



Optical properties of microphytobenthic biofilms (MPBOM): Biomass retrieval implication

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ABSTRACT

Microphytobenthos Optical Model (MPBOM) provides the optical properties, absorption coefficient and refractive index, of a laboratory simulated microphytobenthic biofilm using the reflectance measurements derived from HySpex laboratory images, with the final aim of estimating photosynthetically active biomass. The high correlation between this biomass, expressed in chlorophyll *a* ($\text{mg Chl } a \text{ m}^{-2}$) and the absorption coefficient at the corresponding absorption wavelength of Chl *a* (673 nm) made possible the estimation of biomass for any absorption coefficient calculated from reflectance measurements of any other data set. The latter was validated for an independent data set which performed an acceptable estimation of biomass in comparison with the biomass measured by HPLC ($R^2=0.93$). Finally, this model is designed to be applied to hyperspectral images, like airborne or satellite, in order to map biomass in the field.

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1. Introduction

Microphytobenthos (MPB) consists of unicellular phototrophic microorganisms, dominated by diatoms (Bacillariophyceae class) at northern mid-latitudes (Europe and America) and inhabiting the first millimeters of sediment. Epipelagic diatoms (Fig. 1a), until now the most studied group of MPB, are able to migrate through the sediment and form a brown biofilm at the mudflat surface during diurnal low tide (e.g. [1–4]; Fig. 1b). These biofilms are easily observable (Fig. 1c) and can cover several hectares [5–8]. In highly turbid intertidal areas, MPB contributes up to 50% of primary production (e.g. [9]). Thus, it is frequently the major primary producer in estuarine mudflat systems [2,3,9], where it represents a significant food source for cultivated oysters (e.g. [10]).

MPB also has an important role in the mediation of nutrient fluxes between sediment and the water column [11] and exudes extracellular polymeric substances (EPS) which can have a strong influence on sediment stabilization [12]. Despite the importance of such ecosystem functioning, only a few studies have dealt with microphytobenthic structure, including biomass assessment, using field samples at mesoscale [1,13–17] and only one at macroscale [6] because of the difficulty of reaching the muddy regions. Therefore, remote sensing became an important tool to detect at once on a wide area, from an aircraft or from a satellite, a collection of pigments (chlorophylls and carotenoids) revealing the presence of a phototrophic assemblages like MPB [1,5,7,18–20]. The chlorophyll *a* (Chl *a*) is the main photosynthetic pigment commonly used as oceanic plant biomass and productivity indicator [21]. In case of MPB study, Chl *a* is an indicator of photosynthetically active biomass [15,22], although this biomass estimator has some limitations because of carbon/Chl *a* ratio variability [23]. It displays a specific spectral response in accordance with the fraction

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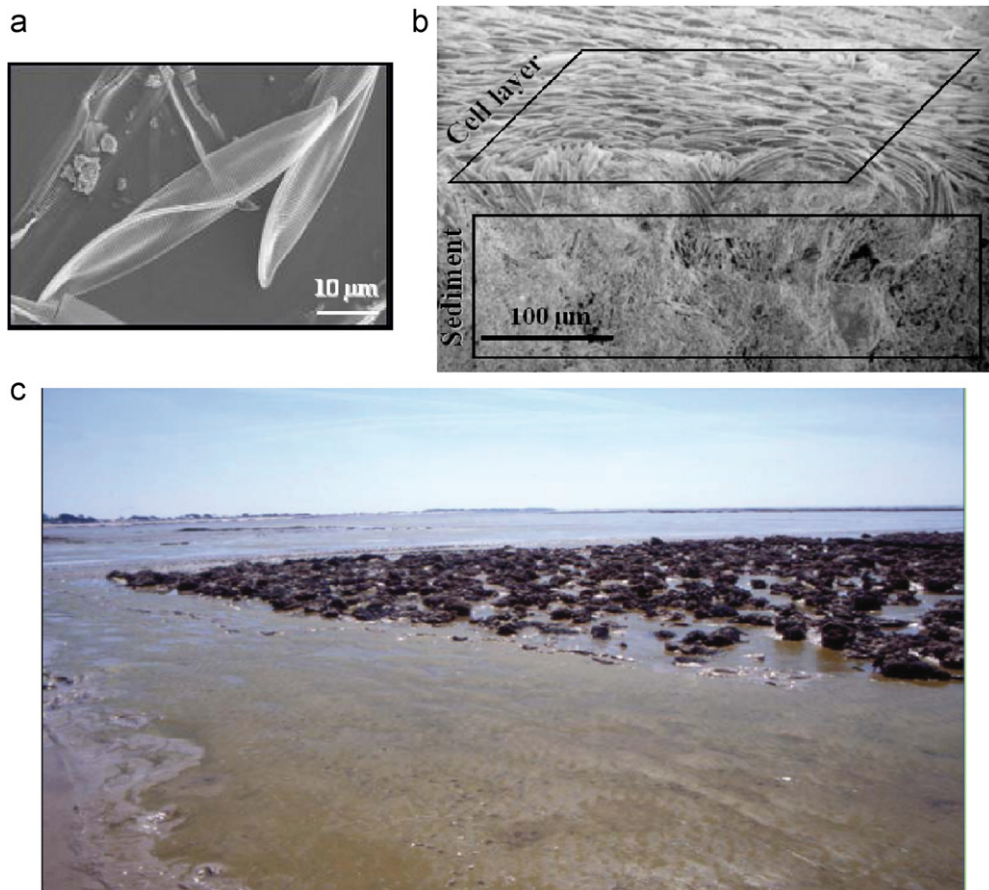


Fig. 1. (a) *E. paludosa* frustules under a scanning electron microscope (SEM); (b) microscopic view of a vertical section of layered cells on the sediment surface, from [6]; and (c) visible biofilm on the sediment surface of the intertidal zone during diurnal low tide.

of MPB cell raising the top of mudflat due to cell concentration but also by the substrate on which the biofilm is formed. Such a complex problem could cause an inaccurate estimation of biomass by semi-empirical methods [5,8].

To overcome these difficulties, the present work focused on constructing a physical model which links MPB photosynthetically active biomass concentration per area of substrate, expressed in $\text{mg Chl } a \text{ m}^{-2}$ called 'MPB biomass', to spectral data by means of the inherent optical properties of the biofilm. Several studies have presented empirical or physical models of spectral absorption characteristics as a function of the pigment concentration of phytoplankton in water [24–27] and also the diatom cell suspension in water [28]. Until now, however, no model has been proposed to predict the pigment content or biomass of the MPB biofilm. Therefore, the simulation of a biofilm and its spectral properties still remains a challenge.

In this work, we are interested in estimating the optical properties of a biofilm simulated in laboratory, Microphytobenthos optical model (MPBOM), and describing the essential properties of a natural biofilm combined with the substrate effect. This modeling approach requires

data acquired under controlled conditions and in the absence of other effects influencing field data such as roughness and shadowing. Thus, the determination of the optical properties of MPB biofilm involved estimating the characteristics of both scattering and absorption. In fact, these characteristics are highly correlated with the biophysical and biochemical parameters of a biofilm and are represented by refractive index and absorption coefficient, respectively. The latter is directly affected by pigment content and thus could be used to estimate some quantitative information such as the biomass.

The proposed model is mainly based on radiative transfer formulae and the assumption that a biofilm is a thin homogenous layer. Following [29,30], a thin homogenous layer is characterized by its absorption coefficient, α , and refractive index, n , calculated using reflectance/transmittance spectra. In order to study more precisely the scattering and absorption properties of a biofilm, two kinds of biofilms were analyzed. The first was formed by cells deposited on a polycarbonate substrate, and the second one by cells trapped in a gelatin substance to assess the scattering properties of the cells. Finally, a new data set was used in order to test and validate the most reliable model of MPB, in both direct and inverse mode.

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