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Cryptic speciation of benthic *Prorocentrum* (Dinophyceae) species and their potential as ecological indicators

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ABSTRACT

The response of marine ecosystems to rapid climate changes has been well recognized but not studied extensively. Benthic microalgae, in contrast to the phytoplankton that is able to be transported by currents, have limited dispersal ability and thus are a better ecological indicator to climate changes. Here we performed sampling in the Yellow Sea, the East China Sea and South China Sea and established twenty-six strains of benthic *Prorocentrum* for detailed morphological and molecular examinations. Five *Prorocentrum* species, including *P. concavum*, *P. fukuyoi*, *P. mexicanum*, *P. tsawwassenense*, and *P.* cf. *sculptile*, were identified. Both *P. concavum* and *P. fukuyoi* displayed marked intraspecific divergences in large subunit (LSU) ribosomal RNA gene sequences, corresponding to their geographical origins. In contrast, *P. mexicanum* strains shared identical LSU sequence. *Prorocentrum tsawwassenense* and *P.* cf. *sculptile* are not suitable ecological indicators as they were rarely observed. *Prorocentrum mexicanum* is not recommended either as it is present across the region. In contrast, *P. concavum* and *P. fukuyoi* have advantages as ecological indicators for climate changes in the Western Pacific as they comprise several ribotypes with differentiated biogeography. Toxin analysis was also performed on all five species except *P. fukuyoi* by liquid chromatography coupled to tandem mass spectrometry, but okadaic acid was not detectable.

1. Introduction

Global surface temperature has been increasing with a record of 1 °C higher in the last decades compared to the beginning of the industrial revolution, and an intermediate scenario projects an increase of 2 °C by 2300 (Masson-Delmotte et al., 2021). As a response to global warming, marine taxa moved poleward with an average rate of 70 km each decade (Poloczanska et al., 2013). Climate-driven species redistribution at both regional and global scales is expected to have profound consequences for ecosystem structure and function (Pecl et al., 2017). The geographic range of species is regarded as the basic unit of biogeography and refers to the area where the species is present (Brown et al., 1996). The diversity, abundance, growth rate of one or more species in a specific site reflect the effects of current and past environmental changes, and thus identification of easily monitored ecological indicators helps to track or predict the environmental conditions where they are found (Burger, 2006).

Phytoplankton has high biomass and dispersal potential, and poleward dispersal has been predicted using mechanistic species distribution models (Thomas et al., 2012), and observed during long-term

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