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Establishing boundary classes for the classification of UK marine waters using phytoplankton communities

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Abstract

This paper presents a description of three of the proposed phytoplankton indices under investigation as part of a classification framework for UK and ROI marine waters. The three indices proposed for the classification process are (i) phytoplankton biomass measured as chlorophyll, (ii) the frequency of elevated phytoplankton counts measuring individual species and total cell counts and (iii) Seasonal progression of phytoplankton functional groups through the year. Phytoplankton biomass is calculated by a 90th percentile measurement of chlorophyll over the growing season (April to September) compared to a predetermined reference value. Calculation of functional groups and cell counts are taken as proportional counts derived from the presence of the indicator species or group as compared to the total phytoplankton count.

Initial boundary conditions for the assessment of high/good status were tested for each index. Chlorophyll reference conditions were taken from thresholds developed for previous EU directives with the setting of offshore concentrations as a reference condition. Thresholds for elevated counts of phytoplankton taxa were taken from previous EU assessments describing counts that could be impact negatively on the environment. Reference seasonal growth curves are established using phytoplankton counts from "high status" waterbodies.

To test the preliminary boundaries for each index, a risk assessment integrating nutrient enrichment and susceptibility for coastal and transitional waters was carried out to identify WFD waterbodies in England and Wales at different levels of risk. Waterbodies assessed as having low or medium risk from nutrient enrichment were identified as type 1 and type 2 waterbodies, and waterbodies assessed as high risk were identified as type 3 waterbodies. Phytoplankton data was extracted from the risk assigned waterbodies and applied to each phytoplankton index to test the robustness of the preliminary classification ranges for each phytoplankton index.

Keywords: Nutrients; Phytoplankton; Functional groups; Water Framework Directive; Boundary conditions; Classification techniques

1. Introduction

The overall aim of the Water Framework Directive (CEC, 1991, 2000) is to establish good ecological status in all European waters by 2015. Phytoplankton, along with benthic invertebrates, estuarine fish and macrophytes are known as biological quality elements in the WFD process. The WFD directive uses a "classification scheme" for the overall classification of the waterbody which includes some measure of these biological elements. Classification is a way of reporting the state of the environment and provides a

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way of comparing waters and looking at changes over time and "classification tools" are used for assessing the status of each individual quality element against high status (Vincent et al., 2002). Accordingly, the ecological status is expressed as a ratio between the values of the biological elements observed by a given body of surface water and the values for these elements in a site with no, or very minor, disturbance from human activities (reference ecological status). The WFD provides general definitions for the first three quality conditions or classes (high, good, and moderate), known as the "normative definitions". Each describes a different degree of impact on the plants and animals. Member states are responsible for further defining these and providing definitions for the poor and bad classes.

Assessments relating to phytoplankton are required to encompass taxonomic composition, abundance, biomass and plankton blooms for the ecological classification of transitional and coastal waters (CEC, 1991, 2000). More specifically the wording of the directive states that if a water body is to attain "high" ecological status "the composition and abundance of phytoplanktonic taxa are to be consistent with undisturbed conditions". Phytoplankton succession and community composition reflect the environmental conditions of the ecosystem, among which nutrient availability plays a significant role (Sommer, 1989; Gallegos et al., 1992; Bemen et al., 2005) in structuring that community. The primary biological response to nutrient enrichment in aquatic environments, given suitable environmental conditions (such as light availability and water temperatures), is the growth of phytoplankton and higher plants. Known consequences of marine eutrophication on the phytoplankton community include elevated chlorophyll levels (Boynton et al., 1996; Bricker et al., 2003), red tides, water discolouration and foaming – such as that caused by the colonial flagellate *Phaeocystis pouchetii* in the southern North Sea (Lancelot et al., 1987), increased production, which may give rise to extra biochemical oxygen demand (BOD) and hence increased removal of oxygen, in enclosed waters resulting in local anoxia. These include sea-lochs such as Striven (Tett et al., 1986) and the Baltic Sea (Larsson et al., 1985). Other consequences include shifts in species composition, from diatoms to flagellates (Gillbricht, 1988). In general terms, nutrient input is assumed to result in the rapid growth of opportunistic, fast growing primary producers and the accumulation of extra biomass which may have a negative impact on the ecosystem. Other attributes considered to be symptoms of negative impacts of nutrient enrichment include blooms of toxic algae, increased growth of epiphytic algae, the growth of nuisance macroalgae, the loss of submerged vegetation due to shading, the development of hypoxic (and anoxic) conditions due to decomposition of the accumulated biomass, and changes in the community structure of benthic animals due to oxygen deficiency or the presence of toxic phytoplankton species (see Bricker et al., 1999, 2003; Tett, 1987; Smayda and Reynolds, 2001). The potential ecological ramifications of nutrient enrichment and disturbance also include alterations of the natural phytoplankton community composition, which may in turn change ecosystem food web and nutrient cycling dynamics. For example, if the growth of more readily grazed phytoplankton functional groups (e.g. diatoms) is favoured, trophic transfer and nutrient cycling will take place largely in the water column, with enhanced export of the assimilated algae (as fish) to marine waters. In contrast, if the nutrient loading favours phytoplankton functional group that may not be readily grazed (e.g. dinoflagellates), tropic transfer will be poor and relatively large amounts of unconsumed algal biomass will ultimately settle to the bottom. This unconsumed biomass will stimulate microbial decomposition and oxygen consumption, exacerbating the potential for the development of hypoxia conditions and alterations in the food chain.

Despite the complexities associated with the phytoplankton community, there are general characteristics of the phytoplankton community which can be explored to identify indicators of ecosystem function and change linked to nutrient enrichment. Other common indices or attributes of the phytoplankton population that have been used in ecological assessments include bulk measurements of biomass and abundance (OSPAR, 2003; CSTT, 1994, 1997), taxon diversity (Karydis and Tsirtsis, 1996), seasonal succession (Hallegraeff and Reid, 1986; Belin et al., 1995; Gailhard et al., 2002) and indicator species (Edwards et al., 2001; Paerl et al., 2003). Phytoplankton biomass has typically been used as indicators of nutrient enrichment (CSTT, 1997; Malcolm et al., 2002; Gowen et al., 1992; Painting et al., 2005). Phytoplankton biomass is a direct measurement of the phytoplankton abundance and in UK waters, it should reflect low numbers in the winter, high spring concentrations, and variable, periodic summer and autumnal blooms. Chlorophyll concentrations represent a very simple and integrative measure of the phytoplankton community response to nutrient enrichment. Increase in the phytoplankton biomass can be measured as an increase in the chlorophyll concentrations. Chlorophyll is a useful expression of phytoplankton biomass and is arguably the single most responsive indicator of N and P enrichment in the marine system (Harding, 1994).

A number of these ecological assessment schemes using phytoplankton have identified the use of response ranges in water types and separate out types based on a gradient response. Differences in phytoplankton responses along a gradient can be used to set a scale for WFD boundary assessments within the phytoplankton community.

Development of all classification tools under the Directive must relate to the normative definitions as set out in the Directive guidelines. Phytoplankton normative definitions encompass the composition and abundance of phytoplanktonic taxa, phytoplankton biomass and blooms. These definitions serve as an anchor on which we have established simple qualitative measurements related to increases in blooms, biomass and phytoplankton abundance. The difficulty lies, as with all of the WFD biological