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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This manuscript is dedicated to Dr. Theodore J. Smayda (1932–2017) in honor of his lifetime dedication to phytoplankton ecology and service as former editor of Harmful Algae.

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ABSTRACT

The genus Amphidinium is an important group of athecate 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 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 confusion. Thirty years have 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. fijensis, A. magnum, A. paucianulatum, A. pseudomassartii, A. theodori, and A. tomasii.

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1. Introduction

The genus Amphidinium is a group of athecate dinoflagellates that are incredibly diverse in that, while highly conserved morphologically, they thrive world-wide in a wide variety of habitats (Dodge, 1982; Dolapsakis and Economou-Amillii, 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 Gambardiscus in affected areas (Baig et al., 2006; Rhodes et al., 2010; Tindall and Morton, 1998). They also have beneficial effects, producing compounds that exhibit 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. gibbosum (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...