

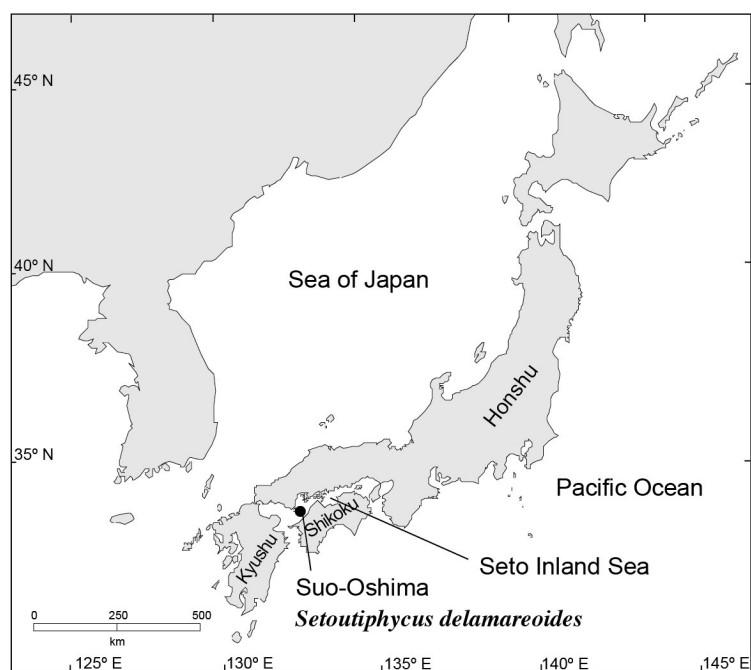
Supplementary Information

Discovery of a novel brown algal genus and species *Setoutiphycus delamareoides* (Phaeophyceae, Ectocarpales) from the Seto Inland Sea, Japan

Hiroshi Kawai^{1,*}, Takeaki Hanyuda¹

¹Kobe University Research Center for Inland Seas, Rokkodai, Kobe 657-8501, Japan

*kawai@kobe-u.ac.jp



Supplementary Information 1

Map showing the collection site of *Setoutiphyicus delamareoides* (Suo-Oshima, Yamaguchi Pref. in the Seto Inland Sea, Japan).

Supplementary Information 2. Origin of specimens and sequence data used for molecular analyses of chloroplast and mitochondrial genes, including their database accession numbers. Sample codes [KU-####] correspond to KU-MACC (Kobe University Macroalgal Culture Collection) strain codes, and [KU-d####] corresponds to silica-gel dried specimens housed at Kobe University Research Center for Inland Seas. Accession codes of newly determined sequences in the present study are indicated in bold.

Species	Origin	Locality	Name of sequenced genes and their accession code					
			<i>cox1</i>	<i>cox3</i>	<i>atpB</i>	<i>psaA</i>	<i>psbA</i>	<i>rbcL</i>
Asterocladales								
<i>Asterocladon lobatum</i>	KU-1881	São Paulo, Brazil	-	-	-	-	-	LC603806
<i>Asterocladon rhodochortonoides</i>	Uwai <i>et al.</i> (2005)	Tsuyazaki, Fukuoka, Japan	-	-	-	-	-	AB102867
Ectocarpales								
Acinetosporaceae								
<i>Acinetospora asiatica</i>	Yaegashi <i>et al.</i> (2015)	Innoshima, Hiroshima, Japan	-	-	-	-	-	LC060517
<i>Feldmannia irregularis</i>	Siemer & Pedersen (only in database)	unknown	-	-	-	-	-	AF207800
<i>Geminocarpus austrogeorgiae</i>	Peters & Ramírez (2001)	unknown	-	-	-	-	-	AJ295830
<i>Herponema velutinum</i>	Silberfeld <i>et al.</i> (2014)	unknown	-	-	-	-	-	JF796585
<i>Hincksia hincksiae</i>	Siemer & Pedersen (only in database)	unknown	-	-	-	-	-	AF207803
<i>Pogotrichum filiforme</i>	Siemer <i>et al.</i> (1998)	Godthab, Greenland, Denmark	-	-	-	-	-	AF055409
<i>Pylaiella washingtoniensis</i>	Kawai <i>et al.</i> (2015)	San Juan I., WA, USA	AB899179	AB526446	AB899197	AB899222	AB899265	AB899288
Adenocystaceae								
<i>Adenocystis utricularis</i>	Peters & Ramírez (2001)	unknown	-	-	-	-	-	AJ295823
<i>Caepidium antarcticum</i>	Peters & Ramírez (2001)	unknown	-	-	-	-	-	AJ295826
<i>Chordariopsis capensis</i>	Silberfeld <i>et al.</i> (2014)	unknown	-	-	-	-	-	JF796581
<i>Utriculidium durvillei</i>	Peters & Ramírez (2001)	unknown	-	-	-	-	-	AJ295835

Chordariaceae

<i>Acrothrix pacifica</i>	Kawai <i>et al.</i> (2016)	Oshoro, Hokkaido, Japan	LC107827	LC107952	LC107972	LC107993	LC108012	-
	Tanaka <i>et al.</i> (2010)	Oshoro, Hokkaido, Japan	-	-	-	-	-	AB302285
<i>Ascoseiophila violodora</i>	Peters (2003)	King George I., Antarctica	-	-	-	-	-	AJ439835
<i>Asperococcus bullosus</i>	Kawai <i>et al.</i> (2016, 2019a)	Ehime, Japan	LC205693	LC016522	LC205701	LC205706	LC205711	LC016509
<i>Austrofilum incommodum</i>	Peters (2003)	King George I., Antarctica	-	-	-	-	-	AJ439838
<i>Botrytella micromora</i>	Tanaka <i>et al.</i> (2010)	unknown	-	-	-	-	-	AB302288
<i>Chordaria flagelliformis</i>	Kawai <i>et al.</i> (2015, 2019a)	Isle of Man, UK	AB899177	LC205698	AB899195	AB899220	AB899263	AB899286
<i>Cladosiphon umezakii</i>	Kawai <i>et al.</i> (2016)	Takeno, Hyogo, Japan	LC107831	LC016526	LC107976	LC107996	LC108016	LC016511
<i>Cladothele decaisnei</i>	Kawai <i>et al.</i> (2016)	Puerto Williams, Chile	LC107833	LC016527	LC016527	LC107998	LC108018	LC016512
<i>Coelocladia arctica</i>	Kawai <i>et al.</i> (2016)	Oshoro, Hokkaido, Japan	LC107834	LC016528	LC107979	LC107999	LC108019	-
	Siemer <i>et al.</i> (1998)	Godthab, Greenland, Denmark	-	-	-	-	-	AF055395
<i>Coilodesme japonica</i>	Tanaka <i>et al.</i> (2010)	Muroran, Hokkaido, Japan	-	-	-	-	-	AB302295
<i>Delamarea attenuata</i>	KU-d5871	Abashiri, Hokkaido, Japan	LC603790	LC603793	LC603797	LC603800	LC603803	LC603807
<i>Dictyosiphon foeniculaceus</i>	Kawai <i>et al.</i> (2019a)	Newfoundland, Canada	-	LC205699	LC205702	LC205707	LC205712	LC205714
	Silberfeld <i>et al.</i> (2014)	unknown	JF796539	-	-	-	-	-
<i>Elachista flaccida</i>	Silberfeld <i>et al.</i> (2014)	unknown	JF796541	JF796556	JF796631	JF796601	JF796615	JF796583
<i>Elachista fucicola</i>	Siemer <i>et al.</i> (1998)	Godthab, Greenland, Denmark	-	-	-	-	-	AF055398
<i>Eudesme virescens</i>	Kawai <i>et al.</i> (2019a)	Roscoff, Brittany, France	LC201528	LC201560	LC201534	LC201540	LC201546	LC201554
<i>Giraudia sphacelarioides</i>	Siemer <i>et al.</i> (1998)	Arrieta, Lanzarote, Spain	-	-	-	-	-	AF055399
<i>Halothrix lumbricalis</i>	Siemer & Pedersen (only on database)	unknown	-	-	-	-	-	AF207801
<i>Haplospora globosa</i>	Siemer <i>et al.</i> (1998)	Godhavn, Greenland, Denmark	-	-	-	-	-	AF055400
<i>Hecatonema</i> sp.	Siemer <i>et al.</i> (1998)	Hvidøre, Denmark	-	-	-	-	-	AF055401
<i>Hummia onusta</i>	Siemer <i>et al.</i> (1998)	Florida, USA	-	-	-	-	-	AF055402
<i>Isthmoplea sphaerophora</i>	Siemer <i>et al.</i> (1998)	Godthab, Greenland, Denmark	-	-	-	-	-	AF055403
<i>Kurogiella saxatilis</i>	Tanaka <i>et al.</i> (2010)	St. Lawrence I., AK, USA	-	-	-	-	-	AB302308
<i>Laminariocolax tomentosoides</i>	Siemer <i>et al.</i> (1998)	Helgoland, Germany	-	-	-	-	-	AF055404

<i>Laminarionema elsbetiae</i>	Kawai <i>et al.</i> (2016)	Helgoland, Germany	LC107836	LC016534	LC107982	LC108002	LC108022	-
	Peters (2003)	Helgoland, Germany	-	-	-	-	-	AJ439858
<i>Leathesia marina</i>	Kawai <i>et al.</i> (2016)	Ashigezaki, Aomori, Japan	LC107837	LC107964	LC107983	LC108003	LC108023	LC108037
<i>Leptonematella fasciculata</i>	Kawai <i>et al.</i> (2016)	Coquimbo, La Herradura, Chile	-	-	-	-	-	LC016518
<i>Litosiphon laminariae</i>	Siemer <i>et al.</i> (1998)	Frederikshavn, Denmark	-	-	-	-	-	AF055406
<i>Mesogloia vermiculata</i>	Kawai <i>et al.</i> (2016)	Carantec, Brittany, France	LC107839	LC107965	LC107985	LC108005	LC108025	LC108038
<i>Microspongium stilophorae</i>	Siemer <i>et al.</i> (1998)	Denmark	-	-	-	-	-	AF055414
<i>Mikrosyphar porphyrae</i>	Siemer & Pedersen (only on database)	unknown	-	-	-	-	-	AF207806
<i>Myriactula clandestina</i>	Silberfeld <i>et al.</i> (2014)	unknown	-	-	-	-	-	JF796587
<i>Myriogloea simplex</i>	Kawai <i>et al.</i> (2019b, c)	Ehime, Japan	LC382487	LC382495	LC382503	LC424529	LC382518	LC382526
<i>Myrionema papillosum</i>	Silberfeld <i>et al.</i> (2014)	unknown	JF796544	-	JF796636	JF796605	JF796620	JF796588
<i>Myrionema strangulans</i>	Siemer <i>et al.</i> (1998)	Frederikshavn, Denmark	-	-	-	-	-	AF055407
<i>Myriotrichia clavaeformis</i>	Siemer <i>et al.</i> (1998)	Frederikshavn, Denmark	-	-	-	-	-	AF055408
<i>Nemacystus decipiens</i>	Kawai <i>et al.</i> (2019b)	Ishikawa, Japan	LC382489	LC382497	LC382505	LC382512	LC382520	LC382528
<i>Neoleptonema</i> sp.	Tanaka <i>et al.</i> (2010)	Shimoda, Shizuoka, Japan	-	-	-	-	-	AB302312
<i>Papenfussiella kuromo</i>	Kawai <i>et al.</i> (2016)	Ofunato, Iwate, Japan	LC107840	LC107966	LC107986	LC108006	LC108026	-
	Tanaka <i>et al.</i> (2010)	Fukaura, Aomori, Japan	-	-	-	-	-	AB302314
<i>Punctaria latifolia</i> Greville	Kawai <i>et al.</i> (2019a)	Pardelas, Argentina	LC205696	LC205700	LC205704	LC205710	LC205713	LC205715
<i>Punctaria plantaginea</i>	Siemer <i>et al.</i> (1998)	Godthab, Greenland, Denmark	-	-	-	-	-	AF055410
<i>Saundersella</i> sp.	Kawai <i>et al.</i> (2016)	Abashiri, Hokkaido, Japan	LC107841	LC016536	LC107987	LC108007	LC108027	LC016519
<i>Sauvageaugloia divaricata</i>	Kawai <i>et al.</i> (2016)	Porz Liogan, Brittany, France	LC107842	LC107967	LC107988	LC108008	LC108028	LC108039
<i>Setoutiphycus delamareoides</i> gen. & sp. nov.	Isotype: KU-d17418	Suo-Oshima, Yamaguchi, Japan	LC603791	LC603794	LC603798	LC603801	LC603804	LC603808
	Holotype: SAP115639 (=KU-d17417)	Suo-Oshima, Yamaguchi, Japan	-	LC603795	-	-	-	-
<i>Soranthera ulvoidea</i>	Silberfeld <i>et al.</i> (2014)	unknown	-	-	-	-	-	JF796589
<i>Sphaerotrichia divaricata</i>	Siemer <i>et al.</i> (1998)	Falshoft, Gelting, Germany	-	-	-	-	-	AF055412
<i>Stictyosiphon soriferus</i>	Kawai <i>et al.</i> (2013)	Bergen, Norway	-	-	-	-	-	AB775343
<i>Stilophora tenella</i>	Kawai <i>et al.</i> (2019a)	Dorset, England, UK	LC201533	LC201584	LC205705	LC201545	LC201553	LC201559

<i>Striaria attenuata</i>	KU-d17414	Suo-Oshima, Yamaguchi, Japan	LC603792	LC603796	LC603799	LC603802	LC603805	LC603809
<i>Tinocladia crassa</i>	Kawai <i>et al.</i> (2016, 2019a)	Nomozaki, Nagaki, Japan	LC205697	LC107970	LC107990	LC108009	LC108030	LC382529
<i>Trachynema groenlandicum</i>	Kawai <i>et al.</i> (2016)	Muroran, Hokkaido, Japan	LC107844	LC016539	LC107991	LC108010	LC108031	LC016521
<i>Ulonema rhizophorum</i>	Silberfeld <i>et al.</i> (2014)	unknown	-	-	-	-	-	JF796592
<i>Vimineoleathesia japonica</i>	Kawai <i>et al.</i> (2016)	Shimamaki, Hokkaido, Japan	LC107845	LC107971	LC107992	LC108011	LC108032	-
	Tanaka <i>et al.</i> (2010)	Shimamaki, Hokkaido, Japan	-	-	-	-	-	AB302284
Ectocarpaceae								
<i>Ectocarpus</i> sp.	Cock <i>et al.</i> (2010)	San Juan de Marcona, Peru	FP885846	FP885846	-	-	-	-
	Le Corguille <i>et al.</i> (2009)	San Juan de Marcona, Peru	-	-	FP102296	FP102296	FP102296	FP102296
<i>Kuckuckia spinosa</i>	Kawai <i>et al.</i> (2015)	Villefranche-sur-Mer, France	-	-	-	-	-	AB899287
<i>Pleurocladia lacustris</i>	SAG 25.93; Wang <i>et al.</i> (only in database)	River Fischs-Dagnitz, Austria	-	-	-	-	-	KU164872
<i>Spongonema tomentosum</i>	Bringloe <i>et al.</i> (2019)	Hordaland, Norway	-	-	-	-	-	MN184545
Petrospongiaceae								
<i>Petrospongium rugosum</i>	Cho & Boo (2006)	Jejudo, Korea	-	-	-	-	-	AY996361
Scytosiphonaceae								
<i>Chnoospora minima</i>	Kogame <i>et al.</i> (2011)	Lanai, HI, USA	-	-	-	-	-	AB578987
<i>Colpomenia sinuosa</i>	Kogame <i>et al.</i> (1999)	Kasumi, Hyogo, Japan	-	-	-	-	-	AB022234
<i>Dactylosiphon bullosus</i>	Hanyuda <i>et al.</i> (2020)	Kirikiri, Iwate, Japan	-	-	-	-	-	LC472403
<i>Hapterophycus canaliculatus</i>	Kogame <i>et al.</i> (1999)	Oshoro, Hokkaido, Japan	-	-	-	-	-	AB022239
<i>Hydroclathrus clathratus</i>	Hanyuda <i>et al.</i> (2020)	Shibushi, Kagoshima, Japan	-	-	-	-	-	LC472404
<i>Iyengaria stellata</i>	Santiañez <i>et al.</i> (2020)	Doha, Kuwait Bay, Kuwait	-	-	-	-	-	MN587741
<i>Melanosiphon intestinalis</i>	Hanyuda <i>et al.</i> (2020)	Shizunai, Hokkaido, Japan	-	-	-	-	-	LC472401
<i>Myelophycus simplex</i>	Hanyuda <i>et al.</i> (2020)	Kada, Wakayama, Japan	-	-	-	-	-	LC472397
<i>Petalonia fascia</i>	Hanyuda <i>et al.</i> (2020)	Kamaishi, Iwate, Japan	-	-	-	-	-	LC472405
<i>Planosiphon gracilis</i>	Hanyuda <i>et al.</i> (2020)	Misaki, Osaka, Japan	-	-	-	-	-	LC472406
<i>Pseudochnoospora implexa</i>	Kogame <i>et al.</i> (1999)	Sesoko, Okinawa, Japan	-	-	-	-	-	AB022231

<i>Rosenvingeia intricata</i>	Kogame <i>et al.</i> (1999)	Gushikawa, Okinawa, Japan	-	-	-	-	-	AB022232
<i>Scytosiphon lomentaria</i>	Kogame <i>et al.</i> (1999)	Oshoro, Hokkaido, Japan	-	-	-	-	-	AB022238
<i>Tronoella ryukyuana</i>	Santiañez <i>et al.</i> (2020)	Itoman, Okinawa, Japan	-	-	-	-	-	MF431947

References of Supplementary Information 2

- Bringloe, T. T., Sjøtun, K. & Saunders, G. W. A DNA barcode survey of marine macroalgae from Bergen (Norway). *Mar. Biol. Res.* **15**, 580–589. (2019).
- Cho, G. Y. & Boo, S. M. Phylogenetic position of *Petrospongium rugosum* (Ectocarpales, Phaeophyceae): insights from the protein-coding plastid *rbcL* and *psaA* gene sequences. *Cryptogam. Algal.* **27**, 3–15. (2006).
- Cock, J. M., Sterck, L., Rouze, P. *et al.* The *Ectocarpus* genome and the independent evolution of multicellularity in brown algae. *Nature* **465**, 617–621. (2010).
- Hanyuda, T., Takeuchi, K. & Kawai, H. *Tinocladia sanrikuensis* sp. nov. (Ectocarpales s.l., Phaeophyceae) from Japan. *Phycol. Res.* **67**, 221–227. (2019).
- Hanyuda, T., Aoki, S. & Kawai, H. Reinstatement of *Myelophycus caespitosus* (Scytosiphonaceae, Phaeophyceae) from Japan. *Phycol. Res.* **68**, 126–134 (2020).
- Kawai, H., Hanyuda, T., Ridgway, L. M. & Holser, K. Ancestral reproductive structure in basal kelp *Aureophycus aleuticus*. *Sci. Rep.* **3**, 2491. (2013).
- Kawai, H., Hanyuda, T., Draisma, S. G., Wilce, R. T. & Andersen, R. A. Molecular phylogeny of two unusual brown algae, *Phaeostrophion irregulare* and *Platysiphon glacialis*, Stschapoviales ord. nov. and Platysiphonaceae fam. nov., and a re-examination of divergence times for brown algal orders. *J. Phycol.* **51**, 918–928. (2015).
- Kawai, H., Hanyuda, T., Kim, S.-H., Ichikawa, Y., Uwai, S. & Peters, A. F. *Cladosiphon takenoensis* sp. nov. (Ectocarpales s.l., Phaeophyceae) from Japan. *Phycol. Res.* **64**, 212–218. (2016).
- Kawai, H., Hanyuda, T., Sun, Z., Barbara, I. & Peters, A. F. Taxonomic revision of *Eudesme* (Ectocarpales s.l., Phaeophyceae) proposing a new species *E. borealis* sp. nov. *Phycologia* **58**, 351–358. (2019a).
- Kawai, H., Hanyuda, T., Shibata, K., Kamiya, M. & Peters, A. F. Proposal of a new brown algal species, *Mesogloia japonica* sp. nov. (Chordariaceae, Phaeophyceae), and transfer of *Sauvageaugloia ikomae* to *Mesogloia*. *Phycologia* **58**, 63–69. (2019b).
- Kogame, K., Horiguchi, T. & Masuda, M. Phylogeny of the order Scytosiphonales (Phaeophyceae) based on DNA sequences of *rbcL*, partial *rbcS*, and partial LSU nrDNA. *Phycologia* **38**, 496–502. (1999).

- Le Corguillé, G., Pearson, G., Valente, M. *et al.* Plastid genomes of two brown algae, *Ectocarpus siliculosus* and *Fucus vesiculosus*: further insights on the evolution of red-algal derived plastids. *BMC Evol. Biol.* **9**, 253–266. (2009).
- Peters, A. F. Molecular identification, distribution and taxonomy of brown algal endophytes, with emphasis on species from Antarctica. *Proc. Int. Seaweed Symp.* **17**, 293–302. (2003).
- Peters, A. F. & Ramírezb, M. E. Molecular phylogeny of small brown algae, with special reference to the systematic position of *Caepidium antarcticum* (Adenocystaceae, Ectocarpales). *Cryptogam. Algal.* **22**, 187–200. (2001).
- Santiañez, W. J. E., Lee, K. M., Uwai, S., Kurihara, A., Geraldino, P. J. L., Ganzon-Fortes, E. T., Boo, S. M. & Kogame, K. Untangling nets: elucidating the diversity and phylogeny of the clathrate brown algal genus *Hydroclathrus*, with the description of a new genus *Tronoella* (Scytosiphonaceae, Phaeophyceae). *Phycologia* **57**, 61–78. (2020).
- Siemer, B. L., Stam, W. T., Olsen, J. L. & Pedersen, P. M. Phylogenetic relationships of the brown algal orders Ectocarpales, Chordariales, Dictyosiphonales, and Tilopteridales (Phaeophyceae) based on Rubisco large subunit and spacer sequences. *J. Phycol.* **34**, 1038–1048. (1998).
- Silberfeld, T., Rousseau, F. & de Reviers, B. An updated classification of brown algae (Ochrophyta, Phaeophyceae). *Cryptogam. Algal.* **35**, 117–156. (2014).
- Tanaka, A., Uwai, S., Nelson, W. & Kawai, H. *Phaeophysema* gen. nov. and *Vimineoleathesia* gen. nov., new brown algal genera for the minute Japanese members of the genus *Leathesia*. *Eur. J. Phycol.* **45**, 109–117. (2010).
- Uwai, S., Nagasato, C., Motomura, T. & Kogame, K. Life history and molecular phylogenetic relationships of *Asterocladon interjectum* sp. nov. (Phaeophyceae). *Eur. J. Phycol.* **40**, 179–194. (2005).
- Yaegashi, K., Yamagishi, Y., Uwai, S., Abe, T., Santiañez, W. J. E. & Kogame, K. Two species of the genus *Acinetospora* (Ectocarpales, Phaeophyceae) from Japan: *A. filamentosa* comb. nov. and *A. asiatica* sp. nov. *Bot. Mar.* **58**, 331–343. (2015).

Supplementary information 3. List of primers used for polymerase chain reaction (PCR) and sequencing

Code	F/R	Sequence (5'-3')	Region	Reference
ycf3-F1P	F	CAAGCDYTAAATAATATWGCTG	<i>ycf3</i>	Kawai <i>et al.</i> (2013)
atpB-F1.3P	F	GTHMGHGCNATTGCNATGAGTGC	<i>atpB</i>	Kawai <i>et al.</i> (2013)
atpB-2R	R	AGCTTGWACAAATCTAAAAATA	<i>atpB</i>	Silberfeld <i>et al.</i> (2010)
atpB-R1P	R	TTTGCTTTAGMDATWGCTTC	<i>atpB</i>	Kawai <i>et al.</i> (2013)
psaA130F	F	AACWACWACTTGGATTTGGAA	<i>psaA</i>	Yoon <i>et al.</i> (2002)
psaA970R2	R	TRCTATGDCCRATNCCCCAA	<i>psaA</i>	Kawai <i>et al.</i> (2013)
psaA1760R2	R	CCRTCACAHGGRAAWCGGAA	<i>psaA</i>	Kawai <i>et al.</i> (2013)
psaA1760R	R	CCTCTWCCWGGWCCATCRCAWGG	<i>psaA</i>	Yoon <i>et al.</i> (2002)
psaA-P4	R	NGATTCAATHARYTCTTGCC	<i>psaA</i>	Kawai <i>et al.</i> (2012)
psbA-F2	F	GCAACTTTAGAAAGACGCGA	<i>psbA</i>	Yoon <i>et al.</i> (2002)
psbA500F	F	CTCTGATGGWATGCCWYTAGG	<i>psbA</i>	Yoon <i>et al.</i> (2002)
psbA600R	R	CCAAATACACCAGCAACACC	<i>psbA</i>	Yoon <i>et al.</i> (2002)
psbA-R1.2	R	YYWGAWGCTAAATCTAATGGG	<i>psbA</i>	Kawai <i>et al.</i> (2018)
rbcL-P2	F	GAWCGRACCTCGAWTWAAAAGTG	<i>rbcL</i>	Kawai <i>et al.</i> (2007)
rbcL-P2.2	F	CTCGAWTWAAAAGTGAVCGWTAYGAATC	<i>rbcL</i>	Kawai <i>et al.</i> (2012)
rbcL-Rh3	F	TTAAYTCTCARCCDTTYATGCG	<i>rbcL</i>	Hanyuda <i>et al.</i> (2004)
Ral-R952	R	CATACGCATCCATTTACA	<i>rbcL</i>	Kawai <i>et al.</i> (2007)
rbcS-P1	R	GGATCATCTGYCCATTCTACAC	<i>rbcS</i>	Kawai <i>et al.</i> (2007)
GazF2	F	CCAACCAYAAAAGATATWGGTAC	<i>cox1</i>	Lane <i>et al.</i> (2007)
cox1-P1.2	F	GATHTTYTTTATGGTDATGCC	<i>cox1</i>	Kawai <i>et al.</i> (2013)
GazR2	R	GGATGACCAAARAACCAAA	<i>cox1</i>	Lane <i>et al.</i> (2007)
cox1-P3	R	CNGTAAACATRTGRTGVGCC	<i>cox1</i>	Kawai <i>et al.</i> (2013)
cox1-P2	R	GGDATAACGDCGHGGCATACC	<i>cox1</i>	Kawai <i>et al.</i> (2013)
trnI-P1.3	R	AACTCTACCRCTGAGTTAC	<i>trnI</i>	This study
trnI-P1.2	R	GCTTATCAGGCGTACACTCT	<i>trnI</i>	Kawai <i>et al.</i> (2013)
trnI-P1	R	TTGAACGAWCGVCTTTACGC	<i>trnI</i>	Kawai <i>et al.</i> (2013)
trnY-P2	F	GKCAGATTGTAAATCTGTTGG	<i>trnY</i>	Kawai <i>et al.</i> (2012)
trnY-P1	F	TCYATCRTAGGTTCGAATCC	<i>cox3</i>	Ni-Ni-Win <i>et al.</i> (2008)
cox3-P2	R	ACAAARTGCCAATACCAAGC	<i>cox3</i>	Ni-Ni-Win <i>et al.</i> (2008)

Reference for Supplementary information 3.

- Hanyuda, T., Suzawa, Y., Suzawa, T., Arai, S., Sato, H., Ueda, K. & Kumano, S. Biogeography and taxonomy of *Batrachospermum helminthosum* Bory (Batrachospermales, Rhodophyta) in Japan inferred from *rbcL* gene sequences. *J. Phycol.* **40**, 581–588. (2004).
- Kawai, H., Hanyuda, T., Draisma, S. G. A. & Müller, D. G. 2007. Molecular phylogeny of *Discosporangium mesarthrocarpum* (Phaeophyceae) with a reassessment of the Discosporangiales. *J. Phycol.* **43**, 186–194. (2007).
- Kawai, H., Kogishi, K., Hanyuda, T. & Kitayama, T. Taxonomic revision of the genus *Cutleria* proposing a new genus *Mutimo* to accommodate *M. cylindrica* (Cutleriaceae, Phaeophyceae). *Phycol. Res.* **60**, 241–248. (2012).
- Kawai, H., Hanyuda, T., Ridgway, L. M. & Holser, K. Ancestral reproductive structure in basal kelp *Aureophycus aleuticus*. *Sci. Rep.* **3**, 2491. (2013).
- Lane, C. E., Lindstrom, S. C. & Saunders, G. W. A molecular assessment of northeast Pacific *Alaria* species (Laminariales, Phaeophyceae) with reference to the utility of DNA barcoding. *Mol. Phylog. Evol.* **44**, 634–648. (2007).
- Ni-Ni-Win, Hanyuda, T., Arai, S., Uchimura, M., Abbott, I. A. & Kawai, H. Three new records of *Padina* in Japan based on morphological and molecular markers. *Phycol. Res.* **56**, 288–300. (2008).
- Silberfeld, T., Leigh, J. W., Verbruggen, H., Cruaud, C., de Reviers, B. & Rousseau, F. 2010. A multi-locus time-calibrated phylogeny of the brown algae (Heterokonta, Ochrophyta, Phaeophyceae): investigating the evolutionary nature of the “brown algal crown radiation”. *Mol. Phylogen. Evol.* **56**, 659–674. (2010).
- Yoon, H. S., Hackett, J. D. & Bhattacharya, D. A single origin of the peridinin- and fucoxanthin-containing plastids in dinoflagellates through tertiary endosymbiosis. *Proc. Natl. Acad. Sci. U.S.A.* **99**, 11724–11729. (2002).

Supplementary Information 4. Sequence divergence (p-distance) of *rbcL* gene between representative genera within selected brown algal orders.

Genera compared within each order / number of genera in each order	p-distance	Species and DNA database codes
Dictyotales (<i>Dictyota</i> , <i>Exallosorus</i> , <i>Padina</i> and <i>Stypopodium</i>) / 20	−0.127	<i>Dictyota crenulata</i> (GU290253) <i>Exallosorus olsenii</i> (DQ866923) <i>Padina japonica</i> (AB358910) <i>Stypopodium schimperi</i> (DQ866926)
Ectocarpales s.l. (<i>Acinetospora</i> , <i>Adenocystis</i> , <i>Ectocarpus</i> , <i>Petrospongium</i> , <i>Scytosiphon</i> , <i>Setoutiphycus</i> and <i>Stictyosiphon</i>) / 139	−0.092	<i>Acinetospora asiatica</i> (LC060517) <i>Adenocystis utricularis</i> (AJ295823) <i>Ectocarpus</i> sp. (FP102296) <i>Petrospongium rugosum</i> (AY996361) <i>Scytosiphon lomentaria</i> (AB022238) <i>Setoutiphycus delamareoides</i> (LC603808) <i>Stictyosiphon soriferus</i> (AB775343)
Fucales (<i>Fucus</i> , <i>Hormosira</i> , <i>Phyllospora</i> and <i>Sargassum</i>) / 50	−0.101	<i>Fucus vesiculosus</i> (FM957154) <i>Hormosira banksii</i> (AB776774) <i>Phyllospora comosa</i> (EF990249) <i>Sargassum muticum</i> (AB776776)
Ishigeales (<i>Diplura</i> , <i>Ishige</i> and <i>Petroderma</i>) / 3	−0.163	<i>Diplura simplex</i> (AB250084) <i>Ishige okamurai</i> (AY372974) <i>Petroderma maculiforme</i> (EU579934)
Chordales (<i>Akkesiphycus</i> , <i>Chorda</i> and <i>Pseudochorda</i>) / 3	−0.080	<i>Akkesiphycus lubricum</i> (AB036038) <i>Chorda asiatica</i> (AB775335) <i>Pseudochorda nagaii</i> (AB775342)
Laminariales (<i>Aureophycus</i> , <i>Macrocystis</i> , <i>Neoagarum</i> and <i>Undaria</i>) / 33	−0.082	<i>Aureophycus aleuticus</i> (AB355025) <i>Macrocystis pyrifera</i> (AB775339) <i>Neoagarum oharaense</i> (LC148138) <i>Undaria pinnatifida</i> (AB775334)
Sphacelariales (<i>Bodanella</i> , <i>Halopteris</i> , <i>Phaeostrophion</i> and <i>Sphacelaria</i>) / 10	−0.123	<i>Bodanella lauterborni</i> (FM956110) <i>Halopteris gracilescens</i> (AB899291) <i>Phaeostrophion irregulare</i> (AB899292) <i>Sphacelaria radicans</i> (FM956112)
Sporochnales (<i>Bellotia</i> , <i>Carpomitra</i> and <i>Sporochnus</i>) / 11	−0.057	<i>Bellotia eriophorum</i> (AB899295) <i>Carpomitra costata</i> (AB776780) <i>Sporochnus scoparius</i> (AB776781)
Stschapoviales (<i>Halosiphon</i> , <i>Platysiphon</i> and <i>Stschapovia</i>) / 3	−0.057	<i>Halosiphon tomentosus</i> (AB545977) <i>Platysiphon glacialis</i> (AB776772) <i>Stschapovia flagellaris</i> (AB117920)
Tilopteridales (<i>Cutleria</i> , <i>Saccorhiza</i> and <i>Tilopteris</i>) / 7	−0.077	<i>Cutleria adspersa</i> (AB545967) <i>Saccorhiza polyschides</i> (AB545978) <i>Tilopteris mertensii</i> (AB776784)