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Molecular phylogenetic analysis of *Sciadophycus stellatus* (Rhodymeniales, Rhodophyta) supports its placement in the family Rhodymeniaceae

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The marine red alga *Sciadophycus stellatus* E.Y.Dawson (1945) (Figure 1) was described from specimens dredged at 40–50 meters from the Kellett Channel, south shore of Cerros Island (also known as Cedros Island), Baja California, Mexico (Dawson 1945). This uncommon subtidal species occurs in southern California, Baja California, Mexico and Isla Floreana, Galapagos Islands (as *Fauchea rhizophylla* Taylor) (Dawson 1945, Abbott and Hollenberg 1976, Millar 2001, Aguilar-Rosas *et al.* 2010). In California, *S. stellatus* has been collected in San Diego County (UC2003699) and Palos Verdes Peninsula, Los Angeles County (UC1882843), on the mainland coast of southern California and, more commonly, offshore from Santa Catalina (UC1471598), Santa Barbara (UC2034301), Anacapa (WTU-A-012879) and Santa Cruz Islands (UC1965240). In Mexico, in addition to the type locality, it has been collected from Isla Los Coronados (UC1574390), La Bufadora (Aguilar-Rosas *et al.* 2010), Isla Natividad (UC1882846), Punta Eugenia (US13095) and Bahia Tortugas (US42090), Baja California (distribution records, unless otherwise cited, are based on specimens in herbaria at the University of California at Berkeley [UC], University of Washington [WTU-A], and the Smithsonian Institution [US]).

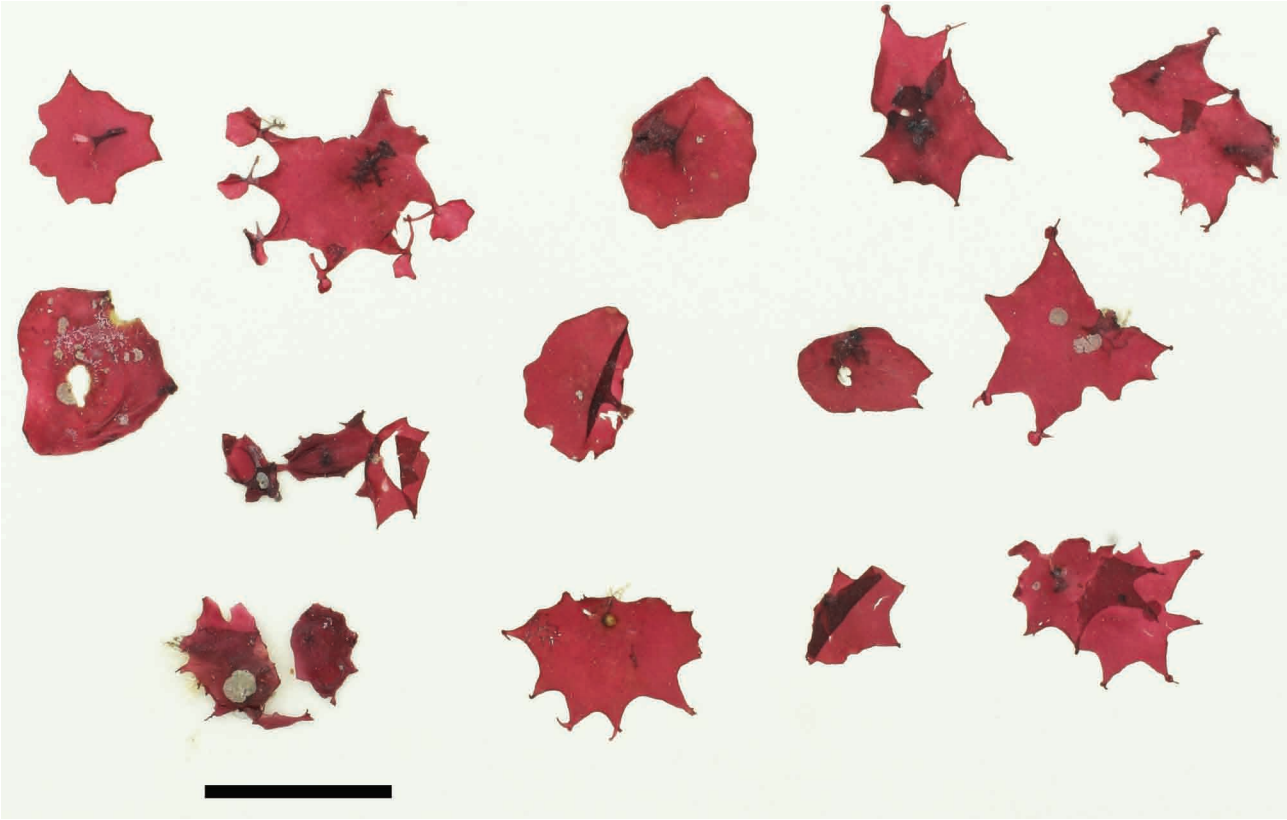

FIGURE 1. *Sciadophycus stellatus* from Arch Point, Santa Barbara Island, California (UC2034301). Scale bar = 3 cm.

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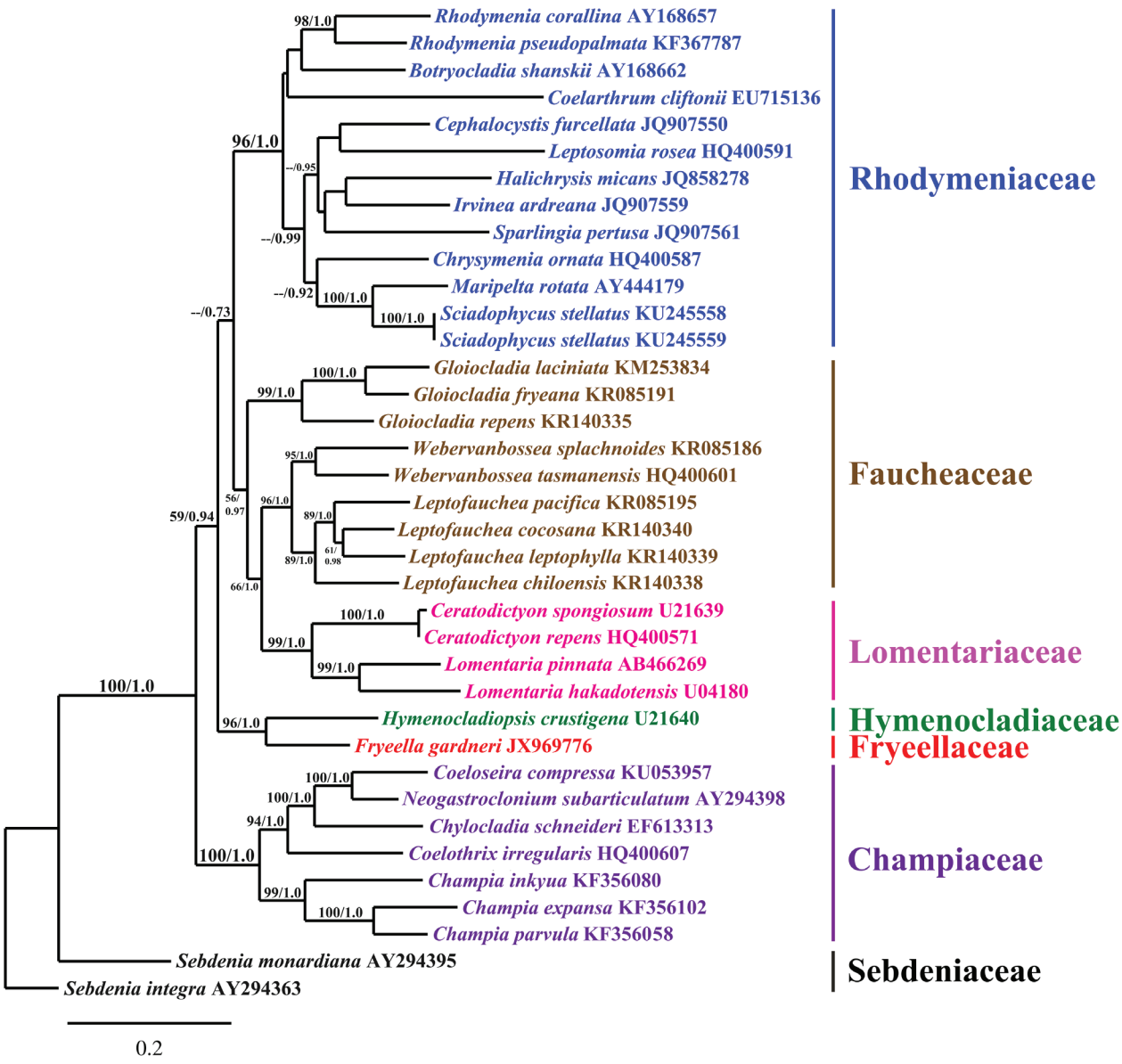

FIGURE 2. Phylogram of the RAxML BlackBox maximum likelihood analysis of species of Rhodymeniales based on *rbc*L sequences. Bootstrap support (nreps=100)/Bayesian posterior probabilities are cited at the nodes. GenBank accession numbers are cited after the binomials. The bar below represents the scale for nucleotide substitutions.

Sciadophycus stellatus is described (Dawson 1945, Millar 2001) as stipitate, peltate, with a sympodial mode of submarginal secondary branching of stellate blades with a nearly monostromatic, large-celled medulla. Tetrasporangia are cruciate, terminal and occur in slightly raised nemathecial sori scattered over the thallus. Cystocarps have a network of sterile filaments (*tela arachnoidea*) surrounding the gonimoblast and carposporangia, which led Dawson to conclude that *S. stellatus* was a member of the subfamily Faucheae Kylin in the Rhodymeniaceae Harvey. Abbott and Hollenberg (1976) merged *Fauchea rhizophylla* W.R.Taylor (1945) with *S. stellatus*; Millar (2001) corroborated this conclusion with an examination of type specimens. These authors placed *S. stellatus* in the Rhodymeniaceae. Le Gall *et al.* (2008) published a systematic analysis of the Rhodymeniales using large-subunit nuclear ribosomal DNA (LSU) and elongation factor 2 (EF2) DNA sequences, but *Sciadophycus* was not included in their study. On the basis of cruciate tetrasporangia in nemathecia, Le Gall *et al.* (2008) predicted that *Sciadophycus* would likely be a member of the Fryeellaceae L.Le Gall, Dalen & G.W.Saunders or the Faucheaceae I.M.Strachan, G.W.Saunders, & G.T.Kraft.

To determine the familial placement of *S. stellatus* and its relationship to other genera in the Rhodymeniales, DNA was isolated from two herbarium specimens of *S. stellatus* from the Channel Islands, California (UC2034301 from Santa Barbara Island and UC1965240 from Santa Cruz Island) following Lindstrom *et al.* (2011) and adhering strictly to the precautionary steps proposed by Hughey and Gabrielson (2012). Isolated DNA was amplified using the thermocycling

parameters described by Lindstrom *et al.* (2011) and the elevated primer concentrations implemented by Lindstrom *et al.* (2015) with primers F57-R753 (Hommersand *et al.* 1994), F625-R900 (Lindstrom *et al.* 2015), and F850Sciado (5' GTTTGCCAAGCAGCTAGGAACC 3')-R1460Sciado (5' CTAAAGCTGTTTGTAGAGGACCAC 3'). Maximum likelihood analysis of 35 ingroup and two outgroup taxa with RAxML BlackBox was performed using 100 bootstrap replicates with the GTR substitution matrix, GAMMA+P-Invar model of rate heterogeneity, and ML estimate of alpha-parameters in effect (Stamatakis *et al.* 2008). The Bayesian analysis was conducted with MrBayes 3.2.1 (Uppsala, Sweden) (Huelsenbeck *et al.*, 2001; Ronquist & Huelsenbeck, 2003) using the parameters described by Lindstrom *et al.* (2015).
Phylogenetic analyses using the resulting 1,277 bp of the *rbc*L gene placed *S. stellatus* in a strongly supported clade sister to *Maripelta rotata* (E.Y.Dawson) E.Y.Dawson (Figure 2). The two genera differ by 7.0% for the *rbc*L gene, and are situated well within the Rhodymeniaceae. On the basis of *rbc*L gene sequences, we assign the generitype of *Sciadophycus*, *Sciadophycus stellatus*, to the Rhodymeniaceae. Since we did not possess material of *S. expansus* (Weber-van Bosse) A.J.K.Millar (2001), we were unable to confirm its placement in *Sciadophycus*.

Sciadophycus is distinguished from its sister genus, *Maripelta*, by its sympodial secondary blades from blade margins, terminal tetrasporangia, and the presence of a *tela arachnoidea* (Eiseman & Moe 1981). Our results indicate that the *tela arachnoidea* is not a character shared only by members of the Faucheaceae, Fryeellaceae and Champiaceae, as stated by Le Gall *et al.* (2008), but occurs in the Rhodymeniaceae as well.

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