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Temporal Variation of Bacterial Respiration and Growth Efficiency in Tropical Coastal Waters[∇]

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We investigated the temporal variation of bacterial production, respiration, and growth efficiency in the tropical coastal waters of Peninsular Malaysia. We selected five stations including two estuaries and three coastal water stations. The temperature was relatively stable (averaging around 29.5°C), whereas salinity was more variable in the estuaries. We also measured dissolved organic carbon and nitrogen (DOC and DON, respectively) concentrations. DOC generally ranged from 100 to 900 μM, whereas DON ranged from 0 to 32 μM. Bacterial respiration ranged from 0.5 to 3.2 μM O_2 h^{-1}, whereas bacterial production ranged from 0.05 to 0.51 μM C h^{-1}. Bacterial growth efficiency was calculated as bacterial production/(bacterial production + respiration), and ranged from 0.02 to 0.40. Multiple correlation analyses revealed that bacterial production was dependent upon primary production ($r^2 = 0.169$, df = 31, and $P < 0.02$) whereas bacterial respiration was dependent upon both substrate quality (i.e., DOC/DON ratio) ($r^2 = 0.137$, df = 32, and $P = 0.03$) and temperature ($r^2 = 0.113$, df = 36, and $P = 0.04$). Substrate quality was the most important factor ($r^2 = 0.119$, df = 33, and $P = 0.04$) for the regulation of bacterial growth efficiency. Using bacterial growth efficiency values, the average bacterial carbon demand calculated was from 5.30 to 11.28 μM C h^{-1}. When the bacterial carbon demand was compared with primary productivity, we found that net heterotrophy was established at only two stations. The ratio of bacterial carbon demand to net primary production correlated significantly with bacterial growth efficiency ($r^2 = 0.341$, df = 35, and $P < 0.001$). From nonlinear regression analysis, we found that net heterotrophy was established when bacterial growth efficiency was <0.08. Our study showed the extent of net heterotrophy in these waters and illustrated the importance of heterotrophic microbial processes in coastal aquatic food webs.

As our understanding of the marine food web evolves, we recognize the importance of microorganisms in aquatic ecosystems. Bacteria are the main respirers and recycle a large pool of dissolved organic matter to higher trophic levels (6, 13). Therefore, bacterial production is a key process in dissolved organic matter flux. However, the transfer of dissolved organic matter to bacteria is more accurately reflected by bacterial carbon demand (BCD) or carbon consumption (23). One way to obtain BCD from bacterial production is through bacterial growth efficiency (BGE) or growth yield. BGE is an important parameter to evaluate the fate of organic carbon inputs and to determine whether bacteria act as a link (recyclers) or sink (mineralizers). Therefore, understanding the patterns of variation in BGE is fundamental for our knowledge of carbon cycling (14).

BGE is essentially the ratio of carbon converted to biomass relative to all the carbon consumed, where carbon consumption is either measured as the sum of bacterial production and respiration (5, 24), dissolved organic matter utilization (3), or both (12). Although bacterial production is frequently measured, bacterial respiration measurements are still scarce (23) and are often derived from production rates assuming constant growth efficiency (7, 30). The use of a constant growth efficiency is, however, not valid in some situations as studies have shown that BGE varies over both time and space (8, 27, 28, 32).

From cross-system compilations (15, 38, 49) and a comprehensive study in a temperate salt marsh estuary (4, 5), we begin to understand the factors that affect bacterial growth efficiency. Although substrate quantity and quality affect growth efficiency (4, 15), temperature is also an important factor (49). However, the effect of temperature differs for both bacterial production and bacterial respiration (5) and is distorted by substrate limitation (38).

Most of the above studies are from temperate regions where there is marked seasonality in temperature. In temperate regions, the effects of temperature are usually more apparent (5, 32) and can sometimes distort the effects of other factors (4). Although temperature plays a major role in controlling heterotrophic activity in temperate regions, it plays a lesser role in the tropics, where temperatures are more stable and relatively higher. Tropical oceans cover about 40% of the global ocean (37), and yet knowledge of the structure and function of this ecosystem remains limited, especially in the region of Southeast Asia (29). Only a few related studies are available, and those are from tropical coastal waters in Goa, India (45), and mangrove and estuarine waters in Peninsular Malaysia (27, 28). Substrate quality is often suggested as a more important factor than temperature (27, 28, 45).

In this paper, we addressed the following question: What is

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