



# Mitochondrial phylogenomics of eucheumatoids (Solieriaceae, Rhodophyta) from the Indo-Pacific

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## Abstract

Eucheumatoid seaweeds are highly valued globally for their carrageenan. Members of this group are widely distributed and cultivated throughout the Indo-Pacific. Despite various molecular studies on this group, mitogenome research in eucheumatoids has only recently explored a limited number of species, leaving overall diversity largely unexplored. In this study, 26 complete mitogenomes of eucheumatoids from the Indo-Pacific were sequenced, including the first complete sequences for wild genotypes of *Eucheuma platycladum*, *Kappaphycus striatus*, *Kappaphycopsis cottonii*, and an unidentified species of *Kappaphycus* from Africa. The eucheumatoid mitogenomes range from 25.1 to 25.5 kb in size, containing 50 genes (24 protein-coding genes, 24 tRNA genes, two rRNA genes, and a single intron) bearing extensive gene synteny across species. Phylogenetic analyses using concatenated mitochondrial genes recovered strong clades for each group, with the exception of the genus *Eucheuma*. Apart from *atp9*, gene marker evaluations showed that all genes could be used for species identification. The utility of four genes, *atp4*, *nad3*, *nad4*, and *nad6*, was found to be effective for resolving intergeneric relationships. These findings provide a foundation for comparative analysis useful for resolving phylogenetic relationships and outstanding taxonomic issues, cultivar development, and conservation efforts. Expanding species coverage and incorporating plastome analyses would contribute to a more complete understanding of the genomic diversity and evolutionary history of this economically important group of seaweeds.

**Keywords** *Kappaphycus* · *Eucheuma* · Molecular · Mitogenome · Phylogeny · Phylogenomic

## Introduction

Eucheumatoids are tropical red seaweeds belonging primarily to the genera *Betaphycus*, *Eucheuma*, *Mimica*, *Kappaphycopsis*, and *Kappaphycus*. These seaweeds contain carrageenan, a commercially valuable polysaccharide widely used in the food and cosmetic industries. By far, only *Kappaphycus* and *Eucheuma* are cultivated commercially. The global carrageenan market reached US\$ 967.6 million in 2024 and is projected to increase to US\$ 1,607.12 million by 2033 (Straits Research 2025). Indonesia and the Philippines dominate global carrageenan production, primarily supplying China, which has recently emerged as a major carrageenan processor and exporter through expanded facilities and value-chain integration (Zhang et al. 2024). Eucheumatoid farming plays an important role in coastal communities

of developing countries, providing a source of livelihood and contributing to poverty alleviation (Hurtado et al. 2013; Tan et al. 2013; Msuya et al. 2022).

Although genetic markers have proven useful for addressing key challenges in eucheumatoids, their taxonomy remains unresolved due to missing critical information from type specimens that originally defined the generic and species concepts (Tan et al. 2024). The morphologically plastic nature of eucheumatoids also makes them difficult to identify based on morphology alone, and this is compounded by the confusing use of commercial and vernacular names (Zuccarello et al. 2006; Lim et al. 2014; Dumilag et al. 2022; Tan et al. 2024). The use of genetic markers facilitated the identification of seaweed cultivars which improved efficiency in farm management and carrageenan processing, while the identification of wild specimens provided valuable insights into eucheumatoid genetic diversity and conservation, as well as the

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