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REVIEW ARTICLE

The toxic cosmopolitan cyanobacteria *Moorena producens*: insights into distribution, ecophysiology and toxicity

Emily Curren[1] · Chui Pin Leaw[2] · Po Teen Lim[2] · Sandric Chee Yew Leong[1]

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Abstract

Moorena producens is a benthic filamentous cyanobacteria that has been widely documented for its toxicity. This cyanobacterium colonizes both temperate (37%) and tropical (63%) regions, making it a cosmopolitan cyanobacterium with a global distribution. *M. producens* grows across coral reefs in multiple locations but recurringly blooms in Queensland, Australia. Today, nuisance blooms of *M. producens* have resulted in major disruptions to recreational activities along coastal areas and are known to cause adverse effects on organism and human health upon contact or ingestion. Specifically, marine organisms such as the green turtle *Chelonia mydas* and hawksbill turtle *Eretmochelys imbricata* were fatally poisoned by *M. producens* after consumption of this cyanobacterium. Reports record a range of effects on human health, from pain and blistering or even death upon ingestion of contaminated seafood. Blooms of *M. producens* are triggered by influxes of nitrogen, phosphate and iron, from surrounding coastal runoffs or sewage effluents. Additions of these nutrients can result in an increase in growth rate by 4–16 times. Iron bioavailability also plays a crucial role in bloom formation. A total of 231 natural products from 66 groups were identified from *M. producens*, with the three dominant groups: malyngamides, microcolins and dolastatins. These bioactive secondary metabolites have displayed toxicities against a range of carcinoma cell lines and organisms such as brine shrimp *Artemia salina* and goldfish *Carassius auratus.* This review provides a thorough insight to the distribution, ecophysiology and toxicity of *M. producens*, with reports on bloom events and implications on organism and human health.

Keywords Marine · Cyanobacteria · Distribution · Ecology · Toxicity

Introduction

Cyanobacteria are ancient phototrophic organisms that play important roles in marine ecosystems. The oldest specimens of cyanobacteria date back to three billion years ago (Stal 2007). They are oxygenic and function to fix atmospheric nitrogen for nutrient recycling. Nitrogen fixation has been widely studied in cyanobacteria, as this function contributes to a significant proportion of biological nitrogen fixation in marine environments (Latysheva et al. 2012). During periods of nitrogen limitation, nitrogen fixation protects the ecosystem as cyanobacteria supplies bioavailable nitrogen for the growth of surrounding organisms (Stal 2015). Across the decades, there have been increasing anthropogenic pressures on marine ecosystems, with rapid urbanization altering coastlines. In many countries, this has led to the increased nutrient loading in coastal waters, resulting in eutrophication. Together with global warming and rising CO_2 levels, this has resulted in an increased magnitude and frequency of harmful cyanobacterial blooms. This has been observed in the Baltic Sea, where summer blooms of harmful *Aphanizomenon* sp. and *Nodularia spumigena* are observed to stretch over 20 days since the 2000s, which increased from an average of 8 days in previous decades. (Finni et al. 2001). Furthermore, these blooms are increasing in surface area and have covered an area of 200 000 km^2 in 2014 (Finni et al. 2001). New locations of cyanobacterial blooms have also been reported, where extensive blooms of the filamentous *Trichodesmium erythraeum* were first recorded in the Mediterranean Sea in 2010. In 2017, a bloom of freshwater

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✉ Emily Curren
e0013223@u.nus.edu

[1] St. John's Island National Marine Laboratory, Tropical Marine Science Institute, National University of Singapore, 18 Kent Ridge Road, Singapore 119227, Singapore

[2] Bachok Marine Research Station, Institute of Ocean and Earth Sciences, University of Malaya, Bachok, Malaysia

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