Key Challenges in Geography
EUROGEO Book Series

Kostis C. Koutsopoulos
Jan H. Stel *Editors*

Ocean Literacy: Understanding the Ocean

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Key Challenges in Geography

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The Importance of Ocean Literacy in the Mediterranean Region—Steps Towards Blue Sustainability

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Abstract Ocean Literacy (OL) is considered to be important for raising awareness of the people concerning conservation, restoration and sustainable use of the ocean and its resources. Addressing environmental issues related to the Mediterranean Sea and increasing OL can be the first step to achieve Sustainable Development Goal 14 (focusing on the ocean) within the UN Agenda 2030 in the Mediterranean region. The adaptation of the Ocean Literacy Framework to the specificities of the Mediterranean Sea can introduce knowledge about different natural, geographical and social components of its marine life and society. This can help different stakeholders (e.g.

The views and opinions of Maria Cheimonopolou in this chapter are her own and do not necessarily reflect those of her institution.

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teachers, educators, scientists, policy- and decision-makers, private sector) to better understand the influence that people have on the Mediterranean Sea, and the influence that the Mediterranean Sea has on them. This chapter gives an insight into the main pressures on the natural environment of the Mediterranean Sea, the legal framework for its protection and sustainability, the importance of integrated coastal zone management and marine protected areas in relation to ocean literacy and the role of education in the creation of an ocean-literate society right across the Mediterranean region. The geographical approach contributes significantly to the exploration and understanding of the relationship between the environment and human communities. Formal and non-formal education in different scientific fields, e.g. geography, biology, etc., as well as increased awareness about the interrelation between people and the Mediterranean Sea, could lead to increased protection and conservation of marine wildlife, sustainable management of Mediterranean marine resources and therefore sustainable blue development of the region.

Keywords Ocean Literacy · SDG 14 · Mediterranean Sea · Mediterranean Sea Literacy · Environmental Education · UN Decade of Ocean Science for Sustainable Development

Introduction

The "Sea in the middle of the Earth", the Mediterranean Sea, is the largest and deepest enclosed sea on earth, the cradle of western civilization and one of the most important global biodiversity hotspots, with iconic species worthy of conservation. It is a natural laboratory for geologists, naturalists, biologists and other scientists, and an inspiration for photographers, writers and people who love nature; an extraordinary and fragile treasure chest of biodiversity which needs to be protected. The Mediterranean Sea is also a crucial route for the global economy and trade, geopolitically important, home for approximately 500 million people and a holiday destination attracting more than 300 million tourists per year.

The unique geographic and oceanographic features of the Mediterranean Sea combined with anthropogenic pressures such as coastal urbanization, tourism, overfishing, marine aquaculture, pollution and climate change (Fernandes et al. 2017; Grigorakis and Rigos 2011; Piroddi et al. 2017) have inevitably lead to crucial alterations in the Mediterranean Sea environment. In particular, these pressures affect species, biological communities, ecosystem functioning and its capacity to provide essential goods and services to the society (Guidetti et al. 2014). A geographical approach to these issues can help us to visualize their spatial distribution on different scales, from the global to the local, as well as their potential impact on society and the ability to provide solutions. Geographic tools, such as world and geological maps, bathymetric maps, global ocean circulation models, Geographic Information Systems (GIS), Global Positioning System (GPS), European Atlas of the Sea, Google Earth and Google Maps, can make valuable contributions to our knowledge concerning the

relationships between marine natural elements and societal phenomena and processes in the Mediterranean region, thus bridging the environmental and social sciences.

In 2017 the United Nations convened a high-level Our Ocean Conference to support the implementation of Sustainable Development Goal 14 (SDG 14): Conserve and Sustainably Use the Oceans, Seas and Marine Resources, of the 2030 Agenda for Sustainable Development. One outcome of this conference was an intergovernmentally agreed declaration, a "Call for action", who's Article 13.a reads as follows: "*Support plans to foster ocean-related education, for example as part of education curricula, to promote ocean literacy and a culture of conservation, restoration and sustainable use of our ocean*", hence emphasizing the importance of ocean literacy. This demonstrates the strong commitment of the UN to conserve and manage ocean and marine resources for sustainable development both now and in the future. Moreover, the UN has declared a Decade of Ocean Science for Sustainable Development 2021–2030 to support and achieve SDG 14, which simultaneously supports other SDGs (Ryabinin et al. 2019). The Decade aims to achieve major scientific and technological progress by generating seven societal outcomes, one of which is "an inspiring and engaging ocean where society understands and values the ocean in relation to human wellbeing and sustainable development", which includes considerable advancement and increase of ocean literacy in society, from education and school curricula, to decision-makers and the public at large (UN 2020). Moreover, the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) is currently developing the Ocean Literacy Strategy—ocean literacy for the UN Decade of Ocean Science for Sustainable Development—in order to advance ocean literacy during the UN Decade.

In order to achieve SDG 14 in the Mediterranean region, citizens need to know and be aware of both the sea-related benefits and the threats that might cause the loss of those benefits. Education, which is essential if SDGs are to be achieved, has its own dedicated Goal 4, which aims to "*ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*". Therefore, empowering citizens to make environmentally responsible decisions through ocean literacy education and Mediterranean Sea Literacy (MSL) can make a substantial contribution towards the achievement of SDG 14 in the Mediterranean.

The Mediterranean Sea Literacy Guide was developed by the regional Mediterranean group of the European Marine Science Educators Association (EMSEA-Med), a group consisting of scientists and educators whose aim is to relate the concept of ocean literacy to the Mediterranean region. It is based on ocean literacy principles and concepts adapted to the specificities of the Mediterranean Sea (the latest version of the Mediterranean Sea Literacy guide is available at: http://www.emsea.eu/default.php). MSL guide introduces knowledge about different natural, geographical and social components of marine life and society related to the Mediterranean Sea. Its goal is to help different parts of society including teachers, educators, scientists, policy/decision-makers and the private sector, to better understand the vital importance of the two-way interaction between the Mediterranean Sea and its regional human societies. Raising awareness and creating an ocean-literate society

Fig. 1 NGO voluntary teaching about marine animals' identification for creating an ocean-literate society (project from Liguria, Italy, since 2012) (Photo by: Informare)

can contribute to achieving conservation, restoration and a sustainable blue economy in the "Mare Nostrum".

This chapter will give an insight into the main pressures on the natural environment of the Mediterranean Sea, the legal framework for its protection and sustainability, the importance of integrated coastal zone management and marine protected areas in relation to ocean literacy and the role of education in the creation of an ocean-literate society across the Mediterranean (Fig. 1).

Anthropogenic Pressures Affecting the Mediterranean Sea and Its Resources

Coastal Urbanization

In ancient times, many urban areas around the Mediterranean Sea were located inland from the coast for defensive reasons (Greek urbanization model; UNEP 2001). However, in recent times this well-established pattern changed rapidly, as secondary urban areas were built along the shoreline (UNEP 2001). These new settlements, along with others established initially on the coast (UNEP 2001), have been growing

Fig. 2 An example of the coastal urbanization in Genoa, Italy (Photo by: M. Stefanolo)

ever since, in many cases in a rapid and uncontrolled manner, thus fundamentally transforming Mediterranean coastal environments (Fig. 2).

Nowadays, urbanization is an important driver of change in land use in the Mediterranean basin (Garcia-Nieto et al. 2018). Approximately one-third of the Mediterranean population is situated in the coastal area. The population of the coastal countries is predicted to grow from 466 million in 2010 to 529 million by 2025 (UNEP/MAP 2016).

Demographic growth, rural depopulation and tourism development are among the growth factors of the coastal urbanization phenomenon (Enne et al. 2009; UNEP 2001). High urban occupation leads directly and/or indirectly to soil loss, coastline erosion, reduction of water resources, pollution of groundwater, surface and seawater biodiversity loss, ecosystem fragmentation, soil and groundwater salinization, irreversible loss of fragile, coastal ecosystems (e.g. wetland areas, dune systems), desertification, high flood risk, etc. (Enne et al. 2009; Malak et al. 2011; UNEP/MAP/PAP 2001). In addition, the densely populated, low-elevation coastal Mediterranean zone, along with its fragile ecosystems, is expected to be highly impacted by sea-level rise (Wolff et al. 2018), thus affecting the development of coastal planning, e.g. tourism, human migrations (Galassi and Spada 2014).

Tourism in the Mediterranean

The Mediterranean basin is one of the most popular tourist destinations in the world with over 30% of total global tourism occurring in this region. While tourism in the Mediterranean contributes largely to the region's economic production, it also plays a critical role in the deterioration of the marine environment (Randone et al. 2017).

Coastal and maritime tourism therefore exerts immense pressure on the Mediterranean region. The development of tourism in coastal and marine regions changes the original features of the visited destinations which had attracted tourists in the first place. Decades of mass tourism have led to the decline of previously pristine areas, thus threatening the health of the iconic Mediterranean coasts. Unfortunately, according to Zahedi (2008), nations prioritize immediate economic benefit before long-term environmental sustainability and protection.

Marine and coastal ecosystems are threatened by mass tourism development, which is one of the main drivers of ecosystem degradation in the region, intensifying the littoralization process, and consequently, resulting in the loss of natural resources and the accumulation of waste (Fosse and Le Tellier 2017; Randone et al. 2017; Zahedi 2008).

Cruise ship tourism in the Mediterranean makes up 18.7% of all world cruise destinations (Dowling and Weeden 2017; Ocean Atlas 2017). The United Nations Environment Programme (UNEP) has identified tourist ships as one of the main pollution sources in the marine environment (Carić and Mackelworth 2014). Even though modern ships have reduced their environmental impacts, they are still a significant source of air, noise and marine pollution. Ships' biofouling and ballast water release systems constitute major pathways for the introduction of invasive species into the marine environment of the Mediterranean Sea. In addition, recreational boating has a significant ecological impact on the environment through habitat degradation via anchoring (Fig. 3), construction of marinas and ports, production of waste water and litter, noise, etc. For example, anchoring in the beds of the endemic species

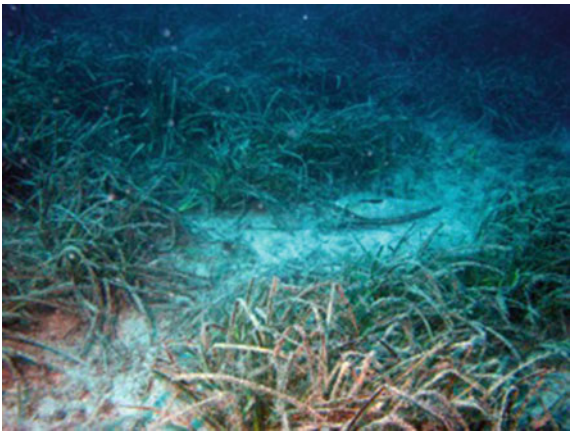

Fig. 3 Mediterranean endemic species *Posidonia oceanica* and *Pinna nobilis* are some of the most threatened species caused by human impacts such as anchoring (Photo by: H. Čižmek)

of *Posidonia oceanica* (Linnaeus) Delile (1813) can have a severe negative impact on this particular habitat and on related organisms (Montefalcone et al. 2006, 2008). Anchors can also damage individual species as evidenced by the mass mortality event of the noble pen shell, *Pinna nobilis* (Linnaeus, 1758) (Fig. 3) around the western Mediterranean, or the Mediterranean pillow coral, *Cladocora caespitosa* (Linnaeus, 1767) (Vázquez-Luis et al. 2017), and impact community assemblages such as the coralligenous bio-concretions (Gerovasileiou et al. 2009; Milazzo et al. 2002). In addition, mechanical destruction of seagrass beds can cause the erosion of organic carbon stocks conserved in the sediment, which may lead to increased atmospheric CO_2 (Serrano et al. 2016).

Overfishing and Marine Aquaculture

Fish stocks in the Mediterranean Sea have been declining for decades. Targeted or multi-species fisheries are the most common threat to marine fishes, directly affecting 33% of native species in the Mediterranean Sea, and another 18% indirectly which are caught as bycatch species (Malak et al. 2011). In particular, during the last 60 years there was a reduction in the abundance of fish species (~34%) and top predators (~41%) (Piroddi et al. 2017). Most stocks continue to be fished beyond biologically sustainable limits. The European hake, *Merluccius merluccius* (Linnaeus, 1758), is by far the most overexploited species in the Mediterranean, followed by red mullet, *Mullus barbatus* (Linnaeus, 1758), and sardine, *Sardina pilchardus* (Walbaum 1792) (FAO 2018). The iconic and commercially important Atlantic bluefin tuna, *Thunnus thynnus* (Linnaeus, 1758) is listed as endangered in the IUCN Red List of Threatened Species, due to its population decline resulting from decades of overfishing and mismanagement in the Mediterranean (Malak et al. 2011). Nowadays, the Mediterranean and the East Atlantic bluefin tuna stocks show signs of population growth. Although there is uncertainty regarding the level of this recovery, it demonstrates that effective management of international fisheries regarding highly valuable species, overexploited for decades, is still possible (Fromentin and Rouyer 2018). In addition, native Mediterranean cartilaginous fish (e.g. sharks, rays) face a 53% risk of extinction, as they constitute a retained valuable fisheries bycatch (IUCN 2016).

Overfishing causes a reduction in density, biomass and reproductive potential of fish stocks, as well as dramatic changes in the structure and functioning of food webs and in the physical properties of the seafloor (Guidetti et al. 2014). Bottom trawling, in particular, directly causes a reduction in the complexity and availability of benthic habitats (Malak et al. 2011), a decrease in benthic biomass and biodiversity and affects the functioning and productivity of benthic ecosystems (Eigaard et al. 2017). Non-resilient deep-water Mediterranean benthic ecosystems are especially vulnerable (Paradis et al. 2017), as traditional fishing grounds have been shifting to deeper habitats over the last 50 years.

Food resource depletion resulting from overfishing also impacts marine mammals, turtles and birds (Soriano-Redondo et al. 2016; UNEP/MAP 2012). Characteristic

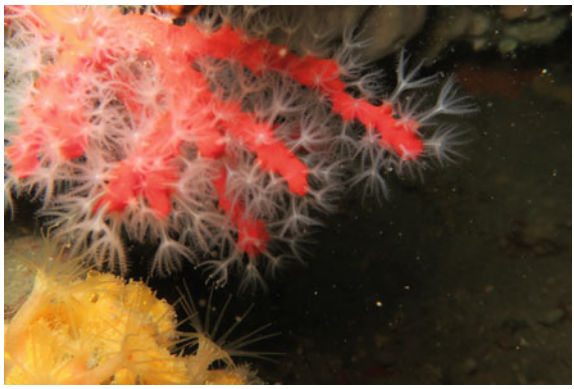

Fig. 4 *Corallium rubrum* is a characteristic Mediterranean habitat-forming species impacted by overfishing (Photo by: Informare)

Mediterranean habitat-forming species, such as the red coral, *Corallium rubrum* (Linnaeus, 1758) (Fig. 4) and *P. oceanica* meadows, as well as inshore rocky habitats, are also impacted (Cattaneo-Vietti et al. 2016). Overfishing of natural fish stocks is a contributing factor which has led to a rapidly growing mariculture sector in the Mediterranean region. Over the recent decades, Gilthead sea bream, *Sparus aurata* (Linnaeus, 1758) sea bass, *Dicentrarchus labrax* (Linnaeus, 1758), have become the most commercially important finfish followed by molluscs as aquaculture species (Grigorakis and Rigos 2011).

Aquaculture production around the Mediterranean and the Black Sea, coming mostly from marine and brackish waters, reached more than 2.3 million tonnes in 2013, having increased by 164% since 1993 (Massa et al. 2017). Consequently, intensive farming of marine animals impacts the Mediterranean marine environment in many ways, such as genetic interactions between native and escaped cultured fish, introduction of alien species, transfer of diseases, release of organic wastes, habitat alteration, etc. (Grigorakis and Rigos 2011).

Pollution

Eighty percent of pollutants in the Mediterranean Sea (UNEP/MAP-MEDPOL/WHO 2008; UNEP/MAP 2012) come from land-based sources. Marine and coastal pollution can be linked to the presence of nutrients, organic matter, microorganisms, heavy metals, persistent organic pollutants (POPs), oil pollution, litter as well as types of energy as underwater sound (European Commission 2017; UNEP/MAP 2012).

Nutrients, Organic Matter and Microorganisms

Eutrophication is the result of nutrient inputs (e.g. dissolved nitrogen and phosphorus) into Mediterranean waters, which predominantly originate from municipal sewage

and agricultural fertilizer run-off. It causes the decline of macrophytes leading to their replacement by short-lived algal species, as well as causing radical changes in phytoplankton communities which may result in harmful algal blooms (HABs) (UNEP/MAP 2012). Some micro-algae responsible for HABs produce toxins that may bioaccumulate in organisms, with adverse effects on shellfish, fish, marine birds and mammals including humans (Ferrante et al. 2013; UNEP/MAP 2012). Temporary and prolonged bans on the harvesting and sale of mussels resulting from HABs, have frequently affected molluscan aquaculture in the Mediterranean Sea (UNEP/MAP 2012). Within the Mediterranean Sea, eutrophication is a localized phenomenon, occurring mainly in semi-enclosed coastal areas as in the North Adriatic Sea (nutrient inputs from river Po) (Boesch 2019) and not in oligotrophic open waters (UNEP/MAP 2017).

Organic matter originating from eutrophication processes, mostly from urban and industrial waste waters, has a synergetic effect in depleting oxygen by their decomposition and causing a reduction in light penetration in marine and coastal Mediterranean waters. Benthic communities, including seagrass meadows (Fig. 5), are the first to suffer from significant loss of biodiversity in Mediterranean areas such as those adjacent to sewage outfalls or within urbanized bays (UNEP/MAP 2012). These changes cause a deterioration in water quality and consequently have an impact on tourism.

Sewage effluents containing human and animal excreta (wildlife and domestic animals) are cited as possible pathogenic contaminants of Mediterranean recreational waters (Fewtrell and Kay 2015; UNEP/MAP-MED POL/WHO 2008), commonly causing human enteric illness (Kamizoulis and Saliba 2004; UNEP/MAP-MED POL/WHO 2008).

Phytoplankton species under stress conditions, as well as algal blooms, may be responsible for the formation of marine mucilage affecting Mediterranean coastal areas, especially in the northern Adriatic Sea (Carroni et al. 2015; Danovaro et al.

Fig. 5 Seagrass meadow of *Posidonia oceanica* in the shallow water of coastal area of Liguria, Italy (Photo by: Informare)

2009). The consequences for the marine environment are adverse, resulting in lower ecosystem resilience and damage to tourism and fisheries.

Heavy Metals, Persistent Organic Pollutants (POPs) and Oil Pollution

Atmospheric deposition, run-off from metal-contaminated sites and urban and industrial waste waters represent the major sources of toxic metals (e.g. mercury, lead, cadmium) in the Mediterranean Sea. Heavy metal concentrations (e.g. mercury) in Mediterranean fish have been found to be twice as high as those found in the same species living in the Atlantic Ocean (UNEP/MAP 2012). Risks to Mediterranean ecosystems are also present from the effects of bioaccumulation, not only of toxic metals but also of persistent organic pollutants (POPs) in shellfish and/or top predators such as the bluefin tuna (Chiesa et al. 2016). Disruption of the endocrine and reproductive systems of marine organisms (e.g. Mediterranean swordfish, *Xiphias gladius* (Linnaeus, 1758) is among the recorded effects of POPs, leading to the increase of ecological stress in marine and coastal organisms in general (UNEP/MAP 2012).

Oil pollution in the Mediterranean Sea is linked to major shipping routes in open waters and oil-related facilities (e.g. refineries, terminals and ports) in nearshore waters. The latter generally exhibit higher concentrations of polycyclic aromatic hydrocarbons (PAHs), the most toxic compounds of crude oil, in marine organisms and sediments surrounding these facilities (UNEP/MAP 2012). PAHs are known to have multiple effects at the genetic, cellular, biochemical and physiological levels of various species (UNEP/MAP 2012). The extraction of large oil and gas reserves, recently discovered in the eastern Mediterranean, increases pollution risks with unknown effects on the unique deep-sea eastern Mediterranean ecosystems (Liu et al. 2017).

Marine Litter

In the Mediterranean Sea, while marine litter has been an issue of concern since the 1970s, today it poses a critical, complex and multidimensional problem for the region (UNEP/MAP 2015). Marine litter is found washed ashore along the coastline, floating in the water column and also lying on the seafloor. Plastic materials dominate on the beaches (Fig. 6), accounting for over 80% of the marine litter found there (ICC 2016; UNEP/MAP 2017). Microplastics (<5 mm) have been found in the Mediterranean in concentrations which are among the highest in the world (Suaria et al. 2016).

Ingestion of, or entanglement in, marine litter is among the most significant impacts on marine life. In particular, ingested microplastics by zooplankton enter marine food webs. Zooplanktivorous predators (mesopelagic fish, baleen whales, some sharks) are exposed to microplastics by direct ingestion of contaminated zooplankton and/or accidental ingestion during feeding activity (Fossi et al. 2016). Furthermore, microplastics are carriers of toxic chemicals that bioaccumulate, having

Fig. 6 Frequent image on the Mediterranean beaches: plastic bottle that is destined to fragment into smaller pieces known as microplastics (Photo by: Informare)

Fig. 7 Mediterranean red gorgonians *Paramuricea clavata* (Risso, 1826) (Photo by: Informare)

a major toxicological impact on marine organisms (Fossi et al. 2016; Romeo et al. 2015) and possibly on humans (Seltenrich 2015). Ingested marine debris was found in up to 80% of pelagic turtles *Caretta caretta* (Linnaeus, 1758) in the central Mediterranean in a recent study (Casale et al. 2016). Accidental entanglement has been identified as one of the most important threats to the survival of the world's most endangered seal species, the Mediterranean monk seal, *Monachus monachus* (Hermann, 1779) (Karamanlidis et al. 2008). More than half of the recorded debris in the deep-sea floor in the northwestern Mediterranean come mostly from fishing gear, directly impacting benthic organisms, primarily gorgonian corals (Fig. 7), followed by black corals and sponges (Angiolillo et al. 2015). Consequently, Mediterranean marine litter has widespread impacts on marine biodiversity and Mediterranean Sea ecosystem services.

Underwater Sound

Sound travels five times faster in water than in air and consequently covers longer distances (Rako-Gospic and Picciulin 2019). Therefore, it is utilized by marine organisms, i.e. for communication, prey location, mating and navigation (Hildebrand 2009; Rako-Gospic and Picciulin 2019). However, the level of underwater noise caused by anthropogenic activities has alarmingly increased worldwide in the last decades causing different impacts on marine life (Hildebrand 2009; Peng et al. 2015) and therefore has been recognized as a source of pollution by the European Commission (Marine Strategy Framework Directive, 2008/56/EC). It is mainly caused by marine traffic, coastal and offshore works (e.g. harbours, wind farms, oil and gas wells drilling), seismic surveys (e.g. hydrocarbon extraction), naval exercises (e.g. sonars and detonations), fishing, oceanographic experiments and geophysical mapping (Hildebrand 2009; Maglio et al. 2016; Peng et al. 2015).

Potential effects of anthropogenic sound sources target a variety of marine organisms and range from body malformations during larval development to reduction of growth and reproductive rates, auditory damage and hearing loss, displacement from feeding or breeding areas and stranding of certain species (Anguilar de Soto et al. 2013; Carroll et al. 2017; Peng et al. 2015).

The first rough overview of spatial occurrence of noise-producing anthropogenic activities in the Mediterranean Sea was performed for cetacean conservation (e.g. geophysical surveys, coastal and offshore industrial projects, military operations, marine traffic,) and several noise hotspots were identified(Maglio et al. 2016). The Ligurian Sea, the Straits of Sicily and the Northern part of the Hellenic Trench are the areas where cetacean habitats overlap with noise hotspots (Maglio et al. 2016). Military operations (e.g. naval exercises that use mid-frequency active sonars) are responsible for stranding events of Cuvier's beaked whales, *Ziphius cavirostris* (Cuvier, 1823) along the coasts of the Mediterranean Sea for the last two decades (Maglio et al. 2016). Cephalopods of the Mediterranean Sea, such as the European squid, *Loligo vulgaris* (Lamarck, 1798), common cuttlefish, *Sepia officinalis* (Linnaeus, 1758), common octopus, *Octopus vulgaris* (Cuvier, 1797) and southern shortfin squid, *Illex coindeti* (Vérany, 1837), experience acoustic trauma when exposed to high-intensity and low-frequency sound which can be caused by research surveys (André et al. 2011). In the Adriatic Sea, it has also been observed thatacoustic communication of the Mediterranean finfish is possibly affected by boat noise (Codarin et al. 2009). Further studies in the field of marine noise are needed to define impacts of underwater sound on marine biota in the Mediterranean Sea.

Climate Change and Ocean Acidification

Climate change is affecting the Mediterranean region, and it is expected to become drier and warmer over the course of the twenty-first century. Climatic models predict a pronounced decrease in precipitation and an increase in frequency of extremely

Fig. 8 Mediterranean endemic calcifying coral *Cladocora caespitosa* (Linnaeus, 1767) (Photo by: Informare)

high-temperature events in the Mediterranean region, as well as rapid mean warming (Giorgi and Lionello 2008), which will also affect the marine environment. Mediterranean warming has impacts on growth, survival, fertility, early life history, reproduction, migration and phenology of pelagic and benthic organisms, ranging from phytoplankton to marine vegetation, invertebrates and vertebrates (Lacoue-Labarthe et al. 2016; Marbà et al. 2015). In addition, endemic marine species, which are characterized by a limited capacity to adapt to ocean warming, are severely affected (Marbà et al. 2015) (Fig. 8). Disease outbreaks related to climatic events are becoming more frequent in the Mediterranean Sea: faunas are shifting (geographical distribution) and invasive species are spreading and becoming established within an already highly impacted marine biota (Lejeusne et al. 2010).

Climate change is also raising the sea level in the Mediterranean, which will impact densely populated coasts by the flooding of low-lying coastal areas, erosion of beaches and salt intrusion into freshwater aquifers (Aral and Chang 2017; Lichter et al. 2010; Mabrouk et al. 2013). Additionally, the increase of evaporation along with damming of rivers has led to an increase in salinity since the 1960s (Borghini et al. 2014).

Anthropogenic-induced emissions of carbon dioxide are primarily responsible for the acidification of Mediterranean Sea waters. A remarkably decreasing annual trend in the Mediterranean pH has been documented and can be interpreted as an indicator of acidification within the Basin (Flecha et al. 2015). There is evidence that Mediterranean acidification negatively affects the survival, growth and early life history of shellfish (Lacoue-Labarthe et al. 2016). Though fish, as motile species, are more resilient to acidification, they are nonetheless also affected by it. Fisheries and aquaculture, which are of important economic value in the Mediterranean, will, most likely, also be impacted.

Microalgae, seaweed communities and seagrass meadows will be impacted by acidification, causing the potential loss of important habitats for a wide range of

organisms and possibly favouring non-indigenous algal species (Lacoue-Labarthe et al. 2016).

Vermetids and calcifying corals are particularly vulnerable to acidification, which most likely will lead to the loss of biodiversity and shore erosion in the case of vermetid reefs (Lacoue-Labarthe et al. 2016). At the community scale, a shift to more carbon dioxide-tolerant species could lead to a proliferation of jellyfish and anemones, which are resilient to, or actively benefit from warming and/or acidification (Lacoue-Labarthe et al. 2016).

Another consideration is that changes in seawater chemistry can modify the bioavailability of contaminants, favouring bioaccumulation in some sea organisms and consequently in human consumers (Lacoue-Labarthe et al. 2016).

The resulting lack of healthy marine ecosystems can cause severe socio-economic impacts. Decline of fisheries and aquaculture production as well as quality decline of coastal tourism will lead directly and/or indirectly to loss of employment, reduction of food security, human health and wealth of Mediterranean countries (Cramer et al. 2018; Weatherdon et al. 2016). Regional differences also tend to increase, particularly between the North and the South of the Mediterranean region (Linares et al. 2020; Werz and Hoffman 2017). Alterations of Mediterranean marine and coastal environments due to human pressures, but especially due to climate change along with population growth and sociopolitical instabilities, can trigger further migration of human populations and jeopardize human security in the Mediterranean region (Cramer et al. 2018; Werz and Hoffman 2017).

Biodiversity Loss: A Major Consequence of Pressures

The Mediterranean Sea is considered to be a biodiversity hotspot with approximately 17,000 species of marine organisms (Bianchi and Morri 2000; Coll et al. 2010, 2012; Cuttelod et al. 2008). Both its geological history and environmental conditions have led to this great diversity of marine life (Bianchi and Morri 2000; Mannino et al. 2017). However, the Mediterranean Sea is "under siege" when it comes to marine biodiversity, as stated in Coll et al. (2012). The current state of biodiversity reflects the cumulative effects of the anthropogenic pressures affecting the Mediterranean coastal and marine environment, as despite this richness of life the existence of many species is threatened, with some of them subject to multiple pressures (UNEP/MAP 2012).

The Mediterranean Sea is one of the regional seas most impacted by different anthropogenic pressures, which were previously mentioned, in addition to shipping. Biofouling and ballast water transportation along shipping routes have triggered the introduction of non-indigenous species in the Mediterranean Sea. Further non-indigenous species have been introduced via the Suez Canal and through aquaculture. The establishment of non-indigenous species, which may be further encouraged by climate change, is considered one of the main causes of biodiversity loss in the

Fig. 9 A loggerhead turtle, *Caretta caretta*, accidentally caught by a beach seine net in Elounda Bay, Crete, Greece (ICZM project of the IMBBC) (Photo by: C. Dounas)

Mediterranean (Coll et al. 2010; Galil 2007; Otero et al. 2013) as they have the potential to affect many aspects of marine and other aquatic ecosystems.

Many species are currently considered to be threatened in the Mediterranean Sea (UNEP-MAP RAC/SPA 2010), such as the Mediterranean monk seal *Monachus monachus* (Hermann, 1779) and the European eel *Anguilla anguilla* (Linnaeus, 1758). Top predators in the Mediterranean, such as sharks, are facing a particularly high risk of extinction caused by accidental killing, intensive fishing activities and pollution, all of which represent severe threats towards these species (Cuttelod et al. 2008). Incidental entanglement in fishing gears also impacts marine mammals, turtles and birds (Fig. 9), which are long-lived species with low reproductive rates and delayed sexual maturity (Soriano-Redondo et al. 2016; UNEP/MAP 2012).

Conservation actions are needed to protect and preserve this rich biodiversity. Individual species protection measures, networks of Marine Protected Areas (MPAs), conservation of the wider environment using an ecosystem-based approach, additional monitoring and research, communication and education all play complementary roles in preserving Mediterranean biodiversity (Cuttelod et al. 2008) (Fig. 10).

The importance of biodiversity conservation has been reinforced recently during the COVID-19 pandemic, as some diagnostic tests used for detecting the SARS-Cov-2 virus are based on an enzyme isolated from bacteria living in Mediterranean hydrothermal vents (Belkin et al. 1986).

Fig. 10 An example of a Mediterranean coralligenous assemblage, one of the most biodiverse habitats (Photo by: Informare)

Pressures and Ocean Literacy

Pressures, predominantly caused by humans, threaten Mediterranean marine ecosystems as well as their resources and services and, consequently, societies of the region. They are derived not only from coastal activities but also from those inlands. Humans—whether they live, work, holiday by the sea or away from it—influence, most of the time in a negative way, the Mediterranean Sea. Ocean literacy as a common practice can empower people to make informed decisions and take responsible actions, thus contributing to a healthy Mediterranean Sea and support its many different societies and cultures (Stoll-Kleemann 2019). To achieve sustainability of the Mediterranean Sea, different stakeholders and sectors as well as citizens need to understand the relationship between their activities and the resulting pressures they put upon marine ecosystems, their resources and services.

Threats that are pressing marine ecosystems are not always understood by the general public (Kopke et al. 2019; Lotze et al. 2018), which can be a barrier for achieving a pro-environmental societal change (Kopke et al. 2019). Scientific outreach and dissemination can be used to overcome this barrier and favour informed and responsible decisions, concerning marine ecosystems, of all involved stakeholders (researchers, policy makers, local communities, etc.) (Mea et al. 2016). However, knowledge itself doesn't always lead directly to ocean citizenship but knowledge together with public awareness are necessary prerequisites for behavioural and societal changes (Fletcher and Potts 2007). Furthermore, by combining knowledge provision as well as individuals' emotional involvement in choices regarding ocean-related topics, individuals are more likely to engage in pro-environmental behaviours and attitudes that would lead to advanced ocean literacy (Jefferson et al. 2015; Kollmuss and Agyeman 2002; Stoll-Kleemann 2019). A recent study carried out by Ashley et al. (2019) showed that OL initiatives and activities lead to an increase in knowledge, awareness and attitudes of the people

which consequently support actions that reduce negative impacts on the marine environment.

A plethora of educational and citizen science projects have been performed in Mediterranean countries, though the impact of such OL activities is not always thoroughly evaluated (for a detailed list of the projects see "Ocean-Related Educational Projects and Networks in the Mediterranean" subsection of this chapter). These projects promote activities relevant to OL, which provide knowledge concerning human pressures on the marine environment and aim to change behaviours and attitudes of students, teachers, stakeholders and citizens. Several of them (e.g. CIGESMED, COMBER, Green Bubbles, Harmony, MARLISCO, MELTEMI, PERSEUS, Reef Check Italia, Sea for Society, Spot the jellyfish) identify human pressures (e.g. marine litter, tourism) as well as the resulting biodiversity loss and climate change through participatory approaches and involvement of different target groups of participants (e.g. volunteer divers, students, citizens). This way, the projects aim to enhance understanding of the links between natural and anthropogenic pressures and ecosystem functioning of the Mediterranean Sea. The role of Marine Protected Areas (see also section "Marine Protected Areas" of this chapter for the role of MPAs in OL) is also fundamental for promoting OL activities (e.g. MPA-adapt, MPA-engage).

Projects that have been carried out within the OL framework and worth mentioning are: (a) ResponSEAble, aimed to map European marine research and knowledge, to understand the complex human–ocean relationships and to provide a wide range of media and outreach activities; (b) Sea Change, aimed to establish a fundamental "Sea Change" in the way European citizens view their relationship with the sea, by empowering them, as Ocean-Literate citizens, to take direct and sustainable action towards a healthy ocean, healthy communities and ultimately a healthy planet; and (c) MARINE_ECOMED, an Erasmus + project aiming at creating an international strategic partnership in order to promote sustainable marine management and communication strategies in the Mediterranean Region by developing educational materials (for details see "Ocean-Related Educational Projects and Networks in the Mediterranean" subsection).

Additionally, the "Mediterranean Education for Sustainable Development" (MEdIES), the major educational and training initiative of the Mediterranean Information Office for Environment, Culture and Sustainable Development, was launched in Johannesburg during the World Summit on Sustainable Development in 2002. The aim of MEdIES is to facilitate the educational community to contribute in a systematic and concrete way to the implementation of Agenda 21 and Agenda 2030, through the successful application of innovative educational programmes in all Mediterranean countries (for details see "Ocean-Related Educational Projects and Networks in the Mediterranean" subsection).

Legal Framework for the Protection and Sustainability of the Mediterranean Sea

The UN Environment's Regional Seas Programme (1974) has created a unique approach to the protection of the coastal and marine environment. The aim of the programme is to promote cooperation among neighbouring countries to foster the "shared seas" approach, and to develop concerted actions for their protection. In 1975, the Mediterranean Action Plan (MAP) was adopted and this, the first-ever Regional Seas Programme under the UN Environment umbrella, was followed by the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention) (1976). Its main objectives are related to the assessment and control of marine pollution, sustainable management of natural marine and coastal resources, protection of the natural and cultural heritage, solidarity among Mediterranean coastal states and improvement of the quality of life. The Barcelona Convention has seven protocols: dumping at sea; prevention and emergency response to pollution by oil and other harmful substances; land-based pollution; specially protected areas and biodiversity; protection from pollution deriving from offshore activities; transboundary movement of hazardous wastes and integrated coastal zone management.

Under these conventions, the Mediterranean countries must address multiple challenges to improve the sustainability of the marine environment, taking into consideration its physical, geographical and oceanographic characteristics, as well as its geopolitical context. Overall governance of the region should take into account its extremely heavy maritime traffic, the legal and illegal transportation of humans, the over-exploitation of living and non-living marine resources, without forgetting the need to protect its immense cultural heritage and its importance as a hotspot for marine biodiversity.

With regard to shipping, all Mediterranean countries are members of the International Maritime Organization (IMO), which is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships (MARPOL Convention).

In the Mediterranean region there are also some interesting sub-regional arrangements such as: (a) the Agreement concerning the Creation of a Marine Mammal Sanctuary in the Mediterranean, created between France, Italy and Monaco which has resulted in the establishment of the Pelagos Sanctuary (Fig. 11); (b) the RAMOGE Agreement, applicable to the area between Marseille (France) and La Spezia (Italy), which provides for scientific, technical, legal and administrative cooperation to be decided jointly on actions to be undertaken for integrated management of the coastline; and (c) the Agreement on the Conservation of Cetaceans in the Black Sea, the Mediterranean Sea and the contiguous Atlantic Area (ACCOBAMS), which aims to protect cetaceans, and which has been ratified by most Mediterranean States.

There are two regional fisheries organizations in the Mediterranean: (a) the General Fisheries Commission for the Mediterranean (GFCM), which promotes the development, conservation, rational management and best utilization of living marine

Fig. 11 Cetaceans in the Pelagos Sanctuary, the Mediterranean Marine Mammal Sanctuary (Photo by: Informare)

resources, as well as the sustainable development of aquaculture in the Mediterranean, the Black Sea and connecting waters; and (b) the International Commission for the Conservation of Atlantic Tunas (ICCAT), which concerns the conservation and management of tuna and tuna-like species.

Several key EU policies are also important for the protection and sustainability of the Mediterranean region such as: (a) the Water Framework Directive (WFD; 2000/60/EC), which aims to achieve good water quality status for all EU water bodies (including marine waters up to one nautical mile from shore); (b) the Marine Strategy Framework Directive (MSFD; 2008/56/EC), which aims to achieve Good Environmental Status (GES) for the EU's marine waters and to protect the resources upon which marine-related economic and social activities depend; (c) the Blue Growth Strategy (COM (2012) 494), which is Europe's long-term strategy to support sustainable growth in the marine and maritime sectors as a whole; (d) the Maritime Spatial Planning Directive (MSP; 2014/89/EU), which is a framework for the integrated governance of maritime activities in order to mitigate degradation, restore and sustain critical monetary and social/cultural ecosystem services; (e) the Common Fisheries Policy (CFP; EC/170/83), a set of rules for managing European fishing fleets and for conserving fish stocks, which aims to ensure that fishing and aquaculture are environmentally, economically and socially sustainable and that they provide a source of healthy food for EU citizens; (f) the Habitats Directive (92/43/EEC), which aims to promote the maintenance of biodiversity, taking into account economic, social, cultural and regional requirements; (g) the Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 on port reception facilities

for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC; and (h) the Single-Use Plastics Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.

Top-down approaches, such as legal and policy frameworks that define citizens' rights of access to information, consultation and active participation as well as the institutions charged with the application of these rights, are built (OECD 2001). Therefore, they are important for government–citizens relations concerning the protection and conservation of the marine environment as well as sustainable use of its resources and development. On the other hand, bottom-up approaches (e.g. public awareness-raising, citizens' active engagement, individual/societal behaviours and attitudes) towards this direction are also necessary and include the development of tools and practices inevitably connected with ocean literacy (e.g. guides, leaflets, educational materials, workshops for marine educators/students, information centres, events, civil society organizations). The public opinion and actions in shaping the policy agenda (e.g. Single-Use Plastics Directive) are strongly enhanced when a large part of the community becomes ocean literate. The need of large and informed participation of individuals in environmental issues is also important in order to facilitate the required individual/societal behavioural changes and attitudes. This connection invokes a sense of global ownership and responsibility, therefore leading to more stable and sustainable management approaches to ocean governance (French et al. 2015).

Europe has increasingly moved towards an ecosystem-based approach rather than regulating maritime activities through separate sectoral policies, recognizing the complex relationship between environmental problems and human activities (French et al. 2015). To that end, the EU has adopted more than 200 pieces of legislation that affect marine environmental policy and management and has developed an extensive policy framework in order to manage and address the environmental challenges and human activities influencing Europe's seas (French et al. 2015).

Integrated Coastal Zone Management

Integrated Coastal Zone Management (ICZM) is a process which has been embraced by nations around the world as a central concept for the protection and conservation of coastal and marine environment, sustainable use of marine resources and therefore sustainable development, under national jurisdiction in Chapter 17 of Agenda 21, which was adopted at the United Nations Conference on Environment and Development (1992). The goals of this continuous, proactive and adaptive process of resource management are: (a) to maintain essential ecological processes, life support systems and biological diversity in coastal and marine areas; (b) to identify interactions among coastal and ocean uses and the related ecosystems; and (c) to reduce the vulnerability of coastal areas and their inhabitants to natural hazards (Rochette and Billé 2010).

A fundamental issue in this process is the comprehensive understanding of the relationships between coastal resources and their uses, which need to be understood and expressed not only in scientific terms but also in socio-economic ones. Therefore, the ICZM process is designed to overcome the fragmentation in the sectoral management approach, with an integrated methodology in which several dimensions may be involved (e.g. between sectors and levels of governance, across the land–water interface, between nations).

Apart from policies, regulations and management strategies (e.g. Maritime Spatial Planning Directive supporting the ICZM process), public participation is a very important element of the ICZM process, which can be achieved by enhancing knowledge and awareness about the coastal/marine environment and its relevant issues, thus leading to increased public involvement and support for sustainable coastal and marine management strategies.

The ICZM process comes very close to the definition of ocean literacy, which is an understanding of the influence of the ocean on citizens (e.g. goods and services), and the citizens' influence on the ocean (e.g. impacts of human activities on the marine environment). An ocean-literate person is one who is able to make informed and responsible decisions regarding the ocean and its resources.

The elements which characterize the ICZM process (e.g. sustainable development, integration, top-down and bottom-up approaches) are held in common with ocean literacy initiatives, i.e. to combine scientific knowledge with an emotional attachment to nature, and integrate this into the indispensable role of governance for the purpose of promoting ocean sustainability (Santoro et al. 2017).

Even if the ICZM process never explicitly mentions "ocean literacy" it can be clearly considered as a policy that embraces its approach and many of its principles, such as the recognition of the interconnectedness of the ocean and humans, the promotion of individual and collective approaches for the sustainability of the marine environment, and the use of knowledge to promote the full participation of all actors concerned with the use of ocean (French et al. 2015) (Figs. 12 and 13).

In particular, the Protocol on ICZM in the Mediterranean, which complements the existing set of Protocols of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (UNEP/MAP/PAP 2008), includes objectives and principles (Articles 5 and 6) that are in full accordance with the approach of ocean literacy. Furthermore, the Protocol clearly calls for the active involvement of the public in the establishment, implementation and updating of coastal management strategies and plans (Article 14). Finally, Articles 15 and 25 of the Protocol refer to awareness-raising, training, education and research, revealing the crucial role that the Ocean Literacy Framework can and must play for a new vision of sustainable global development (UNESCO 2015).

Fig. 12 Educational initiative concerning marine biodiversity of Crete, Greece, organized by the IMBBC and attended by children of the second grade of an elementary school (Photo by: C. Dounas)

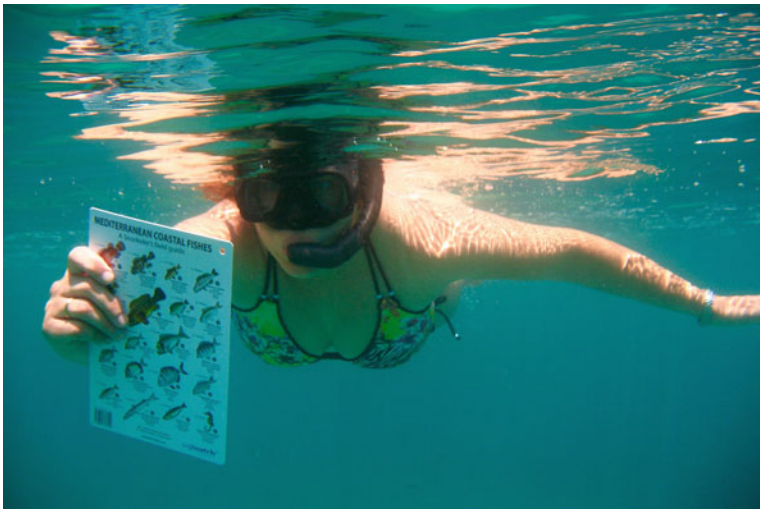

Fig. 13 A snorkeler involved in a citizen science project of the IMBBC (https://comber.hcmr.gr/) about fish identification in the Cretan Sea, Greece (Photo by: C. Dounas)

Marine Protected Areas

Marine Protected Areas (MPAs) are recognized as the most effective management and conservation tool for providing protection of biodiversity, for increasing the resilience of ecosystems to anthropogenic changes and for ensuring sustainable use of natural heritage. They also provide a range of benefits for fisheries, local economies and the marine environment as their goals include: (a) the conservation of biodiversity and ecosystems; (b) the mitigation and potential reversal of the decline in productivity by protecting breeding, nursery and feeding habits; (c) the establishment of fishing uses, regulations, catch quotas and no-take zones; (d) the raising of the profile of an area for marine tourism and recreation and further broadening economic options; (e) enhancing opportunities for environmental education, training, heritage and culture; and (f) providing pristine environments for research and understanding the natural ecosystem (Abdulla et al. 2008; Australian Government 2003; Gabrié et al. 2012). MPAs must be effectively implemented, enforced and managed. However, the establishment of a network of MPAs is a key mechanism as, through interconnections and interdependencies, they contribute to each other's integrity by decreasing overall vulnerability (Gabrié et al. 2012; PISCO & UNS 2016).

Mediterranean countries have legal obligations to protect the marine environment and to designate MPAs according to various agreements, policies and laws (EEA 2015; Gabrié et al. 2012; PISCO & UNS 2016). Key international instruments include the Convention on Biological Diversity's Aichi Target 11 and the United Nations Sustainable Development Goal 14, both of which call for protecting at least 10% of the oceans and seas in MPAs by 2020. The Specially Protected Area and Biological Diversity Protocol (1995), calls upon countries to establish MPAs. The Regional Activity Centre for Specially Protected Areas (RAC/SPA) was tasked with the responsibility of assessing the natural heritage situation and assisting Mediterranean countries in implementing this protocol.

In the Mediterranean Sea, similar to many coastal ecosystems across the world, marine protected areas (MPAs) have become the primary tool for in situ habitat and biodiversity conservation with more than 1,000 MPAs covering approximately 6.5% of its surface (MedPAN & UNEP-MAP-SPA/RAC 2016; PISCO & UNS 2016) (Fig. 14). However, the Convention on Biological Diversity's Target 11 of an effective conservation of at least 10% of each ecological region in the world has not yet been reached.

In the Mediterranean Sea, the term "Marine Protected Area (MPA)" is used to describe any marine and/or coastal area that is under protection by legal means for the conservation of natural habitats, species or specific natural features. It includes a wide range of areas, established under various designations, at various levels (subnational, national, regional or even international), and providing various degrees of protection, reflecting cultural and political differences among the countries (MedPAN & UNEP-MAP-SPA/RAC 2016). The majority have been classified as multiple-use marine areas, which seek a balance between biodiversity conservation and human use (Abdulla et al. 2008). Historically, designation was primarily driven by the presence of charismatic species (Fig. 15) and unique features, more than on a holistic

ecological approach (Abdulla et al. 2008).

Besides the implementation of MPAs in the Mediterranean, Coll et al. (2012) identified that areas with high marine biodiversity in the Mediterranean were mainly located along the central and north shores, with lower values in the south-eastern regions, and areas of potential high cumulative natural and anthropogenic threats were widespread in both the western and eastern basins, with fewer areas located in the south-eastern region. Because the areas where the interaction of high biodiversity and high threats is concentrated overlap only 2% of the existing MPAs, they are the best candidates for the further implementation of management and protection, and thus provide an opportunity for ocean literacy to boost the idea that the MPA network has to be extended.

The community awareness-raising actions concerning marine protected areas have increased all over the world in order to address the increasingly complex threats to marine ecosystems (EEA 2015). The aim of ocean literacy, in this case, is for the broader public to understand the importance of maintaining a healthy marine environment and how they can help by being informed about the role of MPAs for conservation and protection of this environment (Menabit et al. 2017). Ocean literacy in general and MPAs in a specific and local way could also assist services provided by marine and coastal ecosystems, namely: (a) provisioning services (e.g. fisheries, building materials), (b) supporting services (e.g. life-cycle maintenance for fauna, nutrient cycling), (c) regulating services (e.g. carbon sequestration and

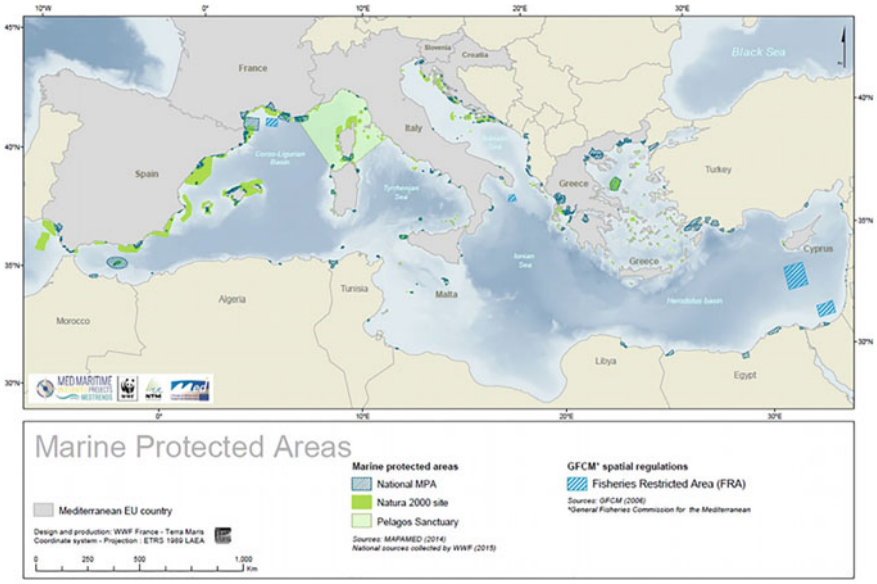

Fig. 14 MPAs and priority areas of conservation in the Mediterranean Sea (*Source* Piante and Ody (2015). Blue Growth in the Mediterranean Sea: the challenge of Good Environmental Status. MEDTRENDS Project. WWF-France. 192 pp.)

Fig. 15 Seahorse *Hippocampus sp.* (Linnaeus, 1758) is classified by International Union for the Conservation of Nature (IUCN) as a near-threatened species in the Mediterranean Sea (Photo by: Informare)

storage, erosion prevention, waste water treatment, moderation of extreme events), and (d) cultural services (e.g. tourism, recreational, aesthetic and spiritual benefits) (Millennium Ecosystem Assessment 2005).

Ocean/marine citizenship offers a potentially reliable tool for monitoring the environmental status of MPAs once-reliable indicators and ad hoc protocols have been designed and citizens have been adequately trained (CIESM 2015). The use of participatory techniques for monitoring changes, as a part of an MPA management plan, provides useful evaluation data and opportunities for administrators and stakeholders to interact and build trust in the management process. The participatory process is also fundamental to: (a) raising awareness; (b) developing the ability to respond to environmental issues; (c) strengthening confidence with institutions; and (d) developing a sustainable local economy.

MPAs have been recognized as suitable places for implementing ocean literacy and several of them are declared for educational purposes (Kasai 2006). The establishment and management of MPAs have provided important educational benefits, because they offer opportunities for people to experience and study relatively pristine/undisturbed marine environments, especially in fully protected MPAs (Kasai 2006). Participants in these learning and leisure activities are more likely to become informed citizens and contribute to future decisions about the marine environment and its resources.

Furthermore, MPAs provide an attraction for tourist visitors seeking local knowledge of the area, while at the same time they provide information, training and support for local people involved in the tourist industry (Australian Government 2003). Finally, MPAs have an important role in educating local communities and visitors about culture, history and heritage associated with the areas they protect, alongside biodiversity conservation and sustainable use (Australian Government

2003). Ocean Literacy Framework is available to support local marine conservation and MPAs (Kasai 2006).

Environmental Education

The role of the Mediterranean Sea is very important in the lives of at least those half a billion people who live around it, because it influences their climate, food, economy and culture; without it, they could not survive. Despite its crucial role, this sea remains largely unexplored while being simultaneously overexploited. Anthropogenic pressures, combined with the unique features of the Mediterranean Sea, are leading directly and/or indirectly to significant alterations of the delicate Mediterranean ecosystems.

For this reason, now more than ever, it is important to improve our knowledge about the sea, and not only to establish sea protection and management plans. People are more inclined to respect what they know well: ocean literacy and citizen science projects are indispensable to educate people, including citizens and tourists, and to involve them in the process of environmental protection (Fig. 16).

The novelty of ocean literacy lies precisely in its aim to connect knowledge, and protection, looking at the sea not only in the scientific and environmental context, but also in the economic, social and cultural contexts.

Fig. 16 Beach cleaning events organized to educate citizens and tourists in Liguria, Italy (Photo by: M'Importa)

How Ocean Literate Are the People of Mediterranean Countries?

It is not easy to answer this question due to the relative recency of ocean literacy as an emergent issue in Europe and in the Mediterranean countries in general. In the United States, the need for and the definition of ocean literacy have been identified since 2002 (Cava et al. 2005), although it required a long and collective effort to result in the completion of the Ocean Literacy Framework in 2009. It was only in 2012 that a European network set its sights on ocean literacy: the European Marine Science Educators Association (EMSEA) was established (Copejans et al. 2012; Dupont and Fauville 2017). In the following years the European Marine Board published its Position Paper 20, claiming that "Europe's maritime ambitions require an ocean- literate population" (European Marine Board 2013) and the Rome Declaration (EurOCEAN 2014) put forward the goal of "Promoting a wider awareness and understanding of the importance of the seas and ocean in the everyday lives of European citizens". Even more recently (2015), within the European Marine Science Educators Association (EMSEA), a regional work-group was founded specifically for the promotion of the ocean literacy in the Mediterranean region. This group, EMSEA Med, has developed the Mediterranean Sea Literacy guide, based on the experience and documents of the Ocean Literacy Framework.

Considering the heterogeneity among European, Asian and African countries, all over the Mediterranean region in various sectors (state of economic development, school systems and curricula, political/governance system, etc.), it is little wonder that research on ocean literacy is still at its infancy. Very few studies have addressed the topic of ocean literacy, often it is only as a part of environmental education, a field with a longer tradition in education as well as in research.

Among the few investigations, Erdoğan et al. (2009) studied the components of environmental literacy in elementary science education in Turkey, finding the mentions of water, water cycle and ocean in Science and Technology textbooks for grades 4–8. In the same year, Yavetz, Goldman and Pe'er (2009) investigated environmental literacy in a sample of Israeli pre-service teachers at the beginning and at the end of their three-year university course. Among the relevant topics, knowledge concerning water distribution on earth, its usage and pollution were addressed. According to the authors, the student teachers, survey showed evidence of poor basic environmental knowledge at the beginning of their course; however, there was significant improvement in their knowledge levels by the end of their course. Curiously, environmental attitudes and behaviours were positive at the beginning of the course, but they did not significantly improve by the end of it. On average, student teachers' environmental literacy was considered to be at an unsatisfactory level for entering the teaching profession (Yavetz et al. 2009).

In 2011, CLAMER, the first EU large-scale investigation addressing ocean issues among the general public, involved three Mediterranean countries: Spain, France and Italy (Buckley et al. 2017). Eighteen percent of respondents chose climate change as the main problem facing the world, with the Spanish sample giving it a ranking even

higher and believing it to be caused by human activity. Nevertheless, pollution was rated the most important environmental matter in relation to the coastline or the sea, followed by coastal erosion, sea-level rise, melting ice caps, sea temperature rise and flooding. Spanish and French participants also mentioned tsunamis. Invasive alien species raised concern mostly among Italian and Spanish respondents, while ocean acidification was overlooked by the entire sample. The knowledge level of ocean issues linked to climate change appeared to be satisfactory across those countries surveyed.

Between 2013 and 2015 the Laboratory of Environmental Research and Education of Democritus University of Thrace published the results of two research studies on ocean literacy-related issues carried out on pre-service teachers enrolled in this University. Boubonari et al. (2013) studied ocean pollution, finding moderate knowledge and positive attitudes, with differences according to the distance the respondents lived from the sea. Mogias et al. (2015) investigated Ocean Literacy Principles by means of questionnaires addressing content knowledge and stewardship attitudes. Pre-service teachers evidenced "moderate" knowledge on ocean issues, respectively, good knowledge for water cycle, ocean surface and ocean influence on climate, and poorer knowledge on more specific topics (e.g. global volume of freshwater on earth, deep ocean ecosystems and the role of the ocean in the carbon cycle).

In 2015, Ben zvi-Assaraf and Orion (2005) performed an extensive study on the perception of the water cycle within earth systems among 1000 7th–9th grade Israeli students. Based on a constructivist approach, they found sparse misconceptions (alternative frameworks) on groundwater dynamic nature, cyclic thinking and global magnitude scale. The authors complained about the effect of traditional theoretical teaching about water, and highlighted the need for "explanatory stories" and fieldwork experiences.

More recently Squarcina and Pecorelli (2017) studied Ocean Citizenship in Italy through an analysis of primary school textbooks and interviews with primary school teachers. According to these authors, Italians have a limited awareness of the sea, whether considered as a recreational activity or as an exploitable economic resource. Moreover, the authors criticize the minor role given to Ocean Citizenship in the national school curriculum and in the environmental education guidelines, where focus was primarily on the local environment and ocean-related topics were generally overshadowed by freshwater issues.

Finally, several studies emerged in 2019, evaluating ocean literacy of school students. One of these refers to a cross-cultural study among primary school students in three Mediterranean countries: Greece, Croatia and Italy (Mogias et al. 2019). The results indicated a rather moderate level of knowledge in the total sample, while slight differences were recorded among the three countries, revealing common knowledge and misconceptions. The moderate level of knowledge regarding ocean-related topics was also confirmed by a pilot study on Mediterranean middle school students among the same countries (Cheimonopoulou et al. 2019a). In Italy, an interventional research on primary and middle school students' knowledge, and attitudes towards ocean issues, confirmed the findings of Mogias et al. (2019), i.e. moderate students' knowledge and rather positive attitudes towards marine environment. The study included

different teaching activities in primary and middle schools, after which, both knowledge and attitudes revealed a significant increase in primary school but no significant change in middle school, showing the importance of well-designed and carefully implemented didactical intervention (Realdon et al. 2019). Positive results on the increase of students' knowledge and behaviours were evident also in a Greek study concerning a European Maritime Day event with a middle school low sample number (Cheimonopoulou et al. 2019b).

Ocean Literacy in the National School Curricula of Mediterranean Countries

The large variety in languages, educational systems and ways of interacting with the sea across the Mediterranean countries leads to a multifaceted picture of ocean literacy in the different school curricula.

Information relevant to the national school curricula provided here is derived from: (a) drawing data from previous studies, (b) TIMSS 2015 Encyclopedia: Education Policy and Curriculum in Mathematics and Science, issued by IEA—International Association for the Evaluation of Educational Achievement (Mullis et al. 2016), and (c) the opinions of researchers and educators from several Mediterranean countries. The information provided here is not exhaustive due to the difficulty in retrieving accessible and verified information. Before giving further details, it should be noted that environment, ecosystems and biodiversity topics are present in most of the addressed curricula.

Spain: In primary schools, there is no specific mention of the sea, which is presumably included in the topic "basic elements of the physical environment". In middle schools, the hydrosphere and tides are mentioned, with details on "properties of water, the water cycle, the importance of water for life and the impact of human activity on water resources".

France: In primary schools, though there is no specific mention of the sea, there is mention of water in general: "a resource; its states and changes of state; its path in nature; and maintaining its quality for different uses".

Italy: In primary schools, there is no mention of the sea in the science curriculum. Oceans, however, are addressed in the geography curriculum. In middle schools, there is no mention of the sea, which is presumably included in the topic "Earth's structure". In high schools, "hydrosphere" is a prescribed topic, with more details for technical and vocational high schools. Investigations into the actual teaching about the sea in Italian high schools showed evidence of generally poor teachers' interest for the topic, even if compulsory and taught in nearly all schools (Realdon et al. 2016; Sturani 2016). On the other hand, sea-related topics are always addressed, even if briefly, in primary and middle school textbooks and more extensively in high school textbooks.

Fig. 17 Education about marine planktonic organisms with children aged 5–6 (Photo by: M. Mokos)

Slovenia: Specific mention of the sea is missing in both primary and middle school curricula, but "substances in nature (e.g., water, soil and air)" are prescribed topics. The Geography curriculum includes "general geography", probably addressing sea-related issues. In 8th grade, teachers can choose further science topics.

Croatia: There are various references concerning water and sea in the primary school curricula. Under Nature and Society subject, the following topics are listed: "water cycle, Adriatic Sea, water as a life condition". Under Geography, "ocean names, sea features (salinity, temperature, tides, waves)" are prescribed. In middle schools, in the Biology curriculum there are topics on: "life conditions in the sea, organisms in the coastal and open sea and on the sea bottom, molluscs, algae, echinoderms, fish"; under Geography: "climate" and "Adriatic Sea"; under Chemistry: "water characteristics"; under Physics: "waves (in general)".

Malta: Given the location, sea issues are present from the early school years (Fig. 17). In primary schools Maltese students develop "awareness of the physical and human elements in Malta, the Mediterranean and the world" and "focus on the contrasts between the Maltese environment and the environment in other Mediterranean countries".

Greece: In the Greek curriculum, at both primary and secondary school level, there is no systematic focus on ocean literacy issues. Nevertheless, there is some basic, although extremely fragmented, information about the sea in the most recent textbooks. Among the topics addressed in primary school textbooks, marine ecosystems and human influence on the sea can be found. Similar topics are also present in more detail in middle school textbooks, with a few references concerning winds, sea temperature and currents under the Geography curriculum (Fig. 18).

Turkey: 7th grade students are taught about ecosystems in general. Marine ecosystems are specifically mentioned—but only in a brief outline. 10th grade students are taught one unit on aquatic biomes. This unit covers freshwater and marine regions.

Fig. 18 Ocean Literacy education projects are also being carried out inland (Veria, Greece) (Photo by: M. Cheimonopoulou)

According to Erdoğan et al. (2009), water, water cycle and ocean topics are addressed in Science and Technology textbooks for grades 4th–8th.

Cyprus: According to Orion and Fortner (2003), since the 1990s there had already been some efforts at science integration and the incorporation of environmental topic areas in the schools of Cyprus. "Several schools across the country participate in the environmental monitoring and data sharing of the GLOBE programme" and "Eco-Schools programme, encouraged and assisted by the Cyprus Marine Environment Protection Association, to adopt curriculum innovations that introduce global environmental issues and local action to elementary students".

Israel: One of the most important environmental issues in the Israeli national school curriculum is the hydrological system. In primary school, general scientific and environmental topics regarding water cycle, energy and geographical zones of the planet include ocean-related content. In lower secondary school, water is addressed in the Geography curriculum as "water cycle within the earth systems". Schools have the possibility to choose certain elective, subsidized (often requiring additional payment from parents) activities and programmes in which they have ocean-related activities coming to the school (EcoOcean) or they can travel to research stations and facilities to learn about marine science (IOLR), or participate in coastal field trips (National Parks Authority, EcoOcean).

Egypt: In primary school, there is only a concise mention of the ocean. In middle school, ocean names and sizes are addressed in Geography. In high school, ocean-related topics are fragmented under different subjects. For example, in Geology and Geography, Egyptian pupils study oceans and rivers and earth topography. Aquatic animals are studied as part of the Biology curriculum; other examples include tides and waves, which could be part of the Physics curriculum, and water composition within the Chemistry course.

Algeria: Ocean and marine topics are briefly mentioned, being used to make students understand certain physical phenomena. The ocean is not yet studied in order to understand its importance, all that it brings to us in our daily life and our

impact on it. The new programmes for primary and middle school which started in 2018, however, do emphasize the importance of the protection of the environment in the various levels and courses.

Morocco: No explicit reference to the ocean was found. Only in 4th grade a mention of "Water and the environment, water use and conservation, pollution, and organisms in nature" was found. In the 8th grade, one of the quoted topics is "Earth system", which should include ocean-related issues.

This incomplete report of ocean literacy-related topics in the school systems of the Mediterranean countries highlights some common features in different educational contexts:

- There exists extreme fragmentation of ocean-related topics under different subjects (Earth science, Geography, Chemistry, Physics);
- There is a lack of a global view on "the ocean's influence on people's lives and their influence on the ocean";
- There is widespread acknowledgement of the existence of environmental issues and problems, common along the Mediterranean coasts.

These elements represent challenges and opportunities at the same time, as they evidence the need to disseminate ocean literacy information and teaching resources among the teachers' community.

In addition to the formal teaching of ocean-related topics in schools, there are many non-formal educational opportunities provided by international and regional NGOs active in Mediterranean countries, which provide fieldwork teaching activities for schools and organize summer camps, beach cleaning, contexts, marine events and festivals for students. Mediterranean aquaria and zoos are also providers of educational activities for students and teachers training in their premises, as well as universities and research institutions, within their outreach initiatives. Recently, EU4Ocean, the European Ocean Coalition that connects different organizations, projects and people contributing to ocean literacy and sustainability, has taken the opportunity of a global coordinated initiative by launching the network of European Blue Schools, aimed at integration of ocean literacy in EU schools.

Ocean-Related Educational Projects and Networks in the Mediterranean

In parallel with the introduction of environmental education in school curricula, and following the recommendations of UNESCO-UNEP Belgrade Charter (UNESCO-UNEP 1976) and the European Union (European Community 1993; European Union 1988), large numbers of educational projects addressing marine environment have been developed in Mediterranean countries (Fig. 19).

Fig. 19 Marine educational project focused on biodiversity in the intertidal rocky zone of the Adriatic Sea, Croatia (Photo by: M. Mokos)

Environmental education activities usually start within the local environment, which, in Mediterranean countries, often includes coastal and marine areas. Therefore, we can affirm that ocean-related educational projects have been common along the coast of the Mediterranean, especially the European ones, since the 1980s (MIO-ECSDE 2003, 2004). From the territorial point of view, most of these projects are on nationwide or local levels, with fewer international projects involving different countries (MIO-ECSDE 2004).

Many of these initiatives address the sea as part of the local environment, while some of them focus exclusively on sea-related issues. Their educational targets can range from students to the general public. The involved initiatives can be of different

natures: formal school education, including the development and distribution of teaching resources, education research and informal active citizenship campaigns and citizen science projects (European Commission—Directorate General for Maritime Affairs and Fisheries 2018). Concerning the temporal dimension, ocean-related educational projects range from an entire year to single events and celebrations, such as World Oceans Day and European Maritime Day. Financial support for these initiatives can come from governments and local authorities; from intergovernmental institutions and organizations such as the EU and UNESCO; from NGOs, ranging from international (e.g. WWF, IUCN, MIO-ECSDE, FEE) to national and smaller.

In the following paragraphs a few examples of ocean-related educational, ocean literacy and citizen science projects, networks and events exclusively about the Mediterranean Sea are briefly presented. The list is incomplete as many projects are initiated spontaneously or may not be financed and consequently are not included in international databases. Although incomplete, this list shows how ocean literacy and ocean education has been growing in recent years and is becoming a key issue for many international projects.

List of Ocean Literacy-related Projects:

Green Bubbles (2015–2018): a Horizon 2020 EU-funded project dedicated to recreational SCUBA diving, an activity engaging millions of people worldwide. The aim of Green Bubbles, which involved students and teachers through classroom and fieldwork activities, was to maximize the benefits associated with diving while minimizing its negative impacts, thus achieving the environmental, economic and social sustainability of underwater tourism (www.greenbubbles.eu).

MARINE_ECOMED (2018–2021): an Erasmus + project aiming to create an international strategic partnership in order to promote sustainable marine management and communication strategies in the Mediterranean Region. The project is developing educational materials, such as Open Education Resources in Planning and management of marine and coastal areas and ocean literacy, a MOOC on Planning and management of marine and coastal areas and a Handbook on Marine education and communication in the Mediterranean, which will be freely available in the MARINE_ECOMED website (https://www.marine-ecomed.net/).

MARLISCO (2012–2015): The main objectives of the MARine Litter in Europe Seas: Social Awareness and CO-Responsibility project were to increase the awareness of the consequences of societal behaviour in relation to waste production and management on marine socio-ecological systems, to promote co-responsibility among the different actors and to define a more sustainable collective vision of marine environment (www.marlisco.eu).

MEdIES (2002–today): Mediterranean Education for Sustainable Development is the major educational and training initiative of the Mediterranean Information Office for Environment, Culture and Sustainable Development (http://mio-ecsde.org), launched in Johannesburg during the World Summit on Sustainable Development (WSSD 2002). The aim of MEdIES is to facilitate the educational community to contribute in a systematic and concrete way to the implementation of Agenda

21 and Agenda 2030, through the successful application of innovative educational programmes in all Mediterranean countries (www.medies.net).

PERSEUS (2012–2015): Policy-oriented marine Environmental Research for the Southern European Seas was a project aiming to identify the interacting patterns of natural and human-derived pressures on the Mediterranean and Black Seas, assessing their impact on marine ecosystems, and to design an effective and innovative research governance framework based on sound scientific knowledge by using the objectives and principles of the Marine Strategy Framework Directive. The project also addressed students through Perseus@School Network (http://www.perseus-net.eu/site/content.php).

ResponSEAble (2015–2017): a Horizon 2020 project aimed to map European marine research and knowledge, to understand the complex human–ocean relationships and the economic benefits deriving from our seas and the ecosystems they support. The project also provided a wide range of media and outreach activities, including videos, film-making competitions, an educational computer game and other learning materials, a social media campaign and an interactive website (www.responseable.eu).

Sea Change (2015–2018): a Horizon 2020 project aimed to establish a fundamental "Sea Change" in the way European citizens view their relationship with the sea, by empowering them, as Ocean-Literate citizens, to take direct and sustainable action towards a healthy ocean, healthy communities and ultimately a healthy planet (www.seachangeproject.eu).

Sea for Society (SFS) (2012–2015): a European-funded project that engaged stakeholders, citizens and youth in an open and participatory dialogue to share knowledge, forge partnerships and empower actors on societal issues related to the Ocean. In doing so, the project aimed to develop and enrich the concept of the "Blue Society", while preparing mechanisms for future cooperation (www.seaforsociety.eu).

List of citizen science projects

Citizen science projects involve a large number of citizens, often with no formal qualifications, who act as observers concerning a specific scientific issue (e.g. invasive species, jellyfish), creating "geo-referenced information" (e.g. records presented in Google Maps). They are largely untrained and voluntarily collect data which are quality-controlled by scientists. Citizen science projects represent an innovation which contributes to different disciplines (e.g. geography, marine science) and their relation to the general public.

CIGESMED SeasEra: a project that aims to enhance understanding of the links between natural and anthropogenic pressures and ecosystem functioning, and to define and maintain the "Good Environmental Status" (GES) of the Mediterranean Sea also by engaging volunteer divers (www.cigesmed.eu).

COMBER (2010–2013): Citizens' Network for the Observation of Marine BiodivERsity project, initiated under the European funded FP7 project ViBRANT, aimed at engaging citizens in a coastal marine biodiversity observation network. A website has also been developed and functioned for communication and promotion of the

network, offering data-entry tools for collecting information (http://www.comber.hcmr.gr).

Harmony: an Interreg Italia–Malta project that aims at protecting marine biodiversity in the Italo-Maltese area with common strategies and the involvement of local communities (https://www.harmony-italiamalta.eu/).

Marine Litter Watch (MLW): MLW includes a mobile application, a web portal and a database for citizen engagement in fighting marine litter and for collecting and sharing comparable data on beach litter. It also provides a platform for marine litter communities to meet, share their knowledge and co-create approaches to marine litter monitoring (https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch).

MELTEMI (2014–2020): an Interreg Balkan-Mediterranean project that promotes a joint effort against marine litter (Albania, Bulgaria, Greece, Cyprus). Through a series of interconnected actions, it foresees the active engagement of the society and key-stakeholders by informing, educating, training and networking them towards an evidence-based policy assessment framework for marine litter (https://meltemi-balkanmed.eu/).

MPA-Adapt: a project guiding Mediterranean MPAs through the climate change era building resilience and adaptation. This is achieved through capacity-building workshops for an effective management, development of risk assessments and an investigation of the potential actions and priorities needed to ensure the adaptability and the resilience of biodiversity and local communities, including fishermen and other stakeholders (https://mpa-adapt.interreg-med.eu/).

MPA-Engage: a project that supports and promotes the role of Mediterranean MPAs as nature-based solutions to adapt and mitigate climate change, even by the stakeholder engagement through participatory approaches, including Marine Citizen Science (https://mpa-engage.interreg-med.eu/).

Reef Check Italia: an organization that created different protocols to monitor the Mediterranean Sea. One of the most important is the Underwater Coastal Environment Monitoring Protocol, intended to assess the ecological status of the Mediterranean marine coastal habitats thanks to the help of short-trained SCUBA divers and snorkelers (www.reefcheckmed.org).

Spot the jellyfish: a campaign in Malta following a citizen science approach and relying on the collaboration of the general public, mariners, divers and especially the younger generations with their teachers and parents, by recruiting their assistance in recording the presence and location of different jellyfish through the use of a specific reporting leaflet (www.ioikids.net/jellyfish).

List of networks

European Marine Science Educators Association (EMSEA): an international non-profit organization committed to boosting ocean literacy in Europe which provides a platform for ocean education in the different European regional seas. The goals are: to raise educators' awareness of ocean issues and of the need for a sustainable future for our coasts, seas and ocean; to promote education and training in the fields of marine sciences; to advance ocean literacy in Europe and worldwide; to improve

the quality of marine science education and to function as a platform for sharing and disseminating information and expertise among its members (http://www.emsea.eu/default.php).

Ocean Literacy Italia (OLI): a network for ocean literacy in Italy created in 2017 with almost 100 representatives from academia, NGOs, the private sector and public entities. The purpose of ocean literacy Italia is to promote the incorporation of marine science into Italian school curricula and to raise awareness of the social, economic and cultural importance of the sea and sea-related services to all stakeholders, including decision-makers, individual citizens and private sector representatives (http://www.oceanliteracyitalia.it).

Conclusion

The Mediterranean Sea has always been a centre of diverse human societies and cultures. The use and exploitation of this Sea had started several millennia ago. Human population growth and anthropogenic pressures are characteristics of nowadays' situation of this region more than ever. Existing pressures are causing severe biodiversity and habitat loss. A region known to be a biodiversity hotspot is also a climate-change hotspot with over 460 million people living in it, thus affecting it with their everyday life activities. To ensure the sustainability of Mediterranean marine ecosystems and their resources and the well-being of people living in the region, individuals need to be aware of the impact that everyday life decisions have towards the marine environment, thus they need to be ocean literate.

If ocean literacy in the Mediterranean region means to understand how the Sea influences people, and how people influence the Sea, to become a Mediterranean-Sea-literate person means to know the fundamental principles and concepts that govern the Mediterranean Sea and, consequently, to make informed decisions in everyday life circumstances. There is an urgent need and challenge at the same time for spreading ocean literacy in the Mediterranean region in order to allow diverse societies and cultures, with different behaviours and attitudes, to become informed and to understand critical issues associated with sea-related topics. Ocean literacy adapted to the specific features of the Mediterranean Sea (Mediterranean Sea Literacy) aims to build sea-literate citizens, which can take initiatives, leading to responsible decisions on marine resources and sustainability. The already existing legal framework aims at the protection of the Mediterranean Sea. Integrated Coastal Zone Management supports sustainable use and development of the Mediterranean region. Biodiversity can be protected through the networks of MPAs, which at the same time have an important role in education, thus increasing OL at the local and regional level. Despite all these, the level of ocean literacy among the Mediterranean citizens is still unknown. Research, done so far, indicates that the knowledge level is low to moderate and needs to be improved. Integrating ocean literacy in school curricula and promotion of formal and non-formal education activities that will enhance pro-environmental

behaviours and attitudes can contribute to a future ocean-literate generation ("Generation Ocean"). Finally, a geographical approach to these issues can help us visualize their spatial distribution on different scales, from the global to the regional and local, as well as their potential impact on society and the ability to provide solutions.

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