

## *Supplementary Material*

### Supplementary Figures and Tables

**Supplementary Table 1.** (A) Site names, regions, within region ID used in figures S3 and S4, coordinates and sampling campaign. (B) Vessel details and timing of campaigns. Sites are ordered by region and latitude

(A)

Site name	Longitude	Latitude	Campaign	Region	ID	Replicates (5m, 10m, 15/20m)
Starnes Fiord	-82.5607	76.7254	Vagabond	Ellesmere I	1	0, 4, 0
Harbour fiord	-84.1835	76.6124	Vagabond	Ellesmere I	2	0, 7, 0
Vaga20.23a	-83.1564	76.4231	Vagabond	Ellesmere I	3	0, 10, 0
Grise fiord	-82.9343	76.4223	Vagabond	Ellesmere I	4	0, 4, 0
Narwhal Cove	-77.4352	72.7685	PICKeR	North Baffin Island	1	8, 7, 0
Trevor's Cove	-77.6222	72.7535	PICKeR	North Baffin Island	2	8, 8, 0
Black Point	-77.9371	72.7031	PICKeR	North Baffin Island	3	8, 7, 0
Sheaties Cabin	-79.8330	72.4651	PICKeR	North Baffin Island	4	8, 8, 0
Iceberg Point	-79.8529	72.4573	PICKeR	North Baffin Island	5	8, 8, 0
Pooh Corner	-78.9038	72.3510	PICKeR	North Baffin Island	6	8, 7, 0
Qik	-64.0728	67.5616	Cape Race	Baffin Bay	1	10, 10, 10
S. of Qik	-64.0620	67.5222	Cape Race	Baffin Bay	2	10, 10, 10
Rocks Durban	-62.2140	67.0392	Cape Race	Baffin Bay	3	10, 10, 10
Durban Harbour	-62.1670	67.0382	Cape Race	Baffin Bay	4	10, 10, 10
Pangnirtung 2	-67.9917	66.2660	Pangnirtung NFA	Davis Strait	1	3, 8, 4
Pangnirtung 1	-65.9917	66.1067	Pangnirtung NFA	Davis Strait	2	3, 2, 3

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Iqualuit T1	-68.5167	63.7358	CAISN DFO	Davis Strait	3	13, 10, 0
Iqualuit T2	-68.4717	63.7247	CAISN DFO	Davis Strait	4	13, 13, 0
Iqualuit T4	-68.4869	63.7167	CAISN DFO	Davis Strait	5	0, 12, 0
Iqualuit T3	-68.4869	63.7167	CAISN DFO	Davis Strait	6	11, 0, 0
Iqualuit T5	-68.5131	63.7117	CAISN DFO	Davis Strait	7	0, 0, 12
Duck Island	-64.3410	60.2339	Cape Race	Davis Strait	8	8, 8, 8
Hogg Island	-63.7300	59.4288	Cape Race	Davis Strait	9	9, 9, 0
Evan's Bight	-63.5230	59.2985	Cape Race	Davis Strait	10	10, 10, 0
Turnagain	-61.3070	56.7660	Cape Race	Davis Strait	11	0, 8, 10
Steensby Inlet T6	-78.5629	70.3254	CAISN DFO	Foxe Basin	1	4, 3, 0
Steensby Inlet T5	-78.5101	70.2733	CAISN DFO	Foxe Basin	2	6, 4, 9
Steensby Inlet T1	78.8572	70.2507	CAISN DFO	Foxe Basin	3	0, 11, 0
Steensby Inlet T2	-78.7638	70.2144	CAISN DFO	Foxe Basin	4	10, 8, 0
Steensby Inlet T3	-78.3909	70.1965	CAISN DFO	Foxe Basin	5	10, 0, 0
Station 14	-84.7338	65.9340	SIMEP	Foxe Basin	6	0, 4, 4
Station 17	-82.9219	64.8720	SIMEP	Foxe Basin	7	0, 7, 8
East Bay	-81.0666	64.0293	SIMEP	Foxe Basin	8	0, 8, 8
Station 13	-86.1737	66.2501	SIMEP	Roes Welcome Sound	1	0, 8, 8
Station 12	-85.6153	65.9092	SIMEP	Roes Welcome Sound	2	0, 8, 4
Station 10	-86.2461	64.9740	SIMEP	Roes Welcome Sound	3	0, 8, 8
Station 8	-86.4057	64.3293	SIMEP	Roes Welcome Sound	4	0, 8, 6

Station 6	-87.3200	63.6917	SIMEP	Roes Welcome Sound	5	0, 8, 4
Bear Island	-83.2202	64.0194	SIMEP	Hudson Strait	1	0, 8, 8
Station 20	-80.1761	63.7819	SIMEP	Hudson Strait	2	0, 8, 8
Station 3	-82.3577	63.6427	SIMEP	Hudson Strait	3	0, 0, 8
Station 21	-80.8404	63.5185	SIMEP	Hudson Strait	4	0, 8, 8
Station 25	-81.8394	62.9473	SIMEP	Hudson Strait	5	0, 8, 7
Station 22	-81.9684	62.9438	SIMEP	Hudson Strait	6	0, 8, 9
Deception Bay T5	-74.6905	62.2567	CAISN DFO	Hudson Strait	7	0, 10, 10
Deception Bay T4	-74.8609	62.2457	CAISN DFO	Hudson Strait	8	0, 11, 10
Deception Bay T3	-74.8102	62.2023	CAISN DFO	Hudson Strait	9	10, 10, 0
Deception Bay T6	-74.7353	62.2022	CAISN DFO	Hudson Strait	10	0, 10, 10
Deception Bay T2	-74.6882	62.1421	CAISN DFO	Hudson Strait	11	0, 10, 10
Deception Bay T1	-74.6109	62.1233	CAISN DFO	Hudson Strait	12	10, 10, 0
Churchill T3	-94.2142	58.8122	CAISN DFO	Hudson Bay	1	0, 13, 13
Churchill T4	-94.2297	58.8006	CAISN DFO	Hudson Bay	2	0, 13, 13
Churchill T2	-94.2189	58.7864	CAISN DFO	Hudson Bay	3	11, 0, 14
Mussel Point	-59.1960	55.1020	Cape Race	Labrador Sea	1	0, 9, 0
Makkovik	-59.1750	55.0880	Cape Race	Labrador Sea	2	0, 8, 0

B.

Campaign	Year	Vessel	Site selection and sampling method	Regions covered
Cape Race	2014 (Sept. 2 – 11)	Cape Race	Sites were selected quasi-randomly, aiming for areas with suitable bottom slope for divers (e.g., avoiding vertical walls)	Baffin Bay, Davis Strait, Labrador

			that coincided with staging locations for the Cape Race. A small zodiac was launched and an appropriate depth (between 5 and 10 m) was chosen as a dive site. Multiple depths were sampled by divers during a single dive (5, 10 and either 15 or 20 m depending on the presence of at least some rock).	
CAISN	2011 (Aug 18-29)  2012 (Aug. 1-19)	Local vessel	Sites were selected for invasive benthic species surveys, and were often near ports and Inuit communities of interest. Sampled by divers.	Steensby Inlet (Foxe Basin), Deception Bay (Hudson Strait), Iqaluit (Davis Strait), and Churchill (Hudson Bay)
SIMEP	2019 (Aug 5 - 26)	R.V. William Kennedy	Sites were selected based closest 10 and 15 m depth location to nearshore oceanographic stations. When the R.V. was on station (> 30 m depth) we launched and drove the zodiac towards shore until it shallowed out to 15 m and 10 m. Often this was >10 km away from the 30 m contour. Sites were within 15 km of the R.V. to maintain radio contact. Sampled by divers.	Southampton Island (Foxe Basin, Roes Welcome Sound and Hudson Bay)
Cumberland Sound Ecosystem Survey (CSES)	2019 (Aug.10-18)	Local fishing vessel	Two nearshore sites at appropriate depths were selected randomly on route to offshore stations. Sampled by video surveys.	Pangnirtung (Davis Strait)
Vagabond	2020 (Aug. 28 - Sept 19)	Sailboat Vagabond	Sites were sampled opportunistically when vessel was anchored at suitable depths. Main field campaign was sampling deeper coralline algae.	Ellesmere Island

			Sampled by divers and videos.	
PICKeR	2019 (Aug 29-Sept 9)	Local fishing vessel	Sites were selected quasi-randomly, aiming for areas with suitable bottom slope for divers (e.g., avoiding vertical walls), and intentionally capturing a gradient of sea ice cover spanning inside to outside Pond Inlet. Sampled by divers.	Eclipse Sound (North Baffin Island)

**Supplementary Table 2.** Kelp presence data in the eastern Canadian Arctic. Average percent occurrence in all quadrats, sites, and regions.

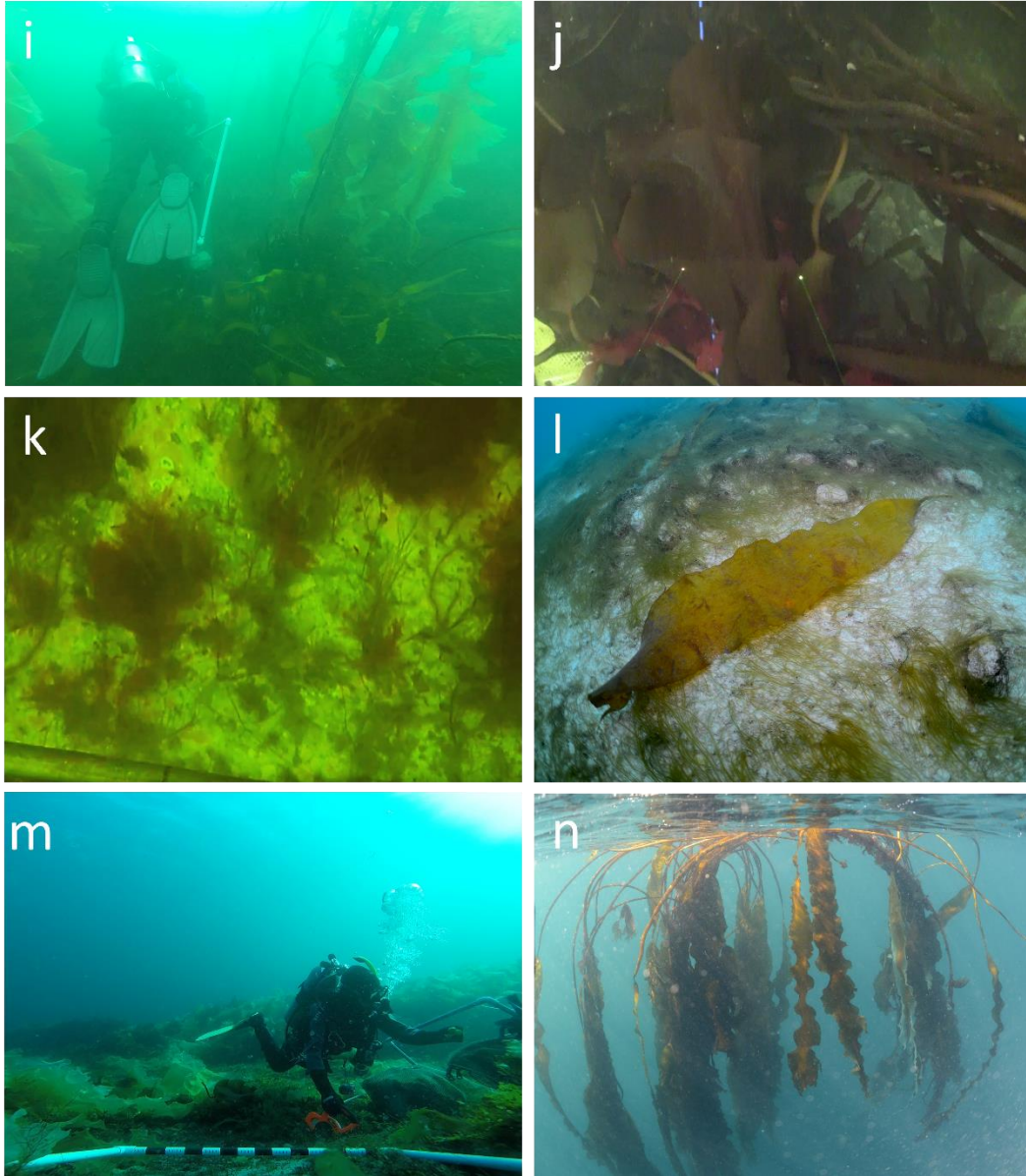
Depth (m)	Kelp presence (%)		
	Quadrat	Site	Region
5	33.4	87.0	100
10	33.6	91.1	100
15	34.0	92.3	100

**Supplementary Table S3.** BIO-ENV results showing combinations of variables giving largest rank correlation ps between seaweed assemblages similarity matrices and abiotic similarity matrices. Bold indicates best combination overall. S: salinity (PSU); T: sea temperature (°C); %Sand; %Rock; OWP: open water period; Ice: sea ice thickness; L: light (PAR). Significance = 0.01%

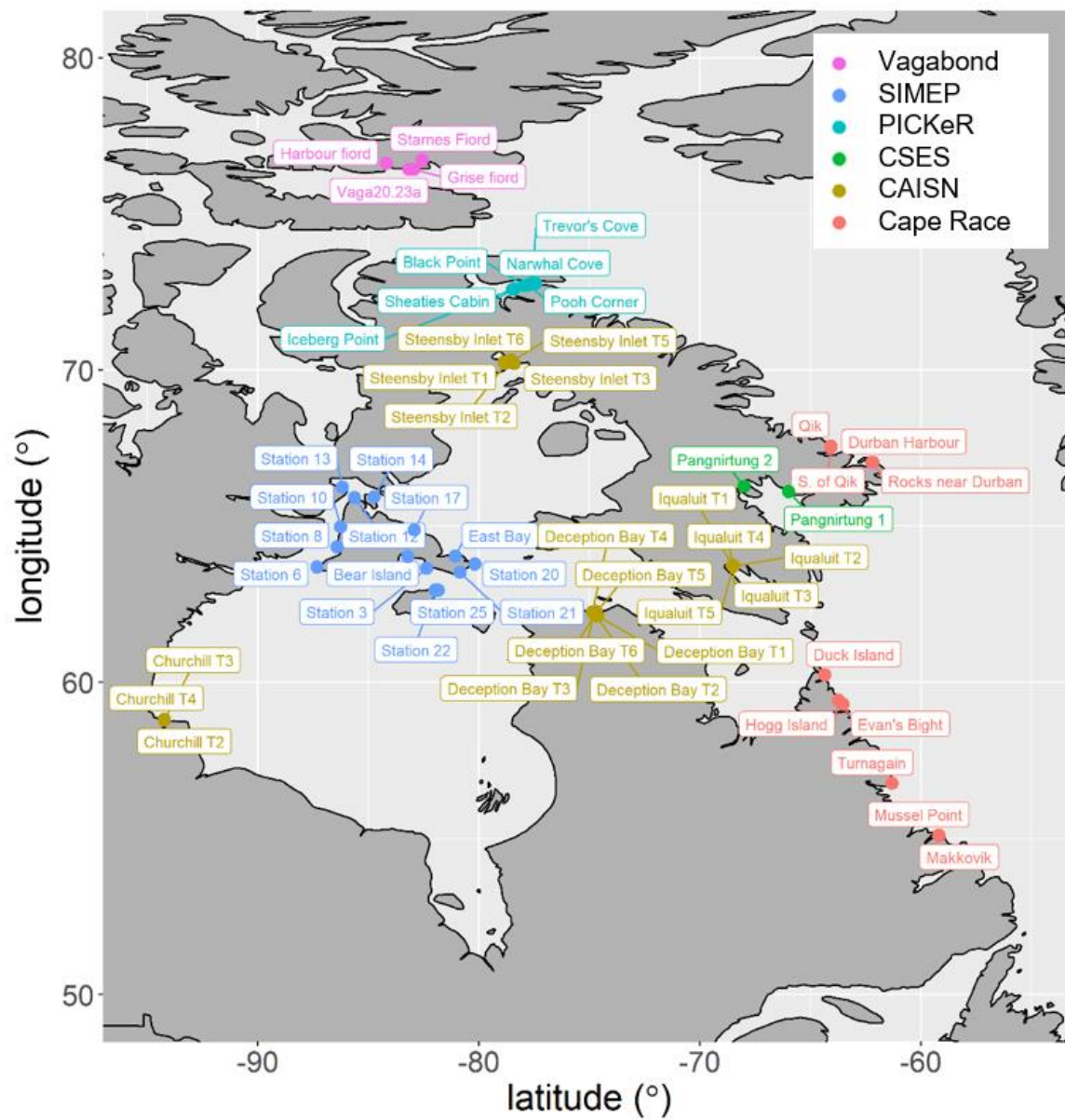
n	Best variable combinations (ps) – Percent cover			
1	<b>Ice (0.329)</b>			
2	T, Ice (0.306)			
3	%Sand, T, Ice (0.282)	T, OWP, Ice (0.282)	L, T, Ice (0.271)	T, S, Ice (0.265)
4	%Sand, Light, T, Ice (0.267)	L, T, OWP, Ice (0.267)	L, N, T, Ice (0.265)	
n	Best variable combinations (ps) – Biomass			
1	S (0.397)			
2	<b>%Sand, S (0.421)</b>	%Rock, S (0.295)		
3	%Rock, %Sand, S (0.318)	%Sand, S, Ice (0.300)	%Sand, S, OWP (0.287)	%Rock, Ice, S (0.282)
4	%Rock, %sand, light, S (0.288)	Ice, %rock, %sand, S (0.283)		

**Table S4.** Predicted extent of kelp forests in the Eastern Canadian Arctic from species distribution models (Goldsmit et al. 2021). Standing stock based on the average biomass per area in our study ( $3.7 \text{ kg m}^{-2}$ ), using 0.21 WW:DW and 0.3 DW:C. Range in total annual productivity are based measures from Southampton I, *S. latissima* and *L. solidungula*,  $23.1 - 67.8 \text{ g C m}^{-2} \text{ y}^{-1}$  and *L. solidungula* from Igloolik,  $19.6 (\pm 12.1 \text{ SD}) \text{ g C m}^{-2} \text{ y}^{-1}$  (Chapman and Lindley, 1980).

Depth limit (m)	Areal extent (km <sup>2</sup> )	Standing stock (TgC)		NPP (Tg C y <sup>-1</sup> )	
		average	SE	min	max
10	94,823	22.1	3.7	2.2	6.4
15	158,577	37.0	6.2	3.7	10.8
20	215,397	50.2	8.5	5.0	14.6
25	265,000	61.8	10.4	6.1	18.0
30	312,173	72.8	12.3	7.2	21.2
35	359,278	83.7	14.2	8.3	24.4
40	407,023	94.9	16.0	9.4	27.6
45	451,727	105.3	17.8	10.4	30.6
50	490,126	114.2	19.3	11.3	33.2



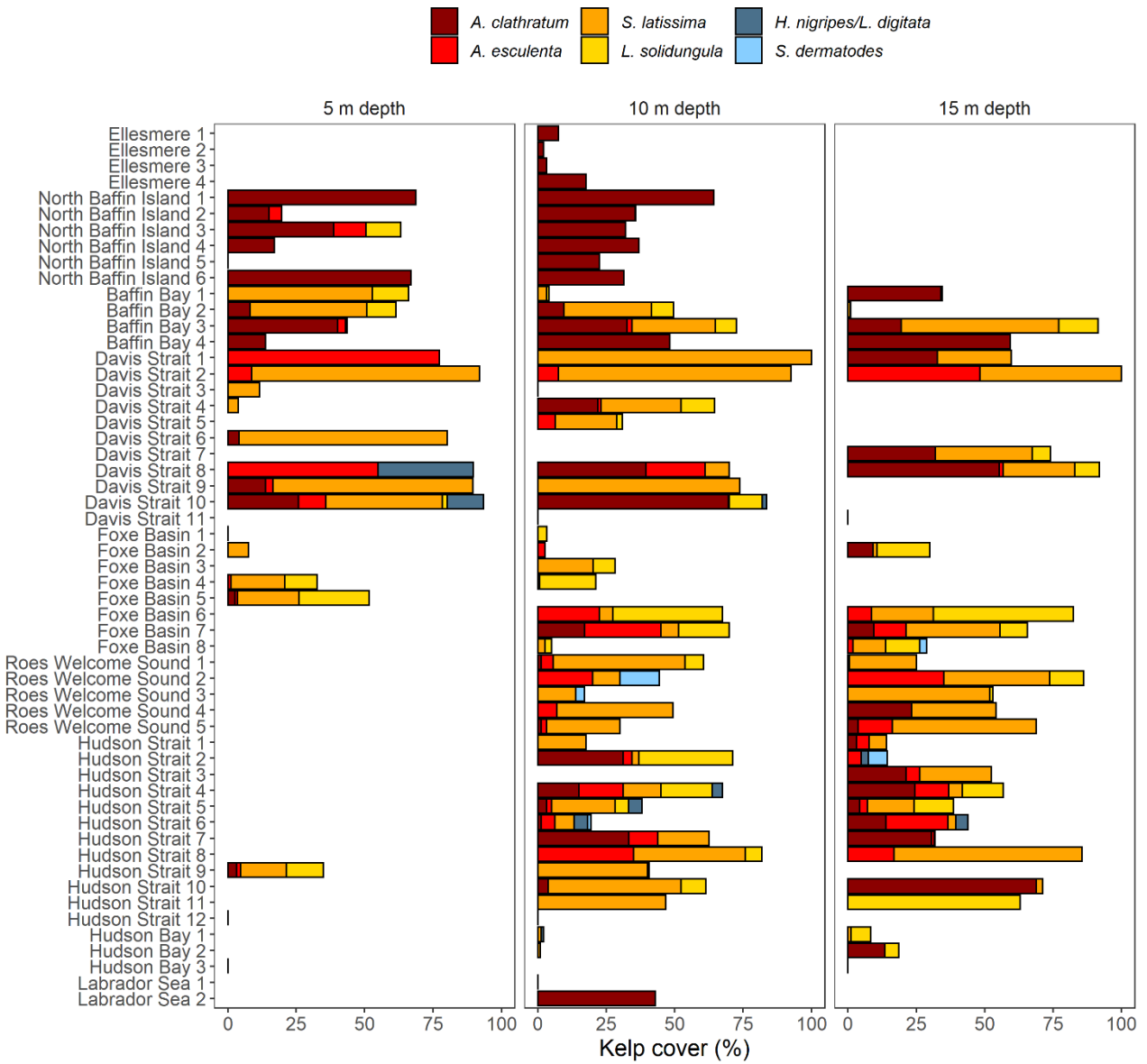
**Supplementary Figure 1.** Continued from Figure 1: i) *S. latissima* forest with floating stipe morphology in Torngats, Davis Strait at 10 m depth (credit: Kathleen MacGregor), j) mixed *L. solidungula* and *S. latissima* forest in Salluit, Hudson Strait (credit: CAISN); k) filamentous algae on cobbles in Churchill at 10 m depth (CAISN); l) sparse *Saccorhiza dermatodea* and *Halosiphon tomentosus* in Roes Welcome Sound at 10 m depth (credit: Ignacio Garrido), m) 'prostrate' *S. latissima* forest in Qikiqtarjuaq, eastern Baffin Island (credit Kathleen MacGregor); n) floating *S. latissima* detritus 25 km offshore of Southampton Island in Roes Welcome Sound (credit: Ignacio Garrido).



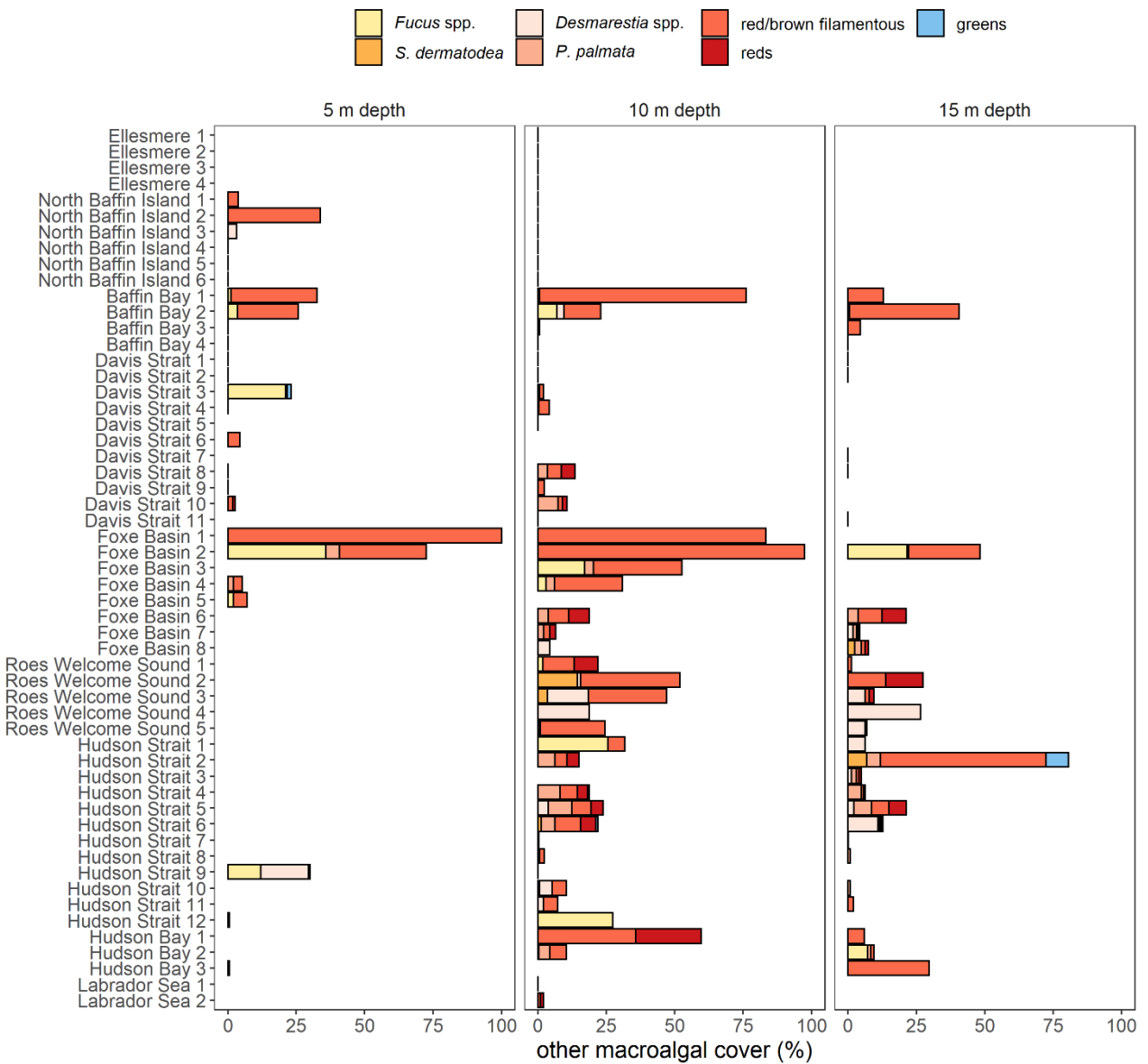
**Supplementary Figure 2.** Locations of named study sites across the Eastern Canadian Arctic. Sites are coloured by campaign.



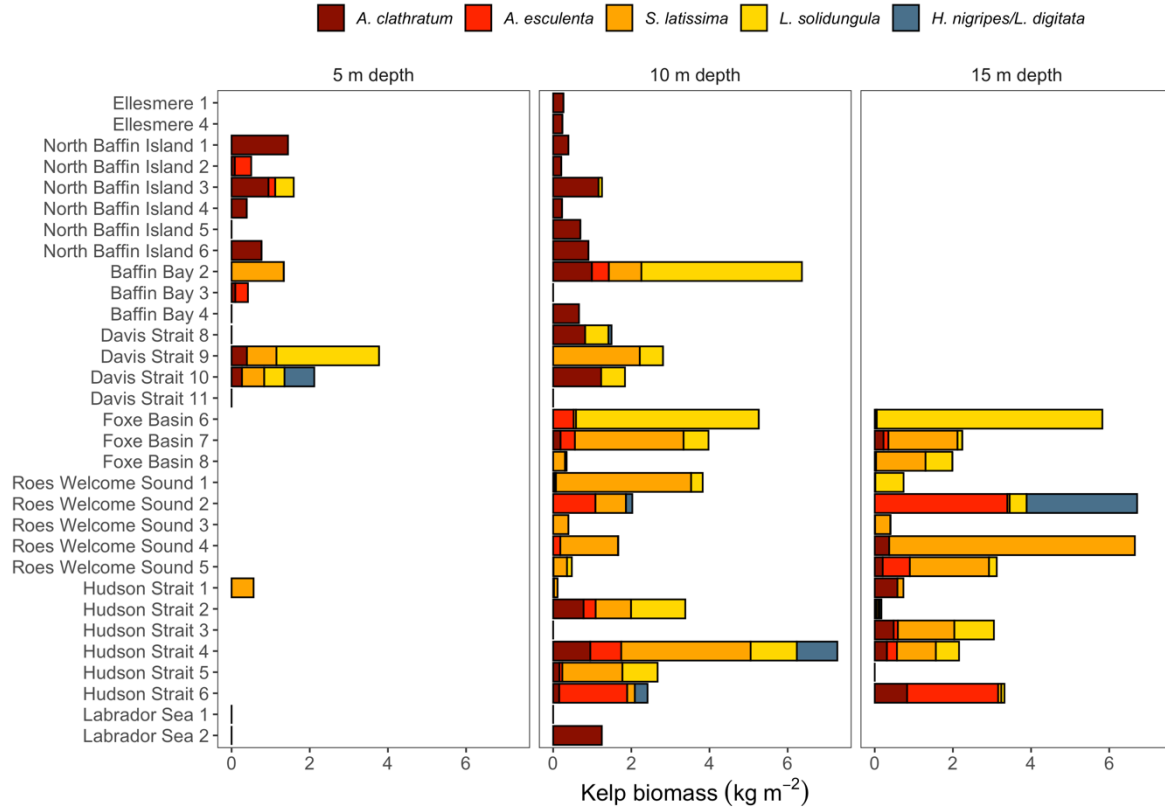
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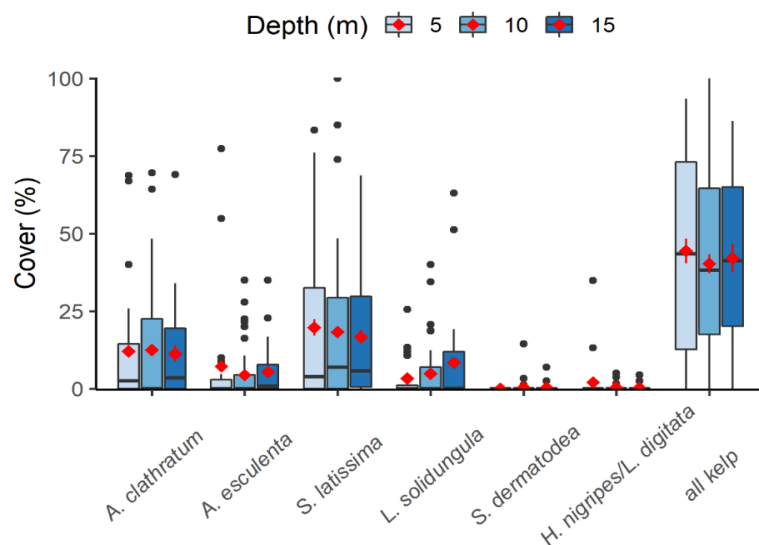
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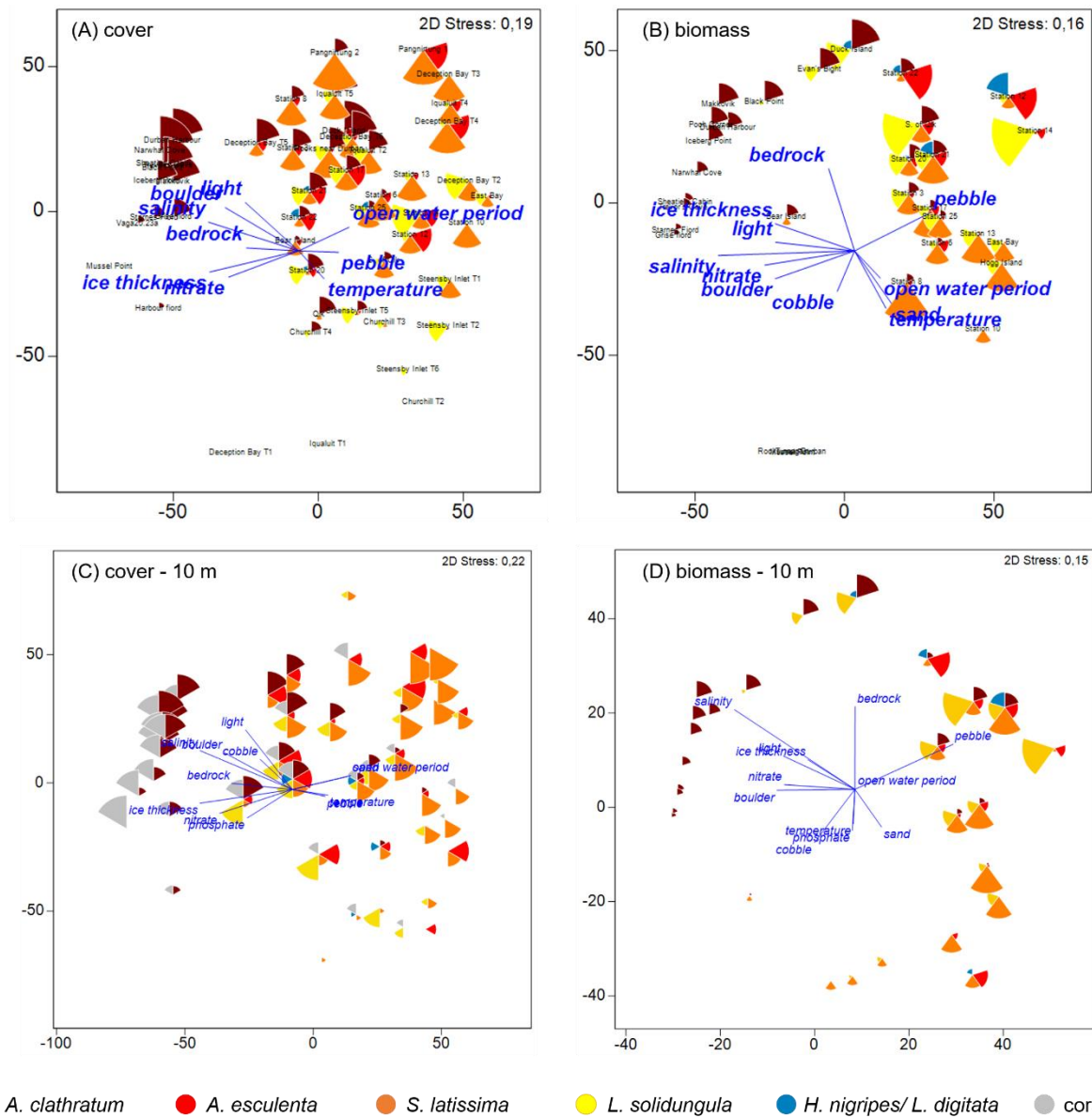
**Supplementary Figure 3.** Average percent canopy cover of kelp species (a) and other macroalgal categories (b) at each depth and each site. Note black vertical lines show sites with zero cover, all other empty site rows were not sampled.



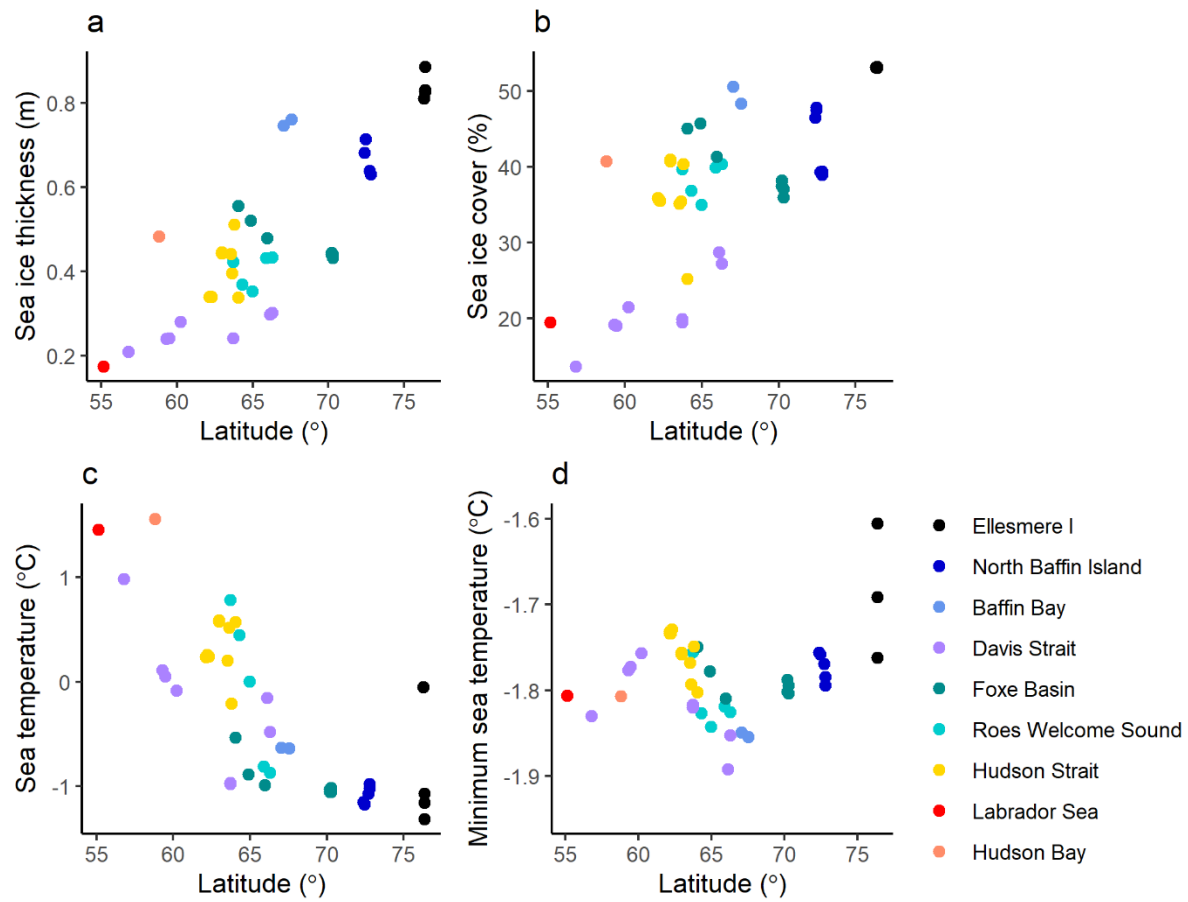
**Supplementary Figure 4.** Average biomass of kelp species at each depth and each site. Note black lines show sites with zero cover, all other empty site rows were not sampled

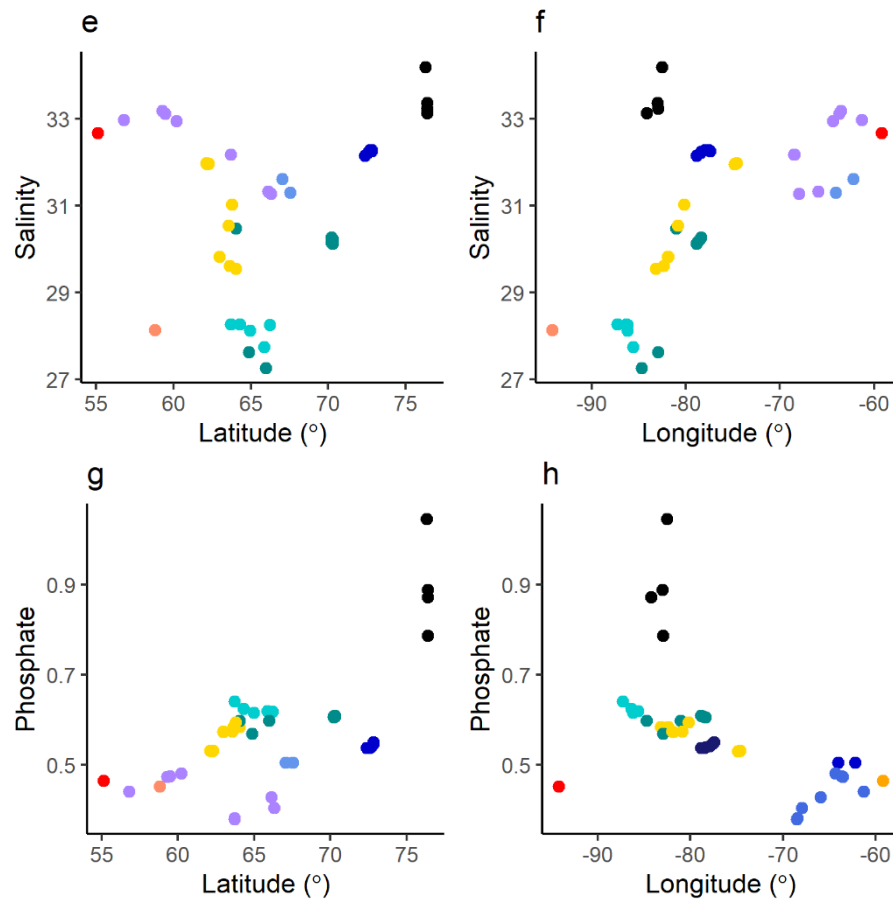


**Supplementary Figure 5.** Percent cover for kelp species at 5, 10, and 15 m depth, at all sites. Final column shows total kelp cover. Red diamonds are average  $\pm$  se. Upper and lower bars of boxplot show first and third quartiles, upper whiskers show 1.5 IQR. Filled circles are outliers. Black centered line is the median.

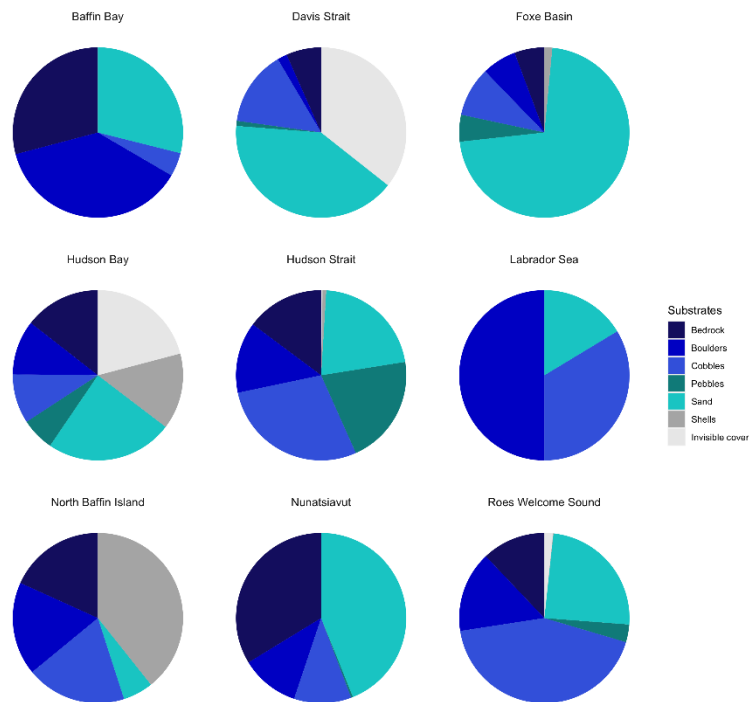


**Supplementary Figure 6.** Metric MDS for a) percent cover (0 - 100%) and b) biomass (0 – 10 kg m<sup>-2</sup>). c) and d) show 10 m depth, which was sampled consistently at all sites.





**Supplementary Figure 7.** Environmental conditions for our study sites (A) average sea ice thickness (m), (B) sea ice cover in proportion of year (C) average and (D) minimum bottom sea temperature, (E, F) average salinity, and (G, H) average phosphate concentration ( $\mu\text{mol}$ ). Colors show regions. Data are derived from Bio-ORACLEv2.1 (Assis et al., 2018b).



**Supplementary Figure 8.** Percent substrata type by region, averaged across study sites and depths.