CHAPTER 5.1. MACROALGAE.

THE BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN


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5.1. Macroalgae

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1. Introduction

Research on Antarctic macroalgae began with the expeditions of Gaudichaud-Bory, Montagne, Hooker and Harvey as early as 1817 (Godley 1965). A second notable period in the exploration of macroalgae from the Southern Ocean and the cold-temperate regions of South America was around the turn of the 19th to the 20th century. The most important studies during this time were conducted by Hariot, Reinsch, Gain, Skottsberg and Kylin (Wiencke & Clayton 2002). These taxonomic and biogeographical studies enabled Papenfuss (1964) to produce the first catalogue of Antarctic and sub-Antarctic benthic marine macroalgae. The introduction of SCUBA diving into the methodological portfolio by Neushul (1965), Zaneveld (1966a, b, 1968) and Delphine et al. (1966) opened a new era. Later on, Moe (Moe & DeLaca 1976), Lamb & Zimmermann (1976), Amsler (Amsler et al., 1995) and Klöser and co-workers (Klöser et al., 1996) conducted numerous diving studies allowing for the first time more precise descriptions of the depth distribution of Antarctic macroalgae. In subsequent years a major attempt was made to investigate the life history of Antarctic species (Wienecke et al. 2007). In this period scientific knowledge of Antarctic macroalgae considerably broadened and the first monographs of these ecologically important species was compiled (Wienecke & Clayton 2002). Moreover, in-depth studies on the physiological thallus anatomy (Wienecke et al. 2007), physiology (Wienecke et al. 2011) as well as on the temperature and light requirements (Gómez et al. 2011, Wiencke & Amsler 2012) of Antarctic species became possible. Detailed investigations on trophic relations between macroalgae and herbivores began in the last decade of the 20th century (Iken et al. 2001, 2011). The degree of endemism is high in the Antarctic marine flora (Clayton 1995) and in Antarctica species of this order occupy the same ecological niche as the order Laminariales (which is absent from Antarctica) in the Northern Hemisphere. There are numerous endemic genera, species and/or endemic species (after Wiencke & Clayton 2002; Table 1). Endemism is highest in the Antarctic Peninsula region (Wienecke & Amsler 2012). Numerous authors have reported on the cover and/or biomass of macroalgal communities in this region (Neushul 1965, Delphine et al. 1966, DeLaca & Lips 1976, Brouwer 1979, Zieliński 1981, 1990, Chung et al. 1994, Klöser et al. 1994, 1996, Amsler et al. 1995, Brouwer et al. 1995, Quarto et al. 2001, 2005, Quarto & Boraso de Zaiixo 2008) and the following description of the zonation of brown, red, and green macroalgae on the western Antarctic Peninsula is a summary of these reports combined with our personal observations of the flora over many years. Throughout the region, large, perennial brown macroalgae usually dominate in terms of both biomass and percent cover of the bottom, with Desmarestia menziesii J.Agardh (Map 2), Desmarestia aniceps Montagne (Map 7) and Himantothallus grandifolius (Map 1) usually reported as most common. Specific zonation patterns of the dominant brown algae vary with site, but the overall pattern is relatively consistent among these reports from multiple sites and years. The upper 2–3 m of the subtidal is typically heavily impacted by ice scour and, with the exception of well protected spots, rarely supports these large perennial algae. Below this heavy scour area, D. menziesii commonly becomes abundant and then grades into and is eventually replaced at greater depths by D. aniceps. At some locations, however, only one of these two Desmarestia species is present, at least in quantity. Unfortunately, because they are very similar morphologically, some reports have lumped these species together, thereby obscuring any patterns. Below the zone dominated by Desmarestia spp., the large, blade-forming H. grandifolius becomes dominant. The depths at which these transitions between dominant species occur vary widely between sites, as will be discussed further below.

Several other large brown macroalgae can occasionally co-dominate with these three most common species. Ascoseira mirabilis (Map 8) is sometimes reported to replace or co-dominate with D. menziesii at shallower depths, although it can also occur deeper (Chung et al. 1994, Klöser et al. 1996, Quarto et al. 2001). Desmarestia antarctica R.L.Moe & P.C.Silva is a relatively fast growing annual or biennial species that can occasionally be locally dominant in the zone typical of D. aniceps (Chung et al. 1994, Amsler et al. 1995, Quarto et al. 2001). Quarto et al. (2001) have suggested that this represents a temporary situation in areas where the competitively dominant D. aniceps has recently been removed by ice scour. This is consistent with our personal observations (Amsler) of areas that have returned to D. aniceps dominance after previously having been dominated by D. antarctica (e.g., Amsler et al. 1995). At greater depths where ice scour is less common, Cystosphaera jaciquinoti (Map 9) can become co-dominant with or locally replace D. aniceps and/or H. grandifolius (Amsler personal observations, Zieliński 1981, Klöser et al. 1996). The small brown alga, Adenocystis utricularis (Bory) Skottsberg (Map 13) is a pioneer species and can be common in frequently ice scour areas of the very shallow subtidal and in intertidal cracks and crevices (e.g., Neushul 1965, DeLaca & Lips 1976, Zieliński 1994). Although this overall zonation pattern of large brown algae is consistent across the above referenced reports, the maximum reported depths of the macroalgal community and the specific depth zonation ranges of the dominant species vary widely. Clearly, the overall depth range is constrained by available light, with the range extending deeper in relatively exposed areas with clearer, open ocean water compared to relatively protected areas with greater turbidity due to glacial melt and/or with more frequent ice cover (Amsler personal observations, DeLaca & Lips 1976, Brouwer et al. 1995). Zieliński (1990) reported maximum depths of 90–100 m for D. aniceps and H. grandifolius. However, these reports were based on dredged material, not direct observations. It is likely that at least some of the algae collected this way at great depth represent individuals dislodged from shallower water by ice scour, rafted on their rock substrates to greater depths via ice, and

Table 1  Levels of endemism in Antarctic macroalgae (after Wiencke & Clayton 2002; including Hommersand et al. 2011).

<table>
<thead>
<tr>
<th>N. species</th>
<th>N. endemic species</th>
<th>% endemic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhodophyta</td>
<td>80 29 36</td>
<td></td>
</tr>
<tr>
<td>Heterokontophyta</td>
<td>27 12 44</td>
<td></td>
</tr>
<tr>
<td>Chlorophyta</td>
<td>17 3 18</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>124 44 35</td>
<td></td>
</tr>
</tbody>
</table>


2. Biodiversity of Antarctic macroalgae

Our knowledge of the biodiversity of Antarctic macroalgae is still hampered by the limited database available. In particular, a great part of the East Antarctic coast between 45°E and 160°E is certainly under-sampled. Many records are only based on dredged or drift specimens, which are of limited usefulness or are doubtful because they have been sampled only very few times and may have been confused with morphologically similar species. Therefore, a precise estimation of the number of species of Antarctic macroalgae is difficult. Skottsberg (1964) listed 96 species, whereas Wiencke & Clayton (2002) recognised at least 119 species. Only recently, five more species were described (Hommersand et al. 2011). Compared to the temperate and tropical regions of the world this is, however, a low species richness, but in a similar range as in the Arctic (Wulf et al. 2011).

The degree of endemism is high in the Antarctic marine flora (Clayton 1994) with highest degrees in the Heterokontophyta and Rhodophyta (Table 1). Within the Phaeophyceae there is one endemic order, the Ascosereales, comprising one species only, the kelp-like Ascoseira mirabilis Skottsberg (Map 8). The order Desmarestiales has its evolutionary origin in the Southern Hemisphere (Peters et al. 1997) and in Antarctica species of this order occupy the same ecological niche as the order Laminariales (which is absent from Antarctica) in the Northern Hemisphere. There are numerous endemic genera, among the Phaeophyceae: Himantothallus Skottsberg (Map 1), Phaeus Skottsberg and Cystosphaera Skottsberg (Map 9), among the Rhodophyta: Notophybus R.L.Moe, Microrhinus Skottsberg, Hymenocladiopsis R.L.Moe, Nereogrigno Kylin, Antarticothamnion R.L.Moe & P.C.Silva, Gania R.L.Moe, Rhodokrambe R.L.Moe, Lensia R.L.Moe, Austropugelia R.L.Moe and

Varienia R.L.Moe, and among the Chlorophyta: Lambda Delphine (Map 10) and Lola A.Hamel & G.Hamel. Species of most of these genera occur in the Antarctic Peninsula region (West Antarctica) only, Himaunothallus grandifolius (A. & E. Gepp) Zinova and Georgiella confluentis (Reinsch) Kylin (Map 3) occur both in West and East Antarctica, Lola irregularis Zaneveld occurs in East Antarctica only. So West Antarctica is — in contrast to East Antarctica — clearly a macroalgal hotspot. Whether this pattern is the result of incomplete colonisation, incomplete dispersal or not remains to be studied.
Macroalgae Maps 1–6
which remained apparently fresh and healthy in the cold, oxygen-rich Antarctic waters. Attached H. grandifolius has, however, been observed down to 70 m depth on the的操作 vehicle (Wiencke & Bergstrøm unpublished). These observations fit well to estimates based on physiological studies on the minimum light requirements of the Antarctic macroalgae Ulothrix (Demers et al. 1995, 1999a, 1999b).

Several authors have considered why the depth zonation patterns of dominant brown algae vary so much, particularly with respect to the transition between D. anceps and H. grandifolius (Richardson 1979, Klöser et al. 1994, 1996, Brouwer et al. 1995, Quintino et al. 2001). Differential resistance to grazing has been hypothesised to perhaps have a role, but more recent studies have demonstrated that all of these large brown macroalgae are unpalatable to a variety of potential consumers because of the production of chemical defenses (Amsler et al. 2005, 2011, Wiencke & Amsler 2012, R.E. McDowell & Amsler unpublished). D. anceps and D. menziesii appear to be competitively dominant to H. grandifolius under ideal conditions (Klöser et al. 1994) and wave exposure, substrate type, and bottom topography all seem to influence when one versus another species will dominate in a particular location (summarised by Klöser et al. 1996). For example, on areas with moderate or calm wave exposure, H. grandifolius commonly predominates in areas with vertical topography while D. anceps commonly predominates in areas with sloping or horizontal topography (Klöser et al. 1996). However, as discussed by Klöser et al. (1994, 1996), these factors probably do not completely explain the distributions, particularly with respect to the depth at which dominance transitions from D. anceps to H. grandifolius. Indeed, based on personal observations (Amsler) during nearly 650 scuba dives near Palmer Station (East Antarctica, 64°46’S, 64°03’W), general patterns described by Klöser et al. (1996), others do not. For example, in areas with moderate wave exposure and bedrock substrates, one can find gently sloping sites which are dominated by H. grandifolius from less than 10 m depth to well as other sites where D. anceps is the only species dominated by D. anceps over this same depth range. It seems likely that other, yet to be discerned factors also influence these distributions over local scales.

Red macroalgae are reported as common in the western Antarctic Peninsula. Several authors have demonstrated that the red algae Phycodula antarctica and Phaeurus antarcticus dominate in areas of the Vestfold Hills. These species also occur in areas with vertical topography while D. anceps commonly predominates in areas with sloping or horizontal topography (Klöser et al. 1996). However, as discussed by Klöser et al. (1994, 1996), these factors probably do not completely explain the distributions, particularly with respect to the depth at which the transition from D. anceps to H. grandifolius occurs. For example, during nearly 650 scuba dives near Palmer Station (East Antarctica, 64°46’S, 64°03’W), in areas with moderate wave exposure and bedrock substrates, one can find gently sloping sites which are dominated by H. grandifolius. These species also occur in areas with vertical topography while D. anceps commonly predominates in areas with sloping or horizontal topography (Klöser et al. 1996). However, as discussed by Klöser et al. (1994, 1996), these factors probably do not completely explain the distributions, particularly with respect to the depth at which the transition from D. anceps to H. grandifolius occurs. For example, during nearly 650 scuba dives near Palmer Station (East Antarctica, 64°46’S, 64°03’W), in areas with moderate wave exposure and bedrock substrates, one can find gently sloping sites which are dominated by H. grandifolius. These species also occur in areas with vertical topography while D. anceps commonly predominates in areas with sloping or horizontal topography (Klöser et al. 1996).

4. Temperature demands

Antarctic macroalgae are very well adapted to the low seawater temperatures of their environment. This applies especially to endemic Antarctic species such as the Antarctic members of the brown algal order Desmarestiales Desmarestia antarctica, D. anceps and D. menziesii which are adapted to the Antarctic cold-temperate zone. Antarctic macroalgae are characterized by an inability to grow above 10°C. In addition, they have a UST of 13–14°C. The Antarctic isolate of the red algae Phycodula antarctica (Setchell & N.L. Gardner) grow only at 0°C, but not at 5°C and exhibit USTs of 7 and 18°C (Table 2; Gómez et al. 2011). These species grow up to 5°C and exhibit upper survival temperatures (USTs) between 9 and 13°C. The red algae Geogorgia confusa grows up to 10°C and exhibits a UST of 14°C. The red algae Gymnomorpha antarctica grows up to 10°C and exhibits a UST of 14°C. The red algae Gymnomorpha antarctica grows up to 10°C and exhibits a UST of 14°C. The red algae Gymnomorpha antarctica grows up to 10°C and exhibits a UST of 14°C.

The brown algae Ascoseira mirabilis grows up to 10°C but exhibits a UST similar to the above mentioned species. The red algae Gymnomorpha antarctica grows up to 10°C and exhibits a UST similar to the above mentioned species. The red algae Gymnomorpha antarctica grows up to 10°C and exhibits a UST similar to the above mentioned species.

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5. Geographic distribution

5.1. Endemic Antarctic species

Species with a circum-Antarctic distribution include *Himantothallus grandifolius* (Map 1), *Desmarestia menziesii* (Map 2), *Georgiella confuens* (Map 3), *Phycodrys antarctica* (Map 4), the red alga *Phylliphora antarctica* (Map 5) and the intertidal species *Porphyra endivillia* (Map 6). Species occurring in West Antarctica only are *Desmarestia anceps* (Map 7), *Ascoseira mirabilis* (Map 8), *Cystosphaera jacquiniotii* (Map 9), *D. antarctica* (Map 10), *Myriogramme margini* (Map 11) and *Lambia antarctica* (Skottsberg) Delépine (Map 11). *Chaetomorpha mawsonii* A.H.S. Lucas (Map 12) occurs in East Antarctica only.

The northern distribution of six of these species (*Desmarestia anceps*, *D. antarctica*, *Himantothallus grandifolius*, *Georgiella confuens*, *Myriogramme margini*, *Phylliphora antarctica*) is limited by the temperature-growth pattern allowing growth only at temperatures at 5°C or below (Table 2). In the remaining seven species no or not sufficient data on the temperature requirements are available to explain their geographic distribution. As indicated above, their northern boundary may be determined by the temperature demands for reproduction in some cases.

The southern distribution boundaries of endemic Antarctic species are possibly determined by their inability to sustain the long periods under ice cover in almost total darkness or to withstand ice-abrasion. In species, whose reproduction is governed by photoperiod, e.g. in *Himantothallus grandifolius*, *Desmarestia anceps* and *D. antarctica*, the intertidal species *Porphyra endivillia* and *Phycodrys antarctica* (Skottsberg) Delépine (Map 11), *Chaetomorpha mawsonii* A.H.S. Lucas (Map 12) occurs in East Antarctica only.

Table 2 Temperature requirements for growth and survival of endemic Antarctic species and species distributed in the Antarctic-cold temperate region (n.d.: no data; *: higher temperature requirements compared to endemic Antarctic species).

### 5.2. Antarctic-cold temperate species

Species extending from West Antarctica into the cold temperate region are *Adenocystis utricularis* (Map 13), *Gigartina skottsbergii* (Map 14) and *Porphyra plocamiestris* R.W. Ricker (Map 13). Species with a circum-Antarctic cold-temperate distribution include *Plocamium cartilagineum* (Map 15), *Monostroma hariotii* (Map 16), *Palmaria decipiens* (Map 17), *Iridaea cordata* (Map 18), and the intertidal species *Ulva hookeriana* (Map 18) and *Urospora penicilliformis* (Map 19).

*Palmaria decipiens*, *Iridaea cordata*, *Monostroma hariotii* and *Urospora penicilliformis* occur as far south as 77°S. The southernmost location of *Plocamium cartilagineum* is 74°S, 68°S in *Ulva hookeriana*, and 65–66°S in *Adenocystis utricularis*, *Gigartina skottsbergii* and *Porphyra plocamiestris*. These boundaries are certainly determined by the same characteristics as mentioned above for the endemic Antarctic species.

The northern distribution limit of *Palmaria decipiens* is probably a growth boundary located at the 4°C winter isotherm (Wiecnke & tom Dieck 1989). Lethal boundaries seem to limit the Northern distribution of the supra- and eulittoral species *Adenocystis utricularis*, *Urospora penicilliformis* and *Ulva hookeriana* (Wiecnke & tom Dieck 1990). The temperature requirements of *Monostroma hariotii*, *Porphyra plocamiestris* and the northern populations of *Iridaea cordata*, *Gigartina skottsbergii* and *Plocamium cartilagineum* have not been investigated so far. As indicated above, South American populations of these three species probably represent ecotypes or even different species according to molecular data (Hommersand et al. 2011).

### 6. Impact of global climate changes

Several studies were performed on the effect of UV radiation (UVR) on Antarctic macroalgae (Karsten et al. 2011), especially on their spores, which are the most UV-susceptible stages in their life history (Rodea et al. 2007, 2008, 2009, Zacher et al. 2007b, 2009). Therefore, enhanced UVR due to stratospheric ozone depletion may lead to changes in particular in depth distribution and during early succession (Zacher et al. 2007, Campana et al. 2011).

### Table 2

<table>
<thead>
<tr>
<th>Species</th>
<th>Growth range (°C)</th>
<th>UST (°C)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phaseophyceae (brown algae)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ascoseira mirabilis</em> Skottsberg</td>
<td>≤ 10</td>
<td>11</td>
<td>Wiecnke &amp; tom Dieck 1989</td>
</tr>
<tr>
<td><em>Desmarestia anceps</em> Montagne</td>
<td>≤ 5</td>
<td>11-12</td>
<td>Wiecnke &amp; tom Dieck 1989</td>
</tr>
<tr>
<td><em>Himantothallus grandifolius</em> (A&amp;E.Gapp) Zinova</td>
<td>≤ 5</td>
<td>11-13</td>
<td>Wiecnke &amp; tom Dieck 1989</td>
</tr>
<tr>
<td><em>Phaeurus antarcticus</em> Skottsberg</td>
<td>≤ 5</td>
<td>11</td>
<td>Wiecnke &amp; tom Dieck 1989</td>
</tr>
<tr>
<td><em>Phaeophractis red algae</em> (red algae)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Georgiella confuens</em> (Reinsch) Kylin</td>
<td>≤ 10</td>
<td>11</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
</tr>
<tr>
<td><em>Dyemogorgia antarctica</em> Skottsberg</td>
<td>≤ 10</td>
<td>10(15)</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
</tr>
<tr>
<td><em>Myriogramme margini</em> (Gain) Skottsberg</td>
<td>≤ 5</td>
<td>11</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
</tr>
<tr>
<td><em>Pantoneura plocamioides</em> Kylin</td>
<td>≤ 5</td>
<td>9</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
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<tr>
<td><em>Phylliphora ahrifollioides</em> Skottsberg</td>
<td>≤ 10</td>
<td>15</td>
<td>Eggert &amp; Wiecnke 2000</td>
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<tr>
<td><em>Phylliphora antarctica</em> A. &amp; E.Gapp</td>
<td>≤ 5</td>
<td>12</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
</tr>
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<td><em>Phytothorda austrogeorgica</em> Skottsberg</td>
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<td>14</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
</tr>
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<td>Antarctic-cold temperate species</td>
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</tr>
<tr>
<td><em>Adenocystis utricularis</em> (Bory) Skottsberg</td>
<td>≤ 15</td>
<td>18</td>
<td>Wiecnke &amp; tom Dieck 1990</td>
</tr>
<tr>
<td><em>Semimuricaps geminatus</em> (J.D.Hooker &amp; Harvey) Skottsberg</td>
<td>≤ 10</td>
<td>14-15</td>
<td>Wiecnke &amp; tom Dieck 1990</td>
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<tr>
<td><em>Desmarestia confervoides</em> (Bory) M.Ramirez &amp; A.Peters (cold-temperate isolate)</td>
<td>≤ 10</td>
<td>14-15</td>
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<tr>
<td>*Phaeophyceae (green algae) red algae</td>
<td></td>
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</tr>
<tr>
<td><em>Ballia callitricha</em> (C.Agardh) Kützing (Antarctic isolate)</td>
<td>≤ 5</td>
<td>14</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
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<td><em>Delesseaea lanata</em> A.Agardh</td>
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<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
</tr>
<tr>
<td><em>Gigartina skottsbergii</em> Setchell &amp; N.L.Gardner (Antarctic isolate)</td>
<td>≤ 9</td>
<td>13-14</td>
<td>13-14</td>
</tr>
<tr>
<td><em>Palmaria decipiens</em> (Reinsch) R.W.Ricker</td>
<td>≤ 10</td>
<td>16-17</td>
<td>Wiecnke &amp; tom Dieck 1989</td>
</tr>
<tr>
<td><em>Plocamium cartilagineum</em> (Linnaeus) H.L.Dixon (Antarctic isolate)</td>
<td>0</td>
<td>7</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
</tr>
<tr>
<td><em>Rhodochorton purpureum</em> (Lichtfuss) Rosevinge</td>
<td>≤ 10</td>
<td>18</td>
<td>Bischof-Bäsmann &amp; Wiecnke 1996</td>
</tr>
<tr>
<td>Chlorella (green algae)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Acrosiphonia arctica</em> (Dillwyn) Gain</td>
<td>≤ 15</td>
<td>21-22</td>
<td>Wiecnke &amp; tom Dieck 1990</td>
</tr>
<tr>
<td><em>Cladophora corielloeformis</em> Kützing</td>
<td>≤ 12*</td>
<td>n.d.</td>
<td>McLay &amp; Amsler 2006</td>
</tr>
<tr>
<td><em>Prasilla crispa</em> (Lichtfuss) Kützing</td>
<td>≤ 20</td>
<td>24-28</td>
<td>Wiecnke &amp; tom Dieck 1990</td>
</tr>
<tr>
<td><em>Ulothrix eplsea</em> (Kützing) Kützing</td>
<td>≤ 20</td>
<td>25-26</td>
<td>Wiecnke &amp; tom Dieck 1990</td>
</tr>
<tr>
<td><em>Urospora perhififormis</em> (Roth) Ascherson</td>
<td>≤ 15</td>
<td>19</td>
<td>Wiecnke &amp; tom Dieck 1990</td>
</tr>
</tbody>
</table>
Macroalgae Maps 13–14

Map 13
- Adenocystis utricularis
- Porphyra plocamiestris

Map 14
- Gigartina skottsbergii

Map 15
- Urospora penicilliformis
- Plocamium cartilagineum

Map 16
- Monostroma hariotii

Map 17
- Palmaria decipiens

Map 18
- Ulva hookeriana
- Iridaea cordata

As explained above, temperature is one of the most important factors controlling biogeographic distribution of macroalgae. Therefore, shifts in their distribution are related to patterns of changing temperature. These patterns are demonstrated in the geological past e.g. during the last glaciation. At this time, Antarctic species were able to extend their distribution towards the high latitudes (e.g. during the last glaciation). Macroalgae are particularly vulnerable to changes in temperature, which may be provoked by the present period of global warming. Modelled temperature changes through the end of 21st century indicate that many Antarctic macroalgae will, however, probably not strongly alter latitudinal distributions (Müller et al. 2011). But, beside the direct effect of temperature on geographic distribution, there may be indirect effects mediated by milder and shorter periods of sea ice cover, particularly along the southern portion of the western Antarctic Peninsula (Smith & Stammerjohn 2001, Stammerjohn et al. 2008). Such changes are thought to exert a significant additional control on marine communities (Clarke et al. 2007, Ducklow et al. 2007, McClintock et al. 2008). Therefore, macroalgal communities will presumably expand southward due to less strong ice abrasion and improved light conditions, and new ice-free areas appearing due to glacier retreat will be colonised by seaweeds. Beside changes in geographic distribution global warming may also result in changes in zonation patterns. As increasing inflow of turbid meltwater during summer will reduce the light penetration into the water and, hence, elevate the lower depth distribution limits of seaweeds. Increased ambient UV radiation and temperature (Müller et al. 2004). As the solubility of gases concentrations will increase (Fealy et al. 2000, 2004). Impact of seaweed and their performance under elevated CO2 levels as these stages is higher in colder waters, especially polar regions will be strongly affected. Elevated CO2 levels may support photosynthesis (Gordillo et al. 2003), but calcification of calcareous algae will be impaired (Leclercq et al. 2000, McClintock et al. 2009). Further studies are needed here. In this respect special attention has to be paid to the juvenile developmental stages of seaweeds and their performance under elevated CO2 levels as these stages are the most susceptible to environmental perturbations as exemplified for use in experimental studies. (Müller et al. 2008, Roleda et al. 2007, 2008; Zacher et al. 2007a, 2007b).

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References

THE BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

Scope

Biogeographic information is of fundamental importance for discovering marine biodiversity hotspots, detecting and understanding impacts of environmental changes, predicting future distributions, monitoring biodiversity, or supporting conservation and sustainable management strategies.

The recent extensive exploration and assessment of biodiversity by the Census of Antarctic Marine Life (CAML), and the intense compilation and validation efforts of Southern Ocean biogeographic data by the SCAR Marine Biodiversity Information Network (SCAR-MarBIN) provided a unique opportunity to assess and synthesise the current knowledge on Southern Ocean biogeography.

The scope of the Biogeographic Atlas of the Southern Ocean is to present a concise synopsis of the present state of knowledge of the distributional patterns of the major benthic and pelagic taxa and of the key communities, in the light of biotic and abiotic factors operating within an evolutionary framework. Each chapter has been written by the most pertinent experts in their field, relying on vast improved occurrence datasets from recent decades, as well as on new insights provided by molecular and phylogeographic approaches, and new methods of analysis, visualisation, modelling and prediction of biogeographic distributions.

A dynamic online version of the Biogeographic Atlas will be hosted on www.biodiversity.aq.

The Census of Antarctic Marine Life (CAML)

CAML (www.caml.aq) was a 5-year project that aimed at assessing the nature, distribution and abundance of all living organisms of the Southern Ocean. In this time of environmental change, CAML provided a comprehensive baseline information on the Antarctic marine biodiversity as a sound benchmark against which future change can reliably be assessed. CAML was initiated in 2005 as the regional Antarctic project of the worldwide programme Census of Marine Life (2000-2010) and was the most important biology project of the International Polar Year 2007-2009.

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The SCAR Marine Biodiversity Information Network (SCAR-MarBIN)

In close connection with CAML, SCAR-MarBIN (www.scarmarbin.be, integrated into www.biodiversity.aq) compiled and managed the historic, current and new information (i.a. generated by CAML) on Antarctic marine biodiversity by establishing and supporting a distributed system of interconnectable databases, forming the thematic regional node of the Ocean Biodiversity Information System (OBIS, www.iobis.org), under the aegis of SCAR (Scientific Committee on Antarctic Research, www.scar.org). SCAR-MarBIN established a comprehensive register of Antarctic marine species and, with biodiversity.aq provided free access to more than 2.9 million Antarctic georeferenced biodiversity data, which allowed more than 60 million downloads.

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