SG364 Title: A pan-Arctic assessment of biodiversity and ecosystems services provided by coralline algae reefs.

This MASTS funding facilitated subtidal surveys of maerl bed habitats and kelp forests in southwestern Greenland July31st - August 27th 2016. Identical surveys were done in Stefansson Sound, Alaska by Arley Muth (University of Texas at Austin). I present preliminary data from the field season below which will be combined with that from A. Muth to present a comprehensive assessment of coralline algae function in both Arctic regions. I have also created two educational videos that are accompanied by voucher specimens and presentation materials and will be used at the Greenland Institute of Natural Resources (GINR) for teaching about both kelp forest and maerl habitats. The aim was to draw in younger audiences with these multimedia materials that are accompanied by music created by Danish and Irish musicians. The links are below:

Maerl beds- www.youtube.com/
Kelp forest- *in progress*

This funding paid for the petrol and maintenance (hardware and logistics) of the research vessel Nina Simone (U. Liverpool) as well as shipping and preservation of samples and camera gear. I am very grateful for the support and look forward to presenting and publishing this data with our collaborators.

The Project

Non-geniculate coralline algae, both crustose and free-living forms (maerl), are some of the most prominent reef builders in the shallow marine environment [1, 2]. In the Arctic, corallines structure reef habitats in both crustose reef flats (Alaksan Arctic) [3] and in large maerl beds (North Atlantic) [4, 5]. Both communities are known to be biodiversity hotspots in this extreme environment, [3, 4, 5] however very few geographic regions have been investigated in the Arctic. In the current regime of climate change, coralline habitats are highly vulnerable, [6] and the potential to lose ecosystem services that have not been previously assessed in these regions is high.

I collaborated with researchers from University of Texas at Austin (Arley Muth and Dr. Kenneth Dunton) who work extensively in the Alaskan Arctic, and Dr. Martin Blicher at the Greenland Institute of Natural Resources (GINR), Nuuk, to characterise both kelp forest and maerl bed habitats in these high latitude reefs (Figure 1). Diversity of reef habitats is commonly assessed using survey methods like transects and photos quadrats. A. Muth and I used the same protocol for subtidal transects and photo-quadrats (described by PISCO[7]), along with substrate grabs to characterise infauna and micro-fauna associated with the substrate or detritus at these sites. In this report I focus only on data collected in Greenland.

Figure 1. Dive sites for the field research are highlighted with stars. The Boulder Patch, Alaska, and the Akia Peninsula near Nuuk, Greenland.

Species richness (S) and evenness (J) were calculated for each transect and grab at each site. Biodiversity was assessed at three scales (alpha, beta and gamma diversity) in each habitat (kelp and maerl) using R (v3.1.0) package 'vegan'[8] and Shannon diversity (H) and rarefied diversity were used to determine if diversity is skewed by presence of specific species. ANOSIM and SIMPER analyses were run in Primer (v6.0)[9] to determine how similar kelp forest and maerl communities are and which species account for significant differences. MDS plots are used to demonstrate differences in community composition in each habitat.

Dominant species in these two habitats are not mutually exclusive which is exemplified by kelp swaths and estimated percent cover of coralline algae from transects (Figure 2 *a* and *b*). I measured kelp density because one species, *Agarum clathratum*, can be particularly abundant in maerl beds and crustose coralline algae (CCA) is very common on the hard substrate, underneath invertebrates and algae, in kelp forests. These values provide a quantifiable metric of the dominant algae in each habitat that can be used as a factor in later analyses.

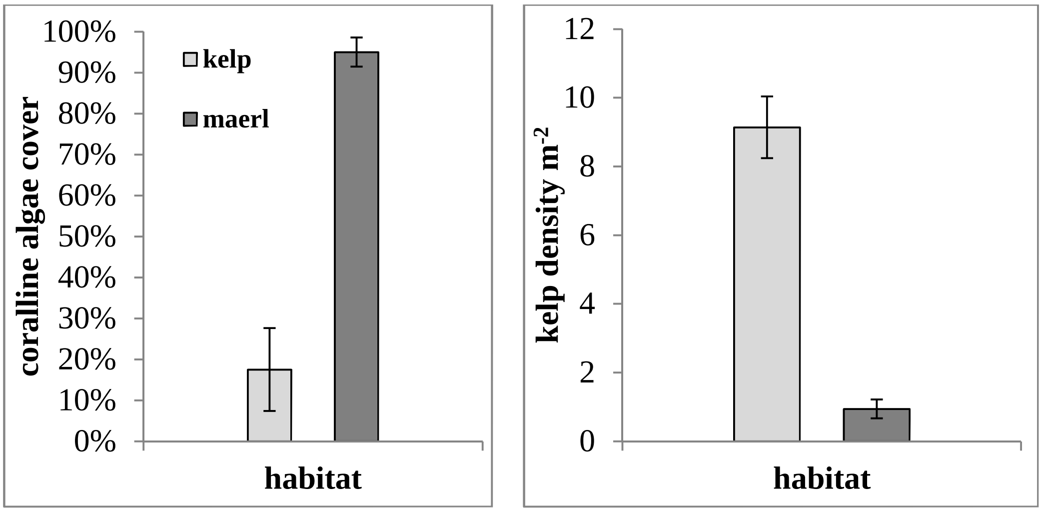

Figure 2. *a*) coralline algae cover in maerl and kelp bed habitats (% of bottom substrate), *b*) kelp density in each habitat (number of individuals per m^2).

Kelp forest and maerl beds were alternatively more diverse depending on the scale of measurement. Transects, which capture macro-organisms in the habitat, were more diverse (calculated using alpha and rarefied diversity) in kelp forests than maerl beds (2-tailed t-test, $p < 0.005$, Table 1), and species evenness was significantly higher (2-tailed t test, $p = 0.05$, Table 1). Grabs, which capture meso- and micro- organisms (3 cm to 2 mm in size) associated with the substrate as well as infaunal species, were significantly more diverse in maerl beds (2-tailed t test $p < 0.000005$ (alpha, H, and rarefied indices), Table 1). Species richness and evenness were significantly higher in grabs from maerl beds as well (2-tailed t test, $p < 0.00005$, Table 1).

	Habitat Diversity							
	N	S	J	alpha	beta	gamma	rareified	H
grabs								
kelp forest	20	5.91 ± 0.16	0.68 ± 0.01	1.86 ± 0.19	2.87	24	1.55 ± 0.02	2.07 ± 0.01
maerl bed	18	11.33 ± 0.12	0.87 ± 0.004	7.10 ± 0.04	1.74	31	1.87 ± 0.003	1.20 ± 0.02
transects								
kelp forest	4	6.25 ± 2.39	0.47 ± 0.07	1.98 ± 0.29	1.72	17	1.46 ± 0.17	0.95 ± 0.38
maerl bed	4	4.75 ± 0.48	0.073 ± 0.02	0.68 ± 0.07	0.47	7	1.04 ± 0.01	0.11 ± 0.03

Table 1. Diversity indices, species richness and evenness for both habitats in Greenland (± SE).

ANOSIM and SIMPER analyses define significant differences in community composition in kelp and maerl habitats (Table 2) which are further highlighted by MDS plots (Figure 3 and 4).

ANOSIM and SIMPER results							
Grabs		R	p-value				
	ANOSIM	0.448	0.029				
	SIMPER	kelp	maerl	habitat dissimilarity			
		44.25	40.62	69.69			
	Species	Average abundance	Average abundance	Average dissimilarity	Dissimilarity/ SD	% contribution to community	% total
	Weyphrechtia pinguis	1.65	3.39	8.74	1.16	12.54	12.54
	Hyas coarctatus	0.73	1.95	5.55	0.94	7.97	20.51
	Ennucula tenuis	1.16	2.14	4.9	1.46	7.03	27.54
	Mytilus spp.	1.35	2.03	3.85	1.16	5.52	33.07
	Macoma calcarea	1.2	0	3.62	1.19	5.2	38.26
	Euchurian sp.	1.14	1.26	3.61	1.33	5.18	43.45
	Margarites helicinus	0.08	1.01	3.19	0.52	4.57	48.02
	Semibalanus balanoides	1.08	0.3	3.11	0.99	4.47	52.49
	Hiatella arctica	1.08	0.3	3.11	0.99	4.47	56.96
	Sargatiogeton laceratus	1.02	0	3.01	1.22	4.32	61.28
	Ophiura sarsi	0.84	0	2.91	0.94	4.17	65.45
	Tectura testudinalis	0.87	0	2.71	1.03	3.89	69.35
	Phyllodoce groenlandica	0.48	0.26	2.31	0.68	3.31	72.66
	Nipponnemertes pulcher	0.69	0.31	2.25	1	3.23	75.89
	Asteroidea	0.65	0	2.17	0.81	3.11	78.99
	Tonicella rubra	0.29	0.32	1.59	0.7	2.28	81.27
	Gibula sp.	0.32	0.16	1.41	0.66	2.02	83.3
	Helicon sp.	0.43	0	1.26	0.65	1.81	85.1
	Margarites sp.	0.27	0.19	1.07	0.64	1.54	86.64
	Amphipoda	0.3	0	1.02	0.6	1.47	88.11
	Siphonoclentallium lobatum	0.27	0.05	0.94	0.47	1.36	89.47
	Psolus fabricii	0.06	0.29	0.94	0.53	1.35	90.82
Transect		R	p-value				
	ANOSIM	0.48	0.01				
	SIMPER	kelp	maerl	habitat dissimilarity			
		24.36	84.43	73.92			
	Species	Average abundance	Average abundance	Average dissimilarity	Dissimilarity/ SD	% contribution to community	% total
	Strongylocentrotus droebachiensis	4.39	27.22	50.09	2.02	67.76	67.76
	Semibalanus balanoides	4.2	2.7	5.58	1.33	7.54	75.3
	Psolus fabricii	2.84	0	4.27	0.96	5.77	81.08
	Cucumaria frondosa	0	1.37	2.83	2.77	3.83	84.9
	Leptocottus armatus	0.91	0.25	1.72	0.98	2.33	87.23
	Cellaria sp.	1.12	0	1.56	0.56	2.1	89.34
	Myxilla sp.	0.97	0	1.35	0.56	1.82	91.16

Table 2. Data from ANOSIM and SIMPER analyses.

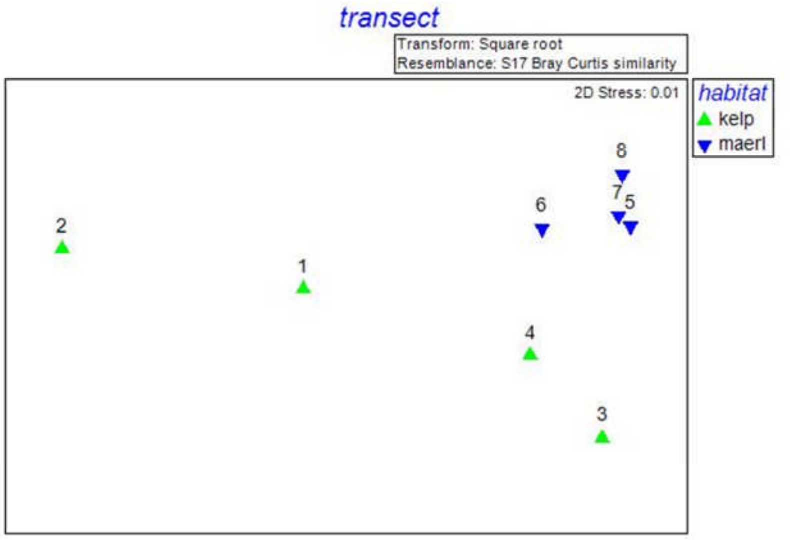

Figure 3. MDS plot of transects characterising species diversity in each habitat, kelp forest and maerl beds.

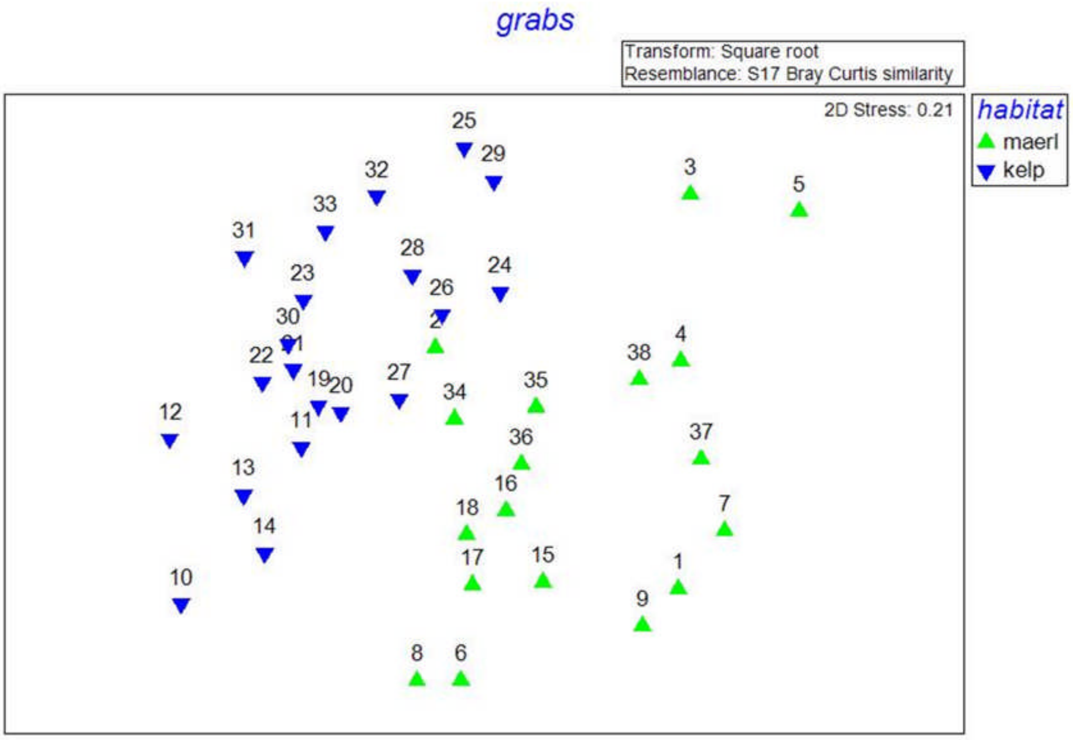

Figure 4. MDS plot of grabs characterising species diversity in each habitat, kelp forest and maerl beds.

<u>Future work</u>

The low abundance of fish we observed in each habitat suggests that more replicates of these surveys at each site might be needed to determine the importance of the habitats to fisheries. However, ecosystem services will still be assessed by size class of dominant community members including grazers (urchins) and kelps (Brown algae, Laminariales) which buffer coastal life from environmental disturbance. Further, the additional data from Alaska will prove interesting as CCA are always associated with higher biodiversity and kelp densities than areas without CCA (personal communication, A. Muth). Using these metrics, we will describe the importance of coralline algae in the Arctic and provide baseline information for previously undescribed habitats (Greenland).

References
[1] Steneck, R.S. 1986. The ecology of coralline algae crusts: convergent patterns and adaptive strategies. *Ann. Rev. Ecol. Syst.* 17: 273-303.
[2] Foster, M.S. 2001. Rhodoliths: between rocks and soft places. *J. Phycol.* 37: 659-67.
[3] Chenelot, H., S.C. Jewett, and M.K. Hoberg 2011. Macrobenthos of the nearshore Aleutian Archipelago, with emphasis on invertebrates associated with *Clathromorphum nereostratum* (Rhodophyta, Corallinaceae). *Mar. Biodiv*. 41: 413-24.
[4] Friewald, A. and R. Heinrich 1994. Reefal coralline algal build-ups within the Arctic circle: morphology and sedimentary dynamics under extreme environmental seasonality. *Sedimentology* 41: 963-84.
[5] Tiechert, S. 2014. Hollow rhodoliths increase Svalbard's shelf biodiversity. *Scientific Reports*. 4: 6972.
[6] McCoy, S.J. and N.A. Kamenos 2014. Coralline algae (Rhodophyta) in a changing world: integrating ecological, physiological, and geochemical responses to global change. *J. Phyc*. 51: 1-19.
[7] www.piscoweb.org
[8] Oksanen, J., F. G. Blanchet, R. Kindt, P. Legendre, P.R. Minchin, R.B. O'Hara, G.L. Simpson, P. Solymos, M.H.H. Stevens, and H. Wagner 2016. Vegan: Community Ecology Package. R package version 2.3-5 http://CRAN.R-project.org/package=vegan
[9] Clarke, KR, Gorley, RN, 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth, 192pp.

Acknowledgements
This work was made possible by funding from MASTS small grants scheme, SAGES PECRE research exchange funding, and FEMS research grants awarded to K. Schoenrock. The logistics and boat time in Greenland were further supported by the Leverhulme grant CALVE and co-workers Doug Mair, Nicholas Kamenos, Danni Pearce, Brice Rea, James Lea, and Alex Ingle. The field work would not have been possible without the expert dive skills of Johanne Vad (Herriot-Watt) and boat captain Mackenzie Haberman and the local knowledge and lab space provided by Martin Blicher, Thomas Juul Pederson at the GINR. Other support for the research was provided by an EPA STAR Fellowship awarded to A. Muth (Alaskan portion of project).

Dr. Kathryn Schoenrock
School of Geographical and Earth Sciences
University of Glasgow

IRC Postdoctoral Fellow
Nation University of Ireland, Galway