm whales have been documented on at least four other occasions between October 2004 and November 2012[133]. Large portions of what is likely critical habitat for sperm whales remain unexplored (e.g., Rhodes Basin, the Egyptian EEZ), or still fall outside any type of protective regime (e.g., south-western Turkey). Those that have been established vary highly in the effectiveness of the protective measures deployed and enforced, which is challenging for pelagic waters. Nonetheless, the establishment of a network of genuinely protected areas, decrease noise and interaction with maritime traffic and the increase enforcement of the prohibition of pelagic driftnets across the basin should be important conservation goals for this species.

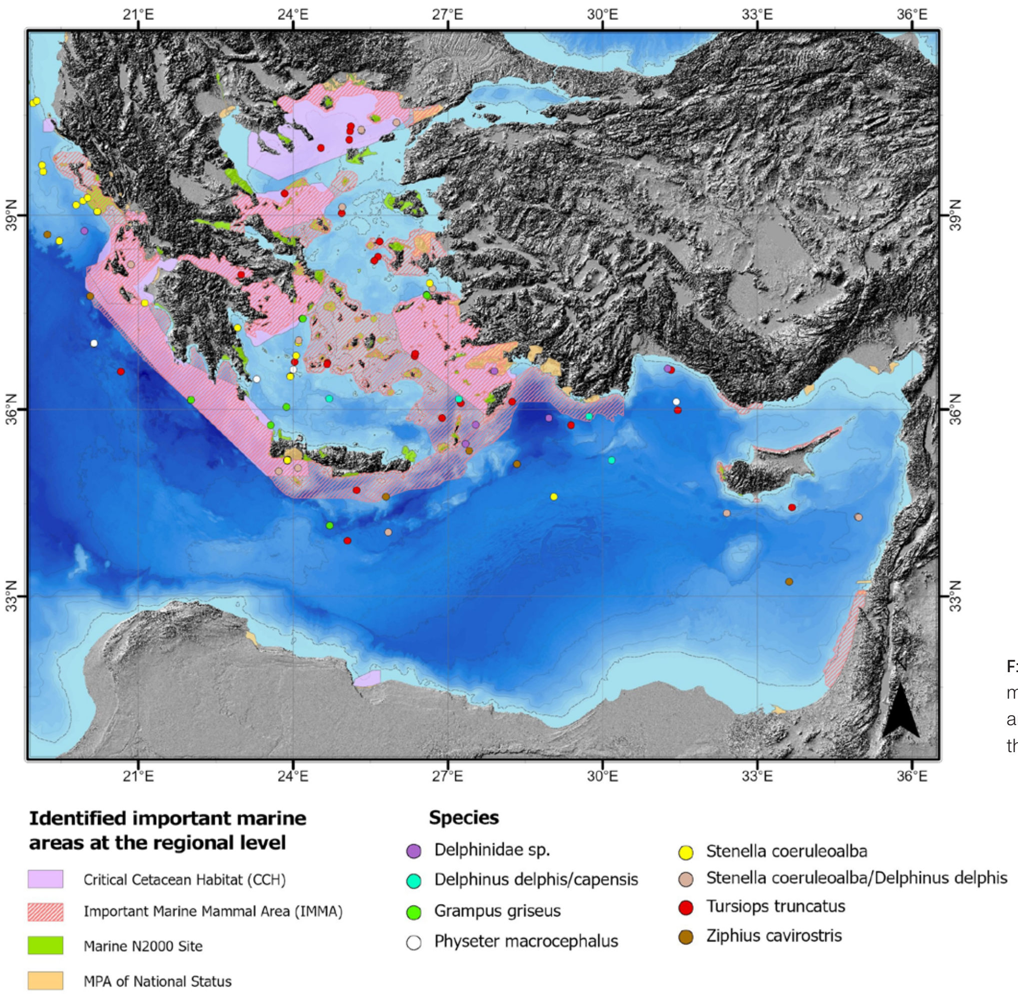

Fig. 6.22. Identified important marine areas at the regional level and sightings of cetaceans in the Eastern Mediterranean.

Further research effort is required to detect the seasonal use of the different sub-regions by sperm whales as all documented sightings have occurred between July and November; yet, it remains unclear if this is due to an effort bias. The occasional presence in Egyptian and Syrian´s waters call for further research and precautionary measures.

> “Spatio-temporal measures including MPA designation sites, to reduce underwater noise and military exercises are needed at least in hotspot areas of both sperm whales and Cuvier' s beaked whales occurrence”

> “Ikaria and Rhodes basins could be areas to consider special attention for the sperm whale protection”

The northern Levantine Sea and precisely between the Anaximander Seamounts, Antalya Canyon, and Adana Trough, is considered to be an area of importance for the distribution of Cuvier's beaked whales[140]. The present review showed that areas such as the E. Ionian (northern and central), the Hellenic Trench south of Crete, North Ikarian Basin and Anaximander Seamounts among other small locations are important areas of sightings and strandings for this species. Taking into account that the strandings coincide with the areas of high concentration of Cuvier's beaked whales (*Ziphius cavirostris)* these hotspot areas should receive special attention in terms of the species protection.

Risso's dolphins have also well-known strong habitat preferences for slope areas and the **creation of a network of cetacean sanctuaries for deep-water and coastal cetaceans in the Eastern Mediterranean as for example along the southern part of the Eastern Ionian Sea (Hellenic Trench)** will offer protection of critical habitats for a number of endangered and vulnerable cetacean species.

The promulgation and implementation of good management plans for the conservation of these species should be an important priority, despite the existing gaps regarding their population status. The emphasis should be on improving our existing knowledge and creating a more integrated approach to marine activities around the Eastern Mediterranean. Generally speaking, the management can be improved by:

- Enforcing the existing national and international legislation on protection

- Increasing efforts to identify and establish any possible conservation areas that cover the full range of resident or frequently visited sites for these marine mammals and sea turtles

- Taking inventories to assess abundance and changes over time and to allow potential problems to be identified well in advance

- **Mitigate** mortality due to ship strikes by addressing measures to reduce ship velocity in areas overlapping with intense traffic and lanes as well as limiting the spread and intensity of noise by adapting vessels and other marine operational procedures

- **Mitigate** noise resulting from use of military sonars and seismic surveys.
  - Developing a comprehensive outreach and education strategy to promote responsible viewing of wild mammals by tourists and commercial marine operators, particularly in coastal waters
  - Identifying and implementing other specific measures, such as the study of the interactions between the fishery and their presence. If locations of repeated bycatch of cetaceans or sea turtles occur, test and adopt spatio-temporal technical measures for environmental friendly static nets and long lines, that can promote the avoidance of the sea turtle or cetacean entanglement on them.

- Reduce inputs of particular pollutants, including plastics.

CHAPTER 6 /

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Essential Fish Habitats in the Mediterranean is being defined as “habitats essential to the ecological and biological requirements for critical life history stages of exploited fish species, and which may require special protection to improve the status of the stocks and long-term sustainability[3]”

CHAPTER 7 /

Towards the identification of essential fish habitats for commercial deep-water species

An ecosystem approach to Fisheries is intended to ensure that the planning, development, and management of fisheries will meet social and economic needs, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems[1].

Implementing an ecosystem approach to fisheries is now a widely accepted concept for delivering management provisions and advice encompassing multiple stocks which inhabit a common and geographically-defined area. It complements the traditional approach to fisheries management.

Among the different management tools available to implement this approach, the identification and protection of **Essential Fish Habitat** (EFH), is known to play a significant role in maintaining populations of commercial species as well as restoring and preserving the ecosystem that sustained it. This is particularly relevant as many of the Mediterranean stocks are overfished[2] and habitat loss and degradation may also be contributing to this. Hence, EFH identification needs to be supported by a policy and a programme of technical management measures to reduce fishing mortality and the indirect impact of fishing in those areas.

This concept was introduced in the Mediterranean fisheries policy to enhance the efforts of recovery plans for fisheries. To date, as part of this approach, a minimum distance from the coastline or a minimum depth has been legislated[1] and a few Fisheries Restricted Areas, e.g. areas identified as EFH, have been declared in the Mediterranean with this main focus (e.g. the Gulf of Lion Rec. GFCM/33/2009/1; Strait of Sicily, EC.CM-GFCM/40/2016/4 and in the Jabuka/Pomo Pit, Rec. GFCM/41/2017/3). At a national level, other spatial-temporal restrictions of fishing activities might contribute towards this objective.

Despite these efforts, additional fisheries recommendations under GFCM (GFCM/41/2017/5) requested that countries make an effort to endorse further actions towards EFH. These action included the adoption of multiannual management plans based on an ecosystem approach to fisheries to guarantee the maintenance of stocks above the levels which can produce maximum sustainable yield (MSY), the establishment of more fisheries restricted areas (FRAs), and the definition of a consistent network of essential fish habitats that also take in to account sensitive habitats.

EFH mapping has been initiated at various levels as an integrated part of the 2017-2020 Mid-Term Strategy for Mediterranean Fisheries[2]. Field data surveys and species distribution modelling has been used as tools to map specific habitat requirements for different life stages of various species. The first maps using model approaches have been produced to identify nurseries and spawning grounds as potential Mediterranean EFH of the European hake *Merluccius merluccius* and mullets *Mullus* sp[3]. These fish resources are considered high priority species for fisheries management in the Mediterranean region given the high exploitation rate and low level of biomass of the stocks.

Potential EFH for exploited deep-sea species is less investigated. These species may use different habitats (nursery, feeding, spawning) during their lives and are dependent on the availability and condition of these habitats to sustain them even at the population level [4,5] and the causes of these declines, apart from overfishing, remain largely unresolved. Degradation of essential habitats has resulted in habitats that are no longer adequate to fulfil nursery, feeding, or reproductive functions. The identification of such areas on both horizontal and vertical (depth) dimensions are important for both the conservation of biodiversity and sustainable management of the fisheries. Identifying and protecting the essential fish habitat (EFH) of deep-water species might also include actions on coastal habitats as some deep-water species might be also highly dependent on these areas for their reproduction and protection during juvenile stages. Yet, the degree to which coastal habitats are important for exploited species has not been quantified.

Even though it may be difficult to define the boundaries of EFH for these deep-sea species, initiating efforts towards the definition of EFH areas, combined with a management which recognizes the importance of such areas, represents an important step towards facilitating an Ecosystem Approach to deep-water fisheries.

The most important criteria used to define EFH are:

- **Nursery grounds where the highest aggregations of recruits are found, and persist over time.**
- **Spawning areas with large seasonal aggregations of mature females, and persist over time.**

For demersal commercial species, for example, these may depend upon a particular type of sea bottom, complex topography or biogenic habitats for their growth and survival. The effective EFH habitat for these species may be a result of the interaction of ecosystem productivity, population dynamics and connectivity. For pelagic species, on the other hand, as their life cycle is intrinsically associated with the water column, the combination of particular oceanographic features and/or the presence of a hydrographic process is a key and needs to be taken into account to identify the hotspots that might be considered as EFH in relation to the main spawning grounds and juvenile concentration areas[3]. The identification of EFH sites for deep-water species

1 EU Council Regulation No 1967/2006 of 21 December 2006. Official Journal of the European Communities, 269: 1–15.
2 http://www.fao.org/gfcm/publications/brochures/midtermstrategy-2017-2020/en/
3 GFCM WGMPA, 2019. http://www.fao.org/gfcm/meetings/info/es/c/1176435/


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> “Deep-water species are generally vulnerable to fishing activities, because of their special biological characteristics (longevity, low fecundity, low growth rate, high food competition) and the vulnerable ecosystems they are living in”

brings additional challenges, given the little knowledge we have of the fisheries footprint in most of the Mediterranean, the limited knowledge on many of the commercial species and their relation to the environment. Despite current limitations, we attempt to compile the existing information on some of the most important deep-water fisheries resources in the Eastern Mediterranean to date and identify those potential EFH sites. The ecosystem-based fisheries of EFH sites and the incorporation of ecosystem based fisheries managed measures such as reducing the fishing effort on these grounds, could provide important benefits to those deep-sea fisheries and contribute to improving the state of the communities and resources exploited in the Eastern Mediterranean.

To identify EFH, field survey data from grey and published literature has been gathered in order to:

- estimate and map the spatial distribution of the abundance of juveniles (number of individuals/km^2) for each species and identify their hotspot areas - nurseries
- identify the hotspots of the spawning grounds, where high abundances of female individuals of each species at the spawning stage occur.
- assess the nursery and spawning ground habitats and provide recommendations for further management measures

Annex I lists the datasets and sources that were used to identify key areas where juveniles and/or spawners aggregate.

In this analysis, five deep-water exploited species were chosen to be reviewed because of their economic importance. The two deep-water red shrimps, **the giant red shrimp** (*Aristaeomorpha foliacea*) and **the blue red shrimp** (*Aristeus antennatus*), **the blackbelly rosefish** (*Helicolenus dactylopterus*), **the blackspot seabream** *(Pagellus bogaraveo)* and **the wreckfish** *(Polyprion americanus).*

Although red shrimps are not long-living and a low growth rate species, they have been mentioned as vulnerable to intensive fishing. According to the Reports of the Working Group of Stock Assessment of Demersal Species (WGSAD-GFCM, 2014; 2018, 2021) many of the stocks of *A. foliacea* and *A. antennatus* in various Geographical subareas (GSAs) of the Mediterranean Sea were assessed as overexploited, particularly in the western Mediterranean. Since a new deep-water red shrimp fishery is nowadays under development in the Eastern Mediterranean, information on these species is required for their sustainable management. Also, both red shrimp species occur in vulnerable ecosystems, such as sea canyons, and have not yet been assessed in the Mediterranean for the IUCN Red List.

Blackbelly rosefish has been considered particularly vulnerable to overfishing due to its biological characteristics (long-lived, late maturity, slow growth) and the abundance of the species was found to be linearly affected by the fishing effort intensity[6]. However, blackbelly rosefish is listed as **Least Concern** for the European and Mediterranean waters[7,8].

Regarding the **blackspot seabream** (*Pagellus bogaraveo*), the historical evidence of overexploitation and population collapse in the Bay of Biscay fishery and in other parts of its geographical distribution, along with its specific biological traits (low growth rate, hermaphroditism) are a cause of concern. As a result of the species vulnerability to overexploitation, the species population dynamics are annually evaluated under WGDEEP (ICES group) for the Atlantic stocks and COPEMED (FAO regional project) for the Western Mediterranean. No particular attention has been received for the species in the Eastern Mediterranean. This species has been listed as **Near Threatened** both globally and in the European waters[9], whilst being listed as **Least Concern** in 2011 for the Mediterranean region[10].

The **wreckfish** *Polyprion americanus* is generally considered as a long-lived, slow growth and late maturity fish species[11], making it highly vulnerable to fishing exploitation. In addition, it has a long pelagic phase that might increase its vulnerability. Moreover, it is living in vulnerable habitats, such as banks and seamounts, that could additionally affect its vulnerability.

Therefore, it is obvious that the above species demand particular attention and any information related to their nurseries and spawning grounds would be essential for their sustainable management.

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Deep-water shrimps

Kapiris K., Bordbar L., Otero M., Thasitis I., Lteif M., Mytilineou Ch., Ali M., Farrag M., Jemaa S., Adamidou A., Dokos J., Kavadas S.

The two red shrimps, *Aristaeomorpha foliacea* and *Aristeus antennatus* are of great economic interest in the Mediterranean, being among the main target species for the demersal deep-water fishery in the Western and Central Mediterranean. Both species are captured exclusively by trawlers on muddy bottoms in deep waters off the continental shelf, especially near submarine trenches and canyons along the continental slope[12,13]. The giant red shrimp or deep-sea red shrimp *A. foliacea* is a cosmopolitan species while the geographical distribution of the blue and red shrimp *A. antennatus* is confined to the Eastern-Central Atlantic (from the Iberian Peninsula to Angola), the Mediterranean with the exception of the Adriatic Sea[14,15] and the Indian Ocean[16]. The deep-sea red shrimps, *A. antennatus* and *A. foliacea*, are the only Mediterranean representatives of the Aristeidae family.

“The giant red deep-water shrimp, *Aristaeomorpha foliacea* plays a key role in deep-sea communities and it is considered one of the most important targets of deep-water trawl fishing. Its distribution has been linked to the distribution of the Levantine Intermediate Water (LIW) from the Eastern Mediterranean Sea”

One important feature of these two commercial species is their longitudinal differentiation along the Mediterranean: The giant red shrimp *A. foliacea* increases in abundance from the Western to the Eastern Mediterranean, while the opposite is true for *A. antennatus.* Their geographical distribution seems to be patchy[17,18]. The bathymetric distribution of them is also different, *A. antennatus* is known to occur at depths ranging from 80 to 3,300 m[19], while *A. foliacea* has been recorded at depths from 123 to 1,100 m, generally on muddy bottoms[20,21].

The biology (reproduction, sex-ratio, feeding habits and population dynamics) of both species is relatively well known particularly in the Western and Central Mediterranean. Genetic studies[22] indicated that *A. antennatus* presented two genetic stocks (or Management Units) in the Mediterranean: one in the Western and the other in the E. Mediterranean. It should be noted that in this study the sampling area of the Eastern Mediterranean was limited only to the Eastern Ionian Sea (GSA 20). According to the authors of this study[22], it is possible that the Strait of Sicily may be serving as a barrier for the migration of individuals and gene flow between the two basins. Moreover, recent studies in the same sampling areas[23], suggest the same genetic differentiation between the Western and Eastern basins for this species, most likely related to differences in environmental conditions. However, other studies with samples geographically closer to both sides of the Strait of Sicily showed that Western and Central Mediterranean (including the South-eastern part of the Sicily Straits, GSAs 13-16) is structured into a large genetically undifferentiated unit[24]. Therefore, it could be suggested that the Western (GSA 13-16[4]) and Eastern (GSA 20) part of the Ionian Sea are genetically differentiated. No genetic studies have been published for the other Eastern Mediterranean (GSAs) for either of the red shrimps. However, recently genetic research is conducted in the framework of the MEDUnits project[5].

4 Mediterranean Geographical Sub-Areas (GSAs) of FAO-GFCM. http://www.fao.org/gfcm/data/maps/gsas/en/
5 DG MARE Specific Contract No. 03EASME/EMFF/2017/1.3.2.3/01/ SI2.793201 -SC03.

FISHERIES

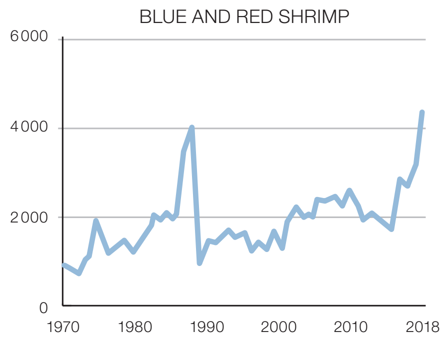
Red shrimps have been exploited commercially since the 1930s in the Western Mediterranean basin[25,26] while new deep fishing grounds have been discovered in recent decades, especially in the Eastern Mediterranean.

Both red shrimps are harvested by bottom trawlers on the slope, commonly at depths ranging from 400 to 800 m. The giant red shrimp *A. foliacea* was heavily exploited in the Western Mediterranean. It is still being fished in the Central Mediterranean whereas its stocks have been considered quasi pristine in the Eastern Mediterranean[13,27,28,29] due to not very developed exploitation. Nonetheless, over the last decades, the red shrimp fishing fleets have expanded their operations to various areas of the E. Mediterranean[30,31,32]. The blue-red deep-water shrimp (*A. antennatus*) although less abundant in the E. Mediterranean, is also an important commercially targeted species.

According to the latest published stock assessment in 2021, the stocks of *A. antennatus* in the regions GSAs 01 (Northern Alboran), 02 (Alboran Island), 05 (Baleares Islands) and 06 (Northern Spain), as well as the stocks of *A. foliacea* and *A. antennatus* for GSA 09 (Ligurian Sea and North Tyrrhenian Sea), 10 (Southern and Central Tyrrhenian Sea) and 11 (Sardinia) were overexploited and the management advice was to reduce fishing mortality. For GSA 18 (Southern Adriatic) and 19 (Western Ionian Sea) the stocks were considered in low overexploitation and relative low biomass. At present, the two recommendations establishing multiannual management plans for sustainable trawl fisheries targeting deep-water red shrimp species in the Levant Sea (GSAs 26–27) and the Ionian Sea (GSAs 20–21) have been established. Another recommendation establishing management measures for sustainable trawl fishing activities targeting giant red shrimp (*Aristaeomorpha foliacea*) and blue and red shrimp (*Aristeus antennatus*) in the Strait of Sicily has also recently been adopted in 2021[6].

> “Bottom trawlers targeting deep-water shrimps affect deep-sea ecosystems, modifying the seafloor morphology and its physical properties, with dramatic consequences on benthic vulnerable communities”

The SOMFI 2020 report shows that the catches of both species have an increasing trend over recent years with an increasing exploitation ratio for blue and red shrimp at Mediterranean level[34]. The maximum landing for the latter was reached in 2018 with 4,400 t while for the giant red shrimp it was 2,900 t in 2017. The available FAO catch data on red shrimps from the Central-Eastern Mediterranean (FAO FishSTAT 1999-2017) showed strong fluctuations between the years from 1999 to 2017, with the highest reported value of 3,721 t in 2000. Catches from the available data in the last 5 years were, on average, 2000 t per year. It is likely that unreported catches are significant[2], since from the Automatic Identification System (AIS) data, it is known that there is an increasing fishing activity in the area nowadays (see Chapter 8). However, It should be taken into consideration that more than 99% of these catches were from the Ionian Sea and less than 1% belong to the Aegean, Libyan and Levantine Seas.



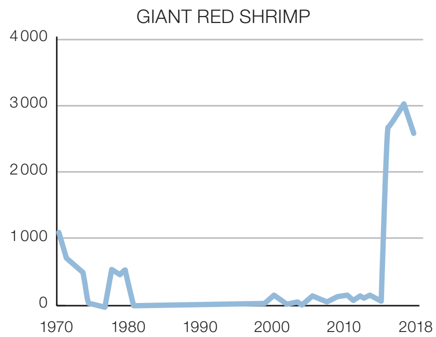


Fig. 7.1. Fisheries landings of both deep-water shrimp species between 1970-2018 in the Mediterranean. Source: SOMFI 2020.

6 Recommendation GFCM/44/2021/6 on a multiannual management plan for sustainable trawl fisheries targeting giant red shrimp and blue and red shrimp in the Levantine Sea (geographical subareas 24 to 27) and Recommendation GFCM/44/2021/8 in the Ionian Sea (geographical subareas 19 to 21). Recommendation GFCM/44/2021/7 on management measures for sustainable trawl fisheries targeting giant red shrimp and blue and red shrimp in the Strait of Sicily (geographical subareas 12 to 16).

7 FAO. 2020. The State of Mediterranean and Black Sea Fisheries 2020. General Fisheries Commission for the Mediterranean. Rome.

In the Central Mediterranean, red shrimp fishery has been traditionally conducted by Italian trawlers. However, the continuous decrease in the catch rate of deep water shrimps in the Strait of Sicily and the absence of deep trawling in the Eastern Mediterranean drove some fishing vessels to start fishing off Crete and Cyprus and off the Turkish coast since 2004[30,35] (Fig. 7.2). In recent years, more trawlers from Greece, Egypt and Turkey have also begun fishing in the Eastern Ionian and Levantine Seas[36]. The fishery in these new fishing grounds resulted in high catch rates and high proportion of large-sized individuals. Nonetheless, limited data is available for most of the regions. Most of the information on both red shrimps from the Eastern Mediterranean originates from the Eastern Ionian Sea, with a very small contribution from the Levantine Sea. Although high catches of red shrimps are known anecdotally in the area, these are probably not all officially registered. According to vessel monitoring system (VMS) data, questionnaires and log book data, the total production of both red shrimps from Greek trawlers in the Eastern Ionian (GSA 20) and Aegean Sea (GSA 22) was estimated to be around 155 t in 2018; from them, half were fished in the Eastern Ionian Sea (GSA 20)[37].

Furthermore, deep-water trawl fishery is practiced mainly off the south coasts of Turkey to exploit both types of red shrimp over the last years. Likewise, other decapod crustaceans such as the deep-water rose shrimp *Parapenaeus longirostris,* the golden shrimp *Plesionika martia* and the striped soldier shrimp *Plesionika edwardsii* are also part of the main target species of these deep-water bottom trawl fishers[38]. In 2013, it was reported that annual landings of red shrimps in Turkish seas were 1364 t[39]. Later in 2016, the trawling fleet from the Antalya Bay, one of the two major fishing areas in Turkey, was composed of 136 boats with a total length between 12 and 24 m and another fleet with 15 vessels having a total length of more than 24 m. In 2017, the number of bottom trawlers increased to 138 and 27, respectively while the total number of Turkish trawlers and beam trawlers working in the Mediterranean in 2020 was 226[34,40]. However, it is unclear how many of these fishing vessels are actively targeting red shrimps.

The fishery of red shrimps is also ongoing in Egypt (GSA 26, Southern Levantine Sea). According to the official authorities the total landings of red shrimps caught by 9 registered commercial trawlers ranged between 504-979 t in 2015-2017. The total port landings of *A. foliacea* in the Egyptian ports in 2017 were 682.2 t, while that of *A. antennatus* were much lower (209.8 t) [41]. In the Egyptian deep-water fishery, the term “red shrimps” includes the four species: *A. foliacea* (69.7%), *A. antennatus* (21.4%), *P. longirostris* (3.8%) and *Plesionika edwardsii* (5.1%). Here, most fishing activities are practised at a depth lower than 250 m, however, there is now a pronounced shift of fisheries from shallow to deep waters[42].

In both national (GSA 25) and international waters (including GSAs 24, 25, 26) around Cyprus, deep-water red shrimp catches, although of minor market relevance for local consumers, have also had an increasing trend between 1965 and 2004 (pers. comm. Thasitis). It is worth noting that, since 1985, Italian and Egyptian fishermen fish in this area and the majority of these activities are related to catching *A. foliacea.* The volume of these catches is unknown.

In Israel, both the giant red shrimp (*A. foliacea*) and the blue and red shrimp (*A. antennatus*) are characterized as commercial and reported in the same localities and depths[43]. No recent fisheries data is available. *A. foliacea* was known to be fished in the Haifa area throughout the year on the edge of a submarine canyon, while *A. antennatus* was known to be caught commercially by trawlers in spring and autumn in muddy bottoms of more than 180 m[43]. Experimental surveys carried out off the coast of Israel at depths between 734 and 1,558 m, between 1988 and 1999, also indicated the presence of *A. antennatus* in the depth range 1,000-1,527 m. At that time, the species was considered abundant, since it consisted of 14% of all the crustaceans caught[44,45].

The contribution of Libyan trawlers to red shrimp catches is considered negligible today[8] and information from Syrian waters relies on anecdotal evidence. The blue and red shrimp (*Aristeus antenna*) has been reported off Lattakia (Syria) in depths between 200-225 m in August 2005[46]. Previous records have reported the presence of *A. foliacea*[44,45] in the same area.

The available information indicates a future offshore expansion of the deep-water red shrimp fishing grounds in the Eastern Mediterranean. The status of the stocks of deepwater red shrimp stocks in the eastern central Mediterranean is not known, but indications provided by SoMFi 2020 report point towards a possible over-exploitation of these stocks at the Mediterranean level. Given the unclear situation of the red shrimp stocks, information of fisheries landings by GSA of origin and the increase of the fishing effort and capacity in the area, both *A.foliacea* and *A. antennatus* have been proposed to be incorporated into the list of priority species for data gathering and stock assessments in the Eastern Mediterranean and a set of adopted decisions have been taken[9] with additional precautionary measures to be considered.

Short-term actions by the Mediterranean countries as agreed at the General Fisheries Commision will be driven to work on:

- Definition of Eastern deep-water red shrimp fishing grounds.
- Advancing the work plan for stock assessment and the determination of fishing grounds,
- Improving the monitoring of authorized vessels and establishing a catch certification scheme towards recording the origin of the catch.
- Identification of nursery areas in the Eastern Mediterranean for deep-water blue and red shrimp and particularly the giant red shrimp, *A. foliacea*.
- Analysing the overlap between Vulnerable Marine Ecosystems and deep-water red shrimp fishing grounds.

Fig. 7.2.
Deep-water red shrimps exploited by trawlers in the Eastern Mediterranean (Source: JointMesudmed/EastMed/GFCM; 62, present work).

8 FAOSubMed Report on *A. foliacea*.
9 GFCM Scientific Advisory Commission, 2019.

Essential Fish Habitats

1

EASTERN IONIAN SEA

The two red shrimps coexist in the Eastern Ionian, both horizontally and vertically. However, the blue and red shrimp (*A. antennatus*) has a lower abundance than the giant red shrimp (*A. foliacea*)[49,50].

In the Eastern Ionian, the recruitment, and respectively the reproductive period, seems to last for a long period[51]. The spawning season of female giant red shrimps extends in the Eastern Ionian from late spring to late summer. More particularly, the spawning of the giant red shrimp (*A. foliacea*) begins in April-May, increasing sharply in summer and ending in September[52]. Moreover, *A. foliacea* males can reproduce throughout the year, while *A. antennatus* male reproductive activity seems to be more pronounced during late winter-early spring[51]. In the Eastern Ionian Sea, the smallest reported mature female was 27 mm carapace length (CL) and belongs to 1+ age group[52,53,54]. The deep-water blue and red shrimp (*A. antennatus*) is already sexually active from its first year of life (age 0), and mature individuals are found at a smaller size than those of the giant red shrimp *A. foliacea*. The smallest mature female *A. antennatus* was found to be 18 cm carapace length[51]. According to these studies, the length at first maturity of female *A. foliacea* and *A. antennatus* is considered as 37 and 26 mm CL, respectively[51]. Based on the size at first maturity and the minimum carapace length of the spawning individuals, the analysis considers juvenile individuals as those with CL < 35 mm for *A. foliacea* and < 25 mm for *A. antennatus*.

In the E. Ionian Sea, based on data from 1998 to 2008, the highest values of *A. foliacea* juvenile aggregations (< 35 mm CL) (N/km^2) were found in the Kyparissiakos Gulf and SW of Corfu Island (~ 19,000 N/km^2). Other hot-spot areas (> 10,000 N/km^2) showed a patchy distribution, mainly found West of Corfu Island, SW of Kefallinia Island, in the area between Eastern Zakynthos Island and Western Peloponnese coasts, off the Pylos Gulf and South of Paxi Islands. A lower but distinguished juvenile aggregation was also reported in the Messiniakos Gulf (~ 8,000 N/km^2). It is worth mentioning that high juvenile aggregation was repeatedly found in the first five areas mentioned above (Fig. 7.3).

The areas of higher juvenile blue and red shrimp (*A. antennatus*) aggregations in the Eastern Ionian Sea, based on the data for the period 1998–2018, are presented in Fig. 7.4. The highest value was found in the Kyparissiakos Gulf (~ 200 N/km^2). Other hotspots areas were found South of Othonoi Islands and in the Messiniakos Gulf (~ 100 N/km^2).

Recruitment of *A. antennatus* takes place about four and five months after spawning, which is not significantly different from the 3-month interval period reported for other areas in the Mediterranean[55]. Submarine canyons have been suggested as potential recruitment areas, due to the high abundance of juveniles[55]. These facts along with the limited sampling period clarify the low juvenile abundance reported above.

The highest spawning aggregations of female *A. foliacea* were found in the Kyparissiakos Gulf and S of Kefallinia island (~ 3,000 N/km^2) in late July. Other hot-spot areas were found off the Pylos Gulf, Western and Southwest of Corfu Island (~ 2,000 N/km^2), Southwest of Kefallinia Island, in the area between Eastern Zakynthos Island and Western Peloponnese coasts and South of Paxi Islands (1,000-1,500 N/km^2). It is noteworthy that high aggregations of spawning females were recorded in these areas repeatedly. Furthermore, the areas of highest juvenile aggregations overlap with those of highest spawning female aggregations (Fig. 7.3).

The highest spawning aggregations of female *A. antennatus,* based on data from 1998 to 2018, are presented in Fig. 7.4. The highest value was found SW of Corfu Island (~ 1,000 N/km^2) in late July. Other hotspot areas (500-1,000 N/km^2) were found in the Kyparissiakos Gulf, W of Corfu Island, S-SW of Kefallinia Island and SE of Zakynthos Island. Similarly, juvenile abundance of *A. antennatus*, female spawning individuals were found in less abundance than *A. foliacea*, which might be related to the lower occurrence of this species in the Eastern Ionian Sea and the limited sampling.

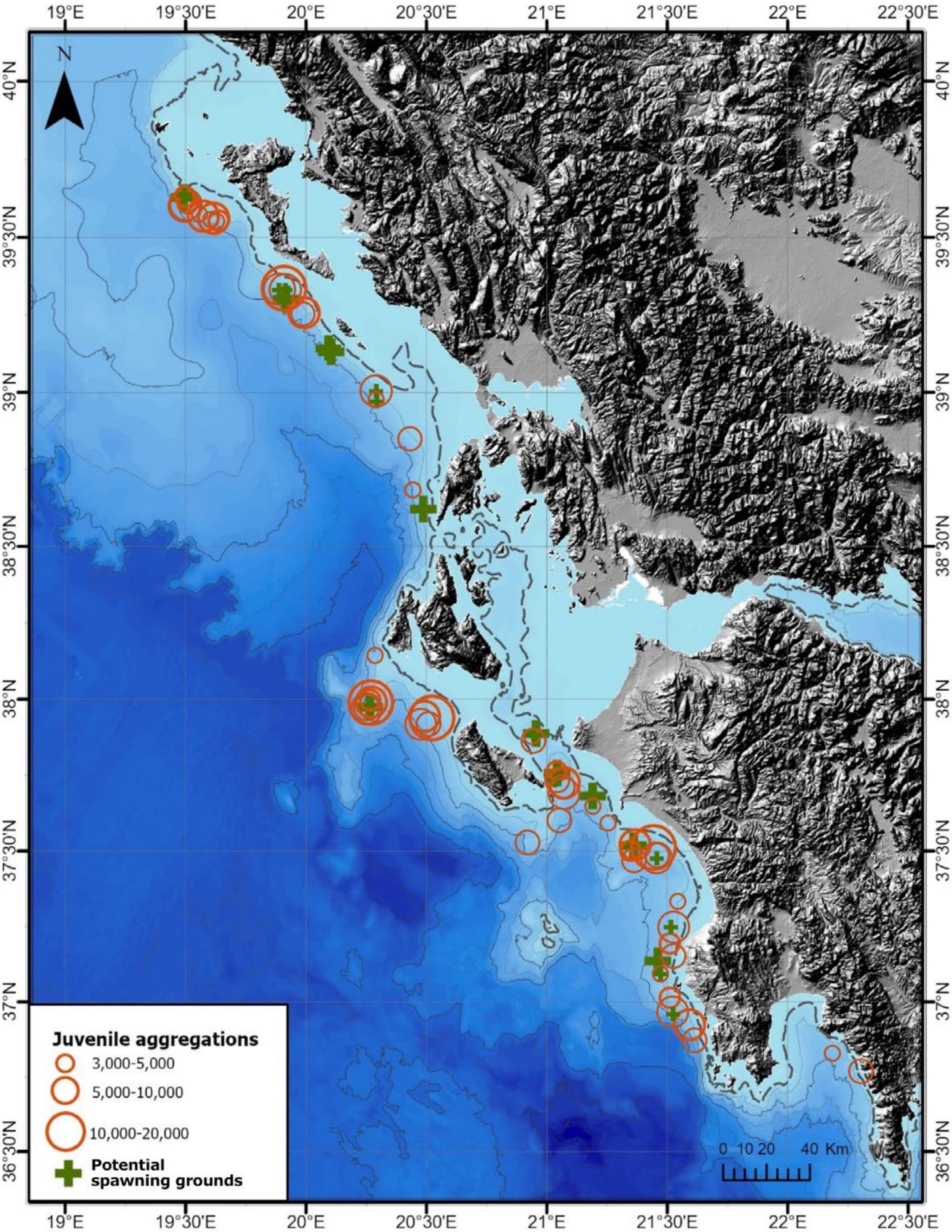


Fig. 7.3. Potential hotspots of juvenile aggregations (red circles) and spawning grounds (green crosses) of *Aristaemorpha foliacea* (N/km^2) in the deep waters of the Eastern Ionian Sea based on HCMR available data from 1998 to 2018.

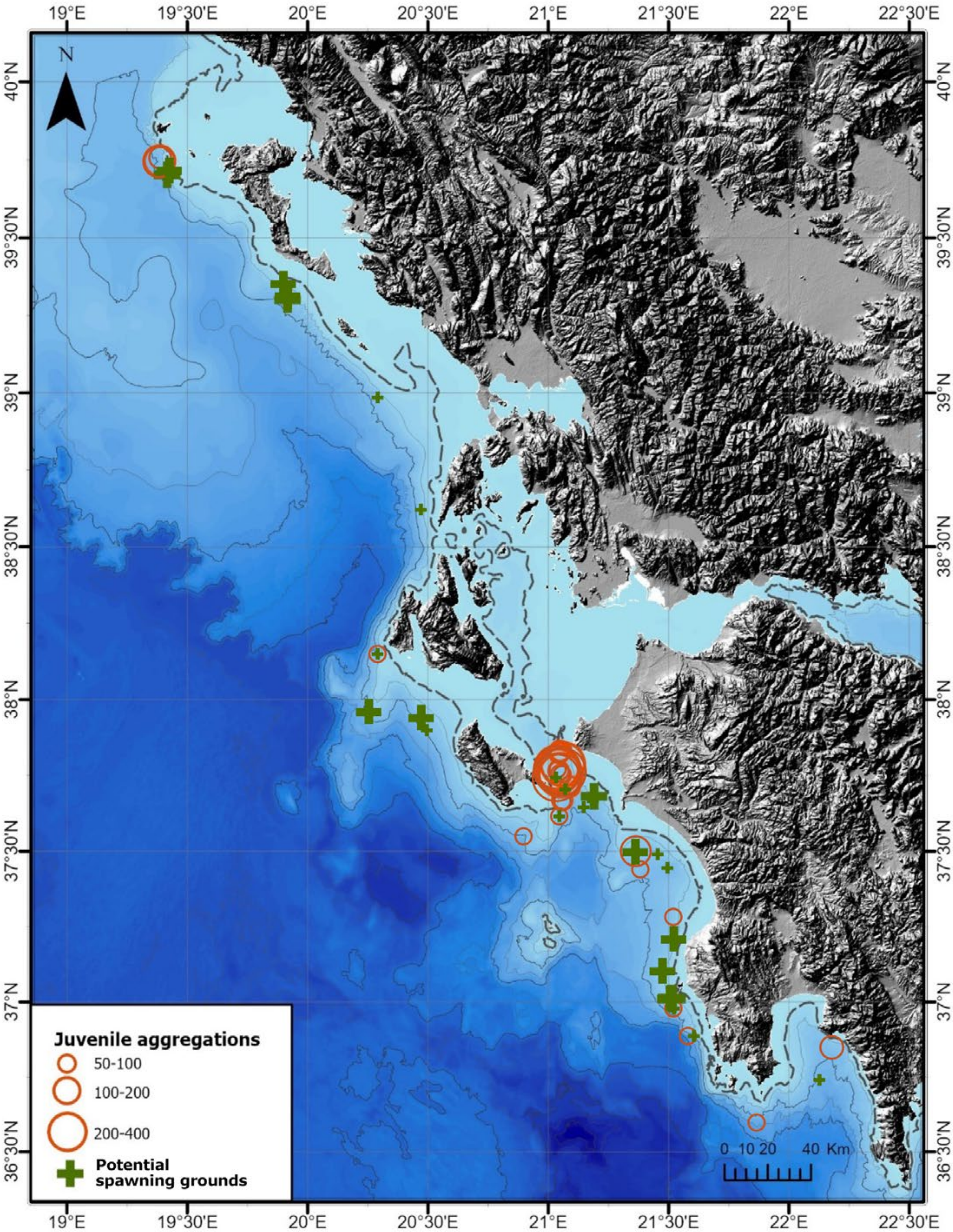


Fig. 7.4. Potential hotspots of juvenile aggregations (red circles) and spawning grounds (green crosses) of *Aristeus antennatus* (N/km²) in the deep waters of the Eastern Ionian Sea based on HCMR available data from 1998 to 2018.

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2 AEGEAN SEA

Based on available Greek data from 1998 to 2018 in the North Aegean Sea, very low abundance has been reported for the giant red shrimp *A. foliacea* and particularly for the blue and red shrimp *A. antennatus*. Conversely, in the South Aegean Sea, the abundance of adults of *A. foliacea* was high.

Regarding potential nursery habitats, high abundance of juveniles for *A. foliacea* has been found repeatedly Northeast of Tilos Island (5,000-13,000 N/km^2) and in the Agolikos Gulf, off NE. of Crete Island and South of Kos and Southwest of the Symi Islands (1,000-5,000 N/km^2) (Fig. 7.5). Similarly, the highest abundance of spawning female giant red shrimp have been found in the Argolikos Gulf (~ 1,500 N/km^2) as well as in the NE of Tilos Island (< 500 N/km^2).

The most important juvenile aggregations of blue and red shrimp (*A. antennatus*), indicating potential nursery areas, has been reported in NW Kalymnos Islands (~ 200 N/km^2) followed by NE of Crete Island and SW of Symi Island (100-200 N/km^2) (Fig. 7.6). Hotspots of spawning grounds where the highest abundance of spawning females of this species are, were found SW of Symi island and in the Argolikos Gulf (~ 230 N/km^2) followed by NE of Crete Island (~ 100 N/km^2).

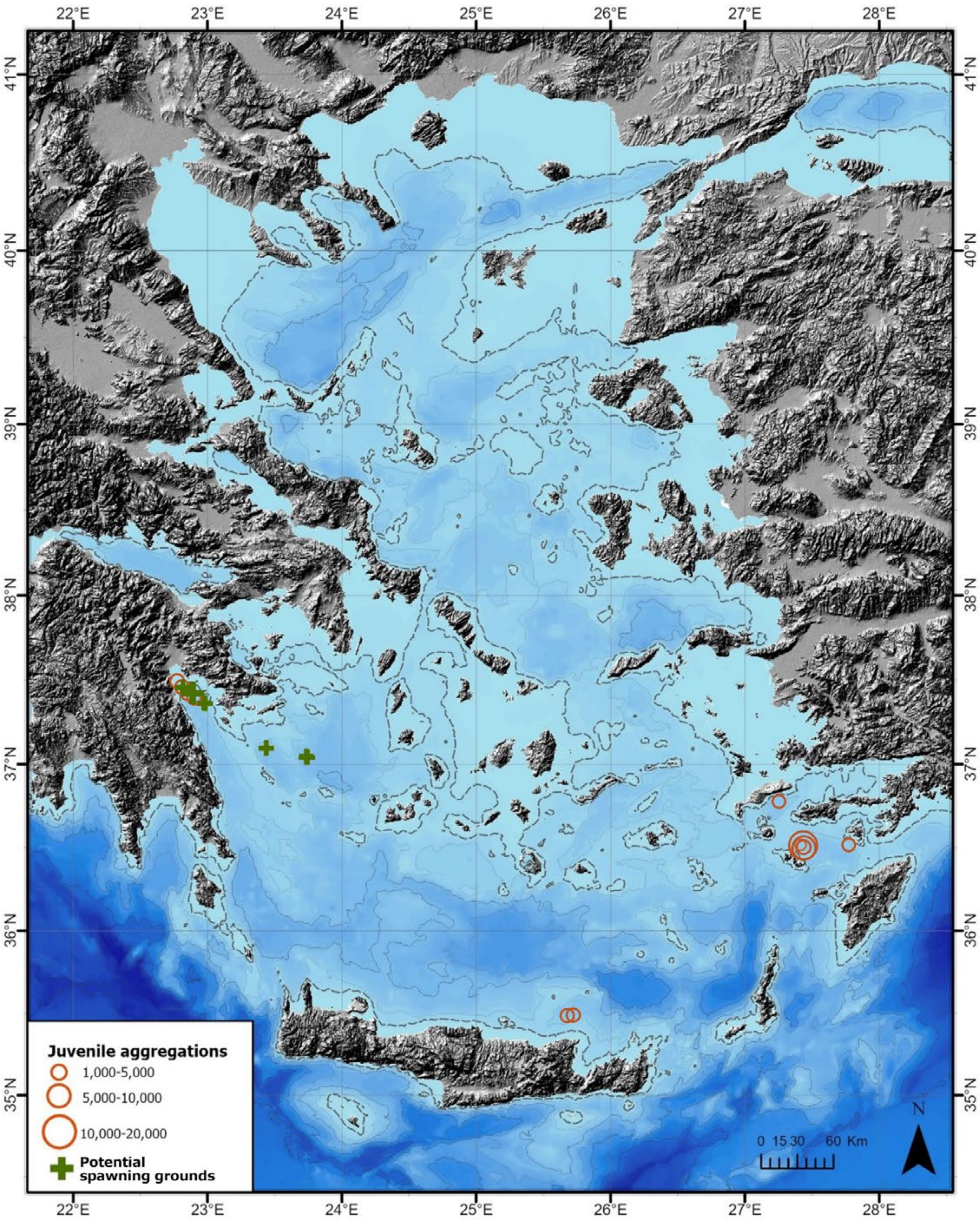

Fig. 7.5. Potential hotspots of juvenile aggregations (red circles) and spawning grounds (green crosses) of *Aristaemorpha foliacea* (N/km^2) in the deep waters of the Aegean Sea based on Greek available data from 1998 to 2018.

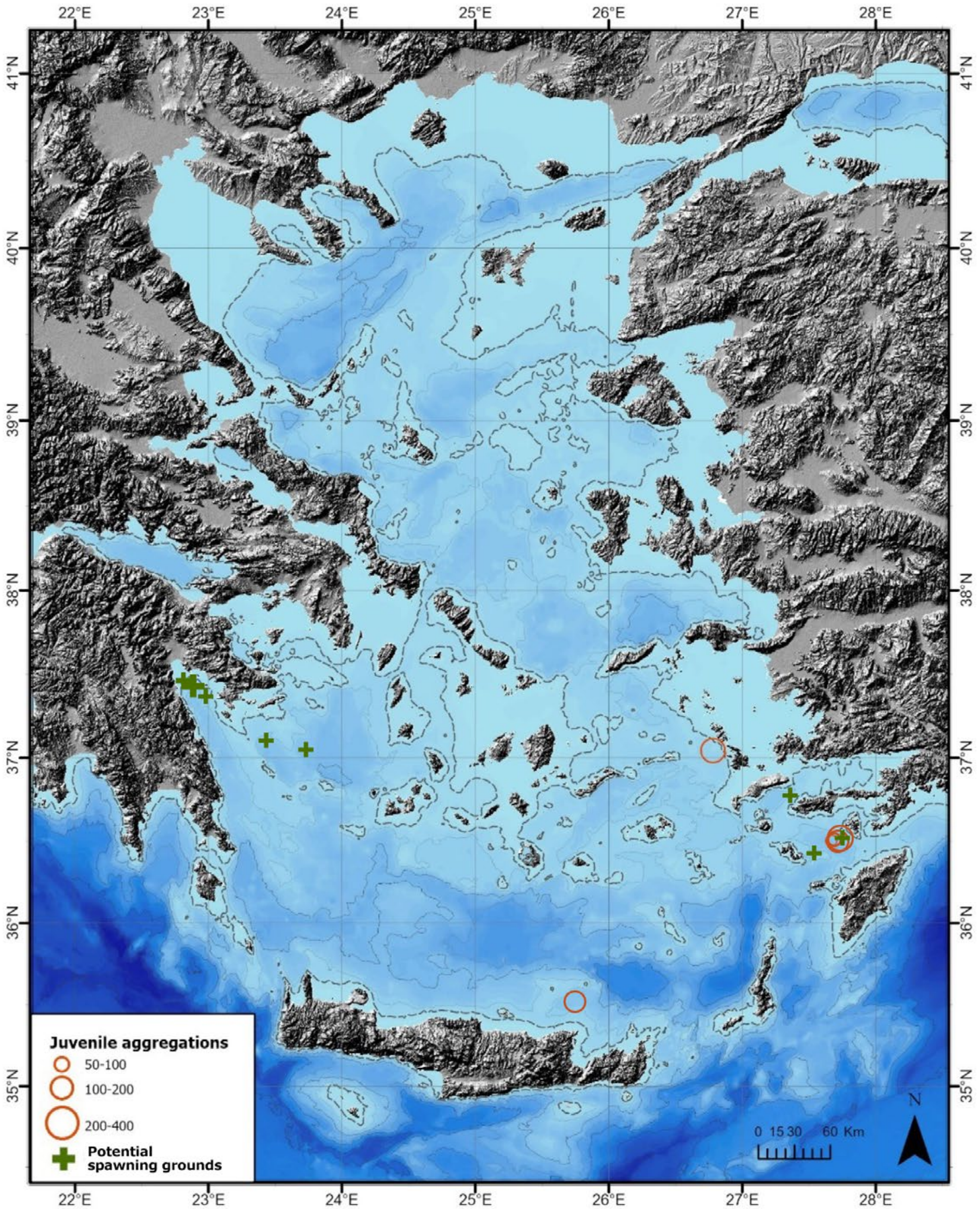

Fig. 7.6. Potential hotspots of juvenile aggregations (red circles) and spawning grounds (green crosses) of *Aristeus antennatus* (N/km^2) in the deep waters of the Aegean Sea based on Greek available data from 1998 to 2018.

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3 LEVANTINE AND LIBYAN SEAS

Both species of red shrimps have been reported in considerable abundance off South Turkey[40,56,57], Cyprus (Cyprus National Programme 1965-2004; MEDITS data 2005-2017; Thasitis pers. comm.), Syria ([48] Ali pers. comm.), Lebanon[58,59,60], Israel[44,61] and Egypt[41,42,62]. Nevertheless, very limited information is available on spatial distribution and no information on the presence of red shrimps juveniles and spawning females is available from these areas to enable identification of hotspots of nursery and spawning grounds.

GENERAL CONSIDERATIONS

From the biology, population dynamics or ecology point of view, many aspects for both red shrimps are still unknown for the majority of the Eastern Mediterranean waters, namely the stocks of Levantine, Libyan and Aegean Seas. Scarce information is available from the Antalya Bay (Levantine Sea). Even in the Eastern Ionian Sea, where the biological data is more detailed, the information is insufficient and needs updating.

Most Eastern Mediterranean countries do not report the catches of deep-water red shrimps by species; more commonly, catches are reported at the family level. Thus, it is difficult to evaluate the catch trends of each individual species. Moreover, it is clear that the current catches of deep-water red shrimps in the Central-Eastern Mediterranean are higher than what is being reported. Further efforts are also needed in the available data collected by FAO-GFCM from the Eastern Mediterranean to distinguish the origin of the catches from bottom trawl fisheries targeting deep-water rose shrimp or deep-water red shrimps. The data would thus allow a comparison of specific trends in catches at the sub-basin level (Eastern GSA) and more realistic management recommendations to be proposed.

Furthermore, considering the relevance of the deep-water red shrimp fishery, additional assessment of the status of giant red shrimp (*Aristeomorpha foliacea*) and blue and red shrimp (*A. antennatus*) stocks should be conducted in the future, taking into account the peculiarities of the different fleets, including those working in the Eastern Mediterranean basin.

Long-term monitoring is required to define the population dynamics of the red shrimp stocks and elucidate specific aspects associated with the biology/ecology of the species and the possibility of exploitation of the newly identified fishing grounds and the exploitation status of the already exploited stocks in the Eastern Mediterranean. New explorative surveys are also necessary to describe the spatiotemporal distribution of nursery and spawning grounds of both species in the Eastern Mediterranean basin, information that may help their protection and management. With more robust and comprehensive habitat assessments EFH identification could be improved. A preliminary assessment of both deep-sea shrimps in the Eastern Mediterranean with data limited methods is needed in order to have a primary evaluation of their stocks. It should be mentioned that the data used here should be updated since no monitoring survey has been conducted for some years.

In this context, a significant challenge for the sustainable management of deep-water red shrimps in the Eastern Mediterranean should be to elaborate a precautionary management framework before arriving at an overexploited status of the stocks, even if all the required information is not available. In order to achieve a sustainable management plan for this fishery, a series of different measures with a roadmap for implementation have been recommended:

- collecting enough data to support continuous analytical stock assessments
- identify EFH and spawning grounds
- initiate the fisheries footprint, overlap with vulnerable marine ecosystems and incorporating *inter alia* aspects of the FAO DSF Guidelines
- establish fishing authorizations in the immediate future, with the following provisions: landing at designated landing points, ensuring the presence of observers on board, obligation to use VMS, reporting the information on fishing activities
- establishment of a fishing season
- mitigate accidental catch of vulnerable species

Hotspots for juveniles in the Aegean Sea are not very well documented, and further investigation is needed. The lack of information on juveniles and spawning grounds of deep-water red shrimps from the other Eastern Mediterranean regions, particularly the Levantine Sea, highlight the demand for more research, precautionary management measures and the close collaboration of the countries in this area.

“

Areas such as the southwest of Corfu, Kefallinia and Paxi islands, Kyparissiakos Gulf and the area between Zakynthos island and the Peloponnese are potential EFH and spawning grounds for deep-water shrimps in the Eastern Ionian”

10 (GFCM SAC, 2017).

BLUEMOUTH ROCKFISH *HELICOLENUS DACTYLOPTERUS*

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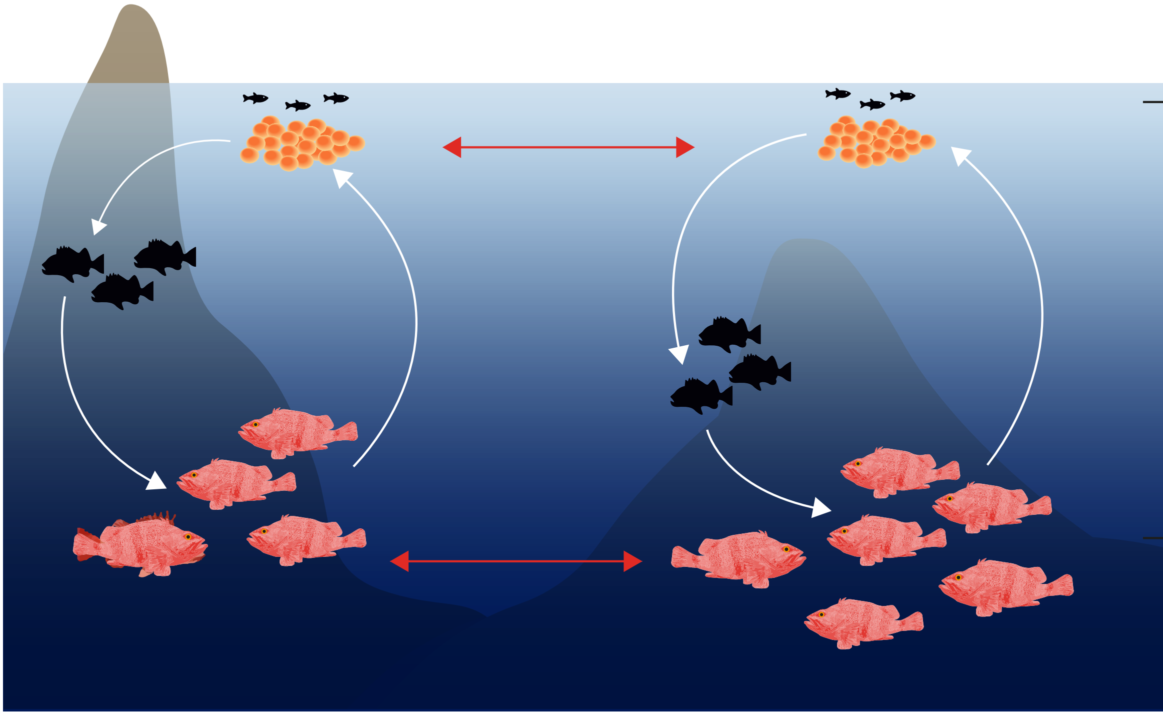
Blackbelly rosefish

Anastasopoulou A., Mytilineou Ch., Thasitis I., Jemaa S., Lteif M., Otero M., Lefkaditou E., Kavadas S., Adamidou A., Dokos I.

The blackbelly rosefish *Helicolenus dactylopterus* also known as the bluemouth rockfish, is a medium sized deep-sea scorpionfish widely distributed in the Eastern and Western Atlantic Ocean, Southern Indian Ocean and Mediterranean basin (except the Black Sea), where it plays an important ecological role in deep-sea fish communities on the coarse and mud-sandy bottoms of the continental shelf and mostly on the upper slope as deep as 1,000 m[64,65]. The species lives in the near-bottom environment of the deep-sea, commonly between 200-1,000 m and is known to be associated with seamounts, living in the vicinity of deep canyons[67], and cold-water corals including black corals, gorgonians and sponges[68].

Research studies reveal that the juveniles are mainly located around 150–300 m depth, whereas the adult specimens are spread over a wider depth range from 200 m to as deep as 1,000 m[69,70].

Available information for the species in the Eastern Mediterranean Sea is related to age and growth, diet, reproduction, length-weight relationships, population structure and fishery. This scorpion fish has a complex reproductive strategy and has been reported to live up to 27 years in the Eastern Mediterranean. From studies carried out in the Western and Eastern Mediterranean, it is known that it has a late maturity at the age of four years, being approximately 13 cm for males and 14.5 cm for females[74,70]. The fertilization is internal and females are able to store sperm in the ovaries for long periods of time and later spawn them in multiple batches of embryos enclosed within a gelatinous matrix. In the Eastern Mediterranean, the spawning period of the Bluemouth rockfish takes place over the winter months from December to April[75,76,77].



Research studies reveal that the juveniles are mainly located around 150–300 m depth, whereas the adult specimens are spread over a wider depth range from 200 m to as deep as 1,000 m[69,70]. Here, a diagram of the life cycle of the species and connectivity hypotheses among different habitats and seamounts. Adapted illustration by IUCN from[162].

FISHERIES

The blackbelly rosefish (*Helicolenus dactylopterus*) has important economic value in some areas of its distribution (e.g. Azores, Central Mediterranean) but the information available on its commercial harvest is scarce. The species is fished by long-lines and bottom trawl in the Atlantic and Western Mediterranean, but in the Central and Eastern Mediterranean mostly appears in the bycatch of bottom trawls and pots targeting other deep-water commercial species such as crustaceans and fish[78-80].

Regarding the fishing pressure, information is scarce. Reported data from landings are available for 2007 from three important fishing ports in the north-west Mediterranean where trawlers captured 70% of the total landings for this species and longliners the remaining 30%[81]. A few other reports also indicated that the species is commonly caught by fishing trawlers such as in the Thyrrenian Sea and the Eastern Mediterranean (e.g. Iskerenderum bay) although there is a lack of information on the catch and effort from the fleets exploiting this resource [70,82]. Fishery-independent data collected through the scientific bottom trawl survey of the MEDITS programme since 1994, also indicates that the species is caught by trawlers[82,83].

The blackbelly rosefish is particularly vulnerable to overfishing due to its biological characteristics (long life, large size, late maturity and slow growth) and the high pressure of trawl fishery in its distribution range [75,82,84-86].

Essential Fish Habitats

Knowledge on spawning grounds and juvenile aggregations of this species are scarce. As in other areas of its distribution, the species seems to prefer canyon areas for spawning[66,67].

1 EASTERN IONIAN SEA

Based on HCMR data from 1984 until 2016, the species presents high abundance values (> 1,000 N/km^2) in the upper slope (500-750 m) of the E. Ionian Sea (Fig. 7.7). The highest values (6,112 and 6,260 individuals/km^2) have been recorded off the Western and SW of Lefkas Island between 214 and 703 m depths.

Potential spawning grounds (high concentrations of mature individuals) were detected in waters deeper than 450 m between the South-East of Zakynthos Island and the West Peloponnese and North of the Kyparisiakos Gulf with a lower aggregation of mature individuals off South-West Lefkas Island (Fig. 7.7). These are areas of sea canyons that may indicate that mature females prefer the canyon areas to breed, a reason that may also explain the low occurrence of mature females in the trawl catches.

Areas of juvenile aggregation (individuals < 10 cm total length) in the Eastern Ionian Sea have been found in the shallower waters of the species spatial distribution, with the highest aggregations occurring in two areas: i) between S Paxoi and NW Lefkas Islands (1,523 N/km^2) and ii) off E. Ithaki (1,237 N/km^2) and E. Kephallinia (417-464 N/km^2) Islands (Fig. 7.7) at depths ranging between 190 and 390 m during the summer months.

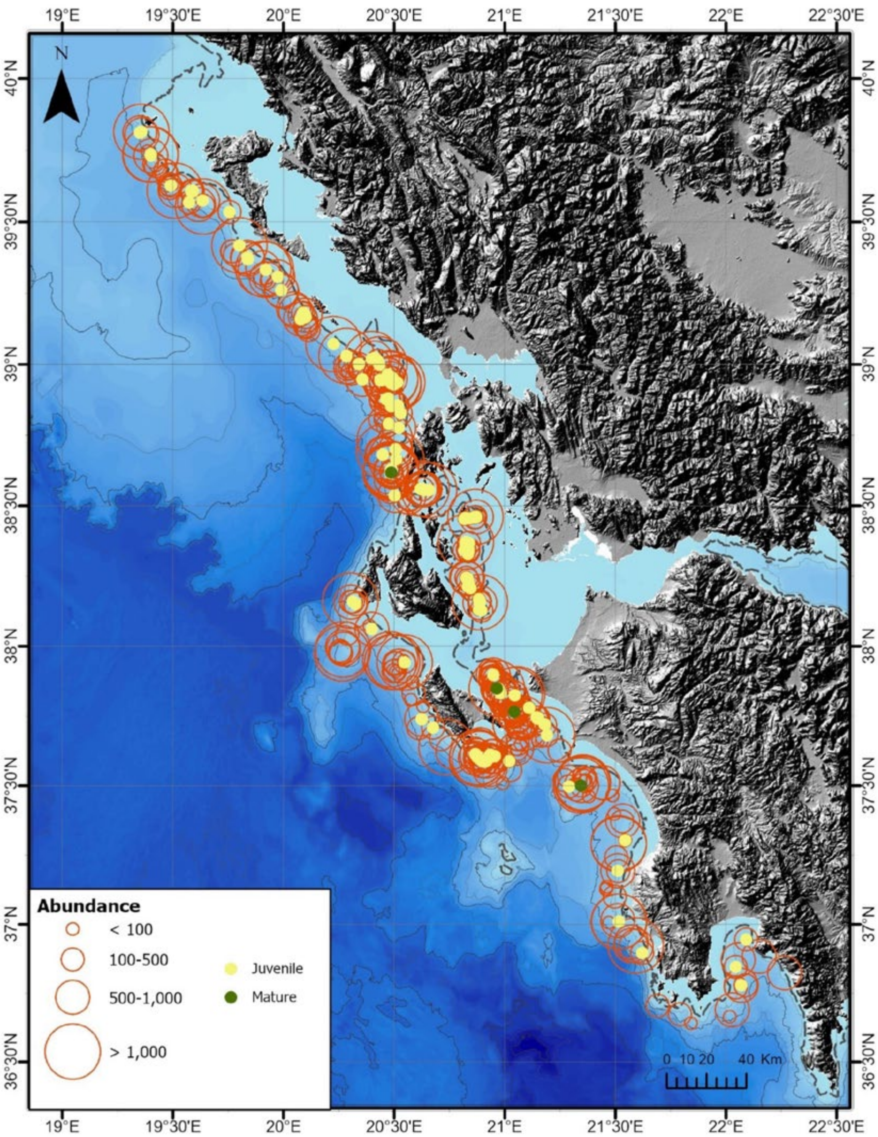


Fig. 7.7. Map of the spatial distribution of the abundance (N/km^2) of *Helicolenus dactylopterus* in the deep waters (> 200 m depth) of the Eastern Ionian Sea from data collected between 1984 and 2016, with hotspot areas of juvenile (yellow dots) and mature female (green dots) aggregations (> 80% occurrence per station). Abundance ranged between 9 and 6,260 N/km^2.

2 NORTH AEGEAN SEA

For the deep waters of the North Aegean Sea, information on blackbelly rosefish is very limited. Based on HCMR and Fisheries Research Institute data from 1990 until 2016, the species abundance ranged from 1.4 to 902 N/Km^2, much lower than that of the E. Ionian Sea, although this could be related to the sampling scheme realized in each area. The highest abundance (902 N/Km2) was observed off West Lesvos Island at 286 m depth (Fig. 7.8).

In the North Aegean, the only area with mature females was detected in the open waters South of Chios Island at 302 m depth (Fig. 7.8). However, it should be noted that the number of mature females was very low as in the case of the Eastern Ionian Sea.

Only one area of high juvenile aggregation (individuals < 10 cm total length) was found in the North Aegean Sea, located off West Lesvos Island at 473 m depth, with highest abundance 418 N/Km^2 (Fig. 7.8).

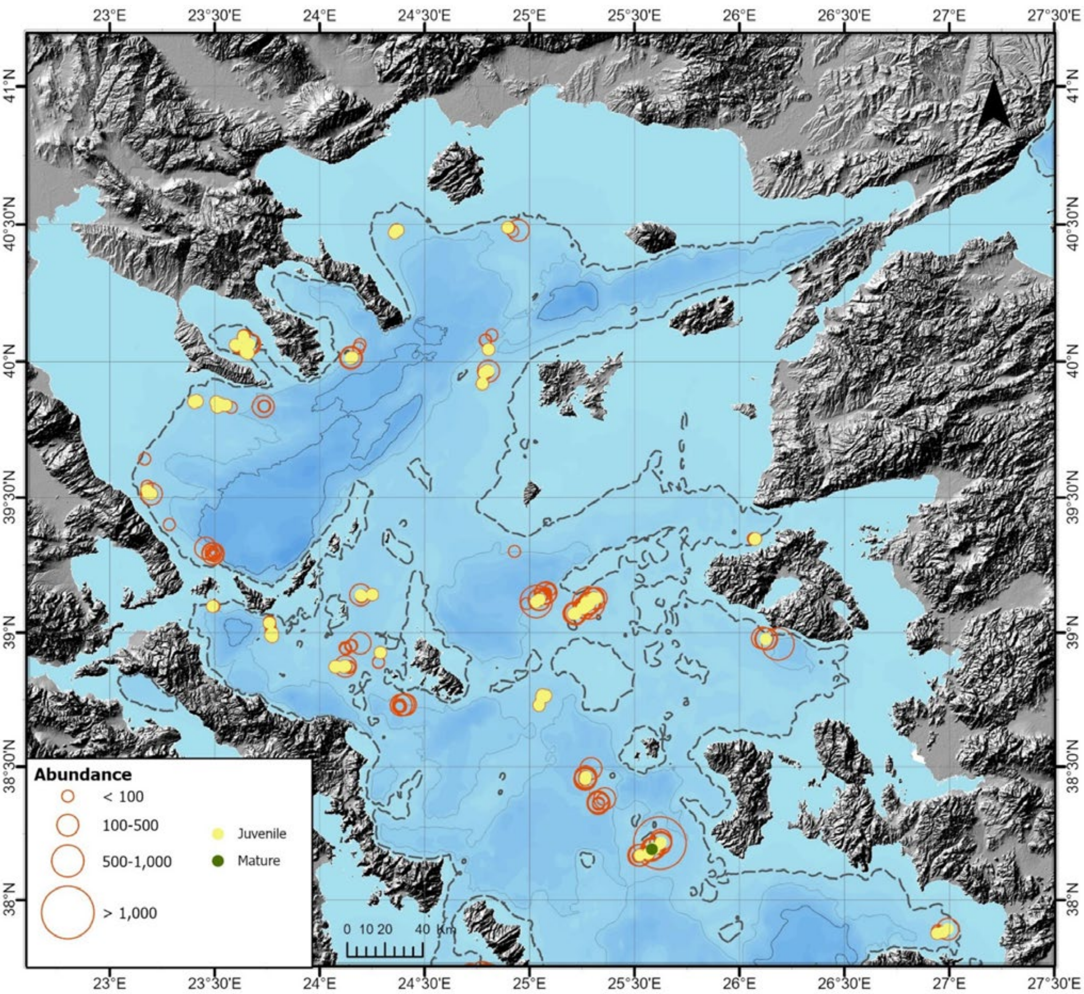


Fig. 7.8. Map of the spatial distribution of the abundance (N/km^2) of *Helicolenus dactylopterus* in the deep waters (> 200 m depth) of the North Aegean Sea, based on data collected from 1994 to 2016, with hotspot areas of juveniles (yellow dots) and mature (green dots) female (> 80% occurrence per station) aggregations.

3 SOUTH AEGEAN SEA

In the South Aegean Sea, existing published information on blackbelly rosefish comes from grey literature[87,88].

Data from 1984 until 2016, the species highest abundance was found: i) off the north coasts of Crete Island and more specifically in the area between the Gulf of Heraklion and Dia Island (2,310-4,207 N/Km^2) at depths between 231 and 241 m, ii) in the area E of Poros Island- Saronikos Gulf (2,384 N/Km^2) at depths ranging between 220 and 400 m, iii) in the Gulf of Mirabelou (off Ag. Nikolaos) (1,315-1,694 N/Km^2) between 315 and 331 m depth and iv) in the area off E Serifos Island-Cyclades (1,359 N/Km^2) (Fig. 7.9). In 2000-2001, experimental fishing with traps, conducted in the area between the Islands of Astypalaea, Kalymnos and Kos at depths ranging between 300-600 m, showed that the abundance in the deeper limit of 600 m depth was quite high, suggesting that the bathymetric distribution of the species may extend into even deeper waters than those initially studied[88].

In the South Aegean, mature individuals were found only in two areas: off the West of Kythnos Island at 548 m and off SE Spetses Island at 530 m, although the number of specimens was always very low (Fig. 7.9).

Hotspot areas of juvenile aggregation coincide with the areas of high abundance: off the area between the Gulf of Heraklion and Dia Island, ii) in the area E of Poros Island- Saronikos Gulf, iii) in the Gulf of Mirabelou (off Ag. Nikolaos) and iv) in the area off E Serifos Island-Cyclades (Fig. 7.9).

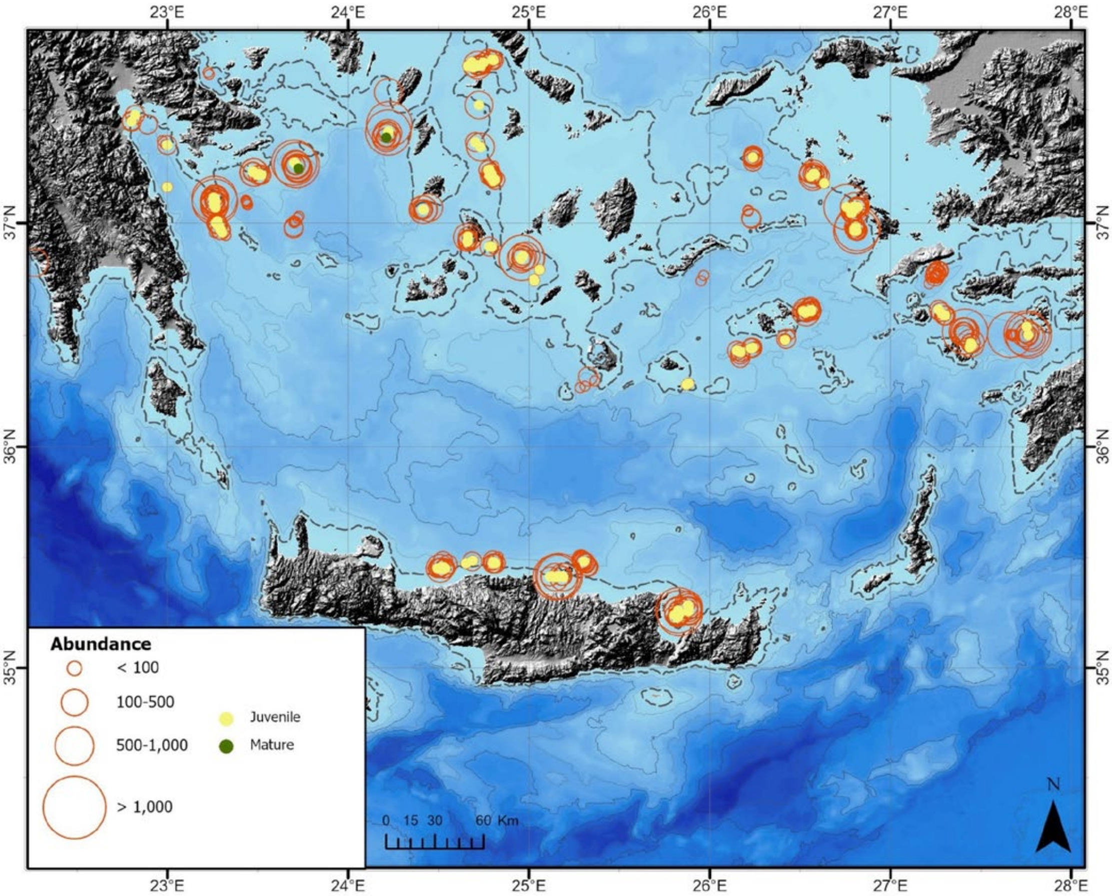


Fig. 7.9. Map of the spatial distribution of the abundance (N/km^2) of *Helicolenus dactylopterus* in the deep waters (> 200 m depth) of the South Aegean Sea, based on data collected from 1984 to 2016, with hotspot areas of juvenile (yellow dots) and mature (green dots) female (> 80% occurrence per station) aggregations.

4 LEVANTINE SEA

The Blackbelly rosefish has been mentioned as the dominant species in terms of abundance in all experimental trawl operations carried out by commercial trawl in the deep waters ranging between 300 and 601 m in the Mersin Bay (Turkey)[57]. In Antalya Bay, the abundance values of this species from experimental surveys varied between 12 and 2,714 N/km^2[75]. Higher abundance values were found in the upper slope (200-499 m) (80.9% of the total catch). Mature individuals have been found mostly (88%) distributed in the middle slope (500-700m), whereas almost all recruits of *H. dactylopterus* (98.6%) were distributed in the waters < 500 m[75].

The analysis of data from MEDITS 2005 to 2017 surveys, carried out off south Cyprus (Fig. 7.10) showed that the highest abundance (533 N/km^2) of the species was observed in a station SW of Cyprus at 307 m depth (Fig. 7.10). However, this may be related to the low sampling effort in deep areas. Mature females and nursery hotspot areas could not be detected.

Experimental fishing trials with gillnets and traps, targeting hake and the *Plesionika edwardsii* shrimp, carried out on the deep shelf and upper slope of South Lebanon at depths ranging between 200 and 320 m in 2012, revealed low abundance (139.2 g/km*day) for the blackbelly rosefish, which was caught as a bycatch[89]. This fact may be related to the sampling depth, location and gear used. In fact, high abundance of the species has been observed in the bathyal (until 842 m) soft substrates of the Lebanon canyons[60] confirming previous findings that this species seems to be associated with canyons. Analysis of Lebanese data from 2013 to 2017 collected by gillnets in depths from 200 to 300 m off Lebanon showed that the abundance of the species in this coastal zone seems relatively low (Fig. 7.11).

The presence of the species in Egyptian waters has been reported in the deep waters (350-750 m) off Alexandria when targeting deep red shrimps (Aristeidae), but no additional information is available[42].

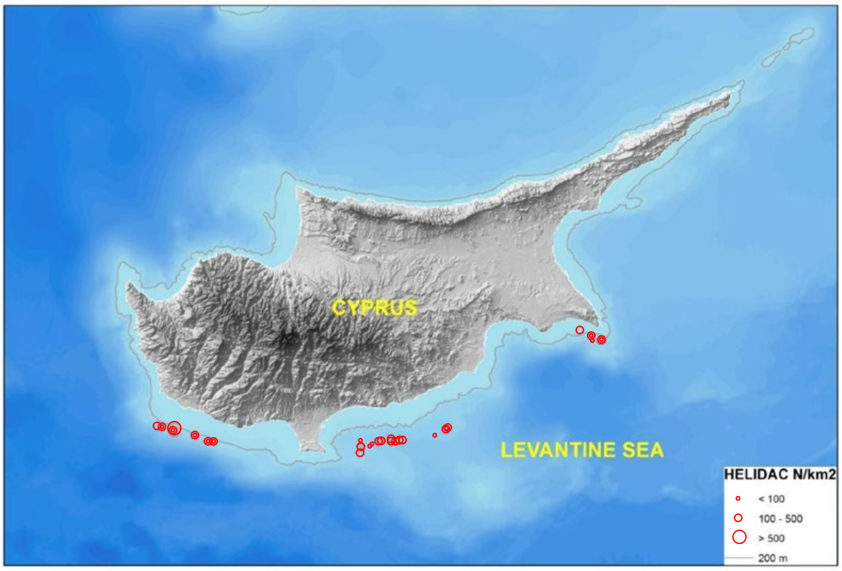


Fig. 7.10.
Map of the spatial distribution of the abundance (N/km^2) of *Helicolenus dactylopterus* in the deep waters off Cyprus from 2005 to 2017.

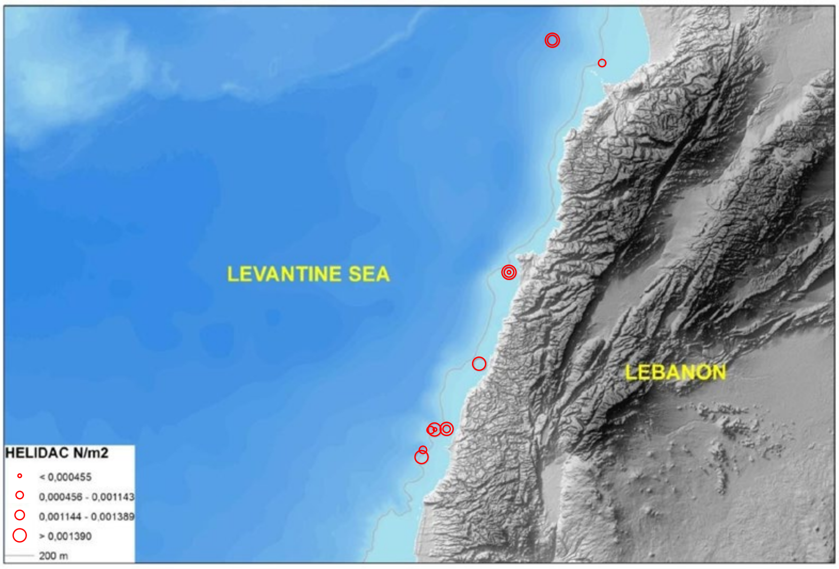


Fig. 7.11.
Map of the spatial distribution of the abundance (N/m^2) of *Helicolenus dactylopterus* caught by gillnets in the deep waters off Lebanon (Levantine Sea) from 2013 to 2017.

5 LIBYAN SEA

No specific information on the blackbelly rosefish (*H. dactylopterus*) is available from the Libyan Sea, although the presence of the species in the area has been documented (Machias, unpublished data).

GENERAL CONSIDERATIONS

The review based on published and unpublished information for the blackbelly rosefish *H. dactylopterus* highlighted serious gaps in the basic knowledge for the species in the E. Mediterranean. It should be noted here, that even in the case where data on the species occurrence exist, these are based on scientific surveys with different targets or the data were collected for a limited time period (with the exception of MEDITS surveys). These gaps are more evident for the Aegean, Libyan and Levantine Seas.

The information collected from the literature and the current analysis indicated that the blackbelly rosefish and particularly mature females occur mainly in canyon and coral areas, which enhance the importance of these deep habitats to the species sustainability. In contrast, juveniles occur on the upper slope (< 500 m), grounds that are frequently exploited. This fact may increase juvenile mortality and therefore the vulnerability of the species.

Hotspot spawning and juvenile areas for blackbelly rosefish in the Eastern Ionian Sea and Aegean Sea are indicated here as potential EFHs for the species. Considering the size at first maturity and the low selectivity of the Mediterranean trawl gear for this species (Mytilineou, unpublished data), along with the recent development of the deep-water fishery in the Mediterranean, the sustainability of the species is doubtful. Therefore, given the vulnerability of this resource, more specific work should be planned in the future in order to study and make clear several aspects on the distribution and biology of the species as well the species stock status in areas where deep-water fisheries have already been developed or are under development in the Eastern basin. This information can contribute to the development of adequate management approaches for demersal fisheries resources in this region to ensure the sustainability of these resources and the protection of their essential habitats from adverse fishing effects.

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THE BLACKSPOT SEABREAM *PAGELLUS BOGARAVEO* (FAMILY *SPARIDAE*).

Blackspot seabream

Mytilineou Ch., Anastasopoulou A., Otero M., Thasitis I., Damalas D., Lefkaditou E., Kapiris K., Kavadas S., Adamidou A., Dokos I., Ali M., Lteif M.

The blackspot seabream *Pagellus bogaraveo* is a demersal fish that lives near the coast as a juvenile and on the slope down to 800 m as an adult[20,90]. It is found in regions of the Eastern Atlantic Ocean, extending from Mauritania to Norway and the archipelagos of Madeira, Canary Islands and the Azores. Within the Mediterranean, it is more common in the Western basin and less common in the Eastern part, being absent from the Black Sea. The distribution of the species is reported to be closely associated with two atmospheric oscillations, the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO)[91].

Adults of blackspot seabream can be found forming relatively small shoals above muddy or rocky bottoms, near offshore banks, on seamounts and in cold-water reefs, but juveniles occur in shallower waters. The species presents a peculiar biology with sequential hermaphrodism, it develops as male, but can later reproduce as female although a fraction of the population never changes sex.

This particularity together with the late maturity of the species (the smallest observed mature female was 30 cm long and 5–8 years old) makes them especially sensitive to overfishing and to being affected by different fishing gears[28,89]. In the Strait of Gibraltar, the size at first maturity of females is estimated at 35.7 cm total length[93]. Fishing gears may also affect the species stocks since longlines catch the larger specimens which are females, whereas trawls catch smaller individuals which are males.

FISHERIES

The following three examples from the eastern Atlantic clearly show the vulnerability of the species to fisheries. The blackspot sea bream (*Pagellus bogaraveo*) used to be a major species in the Atlantic landings from the Bay of Biscay up to the early 1980s[92]. From the 1950s to 1970s, the blackspot seabream was exploited intensively, mainly by French and Spanish bottom offshore trawlers, by artisanal pelagic trawlers in the Bay of Biscay and by Spanish longliners in the Cantabrian Sea. The fishery in these areas strongly declined in the mid-1970s, and the stock got seriously depleted. Since the 1980s, it was mainly captured as bycatch and only a few small-scale handliners were still targeting the species. Landings in these areas continued to decrease from 461 t in 1989 to 164 t in 2016[94]. In the years 2019 and 2020, the advice by ICES for the northern region (Celtic Seas and the English Channel, Bay of Biscay) was zero catch and it is recommended to be maintained for years 2021 and 2022[11]. Therefore, no directed fisheries are permitted and catch should be only as bycatch.

11 ICES Advice on fishing opportunities, catch, and effort Celtic Seas and Bay of Biscay and the Iberian Coast ecoregions. 2019, 2020.

In the Azores area, where a longline fishery for the species exists, a decrease was observed since 2005 with a significant expansion of the fishery to offshore seamounts. During the period 2010–2012 the landings continued to decrease significantly. As a consequence, during 2015–2017 technical measures were introduced limiting the fishing areas, updating the minimum conservation reference size to 33 cm, and establishing marine protected areas in coastal and oceanic areas. The current advice given the status of the stocks in Azores grounds is that catches should be no more than 119 t in each of the years 2021 and 2022 for ICES 27.9 (Subarea 9 Atlantic Iberian waters) as well as in other (adjacent) areas, for the Spanish and Moroccan fleets (FAO 34.1.11 and FAO 37.1.1)[12].

The species is also exploited in the Strait of Gibraltar (Atlantic and Mediterranean area) mainly by Spanish, Portuguese and Moroccan fleets using lines and longlines. For the Atlantic waters, the landings from 854 t in 1994, decreased rapidly to 282 t in 1998, when TAC and Quotas were applied (council regulation (EC) No. 2340/2002). Catches in this region continued to be very low (174-165 t during 2017-18) compared to the maximum catches observed in the past during 1993–1994 and 1997 (about 1,000 t) and current ICES advice is that catches should be no more than 119 t in each of the years 2021 and 2022. Given that part of the stock is outside ICES Subarea 9, the TAC does not apply for those adjacent areas in the Strait of Gibraltar (geographical Mediterranean subareas GSA 1 and 3) and those that are part of the management by the Fishery Committee for the Eastern Central Atlantic (CECAF). For the Mediterranean, in 2019, an adaptive multiannual management plan for the sustainable exploitation of blackspot seabream in the Alboran Sea (including Strait of Gibraltar (GSA 1 and 3) was adopted by the General Fisheries Commission of the Mediterranean (GFCM). The operational objective of this recommendation aims to maintain fishing mortality for blackspot seabream in these subareas within agreed precautionary reference points in order to reach and maintain, as soon as possible, a fishing mortality level consistent with the maximum sustainable Yield (MSY). Among the technical measures in place in the short-term are: the prohibition to land specimens of blackspot seabream where the total length of the fish is smaller than 30 cm; the establishment of a register of authorized fishing vessels; the use of a vessel monitoring system (VMS) or any similar system for vessels above 12 metres to track their activity at all times during the fishing trips; the designation of landing ports and catch reporting; and scientific monitoring.

At present, no particular attention has been given to the species in the Eastern Mediterranean although some studies have described the blackspot seabream stock status. The fishery of red seabream in the Eastern Ionian started mainly in the early ’80s with longlines[95,96]. However, this gear was gradually replaced by gill nets. In the early years of this fishery the catches of the species were extremely high, but very soon they declined dramatically. The main reasons for the decline seemed to be overfishing, the introduction of gill nets, recreational fishing and ghost fishing[95].

Today, the species is fished mainly in the Eastern Ionian, South Aegean and Cretan Seas with long-lines, gill nets and trammel nets on rocky banks at depths from 200 to 600 m. In the Eastern Ionian Sea and South-eastern Aegean Sea, a total catch of about 80-100 kg/day was common with long-lines in the past[97]. A few years later, the reported average catch was 61.7 kg/day[95]. In the Cretan Sea, during the same period, the maximum reported daily catch was 200 kg/day, decreasing thereafter. Catches have declined in all areas. At the end of the ’90s, the catch consisted almost exclusively of *P. bogaraveo*, but a few years later, it decreased to 76% by number and 47% by weight[96]. As a response to this situation, some fishers abandoned this metier, whereas others decreased the mesh size with negative consequences such as the increased quantities of discards, lower price in the market, higher pressure on the stock and reduction of the spawning biomas[98]. The length and age composition of the red seabream in the catches also changed over the years including more young and less older individuals; the length of the red seabreams ranged from 16 to 40 cm[95], whereas in the past the main bulk of the catch ranged between 25-30 cm (Petrakis et al., 1999). According to the HELSTAT data, the annual landings of *P. bogaraveo* from passive gears (longlines, nets) for the years 1994-2004, showed a generally slight declining trend[96].

12 ICES Advice on fishing opportunities, catch, and effort Bay of Biscay and the Iberian Coast ecoregion, 2020.

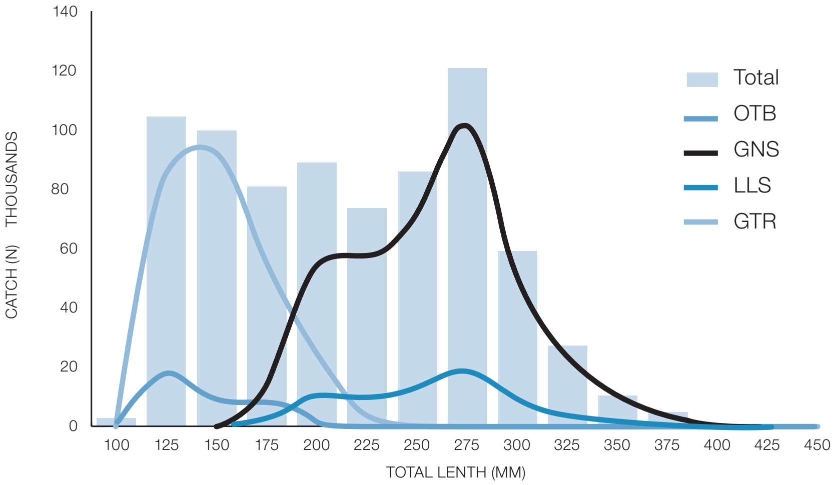

Fig. 7.12.
Catches of blackspot seabream *P. bogaraveo* from different fishing gears in the E. Ionian Sea based on DCF data 2003-2008. OTB: otter trawl; GNS: Gillnet; LLS: longline; GTR: trammel net[99].

An attempt to assess the state of the blackspot seabream stock in the Eastern Ionian Sea during the EU project, DEEPFISHMAN, suggested that the stock was close to overfishing during the period 1998-2002 followed by some improvement in subsequent years, reaching a level of sustainable exploitation in 2008[99]. However, this analysis was based on very poor data and, since then, no further study on the state of the stock has been done. The same study also estimated the size composition of blackspot seabream by fishing gear in this area, indicating that trawl and trammel net catches mainly consisted of young individuals (< 18 cm) (Fig. 7.12), with the latter gear indicating particularly high catches of juveniles.

Blackspot seabream is also an important target of recreational fishery that increases mortality of the species. However, no information on the catches of the species by this type of fishery is available.

Essential Fish Habitats

The existing information for the species in the Eastern Mediterranean Sea is limited. It is known to be abundant in the Ionian and Aegean Sea[90,100,101,102], as shown in Fig. 7.13 and Fig. 7.14, and rare in the Levantine Sea[54,102]. A few individuals (13.7-15.5 cm) have been reported in Israeli waters from 300 to 350 m depth [104] and from the coastal waters of the west coasts of Libya, but in low abundance[105]. Relatively

small *P. bogaraveo* (15-19 cm) have also been recorded from Mersin bay in depths ranging between 300-600 m (Turkish Levantine waters[57]). In Lebanese waters, based on ROV observations, the species was identified in the areas of Sayniq, St. George and Tarablus/ Batroum at 178-505 m depth with a sporadic distribution[60]. The first record of *P. bogaraveo* in the Egyptian Mediterranean waters was in the east of the Suez Canal, off Port Said [106]. The species has also been recently reported from Syrian waters[107,108]. The main information on the species essential habitats is mostly from the Eastern Ionian and the Aegean Seas.

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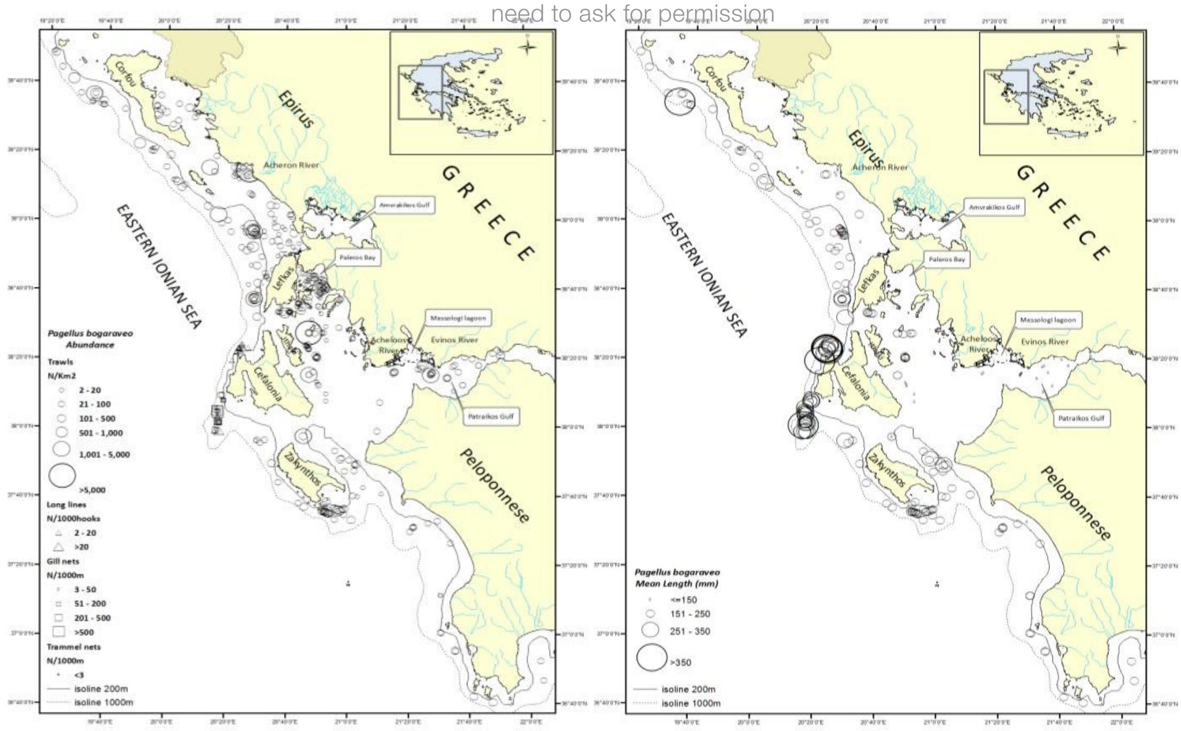

Fig. 7.13. Left: Map of the spatial distribution of the abundance (N/km² for trawl, N/1000 m for trammel and gill nets and N/1000 hooks for long lines) of blackspot seabream *Pagellus bogaraveo* in the Eastern Ionian Sea; Right: Map of the spatial distribution the species mean size (mean LT, mm); data from 1983 to 2010[100].

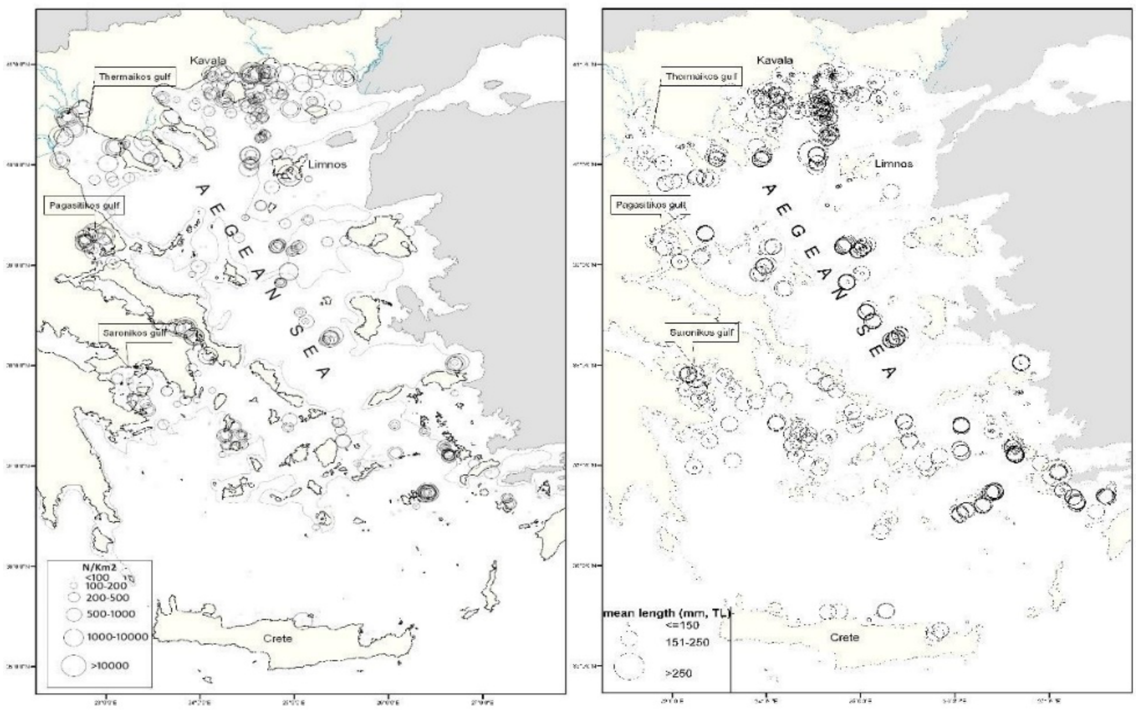

Fig. 7.14. Left: Map of the spatial distribution of the abundance (N/km²) of blackspot seabream *Pagellus bogaraveo* in the Aegean Sea. Right: Map of the spatial distribution of the species mean size (mean LT, mm); data from 1986 to 2009[100].

1

EASTERN IONIAN SEA

Based on the analysis of data from 1983-2010, distribution of the blackspot seabream in the Eastern Ionian is continuous along all the E. Ionian[90], with areas of high abundance in shallow waters or mainly close to river deltas (Fig. 7.13. Left). These areas correspond to juvenile (individuals < 15 cm total length) aggregations (Fig. 7.13. Right). Adults (> 25 cm of total length) are always encountered in deep offshore waters (> 200 m depth).

The analysis of HCMR data from 1998 to 2016 showed that juveniles (< 15 cm TL) of blackspot seabream aggregate in shallow waters, mainly close to river deltas or in closed gulfs. Two of the areas considered as nursery grounds for *Pagellus bogaraveo* in the Eastern Ionian Sea, are located close to Acheron River Delta (western coast of Epirus) and in the area between the east coasts of Ithaki and the west coasts of central Greece, off Acheloos River Delta (Fig. 7.15). Another area, but of lower importance, has been found close to the Evinos River Delta (in Patraikos Gulf), where a non-permanent and of lower abundance juvenile aggregation was found, a fact that may be related to the Evinos river Dam construction in 2002, which reduced river discharge.

2

NORTH AEGEAN SEA

In the North Aegean Sea**,** the analysis of Greek data from the 1986-2009 period, revealed areas with a high presence of juveniles (< 15 cm TL) located close to the Deltas of the Axios, Nestos and Evros Rivers (Fig. 7.14[100]). The analysis of Greek data from 1986 to 2016, revealed a quite similar situation with the highest juvenile aggregations detected in the Thracian Sea, close to Nestos River and in the Toronaios Gulf (in Chalkidiki Peninsula). However, lower concentrations of juveniles were also found north of Samothraki Island and in Thermaikos and Pagassitikos Gulfs (Fig. 7.15)

Information regarding potential spawning grounds of the species in the North Aegean Sea, and particularly off W Limnos and off S. Sporades Islands, is also shown in Fig. 7.15. Similar to the E. Ionian Sea, in the North Aegean Sea, only a small fraction of females were found to be mature. This can be explained by the fact that most of the blackspot seabream data were derived from trawl fishing (and therefore were juveniles), whereas adults of this species (and therefore mature females) are mainly caught by other gears (longlines or gillnets). Further studies, using a more adequate sampling design, are necessary to elucidate the life history of the species in the North Aegean Sea.

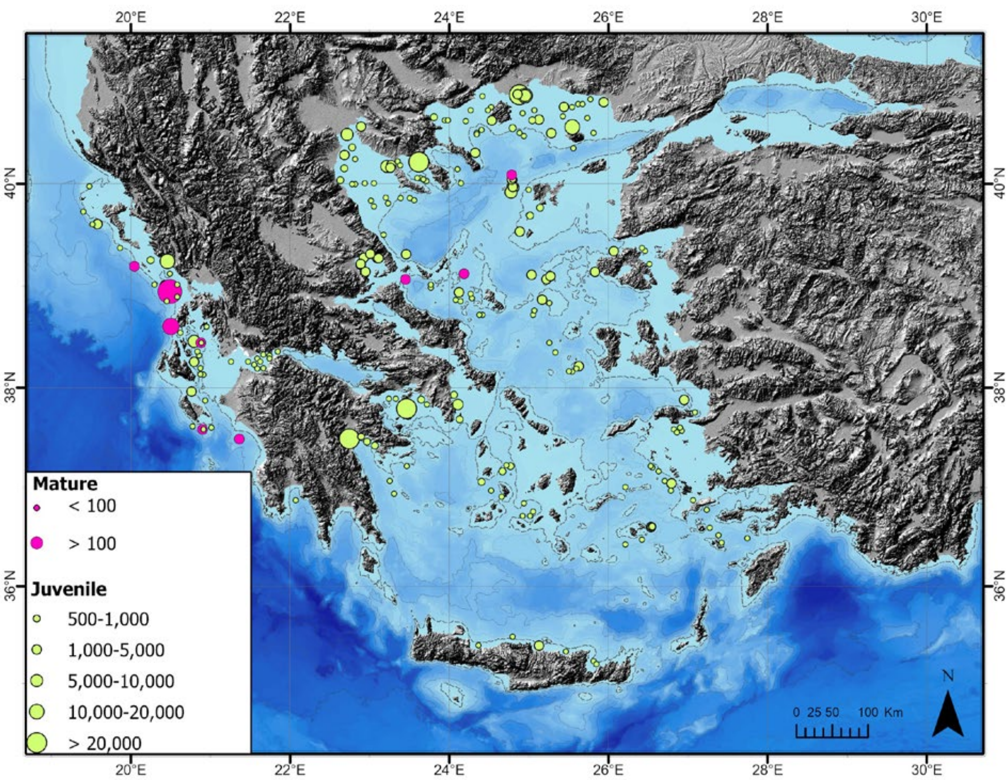

Fig. 7.15.
Map of the spatial distribution of the abundance (N/km²) of juvenile and mature female blackspot seabream *Pagellus bogaraveo* in the E. Ionian and Aegean Seas, based on data from 1983 to 2016 (HCMR & FRI data).

Information on the blackspot seabream from the Turkish waters in the North Aegean is related more to the occurrence of the species in Gökçeada Island and Saros Bay[101,102]. *P. bogaraveo* is one of the most abundant fish species in all depths (< 400 m depth) in Gökçeada Island waters[101] and other reports indicate that the species is among the ones with higher abundance in the adjacent area of Saros Bay, at 200-500 m depth[102]. Significant quantities of young individuals (< 15 cm), caught by trawling, have been reported from waters off Gökçeada Island (< 400 m depth), probably discarded or sold at a low price, since the species is not regulated by a minimum landing size in Turkish waters[101]. No other information on juveniles and spawning grounds of *P. bogaraveo* is available from the Turkish waters in the North Aegean Sea.

3 SOUTH AEGEAN SEA

In the South Aegean Sea**,** the analysis of Greek data from the 1986-2009 period, revealed areas with a high presence of juveniles (< 15 cm TL), mainly in the Saronikos and Argolikos Gulfs (Fig. 7.14. right[100]). More data until 2016 for the South Aegean Sea, showed similarly high juvenile *P. bogaraveo* aggregations (Fig. 7.15) in the Saronikos Gulf and Argolikos Gulfs, and some aggregations of lower importance in the Petalioi Gulf (South Evoikos Gulf) and in the Cretan waters. However, the species lower occurrence in these locations may be related to the uneven sampling effort exerted among the different areas.

No information is available for the spawning activity or grounds of the species from the South Aegean Sea.

4 LEVANTINE SEA

No specific information on the essential habitats of the species is available from the Levantine Sea, because of the species' low abundance in these waters as well as the lack of a dedicated sampling effort.

The most systematic information comes from Cyprus, based on the MEDITS survey, conducted in the waters of Cyprus from 2005 to 2017. A few young *P. bogaraveo* (~ 9 cm TL) were reported in 2012, close to Lemesos (South Cyprus) in shallow waters (< 100 m depth). The largest individual (22 cm TL) was also found in the same area (off Lemesos) in 2011 in deeper waters (600 m depth). A few individuals (20-21 cm TL) were also collected in the area between Lemesos and Larnaka in depths ranging between 560 and 600 m in 2009 and 2010. Furthermore, a small number of recreational fishers target the species in deep waters using electrical reels (Thasitis, unpublished data).

5 LIBYAN SEA

No specific information on *P. bogaraveo* is available from the Libyan Sea**.** The species has been reported from the Gulf of Messara (South Crete Island) from surveys conducted by HCMR in 2007, but its abundance was greater in surveys conducted from 1988 to 1992, indicating the potential impact of fisheries on this species, as found for other species and the whole fish assemblage in the study area[109].

The species has also been reported from the coastal waters (< 200 m depth) of the west coasts of Libya, presenting, however, some of the lowest catches compared to other species[105].

GENERAL CONSIDERATIONS

The blackspot seabream (*P. bogaraveo)* seems to be relatively important in the commercial fisheries of the Eastern Mediterranean, depending on the area. Specifically, in the Eastern Ionian and Aegean Sea it is fished by both recreational and commercial fisheries, even sometimes indirectly taken as bycatch.

Young *P. bogaraveo* live close to the coasts, in river deltas and closed gulfs. In Greek seas, trawl fishing is not allowed close to river deltas, in waters shallower than 50 m of depth and less than 1.5 km from the coasts[110]. Similar measures exist for the Turkish waters[101]. Therefore, very young specimens (< 15 cm TL) of this species seem to be protected from trawl activities in the coastal areas. However, this work shows that trammel nets, operating in shallow waters, also catch significant quantities of juveniles. Moreover, the part of the larger juveniles that are still immature as a result of the hermaphroditism of the species, live in waters down to 150 m depth[90] which are intensively fished by the trawl, resulting in discards or low value landings[101].

Juveniles are also protected by the existing regulation with a Minimum Conservation Reference Size (MCRS) for the European Mediterranean fisheries, not allowing blackspot seabream < 33 cm to be landed, with the exception of the Gibraltar Strait where a recent recommendation of 30 cm was adopted. However, the MCRS application and the fishermen's compliance with this rule for European Mediterranean countries is difficult given the following factors: a) very few individuals are caught at sizes > 30 cm; b) there is poor monitoring, control and enforcement for MCRS application; c) most individuals at sizes > 20 cm are caught by small scale fishing fleets selling their products unofficially at local markets and restaurants and d) the species is not a target in the sampling frame of the Data Collection Framework (DCF) in the Eastern Mediterranean, resulting in scarce information and absence of a time series, required for accurate assessment. Moreover, the value of MCRS provided for the species in the Mediterranean is based on information for the species biology from the Eastern Atlantic waters**[13]**, where the species reaches very large sizes (52 cm TL[111]) compared to those observed in the Eastern Mediterranean[31].

With regard to the larger individuals (some of them probably still immature), which live in deeper waters near banks, these are mainly caught by longlines and gillnets, which operate without specific management measures, as also happens for recreational fishing, mainly practised in Greek waters by using one line with many hooks.

Significant gaps have been identified through this critical examination of the available information on *P. bogaraveo* biology and population dynamics as well as its commercial and recreational fishery in the two main areas of the species distribution and exploitation, the Ionian and Aegean Seas. These gaps should be addressed in order to achieve a sustainable fishing of this vulnerable species. This implies the necessity to i) conduct more specific surveys with adequate sampling gears focusing on the study of this species, ii) monitor the species by including it in the DCF national fisheries data collection programme and conduct common stock assessments in each GSA region, iii) implement the use of Vessel Monitoring Systems (VMS) to gather information of fishing operations per boat and areas, linking data with landings (and CPUE) geographical distributions and sales at landing port, iv) regulate the commercial and recreational fishing of the species by improving the selectivity of the gears used and by establishing a minimum conservation reference size close to the size at first maturity of this species in the Eastern Mediterranean Basin.

13 STECF-16-09.

Wreckfish

Lefkaditou E., Otero M., Lteif M.,
Kavadas S., Mytilineou Ch.

The wreckfish *Polyprion americanus* is a large demersal fish, distributed worldwide on both sides and hemispheres of the Atlantic Ocean, the Mediterranean, Indian Ocean and the South-western Pacific[112]. Like other deep-water species, the wreckfish is generally considered a long living, slowly growing and late maturing fish species[11]. It inhabits continental slopes, oceanic islands and seamounts of temperate and subtropical waters at depths from 40 to 800 m, although they are more frequently found in waters deeper than 300 m down. Juveniles are pelagic until approximately 45-65 cm total length and often found drifting with the currents, associated with floating seaweeds or wreckage[102,104]. To reach sexual maturity and become adults, juvenile wreckfish migrate to the benthic habitat in offshore waters. As adults, they show a preference for habitats of seamounts and banks with deep-water carbonate mounds and cold-water coral colonies at depths from 300-800 m[113,114].

Studies addressing several aspects of wreckfish biology, such as reproductive mode, spawning period, feeding in different life stages, age and growth estimation, length and age at maturity, have been performed in areas where it is commercially exploited. Particularly in the Eastern Mediterranean, wreckfish fisheries and life history have been studied in the framework of a specific European Study project entitled "State of the stocks of European wreckfish (*Polyprion americanus*)"[53]. Even so, little is known of the wreckfish's life history. This fact together with exceptional longevity and related life history attributes suggest that *P. americanus* is highly vulnerable to fishing exploitation and represents an important challenge for fisheries management (Table 7.1).

Studies from rearing in captivity and wild specimens revealed that wreckfish experience rapid growth during the early years of life reaching a plateau in their growth by 20 years of age[11,117]. It reproduces at great depths shortly after settlement on the bottom[112,118]. Size at first maturity of males is generally slightly lower than that of females, at 68-81 cm. (8-9 years) and 77-95 cm (10-12 years), respectively. Fully mature individuals have been recorded from late autumn to early spring but spawning has also been confirmed in the Eastern Mediterranean during winter over depths of about 1,000 mm off North Crete[118].

FISHERIES

Table 7.1. Technical characteristics of professional fishing gears targeting or having an important by-catch of *Polyprion americanus* in the Eastern Mediterranean

Area	Fishing Gear	Target species	Hook Size	Number of hooks	Length (m)	Snood Distance (m)	Bait	Soak time (hours)	Fishing period	Depth (m)	Source
E. Ionian	Long-line	*M. merluccius*	6-8	600-2,000	3,000-18,000	5-9	*S. pilchardus*	0.2-2	all year	400-700	[97,119,120]
E. Ionian	Long-line	*P. americanus*	6	250	2,700	11	*S. pilchardus*	4-5			[120]
North Aegean (East of Evia Island)	Long-line	*P. bogaraveo*, *P. pagrus*, *M. merluccius*, *P. americanus*, *Mustellus spp.*	12-5		5,000-6,000	6-9	*Scomber* spp., S. pilchardus, ommastre-phids	2-3	all year	100-700	[97,119,121]
North Aegean (East of Evia Island)	Drop-line	*P. bogaraveo*	10	50-70			Scomber spp.	0.25-1			[121]
North Aegean (East of Evia Island)	Drop-line	*P. americanus*	0.1	5			Loligo spp.				[121]
SE Aegean (Myrtoan)	Long-line	*P. americanus*							sporadically		[97,119]
SE Aegean	Long-line	*P. bogaraveo*	10		< 300	2	*Scomber* spp.		all year	350-700	[97,119]
SE Aegean	Long-line	*M. merluccius*	5-Iouv	~ 2,000	20,000	10	*S. pilchardus*		all year	400-800	[97,119]
Cretan	Long-line	*M. merluccius*	6	~ 1,800	11,000	12	*S. scombrus*	2-3	winter	< 600	[97,119]
Cretan	Long-line	*P. americanus*	3	500-4,000	6,000-40,000	10-15	*Scomber* spp.	2-3	October-January	300-1,000	[97,114,119]
Cyprus	Drop-line	*P. americanus*, *P.bogaraveo*, *M. merluccius*, *e.t.c.*		12-20	0.15	0.2	*S. pilchardus*, *Scomber spp.*		September-May		DFMR (2009)*14

The wreckfish *Polyprion americanus* is a valuable demersal fish, considered among primary commercial seamount species, i.e. those caught primarily or exclusively on seamounts[122]. It has supported substantial fisheries in:

- the south-western Pacific Ocean: off Tasmania[123] and New Zealand[124];
- the western Atlantic Ocean: at the Blake plateau off south-eastern USA[112,125] and off southern Brazil[126,127];
- some islands in the high seas of the Atlantic: Bermuda, Azores, Madeira[112,128,129,130];
- the Mediterranean Sea: at the sea mount Emile Baudot off the Balearic islands[131], in the Ligurian Sea[132], off west Sardinia in the Tyrrhenian Sea[118], off Malta and the Pelagie Islands in the Sicily strait[133,134], in the South Adriatic[135], the Ionian, southern Aegean and Cretan Seas[31], as well as in the northern Levantine Sea[136,137].

The wreckfish is mainly exploited by small-scale professional and recreational fisheries, the catches of which are not usually included in the official statistics of fisheries. Bottom long-lines and droplines are used to catch adult wreckfish greater than 45 cm and 1.5 kg in weight, with a maximum size recorded of 100 kg for drop-line and around 70 kg for bottom long-lines.

14 Department of Fisheries and Marine Research 2009.

Drop-line or dropper or "filacciuolo" in Italian, is the specific fishing gear used, consisting of a long fishing handline, set vertically down into the water, with a series of fishing hooks (No 0.1-3) attached to snoods, a weight at the bottom of the line and usually a float at the top. Bottom long-lines consist of 800 to 4,000 hooks, bated with squid, mackerel, jack mackerel or gilt sardine. The main line of the gear is 2-3 mm thick, while each hook is fitted to the main line with one or two single lines 1.5-1.8 mm thick and 3-4 m in length. The inter-hook distance is 10-15 m. However, these gear characteristics may change from area to area (Table 7.1).

Small sized individuals, not exceeding 800 g in weight have been reported as bycatches of fisheries using FAD (Fish Aggregation Devices) targeting common dolphinfishes (*Coryphena hippurus*), greater amberjack (*Seriola dumerili*) and pilotfishes (*Naucrates doctor*) off the coasts of Mallorca island, Sicily island and Malta[113,138,139].

Information on the species occurrence, commercial and experimental fisheries in the Eastern Mediterranean has been collected since the 1990's within the framework of short-term projects and studies relevant to deep-sea small scale fisheries (Fig. 7.16). Because of the particular habitat where the species occurs (banks, seamounts) and the lack of specific surveys focusing on the study of this species, information of the species occurrence is based on any available published and unpublished scientific or fisheries information.

Wreckfish catches from the Eastern Mediterranean appeared in Fisheries Official Statistics in 2002, reported mainly by Greece from fisheries in the Aegean and the Eastern Ionian Seas, for some years by Cyprus from a fishery in the Levantine Sea and by Albania in the north-eastern Ionian (Fig. 7.16). Spain is the only country reporting catches of wreckfish from 3 different areas of the western Mediterranean (Fig. 7.17). The Spanish fleet is known to perform bottom longline fishery targeting hake since 1980 in the Gulf of Lions, operating mainly on the slope along the canyons between 160 and 600 m depth off the western Gulf of Lions and progressively expanding to deeper waters and eastwards[148]. In this fishery, wreckfish is a regular by-catch[149].

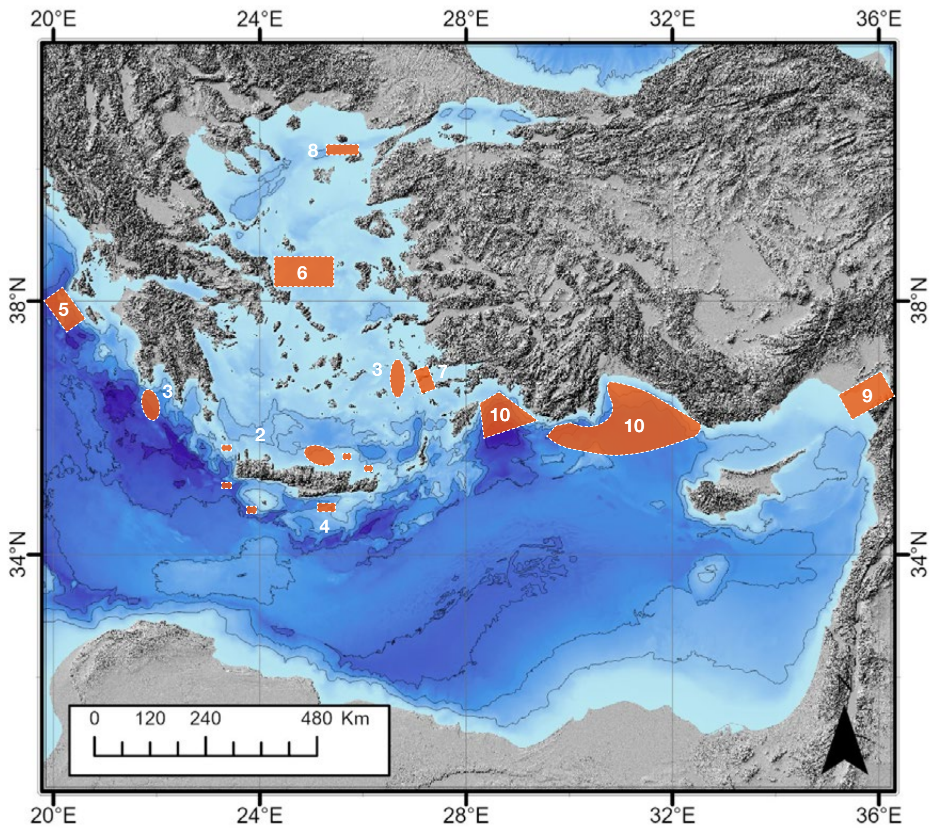

Fig. 7.16. Studied areas and respective studies relevant to wreckfish (*Polyprion americanus*) occurrence and fisheries in the northeastern Mediterranean.

1[119], 2[140], 3[141], 4[142], 5[143], 6[144], 7[145], 8[146], 9[137], 10[147]

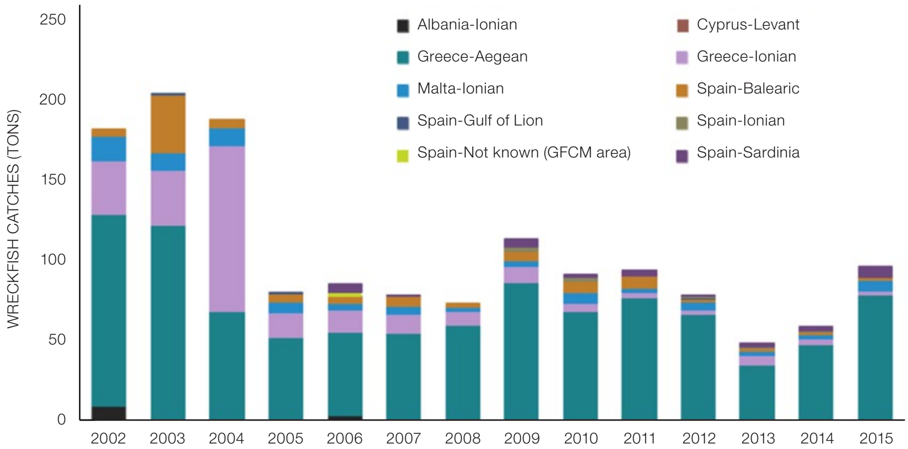

Fig. 7.17. Wreckfish (*Polyprion americanus*) catches in the Mediterranean Sea by country and fishing sub-area during the period 2002-2015. (Source: FAO fishery statistical time)

In the central Mediterranean, wreckfish catches from the Ionian Sea have been reported by Malta since 1996 and by Spain since 2009. Italian catches are not reported, since the species is not commercialized through the fish market but is sold directly to restaurants or to fish shops. In general, due to the small-scale nature of wreckfish fishery, precise landings are hard to monitor by the Statistical Services, thus, only a portion of the catches are expected to be included in the official production data[118]. Furthermore, in many cases *Polyprion americanus* and large-sized Serranids are reported under the category "Groupers" in Official Fisheries Statistics (Gucu, pers. comm.).

1 EASTERN IONIAN SEA

Among other Mediterranean GSAs, the highest wreckfish catches appear in the Eastern Ionian Sea, landed by the Greek fishing fleet. However, landings of wreckfish have been considerably reduced in the area since 2003 (Fig. 7.17). Analysis of longline fishery landings data in the E. Ionian Sea, collected during 2002-2006 under the Data Collection Regulation framework[150,151] indicated important wreckfish catches by métiers targeting hake[152]. However, it is known that, at least until 2013, *Polyprion americanus* was reported in Greek Fisheries Statistics under the common name "stone bass" including also some landings of *Epinephelus caninus.*

According to the information on wreckfish fishing, collected in the framework of the EC FAIR 95-655 on "Developing deep-water fisheries: data for their assessment and for understanding their interaction with and impact on a fragile environment (Deep-fisheries)" Greek small scale fishing fleets comprising of vessels practicing deep-water bottom long-lining, targeted wreckfish from time to time in the Eastern Ionian, using specifically equipped gear. However, as good catches last only for a short period (1-2 weeks) and a long time (> 3 years) is needed for the stock to recover, fishermen target it less frequently and *P. americanus* catches are mainly by-catch of long line fishery targeting hake[119].

Surveys with experimental long-lining (18,000 hooks) in the Eastern Ionian Sea, in the Argostoli Ridge seamounts, in summer and autumn of 2010, resulted in considerable wreckfish catches, comprising of 35 individuals that ranged between 45.5 and 101.0 cm in size (1,800-14,500 g in weight), with individuals larger than 77 cm caught only during summer. Average catch per unit effort (CPUE) was 15.2 kg/1,000 hooks in summerand 3.4kg/1000 hooks in autumn[31]. Observations on professional fishery catches with bottom long-lines, in the framework of DCF (2013-2019), have revealed wreckfish by-catches off the south coasts of the Peloponnese (HCMR, unpublished data) (Fig. 7.16).

Fortnightly experimental fishing with FADs (fish aggregating devices) off the south-western Peloponnese revealed the presence of a few solitary wreckfish juveniles (220-270 mm in TL) only in June and July[153,154] (Fig. 7.16).

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2 AEGEAN SEA

Since 2004, the landings of wreckfish in the Aegean Sea have been considerably reduced (Fig. 7.17).

In the North Aegean Sea, the limited available information comes from an investigation of small scale fisheries off the eastern coasts of Evia Island in 2010. Due to the geomorphology of this area, deep-water basins (> 500 m depth) located quite close to the coast, small scale fleet fishing grounds are visited almost all year round. Wreckfish is targeted by a few vessels using specific drop-lines from April until October, but it also consists of important by-catch from bottom long-lines for hake and drop-line fisheries for blackspot seabream practiced throughout the whole year[121].

Frequently published news in the local newspaper "SPORADES" about big wreckfish (17-72 kg) captured by fishermen of the near-by area of Sporades islands, as well as relevant posts on the web regarding fishing off the coasts of the Chalkidiki Peninsula, indicate the occurrence of an important population of the species in the deep-water basins of the north-western Aegean Sea.

Experimental bottom longline fishery carried out from March to August 2016, by Istanbul University in the deep waters between Samothraki and Gökceada (Imvros) Islands (Fig. 7.16), resulted in the capture of only 3 wreckfish individuals from a total of 6,000 hooks used during the study. Sizes of the caught specimens, ranged between 36-71 cm in TL and between 689-5,100 g in weight[155].

Life history and fisheries of wreckfish in the South Aegean Sea were mainly studied in the framework of a specific European Study project entitled "State of the stocks of European wreckfish (*Polyprion americanus*)" (Contract 98/041), whereas the first information was collected during the "Deep-Fisheries project".

Greek small scale fishing fleets comprising of vessels practicing deep-water bottom long-lining, targeted wreckfish from time to time in the Myrtoan, the Cretan and southeastern Aegean Seas, using specifically equipped gear (Table 7.1). In the late '90s, a trammel net fishery also started up in the Cretan Sea targeting wreckfish at depths from 150 to 550 m during daylight, but was not further developed as fishers are not used to targeting wreckfish over flat hard bottoms, but rather in areas of steep slope, which are easier to locate in the open sea and result in higher catches but are not suitable for fishing with nets[118].

Drop-lines were also used, however, as good catches generally lasted only for a short period, fishermen targeted *P. americanus* less and less over the years, exploiting it mainly as by-catch during bottom long line fishery, targeting big-sized fish at depths of between 500 and 850 m. Nowadays, drop-lines are mainly used by sport fishermen as shown by web-news on catches of large specimens (40-105 kg weight) on the slope off Milos, Sifnos and Mykonos island coasts, which might be considered as evidence of wreckfish populations in the deep water basins around the Cyklades Plateau.

In Crete, wreckfish fishing by specific long-lines (Table 7.1) seems to be an alternative to that of the swordfish, as the same fleet operates on both resources, targeting wreckfish when swordfish production is low[118]. The Catch per Unit Effort (CPUE) for *P. americanus* in 1999-2000 was 10-116 kg/1,000 hooks, with a mean of about 50 kg/1,000 hooks. The CPUE declined as the number of hooks increased, although the total catch also increased. Furthermore, the total quantity of catches depended more on the fishing site than on the fishing effort applied (number of hooks). Similarly, Turkish vessels fishing swordfish in the south-eastern Aegean due to low catches have skipped to gillnetting and demersal longlining, targeting mainly groupers, with wreckfish CPUE around 12 kg/1,000 m of gillnets[147].

Two types of experimental FADs (fish aggregating devices), which are not a traditional type of fishing in Crete, were tested in the Northeast Cretan Sea at depths from 80 to 200 m, but they did not attract any wreckfish[118].

3 LIBYAN SEA

The occurrence of fishing grounds visited by Cretan small scale fishing fleet have been mapped off the south-eastern coasts of Crete during the "WreckFish" project, whereas the species has also been recorded during ROV surveys off the south Ierapetra coast and Chryssi Island, over large outcrops and seeps, close to hard substrate reefs colonised by deep-sea corals[142].

The inclusion of *Polyprion americanus* in the ichthyophauna of Libyan[156] waters indicates the species wide distribution in this area.

4 LEVANTINE SEA

In the Levantine Sea, official data on fisheries catches are reported from time to time only by Cyprus, where a few fishermen target *P. americanus* with a specific deep water dropline[136,157].

Fishermen interviews carried out along the south coasts of Turkey between October 2016 and February 2017 showed that wreckfish catches were relatively low (daily catch did not exceed 12 kg) and presented considerable spatial variation in the studied area, however, they were reported all year round among long-line catches and in May and June among those of static nets[137].

According to Lakkis[158] *Polyprion americanus* is very common in the fish markets of Syria and Lebanon. However, the species is not included in the fish species lists published for these areas[107,159] nor is information regarding catches and fishing gears used available. In addition, in the most recent Species Identification Guide for Fishery Purposes in the Eastern and Southern Mediterranean[160] it is mentioned that wreckfish is occasional to rare in the area, a fact that might be also due to the limitation of fishing activities at lower depths than those inhabited by the species and that reporting of occasional catches is mixed with those of groupers. Furthermore, the species is also included in the ichtyofauna list for the Egyptian waters[106], a fact that indicates that the species has a wide distribution in the south-eastern Mediterranean.

Essential Fish Habitats

In conclusion, ecologically important habitats for the wreckfish described here are based on descriptive information, mostly from small-scale fisheries and indirect evidence from recreational fisheries and experimental fishing surveys. Quantitative information, however, is lacking from many areas, making it difficult to visualize hotspots of fish abundance or spawning and nursery grounds.

Nonetheless, deep-water banks are preferred habitats where adult wreckfish can occur in higher concentrations. Areas of presumably high abundance in the Eastern Ionian Sea are known, along the Argostoli Ridge seamounts, particularly during summer and autumn (HCMR, unpublished data). In the North Aegean Sea, locations such as off the eastern coasts of Evia Island as well as Sporades islands and off the coasts of the Chalkidiki Peninsula seem to be important areas, while in the South Aegean, information coming from sport fishers indicate catches of large specimens on the slope off Milos, Sifnos and Mykonos islands, which might be considered as evidence of wreckfish in the deep water basins around the Cyklades Plateau.

As for juveniles, only a few have been recorded during experimental fishing with FADs off the south-western Peloponnese[154,161].

In other areas and sub-regions of the Eastern Mediterranean, little seems to be known to be able to judge where there are other essential habitats (sites) or important fishing grounds of wreckfish.

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GENERAL CONSIDERATIONS

The Wreckfish seems to be widely distributed over the slope of the Eastern Mediterranean, associated with deep sea coral habitats and seamounts, although **information coming from the Levantine Sea is very limited**.

Official Statistical Data from Commercial Fisheries in the E. Mediterranean are provided only by Greece and Cyprus, whereas detailed information on the synthesis of fisheries catches is quite limited due, most probably, to the generally low fishing activity in deep waters by the fleets of the Eastern Mediterranean countries and consequently the insufficient sampling of these fisheries even in the European countries under DCF National programmes. In the meantime, the technological improvement in electronic equipment and vessel capacity has facilitated the detection of species-specific localized habitats, both by professional and by sport fishermen. **Monitoring of recreational fishery activity may provide valuable information for the estimation of overall fishing pressure**.

Based on information derived from specific short-term, spatial scale research projects, commercial wreckfish catches consist of large specimens (TL > 45 cm, W > 1.5 kg exploited mainly by deep-water bottom long-lines targeting large hake and, to a lesser extent, as by-catch of nets targeting groupers and other large-sized species. It is occasionally targeted by specific bottom long-lines and drop-lines, the latter, used mainly nowadays by recreational fishermen, resulting in larger specimen catches (W: 30-105 kg). FAD fisheries (with fish aggregating devices), exploiting younger individuals, are not operated by small scale fishing fleets in the Eastern Mediterranean. Furthermore, during the reproduction period (winter) the fishing effort of small scale fisheries declines notably due to the bad weather conditions, thus, wreckfish spawning aggregations are somewhat protected. However, landings (at least from Greek vessels) were reduced during the last 15 years.

Minimum reference conservation size (45 cm) is somewhat lower than the species length at first maturity estimated at 68-81 cm and 77-95 cm for males and females, respectively, and should be reconsidered.

To decrease uncertainty related to the species age estimation, the study of otolith microstructure, at least in individuals with TL < 500 mm, should be undertaken in order to clarify the growth rate of juvenile wreckfish under physical environment conditions. As for larger individuals, growth rate confirmation might be attempted through tagging experiments. In general, **further investigation on the biological traits of the species will help assess the status of its stocks.** •

CHAPTER 7 /
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CHAPTER 8/

Fisheries footprint

*Kavadas S., Damalas D., Maina I., Thasitis I.,
Ali M., Jemaa S., Farrag M., Lteif M.,
Mytilineou Ch., Otero M., Samaha Z., Schüler M.*

Latest status of Mediterranean fisheries indicated that 75% of assessed stocks remain overexploited in 2018, including stocks of all priority species – are regarded as overexploited, being the European hake being the most seriously overexploited[1]. Different management efforts are underway to shift this trend across the Mediterranean, as well as to gather a better understanding of fisheries dynamics.

In 2019, the Scientific Advisory Committee on Fisheries (SAC) of General Fisheries Commission of Mediterranean (GFCM) recognise the importance of understanding the extent of fishing footprint impacts for management purpose and advice on the need to adopt binding decisions on mapping the fishing footprint of deep-sea fisheries. Bottom trawling activities in waters deeper than 1,000 m are prohibited in the Mediterranean (Recommendation GFCM/29/2005/1) and two fisheries restricted areas (FRA) has been established to protect the deep-sea sensitive habitats in the E. Mediterranean: Eratosthenes Seamount and the Deep-sea Nile Delta.

Today, robust quantification of the distribution and intensity of fishing vessels working in the deep Eastern Mediterranean is not available. This information can provide evidence base to assess the pressures on deep-sea seabed habitats, enable the characterization of fisheries working on these environments and to estimate the potential impact that the establishment of fisheries closures fisheries closures (e.g. FRAs) or MPAs could have on the fishing industry before and after.

TRACKING SYSTEMS AND FISHING EFFORT ESTIMATE APPROACHES

The introduction of Vessel Monitoring System (VMS), a closed-source tracking system has increased the ability to provide high resolution information on location of individual fishing vessels (typically one position record every 1-2 h) and map fishing grounds and footprint.

Within the European Union, this system is required for all fishing vessels with overall length over 12 m. The data collected by VMS enable management authorities to control and monitor dynamics of fishing activities and asses the implementation of regulations. The information can also be linked to catch and landings data and analyse fishing captures and fishing effort trends.

Complementary to this, the use of other technologies such as the Automatic Identification System (AIS), initially designed as a safety mechanism for vessels to avoid collisions at sea, provides the possibility to enrich the information from larger vessels (e.g. > 15 m length), those that don't have incorporated VMS system as well as for having a higher frequency of the position data recorded (every few seconds). **The roadmap for the implementation of a vessel monitoring system and electronic logbooks in the Mediterranean had recently been agreed in support of monitoring and control of fisheries activities (Resolution GFCM/43/2019/3).**

Vessels over 24 m, which are the vessels most likely to have AIS, account for 2.4% of the Mediterranean region's fleets and vessels between 12 and 24 m represent 8.5% of the region's fleets. Most of the vessels under 12 m and non-motorized vessels (respectively 50.9% and 23.5% of the total fleet) are not likely to have AIS. In the northern Mediterranean, European fleets have adopted AIS for almost 100% of vessels larger than 15 m. By contrast, North African countries have no VMS equipment and an extremely low AIS use, with almost no vessels using this technology[2,3]. As a result, VMS and AIS cannot currently be used to estimate the fishing activity by the African nations in the area (mostly in the southern parts of the Mediterranean Sea) where most of the estimated activity is due to European vessels[4].

This chapter assess, through the use of VMS and AIS data the fishing effort (expressed as days at sea) in the Eastern Mediterranean, particularly that of the bottom trawlers in deep-waters. A fishing pressure index for the deep-water fishing activities of small scale fishing vessels, not equipped with a tracking system (VMS/AIS), was estimated based on a Multi-Criteria Decision Analysis (MCDA). **Accurate mapping estimation of the spatial distribution of these vessels would provide valuable information for Mediterranean fisheries to assess the extent to which it contributes to fishing efforts, where trawling is the main fishing activity and where in some areas its footprint exceeds 80% of the continental shelf[5].**

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A vessel monitoring system (VMS) uses satellite-based technology to help locate and identify vessels at sea. The use of Automatic Identification Systems (AIS) with higher resolution signals and other Electronic Monitoring (EM) systems such as those using cameras and gear sensors can also serve as tools to increase monitoring of the fishing effort, tackle IUU fishing and manage MPAs, other vulnerable biodiversity hotspots and restricted areas.

Greek fishing fleet VMS data from 2010 to 2016 were used to map the cumulative fishing footprint from trawlers in the deep waters[1]. Cypriot trawl fishing fleet VMS data from 2014-2015 were also analysed. No VMS data from other Eastern Mediterranean countries were available. As a result the geographical coverage of VMS signals referred to the GSA 20 (Eastern Ionian Sea), GSA 22 (Aegean Sea), GSA 23 (Cretan Sea) and GSA 25 (Cyprus). The analysis of the commercial Greek and Cypriot fishing fleet was performed through the integrated fisheries information system IMAS-Fish[6].

The analysis of VMS data was based on methods developed in the Institute of Biological Recourses and Inland Waters (IMBRW) of the Hellenic Centre of Marine Research (HCMR)[7,8,9]. On that basis, common errors and outliers in VMS dataset were filtered out and removed. Subsequently, speed thresholds for bottom trawlers depending on depth stratum were used to define the 'fishing' activity. It was considered that VMS readings of speed lower than 4 knots correspond to 'fishing', otherwise the signals are characterized to 'steaming'. Vessel positions in or close to harbours were also excluded.

Moreover, the activity of fishing bottom trawlers in other Eastern Mediterranean areas in national and international waters has been addressed through a review of published works as well as publically available aggregated AIS data from 2012 to 2016[2]. Small Scale Fishing (SSF) activities in the Greek and Cypriot waters were also examined using AIS data and a Multi-Criteria Decision Analysis (MCDA) methodological approach. The spatial extent of SSF sector activities is largely unknown therefore; the potential fishing footprint with the corresponding fishing intensity was derived by means of MCDA conducted through a stepwise procedure[10]. Given that the fishing activity of SSF vessels with static gears (nets, long lines) also occur in the deep waters of the Eastern Mediterranean, AIS data from the Global Fishing Watch platform were compiled by flag state and gear type[2]. In this work, over 22 billion AIS signals were processed over a five-year period (2012 to 2016). Estimating the spatial distribution of SSF activities using an MCDA methodological approach as well as information from AIS data, was of utmost importance for verification purposes.

Other type of data such as the commercial fishing fleet operating in deep waters in other areas of the Eastern Mediterranean were also presented based on several published and unpublished information.

1 source: Ministry of Shipping and Island Policy
2 *http://globalfishingwatch.org/map*, *https://www.marinetraffic.com/en/ais/home*

Fishing fleet capacity and deep-water fishing effort of trawlers by country

GREECE

The Greek fishing fleet is largely a coastal fleet made up of vessels in 2020, with the majority (96.52%) being SSF coastal boats3. An outline of the fishing fleet in the previous 2017 and the reduction since 1991 is summarized in Table 8.1. Over this period, the Greek fishing fleet has been reduced by 32.39% and 37.64% in terms of numbers and engine power (kW), respectively. The 56.42% of fishing vessels registered in GSA 22 (Aegean Sea) are distributed in the North Aegean Sea.

The estimated fishing effort of the Greek trawlers operating in the Eastern Ionian Sea (GSA-20) represents the ~12.5% of the total effort (days at sea) exercised by this fleet in all GSAs (GSAs 20, 22, 23). In the Eastern Ionian, approximately 27 trawlers are active, usually fishing in the continental self and only 15% of the effort on the Eastern Ionian Sea (GSA 20) is performed in deep waters (> 200 m).

In the North Aegean Sea and northern part of the South Aegean Sea, bottom trawlers are in larger proportion compared to other areas and the estimated fishing effort of Greek fleet in GSA 22 is ~82% (~210 active trawlers), where the ~27% is practiced in waters deeper than 200 m (~18% in the North Aegean Sea and ~9% in the northern part of the South Aegean). For Cretan Sea - southern part of the South Aegean (GSA 23), the fishing effort is very low and represents 3% of the effort of all GSAs (~9 active trawlers), where the ~34% is performed in waters deeper than 200 m.

From 2010-2016, the cumulative fishing footprint from Greek trawlers operating in deep waters in GSAs 20, 22, 23 is presented in Fig. 8.1. The highest values of deep-water fishing effort are located in Saronikos and Korinthiakos Gulfs in depths 200-400 m. Medium-Low deep-water activities are distributed in all the extend of Greek waters (Ionian, Aegean and Cretan Seas).

Table 8.1. The Greek commercial fishing fleet by Geographical Area (GSA) and fishing category and the reduction (%) from 1991 up to December 2020; Number of fishing vessels and their engine power (in kW) is given by Geographical Area (GSA).

		2017		Reduction (%) (from 1991 to 2020)	
	Fishing category	**Number of fishing vessels**	**kW**	**Number of fishing vessels**	**kW**
GSA 20 EASTERN IONIAN SEA	Artisanal	3405	54396	33,03	33,64
	Boat seine	75	3543	54,27	58,99
	Purse seine	35	6154	12,50	1,38
	Trawl	26	6760	49,02	46,66
	Total	3541	70852,98	148,8130776	140,6638183
GSA 22 AEGEAN SEA	Trawl	9022	191081	38,03	43,86
	Purse seine	142	9198	71,60	74,45
	Artisanal	198	37298	36,33	31,57
	Boat seine	212	63851	40,28	39,13
	Total	9574	301428,25	186,2475535	189,0038711
GSA 23 CRETAN SEA	Artisanal	817	14718	21,37	39,24
	Boat seine	4	349	82,61	77,08
	Purse seine	6	1041	62,50	53,07
	Trawl	10	2937	23,08	32,29
	Total	837	19044,98	189,5523175	201,6859098

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CYPRUS

The Cyprus fishing fleet included in the Fleet Register[3] in 2019 was composed of 858 fishing vessels. The latest report indicates that between the period 2009-2019, the fishing Cyprus capacity has been reduced by 27.1% and 17.6% in terms of vessel number and engine power (kW), respectively (due to a scraping program both for trawlers and small scale fishing).

Demersal trawlers range from 19 to 27 m overall length and are categorised based on their type of license to a) those fishing in the territorial waters of Cyprus and b) those fishing in international waters (eastern and central Mediterranean). Regulations and restrictions on the use of trawl nets and minimum landing sizes are established in accordance with national and EU policy regulations.

Table 8.2. Description and development of Cyprus fishing fleet interacting in deep-waters.

Fishing technique	Vessel length (m)	2019			Reduction (%) (from 2008 to 2018)		
		Number of fishing vessels	GT	kw	Number of fishing vessels	GT	kw
Demersal trawlers and demersal seiners	24 - < 40	6	582	2013	-33	-41	-38
Inactive	18 - < 24	-	-	-	-100	-100	-100
Inactive	24 - < 40	1	128	493	-67	-68	-49

Based on the "*Management Plan for the Bottom Trawl Fishery within the Territorial Waters of Cyprus"* which is implemented since the end of 2011[4] (Article 19 of Council Regulation (EC) 1967/2006), only 2 bottom trawlers are licenced to work on a rotational basis in 2 restricted areas. Additionally an extended closed season (from 1st of June until the 7th of November) is employed since the '80s. Other provisions of the Mediterranean Regulation in the relevant Management Plan include minimum distance from the shore and minimum depth.

No fishing footprint from bottom trawlers at depths of more than 200 m was detected over the 2010-2016 time period, as detected from the VMS & AIS data of Cyprus. This is due to that the remaining two vessels operating in national waters had moved their operation closer to the shore, based on the derogation that has been granted to operate at 0.7 nm distance from shore and 50 m depth[5]. No information about static nets and longlines in deep waters is available.

Recently, Fisheries Department of Cyprus started to collect VMS data from the entire SSF vessels.

3 on the 31st of December 2019.
4 Article 19 of Council Regulation (EC) 1967/2006
5 EC 1967/2006.

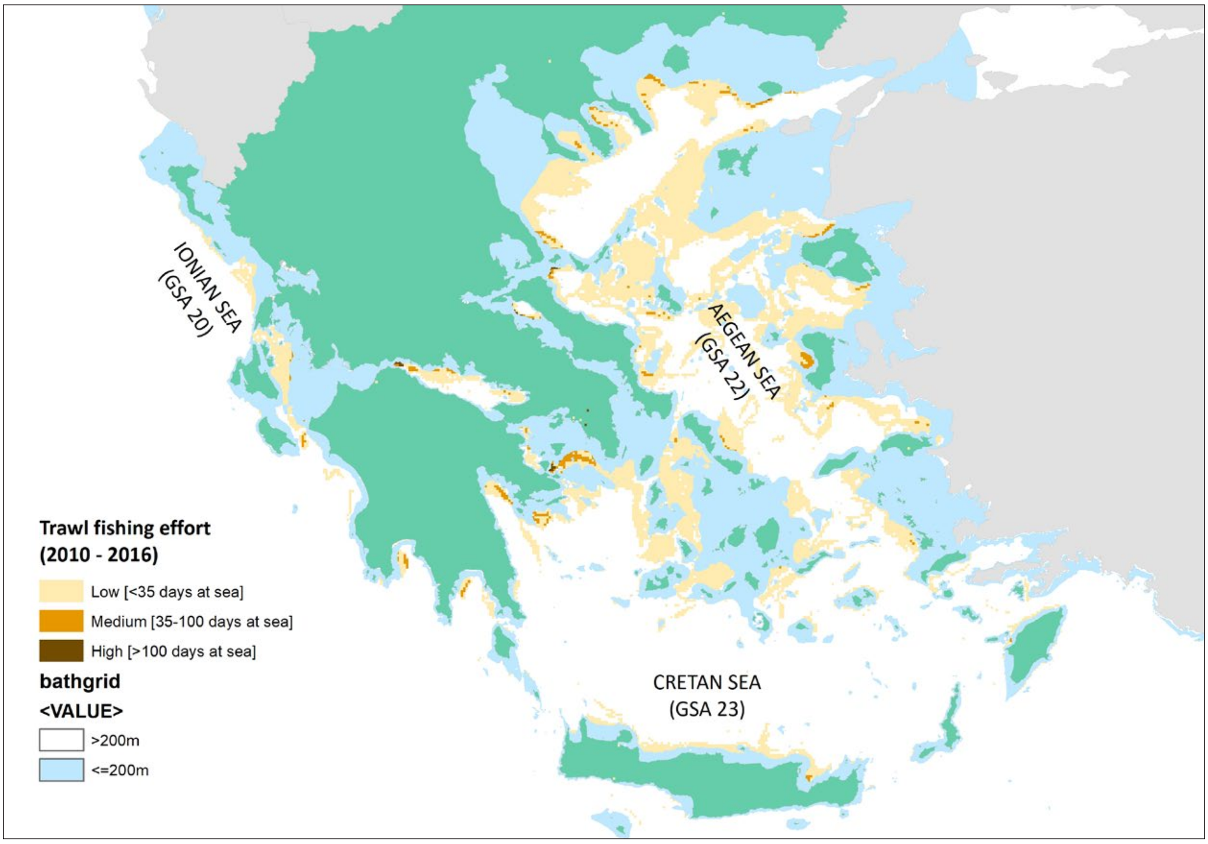

Fig. 8.1. Cumulative fishing footprint of Greek bottom trawlers operating in deep waters in GSAs 20, 22, 23 (period 2010-2016).

TURKEY

The number of marine fishing vessels in Turkey is around 15,877[11]. In 2013, around 32% of the total fishing fleet (4509 vessels) operated in the Aegean Sea where the 95% were artisanal[22]. In the Levantine Sea, the fishing fleet accounted for approx. 1,847 vessels (13.5%) in 2013 where trawlers consisted an important category corresponding to 11% of the fishing fleet in this area, but small scale boats still remain the highest in numbers.

Fishing activities of the Turkish fleet in the Aegean Sea are spatially limited due to the narrow continental shelf, the steep slope and its geomorphological characteristics. The main fishing grounds are mainly located in several bays (e.g. Saros and Edremit Bay in the north, Çandarlı, İzmir, Sığacık and Kuşadası Bays in the centre, and Güllük and Gökova Bays in the south) and around Gökçeada and Bozcaada Islands[12,13]. In 2010, 118 purse seiners and 188 trawlers were certified for fishing in international waters of the Aegean Sea. This increased to 160 in 2014 and 171 in 2015, while it was only 65 in 1997[14]. The main fishing areas known to be used by the Turkish fishing fleet in the international waters of the Aegean Sea Fig. 8.2 are located off Saros Bay, in the Eastern North Aegean Trough, Edremit Ridge, North Psara mounts and off Kuşadası Bay. The main target fish that are caught by the bottom trawl in the deeper waters of the Aegean Sea are the rose shrimp (*Parapenaeus longirostris*), the Norway lobster (*Nephrops norvegicus*), hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), greater forkbeard (*Phycis blennoides*), blackbelly rosefish (*Helicolenus dactylopterus*), four-spotted megrim (*Lepidorhombus boscii*) and Atlantic horse mackerel (*Trachurus trachurus*)[15,16].

The fisheries along the Levantine coasts of Turkey take place mainly within the territorial waters[17] Iskenderun Bay is the most important fishing area on the Turkey's Levantine coast[18], where small- scale fishery is mainly practiced. The deep red shrimp *Aristaeomorpha foliacea* is the dominant species fished mainly at the depth of 400 m in Mersin Bay[19] and in the deep waters in the Gulf of Antalya[20,21] while other shrimp species

Table 8.3. Commercial fishing fleet in Turkey by Geographical Area (GSA) and fishing category (February 2022; Source: GFCM Fleet Register) with indication of number of fishing vessels larger than 15m length overall (LOA).

	GSA 22	GSA 24	GSA 28
	Aegean Sea	**Northern Levant Sea**	**Marmara Sea**
All vessels			
Towed dredges	0	0	0
Miscellaneous gear	3.982	1.548	2.301
Single boat bottom otter trawls	59	176	0
Purse seines	74	43	155
Midwater pair trawls	0	0	0
Beam trawls	0	0	387
Total	**4.115**	**1.767**	**2.843**
VESSELS >15m LOA			
Towed dredges	0	0	0
Miscellaneous gear	2	0	8
Single boat bottom otter trawls	31	116	0
Purse seines	55	22	131
Midwater pair trawls	0	0	0
Beam trawls	0	0	172
Total	**88**	**138**	**311**

(*Parapenaeus longirostris* and *Aristeus antennatus*) are also commercialised.

The Turkish fishery production in the Aegean Sea is estimated to correspond to 10% of the total production of Turkey, whereas that in the Levantine Sea corresponds to only 6%[22].

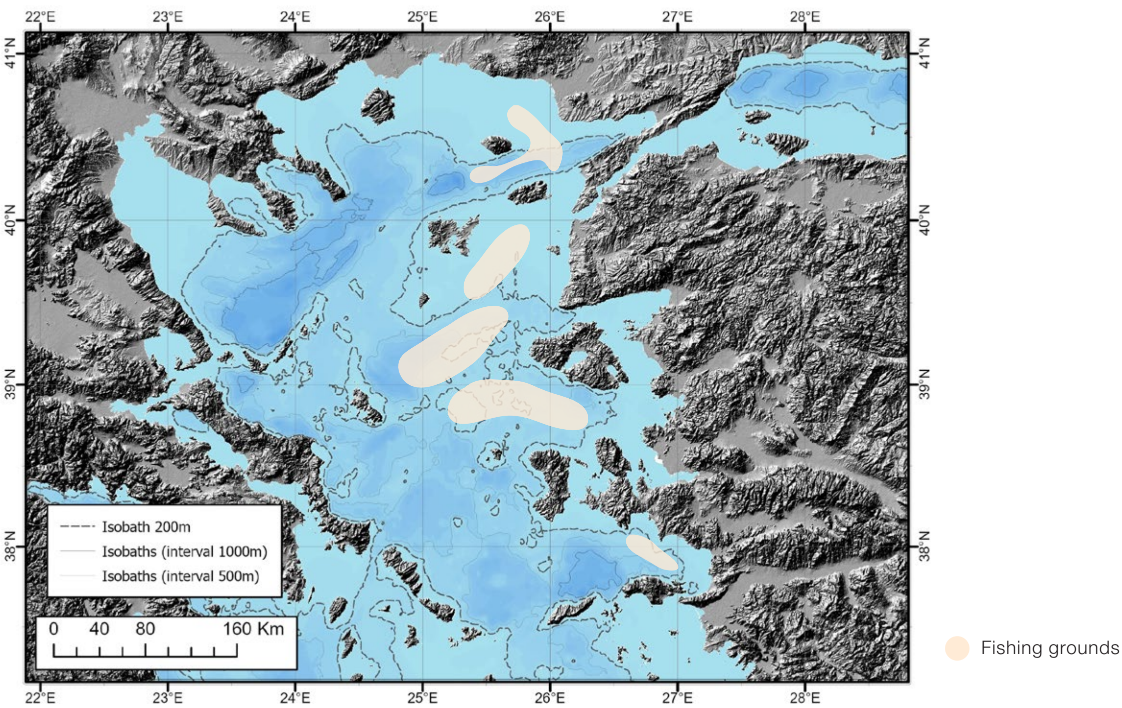

Fig. 8.2. Known fishing grounds in the waters of the Eastern Aegean Sea outside territorial waters[23].

SYRIA

Syria has a very narrow continental shelf (1,160 km^2) that reaches a maximum of 6-8 km in length. Following the short occurrence of the continental edge, the slope leads to the abyssal plain (in some areas, in just 2 km off the shore, bottom depth exceeds 1,500 m). As updated statistical information is unavailable, here we provide a description of the available knowledge on fishing activities and gears used that could be operating in deep-waters.

The trawling area on the shelf is limited to about 310 km^2 (27%) and most commonly other fishing gears (purse seine, gill nets, hooks, longlines, traps, etc) are operating. Before the started the civil war, the fishing fleet consisted of 28 trawlers operating in international waters and 1,850 small scale vessels operating in territorial waters, at depths less than 250 m using various fishing gears (2010). Only bottom longlines were operating in deep waters down to 1,500 m depth. Before 2005, bottom trawling was exerted in Syrian waters at depths less than 250 m. During the 90's, the average catch of trawlers started to decline gradually: from 14.2 kg / boat / hour in 1997, to 11.3 kg / boat / hour in 2002; as a result, the trawling ban since 2005.

In 2017 for a period of 6 months, 5 trawlers were licensed to operate in the deep waters from sunrise to sunset operating at a distance more than 6 nm off the shore (where the depth is more than 250 m). Vessels usually operate at depths ranging between 300 and 750 m, usually fishing 8 to 11 hours per day or 20 days per month. The departure fishing port was Latakia directed towards the south (between 35° 29´ N., and 35° 10´ N.). Fishing trawling gear in used is described by having a wire length used of 1,500 m, followed by 200 m of ropes. The length of the trawl net arms is 14 m, and the total length of the trawl net is 45 m. The horizontal opening of the trawl net is 4 meters, the meshes at the anterior area of the net are 60 mm diamond, and those of the codend 3 are 30 mm diamond.

Annual units effort or catch per effort of trawlers is unknown although is estimated that the average catch is 20.4 kg per boat per hour. The catch composition consists of 52% crustaceans and 48% fish, approximately. No fishing footprint from bottom trawlers was detected from AIS signals by other flag vessels or Syrian trawl vessels as fleets operating in the area don't use AIS or VMS monitoring devices.

LEBANON

The fishing fleet in Lebanon mainly consists of small wooden vessels less than 12 m of length. Trawlers are prohibited by law. Only a small number operate at depths deeper than 50 m, while the majority of fishing vessels are fishing at the bathymetric zone < 50 m, exerting high pressure on the coastal zone. Few artisanal fishermen have proper means and gears to perform deep-water fishing activities, but no information is available about their fishing grounds and catch. Some fishermen set trammel nets with bait up to depths of 300 m and longlines up to depths of 500 m in some regions. The National Centre for Marine Sciences/CNRS-L in collaboration with the Lebanese Ministry of Agriculture (MoA) and the Food and Agricultural Organization of the United Nations (FAO) have implemented several projects to encourage fishermen to invest in deep-water fishery. For example, in the framework of the CIHEAM PESCA-Libano project, which assessed the potentiality of marine coastal resources to support the Lebanese government in strengthening the management of marine resources, a survey was conducted in 2012 and 2013, where gillnets, longlines and trammel nets were set along the coast of Lebanon at depths ranging from 30 to 250 m. Several deep-water fish and shrimp species were caught throughout this survey. In addition, in the framework of the FAO-EastMed project, several experimental fishing trials have been implemented annually since 2015. These trials have also encouraged fishermen to target *Plesionika edwardsii* using Spanish traps, and sustainable trammel nets to help target the European hake *Merluccius merluccius* and the deep-sea red shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus*. Deep-water resources are the priority of fishermen-targeted studies in an attempt to relieve the coastal area from artisanal fishing pressure.

The proposal for the development of Vessel Monitoring System (VMS) for Small Scale Fisheries in Lebanon is underway. For the observational period of 2010-2016, no transmitting AIS signals were observed as transponders are not used by Lebanese fishing vessels or those operating in their waters. According to the Lebanese Ministry, only one large vessel (> 12 m) registered in 2020 was obliged to install an AIS transponder. The latter is the only Lebanese fishing vessel sending an AIS signal currently.

ALEXANDRIA. © JAVARMAN DREAMSTIME.COM

EGYPT

The Egyptian coast of the Mediterranean basin extends for about 1,050 km. However, there is insufficient knowledge about deep-sea fisheries practices[24]. Earlier studies indicated that most fishing activities did not operate at a depth greater than 250 m prior 2011. This is because the main fishing ground is located in the continental shelf off the Nile Delta over shallow waters extending from Alexandria to Port Said[24]. Moreover, the majority of the bottom trawlers operate mainly within the depth range of 100–250 m as the engine power, not exceeding 450 hp, ranges mainly from 100-250 hp. A low number of up to 800 hp vessels operate at the mouth off the Nile Delta[24,25,26].

The first **deep-water fishing activities in Egypt** in depths more than 400 m, were conducted by an Italian trawler during 2009. **The collected catch and effort data on deep shrimps together with other species were published by Ibrahim et al.[24]. Since then, the fishermen have been encouraged to practice in deep waters**. Over the last years (2014-2020), a few trawlers have been licensed to operate in deep- waters, but no sufficient information is available on their activities. From 2015, the catch of deep-water red shrimps started to be recorded from Damietta landing port, representing an amount of 504 tonnes[25]. Egypt has anticipated the installation of VMS devices on board of commercial fishing vessels for monitoring in 2015 to collect information lacking for monitoring fishing activities. However no VMS information is available to date. Fishing landings data in different fishing harbors such as Damietta and Alexandria, indicates an increase of the vessels operating in deep waters in recent years.

The deep-water trawl fishery in Egypt, targeting particularly deep-water shrimps, use the Italian trawl gear in the western and eastern parts of the Nile Delta. Bycatch constitutes about 16-22% of the landed catch, comprising 21 species dominated by *Merluccius merluccius*[24], and another study[27] indicates the occurrence of more than 40 species collected from its deep-waters. The latter study has updated the species in deep-waters with new records reflecting the importance of deep-water fisheries monitoring.

The first record of deep-water shrimps catch from Egypt in 2015 was followed by systematic records of 757 t in 2016, 979 t in 2017 and 845 t during 2018[26]. The European hake fished in deep waters started to be recorded later during 2017 (270 t) and 2018 (845 t)[26]. It is worth noting the decrease of red shrimps catch in contrast of European hake. Further efforts are needed to monitor deep-water bottom trawlers (licensed and not licensed) targeting red shrimps in Egypt to avoid overfishing of their resources and habitats conservation. The establishment of a management plan for deep-water fishery and the use of VMS equipment should be considered among management strategies.

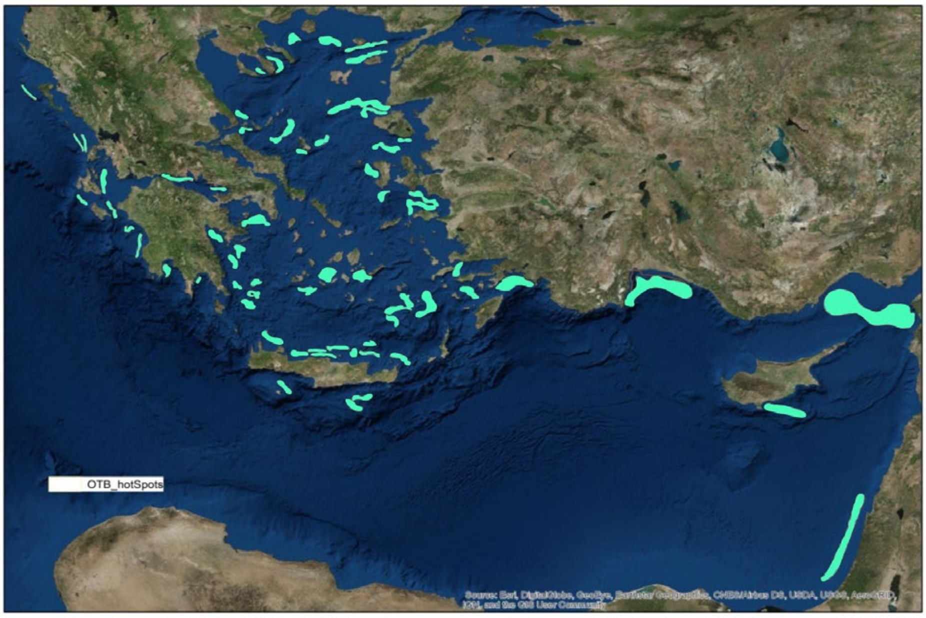

Fig. 8.3. Main fishing grounds of trawlers in the deep waters of the E. Mediterranean based on AIS monthly maps.

(Provided by Marine Traffic and Global Fishing Watch Platforms) during the whole study period (2012-2016).

TRAWLING FOOTPRINT WITH AIS DATA (2012-2016)

1 EASTERN IONIAN SEA

Satellite AIS data indicates that all Greek trawlers operate in the deep waters of the Eastern Ionian Sea (Fig. 8.3). Usually they operate down to 400 m depth (targeting hake, rose shrimp and anglerfish), although some of the fishing vessels operates in waters down to 700 m, **mainly in the Messiniakos Gulf** and in the **area between East Zakynthos Island and the West Peloponnese coasts** targeting deep-water red shrimps (Fig. 8.4). Data analysis also shows over the period of 2012-2016, trawling activity was also exercised by 10 italian vessels, probably targeting red shrimps, in the deep waters of the Eastern Ionian Sea (GSA 20) between 450-900 m depth. Bottom fisheries activities were carried out **on the slope (off north-western Lefkas Island) and close to the sea-canyons** (e.g. west of Othonioi Islands, off Katakolo and Kyparisiakos Gulf) **or seamounts (e.g. off south Kephallinia Ridge)**. Recently, deep-water fishing activity of Italian trawlers (since 2016) is exerted close to **Kythira mount and Lissos Ridge** (west of Antikythira Island) from 300 to 600 m depth.

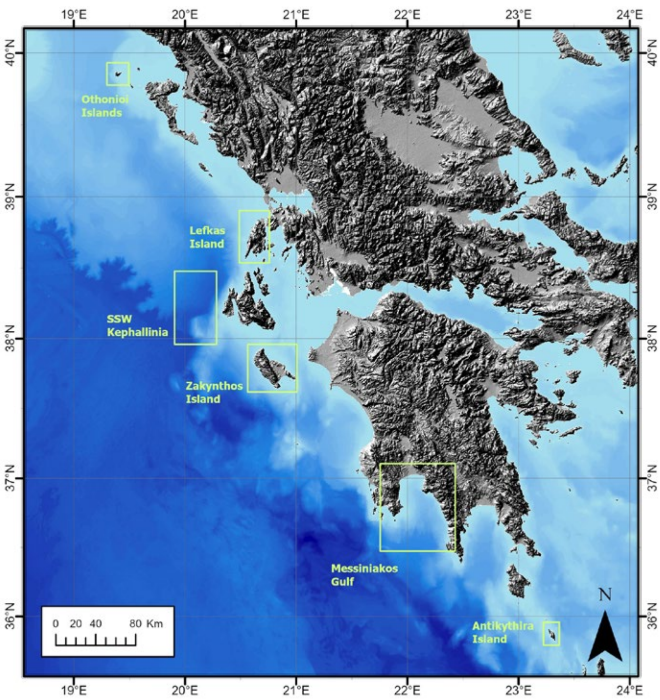

Fig. 8.4. Geographical reference points for trawling footprint in the Ionian Sea.

2 NORTH AEGEAN SEA

The geographical extension of fishing footprint shows that Greek trawlers operate in the deep waters of the North Aegean Sea (GSA 22) at depths less than 600 m, mainly on the slope **(north of Samos basin, W. Skyros basins, around Cavo Doro Ridge basins)** or **close to shallow seamounts (banks)** (e.g. Limos Ridge, N. Ikaria mounts, S. Psara mounts, Cavo Doro North Ridge, between Andros-Tinos N. mounts, N. Psara mounts, Edremit Ridge, S. Sporades mounts) (Fig. 8.5). These fishing vessels are mainly target hake, *Merluccius merluccius*; rose shrimp, *Parapenaeus longirostris*; Norway lobster, *Nephrops norvegicus*, and anglerfish, *Lophius piscatorius*.

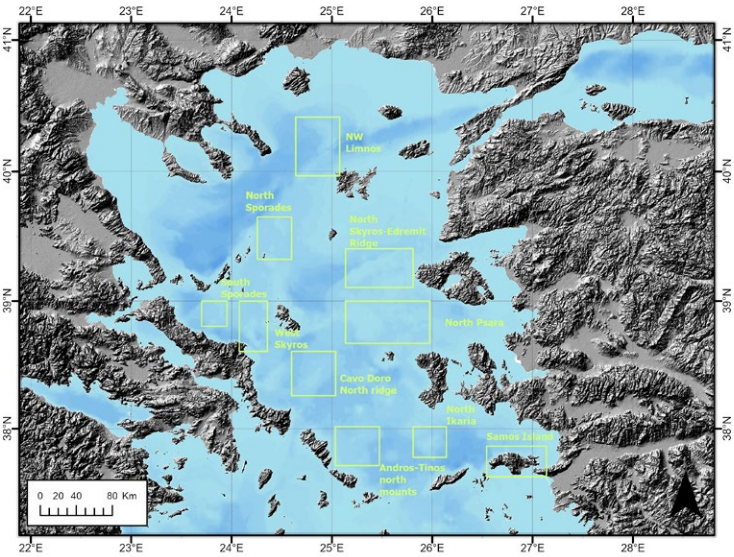

Fig. 8.5. Geographical reference points for trawling footprint in the North Aegean Sea.

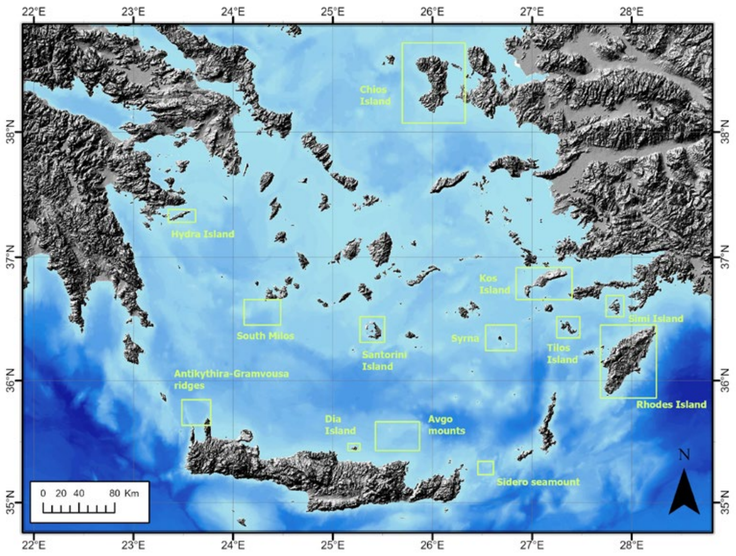

Fig. 8.6. Geographical reference points for trawling footprint in the South Aegean Sea.

From 2012-2016, trawling effort from Turkish vessels were found to operate in the North Aegean Sea mainly **in the Edremit Ridge** in waters less than 300 m depth, **off North Ikaria** and **North Samos Islands** in waters from 200 to 550 m depth from 2013 to 2016 and **in north Psara mounts in < 400 m depths** from 2014 to 2016. These results are in agreement with those reported in the published literature[23]. Considering the the depth range of their activities, it is supposed that fishing vessels mainly target hake, rose shrimp and Norway lobster. Fig. 8.3 presents the main areas of trawlers fishing activity in the deep waters of the study area.

3 SOUTH AEGEAN SEA

Within this region (GSA 22), Greek fishing trawlers operate at depths less than 700 m, mainly **on the slope (South of Chios Island, north of Santorini)** or close to seamounts (e.g. **South Milos mounts, north of Gramvousa mounts**) over the period 2012-2016 (Fig. 8.6). These vessels were mainly targeting hake, *Merluccius merluccius*; rose shrimp, *Parapenaeus longirostris*; and anglerfish, *Lophius piscatorius*.

From 2015, Greek trawlers appear also south of **Hydra Island** at 500-550 m depths, **off Tilos and Simi Islands** at 400-650 m depths and south of Kos at 500-600 m depth including red shrimps among their target species. Other coastal flag state vessels were found working in these waters. Turkish trawlers were found to operate in the South Aegean Sea from 2013 mainly in waters of less than 600 m south **of Chios Island, south of Kos Island, off Tilos and Simi Islands** and in the **northern part of Rhodos Basin**. These deep-water trawl fishery probably target hake, deep-water rose shrimp, blue and red shrimps and other decapod crustaceans. A Spanish trawler was also found to operate close to south Milos mounts operating at 200-500 m depth in 2013 and 2014.

The analysis of the bottom trawl footprint generated with the AIS data further shows that over 2012-2016, italian trawlers operate in the deep waters of the S. Aegean Sea (GSA 22) down to 900 m depth, mainly **north of Crete Island** (north of Gramvousa mounts, Avgo mounts, north of Dia Island, northern part of Rhodos Basin, off Tilos and Simi Islands). From 2015, Italian fishing vessels also appear in the waters **south of Milos mounts** (200-500 m depth) and **in the Syrna mount** (south of Astypalaia Island) (300-700 m depth) and from 2016 in **Sidero Seamount east of Crete**. They probably target deep-water red shrimps. These areas are in agreement with the fishing grounds presented by other authors[28]. Fig. 8.3 presents the main areas of trawlers fishing activity in the deep waters of the study area.

4

LIBYAN SEA

The limited AIS information available in this area (South of Crete - GSA 23), shows only fishing operations from two Italian trawlers from 2015 and a Greek trawler from 2016; along the **north of Gavdos** from 550 to 700 m depth and **in the Chryssi Seamounts** from 600 to 900 m depth (Fig. 8.7) . Most of this fishing activity identified by AIS can be associated with trawlers targeting deep-water red shrimps. Fishing activity of Italian trawlers for red shrimps in the deep waters off Libya coasts (GSA 21) has been previously reported in the area.

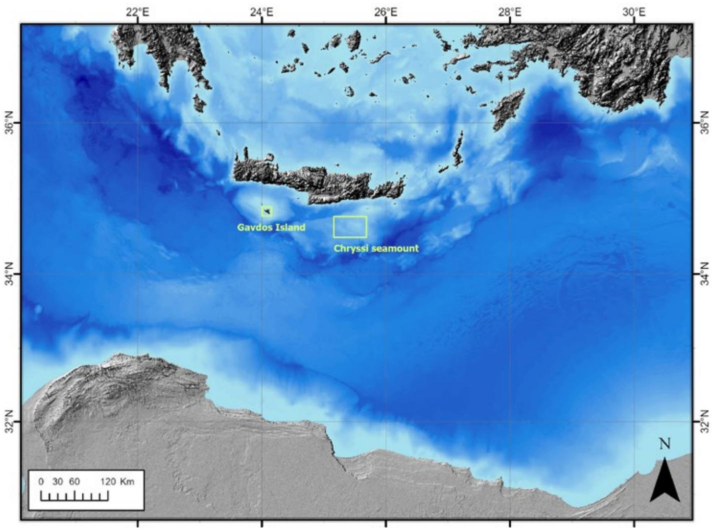

Fig. 8.7. Geographical reference points for trawling footprint in the Libyan Sea.

5

LEVANTINE SEA

The analysis of AIS data suggest the detection of some fishing activities in discrete areas in the Levantine Sea. Individual fishing trips could be identified by Turkish trawl vessels in the area **north of Rhodes basin** and off the south coasts of Turkey operating at depths between 150-800 m and **on the slope off Antalya** fishing from 300 down to 800 m depth from 2013 to 2016 (Fig. 8.8). Turkish trawlers activity, probably targeting red shrimps, was found to extend on the **slope off Iskenderum and Mersin bays** from 2015 to depths ranging between 300-700 m, as reported by literature [19,20,29].

Trawlers from other European countries were found fishing on the **slope off Mersin and Iskenderum bays** at depths ranging between 300-700 m during the whole study period, probably targeting red shrimps.

In Cyprus, AIS effectively documented fishing activity also by a trawler observed on the southern slope, operating at depths ranging between 500-900 m only in 2015 and 2016. Trawlers from other EU countries were also observed operating in **Hecateus seamount, south of Cyprus**, at depths ranging between 500-900 m from 2013 to 2016 (Fig. 8.3). Israeli trawlers were also observed operating systematically on the **slope off Israel coasts** at depths ranging between 200-500 m. In the Southern Levantine, AIS data fail to describe the fishing activity, detecting only an Italian trawler in 2012 operating in waters between 600-700 m depth, probably targeting red shrimps. However, previous publications mention that Italian trawlers operate in the area from 2004 until today[30,28].

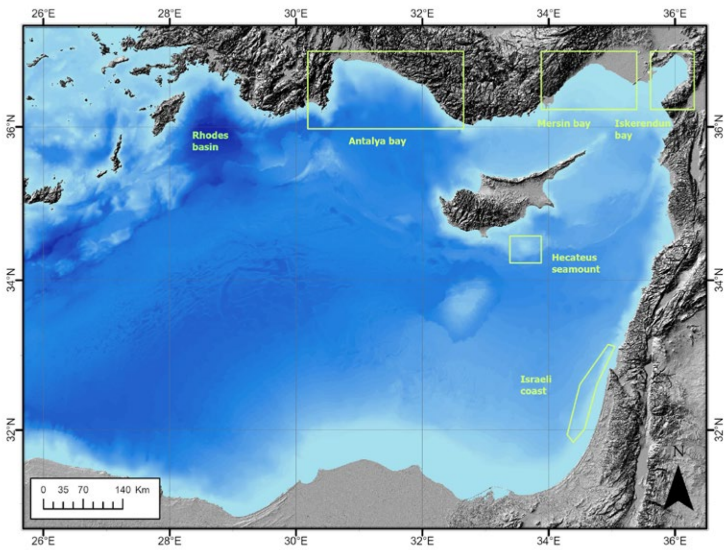

Fig. 8.8. Geographical reference points for trawling footprint in the Levantine Sea.

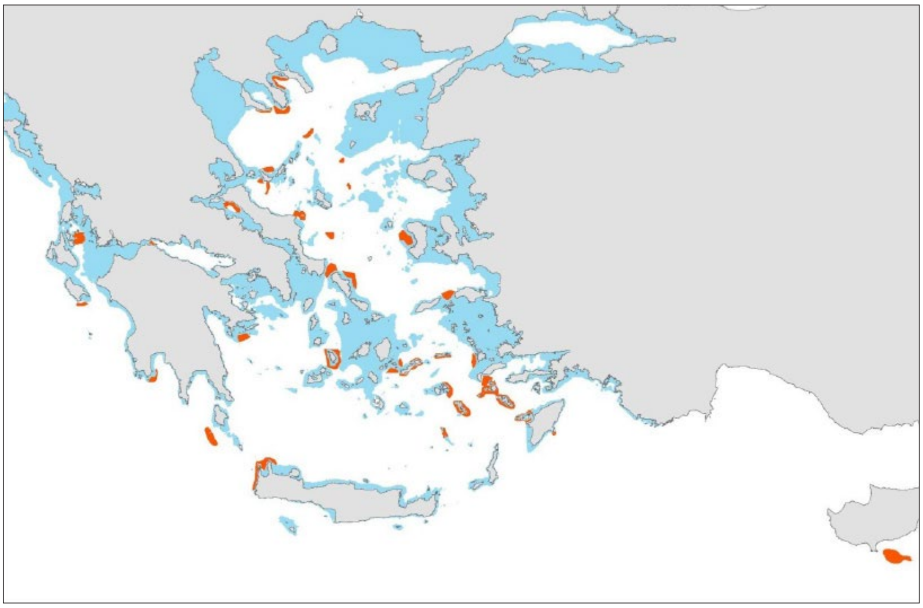

Fig. 8.9. Hotspot areas of Greek and Cypriot small scale vessels fishing activity in waters > 200 m depth, based on AIS and VMS data and MCDA approach.

SMALL SCALE FISHERIES

The study of AIS data from small scale fishing vessels cannot provide reliable estimates due to the fact that the fishing techniques (e.g. static nets, longlines and other passive gears) cannot been correctly attributed to each vessel and because the number of vessels providing data is limited. Therefore, it was not possible to identify and map this fishing activity in the whole E. Mediterranean from the available AIS data set. Nonetheless, for the GSAs 20, 22, 23 and 25, information from VMS and AIS data was combined with the results of MCDA and a series of hot-spot fishing areas at depths > 200 m were identified Fig. 8.9). It is estimated that 850 vessels are occasionally operating in depths deeper than 200 meters, targeting mainly species such as *Merluccius merluccius, Pagrus pagrus, Dentex dentex, Polyprion americanus,* and *Pagellus bogaraveo*. Some of the hotspot areas are located close to seamounts.

Greek small scale vessels were found to operate in the N. Aegean Sea with static gears mainly at Psathoura seamount (North Sporades) at 300-500 m depth (2012-2014), south of Agios Efstratios Island in waters 400-450 m depth (2014-2015), off Cavo Doro North Ridge at 500-700 m depth (2013-2016) and south of Skyros Island at

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600-750 m depth (2014-2016) Fig. 8.9). Nevertheless, given that most vessels lack AIS devices, these observations can be considered as indicative of the overall fishing activity in the area. In the S. Aegean Sea, research studies mentioned small scale fishing vessels work in the area of Kymi in E. Evia Island with gill nets targeting *Pagrus pagrus, D. dentex, Spondyliosoma cantharus*, *Diplodus sargus*, *Merluccius merluccius*, *Mustellus* spp., *Pagellus bogaraveo* and *Polyprion americanus*[31].

Small scale vessels from Cyprus were found to operate in the deep waters off Lemessos Gulf (Fig. 8.9).

It is worth mentioning that in 2013 and 2014, two EU vessels have been identified working in the Kythera seamounts area and in the deep waters south of Folegandros and east of Santorini Islands at 450-550 m depth, close to Hydra Island East mounts at 300-450 m, close to Karavi South seamount (Myrtoon Sea mounts) (2014) and in Avgo mounts (off N. Crete).

General Remarks

Fishing activities in the deep waters of the E. Mediterranean are nowadays increasing. Many gaps in knowledge, monitoring and management still exist for this activity. It is of concern that in some cases deep water fishing is conducted in vulnerable ecosystems (e.g. red shrimps fishing grounds coincide with the bamboo coral Isidella fields, *Polyprion americanus,* and *Pagellus bogaraveo* are exploited close to the seamounts). Some bycatch species in deep-water fishing are also characterized as vulnerable (e.g. sharks).

Present findings showed that no specific information exists regarding fishing effort and the corresponding fishing grounds where deep-water trawl fishery is practiced. VMS and AIS data is a helpful tool to visualize this activity, however, fishing vessels operating in the Mediterranean southern areas and in the eastern central region are not equipped with these devices, yet. Moreover, most small-scale vessels even working on static gear and in deep-waters are not using AIS.

The implementation of additional monitoring, control and surveillance actions are needed for a more reliable reporting and management of fishing activities in the deep-sea. Some inconsistencies were detected between information coming from AIS data and fishing activities reported in the literature for various fishing. Moreover, catches and landings are reported not in the GSAs of the fishing activity, but in the landing sites, resulting in bias in the assessment of the stocks of each GSA. For EU member states the mechanism and infrastructure of reporting (ERS) the exact catch composition in place should be revised. No observer system exists for the fishing activities outside national waters, although these should also be reported and monitored in the framework of the national data collection programmes.

While in the right paths, efforts are very needed for the development of an adequate programme to estimate the fishing footprint in the deep-waters of the Eastern Mediterranean, while also have adequate mapping of vulnerable biodiversity impacts and the realisation of specific management measures to protect vulnerable marine ecosystems and the exploited fisheries stocks. To this end, the GFCM Recommendations[6] on a multi-annual management plan for sustainable trawl fisheries targeting giant red shrimp and blue and red shrimp in the Levant Sea (geographical subareas 24, 25, 26 and 27) and Ionian Sea (geographical subareas 19, 20 and 21) are very promising. •

6 Recommendations GFCM/44/2021/6 and GFCM/44/2021/8

CHAPTER 8 /

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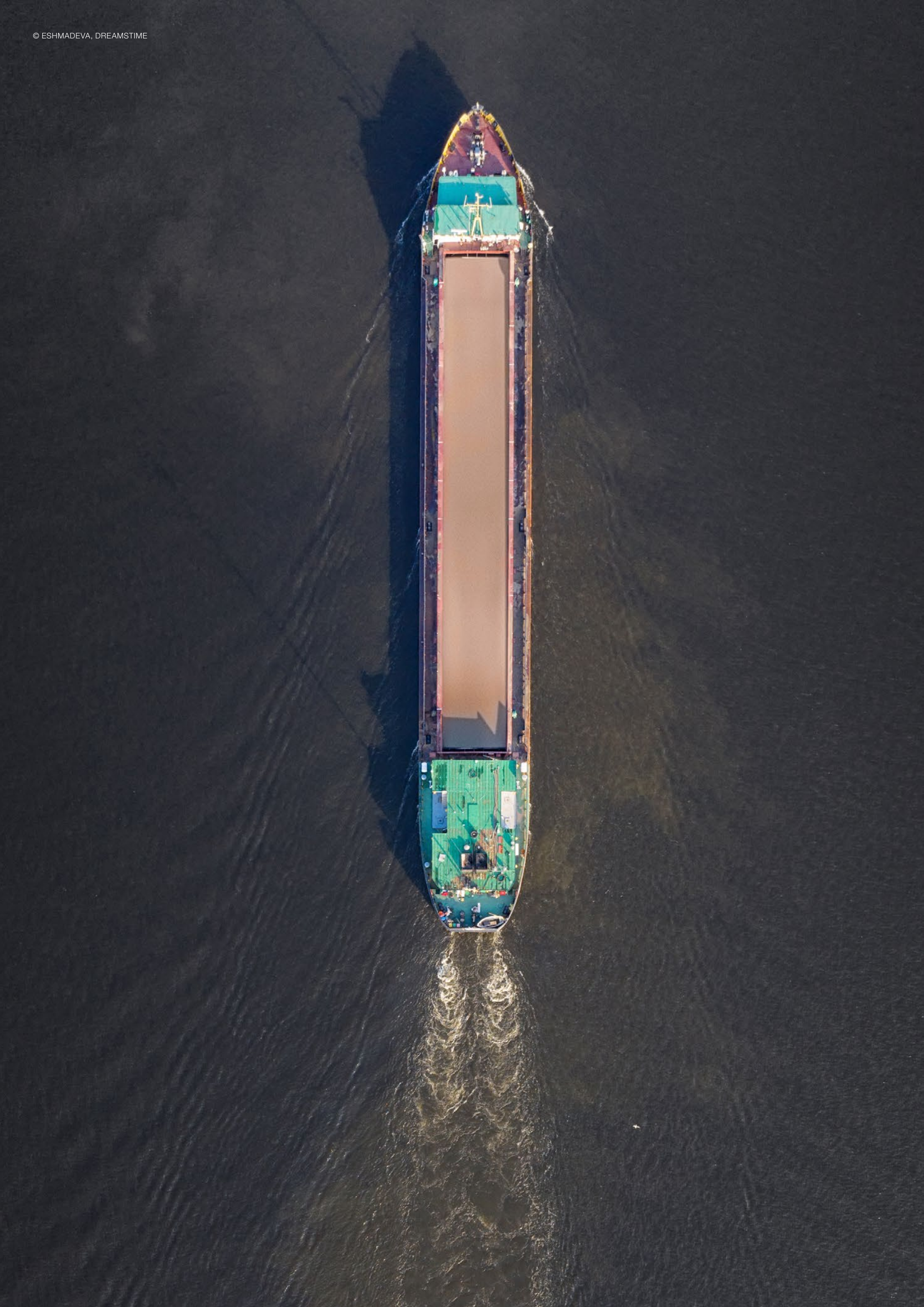

CHAPTER 9/

Anthropogenic impacts

Anastasopoulou A., Rousakis G., Otero M., Mytilineou Ch., Kamidis N., Thasitis I., Papadopoulou K-N., Kiparisis S., Smith CJ., Samaha, Z., Lefkaditou E., Ali M., Kavadas S., Dokos I., Schüler M.

Anthropogenic impacts other than fisheries include marine litter, placement of underwater cables and pipes, oil and gas extraction, ship traffic (through noise generation, pollution, accidents and litter) and mining. The latter two are expected to increase in the future in the Eastern Mediterranean.

The anthropogenic impacts on the deep-water Mediterranean environment may have a strong influence on such a fragile ecosystem, although the number of studies addressing this issue is still limited, especially for the Eastern and Southern regions of the Mediterranean basin. Information concerning the anthropogenic impacts on the Mediterranean deep-sea environments and especially those of the Eastern Mediterranean has received much less attention than that of shallow habitats[1,2].

The following sections examine the knowledge available for each of these pressures in the Eastern deep-sea environment.

Marine Litter

Anthropogenic litter has been identified as a significant and increasing problem for the marine environment over recent decades worldwide. Considerable amounts of waste are generated globally each year while waste production varies among countries[3]. This problem has also been recognized as a critical issue in the Mediterranean[4,5]. Latest estimations indicate that the total plastic accumulated in the Mediterranean is in the order of 1,178,000 tonnes, with a possible range from 53,500 to 3,546,700 tonnes[5]. The annual plastic flow leaking in to the Mediterranean is estimated at 229,000 tonnes (low and high leakage estimates equate to 150,000 and 610,000 tonnes per year, respectively) and made up of 94% macroplastics and 6% microplastics. According to this latest report, the top three countries contributing to plastic leakage to the Mediterranean Sea are Egypt, Italy and Turkey.

Within the framework of the Barcelona Convention, in 1980 the Mediterranean countries adopted a Protocol for the Protection of the Mediterranean Sea against Po-

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Plastics are of particular concern because, although they fragment, they persist in the marine environment for hundreds to thousands of years and the toxins they contain can seriously affect ecosystems and bioaccumulate through trophic change[11,12]”

llution from Land-Based Sources. This Protocol was later amended (1996) including in its Annex 1 a list of categories of substances and sources of pollution to serve as guidance in the preparation of action plans, programmes and measures. Among them, litter is defined as “*any persistent manufactured or processed solid material which is discarded, disposed of, or abandoned in the marine and coastal environment*”. Subsequently, a step forward towards dealing with the Mediterranean marine litter problem was the adoption of Decision IG.20/10 at the 17th Meeting of the Contracting Parties of the Barcelona Convention (Paris, February 2012) entitled **“Strategic Framework for Marine Litter management”**. This Strategic Framework provided a first analysis of the problem and proposed a number of activities to address, in a systematic way, the problem of Mediterranean marine litter. The parties of the Convention then went further with the adoption in 2013 of the **Marine Litter Regional Plan** by COP18 and a new updated plan is under negotiation. Other regional bodies and international instruments have also recognised this problem and developed legal frameworks and programmes for addressing this pressure such as the EU Marine Strategy Framework Directive (MSFD) and the disposal regulations under Annex V of MARPOL 73/78 addressing ocean-based litter pollution from ships.

To date, the existing knowledge on litter density and composition in deep-sea ecosystems is, however, still limited, mostly due to financial and technical limitations on sampling at great depths. Deep-water litter information has been provided, usually incidentally, by bottom trawl surveys for benthic fauna[6] or for fisheries, although valuable information has also been collected through video/ROV (Remotely Operated Vehicle) surveys documenting various types of litter and lost fishing gears[7,8,9]. Deep-sea surveys targeting litter are important because ca. 50% of plastic litter items sink to the seafloor and even low-density polymers such as polyethylene and propylene may lose buoyancy under the weight of fouling[10]. Plastics affect marine species by ingestion, suffocation and entanglement as well as by introducing possible toxic contaminants as additives and hydrophobic chemicals that can become adsorbed from the surrounding water. Floating litter can also transport non-native species into new environments and tiny plastic fragments, **‘microplastics’**, have been shown to be long-term sources of pollutants, such as phthalates.

"

The highest percentage of marine litter found on the Mediterranean seafloor is plastics"

Studies on marine litter in the Mediterranean Sea have mainly been carried out over the last 20 years. Most of these available studies are from shelf habitats, while very little has been done on deep waters. A review of the available information on the marine litter in the deep waters of the Mediterranean have been published for a few initiatives[1,5]. The known published information for the deep waters of the Eastern Mediterranean is much less than that for the Western part.

The following section presents the available information collected from published works, congress contributions and grey literature reports for the deep-waters in the Eastern basin in terms of marine litter density and composition. Some of these studies are based on direct on-board collection of litter data from trawl hauls, others have used photographic material from trawl hauls, while still others have been based on ROV underwater videos. Differences in the sampling design among the various studies, as well as the depth range of the works, make comparison of their results and findings difficult. Nonetheless, they present an assessment of the existing knowledge, data gaps and impacted areas and species for the Deep Eastern Mediterranean Sea.

1 EASTERN IONIAN SEA

For the deep waters of the Eastern Ionian Sea, information on marine litter was derived from study surveys carried out in the area targeted towards the study of a variety of issues and with different survey techniques such as photographic material from trawl hauls, direct on-board collection of litter data from trawl hauls, and ROV underwater videos. Results from these and observations in other Eastern Mediterranean regions are presented in Table 9.1.

Even with the differences in the sampling design among the various studies, the results of the available information provide the following conclusions and suggestions:

- Litter density in terms of number of litter items per surface area, in the deep Eastern Ionian Sea ranged from 72 to 679 items/km^2. The highest density of litter items was found off northern Corfu Island coasts. However, the high rates encountered should not be considered representative of the Eastern Ionian deep waters, because only a few sampling stations were conducted in these deep waters.

- An annual increasing trend of litter density from 1996-2008 has been observed on the slope along the Eastern Ionian Sea, particularly of metallic and glass/ceramic litter[13]. This trend seems to be continuing (Lefkaditou, personal communication) over time with an increase in the litter density from 74 items/km^2 until 2008 to 100 items/km^2 in 2016. However, these differences may be due to the fact that the most recent observations were based on on-board collection of litter from trawl catches, whereas those of the first works were derived from the analysis of trawl catch photographs, which may result in underestimating litter occurrence and density. The hypothesis of an increasing trend in litter density over time is nonetheless strengthened by the fact that the area of the Echinades Gulf, located on the west coast of Greece, also shows a higher density of litter (300 items/km^2) compared to previous estimations (89 items/km^2)[14,15].

- Considering the relation of marine litter at depth in the deep waters of the Eastern Ionian Sea, a previous review analysing litter from 4 depth layers, indicated that the density of marine litter decreased from 300 to 900 m but increased again in waters deeper than 900 m depth[16].

Table 9.1. Density of marine litter (items/km²) in the deep waters of the Eastern Ionian Sea, North Aegean Sea, South Aegean Sea, Libyan Sea and Levantine Sea from the available literature during the period 1993-2016. Information on sampling location, sampling date, sampling gear, depth, and percentage of plastics is also shown. (*) indicates sites where more information is given in the text.

Eastern Ionian Sea						
Survey Location	**Date**	**Survey Type/ Sampling gear**	**Depth (m)**	**Density (items/ km²)**	**Plastics**	**Reference**
Off Pylos Gulf	1993	Beam trawl	3,838	12**	42%	17
Eastern Ionian Sea	1996-2008	Trawl (20 mm mesh size) #	10-800	75	36%	13
Echinades	1998	Trawl (15 mm mesh size)	247-360	89	79%	14
Northern E. Ionian Sea	1999-2000	Trawl (32 mm mesh size) *#	300-1200	98	70%	16
Southern E. Ionian Sea	2000	Trawl (32 mm mesh size) *#	323-855	111	58%	18
Messiniakos Gulf	2000	Trawl (32 mm mesh size) *#	360-865	103	48%	18
Echinades	2000-2003	Trawl (15 mm mesh size)	15-320	72	56%	19
Corinth Gulf	2000-2003	Trawl (15 mm mesh size)	15-320	116	56%	19
E. Ionian (off Kephallinia Isl.)	2010	ROV (Remotely Operated Vehicles)	300-800		26%	7
Echinades*	2013	Trawl (50 mm mesh size)	Max 320	300 (in 200 isobath)	67%	15
Off Corfu Island*	2014-2015	Trawl (40 mm mesh size) *	43-281	679	91%	20
Eastern Ionian Sea & ArgoSaronikos Gulf	2014 & 2016	Trawl (20 mm mesh size)	10-800	100		Lefkaditou (in preparation)
NE Ionian*		Trawl (40 mm mesh size) *	43-287	679	91%	21

North Aegean Sea						
Survey Location	**Date**	**Survey Type/ Sampling gear**	**Depth (m)**	**Density (items/ km²)**	**Plastics**	**Reference**
Saros Bay to Bodrum area (northern to mid Aegean eastern coasts)*	2008	Trawl	65-880	211–299 (in gulfs); 48 (in open sea)	84.13%	22

South Aegean Sea						
Survey Location	**Date**	**Survey Type/ Sampling gear**	**Depth (m)**	**Density (items/ km²)**	**Plastics**	**Reference**
Saronic Gulf*	2013	Trawl (50 mm mesh size)	Max 450	1,423 (250 isobath); 979 (300 isobath); 1,182 (350 isobath)	95 ± 12%	15
Argo-Saronic Gulf	1996-2008	Trawl (20 mm mesh size)	226-778	87	47%	13

Libyan Sea						
Survey Location	**Date**	**Survey Type/ Sampling gear**	**Depth (m)**	**Density (items/ km²)**	**Plastics**	**Reference**
Crete-Rhodes Ridge (Continental slope)	2009	Trawl (40 mm cod-end mesh)	1,500	110 ± 30 kg/km²	17%	8
Crete-Rhodes Ridge (Deep basin)	2009	Trawl (40 mm cod-end mesh)	3,000	120 ± 30 kg/km²	19.5%	8
Crete-Rhodes Ridge	2009	Trawl (40 mm cod-end mesh)	1,200-3,000	< 200 kg/km²	In 80% of the samples	23
S. of Crete	1993	Beam Trawl (10 mm cod-end mesh)	1,363	64 items/cm²	17.2%	17

Levantine Sea						
Survey Location	Date	Survey Type/ Sampling gear	Depth (m)	Density (items/ km²)	Plastics	Reference
Antalya Bay*	2012	Trawl (44 mm cod-end mesh)	200-800	115-2,762	81.1%	24
Limassol Gulf	2013	Trawl (50 mm mesh)	60-420	24 ± 28	67.4%	15
Levantine	1993	Beam Trawl (10 mm cod-end mesh)	227-2,812.5	184*	42.4%	17
Antalya coasts*	2014-2015	Trawl (44 mm cod-end mesh)	10-300	13.3 and 651.1	72.1%	25
Lebanese deep waters	2016	ROV				26

* stretched mesh; # analysis based on photographic material of each haul; ** items/cm^2

The litter densities published to date for the Eastern Ionian Sea showed that in most areas of the Ionian Sea, the values are lower than those reported for many other areas in the Mediterranean (Gulf of Lion, East-Corsica, Adriatic Sea and NW Mediterranean)[27] and those reported for eastern Corsica and the waters around Cyprus[28]. Litter density for Echinades[15] (in the isobath of 200 m) is similar to that reported for the Adriatic Sea[27]. As an example, in eastern Corsica, recent studies indicated more than 800 items/km^2 at 500-800 m depth[28]. However, as noted before, comparisons are difficult because of the use of different sampling schemes for each of the studies. Although there are not yet agreed reference points for the litter density in the Mediterranean, the comparison with the mean baseline of 179 items/km^2 proposed previously[4] showed that the litter densities for the E. Ionian Sea are lower than the above number.

As with other regions, plastics were the dominant material found on the seafloor of the areas investigated in the Eastern Ionian Sea, ranging between 42 to 91% of the total litter items.

Plastic litter composition in the deep waters of the northern part of the Eastern Ionian Sea (Fig. 9.1) indicates that sheets, industrial packaging and plastic sheeting were the most dominant subcategories of plastics observed[21]. Other litter categories identified in the deep waters of the E. Ionian Sea were metal, glass, ceramic, wood, clothing, rubber, synthetic and package/use (food packaging, beverage packaging, general packaging).

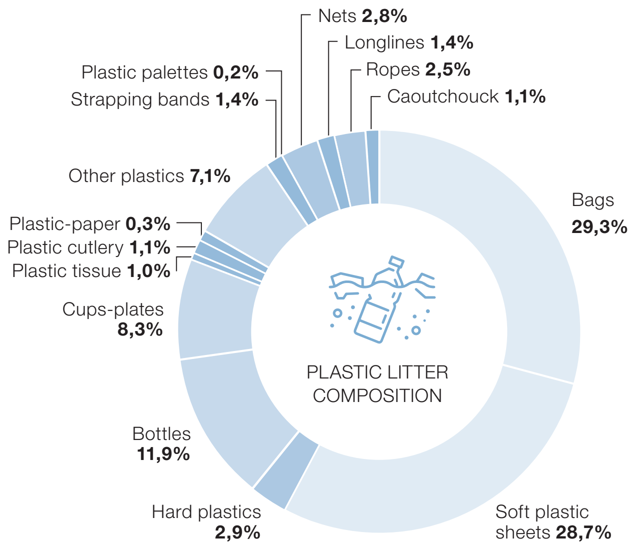


Fig. 9.1. Plastic litter composition in the deep waters of the northern part of the Eastern Ionian Sea[16].

Marine litter on the seafloor in an area of high ecological value, Kephallinia Island

Presence of marine litter off Kephallinia Island (also known as Cephalonia or Kefalonia) of the Ionian Sea in a deep-water coral area was also evident in ROV (Remotely Operated Vehicle) videos. Observations from coral and no-coral close by areas reported that, from a sub-sampling of 15 hours of video transects (observing 10 seconds every minute), visible litter items appeared in 5.1% of seabed observations. Most of the litter was plastic, metal, and glass in both coral and no-coral areas (Fig. 9.2) The presence of ghost nets was also documented in some locations of deep-water coral areas.

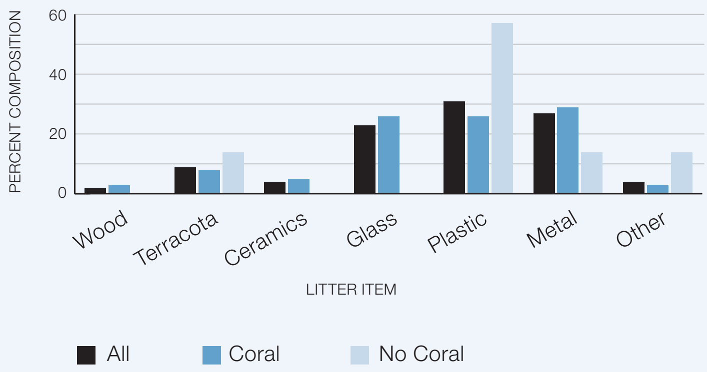
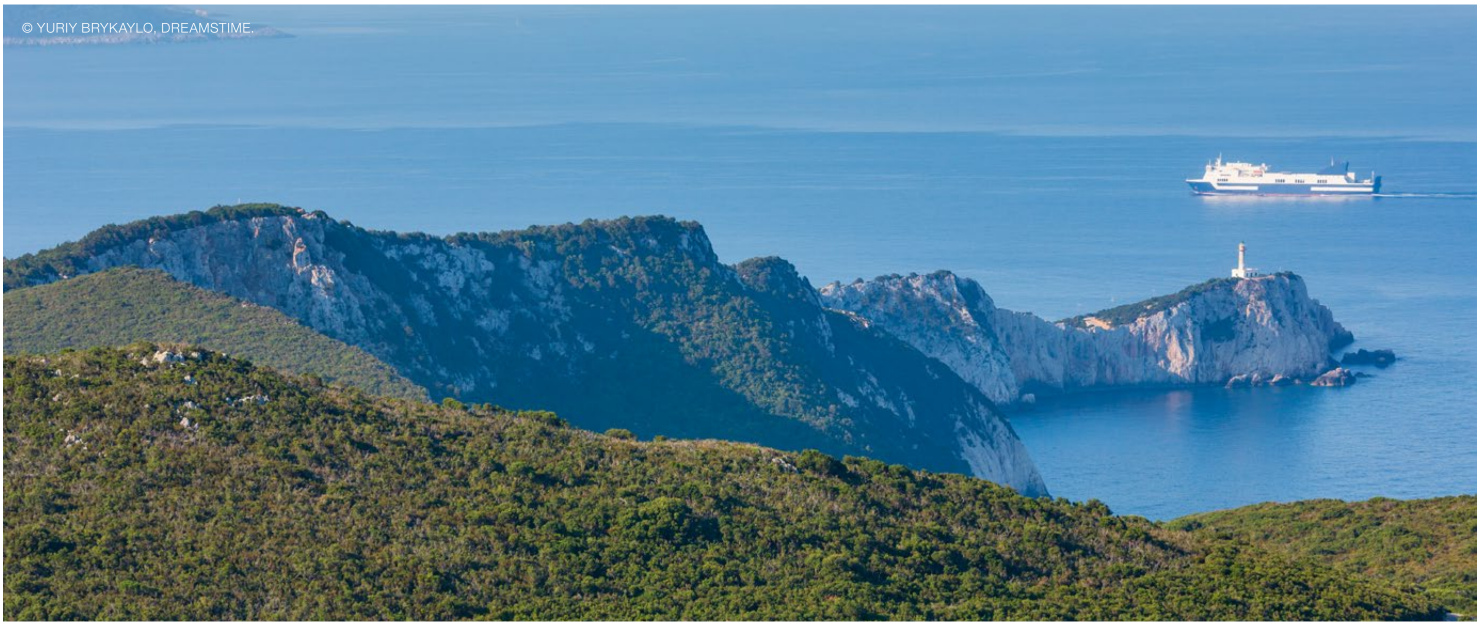


Fig. 9.2. Composition of the litter for pool data (all), coral area, and no-coral area. Source: Smith et al., 2012[7]

A compilation spatial distribution map of litter density (items/km^{2}) from recent scientific surveys (INTERREG, RESHIO, MEDITS[1]) at depths > 200 m of the Eastern Ionian Sea shows that the range of values reported are similar to previous works (Fig. 9.3). The deep-water areas with the highest litter density (> 1,000 items/km^{2}) were Southwest of Lefkas Island (2,475 items/km^{2}), South of Zakynthos Island (1,253 items/km^{2}) at depths between 500-700 m and in the Othonioi Islands (1,291-2,024 items/km^{2}) at 270 m (Fig. 9.3). These values are much higher compared with those derived from the published literature. However, the mean litter density of all studied stations showed moderate litter pollution (159 items/km^{2}) with the highest litter density (1,612

1 MEDITS survey programme (International bottom trawl survey in the Mediterranean)



Lefkas island.

items/km²) found, as in the previous years, Southwest of Lefkas Island at 533 m depth, an area very close to navigation routes[29]. Here it seems that **the highest litter density Southwest of Lefkas Island coincides with shipping lanes** (Fig. 9.3).

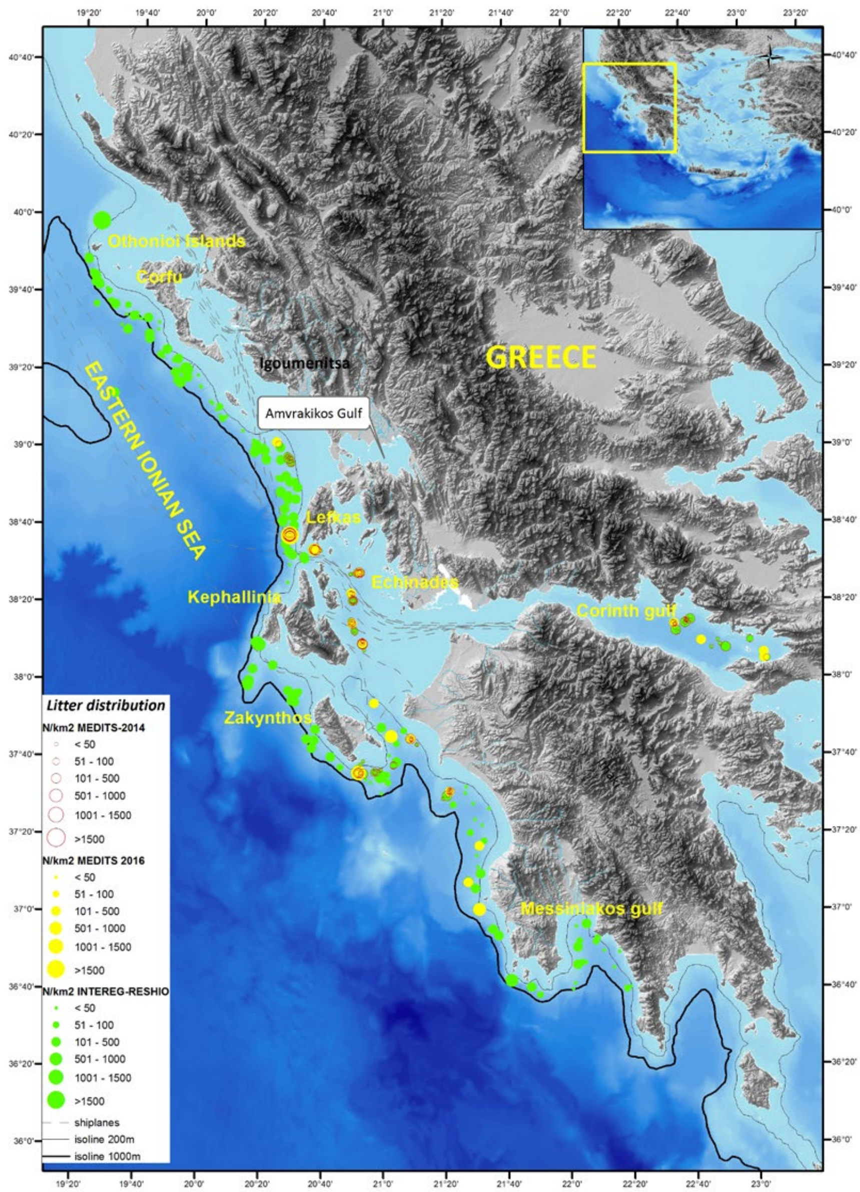
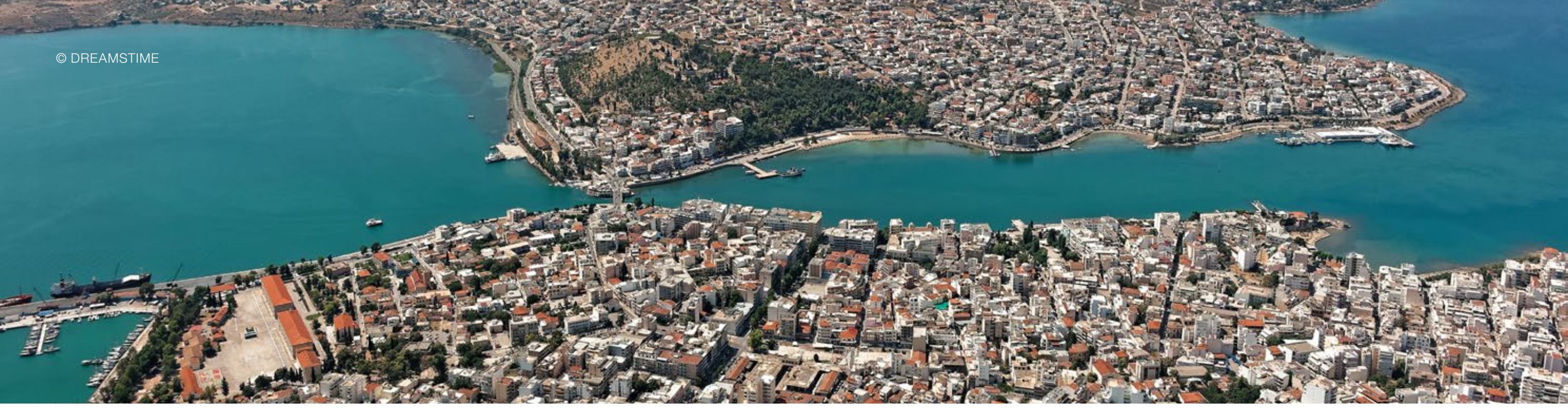


Fig. 9.3. Compilation map of the litter density in the deep waters (> 200 m) of the southern E. Ionian Sea including all unpublished data from the HCMR database. (○: litter records based on photographic material of INTERREG (1999-2000) and RESHIO (2000) hauls; ●: litter records based on photographic material of MEDITS hauls; ●: litter collected on board during MEDITS survey). Shipping lanes are also shown with dashed lines on the map.

Fishing related litter (abandoned, lost or disposed fishing gear) was not found to be of major importance for this sub-region, as the activity is quite low in the deep waters of the Eastern Ionian Sea[14,7,16] (Fig. 9.4). However, it is worth mentioning that small litter items linked to fishing (e.g., pieces of strings) are not easily detectable in underwater observations or in photos.

To date, information on the ingestion of litter by marine organisms in the Eastern Ionian Sea has been reported by few studies[30,31,32,33]. Litter ingestion studies in deep-water fishes showed that 1.9% of the examined species had litter in their guts[34]. Sharks and rays such as the pelagic sting ray *Pteroplatytrygon violacea*, the blackmouth catshark *Galeus melastomus,* longnose spurdog shark *Squallus blainville,* and the velvet belly lantern shark¡ *Etmopterus spinax* have been shown to ingest litter more frequently than bony fishes (e.g. blackspot seabream *Pagellus bogaraveo*) and the ingested litter was primarily plastics (86.5%). The presence of macroplastics has also been reported in the stomachs of four marine mammals (the harbour porpoise *Phocoena phocoena,* the Risso's dolphin *Grampsus griseus,* the Cuvier's beaked whale *Ziphius cavirostris* and the sperm whale *Physeter macrocephalus*) as they stranded along the Greek coasts from 1993 to 2014. This supports the idea that plastics are ingested by the half of the cetacean species that regularly occur in the Greek Seas[35].

Discarded plastic is a marine menace for Risso's dolphins, entangling them and filling their stomachs.



Evoikos Gulf in the North Aegean Sea.

1 NORTH AEGEAN SEA

To date, there has been no published study to show the presence of marine litter in the deep waters of the North Aegean Sea, with the exception of one scientific study carried out in the eastern part in 2008[22] and the information provided by the MEDITS surveys. According to the results of the study of 2008 (Table 9.1), litter was abundant mainly in the gulfs of the Turkish coasts (211.75-299.98 items/km^2), whereas it was very low (48 items/km^2) in the open sea between Lesbos and Chios Islands. Low amounts of litter had also been observed by underwater video observations during ROV missions.

From MEDITS surveys, litter density values in the deep waters (> 200 m) of the North Aegean Sea were found to be between 7.7 and 766.4 items/km^2 (Fig. 9.4). The three sites with the highest litter density (> 300 items/km^2) were in the **central basin of the North Evoikos Gulf** (at depths from 430 to 440 m), the area **between Limnos Island and Chalkidiki Peninsula** at a depth of around 550 m and **north of Lesvos Island** at 223 m depth.

The North Evoikos Gulf is a semi-enclosed marine gulf with limited communication with the open Aegean Sea. The central part of the N. Evoikos Gulf, where the high litter density was found, is very steep and the vertical throw exceeds 1,000 m, which may contribute to the litter accumulation. The area off Limnos Island situated on the Limnos Plateau has a water circulation that creates various thermohaline fronts and gyres especially in the summer season[36], which could be the reason for the observed litter accumulation. The third area, north of Lesvos Island, is very close to the Turkish coasts and 56.8% of the litter found in its north-eastern coastline has been reported to be related with the immigration taking place in this area[37].

According to the results derived from MEDITS surveys across the North Aegean Sea, the mean litter density of all studied stations in the North Aegean Sea was 114.2

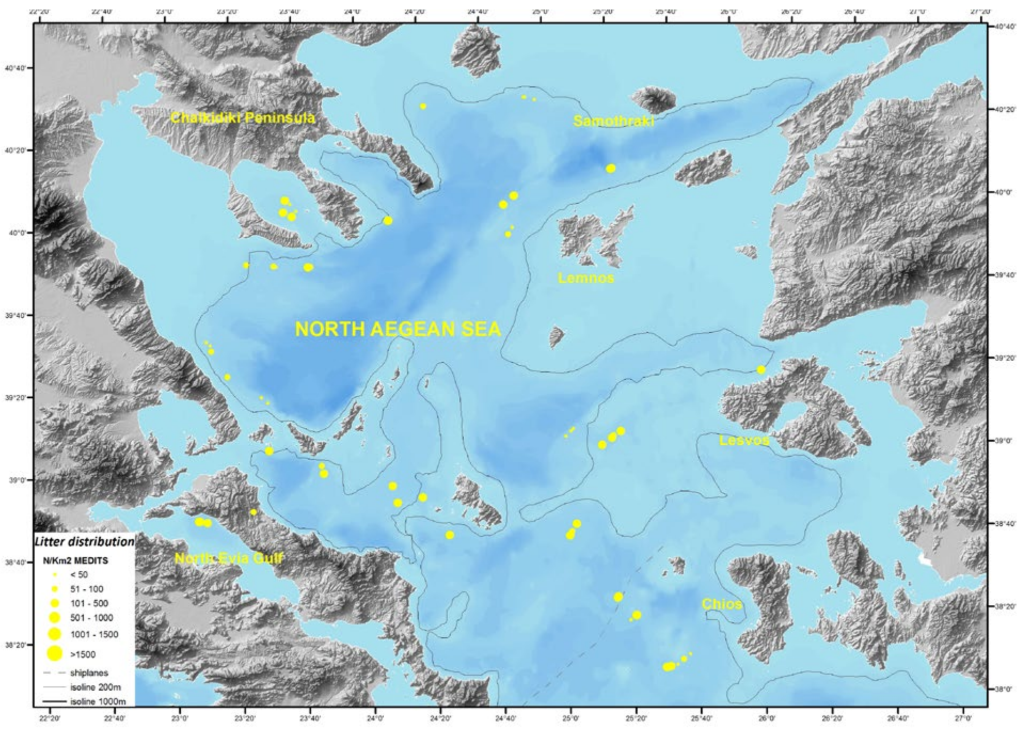


Fig. 9.4. Map of the litter density in the deep waters (> 200 m) of the North Aegean Sea based on MEDITS surveys for the years 2013, 2014, 2016 and 2018.

items/km^2 with plastics accounting for 74%. A variation in the mean density was observed across the years; in 2013, 2014, 2016 and 2018 the mean density was 155.9, 78.8, 59.4 and 162.9 items/Km^2, respectively.

Low amounts of litter had also been observed by underwater video observations during ROV missions.

Few reports mentioned the impact of marine litter on deep-sea species in the North Aegean Sea. In 2007, it was reported that 13 dead striped dolphins (*Stenella coeruleoalba*), one Risso's dolphin (*Grampus griseus*), one shark and some tuna were found off the island of Samothraki, in an abandoned illegal driftnet, indicating the impact of ghost fishing of marine life. Early studies on the diet of the Norway lobster, *Nephrops norvegicus* from several areas, including the North Evoikos Gulf (North Aegean) between 150 and 200 m depth, have also found plastic material (nylon threads, probably from fishing gears), wood and charcoal in the stomachs of several individuals.[38]

SOUTH AEGEAN SEA

There is very limited information on deep-sea floor litter in the South Aegean Sea and the differences from the available studies on sampling and observation design (e.g., direct on-board collection of litter data versus detection of litter from photographic material of MEDITS trawl hauls) make the results difficult to compare (Table 9.1).

More recent data for the litter density in the deep-waters of the South Aegean Sea, derived from surveys conducted between 1996 and 2016 (Fig. 9.5), indicated that litter density ranged between 8.4 and 3,056.7 items/km^2.

The **highest values of litter density (> 1,000 items/km^2) were observed in two locations in the western basin of the Saronic Gulf** in 2014 (3,057 items/km^2) and 2016 (1,286 items/km^2) at 381 to 404 m depths. These values were much higher than those previously reported for the same area during the period 1996–2013.

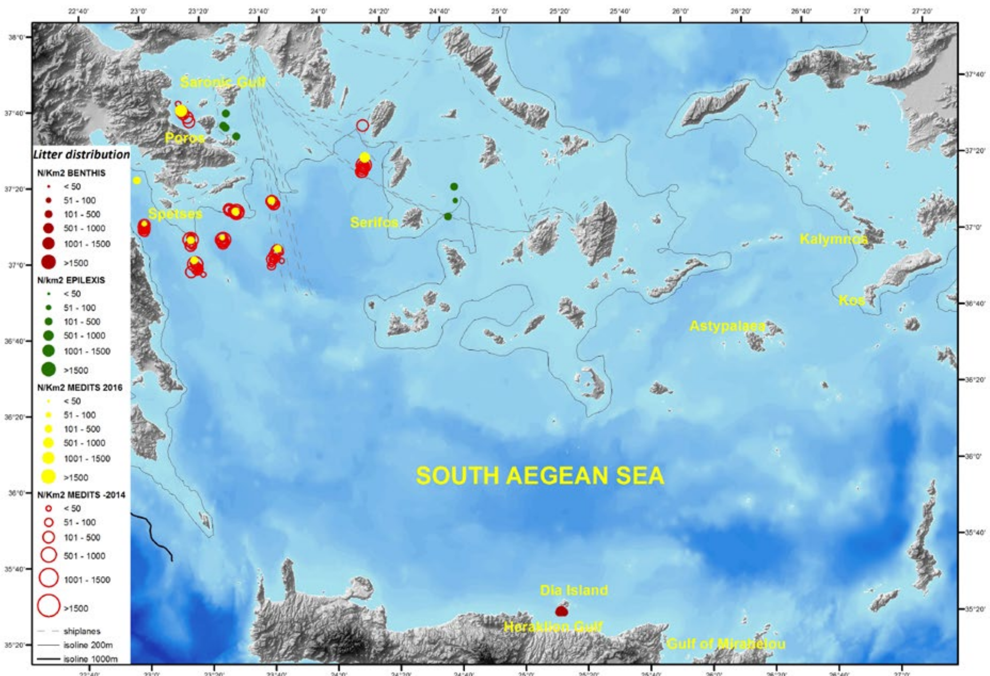
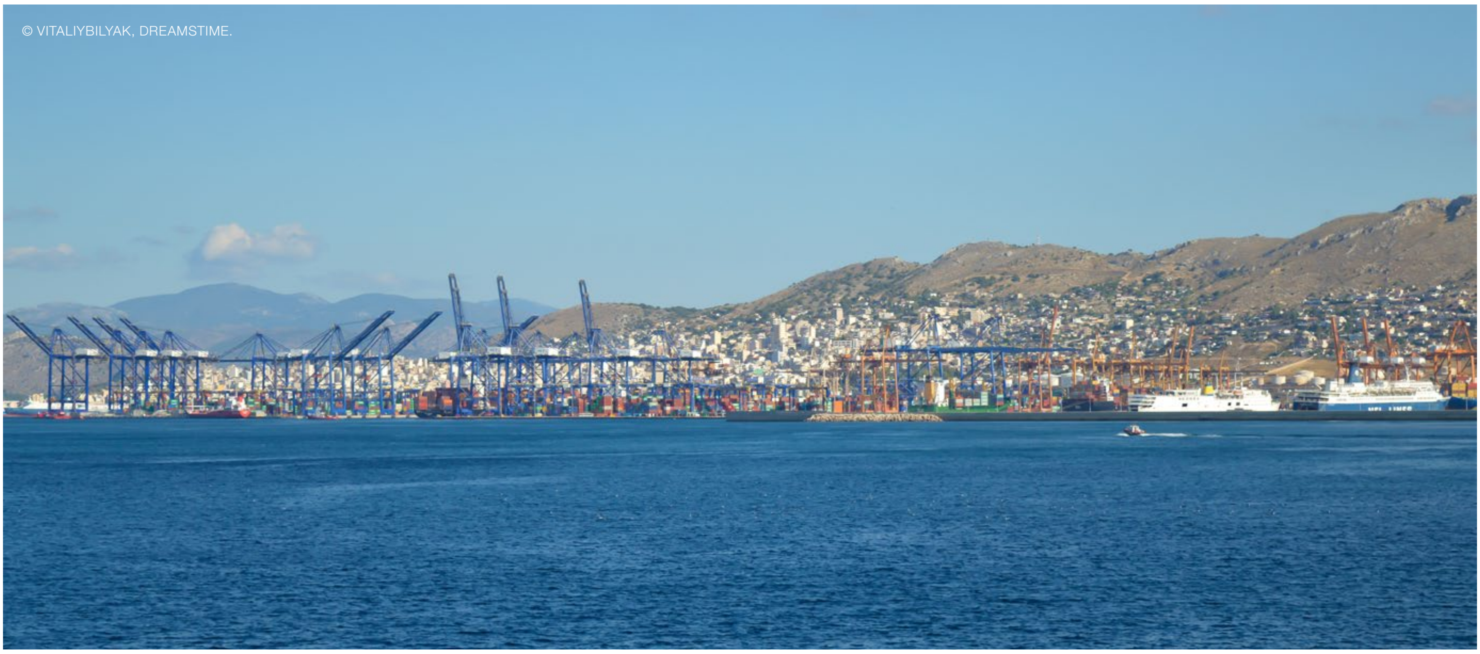


Fig. 9.5. Map of the litter density in the deep waters (> 200 m) of the South Aegean Sea based on on-board litter collection from BENTHIS surveys (●) EPILEXIS surveys (●) and MEDITS 2014 & 2016 surveys (●).
The data derived on the litter occurrence based on the photographic material of the MEDITS 1996-2008 surveys are also shown (○).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Piraeus port in Saronic Gulf.

Lower litter density values (95-1,056 items/km^2) were found in the Saronic Gulf from the data derived by the MEDITS survey of 2018, although stations of shallow waters (< 200 m) were also included which might be responsible for the large variation observed. Among the deep-water stations, the highest litter density with 1,054 items/km^2 was found, as in the previous years, in the western basin of the Gulf[29].

The Saronic Gulf is a semi-enclosed embayment and constitutes the natural marine gateway of the city of Athens and the Piraeus harbour and thus is affected by multiple coastal and marine activities. The anticyclonic circulation in the Saronic Gulf has been documented to be responsible for the increase of floating litter particles in the broader area[39] making these available to sink and accumulate in the Gulf. Other factors, which also contribute to the high litter density in the area, maybe related to the tourism and maritime traffic that take place there.


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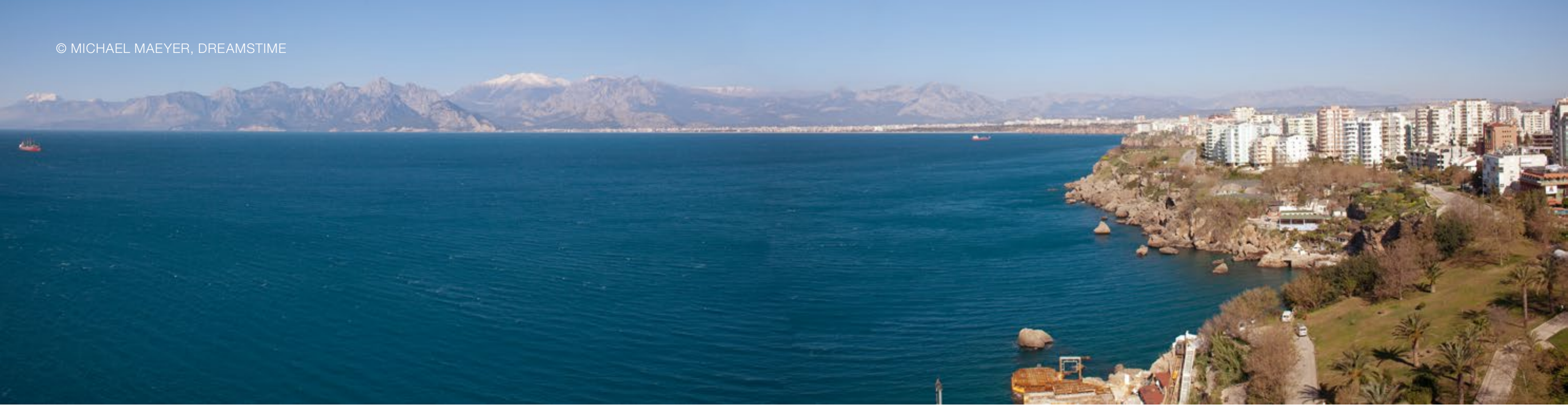
4 LIBYAN SEA

Information on the seafloor litter in the deep-waters of the Libyan Sea has only been documented in a few published works mostly related to surveys along the Crete-Rhodes Ridge (Table 9.1).The results from these works derived by using different sampling gears (e.g., different trawl and mesh sizes) and seafloor litter density metrics (kg/km^2 or items/cm^2) make comparisons between them, as well as with the findings from other areas, difficult to interpret. Important gaps exist for much of this region such as from the deep waters of the Gulf of Sirte where maritime traffic and activities are considerable.


© MICHAEL MAEYER, DREAMSTIME

The deep basin of Antalya Bay in Turkey record high densities of marine litter on its seafloor.

5 LEVANTINE SEA

As with other regions, information on the seafloor marine litter in the deep Levantine Sea is documented in very few published works and grey literature. For Turkey, the highest litter density has been reported for the bathyal grounds (200-800 m) of the Antalya Bay with densities of 500-3,000 litter items/km^2 (South Turkey) [40]). In this area, 81% of the litter reported was plastic. The coast of Antalya is under the influence of large affluence and touristic activities, commercial and touristic boat traffic, particularly over the summer period. Related pressures with the intense fishing activity, affluent of residential areas and river discharges are also identified causes of the increase of land-based pollutants. The hydrodynamic circulation of currents along neighbour coastal areas and local upwellings further increase the transportation of debris in this area.

A widespread presence of marine litter has also been reported with ROV observations in deep Lebanese waters (“Deep-Sea Lebanon” project[26]) with plastic debris, urban waste and oil drums found in all the canyons examined (Fig. 9.7). Moreover, evidence of indirect fishing impacts (e.g., lost or discarded fishing gears) were also observed mainly in areas of canyon heads.

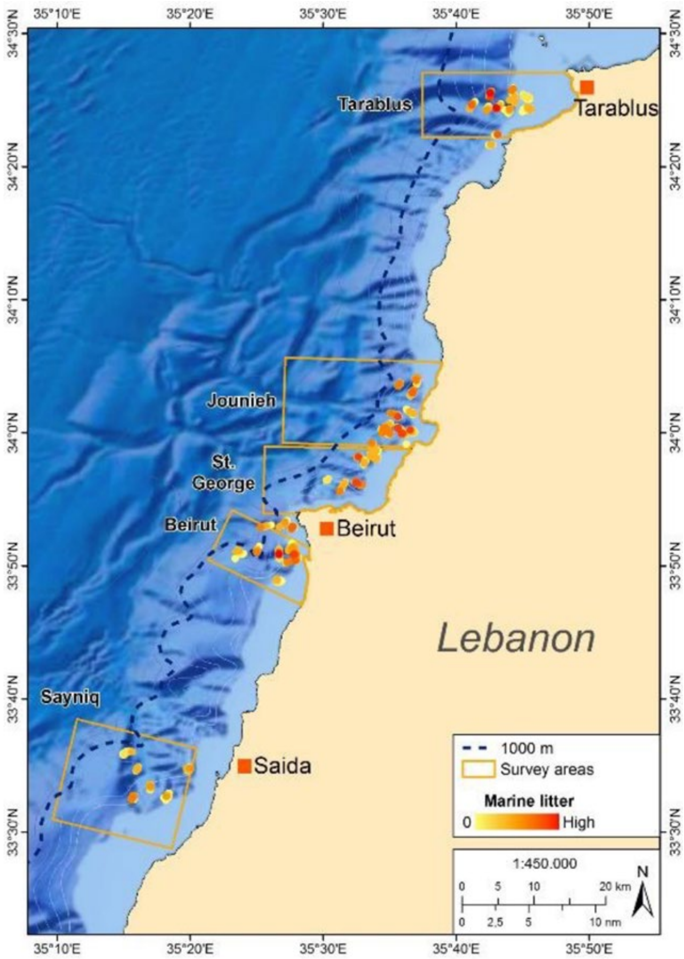


Fig. 9.7.
Marine litter distribution and density in the Lebanese deep seafloor[26].

> “Deep-sea canyons along the coast of Lebanon are plastic dumps and also biodiversity hotspots”

Marine litter observed in the sea canyons of Lebanon.
© Oceana/IUCN/RAC-SPA Deep Sea Lebanon Project

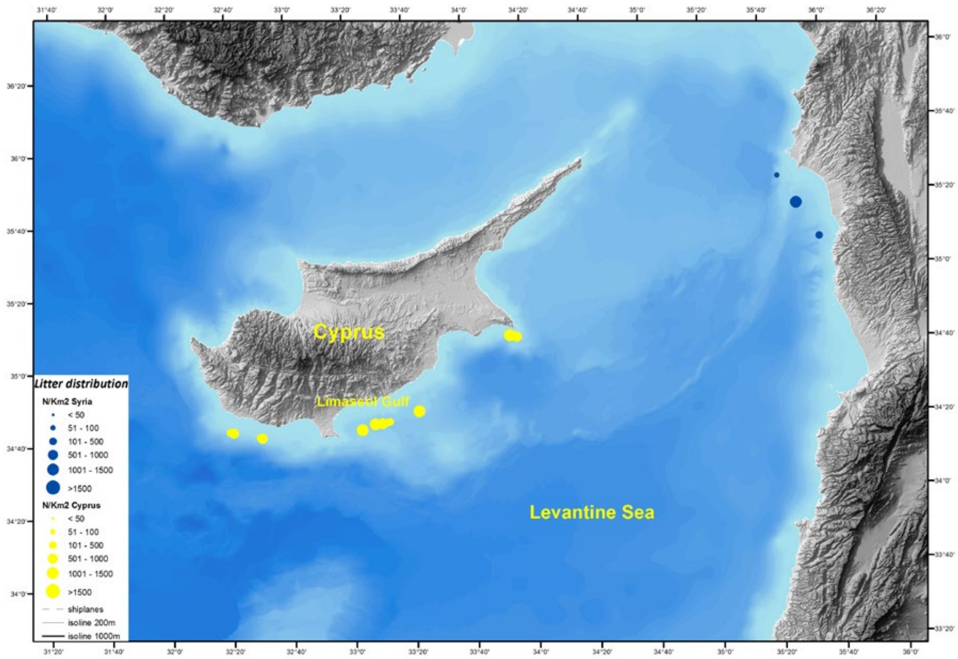
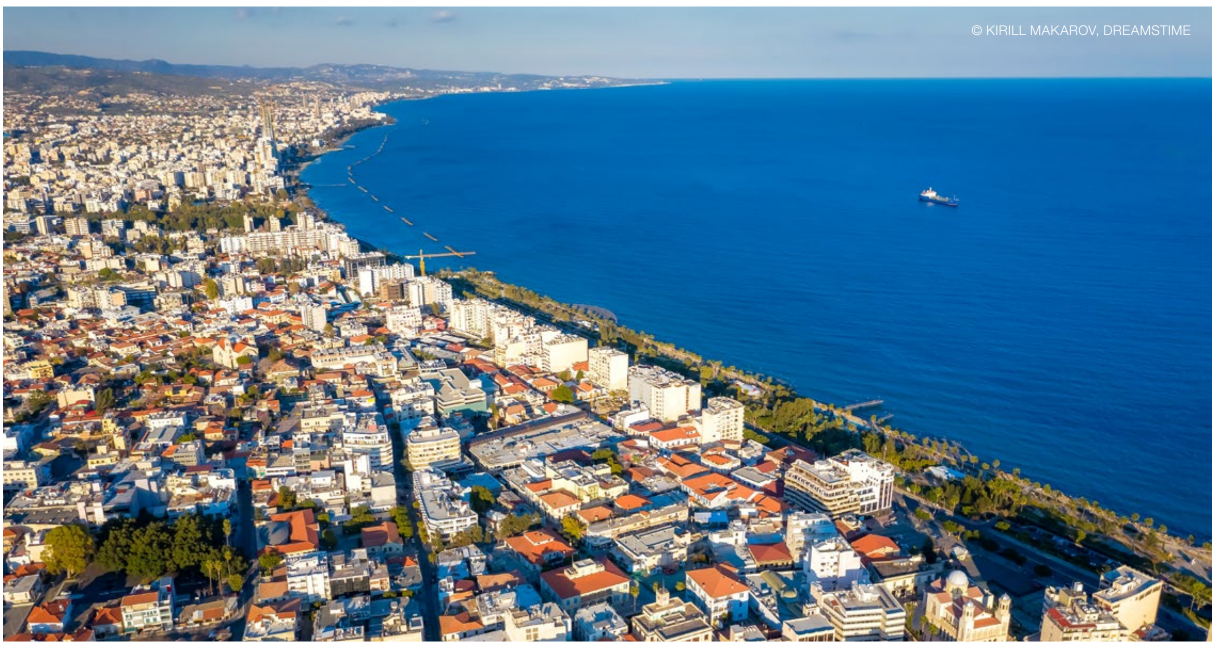


Fig. 9.8. Map of the litter density in the deep waters (> 200 m) off Cyprus (litter collected on board during MEDITS surveys; yellow circles) and Syria (litter defined based on photographic material; blue circles).

Litter density in the deep-waters (> 200 m) off Cyprus Island (Levantine Sea) from the MEDITS surveys of Cyprus and from photographic material of trawl hauls conducted off Syria (Fig. 9.8) ranged between 56 and 1,345.9 items/km^2. **The highest values of litter density (1,132-1,346 items/km^2) was observed in the deeper part of the Limassol Gulf**, south of Cyprus, at 575-620 m depths and very close to marine navigation routes. In the South-eastern area of Cyprus, another area of high litter density has also been observed (1,000 items/ km^2) at 300-350 m. The Limassol Gulf, although it is a gulf of open topology, receives litter carried by the existing currents and from various kinds of land and sea activities in the area (urbanization, tourism, commercial, industry, crafts, warehouses and aquaculture).



The Limassol Gulf, although it is a gulf of open topology, receives litter carried by the existing currents and from various kinds of land and sea activities in the area (urbanization, tourism, commercial, industry, crafts, warehouses and aquaculture).

Preliminary work on marine litter carried out in the deep-waters (> 350 m) off Syria in 2017 reported density that ranged between 81 and 911 items/km^2. The highest value of litter density (911 items/km^2) was observed in the open waters west of the Jablah area, at 400 to 680 m depth.

The cyclonic and anticyclonic gyres, interconnected by jets and currents that occur in the Eastern Levantine basin, may enhance litter accumulation in the northern shores and some of the deep waters. The eastern part of the Levantine Sea is an important habitat for whales, dolphins, and sea turtles as many sightings and strandings of several species have been recorded there[2]. Ingestion of pieces of plastic bags, for example, has been reported for stranded Risso's dolphins (*Grampus griseus*) and leatherback marine turtles *Dermochelys coriacea* along the Mediterranean coast of Israel[42,43].

GENERAL CONSIDERATIONS

The spatial distribution and accumulation of litter on the seafloor is a result of complex interactions between the geomorphology, hydrography, environmental, meteorological conditions and anthropogenic activities. In some geographical areas, there is also a notable temporal, particularly seasonal, variation of marine litter accumulation, indicating the varying effect of different environmental or anthropogenic factors. Other factors contributing to litter distribution, accumulation and density on the seafloor are related to river inputs, proximity to urban and industrial areas, maritime traffic, agriculture and aquaculture, fishing effort, proximity to coast, tourism and extreme oceanographic events[8,44]. Plastic hotspots tend to appear in shallow waters near the mouth of major rivers (e.g. the Nile) and close to large cities or urban areas[5].

The mean litter density derived from scientific survey data was under the baseline of 179 items/km^2 in most of the examined areas except the deep waters of the S. Aegean and the Levantine off Cyprus[4]. However, in some locations (e.g., S. Aegean: western basin of the Saronic Gulf; Levantine: Limassol Gulf, Antalya Bay) there are extremely high values (> 1,000 items/km^2), which are much higher than those reported for the North West Mediterranean. In contrast, these values were much lower than those reported for the Gulf of Seine located in northern France[27,28]. It seems that litter density is higher in highly urbanized gulfs and particularly in the deeper parts of them. Furthermore, very high litter densities (> 1,000 items/km^2) were also found in the open sea (e.g., E. Ionian Sea: southwest of Lefkas Island, south of Zakynthos Island, Othonioi Islands; Levantine: south of Cyprus, off Jablah in Syria), which may indicate different reasons of litter accumulation, among them maritime traffic. Submarine canyons have also been reported to act as the main vectors for the transport of marine litter, conveying it from the continental shelf into the deep seafloor. These observations from other areas in the Mediterranean also correspond to those in the Lebanese canyon systems, located close to the coastline.

Nonetheless, certain considerations regarding the present values of marine litter density are needed as they do not necessarily reflect the general pattern of litter density in the Eastern Mediterranean due to the lack of extensive specific monitoring surveys for litter detection and the lack of a common methodological approach for assessments in the whole area. Many deep-sea ecosystems seem to be very vulnerable and marine litter may have a large impact on the species inhabiting these ecosystems.

A recent review[45] estimated that up to seventy-eight taxa resulted impacted by marine litter on Mediterranean reefs, and the majority belonged to the phylum Cnidaria (41%), including endangered species like the red coral (*Corallium rubrum*) and the madrepora coral (*Madrepora oculata*). Entanglement, caused mainly by abandoned, lost, or otherwise discarded fishing gear (ALDFG), has been reported the most frequent impact, playing a detrimental effect mainly on coralligenous arborescent species and cold-water corals (CWCs). However, there is a gap in the knowledge about the extent of litter in the deep waters of the Eastern Mediterranean and its impact on its biota and habitats. From ingestion, reports already indicate that highly affected species may include deep-sea fish, invertebrates, sea turtles and cetaceans. Lost fishing gears can also harm

2 The Whales & Dolphins of Cyprus: Summary of 2016 & 2017 Research Surveys, 2017

benthic organisms and habitats but the information is limited in this regard besides the presence of lost fishing gears entangled on corals, rocks or soft sediment and bottom trawl traces on the seabed.

Although monitoring of marine litter is expensive and time consuming, further studies are necessary to address this gap and to provide data on the density, distribution, impacts and qualification of different litter categories in the deep-sea. This will assist to enhance a more complete comprehension of the marine litter issue and to provide early detection of potential problems in areas of high ecological value.

Plastics represented the highest proportion of marine litter in the deep waters of the Eastern Mediterranean as has been reported for the seafloors of all seas and oceans of the world and particularly in deep waters. Plastic production has obtained popularity in manufacturing and packaging applications because of the ease of processing, durability and relatively low cost. Despite their benefits, plastics have now become a global concern due to their effects on the environment, the economy and marine life when not properly disposed of or recycled.

In the Mediterranean, the problem of marine litter and plastics in particular, has also been behind the adoption by the Barcelona Convention parties for "**The Strategic Framework for Marine Litter management**". This also enables the subsequent development of the "**Regional Plan for the Marine Litter Management in the Mediterranean**" (Decision IG.21/7) with a series of main objectives to prevent and reduce this type of pollution, enhance knowledge, and remove, to the extent possible, marine litter by using environmentally respectful methods. For EU countries, the EU's Waste Framework Directive has further prioritised prevention measures in waste management[46].

Moreover, in order to develop effective strategies, it is useful to understand the problem of plastic waste in coastal and deep-water environments as well as the sources, impacts and the risks. Both the EU's Marine Strategy Framework Directive (MFSD) and the Barcelona Convention, with the implementation of the IMAP programme (the EcAp based integrated monitoring and assessment programme) have included descriptors for marine litter monitoring to support the country´s assessments and national monitoring programmes for litter and mitigating actions towards addressing hotspots (rivers and coastal cities) and waste water management and ban certain plastic products would be most beneficial[5].

Comparing results across countries or areas proves difficult as seafloor monitoring with visual surveys using ROVs or with bottom trawls, whether fishing and research vessels, can lead to differentiated handling operations and observation results. Moreover, these programmes collect litter data in an opportunistic manner or voluntary basis (e.g. MEDITS trawl survey, Fishing observer's surveys) or do not necessary cover the whole region. In order to enhance the monitoring of marine litter on the seafloor and facilitate the implementation process of the EU MSFD and the UNEP/MAP Regional Plan on Marine Litter Management with regards to setting baselines towards achieving GES, it is highly recommended to make the collection of seafloor litter data mandatory for ongoing sea survey programmes.

Efforts have been made to enhance marine litter knowledge, although information from deep waters is still scarce. A move towards increased awareness within society is needed including all stakeholder sectors e.g., manufacturers, consumers, citizens, and governments, focusing on changes in attitudes and behaviours in relation to marine litter and plastics (e.g. recycling, plastic usage). Several successful initiatives from businesses, entrepreneurs and the public have focused on the reduction of plastics, e.g., the legal banning of plastic bags and bans on single-use plastic products, zero-waste cities initiatives, beach clean-ups, research into new technological solutions to deal with waste, and proposals to use international legal frameworks to address plastic pollution globally[47] (MARPOL for ships). Further initiatives and exchange of good practices considering the needs of adaptation and enabling conditions will help to take these experiences further.

A CABLE LAYING SHIP. © STEIRUS.DREAMSTIME.

Submarine power cables and telecommunications networks

The importance of submarine power cables and telecommunications networks has increased steadily in recent decades and its demand will continuously grow in the near future. Submarine power cables are electricity transmitting cables laid in the sea to provide energy between countries, supply power to islands and oil platforms and transferring electricity from offshore marine renewable energy devices on shore (i.e., wind, waves, tides, and water currents)[48].

“

Today, there are around 428 underwater cables in operation around the world, spanning a length of over 1.2 million km. The offshore expansion of submarine power grids associated with wind-turbine farms and telecommunications has raised concerns on its impact on the marine environment”

Most of the power cables are used to transfer electricity at a high voltage. In 2015, almost 8,000 km of commercial High Voltage Direct Current (HVDC) submarine cables were present on the seabed worldwide. In comparison, the total length of all submarine cables deployed (including using alternating current "AC" and direct current "DC" power cables and telecommunication cables) was in the order of 10^6 km[48].

The main existing marine power cables in the Mediterranean (SAPEI, SACOI, HVDC Italy-Greece and COMETA HVDC), stretch for about 945 km and there is another 1,000 km of cables to be laid within the new Euro-Asia Interconnector programme in 2022 in the Eastern basin. In addition to power cables, an extensive submarine fibre-optic cable network for telecommunications is also present in the whole Mediterranean basin.

Fig. 9.9 and Fig. 9.10 show a compilation of high resolution maps of the present power cables and telecommunication cable routes for the Ionian Sea and for the Aegean Sea. A denser network of cables is evident in the Libyan and Levantine Seas (Fig. 9.11 and Fig. 9.12, respectively) linking individual countries with Europe and Asia. In addition, landing stations for new submarine cables are planned in several of these countries, which will further increase international broadband connectivity in the coming years.

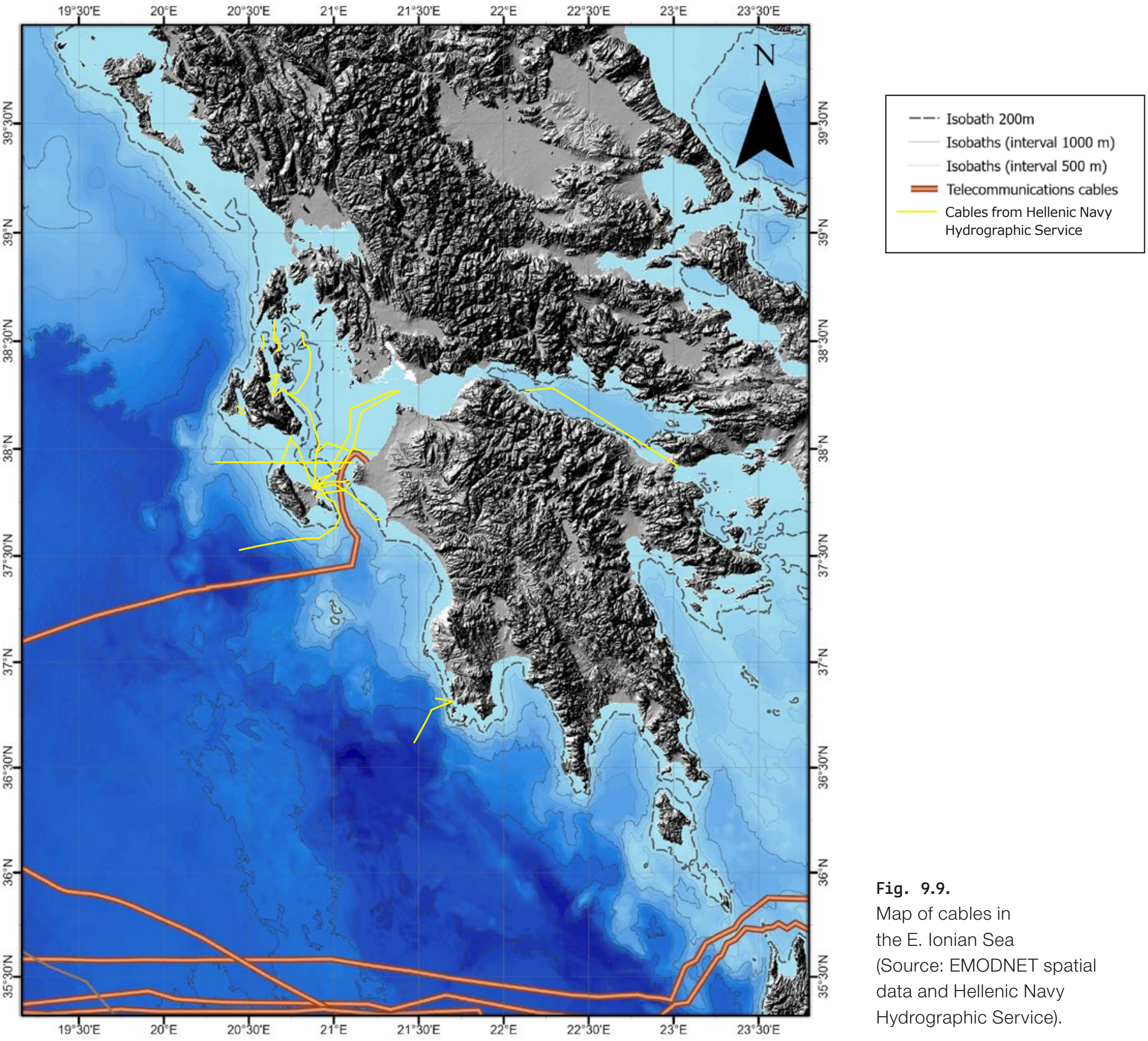


Fig. 9.9.
Map of cables in the E. Ionian Sea (Source: EMODNET spatial data and Hellenic Navy Hydrographic Service).

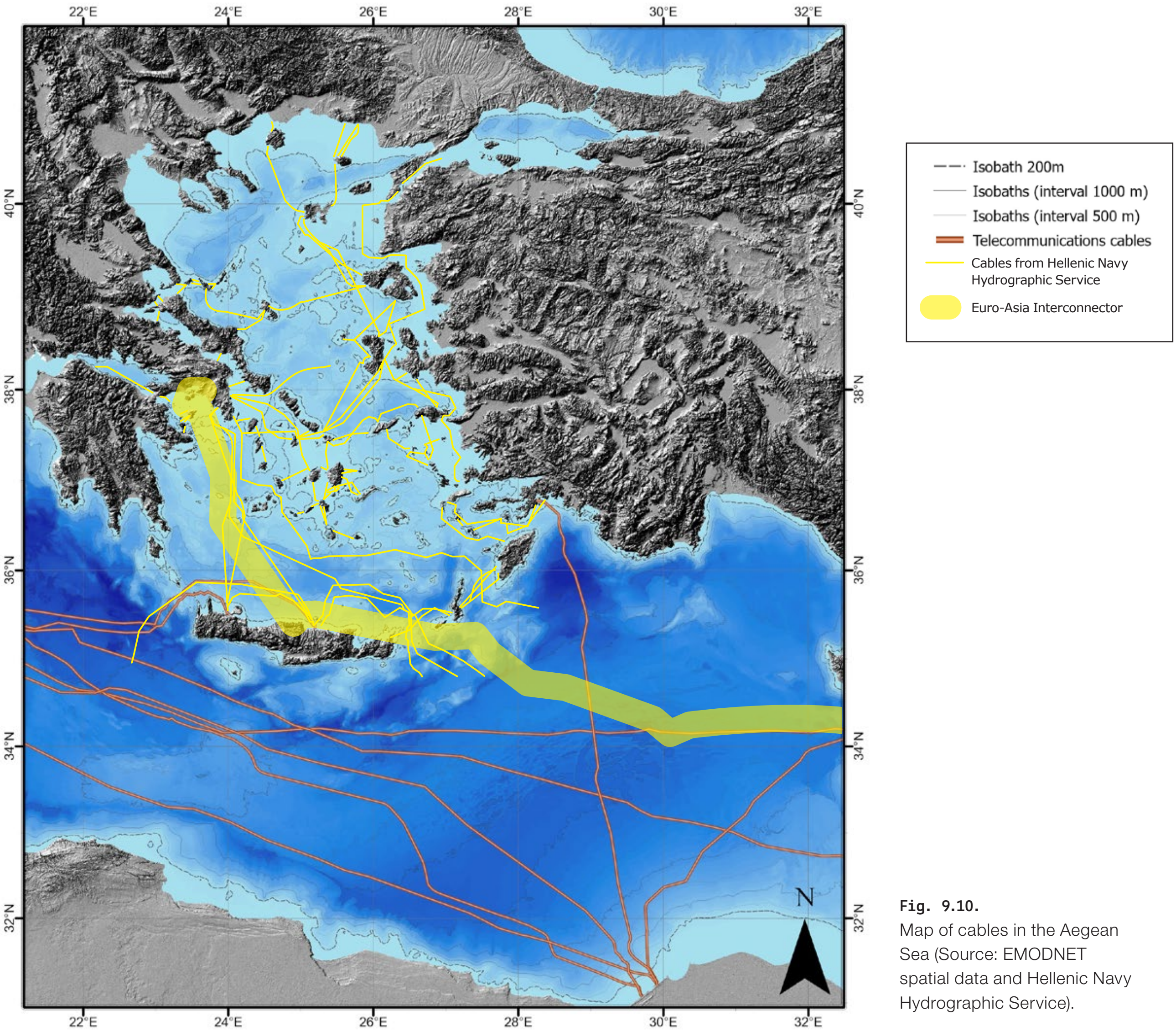


Fig. 9.10.
Map of cables in the Aegean Sea (Source: EMODNET spatial data and Hellenic Navy Hydrographic Service).

A number of recent studies to examine the environmental impacts of submarine cables and cable laying on marine communities and habitats suggest that the impacts are either small or moderate or only temporary as a result of cable laying. Although many uncertainties remain regarding the impacts of the different types of submarine power cables, particularly concerning electromagnetic effects[49]. They are often specific for a certain phase in cable life, such as during the laying, operation and removal. The potential impacts that occur, whether in shallow or deep-waters, include seabed disturbance, contamination, heat dissipation, production of underwater noise, electromagnetic fields and heat emission.

Impact assessment studies for cable projects in the Eastern Mediterranean deep-waters are not currently available. Research and the application of effective monitoring programmes to on-going developments are needed to examine aspects such as the spatial extent, timescale (duration, frequency, reversibility), and magnitude of impacts as well as their relevance for the various cable types and different phases in cable life. Given the vulnerability of deep-sea ecosystems and marine fauna communities, understanding the impacts such as those caused by electromagnetic fields on fauna (e.g. sharks, marine mammals), physical disturbance and associated impacts of fauna living on the seabed and those resulting from the effects of heat dissipation or concentration of cables and other infrastructure (e.g. gas pipelines) in designated corridors would provide information to allow the development of adequate assessments and mitigation programmes.

Sperm whales. © Martin Procházka, Dreamstime.

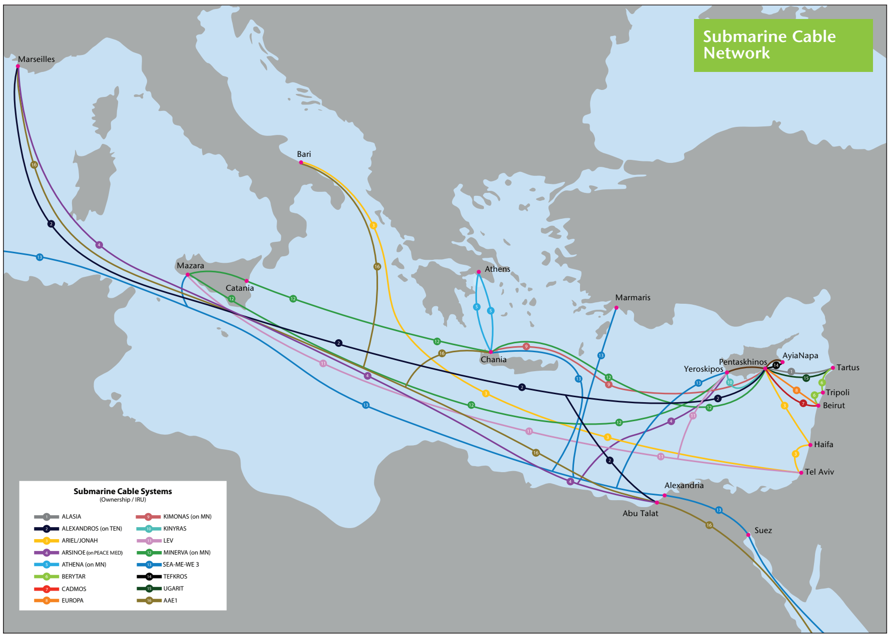


Fig. 9.11. Schematic map of telecommunication (fibre-optic) cable network in the Eastern Mediterranean basin based on the submarine fibre optic cable systems currently in service. (Source: Submarine Cable Networks (https://www.submarinenetworks.com/)

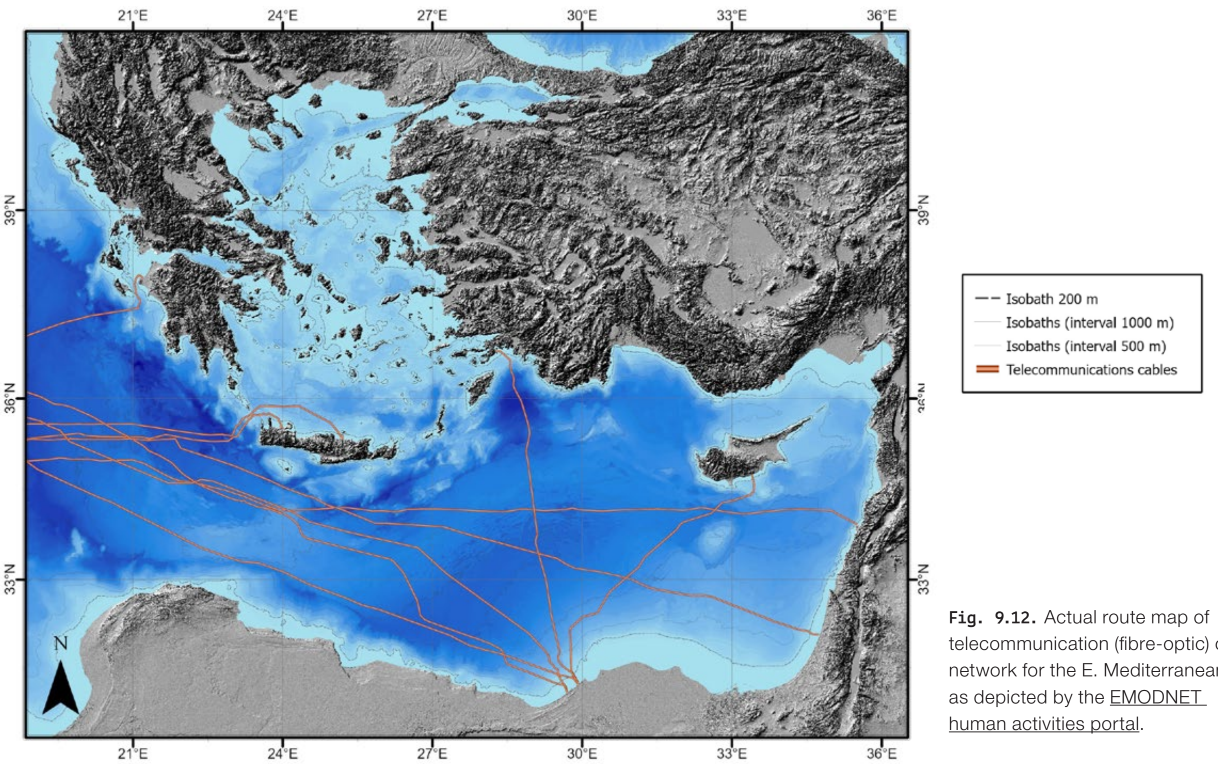


Fig. 9.12. Actual route map of telecommunication (fibre-optic) cable network for the E. Mediterranean as depicted by the EMODNET human activities portal.

Oil and Gas Exploration and Extractions

The Mediterranean region has so far been a relatively small producer of offshore oil and gas as compared to world production. However, marine petroleum exploration projects and associated drilling activity have greatly increased all around in recent years, including in environments with extreme physical conditions in the deep-sea floor[50].

Significant amounts of natural gas have continued to be discovered offshore in the Eastern Mediterranean, mainly in the last ten years, making the basin an important natural gas field worldwide. These findings bring new opportunities for countries to develop massive gas fields (with offshore and onshore infrastructure), increase their energy security and even export natural gas to other regions. Offshore natural gas and oil licensing rounds for extractions and production are already taking place in the region (e.g. Israel, Greece, Egypt) and timetables to start have been announced by other Eastern Mediterranean countries (e.g. Lebanon). The findings of additional gas and oil reserves in deep areas off the Levant Basin, the Aegean Basin, offshore Greece and the Nile Delta Basin, if developed fully, will pose significant challenges, risks and impact to the marine environment.

1

EASTERN IONIAN SEA

This region contains important oil and gas shale reservoirs[3]. Even though the scientific knowledge and research in Greece is very limited, the existence of oil reserves in the E. Ionian Sea is widely known because of the great number of surface oil shows, for example, in the Epirus region, the Keri oil seep on Zakynthos Island or the oil shows in Kyllene (NW Peloponnese)[51]. The first oil wells were drilled by companies in the areas of Keri (Zakynthos, E. Ionian), NW Peloponnese (E. Ionian) and Evros in NE Greece (N. Aegean). Several licences were granted in 1995 to start marine explorations in the NW Peloponnese, Aitoloakarnania and the off-shore Western Patraikos Gulf in the Eastern Ionian Sea, which were later stopped due to technical and administrative issues[4] (Fig. 9.13a). New explorations have been granted since then in deep areas, although they are currently on hold due to the unfavourable market conditions, the costs of exploitation, as well as climate change policies being adopted[5]. The Katakolo license is one of the new explorations and covers onshore, shallow water and deep waters on the west coast of the Peloponnese. The block, 545 km^2 both offshore and onshore, contains 3 discoveries and multiple leads. The water depth is 200–300 m while the depth of the reservoir is 2,300-2,600 m [6].

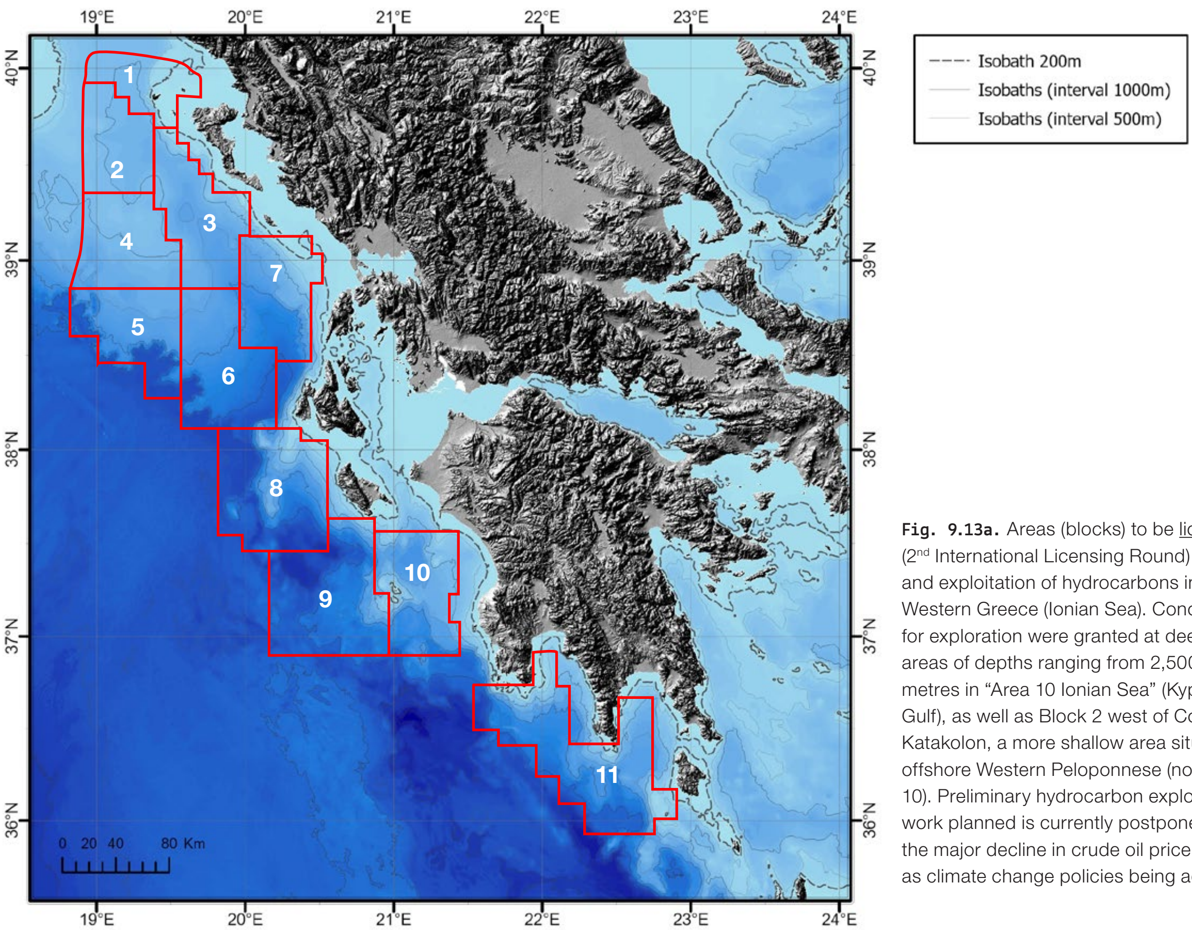


Fig. 9.13a. Areas (blocks) to be licenced (2nd International Licensing Round) for exploration and exploitation of hydrocarbons in Offshore Western Greece (Ionian Sea). Concessions for exploration were granted at deep-sea areas of depths ranging from 2,500 to 3,000 metres in "Area 10 Ionian Sea" (Kyparissia Gulf), as well as Block 2 west of Corfu and Katakolon, a more shallow area situated offshore Western Peloponnese (north of block 10). Preliminary hydrocarbon exploration work planned is currently postponed given the major decline in crude oil prices, as well as climate change policies being adopted.

3 Shale gas reservoir is a natural storage where natural gas is created through the decomposition of organic matter and it is stored in the shale formation.
4 Greek Ministry of Environment and Energy official site: http://www.ypeka.gr/Default.aspx?tabid=765&locale=en-US&language=el-GR
5 https://energypress.eu/tag/ionian/
6 https://www.greekhydrocarbons.gr/en/Katakolon_en.html

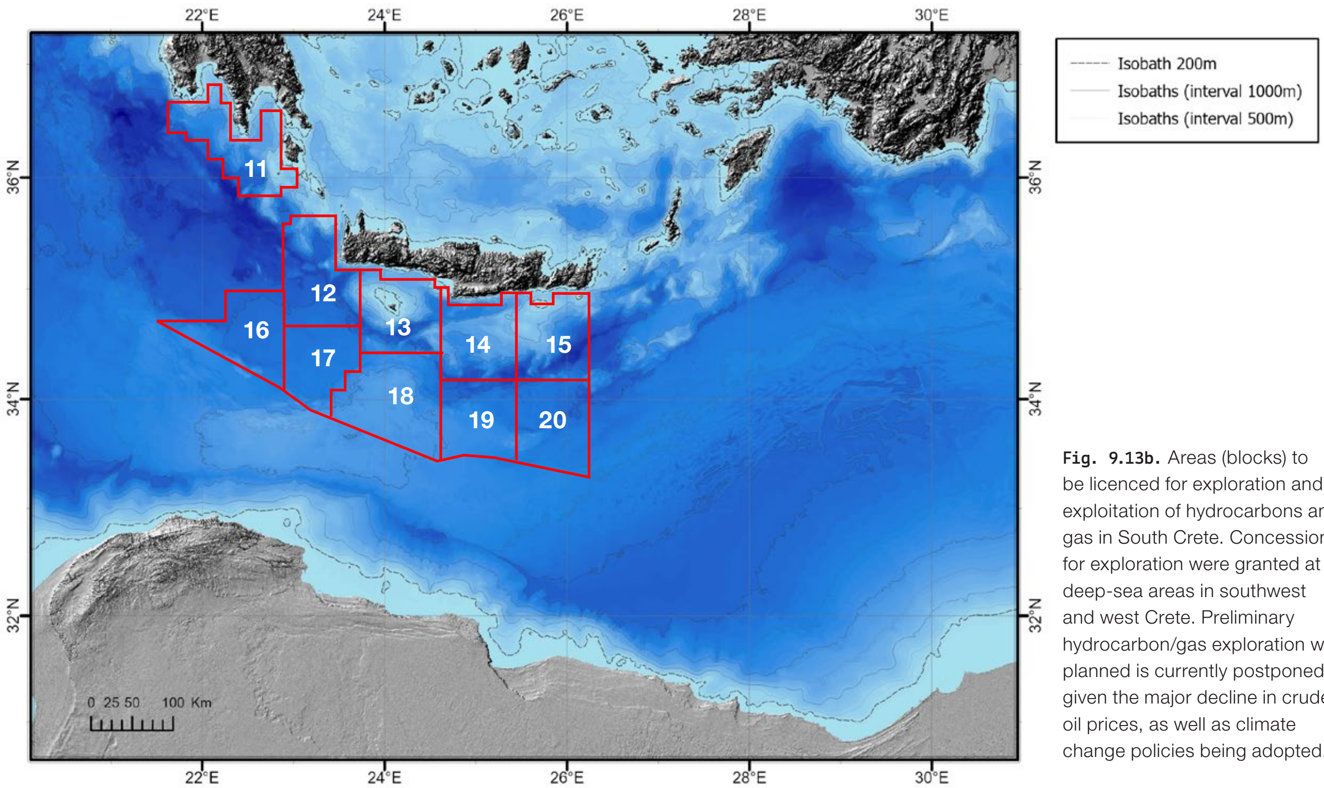


Fig. 9.13b. Areas (blocks) to be licenced for exploration and exploitation of hydrocarbons and gas in South Crete. Concessions for exploration were granted at deep-sea areas in southwest and west Crete. Preliminary hydrocarbon/gas exploration work planned is currently postponed given the major decline in crude oil prices, as well as climate change policies being adopted.

2 NORTH AEGEAN SEA

Oil and gas exploration in the North Aegean Sea begun in 1969, when Greece granted 26 hydrocarbon exploration concession rights, in the Gulf of Kavala, to a Consortium of foreign companies. The first 27 well drilling in the region was the «EAST THASSOS-1» in 1971, while in 1972 the "SOUTH KAVALA" 28 natural gas reservoir was discovered. Nowadays, there are three sour crude oil reservoirs in the 29 Prinos area and one sweet gas reservoir in south Kavala, which has been found in shallow waters between the city of Kavala and the island of Thassos[52].

3 SOUTH AEGEAN SEA

No information is available concerning the South Aegean Sea.

4 LIBYAN SEA

Current exploration licenses for oil and gas in the region correspond to three offshore blocks. Two of them (blocks 12 & 13) in the west and southwest of Crete covering a large sea area of 40,000 km^2 (Fig. 9.13b) and one in the Libyan waters. Other offshore areas for hydrocarbon research off western and north-western Crete for oil and gas exploration are also being undertaken[7].

The Crete licences cover a huge area in very deep-water, averaging 3,200 m. As yet, the potential of these reserves is unknown but the technology needed to allow drilling in these deep waters will be developed in the near future[8].

Additionally, Libya also has some offshore oil and gas fields (at Bouri and Al-Jurf) although more than 85% of its oil production is onshore. In 2010, it was estimated that there are still undiscovered oil and gas fields within the geologic province of Sirte Basin in Libya[53].

7 http://www.ekathimerini.com/230302/article/ekathimerini/business/helpe-total-exxonmobil-consortium-selected-for-oil-exploration-off-crete
8 https://www.greekhydrocarbons.gr/news_en/PetroleumEconomist_Sep2018.pdf

Offshore flaring operation in Zohr gas field, Egypt.

5 LEVANTINE SEA

In the past few years, large gas fields have been discovered in this sub-region and interest to explore the seabed for petroleum resources has picked up elsewhere. In 2010, the United States Geological Survey (USGS) estimated the undiscovered oil and gas resources of the Levant Basin Province to be at 1.7 billion barrels of oil and 3.5 trillion cubic metres of natural gas[54]. Currently, the best known discoveries in this part of the Eastern Mediterranean are Israel's Tamar (1,700 m depth) and Leviathan (at 1,500 m depth) fields, discovered in 2009 and 2010, respectively; Aphrodite about 1,700 m depth in 2011 in offshore Cyprus, followed a few years later by the giant field Zohr in 2015 at a depth of 1,450 metres in offshore Egypt (Fig. 9.14). Most recently, other potentially significant discoveries were in 2018 and 2019 off Cyprus with the reserves called Calypso at 2,074 m depth and Glaucus-1 at 2,063 m depth. Lebanon and Turkey have also started drilling in deep-waters[9]. Syria's marine oil and gas reserves are more uncertain due to halted exploration activities caused by the current political and military conflict and international sanctions on the country. Another smaller reservoir, the Gaza Marine gas field, at a water depth of 603 m, is still not developed.

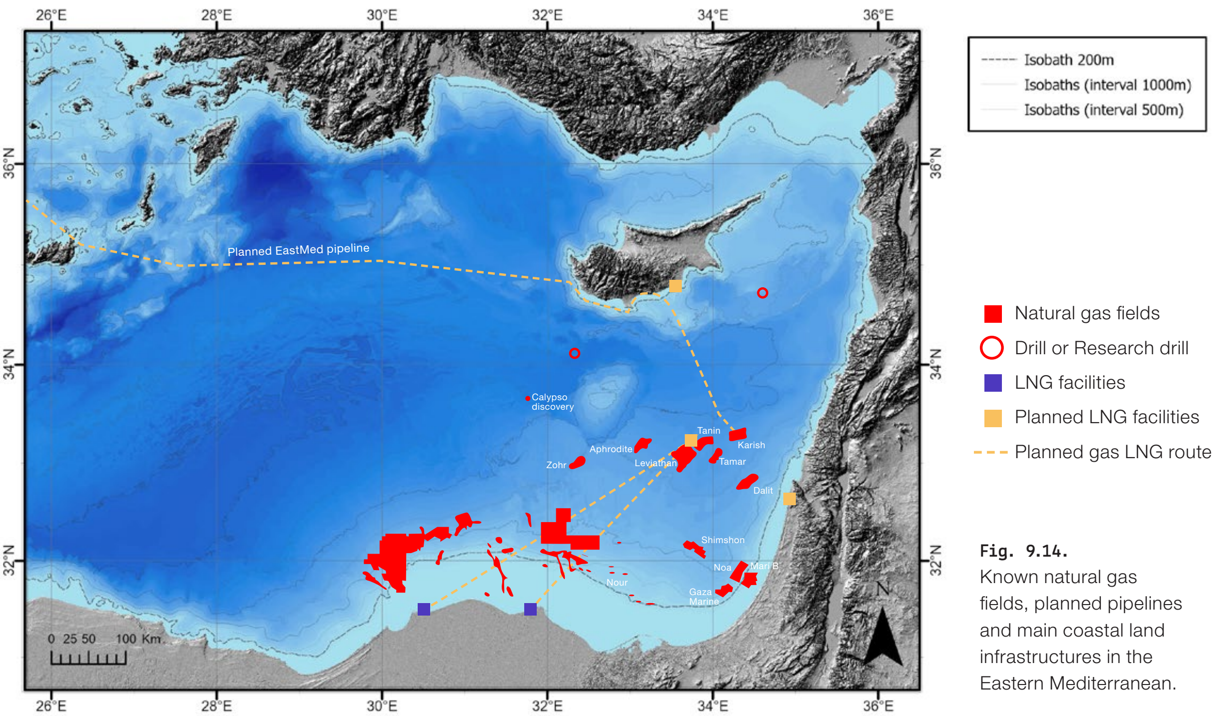


Fig. 9.14. Known natural gas fields, planned pipelines and main coastal land infrastructures in the Eastern Mediterranean.

9 https://www.dailysabah.com/energy/2019/05/08/turkish-drilling-in-eastern-mediterranean-in-compliance-with-international-law; http://www.hurriyetdailynews.com/turkey-starts-shallow-water-drilling-in-mediterranean-sea-139217; https://www.offshore-technology.com/news/total-deepwater-well-lebanon/

Table 9.2. Locations, sites and blocks of oil and natural gas exploration and extraction in Eastern Mediterranean deep waters (2020).

Site	Location	Area	Block	Status	Company
Katakolo	W. Peloponesse	Ionian Sea	-	Development	Energean Oil & Gas (100%)
Patraikos Gulf (west block)	W. Peloponesse	Ionian Sea	-	Research	Hellenic Petroleum (50%), Edison (50%)
Ionian Block	Ionian Sea			Research	REPSOL (50%) & Hellenic Petroleum (50%)
Kyparissiakos Gulf	W. Peloponesse	Ionian Sea	10	Research	Hellenic Petroleum (100%)
Paxoi	South of Corfu	Ionian Sea	3		Public Petroleum Corporation and Exploitation of Hydrocarbons (DEP-EKY).
West Corfu Isl.	West of Corfu	Ionian Sea	2	Research	Total (50%), Edison (25%) & Hellenic Petroleum (25%)
West of Crete	Cretan Sea	Creatan Sea	-	Research	Total (40%), ExxonMobil (40%) and Hellenic Petroleum (20)
SW of Crete	Libyan Sea	Libyan Sea	-	Research	Total (40%), ExxonMobil (40%) and Hellenic Petroleum (20)
South of Cyprus	Cyprus-offshore	Levantine Sea	2		ENI Cyprus Limited (60%), Kogas (20%) & TOTAL E&P Cyprus BV (20%)
South of Cyprus	Cyprus-offshore	Levantine Sea	3		ENI Cyprus Limited (50%), Kogas (20%) & TOTAL E&P Cyprus BV (30%)
Calypso Gas field	Cyprus-offshore	Levantine Sea	6		ENI Cyprus Limited (50%), TOTAL E&P Cyprus BV (50%)
South of Cyprus	Cyprus-offshore	Levantine Sea	7		TOTAL E&P Cyprus BV (50%) as Operator, & ENI Cyprus Limited (50%)
South of Cyprus	Cyprus-offshore	Levantine Sea	8		ENI Cyprus Limited (60%) & TOTAL E&P Cyprus BV (40%).
South of Cyprus	Cyprus-offshore	Levantine Sea	9		ENI Cyprus Limited (60%), KOGAS Cyprus Limited (20%) & TOTAL E&P Cyprus BV (20%)
Claucus-1 Gas field	Cyprus-offshore	Levantine Sea	10		ExxonMobil Exploration and Production Cyprus (Offshore) Limited (60%) & Qatar Petroleum International Upstream LLC (40%)
South of Cyprus	Cyprus-offshore	Levantine Sea	11		TOTAL E&P Cyprus BV (50%) & ENI Cyprus Limited (50%)
Aphrodite	Cyprus-offshore	Levantine Sea	12		Noble Energy (35%), Delek Drilling (30%), and BG Group (now Shell)
Zohr	within the offshore Shorouk Block, approximately 190 km away from Port Said, Egypt	Levantine Sea	-	unknown	ENI (50%), Rosneft (30%), BP (10%) & Mubadala Petroleum (10%). It could house 850 billion m^3
West of Lebanon	Lebanon	Levantine Sea	4	On hold further research exploration	Total(40%), ENI (40%), Novatek (20%)
SW of Lebanon	Lebanon	Levantine Sea	9		Total (40%), ENI (40%), Novatek (20%)
Tamar Gas field (50 miles from Haifa)	Israel-offshore	Levantine Sea	-	Development	Under operation since 2013. Nobel Energy holding a 36% stake in the field, and the three Israeli partners - Delek Drilling (31%), Isramco (29%) and Dor Alon (4%). Its reserves are estimated at 238 billion m^3.
Leviathan (located 130 kilometres off the coast of Haifa)	Israel-offshore	Levantine Sea	-	Development	Noble Energy operates Leviathan with a 39.66% working interest; Delek Drilling holds 22.67%; Avner Oil Exploration holds 22.67%; and Ratio Oil Exploration holds the remaining 15%. Delek Drilling began exploiting in January 2020. Discovered in 2010, it is thought to contain 539 billion m^3 of natural gas
Tanin and Karish Gas Fields	Israel-offshore	Levantine Sea		Research	Energean Oil & Gas (subsidiary Energean Israel)

GENERAL REMARKS

There are still significant obstacles and challenges to exploit many gas and oil resources due to geo-political struggles, military conflicts, border disputes, as well as a large requirement of financial resources due to the technical complexity and high development costs (including oil and natural gas transit pipelines) for many of these fields at deep-waters. Nonetheless, some of the exploration and production fields are well underway. In the very near future, extensive natural gas pipeline networks will also be installed. The construction of the East-Mediterranean Pipeline expanding from the natural gas fields occurring off Cyprus and Israel to the Aegean Sea and the Greek mainland will be one of them. It will have 1,300 km of pipeline in the maritime domain connecting the offshore fields to Greece and Italy. These pipeline systems will inevitably extend from the coastal zone down to deep-waters and they will include diverse operations from installation tie-in, commissioning and decommissioning aspects and an environmental impact.

The potential environmental effects of offshore oil and gas development have long been recognized[55], including an awareness of the potential and documented hazards from oil spills associated with offshore production. Risk evaluation for offshore gas and oil exploration and production should involve examining the potential impact of the operations generated from exploration activities (e.g. seismic prospections) to drilling activities, setting facilities offshore, installation of pipelines as well as potential spills and blowouts. Examining all these aspects with short-long term effects should enable the identification of the mitigation procedures to be followed to eliminate any risk of contamination. However, it is also important to stress that there is hardly any published information on the effects of oil and gas exploration activities in the deep-waters of the Eastern Mediterranean or its effects on populations or communities. Existing monitoring data does not allow us to confirm whether or not the observed biological responses are of significance for marine life and ecosystems. Moreover, extensive activities can also lead to risks of bioaccumulation and biomagnifications through the continuous use of chemicals and their release into the surrounding environment.

Due to the risks and following recent environmental drilling disasters, the Barcelona Convention Contracting Parties have recently adopted new environmental standards and requirements for these offshore activities (2019): (**a) Common Standards and Guidance on the Disposal of Oil and Oily Mixtures and the Use and Disposal of Drilling Fluids and Cuttings; (b) Common Standards and Guidelines for Special Restrictions or Conditions for Specially Protected Areas (SPA)** within the Framework of the Mediterranean Offshore Action Plan (Decision IG.24/09). These new guidelines bring a series of recommendations for countries to enable legislations as well as for operators to prepare environmental impact assessments, site-specific contingency plans and emergency response plans for offshore exploration and production. To mitigate potential impacts, offshore geophysical surveys in Specially Protected Areas (SPA) of the Mediterranean should be permitted and approved by the relevant Competent Authority taking particular account on the most up to date knowledge of the spatial and temporal distributions and life cycle stages of protected species existing within the proposed area of investigation so that sensitive locations and periods can be avoided. Additional relevant regulations are also established for avoiding the introduction or expansion of non-native species, detecting the presence of marine mammals and avoiding collisions, carrying out Environmental Impact Assessments (EIA) and minimising the risk of damage to sensitive habitats and species.

Impacts from deep-water oil and gas development activities begin during seismic surveys that are used to reveal the subsurface geology and locate potential reservoirs; these impacts include underwater sound and light emissions and increased vessel activity[56].

Seismic activities, used to discover oil and gas deposits under the seafloor, have been accountable for introducing a significant amount of underwater sound energy in the marine environment[57]. Animals that are exposed to elevated or prolonged anthropogenic noise may experience direct injury ranging from bruising to organ rupture and death (barotrauma). This damage can also include permanent or temporary auditory threshold shifts, compromising the animal's communication and ability to detect threats[56,58].

A number of studies have shown that the effects of anthropogenic sound on marine organisms can range from no influence to immediate death, depending on the differences in the intensity and frequency of the noise and the distance from the noise source. However, there is still a fundamental knowledge gap on the impact of seismic surveys on species in general. Marine mammals have been studied more than the other organisms

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Gas exploration seismic vessel for identifying geological features that could contain oil or gas deposits. Observations onboard and undersea on the consequences of the sounds generated from seismic operations could help to build a good code of conduct for limiting acoustic disturbance to marine mammals and other vulnerable fauna.

for the impact of the anthropogenic underwater noise, which is one of the major threats for them in the Mediterranean Sea[58]. Although there is no current information on the overlapping of oil and gas activities with marine mammal species, there is a potential impact of underwater noise resulting from the offshore oil and gas industry in relation to seismic and drilling activities. Hotspot sites will be around the marine area of Southern Crete, which has been identified as an Important Marine Mammal area (IMMA)[10] for Cuvier's beaked whale *Ziphious cavirostris* and the sperm whale *Physeter microcephalus*. For the latter, this region is considered the core habitat for the Eastern Mediterranean sub-population, which is believed to number no more than two to three hundred individuals[59]. Furthermore, the Hellenic trench, as well as the south Ionian Sea, are also identified as Cetacean Critical Habitats by the ACCOBAMS Agreement.

The potential effects of noise sound to other fauna remains poorly understood but may be significant[56]. The sensitivity to certain frequencies varies in different fish species. For instance, the cartilaginous fish (sharks, rays), which lack gas-filled air bladders, are highly sensitive to low frequency sound (approximately 20 to 1,500 Hz). Fish with swim bladders are more susceptible to physical injury such as barotrauma and some invertebrates have structures which enable detection of sound waves in their immediate vicinity[58].

During production on reservoirs and transportation, there may occur potential impacts that directly affect marine life as a result of the physical and sound disturbance and indirectly, through the water quality.

- **Physical disturbance**: Benthic habitats and species associated with the seabed at oil or gas rigs will be affected by the direct physical disturbance resulting from drilling activities or the laying of pipelines[60]. For this reason, activities conducted in areas of rich biodiversity or vulnerable habitats, such as where deep-water corals (which are fragile and have low resilience to physical forces) occur, might be evaluated carefully before potential impacts happen.

For example, the presence of the critically endangered bamboo coral, *Isidella elongata* was documented in the Hellenic Trench (Oil and gas Blocks 11-15)[61]. Future plans for offshore oil and gas exploration along these areas can pose a threat for the species conservation in the area. Fig.

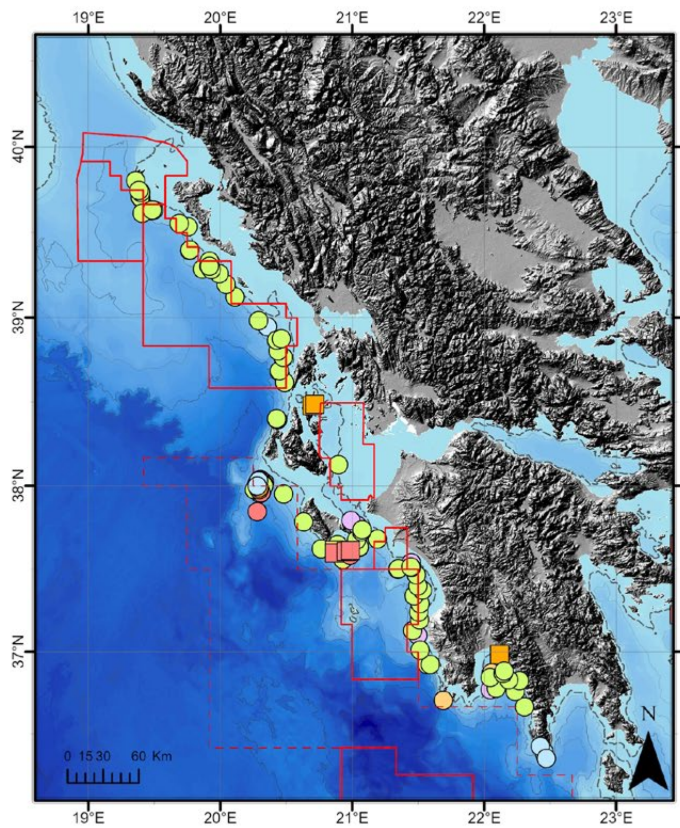
10 https://www.marinemammalhabitat.org/imma-eatlas/

9.15 (a & b) represents the occurrence of benthic habitat forming species in relation to the areas in which the oil and gas blocks in the East Ionian, SW. Peloponnese and the Hellenic Trench were located. It seems that block locations are close to *I. elongata* habitats mainly in the SW Peloponese and Eastern Ionian (Fig. 9.15).

- **Noise:** It will be generated during the equipment mobilization and primary installation activities. The sound and vibration generated during drilling may lead to the migration of some mobile species from the immediate vicinity of the drilling area.

- **Drilling Fluids and disposal waste**: Different based muds are commonly used as a drilling fluid, which are thereafter dumped with its cuttings into the sea. The chemical composition of these drilling fluids is diverse and range from the more toxic oil-based fluids to more modern synthetic and water-based fluids[56]. Drilling operations can also generate oil contaminated fluids during well clean-up, cementing, mud pit cleaning and operations where well bore fluids become contaminated with oil-based mud, crude oil or condensate. Disposal of these fluids and derived products on the surrounding environment will therefore vary according to the materials used and the system procedures exposure (e.g. closed or open circulation drainage system for the drilling fluids). The current decision (Decision IG.24/09) by Barcelona Convention parties with the Offshore Protocol adopted the common standards (limits and prohibitions) for the disposal of drilling fluids, oil and oily mixtures from installations into the Protocol (Mediterranean) Area.

- **Accidental releases of hydrocarbons and other components:** Oil and gas operations have the potential to result in accidental releases of hydrocarbons and other components. Accidental pollution (potential oil spills) can originate from different sources of oil pollution caused by offshore installations (e.g. well blowouts, sub-sea equipment, pipelines, structural failure or damage to production or pumping platforms, platform-tanker loading activities and other accidental spillage) [62]. Examples of such accidental pollution are the El-Jiyeh oil spill in Lebanon in 2006 that released 15,000 tn of oil in the coast line or the explorato-



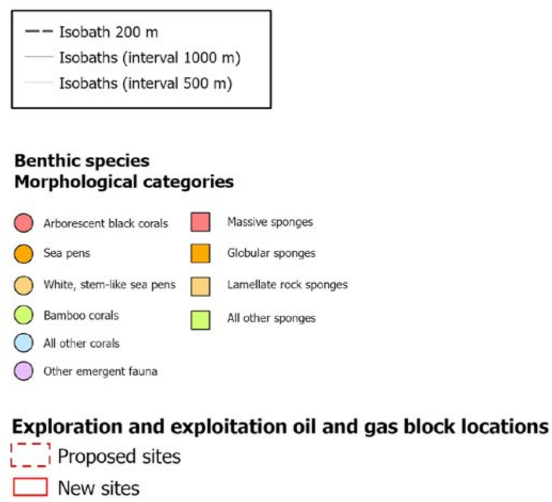


Fig. 9.15a. Overlapping map of the exploration and exploitation oil and gas block locations (new and proposed sites) with the occurrance of different habitat forming species in the East Ionian Sea.

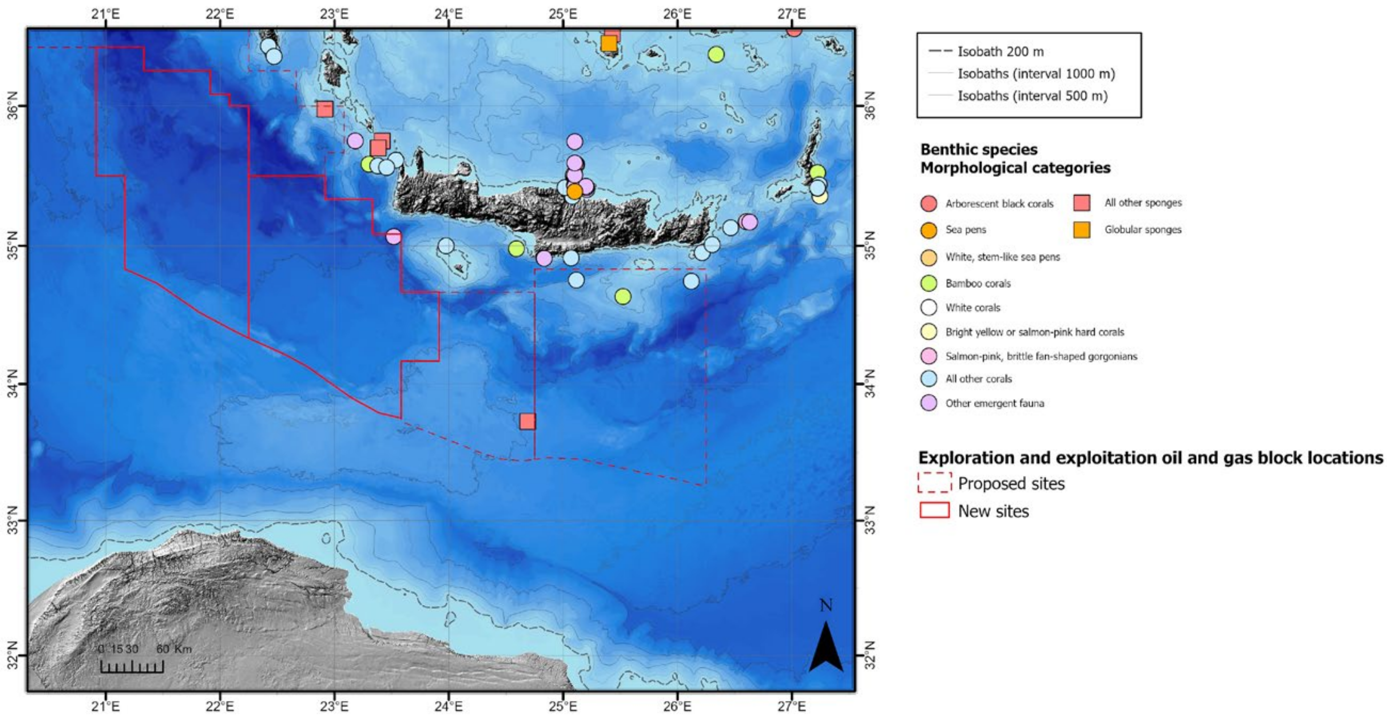


Fig. 9.15b. Overlapping map of the exploration and exploitation oil and gas block locations (new and proposed sites) with the reported presence of habitat forming benthic species occurrance in the NW Peloponnese and the Helenic Trench.

ry deep drilling in the Leviathan gas field (Israel) that caused a major leak of brine[63]. Oil spill accidents in the Eastern Mediterranean would have dramatic consequences for the entire region for marine life, which can lead to economic impacts in other sectors (e.g. fisheries, tourism). The risk of widespread, long term impacts on the deep-water may persist for many years, and likely longer, for its more fragile ecosystems.

Overall, given the increasing oil and gas exploration activities in the Eastern Mediterranean and the limited knowledge and baseline data of its deep-sea ecosystems, an effective management strategy will need to assess the potentially significant effects, at species and ecosystem levels, from the different operational activities, ensure the effective implementation of regulations of the activity itself (e.g., discharge practices, materials used), monitor the changes and establish spatial (e.g., avoidance rules on sensitive areas and/or with endangered fauna), and temporal measures (e.g., restricted activities during certain periods for sensitive fauna) to mitigate risks.

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Mining

Marine minerals could contribute to the future supply of the rapidly growing demand of raw materials, including certain metals such as rare earth elements and cobalt.

Three types of deep seabed mineral deposits have attracted commercial interest: i) **seafloor massive sulphides** (also known as polymetallic sulphides or hydrothermal sulphides, ii) **polymetallic nodules** and iii) **cobalt-rich ferromanganese crusts**[64].

The formation of polymetallic (or ferromanganese) crusts occur as pavements on seamounts, ridges and plateau, and, like nodules, take millions of years to form. Sulphide deposits, on the other hand, are make in active and inactive hydrothermal vent fields and can accumulate rapidly or take thousands of years to develop significant deposits [64].

“

Polymetallic nodules, develop over millions of years to recoverable size, and require stable environments for their formation in deep-sea abyssal environments”

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Deep-sea mineral mining involves the excavation of mineral deposits at great depths and requires the installation of mining systems, operating high pressure hoisting pipes and surface-level mining platforms connected to transportation vessels[64]. So far, there are currently no ongoing commercial exploration or exploitation operations in the Mediterranean Sea, but some potential areas for deep seabed mining for sulphide deposits and ferromanganese crusts have been identified in the Alboran Sea, the Italian coastline, the Aegean Sea and South of Cyprus[11][65,66]; (Fig. 9.16).

Nonetheless, the outlook for seabed mining at great depths remains uncertain given the difficulties and the low technological development, the high costs involved and the potential environmental impacts. Moreover, the exploitation of these resources in the Mediterranean probably does not represent a great opportunity when compared to the richer resources found at other locations such as the Pacific Ocean[67,66].

The potential impacts of deep-sea mineral mining on deep sea ecology are almost unknown, however, there have been an increasing number of scientific studies that suggest effects will be long-lasting and widespread[68]. These include a) disturbance of the seafloor during exploitation, for example, excavating and ploughing of the seabed; b) stirring up potentially toxic sediment plumes and c) pollution from noise, vibration and light, or through dumping of waste[69]. As a consequence, fragmentation and habitat loss (for example through the removal of nodules and associated attached fauna), impacts on biodiversity, and loss of unique endemic fauna as bio-chemosynthetic benthic communities associated to hydrothermal vents and chimneys can occur[70].

The only study carried out in the Mediterranean looking at potential effects of deep mining was carried out at Palinuro Seamount in the Central Mediterranean Sea. Here, rock drilling and dredging was observed

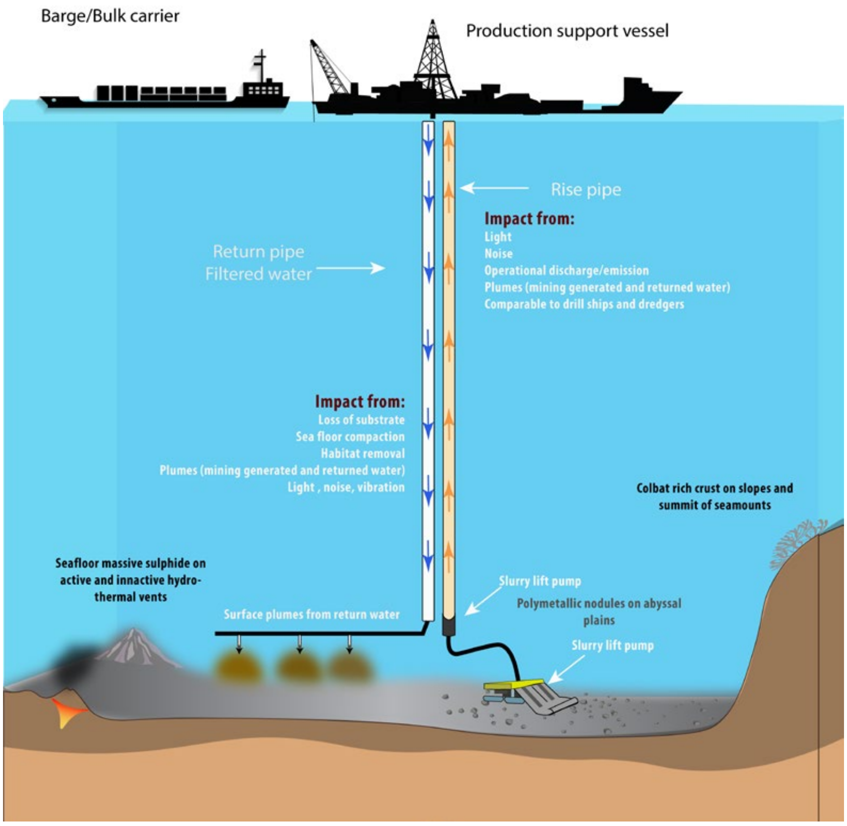

Illustration of potential impacts from deep-sea mining. © IUCN, Mira Housseini, adapted from Secretariat of the Pacific Community (2013).

11 Until 2021, only one request for exploration has been submitted by a deep-sea mining company to examine seafloor massive sulphides located at a depth of 500 to 1000 metres in the Tyrrhenian Sea in 2014

Fig. 9.16. Deep-sea mineral resources in the Mediterranean.
Source: [62]; GeoERA-MINDeSEA EU project, 2020.

▲ Cobal deposit
● Sulphide deposit

to cause localised disturbances. Seven years after the disturbance event, abundances, biomass and diversity of microscopic meiofauna were fully recovered, whereas community composition had not returned to control conditions[71].

The scale and potential severity of deep mining-impacts requires careful consideration, innovation and environmentally friendly technology that could limit adverse environmental impacts during mining (e.g. precautionary controls and improving mining equipment to reduce seafloor disturbances). Notwithstanding this, reducing the commercial demand for these minerals by repair, recycling and reuse of products and by developing adjusted policies will be key in mitigating the development of these activities in these fragile environments.

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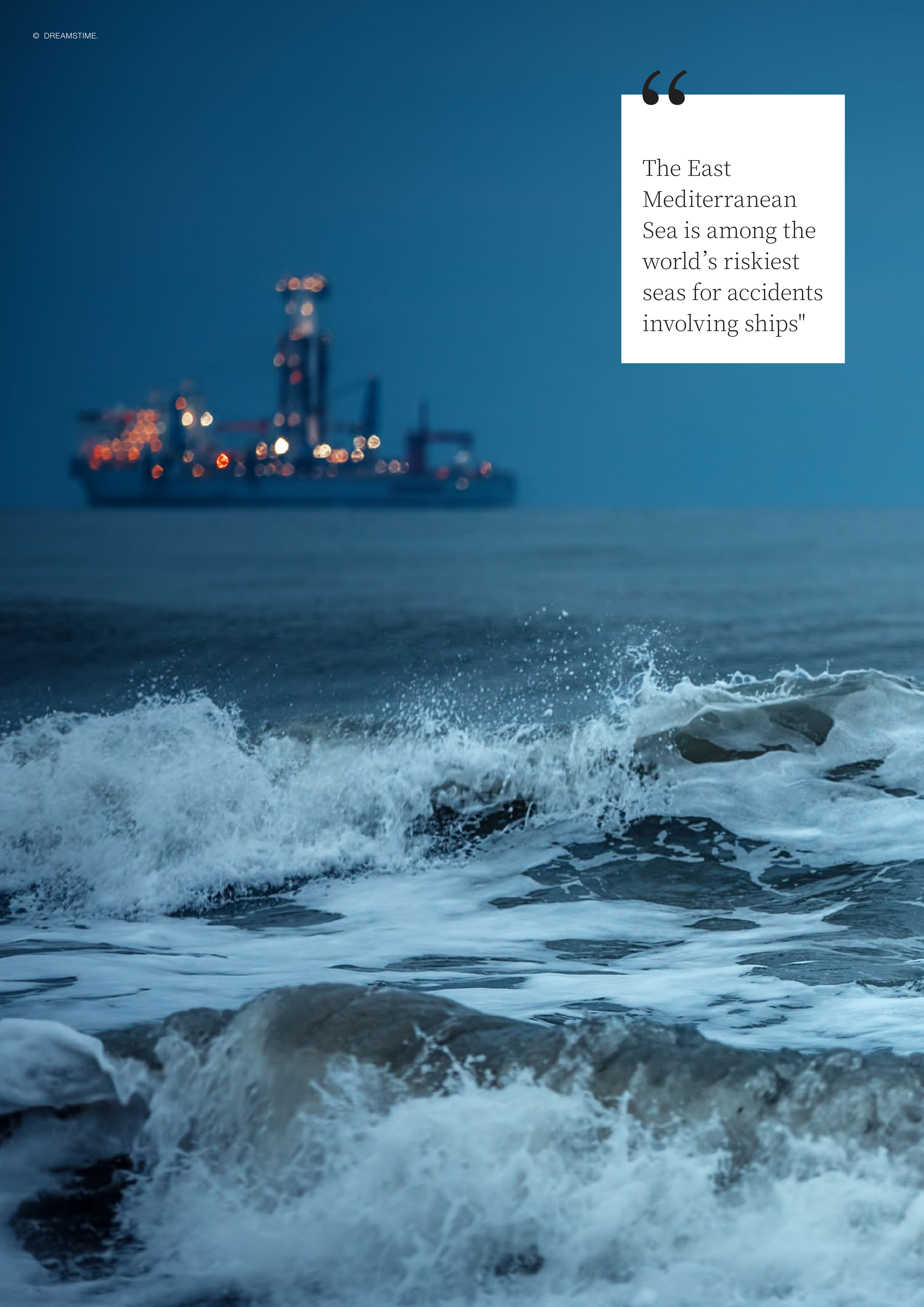


> The East Mediterranean Sea is among the world's riskiest seas for accidents involving ships"

Maritime traffic

The Mediterranean Sea is among the busiest shipping routes in the world accounting for 25% of global shipping and 30% of the world's oil traffic. Major hub ports serve as redistribution points for the largest container ports, with passage via maritime hubs; among them, in the Eastern Mediterranean near the entrance/exit to the Suez Canal, in the central Mediterranean area with Maltese and southern Italian ports, and in the Straits of Gibraltar area with Algeciras and Tangiers. Most recent estimations state that around 120,000 ship transits annually pass through the Straits of Gibraltar, over 18,500 vessels through the Suez Canal, accounting for over 963 million tons in 2018 (Fig. 9.17).

In the Eastern Mediterranean, there are 16 large ports for passenger cruises[71] and cargo[71] besides a number of intermediate container hubs and liner shipping networks (Fig. 9.18). Intensive traffic density is observed within the Aegean Sea, while there are other high traffic branches towards the Levantine Sea. With the increased renewable energy production, offshore oil and, in particular, natural gas projects, a significant part of the traffic will also increase in the future due to offshore support vessels, such as, offshore construction vessels, dive support vessels, stand-by vessels, inspections, etc. The dense maritime traffic could increase the risk of accidents, including in important conservation areas (Fig. 9.19).

The large cargo and passenger shipping traffic along the region produces a number of negative effects on the marine environment. Of particular environmental concern are the emissions caused by ships, risk of accidents and acute pollution events, underwater noise, introduction of invasive alien species with ballast waters, collision, and habitat degradation[72,73]. Shipping also contributes to the eutrophication of marine waters through emissions, and is intensified through cumulative activities.

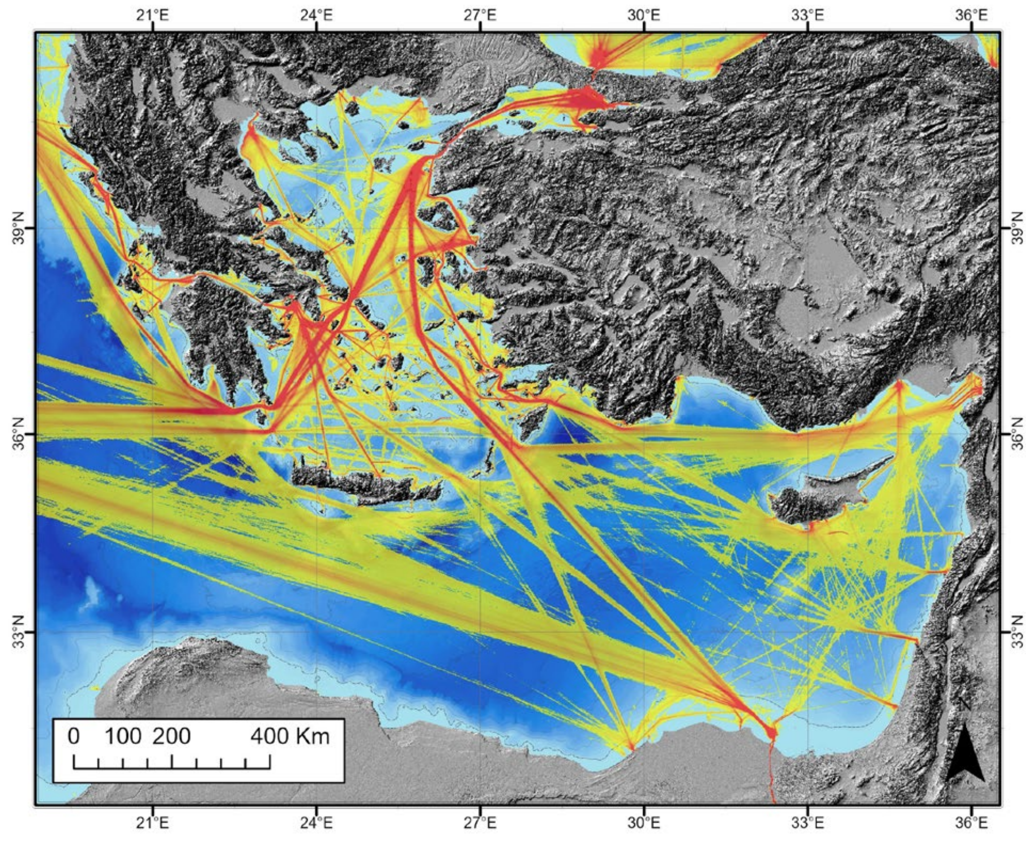
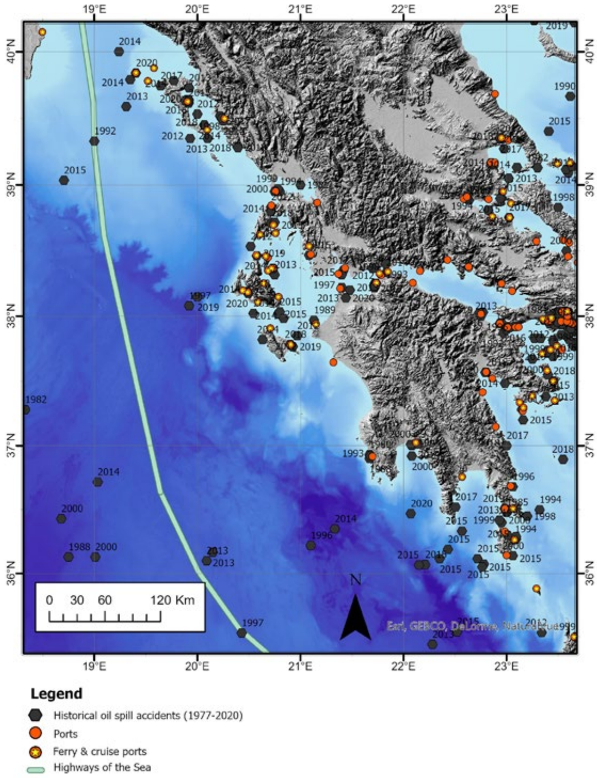
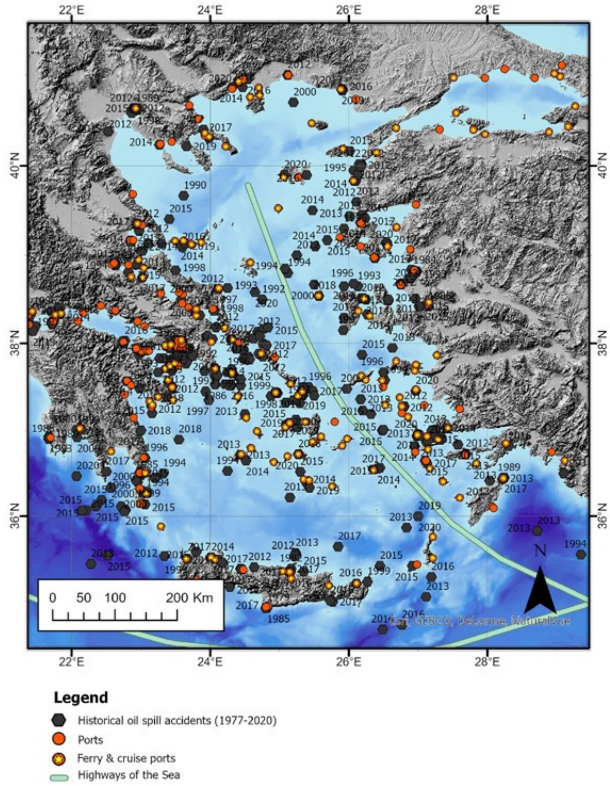
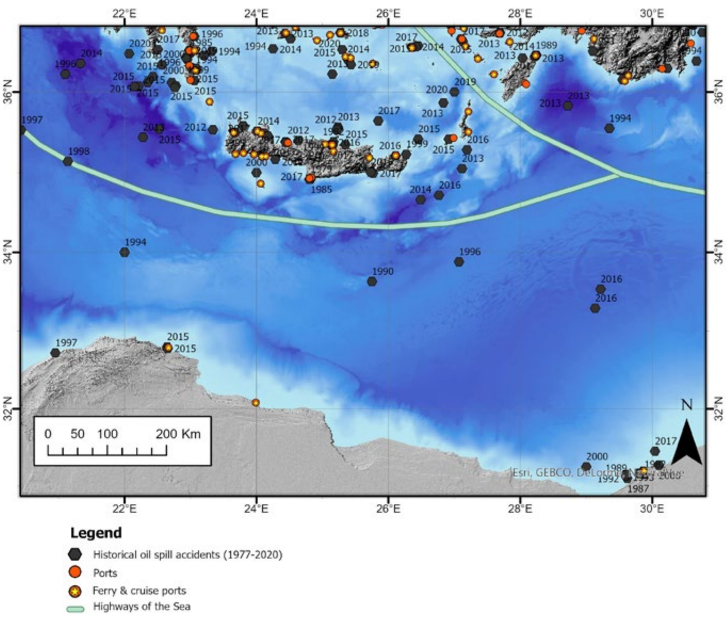


Fig. 9.17. Maritime traffic density in the Mediterranean Sea. (Source: EMODnet Human Activities portal).







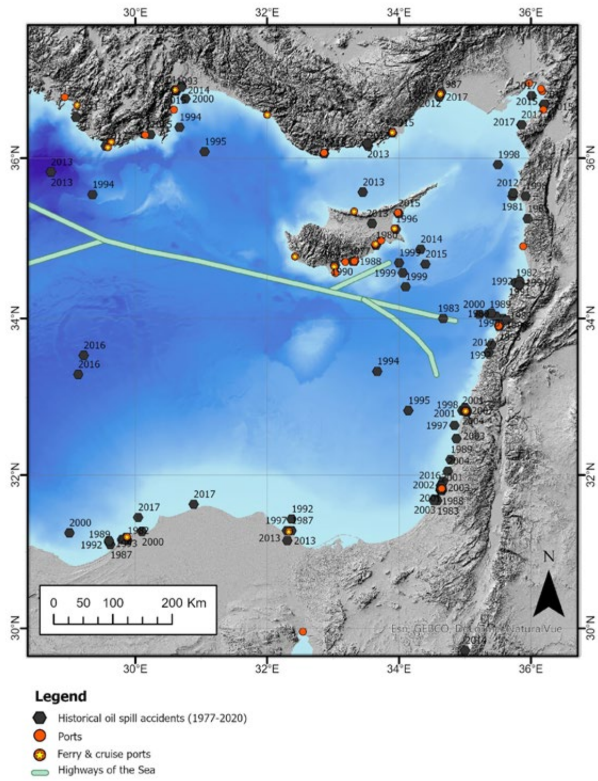


Fig. 9.18. Main ports for ferry and passenger cruises as well as cargo container ports with the historical reports of oil spill accidents (1977-2020).

As mentioned previously, some of the major maritime routes cross priority areas for the conservation of marine mammals affected by pollution and noise[62]. Marine noise pollution is reported to interfere with: (1) vocalizations emitted by many animals to communicate with their conspecifics, (2) natural sounds that animals perceive and use as clues for orientation in space, movements in search of food, migration to reproductive areas, and detection of appropriate habitats for settlement[74].

> “With the increasing trend of maritime traffic in the Mediterranean, a cleaner shipping and an increase of the regulation for the traffic control and noise, particularly in hotspot areas, requires urgent attention”

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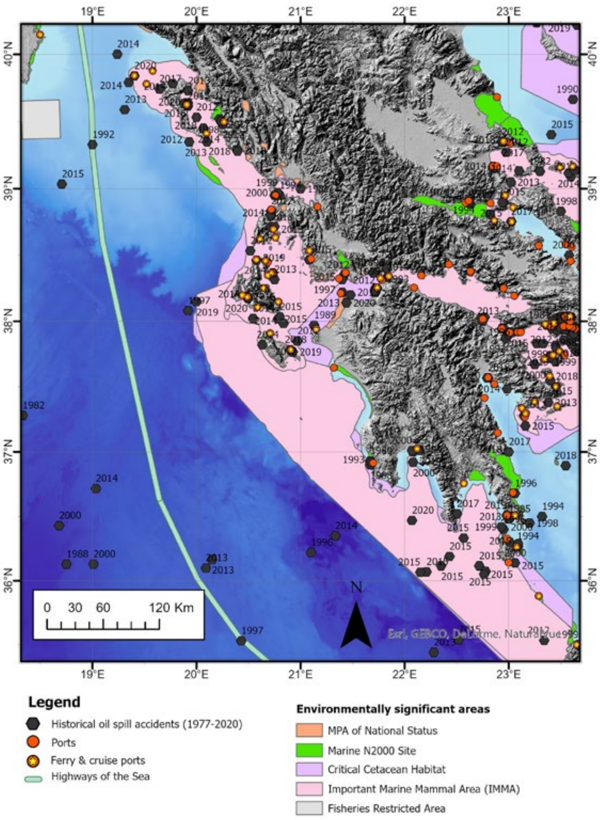

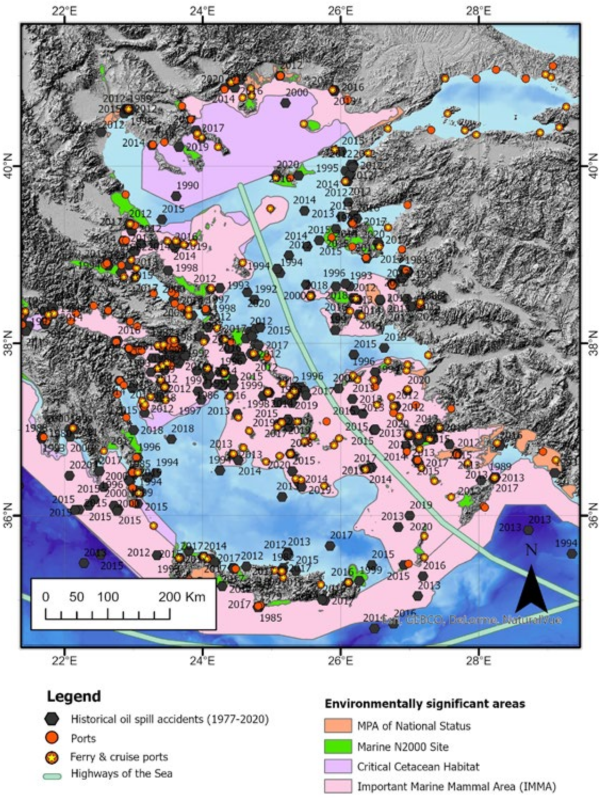

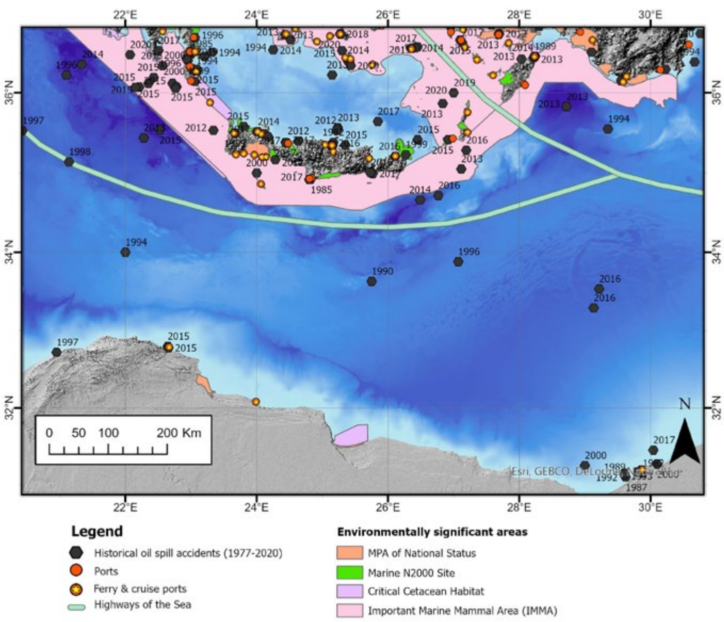

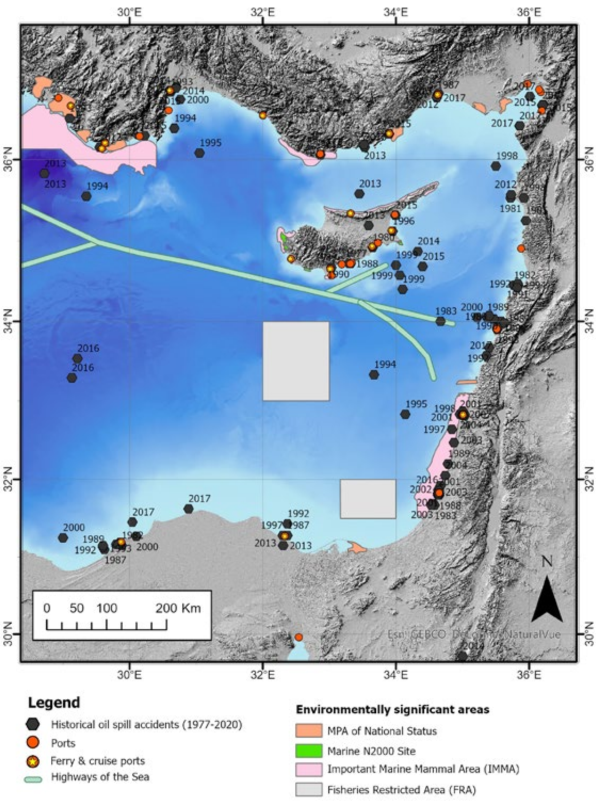

Fig. 9.19. Historical oil spill accidents, ports and environmental significant designated areas in the Eastern Mediterranean Sea (1977-2020).

Similarly, collision with fast moving vessels is also of concern for vulnerable megafauna such as sea turtles and cetaceans[41] and reported cases of ship strikes with sperm whales are relatively common in the region. A clear example comes from the Hellenic Trench with the overlap of the major shipping routes and the encounters with sperm whales in both the Aegean and Ionian Seas (Fig. 9.20). In the Hellenic Trench, the average shipping density that whales are exposed to (220 km^{-1} $year^{-1}$) is among the highest in the Eastern Basin[59]. These results highlight that alternative traffic routes could considerably reduce the overall collision risk for sperm whales and other cetaceans in these areas.

There have been remarkable efforts aimed at the regulation of maritime traffic operations at the EU and Mediterranean level with the recent introduction of further international standards. Among them:

- the control and management of ballast water and sediments of ships and water treatment systems (Convention of Ballast Water; Ballast Water Management Strategy for the Mediterranean Sea (2022-2027).
- legislation regarding port reception facilities for ships' operating waste and cargo residues (EU Directive 2000/59/EC) regulations regarding the energy efficiency of shipping vessels with progressively restrictive policies on air pollution from ships, green house emission targets and sulphur content used in marine fuel oils (MARPOL Convention). The designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides (MED SOx ECA) pursuant to MARPOL Annex VI will be proposed for the possible designation by the IMO.
- the common standards for the oil and gas industry with the Offshore Protocol of the Barcelona Convention.

- the maritime surveillance and the European Union Maritime Security Strategy (EUMSS) adopted in 2014; Marine Strategy Framework Directive (MSFD), with targets for healthy and sustainable marine and coastal ecosystems with the descriptions of Good Environmental Status (GES) and the Integrated Maritime Policy (IMP).

The forecast of increasing maritime traffic in the Mediterranean and the concentrations of maritime transport will continue to place direct and indirect pressures on marine ecosystems (including deep-sea environments) caused by both regular operating activities as well accidents or incidents. The recent policy and regulatory mechanisms established should help to partially address the environmental pressures that will occur. Other policies to enhance cooperation and information sharing between countries, the impacts of underwater noise and the spatial or temporal impacts of maritime traffic in certain areas are also needed. Additional research should also be conducted in order to further determine these impacts and address new regulations or measures. •

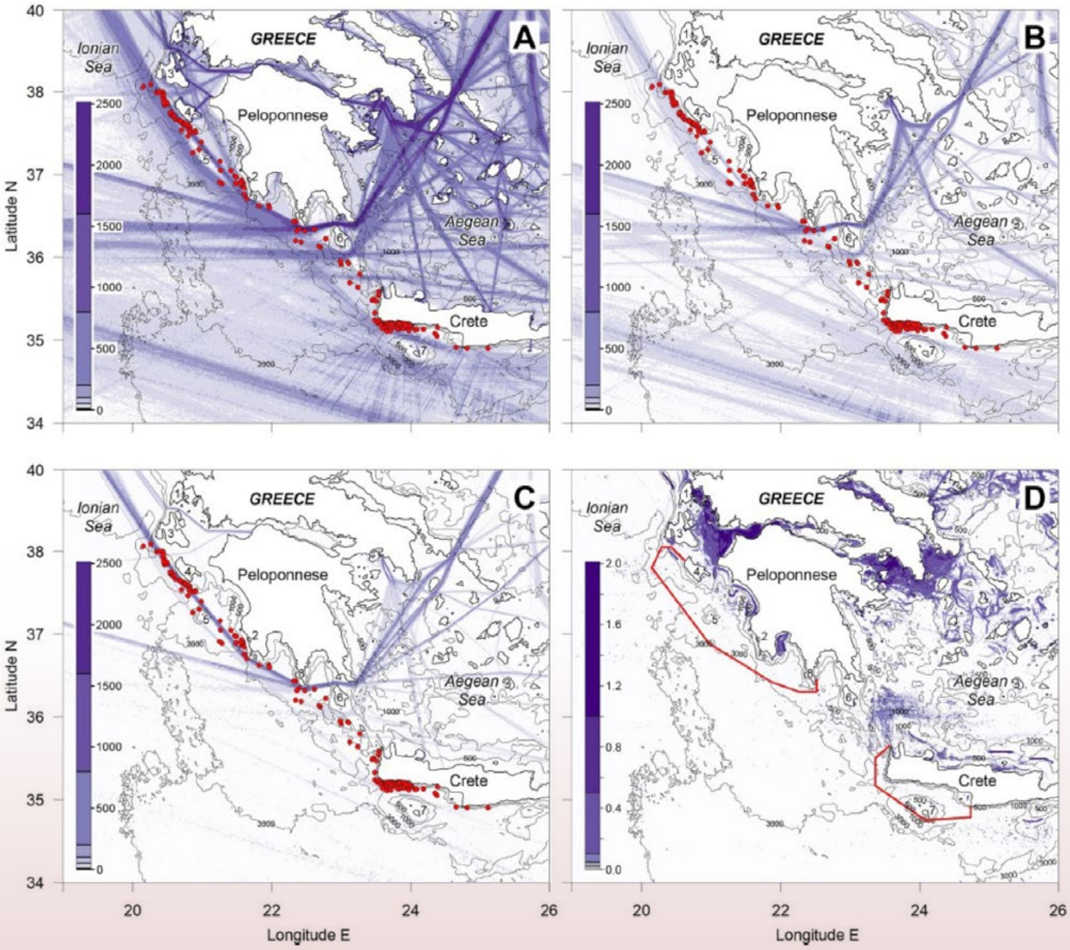

Fig. 9.20. Density of ship traffic reported through AIS transmissions and sperm whale sightings (red dots) from surveys. (A) Density of all ship traffic, excluding fishing vessels. (B) Density of container ship traffic. Traffic to the SW of Crete north of Gavdos Island is mainly dominated by container ships heading to or from the Eastern Mediterranean (ports to the east of Port Said and the Suez Canal) through the Strait of Otranto or Strait of Messina. (C) Density of Ro-Ro cargo traffic. The main route of concern for sperm whales is between the Strait of Otranto and the Aegean via the Elafonisos Strait, north of Kythira Island. (D): Fishing vessel presence by time spent in each grid square. The scale for shipping density plots (A), (B) and (C) is in km-1year-1 and for plot (D) is in days.km-2.year-1. Numbers indicate Greek locations mentioned in the text as follows. 1: Lefkada Island, 2: Pylos, 3: Kefallonia Island, 4: Zakynthos Island, 5: Strofades Islands, 6: Kythira Island, 7: Gavdos Island, 8: Cape Tainaron (source: Plos One [59]).

CHAPTER 9 /

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CHAPTER 10/

Concluding remarks

Otero M., Mytilineou C.

The known and unknown Eastern Mediterranean Deep-Sea

The deep-sea was once regarded as vast, stable, monotonous desert-like ecosystem, with conditions too extreme for life to thrive. Building on knowledge over the years, we now know that these extreme environments are highly variable and diverse [1]. In the Eastern Mediterranean Sea, despite its ultra-oligotrophic water environment and oceanographic physical conditions, the deep-sea hosts a large diversity of ecosystems and species. It is shaped by topographically complex geomorphological structures and geological heterogeneity with submarine canyons, seeps, vents, seamounts and submarine ridges. A variety of extreme environments such as active cold seep systems, including mud volcanoes, pockmarks and brine lakes, have recently been detected on the active ridges and passive continental margins of the Eastern basin (see Chapter 2 & 5; [2]). They support the life of rare and unique species fuelled by fluid and gas emissions to the sea floor. Within each of these areas, seafloor topography, heterogeneity of sedimentary habitats, depth and water masses strongly affect the faunal communities that have developed.

The high biodiversity associated with the Eastern Mediterranean deep-sea ecosystems remain largely undescribed. The results presented in previous chapters indicate that there have been only sparse studies in most of this basin and sub-regions and large gaps in knowledge still exist, particularly in the Levantine and Libyan Sea waters where there has been considerably less sampling effort. Most of the information is concentrated on the upper continental slopes and shelf breaks and only few more recent reports have described deep-sea faunas associated with deep-straits, seamounts, canyons and slope disturbances. The review of the published and grey literature with the new analysis conducted on historical video material and by-catch data (Chapter 3 and 4), has offered an opportunity to understand the rich biodiversity values of some of these remote locations and diverse ecosystems formed. It also shows the untapped scientific value of existing underwater videos that could be used to shine new light on deep-sea locations and retrospectively observe past baselines.

More data is certainly needed, to better quantify biodiversity in those areas, understand their present conservation status and the overlapping effects of different pressures on the same areas over time. Nonetheless, the information gathered here shows that the current accumulated knowledge has the potentiality to facilitate efforts for a comprehensive programme to ensure the conservation of these vulnerable marine ecosystems and their biodiversity in the Eastern Mediterranean.

As Mediterranean blue economies develop, and the human and climate footprints extend into the deep waters, sustainable environmental management of deep-sea ecosystems and resources will need to grow in importance. The current spectrum of human activities affecting presently or with the potential to impact the Eastern Mediterranean deep-sea ecosystems in the future is diverse and increasing. Fishing activities are expanding towards offshore and in deeper marine areas (Chapter 7 and 8), and some countries have enabled the first licenses for offshore oil and gas activities (exploration and exploitation) in the region (Chapter 9). In addition to this, the expansion of submarine cable networks (power and telecommunication) and gas pipelines have raised concerns on their impact on the marine environment and its fauna, with very limited information available. New opportunities to develop renewable energy development projects (e.g. wind park with floating turbines in the deep waters of the Aegean Sea) in marine offshore areas might surge in the near future and research with the application of effective monitoring programmes to the different on-going developments is needed.

Studies shedding light to describe the large problem of marine litter in these deep-waters are scant. The majority of the plastic waste from the coast breaks down into microplastics and disperses through the waters, before finally sinking into the deep depths. Deep-sea areas with high concentrations of macroplastics, polluted through highly urbanized gulfs (e.g. Limassol Gulf,

Waste from the coast disperses through the waters, before finally sinking into the deep depths.

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Renewable energy development projects (e.g. the wind parks) in marine offshore areas need impact assessments and the application of effective monitoring programmes.

Antalya Bay and Saronic Gulf), have been described in the Eastern Mediterranean and are particularly severe in their deeper parts (Chapter 9). They have also been described in several submarine canyons and open sea areas (e.g. southwest of Lefkas Island, south of Cyprus, off Jablah in Syria). The reasons for litter accumulation in open-sea areas and on the seafloor could be related to hydrographic conditions and activities from maritime traffic. The role of submarine canyons (e.g. Lebanon coast canyons) close to the coast as organic matter corridors but also as conveying vectors for marine litter from the continental shelf into the deep abyssal seafloor is of considerable importance. The development and the implementation of appropriate policies, legal instruments and institutional arrangements as well as adequate management plans to address this problem have been recently agreed in the Mediterranean. Both strategic actions, the Regional Plan on Marine Litter Management and the Regional Plan on Urban Wastewater Treatment and Sewage Sludge Management in the Framework of Article 15 of the Land Based Sources Protocol[1] will be a key to achieve a real reduction of litter in the marine environment.

Overall, there is limited published information on the quantification of the human impacts on deep-sea ecosystems or the spatio-temporal intensity of different user industries. For some activities, the information remains dispersed among different institutions or is not available. In situ assessments of the impact of offshore activities on nearby deep-sea sediments and associated benthic and demersal fauna are rarely available. For example, information on meiofauna, the main benthic component found in significant densities in the oligotrophic deep eastern Mediterranean basins, remains very scarce and fragmented for most of its habitats (Chapter 5). This together with the limited information and monitoring effort about the nature, distribution, variability, and vulnerability of biodiversity and resources prevents the matching of information on threat intensity in specific locations. In some areas, it is already evident that economic activities of concern such as the gas leased blocks and the presence of endangered species are very close or overlap (Chapter 9; Fig.9.15a). At some deep-sea Ecologically or Biologically Significant Marine Areas (EBSAs)[2] the overlapping with potential or planned seems relatively important (Fig. 10.1; >30-50%).

1 UNEP/MED IG.25/12; IG.25/11
2 https://www.cbd.int/ebsa/

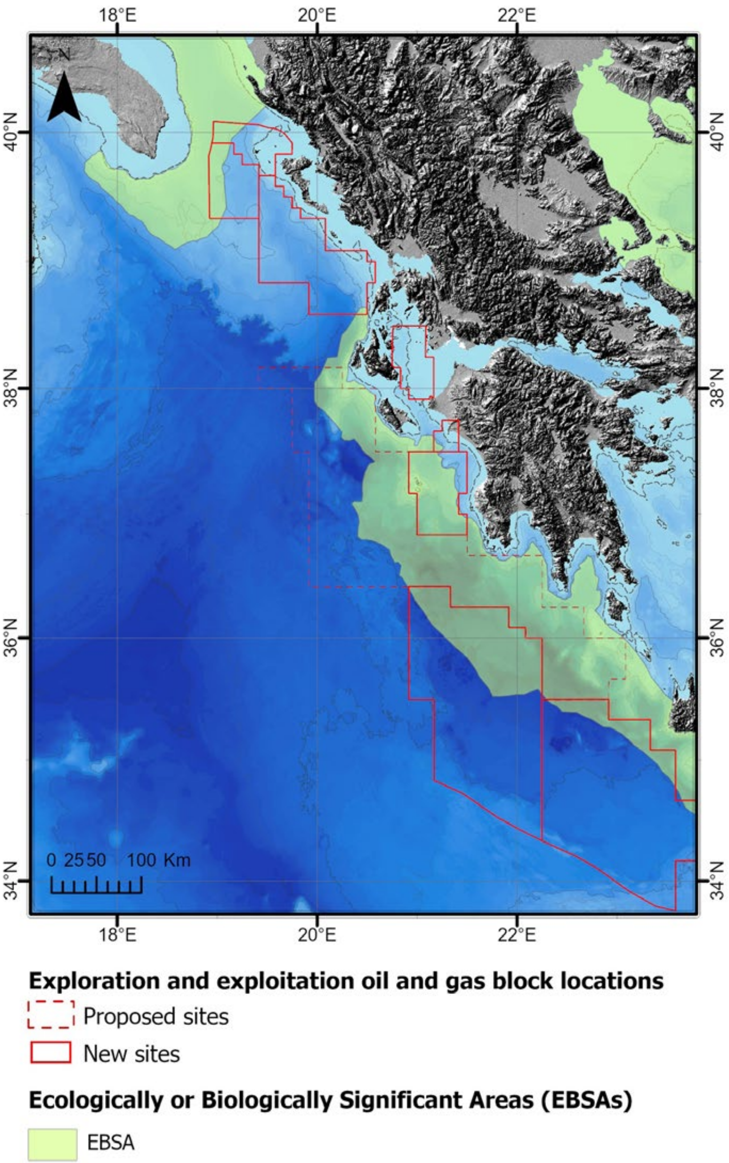

Fig. 10.1. Overlapping of the Hellenic Trench and South Adriatic Strait and Ionian Ecologically or Biologically Significant Marine Areas (EBSAs) with potential and/or planned exploitation and exploration oil and gas locations in the Eastern Ionian Sea.

Considering the current and planned expansion activities of deep-water gas exploration and exploitation in the Eastern Mediterranean, that may overlap with key biodiversity areas will pose potential further threats to the deep-sea biodiversity as well as the species using this pelagic environment (e.g. effects produced by military sonars activities on endangered species as Sperm and Cuvier's beaked whales). In the absence of dedicated surveys, alternative methodologies are needed, such as the use of data collected from platforms of opportunity and modelling techniques to predict distribution in unsurveyed areas. Moreover, a more transparent process involving stakeholders should be put in place to monitor and enhance the effective implementation of regulations concerning these activities, monitor changes and establish spatial (e.g., avoidance rules on sensitive areas and/or where endangered fauna is present), and temporal measures (e.g., restricted activities during certain periods for sensitive fauna) to mitigate risks from these activities.

Knowledge on deep-water fishing resources and fisheries in the Eastern Mediterranean is discussed in detail in Chapter 7 and Chapter 8. Deep-water fishing occurs in the upper and lower slope, submarine canyons and on many seamounts, and the overexploited status of many of the commercial Mediterranean commercially important stocks is recognised [3]. No specific information exists on the fishing effort and the corresponding fishing grounds where deep-water trawl fisheries are practiced, although it is expected to be soon available.

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The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assessment [4] suggests that the direct exploitation of organisms (mainly through fishing) has one of the largest impacts on the marine environment. At present, scarce information is available on the extent of the fishing activities and impacts on deep seafloor communities and biodiversity in the Eastern basin. It is of concern that in some cases deep-water fishing is known to occur close to or in vulnerable ecosystems (Fig.10.2). Examples of this are areas where deep-water shrimp fishing grounds are close or coincide with fields of bamboo coral *Isidella* presence (Chapter 3, 4 and 8-Fig.8.3) on the Kephallinia seamount[5] or areas where commercial species such as *Polyprion americanus*, and *Pagellus bogaraveo* are exploited close to seamounts and banks (Chapter 7[5]). Areas around seamount features offer suitable habitats often harbouring highly productive, biodiverse and structurally complex habitats such as sponge gardens or cold-water corals. Their presence could be likely of higher relevance in the oligotrophic offshore waters of the Eastern Mediterranean.

The observed spatial patterns of some deep-water fishing activities (Chapter 8) corroborates the known deep-water fishing operations with activities near seamount ridges, canyons and slopes in the five sub-basins. As fishing vessels operating in the southern and most eastern Mediterranean areas are not equipped with VMS or AIS monitoring devices, there is very limited knowledge where deep-water trawl fishery is practiced. Identifying those deep-sea areas that are vulnerable to fishing impacts is important in conservation efforts behind Marine Protected Areas or No-Take Zones. Criteria for identifying these vulnerable marine ecosystems (VME) where fishing pressure is known to exist in the Mediterranean have started to be defined[3] and potential sites for the Eastern Mediterranean are here suggested and proposed for further investigation.

As the deep-sea ecosystems are highly sensitive to changes, it is likely their ability to recover from continuous or short-term impacts will largely depend on the different pressures on these ecosystems [6,7,8]. Therefore, a great deal more understanding of how these interactions affect the deep-sea environment is necessary in order to make sound resource management decisions in a consistent and evidence-supported manner.

There are also numerous uncertainties about how deep-sea ecosystems will respond to climate change and what this will mean for their resilience to human activities. The Mediterranean Sea is considered as one of the most responsive regions to climate change [9].

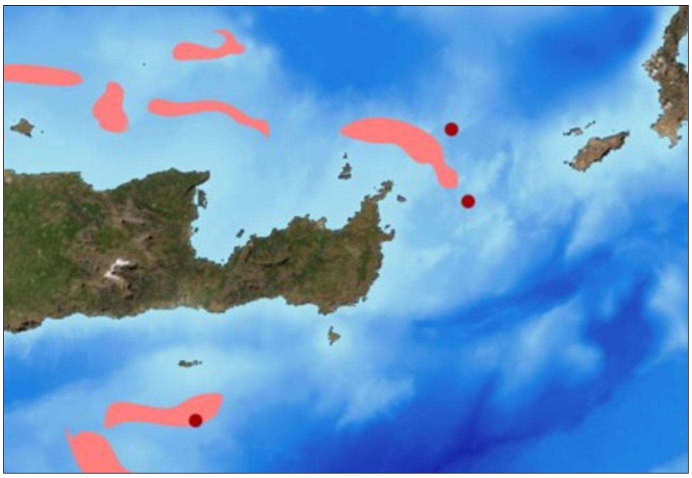
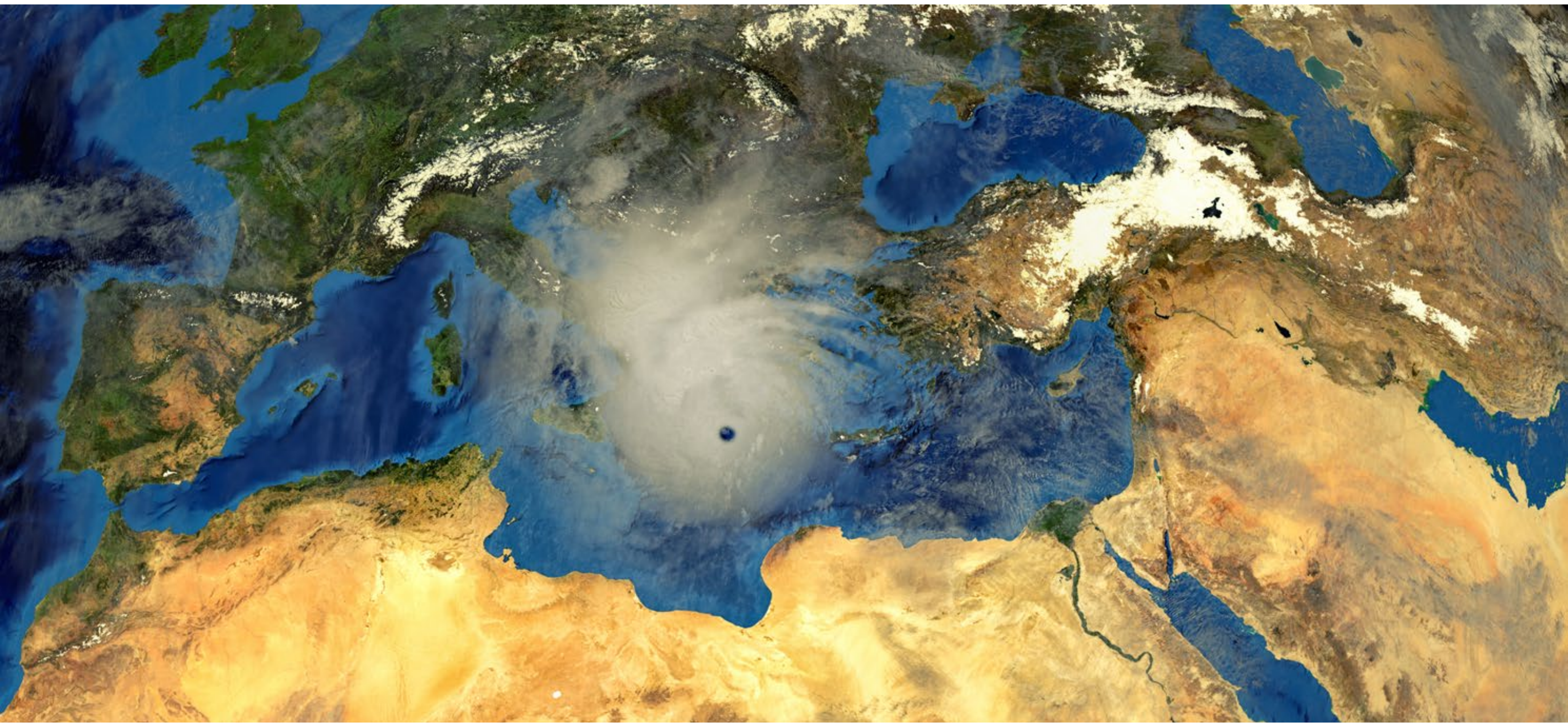


Fig 10.2. Main deep-water trawl fishing grounds in the East Crete area (2019) (Orange) with areas where the presence of cold-water corals (red dots) has been mentioned in the present work.

3 GFCM/43/2019/6; GFCM/41/2017/5



The Eastern Mediterranean basin is one of the most prominent and vulnerable climate change hotspots.

Representation of a seamount community showing potential currents and how dispersal and colonization among deep-sea benthic populatioons may occur.

Surface seawater temperatures are expected to rise between 1.8°C and 3.5°C by 2100 and the Eastern Mediterranean will be one of the hotspots where the largest changes are predicted. Ocean acidification, a consequence of higher CO_2 levels will likely impact the marine trophic chain, from its primary producers (phytoplankton, phytobenthos and zooplankton) to deep-water corals [10] although it is less clear to what degree marine organisms might adapt to slowly changing pH over the next century. Overall, understanding how climate impacts will interact with these induced physical and chemical changes as well as pressures from other human activities occurring close to the seabed or the deep pelagic environment such as those coming from fishing and pollution will require further work. The implementation of mitigation actions in the coming years can reduce part of the impacts that are starting to be observed now and allow some restoration progress. Protection of seamount summits may provide a refuge from acidification for species that otherwise only occur in deeper more greatly affected habitats [10,11]. The present evidence also shows the role of seamounts and seamount-like structures as hotspots for some top-predators or consumers including large sharks and cetaceans (Chapter 6).

Improving the capability to monitor the present cumulative impacts, assess the vulnerabilities of deep-sea ecosystems, inform on ecosystem health and integrity, and understand socioeconomic values of these marine areas will help the success of an integrated planning of marine resource management.

The Road to protect 30% of the Mediterranean Sea

The Mediterranean countries have made strong national commitments to effectively manage their marine resources, which are embedded in regional and international efforts and commitments, such as the Convention on Biological Diversity (CBD) Biodiversity Targets (Post-2020 Global Biodiversity Framework), the United Nations Oceans Conference in support of the 2030 Agenda for Sustainable Development, the Barcelona Convention and the General Fisheries Commission for the Mediterranean (GFCM) 2030 Strategy. Moreover, they have recently increased their goals under the Post-2020 roadmap on marine protected areas (MPAs) and other effective area-based conservation measures (OECMs) in the Mediterranean.

To date, Mediterranean countries have declared the spatial protection of 8.33% of the Mediterranean Sea, almost all concentrated in the northern basin and coast al areas or as sanctuaries to reduce specific threats to some taxa (e.g. cetaceans sanctuaries). However, the present surface of MPAs has only 0.04% of waters that are in fact strongly protected with no-go, no-take or no-fishing areas [12]. The existing set of MPAs in the Eastern Mediterranean and areas designated to mitigate specific threats need to enforce their coherence, connectivity, and representativeness; and more progress has to be made in giving the deserved attention to the need of MPAs and/or FRAs designation at the open sea to protect migratory and endangered fauna as well as vulnerable biodiversity hotspots (Fig.10.3).

Mediterranean countries have committed specific goals for Protected Areas:

i) by 2030, at least 30 % of the Mediterranean Sea will be protected and conserved through a well-connected, ecologically representative and effective systems of marine and coastal protected areas (MCPAs) and other effective area-based conservation measures (OECMs), ensuring adequate geographical balance, with the focus on areas particularly important for biodiversity.

ii) by 2030, the number and coverage of MPAs with enhanced protection levels is increased, contributing to the recovery of marine ecosystems"

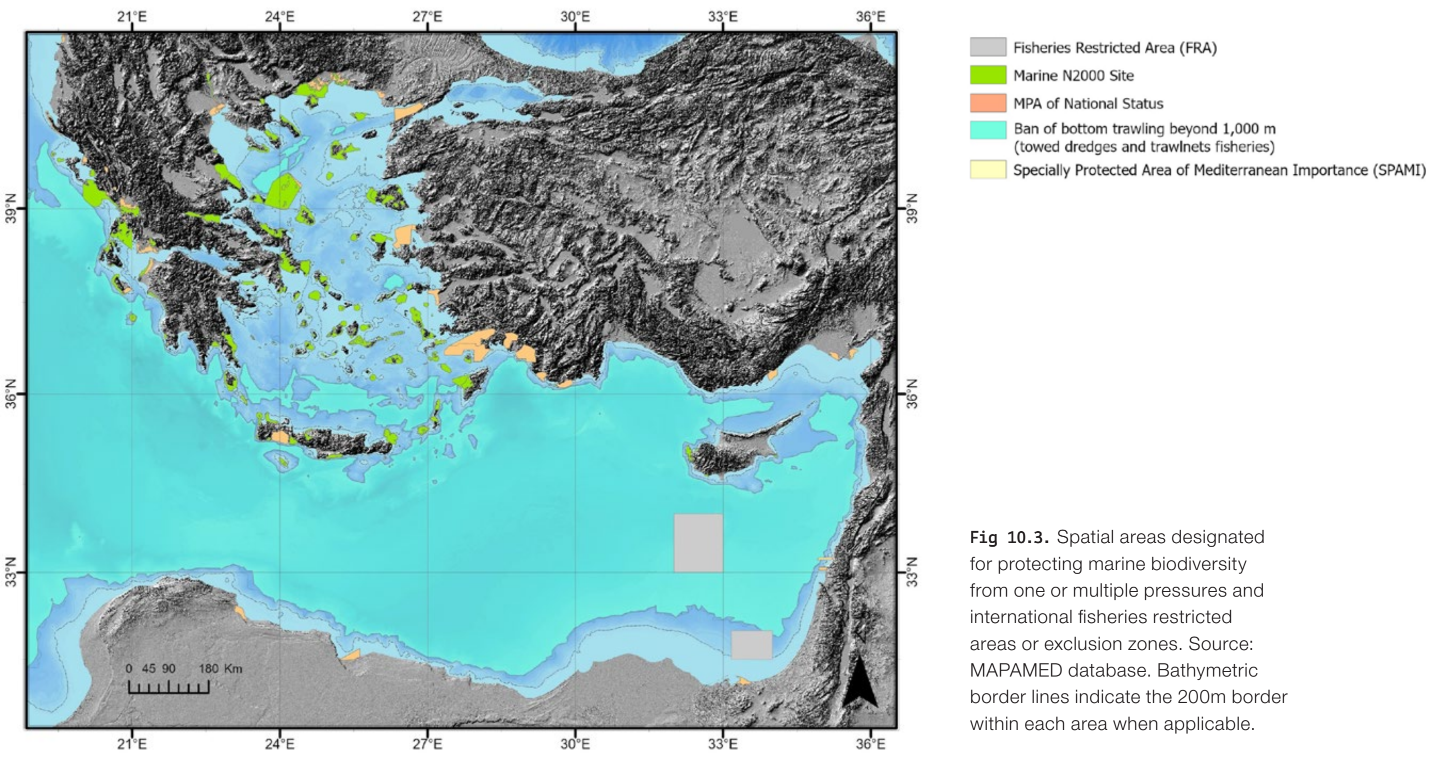


Fig 10.3. Spatial areas designated for protecting marine biodiversity from one or multiple pressures and international fisheries restricted areas or exclusion zones. Source: MAPAMED database. Bathymetric border lines indicate the 200m border within each area when applicable.

Achieving connected and ecologically representative conservation areas around the whole Mediterranean will clearly require balanced protection across ecosystems in each of the sub-basins.

As a result of the present exercise, different areas and locations can be indicated as suitable for further investigations of their ecological conditions, consultative process and the need for establishment of diverse legally and non-legally binding protection areas. They could reinforce the efforts to protect these fragile and unique ecosystems in synergy with other sectorial management measures.

Extending the CBD concept of the existing Ecologically or Biologically Significant Marine Areas (EBSAs), a number of potential biodiversity hotspots for key habitat forming fauna have been here pre-identified over the course of the present work (Fig. 10.4, see also Chapter 3 and 4). Some of these sites should be taken forward as sites requiring more recent investigation and potentially some form of protection, particularly specific areas such as in the SW of Kephallinia in the Ionian Sea, in the west and east Cretan straits (off Antikythira and off South Kasos), the Toroneos Gulf in the North Aegean, the Cyclades Plateau and the Volcanic Arc in the South Aegean, and at the Palmahim disturbance (off Israel). Historical records also showed several sites of interest in the Levantine sub-basin and off the southern coasts of Cyprus (Chapter 3).

In the North Aegean Sea, the flow of more nutrient rich Black Sea water towards the south west and the presence of geological features with low mounds (banks) and seamounts as well as the presence of other geomorphological features seem to be related to the presence of some corals and sponge grounds (Chapters 2, 3, 4). The volcanos in the Southern Aegean Sea provided a rich range of habitats in terms of hard substrate types, but also very soft sediments for a diverse benthic fauna in monospecific habitats. In the Eastern Ionian Sea, hydrological conditions associated with a variety of geomorphological formations such as seamounts, canyons or the continental shelf-break seem to be related to the higher biodiversity or abundance of benthic biodiversity in those sites (Fig. 10.5).

> “
>
> The occurrence of rocky substrates in seamounts compared to surrounding deep environments provides an environment for habitat building organisms such as corals and sponges as well as a rich associated biodiversity”

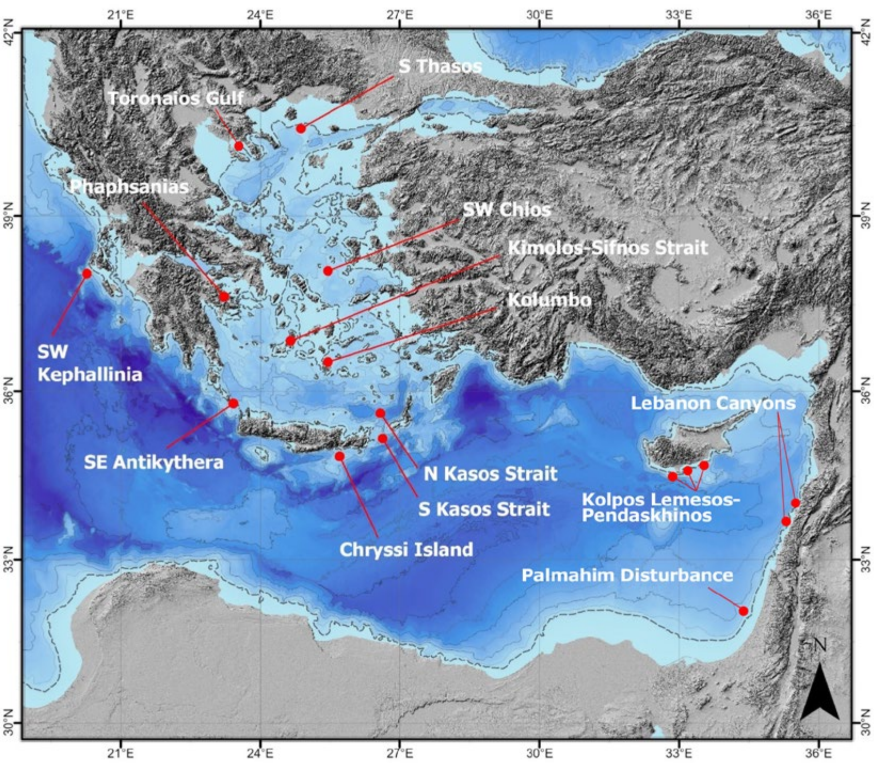


Fig. 10.4. Deep-sea hotspots of benthic biodiversity identified in this work (Chapter 3 and 4).

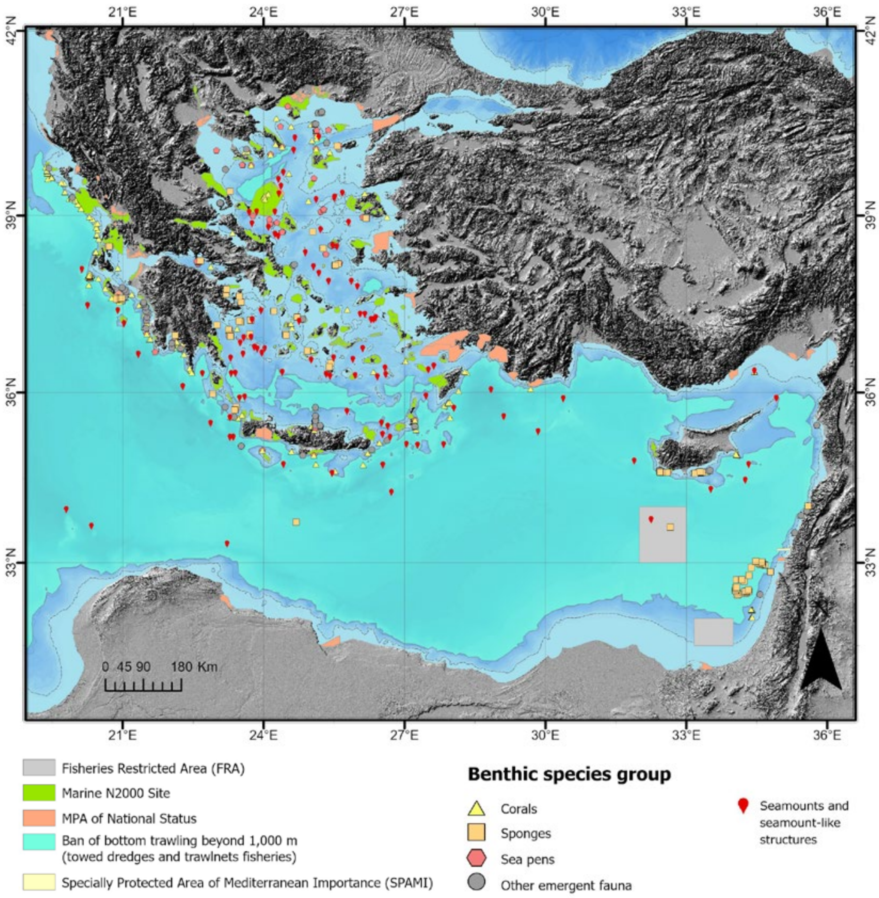


Fig 10.5. Overlapping areas of specific geomorphological features (e.g. seamounts and seamount-like structures, spatial protected areas and recorded presence of different benthic fauna (Chapter 3 & 4) with recorded presence of different benthic fauna. Similar links can be created with other geomorphological features like sea canyons.

The present results could be biased because of the sampling intensity in each area. Therefore updated information on the species and habitat distribution in these areas incorporating both detailed hydrological and biodiversity data will be required to formulate and monitor the management of the marine resources, including the establishment of MPAs or other spatial management measures.

Adding to this, efforts to mitigate the many threats posed to megafauna such as marine mammals and sharks require area-based management measures in the areas that are most important for their life processes, including feeding, reproduction, migration, and resting [13,14]. Identifying these important areas has started in the Mediterranean using a globally standardized methodology produced by IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force for marine mammals with Important Marine Mammals Areas (IMMAs) (Fig.10.6). Further recent efforts by the IUCN MMPA Task Force, IWC and ACCOBAMS are now aimed to evaluate and systematically identify areas of high risk for cetaceans [15]. The Hellenic Trench IMMA for Sperm whales and Cuvier's beaked whales is already considered potentially at risk from merchant shipping traffic [16]. A range of different management tools to keep vessels away from key areas, slow vessels speed and avoidance manoeuvres have been suggested for different situations [17]. Volunteer solutions to prevent ship strikes such as the one recently taken by the shipping and logistics MSC Group and EURONAV[4] with the re-routing of their container and cruise ships on the west coast of Greece in order to reduce the risk of collisions with sperm whales are a substantial contribution to the protection of these endangered cetaceans in the Eastern Mediterranean.

The ongoing review and identification of Critical Cetaceans Habitats (CCH) under ACCOBAMS and the dynamic identification of IMMAs considering any potential spatio-temporal shifts of cetacean populations from climate driven stressors and increasing human-derived pressures can enable the identification and establishment of a network of Marine Protected Areas (MPAs) or OECMs for cetaceans' protection in the Mediterranean.

Adopting a more integrated approach to limit multiple human pressures affecting not only cetaceans but also other endangered megafauna and key biodiversity ar-

4 "Recommended Routing Guidelines for Hellenic Trench, Greece", που δημοσιεύτηκε πρόσφατα στον ιστότοπο του διεθνούς προγράμματος Whale Guardians

eas (Fig 10.6) can further provide the critical elements for an integrated protected area network that ensure key ecological sites to be protected for multiple species, with some areas fully protected while others allowing the occurrence of some environmentally sustainable human activities. Numerous areas where critically endangered species have been observed, fall outside established MPAs, and overlapping knowledge of the characteristics of these areas or future prospective areas needs urgent attention for addressing existing and potential drivers and pressures that may directly or indirectly affect them (e.g. bycatch measures).

POTENTIAL MEASURES TO REDUCE IMPACTS ON MARINE MAMMALS IN IMPORTANT MARINE MAMMAL AREAS (IMMAS)

- Permanent routing measures through TSS, ATBA or port approach routes
- Seasonal routing measures
- Voluntary recommended routes
- Short-term routing measurest
- Permanent speed restriction zones
- Seasonal or Dynamic speed restriction zones
- Real-time alerting tools to warn vessels of the presence of whales or aggregations that allow vessels to alter course or slow down
- Declare East Mediterranean Sea important areas for Cetaceans as “military sonars” free areas

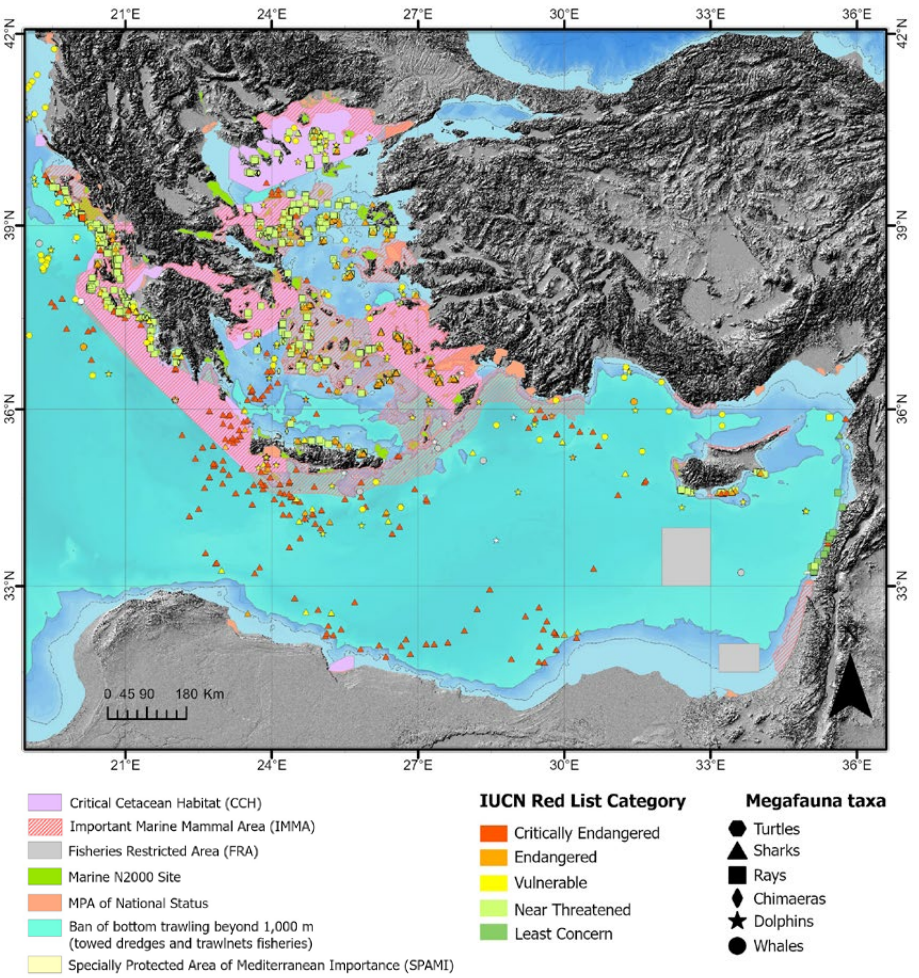


Fig. 10.6. Biodiversity Important Areas for cetaceans and permanent spatial management areas (excluding national fisheries restricted areas) in the Eastern Mediterranean with sightings of different megafauna taxa (2018, Chapter 6) and their IUCN Red list category.

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In this work, it was attempted to compile the existing information on some of the most important deep-water fisheries resources in the Eastern Mediterranean to date and identify their potential Essential Fish Habitats (EFH) sites. In this analysis, five deep-water exploited species were chosen to be reviewed because of their economic importance; the two deep-water red shrimps, the giant red shrimp (*Aristaeomorpha foliacea*) and the blue red shrimp (*Aristeus antennatus*), the blackbelly rosefish (*Helicolenus dactylopterus*), the blackspot seabream (*Pagellus bogaraveo*) and the wreckfish (*Polyprion americanus*) (Chapter 7). Even though it was difficult with the available information (lack of time series data) to define the EFH boundaries for these commercial deep-sea species, initial efforts towards the definition of such areas (Table 10.1) has been made. The sites may be a result of the interaction of the ecosystem productivity, population dynamics and connectivity for some species, while for others the particular oceanographic features and/or the presence of hydrographic processes in combination with species life-cycle may drive the distribution in these sites. As with other available data, information coming from the Levantine Sea and Libyan Sea is very limited to draw inferences.

For demersal commercial species, submarine canyons and cold-water corals are observed to have a role as spawning grounds for species like the blackbelly rosefish or as recruitment areas for deep-water blue and red shrimp, a fact observed from the high abundance of juveniles in some of these geomorphological feature areas. Seamounts and seamount-like structures (e.g. banks) are reported as preferred habitats where species like adult wreckfish or blackspot seabream can occur in higher concentrations. Young individuals live on the up-per continental slope for the former species or as in the case of the blackspot seabream close to the coasts, in river deltas and closed gulfs, which are fishing grounds that are frequently exploited by both recreational and commercial fisheries, and where many times are taken indirectly as bycatch. The ecosystem-based management approach to fisheries at EFH sites including measures such as reducing fishing effort on these grounds, could provide important benefits to the sustainability of these resources while reducing juvenile mortality and therefore, the species vulnerability.

As observed in other Mediterranean areas (e.g. Pomo Pit, Santa Maria de Leuca and Bari Canyon), overlapping between Vulnerable Marine Ecosystems (VME) with some EFHs can occur. This further emphasises the important influence of structure-forming vulnerable marine benthos species for commercial species and how efforts to protect these deep-sea areas (e.g., by spatial closures to destructive fishing practises as foreseen by the Mediterranean Fisheries Regulation, and other pressures) will be key to conserve hotspots of biodiversity and ecosystem functioning in the Eastern Mediterranean deep-sea.

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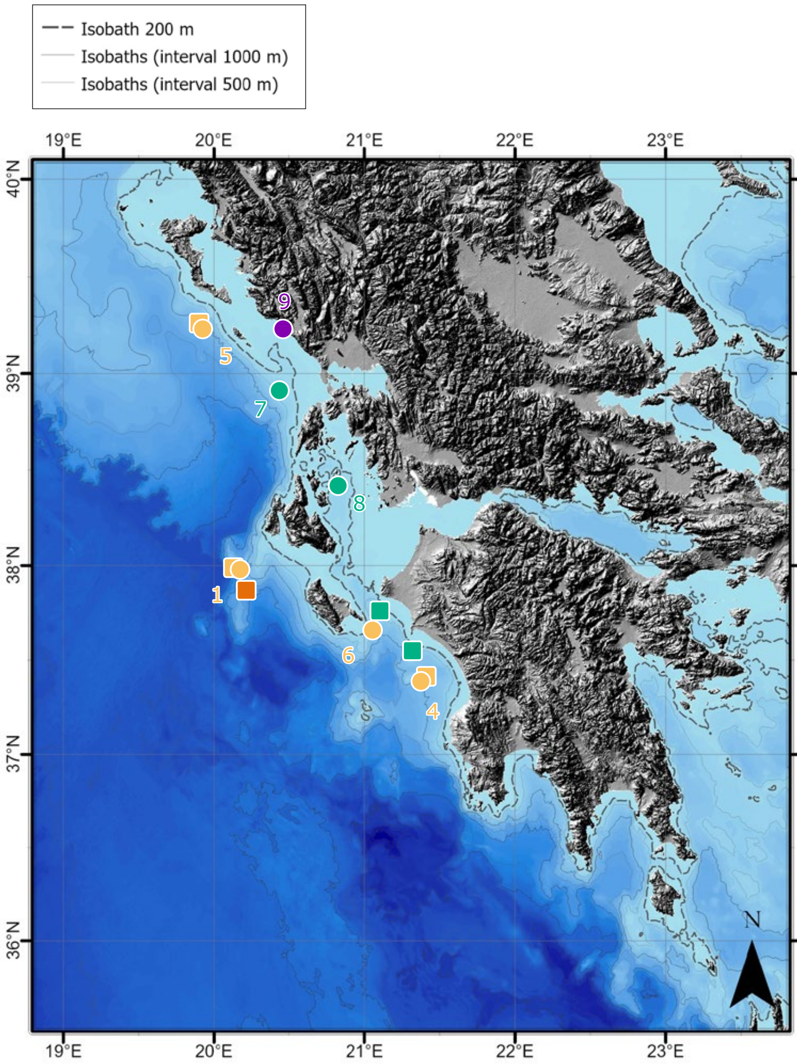
Wreckfish (*Polyprion americanus*) adults show a preference for habitats of seamounts and banks with cold-water coral colonies at depths between 300-800 m. Information of the species occurrence is based on a few reports and studies.

Table 10.1. List of species (common names) for which species-specific potential EFHs were indicated per sub-region.

Eastern Ionian		
Deep-water shrimps	Spawning grounds	For giant red shrimp, the Kyparissiakos (Gulf of Kyparissia), S of Kefallinia (Kefalonia) island Eastern Zakynthos, For blue and red shrimp, SW of Corfu Island, S-SW of Kefallinia (Kefalonia) island and SE of Zakynthos Island.
	Nursery grounds	For giant red shrimp, the Kyparissiakos (Gulf of Kyparissia) and SW of Corfu Island, West of Corfu Island, SW Kefallinia (Kefalonia) island, Eastern Zakynthos For blue and red shrimp, Kyparissiakos (Gulf of Kyparissia)
Blackbelly rosefish	Spawning grounds	Waters deeper than 450 m between the South-East of Zakynthos Island and the West Peloponnese and North of the Kyparissiakos (Gulf of Kyparissia)
	Nursery grounds	Between S Paxoi and NW Lefkas Islands, and off E. Ithaki Island
Wreckfish	Spawning grounds	Argostoli Ridge seamounts
Blackspot seabream	Nursery grounds	Acheron River Delta (western coast of Epirus)
North Aegean		
Blackberry rosefish	Spawning grounds	Open waters South of Chios Island
	Nursery grounds	Off West Lesvos Island
Wreckfish	Spawning grounds	Eastern coasts of Evia Island as well as Sporades islands and off the coasts of the Chalkidiki Peninsula
Blackspot seabream	Spawning grounds	Off W Limnos and off S. Sporades Islands Gökçeada Island waters, adjacent area of Saros Bay
	Nursery grounds	Deltas of the Axios Nestos and Evros Rivers and Toronaios Gulf in Chalkidiki peninsula
South Aegean		
Deep-water shrimps	Spawning grounds	For giant red shrimp, Northeast of Tilos Island, Argolikos (Argolic) Gulf For blue and red shrimp, SW of Symi island and in the Argolikos (Argolic) Gulf
	Nursery grounds	For giant red shrimp, Northeast of Tilos Island, Argolikos (Argolic) Gulf, NE of Crete Island and South of Kos and Southwest of the Symi Islands. For blue and red shrimp, NW Kalymnos Islands, NE of Crete Island and SW of Symi Island .
Blackbelly rosefish	Spawning grounds	West of Kythnos Island at 548 m and off SE Spetses Island
	Nursery grounds	North coasts of Crete Island and more specifically in the area between the Gulf of Heraklion and Dia Island; in the area E of Poros Island- Saronikos Gulf; in the Gulf of Mirabelou (off Ag. Nikolaos); in the area off E Serifos Island-Cyclades
Wreckfish	Spawning grounds	On the slope off Milos, Sifnos and Mykonos islands, during winter over depths of about 1,000 mm off North Crete
Blackspot seabream	Nursery grounds	Saronikos Gulf, Argolikos (Argolic) Gulf

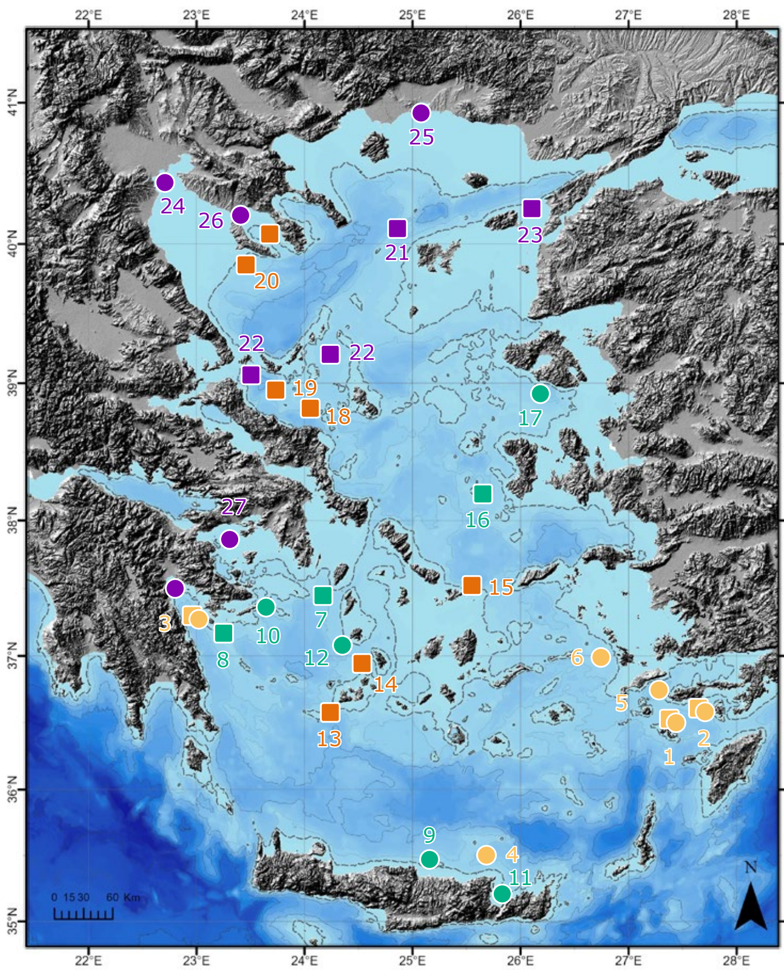


Potential Spawning Grounds
Potential Nursery grounds

Deep-water shimps
Wreckfish
Blackspot seabream
Blackbelly rosefish

1. SW of Kefallinia Island and Argostoli Ridge seamounts
4. N and S Kyparissiakos (Gulf of Kyparissia)
5. SW and W of Corfu Island
6. SE of Zakynthos Island.
7. Paxoi-Lefka islands
8. E Ithaki Island
9. Acheron River Delta

`Fig. 10.7a.` Species-specific potential EFHs in the Eastern Ionian Sea for the deep-water shrimps (*Aristaeomorpha foliacea*, *Aristeus antennatus*), blackbelly rosefish (*Helicolenus dactylopterus*), blackspot seabream (*Pagellus bogaraveo*) and the wreckfish (*Polyprion americanus*).



Potential Spawning Grounds
Potential Nursery grounds

Deep-water shimps
Wreckfish
Blackspot seabream
Blackbelly rosefish

1. NE Tilos Island	14. Sifnos Island slope
2. SW Symi island	15. Mikonos Island slope
3. Argolikos (Argolic) Gulf	16. S Chios Island
4. NE Crete	17. West Lesvos Island
5. SW Kos Island	18. E Evia Island
6. NW Kalymnos Islands	19. Sporades islands
7. W Kythnos Island	20. Chalkidiki Peninsula
8. SE Spetses Island	21. W Limnos (Lemnos)
9. N Crete Island (Heraklion-Dia Island)	22. S Sporades Islands
	23. Gökçeada Island
10. E Poros Island	24. Axios Nestos Delta
11. Gulf of Mirabello	25. Evros Nestos Delta
12. E Serifos Island	26. Toronaios Gulf
13. Milos Island slope	27. Saronikos Gulf

`Fig. 10.7b.` Species-specific potential important EFHs in the North and South Aegean Sea for the deep-water shrimps (*Aristaeomorpha foliacea*, *Aristeus antennatus*), blackbelly rosefish (*Helicolenus dactylopterus*), blackspot seabream (*Pagellus bogaraveo*) and the wreckfish (*Polyprion americanus*).

> “Recovery of deep-sea ecosystems requires a long time horizon and passive recovery may need as long as four decades or more [18,19]”

The lack of quantitative information on juveniles and spawning grounds for deep-sea commercial species from the other Eastern Mediterranean regions, particularly the Levantine Sea, highlight the demand for more research, precautionary management measures and the close collaboration of the countries in this area.

Governance of the offshore Mediterranean environment is complicated by the presence of multi-level responsibilities, the international legally binding instrument on the conservation and sustainable use of marine biological diversity in Areas Beyond National Jurisdiction (ABNJ) under negotiation by UNCLOS umbrella as well as the lack of EEZ agreements between some countries. The construction or the use of the existing governance frameworks (e.g. under UfM, GFCM or Barcelona Convention) could facilitate coordination between multiple responsible authorities towards a shared common vision for the effective protection of the deep-sea marine environment, and the sustainable use of marine resources and space.

Despite the remoteness of the deep-sea, with new technologies and advance in modelling, there are opportunities to improve and advance the information data of this atlas. The process of knowledge building, implementation of a multi-sectoral portfolio of management measures rooted within the Ecosystem approach and Marine Spatial Planning approach with the use of precautionary principles should be the cornerstone for any management at the basin or sub-regional level for the Eastern Mediterranean maritime area. Undoubtedly, improved management measures should be put in place considering the need to target the full array of drivers of pressures that might affect different species and ecosystems. It should also document potential negative effects of the land- and sea-based pressures, reduce these threats and monitor the consequences of the existing and future management measures in the area in the long term.

We hope this publication has contributed on these efforts.

CHAPTER 10 /

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Annexes /

CHAPTER 3

Annex 3.1. Data sources recording presence of deep-sea vulnerable sessile invertebrate taxa in the North Aegean Sea, showing alongside Data Provider, Source Type, and Year and Method of Collection/Observation (ranked by chronological order).

Location	Data Source	Data Provider	Source Type	Year of Record(s)	Method
North Aegean Sea	[6]		Cruise Report	1955	Dredge
	[17]		Review Article	1955-1970	Various
	GBIF	Issaris Y.; Gerovasileiou V.	Online Database (Last Accessed 10/2018)	1960-1972	Various
	[18]		Research Article	1970	Trawl/Fish nets/Dredge
	[19]		Research Article	1970	Trawl/Fish nets/Dredge
	[20]		Atlas	-	-
	[21]	Gönülal O.	Research Article	1973-2013	Various fishing gear
	MATER Project	Smith C.	unp. data	1997-1998	Otter/Agassiz Trawl
	NEPGM Project	Smith C.	unp. data	1998-1999	Otter Trawl
South Aegean Sea	[22]		Monograph	1893	-
	[6]		Cruise Report	1955	Dredge
	GBIF (Last Accessed October 2018)	Gerovasileiou V.; Issaris Y.	Online Database	1956	-
	Nautilos Project	Nomikou E.	unp. data	2010	Submersible
	[23]		Research Article	2012	ROV
	[24]		Dissertation	1964-1968	Dredge
	[17]		Review Article	1970-2010	Fish nets
	CINCS Project	Smith C.	unp. data	1994-1995	Otter/Agassiz Trawl
	FGEII Project	Smith C.	unp. data	1999-2000	Agassiz Trawl
	Natura Monitoring Project	Salomidi M.	unp. data	2013-2014	Trawl/Fishnets
Libyan Sea	[25]	-	Research Article	1964	-
	[14]	-	Monograph	1975	Dredge
	[9]	-	Research Article	1998	Submersible
	[26]	-	Research Article	2005	Rock dredge
	[27]	-	Conference Proceedings	2008	Submersible
Levantine Sea	[14]		Monograph	1956	Dredge
	[12]		Research Article	1994	Beam trawl
	[28]	Ali M.F.	Research Article	2004	Trawl
	[20]		Atlas	2007	-
	[29]		Cruise Report	2016	ROV
	GBIF (Last Accessed October 2018)	Issaris Y.	Online Database	1984-1994	-
	[30]		Research Article	-	Trawl
	[31]		Research Article	1996-1998	Trawl
	[32]		Research Article	2012-2013	Otter trawl
	[13]		Research Article	2015	ROV
	Various projects	Jimenez C.	unp. data	2016-2017	Trawl
		Makovsky Y. et al.	Reports	2020	ROV

Annex 3.2. Research projects in the framework of which the examined photographic material was collected. For each project, the responsible institute, year(s) of implementation, gear type, and geographic area covered, are given. HCMR: Hellenic Centre for Marine Research, Greece; FRI: Fisheries Research Institute of Kavala, Greece; DFMR: Department of Fisheries and Marine Research, Cyprus.

Project	Institute	Year	Gear type	Geographic areas
INTERREG	HCMR	1999-2000	Commercial trawl	Eastern Ionian Sea
RESHIO	HCMR	2000-2001	Commercial trawl	Eastern Ionian Sea
NECESSITY	HCMR	2006	Otter trawl	North Aegean Sea
CORALFISH	HCMR	2010	Longline	Eastern Ionian Sea
ECODISC	HCMR	2014	Agassiz Trawl	Eastern Ionian Sea
EPILEXIS	HCMR	2014-2015	Commercial trawl	South Aegean Sea North Aegean Sea
MEDITS Greece	HCMR HCMR HCMR FRI	1994-2018 1994-2018 1994-1995 2014-2017	MEDITS trawl	Eastern Ionian Sea South Aegean Sea North Aegean Sea North Aegean Sea
BENTHIS	HCMR	2014	Otter trawl	North Aegean Sea

CHAPTER 4

Annexe 4.1: Underwater Survey Site Metadata

ALL SITES

Eastern Ionian Sea	North Aegean Sea	South Aegean Sea	Libyan Sea
1. W. Kerkyra	9. S. Thasos	19. Saronikos, Paphsanias Methana	31. S. Sfakia, Crete
2. NW. Kephallinia	10. W. Samothraki	20. Saronikos, Paphsanias Epidavrus	32. S. Chryssi Island, Crete
3. W. Kephallinia	11. W. Limnos	21. NE. Mykonos, Cyclades	33. S. Kasos Strait
4. S. Zakynthos	12. NW. Mytilini	22. Kimolos-Sifnos Strait, Cyclades	
5. W. Peloponnese	13. N. Alonnisos	23. Kolumbo, Cyclades	
6. Pylos	14. S. Skopelos	24. Santorini, Cyclades	**Levantine Sea**
7. SE. Antikythera (Cretan Straits)	15. S. Skiathos	25. S. Thirassia, Cyclades	34. Nile Delta 1
8. SE. Antikythera (Pontikonisi)	16. W. Skyros	26. N. Heraklion, Crete	35. Nile Delta 2
	17. N. Evoikos	27. Heraklion Bay, Crete	36. SW. Cyprus, Protaras
	18. SW. Chios	28. Milatos, Crete	
		29. Psira Island, Crete	
		30. N. Kasos Strait	

EASTERN IONIAN SEA SITES

1. W. Kerkyra		
1. Area and Position	**2. Depth Range**	
39 42.553 N, 18 58.799 E; 39 13.748 N, 19 50.869 E	330-1370 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
May 2012	9 Dives	20 hours
6. Mission, Project, Platform		
Pipeline route survey from Greece to Italy. Identification of side scan-sonar targets of interest. Max Rover ROV observations.		

2. NW. Kephallinia		
1. Area and Position	**2. Depth Range**	
38 22.866 N, 20 23.868 E; 38 24.578 N, 20 27.289 E	270-795 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
May and September 2010	4 Dives	13 hours & 40 minutes
6. Mission, Project, Platform		
Site survey transects for corals, fish and anthropogenic impacts. CoralFish Project, Max Rover ROV.		

3. SW. Kephallinia		
1. Area and Position	**2. Depth Range**	
38 02.743 N, 20 16.002 E; 37 57.216 N, 20 17.463 E	390-841 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 2009 May and September 2010	3 Dives 4 Dives	9 hours & 17 minutes 21 hours & 5 minutes
6. Mission, Project, Platform		
Site survey transects for corals, fish and anthropogenic impacts. CoralFish project, Max Rover ROV.		

4. S. Zakynthos		
1. Area and Position	**2. Depth Range**	
37 38.468 N, 21 02.237 E	312-530 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
December 2006	1 Dive	4 hours & 7 minutes
6. Mission, Project, Platform		
Red shrimp survey. Nautilos project, Max Rover ROV.		

5. W. Peloponnese		
1. Area and Position	**2. Depth Range**	
37 17.572 N, 21 30.912 E	680-796 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
December 2006	1 Dive	5 hours & 23 minutes
6. Mission, Project, Platform		
Red shrimp survey. Nautilos project, Max Rover ROV.		

6. Pylos		
1. Area and Position	**2. Depth Range**	
36 44.72 N, 21 37.60 E	205-923 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 2006	1 Dive	11 hours & 23 minutes
6. Mission, Project, Platform		
Cable Survey. NESTOR/Pylos Cable Survey, Max Rover ROV.		

7. SE Antikythera (Cretan Straits)		
1. Area and Position	**2. Depth Range**	
35 42.478 N, 23 31.123 E; 35 40.073 N, 23 29.110 E	370-816 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
May 2010	2 Dives	3 hours & 49 minutes
6. Mission, Project, Platform		
Site survey transects for geomorphology, habitats and fauna. HERMIONE project, Max Rover ROV.		

8. SE Antikythera (Pontikonisi)		
1. Area and Position	**2. Depth Range**	
35 34.590 N, 23 27.382 E; 35 36.363 N, 23 29.580 E	215-997 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
May 2010	2 Dives	5 hours & 19 minutes
6. Mission, Project, Platform		
Site survey transects for geomorphology, habitats and fauna. HERMIONE project, Max Rover ROV.		

NORTH AEGEAN SEA SITES

9. S. Thasos		
1. Area and Position	**2. Depth Range**	
40 27.487 N, 24 51.275 E	424-433 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 1996	1 Video Sled Transect	2 hours & 30 minutes
6. Mission, Project, Platform		
Survey and assessment of *Nephrops norvegicus*. NepTV Project. HCMR towed video sled.		

10. W. Samothraki		
1. Area and Position	**2. Depth Range**	
40 24.701 N, 25 08.513 E	390-460 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
Sept 1997, March 1998	2 Video Sled Transects	3 hours & 32 minutes
6. Mission, Project, Platform		
Visual inspection of the Limnos Trench slope. MATER Project. HCMR towed video sled.		

11. W. Limnos		
1. Area and Position	**2. Depth Range**	
39 50.667 N, 24 47.857 E	278-282 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 1996	1 Video Sled Transect	2 hours & 40 minutes
6. Mission, Project, Platform		
Survey and assessment of *Nephrops norvegicus*. NepTV Project. HCMR towed video sled.		

12. NW. Mytilini		
1. Area and Position	**2. Depth Range**	
39 21.926 N, 25 22.617 E	359-365 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 1996	1 Video Sled Transect	2 hours
6. Mission, Project, Platform		
Survey and assessment of *Nephrops norvegicus*. NepTV Project. HCMR towed video sled.		

13. N. Alonnisos		
1. Area and Position	**2. Depth Range**	
Three dive sites within the area a) 39 21.117 N, 23 57.226 E b) 39 18.215 N, 23 52.301 E c) 39 23.860 N, 23 55.573 E	902-1267 m 1407-1560 m 1212-1110	
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 2014	2 Dives 1 Dive 1 Dive	13 hours & 49 minutes 11 hours & 05 minutes 12 hours & 30 minutes
6. Mission, Project, Platform		
Visual survey of the SW Anatolian Trough. Aegean Exploration Project HCMR. Max Rover ROV.		

14. Panormos Bay, S. Skopelos		
1. Area and Position	**2. Depth Range**	
39 05.845 N, 23 38.50 E	220-200 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 1995	1 Dive	15 minutes
6. Mission, Project, Platform		
Visual inspection of the South Skopelos slope. CINCS Project. Jago Manned Submersible.		

15. S. Skiathos		
1. Area and Position	**2. Depth Range**	
39 03.226 N, 23 26.531 E	424-454 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 1996	1 Video Sled Transect	2 hours
6. Mission, Project, Platform		
Survey and assessment of *Nephrops norvegicus*. NepTV Project. HCMR towed video sled.		

16. W. Skyros		
1. Area and Position	**2. Depth Range**	
38 55.818 N, 24 13.947 E	384-403 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 1996	1 Video Sled Transect	2 hours
6. Mission, Project, Platform		
Survey and assessment of *Nephrops norvegicus*. NepTV Project. HCMR towed video sled.		

17. N. Evoikos		
1. Area and Position	**2. Depth Range**	
38 48.892 N, 23 06.602 E	442-445 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 1996	1 Video Sled Transect	2 hours
6. Mission, Project, Platform		
Survey and assessment of *Nephrops norvegicus*. NepTV Project. HCMR towed video sled.		

18. SW. Chios		
1. Area and Position	**2. Depth Range**	
38 04.243 N, 25 26.248 E; 38 02.669 N, 25 29.054 E	473-540 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
Dec 2003	5	Approx. 12 hours
6. Mission, Project, Platform		
Seabed search for lost airplane around a reported position and recovery. AirForce2003. Max Rover ROV.		

SOUTH AEGEAN SEA SITES

19. Saronikos, Paphsanias Volcano, Methana		
1. Area and Position		**2. Depth Range**
37 38.58 N, 23 17.40 E		200-350 m
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 1995	1 Dive	60 minutes
6. Mission, Project, Platform		
Visual survey of the Paphansias volcano and wall. CINCS Project. Jago Manned Submersible.		

20. Saronikos, South of Paphsanias Volcano, Epidavrus		
1. Area and Position		**2. Depth Range**
37 36.71 N, 23 12.17 E		200-279 m
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 1995	1 Dive	30 minutes
6. Mission, Project, Platform		
Visual survey of the south flank of the Paphsanias volcano. CINCS Project. Jago Manned Submersible.		

21. NE. Mykonos, Cyclades		
1. Area and Position		**2. Depth Range**
37 30.129 N, 25 29.589 E		200-400 m
3. Date	**4. Number of Dives**	**5. Duration Observed**
July 2017	1 Dive	2 hours
6. Mission, Project, Platform		
Visual seabed survey for litter. Greenpeace-HCMR Expedition. Drop cabled video camera system (off bottom towed).		

22. Kimolos-Sifnos Strait, Cyclades		
1. Area and Position		**2. Depth Range**
36 54.067 N, 24 39.205 E		540-658 m
3. Date	**4. Number of Dives**	**5. Duration Observed**
May 2014	1 Dive	7 hours & 15 minutes
6. Mission, Project, Platform		
Visual geological survey of the deep water in the island straits. Aegean Exploration Project HCMR. Max Rover ROV.		

23. Kolumbo (NE Santorini), Cyclades		
1. Area and Position		**2. Depth Range**
a) 36 31.596 N, 25 29.198 E b) 36 31.623 N, 25 29.223 E		477-498 m 206-484 m
3. Date	**4. Number of Dives**	**5. Duration Observed**
a) May 2014 b) August 2006	3 Dives 1 Dive	5 hours & 50 minutes 2 hours & 9 minutes
6. Mission, Project, Platform		
a) Visual survey and microbial sampling of Kolumbo volcano base. Aegean Exploration Project HCMR. Max Rover ROV. b) Visual survey Kolumbo volcano base and wall. Nautilos Project HCMR. Max Rover ROV.		

24. Santorini, Cyclades		
1. Area and Position	**2. Depth Range**	
a) 36 23.506 N, 25 24.152 E b) 36 25.228 N, 25 23.898 E	177-260 m 200-295 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
a) May 2014	2 Dives	4 hours & 46 minutes
6. Mission, Project, Platform		
Visual survey and sampling Santorini in caldera (south and north of the Kameni Islands). Aegean Exploration Project HCMR. Max Rover ROV.		

25. S. Thirassia Island (outside the Santorini Volcano)		
1. Area and Position	**2. Depth Range**	
36 24.70 N, 25 19.186 E	235-200 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 1995	1 Dive	40 minutes
6. Mission, Project, Platform		
Visual survey of the south flank of Thirassia Island from outside of the Santorini Volcano. CINCS Project. Jago Manned Submersible.		

26. N. Heraklion, Crete		
1. Area and Position	**2. Depth Range**	
35 29.500 N, 25 01.900 E	478 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
Nov 2004	1 Dive	30 minutes
6. Mission, Project, Platform		
Visual survey of the deep water fault line north of Heraklion, Crete. AMASON Project. Max Rover ROV.		

27. Heraklion Bay, Crete		
1. Area and Position	**2. Depth Range**	
35 25.588 N, 25 12.635 E	220 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 1995	1 Dive	2 hours
6. Mission, Project, Platform		
Visual survey of the fishing lane to the north of Heraklion Bay. CINCS Project. Jago Manned Submersible.		

28. N. Milatos, Crete		
1. Area and Position	**2. Depth Range**	
35 24.2 N, 25 34.2 E (approximate)	220 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 1995	1 Dive	30 minutes
6. Mission, Project, Platform		
Visual survey of the seabed north of Milatos. CINCS Project. Jago Manned Submersible.		

29. Psira Island, Crete		
1. Area and Position	**2. Depth Range**	
35 11.962 N, 25 51.360 E	250 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 1995	1 Dive	30 minutes
6. Mission, Project, Platform		
Visual survey of the seabed leading onto the Psira cliff. CINCS Project. Jago Manned Submersible.		

30. N. Kasos Strait		
1. Area and Position	**2. Depth Range**	
35 32.540 N 26 31.808 E; 35 27.018 N 26 31.950 E	658-1109 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
May and June 2009	8 Dives	25 hours & 4 minutes
6. Mission, Project, Platform		
Seabed search (identify side scan sonar targets) for ancient archaeological remains. DANAOS 2009. Max Rover ROV.		

LIBYAN SEA SITES

31. S. Sfakia, Crete		
1. Area and Position	**2. Depth Range**	
35 08.477 N, 24 08.367 E	958-987 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
December 2014	3 Dives	15 hours & 14 minutes
6. Mission, Project, Platform		
Seabed search for lost airplane around a reported position and engine recovery. AirForce2014. Max Rover ROV.		

32. S. Chryssi Island, Ierapetra, Crete		
1. Area and Position	**2. Depth Range**	
34 44.942 N, 25 42.575 E; 34 45.787 N, 25 36.498 E	450-692 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 2008	5 ROV Dives 1 Submersible Dive	14 hours & 46 minutes
6. Mission, Project, Platform		
Seabed search (identify side scan sonar targets) for ancient archaeological remains. DANAOS 2008. Max Rover ROV.		

33. S. Kasos Strait		
1. Area and Position	**2. Depth Range**	
35 11.134 N, 26 35.586 E; 35 11.465 N, 26 34.220 E	450-623 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 2008 June 2009	3 ROV Dives 1 Submersible Dive	15 hours & 20 minutes
6. Mission, Project, Platform		
Seabed search (identify side scan sonar targets) for ancient archaeological remains. DANAOS 2008 and 2009. Max Rover ROV.		

LEVANTINE SEA SITES

34. Area: Levantine Sea, Nile Delta 1		
1. Area and Position	**2. Depth Range**	
31 58.180 N, 30 08.122 E; 31 54.065 N, 30 09.792 E	242-512 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 2010	13 Dives	23 hours & 54 minutes
6. Mission, Project, Platform		
Seabed search, placement and recovery of seismic instrumentation. West Nile Delta Survey. Max Rover ROV.		

35. Area: Levantine Sea, Nile Delta 2		
1. Area and Position	**2. Depth Range**	
31 40.494 N, 29 45.314 E	672-680 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 2010	3 Dives	5 hours & 53 minutes
6. Mission, Project, Platform		
Seabed search, placement and recovery of seismic instrumentation. West Nile Delta Survey. Max Rover ROV.		

36. Area: Levantine Sea, SW Cyprus, Protaras		
1. Area and Position	**2. Depth Range**	
35 00.708 N, 34 05.821 E	304-428 m	
3. Date	**4. Number of Dives**	**5. Duration Observed**
June 2015	1 Dive	1 hour
6. Mission, Project, Platform		
Visual surveys of the seabed. CYCLAMEN Project-TOTAL foundation (BIO_2014_091_Juin_CS-8). Max Rover ROV		

CHAPTER 5

Table 5.1. Overview of projects, surveys and investigated areas from canyons, seamounts, brine lakes, mud volcanoes, deep-sea basins and slopes of the eastern Mediterranean.

Area	Habitat	Project	Expedition	Research Vessel	Date	No of Stations	Depth range (m)
Ionian Sea (Area 1)	Basin	ADIOS	Cruise 2	AEGAEO	Oct-2001	9	2765 - 2840
		BIODEEP	Cruise 1	AEGAEO	Aug-2001	14	3078 - 3424
		BIOFUN	TRANS-MED	SARMIENTO DE GAMBOA	Jun-2009	3	3335 - 3335
		MATER	TransMediterranean	AEGAEO	Jun-1999	2	3200 - 3200
		REDECO	REDECO Cruise 1	AEGAEO	May-2010	3	3302 - 3315
	Brine	BIODEEP	Cruise 1	AEGAEO	Aug-2001	11	3179 - 3521
	Slope	BIOFUN	TRANS-MED	SARMIENTO DE GAMBOA	Jun-2009	2	2011 - 2012
		REDECO	REDECO Cruise 1	AEGAEO	May-2010	3	2960 - 2980
North Aegean Sea (Area 2)	Basin	MATER	MATER Cruise 1	AEGAEO	Mar-1997	2	798 - 805
			MATER Cruise 2	AEGAEO	Sep-1997	8	115 - 1300
		MITTELMEER 1997/98	METEOR 40/3	METEOR	Dec-1997	9	1244 - 1271
	Slope	MATER	MATER Cruise 2	AEGAEO	Sep-1997	6	145 - 340
			MATER Cruise 3	AEGAEO	Mar-1998	3	650 - 650
South Aegean Sea (Area 3)	Basin	MATER	MATER Cruise 1	AEGAEO	Mar-1997	3	914 - 914
			MATER Cruise 2	AEGAEO	Sep-1997	15	1190 - 2280
		MITTELMEER 1997/98	METEOR 40/3	METEOR	Dec-1997	5	1875 - 1876
	Slope	REDECO	REDECO Cruise 1	AEGAEO	May-2010	2	1049 - 1619
Libyan Sea (Area 4)	Basin	BIOFUN	TRANS-MED	SARMIENTO DE GAMBOA	Jun-2009	1	2845 - 2845
		HERMES	HERMES3 (HCMR)	AEGAEO	May-2006	4	2670 - 3603
		MATER	TransMediterranean	AEGAEO	Jun-1999	3	2950 - 3870
		MITTELMEER 1997/98	METEOR 40/3	METEOR	Dec-1997	9	4282 - 4392
		REDECO	REDECO Cruise 1	AEGAEO	May-2010	3	2707 - 3607
			REDECO Cruise 2	AEGAEO	May-2011	1	3564 - 3564
	Canyon	HERMES	HERMES3 (HCMR)	AEGAEO	May-2006	2	1220 - 2420
	Mud volcano	HERMES	MEDECO Leg 2	POURQUOI PAS ?	Nov-2007	9	1941 - 1943
	Slope	BIOFUN	TRANS-MED	SARMIENTO DE GAMBOA	Jun-2009	2	1204 - 2015
		HERMES	HERMES3 (HCMR)	AEGAEO	May-2006	6	508 - 1910
Levantine Sea (Area 5)	Basin	HERMES	MEDECO Leg 2	POURQUOI PAS ?	Nov-2007	1	2152 - 2152
		ZOOTOP	MSM 14/1	MARIA S. MERIAN	Jan-2010	1	2419 - 2419
	Mud volcano	HERMES	MEDECO Leg 2	POURQUOI PAS ?	Nov-2007	7	2024 - 2029
	Seamount	ZOOTOP	MSM 14/1	MARIA S. MERIAN	Jan-2010	12	874 - 2239

Table 5.2. Presence/absence data of meiofaunal taxa found at the five different areas and habitat types (Bas: Basin; Bri: Brine; Slo: Slope; MV: Mud volcano; SM: Seamount; Can: Canyon).

	Ionian Sea			Levantine Sea			Libyan Sea				North Aegean Sea		South Aegean Sea	
Taxon	Bas	Bri	Slo	Bas	MV	SM	Bas	Can	MV	Slo	Bas	Slo	Bas	Slo
Amphipoda					•	•	•				•	•		•
Annelida incertae sedis				•				•						
Aplacophora											•		•	
Bivalvia	•	•			•	•	•		•	•	•	•	•	
Caudofoveata				•	•				•					
Cnidaria						•								
Copepoda	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Crustacea		•									•		•	•
Cumacea					•						•		•	
Echinodermata							•				•			
Gastropoda		•			•						•	•		
Gastrotricha				•	•	•	•		•	•		•		•
Halacaroidea	•		•	•	•	•	•		•	•	•	•	•	•
Isopoda					•	•			•		•	•	•	•
Kinorhyncha	•		•	•	•	•	•			•	•	•	•	•
Loricifera						•	•			•				•
Mollusca							•				•		•	
Nematoda	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Nemertina							•			•	•	•	•	
Oligochaeta				•	•	•	•		•		•	•	•	
Ostracoda	•	•	•	•	•	•	•		•	•	•	•	•	•
Other	•				•	•	•	•	•	•	•	•	•	
Polychaeta	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Priapulida	•			•	•	•	•		•	•	•	•	•	
Rotifera	•		•	•	•	•	•		•	•				•
Scaphopoda											•			
Sipuncula	•			•	•	•	•		•		•	•	•	
Soft bodied	•	•					•				•		•	
Tanaidacea	•				•	•	•		•	•	•	•	•	•
Tardigrada	•		•	•		•	•	•		•	•	•	•	•
Turbellaria	•	•		•	•	•	•	•	•	•	•	•	•	

CHAPTER 7

Annex 7.1. Projects carried out in the Eastern Ionian and Aegean Seas from 1983 to 2018, the data of which were analysed during this work.

Programmes	Year	Depth range (m)	Gear	Survey type
PATR (Papaconstantinou *et al*., 1987)	1983- 1985	25-364	Bottom trawl	Experimental
Evoikos-Pagassitikos	1985-1988	15-346	Bottom trawl	Experimental
North Aegean	1990-1992	25-546	Bottom trawl	Experimental
Thermaikos-Thrakiko	1991-1993	16-416	Bottom trawl	Experimental
Cyclades-Dodekanisa	1995-1996	30-633	Bottom trawl	Experimental
DEEPFISH (FAIR CT95-0655)	1996-1997	225-777	Bottom trawl	Experimental
INTERREG II Greece-Italy. Measure 3.1)	1999-2000	288-1192	Bottom trawl	Experimental
MEDITS (DGXIV 93/025, 94/051, 95/27, 96/016, 97/41, 99/038, 00/010, DCR 1543/2000) DCF	1994-2001, 2003-2006 and 2008/ 2013-2016 2018	20-800	MEDITS bottom trawl	Experimental
DISC (DGXIV 94/065, 95/061, 97/044)	1995-2000	50-200	Bottom trawl	Commercial
Pagasitikos	1999	21-94	Bottom trawl	Experimental
State of the stocks of European wreckfish (IMBC,98/041)	1999-2001	400-4000	Long lines (LL)	Experimental
RESHIO: DGXIV 99/29)	2000-2001	297-879	Bottom trawl	Experimental
PABOG (DGXIV 00/046)	2001	270-550	Gill net (GN)	Experimental and commercial
CFIS (DGXIV 00/019)	2001	65-245	Bottom trawl	Commercial
Fish aggregating devices (FAD, 99/030)	2001-2003	surface	FAD	Experimental
DCR National Programmes (1543/2000)	2003-2008	48-260	Bottom trawl	Commercial
IMAS (IMAS-Fish, Kavadas *et al*., 2013)	2003-2004	9-135	Trammel nets (TN)	Commercial
		31-655	Bottom trawl	Experimental
		25-70	Bottom trawl	Experimental
Deep water archaeological programme (DANAOS)	2007-2008	550-650	ROV	Experimental
ARG (Argolikos Gulf)	2008	43-611	Bottom trawl	Experimental
MESSARA (EPAL 2008.Measure 4.4)	2008	20-160	Bottom trawl	Experimental
KERK (EPAL 2000-2006.Measure 4.4)	2008	36-70	Bottom trawl	Experimental
CORALF (CoralFISH, FP7 N° 213144)	2010	290-860	Long lines (LL)	Experimental
DCF National Programme	2013-2018	50-500	Bottom trawl	Commercial
COCONET	2013-2014	37-157	Bottom trawl	Experimental
EPILEXIS (EPAL 2007-2013, Measure 3.5)	2014-2015	65-316	Bottom trawl	Experimental

INTERNATIONAL UNION
FOR CONSERVATION OF NATURE

IUCN Centre for Mediterranean Cooperation
C/ Marie Curie 22
29590 Campanillas
Malaga, Spain
Tel. : +34 952 028430
Fax: +34 952 028145
uicnmed@iucn.org

www.iucn.org/mediterranean
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