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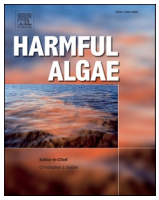

Temporal bloom dynamics of the marine dinoflagellate *Tripos furca* in the Penang Strait

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ABSTRACT

The dinoflagellate *Tripos furca*, known for its frequent and massive blooms in coastal waters, has been associated with significant fish mortality in aquaculture areas. In mid-May 2022, a notable bloom event, characterized by intense red discoloration, was observed along the Penang Strait in the northern Malacca Strait. Our field survey identified a high-density bloom of *T. furca*. To investigate the mechanisms driving the bloom dynamics of this species, monthly sampling was undertaken until the bloom subsided, covering 19 stations across the Penang Strait. Our results showed that the abundances of *T. furca* changed over time and space, a bloom peak of 8.2×10^5 cells L^{-1} was observed in late June, triggered by elevated sea surface temperatures and phosphate availability, while nitrogen was consistently abundant. The bloom's persistence was associated with the influence of the 2020–2022 La Niña and Indian Ocean Dipole, which caused warmer sea temperatures. Metabarcoding of the V7-V9 18S rDNA region revealed high intraspecific genetic diversity within the *T. furca* bloom subpopulations, suggesting both clonal reproduction and possible sexual processes. The bloom termination was linked to a seasonal shift in temperatures and changes in nutrient regimes that caused a transition of phytoplankton compositions to *Noctiluca*- and diatom-dominated populations contributed to the bloom's decline. Early detection of the bloom has successfully prevented severe losses to the aquaculture farms in the area, emphasizing the importance of early intervention. This study also enhances our understanding of *T. furca* bloom dynamics and provides insights into managing harmful algal blooms in tropical coastal regions.

1. Introduction

Harmful algal blooms (HABs) have become increasingly prevalent in coastal ecosystems worldwide, particularly in regions experiencing significant anthropogenic pressures. In Southeast Asia, numerous HAB events have been reported since the 1970s (Yñiguez et al., 2021). The increased occurrence and distribution of HABs are mostly attributed to coastal eutrophication (e.g., Er et al., 2018; Mohd-Din et al., 2020; Law et al., 2023), often linked to the expansion of aquaculture and other anthropogenic activities along the coastline (Azanza et al., 2024; San Diego-McGlone et al., 2024).

The Penang Strait, located in the northern Malacca Strait (MS), is a vital aquaculture area in Malaysia and one such ecosystem under these pressures. The aquaculture sector, which produced 0.57 million metric tonnes in 2022, has been pivotal to Malaysia's economic growth (Department of Fisheries Malaysia, 2023). However, the environmental impacts, including release of nutrient-rich effluents by feed wastes (Islam et al., 2005), exacerbate coastal eutrophication, subsequently increased the risk of HABs (e.g., Er et al., 2018; Mohd-Din et al., 2022). Eutrophication in the Penang Strait is particularly severe (Gasim et al., 2013), with levels of macronutrients such as phosphate, nitrate, and ammonium often exceeding the limits of the Malaysian Marine Water Quality Standard (MMWQS). Such nutrient enrichment fosters conditions conducive to HABs, leading to hypoxic and anoxic zones, adverse impacts on marine life, and disruption to ecological balance (Smayda, 1998, 2008).

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