Annual spatio-temporal variation of the euphotic depth in the SW-Finnish archipelago, Baltic Sea*

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Abstract

We measured depth profiles of underwater PAR (photosynthetically active radiation) together with optically derived turbidity and chlorophyll fluorescence values at 11 sampling stations in the South-West Finnish archipelago of the Baltic Sea. The data were collected eight times during the spring, summer and early autumn of 2010. The results illustrate complex and multidimensional variations in the euphotic depth, which was subject to fourfold and twofold differences in the geographical and seasonal dimensions respectively. The spatio-temporal inconsistency and non-linearity of the seasonal euphotic depth variation calls for further studies at different spatial and temporal scales.

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1. Introduction

Many biological functions in aquatic ecosystems are driven by solar radiation penetrating into the water. Photosynthetically active radiation (PAR, 400–700 nm) – which approximately corresponds to visible light – is crucial to aquatic primary production, for example. Underwater radiation is attenuated as a function of distance by two mechanisms: absorption and scattering (Kirk 2011). The efficiency of these processes varies according to the optical properties of the water, as natural waters contain, in addition to water molecules, an assortment of suspended and dissolved substances. Consequently the quantity and quality of the underwater light vary in space and time, induced by changes in the concentrations of these substances (Dera & Woźniak 2010, Suominen et al. 2010, Woźniak et al. 2011). Thus, underwater light availability must be examined as a multidimensional phenomenon with several spatial (including both horizontal and vertical dimensions) and temporal scales.

In clear oceanic waters, the PAR attenuation is dominated by the seawater itself, and additionally, if present, by chlorophyll and other photosynthetic pigments of living phytoplankton. The optical properties of coastal waters are usually also influenced by the concentrations of suspended particulate matter (SPM) and coloured dissolved organic material (CDOM) (Kirk 2011). In the Baltic Sea, the exceptionally high CDOM concentration places particular demands on optical water research in the area, as many models and algorithms developed elsewhere are not directly applicable (Kratzer et al. 2003, Darecki & Stramski 2004).

The layer in which photosynthesis takes place can be studied by assessing the ratios of photoautotrophic production and heterotrophic consumption within a given time-scale. The compensation depth is the depth at which primary production is equal to all community loss processes, and the critical depth refers to the lower limit of the water column at which vertically integrated productivity balances out integrated losses (Sverdrup 1953, Tett 1990, Kirk 2011).

The thickness of the photosynthetically active water layer can also be estimated indirectly on the basis of underwater light conditions. This is usually done by defining the thickness of the euphotic zone, limited by the euphotic depth, at which 1% of the sea surface PAR remains (Kirk 2011). The absolute amount of PAR at this 1% depth varies somewhat according to the instantaneous conditions, such as cloudiness and solar zenith angle (e.g. Dera & Woźniak 2010). Also, the minimum radiation requirement for photosynthesis varies among phytoplankton species (e.g. Kirk 2011). Nevertheless, according to a study conducted in Finnish and Estonian lakes, the depth at which 1% of the surface radiation remains