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Vertical migration and positioning behavior of copepods in a mangrove estuary: Interactions between tidal, diel light and lunar cycles

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ABSTRACT

Two-hourly zooplankton samplings encompassing tidal (semi-diurnal), diel (24 h), and lunar (4 phases) cycles during the dry (July 2003) and wet (November 2003) monsoon periods were conducted in the Matang estuary to investigate the vertical distribution and behavior of five different groups of copepods (estuarine, euryhaline, marine euryhaline, stenohaline and nocturnal pontellids) in response to the tidal and light regime. Diel vertical migration (DVM) was evident for all copepod groups but the observed patterns differed among species and sampling period (wet or dry and neap or spring tide). Tidally-induced vertical migration (TVM), superimposed by DVM, was observed for estuarine, marine euryhaline and stenohaline copepods but not for euryhaline and nocturnal pontellid copepods. Estuarine copepods tended to ascend during night-flood tide and descent to the bottom during day-ebb tide; this suggests a selective mechanism to penetrate upstream and maintain position in the estuary. In contrast, the marine euryhaline and stenohaline copepods remained at the bottom especially during day-flood tide and ascended into the water column during night-ebb tide; this suggests a selective mechanism to avoid upstream transport. Euryhaline copepods did not respond to tidal advection probably due to their wide range of salinity tolerance, while the large nocturnal pontellid copepods have strong swimming ability. Adaptive vertical migration appears to be a major factor structuring the copepod community in tropical estuaries, and its occurrence in most copepods suggests that neritic marine zooplankton tidally-advected into estuaries and nearshore waters can survive better than previously thought.

1. Introduction

Estuarine copepods have evolved adaptive mechanisms to compensate for their loss in numbers due to the strong bi-directional tidal-river flow, large salinity fluctuations and intense predation pressure. Among the hypothesized adaptive mechanisms, such as high reproductive rate (Ketchum, 1954; Kimmerer and McKinnon, 1987; Gupta et al., 1994), passive accumulation in the turbidity maximum zone (Castel and Veiga, 1990; Morgan et al., 1997; Roman et al., 2001), behavioral responses that involve vertical (e.g. Zaret and Suffern, 1976; Wooldridge and Erasmus, 1980) and horizontal (Cronin et al., 1962; Wooldridge and Erasmus, 1980; Roddie et al., 1984) migrations are the most studied. Studies have shown that copepods can sustain their population numbers in estuaries through a combination of these mechanisms (Ueda et al., 2010; Schmitt et al., 2011).

Behavioral responses with respect to diel and tidally-induced vertical migrations are mediated by several factors. Light is a major environmental cue regulating diel vertical migration (DVM) observed in marine copepods (Forward, 1988; Cohen and Forward, 2009). Predator avoidance is a prime selective force for DVM since strong evidence shows that large marine copepods move down below the surface layer to avoid visual predators during daytime (e.g. Bollens et al., 1992; Hays, 1994). While large adult copepods ascend the water column during night, small or young copepods may adopt a reverse migrating behavior as their adults to evade

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