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Mediterranean Sea Literacy: When Ocean Literacy becomes region-specific

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Abstract

Ocean Literacy (OL) has been defined as an understanding of the ocean's influence on people and their influence on the ocean. The OL movement was born in the US and its framework consisted of seven essential principles and 45 fundamental concepts; it is now largely accepted worldwide for use in both formal (schools and universities) and non-formal (research institutes, aquaria, museums, etc.) education settings. Based on this framework, marine scientists and educators developed the "Mediterranean Sea Literacy" (MSL) guide adapted to the specificities of the Mediterranean region, presented here. The MSL principles (7) and concepts (43), serving as guidance for research, education, informed decision-making, and improved citizens' lifestyles, aim to contribute to environmental protection, conservation, and restoration of the Mediterranean Sea as well as to help to achieve a blue innovative and sustainable economy.

Keywords: Ocean Literacy; Mediterranean Sea Literacy; Environmental Education; Sustainable Development Goal 14; Mediterranean Sea.

Introduction

Although the Mediterranean Sea is among the most important global biodiversity hotspots, it is also described as being "under siege" (Coll *et al.,* 2012) as a result of multiple human pressures on biodiversity, the functioning of marine ecosystems, and their capability for providing essential goods and services to human society (Guidetti *et al.,* 2014). Many key EU and international policies, arrangements and organizations such as the Mediterranean Action Plan (established in 1975), the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention, 1976), the Common Fisheries Policy (EC/170/83), the Habitats Directive (92/43/EEC), the Water Framework Directive (2000/60/EC), the Marine Strategy Framework Directive (2008/56/EC), the General Fisheries Commission for the Mediterranean (GFCM), the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Agreement on the Conservation of Cetaceans in the Black Sea, the Mediterranean Sea and the contiguous Atlantic Area (ACCOBAMS), demonstrate just how aware institutions

and the general public are of the current situation of the Mediterranean Sea. Furthermore, a considerable number of EU-funded and other research projects have focused on or included the Mediterranean Sea (e.g. see at https://keep.eu/projects/).

If Mediterranean marine resources are to be protected, conserved, and sustained, then there is an urgent need for the people of the Mediterranean region to know and understand the connection between them and the Sea, i.e. to be ocean-literate citizens (Cava *et al.,* 2005). Ocean Literacy empowers citizens to use knowledge of the marine environment and awareness of its issues to communicate about the sea in a meaningful way and make informed and responsible decisions. The United Nations declared the Decade of Ocean Science for Sustainable Development (2021-2030) and laid down the Agenda 2030 Action Plan including 17 Sustainable Development Goals (SDGs, 2017), among which a stand-alone goal is focused on the ocean (i.e., SDG 14). The Decade aims to achieve scientific and technological progress including considerable advancement and increase of OL in the society, from education and school curricula, decision-makers to the public at large (Santoro *et al.,* 2017). Furthermore, the European Union (EU) has invested more than €7 M in two large international ocean literacy-dedicated projects, SeaChange and ResponSEAble, both involving partners from Mediterranean countries and several education resources. In addition, initiatives such as World Oceans Day, European Maritime Day, and Mediterranean Coast Day are traditionally celebrated in many locations around the Mediterranean Sea (e.g. European Researcher's Night 2019 at the Cretaquarium, HCMR, Crete). In 2019, sixty-six European Maritime Day registered events were run along the Mediterranean coast (e.g. Cheimonopoulou *et al.,* 2019a). Finally, the U.S. National Marine Educators Association (NMEA), the International Pacific Marine Educators Network (IPMEN), the Canadian Network for Ocean Education (CaNOE), the European Marine Science Educators Association (EMSEA), the Asia Marine Educators Association (AMEA), and Latin America Marine Educators Association (RELATO) are committed to promote OL across continents.

More specifically, the EMSEA was established in 2012 (Copejans *et al.,* 2012), following the publication of the European Marine Board's Position Paper 20 in 2013 (which claims that "Europe's maritime ambitions require an ocean-literate population"), and the Rome Declaration in 2014 (the goal of which is to promote " a wider awareness and understanding of the importance of the seas and ocean in the everyday lives of European citizens"). In 2015, the EMSEA Med-Working Group (Med-WG) was formed (Previati *et al.,* 2018; Realdon *et al.,* 2018) resulting in the emergence of the "Mediterranean Sea Literacy" (MSL) guide, comprising seven principles and 43 concepts, all adapted to the specificities of the Mediterranean Sea. The MSL principles and concepts, serving as guidance to educators, teachers, scientists, non-governmental organizations, policymakers, the blue business sector, and the general public, are expected to raise awareness and create a Mediterranean-Sea-literate society.

Materials and Methods

In 2015, under the umbrella of the EMSEA annual conference in Crete (Greece), an initiative was launched to set up EMSEA Working Groups (WGs) for disseminating OL in Europe's different sea basins. In parallel, already-established international teams put into effect several projects mainly regarding the assessment of elementary and secondary education students' knowledge, attitudes, and/or behaviours in terms of OL issues (e.g. Mogias *et al.,* 2015; Fauville *et al.,* 2018; Realdon *et al.,* 2019a). Considering the rather unpromising findings of the above research efforts, and at the same time closely observing the various international communication strategies, derived over the last few years from organizations such as UNESCO and UN, the EMSEA Med-WG designed and launched a region-specific framework of OL for the Mediterranean Sea also taking into account the diverse societies and cultures of the Mediterranean countries.

The first version of this framework called "Mediterranean Sea Literacy (MSL) guide" was developed, based on existing relevant documents such as the Ocean Literacy Framework (NOAA, 2013), and the Great Lakes Ocean Guide (Ohio Sea Grant, 2013), as well as fundamental knowledge about different natural, geographical, and social components related to the Mediterranean Sea (e.g. Robinson *et al.,* 2001; Emig & Geistdoerfer, 2004; Verheye & De La Rosa, 2005; Lionello *et al.,* 2006; López, 2006; Lotze *et al.,* 2006; Bazairi *et al.,* 2010; Blondel *et al.,* 2010; Chappuis *et al.,* 2014; Goffredo & Dubinsky, 2014; McIntosh & Pontius, 2017; Cerrano *et al.,* 2019). A long-term process, which lasted almost three years, was carried out by working groups of different disciplines for each one of the principles while regular on-line monthly meetings were held. Multiple drafts of the proposed principles and concepts in English have gone through review and editing among the different working groups as well as by marine scientists and educators outside the working groups. This effort resulted in the emergence of MSL with seven essential principles and 43 fundamental concepts, all adapted to the specificities of the Mediterranean Sea.

Results

The seven principles and 43 concepts of the MSL guide are as follows:

PRINCIPLE 1: The Mediterranean Sea, semi-enclosed by land of three continents, is part of one big ocean and has many unique features.

ML1-A: The Mediterranean Sea is the largest and deepest semi-enclosed sea on earth, surrounded by Europe, Asia, and Africa, currently including 21 countries, representing less than 1% of the ocean's surface. It is connected through the Strait of Gibraltar to the Atlantic Ocean in the west and through the Dardanelles to the Sea

of Marmara and the Black Sea in the northeast. In the southeast, the Suez Canal links the Mediterranean to the Red Sea and the Indian Ocean.

ML1-B: The Mediterranean is characterized by narrow continental shelves and a large area of offshore, open deep-sea water with islands, volcanoes, and trenches. A shallow submarine ridge, underlying the Strait of Sicily, divides the Sea into two main sub-regions, the western and the eastern Mediterranean, consisting of many biogeographic regions and basins.

ML1-C: The complex Mediterranean water circulation is forced by water exchange through the Straits, wind stress, and buoyancy fluxes at the surface due to freshwater and heat input. Mediterranean water takes 80 to 100 years to be completely renewed due to the limited water exchange with the Atlantic Ocean.

ML1-D: Evaporation greatly exceeds precipitation and river runoff, affecting the water circulation within the basin. It is higher in the eastern basin, causing the water level to decrease and salinity to increase eastward. This imbalance causes a pressure gradient, and therefore seawater flow is eastward in the surface waters, and westward in the deeper layers. However, a relatively stable sea level is maintained, due to a surface current entering from the Atlantic.

ML1-E: Mediterranean seawater is characterized by unusual features such as high temperatures in the deeps, remaining at approximately 13°C throughout the year due to high salinities allowing deep vertical mixing driven by winter storms during the non-stratified period. The basin is characterized by strong environmental gradients, in which the eastern part is more oligotrophic than the western one. However, regional features enrich the coastal areas with nutrients depending on wind conditions, thermocline, currents, and river run-off as well as human activities. The biological production decreases from north to south and from west to east and is inversely related to the increase in temperature and salinity.

ML1-F: The European shores of the Mediterranean are traversed by important rivers (e.g. Ebro, Rhône, Po) and several smaller rivers in the Balkans. Connected with the Mediterranean Sea is the Black Sea which has lower salinity due to riverine inputs. The inflow of freshwater from North Africa is relatively low, gradually decreasing from the western basin to the eastern one. Exceptionally, there are considerable inputs from the river Nile despite the construction of the massive Aswan Dams. The inputs of freshwater comprise only one-third of the amount lost through evaporation, thus severely influencing the hydrological cycle.

ML1-G: The Mediterranean Sea is finite and its resources are limited. The limited water exchange with the Atlantic Ocean, along with the presence of approximately 250 million people living along its coasts, makes the Mediterranean vulnerable to pollution and over-exploitation of natural resources.

PRINCIPLE 2: The Mediterranean Sea and its living organisms shape the features of the Mediterranean region and its adjacent landmasses.

ML2-A: Mediterranean Sea life is at the origin of the many limestone Mediterranean soils and substrates. Limestone rocks underlie most of the Mediterranean basin giving rise to a mosaic of soil types suitable for typical Mediterranean cultivations (e.g. “terra rossa” for vineyards). Siliceous and crystalline rocks form soils which have a fine sandy consistency. Mediterranean sandy beaches with clear blue waters and small-scale tides attract millions of tourists annually.

ML2-B: The Mediterranean Sea is the result of convergence and recession of the African and Eurasian plates. It dried up almost completely, creating vast continental plains about 6 million years ago with many subsequent effects on terrestrial and marine ecosystems. As the waters of the Atlantic Ocean refilled the Mediterranean basin, the main geomorphological features of the Mediterranean Sea were established.

ML2-C: Erosion occurs in coastal Mediterranean areas as wind, waves, rivers, deep-sea currents, and plate tectonic mechanisms create, move, and redistribute sediments. As the Mediterranean is a semi-enclosed sea with narrow continental shelves, the contribution of tides in the shaping of its coasts is minor, while wave action has a greater influence.

ML2-D: Carbonate sediments and organic matter-rich layers are essential for the carbon cycle in the Mediterranean Sea, with feedbacks on the global biogeochemical cycle. Carbon has an important role in forming the hard parts of sea-living organisms (molluscs, urchins, corals, algae, etc.). Seagrass meadows, particularly *Posidonia oceanica*, have a great capacity to sequester and store carbon, thus representing a significant carbon stock.

ML2-E: Tectonic activity also shapes the geomorphological structure of the Mediterranean coast and basin, creating distinctive spatial regions. Deep submarine canyons are present throughout the basin and are the result of river erosion during the major Mediterranean Sea level drawdown.

PRINCIPLE 3: The Mediterranean Sea has a major influence on the climate and weather of the Mediterranean region.

ML3-A: The Mediterranean Sea interacts with the atmosphere and this interaction shapes the climate and thus the weather of this region.

ML3-B: The Mediterranean Sea absorbs the heat from the atmosphere. It cools and warms more slowly than the inland regions. Hence winters are warmer and milder near the coastal zone compared to the inland regions and summers are warm and dry resulting in short spring and autumn seasons. Complex coastal orography and many mountainous islands influence local scale atmospheric circulation giving rise to strong regional wind regimes. In the western Mediterranean, the north-north-west cold and

dry mistral prevails, while in the eastern basin the Etesians (meltemi) strong north dry winds occur regularly.

ML3-C: The Mediterranean region lies in a transitional zone between the arid North African climate and the more temperate and rainier central European climate. The basin and surrounding lands are affected by interactions between mid-latitude and tropical processes resulting in specific phenomena, such as heatwaves and droughts, intrusions of Sahara dust, and the development of specific types of cyclones.

ML3-D: The Mediterranean Sea is an important source of energy and moisture for the atmosphere. Local evaporation largely exceeds precipitation during all seasons and the characteristics of the local water budget influence the amount of moisture available for the surrounding land areas. The region is characterized by different levels of precipitation between its eastern and western parts, as well as the northern and southern parts, with plants and animals experiencing water deficit in many cases.

ML3-E: The Mediterranean Sea is warming at two to three times the rate of the ocean. Warming of the region will lead to reduced water availability and will trigger losses in Mediterranean ecosystems and their biodiversity.

PRINCIPLE 4: The Mediterranean Sea made the Mediterranean region habitable through its richness of life thus becoming the cradle of western civilization.

ML4-A: A significant amount of the atmospheric oxygen in the Mediterranean region originates from marine photosynthetic organisms such as phytoplankton, algae, and seagrasses.

ML4-B: The recent marine biota in the Mediterranean Sea is primarily derived from the Atlantic Ocean, but the wide ranges of climate and hydrology have contributed to the co-occurrence and survival of both temperate and subtropical organisms.

ML4-C: The Mediterranean Sea is a provider of water, oxygen, and nutrients. The unique and mild climate in the Mediterranean region is a result of the heat transfer and circulation of the Mediterranean Sea, which contributes to the entire climate system of the region. The favourable climate conditions resulted in the development of many diverse ancient civilizations in the Mediterranean region.

PRINCIPLE 5: The Mediterranean Sea is a marine biodiversity hotspot, with a high level of endemism.

ML5-A: Mediterranean Sea life ranges in size from the smallest organisms such as viruses and bacteria to the larger animals, such as sea turtles, monk seals, and cetaceans.

ML5-B: The Mediterranean Sea is characterized by extremely high species diversity and endemism, due to its position at the crossroad of various biogeographic provinces, its turbulent geological past, and the prevailing complex climatic and hydrologic conditions. In general, a west-east impoverishment of species diversity, abundance, and biomass is observed reflecting extreme climatic and trophic gradients.

ML5-C: The Mediterranean Sea has its own set of emblematic species of conservation concern, such as sea turtles, several cetacean species and the critically endangered Mediterranean monk seal. It is the main spawning ground of the eastern Atlantic Bluefin tuna. It includes several unique and endangered habitats, including seagrass meadows of the endemic *Posidonia oceanica*, vermetid reefs, and coralligenous assemblages.

ML5-D: The Mediterranean Sea provides several different types of adaptations and relationships among organisms. Different examples of symbiosis (e.g. corals and gorgonians with algae), predator-prey dynamics (e.g. predatory fish, grazing sea urchins, and macroalgae), and energy transfer through food webs (from phytoplankton organisms to marine mammals) are also found in this particular marine area.

ML5-E: The geological evolution of the Mediterranean Sea, combined with its location at the intersection of three major landmasses, has resulted in the formation of numerous and unique wetlands, such as deltas, coastal lagoons and estuaries, temporary marshes and intertidal mudflats, thus creating an extraordinary diversity of coastal marine habitats.

ML5-F: Mediterranean ecosystems are defined by certain unique characteristics stemming both from environmental factors and biological communities. The hydrodynamics, the thermohaline circulation system, the relatively high temperature of the deep-sea waters, the salinity gradient across the two main sub-basins, the low nutrient concentrations, the deep sunlight zone, the absence of large-scale tidal movement, combined with extremely high biological diversity, all result in the emergence of a mosaic of exceptional ecosystems.

ML5-G: The Mediterranean Sea is a deep-sea with an average depth of 1500 m (maximum depth of 5267 m in the Calypso Deep in the Ionian Sea). Its bathyal (~shelf break-3000m) and abyssal (~3000-5000m) zones include seamounts, mud volcanoes, deep trenches, cold seeps, and submarine canyons. Submarine canyons are hotspots of species diversity with a high proportion of endemism.

ML5-H: Many abiotic and biotic factors as well as the interactions between them (depth, wave action, light penetration, nutrient supplies, substrate, predation, etc.) cause vertical zonation patterns of organism distribution and diversity along the coast and in the open waters of the Mediterranean Sea. However, the small-scale tides of the Mediterranean Sea make a minor contribution to these patterns along its coasts, while trophic relations and biological interactions may explain the patterns of deep-sea Mediterranean species due to the high thermal and saline stability of the water masses below 150 m.

ML5-I: Deltas and coastal lagoons along with estuaries provide important and productive nursery areas for many marine and aquatic species, thus contributing to the conservation and maintenance of biological resources.

ML5-J: Mediterranean marine biota is composed of species with many different biogeographic origins. Since

the opening of the Suez Canal (1869), hundreds of Indo-Pacific species have entered the Mediterranean Sea. The invasion of non-indigenous species (also due to maritime traffic and escapes from aquaculture and aquaria) affects the biodiversity of the Mediterranean Sea and could expand rapidly due to climate change (e.g. global warming).

PRINCIPLE 6: The culture, history, economy, lifestyle, health, and well-being of the peoples of the Mediterranean region are inextricably interconnected.

ML6-A: The Mediterranean Sea affects all aspects of the lives of its inhabitants. Complex terrestrial and marine morphology, together with its distinctive hydrological cycle have created the Mediterranean climate, which exerts a strong influence over human activities (e.g. agriculture, mariculture, tourism).

ML6-B: The Mediterranean Sea provides food, medicines, minerals, and energy resources. The Mediterranean diet is acknowledged as a healthy combination of land and seafood in this region. The Mediterranean Sea is one of the major pathways of maritime transport as well as of trade and cultural exchanges. As the world's leading tourist destination (over 30%), the Mediterranean region supports jobs and national economies on a large scale. In addition, its geostrategic position plays a key role in world security.

ML6-C: Situated at the crossroads of Africa, Europe, and Asia, the Mediterranean region has witnessed both the flourishing as well as the decline of many civilizations that developed and exchanged ideas, technologies, and raw materials. The Mediterranean region includes more than 200 UNESCO World Heritage sites, more than 50 Elements on the UNESCO Intangible Cultural Heritage List, and numerous underwater cultural elements (e.g. more than 150 sunken cities).

ML6-D: The Mediterranean Sea is affected by its inhabitants and its visitors in a variety of ways. Major human impacts are made by marine pollution from land and sea-based sources (marine litter, eutrophication, etc.), over-fishing, over-exploitation of other marine biological resources, and consequent degradation of habitats. Moreover, the Mediterranean Sea is one of the seas in the world most affected by biological invasions.

ML6-E: Rising CO_2 levels in the atmosphere, caused by human activities, are responsible for the warming of the surface waters of the Mediterranean Sea and its acidification, leading to loss of biodiversity, degradation of habitats, increase in harmful algal and jellyfish blooms which might adversely affect fish stocks and tourism.

ML6-F: The Mediterranean region is home to nearly 522 million people, one-third of whom are concentrated along its coastal regions. The coasts are threatened by natural hazards, such as earthquakes, volcanic eruptions, tsunamis, droughts, and floods. Moreover, coastal erosion has been a major issue around the deltaic areas as well as the municipal or tourist resort beaches.

ML6-G: Mediterranean residents and tourists alike have a shared responsibility for protecting the Mediterranean Sea, which sustains not only life, but also the traditions, culture, and history of the region, and they must find ways to ensure its preservation. Mediterranean resources have to be managed sustainably through individual and collective actions.

ML6-H: Legal and institutional frameworks, dedicated centres and other initiatives exist to ensure the protection of the environment and sustainable development (e.g. the United Nations Convention on the Law of the Sea (UNCLOS), the United Nations Framework Convention on Climate Change (FCCC), the FAO Code of Conduct for Responsible Fishing, Barcelona Convention accompanied by seven protocols, Regional Marine Pollution Emergency Response Centre for the Mediterranean, Euro-Mediterranean Centre for Climate Change, Monk Seal Action Plan, Action Plan for the Conservation of Mediterranean Marine Turtles, Action Plan on Introduction of Species and Invasive Species in the Mediterranean Sea). Citizen science projects not only increase public knowledge and awareness but can also help researchers to collect and interpret scientific data.

PRINCIPLE 7: Although the Mediterranean Sea has been explored for centuries, it still remains largely unknown.

ML7-A: The biodiversity of the Mediterranean Sea is not as well-known as its terrestrial counterpart and its exploration can provide an opportunity for new research and knowledge in different research areas.

ML7-B: New knowledge about the Mediterranean Sea is fundamental for understanding its function and complexity (e.g. study of mesophotic benthic assemblages). Only by knowing the Mediterranean Sea in depth, is it possible to protect it and sustain its resources for the future.

ML7-C: While resources in the Mediterranean Sea have been significantly decreasing during the last 50 years, fully protected areas currently cover only 0.04% of its total area. Mediterranean resources are limited and must be protected by extending the size and the degree of protection of Marine Protected Areas (MPAs) already in existence as well as establishing new ones (e.g. priority areas should include mesophotic habitats characterized by important ecosystem engineers).

ML7-D: To better explore and understand the Mediterranean Sea and its influence on earth systems and human society, we need to make use of new methods, technologies, and mathematical models, in an inter-disciplinary way.

ML7-E: Different scientific approaches combined with education, training, public awareness, and trans-national co-operation, can pave the way towards an inter-disciplinary direction of exploration, understanding, and protection of the Mediterranean Sea. Everybody should collaborate to preserve and sustain Mediterranean Sea resources: scientists, educators, teachers, policy-/decision-makers, artists, and the private sector.

Discussion and Conclusions

Having in mind what Strang *et al.* (2007) elegantly emphasized, that "one cannot be considered science-literate without being ocean-literate", educators, from both formal and non-formal education settings, as well as scientists, are expected to be the primary actors that will adopt and use the Mediterranean Sea principles and concepts for education and outreach purposes, aiming to inspire a new generation of Mediterranean-Sea-literate citizens. Towards this direction, educators and scientists need to move on with several actions, such as (a) developing the newly launched Blue Schools network in Europe by focusing on Mediterranean region issues; (b) enhancing inter-disciplinary collaborations in terms of specific projects and other networks focusing on the Mediterranean Sea basin (e.g., the ERASMUS+, EMSEA, EuroGOOS, EU4Ocean, MIO-ECSDE); (c) supporting pre-service teachers' preparation programmes in each Mediterranean country; (d) implementing seminars/webinars and workshops for classroom teachers by close collaborations between the universities and research centres/institutes; (e) developing educational activities and teaching resources; (f) promoting of science communication and outreach of research results. Such approaches, especially when combined with an evaluation of students' knowledge and attitudes concerning the Mediterranean Sea, following the paradigm of OL (e.g. Boubonari *et al.,* 2013; Mogias *et al.,* 2015; 2019; Fauville *et al.,* 2018; Cheimonopoulou *et al.,* 2019b; Realdon *et al.,* 2019a), can provide a common framework for the curriculum designers, textbook authors, and education officials to design and put into effect up-to-data science curricula across the Mediterranean countries, while preserving the most valuable characteristics of their diverse societies and cultures.

Apart from educational and outreach purposes (schools, museums, aquaria, science centres, parks, etc.), the MSL principles and concepts can serve as a practical source for informed and responsible decision-making for the Mediterranean Sea and its sources (e.g. stakeholders, policy-/decision-makers, non-governmental organizations, Blue Economy actors) as well as improved citizens' lifestyles in the region. Therefore, the translation of the MSL guide into the different languages of Mediterranean countries is necessary. Relevant activities of combining efforts and expertise such as projects, publications, conferences, networks, training courses and events (e.g. Santoro *et al.,* 2017; Previati *et al.,* 2018; Realdon *et al.,* 2019b; Cheimonopoulou *et al.,* 2019a), under the proposed MSL framework can make a substantial contribution towards the protection, conservation, and restoration of the Mediterranean Sea as well as the achievement of a blue innovative and sustainable economy and therefore the achievement of the Sustainable Development Goal 14 in the Mediterranean region.

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