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A DNA barcode examination of the Laminariaceae (Phaeophyceae) in Canada reveals novel biogeographical and evolutionary insights

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Abstract

DNA barcoding is becoming a widely applied tool for the rapid and accurate identification of eukaryotic species. In this study we used the DNA barcode for large scale screening of the brown algal family Laminariaceae in Canada. With the examination of 194 COI-5P (5' end of cytochrome c oxidase 1) sequences from representatives of this family, we confirmed the presence of 12 species in Canadian waters (*Cymathere triplicata, Laminaria digitata, L. ephemera, L. setchelii, L. solidungula, L. yesoensis, Macrocyctis integrifolia, Nereocystis leutkeana, Postelsia palmaeformis, Saccharina groenlandica, S. latissima,* and *S. sessilis*). *Saccharina groenlandica,* a species with a history of taxonomic confusion, was found in the Pacific, Hudson Bay (subarctic) and Atlantic Canada extending greatly our comprehension of the biogeography of this species. Additionally, COI-5P data from *Saccharina latissima,* combined with ITS results, provided insights into historical distributional patterns and uncovered a hybridization zone between incipient species in this complex. These discoveries highlight how the growth of a worldwide barcode database for the assignment of individuals to genetic species will uncover new perspectives on biogeography and species diversity on a global scale.

Introduction

The use of molecular tools for identification of unknown algal specimens is hardly a new idea (e.g., McIvor *et al.* 2001; Zuccarello and West 2003; Lane and Saunders 2005; Saunders and Lehmkuhl 2005; Fox and Swanson 2007). In the phycological world, simple morphologies, phenotypic plasticity and convergence can make traditional morphology-based identification difficult. Given these challenges, the large numbers of overlooked species that have been reported recently are no surprise (e.g., Cho *et al*. 2006; Lindstrom 2008; Saunders 2008). Historically, numerous markers have been used for molecular-assisted identification, for example the plastid rubisco operon (rbcL; Hughey *et al*. 2001; Yoon *et al*. 2001) and photosystem I (psaA; Cho *et al*. 2006), the nuclear large subunit ribosomal cistron (LSU; Erting *et al*. 2004; Saunders and Lehmkuhl 2005) and the internal transcribed spacer region of the nuclear ribosomal cistron (ITS; Hughey *et al*. 2001; Ross *et al*. 2003; Shi *et al*. 2005). However, the lack of a standardized marker for rapid specimen identification makes comparison between studies difficult. In recognition of this shortcoming, Hebert *et al*. (2003a; 2003b) championed the use of a mitochondrial marker, the 5' end of cytochrome c oxidase 1 (COI-5P), as a universal tool for species identification (DNA barcode). Less than 700 bp of COI are necessary for species level resolution. Short size along with ease of alignment makes COI-5P preferable to other markers (such as ITS or rbcL) for conducting large-scale floristic surveys.

Previous studies have shown the utility of COI-5P for species differentiation in red (Saunders 2005, 2008; Roba *et al*. 2006) and brown (Lane *et al*. 2007; Kucera and Saunders 2008; McDevit and Saunders 2009) macroalgae. However, the simple assignment of biological specimens to accepted species is not the only use for DNA barcoding. For example, Smith *et al*. (2005) utilized barcode data for a biodiversity assessment in Madagascar. Morphological species data were compared to molecular species data and showed that the accepted morphological species concepts were too conservative. In a series of studies, Saunders (2008; 2009) demonstrated the utility of COI-5P for what he termed "a contemporary molecular-assisted macroalgal survey of Canadian waters." These studies revealed several cryptic species and the presence of a putative invasive, *Gracilaria vermiculophylla* (Ohmi) Papenfuss in the relatively well-studied coastal waters of British Columbia. Considering the utility of COI-5P for species discrimination in the Phaeophyceae, and the rather significant levels of phenotypic plasticity attributed to many of its members (e.g. Scott *et al*. 2001; Roberson and Coyer 2004; Harvey and Goff 2006), we have initiated a similar COI-5P-assisted survey of the Canadian brown macroalgae. Here we present data for the brown algal family Laminariaceae.

The Laminariaceae is one of seven families within the order Laminariales. Members of the Laminariaceae occur primarily in the northern hemisphere though some genera are present in both hemispheres (Lüning and tom Dieck 1990). Traditionally this family was defined by blade morphology. Members had simple (undivided) blades or longitudinally divided blades where the split was always above the transition zone. However, molecular data from numerous studies (Saunders and Druehl 1993; Yoon *et al*. 2001; Lane *et al*. 2006) have shown that the traditional morphology-based classification was not congruent with evolutionary relationships as predicted from sequence data. Lane *et al*. (2006), in particular, have dramatically changed classification for the Laminariales. Many genera traditionally placed in the Lessoniaceae, *viz. Macrocystis, Nereocystis, Pelagophycus* and *Postelsia,* were transferred to the Laminariaceae, and an additional genus, *Saccharina,* was resurrected to accommodate molecularly divergent members of the genus *Laminaria*. Currently, there are twelve genera recognized in the Laminariaceae (Guiry and Guiry 2008), six of which (*Cymathaere, Laminaria, Macrocystis, Nereocystis, Postelsia,* and *Saccharina*) are found in Canadian waters. In this study we utilize the COI-5P barcode to explore the genetic diversity within and among the Canadian members of this family and uncover previously cryptic biogeographical patterns for two notoriously plastic species.

Materials and Methods

Molecular

Samples for the current study are summarized in Table 1. Preparation of field collections, as well as total DNA extraction, followed McDevit and Saunders (2009). The barcode region was amplified using previously published primers GazF2 and GazR2 (Lane *et al*. 2007), as well as the additional forward primers GHalF (Saunders 2008) and DiamF3 5'-CCAACCAYAAAGATATWGGWAC-3'. The ITS region was amplified using previously published primers P1 and KG4 (Tai *et al*. 2001; Lane *et al*. 2006). The PCR thermal profiles, PCR product cleaning and sequencing followed McDevit and Saunders (2009). Forward and reverse sequence reads were edited to produce contigs in Sequencher 4.5 (Gene Codes Corporation, Ann Arbor, MI, USA) and multiple sequence alignments were generated in MacClade 4.08 (Maddison and Maddison 2005). Sequence assessments were conducted in PAUP 4.0b10 (Swofford 2002). Distances were corrected using a general time reversible model and the NJ algorithm was used to provide a visual display of COI-5P variation within and between species.

Anatomy

Sections were made in a cryostat (CM1850, Leica, Heidelberg, Germany) and subsequently stained with 1% aniline blue in 7% acetic acid and mounted in 40-50% corn syrup. Observations were made on a Leica DM5000B light microscope and recorded on a Leica DFC480 digital camera.

Results

Molecular

The 150 COI-5P sequences generated in this study were analyzed along with 44 previously published records (McDevit and Saunders 2009; Table 1). Within species divergence was generally between 0 to 0.5%, with the exception of *Saccharina latissima* where within 'species' divergence ranged from 0 to 1.2% (discussed below) (Fig. 1). Between species divergence values were generally greater than 4%, but dropped to greater than 2.9% between *Laminaria digitata* and *L. hyperborea* and 2.1% between *Saccharina bongardiana* and *S. groenlandica* (Fig. 1). In the Canadian Pacific, the expected 10 species were resolved with COI-5P (Fig. 1), whereas in the Canadian subarctic and Atlantic four species were resolved rather than the expected three (*S. groenlandica* is not currently recognized in these waters; Fig. 1).

Larger than expected divergence was observed in *Saccharina latissima* COI-5P – as high as 1.2% (Fig. 1). However, the COI-5P sequences clustered into three groups (here on referred to as mitotypes) corresponding to biogeography, viz., Atlantic mitotype (including all collections from Atlantic Canada and all collections from the Arctic with a '*longicruris*' morphology (= long hollow stipes)), Pacific mitotype (including all Pacific collections and all collections from the Arctic with a '*latissima*' morphology (= short solid stipes)) and European mitotype (including all collections from Atlantic Europe) (Fig. 2). Owing to the similarity in COI-5P sequences (see Lane *et al*. 2007), ITS data were generated for this species and showed greater than 1% within species divergence (Fig. 3). Whereas Pacific collections grouped together, as did European collections, the Atlantic and Arctic collections were dispersed throughout the tree and commonly (northern) to occasionally (more southern) displayed ambiguous nucleotide states (Fig. 3).

Anatomy

Anatomical examinations of blade and stipe sections were conducted for collections of *S. latissima* (n=15), *L. digitata* (n=15) and *S. groenlandica* from the Pacific (n=5), Arctic (n=4) and Atlantic (n=5). Mucilage ducts were not found in the blade or the stipe of *Saccharina latissima* (Fig. 4A and B), but were found in the blade and stipe of *S. groenlandica* (Fig. 4C and D). For *L. digitata* ducts were found in the blade (Fig. 4E), but not the stipe (Fig. 4F).

Discussion

Mitochondrial DNA is ideally suited for inferring population histories due to its high mutation rate, lack of recombination and small effective population size (Avise *et al*. 1987; Wares and Cunningham 2001). In addition, mitochondrial DNA trees are continually 'self pruning' leading to monophyly rapidly in separated populations (Avise *et al*. 1987). In brown algae, though not widely studied, inheritance of mitochondrial DNA is thought to be uniparental (Motomura 1990; Kato *et al*. 2006). Therefore trees built upon mitochondrial genes are devoid of factors such as recombination and hybridization that can make nuclear trees difficult to interpret among closely related populations and species. With these factors in mind, we can use barcode data to explore large-scale patterns of species biogeography and evolution.

The COI-5P barcode successfully differentiated species within the Laminariaceae in Canada, the within species divergence values being between 0 and 0.5% in all but one case, whereas between species divergences were typically greater than 4% (Fig. 1). These values are comparable to those found in red macroalgae (Saunders 2005, 2008). Further, and despite considerable phenotypic plasticity, the species resolved with the COI-5P barcode generally agreed with published species lists (Gabrielson *et al*. 2006; Sears 2002), but again with interesting exceptions. Firstly, larger than expected within 'species' COI-5P divergence was observed for *Saccharina latissima* across the northern oceans, but within 'species' clusters nonetheless resolved along clear biogeographical patterns. Secondly, the data indicate a considerable extension in the known range of *Saccharina groenlandica*.

Saccharina latissima

The COI-5P data resolved three closely related clusters within *Saccharina latissima* (two from Canada and one from Europe, Fig. 2). Divergence was generally around one percent between clusters, but less than 0.4% within clusters. These data are consistent with the interpretation of incipient speciation or a species complex, which requires additional data in order to detect hybridization and ultimately to resolve the issue of how many species should be recognized (see Saunders 2005; Lane *et al*. 2007). We thus generated data from the nuclear ITS, which did not show the same structure as noted for COI-5P (Fig. 3). Within *Saccharina latissima* collections there was 0 – 1% divergence with clustering not obviously based on geography or mitotype. The European collections clustered together with identical ITS sequences and all collections with Pacific mitotypes fell in one of two closely related ITS clusters, but collections with Atlantic mitotypes grouped variously with the previous two, formed distinct lineages and were commonly characterized by ITS sequences with ambiguous base calls indicative of introgression of nuclear DNA from the European and Pacific populations into the Atlantic population.

The DNA barcode can be a powerful tool for examining large-scale biogeographical patterns. As seen previously (Lane *et al*. 2007), mitochondrial data can give insight into historic incipient speciation events even when interbreeding has subsequently resumed. Closer examination of *Saccharina latissima* COI-5P molecular data revealed three fixed base differences between Canadian Atlantic and European collections, three fixed differences between European and Canadian Pacific collections and six fixed differences between Canadian Atlantic and Pacific collections (Fig. 5C). This suggests a closer relationship of the European collections to the two Canadian populations than they are relative to one another. The relatively high level of divergence in COI-5P between Atlantic and Pacific Canadian populations of *Saccharina latissima* is consistent with genetic isolation (even sibling species), yet neither is sufficiently divergent from the European population to warrant similar status (Saunders 2005). Further, ITS data suggest that interbreeding has resumed between these populations in Canadian Arctic and Atlantic waters. One explanation for this pattern is a historic circumpolar distribution of *S. latissima* from a European origin to the Canadian Atlantic and Pacific (Fig. 5A). At some point (possibly during a period of glaciation) these three populations became isolated and incipient speciation occurred (Fig. 5B). However, recent contact and thus gene-flow between these populations in eastern Canada (Fig. 5C) has resulted in mixing of nuclear DNA. Due to the lack of recombination and uniparental inheritance of mitochondrial DNA, the Atlantic and Arctic populations have retained distinct mitotypes as a signature of this past biogeographical pattern. The high level of ambiguous sites in ITS data from Churchill and Newfoundland collections is a further signature of this interbreeding at what appears to be a hybridization zone between would-be incipient species. This pattern is consistent with the hypothesis of Pacific to Atlantic transfer of species by way of Arctic water currents (Fig. 5C; see Adey *et al*. 2008).

The distinction between *Saccharina latissima* and *S. longicruris* (Bachelot de la Pylaie) Kuntze has been questioned for some time (South and Tittley 1986). The '*longicruris*' morphology has been reported from the Canadian arctic to Rhode Island. Consistent with the hypothesis that they are not distinct species, we found no difference in COI-5P between Atlantic *'latissima'* and '*longicruris'* morphologies (Fig. 2 – '*longicruris'* morphology indicated in bold). Perhaps the '*longicruris*' morph was a derivation of the incipient Atlantic species that is now diluted by the renewed influx of

European and Pacific nuclear DNA. In any event, we find no evidence in support of *S. longicruris* as a species distinct from *S. latissima* and consider the former a synonym of the latter.

Saccharina groenlandica

Though only three members of the Laminariaceae are reported from the Eastern Arctic and Atlantic Canada (*Saccharina latissima, Laminaria digitata* and *L. solidungula*) DNA barcoding uncovered four. The fourth was a perfect match to the Pacific *Saccharina groenlandica* (Fig. 1). Anatomical examination revealed mucilage ducts in the stipe and the blade of these collections (Fig. 4), contrasting our observations for both *L. digitata,* which only has mucilage ducts in the blade, and *S. latissima,* which has no mucilage ducts. This is a fortunate anatomical feature because these two species can be easily confused with *S. groenlandica* morphologically (Fig. 6). Mucilage ducts have historically been used to differentiate species of kelp though their presumed plasticity has led to taxonomic confusion. Burrows (1964), working with collections of *Laminaria* from Canada and Europe, examined the response of mucilage ducts to changes in growth temperature establishing that duct size was smaller in response to colder water. In contrast, Wilce's (1965) observations in nature led him to hypothesize that kelps with mucilage ducts were favored in colder water. He concluded that mucilage ducts were a plastic feature (increasing with decreasing water temperature) and thus not a valid taxonomic character. Our observations contradict Wilce's perspective and again highlight the taxonomic utility of this character, at least for the species in eastern

Canadian waters. The pattern of mucilage duct presence and absence was consistent with molecular identification of the species.

Saccharina groenlandica (Rosenvinge) C.E. Lane, C. Mayes, Druehl & G.W. Saunders was first described by Rosenvinge from the coast of Greenland (basionym: *Laminaria groenlandica* Rosenvinge 1893) as having mucilage ducts in both the stipe and blade. Wilce (1959, 1960) considered that *L. groenlandica* was not distinct from *L. cuneifolia* J.G. Agardh, a kelp described based on specimens from the Kamchatkan Peninsula. However, the name *L. cuneifolia* J.G. Agardh is a later homonym of *L. cuneifolia* Kützing (described from Helgoland and likely a form of *S. latissima*) and thus illegitimate prompting Wilce (1960) to apply the name *L. groenlandica* Rosenvinge to this species. Shortly thereafter, Wilce (1965) questioned whether or not *L. groenlandica* was distinct from *Saccharina latissima* (as *Laminaria saccharina* (Linnaeus) J.V. Lamouroux), as well as the taxonomic utility of mucilage ducts – their occurrence versus absence the main distinguishing feature between these species. This uncertainty appears to stem from a perpetuating misinterpretation (Wilce 1965; South and Tittley 1986; Lüning and tom Dieck 1990) of Burrows' (1964) report of changes in the size of mucilage ducts in response to temperature, which has apparently transposed to presence versus absence of this attribute. However, we have shown that mucilage ducts in the stipe are a valid taxonomic character and we must regard *S. groenlandica* as distinct from *S. latissima*.

The most recent name to be associated with Pacific populations of *Saccharina grownlandica* is *Saccharina subsimplex* (Setchell & N.L. Gardner) Widdowson, S.C. Lindstrom & P.W. Gabrielson in Gabrielson *et al*. (2006), which is based on *Laminaria bullata* f. *subsimplex* Setchell & N.L. Gardner 1903 (type collection from Whidbey Island, Washington, USA). Citing multiple authors (Wilce 1960; Druehl 1968; Lüning and tom Dieck 1990) who considered that Atlantic and Pacific populations of *S. groenlandica* (as *L. groenlandica*) were not conspecific, Widdowson *et al*. (in Gabrielson *et al*. 2006) chose the available name *L. subsimplex* (Setchell & N.L. Gardner) Miyabe & Nagai for the latter and transferred it to *Saccharina*. Our results clearly resolve a single species widely distributed in the Arctic, Atlantic and Pacific for which the name *Saccharina groenlandica* has priority.

The Kamchatkan *S. bongardiana* (Postels & Ruprecht) Selivanova, Zhigadlova & G.I. Hansen, another kelp described with mucilage ducts in both the blade and stipe has been applied as a name to the northeast Pacific *S. groenlandica* (Lüning and tom Dieck 1990; Gabrielson *et al*. 2000). However, collections of *S. bongardiana* from Kamchatka (the type locality) differ by 2.1% in their COI-5P sequence from our Canadian collections of *S. groenlandica*. In our extensive collections from British Columbia we have yet to come across a collection that molecularly matches *S. bongardiana* from Kamchatka. Therefore it is unlikely that *S. bongardiana* extends into British Columbian coastal waters.

Conclusions

The DNA barcode is a powerful tool for processing large numbers of specimens as a first pass for species assignments (Saunders 2008). The use of this standardized barcode region by researchers around the globe will allow for a rapid accumulation of highly standardized data. In this study we have shown some of the additional insights that will emerge from barcode data as global contributions to genetic databases accrue. With our relatively small data set we were able to uncover unexpected and exciting aspects regarding the biogeography (*S. groenlandica*) and evolutionary history (*S. latissima*) of kelp species in the circumboreal region with an emphasis on Canadian waters. This study also reminds us that although COI can be a powerful tool for identifying potential species complexes, it is important to confirm these findings with other molecular markers (nuclear, for example) as well as integrate morphological data.

In the field of phycology, where accurate identifications are often difficult even for experts, a global data set will reduce confusion, speed routine identifications, help identify exotics and greatly expand our knowledge of the biological world.

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Table 1. List of samples used in this study and accession numbers for barcode (Cytochrome c oxidase 1(COI-5P)) and internal transcribed spacer (ITS) sequences (where determined), respectively. Sequences from McDevit and Saunders (2009) indicated in italics. Collectors abbreviated as follows: AM, A. Mortensen; BC, B. Clarkston; BH, B. Hooper; CM, C. Maggs; DM, D. McDevit; DS, D. Saunders; GWS, G. Saunders; HK, H. Kucera; JD, J. DeWaard; JU, J. Utge; KR, K. Roy; LLG, L. LeGall; NY, N. Yotsukura; RW, R. Withall; SC, S. Clayden.

Species	Voucher	Collection Information	Lat/Long	BOLD	Genbank COI-5P/ITS
Cymathere triplicata (Postels & Ruprecht) J. Agardh					
	GWS004227	Sooke Harbour, BC, Canada. GWS, BC, DM	48.3521/-123.7281	MACRO588-07	***/-
	GWS004945	Ridley Island, BC, Canada. GWS, BC, DM	54.2212/-130.3293	MACRO605-07	***/-
Laminaria digitata (Hudson) J.V. Lamouroux					
	GWS003799	Meadow Cove, NB, Canada. DM	45.0381/-66.8913	MACRO194-06	***/-
	GWS005181	Meadow Cove, NB, Canada. GWS, BC	45.1029/-66.3884	MACRO253-06	***/-
	GWS005325	Churchill, MB, Canada, GWS, BC, DM	58.78057/-94.27670	MACRO272-06	*FJ409151*/-
	GWS005326	Churchill, MB, Canada. GWS, BC, DM	58.78057/-94.27670	MACRO615-07	***/-
	GWS005603	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO467-07	***/-
	GWS005604	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO468-07	***/-
	GWS005607	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO470-07	***/-
	GWS005608	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO471-07	***/-
	GWS005609	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO472-07	***/-
	GWS005610	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO473-07	***/-
	GWS005640	Portland, ME, USA. GWS, BC, DM	43.6256/-70.2138	MACRO479-07	***/-
	GWS005649	Portland, ME, USA. GWS, BC, DM	43.6256/-70.2138	MACRO483-07	***/-
	GWS005650	Portland, ME, USA. GWS, BC, DM	43.6256/-70.2138	MACRO484-07	***/-
	GWS005663	Meadow Cove, NB, Canada. DM, LLG, DS, GWS	45.0381/-66.8913	MACRO486-07	***/-
	GWS005664	Meadow Cove, NB, Canada. DM, LLG, DS, GWS	45.0381/-66.8913	MACRO487-07	***/-
	GWS005665	Meadow Cove, NB, Canada. DM, LLG, DS, GWS	45.0381/-66.8913	MACRO488-07	***/-
	GWS005666	Meadow Cove, NB, Canada. DM, LLG, DS, GWS	45.0381/-66.8913	MACRO706-07	***/-
	GWS005667	Meadow Cove, NB, Canada. DM, LLG, DS, GWS	45.0381/-66.8913	MACRO968-08	***/-
	GWS005669	Meadow Cove, NB, Canada, DM, LLG, DS, GWS	45.0381/-66.8913	MACRO490-07	*FJ409150*/-

GWS005673	Peggy's Cove, NS, Canada. GWS, DS	44.4905/-63.9166	MACRO619-07	***/-
GWS005682	Lepreau, NB, Canada. DM	45.0722/-66.4690	MACRO622-07	***/-
GWS005683	Lepreau, NB, Canada. DM	45.0722/-66.4690	MACRO623-07	***/-
GWS005684	Lepreau, NB, Canada. DM	45.0722/-66.4690	MACRO624-07	***/-
GWS005685	Lepreau, NB, Canada. DM	45.0722/-66.4690	MACRO625-07	***/-
GWS005900	Beaver Harbour, NB, Canada. DM	45.0563/-66.7358	MACRO719-07	***/-
GWS006000	Narragansett, RI, USA. GWS, BC, DM	41.42255/-71.45460	MACRO744-07	***/-
GWS006003	Narragansett, RI, USA. GWS, BC, DM	41.42255/-71.45460	MACRO745-07	***/-
GWS006073	Fort Wetherill, RI, USA. GWS, BC, DM	41.47910/-71.36066	MACRO764-07	***/-
GWS006075	Fort Wetherill, RI, USA. GWS, BC, DM	41.47910/-71.36066	MACRO766-07	***/-
GWS007230	Bonne Bay, NL, Canada. LLG, BH, JU	49.5484/-57.9542	MACRO508-07	***/-
GWS007563	English Harbour, NL, Canada. LLG, DM, JU	47.6331/-54.87	MACRO311-06	***/-
GWS007680	St. Brides, NL, Canada, LLG, HK, DM, JU	46.92068/-54.17384	MACRO317-06	*FJ409149*/-
GWS007694	St. Brides, NL, Canada. LLG, HK, DM, JU	46.92068/-54.17384	MACRO430-06	***/-
GWS007697	St. Brides, NL, Canada. LLG, HK, DM, JU	46.92068/-54.17384	MACRO318-06	***/-
GWS007822	White Point, NS, Canada, LLG, DM	46.88226/-60.35077	MACRO325-06	*FJ409148*/-
GWS007823	White Pt., NS, Canada. LLG, DM	46.88226/-60.35077	MACRO326-06	***/-
GWS007874	Digby, NS, Canada. LLG, JU	44.6919/-65.7853	MACRO328-06	***/-
GWS007905	Cape St. Marys, NS, Canada. LLG, JU	44.0871/-66.2034	MACRO537-07	***/-
GWS009228	Giant's Causeway, Ireland. CM		MACRO1004-08	***/-
GWS009229	Giant's Causeway, Ireland. CM		MACRO1005-08	***/-
GWS009230	Giant's Causeway, Ireland. CM		MACRO1006-08	***/-
SC3	Oranmore, Ireland. SC	53.27/-8.93	MACRO548-07	***/-
Laminaria ephemera Setchell				
GWS003985	Bamfield, BC, Canada, GWS, BC, DM	48.8391/-125.2075	MACRO211-06	*FJ409153*/-
GWS003986	Bamfield, BC, Canada, GWS, BC, DM	48.8391/-125.2075	MACRO582-07	*FJ409152*/-
GWS010197	Thasis, BC, Canada. GWS, BC	49.82104/-126.97653	MACRO1086-08	***/-
GWS010810	Bamfield, BC, Canada. GWS, BC	48.8391/-125.2075	MACRO1090-08	***/-
Laminaria hyperborea (Gunnerus) Foslie				
GWS009234	Fanad Head, Ireland, C.A.Maggs	55.2764/-7.6344	MACRO1007-08	*FJ409156*/-
GWS009235	Fanad Head, Ireland, C.A.Maggs	55.2764/-7.6344	MACRO1008-08	*FJ409155*/-
GWS009236	Fanad Head, Ireland, C.A.Maggs	55.2764/-7.6344	MACRO1009-08	*FJ409154*/-
Laminaria setchellii Silva				
GWS002860	Bamfield, BC, Canada. GWS	48.8583/-125.1588	MACRO064-06	***/-

	GWS002861	Bamfield, BC, Canada. GWS	48.8583/-125.1588	MACRO065-06	***/-
	GWS003404	Bamfield, BC, Canada, GWS, BC, DM	48.7862/-125.1191	MACRO147-06	*FJ409160*/-
	GWS003991	Bamfield, BC, Canada, GWS, BC, DM	48.8391/-125.2075	MACRO212-06	*FJ409159*/-
	GWS004442	Port Renfrew, BC, Canada, GWS, BC, DM	48.5304/-124.4535	MACRO234-06	*FJ409158*/-
	GWS004937	Prince Rupert, BC, Canada, GWS, BC	54.3390/-130.9365	MACRO603-07	*FJ409157*/-
Laminaria solidungula J. Agardh					
	GWS005335	Churchill, MB, Canada, GWS, BC, DM	58.78057/-94.27670	MACRO616-07	*FJ409166*/-
	GWS005378	Churchill, MB, Canada, GWS, BC, DM	58.81154/-94.21970	MACRO283-06	*FJ409165*/-
	GWS005385	Churchill, MB, Canada, DM	58.81154/-94.21970	MACRO617-07	*FJ409164*/-
	GWS005386	Churchill, MB, Canada, DM	58.81154/-94.21970	MACRO466-07	*FJ409163*/-
	GWS005387	Churchill, MB, Canada. GWS, BC, DM	58.81154/-94.21970	MACRO964-08	***/-
	GWS005422	Churchill, MB, Canada, DM, JD	58.81154/-94.21970	MACRO976-08	*FJ409162*/-
	GWS007069	Bonne Bay, NL, Canada, LLG, JU	49.52826/-57.82495	MACRO499-07	*FJ409161*/-
Laminaria yezoensis Miyabe					
	05-758A	Ridley Island, BC, Canada, SB	54.2454/-130.3386	MACRO101-06	*FJ409168*/-
	GWS004941	Ridley Island, BC, Canada, GWS, BC, DM	54.2212/-130.3293	MACRO244-06	*FJ409167*/-
	GWS008310	Prince Rupart, BC, Canada. GWS, BC, DM, KR	54.3007/-130.2507	MACRO1065-08	***/-
	GWS008314	Prince Rupart, BC, Canada. GWS, BC, DM, KR	54.2212/-130.3293	MACRO1066-08	***/-
	GWS008369	Prince Rupart, BC, Canada. DM, BC, GWS	54.2212/-130.3293	MACRO1067-08	***/-
	GWS008370	Prince Rupart, BC, Canada. DM, BC, GWS	54.2212/-130.3293	MACRO1068-08	***/-
	GWS008389	Prince Rupart, BC, Canada. DM, BC, GWS	54.2212/-130.3293	MACRO1069-08	***/-
Macrocystis integrifolia Bory					
	GWS002852	Bamfield, BC, Canada, GWS	48.8583/-125.1588	MACRO066-06	*FJ409174*/-
	GWS003990	Bamfield, BC, Canada, GWS, BC, DM	48.8391/-125.2075	MACRO446-07	*FJ409173*/-
Nereocystis luetkeana (Mertens) Postels & Ruprecht					
	GWS002927	Bamfield, BC, Canada. HK, SC	48.8240/-125.1621	MACRO067-06	***/-
	GWS003400	Bamfield, BC, Canada. GWS, BC, DM	48.7862/-125.1191	MACRO146-06	***/-
	GWS004272	Victoria, BC, Canada. GWS, BC, DM	48.4227/-123.4195	MACRO225-06	***/-
	GWS004440	Port Renfrew, BC, Canada, GWS, BC, DM	48.5304/-124.4535	MACRO387-06	*FJ409182*/-
	GWS004470	Bamfield, BC, Canada, GWS, BC, DM	48.8187/-125.2084	MACRO594-07	*FJ409181*/-
	GWS004546	Bamfield, BC, Canada, GWS, BC, DM	48.8622/-125.1768	MACRO388-06	*FJ409180*/-
	GWS004711	Palmerston, BC, Canada, BC, DM	50.5933/-128.2583	MACRO390-06	*FJ409179*/-

GWS004947	Ridley Island, BC, Canada, GWS, BC, DM	54.2212/-130.3293	MACRO460-07	*FJ409178*/-
GWS006545	Thasis, BC, Canada, BC, DM, KR, SH	49.724722/-126.6425	MACRO974-08	*FJ409177*/-
GWS008535	Backeddy Resort, BC, Canada. GWS, BC, DM, KR	49.7585/-123.938	MACRO1070-08	***/-
Postelsia palmaeformis Ruprecht				
GWS002985	Bamfield, BC, Canada. GWS	48.7895/-125.2163	MACRO068-06	***/-
GWS003207	Bamfield, BC, Canada. GWS, RW	48.7715/-125.1578	MACRO069-06	***/-
GWS003386	Bamfield, BC, Canada. GWS, BC, DM	48.7862/-125.1191	MACRO139-06	***/-
Saccharina bongardiana (Postels & Ruprecht) Selivanova, Zhigadlova & G.I. Hansen				
L.bong2	Kamtchatka, Russia. NY		***	***/-
L.bong3	Kamtchatka, Russia. NY		***	***/-
L.bong4	Kamtchatka, Russia. NY		***	***/-
L.bong5	Kamtchatka, Russia. NY		***	***/-
Saccharina groenlandica (Rosenvenge) C.E. Lane, C. Mayes, Druehl & G.W. Saunders				
GWS002500	Brier Island, NS, Canada. GWS	44.2876/-66.3422	MACRO122-06	***/-
GWS003773	Grand Manan, NB, Canada. DM	44.6249/-66.8604	MACRO187-06	***/-
GWS003832	Lepreau, NB, Canada. HK	45.0722/-66.4690	MACRO335-06	***/-
GWS004436	Botanical Beach, BC, Canada, GWS, BC, DM	48.5304/-124.4535	MACRO232-06	*FJ409198*/-
GWS004942	Ridley Island, BC, Canada, GWS, BC, DM	54.2212/-130.3293	MACRO245-06	*FJ409197*/-
GWS004944	Ridley Island, BC, Canada, GWS, BC, DM	54.2212/-130.3293	MACRO246-06	*FJ409196*/-
GWS005105	Butze Rapids, BC, Canada, GWS, BC, DM	54.3007/-130.2507	MACRO249-06	*FJ409195*/-
GWS005108	Butze Rapids, BC, Canada, GWS, BC, DM	54.3007/-130.2507	MACRO250-06	*FJ409194*/-
GWS005291	Churchill, MB, Canada. GWS, BC, DM	58.7703/-93.8474	MACRO264-06	***/-
GWS005376	Churchill, MB, Canada. GWS, BC, DM	58.81154/-94.21970	MACRO281-06	***/-
GWS005377	Churchill, MB, Canada. GWS, BC, DM	58.81154/-94.21970	MACRO282-06	***/-
GWS005515	Churchill, MB, Canada. GWS, BC, DM, KR	58.7678/-93.8897	MACRO695-07	***/-
GWS006992	Cape Ray, NL, Canada. LLG, JU	47.62269/-59.29108	MACRO415-06	***/-
GWS007567	English Harbour, NL, Canada. LLG, DM, JU	47.6331/-54.87	MACRO365-06	***/-
GWS007873	Digby, NS, Canada. LLG, JU	44.6919/-65.7853	MACRO327-06	***/-
GWS007875	Digby, NS ,Canada. LLG, JU	44.6919/-65.7853	MACRO329-06	***/-
GWS008660	Comox, BC, Canada. GWS, BC, DM, KR	49.6903/-124.87	MACRO1072-08	***/-
Saccharina latissima (Linnaeus) C.E. Lane, C. Mayes, Druehl & G.W. Saunders				
DM05-001	Beaver Harbour, NB, Canada. DM	45.0717/-66.7372	MACRO076-06	***/***

GWS002491	Brier Island, NS, Canada. GWS	44.2876/-66.3422	MACRO070-06	***/***
GWS002492	Brier Island, NS, Canada. GWS	44.2876/-66.3422	MACRO071-06	***/-
GWS002493	Brier Island, NS, Canada. GWS	44.2876/-66.3422	MACRO072-06	***/***
GWS002495	Brier Island, NS, Canada. GWS	44.2876/-66.3422	MACRO073-06	***/***
GWS002496	Brier Island, NS, Canada. GWS	44.2876/-66.3422	MACRO074-06	***/***
GWS002497	Brier Island, NS, Canada. GWS	44.2876/-66.3422	MACRO075-06	***/-
GWS002499	Brier Island, NS, Canada. GWS	44.2876/-66.3422	MACRO121-06	***/***
GWS002505	Digby, NS, Canada. GWS	44.3951/-66.2042	MACRO077-06	***/***
GWS002506	Digby, NS, Canada. GWS	44.3951/-66.2042	MACRO078-06	***/***
GWS002507	Digby, NS, Canada. GWS	44.3951/-66.2042	MACRO079-06	***/***
GWS003836	Lepreau, NB, Canada. HK	45.0722/-66.4690	MACRO204-06	***/***
GWS004199	Otter Point, BC, Canada, GWS, BC, DM	48.3625/-123.8048	MACRO587-07	*FJ409204*/*FJ042735*
GWS004269	Saxe Point, BC, Canada, GWS, BC, DM	48.4227/-123.4195	MACRO223-06	*FJ409203*/*FJ042736*
GWS004271	Saxe Point, BC, Canada, GWS, BC, DM	48.4227/-123.4195	MACRO224-06	*FJ409202*/*FJ042738*
GWS004286	Maple Bay, BC, Canada, GWS, BC, DM	48.8147/-123.6099	MACRO227-06	*FJ409201*/***
GWS004652	Vivian Island, BC, Canada, BC, DM	48.8395/-124.7010	MACRO240-06	*FJ409200*/*FJ042746*
GWS004844	Prince Rupert, BC, Canada. GWS, BC, DM		MACRO602-07	***/-
GWS005232	Churchill, MB, Canada. GWS, BC, DM	58.7787/-94.1582	MACRO612-07	***/-
GWS005233	Churchill, MB, Canada. GWS, BC, DM	58.7787/-94.1582	MACRO255-06	***/***
GWS005252	Churchill, MB, Canada. GWS, BC, DM	58.7787/-94.1582	MACRO257-06	***/***
GWS005323	Churchill, MB, Canada. GWS, BC, DM	58.78057/-94.27670	MACRO270-06	***/***
GWS005324	Churchill, MB, Canada. GWS, BC, DM	58.78057/-94.27670	MACRO271-06	***/***
GWS005399	Churchill, MB, Canada. GWS, BC, DM	58.81154/-94.21970	MACRO285-06	***/***
GWS005400	Churchill, MB, Canada, GWS, BC	58.81154/-94.21970	MACRO966-08	*FJ409199*/-
GWS005421	Churchill, MB, Canada. DM, JD	58.81154/-94.21970	MACRO1025-08	***/-
GWS005426	Churchill, MB, Canada. GWS, BC	58.78671/-94.21583	MACRO1026-08	***/***
GWS005427	Churchill, MB, Canada. DM, JD	58.78671/-94.21583	MACRO1027-08	***/***
GWS005461	Churchill, MB, Canada. GWS, BC, DM	58.81154/-94.21970	MACRO1030-08	***/***
GWS005462	Churchill, MB, Canada. GWS, BC, DM	58.81154/-94.21970	MACRO1031-08	***/***
GWS005501	Churchill, MB, Canada. GWS, BC	58.8020/-94.2078	MACRO1039-08	***/-
GWS005502	Churchill, MB, Canada. GWS, BC	58.8020/-94.2078	MACRO1040-08	***/-
GWS005509	Churchill, MB, Canada. GWS, BC, DM, KR	58.7678/-93.8897	MACRO690-07	***/***
GWS005510	Churchill, MB, Canada. GWS, BC, DM, KR	58.7678/-93.8897	MACRO691-07	***/***

GWS005511	Churchill, MB, Canada. GWS, BC, DM, KR	58.7678/-93.8897	MACRO1041-08	***/***
GWS005512	Churchill, MB, Canada. GWS, BC, DM, KR	58.7678/-93.8897	MACRO692-07	***/***
GWS005513	Churchill, MB, Canada. GWS, BC, DM, KR	58.7678/-93.8897	MACRO693-07	***/***
GWS005514	Churchill, MB, Canada. GWS, BC, DM, KR	58.7678/-93.8897	MACRO694-07	***/***
GWS005516	Churchill, MB, Canada. GWS, BC, DM, KR	58.7678/-93.8897	-	-/***
GWS005601	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO618-07	***/***
GWS005606	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO469-07	***/***
GWS005630	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO474-07	***/-
GWS005634	Cape Neddick, ME, USA. GWS, BC, DM	43.1658/-70.5924	MACRO475-07	***/***
GWS005646	South Portland, ME, USA. GWS, BC, DM	43.6256/-70.2138	MACRO480-07	***/-
GWS005647	South Portland, ME, USA. GWS, BC, DM	43.6256/-70.2138	MACRO481-07	***/***
GWS005648	South Portland, ME, USA. GWS, BC, DM	43.6256/-70.2138	MACRO482-07	***/***
GWS005662	Meadow Cove, NB, Canada. DM, LLG, DS, GWS	45.0381/-66.8913	MACRO485-07	***/***
GWS005668	Meadow Cove, NB, Canada. DM, LLG, DS, GWS	45.0381/-66.8913	MACRO489-07	***/-
GWS005686	Lepreau, NB, Canada. DM	45.0722/-66.4690	MACRO626-07	***/-
GWS005898	Beaver Harbour, NB, Canada. DM	45.0563/-66.7358	MACRO717-07	***/***
GWS005899	Beaver Harbour, NB, Canada. DM	45.0563/-66.7358	MACRO718-07	***/-
GWS005901	Beaver Harbour, NB, Canada. DM	45.0563/-66.7358	MACRO720-07	***/***
GWS005923	Letete, NB, Canada. DM	45.0382/-66.8912	MACRO729-07	***/-
GWS006005	Narragansett, RI, USA. GWS, BC, DM	41.42255/-71.45460	MACRO747-07	***/***
GWS006006	Narragansett, RI, USA. GWS, BC, DM	41.42255/-71.45460	MACRO748-07	***/-
GWS006065	Fort Wetherill, RI, USA. GWS, BC, DM	41.47910/-71.36066	MACRO760-07	***/-
GWS006074	Fort Wetherill, RI, USA. GWS, BC, DM	41.47910/-71.36066	MACRO765-07	***/***
GWS007068	Bonne Bay, NL, Canada. LLG, JU	49.52826/-57.82495	MACRO498-07	***/***
GWS007121	Bonne Bay, NL, Canada. LLG, BH, JU	49.5253/-57.8256	MACRO501-07	***/-
GWS007277	Bonne Bay, NL, Canada. LLG, HK	49.68198/-57.96275	MACRO514-07	***/-
GWS007307	Bonne Bay, NL, Canada. LLG, JU	49.4778/-57.9014	MACRO358-06	***/***
GWS007378	Bottle Cove, NL, Canada. DM, JU, LLG	49.1142/-58.4136	MACRO301-06	***/***
GWS007417	Eastport, NL, Canada. LLG, HK, DM, JU	48.65521/-53.75191	MACRO520-07	***/***
GWS007493	English Harbour, NL, Canada. LLG, DM, JU	47.63192/-54.88630	MACRO425-06	***/***
GWS007517	English Harbour, NL, Canada. LLG, DM, JU	47.63192/-54.88630	MACRO308-06	***/-
GWS007538	English Harbour, NL, Canada. LLG, DM, JU	47.6331/-54.87	MACRO309-06	***/***
GWS007617	Grand Barrachois, NL, Canada. LLG, HK, DM, JU	47.0065/-56.3598	MACRO367-06	***/***

	GWS007820	White Pt., NS, Canada. LLG, DM	46.88226/-60.35077	MACRO660-07	***/-
	GWS008004	Pointe Sapin, NB, Canada. LLG, HK, JU	46.96/-64.83	MACRO544-07	***/***
	GWS008083	Escoumins, PQ, Canada. GWS, DM, HK	48.35062/-69.39722	MACRO797-07	***/***
	GWS008085	Escoumins, PQ, Canada. GWS, DM, HK	48.35062/-69.39722	MACRO798-07	***/***
	GWS008087	Escoumins, PQ, Canada. GWS, DM, HK	48.35062/-69.39722	MACRO799-07	***/-
	GWS008088	Escoumins, PQ, Canada. GWS, DM, HK	48.35062/-69.39722	MACRO800-07	***/***
	GWS008089	Escoumins, PQ, Canada. GWS, DM, HK	48.35062/-69.39722	MACRO801-07	***/-
	GWS008659	Comox, BC, Canada. GWS, BC, DM, KR	49.6903/-124.87	MACRO1071-08	***/-
	GWS010950	Sinabour, Denmark. AM	62.1/-6.817	***	***/-
	GWS010955	Kaldbaksbornur, Denmark. AM	62.067/-6.817	***	***/-
	GWS010956	Dratturin, Denmark. AM	61.533/-6.817	***	***/-
	GWS010957	Dratturin, Denmark. AM	61.533/-6.817	MACRO1091-08	***/***
	GWS010958	Dratturin, Denmark. AM	61.533/-6.817	***	***/***
	SC1	Oranmore, Ireland. SC	53.27/-8.93	MACRO547-07	***/-
Saccharina sessilis (C. Agardh) Kuntze					
	GWS002926	Bamfield, BC, Canada. HK, SC	48.8240/-125.1621	MACRO124-06	***/-
	GWS003208	Bamfield, BC, Canada, GWS, RW	48.7715/-125.1578	MACRO080-06	*FJ409208*/-
	GWS003407	Bamfield, BC, Canada, GWS, BC, DM	48.7862/-125.1191	MACRO148-06	*FJ409207*/-
	GWS004443	Port Renfrew, BC, Canada, GWS, BC, DM	48.5304/-124.4535	MACRO235-06	*FJ409206*/-
	GWS004714	Palmerston, BC, Canada, BC, DM	50.5933/-128.2583	MACRO241-06	*FJ409205*/-
	GWS008124	Bamfield, BC, Canada. BC, DM, KR, HK	48.7715/-125.158	MACRO1064-08	***/-

Figure 1. NJ phylogram displaying clustering in COI-5P sequences including a matrix of percentage nucleotide differences within and between clusters. Voucher numbers correspond to records in Table 1. Biogeography is indicated after the binomial as follows: Arc = Canadian Arctic, Atl = Atlantic Canada, AtlE = Atlantic Europe, Kam = Kamtchatka and Pac = Pacific Canada.

Figure 2. NJ phylogram displaying COI-5P clustering in collections of *Saccharina latissima* including a matrix of percentage nucleotide differences within and between clusters. Voucher numbers correspond to records in Table 1. Biogeography is indicated for each mitotype (Legend Figure 1). Collections with '*longicruris'* morphology are indicated in **bold**.

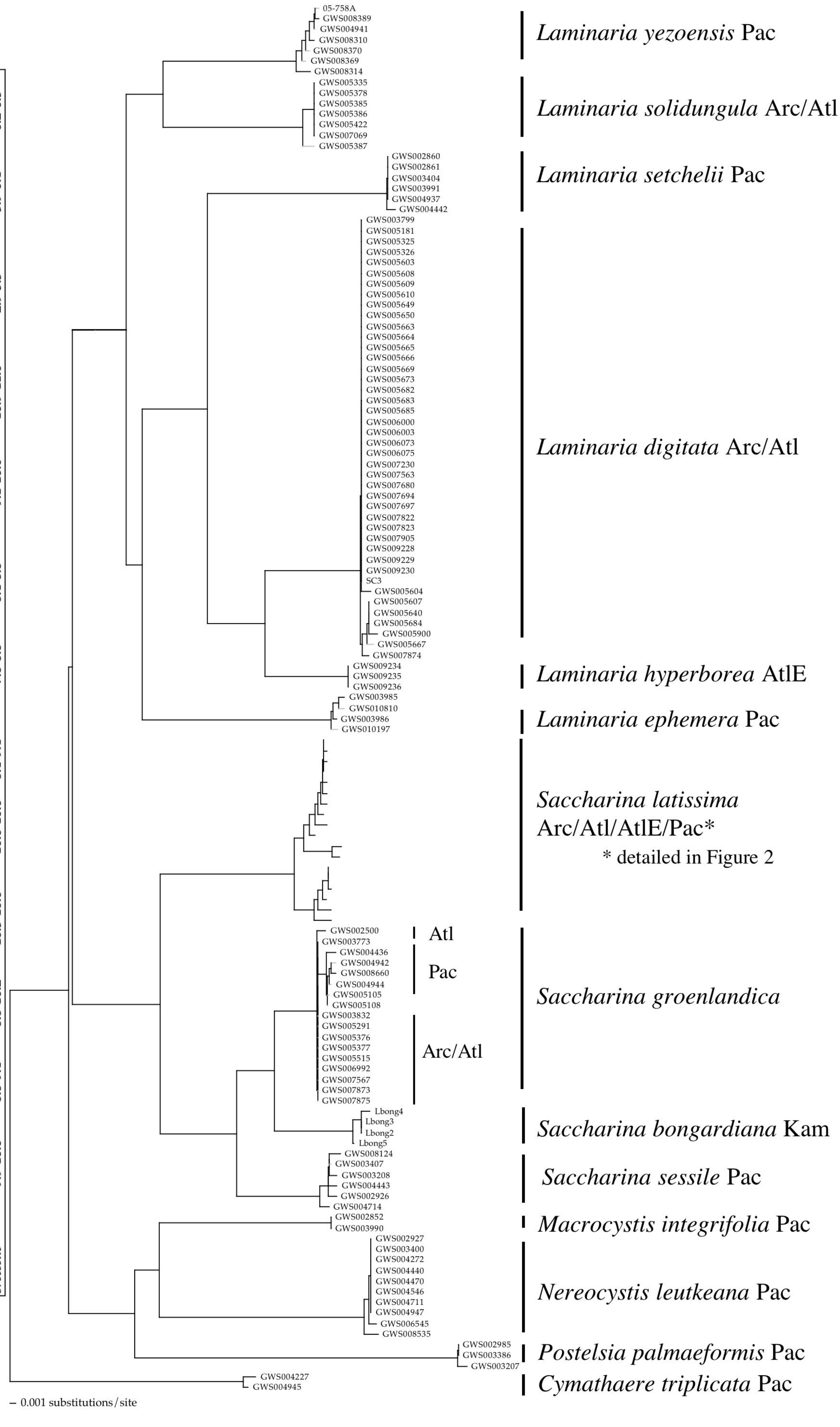
Figure 3. NJ phylogram displaying ITS clustering for collections of *Saccharina latissima*. Voucher numbers correspond to records in Table 1. Biogeography is indicated for each collection. Collections with '*longicruris'* morphology are indicated in **bold.** * Denotes presence of ambiguous base calls. All Atlantic, European and Pacific collections have the corresponding mitotype. For Arctic collections the mitotype is indicated (MA = Atlantic, MP = Pacific).

Figure 4. Cross-section of GWS006005 (*Saccharina latissima)* blade (A) and stipe (B), GWS005515 (*S. groenlandica)* blade (C) and stipe (D) and GWS005664 (*Laminaria digitata)* blade (E) and stipe (F). Scale bars represent 20μm. Arrows indicate position of mucilage ducts.

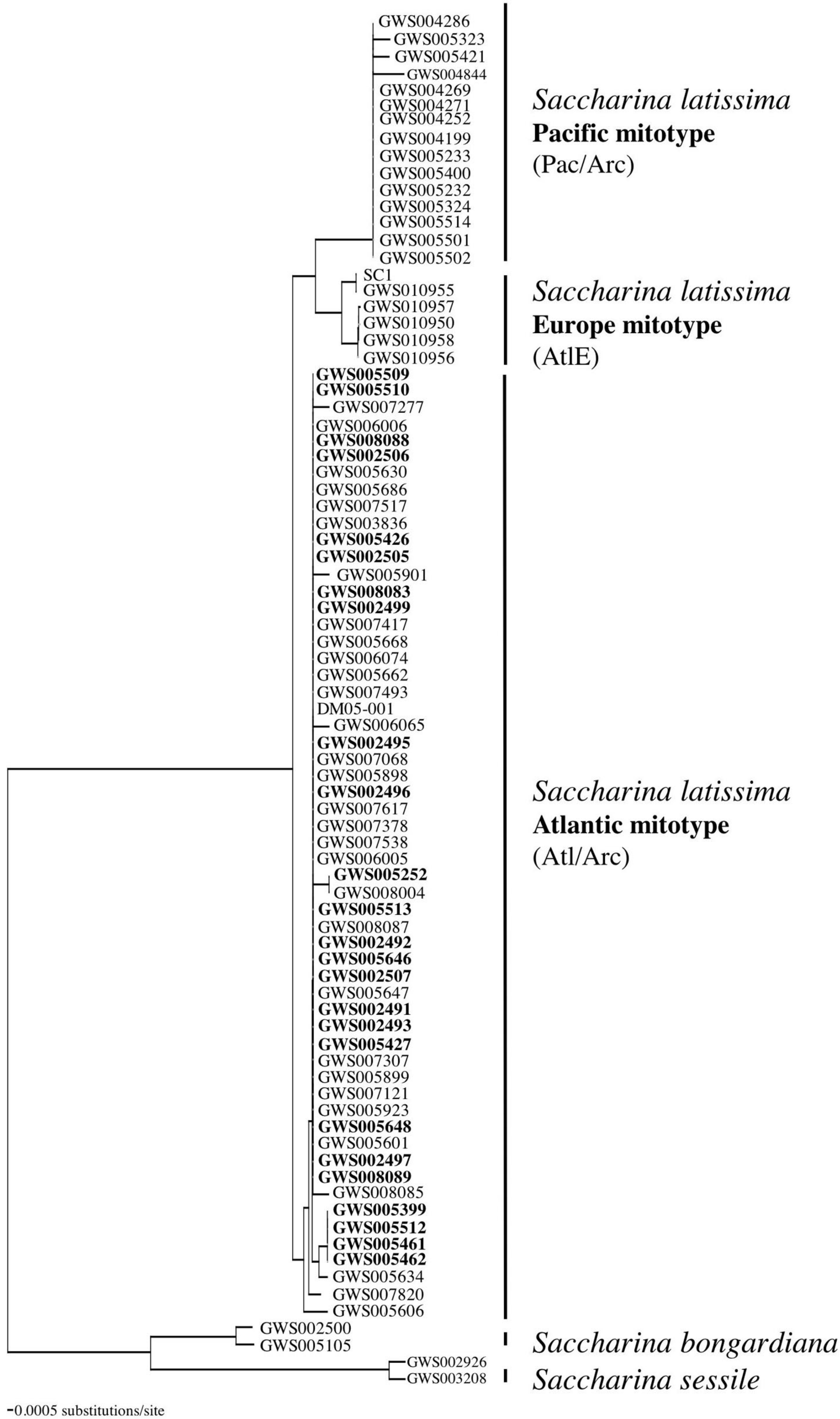
Figure 5. A. Map displaying hypothetical source (S), path of dispersal (dashed lines) and Canadian distribution (solid lines) of *Saccharina latissima* from a putative southern European population. B. Hypothetical isolated populations during recent glaciation. C. Dispersal pathways after resumption of gene flow, including Pacific to Atlantic dispersal through Canadian Arctic. Numbers represent fixed differences in COI-5P sequences between European, Canadian Pacific and Canadian Atlantic collections.

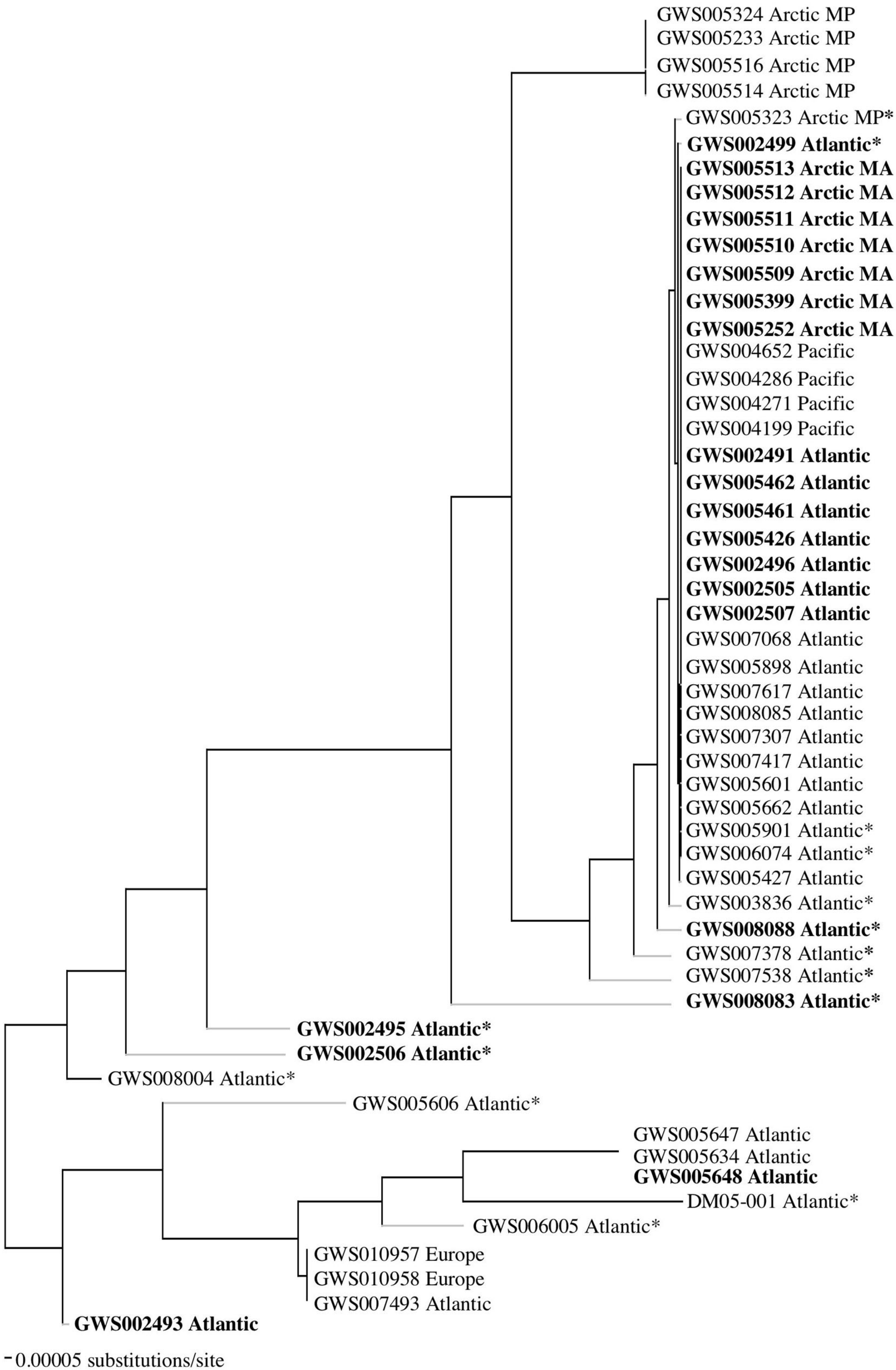
Figure 6. Gross morphology of A. *Saccharina groenlandica* with a digitate blade (GWS002500), B. *Saccharina groenlandica* with a solid blade (GWS007567), C. *Laminaria digitata* (GWS007697) and D. *Saccharina latissima* (DM05-001).

	C. triplicata	L. digitata	L. ephemera	L. hyperborea	L. setchelii	L. solidungula	L. yezoensis	M. integrifolia	N. leutkeana	P. palmaeformis	S. bongardiana	S. latissima	S. sessile
C. triplicata	0.3												
L. digitata	9.6-10.3	0-0.2											
L. ephemera	8.2-9.7	6.2-7.1	0-0.3										
L. hyperborea	9.6-9.9	2.9-3.2	6.2-6.8	0									
L. setchelii	10.6-11.1	5.3-5.9	7.0-7.9	5.0-5.2	0-0.2								
L. solidungula	8.2-9.3	6.2-7.3	4.7-5.9	6.2-7.1	5.5-6.7	0							
L. yezoensis	7.4-8.5	6.4-7.0	5.9-6.8	7.3-7.6	6.4-7.1	4.0-5.2	0-0.5						
M. integrifolia	9.4	9.1-9.6	6.7-8.1	9.7	7.9-8.1	7.0-8.2	7.3-8.7	0					
N. leutkeana	10.9-11.4	9.7-10.2	9.1-10.3	10.0-10.2	8.5-8.8	8.4-9.6	8.8-9.9	6.2-6.7	0-0.5				
P. palmaeformis	11.1-11.2	10.6-11.7	9.7-11.1	11.9-12.0	11.2-11.4	9.0-10.2	9.0-10.3	9.1-9.3	8.7-9.4	0-0.2			
S. bongardiana	8.9-10.2	8.4-9.3	8.7-10.2	9.7-10.6	9.4-10.3	8.4-9.9	7.3-8.8	7.6-8.2	9.0-9.4	10.5-11.6	0-0.5		
S. latissima	8.5-9.4	8.4-9.4	8.5-10.5	9.1-9.9	9.6-10.6	7.3-8.7	7.0-8.8	8.1-8.8	10.0-11.1	9.6-11.2	4.0-5.6	0-1.2	
S. sessile	9.9-10.0	8.8-9.4	8.8-10.2	10.5-10.6	10.0-10.6	8.4-9.4	7.8-8.8	8.4-8.8	9.1-10.0	10.9-11.6	2.9-3.3	5.9-6.4	0.2-0.5



	S. bongardiana	S. latissima (Atl/Arc)	S. latissima (AtlE)	S. latissima (Pac/Arc)	S. sessile
S. bongardiana	0-0.5				
S. latissima (Atl/Arc)	4.0-5.3	0-0.5			
S. latissima (AtlE)	4.6-5.6	0.8-1.1	0.2		
S. latissima (Pac/Arc)	4.6-5.6	0.9-1.2	0.8-1.1	0-0.3	
S. sessile	2.9-3.3	5.9-6.4	5.6-6.4	6.2-6.5	0.2-0.5

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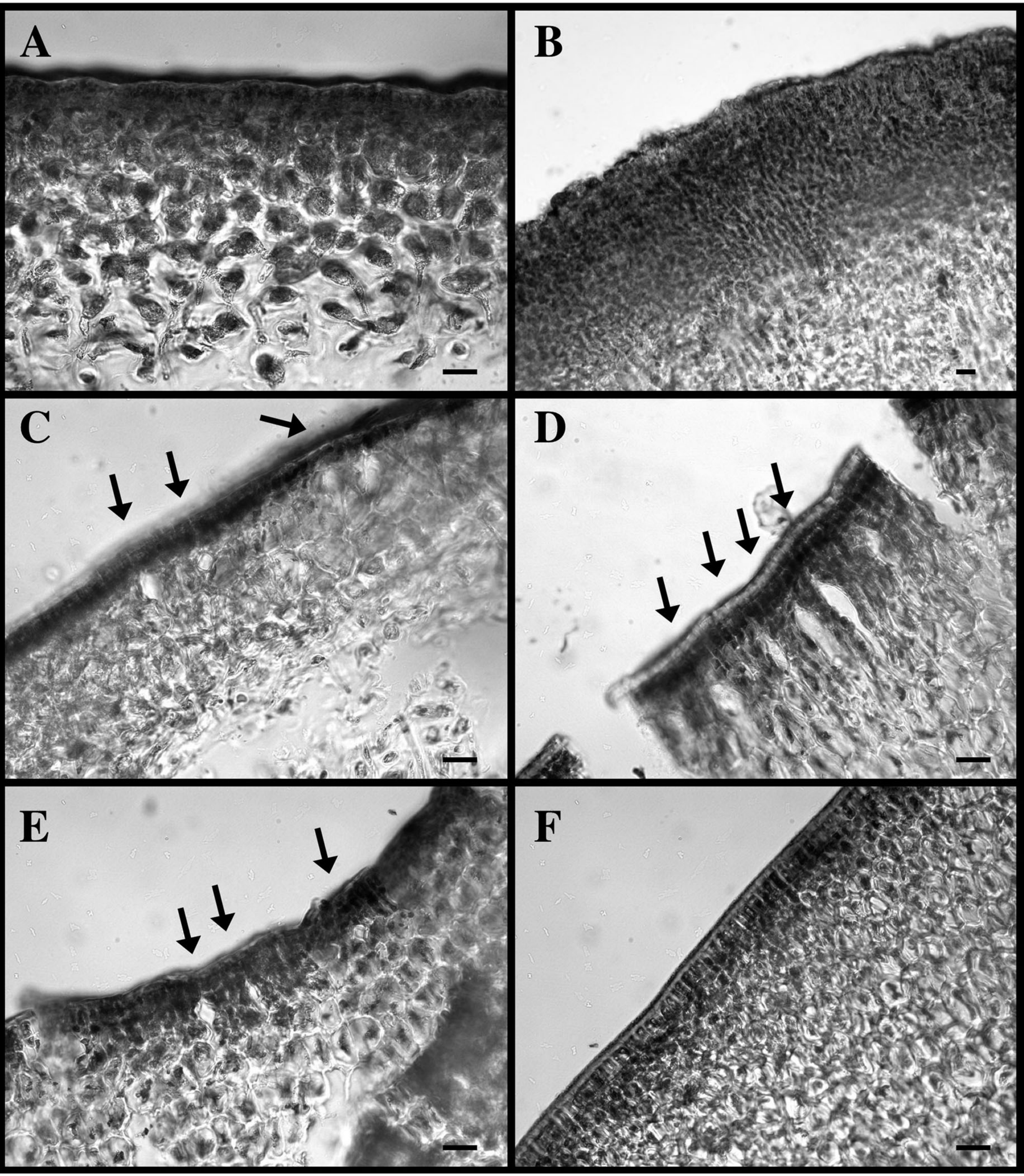
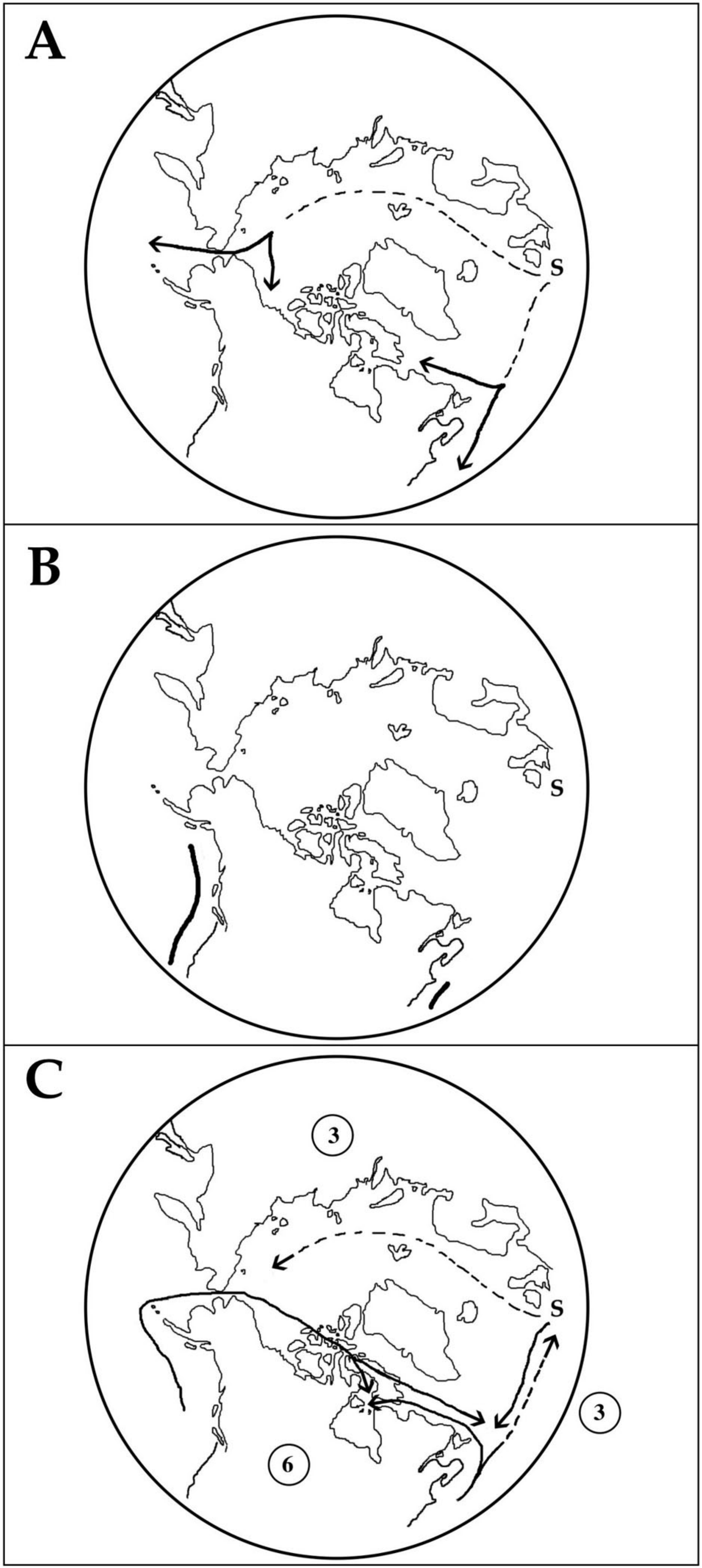


A
B
C
D
E
F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B
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C
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S
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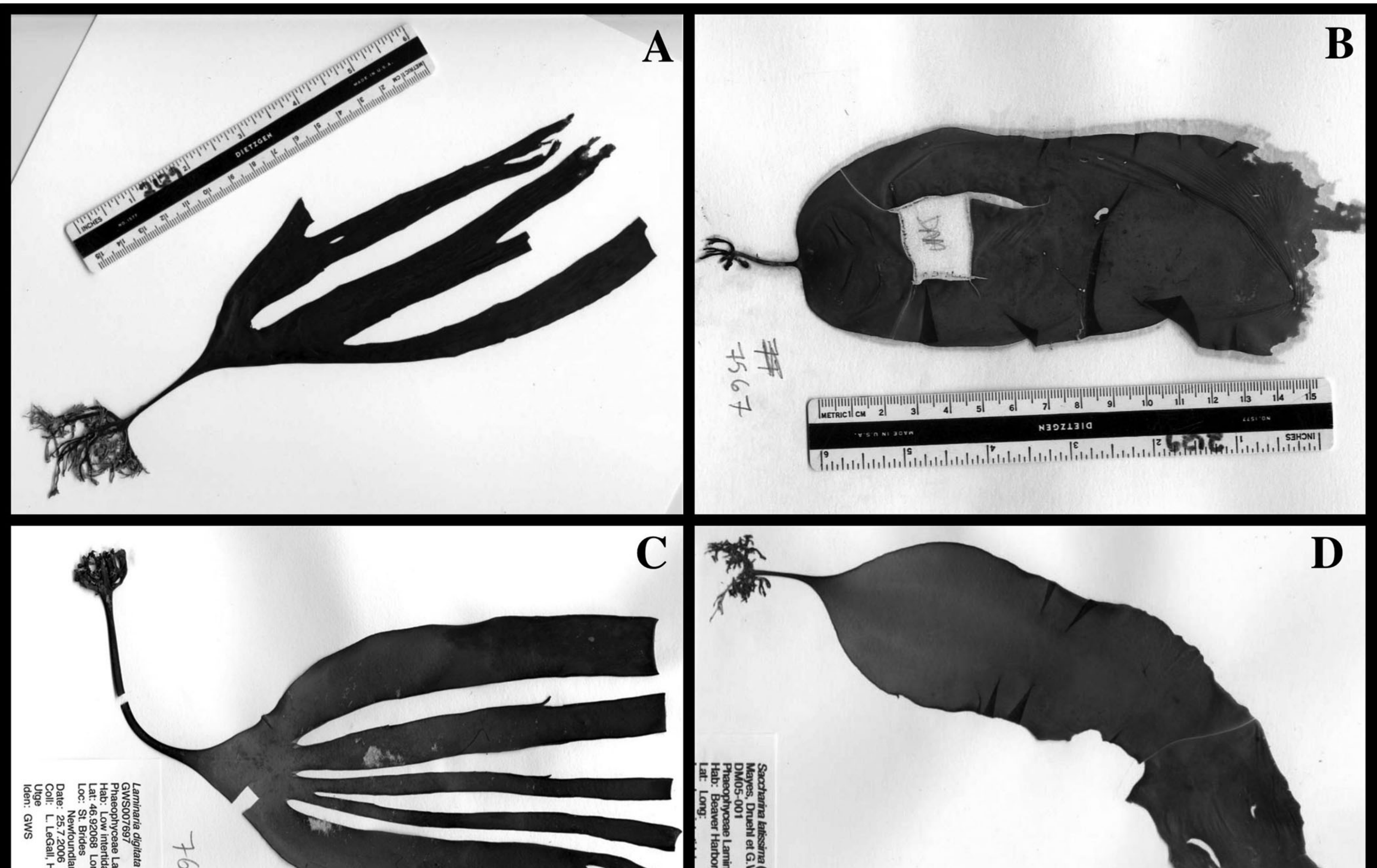
6


A
B
C
D
DIETZGEN
DNA
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Laminaria digitata (Hudson) J.V. Lamouroux
GWS007697
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Hab: Low intertidal on rock
Lat: 46.92068 Long: -54.17384
Loc: St. Brides
Newfoundland and Labrador Canada
Date: 25.7.2006
Coll: L. LeGall, H. Kucera, D, McDevit & J. Utge
Iden: GWS
7697
Saccharina latissima (Linnaeus) C.E. Lane, Mayes, Druehl et G.W. Saunders
DM05-001
Phaeophyceae Laminariales Laminariaceae
Hab: Beaver Harbor
Lat: Long:
DM05-001

A DNA barcode examination of the Laminariaceae (Phaeophyceae) in Canada reveals novel biogeographical and evolutionary insights

McDevit, Daniel, C.; Saunders, Gary, W.

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