

Deep penetration of kelps offshore along the west coast of Greenland

Supplementary material

Table S1. Kelp depth limits, Disko Bay, Greenland, August/September 2009. The cruise included eleven sites, each with three transect lines. The following information is provided: Site/transect, depth limit (m), kelp species constituting the depth limit (A. =Agarum), Geographical position (decimal degrees), Days of light, exposure category (Exp. cat.: Protected=1, semi-exposed=2, exposed=3; as a transect average (tr.avg.), and at the depth limit (deep)), sea urchin density (# m⁻²) as a transect average (tr.avg.), substrate characteristics: 1=rock, 2=rock/sand, 3=sand, offshore/coastal)

| Site/transect 1-3 | Depth limit (m) | Species | Latitude | Longitude | Days of light | Exp. cat. | Sea urchin dens. (# m ⁻²) (tr. avg) | Subst. cat. (tr. avg) | Subst. cat. (deep) | Offshore/coastal |
|-----------------------|-----------------|--|----------|-----------|---------------|-----------|---|-----------------------|--------------------|------------------|
| Rifkol 1 | 46.4 | <i>A. clathratum</i> | 67.96465 | 53.88731 | 266 | high | 0.0 | 1.0 | 1 | offshore |
| Rifkol 2 | 41.4 | <i>A. clathratum</i> | 67.97013 | 53.75327 | 266 | low | 0.0 | 1.0 | 1 | offshore |
| Rifkol 3 | 41.4 | <i>A. clathratum</i> , <i>Saccharina/Laminaria</i> | 67.96857 | 53.75517 | 266 | low | 0.0 | 2.8 | 3 | offshore |
| Kronprinsens Ejland 1 | 61.4 | <i>A. clathratum</i> | 68.97742 | 53.34278 | 254 | high | 0.2 | 1.5 | 2 | offshore |
| Kronprinsens Ejland 2 | 32.4 | <i>A. clathratum</i> , <i>Saccharina/Laminaria</i> | 68.98323 | 53.3138 | 254 | low | 1.0 | 1.5 | 2 | offshore |
| Kronprinsens Ejland 3 | 31.4 | <i>A. clathratum</i> , <i>Saccharina/Laminaria</i> | 68.97398 | 53.4154 | 254 | high | 0.0 | 1.0 | 1 | offshore |
| Laksebugten 1 | 36.4 | <i>A. clathratum</i> , <i>Saccharina/Laminaria</i> | 69.2849 | 53.8564 | 288 | low | 3.9 | 1.9 | 2 | coastal |
| Laksebugten 2 | 10.4 | <i>A. clathratum</i> , <i>Saccharina/Laminaria</i> | 69.31 | 53.9017 | 288 | low | 0.0 | 2.4 | 3 | coastal |
| Laksebugten 3 | 36.4 | <i>A. clathratum</i> | 69.31205 | 54.01992 | 288 | high | 1.8 | 1.5 | 2 | coastal |
| Diskofjord 1 | 5.4 | <i>A. clathratum</i> | 69.51153 | 54.3238 | 253 | high | 13.5 | 2.0 | 3 | coastal |
| Diskofjord 2 | 11.4 | <i>A. clathratum</i> | 69.44887 | 54.20022 | 253 | med | 4.6 | 2.9 | 1 | coastal |
| Diskofjord 3 | 1 | <i>A. clathratum</i> , <i>Saccharina/Laminaria</i> | 69.48493 | 53.93982 | 253 | low | 40.0 | 2.5 | 3 | coastal |
| MellemFjord 1 | 38.4 | <i>A. clathratum</i> | 69.74407 | 54.9207 | 232 | high | 15.9 | 1.3 | 3 | coastal |
| MellemFjord 2 | 43.6 | <i>A. clathratum</i> | 69.78622 | 54.81483 | 232 | high | 11.1 | 2.4 | 2 | coastal |
| MellemFjord 3 | 19.4 | <i>Saccharina/Laminaria</i> | 69.74035 | 54.77538 | 232 | high | 7.5 | 1.7 | 2 | coastal |
| Hareøen 1 | 38.4 | <i>A. clathratum</i> | 70.38425 | 54.95425 | 237 | high | 0.1 | 1.9 | 2 | offshore |
| Hareøen 2 | 38.4 | <i>A. clathratum</i> | 70.37513 | 54.82572 | 237 | high | 0.0 | 2.5 | 3 | offshore |
| Hareøen 3 | 51.4 | <i>A. clathratum</i> , <i>Saccharina/Laminaria</i> | 70.26673 | 54.6663 | 237 | high | 0.0 | 2.7 | 3 | offshore |
| Nordfjorden 1 | 37.4 | <i>A. clathratum</i> | 69.97223 | 54.55428 | 233 | low | 0.0 | 2.6 | 3 | coastal |
| Nordfjorden 2 | 20.4 | <i>A. clathratum</i> | 70.01205 | 54.66863 | 233 | med | 1.4 | 2.5 | 3 | coastal |
| Nordfjorden 3 | 41.4 | <i>A. clathratum</i> | 69.94507 | 54.85058 | 233 | high | 1.5 | 1.8 | 3 | coastal |
| Disko Sydkyst 1 | 36.4 | <i>A. clathratum</i> | 69.31992 | 53.16547 | 246 | high | 0.0 | 2.4 | 3 | coastal |
| Disko Sydkyst 2 | 41.4 | <i>Saccharina/Laminaria</i> | 69.3187 | 53.19283 | 246 | high | 0.0 | 2.6 | 3 | coastal |
| Disko Sydkyst 3 | 41.4 | <i>Saccharina/Laminaria</i> | 69.28777 | 53.28662 | 246 | high | 0.5 | 2.0 | 2 | coastal |
| Hunde Ejland 1 | 51.4 | <i>A. clathratum</i> | 68.85565 | 53.14188 | 256 | high | 0.2 | 1.3 | 2 | offshore |
| Hunde Ejland 2 | 31.4 | <i>A. clathratum</i> | 68.87741 | 53.15287 | 256 | high | 0.1 | 1.6 | 2 | offshore |
| Hunde Ejland 3 | 61.4 | <i>A. clathratum</i> | 68.8672 | 53.08751 | 256 | med | 0.0 | 1.3 | 2 | offshore |

| | | | | | | | | | | |
|--------------|------|--|----------|----------|-----|------|-----|-----|---|---------|
| Eqalunguit 1 | 56.4 | <i>A. clathratum</i> | 67.48758 | 53.64008 | 240 | low | 0.0 | 2.4 | 2 | coastal |
| Eqalunguit 2 | 51.4 | <i>A. clathratum, Saccharina/Laminaria</i> | 67.46973 | 53.63378 | 240 | high | 6.0 | 1.0 | 1 | coastal |
| Eqalunguit 3 | 46.4 | <i>A. clathratum, Saccharina/Laminaria</i> | 67.4805 | 53.66445 | 240 | high | 8.7 | 1.8 | 2 | coastal |
| Kumikume 1 | 31.4 | <i>A. clathratum, Saccharina/Laminaria</i> | 67.31857 | 53.86607 | 258 | high | 0.0 | 1.2 | 2 | coastal |
| Kumikume 2 | 19.4 | <i>A. clathratum, Saccharina/Laminaria</i> | 67.3157 | 53.86222 | 258 | med | 0.0 | 2.0 | 2 | coastal |
| Kumikume 3 | 19.4 | <i>A. clathratum, Saccharina/Laminaria</i> | 67.3093 | 53.86765 | 258 | high | 0.0 | 1.0 | 1 | coastal |

Table S2. Kelp depth limits compiled from the literature. Country, Site, Sampling year, depth limit (m), species, geographical position and reference are indicated. For species the following abbreviations are used: A: Agarum or (when followed by esculenta) Alaria, E: Eualaria, L: Laminaria, S: Saccharina or (when followed by dermatodea) Saccorhiza. The compilation is an extension of earlier compilations by Vadas and Steneck (1988), Gattuso et al., (2006), and Filbee-Dexter et al., (2019). Complete list of cited literature below.

| Country | Site | Sampling year | Depth limit (m) | Species | Latitude | Longitude | Reference |
|-----------|---------------------|---------------|-----------------|---|----------|-----------|---------------------------|
| Greenland | Siorapaluk 1 | 2009 | 12.6 | <i>Saccharina/Laminaria</i> | 77.7845 | 70.66991 | Krause-Jensen et al. 2012 |
| Greenland | Siorapaluk 2 | 2009 | 13.5 | <i>Saccharina/Laminaria</i> | 77.78167 | 70.68262 | Krause-Jensen et al. 2012 |
| Greenland | Siorapaluk 3 | 2009 | 18.7 | <i>Saccharina/Laminaria</i> | 77.78557 | 70.65366 | Krause-Jensen et al. 2012 |
| Greenland | Siorapaluk 4 | 2009 | 13.6 | <i>Saccharina/Laminaria</i> | 77.78467 | 70.64529 | Krause-Jensen et al. 2012 |
| Greenland | Thule 1 | 2009 | 17.3 | <i>A. clathratum</i> | 77.4645 | 69.26530 | Krause-Jensen et al. 2012 |
| Greenland | Thule 2 | 2009 | 17.4 | <i>A. clathratum</i> | 77.467 | 69.26219 | Krause-Jensen et al. 2012 |
| Greenland | Thule 3 | 2009 | 22.4 | <i>A. clathratum</i> | 77.4605 | 69.21703 | Krause-Jensen et al. 2012 |
| Greenland | Upernavik 3 | 2009 | 43.1 | <i>A. clathratum</i> | 72.7966 | 56.13765 | Krause-Jensen et al. 2012 |
| Greenland | Uummannaq 1 | 2009 | 32.7 | <i>A. clathratum</i> | 70.6638 | 51.59885 | Krause-Jensen et al. 2012 |
| Greenland | Uummannaq 2 | 2009 | 34 | <i>A. clathratum</i> | 70.6635 | 51.61132 | Krause-Jensen et al. 2012 |
| Greenland | Eqip Sermia 1 | 2009 | 25.5 | <i>Saccharina/Laminaria</i> | 69.7585 | 50.35782 | Krause-Jensen et al. 2012 |
| Greenland | Eqip Sermia 2 | 2009 | 27.5 | <i>Saccharina/Laminaria</i> | 69.76112 | 50.36505 | Krause-Jensen et al. 2012 |
| Greenland | Ilulissat 1 | 2009 | 28 | <i>A. clathratum</i> | 69.23825 | 51.10553 | Krause-Jensen et al. 2012 |
| Greenland | Ilulissat 2 | 2009 | 32.1 | <i>A. clathratum</i> | 69.23867 | 51.09683 | Krause-Jensen et al. 2012 |
| Greenland | Itelleq 1 | 2009 | 35.8 | <i>A. clathratum</i> | 66.57927 | 53.51131 | Krause-Jensen et al. 2012 |
| Greenland | Itelleq 2 | 2009 | 34.7 | <i>A. clathratum</i> | 66.57375 | 53.51213 | Krause-Jensen et al. 2012 |
| Greenland | Itelleq 3 | 2009 | 34.9 | <i>A. clathratum</i> | 66.57498 | 53.51139 | Krause-Jensen et al. 2012 |
| Greenland | Kobbefjord: Nuuk 1 | 2008 | 35 | <i>A. clathratum</i> or <i>S. latissima</i> | 64 | 51 | Krause-Jensen et al. 2012 |
| Greenland | Kobbefjord: Nuuk 2 | 2008 | 28 | <i>A. clathratum</i> or <i>S. latissima</i> | 64 | 51 | Krause-Jensen et al. 2012 |
| Greenland | Kobbefjord: Nuuk 3 | 2008 | 33 | <i>A. clathratum</i> or <i>S. latissima</i> | 64 | 51 | Krause-Jensen et al. 2012 |
| Greenland | Kobbefjord: Nuuk 9 | 2008 | 22.3 | <i>A. clathratum</i> or <i>S. latissima</i> | 64 | 51 | Krause-Jensen et al. 2012 |
| Greenland | Kobbefjord: Nuuk 10 | 2008 | 33.5 | <i>A. clathratum</i> or <i>S. latissima</i> | 64 | 51 | Krause-Jensen et al. 2012 |
| Greenland | Kobbefjord: Nuuk 11 | 2008 | 28 | <i>A. clathratum</i> or <i>S. latissima</i> | 64 | 51 | Krause-Jensen et al. 2012 |
| Greenland | Kobbefjord: Nuuk 2b | 2008 | 41.4 | <i>A. clathratum</i> or <i>S. latissima</i> | 64 | 51 | Krause-Jensen et al. 2012 |
| Greenland | Young Sound | 2002 | 20 | <i>S. latissima</i> | 74.32 | -20.23 | Borum et al. 2002 |

| | | | | | | | |
|---------------|--------------------------------------|-------|----|----------------------|----------|----------|---------------------|
| Iceland | W: Breidifjörður Bay, Fagurey | 1982 | 11 | <i>S. latissima</i> | 65.3333 | 22.1 | Gunnarsson 1991 |
| Iceland | W: Breidifjörður Bay, Fagurey | 1982 | 15 | <i>L. digitata</i> | 65.33333 | 22.1 | Gunnarsson 1991 |
| Iceland | W: Breidifjörður Bay, Skaro | 1982 | 14 | <i>L. digitata</i> | 65.26667 | 22.4 | Gunnarsson 1991 |
| Iceland | W: Breidifjörður Bay, Langey | 1982 | 12 | <i>L. hyperborea</i> | 65.41667 | 23 | Gunnarsson 1991 |
| Iceland | W: Breidifjörður Bay, Oddbjarnarsher | 1982 | 16 | <i>S. latissima</i> | 65.3 | 23.2 | Gunnarsson 1991 |
| Iceland | W: Breidifjörður Bay, Oddbjarnarsher | 1982 | 19 | <i>L. hyperborea</i> | 65.3 | 23.2 | Gunnarsson 1991 |
| Iceland | N: Eyjafjörður | <1979 | 3 | <i>Laminariales</i> | 65.85 | 18.33 | Gunnarsson 1991 |
| Iceland | N: Eyjafjörður | <1979 | 10 | <i>Laminariales</i> | 65.85 | 18.33 | Gunnarsson 1991 |
| Iceland | N: Eyjafjörður | <1979 | 27 | <i>Laminariales</i> | 65.85 | 18.33 | Gunnarsson 1991 |
| Faroe Islands | 1a | 1997 | 15 | <i>Laminarians</i> | 62.06525 | -6.79976 | Bruntse et al. 1999 |
| Faroe Islands | 2a | 1997 | 12 | <i>Laminarians</i> | 62.06490 | -6.80304 | Bruntse et al. 1999 |
| Faroe Islands | 10a | 1997 | 12 | <i>Laminarians</i> | 62.04803 | -6.77880 | Bruntse et al. 1999 |
| Faroe Islands | 11a | 1997 | 15 | <i>Laminarians</i> | 62.04121 | -6.76544 | Bruntse et al. 1999 |
| Faroe Islands | 12a | 1997 | 20 | <i>Laminarians</i> | 62.11532 | -6.63163 | Bruntse et al. 1999 |
| Faroe Islands | 13a | 1997 | 20 | <i>Laminarians</i> | 62.14405 | -6.69103 | Bruntse et al. 1999 |
| Faroe Islands | 14a | 1997 | 20 | <i>Laminarians</i> | 62.29701 | -6.94624 | Bruntse et al. 1999 |
| Faroe Islands | 15a | 1997 | 20 | <i>Laminarians</i> | 62.29107 | -6.86517 | Bruntse et al. 1999 |
| Faroe Islands | 20a | 1997 | 19 | <i>Laminarians</i> | 62.08429 | -7.40215 | Bruntse et al. 1999 |
| Faroe Islands | 24a | 1997 | 20 | <i>Laminarians</i> | 62.31519 | -6.63517 | Bruntse et al. 1999 |
| Faroe Islands | 25a | 1997 | 20 | <i>Laminarians</i> | 62.36150 | -6.66834 | Bruntse et al. 1999 |
| Faroe Islands | 41a | 1997 | 17 | <i>Laminarians</i> | 61.45691 | -6.75585 | Bruntse et al. 1999 |
| Faroe Islands | 43a | 1997 | 17 | <i>Laminarians</i> | 61.63628 | -6.91170 | Bruntse et al. 1999 |
| Faroe Islands | 44a | 1997 | 25 | <i>Laminarians</i> | 61.53307 | -6.90215 | Bruntse et al. 1999 |
| Faroe Islands | 45a | 1997 | 13 | <i>Laminarians</i> | 61.63628 | -6.91170 | Bruntse et al. 1999 |
| Faroe Islands | 6a | 1997 | 11 | <i>Laminarians</i> | 62.07330 | -6.80532 | Bruntse et al. 1999 |
| Faroe Islands | 16a | 1997 | 14 | <i>Laminarians</i> | 62.26115 | -6.95066 | Bruntse et al. 1999 |
| Faroe Islands | 17a | 1997 | 19 | <i>Laminarians</i> | 62.28101 | -6.95828 | Bruntse et al. 1999 |
| Faroe Islands | 21a | 1997 | 20 | <i>Laminarians</i> | 62.07811 | -7.38139 | Bruntse et al. 1999 |
| Faroe Islands | 23a | 1997 | 8 | <i>Laminarians</i> | 62.34230 | -6.57807 | Bruntse et al. 1999 |
| Faroe Islands | 26a | 1997 | 16 | <i>Laminarians</i> | 62.30232 | -6.59135 | Bruntse et al. 1999 |
| Faroe Islands | 28a | 1997 | 25 | <i>Laminarians</i> | 62.18427 | -6.44161 | Bruntse et al. 1999 |
| Faroe Islands | 29a | 1997 | 20 | <i>Laminarians</i> | 62.22938 | -6.47190 | Bruntse et al. 1999 |
| Faroe Islands | 32a | 1997 | 15 | <i>Laminarians</i> | 62.32748 | -6.54156 | Bruntse et al. 1999 |

| | | | | | | | |
|---------------|---------------------------------------|------|----|--|----------|----------|---------------------|
| Faroe Islands | 34a | 1997 | 20 | <i>Laminarians</i> | 62.25788 | -6.43414 | Bruntse et al. 1999 |
| Faroe Islands | 35a | 1997 | 15 | <i>Laminarians</i> | 62.29207 | -6.67199 | Bruntse et al. 1999 |
| Faroe Islands | 37a | 1997 | 20 | <i>Laminarians</i> | 61.54501 | -6.76454 | Bruntse et al. 1999 |
| Faroe Islands | 38a | 1997 | 15 | <i>Laminarians</i> | 61.53395 | -6.79521 | Bruntse et al. 1999 |
| Faroe Islands | 40a | 1997 | 16 | <i>Laminarians</i> | 61.47054 | -6.78580 | Bruntse et al. 1999 |
| Faroe Islands | 4a | 1997 | 8 | <i>Laminarians</i> | 62.05643 | -6.85205 | Bruntse et al. 1999 |
| Faroe Islands | 5a | 1997 | 8 | <i>Laminarians</i> | 62.06137 | -6.89430 | Bruntse et al. 1999 |
| Faroe Islands | 7a | 1997 | 10 | <i>Laminarians</i> | 62.08990 | -6.82353 | Bruntse et al. 1999 |
| Faroe Islands | 8a | 1997 | 15 | <i>Laminarians</i> | 62.10162 | -6.85163 | Bruntse et al. 1999 |
| Faroe Islands | 9a | 1997 | 10 | <i>Laminarians</i> | 62.10814 | -6.87534 | Bruntse et al. 1999 |
| Faroe Islands | 18a | 1997 | 10 | <i>Laminarians</i> | 62.25504 | -6.95727 | Bruntse et al. 1999 |
| Faroe Islands | 19a | 1997 | 10 | <i>Laminarians</i> | 62.24291 | -6.93914 | Bruntse et al. 1999 |
| Faroe Islands | 22a | 1997 | 14 | <i>Laminarians</i> | 62.07434 | -7.35008 | Bruntse et al. 1999 |
| Faroe Islands | 27a | 1997 | 12 | <i>Laminarians</i> | 62.27960 | -6.59303 | Bruntse et al. 1999 |
| Faroe Islands | 30a | 1997 | 17 | <i>Laminarians</i> | 62.25294 | -6.52676 | Bruntse et al. 1999 |
| Faroe Islands | 33a | 1997 | 15 | <i>Laminarians</i> | 62.28000 | -6.51748 | Bruntse et al. 1999 |
| Faroe Islands | 36a | 1997 | 18 | <i>Laminarians</i> | 62.25318 | -6.58078 | Bruntse et al. 1999 |
| Faroe Islands | 39a | 1997 | 13 | <i>Laminarians</i> | 61.54820 | -6.81337 | Bruntse et al. 1999 |
| Faroe Islands | 42a | 1997 | 12 | <i>Laminarians</i> | 61.45165 | -6.77600 | Bruntse et al. 1999 |
| Canada | Hudson and Ungava Bay: Basking I | | 10 | <i>L. solidungula, S. longicuris</i> | 59.9848 | -69.9478 | Sharp et al. 2008 |
| Canada | Hudson and Ungava Bay: Tuvalik Pt. | | 12 | <i>A. clathratum, A. esculenta, L. solidungula, S. groenlandica, S. longicuris</i> | 60.0568 | -69.6745 | Sharp et al. 2008 |
| Canada | Hudson and Ungava Bay: Pikyuluk I | | 12 | <i>A. esculenta, L. digitata, L. solidungula, S. longicuris</i> | 59.9868 | -69.9337 | Sharp et al. 2008 |
| Canada | Labrador Sea: E. Port Markham | 2003 | 30 | <i>A. clathratum, A. esculenta</i> | 52.3667 | -55.7333 | Adey & Hayek 2011 |
| Canada | Labrador Sea: Tilcey I | 2003 | 20 | <i>A. clathratum, A. esculenta, L. digitata, S. dermatodea, S. latissima</i> | 52.2167 | -55.6333 | Adey & Hayek 2011 |
| Canada | Labrador Sea: South Cove | 2003 | 30 | <i>A. clathratum, A. esculenta, S. dermatodea, S. latissima, S. longicuris</i> | 53.2167 | -55.6333 | Adey & Hayek 2011 |
| Canada | Baffin Bay: Walls I, Cape St. Charles | 2003 | 12 | <i>A. clathratum, A. esculenta, L. digitata, S. dermatodea, S. latissima</i> | 52.2167 | -55.6333 | Adey & Hayek 2011 |
| Canada | Newfoundland | | 30 | <i>S. longicuris</i> | 53.1355 | | South 1983 |
| Canada | Newfoundland | | 40 | <i>L. solidungula</i> | 53.1355 | | South 1983 |

| | | | | | | | |
|--------|-----------------------------|------|----|--|---------|----------|---------------------------|
| Canada | Newfoundland | | 25 | <i>A. cibrosum</i> | 53.1355 | | South 1983 |
| Canada | Igloolik Island, Turton Bay | 1979 | 20 | <i>L. solidungula</i> | 69.365 | -81.77 | Chapman & Lindley 1980 |
| Norway | Bergen | | 30 | <i>L. hyperborea</i> | 60.39 | | Jorde 1966 |
| Norway | Finnøy-Håvær V | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 62.8203 | 6.5472 | Christie et al. 2014 |
| Norway | Vega-Ivarsbraken | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 65.6764 | 11.5494 | Christie et al. 2014 |
| Norway | Vega-Bubraken | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 65.6802 | 11.5984 | Christie et al. 2014 |
| Norway | Senja-Sjursvika | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 69.0956 | 16.7792 | Christie et al. 2014 |
| Norway | Senja-Stongeland | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 69.0427 | 16.8795 | Christie et al. 2014 |
| Norway | Senja-Halvardsøya | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 69.1599 | 16.8958 | Christie et al. 2014 |
| Norway | Senja-Kjerringbergnes | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 69.311 | 16.8978 | Christie et al. 2014 |
| Norway | Senja-Månesodden | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 69.3111 | 16.8978 | Christie et al. 2014 |
| Norway | Senja-Lemmingsvær | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 69.027 | 16.9326 | Christie et al. 2014 |
| Norway | Hekkingen I | 2016 | 10 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 69.6167 | 17.886 | Filbee-Dexter et al. 2019 |
| Norway | Finnmark-Kongsfjord | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 70.6991 | 29.4393 | Christie et al. 2014 |
| Norway | Finnmark-Bøkefjord | 2012 | 20 | <i>A. esculenta, L. hyperborea, S. latissima</i> | 69.8525 | 30.13 | Christie et al. 2014 |
| Norway | Kongsfjorden (Hansneset) | 2014 | 18 | <i>Alaria</i> | 78.985 | 11.96327 | Bartsch et al. 2016 |
| Norway | Kongsfjorden (Hansneset) | 2014 | 14 | <i>S. latissima</i> | 78.985 | 11.96327 | Bartsch et al. 2016 |
| Norway | Kongsfjorden (Kapp Mitra) | 1998 | 11 | <i>A. esculenta</i> | 79.112 | 11.133 | Hop et al. 2016 |
| Norway | Kongsfjorden (Kapp Mitra) | 1998 | 9 | <i>L. digitata, S. latissima</i> | 79.112 | 11.133 | Hop et al. 2016 |
| Norway | Kongsfjorden (Kap Guissez) | 1998 | 14 | <i>S. dermatodea</i> | 79.064 | 11.63 | Hop et al. 2016 |
| Norway | Kongsfjorden (Kap Guissez) | 1998 | 13 | <i>A. esculenta</i> | 79.064 | 11.63 | Hop et al. 2016 |
| Norway | Kongsfjorden (Kap Guissez) | 1998 | 11 | <i>S. latissima</i> | 79.064 | 11.63 | Hop et al. 2016 |
| Norway | Kongsfjorden (Hansneset) | 1998 | 10 | <i>L. digitata</i> | 78.986 | 11.964 | Hop et al. 2016 |
| Norway | Kongsfjorden (Hansneset) | 1998 | 20 | <i>Laminaria sp.</i> | 78.986 | 11.964 | Hop et al. 2016 |
| Norway | Kongsfjorden (Hansneset) | 1998 | 11 | <i>S. latissima/Alaria</i> | 78.986 | 11.964 | Hop et al. 2016 |
| Norway | Kongsfjorden (Juttaholmen) | 1998 | 15 | <i>L. digitata/S. latissima</i> | 78.945 | 12.262 | Hop et al. 2016 |
| Norway | Kongsfjorden (Ossian Sars) | 1998 | 19 | <i>L. digitata</i> | 78.894 | 12.556 | Hop et al. 2016 |

| | | | | | | | |
|----------------|--------------------------------|------|------|---|---------|-----------|--|
| Russia | Cape Abram | | 15 | <i>S. latissima</i> | 69.021 | 33.0226 | Shoshina et al. 2016 |
| Russia | Cape Mishukov | | 6 | <i>A. esculenta, S. latissima</i> | 69.0595 | 33.0429 | Malavenda and Malavenda 2012 |
| Russia | Belokamenka Bay | | 6 | <i>S. latissima</i> | 69.0777 | 33.1807 | Malavenda and Malavenda 2012 |
| Russia | Cape Retinskiy | | 6 | <i>A. clathratum, L. digitata, S. latissima</i> | 69.1122 | 33.3793 | Malavenda and Malavenda 2012 |
| Russia | Ostrov Asafiy | 1973 | 9 | <i>S. latissima</i> | 66.421 | 33.6559 | Myagkov 1975 |
| Russia | Nikolskaya Bay | | 8 | <i>L. digitata, S. latissima</i> | 66.2167 | 33.8333 | Plotkin et al. 2005 |
| USA | Beaufort Sea, Boulder patch | 1980 | 7 | <i>A. esculenta, L. solidungula, S. latissima</i> | 70.3208 | -147.5833 | Dunton & Schell 1986, Dunton et al. 1982 |
| USA | Adak I | 1987 | 30 | <i>E. fistulosa, Laminaria spp.</i> | 51.6102 | -177.0966 | Duggins et al. 1989 |
| USA | Amchitka I | 1987 | 30 | <i>E. fistulosa, Laminaria spp.</i> | 51.5043 | -178.7812 | Duggins et al. 1989 |
| USA | Stefansson Sound Boulder Patch | | 6.4 | <i>L. solidungula</i> | 70.23 | -147.45 | Dunton 1990 |
| United Kingdom | Isle of Man | | 20 | <i>L. hyperborea</i> | 54.24 | | Kain 1971 |
| United Kingdom | | | 24 | <i>L. hyperborea</i> | | | Kain 1976 |
| Ireland | | | 32 | <i>L. hyperborea</i> | | | Maggs & Guiry 1982 |
| Ireland | | | 22 | <i>L. hyperborea</i> | | | Cullinane & Whelan 1983 |
| Germany | Helgoland | | 8 | <i>L. hyperborea</i> | 54.18 | 7.8805 | Luning & Dring 1979 |
| Germany | Helgoland | 2005 | 2.5 | <i>L. digitata</i> | 54.18 | 7.8805 | Pehlke & Bartsch 2008 |
| Germany | Helgoland | 2005 | 10.5 | <i>L. hyperborea</i> | 54.18 | 7.8805 | Pehlke & Bartsch 2008 |

Cited literature: Jorde, 1966; Kain, 1971; Myagkov, 1975; Kain, 1976; Lüning and Dring, 1979; Chapman and Lindley, 1980; Dunton et al., 1982; Maggs and Guiry, 1982; Cullinane and Whelan, 1983; b; South, 1983; Dunton and Schell, 1986; Duggins et al., 1989; Dunton, 1990; Gunnarsson, 1991; Bruntse et al., 1999; Dean et al., 2000; Borum et al., 2002; Plotkin et al., 2005; Pehlke and Bartsch, 2008; Sharp et al., 2008; Adey and Hayek, 2011; Krause-Jensen et al., 2012; Malavenda and Malavenda, 2012; Christie et al., 2014; Bartsch et al., 2016; Hop et al., 2016; Shoshina et al., 2016; Konar et al., 2017; Filbee-Dexter et al., 2019.

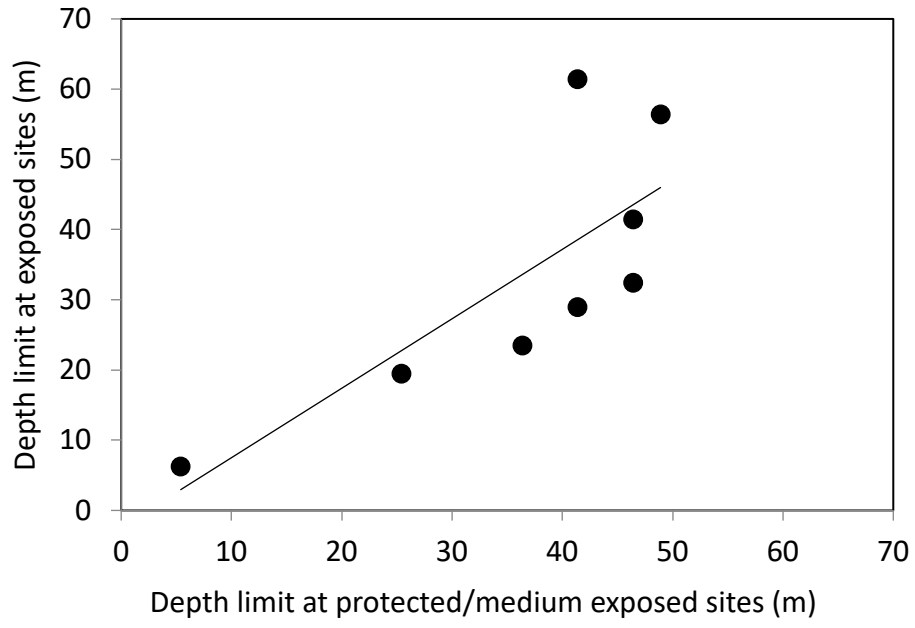


Fig. S1. Kelp depth limits along relatively exposed vs. relatively protected transects at 8 sites in the Disko Bay area assessed in August/September 2009.

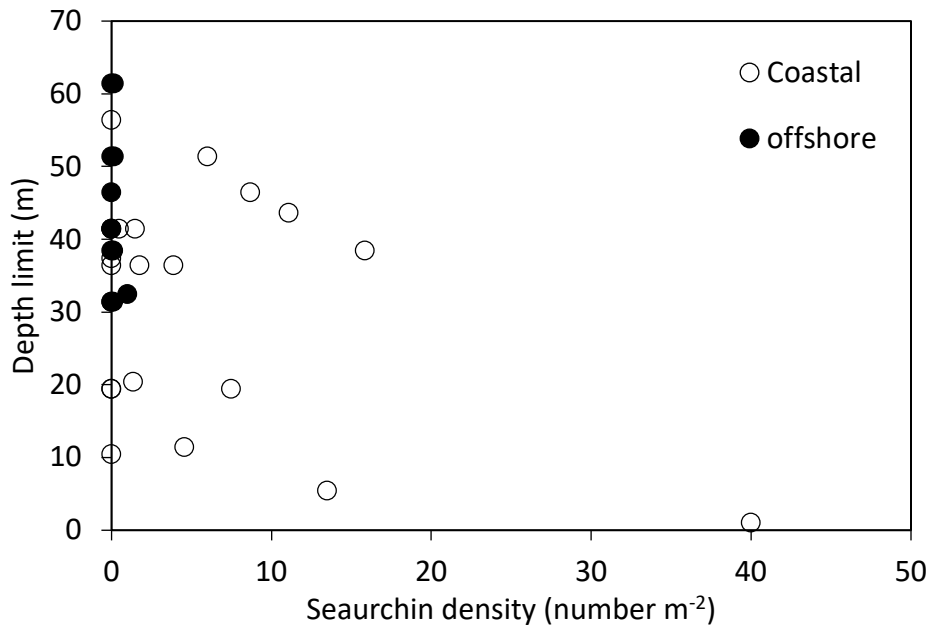


Fig. S2. Kelp depth limits as a function of average sea urchin density along 33 transect lines in the Disko Bay area studied in August/September 2009.

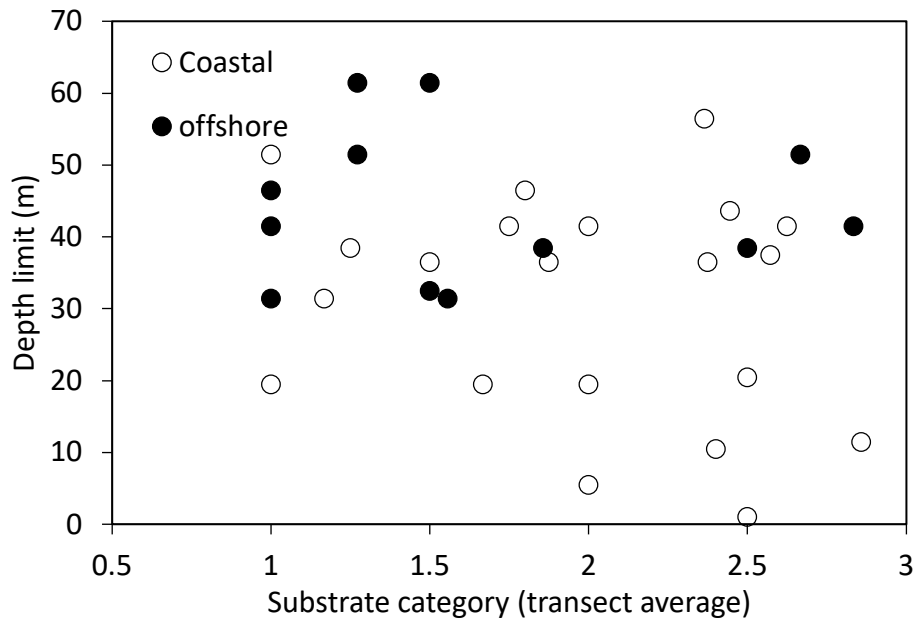


Fig. S3. Kelp depth limits as a function of average substrate composition along 33 transect lines in the Disko Bay area studied in August/September 2009. Substrate categories: rock (1), rock/sand (2), sand (3).

References

- Adey, W.H., and Hayek, L.A.C. (2011). Elucidating marine biogeography with macrophytes: Quantitative analysis of the north Atlantic supports the thermogeographic model and demonstrates a distinct subarctic region in the northwestern Atlantic. *Northeast. Nat.* 18, 1-128. doi: 10.1656/045.018.m801
- Bartsch, I., Paar, M., Fredriksen, S., Schwanitz, M., Daniel, C., Hop, H., et al. (2016). Changes in kelp forest biomass and depth distribution in Kongsfjorden, Svalbard, between 1996–1998 and 2012–2014 reflect Arctic warming. *Pol. Biol.* 39(11), 2021-2036. doi: 10.1007/s00300-015-1870-1.
- Borum, J., Pedersen, M., Krause-Jensen, D., Christensen, P., and Nielsen, K. (2002). Biomass, photosynthesis and growth of *Laminaria saccharina* in a high-arctic fjord, NE Greenland. *Mar. Biol.* 141(1), 11-19. doi: 10.1007/s00227-002-0806-9.
- Bruntse, G., Lein, T.E., and Nielsen, R. (1999). Marine benthic algae and invertebrate communities from the shallow waters of the Faroe Islands. A baseline study. *Kaldbak Marine Biological Laboratory, Faroe Islands.*
- Chapman, A.R.O., and Lindley, J.E. (1980). Seasonal growth of *Laminaria solidungula* in the Canadian high arctic in relation to irradiance and dissolved nutrient concentrations. *Mar. Biol.* 57(1), 1-5.
- Christie, H., Gundersen, H., Rinde, E., and Bekkby, T. (2014). "*Laminaria hyperborea* kelp forest as an indicator in "Nature index of Norway", in: *Norwegian Institute for Water Research (NIVA-rapport, 6609). ISBN 978-82-577-6344-2.*
- Cullinane, J.P., and Whelan, P.M. (1983). Subtidal algal communities on the south coast of Ireland. *Cryptogam. Algol.* 4, 17-125.
- Dean, T.A., Bodkin, J.L., Jewett, S.C., Monson, D.H., and Jung, D. (2000). Changes in sea urchins and kelp following a reduction in sea otter density as a result of the Exxon Valdez oil spill. *Mar. Ecol. Prog. Ser.* 199, 281-291.
- Duggins, D.O., Simenstad, C.A., and Estes, J.A. (1989). Magnification of secondary production by kelp detritus in coastal marine Ecosystems. *Science* 245(4914), 170-173. doi: 10.1126/science.245.4914.170.
- Dunton, K.H. (1990). Growth and production in *Laminaria solidungula*: relation to continuous underwater light levels in the Alaskan High Arctic. *Mar. Biol.* 106(2), 297-304. doi: 10.1007/bf01314813.
- Dunton, K.H., Reimnitz, E., and Schonberg, S. (1982). An arctic kelp community in the Alaskan Beaufort Sea. *Arctic* 35, 465-484.
- Dunton, K.H., and Schell, D.M. (1986). Seasonal carbon budget and growth of *Laminaria solidungula* in the Alaskan High Arctic. *Mar. Ecol. Prog. Ser.* 31, 57-66.
- Filbee-Dexter, K., Wernberg, T., Fredriksen, S., Norderhaug, K.M., and Pedersen, M.F. (2019). Arctic kelp forests: Diversity, resilience and future. *Glob. Planet. Change* 172, 1-14. doi: <https://doi.org/10.1016/j.gloplacha.2018.09.005>.
- Gattuso, J.P., Gentili, B., Duarte, C.M., Kleypas, J.A., Middelburg, J.J., and Antoine, D. (2006). Light availability in the coastal ocean: impact on the distribution of benthic photosynthetic organisms and their contribution to primary production. *Biogeosci.* 3(4), 489-513. doi: 10.5194/bg-3-489-2006.
- Gunnarsson, K. (1991). Populations de *Laminaria hyperborea* et *Laminaria digitata* (Pheophycees) dans la baie de Breidifjordur, Island. *Rit Fiskideildar* 12(1s).

- Hop, H., Kovaltchouk, N.A., and Wiencke, C. (2016). Distribution of macroalgae in Kongsfjorden, Svalbard. *Pol. Biol.* 39(11), 2037-2051. doi: 10.1007/s00300-016-2048-1.
- Jorde, I. (1966). Algal associations of a coastal area south of Bergen, Norway. *Sarsia* 23, 1-52.
- Kain, J.M. (1971). Biology of *Laminaria hyperborea*. 6. Some Norwegian populations. *J. Mar. Biol. Assoc. UK.* 51(2), 387-&. doi: 10.1017/s0025315400031866.
- Kain, J.M. (1976). Biology of *Laminaria hyperborea*. 8. Growth on cleared areas. *J. Mar. Biol. Assoc. UK.* 56(2), 267-290. doi: 10.1017/s0025315400018907.
- Konar, B., Edwards, M.S., Bland, A., Metzger, J., Ravelo, A., Traiger, S., et al. (2017). A swath across the great divide: Kelp forests across the Samalga Pass biogeographic break. *Continent. Shelf Res.* 143, 78-88. doi: https://doi.org/10.1016/j.csr.2017.06.007.
- Krause-Jensen, D., Marbà, N., Olesen, B., Sejr, M.K., Christensen, P.B., Rodrigues, J., et al. (2012). Seasonal sea ice cover as principal driver of spatial and temporal variation in depth extension and annual production of kelp in Greenland. *Glob. Chang. Biol.* 18(10), 2981-2994. doi: 10.1111/j.1365-2486.2012.02765.x.
- Lüning, K., and Dring, M.J. (1979). Continuous underwater light measurement near Helgoland (North Sea) and its significance for characteristic light limits in the sublittoral region. *Helgoland. Wiss. Meer.* 32(4), 403-424. doi: 10.1007/bf02277985.
- Maggs, C.A., and Guiry, M.D. (1982). Notes on Irish marine algae 5. Preliminary observations of deep water vegetation off west Donegal. *Ir. Nut. J.* 20, 357-361.
- Malavenda, C., and Malavenda, C. (2012). Черты деградации в фитоценозах южного и среднего колен Кольского залива Баренцева моря. *Bull. Moscow State Tech. Univ.* 15, 794-802.
- Myagkov (1975). Composition, distribution and the seasonal dynamics of algal biomass in the *Laminaria biocenosis* of the bay of the White Sea USSR based on diving data. *Bull. Leningr. State Univ. Ser. Biol.* 3, 48-53.
- Pehlke, C., and Bartsch, I. (2008). Changes in depth distribution and biomass of sublittoral seaweeds at Helgoland (North Sea) between 1970 and 2005. *Clim. Res.* 37(2-3), 135-147. doi: 10.3354/cr00767.
- Plotkin, A.S., Railkin, A.I., Gerasimova, E.I., Pimenov, A.Y., and Sipenkova, T.M. (2005). Subtidal underwater rock communities of the White Sea: Structure and interaction with bottom flow. *Russ. J. Mar. Biol.* 31(6), 335-343. doi: 10.1007/s11179-006-0001-9.
- Sharp, G., Allard, M., Lewis, A., Semple, R., and Rochefort, G. (2008). The potential for seaweed resource development in subarctic Canada; Nunavik, Ungava Bay. *J. Appl. Phycol.* 20(5), 491-498. doi: 10.1007/s10811-008-9323-7.
- Shoshina, E., Kapkov, V.I., and Belenikina, O.A. (2016). Ecological factors regulating growth of seaweeds in Arctic communities. *Вестник МГТУ* 19, 334-344.
- South, G.R. (1983). Benthic marine algae. In South, G. R. [Ed.] *Biogeography and Ecology of the Island of Newfoundland*. Dr. W. Junk Publishers, The Hague, 385-420.

Vadas, R.L., and Steneck, R.S. (1988). Zonation of deep water benthic algae in the Gulf of Maine. *J. Phycol.* 24(3), 338-346. doi: 10.1111/j.1529-8817.1988.tb04476.x.