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Wind-driven development and transport of *Gymnodinium catenatum* blooms along the coast of Fujian, China

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ABSTRACT

Gymnodinium catenatum is a cosmopolitan, bloom-forming dinoflagellate known to produce a suite of potent paralytic shellfish poisoning (PSP) toxins. Here, we revisit two major blooms of *G. catenatum* along the Fujianese Coast, China, in 2017 and 2018. The impact area of the 2017 bloom was larger than that of the 2018 event. Field sampling and remote satellite sensing revealed that alongshore transport driven by the southwest wind, as well as physical accumulation driven by the northeast wind, played important roles in the development and distribution of the two bloom events. The relationship between wind-induced hydrodynamic conditions and the unprecedented HAB events established in this study adds greatly to our understanding of algal bloom dynamics along the Fujianese coast. These results improve our ability to detect, track, and forecast *G. catenatum* blooms, thereby potentially minimizing the negative impacts of future HAB events.

1. Introduction

Harmful algal bloom (HAB) events impact coastal nations worldwide. In many areas, these events are increasing in frequency, distribution, and intensity (Anderson et al., 2012; Hallegraeff, 1993). Such increases have been linked to many different factors, including ballast water transport (Bolch and de Salas, 2007), improved detection capabilities, and the stimulatory effects of anthropogenic nutrient inputs, coastal development, and climate change (Anderson, 1989). Toxic HABs lead to the biotoxin contamination of seafood products (especially shellfish) and threaten the environment, public health, and socio-economic growth of affected areas (Anderson, 1995). Analyses of the bloom dynamics of HAB species in localized settings, as well as their physical–biological interactions, are therefore extremely important.

The unarmored chain-forming dinoflagellate *Gymnodinium catenatum,* which produces paralytic shellfish toxins, was first described from the Gulf of California (Graham, 1943), but this species is globally distributed in temperate, tropical, and equatorial coastal and shelf waters, including those of North and South America (Band-Schmidt et al., 2004; Graham, 1943), Europe (Bravo et al., 2010; Fermín et al., 1996), Australia (Bolch and de Salas, 2007), New Zealand (Mackenzie and Beauchamp, 2001), Japan, and Southeast Asia (Matsuoka and Fukuyo, 1994). In China, *G. catenatum* is distributed in the Pearl River estuary (Qi et al., 1996; Tang et al., 2003) and the Yellow Sea (Gu et al., 2013). *Gymnodinium catenatum* has a cyst stage in its life cycle, and this cyst is characterized by a unique microreticulate surface (Anderson et al., 1988).

The first reported outbreaks of paralytic shellfish poisoning (PSP) attributed to *G. catenatum* occurred in 1976 in Spain (Estrada et al., 1984). Hallegraeff et al. (2012) reviewed *G. catenatum* bloom dynamics in Tasmanian, Spanish/Portuguese, and Mexican waters, and found that this species tolerated a wide range of temperatures and salinities, consistent with the findings of Band-Schmidt et al. (2004). *G. catenatum* has strong vertical migration behaviors (Doblin et al., 2006), which confer a selective advantage on *G. catenatum* in downwelling areas, and in the more turbulent waters surrounding upwelling areas (Moita et al., 2003; Tilstone et al., 1994). Offshore populations of *G. catenatum* have been transported by estuarine circulation or alongshore currents, and have developed into nearshore blooms (Crespo et al., 2007; Fermín et al., 1996; Sordo et al., 2001).

Rapid economic development and intensive coastal aquaculture have led to the serious eutrophication of Chinese coastal waters (Zhou et al., 2008). The frequencies of HABs along the Chinese coast have increased since the 1970s (Yan et al., 2002).

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