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STATE OF THE ART AND PERSPECTIVES ON THE USE OF PLANKTONIC COMMUNITIES AS INDICATORS OF ENVIRONMENTAL STATUS IN RELATION TO THE EU MARINE STRATEGY FRAMEWORK DIRECTIVE

STATO DELL'ARTE E PROSPETTIVE NELL'UTILIZZO DELLE COMUNITÀ PLANCTONICHE COME INDICATORI DI STATO AMBIENTALE SECONDO LA DIRETTIVA QUADRO EUROPEA SULLA STRATEGIA MARINA

Abstract *- Planktonic communities hold a relevant role in the framework of the EU Marine Strategy Framework Directive. This paper summarizes the current state of art in the use of plankton as indicator for the assessment of the environmental status of marine environments, contributing to the discussion of new perspectives in its application for the implementation of the Directive.*

Key-words: *bacteria, phytoplankton, zooplankton, Marine Strategy Framework Directive.*

Introduction - The Marine Strategy Framework Directive (2008/56/EC, hereafter MSFD) has been developed with the overall aim of promoting sustainable use of the seas and conserving marine ecosystems. It represents the response to concerns that existing legislation for the protection of the sea from some specific impacts was too sectorial and fragmented. In the MSFD there is recognition that the diverse conditions, problems and needs of the various marine regions or subregions in the Community require different and specific solutions. Member States are therefore working on the 'building blocks' leading to the preparation and planning of measures to achieve Good Environmental Status (GES) at the level of marine regions or subregions. The 'building blocks' of the MSFD are: i) the assessment (Article 8) of essential features and characteristics, and of predominant pressures and impacts; ii) the determination of GES (Article 9) for 11 qualitative descriptors by using a set of criteria and indicators (Commission Decision 2010/477/EU); iii) the establishment of Environmental Targets (Article 10) and associated indicators so as to guide progress towards achieving GES in the marine environment; iv) the establishment and implementation of coordinated Monitoring programmes (Article 11) for the ongoing assessment of the environmental status of their marine waters. Planktonic communities need to be taken into consideration in several descriptors of the MSFD, namely D1 (Biological Diversity), D2 (Non indigenous species), D4 (Food Webs), D5 (Eutrophication) and D9 (Contaminants in fish and other seafood). Substantial work is still needed to clearly define the use of planktonic communities as indicators for the assessment of GES due

to the lack of data with adequate spatial and temporal coverage and lack of established methods at the regional and/or subregional level. The aim of this paper is to describe the potential use of planktonic communities as indicators of environmental status and the perspectives to better define the functionality of the ecosystem and its quality conditions.

Phytoplankton - Phytoplankton biomass, mainly in terms of chlorophyll concentrations, was used as an indicator of trophic conditions already in the 1960s. Later on, the need of assessing trophic status of aquatic ecosystems became a priority worldwide due to the serious impacts caused by eutrophication phenomena. Chlorophyll concentration became the most commonly and routinely used indicator of trophic conditions, being easily measurable and well-correlated with nutrient enrichment (i.e. Ferreira *et al*., 2011 and references therein). The Water Framework Directive (WFD - Directive 2000/60/EC) and the marine conventions (OSPAR, HELCOM and Barcelona Convention) require the use of phytoplankton to assess water quality, and promoted and addressed several approaches on the use of various metrics beyond chlorophyll concentration, such as cell abundance, biomass as carbon content, cell size, diversity, etc. (see references in Garmendia *et al.*, 2013). The WFD, in particular, explicitly requires the assessment of ecological status of coastal and transitional waters based on the Biological Quality Element (BQE) 'Phytoplankton', which is considered in terms of abundance and species composition. So far, the second intercalibration exercise of the BQE Phytoplankton carried out at the Mediterranean level within the WFD (MED-GIG) did not lead to a shared and coherent view, among Euromediterranean countries, on how to use Phytoplankton for the assessment of ecological status of coastal waters. Further work is therefore needed and a Commission Decision on this specific BQE is expected by 2015. Likewise, although phytoplankton could be considered as an indicator for the evaluation of GES in several MSFD Descriptors (cfr. Commission Decision 2010/477/EU), a quantitative approach on how such indicator contributes to the definition of GES has yet to be determined and is expected to be finalized by 2018. In order to achieve that, it has been proposed to combine chlorophyll measurements with the study of shifts in community composition (relative abundance of diatoms, flagellates, dinoflagellates, etc.) and possibly the presence of harmful species correlated to nutrient enrichments or other anthropogenic pressures. The compelling requirements of bio-monitoring (high frequency, large scale and long time series) could be highly facilitated by optical detection of blooms both through remote and in situ, active and passive measurements (Zampoukas *et al*., 2012) as they allow not just bulk assessment, but also functional types discrimination. At present the use of marker pigments to identify and quantify the various algal groups of phytoplankton has been widely and successfully used in marine environments. The few HPLC-based studies performed on phytoplankton size fractions revealing that this approach can provide insights into the taxonomic diversity of the small phytoplankton groups. Other indicators have recently been proposed to evaluate the potential of the use of phytoplankton as indicator to discriminate between pristine and disturbed marine systems, and that are based both on size structure and functional attributes (autotrophs vs. heterotrophs) (see Garmendia *et al*., 2013 for a review).

Zooplankton - Information on the zooplankton communities, including the species composition/distribution and seasonal/geographical variability, provide a relevant

contribution to the definition of GES for various MSFD Descriptors. There is considerable scientific and practical interest in understanding how the biological components of marine systems respond to both single and multiple stressors. The response of zooplankton to environmental conditions is of particular interest due to the central and mediating role that this group occupies as a trophic link between planktonic primary producers and larger consumers. Consequently, any variation in zooplanktonic biomass has implications on biogeochemical cycling, trophodynamics, fisheries and other ecosystems services (e.g. target organisms are important trophic links to many commercially and recreationally important species). Zooplankton as GES indicator can include varying levels of research, ranging from rather reductionistic to holistic indicators, integrating a broad range of environmental information. In general, in marine coastal ecosystems, the plankton community is often characterized by a pronounced degree of unpredictability, a feature that hinders the definition of the "baselines" necessary to identify a "Threshold Value" for the definition of GES. Although the zooplankton generally is poorly studied in the Mediterranean Sea, an overview of the plankton studies conducted during the last 25 years in the epipelagic waters on the Mediterranean Sea offers an important characterisation of zooplankton communities and reveal a considerable diversity and variability over spatial and temporal scales: for example the distinct seasonal or spatial pattern of the species-rich copepod genera or families which dominate the western and eastern basins. Mesozooplankton communities are highly diversified in terms of taxonomic composition, but copepods represent the major group both in terms of abundances and biomass (Siokou-Frangou *et al.*, 2010). Other indicators, as their productivity at sea, are considered important to predict future recruitment and biomass variation. Mesoscale circulation and hydrodynamic features affect not only standing stock but also composition and structure of mesozooplankton communities. Recently, some authors refer to zooplankton, in particular total copepod abundance, as a "biotic proxy" because it has shown a rather abrupt shift at the end of the 1980s (Conversi *et al.*, 2010). The whole copepod community in the different areas underwent a substantial transformation in recent years, which included changing in abundance and phenology in the majority of the species, increase of smaller species, etc. (Bernardi Aubry *et al*., 2012).

Bacteria - Within the MSFD, the bacterial component which represents the lower level of the trophic web, is considered in terms of microbial pathogens, whose introduction is responsible for biological disturbance in the marine environment. Since 2010 in Italy reports on bathing waters take into account as indicators of sewage pollution *Escherichia coli* and enterococci only (Directive 2006/7/EC). Monitoring of microbial pathogens in shellfish waters is also required by the Shellfish Water Directive 2006/113/EC, and the Shellfish Hygiene Regulations (854/2004, 853/2004, 2073/2005, 1021/2008). Besides the commonly used indicators (enterococci, *Escherichia coli* and *Salmonella* spp.), other microorganisms such as *Vibrio* spp., enteric viruses as well as protozoa, which are recognised as emerging pathogens, are highly recommended to be included in the implementation of MSFD. In addition, the role of bacteria in ecosystem functioning and the ability of modulating its metabolism in response to environmental changes should be taken into account in biodiversity and ecological quality monitoring programmes, as previously stated by Caruso *et al*. (2010) and Cochrane *et al.* (2010).

Conclusions - Although there is a clear recognition that planktonic communities are relevant indicators for the definition of GES in the MSFD, future research and monitoring studies have to focus on the acquisition of further data and the identification of the most useful metrics to be used at the subregional and, possibly, regional scale. For phytoplankton, coordination and coherence of methods and approaches are of primary importance, as well as the strengthening of taxonomic skills, at the national and Mediterranean level. With respect to the zooplankton, support and maintenance of the Long Term Ecological Research appears to be essential to understand zooplankton dynamics: a major activity is required to deepen the knowledge of the community response and to set up an index that would combine the different metrics. Concerning the bacteria, while some monitoring activities - like those related to faecal pollution - are well stated in the current regulations, a further effort is required in order to consider, in a future implementation of the MSFD, a new integrated approach combining the study of microbial activities with that of trophodynamics. This could provide useful insights on the functional role of bacteria in organic matter turnover and nutrient recycling as well as on the susceptibility of the marine environment to pressures such as global warming and ocean acidification.

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