Table S1: New GenBank accessions for epi-endophyte sequences, including whole organellar genome data in *Alaria* and the phaeophycean parasite*.* s.l.=sensu lato, s.s.=sensu stricto; M=mitochondrial, P=plastid. Annotations for plastid contigs of TTB000062 can be accessed via https://doi.org/10.6084/m9.figshare.13140464.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | **Specimen ID** | **Date collected** | **Lat.** | **Long.** | **Organellar****genome (M/P)** | ***cox*1** | ***rbc*L** |
| *Alaria esculenta* s.l. (*crispa* type) | A8 | 21-Aug-2018 | 52.913 | 158.637 | MT767059/MT767060 |  |  |
| *Alaria esculenta* s.s. | AT001 | 06-Jun-2019 | 45.044 | -66.809 | MT767061/MT767062 |  |  |
| *Alaria esculenta* s.s. | TTB000192 | 06-Jun-2019 | 45.044 | -66.809 | NA |  |  |
| *Alaria esculenta* s.s. | TTB000062 | 23-Aug-2019 | 64.079 | -51.467 | Short-read files: SAMN16729885 |  |  |
| *Alaria esculenta* s.s. | TTB000067 | 23-Aug-2019 | 64.079 | -51.467 | NA |  |  |
| *Alaria esculenta* s.s. | TTB000079 | 23-Aug-2019 | 64.079 | -51.467 | NA |  |  |
| *Acrochaetium alariae* | A8\_1 | 21-Aug-2018 | 52.913 | 158.637 |  | MT766282 | MT766297 |
| *Coilodesme japonica* | A8\_2 | 21-Aug-2018 | 52.913 | 158.637 |  | MT766283 | MT766298 |
| *Laminariocolax aecidioides* | A8\_3 | 21-Aug-2018 | 52.913 | 158.637 |  | MT766284 | MT766299 |
| *Microspongium globosum* | A8\_4 | 21-Aug-2018 | 52.913 | 158.637 |  | MT766285 | MT766300 |
| *Hecatonema maculans* | AT001\_1 | 06-Jun-2019 | 45.044 | -66.809 |  | MT766286 | MT766301 |
| *Phaestroma pustulosum* | AT001\_2 | 06-Jun-2019 | 45.044 | -66.809 |  | MT766287 | MT766302 |
| *Thallasiosira* sp. | AT001\_3 | 06-Jun-2019 | 45.044 | -66.809 |  |  | MT766303 |
| *Hecatonema maculans* | TTB000192\_1 | 06-Jun-2019 | 45.044 | -66.809 |  | MT766295 | MT766306 |
| *Phaeostroma pustulosum* | TTB000192\_2 | 06-Jun-2019 | 45.044 | -66.809 |  | MT766296 | MT766307 |
| Putative phaeophycean parasite | TTB000062\_1 | 23-Aug-2019 | 64.079 | -51.467 | MT747832/MW266086-97 | MT766288 |  |
| *Phaestroma pustulosum* | TTB000062\_2 | 23-Aug-2019 | 64.079 | -51.467 |  | MT766289 | MT766304 |
| *Phaeostroma* sp. | TTB000062\_3 | 23-Aug-2019 | 64.079 | -51.467 |  | MT766290 |  |
| *Protectocarpus* sp. | TTB000062\_4 | 23-Aug-2019 | 64.079 | -51.467 |  | MT766291 | MT766305 |
| *Obelia longissima* | TTB000062\_5 | 23-Aug-2019 | 64.079 | -51.467 |  | MT766292 |  |
| *Obelia longissima* | TTB000067\_1 | 23-Aug-2019 | 64.079 | -51.467 |  | MT766293 |  |
| *Obelia longissima* | TTB000079\_1 | 23-Aug-2019 | 64.079 | -51.467 |  | MT766294 |  |
| *Coilodesme californica* | GWS036767 | 15-May-2014 | 48.454 | -122.963 |  | MT806364 | MT806365 |
| *Microspongium globosum* | GWS004596 | 28-Jun-2006 | 48.786 | -125.119 |  | MT520140 | MT520141 |

Table S2: GenBank accession information for sequences used in phylogenetic analyses*.* Molecular data from multiple strains of *Nemoderma* were combined on the basis of being a monotypic genus. Data for *Chorda asiatica* also included *nad*2 (LC148200) and *nad*5 (LC148258).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Species (strain ID for amplicon data)** | **Mitochondria** | **Plastid** | ***atp*9** | ***cox*1** | ***cox*3** | ***nad*1** | ***nad*4** |
| **Fragilariales (Bacillariophyceae)** |
| *Nanofrustulum shiloi* |  | MN276191 |  |  |  |  |  |
| **Vaucheriales (Xanthophyceae)** |
| *Vaucheria litorea* |  | EU912438 |  |  |  |  |  |
| **Ishigeales** |
| *Ishige okamurae* | MG940857 |  |  |  |  |  |  |
| **Onslowiales** |
| *Verosphacela sylvae* (GR11-s#8-3) |  |  |  | LM995421 |  |  |  |
| **Dictyotales** |
| *Dictyopteris divaricata* | MG940856 | NC 036804 |  |  |  |  |  |
| *Dictyota dichotoma* | AY500368 |  |  |  |  |  |  |
| **Syringodermatales** |
| *Syringoderma phinneyi* (FRA0140) |  |  |  | EU681429 |  | EU681512 | EU681543 |
| *Cladostephus spongiosus* (FRA0511) |  |  |  | EU681396 |  |  | EU681520 |
| **Sphacelariales** |
| *Sphacelaria* sp. | SAMN10026787 | SAMN10026787 |  |  |  |  |  |
| *Nemoderma tingitanum* (*atp*9, *nad*1, *nad*4: FRA0530; *cox*1: KU-d13284) |  |  | EU681567.1 | LC065621 |  | EU681496 | EU681530 |
| Fucales |
| *Fucus distichus* | KY678904 | MG922855 |  |  |  |  |  |
| *Coccophora langsdorfii* | KU255794 |  |  |  |  |  |  |
| *Sargassum muticum* | KJ938301 |  |  |  |  |  |  |
| *Sargassum horneri* |  | MN265366 |  |  |  |  |  |
| *Turbinaria ornata* | KM501562 |  |  |  |  |  |  |
| **Tilopteridales** |
| *Saccorhiza dermatodea* (FRA0144) |  |  | EU681576 | EU681421 |  | EU681506 | EU681538 |
| **Sporochnales** |
| *Carpomitra costata* (TJS0096) |  |  |  |  | EU681437 | EU681478 |  |
| *Perithalia caudata* (TJS0095) |  |  |  |  |  | EU681500 |  |
| *Bellotia eriophorum* (TJS0128) |  |  | GQ368298 | GQ368255 | GQ368270 | GQ368284 |  |
| *Sporochnus pedunculatus* (FRA0494) |  |  | EU681583 | EU681428 | EU681466 | EU681511 | EU681542 |
| **Stschapoviales** |
| *Halosiphon tomentosus* (KU-1171) |  |  |  | AB776652 | AB543505 |  |  |
| **Ralfsiales** |
| *Analipus japonicus* (TJS0188) | SAMN10026788 | SAMN10026788 | EU681545 | EU681389 | EU681432 | EU681472 | EU681516 |
| Scytothamnales |
| *Splachnidium* sp.(KU-1176) |  |  |  | AB776661 | AB776719 |  |  |
| *Splachnidium rugosum* (FRA0086) |  |  | EU681582 | EU681427 | EU681465 |  |  |
| *Scytothamnus fasciculatus* (KU-713) |  |  |  | AB776660 | AB776718 |  |  |
| *Stereocladon rugulosus* (STEREO4) |  |  |  | JF796547 | JF796560 |  |  |
| *Scytothamnus australis* (FRA0085) |  |  | EU681580 | EU681425 |  |  | EU681541 |
| **Desmarestiales** |
| *Desmarestia viridis* | AY500367 |  |  |  |  |  |  |
| *Desmarestia aculeata* |  | SAMN10026789 |  |  |  |  |  |
| **Ascoseirales** |
| *Ascoseira mirabilis* (FRA0145) |  |  |  | EU681391 |  | EU681474 | EU681547 |
| **Ectocarpales** |
| *Cladosiphon okamuranus* | MG488292 | NC 046005 |  |  |  |  |  |
| *Pylaiella littoralis* | AJ277126 |  |  |  |  |  |  |
| *Colpomenia peregrina* | KM244739 |  |  |  |  |  |  |
| *Scytosiphon lomentaria* | KJ995702 |  |  |  |  |  |  |
| *Scytosiphon canaliculatus* |  | NC 044758 |  |  |  |  |  |
| *Endarachne binghamiae* | MF374731 |  |  |  |  |  |  |
| *Petalonia fascia* | KJ957769 |  |  |  |  |  |  |
| *Pleurocladia lacustris* | KU164873 | NC 032045 |  |  |  |  |  |
| *Ectocarpus siliculosus* | NC\_030223 | NC 013498 |  |  |  |  |  |
| **Laminariales** |
| *Alaria marginata* |  | SAMN09506685 |  |  |  |  |  |
| *Arthrothamnus bifidus* |  | SAMN09516535 |  |  |  |  |  |
| *Pterygophora californica* |  | SAMN09506688 |  |  |  |  |  |
| *Postelsia palmaeformis* |  | SAMN09516532 |  |  |  |  |  |
| *Undaria pinnatifida* | KF319031 |  |  |  |  |  |  |
| *Saccharina japonica* | AP011493 |  |  |  |  |  |  |
| *Egregia menziesii* |  | SAMN09516496 |  |  |  |  |  |
| *Ecklonia radicosa* |  | SAMN09516498 |  |  |  |  |  |
| *Hedophyllum subsesille* |  | SAMN09516536 |  |  |  |  |  |
| *Macrocystis integrifolia* | MH411105 |  |  |  |  |  |  |
| *Macrocystis pyrifera* |  | SAMN09516533 |  |  |  |  |  |
| *Nereocystis luetkeana* | MH392199 |  |  |  |  |  |  |
| *Lessonia spicata* | MK965907 | SAMN09516495 |  |  |  |  |  |
| *Lessoniopsis littoralis* |  | SAMN09506687 |  |  |  |  |  |
| *Laminaria digitata* | AJ344328 |  |  |  |  |  |  |
| *Laminaria solidungula* |  | NC 044690 |  |  |  |  |  |
| *Costaria costata* | KF384641 | SAMN09516490 |  |  |  |  |  |
| Chordales |  |  |  |  |  |  |  |
| *Akkesiphycus lubricus* |  | SAMN09506682 |  |  |  |  |  |
| *Chorda asiatica* (KU-503) |  | SAMN09506684 |  | AB775224 | AB775241 |  | LC148230 |
| *Pseudochorda nagaii* |  | SAMN09506683 |  |  |  |  |  |
| **Asterocladales** |
| *Asterocladon rhodochortonoides*(SAP089220**)** |  |  |  |  | AB302287 |  |  |

Table S3. Epi-endophytes detected in specimens of *Alaria.*

|  |  |  |  |
| --- | --- | --- | --- |
| Epi-endophyte ID (Phylum: species) | Marker: length (mean read-depth) | Host species, loation(s) | Notes |
| Bacillariophyta: *Thalassiosira* sp. | *rbc*L: 1445 bp (13) | *A. esculenta* s.s., Bay of Fundy, Canada | The contig was a close match to the diatoms *Thalassiosira aestivalis* Gran 1931 and *T. pacifica* Gran & Angst 1931 (99.75%). |
| Cnidaria: *Obelia longissima* Pallas | *cox*1: 648 bp (7.2-69.6) | *A. esculenta* s.s.*,* Nuuk, Greenland | Detected in all three specimens from Greenland, the contigs were a 99.38% match to *O. longissima*. |
| Ochrophyta: *Coilodesme japonica* Yamada | *rbc*L: 721 bp (8.1);*cox*1: 591 bp (7.8) | *A. esculenta* s.l. (type *crispa*)*,* Kamchatka, Russia | The *rbc*L contig is a 100% match to *C. japonica*, and a second close match to *C. californica* (Ruprecht) Kjellman, while the *cox*1 was a close match to *C. californica* (Ruprecht) Kjellman (98.97%; Fig. 2).  |
| Ochrophyta: *Hecatonema maculans* (Collins) Sauvageau | *rbc*L: 1315-1357 bp (13.9-14.4); *cox*1: 629-642 bp (7.1-14.7)  | *A. esculenta* s.s.*,* Bay of Fundy | Present in both Bay of Fundy specimens, the *cox*1 contig was a 100% match to *H. maculans*. Though *rbc*L data are not available for *H. maculans*, *rbc*L contigs were a 99.85% match to an unknown species of *Hecatonema* (Fig. 2). |
| Ochrophyta: *Laminariocolax aecidioides* Rosenvinge (A.F. Peters) | *rbc*L: 617 bp (3.4); *cox*1: 608 bp (13) | *A. esculenta* s.l. (type *crispa*)*,* Kamchatka, Russia | The *cox*1 contig was a 100% match to *L. aecidioides* (Chodariaceae). Scant read depth failed to resolve the 3’ end of *rbc*L, but the few reads available indicated closer affinity to a genetic group sampled in Hokkaido, Japan, which also likely represents *L. aecidioides* (Fig. 2). |
| Ochrophyta: *Microspongium globosum* Reinke | *rbc*L: 701 bp (5.1); *cox*1: 630 bp (9.6) | *A. esculenta* s.l. (type *crispa*)*,* Kamchatka, Russia | The *cox*1 contig was a close match to *M. globosum* sampled from British Columbia (99.22%), Canada, while *rbc*L was a 99.86% match. The *cox*1 contig was also a close match to *Microspongium alariae* (P.M.Pedersen) A.F.Peters reported from Nome, Bering Sea, Alaska (97.7%; Bringloe and Saunders 2019; Fig. 2). |
| Ochrophyta: Phaeophyceae sp. (putative parasite) | *cox*1: 658 bp (14) | *A. esculenta* s.s.*,* Nuuk, Greenland | Though the contig appeared to be brown algal, it was not a clear match to anything, even at the ordinal level. Numerous gene rearrangements, duplications, the presence of pseudogenes, overall substitution saturation, and the lack of an accompanying plastome suggests this novel brown algae is parasitic (Fig. 1). |
| Ochrophyta: *Phaeostroma* spp. | *rbc*L: 1410-1497 bp (6.6-10.0); *cox*1 (1): 447-656 bp (5.3-12.6)*cox*1 (2): 533 bp (12.7) | *A. esculenta* s.s.*,* Bay of Fundy, Canada; Nuuk, Greenland | Contigs for *Phaestroma pustulosum* were widely resolved, appearing in both Bay of Fundy specimens and one specimen from Greenland. A second *cox*1 genetic group was resolved from Greenland, and is a 93.56% match to the first resolved *Phaeostroma* contig (Fig. 2). Mapping revealed closely related *rbc*L reads, but we were unable to confidently resolve them into a second *Phaestroma rbc*L contig. |
| Ochrophyta: *Protectocarpus* sp. | *rbc*L: 1357 bp (14.8); *cox*1: 664 bp (12.9) | *A. esculenta* s.s.*,* Nuuk, Greenland | The *rbc*L contig was a 99.18% match to *Protectocarpus speciosus* (Børgesen) Kornmann. At least two other North Atlantic species of *Protectocarpus* are recognized, *Protectocarpus faeroeensis* (Børgesen) Kornmann and *Protectocarpus hecatonemoides* Kornmann, of which the contig could represent either. The *cox*1 contig is assigned here based on phylogenetic placement (Fig. 2). |
| Rhodophyta: *Acrochaetium alariae* (Jónsson) Bornet  | *rbc*L: 1353 bp (7.6); *cox*1: 593 bp (2.5) | *A. esculenta* s.l. (type *crispa*)*,* Kamchatka, Russia | The *rbc*L contig matched closest to *Acrochaetium secundatum* (Lyngbye) Nägeli (93.5%; *rbc*L data were not available for *A. alariae*). Though read depth was scant for *cox*1, name assignment was based on this marker (99.5% match to *A. alariae*). Note *A. alariae* *cox*1 data is an 88% match to *A. secundatum*, mirroring our results with *rbc*L. |



Fig. S1. Regression analysis of *cox*I and *rbc*L contig coverage for epi- endophytes detected in shotgun sequencing libraries for *Alaria*. Also depicted is the predicted *rbc*L coverage for a novel Phaeophycean *cox*I contig along with prediction intervals at 95, 99, and 99.9% confidence. The value in red represents the observed value of coverage for recovered plastid scaffolds belonging to the novel Phaeophycean (note, not *rbc*L), with an interval of 2 standard deviations.



Fig. S2. Maximum-Likelihood tree depicting placement of the phaeophycean parasite. The tree is based on whole mitochondrial genome data (21,721 bp alignment of 32 coding genes, as indicated by †), and otherwise available mitochondrial genes (*atp*9, *cox*1, *cox*3, *nad*1, *nad*2, *nad*4, and *nad*5). Trimmed from the tree is the root clade *Ishige okamurae* (Ishigeales; whole mitochondrial genome data) and *Verosphacela silvae* (Onslowiales; *cox*1 data). Bootstrap values are depicted at nodes; \* indicates full support, - indicates a bootstrap value less than 50. GenBank accessions are available in Table S2.