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Morphological and phylogenetic characterization of seven species of *Vaucheria* (Xanthophyceae), including two new species, from contrasting habitats in New Zealand

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Abstract

Vaucheria is a genus of yellow-green algae, the taxonomy of which is based on the morphology of antheridia and oogonia. Distribution of *Vaucheria* in New Zealand is poorly understood. Only two studies have investigated phylogenetic relationships in the genus world-wide and these omitted some of the diversity found in New Zealand. We identified seven species of *Vaucheria* based on morphology of their reproductive structures. Two were described as new species (*V. aestuarii* and *V. edaphica*), two were reported for the first time from New Zealand (*V. erythrospora* and *V. litorea*), one has been reported previously (*V. bursata*), and the identification of the remaining two was inconclusive (*Vaucheria* cf. *borealis* and *Vaucheria* cf. *conifera*). The genetic variation and phylogenetic position of these species were studied using phylogenetic analyses of *rbc*L sequences. These showed the existence of morphologically indistinguishable cryptic species complexes in sect. Corniculatae. Our results were mostly consistent with the current morphology-based sectional classification of the genus.

Keywords: *Vaucheria*; Xanthophyceae; *rbc*L; New Zealand; Canterbury

Introduction

Vaucheria de Candolle (1801: 20) is a genus of yellow-green algae (Xanthophyceae) characterized by siphons with apical growth. It has a cosmopolitan distribution with over 79 accepted species worldwide, although there are no records in South America, Africa, Central Asia and Antarctica (Guiry & Guiry 2014). Taxonomy of the genus is based on a morphological species concept, where species are characterized on morphology, especially the shape, size and arrangement of antheridia and oogonia (Entwisle 1988a). Identification of closely related species is a challenge because of overlapping characteristics (Entwisle 1988a, b) and due to paucity of fertile material in field specimens (Rieth 1980). Cryptic species that are morphologically indistinguishable are known to exist, but there is no current consensus on what to do with such entities (Andersen & Bailey 2002).

The distribution of *Vaucheria* in New Zealand is poorly known, with most records from the North Island. There are reports of seven freshwater species—*V. geminata* (Vaucher 1803: 29) de Candolle in Lamarck & de Candolle (1805: 62) (Chapman *et al*. 1957), *V. dillwynii* (Weber & Mohr 1803: 12) Agardh (1812: 21) (as *V. pachyderma* Walz (1866: 146)) (Hooker 1867, Sarma 1974), *V. hamata* (Vaucher 1803: 27) de Candolle in Lamarck & de Candolle (1805: 63), *V. jaoi* Ley (1944: 92) (Sarma 1973), *V. aversa* Hassall (1843: 429), *V. bursata* (Müller 1788: 96) Agardh (1811: 21) as *V. sessilis* f. *repens* (Hassall 1843: 430) Hansgirg (1886: 95) and *V. undulata* Jao (1936: 741) (Sarma 1974), and four marine species—*V. velutina* Agardh (1824: 312), *V. synandra* Woronin (1869:137) , *V. pseudosessilis* Chapman (1956: 495) (Chapman 1956) and *V. longicaulis* Hoppaugh (1930: 332) (Wilcox 2011). Two additional marine species were listed by Adams (1994) as *Vaucheria* sp. from mudflats in the North Island and *Vaucheria* sp. 'Chathams' from the Chatham Islands. There are no reports of soil-dwelling species in New Zealand.

This study has sought to increase knowledge of *Vaucheria* species in New Zealand. Seven species of *Vaucheria*, including new species, are identified based on the morphology of reproductive structures. The adequacy of the

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Our morphological classification of the other species in this study was found to correlate with the molecular phylogeny. *Vaucheria erythrospora* and *V. litorea* were grouped with other strains of the same species, in both MPB and Bayesian analyses. The morphological classification of the two new species reported in this study, *V. edaphica* and *V. aestuarii* was also well supported by the molecular phylogeny. This was true especially for *V. edaphica* which was found to be genetically distinct from all other species in sect. *Racemosae* and was placed on a long branch in the phylogenetic analyses. All species reported in this study were placed in the correct sections in the phylogenetic analyses, as judged by their morphological characters.

This is the first study involving morphological and molecular phylogenetic characterization of *Vaucheria* strains from New Zealand. Andersen and Bailey (2002) suggested a phylogenetic classification scheme at the sectional level, but further studies which include representative sequences from other sections of *Vaucheria* are required in order to confirm this. Difficulty in distinguishing closely related species that are currently recognized, and genetic variation amongst morphologically identical strains (especially in *Racemosae* and *Corniculatae*), suggest that the morphology-based classification of species may need revision.

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