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Viewpoint

# Phytoplankton composition indicators for the assessment of eutrophication in marine waters: Present state and challenges within the European directives

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ABSTRACT

Several legislations worldwide require assessing the health status of marine ecosystems. In Europe, the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) demand the evaluation of the status with the overall objective of achieving at least ''Good Status'', by 2015 and 2020, respectively. For this purpose, Member States are required to evaluate different biological, physico-chemical and hydro-morphological quality elements (WFD), or qualitative descriptors (MSFD). The assessments of both, the phytoplankton element and the eutrophication descriptor should include several attributes, namely phytoplankton biomass, composition, abundance and blooms. However, few composition-based indicators have been proposed. Principally, phytoplankton still relies on chlorophyll-a concentration measurements, mainly due to the high cost of collecting information on this element and the difficulties establishing significant pressure–impact relationships. This investigation describes the difficulties in the development of a phytoplankton community composition indicator, the state of the art and the main challenges for the future.



## 1. Introduction

Phytoplankton has an important ecological function as primary producer that directly and indirectly fuels the food webs (Domingues et al., 2008). Additionally, it can produce important impacts on water quality (e.g. by affecting turbidity and concentration of dissolved oxygen) and plays a number of other major roles in many ecosystem processes (Domingues et al., 2008). In consequence, phytoplankton is usually employed as an indicator of change in nutrient loads and as a key element for assessing eutrophication in marine systems. Indeed, its assessment has been required by different legislations (e.g. Clean Water Act (PL 92-500, 1972 (Bricker et al., 2008)), in USA; Marine Strategy Framework Directive-MSFD, 2008/56/EC (Ferreira et al., 2011), in Europe) and conventions (e.g. Oslo–Paris Convention (OSPAR, 2009); and Helsinki Convention (HELCOM, 2009)) that explicitly address eutrophication. Also, it is effective in evaluating responses to many other environmental stressors, due to its fast population responses to changes in water quality, hydrology or climate (Domingues et al., 2008; Devlin et al., 2009; Spatharis and Tsirtsis, 2010).

Accordingly, due to these characteristics, phytoplankton has been retained among the biological quality elements for the assessment of the ecological status of water bodies, as defined in the Water Framework Directive (WFD, 2000/60/EC). Different phytoplankton attributes that are essential to assess the ecological status, specifically phytoplankton composition, abundance and biomass, as well as frequency and intensity of phytoplankton blooms, are required to be evaluated by Member States (Domingues et al., 2008). Different phytoplankton status assessment methods employed worldwide, and the metrics these methods include, can be consulted in Ferreira et al. (2011). These methods, proposed by different countries, must be intercalibrated within the WFD, to ensure a similar quality assessment level (Borja et al., 2007).

Chlorophyll-a, as a proxy of biomass, is the most common metric when studying phytoplankton communities, since it represents a simple and integrative measure of the phytoplankton community response to nutrient enrichment (Harding, 1994; Devlin et al., 2007). However, community structure (i.e. the distribution of individuals to species) conveys different information by also considering heterotrophic species that are not represented in chlorophyll measurements (Domingues et al., 2008). Moreover, previous studies have demonstrated that an increase in chlorophyll-a due to eutrophication is usually accompanied by changes in phytoplankton community structure in terms of total abundance, species richness, and evenness (Tsirtsis and Karydis, 1998; Tsirtsis et al., 2008; Spatharis and Tsirtsis, 2010). Additionally, different authors (Devlin et al., 2009; Spatharis and Tsirtsis, 2010; Gallardo et al., 2011) have underlined the importance of combining different phytoplankton metrics under the WFD or in the framework of integrative quality assessment to develop robust tools; since each

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single metric can show a different response of the phytoplankton population to the pressure and may provide with different information on the condition of the aquatic ecosystem.

During the initial European intercalibration exercise for the WFD, the Northeast Atlantic, Baltic and Mediterranean groups agreed on metrics based upon chlorophyll and the Black Sea group agreed on metrics based upon biomass. Only within the Northeast Atlantic group, some Member States made an attempt to intercalibrate metrics related to other phytoplankton attributes, using the bloom frequency of any single taxa and the bloom frequency of *Phaeocystis* spp. (a few area-specific indicator species, which forms nuisance blooms in the southern North Sea) (Carletti and Heiskanen, 2009; Revilla et al., 2009). However, the WFD requires that future assessments also include indicators (metrics) that reflect phytoplankton composition (Henriksen, 2009). Indeed, several authors (Domingues et al., 2008; Carstenesen and Henriksen, 2009; Devlin et al., 2009; Henriksen, 2009; Spatharis and Tsirtsis, 2010; Birk et al., 2012) have remarked the lack of community composition indicators as required by the WFD due to the time-consuming identification, the high spatio-temporal variability, the complexity of these communities and the difficulties in reference conditions and boundaries setting.

The aim of this study is to show the current status of the development and use of the phytoplankton community composition, as a sub-metric/sub-indicator within the phytoplankton quality element in assessing coastal and transitional waters, as required by the WFD. For this purpose, (i) the difficulties in the development of a phytoplankton community composition indicator compliant with the WFD are explained; (ii) the most recent investigations on data acquisition tools and indicators of community composition are summarized; and (iii) some future challenges are discussed.

## 2. Difficulties to evaluate the community composition

Aquatic bio-indicators respond to different human pressures, such as pollution, nutrient enrichment, habitat loss or resources overexploitation (Adams, 2002). Firstly, the bio-assessment process requires the standardization of the sampling and analytical procedures. Next, the collected biological information is summarized in biological metrics, which ultimately are compared to standards or reference values and classified into quality classes (Karr and Chu, 1999; Hering et al., 2006, 2010; Birk et al., 2012). Each of these steps means an important milestone in the bio-assessment process. However, each of these stages has many difficulties, associated which make the development of a community composition indicator an outstanding task. To study these difficulties more in deep, three steps have been described and analyzed in more detail (see Fig. 1) in accordance to Hering et al. (2006, 2010).

### 2.1. Data acquisition

Data acquisition, including field sampling and the analytical procedures employed to obtain biological information, is an important step in the bio-assessment since it provides the data base on which the whole classification will be performed (Birk et al., 2012). As described by Ferreira et al. (2007), high quality data ensure that objectives are met and conclusions are not misled by inaccurate information. An ideal strategy combines the aspects of high precision and representativeness to detect relevant changes in ecological status at reasonable costs (Ferreira et al., 2007; Birk et al., 2012). However, in extensive monitoring networks, as those required by the WFD, it is very difficult to reconcile an adequate sampling and analytical effort that is representative in terms of spatial and temporal coverage, with reasonable costs (see Ferreira et al., 2011). Additionally, these procedures should be standardized to be reproducible enough, to avoid including another source of variability and increase comparability among laboratories (Seoane et al., 2011). Indeed, the standardization of methods will make the analyses more robust (Ferreira et al., 2011).

The sampling frequency applied in some monitoring networks can be insufficient to cover the high temporal variability of the marine phytoplankton (Domingues et al., 2008). Satellite images can be used as an alternative to overcome this problem. Remote sensing techniques are well developed to estimate the chlorophyll-a concentration, not only in large areas of the oceans, but also for the purpose of monitoring phytoplankton status in coastal water bodies (Gohin et al., 2008; Novoa et al., 2012a,b). However, estuaries could show some inconveniences and are still challenging, since the small size of some of them together with their proximity to land require using higher resolution data (Hu et al., 2004). With regard to composition, some authors have proposed a new method to detect the major dominant phytoplankton groups from anomalies of the marine signal measured by ocean color satellites (Alvain et al., 2005, 2006, 2008; Demarcq et al., 2012). However, to our knowledge its use is still limited and it has not been still proposed as an alternative method to assess phytoplanktońs ecological status in coastal water bodies.

With regard to laboratory techniques, those based on light microscopy, such as the Uthermöhl technique (Uthermöhl, 1958; Edler and Elbrächter, 2010), are the most usual techniques to study the phytoplankton community composition. However, those methods present several drawbacks in the context of large

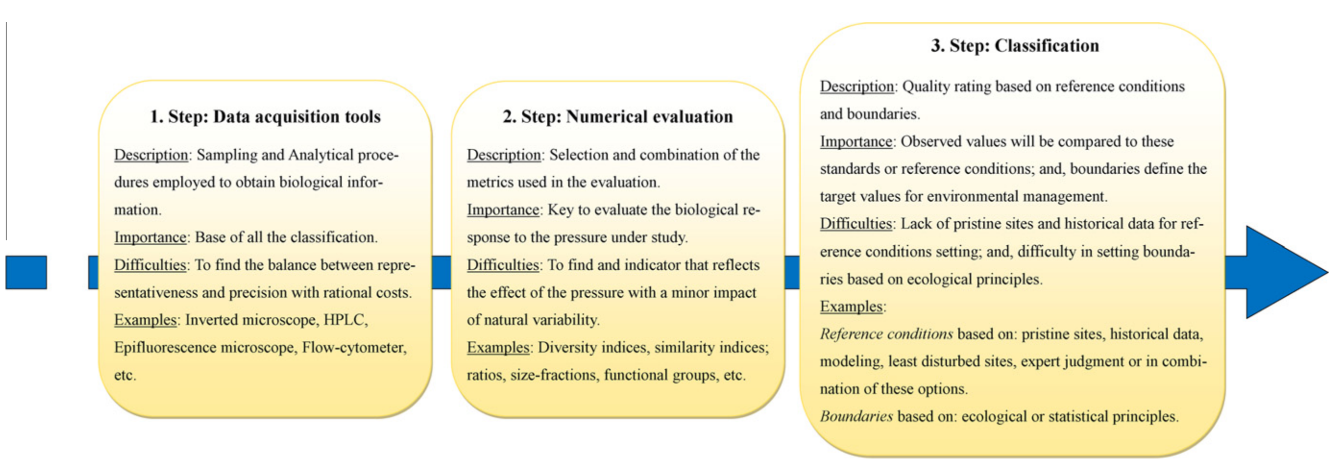


**Fig. 1.** Milestones in the bio-assessment process. Based on Hering et al. (2010).