

Census of Antarctic Marine Life  
SCAR-Marine Biodiversity Information Network

# BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

► **CHAPTER 5.29. SOUTHERN OCEAN BENTHIC DEEP-SEA BIODIVERSITY  
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# THE BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

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## 5.29. Southern Ocean benthic deep-sea biodiversity and biogeography

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### 1. Introduction

The deep sea is the largest environment on Earth though it is the least well known. In the Southern Ocean (SO) the deep sea covers 34.8 million km<sup>2</sup>, the abyssal area about 27.9 million km<sup>2</sup> (Clarke & Johnston 2003). Most of our knowledge on abyssal benthic deep-sea fauna in the Weddell Sea available to date, is based on ANDEEP I–III (ANTarctic benthic DEEP-sea biodiversity: colonisation history and recent community patterns) expeditions, which was the most extensive biological deep-sea survey in the SO, incorporating 41 biological, sedimentological and geological stations in 2002 and 2005 (Brandt & Hilbig 2004, Brandt & Ebbe 2007, Brandt *et al.* 2007a, b, c) and documenting high SO deep-sea biodiversity. In many taxa far more than 90% of species collected are new to science, however, the high degree of “apparent” endemism reflects undersampling of the area.

The SO deep-sea fauna does not differ in composition, at the higher taxonomic level, from that of other deep-sea regions of the world oceans. For some taxa, like Foraminifera, close links at the species level occur between deep Weddell Sea faunas and those from similar depths in the North Atlantic and Arctic. This might be due the SO deep-water production fuelling the world oceans with freshly produced organic matter and possibly transporting early developmental stages northwards due to a missing thermocline. The vertical zonation of many taxa from the shelf edge into deep-water layers is facilitated due to the almost isothermal water column and leads to faunal exchanges as demonstrated by taxa displaying polar submergence into the deep sea or emergence onto the Antarctic shelf. Holocene climate changes led to an increased eurybathy of many SO invertebrate taxa, and faunal changes between shelf and deep-sea occur deeper than elsewhere (1500–2500 m). On the Antarctic shelf the organisms are isolated at the present day, whereas in the SO deep sea the connectivity to adjacent deep-sea basins is high as the water-mass characteristics do not differ very much and there are usually no topographic or hydrographic barriers hampering faunal exchange, reflected by a lower degree of endemism than on the shelf (Kaiser, chapter 5.18, this volume). Thus, the present paper focuses on the less well known organisms at bathyal and abyssal depths occurring usually lower than ~3000 m depth.

### 2. Biodiversity

Large-scale biodiversity and biogeography patterns largely depend on size, biology (feeding mode and reproductive strategies) and mobility of the taxa investigated combined with historical/geologic (evolutionary) processes, productivity (environmental gradients), predation and the relationship between regional and local species diversity (Witman *et al.* 2004 and references therein). Patterns in the biodiversity are highly diverse and biogeography of SO deep-sea meio-, macro- and megafaunal taxa differ. Large-scale biodiversity in the deep sea exhibits a strong poleward decline in the northern hemisphere (Poore & Wilson 1993, Rex *et al.* 1993). However patterns in the southern hemisphere have been shown to be different (Brey *et al.* 1994, Brandt *et al.* 2007b). Intensive investigations since 2002 in the SO during the ANDEEP I–III expeditions (Photo 1) and since 2008 during the ANDEEP-SYSTCO (SYSTem COupling) expeditions reveal that, for some taxa, biodiversity in the

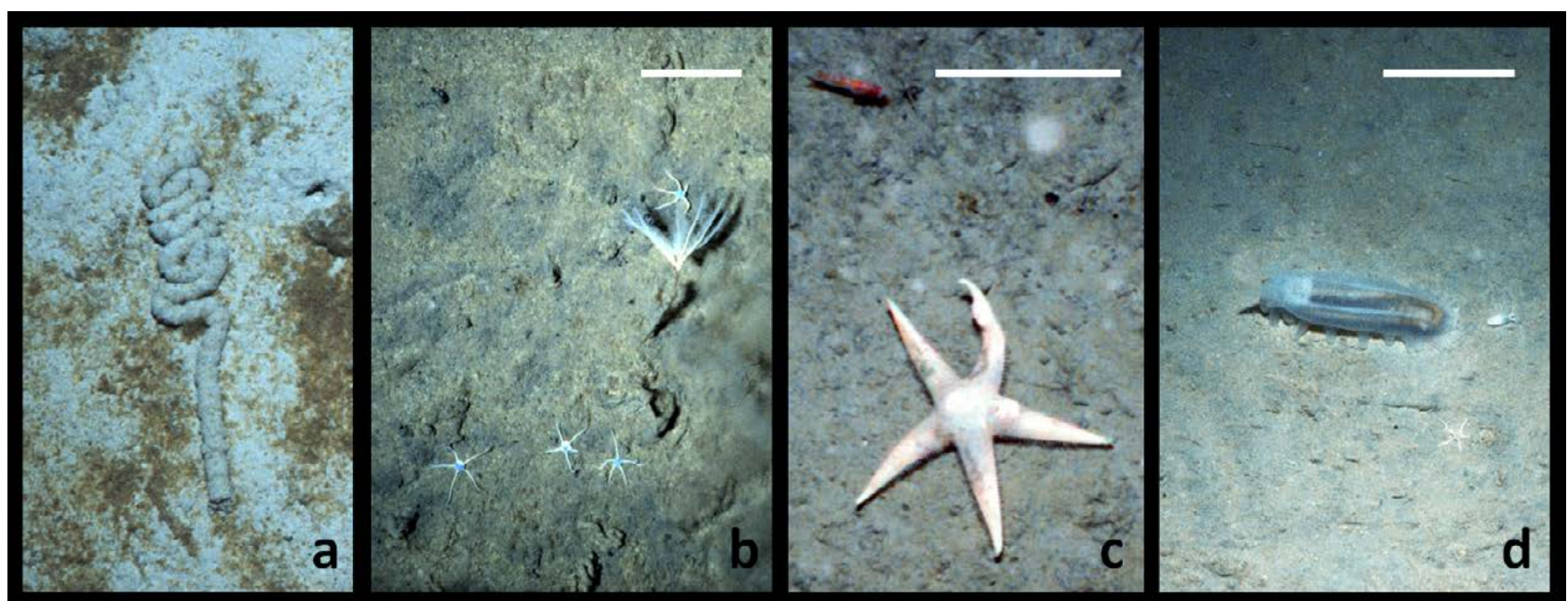
deep SO is highest around 3000 m, and species accumulations curves in the SO deep sea are far from levelling off (Brandt *et al.* 2007a, b, Brandt *et al.* 2009), possibly because >50% of these appear to be rare (Glover *et al.* 2002, Brandt *et al.* 2007a–c, Brandt *et al.* 2012). Due to the sampling bias in the SO deep sea and intensive sampling in the framework of major international projects (ANDEEP, ANDEEP-SYSTCO and BIOPEARL expeditions), most species distributions throughout all size classes are in the deep Scotia Sea, the Weddell Sea and the Amundsen and Bellingshausen Sea (see Maps 1–15; Brandt *et al.* 2007, 2012; Kaiser *et al.* 2009, 2013, Linse *et al.* in press).

### 2.1. Meiofauna

The deep-sea meiofauna (protists and metazoans in the 32–1000 µm size range) is usually dominated by foraminiferans and nematodes, followed by harpacticoid copepods, and other minor taxa (Vincx *et al.* 1994), though our knowledge of these taxa below 3000 m is anecdotal (Maps 1–2). For Foraminifera, published values range from a few percent to more than 90% of the total meiofaunal abundance, but when the rarely studied soft-shelled taxa are included, the proportion of Foraminifera usually exceeds 50% (Gooday 2001). In the western Weddell Sea Foraminifera typically made up 60% to 78% of the meiofauna between 1100–5000 m depth (Cornelius & Gooday 2004) and assemblages comprise a mixture of calcareous, agglutinated and organic-walled taxa resembling those from similar depths in the North Atlantic. Cornelius and Gooday (2004) recognised 158 live foraminiferan species in the western Weddell Sea where diversity indices were highest, and dominance lowest at 3000 m and 4000 m. Komokiaceae are as abundant and diverse in the central Weddell Sea as they are on other abyssal plains (Gooday *et al.* 2007a). Gooday *et al.* (2007b) described three new komokiacean species, including a new genus (*Skeletonia*). Gromiids are also quite widespread and diverse in the Weddell Sea (Gooday *et al.* 2006). New species and the deepest (4392 m) have recently been published by Rothe *et al.* (2009).

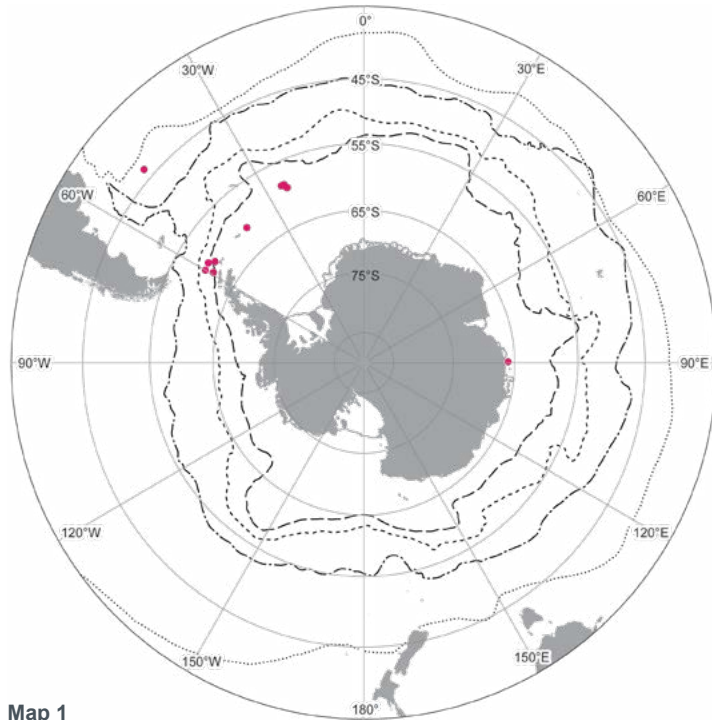
29 taxa have been reported from the SO, with between 3 (Gutzmann *et al.* 2004 and references therein) and 22 coexisting in individual samples. Nematodes comprising 83 and 97% of the total metazoan meiofauna in the Weddell Sea compared to 56 and 97% in the Ross Sea (Fabiano & Danovaro 1999). 204 nematode genera have been recognised, and between 21 (4850 m, Weddell Abyssal plain) and 73 (1000 m, Drake Passage) occur at each station. At the South Sandwich Trench floor (6300 m), 34 nematode genera were counted. Genus diversity is negatively related to depth at several sites studied (Vanhove *et al.* 2004). Studies on species diversity of a number of selected nematode genera (e.g. De Mesel *et al.* 2006, Ingels *et al.* 2006) suggest very high local and regional species diversity, for example, off Vestkapp 23 species of the genus *Acantholaimus* occurred at 2000 m documenting a high species turnover between sites (beta-diversity).

The second most abundant group is the harpacticoid Copepoda and some new harpacticoid species described from the SO deep sea (e.g. Willen 2009). Other taxa regularly found in SO marine sediments include Polychaeta, Kinorhyncha, Ostracoda, Loricifera, Gastrotricha, Tardigrada and Bivalvia.

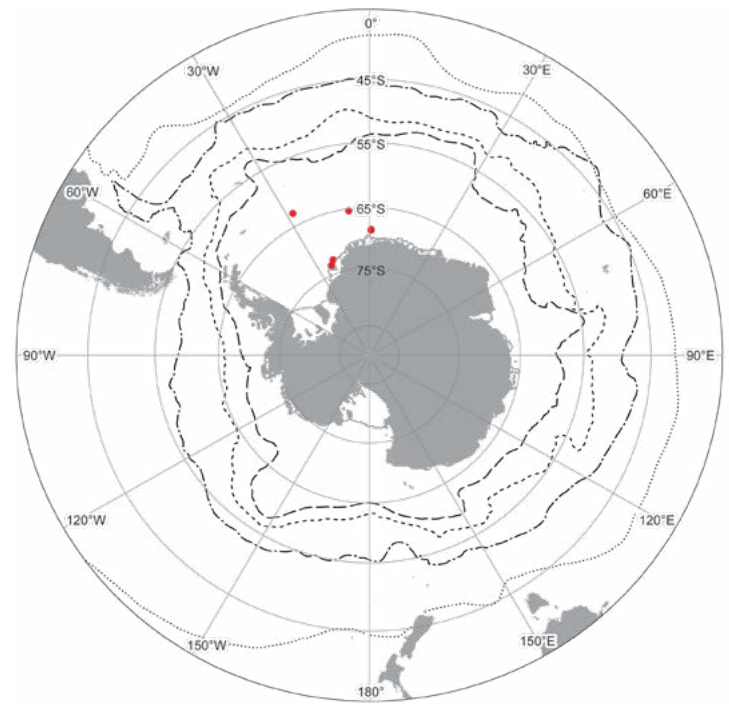


**Deep-Sea Biogeography Photo 1** Examples of Antarctic deep-sea organisms photographed in situ. (a) worm trace, ANDEEP I, stn. 137-4, S of Scotia Arc, 4977 m. (b) Stalked crinoid and opirioids, ANDEEP I, stn. 142-1, E of Scotia Arc, 6355 m. (c) Unidentified starfish and shrimp-like crustacean, ANDEEP I, stn. 046-2, NE of Elephant Island, 2886 m. (d) Elaspod holothurian, ANDEEP I, stn. 043-1, N of Elephant Island, 3958 m. Images © Robert J. Diaz, Virginia Institute of Marine Science. White lines represent a 10 cm scale (unknown scale for picture a).

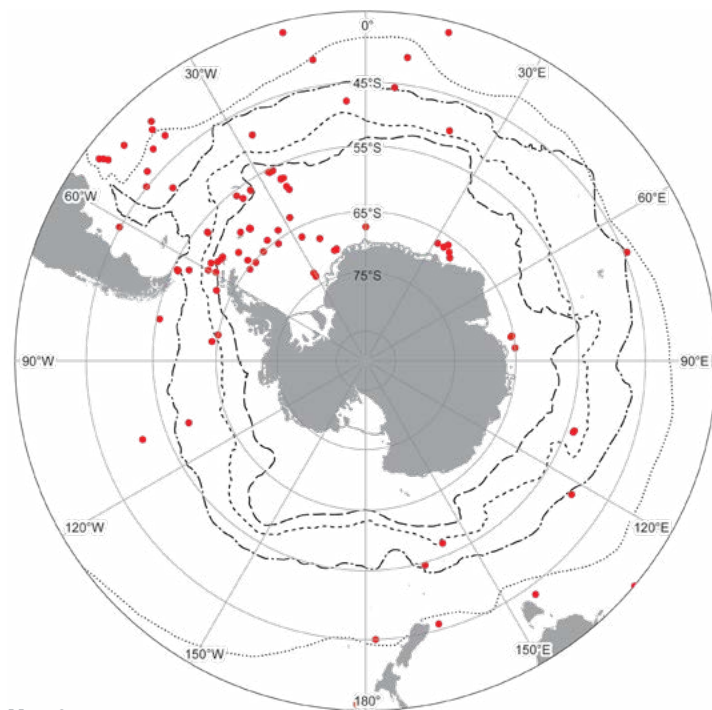




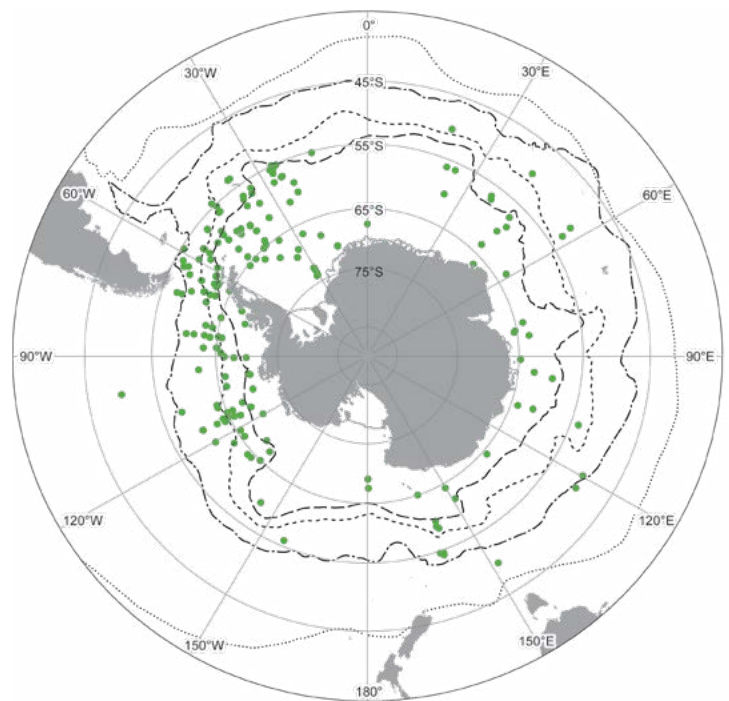
**Map 1**  
● Nematoda



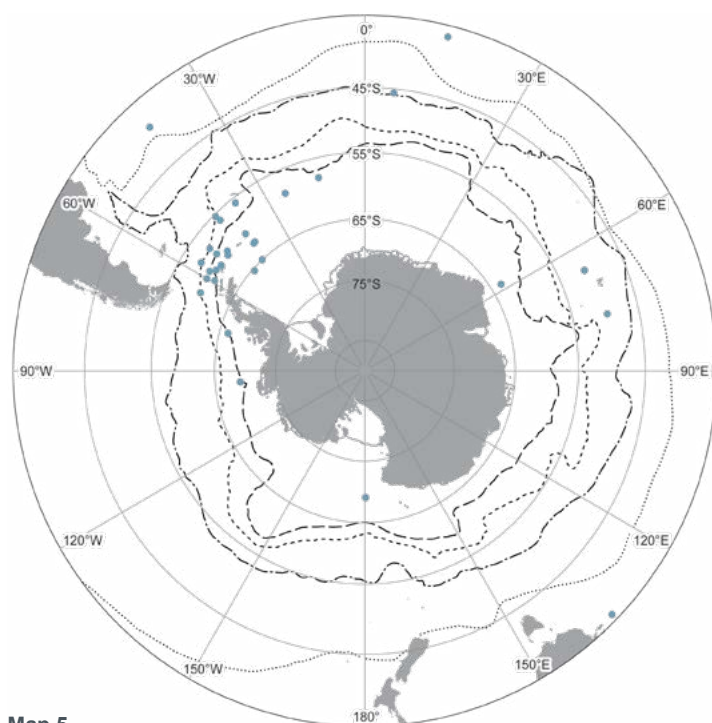
**Map 2**  
● Harpacticoida



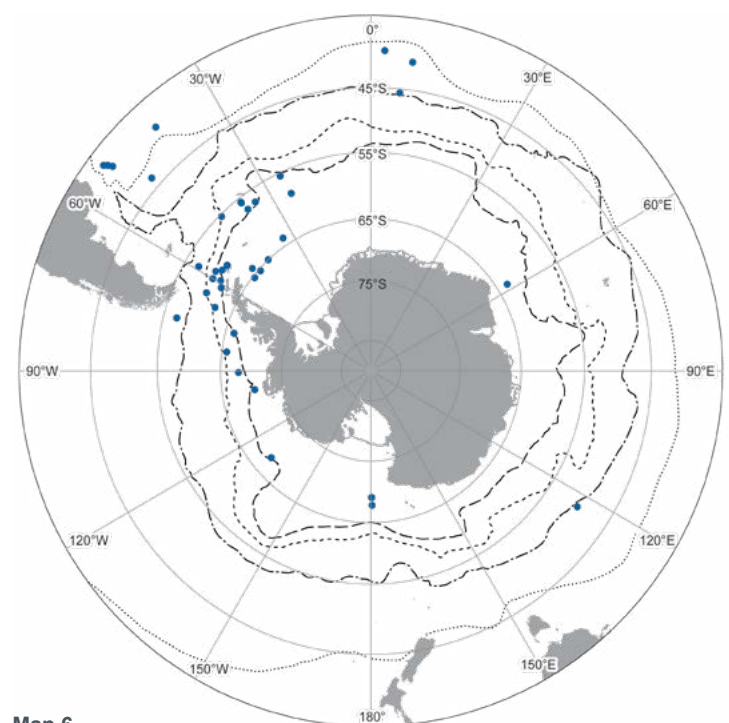
**Map 3**  
● Isopoda



**Map 4**  
● Polychaeta



**Map 5**  
● Gastropoda (shelled)



**Map 6**  
● Bivalvia

**Deep-sea Biogeography Maps 1–2** Maps documenting the knowledge of distribution of species of the meiofauna below 3000 m depth as a consequence of the lack of taxonomists for many taxa as well as the availability of samples. Map 1. Nematoda. Map 2. Harpacticoida. **Map 3–6** Maps documenting the knowledge of distribution of species of the macrofauna below 3000 m depth. Map 3. Isopoda. Map 4. Polychaeta Map 5. Gastropoda. Map 6. Bivalvia.



## 2.2. Macrofauna

Macrofaunal diversity differs across taxa. Decapod crustaceans became impoverished at high latitudes since the Tertiary climatic deterioration, and brachyuran crabs probably became extinct ~15 million years ago (Thatje *et al.* 2005). Within peracarid crustaceans Isopoda are an important component and comprised 35% of all Peracarida sampled and 674 isopod species were identified from the ANDEEP material, 89 (13%) of these were known, others (585 species) were new to the area or new to science and 43 genera were recorded for the first time. Asellota comprised 97% of all ANDEEP Isopoda and 87% of the SO deep-sea Isopoda appear to be “endemic” (Brandt *et al.* 2007b). Within the Asellota, the Munnopsidae were the most dominant isopod family with 50% of the specimens from all ANDEEP stations distributed among 219 species, 31 genera and 8 subfamilies (Malyutina & Brandt 2007). Other important families were the Desmosomatidae 113 species (16.8%), Haploniscidae with 90 (13.4%), Nannoniscidae with 49 (7.3%), Ischnomesidae with 47 (7.0%), and Macrostylidae with 33 (4.9%) species (Brandt *et al.* 2007c, Riehl pers. comm.). Families like the Paramunnidae (11 species) and Munnidae (12 species) were less diverse in the deep sea, as were species of the suborder Scutocoxifera (e.g. the Valvifera with 6 species), and Serolidae (with 3 species). Depth was the most important factor determining isopod communities, and abundance and diversity are highest around 3000 m (83 species) in Isopoda. Russian SO deep-sea isopoda data were summarised by Malyutina (2003, 2004). Isopods brood what limits their dispersal capacities and might lead to evolution of species in situ at bathyal or abyssal depths (Brandt 1991, Raupach *et al.* 2009 and references therein). Isopod species occurrences below 3000 m is illustrated (Map 3).

Monophyly of most asellote families suggest multiple colonisation of the deep sea (Raupach *et al.* 2009). Haploniscidae indicate an impressive radiation, cryptic species were identified in the SO deep sea, for example the *Haploniscus cucullus* complex (Brökeland & Raupach 2008), within Acanthaspidiidae (*Acanthaspidia drygalskii*, Raupach & Wägele 2006) and Munnopsidae (*Betamorphus fusiformis*, Raupach *et al.* 2007, *Eurycope complanata*, *E. iphthima*, Wilson & Hessler 1987 and references therein). These speciation processes resemble adaptive radiations of the shelf families Antarcturidae and Serolidae (Brandt 1991) and amphipod families Epimeriidae and Iphimediidae (Watling & Thurston 1989).

Amphipod crustaceans are among the most speciose taxa in Antarctic coastal and shelf communities (De Broyer *et al.* 2007) and more than 17,500 amphipod specimens were collected during the ANDEEP expeditions (Brandt & Ebbe 2007). In the SO deep sea, below 1000 m, 53 scavenger species (De Broyer *et al.* 2006 and references therein), mostly belong to the Lysianassoidea including 42 species from 19 genera and 9 families.

Tanaidacea are known with 55 species from the SO deep sea (Błażewicz-Paszkowycz chapter 5.19, this volume), of Cumacea only five species occur deeper than 1000 m and of SO ~18 species occur ≥1000 m depth.

Hilbig (2001) investigated 800 individuals of SO polychaetes belonging to 115 species in 28 families from depths >1000 m. Cirratulids (13 species) were most speciose, followed by ampharetids (11 species), terebellids (9 species), paraonids (8 species) and maldanids (8 species). Spionids and capitellids were poorly represented (6 and 2 species), as the highly vagile polynoids, and motile nephtyids and glycerids (Hilbig *et al.* 2006 and references therein). Quantitative investigations indicate that abundance and species richness on average tend to be lower than on the slope in the Weddell and Scotia Seas (Ellingsen *et al.* 2007). Schüller *et al.* (2009) attributed 11,000 individuals of ANDEEP III polychaetes to at least 241 species in 46 families. SO polychaete species seem to have broad distribution ranges below 2000 m depth, thus, sediment composition and sedimentation rate may determine polychaete distribution patterns rather than depth. Polychaete species occurrences below 3000 m is illustrated (Map 4).

270 molluscan macrofaunal species inhabit the SO deep sea. With 150 macrofaunal morphospecies belonging to 37 families, gastropods are the dominant group (e.g. Schrödl 2006, Schwabe & Engl 2008) in terms of species numbers (Map 5), followed by bivalves (Map 6) (82 species from 17 families; Linse *et al.* 2006 and references therein, Schwabe *et al.* 2007a, b). Aplacophoran species are quite common with 6 species of Caudofoveata and 15 of Solenogastres. 7 species of scaphopods, and 2 species of polyplacophorans are known. While most of the bivalve and scaphopod species show a wide distributional range, gastropod species don't (Linse *et al.* 2006, Schwabe *et al.* 2007). For the monoplacophoran *Laevipilina antarctica* bathymetric range increased from 210–644 m to over 3000 m (Schrödl *et al.* 2006). The only polyplacophorans *Leptochiton kerguelensis* and *Stenosemus simplicissimus* occur on the upper continental slope in the Ross and Weddell Seas (Linse *et al.* 2006, Schwabe 2008). Antarctic abyssal buccinoids share no genera with sublittoral or bathyal faunas (Harasewych & Kantor 2004). The deep-sea bivalve fauna is dominated by taxodont taxa, especially of the Nuculanidae and Limopsidae, but carnivorous genera like *Cardiomya* and *Cuspidaria* are also present.

## 2.3. Megafauna

>26 taxa are recognised among the megafauna of the SO deep sea, and echinoderms dominate in terms of abundance, biomass and species richness. Holothurians are more diverse than ophiuroids, asteroids and echinoids (Maps 7–11).

In general, the SO deep-sea megafauna can be divided into three major groups defined by their lifestyles: 1) errant benthopelagic species, 2) errant benthic species and 3) sessile species.

1) The benthopelagic species comprise large scavenging amphipods, deep-water shrimp-like decapods, octopods and bottom-living fish. Of Lithodidae, decapod crabs, 18 species occur in the SO (Thatje *et al.* 2005, Ah Yong & Dawson 2006). Griffiths *et al.* (2013: 1) documented that “there is no evidence for a modern-day “crab invasion”. Recolonisation of the continental shelf might have occurred via the deep sea and there is evidence of recent speciation amongst taxa on isolated seamounts and islands.

2) The cephalopods are the sole megafaunal molluscan class in the SO. 11 of the 36 known octopus species have been reported from the SO deep sea and deep-sea relationships were analysed (Strugnell *et al.* 2008a, b and references therein).

The five classes of the echinoderms, the Ophiuroidea, Asteroidea, Echinoidea, Crinoidea and Holothuroidea, are the dominant errant megafaunal taxa in the SO deep sea. Of 35 regular SO Echinoidea, 31 species are reported from the shelf and 16 from the deep sea (e.g. Poulin *et al.* 2002 and references therein), four of these are endemic to the deep, 12 show eurybathy. Twenty irregular species are known from the SO deep sea, half of them endemic (Linse *et al.* 2008). Brooding has been observed in both regular cidaroid and irregular sea urchins (Pearse *et al.* 2009 and references therein). Remarkable is the occurrence of stalked crinoids from the upper slope to abyssal depth, for example, *Bathycrinus*, *Hyocrinus* and possibly *Rhizocrinus* (Bohn 2006). Holothuroidea of the SO comprise just over 100 species (Clarke & Johnston 2003), large sized, epibenthic elasipodid holothurians occur in almost all deep-water trawls (~30 elasipodid morphospecies in the deep sea), while small, infaunal apodids are less well reported (Bohn 2006). During the three ANDEEP expeditions at least 40 species belonging to 26 genera of holothurians were collected (Bohn 2006).

3) The most diverse components of the sessile megafauna are anthozoan taxa including the Alcyonaria, Pennatularia and Actinaria (Map 12), while sponges (Map 13) are important in terms of biomass. Rare in occurrence and biomass are bryozoans (Map 14), stalked ascidians and stalked crinoids, with the exception of two sites recently discovered in the Weddell and Bellingshausen Seas, where dense beds of stalked crinoids were discovered (Bohn 2006).

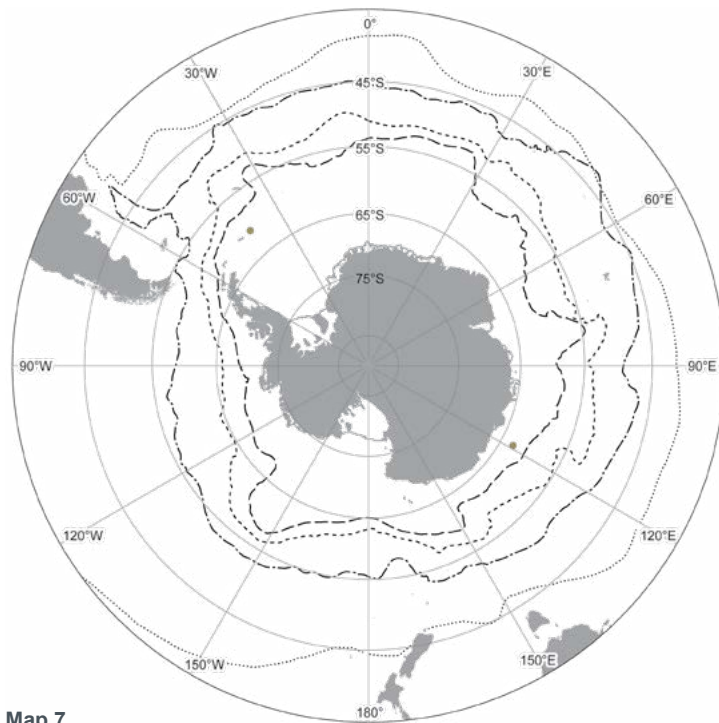
Of the phylum Porifera (see Janussen & Downey, chapter 5.5, this volume) the most diverse group is the Demospongiae with about 420 Antarctic species followed by the Hexactinellida (~60 spp.) and the Calcarea (~25 spp.) (Brandt *et al.* 2007b). About 100 demosponge species, 40–45 hexactinellid species belonging to 15 genera and 5 families (Farreidae, Euretidae, Euplectellidae, Rossellidae and Lanuginellinae) and 10–15 Calcarea were sampled below 1000 m (Janussen & Tendal 2007, Janussen & Reising 2009 and references therein). The Calcarea had been undiscovered in the SO deep sea prior to the ANDEEP expeditions (Rapp *et al.* 2011). In the deep Weddell Sea 21 species of hexactinellids, 47 species of demosponges and 7–8 species of Calcarea were collected. 49% of these species were new to Antarctica and 22 % new to science (Janussen & Tendal 2007). Most specimens from the slope down to about 2500 m depths are representatives of known, eurybathic SO shelf species, like the hexactinellids *Bathydorus*, *Caulophacus* and *Chonelasma*. The bathyal slope poriferan fauna is characterised by a mixture of shallow-water and deep-sea species, below 3000 m typical deep-sea sponge associations can be found, consisting to almost 50% of the carnivorous demosponge family Cladorhizidae (Janussen & Tendal 2007). Noteworthy are also records of several species of Calcarea from abyssal depths, down to >4000 m in the Weddell Sea (Rapp *et al.* 2011) (Map 13).

Only seven cnidarian species are endemic to the SO deep sea (Peña Cantero 2004). The SO actinarian fauna includes 76 species of which 28 are endemic to the region and 21 occur in the deep sea (6 are endemic; Rodriguez *et al.* 2007). Rodriguez *et al.* (2009) described the new, bipolar actinarian family Antipodactidae with *Antipodactis scotiae* from the deep Scotia Sea.

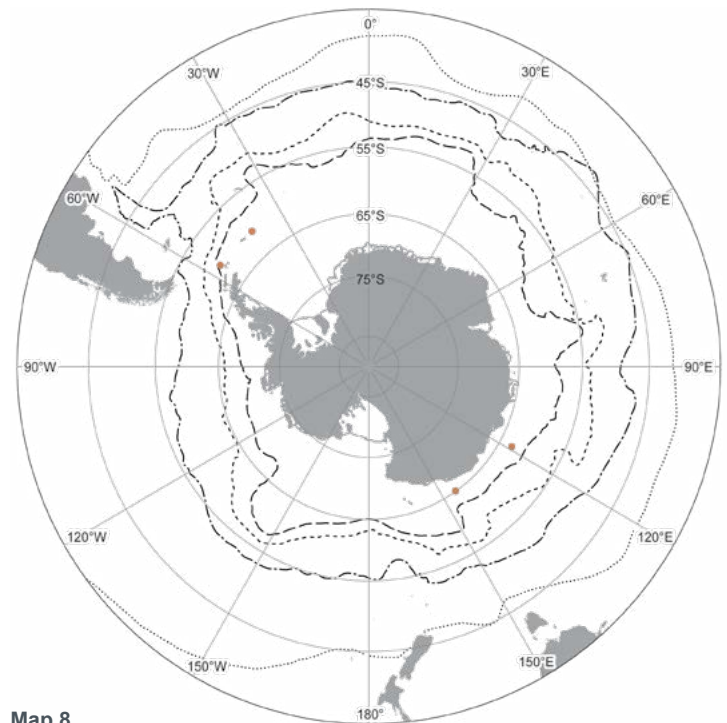
Ascidians are an ecologically important component of the Antarctic shelf fauna and comprise approximately 120 species (Clarke & Johnston 2003), however, data on their species richness are unavailable for the SO deep sea. In the abyssal depths of the Weddell Sea solitary and colonial stalked ascidians similar to the genera *Octacnemus* and *Megalodicopia*, typical deep-sea ascidians, occurred in most trawls.

## 3. Bathymetric and zoogeographic distribution

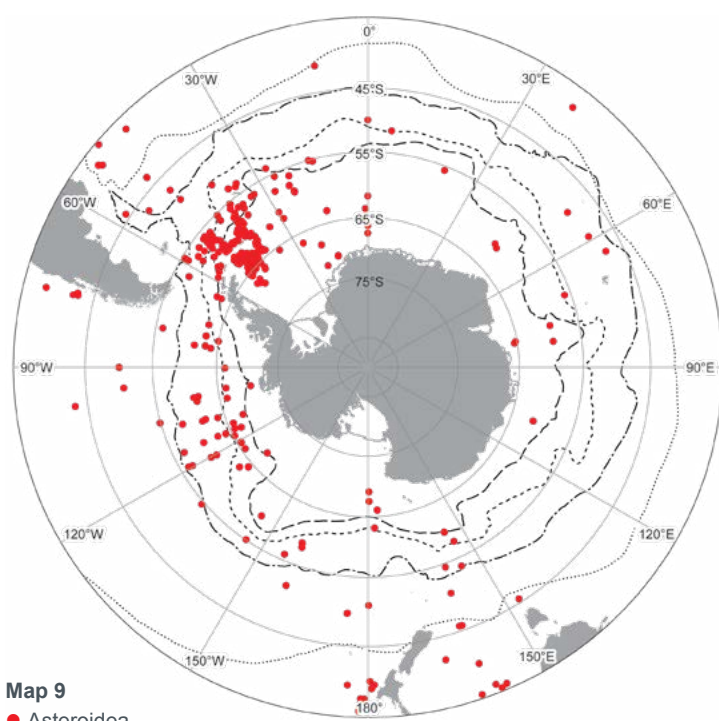
The shelf and slope seabeds are topographically isolated from areas north of the SO and the deep sea is the only area with potential for strong polar-global ocean connectivity (Brandt *et al.* 2007, Pearse *et al.* 2009). The recent proposed biogeography of the deep ocean floor (Watling *et al.* 2013: 92) “adopted the concept that changes in key ecological (chemical, physical, environmental) parameters, as well as water-mass connectivity, drive the turnover and distribution of marine species and communities”. This paper contains important summary information depth, about temperature, salinity, bottom dissolved oxygen and POC flux to the deep sea, however, ignores the strong evolutionary histories based on plate tectonics including palaeogeology and palaeoceanography (e.g. Brown *et al.* 2006) which have probably shaped the present patterns of species occurrences as much as (if not more than) ecological forcing factors. Both, bathyal and abyssal deep-sea benthos is still very poorly sampled and most of the fauna remains undescribed because of



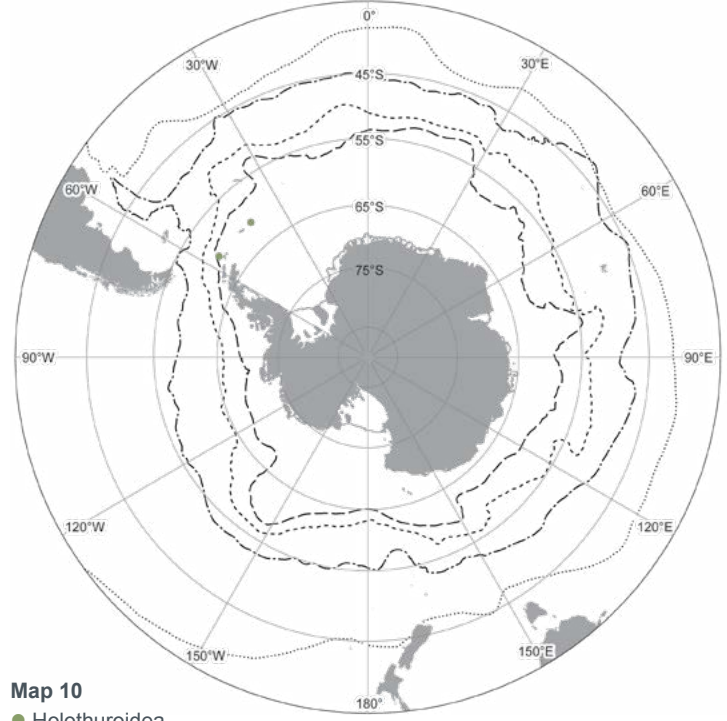
**Map 7**  
● Crinoidea



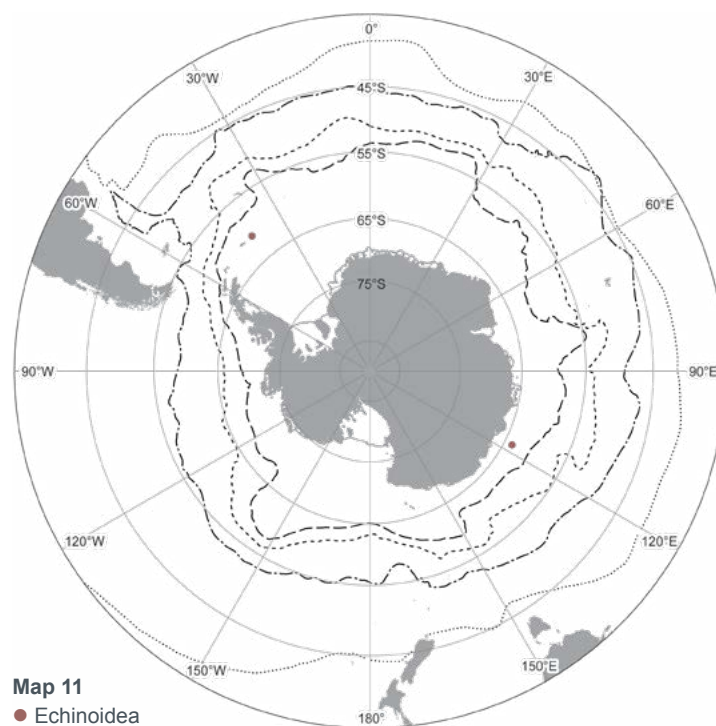
**Map 8**  
● Ophiuroidea



**Map 9**  
● Asteroidea



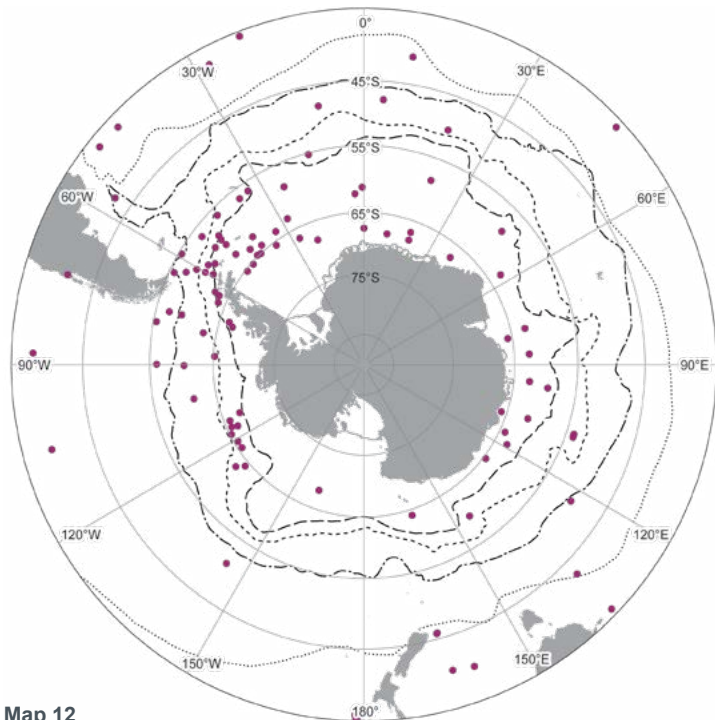
**Map 10**  
● Holothuroidea



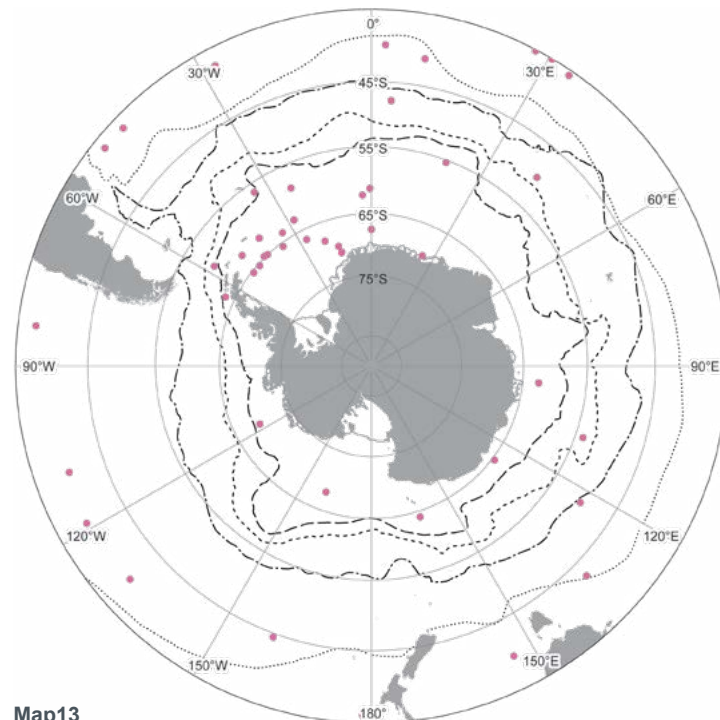
**Map 11**  
● Echinoidea

**Deep-sea Biogeography Maps 7–11** Maps documenting the knowledge of distribution of echinoderm species (megafauna) below 3000 m depth. Map 7. Crinoidea. Map 8. Ophiuroidea. Map 9. Asteroidea. Map 10. Holothuroidea. Map 11. Echinoidea. Asteroidea are worked up best from these depths.

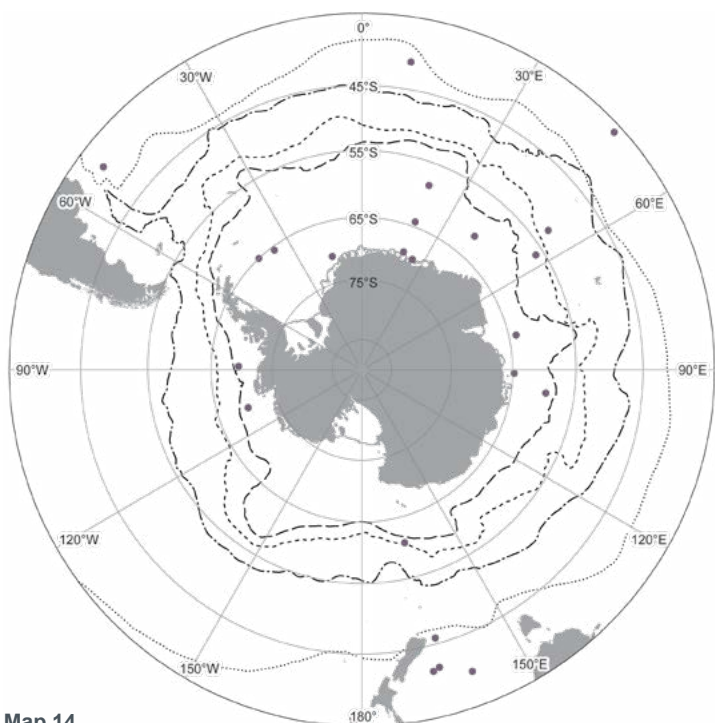




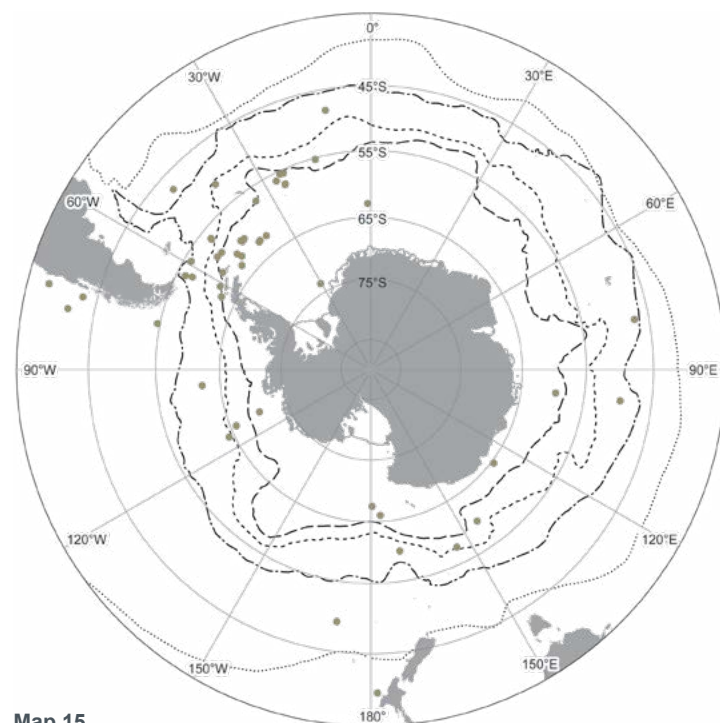
**Map 12**  
● Cnidaria



**Map 13**  
● Porifera



**Map 14**  
● Bryozoa



**Map 15**  
● Pycnogonida

**Deep-sea Biogeography Maps 12–15** Maps documenting the knowledge of distribution of species of the megafauna below 3000 m depth. Map 12. Cnidaria. Map 13. Porifera. Map 14. Bryozoa. Map 15. Pycnogonida.

high species richness and very limited taxonomic descriptions of the fauna (e.g., Rex and Etter, 2010), but >90% of the abyssal macrofaunal species sampled at any single site in the abyssal Atlantic and Pacific typically are new to science (Ebbe *et al.*, 2010). For the Southern Ocean, recent summary papers of the Census of Antarctic Marine Life (CAML) as well as data from the ANDEEP expeditions are not included in Watling's *et al.* (2013) analysis, therefore some important patterns of meio-, macro and megafauna are outlined in the following.

### 3.1. Meiofauna

Mikhalevich (2004) noted that wide bathymetric ranges are characteristic of Antarctic Foraminifera with some deep-water species emerging into the upper bathyal zone and onto the shelf. A number of species occurred from 200 m to more than 3000 m depth. Molecular data (SSU rRNA gene sequences) from a depth transect in the South Sandwich Trench of the allogromiid *Bathyallogromia weddellensis* show almost identical sequences between 1080 m and 6330 m water depth in the Weddell Sea, suggesting a substantial degree of eurybathy of these populations.

A high degree of genetic similarity also exists between deep-water populations of the calcareous species *Epistominella exigua*, *Cibicides wuellerstorfi* and *Oridorsalis umbonatus* from the Southern, North Atlantic and Arctic Oceans (Pawlowski *et al.* 2007a). Moreover, the small-subunit (SSU) and internal transcribed spacer (ITS) rDNA sequences of populations of *E. exigua* from the western Pacific Ocean were almost identical to those from these other

oceans (Lecroq *et al.* 2009). Similar connections exist around the Antarctic continent. Pawlowski *et al.* (2007b) report that populations of *Epistominella vitrea* from <30 m depth in McMurdo Sound and from >1000 m depth on the opposite side of the continent in the Weddell Sea have almost identical SSU and ITS rDNA sequences. Similarly, populations of two monothalamous taxa, *Micrometula* sp. and *Gloioigullmia* sp., from the deep Weddell Sea (6329 and 4749 m water depth respectively) and McMurdo Sound (<30 m) are more closely related genetically than they are to Northern Hemisphere populations. These results document the connectivity between populations of foraminiferal species from parts of the SO that are widely separated, both geographically and bathymetrically.

Within the metazoan meiofauna many taxa (e.g. Copepoda and Tardigrada) show the same general pattern of decreasing densities with increasing water depth. However there is no correlation between the depth and the abundance of the Loricifera and Tantulocarida, and there is only a positive correlation of low significance in the case of the Gastrotricha (Gutzmann *et al.* 2004). In the South Sandwich Trench, Vanhove *et al.* (2004) found the same genera between 750 and 6300 m water depth. However a shift in dominance enabled them to distinguish between a 'shallow' community (750–1100 m) characterised by *Daptonema*, *Dichromadora*, *Molgolaimus* and the families Comesomatidae, Cyatholaimidae and Desmodoridae, and a 'deep' community (4000–6300 m) characterised by the genus *Tricoma*. The intermediate stations (2000 and 3000 m) formed a transit between these two assemblages.



### 3.2. Macrofauna and Megafauna

At generic level there are many similarities between SO species and those from the world oceans (Clarke & Johnston, 2003). A few taxa are rare (e.g. decapod crustaceans), whilst others (e.g. pycnogonids (Map 15) and peracarid crustaceans) appear to be richer than in other areas. The low species numbers of the Decapoda are regarded to be a reason for the success of the brooding peracarid crustaceans in the SO. See species numbers. The size of the SO abyss, coupled with great age and stability may explain high species richness in many taxonomic groups.

Many species of Asellota are more speciose in the deep sea than on the shelf. For example, 45 species of Munnopsidae are described from the SO shelf; in the deep-sea 219 species were observed (Malyutina & Brandt 2007). An investigation of the vertical distribution of the Isopoda revealed for example that Macrostylidae were recorded at depths down to 10,730 m, Acanthaspidiidae and Antarcturidae down to 7200 m, Munnopsidae to 9345 m, Haploniscidae to 6348 m and Ischnomesidae to 6071 m (Brandt *et al.* 2009). Most of the asellotan families lack eyes (except for Janiridae, Munnidae, Paramunnidae), thus speciation and radiation in the SO deep sea and subsequent emergence likely has occurred within these taxa (polar emergence). Serolidae (50 shelf and few deep-sea species) and Valvifera (90 shelf and 6 deep-sea species, mainly Antarcturidae) are examples for polar submergence. Both families are more frequently found down to approximately 1500 m, in contrast stations deeper than 2000 m are characterised by deep-sea asellote isopods (98%).

Values of apparent SO deep-sea endemism (likely biased due to the low sampling effort) are similar to those of the shelf in some taxa (88%, Brandt *et al.* 2007b). With the exception of the benthopelagic amphipod species exhibiting a larger distribution (e.g. *Eurythenes gryllus*, *Paralicella similis*, *Paracallisoma* cf. *alberti*, *Parandania boeckii*), all but 10 of the strictly benthic deep-sea species are restricted to the SO. Within Tanaidacea 29% of the deep-sea species are endemic (Błażewicz-Paszkowycz pers. comm.), and cumaceans show 95% endemism in the SO (Mühlenhardt-Siegel pers. comm.). 18% of the 59 SO species of Mysidacea are known from the deep sea (Brandt *et al.* 1998).

Some amphipod species show eurybathy, like *Eurythenes gryllus*, however, it has been found in both Polar Regions at bathyal and abyssal depths and consists of cryptic species (France & Kocher 1996; Havermans *et al.* 2013).

Polychaetes, unlike other taxa, have wide geographical ranges (Schüller & Ebbe 2007). Some genera represented in the abyssal SO by new typical slope species are, for example, *Cossura* (family Cossuridae) and *Dysponetus* (family Chrysopetalidae). Interestingly, the dorvilleid genus *Ophryotrocha*, is highly under-represented (Hilbig 2004). Polychaetes show a clear depth zonation, with a 'eurybathic' shelf community reaching down to over 2000 m with a diversity peak (160 species, compared to 190 at 1000 m) at this depth (Hilbig 2004). A shift to a true deep-sea community occurs about 2000 to 2500 m. At bathyal depths between 3000 m (149 species) and 4000 m (109 species), species numbers per depth interval slightly decrease, and rapidly decrease to 36 species at 5000 m (Brandt *et al.* 2009).

Species richness among isopods is highest at mid depth ranges, the number of polychaete species showed a negative relationship to depth and bivalves showed no clear relationship (Ellingsen *et al.* 2007).

Molecular results on the SO members of the arcoid genus *Limopsis* show basal positions of deep-sea species (*Limopsis tenella*, *Limopsis* sp. 1, *Limopsis* sp. 2), from which shelf species evolved (Linse unpublished data). The molecular data show evidence against extreme eurybathy and for the existence of cryptic species in the case of *Limopsis marionensis* (Linse pers. comm.). The SO deep-sea bivalves share 90% of their genera with the Antarctic shelf. The remaining 10% of genera are typical deep-sea genera. Most of the bivalve species from the Antarctic deep-sea have lecithotrophic larvae, thus their dispersal range is narrower than in planktotrophic species (Pearse *et al.* 2009 and references therein).

Most Antarctic gastropod species are endemic for the deep sea, especially the brooding and directly developing species of the Buccinoidea, Naticidae and Turridae (Schwabe *et al.* 2007).

Strugnell *et al.* (2008a, b) suggest that the initiation of the global thermohaline circulation provided a conduit for the radiation of SO fauna into the deep sea, at least for octopi (12S rDNA, 16S rDNA and rhodopsin analyses). The development of the thermohaline circulation has been suggested to be a crucial evolutionary driver enabling the SO to become a centre of origin for deep-sea fauna.

Hydroid species' vertical distribution shows three distinct depth from shallow to ~500 m, ~500 m to 1000 m, and deeper than 1000 m (Peña Cantero 2004). 13 of 19 species of SO brachiopods are known occur in the deep sea and five of these are endemic.

Within the regular sea urchins four of 16 and in the irregular urchins 10 out of 20 deep-sea species are endemic. A high proportion of brooding species occurs in Antarctic irregular urchins (Pearse *et al.* 2009).

The more-or-less isothermal water column of the Weddell Sea provides a perfect conduit for the migration of species into the deeper waters. Thus, the SO deep sea might be a centre of evolution for the Isopoda and other taxa and has influenced the world faunas of the deep oceans.

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# 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 / OBIS) 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 vastly 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](http://www.biodiversity.aq).

## The Census of Antarctic Marine Life (CAML)

CAML ([www.caml.aq](http://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.

## The SCAR Marine Biodiversity Information Network (SCAR-MarBIN)

In close connection with CAML, SCAR-MarBIN ([www.scarmarbin.be](http://www.scarmarbin.be), integrated into [www.biodiversity.aq](http://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 interoperable databases, forming the Antarctic regional node of the Ocean Biogeographic Information System (OBIS, [www.iobis.org](http://www.iobis.org)), under the aegis of SCAR (Scientific Committee on Antarctic Research, [www.scar.org](http://www.scar.org)). SCAR-MarBIN established a comprehensive register of Antarctic marine species and, with [biodiversity.aq](http://biodiversity.aq) provided free access to more than 2.9 million Antarctic georeferenced biodiversity data, which allowed more than 60 million downloads.

## The Editorial Team



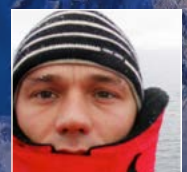
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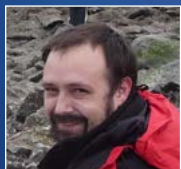
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