Cold temperate regions of the northern hemisphere
- European coasts – cold and warm temperate regions

Fig. 2.45 Phytogeographical regions and provinces in the North Atlantic. A = warm temperate Carolina region; B = western Atlantic tropical region; C, D, E = warm temperate Mediterranean–Atlantic region (C = Canary province; D = Mediterranean province, E = Lusitania province); F, G = cold temperate North Atlantic region (F = eastern province; G = western province), H = Arctic region. (From van den Hoek 1975.)
Due to warm north-Atlantic current many taxa migrated from NW Africa/Gibraltar area to the north after the last glacial. These taxa form a bulk of the today cold temperate European flora.

Northern limits: August 8°C isotherm and February 0°C isotherm; i.e. between Norway and Spitzbergen
Fig. 6. A. Dendrogram showing floristic similarities of biogeographic regions along the North Atlantic Ocean and the Mediterranean Sea. B. Histograms depicting number of species shared and not shared by adjacent biogeographic regions along the North Atlantic Ocean and the Mediterranean Sea. The comparison between cold temperate Eastern and Western regions is also provided (C–E). Bold letters indicate regions shown in Table 3.
Table 2. Seaweed species numbers for each geographic area of the North Atlantic Ocean and major taxonomic groups

<table>
<thead>
<tr>
<th>Area</th>
<th>Chlorophyta</th>
<th>Phaeophyta</th>
<th>Rhodophyta</th>
<th>Whole flora</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Tropical America</td>
<td>203</td>
<td>115</td>
<td>425</td>
<td>743</td>
</tr>
<tr>
<td>2 Warm USA</td>
<td>68</td>
<td>70</td>
<td>189</td>
<td>327</td>
</tr>
<tr>
<td>3 Temperate USA</td>
<td>83</td>
<td>114</td>
<td>124</td>
<td>321</td>
</tr>
<tr>
<td>4 Cold temperate Canada</td>
<td>82</td>
<td>115</td>
<td>119</td>
<td>316</td>
</tr>
<tr>
<td>5 Arctic Canada</td>
<td>55</td>
<td>65</td>
<td>57</td>
<td>177</td>
</tr>
<tr>
<td>6 Spitzbergen Is.</td>
<td>13</td>
<td>32</td>
<td>28</td>
<td>73</td>
</tr>
<tr>
<td>7 Greenland</td>
<td>45</td>
<td>73</td>
<td>63</td>
<td>181</td>
</tr>
<tr>
<td>8 Iceland</td>
<td>46</td>
<td>77</td>
<td>76</td>
<td>199</td>
</tr>
<tr>
<td>9 Færøes Is.</td>
<td>39</td>
<td>77</td>
<td>90</td>
<td>200</td>
</tr>
<tr>
<td>10 Shetland Is.</td>
<td>51</td>
<td>86</td>
<td>128</td>
<td>265</td>
</tr>
<tr>
<td>11 Arctic Norway</td>
<td>42</td>
<td>85</td>
<td>81</td>
<td>208</td>
</tr>
<tr>
<td>12 Southern Norway</td>
<td>68</td>
<td>135</td>
<td>161</td>
<td>364</td>
</tr>
<tr>
<td>13 Denmark</td>
<td>74</td>
<td>125</td>
<td>150</td>
<td>349</td>
</tr>
<tr>
<td>14 Ireland</td>
<td>80</td>
<td>142</td>
<td>243</td>
<td>465</td>
</tr>
<tr>
<td>15 United Kingdom</td>
<td>94</td>
<td>184</td>
<td>289</td>
<td>567</td>
</tr>
<tr>
<td>16 Atlantic France</td>
<td>137</td>
<td>191</td>
<td>335</td>
<td>663</td>
</tr>
<tr>
<td>17 Atlantic Iberia</td>
<td>104</td>
<td>139</td>
<td>328</td>
<td>571</td>
</tr>
<tr>
<td>18 Temperate Africa + Canary Is.</td>
<td>146</td>
<td>127</td>
<td>409</td>
<td>682</td>
</tr>
<tr>
<td>19 Tropical Africa</td>
<td>69</td>
<td>56</td>
<td>214</td>
<td>339</td>
</tr>
<tr>
<td>20 Mediterranean Spain + Balearic Is.</td>
<td>117</td>
<td>116</td>
<td>365</td>
<td>598</td>
</tr>
<tr>
<td>21 Mediterranean France</td>
<td>95</td>
<td>109</td>
<td>331</td>
<td>535</td>
</tr>
<tr>
<td>22 Corsica</td>
<td>69</td>
<td>89</td>
<td>277</td>
<td>436</td>
</tr>
<tr>
<td>23 South-western Italy</td>
<td>101</td>
<td>129</td>
<td>408</td>
<td>638</td>
</tr>
<tr>
<td>24 Adriatic Sea</td>
<td>98</td>
<td>119</td>
<td>306</td>
<td>523</td>
</tr>
<tr>
<td>25 Greece</td>
<td>96</td>
<td>89</td>
<td>296</td>
<td>481</td>
</tr>
</tbody>
</table>
Fig. 2.44  Latitudinal distribution of seaweed species along the coasts from Morocco to Spitsbergen. Each vertical line represents the distribution span of one species. (After van den Hoek 1975.)
FUCUS SPIRALIS

CHOND RUS CRISPUS

HIMANTHALIA ELONGATA
Fig. 3. Typical understory algae at different depths in the sublittoral zone off Helgoland (from Lüning, 1970; 1990).

Fig. 2.49 Zonation off Helgoland. Typical understory algae at different depths in the sublittoral zone. (From Lüning 1970.)
• North Atlantic supralittoral (spray zone) – characteristic genera \textit{Prasiola} + \textit{Rosenvingiella}

• \textit{Prasiola stipitata}

other genera – Ulva (tubular), Blidingia

• vertical zonation - Galicia
Intertidal of NW Europe

- **Ulva intestinalis**
- **Pelvetia canalliculata**
- **Fucus spiralis**
- **Ulva lactuca**
- **Ascophyllum nodosum**
- **Fucus vesiculosus**
- **Fucus serratus**
- **Dumontia contorta**
- **Porphyra spp.**
- **Osmundea pinnatifida**
- **Chondrus crispus**
- **Palmaria palmata**
- **Himanthalia elongata**
- **Saccharina latissima**
- **Laminaria hyperborea**
- **Laminaria digitata**

**Distribution of Choice Seaweeds By Tidal Range**

©GallowayWildFoods.com

**Key:**
- Green Seaweeds
- Brown Seaweeds
- Red Seaweeds

Horizontal Distances Not Illustrated
Pelvetia canaliculata (channelled wrack)
Dumontia contorta

Osmundea pinnatifida
Fucus belt in the NW Atlantic lies in the intertidal

Figure 2.1 Zonation patterns characteristic of Fucus species along (a) intertidal and (b) atidal shores of the Baltic Sea.

de Oliveira et al., 2006, EARSeL eProceedings
underlying physiological data support vertical structure of the Fucus belt
Kelp vegetation ("kelp forests")
major differences between N and S hemispheres in kelp community structure
Kawai et al., 2016, In: Seaweed Phylogeography
evolutionary origin of kelps in N Pacific
secondary colonization of Arctic and N Atlantic
probably three independent transitions to S hemisphere

Starko et al., 2019, Mol Phyl Evol
The dominant seaweed species along the European coastline are brown algae mainly belonging to the Laminariales (kelp) and Tilopteridales (kelp-like) which are distributed from the lower intertidal down to, approximately 30 m in the subtidal zone, depending on the clarity of the water.

In Europe, these orders include the native species:

*Alaria esculenta* (Linnaeus) Greville
*Chorda filum* (Linnaeus) Stackhouse
*Laminaria digitata* (Hudson) J.V. Lamouroux
*L. hyperborea* (Gunnerus) Foslie
*L. ochroleuca* Bachelot de la Pylaie
*L. rodriguezii* Bornet
*L. solidungula* J. Agardh
*Saccharina latissima* (Linnaeus) C.E. Lane, C. Mayes, Druehl and G.W. Saunders

*Phyllariopsis brevipes* (C. Agardh) E.C. Henry and G.R. South
*P. purpurascens* (C. Agardh) E.C. Henry et G.R. South
*Saccorhiza polyschides* (Lightfoot) Batters
*S. dermatodea* (Bachelot de la Pylaie)

*Undaria pinnatifida* (Harvey) Suringar.
<table>
<thead>
<tr>
<th>kelp species &amp; data source</th>
<th>temperature ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sporophyte growth &amp; reproduction</td>
</tr>
<tr>
<td><em>Alaria esculenta</em></td>
<td>upper: 16°C / *</td>
</tr>
<tr>
<td>Sundene, 1962</td>
<td>lower: * / *</td>
</tr>
<tr>
<td><em>Laminaria digitata</em></td>
<td>upper: 18°C / 18°C</td>
</tr>
<tr>
<td>Gayral &amp; Cosson, 1973</td>
<td>lower: 0°C / *</td>
</tr>
<tr>
<td><em>Laminaria hyperborea</em></td>
<td>upper: 15°C / 20°C</td>
</tr>
<tr>
<td>Kain, 1964</td>
<td>lower: 0°C / 19°C</td>
</tr>
<tr>
<td><em>Laminaria ochroleuca</em></td>
<td>upper: 22-23°C / *</td>
</tr>
<tr>
<td>Lüning, 1990</td>
<td>lower: * / *</td>
</tr>
<tr>
<td><em>Laminaria saccharina</em></td>
<td>upper: 18°C / 20°C</td>
</tr>
<tr>
<td>Lüning, 1990</td>
<td>lower: 0°C / *</td>
</tr>
<tr>
<td><em>Saccorhiza polyschides</em></td>
<td>upper: 24°C / *</td>
</tr>
<tr>
<td>Norton, 1977</td>
<td>lower: 3°C / *</td>
</tr>
<tr>
<td><em>Undaria pinnatifida</em></td>
<td>upper: 28-30°C / *</td>
</tr>
<tr>
<td>Akiyama, 1965</td>
<td>lower: * / *</td>
</tr>
</tbody>
</table>

* indicates that the temperature restrictions are not known.

Where two figures are shown these indicate seasonal tolerances.
In appearance this plant is very similar to *L. hyperborea*, but the stipe and the frond are a much lighter colour with a yellowish cast. The stipes are smooth and generally lack epiphytes and epifauna.
Laminaria saccharina

S. latissima
This species is endemic to the Mediterranean and is found on the coasts of Algeria, Tunisia, Majorca, Corsica, Sicily and the shores of the Adriatic Sea. However, it is restricted to depths of 50 - 120 m where the water temperatures do not exceed 15 °C.
Saccharina polyschides
Phyllariopsis breviceps

A warm-temperate species found in deep water. The southern range ends at the Western Sahara border with Morocco, extending northward on the eastern Atlantic coast to Biarritz. This species is also found in the western basin of the Mediterranean.

Phyllariopsis purpurascens

A warm-temperate species found in deep water. The southern range ends at the Western Saharan border with Morocco, extending northward on the eastern Atlantic coast to the Spanish-Galician coast. This species is found in the southern part of the western basin of the Mediterranean.
(A) *Alaria esculenta*
(B) *Laminaria digitata*
(C) *Laminaria hyperborea*
(D) *Laminaria ochroleuca*
(E) *Saccharina latissima*
(F) *Saccorhiza polyschides*
(G) *Undaria pinnatifida*

**Figure 2.** Dark gray hatching indicates the recorded distributions of kelp species in the UK and Ireland (data reproduced from MarLIn, with permission).

**Table 1.** Kelp species in UK and Irish waters. The geographic range and approximate depth range, typical mature sporophyte length, and lifespan of kelps in UK/Irish waters are shown. Also shown is the predicted change in abundance and/or range of each species in response to continued environmental change.

<table>
<thead>
<tr>
<th>Species</th>
<th>Distribution</th>
<th>Depth range (m)</th>
<th>Length (m)</th>
<th>Lifespan (years)</th>
<th>Change (?)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Laminaria hyperborea</em></td>
<td>Arctic–Portugal</td>
<td>0–30</td>
<td>1–3</td>
<td>5–18</td>
<td>Decrease</td>
</tr>
<tr>
<td><em>Laminaria digitata</em></td>
<td>Arctic–France</td>
<td>0–15</td>
<td>1–2</td>
<td>4–6</td>
<td>Decrease</td>
</tr>
<tr>
<td><em>Laminaria ochroleuca</em></td>
<td>UK–Morocco</td>
<td>0–30</td>
<td>1–3</td>
<td>5–18</td>
<td>Increase</td>
</tr>
<tr>
<td><em>Saccharina latissima</em></td>
<td>Arctic–France</td>
<td>0–30</td>
<td>1–3</td>
<td>2–4</td>
<td>Decrease</td>
</tr>
<tr>
<td><em>Alaria esculenta</em></td>
<td>Arctic–France</td>
<td>0–35</td>
<td>1–2</td>
<td>4–7</td>
<td>Decrease</td>
</tr>
<tr>
<td><em>Saccorhiza polyschides</em></td>
<td>Norway–Morocco</td>
<td>0–35</td>
<td>2–3</td>
<td>1</td>
<td>Increase</td>
</tr>
<tr>
<td><em>Undaria pinnatifida</em></td>
<td>Global NIs³</td>
<td>0–15</td>
<td>1–3</td>
<td>1</td>
<td>Increase</td>
</tr>
</tbody>
</table>

Smale et al., 2013, *Ecol Evol*
Fig. 2. Annual temperature variability at a subtidal study site (-2 m depth b.a.d.) within each study region. Temperature record spans July 2014-July 2015, with measurements obtained every 30 min.

Figure 4. The kelp *Laminaria hyperborea* is a dominant canopy former on both subtidal (A) and intertidal (B) rocky reefs around the UK and the wider NE Atlantic. Kelp forests provide habitat for a wide range of flora and fauna, including the hydroid *Obelia geniculata* (C) and the commercially important European Lobster *Homarus gammarus* (D). Although kelps and their epiphytes are grazed directly, by the blue-rayed limpet *Patella pellucida* for example (E), the majority of kelp production is consumed as detritus (F).
climate change effects on European kelps – observed changes and models

$Laminaria hyperborea$ possibly exemplifies species that became extinct in the NW Atlantic during the glaciations, but survived in the NE Atlantic.

**Table 1**

Environmental predictors used in ENM of *Laminaria hyperborea*, their units, the physiological tipping points and relative contribution on the accuracy of models.

<table>
<thead>
<tr>
<th>Environmental predictor</th>
<th>Units</th>
<th>TP</th>
<th>Relative contribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT maximum Ice thickness of summer months</td>
<td>m</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>LT lowest Salinity of winter months</td>
<td>PSS</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>LT Ocean Temp. of the warmest summer month</td>
<td>°C</td>
<td>20.9</td>
<td></td>
</tr>
<tr>
<td>LT Ocean Temp. of the warmest winter month</td>
<td>°C</td>
<td>17.7</td>
<td></td>
</tr>
<tr>
<td>LT Ocean Temp. of the coldest winter month</td>
<td>°C</td>
<td>-0.2</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 1. Potential occurrence of *Laminaria hyperborea* (reclassified ensemble) predicted for (a) the Last Glacial Maximum (LGM; 20,000 years ago), (b) Mid-Holocene (MH; 6,000 years ago), (c) present (1990–2010) and (d, e, f, g) future times (2050s and 2100s) using two scenarios of greenhouse gas emissions (RCP2.6 and RCP8.5). Dashed squares show the regions where *L. hyperborea* was predicted to persist for past and present times. Glacial ice following the reconstruction of Peltier (2002).
**L. digitata** shifts in NW Europe due to climate change

Raybaud et al., 2013, Plos One

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**Figure 2.** Latitudinal gradient in the probability of occurrence of the kelp *Laminaria digitata* along the European coasts, calculated for the periods 1982-2009 with AVHRR SST data and for 2006-2009 and each decade of the 21st century with RCP-SST data. Projected changes in the probability of occurrence are presented for three RCP scenarios: a, the low RCP2.6; b, the medium RCP4.5; and c, the high RCP8.5.

---

**Figure 3.** Percentage of models forecasting a disappearance of *L. digitata* a, for the decade 2010–2019; b, for the decade 2050–2059; and c, for the decade 2090–2099. In each grid cell, a model is considered to predict the disappearance of the species when the probability of occurrence for the reference period (1982–2009) is higher than 0.05 and lower than this threshold for a given decade.

doi:10.1371/journal.pone.0066044.g003

Raybaud et al., 2013, Plos One
Kelp ecosystems of NW American coast

N parts of this region - primary radiation centre of Laminariales
Upper eulittoral of Pacific cold temperate habitats

Postelsia palmaeformis (palm kelp) - only up to Vancouver Island
vertical differentiation in the sublittoral

Fig. 4.20 General structure of a West Coast kelp forest, with a complex understory of plants beneath the dominant *Macrocystis* or *Nereocystis*. 
Figure 2. Kelp forests have undergone regime shifts from lush, structurally complex forests to highly simplified, sediment-laden turf reefs. Examples include the disappearance of forests of Ecklonia radiata from Western Australia (top panel), Saccharina latissima from southwestern Norway (middle panel), and Laminaria digitata and S. latissima from Atlantic Canada (bottom panel). The photographs show healthy kelp forests (a, d, g), sediment-laden turf reefs (b, e, h) and biological drivers: (c) tropical herbivores (Siganus fuscescens) cropping kelp recruits, (f) epiphytes smothering kelps, and (i) the invasive bryozoan (Membranipora membranacea) encrusting and weakening kelp fronds. Photographs: Thomas Wernberg (a, b, c), Hartvig Christie (d, e, f), Karen Filbee-Dexter (g), and Robert Scheibling (i, h).
observed major shifts from kelp forests to turfs (circles)
Kelp forest

- High kelp recruitment
- Low light
- Physical abrasion
- High spore supply

Turf reef

- Low kelp recruitment
- Low kelp recruitment

Factors affecting Kelp forest:
- Warming
- Heat waves
- Storms
- Acidification
- Eutrophication
- Harvesting

Factors affecting Turf reef:
- Epiphytism
- Competition
- Herbivory
- Species invasion

Factors affecting sediment load:
- Limited space
- Low spore supply
- High grazing intensity

Factors affecting high sediment load:
- High sediment load
- Limited space
- Low spore supply
- High grazing intensity
Fig. 1. (A) Destructive grazing front of sea urchins *Strongylocentrotus droebachiensis* advancing into a kelp bed near Halifax, Nova Scotia, Canada. Photo credit: R. E. Scheibling. (B) Extensive urchin (*S. polyacanthus*) barrens in the Aleutian Islands, USA. Photo credit: B. Konar. (C) Urchins *S. droebachiensis* on scoured coralline algae in barrens in Norway. Photo credit: C. W. Fagerli. (D) Range-expanding urchin *Centrostephanus rodgersii* forming patchy barrens in a kelp bed in southeast Tasmania. Photo credit: S. D. Ling. (E) *S. nudus* grazing a kelp bed in Japan. Photo credit: D. Fujita
Sea urchin barrens are benthic communities on rocky subtidal reefs that are dominated by urchins and coralline algae; in the absence of intense herbivory by urchins, these barrens support luxuriant seaweed communities such as kelp beds (or forests). Barrens can extend over 1000s of km of coastline or occur in small patches (10s to 100s of m) within a kelp bed.
urchin barrens – alternative stable-state systems; discontinuous phase shifts between

**Strongylocentrotus droebachiensis** – Norway, **L. hyperborea**
parasitic nematode – **Echinomermella matsu** – may control sea urchin populations

however, the succession towards an ecologically mature kelp forest community has been interrupted by the unexpected recurrence of destructive grazing, and the macroparasite hypothesis must therefore be rejected in its present form

**crabs and common eiders** are also the common predators on urchins

the euphotic hard bottom component of the coastal ecosystem in Northern Norway has entered a cyclical domain

**Filbee-Dexter & Scheibling, 2014, Mar Ecol Progr Ser**

**Strongylocentrotus droebachiensis** – Norway, **L. hyperborea**
parasitic nematode – **Echinomermella matsu** – may control sea urchin populations

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the euphotic hard bottom component of the coastal ecosystem in Northern Norway has entered a cyclical domain

**Filbee-Dexter & Scheibling, 2014, Mar Ecol Progr Ser**
N Europe – sea urchin barrens since 1970s (N Norway, Russia)

Figure 1. Retreating sea urchins. Movement of the border between kelp-dominated areas and barren ground from 1980 until 2007. The barren ground area had its largest extent in 1980 where the border extended south to 63°30' N (Sivertsen 1982). Rav et al. (1990) showed that the border had moved to 63°40' N by 1990 and in 2000 the border had at least moved to 64°10' N (Sjøtun et al. 2001). In 2007 the border was situated at 65°30' N (Nordehaug & Christie 2007).

Figure 5. Conceptual figure describing possibly important interactions (arrows) between kelp (Laminaria hyperborea), sea urchins (Strongylocentrotus droebachiensis) and potentially important predators. Black arrows indicate a negative effect and white arrows a positive effect. (a) Adult kelp provides a habitat for sea urchin recruits, invertebrate predators and a nursery area and habitat for fish. (b) Invertebrate and fish predators prey on sea urchin recruitment. (c) If sea urchins become abundant they aggregate and graze down the kelp forest. Then the kelp and associated predators are lost and only sea urchins survive. (d) When the kelp forest is lost, sea urchin populations prevent kelp from re-establishing by grazing.
(a-)cyclic dynamics of kelp forests in 20th (21th) century

Figure 2: Timing of phase changes in community state of kelp forests of North America. Kelp with vertebrate predators, sea urchins without kelp and kelp without predators have been identified for some or all of the case study locations. Kelp forests are listed from the greatest number of trophic levels on the left to fewest trophic levels on the right. Case studies are listed from lowest species diversity in Maine to highest diversity in southern California. See text or Table 4 for references.

Key: ←→ Transient * spatially limited state

Figure 4: Temporal trends in kelp forests and sea urchins in the Gulf of Maine in the western North Atlantic. Width of arrowheads indicates the magnitude of the forcing function’s impact.

Figure 3: Temporal trends in kelp forests, predators and sea urchins of Amchitka, Alaska. Abundances estimated from several studies (see text) and Estes and Duggins (1995). Arrows indicate the timing of change in major community-changing forcing functions. Width of arrowheads indicates magnitude of the forcing function’s impact.
Figure 5 Temporal trends in kelp forests and sea urchins of Nova Scotia. Abundances estimated from Edelstein et al. (1969), Breen and Mann (1970), Warton and Mann (1981), Scheibling and Stephenson (1984), Scheibling (1986) and Johnson and Mann (1988). Width of arrowheads indicates the magnitude of the forcing function’s impact.

Figure 6 Temporal trends in kelp forests of Point Loma California. Abundance estimates summarized in Leighton et al. (1966), Tegner et al. (1996a), McGowan et al. (1998) and Tegner and Dayton (2000). Width of arrowheads indicates the magnitude of the forcing function’s impact. The boxed area on the right of the figure indicates a period of high resolution subtidal data (see Fig. 3).

Figure 7 Temporal trends in the kelp forest of Point Loma, California, USA, 1983–1996 at 12 m depth (from Tegner et al. 1996a). Population density data are shown for canopy (Macrocystis) and stipitate (Pterygophora) kelps. Percentage cover data are shown for the prostrate kelp Laminaria.
Zostera (marina) [eelgrass] meadows
(Liliopsida, Najadales, Zosteraceae)

Fig. 2. Worldwide distribution of all Zostera species (dots indicate literature reports); shaded area indicates the range of Zostera marina (Green and Short, 2003).

Fig. 5. Reproductive phenology of Zostera marina at different locations (with latitudes) along the east coast of the United States. The approximate temperature that was recorded for each event is also given (modified from Silberhorn et al., 1983).

Europe – Z. marina meadows cover ca 1800 km²

Moore & Short, 2006, Biology of Zostera
Figure 6. Temporal development in eelgrass depth limits in Danish coastal waters. Historical data represent means (± s.e.) of all observations along open coasts (n = 232) and fjords (inner, outer and Limfjorden all together, n = 75) for the period 1880–1930 (Krause-Jensen and Rasmussen, 2009). Data from 1989 to 2009 are nationwide means of deepest observations of 10% eelgrass cover in fjords and open coasts as compiled under the Danish national monitoring and assessment programme and modelled by generalized linear models (Hansen and Petersen, 2011).
The lower sublittoral zone (<5% penetrating light)

- Scattered *L. hyperborea*, but no more canopy-forming.
- Laminarias grow extremely slowly and, consequently, often have a lot of epiphytes (such as *Membranipora membranacea*).
- Typical taxa: *Delesseria sanguinea, Phycodrys rubens, Desmarestia ligulata, Polysiphonia urceolata*

- Morphological adaptations to low light intensities and absence of major wave action.
Maerl vegetation – (3-) to 25 m(-40) meters, sandy bottoms dominated by *Phymatolithon calcareum, Lithothamnion corallioides*

loose lying, encrusted…
maerl beds and disturbance by scallop dredging

Main anthropogenic hazard for live maerl beds is smothering by fine sediment, such as that produced by trawling or maerl extraction, from sewage discharges or shellfish and fish farm waste, and sedimentation resulting from disruption to tidal flow.

Wilson et al., 2004

Hall- Spencer & Moore, 2000, ICES J Mar Sci
Three refugia were recognized based on high haplotype diversities and the presence of endemic haplotypes: southwest Ireland, the northern Brittany-Hurd Deep area of the English Channel, and the northwest Iberian Peninsula.

Irish refugium was the source for a recolonization sweep involving a single haplotype via northern Scotland and throughout Scandinavia, whereas recolonization from the Brittany-Hurd Deep refugium was more limited, probably because of unsuitable soft-bottom habitat in the Bay of Biscay and along the Belgian and Dutch coasts. The Iberian populations reflect a remnant refugium at the present–day southern boundary of the species range.

* Hoarau et al., 2007, Mol Ecol