



Development of temperature-based algorithms for the estimation of microphytobenthic primary production in a tidal flat: A case study in Daebu mudflat, Korea

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ABSTRACT

This study presents the results of field experiments that were designed to investigate the photo-physiological characteristics of microphytobenthos (MPB) and to estimate primary production (PP) in Daebu mudflat, which is located at the west coast of Korea. A typical seasonal (or monthly) fluctuation of intertidal MPB PP was found in association with biotic (benthic Chl-*a*) and/or abiotic parameters (irradiance and temperature) over a period of three years. From a series of field-laboratory experiments using the oxygen micro-profiling method (totaling 28 surveys), three consistent phenomena were observed: 1) winter to early spring algal blooms, 2) seasonal changes in Q_{10} , and 3) temperature dependent MPB photosynthesis-irradiance (P-I). In particular, both the chlorophyll-specific maximum photosynthetic capacity (P_{max}^b) and the saturated light intensity (I_k), derived from 126 P-I curves (1870 data sets of oxygen micro-profiling in the sediment), were significantly correlated with sediment temperature ($p < 0.01$). To develop an empirical MPB PP model, the relationships between P-I parameters and environmental variables were parameterized following established exponential forms (e.g., Q_{10}). It was possible to estimate the MPB PP in Daebu mudflat area by using easily accessible explanatory factor, suitable to be used for future explorations of parameters such as sediment temperature, irradiance, chlorophyll concentration, and tidal height. The estimated annual MPB PP based on the empirical PP model were found to be greater than that in the Wadden Sea and average annual PP in the temperate zones of the world. Authors believe that the present approach of the MPB PP estimation could be combined with remote-sensing techniques (e.g., satellites) to support coastal ecosystem management.

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1. Introduction

Obtaining knowledge about the rate of inorganic carbon fixation by phytoplankton is an integral part of studies on marine food webs and the carbon cycle (Platt et al., 1990). With increasing concerns about the environment and impacts of global warming in the recent

years, the importance of the fundamental role of phytoplankton in removing atmospheric CO₂ has been increasingly acknowledged. The key processes are photosynthesis and the “biological pump,” which is the fate of inorganic carbon subject to biogeochemical transformation to organic materials and their physical mixing and settling (Ducklow, 1995; Dugdale and Goering, 1967; Eppley and Peterson, 1979).

However, compared to pelagic phytoplankton species (and, sometimes, coastal macro algal species), relatively little research has focused on “microscopic” benthic algae, namely microphytobenthos (MPB), dwelling in shallow-water ecosystems. Fortunately, recent efforts have shed new light on the importance

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of MPB diversity and its biological and ecological functions and roles in the ocean (Tréguer et al., 2017). Organic carbon from the “Secret Garden” vegetated by MPB is a major food source for benthic and pelagic herbivores, in addition to deposit and suspension feeders (de Jonge and van Beusekom, 1992, 1995; MacIntyre et al., 1996; Koh et al., 2007). For example, the ecological role of resuspended MPB in shallow water systems contributes from 10% to 70% (maximum) of the whole pelagic productivity during tidal submersion, and is, even, transported offshore (Koh et al., 2006). Previous studies have also reported that MPB contributes up to 50% of total estuarine carbon (de Jonge and van Beusekom, 1992, 1995; Underwood and Kromkamp, 1999). Considering the important role of coastal habitats as major sources for carbon storage, accounting for 50% of total sequestered carbon in the ocean sediment (Regnier et al., 2013), the socio-ecological role of MPB primary production should be the subject of future detailed studies.

In general, primary production is a function of two major factors, say abiotic and autecological factors: first abiotic factors refer to 1) irradiance that initiates the photosynthetic process of algal cells; 2) pore water nutrients, primarily supporting productivity capacity; and second autecological factors include 3) chlorophyll *a* (Chl-*a*), biomass of algal cells, contributing to photosynthetic activity; and 4) the photophysiological state of individual cells or cell assemblages. Of note, the concentration of nutrients is not necessarily a limiting factor in tidal flats (de Jonge, 2000; de Jonge et al., 2012). Thus, the successful assessment of large spatio-temporal scale benthic primary production is dependent on the estimation of the three factors of irradiance, Chl-*a*, and photophysiological state. This study summarizes the findings on the photophysiological characteristics of MPB in mudflats, and presents results as a component of continued efforts from previous studies (Kwon et al., 2012, 2014) to provide ground truthing information for developing decision supporting tools, combined with remote-sensing techniques (e.g., shipboard, airborne including satellite GPS based information) for coastal ecosystem management.

2. Materials and methods

2.1. Study area and sampling

Samples were collected at Daebu mudflat (37° 12' 56.7" N, 126° 34' 57.3" E), located on the west coast of Korea, during 28 surveys in 2008–2010, encompassing 10 consecutive seasons (Figs. 1 and 2). The sampling station was located in the upper mid-tidal zone, which has a macrotidal range (maximum tidal range = 9.8 m) and semi-diurnal tides. The average mud content of the surface sediment during the survey was 88%.

Sediment samples were collected using a Plexiglas tube (length = 10 cm, i.d. = 9.3 cm) to measure benthic primary production. Cores were then stored in an ice-box, and immediately (<1 h) transported to the laboratory, with minimal disturbance to the sediment surface. Five sediment samples were also collected using a syringe core (i.d. = 1.4 cm) on each sampling day to determine microalgal biomass (Chl-*a*) in sediment (thickness = 0.5 cm) using spectrophotometry (Lorenzen, 1967), data given as mean value. Details on the sampling procedures and associated measurements are graphically summarized in Fig. 2. In brief, a total of 28 experiments were carried out to measure MPB PP using sediment cores each month over a 3-year study period. Long term measurements of sediment temperature were collected using an on-site mooring device (HOBO, UA-002-64) during the study period.

2.2. Laboratory measurements

In the laboratory, the individual core was placed in a water bath (40 × 33 × 16 cm) filled with filtered seawater (32 psu) collected at the sampling site. Then, the room temperature was cooled down to the experimental temperature setting of the first day, and the sample was left in the darkness overnight before the onset of measurements in order to adjust to the experimental temperature. MPB PP was measured for four to five light intensities, viz., 125, 250, 500, 1000, and 2000 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$, under four to five

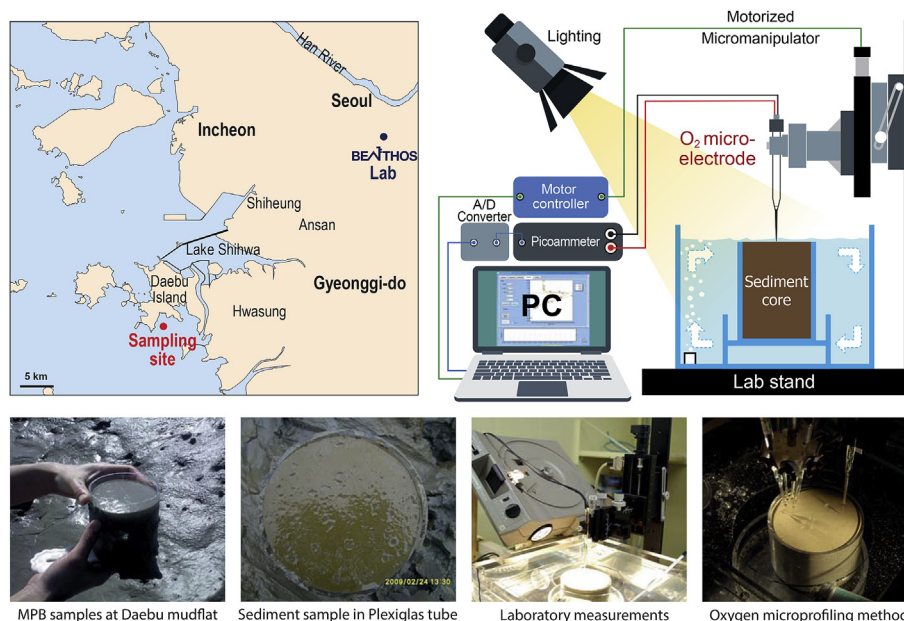


Fig. 1. Map showing the study area of Daebu mudflat, Korea, with brief outline of sampling and laboratory experiment system for the measurement of benthic primary production; depth-profiling of O_2 concentrations obtained by use of O_2 -microelectrode method.

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