



Original research article

Life-history stages of natural bloom populations and the bloom dynamics of a tropical Asian ribotype of *Alexandrium minutum*



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ABSTRACT

In 2015, a remarkably high density bloom of *Alexandrium minutum* occurred in Sungai Geting, a semi-enclosed lagoon situated in the northeast of Peninsular Malaysia, causing severe discoloration and contaminated the benthic clams (*Polymesoda*). Plankton and water samples were collected to investigate the mechanisms of bloom development of this toxic species. Analysis of bloom samples using flow cytometry indicated that the bloom was initiated by the process of active excystment, as planomyces (>4C cells) were observed in the early stage of the bloom. Increase in planozygotes (2C cells) was evident during the middle stage of the bloom, coinciding with an abrupt decrease in salinity and increase of temperature. The bloom was sustained through the combination of binary division of vegetative cells, division of planozygotes, and cyst germination through continuous excystment. Nutrient depletion followed by precipitation subsequently caused the bloom to terminate. This study provides the first continuous record of *in situ* life-cycle stages of a natural bloom population of *A. minutum* through a complete bloom cycle. The event has provided a fundamental understanding of the pelagic life-cycle stages of this tropical dinoflagellate, and demonstrated a unique bloom development characteristic shared among toxic *Alexandrium* species in coastal embayments.

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1. Introduction

Species of *Alexandrium* are planktonic marine dinoflagellates, several of which are capable of producing a group of highly potent neurotoxins, collectively known as saxitoxins (STXs). Among the STX-producing *Alexandrium* species, *Alexandrium minutum* is one coastal species that produces massive discoloration, and is often associated with shellfish contamination that causes paralytic shellfish poisoning (PSP) in humans. The species has been known to be widespread in tropical (Bajarías et al., 2003; Lim et al., 2004) and temperate regions (Chang et al., 1997; Hwang and Lu, 2000; Vila et al., 2001; Galluzzi et al., 2004; Garcés et al., 2004; Anglès et al., 2012b). The wide latitudinal distribution of this species may be due to its remarkably high physiological adaptation to diverse environmental conditions. The species has been demonstrated to possess unique physiological responses to tolerate temperature and irradiance changes (Chang and McClean, 1997; Lim et al., 2006;

Ignatiades et al., 2007), withstanding large salinity range (Lim and Ogata, 2005; Lim et al., 2007, 2011), and with broad nutritional mode (Guisande et al., 2002; Lim et al., 2010; Yang et al., 2011; Hii et al., 2016). Adaptation to adverse conditions is achieved by cyst formation, sexual fusion, and planozygote formation (Turpin et al., 1978; Anderson et al., 1984; Anderson and Lindquist, 1985; Persson et al., 2008; Figueroa et al., 2011), as also explained next.

The species *Alexandrium minutum*, like many marine dinoflagellates, undergoes a haplontic life cycle with sexual and asexual reproduction. Natural population growth of *A. minutum* is achieved by asexual binary division of the haploid cells, while sexual reproduction is thought to be triggered when the environment turns unfavorable for growth or regulated by an endogenous mechanism (Anderson, 1998; references herein). Sexual life cycle of *A. minutum* begins when two gamete cells (isogamous or anisogamous; Figueroa et al., 2007; Liow et al., submitted) fuse and form a planozygote that remains motile for some time, and transforms into a resting cyst that sinks to the bottom sediment. In some cases, planozygotes may bypass cyst formation and undergo division (Figueroa and Bravo, 2005; Figueroa et al., 2015). After a mandatory dormancy period (1–1.5 months, Anglès et al., 2012b),

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