Ecological Indicators 95 (2018) 203–218

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Review

Pelagic habitats in the Mediterranean Sea: A review of Good Environmental Status (GES) determination for plankton components and identification of gaps and priority needs to improve coherence for the MSFD implementation

I. Varkitzi[a,*], J. Francé[b], A. Basset[c], F. Cozzoli[c], E. Stanca[c], S. Zervoudaki[a], A. Giannakourou[a], G. Assimakopoulou[a], A. Venetsanopoulou[a], P. Mozetič[b], T. Tinta[b,d], S. Skejic[e], O. Vidjak[e], J-F. Cadiou[f], K. Pagou[a]

[a] Hellenic Centre for Marine Research HCMR, Institute of Oceanography, Anavyssos, 19013 Attica, Greece
[b] Marine Biology Station, National Institute of Biology, Fornače 41, Piran 6330, Slovenia
[c] University of Salento, Department of Biological and Environmental Sciences and Technologies, S.P. Lecce-Monteroni – Ecotekne, Lecce 73100, Italy
[d] Department of Limnology and Bio-Oceanography, Center of Functional Ecology, University of Vienna, Althanstraße 14, Vienna 1090, Austria
[e] Institute of Oceanography and Fisheries, Šetalište I. Meštrovića 63, Split 21000, Croatia
[f] Institut Français de Recherche pour l'Exploitation de la Mer IFREMER, European and International Affairs Department, Zone Portuaire de Bregaillon CS 20 330, La Seyne-sur-Mer 83507, France

ARTICLE INFO

Keywords:
Plankton indicators
Pelagic habitats
Biodiversity
Mediterranean sea
MSFD
GES assessment

ABSTRACT

At present there is no consistent approach for the definition of Good Environmental Status (GES) and targets in the Mediterranean Sea, especially for Biodiversity Descriptors, according to the Article 12 of the Marine Strategy Framework Directive (MSFD). The use of plankton indicators in the Mediterranean Sea refers mostly to pelagic habitats in coastal waters and to case studies connected with environmental pressures, e.g. in the Adriatic, Aegean etc. The aim of this review is to study the existing biodiversity indicators for different plankton groups in order to compare GES definitions for the Biodiversity Descriptor and identify the relevant gaps and priority needs to improve coherence for the MSFD implementation across the Mediterranean. For these purposes, we focus on plankton indicators for phytoplankton, zooplankton and prokaryotes. Regional conventions (OSPAR, HELCOM, Barcelona and Bucharest Conventions) have long considered phytoplankton as a key element for integrated assessment systems. Phytoplankton biomass, community composition, abundance, frequency and intensity of blooms are used for such assessment purposes. Chlorophyll *a* still remains the most widely used indicator mostly thanks to its time saving, cost-effective and reproducible analytical methods that provide easily comparable datasets. Despite some integrated indices proposed for phytoplankton in the literature at the Mediterranean level, a number of constrains still prevent their wide use. Regarding zooplankton communities, commonly used indicators have a taxonomic base while recently size structure and biomass can provide a valuable index of zooplankton population dynamics and ecosystem production. Jellyfish blooms' occurrence and frequency are also considered important zooplankton indicators in specific areas, e.g. North Adriatic. Concerning the prokaryotes, so far MSFD takes into account only their pathogenic component. The revision of MSFD GES definitions shows that all Mediterranean MSs have defined GES at the Descriptor level (e.g. D1 Biodiversity), but our comparison of approaches shows a low level of coherence in GES related to pelagic habitats and plankton communities. Gaps mostly focus on the lack of thresholds and baselines for many biodiversity indicators, and on the scarcity of common and consistent methodological approaches for biodiversity assessment by the MSs. Suggestions to fill these gaps and inconsistencies among MSs include: integration of EU legislation and Regional Agreements and Conventions; targeting on priority species and habitats; testing of existing biodiversity indices with good performances in case studies; coordination and intercalibration actions for the establishment of threshold values and baselines; determination of common methodologies; undertaking of regular monitoring programs and impact assessment studies at regional and sub-regional levels.

* Corresponding author.
E-mail address: ioanna@hcmr.gr (I. Varkitzi).

https://doi.org/10.1016/j.ecolind.2018.07.036
Received 5 April 2018; Received in revised form 16 July 2018; Accepted 18 July 2018

1. Introduction

The ancient Greek word *Pelagos,* found in Homer's epics, refers to the open sea. The pelagic realm spans through the whole water column and it is the largest ecosystem on Earth (Kaiser et al., 2011). It can be subdivided by the water depth and the distance from shore to the neritic zone, defined as the ocean part within the continental shelf, and to the oceanic zone off the continental shelf. However, the term "pelagic habitat" as used by the Marine Strategy Framework Directive (MSFD 2008/56/EC), relates to the whole pelagic realm, as also delineated by Würtz (2010) in his overview of the Mediterranean pelagic habitats. The Annex 1 of the guidelines for reporting under the MSFD (European Commission, 2012) includes the reference and term lists, which represents a simplified version of the EUNIS classification for the category "water column habitats", with the following divisions: i) Reduced salinity water; ii) Variable salinity (estuarine) water; iii) Marine water: coastal; iv) Marine water: shelf; and v) Marine water: oceanic.

The Mediterranean is the largest European semi-enclosed sea. It has heterogeneous topography, with narrow continental shelf, average depth of approx. 1600 m and highly complex water circulation (Bergamasco and Malanotte-Rizzoli, 2010). Although it is a shallow sea compared to the oceans, a large part of the Mediterranean can be considered as a deep sea, given that several areas reach and exceed 4000 m depth (Coll et al., 2010). The Mediterranean pelagic realm is thus a highly variable four-dimensional structure (Würtz, 2010). All these peculiarities of the Mediterranean pelagial are reflected in the structure and dynamics of the plankton communities (Siokou-Frangou et al., 2010).

The Mediterranean Sea is generally oligotrophic, with increasing nutrient limitation from west to east, mostly as phosphorus limitation. This feature leads to a heterogeneous distribution of primary production and to a decreasing west-east gradient in chlorophyll *a* concentrations (D'Ortenzio and Ribera d'Alcalà, 2009). There are, however, some areas with higher chlorophyll *a* concentrations, which are in coastal waters generally related to river inputs (e.g., western part of the Northern Adriatic, Mangoni et al., 2008; Zoppini et al., 2010, 1995), while there are more connected to air-sea interactions in the open seas. The Mediterranean Sea is generally well oxygenated, which is true also for its deep layers (Siokou-Frangou et al., 2010).

The biodiversity of the Mediterranean Sea is very high, reflecting the wide range of climatic and hydrological conditions that allowed for the survival of both temperate and subtropical organisms, primarily originating from the Atlantic Ocean, and with a high percentage of endemic species (Coll et al., 2010). An important bulk of species diversity is attributed to the prokaryotic (Bacteria and Archaea) and eukaryotic (Protists) marine microbes (as reviewed in Luna, 2015; Sunagawa et al., 2015). Diversity of several microbial groups can be accurately and readily recognized under the optical microscope (e.g. diatoms, dinoflagellates, coccolithophores and silicoflagellates among phytoplankton, and tintinnids, foraminifers and radiolarians among microzooplankton) (Kršinić, 2010; Kršinić and Kršinić, 2012), however the taxonomic determination of a plethora of marine microorganisms requires application of culture-independent molecular-based methods. Much less is known about groups of auto- and heterotrophic nanoflagellates and picoplankton species (Coll et al., 2010). Molecular methods and next generation sequencing tools/platforms, which are growingly applied to uncover microbial diversity, are promising tools that will help to assess the status of the pelagic habitats in a more accurate, rapid and on a long term even less expensive manner also in the Mediterranean Sea in the nearby future.

In the last decades, plenty of Mediterranean Sea plankton investigations were first oriented towards phyto- and zooplankton biomass and structure of plankton communities (species composition, abundance and seasonal distribution), and later included also the heterotrophic components of the pelagic food web and biological processes (reviewed by Siokou-Frangou et al., 2010). Literature oriented towards the assessment of the environmental status with the use of plankton indicators is far scarcer, especially those related to the open waters of the Mediterranean Sea.

So far plankton indicators mostly refer to Mediterranean coastal waters with specific case studies, e.g. in the Adriatic and the Aegean, and their development is always connected to environmental pressures (Markogianni et al., 2017; Ninčević-Gladan et al., 2015; Spatharis and Tsirtsis, 2010; Varkitzi and Markogianni, 2018 in press). The environmental status of the pelagic habitat is addressed in the Biodiversity Descriptor 1 (D1) of the MSFD, for which the new Commission Decision 2017/848/EU sets one primary Criterion (D1C6). The condition of this habitat type is considered as a whole of its biotic and abiotic characteristics and its functions. In this review, we focus on the plankton indicators drawing attention to phytoplankton, zooplankton and prokaryotes. The aim of this study is to review the existing biodiversity indicators for different plankton groups in order to compare the Good Environmental Status (GES) definitions for the Biodiversity Descriptor and identify the relevant gaps and priority needs to improve coherence for the MSFD implementation across the Mediterranean. We also refer to other European Seas for reasons of comparison of available plankton indicators.

2. Existing approaches for the determination of GES and targets

There is no consistent approach for the definition and assessment of GES and targets in the Mediterranean in relation to MSFD Descriptors' (Fig. 1), and this is most obvious in the case of biodiversity descriptors (Paramana et al., 2017). Altogether, the number of biodiversity indicators catalogued for European Seas by the Devotes project (DEVOTool, Teixeira et al., 2016, 2014) is quite high for phytoplankton, benthic invertebrates and fish. However, a high number of those phytoplankton indicators remain at a non-operational level (in conceptual phase or under development) or without any status assigned, despite the fact that most of them were expected to be operational already, as they were parts of the Water Framework Directive (WFD) assessment (Teixeira et al., 2014).

2.1. Review of phytoplankton indicators

The WFD (2000/60 EC), which establishes a framework for the protection of all European waters, was the first to have addressed systematically and Europe-wide the biotic components of water habitats. In the case of coastal waters, the biological quality element used for the assessment of the ecological status in the pelagic habitat is phytoplankton. Phytoplankton parameters to be used for this assessment are biomass, community composition and abundance, as well as frequency and intensity of blooms. Several attempts have been made to develop an integrated assessment of ecological quality of coastal waters based on more than one of these attributes in different European regions, where phytoplankton has long been considered in the assessment systems required by regional conventions, such as OSPAR, HELCOM, Bucharest and Barcelona conventions.

A variety of phytoplankton indicators can be found in the scientific literature, web-pages, different projects' reports and deliverables, which have been developed and/or used at the Mediterranean Sea level, all aiming to assess the status of the marine environment. The use of a combination of multiple phytoplankton related parameters is encouraged by the scientific community and it has been made mandatory in European Directives. Although some integrated indices have been proposed in the literature by different groups of experts at the Mediterranean Sea level (e.g. Pachés et al., 2012; Romero et al., 2013; Spatharis and Tsirtsis, 2010), a number of constrains still prevent the wide use of these assessment systems, especially at the operational level. The methods used to analyse phytoplankton communities are mainly based on time consuming cell counts. This dictates a trade-off between the number of samples in a monitoring plan and the financial