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Bacterial abundance and production, and their relation to primary production in tropical coastal waters of Peninsular Malaysia

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Abstract. In the present study, the relationship between bacteria and phytoplankton in tropical coastal waters was investigated. The bacterial abundance, bacterial production, chlorophyll *a* concentration and net primary production were measured at several locations in the coastal waters of Peninsular Malaysia. Chlorophyll *a* concentration ranged from 0.40 to 32.81 $\mu g\,L^{-1}$, whereas bacterial abundance ranged from 0.1 to 97.5×10^6 cells mL^{-1}. Net primary production ranged from 8.49 to 55.95 $\mu g\,C\,L^{-1}\,h^{-1}$, whereas bacterial production ranged from 0.17 to 70.66 $\mu g\,C\,L^{-1}\,h^{-1}$. In the present study, the carbon conversion factor used to convert bacterial production (cells $mL^{-1}\,h^{-1}$) into carbon units ranged from 10 to 32.8 fg C $cell^{-1}$, and was estimated from the bacterial size distribution measured at each location. Both phototrophic and heterotrophic biomass (bacteria–chlorophyll *a*) and activity (bacterial production–net primary production) were significantly correlated, although their correlation coefficients (r^2) were relatively low ($r^2 = 0.188$ and $r^2 = 0.218$ respectively). Linear regression analyses provided the following equations to represent the relationship between: bacteria and chlorophyll *a* (Chl *a*), log Bacteria = 0.413 log Chl *a* + 6.057 ($P = 0.003$); and between bacterial production (BP) and net primary production (NPP), log BP = 0.896 log NPP − 0.394 ($P = 0.004$), which fitted with published results well. Comparison of annual carbon fluxes confirmed the prevalence of net heterotrophy in these coastal waters, and together with the low correlation coefficients, suggested the role of allochthonous organic matter in supporting heterotrophic activity.

Additional keywords: South China Sea, Straits of Malacca.

Introduction

Rising atmospheric CO_2 (Keeling *et al*. 1995) has accelerated research on the carbon fluxes in oceans because the ocean is an important CO_2 sink that accounts for nearly half of the total CO_2 emissions from anthropogenic activities (Sabine *et al*. 2004). The two major flows of carbon in the upper waters of most aquatic systems are primary production and community respiration (Azam *et al*. 1983). Phytoplankton is the main primary producer of autochthonous dissolved organic matter, whereas bacteria are the main heterotrophs that utilise this organic matter (Azam *et al*. 1983; del Giorgio *et al*. 1997; Cole 1999).

Due to the intricate link between these two components, coupling between phytoplankton and bacteria occurs across a wide range of aquatic ecosystems including coastal waters (Bird and Kalff 1984; Cole *et al*. 1988; White *et al*. 1991; Murrell 2003). However, uncoupling between these two components sometimes does occur and respiration exceeds photosynthesis, resulting in net heterotrophy. Net heterotrophy has been suggested for both oligotrophic seas (del Giorgio *et al*. 1997; Duarte *et al*. 1999; Hoppe *et al*. 2002) and coastal waters (Smith and Mackenzie 1987; Ver *et al*. 1999). Net heterotrophy is usually attributed to the presence of allochthonous organic matter from the land (Peinert *et al*. 1989; Ver *et al*. 1999), upwelling (Arístegui and Harrison 2002) or recycling (Goosen *et al*. 1997; Biddanda and Cotner 2002).

However, these studies have been done in temperate waters, and their findings are not necessarily applicable to the tropics (Alongi 1998). In temperate regions where there is marked seasonality in temperature, both temperature and substrate (Pomeroy and Wiebe 2001) influence whether an ecosystem is net-autotrophic or net-heterotrophic (e.g. Shiah and Ducklow 1995; Amon and Benner 1998; Lee *et al*. 2001). In contrast, bacterial activity is not affected or limited by temperature in the stable temperature regime of tropical waters. Tropical oceans cover ~40% of the global ocean (Longhurst and Pauly 1987), and yet knowledge of the structure and function of this ecosystem remains limited, especially in the South-east Asia region (Ning *et al*. 2004).

In the present study, we measured both autotrophic and heterotrophic processes that occur in coastal tropical waters. Coastal waters are increasingly exploited by humans for food, recreation, transport and other needs, and at present most are in various stages of degradation (Alongi 1998). Although coastal waters account for less than 10% of the ocean area, they are highly productive and account for 25% of primary production in the ocean (Berger *et al*. 1989). Therefore, characterisation of both

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