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Thecal plate morphology, molecular phylogeny, and toxin analyses reveal two novel species of *Alexandrium* (Dinophyceae) and their potential for toxin production

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ABSTRACT

This study describes two novel species of marine dinophytes in the genus *Alexandrium*. Morphological characteristics and phylogenetic analyses support the placement of the new taxa, herein designated as *Alexandrium limii* sp. nov. and *A. ogatae* sp. nov. *Alexandrium limii*, a species closely related to *A. taylorii*, is distinguished by having a shorter 2'/4' suture length, narrower plates 1' and 6", with larger length: width ratios, and by the position of the ventral pore (Vp). *Alexandrium ogatae* is distinguishable with its metasert plate 1' having almost parallel lateral margins, and by lacking a Vp. Production of paralytic shellfish toxins (PSTs), cycloimines, and goniodomins (GDs) in clonal cultures of *A. ogatae, A. limii*, and *A. taylorii* were examined analytically and the results showed that all strains contained GDs, with GDA as major variants (6–14 pg cell^{-1}) for all strains except the Japanese strain of *A. limii*, which exclusively had a desmethyl variant of GDA (1.4–7.3 pg cell^{-1}). None of the strains contained detectable levels of PSTs and cycloimines.

1. Introduction

The genus *Alexandrium* Halim is a marine dinophyte commonly found in coastal waters around the world (Hallegraeff, 1993; Anderson et al., 2012). *Alexandrium* has been extensively studied in recent decades for its ability to produce paralytic shellfish toxins (PSTs) in several toxigenic species. PSTs are a group of potent neurotoxins also known as saxitoxin (STX) variants. The toxin accumulates in shellfish vectors, transfers to humans, and causes severe neurological symptoms, including paralysis and respiratory failure, causing paralytic shellfish poisoning (PSP). Of the 32 taxonomically accepted species to date (Mertens et al., 2020), 16 are listed as harmful species (Lundholm et al., 2023), at least one-third are capable to produce PSP toxins. In recent decades, there have been numerous PSP outbreaks worldwide, particularly in Southeast Asia, resulting in human fatalities (e.g., Lim et al., 2007, 2012, 2020; Yñiguez et al., 2021). Furthermore, blooms of several *Alexandrium* species are known to cause significant losses to aquaculture industries in America, Europe, Asia (Trainer and Yoshida, 2014; Trainer, 2020), Australia, and New Zealand (MacKenzie et al., 2004; Jin et al., 2008; Condie et al., 2019). To cite an instance, the 2016 bloom of *A. catenella* (Whedon & Kofoid) Balech in Chile was a notable case that badly hit the salmon aquaculture industries. This bloom killed over 30, 000 tons of farmed salmon, causing losses of over $800 million (Díaz et al., 2019). There are several species of *Alexandrium* that produce harmful metabolites other than PSTs, such as cycloimines (spirolides, gymnodimines), goniodomins, and some poorly characterized lytic

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