CSIRO PUBLISHING

Marine and Freshwater Research, 2011, **62**, 414–420 www.publish.csiro.au/journals/mfr

The contribution of heterotrophic nanoflagellate grazing towards bacterial mortality in tropical waters: comparing estuaries and coastal ecosystems

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Abstract. Heterotrophic nanoflagellate (HNF) grazing depends on both temperature and trophic status of an ecosystem. As most microbes already function at their temperature optimum in tropical waters, we hypothesised that HNF grazing rates would be higher in more productive sites such as estuaries than in less productive areas such as coastal waters. We sampled two estuaries and three coastal sites along the Straits of Malacca and the South China Sea near the Malaysia Peninsula. Bacterial abundance ranged 0.9–6.3 $\times 10^6$ cells mL^{-1}, whereas HNF abundance ranged 1.8–10.1 $\times 10^3$ cells mL^{-1}. Bacterial production ranged 1.1–12.7 $\times 10^5$ cells mL^{-1} h^{-1}, whereas HNF grazing rates were an order of magnitude lower at 1.0–78.5 $\times 10^4$ cells mL^{-1} h^{-1}. Bacterial abundance, net bacterial production and HNF grazing rates were higher in estuaries than coastal waters but HNF abundance did not differ between the two areas. Across all stations, HNF grazing rates increased with bacterial production, and accounted for ~33% of bacterial production. Our results suggest that in the tropical waters studied, there was a bacterial production–grazing imbalance. Other loss factors such as viral lysis, sedimentation or the presence of benthic filter feeders could account for this imbalance.

Additional keywords: bacterial mortality, top-down control.

Introduction

Since Pomeroy's seminal paper on marine food webs (Pomeroy 1974), there have been significant advances in our understanding of bacteria and their role in marine food webs (Karl 2007). As bacteria are the main respirers in marine planktonic systems and recycle a large pool of dissolved organic matter, it is essential that we understand the factors that regulate bacterial activity and biomass. We can divide the factors that regulate both bacterial production and biomass into bottom-up or resource control, and top-down or predator control, factors (Sherr *et al.* 2007; Suttle 2007).

Among the predators of marine bacteria, heterotrophic nanoflagellates (HNFs) are the most important (Sherr and Sherr 2002). They not only transfer bacterial carbon up to higher trophic levels via the microbial loop (Sherr *et al.* 2007), but can also alter bacterial community composition (Jürgens and Matz 2002; Troussellier *et al.* 2005). It is critical to measure the portion of organic carbon that flows through the multi-step microbial food web versus the main phytoplankton–mesozooplankton food chain in order to understand the stocks of organic carbon in these waters, and the pathways by which carbon is channelled in the food web.

The amount of HNF grazing differs greatly among habitats, and can range from 5 to 430% of bacterial production. Among the factors that affect HNF grazing, temperature is generally considered important (Šolić and Krstulović 1994). When temperature is not limiting, grazers are able to control bacterial biomass (Havens 1993; Riegman *et al.* 1993). Other than temperature, the trophic status or productivity of an environment is also significant, as a more productive system supports higher rates of bacterivory (Krstulović *et al.* 1997).

We investigated top-down control of the microbial food web in order to understand the microbial food web in tropical coastal waters of the Malaysia Peninsula. Measurement of HNF grazing is still relatively rare in tropical waters (Lugomela *et al.* 2001; Murrel and Lores 2004), and in Sunda Shelf waters, the ecology of HNFs is rarely studied, with the exception of mangrove areas (Lee and Bong 2007). In this study, we investigated temporal changes in the grazing pressure of HNFs on bacteria over one year in sites where primary productivity was different (Lee and Bong 2008). As most microbes already function at their temperature optimum in tropical waters (Pomeroy and Wiebe 2001), we tested the hypothesis that HNF grazing rates are higher in more productive sites such as estuaries than in nutrient-poor and less-productive coastal waters.

Materials and methods

Sampling

In this study, we sampled five nearshore sites, both east (Ktn Stn 1 and Ktn Stn 2 at Kuantan) and west (PD Stn 1 and PD Stn 2 at Port Dickson and Klang) of Malaysia Peninsula (Table 1). The stations Klang and Ktn Stn 1 are estuarine, whereas the others

 10.1071/MF10213 1323-1650/11/040414