Harmful Algae 68 (2017) 128–151

Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal

Research Paper

An evaluation of the genus *Amphidinium* (Dinophyceae) combining evidence from morphology, phylogenetics, and toxin production, with the introduction of six novel species

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ARTICLE INFO

Article history:
Received 4 May 2017
Received in revised form 1 August 2017
Accepted 1 August 2017
Available online xxx

Keywords:
Secondary structure
Compensatory base change
Cytotoxicity
Scales
28S
ITS

ABSTRACT

The genus *Amphidinium* is an important group of athecated dinoflagellates because of its high abundance in marine habitats, its member's ability to live in a variety of environmental conditions and ability to produce toxins. Furthermore, the genus is of particular interest in the biotechnology field for its potential in the pharmaceutical arena. Taxonomically the there is a history of complication and confusion over the proper identities and placements of *Amphidinium* species due to high genetic variability coupled with high morphological conservation. Thirteen years has passed since the most recent review of the group, and while many issues were resolved, some remain. The present study used microscopy, phylogenetics of the 28S region of rDNA, secondary structure of the ITS2 region of rDNA, compensatory base change data, and cytotoxicity data from *Amphidinium* strains collected world-wide to elucidate remaining confusion. This holistic approach using multiple lines of evidence resulted in a more comprehensive understanding of the morphological, ecological, and genetic characteristics that are attributed to organisms belonging to *Amphidinium*, including six novel species: *A. fijiensis*, *A. magnum*, *A. paucianulatum*, *A. pseudomassartii*, *A. theodori*, and *A. tomasii*.

1. Introduction

The genus *Amphidinium* is a group of athecated dinoflagellates that are incredibly diverse in that, while being highly conserved morphologically, they thrive world-wide in a wide variety of habitats (Dodge, 1982; Dolapsakis and Economou-Amilli, 2009; Flø Jørgensen et al., 2004a, 2004b; Larsen, 1985; Larsen and Patterson, 1990), temperatures (Murray and Patterson, 2002), and trophic modes (Flø Jørgensen et al., 2004; Murray et al., 2004; Murray and Patterson, 2002). They also produce toxins and bioactive compounds that can have both harmful effects. Reports indicate that *Amphidinium* blooms cause fish kills and that the toxins they produce may increase the effects of Ciguatera Fish Poisoning as they are often found in association with *Gamberdiscus* in affected areas (Baig et al., 2006; Rhodes et al., 2010; Tindall and Morton, 1998). They also have beneficial effects, producing compounds that exibit antifungal or antimicrobial properties (Echigoya et al., 2005; Kobayashi and Kubota, 2007; Kobayashi et al., 1991; Kobayashi, 2008; Meng et al., 2010; Nuzzo et al., 2014; Satake et al., 1991; Washida, 2006). They grow easily in culture, and can be scaled up to mass culturing volumes appropriate for chemical analyses.

Presently the genus includes both heterotrophic and autotrophic forms possessing a characteristically minute epicone that is deflected towards the left. The autotrophic *Amphidinium* consist of two clades (Flø Jørgensen et al., 2004a, 2004b) that are sister to one another. The first will be referred to as the Herdmanii Clade and includes: *A. steinii* Lemmerman, *A. mootonorum* Murray and D. J. Patterson, *A. herdmanii* Kofoid and Swezy, and *A. cupulatisquama* M. Tamura and T. Horiguchi. The second is the Operculatum Clade and includes: *A. carterae* Hulburt, *A. massartii* Biecheler, *A. gibbossum* (L. Maranda and Y. Shimizu) Flø Jørgensen and Murray, *A. trulla* Shauna Murray, Rhodes, and Flø Jørgensen, *A. operculatum* Claparède & Lachmann, and, most recently, *A. thermaeum* Dolapsakis and Economou-Amilli. The organisms in the Herdmanii Clade are distinguishable by a high degree of genetic diversity.

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http://dx.doi.org/10.1016/j.hal.2017.08.001
1568-9883/