Census of Antarctic Marine Life
SCAR-Marine Biodiversity Information Network

BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

CHAPTER 5.27. ASCIDIAN FAUNA SOUTH OF THE SUB-TROPICAL FRONT.

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THE BIOGEOGRAPHIC ATLAS OF THE SOUTHERN OCEAN

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5.27. Ascidian fauna south of the Sub-Tropical Front

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1. Introduction

Ascidians are a group of exclusively marine animals (both colonial and solitary) belonging to Class Ascidiacea (Subphylum Tunicata, Phylum Chordata). The adults are benthic and sessile, occurring both on hard and soft substrates, from intertidal to abyssal depths, ranging from tropical to polar seas. In Antarctic waters, ascidians are known to be one of the main sessile benthic groups in terms of number and biomass (e.g. Arnaud *et al.* 1998, Griffiths *et al.* 2008) and to play a relevant role in the structure of suspension-feeding communities (e.g. Gili *et al.* 2001, Gutt 2007).

Most ascidians produce eggs that develop into pelagic lecithotrophic larvae, whilst about a dozen species are characterised by a direct development (Jeffery & Swalla 1990). Indirect developers can be oviparous (producing eggs that hatch in the water) or ovoviviparous (eggs are brooded within the parent's body and develop into a larva that is released). Hence, larvae represent the only life stage where active dispersal occurs in ascidians. Nonetheless, the larval stage in ascidians is relatively short, varying from a few minutes in tropical seas (Monniot *et al.* 1991) to 8 days or more in cold regions (Strathmann *et al*. 2006). Hence, active dispersal of ascidians is quite limited and most species have a restricted geographical distribution characterised by specific ecological conditions. On the other hand, passive dispersal can occur by transport of eggs or fragments of colonies by currents, or by the displacement of solitary/colonial ascidians attached to other invertebrates or to natural marine debris. However, it has to be noted that no debris carrying fauna has been observed beyond 60° of latitude (Barnes 2002). Dispersal of Antarctic ascidians can also be linked with the phenomenon of iceberg scouring (Monniot *et al.* 2011). Indeed, icebergs abrading the bottom can carry rocks to deeper environments, which represents an alternative method for passive dispersal (Monniot *pers. comm.*). In addition, ascidians represent a common component of the fouling communities on the hulls of ships, and fragments of colonies can also be transported with ballast water (Carlton 1989, Lambert 2007). Hence, anthropogenic vectors might be responsible for the widespread distribution observed in some species.

To present, 245 species of ascidians (excluding dubious identifications) have been recorded below the Sub-Tropical Front (STF) from the intertidal zone to abyssal depths (Primo & Vázquez 2007b, Varela & Ramos Esplá 2008, Monniot 2011, Monniot *et al.* 2011), presenting distinct distributional patterns (Appendix 4, at the end of volume).

The area below the Sub-Tropical Front (considered by a number of oceanographers as the Southern Ocean) comprises the Antarctic continent, Scotia Arc islands (South Orkney, South Sandwich and South Georgia islands), Bouvet Island, the sub-Antarctic islands (including those belonging to New Zealand), and the southernmost part of South America (from Chiloé Island on the west coast to Valdés Peninsula on the east, as well as Falkland Islands). This area is characterised by a number of major oceanic currents and fronts. The Antarctic Divergence (a region of rapid transition located approximately at 65°S) corresponds to the boundary between the Antarctic Coastal Current (flowing westward parallel to the Antarctic continent) and the Antarctic Circumpolar Current (ACC, flowing in the opposite direction). The Polar Front is a circumpolar area within the ACC where the cold superficial water sinks below warmer waters from northern latitudes, leading to a rapid change of temperature within a very small area. Finally, the Sub-Tropical Front limits the ACC and separates its eastward flow from the anticlockwise circulation of the Indian, Atlantic and Pacific oceans.

Photo 1 *Molgula* cf. *pedunculata* Herdman, 1881. Larsen B (*Polarstern* ANT-XXIII/8, st. 714-1, 189–286 m). Image: J. Gutt © AWI/Marum, University of Bremen, Germany.

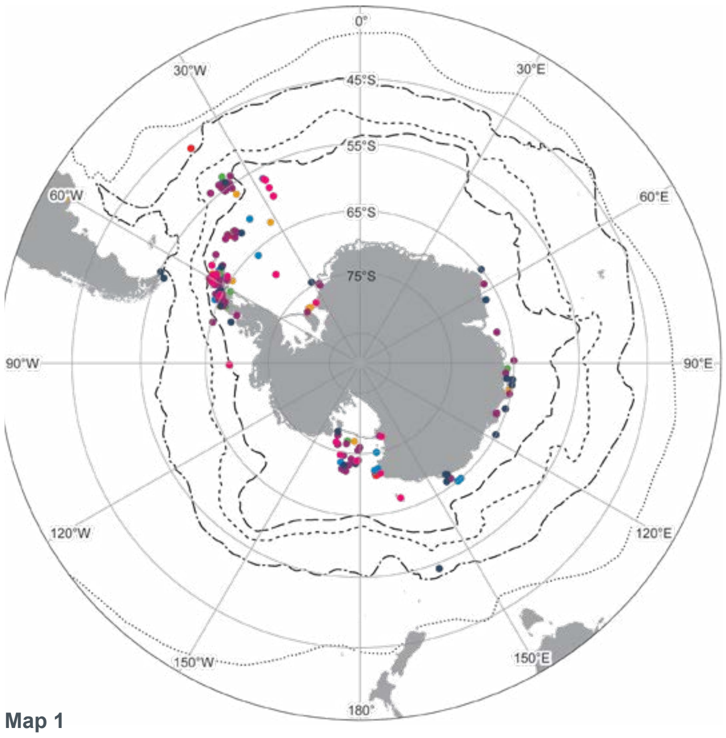
2. Biogeographical divisions and affinities

Many different biogeographical divisions have been proposed through time for the area below the Sub-Tropical Front, since a slightly different scenario seems to emerge for each different group of organisms. However, most authors consider the Antarctic, sub-Antarctic and South American regions to be independent (even if highly related), and the New Zealand sub-Antarctic islands are usually considered as a province belonging to the Southern New Zealand region. Briggs (1974) revised the different biogeographical divisions in the area south of the Sub-Tropical Front; more recent revisions have been done in several studies on ascidian fauna by Primo & Vázquez (2007b, 2008, 2009).

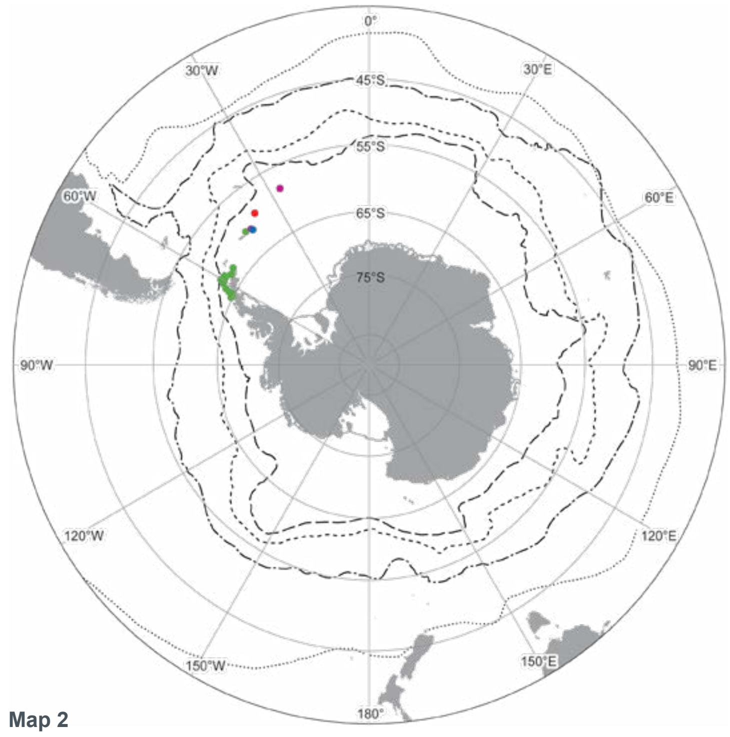
Ascidian taxonomy is relatively well-studied for the regions south of the Sub-Tropical Front (e.g. Sluiter 1906, Millar 1960, Kott 1969, Monniot & Monniot 1983, Sanamyan & Sanamyan 2002, Arntz *et al.* 2006, Primo & Vázquez 2007a, Monniot 2011, Monniot *et al*. 2011), including notes on biogeographical distributions and affinities. Furthermore, several biogeographic studies comprising all or some of the biogeographical areas south of the Sub-Tropical Front have also been conducted during the last decade (e.g. Ramos Esplá *et al.* 2005, Tatian *et al.* 2005, Primo & Vázquez 2007b, 2009). However, the biogeographical assignment of some of these areas remains uncertain, in particular the island regions. In this study, a new analysis has been carried out aiming at clarifying biogeographical affinities, including the most recent studies on Antarctic ascidians. To do so, continental Antarctica was considered as a whole (including the South Shetland Islands due to their geographical proximity), while the Scotia Arc islands were considered separately. The remaining regions/provinces were defined following Briggs (1995): the Sub-Antarctic Region divided in Kerguelen (including Kerguelen, McDonald, Heard, Marion, Prince Edward and Crozet islands) and Macquarie (Macquarie Island) Provinces, the Southern South American Region as a whole, and the New Zealand sub-Antarctic islands grouped under the Antipodean Province (belonging to the Southern New Zealand Region). Biogeographical affinities were calculated using the Sørensen similarity coefficient upon a matrix of presence/absence of species per biogeographical area. Biogeographical areas were analysed with non-metric multi-dimensional scaling (MDS) ordination. Analysis was run using PRIMER 6 (Plymouth Routines in Multivariate Ecological Research).

The position of these different areas in the ordination analysis virtually reproduces their geographical location and is represented on Fig. 1. This analysis showed a close relationship between the Antarctic continent and the Scotia Arc islands, confirming the biogeographical assignment of these islands within the Antarctic Region. The South Sandwich Islands appear slightly separated from the rest of the Antarctic areas (Fig. 1). This might be due to the fact that they are the most remote islands of the Scotia Arc, and hence, under less influence of the Antarctic continent. On the other hand, South Georgia appears as a bridge between the Antarctic continent and South America ascidian faunas in the MDS analysis (Fig. 1). In addition, the similarity indices between South Georgia and the Antarctic continent, and between South Georgia and South America are very close (Table 1) since South Georgia Island is located at a similar distance from the Antarctic Peninsula as from South America. Bouvet Island represents a different case: whilst being often included in the Antarctic Region because of its position south of the Polar Front, it did not appear to be considerably related to the remaining Antarctic areas in the MDS analysis (Fig. 1).

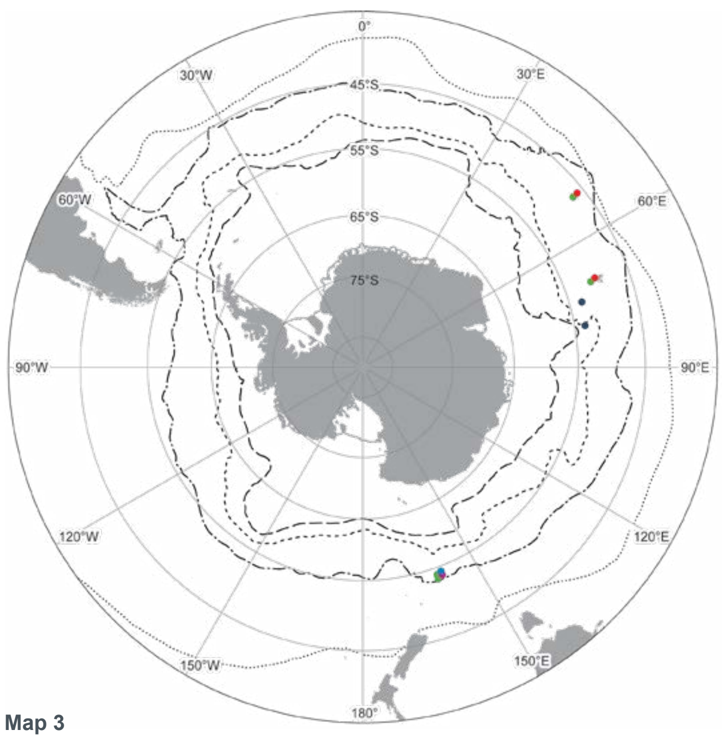
Figure 1 MDS of biogeographical areas south of the Sub-Tropical Front. Abbreviations: CONT, Antarctic continent; SOR, South Orkney Islands; SSA, South Sandwich Islands; SGE, South Georgia; BOU, Bouvet Island; SAM, Southern South American Region; KE: Kerguelen Province; MQ, Macquarie Province; NZI, New Zealand sub-Antarctic islands.



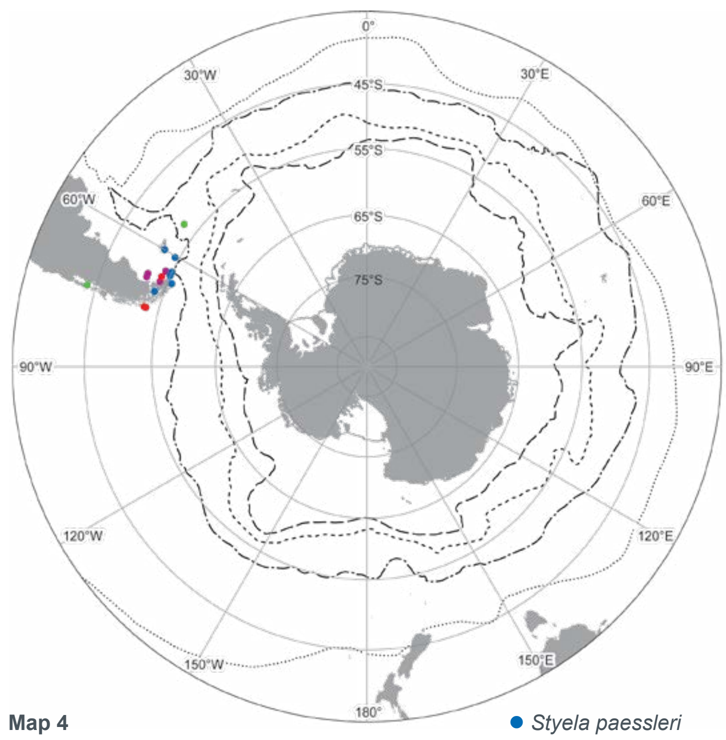
Map 1
- *Aplidium cyaneum*
- *Caenagnesia bocki*
- *Ciona antarctica*
- *Cnemidocarpa pfefferi*
- *Didemnum biglans*
- *Molgula euplicata*
- *Pareugyroides arnbackae*
- *Pyura discoveryi*



Map 2
- *Dicarpa mysogyna*
- *Dimeatus attenuatus*
- *Pyura obesa*
- *Situla rebainsi*



Map 3
- *Aplidium acropodium*
- *Aplidium quadriversum*
- *Molgula macquariensis*
- *Oligocarpa megalorchis*
- *Situla macdonaldi*
- *Styela mallei*



Map 4
- *Alloeocarpa bridgesi*
- *Aplidium gracile*
- *Styela paessleri*
- *Trididemnum auriculatum*

Ascidiacea Maps 1–4 The species plotted on this map are endemic to the Antarctic, Sub-Antarctic or Southern South American regions. Most of the species confined to the Antarctic Region have a wide circumpolar range, including the continent and its surrounding islands. Most of the species with a distribution limited to each of the three regions inhabit depths from less than 100 m to at least 400 m, but many up to 800 m or even 1000 m, beyond the continental shelf. However, ascidian species occurring only on the Scotia Arc islands are generally found at depths below 3000 m, except for those whose distribution extends to the Antarctic Peninsula (*Diplosoma longinquum* and *Pyura obesa*) which can be found between 25 and 350 m. The genera *Cibacapsa*, *Mysterascidia* and *Dimeatus* are endemic to the Antarctic Region; the genus *Polyoctacnemus* is endemic to the Southern South American Region. Map 1. Species endemic to the Antarctic Region: *Aplidium cyaneum, Caenagnesia bocki, Ciona antarctica, Cnemidocarpa pfefferi, Didemnum biglans, Molgula euplicata, Pareugyroides arnbackae, Pyura discoveryi.* Map 2. Species endemic to the Antarctic Region but restricted to the Scotia Arc: *Dicarpa mysogyna, Dimeatus attenuatus, Pyura obesa, Situla rebainsi.* Map 3. Species endemic to the Sub-Antarctic Region: *Aplidium acropodium, Aplidium quadriversum, Molgula macquarensis, Oligocarpa megalorchis, Situla macdonaldi, Styela mallei.* Map 4. Species endemic to the Southern South American Region: *Alleocarpa bridgesi, Aplidium gracile, Styela paessleri, Tridideemnum auriculatum.*

Bouvet Island is an isolated, geologically young island of which the ascidian fauna is known to be impoverished (Arntz *et al.* 2006). Hence, its ascidian faunal composition differs from the rest of the Antarctic areas.

The Southern South American Region showed a high proximity to the Antarctic biogeographical areas. This is likely a consequence of their geological history and geographical proximity through the Antarctic Peninsula and Scotia Arc islands, allowing a faunal exchange despite the presence of the Polar Front between the two regions, as well as the strong eastward flow of the Antarctic Circumpolar Current.

To some extent, the sub-Antarctic Kerguelen Province was also relatively close to the Antarctic Region in the MDS analysis. The lower similarity compared with the relation between Antarctic and Southern South American Regions was probably caused by a higher geographical distance. The islands included in the Kerguelen Province are located in the trajectory of the ACC, which may explain their link with the Antarctic and Southern South American Regions. However, the Macquarie Province, also belonging to the Sub-Antarctic Region, was rather distant from the Kerguelen Province in the MDS ordination (Fig. 1). This separation from the Kerguelen Province is not surprising when considering the geographical distance (around 5300 km between Macquarie Island and Heard Island, the nearest island of the Kerguelen Province), even though both provinces are located between the Polar Front and the Sub-Tropical Front and connected by the ACC. However, the fact that this province is not closer to the New Zealand sub-Antarctic islands in the MDS analysis (Fig. 1) despite their geographical proximity (around 640 km to Auckland Island) and the fact that both are situated in the ACC, might suggest that the Macquarie Province belongs to the Sub-Antarctic Region. In addition, the similarity index with the Kerguelen Province is higher than that with the Antipodean Province (Table 1).

Table 1 Similarity matrix (Sørensen Index) of biogeographical areas below the Sub-Tropical Front. Abbreviations: CONT, Antarctic continent; SOR, South Orkney Islands; SSA, South Sandwich Islands; SGE, South Georgia; BOU, Bouvet Island; SAM, Southern South American Region; KE: Kerguelen Province; MQ, Macquarie Province; NZI, New Zealand sub-Antarctic islands.

	CONT	SOR	SSA	SGE	BOU	SAM	KE	MQ	NZI
CONT									
SOR	53.01								
SSA	39.47	39.53							
SGE	46.93	51.33	38.38						
BOU	9.76	17.54	18.60	17.14					
SAM	33.33	36.23	30.65	47.68	8.42				
KE	29.81	25.35	28.13	36.13	8.08	33.33			
MQ	15.07	17.50	24.24	23.66	5.41	20.34	27.87		
NZI	7.30	14.08	10.53	16.67	14.29	9.17	12.39	23.53	

3. Types of geographic distribution

The 245 ascidian species reported south of the Sub-Tropical Front can be classified in different biogeographical categories (defined here as faunistic groups, depending on the species' global distribution) (Table 2).

Endemic species are those species restricted to a specific area. When considering the entire area south of the Sub-Tropical Front, more than half (51%) of the species are endemic. However, this percentage is slightly lower when considering only the species in the Antarctic Region (i.e. 45% endemism), and considerably lower for the sub-Antarctic and South American regions (36% and 25% of endemism, respectively). No species are endemic to the New Zealand sub-Antarctic islands (possibly due to their locality situated within the pathway of the ACC and in relatively close proximity of New Zealand).

Most of the Antarctic endemic species are characterised by a circumpolar distribution rather than being restricted to a certain area despite their limited capacity for active dispersal (Primo & Vázquez 2009). This could be explained by the long-term homogenising action of the Antarctic Coastal Current, flowing westwards and parallel to the Antarctic coastline. Indeed, the relatively high number of ascidian species with a circumpolar distribution demonstrates a high degree of homogeneity of the ascidian fauna in the Antarctic Region. However, a recent study including molecular analyses showed that ascidian diversity is probably higher and that some circumpolar taxa might have a more restricted distribution than previously assumed (Monniot *et al.* 2011).

The percentage of ascidian species distributed both in Southern South America and Antarctic (and/or Sub-Antarctic) Regions reaches almost 15% (when considering all species south of the Sub-Tropical Front). In addition, the percentage of species restricted to Antarctic and sub-Antarctic waters (and not extending their distribution to South America) is quite low (ca. 3%), which indicates a high affinity between the three regions. Conversely, the percentage of Antarctic/sub-Antarctic species also occurring in New Zealand, Australia or South Africa is very low (slightly higher than 2%, 1% and 1%, respectively), indicating a minor affinity between these regions.

On the other hand, considering their limited active dispersal capacity, there is a surprisingly high percentage of ascidian species with a broad distribution occurring in the area south of the Sub-Tropical Front (20% when including both cosmopolitan and widely distributed species in the Southern Hemisphere). The ACC might have been a vector for passive dispersal of benthic organisms within the Southern Hemisphere, especially during the coldest periods when this current was intensified (Crame 1999). Another hypothesis for the wide distributions observed in some ascidian species is vicariance, after the break-up of Gondwana (Primo & Vázquez 2007b).

However, it is important to notice that the fauna south of the Sub-Tropical Front, and the Antarctic fauna in particular, is currently being exposed to recent anthropogenic phenomena which might be responsible for current and future range expansions within a number of species (Tavares & De Melo 2004). A first trend observed is the increase in faunal dispersal via anthropogenic vectors, including shipping (e.g., Carlton 1989, Coutts & Dodgshun 2007) and transport on anthropogenic debris (Barnes 2002). Hence, ascidians, representing a common component of fouling communities, are excellent candidates to be transported in this way (e.g. Lambert 2007). Considering the increase in tourism, fisheries and scientific activities in the area south of the Sub-Tropical Front (Lewis *et al.* 2003, Lee & Chown 2007), the probability of passive dispersal by species using anthropogenic vectors and the subsequent expansion of their distributional ranges is also increasing. The latter is more likely to occur in the Sub-Antarctic Region, due to higher historical shipping activities and the less extreme temperatures compared with the Antarctic Region (Frenot *et al.* 2005). The second phenomenon contributing to possible species' range expansions is the warming of the Southern Ocean (Tavares & De Melo 2004, Fyfe 2006), in particular of the waters around the Antarctic Peninsula (Meredith & King 2005), since temperature is a limiting factor for the establishment of many species. Although no non-indigenous ascidian species have been reported in Antarctic waters to date, there are records of other organisms that have been introduced or are spreading their distribution range to Antarctica (e.g. Clayton *et al.* 1997, Smith *et al.* 2012). On the other hand, if the area south of the Sub-Tropical Front is considered, two ascidian species are considered being introduced: *Botrylloides leachii* and *Cnemidocarpa humilis*. These species are recognised as non-indigenous species on the New Zealand sub-Antarctic islands (Cranfield *et al.* 1998).

Table 2 Frequency of species in the main biogeographical categories for the considered biogeographical areas. Abbreviations: END, endemism; ANT-SAN, Antarctic and sub-Antarctic distribution; ANT-SAM, Antarctic/sub-Antarctic and southern South American distribution; ANT-NZ, Antarctic/sub-Antarctic and New Zealand distribution; ANT-AU, Antarctic/sub-Antarctic and Australian distribution; ANT-SAF, Antarctic/sub-Antarctic and South African distribution; CM, cosmopolitan; SH, widely distributed in the Southern Hemisphere. See text for more details.

	END	ANT-SAN	ANT-SAM	ANT-NZ	ANT-AU	ANT-SAF	CM	SH
Sub-Tropical Front	51	3	15	2	1	1	5	15
Antarctic	45	5	22	3	1	1	5	18
Sub-Antarctic	36	8	19	3	3	2	7	22
South America	25	-	41	-	-	-	3	20
New Zealand sub-Antarctic islands	0	-	-	-	-	-	10	55

4. Bathymetric distributions

Changes of faunal composition with depth in Antarctic waters have been observed at 500 m (Briggs 1974), 1000 m (Monniot & Monniot 1982) and 2000 m (Lambert 2005). The Antarctic fauna seems to be rather uniform from the surface down to 500 m due to the rather constant temperature and salinity conditions (Briggs 1974). On the other hand, Monniot & Monniot (1982) observed a marked change in ascidian species composition at a depth of 1000 m, and Lambert (2005) mentioned morphological differences between ascidians below 2000 m and shallow-water species.

A high number of shallow species (<500 m; 55%) and a relatively high number of deep sea species (>1000 m; 18%) have been reported, the latter slightly decreasing when considering only strictly abyssal ascidians (>2000 m; 14%). However, the number of species limited to the depth zone between 500 and 1000 m is very low (2%), possibly indicating that the change in faunal composition observed by Briggs (1974) does not apply to ascidians. Indeed, Briggs (1974, 1995) also mentioned several examples of species and taxonomic groups extending beyond the 500 m limit.

Furthermore, when considering bathymetric distributions, a more distinct change in ascidian species composition occurs at 2000 m (with only 7% of species occurring both above and below 2000 m), compared with the transition at 1000 m depth (with 14% of species occurring both above and below this depth).

Therefore, if we only consider the limit of 2000 m, the number of 'shallow' species (<2000 m) reaches 79%, with 7% of these species occurring both above and below 2000 m and 14% abyssal species (>2000 m).

Although there is no definite correlation between depth and geographical distributions, ascidian species with a wide distribution (in the Southern Hemisphere and worldwide) generally are deep-water dwellers (occurring below 2000 m) (Fig. 2). Endemic ascidian species and ascidian species distributed in Antarctic, sub-Antarctic and South American waters comprise a much higher percentage of shallow species (<2000 m depth) (Fig. 2). However, most of the ascidian species endemic to the islands of the Scotia Arc are found in deep waters.

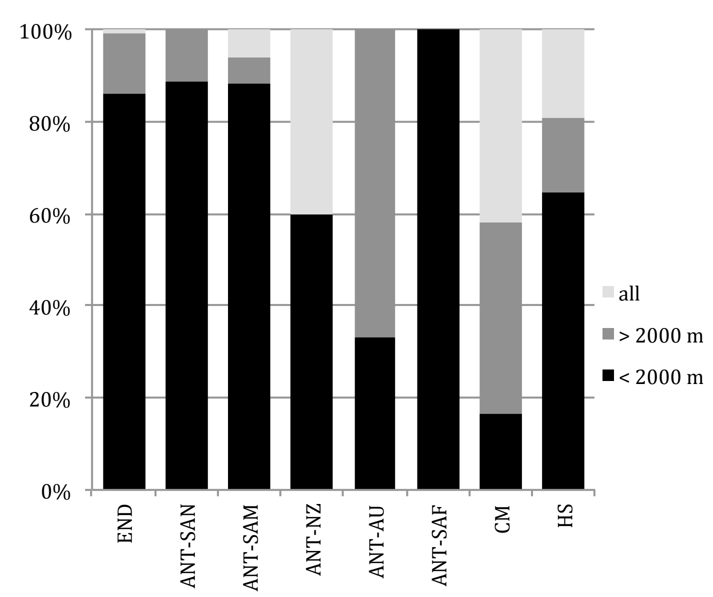
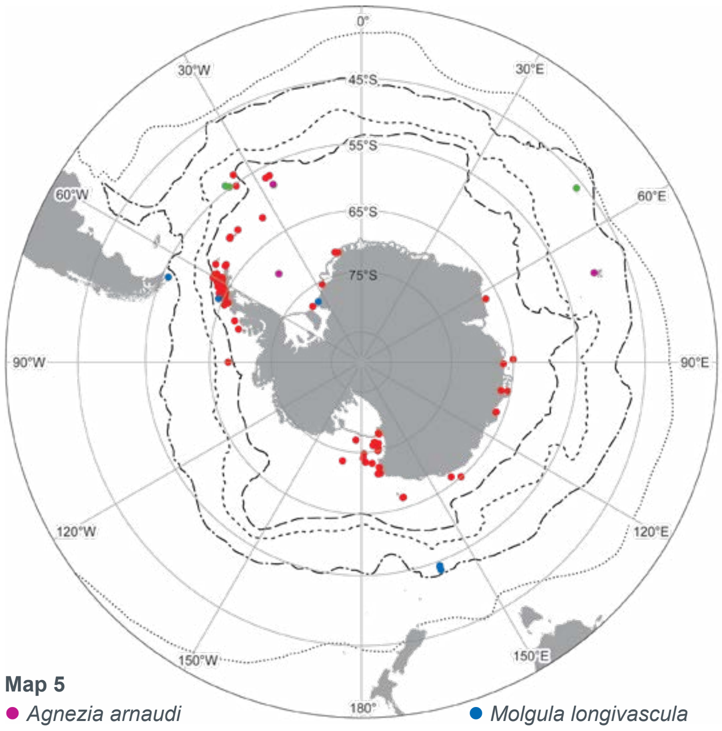
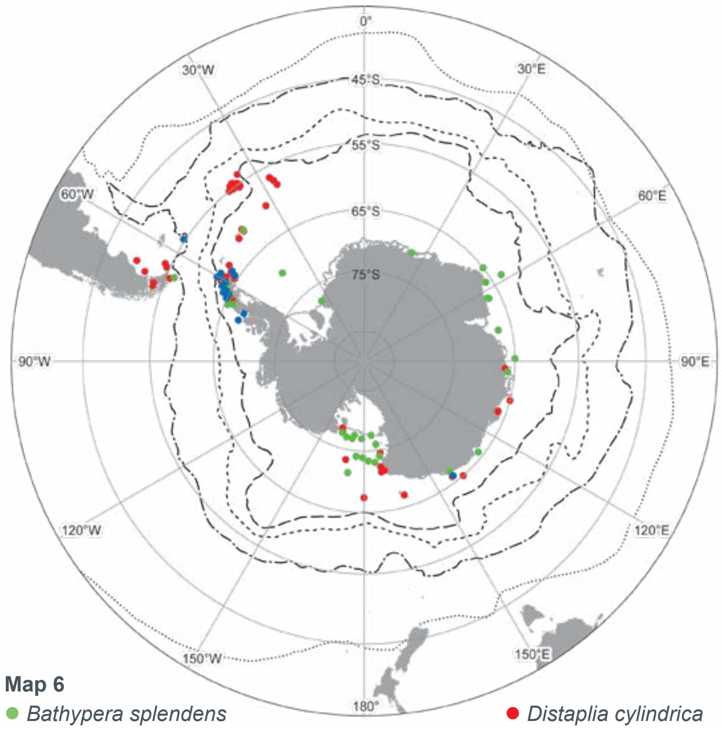


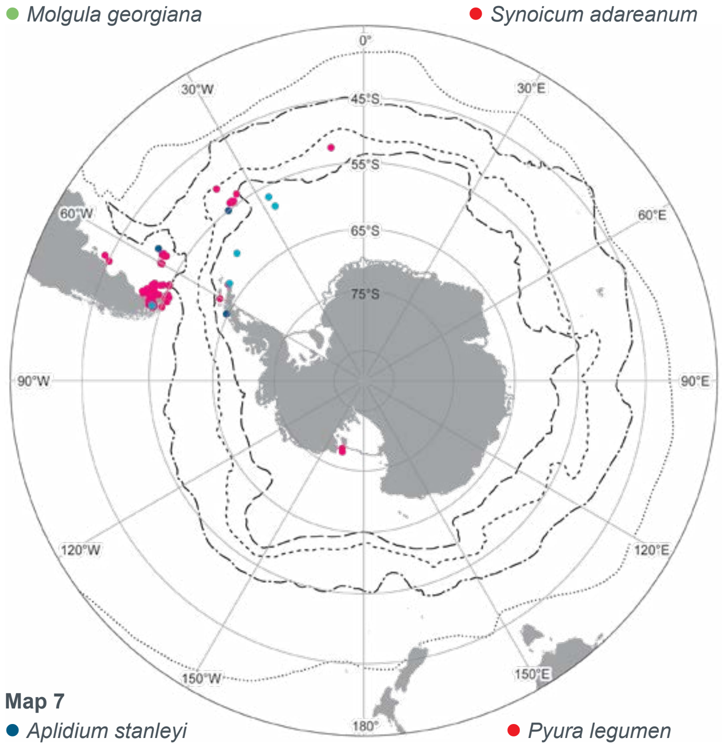
Figure 2 Frequency of ascidian species south of the Sub-Tropical Front in biogeographical categories at different depth ranges. Abbreviations: END, endemism; ANT-SAN, Antarctic and sub-Antarctic distribution; ANT-SAM, Antarctic/sub-Antarctic and Southern South American distribution; ANT-NZ, Antarctic/sub-Antarctic and New Zealand distribution; ANT-AU, Antarctic/sub-Antarctic and Australian distribution; ANT-SAF, Antarctic/sub-Antarctic and South African distribution; CM, cosmopolitan; HS, widely distributed in the Southern Hemisphere.



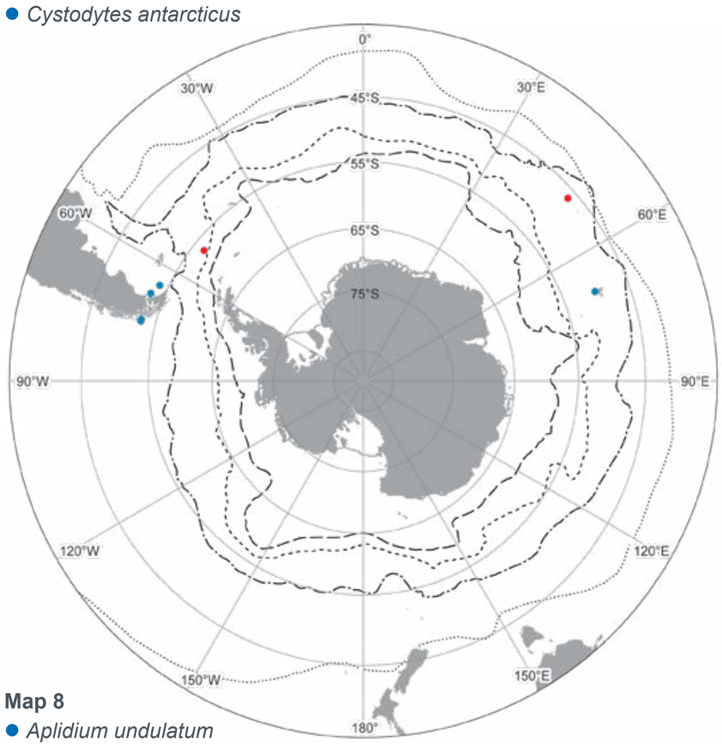
Map 5
- ● *Agnezia arnaudi*
- ● *Molgula georgiana*
- ● *Molgula longivascula*
- ● *Synoicum adareanum*



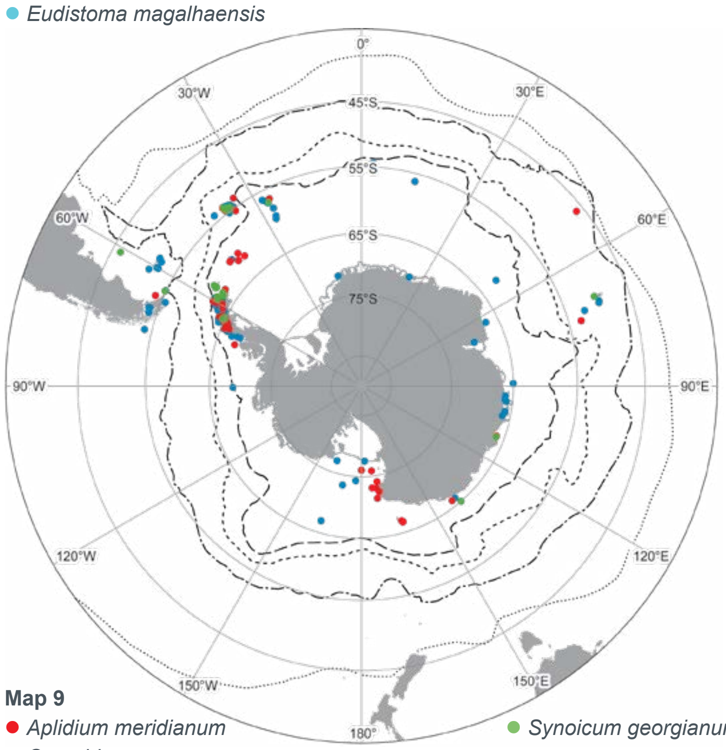
Map 6
- ● *Bathypera splendens*
- ● *Cystodytes antarcticus*
- ● *Distaplia cylindrica*



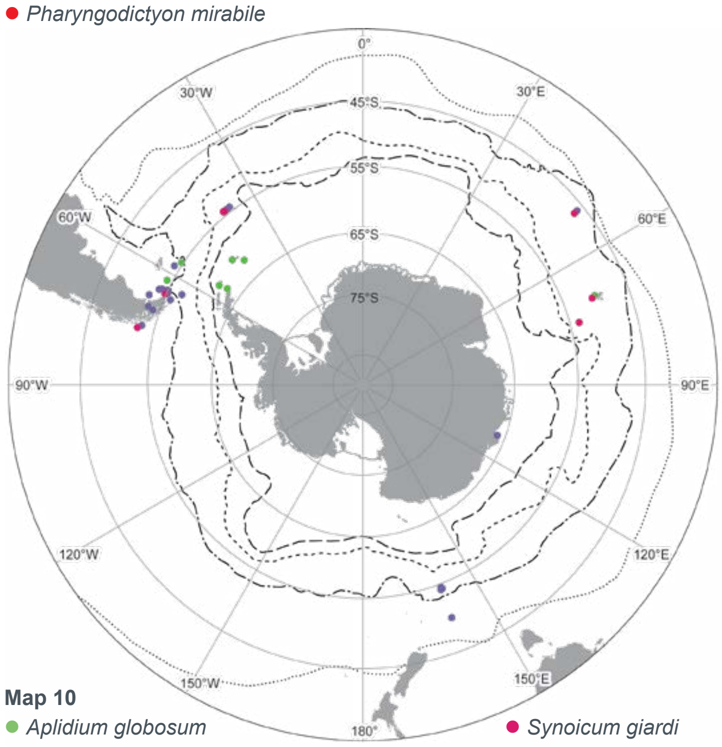
Map 7
- ● *Aplidium stanleyi*
- ● *Eudistoma magalhaensis*
- ● *Pyura legumen*



Map 8
- ● *Aplidium undulatum*
- ● *Pharyngodictyon mirabile*

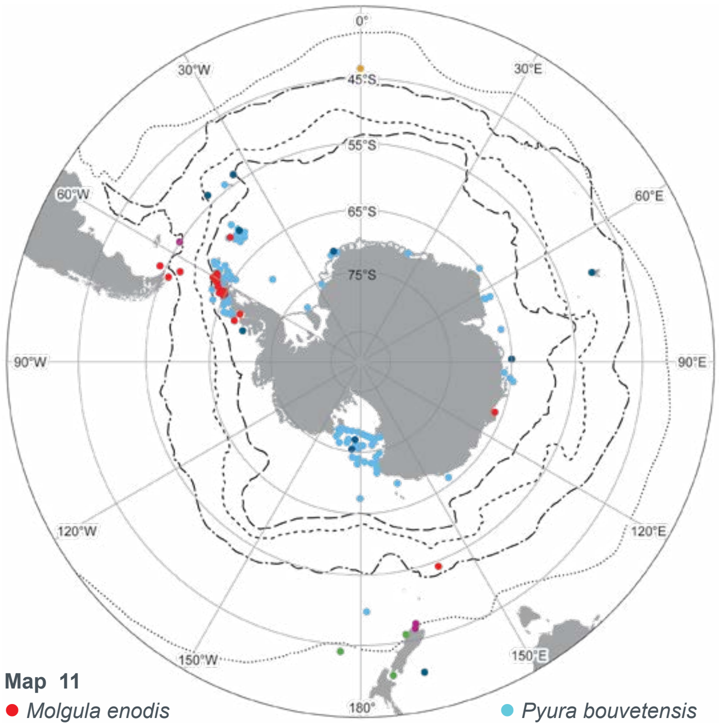


Map 9
- ● *Aplidium meridianum*
- ● *Cnemidocarpa verrucosa*
- ● *Synoicum georgianum*

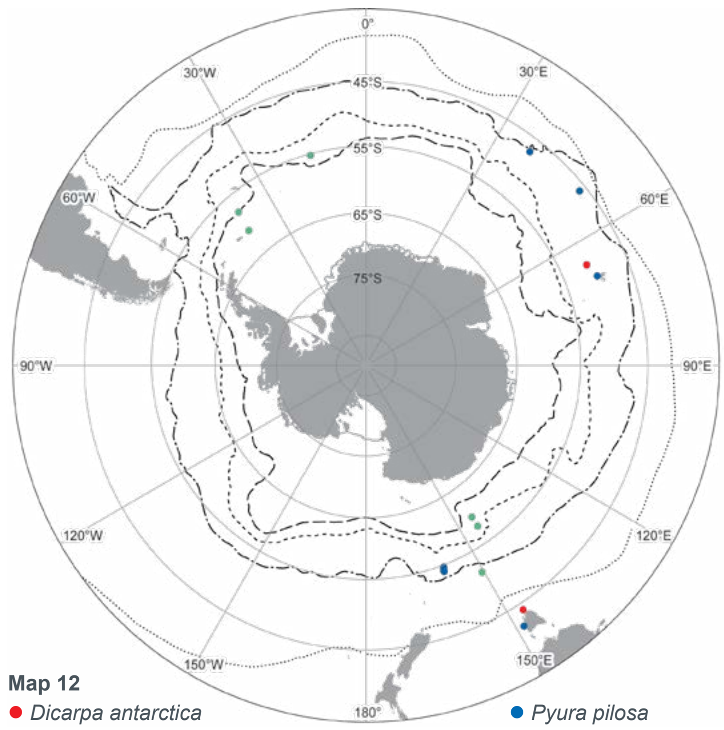


Map 10
- ● *Aplidium globosum*
- ● *Molgula pulchra*
- ● *Synoicum giardi*

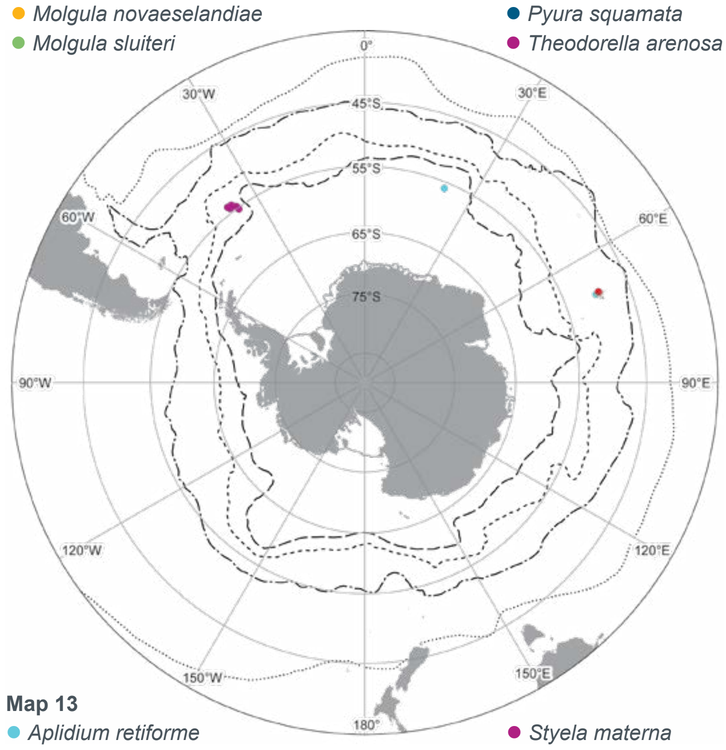
Ascidiacea Maps 5–10 Species shown on this map are confined to the Antarctic, Sub-Antarctic and Southern South American Regions, but not restricted to only one of these regions. More than half of these species are restricted to the Scotia Arc islands (and in some cases extending to the Antarctic Peninsula) in the Antarctic Region. The majority are found around 200–300 m depth or less (many are recorded in shallow waters in the Sub-Antarctic and Southern South American Regions), but the distribution of a number of species extends to depths of 500 m or even 1000 m. A few exceptions occur in abyssal waters. Map 5. Species collected from Antarctic and sub-Antarctic waters only: *Agnezia arnaudi, Molgula georgiana, Molgula longivascula, Synoicum adareanum.* Map 6. Species collected in Antarctic and southern South American waters only: Antarctic Region (including continental Antarctica) and Southern South American Region: *Bathypera splendens*, *Cystodytes antarcticus, Distaplia cylindrica.* Map 7. Species collected in Antarctic and southern South American waters only: Antarctic Region (only Scotia Arc) and Southern South American Region: *Aplidium stanleyi, Eudistoma magalhaensis, Pyura legumen.* Map 8. Species collected in sub-Antarctic and southern South American waters only: *Aplidium undulatum, Pharyngodictyon mirabile.* Map 9. Species collected in the three regions: Antarctic Region (including continental Antarctica), Sub-Antarctic Region and Southern South American Region: *Aplidium meridianum, Cnemidocarpa verrucosa, Synoicum georgianum.* Map 10. Species collected in the three regions: Antarctic Region (only Scotia Arc), Sub-Antarctic Region and Southern South American Region: *Aplidium globosum, Molgula pulchra, Synoicum giardi.*



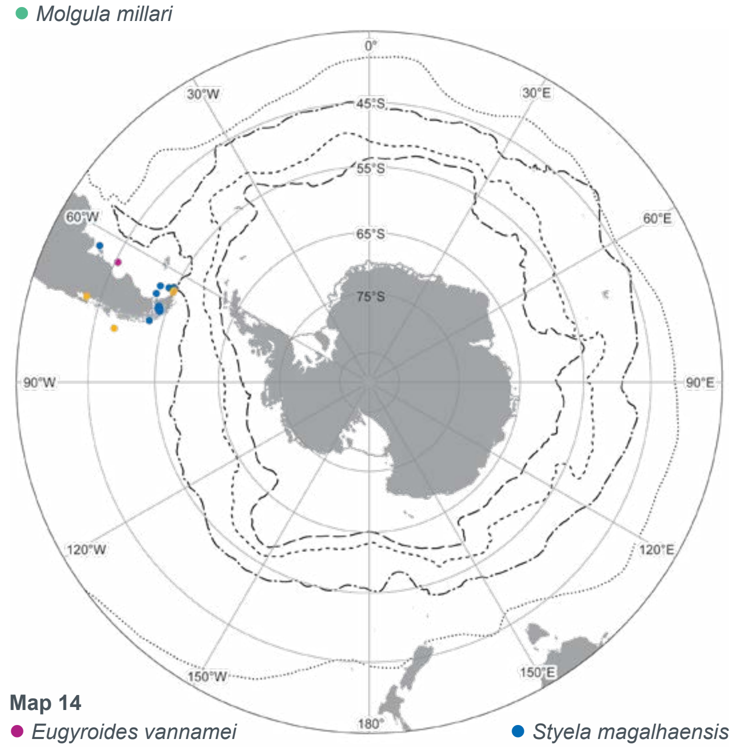
Map 11
- *Molgula enodis*
- *Molgula novaeselandiae*
- *Molgula sluiteri*
- *Pyura bouvetensis*
- *Pyura squamata*
- *Theodorella arenosa*



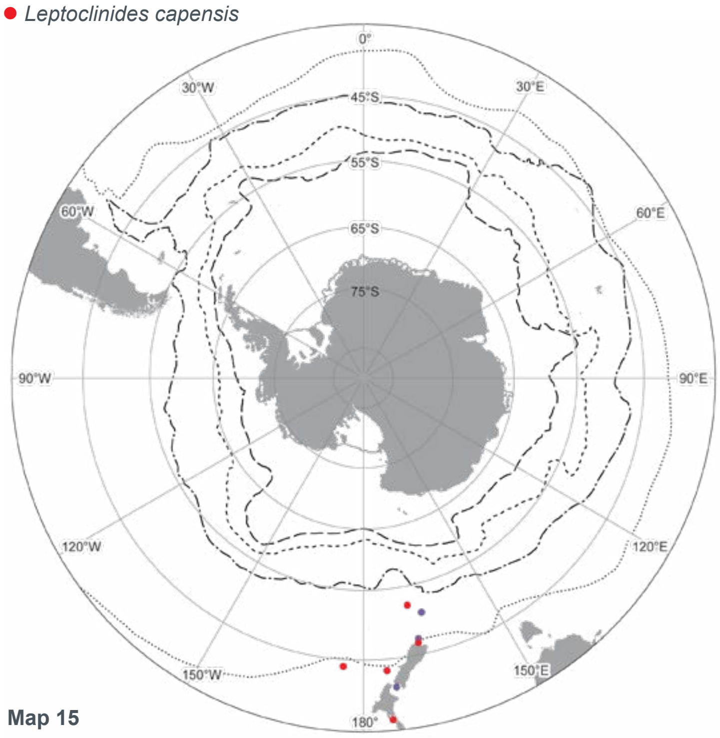
Map 12
- *Dicarpa antarctica*
- *Molgula millari*
- *Pyura pilosa*



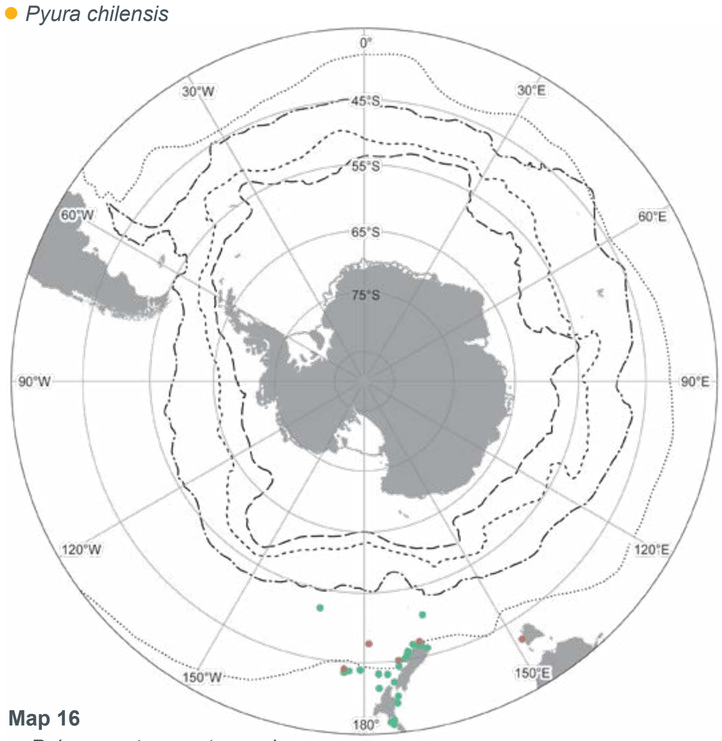
Map 13
- *Aplidium retiforme*
- *Leptoclinides capensis*
- *Styela materna*



Map 14
- *Eugyroides vannamei*
- *Pyura chilensis*
- *Styela magalhaensis*

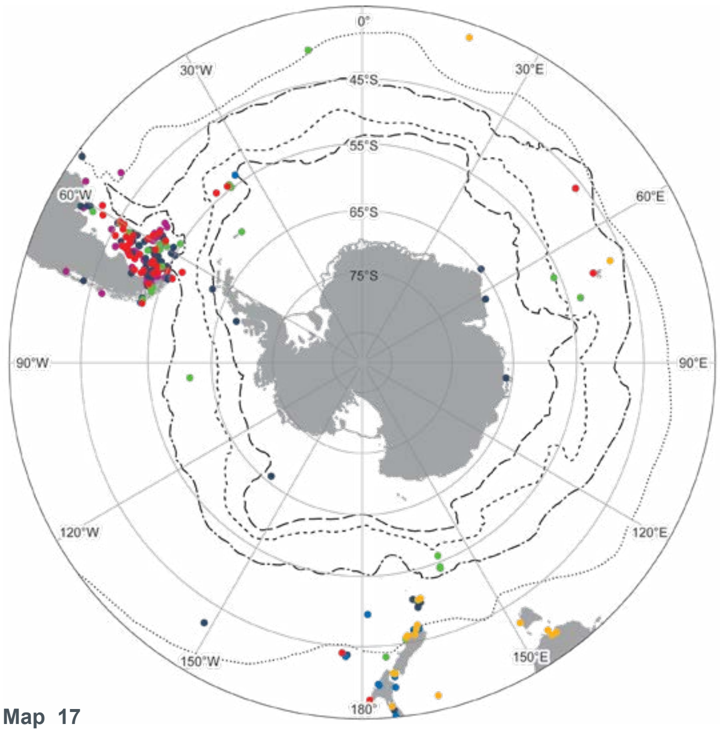


Map 15
- *Alloeocarpa affinis*
- *Didemnum tuberatum*

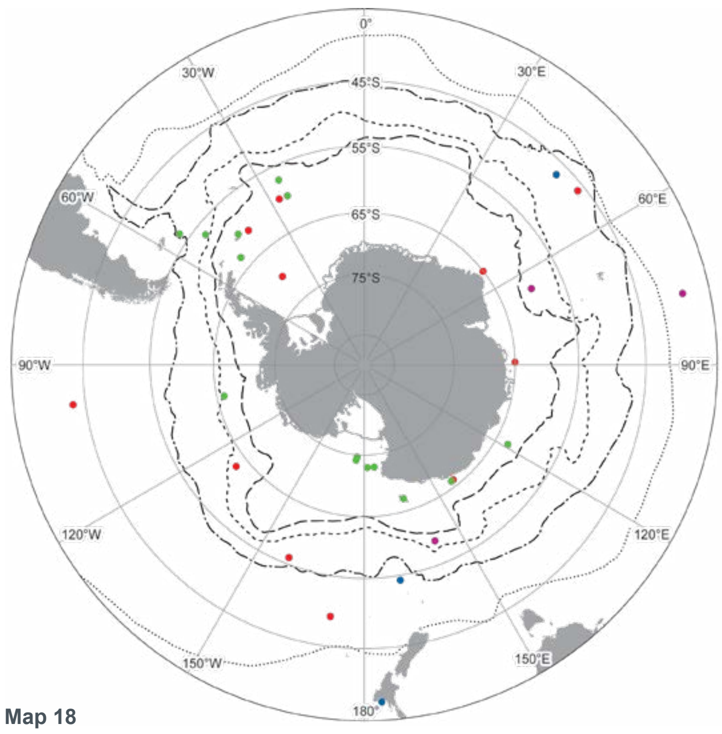


Map 16
- *Polysyncraton mortenseni*
- *Pyura trita*

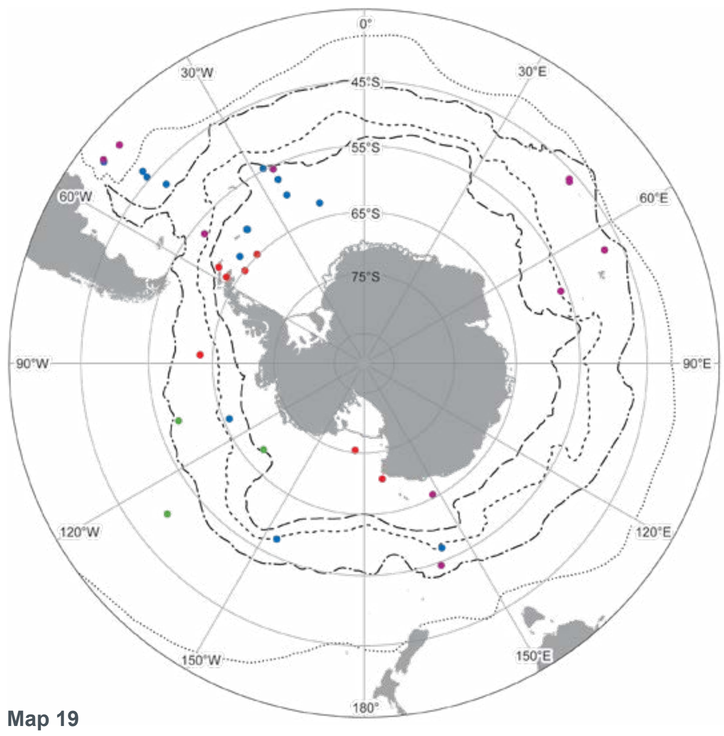
Ascidiacea Maps 11–13 The species shown occur in the Antarctic and/or Sub-Antarctic Regions and the Southern New Zealand, Tasmanian or Southern African Regions (after Briggs 1995). Most of them are found at depths above 400 m (one extending to 600 m), but two of the three species occurring in Antarctic and Tasmanian waters are abyssal species. Map 11. Species collected in the Antarctic and/or Sub-Antarctic Regions and the Southern New Zealand Region: *Molgula enodis, Molgula novaeselandiae, Molgula sluiteri*, *Pyura bouvetensis, Pyura squamata*, *Theodorella arenosa*. Map 12. Species collected in the Antarctic and/or Sub-Antarctic Regions and the Tasmanian Region: *Dicarpa antarctica, Molgula millari, Pyura pilosa.* Map 13. Species collected in the Antarctic and/or Sub-Antarctic Regions and the Southern African Region: *Aplidium retiforme, Leptoclinides capensis, Styela materna.* **Maps 14–16** Species restricted to South America (but beyond the Southern South America Region) and species restricted to New Zealand (but beyond the Antipodean Province) are plotted on this map. Species distributed in New Zealand and in Australian waters are also represented here. Except for two abyssal South American species (*Culeolus likae* and *Molguloides sphaeroidea*; not represented here), all species are found above 100 m, a few extending to depths of 600–700 m. Map 14. South American species: *Eugyroides vannamei*, *Pyura chilensis*, *Styela magalhaensis.* Map 15. New Zealand species: *Alleocarpa affinis*, *Didemnum tuberatum.* Map 16. New Zealand and Australian species: *Polysyncraton mortenseni, Pyura trita.*



Map 17
- ● *Aplidium variabile*
- ● *Cnemidocarpa humilis*
- ● *Didemnum studeri*
- ● *Molgula mortenseni*
- ● *Paramolgula gregaria*
- ● *Sycozoa sigillinoides*



Map 18
- ● *Corynascidia suhmi*
- ● *Culeolus antarcticus*
- ● *Culeolus recumbens*
- ● *Molguloides monocarpa*



Map 19
- ● *Bathyoncus mirabilis*
- ● *Cnemidocarpa sericata*
- ● *Culeolus anonymus*
- ● *Fungulus perlucidus*

Ascidiacea Maps 17–19 Species shown on this map occur south of the Sub-Tropical Front, but are characterised by a wide distribution in the Southern Hemisphere. More than half of these species inhabit waters of 2000 m depth or less, while almost a fifth of them are abyssal. The remaining species are found both above and below 1000 m depth. *Cnemidocarpa humilis* is considered as being introduced onto the sub-Antarctic New Zealand islands. Map 17. Species occurring above 2000 m depth: *Aplidium variabile, Cnemidocarpa humilis, Didemnum studeri, Molgula mortenseni, Paramolgula gregaria*, *Sycozoa sigillinoides.* Map 18. Species occurring both above and below 2000 m depth: *Corynascidia suhmi, Culeolus antarcticus, Culeolus recumbens, Molguloides monocarpa.* Map 19. Abyssal species: *Bathyoncus mirabilis, Cnemidocarpa sericata, Culeolus anonymus, Fungulus perlucidus*.

5. Concluding remarks

Ascidians south of the Sub-Tropical Front are a very diverse group, with no clear biogeographical or bathymetrical distribution patterns for specific orders, families or genus (as observed for other taxonomic groups) in general. Nevertheless, species can be classified in biogeographical categories (faunistic groups) depending on their biogeographical distribution, and a change of ascidian fauna composition has been observed at 2000 m depth.

A large number of species is endemic to the area south of the Sub-Tropical Front, indicating a close relationship between the different biogeographical regions in that area, especially between the Antarctic, Sub-Antarctic and Southern South American Regions (which has been confirmed by ordination analysis). On the other hand, a relatively high percentage of ascidian species has a wide distribution in the Southern Hemisphere and globally, despite their limited capacity for active dispersal. In relation to the latter, it is important to highlight the risk of future range expansions within a number of ascidian species to waters south of the Sub-Tropical Front derived from an increase in dispersal via anthropogenic vectors and the warming of the Southern Ocean, leading to biological invasions.

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References

Arnaud, P., López, C., Olaso, I., Ramil, F., Ramos Esplá, A.A., Ramos, A., 1998. Semi-quantitative study of macrobenthic fauna in the region of the South Shetland Islands and the Antarctic Peninsula. *Polar Biology,* **19**, 160–166.

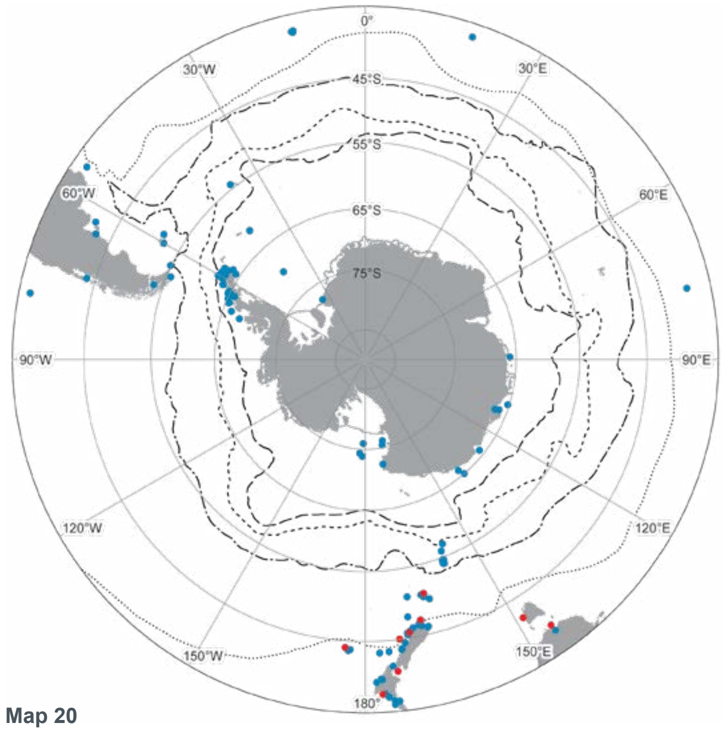
Arntz, W.E., Thatje, S., Linse, K., Avila, C., Ballesteros, M., Barnes, D.K., Cope, T., Cristobo, F.J., De Broyer, C., Gutt, J., Isla, E., López-González, P., Montiel, A., Munilla, T., Ramos Esplá, A.A., Raupach, M., Rauschert, M., Rodríguez, E., Teixidó, N., 2006. Missing link in the Southern Ocean: sampling the marine benthic fauna of remote Bouvet Island. *Polar Biology,* **29**, 83–96.

Barnes, D., 2002. Invasions by marine life on plastic debris. *Nature,* **416**, 808–809.

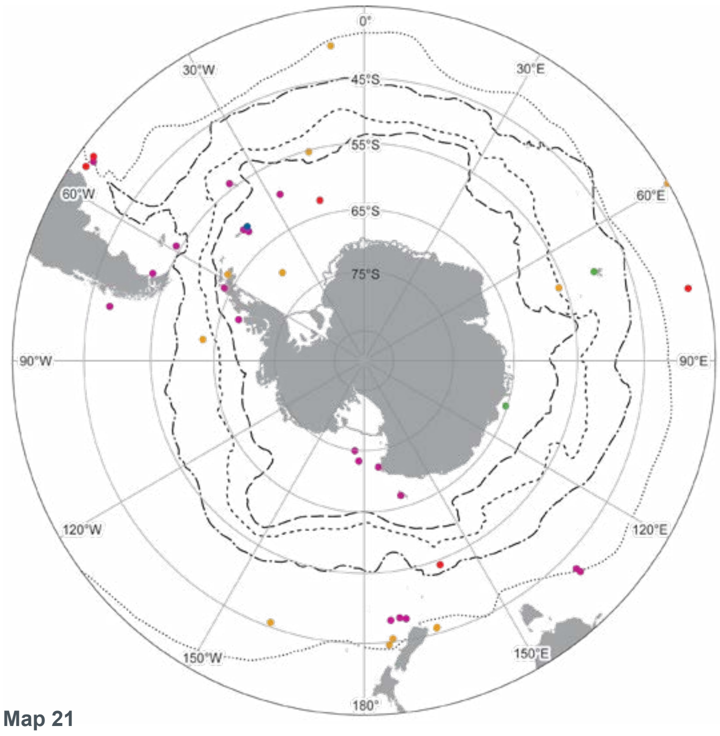
Briggs, J., 1974. Marine zoogeography. New York: McGraw-Hill, 475 pp.

Briggs, J., 1995. Global biogeography. Developments in palaeontology and stratigraphy. Amsterdam: Elsevier Science, 472 pp.

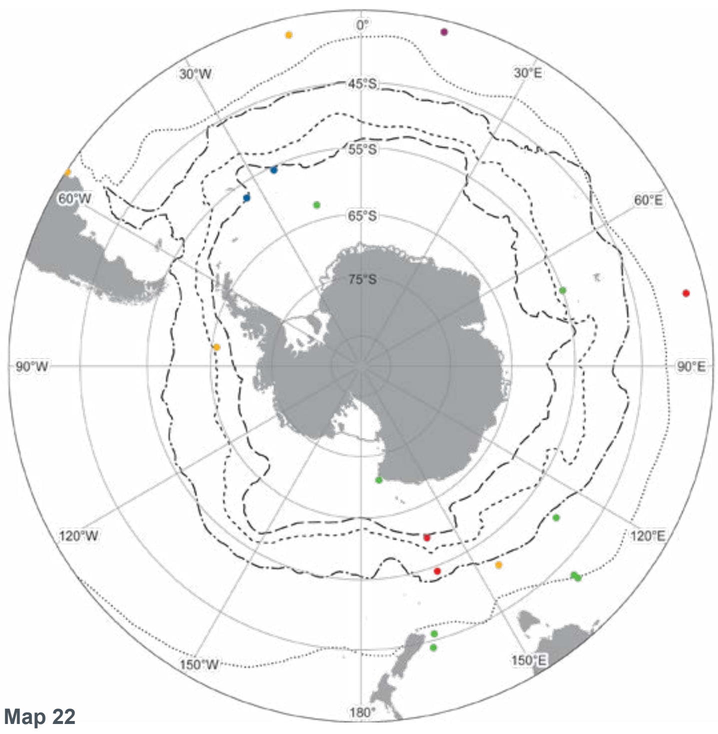
Carlton, J.T., 1989. Man's role in changing the face of the ocean: biological invasions and implications for conservation of near-shore environments. *Conservation Biology,* **3(3)**, 265–273.



Map 20
- *Corella eumyota*
- *Botrylloides leachii*



Map 21
- *Adagnezia charcoti*
- *Bathystyeloides enderbyanus*
- *Cnemidocarpa barbata*
- *Megalodicopia rineharti*
- *Styela squamosa*



Map 22
- *Cnemidocarpa bathypila*
- *Cnemidocarpa bythia*
- *Cnemidocarpa digonas*
- *Proagnezia depressa*
- *Styela crinita*

Ascidiacea Maps 20–22 The species plotted on this map occur south of the Sub-Tropical Front, but have a wide distribution in both the Northern and Southern Hemispheres. Almost half of these species are found only in abyssal depths, and most of the remaining half occur both at abyssal depths and in waters above 2000 m. Only one species, *Botrylloides leachii*, which is considered to be introduced onto the sub-Antarctic New Zealand islands, is restricted to shallow waters. Alternatively, *Corella eumyota* (also above 2000 m depth) is a species common in the Southern Hemisphere, which has recently been introduced in Europe. Map 20. Species occurring above 2000 m depth): *Botrylloides leachii*, *Corella eumyota*. Map 21. Species occurring both above and below 2000 m depth: *Adagnezia charcoti, Bathystyeloides enderbyanus, Cnemidocarpa barbata, Megalodicopia rineharti, Styela squamosa*. Map 22. Abyssal species: *Cnemidocarpa bathypila, Cnemidocarpa bythia, Cnemidocarpa digonas, Proagnezia depressa, Styela crinita*.

Clayton, M.N., Wiencke, C., Klöser, H., 1997. New records of temperate and sub-Antarctic marine benthic macroalgae from Antarctica. *Polar Biology,* **17(2)**, 141–149.

Coutts, A.D., Dodgshun, T.J., 2007. The nature and extent of organisms in vessel sea-chests: A protected mechanism for marine bioinvasions. *Marine Pollution Bulletin,* **54**, 875–886.

Crame, J.A., 1999. An evolutionary perspective of marine faunal connections between southermost South America and Antarctica. *Scientia Marina,* **63(Supl. 1)**, 1–14.

Cranfield, H., Gordon, D., Willan, R., Marshall, B., Battershill, C., Francis, M., Nelson, W., Glasby, C.J., Read, G. 1998. Adventive marine species in New Zealand. *NIWA Technical Report*, **34**, 1–48.

Frenot, Y., Chown, S.L., Whinam, J., Selkirk, P.M., Convey, P., Skotnicki, M., Bergstrom, D.M., 2005. Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews,* **80**, 45–72.

Fyfe, J.C., 2006. Southern Ocean warming due to human influence. *Geophysical Research Letters,* **33(19)**, L19701. doi:10.1029/2006GL027247

Gili, J.-M., Coma, R., Orejas, C., López-González, P., Zabala, M., 2001. Are Antarctic suspension-feeding communities different from those elsewhere in the world? *Polar Biology,* **24**, 473–485.

Griffiths, H.J., Linse, K., Barnes, D.K., 2008. Distribution of macrobenthic taxa across the Scotia Arc, Southern Ocean. *Antarctic Science,* **20(3)**, 213.

Gutt, J., 2007. Antarctic macro-zoobenthic communities: a review and an ecological classification. *Antarctic Science,* **19(2)**, 165–182.

Jeffery, W.R., Swalla, B.J., 1990. Anural development in ascidians: evolutionary modification and elimination of the tadpole larva. *Seminars in Developmental Biology,* **1**, 253–261.

Kott, P., 1969. Antarctic Ascidiacea. A monographic account of the known species based on specimens collected under U.S. government auspices, 1947–1965. *Antarctic Research Series*, **13**, 1–239.

Lambert, G., 2005. Ecology and natural history of the protochordates. *Canadian Journal of Zoology,* **83(34–50)**, 34.

Lambert, G., 2007. Invasive sea squirts: A growing global problem. *Journal of Experimental Marine Biology and Ecology,* **342**, 3–4.

Lee, J.E., Chown, S.L., 2007. *Mytilus* on the move: transport of an invasive bivalve to the Antarctic. *Marine Ecology Progress Series,* **339**, 307–310.

Lewis, P.N., Hewitt, C.L., Riddle, M., Mcminn, A., 2003. Marine introductions in the Southern Ocean: an unrecognised hazard to biodiversity. *Marine Pollution Bulletin,* **46**, 213–223.

Meredith, M.P., King, J.C., 2005. Rapid climate change in the ocean west of the Antarctic Peninsula during the second half of the 20th century. *Geophysical Research Letters,* **32(19)**, 5.

Millar, R., 1960. Ascidiacea. *Discovery Reports*, **30**, 1–160.

Monniot, C., Monniot, F., 1982. Some Antarctic deep-sea tunicates in the Smithsonian collections. *Antarctic Research Series,* **32**, 95–130.

Monniot, C., Monniot, F., 1983. Ascidies antarctiques et subantarctiques: morphologie et biogéographie. *Mémoires du Muséum National d'Histoire Naturelle, Paris*, ser. A (Zool.), **125**, 1–128.

Monniot, C., Monniot, F., Laboute, P., 1991. Coral reef ascidians of New Caledonia. Paris: ORSTOM, 247 pp.
Monniot, F., 2011. *Pelonaia quadrivena* n. sp. a case of bipolarity in Ascidiacea. *Zootaxa,* **2833**, 41–48.
Monniot, F., Dettai, A., Eléaume, M., Cruaud, C., Améziane, N., 2011. Antarctic Ascidians (Tunicata) of the French-Australian survey CEAMARC in Terre Adélie. *Zootaxa,* **2817**, 1–54.
Primo, C., Vázquez, E., 2007a. Ascidians collected during the Spanish Antarctic expedition CIEMAR 99/00 in the Bransfield and Gerlache Straits. *Journal of Natural History,* **41(29–32)**, 1775–1810.
Primo, C., Vázquez, E., 2007b. Zoogeography of the Antarctic ascidian fauna in relation to the sub-Antarctic and South America. *Antarctic Science,* **19(3)**, 321–336.
Primo, C., Vázquez, E., 2008. Zoogeography of the southern New Zealand, Tasmanian and southern African ascidian fauna. *New Zealand Journal of Marine and Freshwater Research,* **42**, 233–256.
Primo, C., Vázquez, E., 2009. Antarctic ascidians: an isolated and homogeneous fauna. *Polar Research,* **28(3)**, 403–414.
Ramos Esplá, A.A., Cárcel, J., Varela, M., 2005. Zoogeographical relationships of the littoral ascidiofauna around the Antarctic Peninsula, in the Scotia Arc and in the Magellan Region. *Scientia Marina,* **69(suppl. 2)**, 215–223.
Sanamyan, K., Sanamyan, N., 2002. Deep-water ascidians from the south-western Atlantic (RV *Dmitry Mendeleev*, cruise 43, and RV *Academic Kurchatov*, cruise 11). *Journal of Natural History,* **36**, 305–359.
Sluiter, C., 1906. Tuniciers. Expédition Antarctique Française (1903–1905). Vol. 6. Paris: Masson, 50 pp., 5 pls., 1 map.
Smith, C.R., Grange, L.J., Honig, D.L., Naudts, L., Huber, B., Guidi, L., Domack, E., 2012. A large population of king crabs in Palmer Deep on the west Antarctic Peninsula shelf and potential invasive impacts. *Proceedings of the Royal Society, Series B,* **279(1730)**, 1017–1026.
Strathmann, R.R., Kendall, L.R., Marsh, A.G., 2006. Embryonic and larval development of a cold adapted Antarctic ascidian. *Polar Biology,* **29**, 495–501.
Tatian, M., Antacli, J.C., Sahade, R.J., 2005. Ascidians (Tunicata, Ascidiacea): species distribution along the Scotia Arc. *Scientia Marina,* **69(Suppl. 2)**, 205–214.
Tavares, M., De Melo, G.A., 2004. Discovery of the first known benthic invasive species in the Southern Ocean: the North Atlantic spider crab *Hyas araneus* found in the Antarctic Peninsula. *Antarctic Science,* **12(2)**, 129–131.
Varela, M., Ramos Esplá, A.A., 2008. *Didemnum bentarti* (Chordata: Tunicata) a new species from the Bellingshausen Sea, Antarctica. *Polar Biology,* **31**, 209–213.

▶ Appendix 4 at the end of volume

Appendix 4: Ascidiacea (Chap. 5.27)

Table 3 List of ascidian species recorded below the Sub-Tropical Front, with bathymetrical and geographical distributions (only distribution below the Sub-Tropical Front represented) and biogeographical groups. Biogeographical groups: END, endemic; ANT-SAN, Antarctic and sub-Antarctic distribution; ANT-SAM, Antarctic/sub-Antarctic and Southern South American distribution; ANT-NZ, Antarctic/sub-Antarctic and New Zealand distribution; ANT-AU, Antarctic/sub-Antarctic and Australian distribution; ANT-SAF, Antarctic/sub-Antarctic and South African distribution; CM, cosmopolitan; HS, widely distributed in the Southern Hemisphere; NZ, New Zealand distribution beyond the New Zealand sub-Antarctic Islands; AU-NZ, Australian and New Zealand distribution. Biogeographical regions: CONT, Antarctic continental shelf and slope; SOR, South Orkney Islands; SSA, South Sandwich Islands; SGE, South Georgia; BOU, Bouvet Island; SAM, Southern South American Region; KE, Kerguelen Province; MQ, Macquarie Province; NZI, New Zealand sub-Antarctic islands.

Species	Depth (meters)	Biogeographical Group	CONT	SOR	SSA	SGE	BOU	SAM	KE	MQ	NZI
Aplidium abyssum Kott, 1969	3500	HS							1		
Aplidium acropodium Monniot & Gaill, 1978	—	END							1		
Aplidium annulatum (Sluiter, 1906)	30	END	1								
Aplidium aurorae (Harant & Vernières, 1938)	200–400	END	1								
Aplidium balleniae Monniot & Monniot, 1983	50–150	END	1								
Aplidium bilinguae Monniot & Monniot, 1983	25–250	END	1			1	1				
Aplidium circumvolutum (Sluiter, 1900)	50–1100	HS	1	1		1		1	1	1	
Aplidium complanatum (Herdman, 1886)	90–220	END							1		
Aplidium cyaneum (Sluiter, 1906)	50–1700	END	1	1			1				
Aplidium didemniformis Monniot & Gaill, 1978	<100	END							1		
Aplidium falklandicum Millar, 1960	0–800	HS	1	1	1	1		1	1		
Aplidium fuegiense Cunningham, 1871	0–350	ANT-SAM	1	1		1		1	1		
Aplidium globosum (Herdman, 1886)	0–1000	ANT-SAM	1	1	1			1	1		
Aplidium gracile Monniot & Monniot, 1983	40–250	END						1			
Aplidium hians Monniot & Gaill, 1978	–	END							1		
Aplidium imbutum Monniot & Monniot, 1983	0–870	ANT-SAM	1	1		1		1	1		
Aplidium irregulare (Herdman, 1886)	0–250	END						1			
Aplidium knoxi (Brewin, 1956)	–	END									1
Aplidium laevigatum (Herdman, 1886)	>100	ANT-SAM						1	1		
Aplidium leviventer Monniot & Gaill, 1978	110	END							1		
Aplidium longicaudatum (Sluiter, 1912)	75	END	1								
Aplidium longum Monniot, 1970	25–100	END							1		
Aplidium loricatum (Harant & Vernières, 1938)	0–650	END	1	1							
Aplidium meridianum (Sluiter, 1906)	5–20	END						1			
Aplidium millari Monniot & Monniot, 1994	0–1700	ANT-SAM	1	1	1	1		1	1		
Aplidium miripartum Monniot & Monniot, 1983	150–400	END	1								
Aplidium nigrum (Herdman, 1886)	0–300	END	1								
Aplidium notti (Brewin, 1951)	50	END							1		
Aplidium novaezealandiae Brewin, 1952	5–25	HS							1		
Aplidium ordinatum (Sluiter, 1906)	0–100	HS						1	1		
Aplidium ovum Monniot & Gaill, 1978	50–700	END	1								
Aplidium paessleri (Michaelsen, 1907)	75–350	ANT-SAM						1	1		
Aplidium pellucidum Kott, 1971	75	ANT-SAM				1		1			
Aplidium peresi (Pérès, 1952)	90–100	END						1			
Aplidium laevigatum (Herdman, 1886)	0	END							1		
Aplidium polarsterni Tatian, Antacli & Sahade, 2005	272	END						1			
Aplidium quadriversum Millar, 1982	430	END								1	
Aplidium radiatum (Sluiter, 1906)	50–750	END	1	1	1						
Aplidium recumbens (Herdman, 1886)	50–600	ANT-SAM	1	1	1			1		1	
Aplidium retiforme (Herdman, 1886)	0–220	ANT-SAF							1		
Aplidium siderum Monniot & Monniot, 1983	70–166	END	1								
Aplidium stanleyi Millar, 1960	100–320	ANT-SAM	1			1		1			
Aplidium triplex (Sluiter, 1906)	0–300	ANT-SAM	1					1			
Aplidium undulatum (Herman, 1886)	0–250	ANT-SAM						1	1		
Aplidium variabile (Herman, 1886)	0–500	HS				1		1	1		
Aplidium vastum (Sluiter, 1912)	50–150	END	1								
Aplidium vexillum Monniot & Gaill, 1978	-	END							1		
Aplidiopsis discoveryi Millar, 1960	40–125	HS						1			
Aplidiopsis pyrimorfis (Herdman, 1886)	0–100	END							1		
Pharyngodictyon mirabile Herdman, 1886	3000–6000	ANT-SAM						1	1		
Placentella translucida Kott, 1969	370	END	1								
Polyclinum minutum Herdman, 1886	40–110	END							1		
Polyclinum sluiteri Brewin, 1956	50–550	HS							1	1	1
Ritterella chetvergovi Sanamyan & Sanamyan, 2002	4500–5500	END						1			
Ritterella mirifica Monniot & Monniot, 1983	150–350	END	1								
Synoicum adareanum (Herdman, 1902)	0–800	ANT-SAN	1	1	1	1			1		
Synoicum georgianum Sluiter, 1932	0–450	ANT-SAM	1	1	1	1		1	1		
Synoicum giardi (Herdman, 1886)	0–100	ANT-SAM				1		1	1		
Synoicum hypurgon (Michaelsen, 1924)	0–200	HS	1								
Synoicum kuranui Brewin, 1950	100–300	HS						1			
Synoicum ostentor Monniot & Monniot, 1983	0–350	END	1	1							

Species	Depth (meters)	Biogeographical Group	CONT	SOR	SSA	SGE	BOU	SAM	KE	MQ	NZI
Synoicum polygyna Monniot & Monniot, 1980	20–250	END	1								
Synoicum ramulosum Kott, 1969	180	END	1								
Synoicum salivum Monniot &Gaill, 1978	–	END							1		
Synoicum tentaculatum Kott, 1969	2800	END		1							
Cystodyes antarcticus Sluiter, 1912	50–250	ANT-SAM	1					1			
Distaplia colligans Sluiter, 1932	0–275	ANT-SAM	1	1		1		1			
Distaplia concreta (Herdman, 1886)	0–100	END							1		
Distaplia cylindrica (Lesson, 1830)	0–650	ANT-SAM	1	1	1	1		1			
Distaplia kerguelenense Monniot, 1970	15	END							1		
Distaplia megathorax Monniot & Monniot, 1982	1500	END	1								
Eudistoma australe Monniot, 1978	190	END							1		
Eudistoma magalhaensis (Michaelsen, 1907)	150–220	ANT-SAM	1	1	1			1			
Polycitor ciemari (Primo & Vazquez, 2007)	140	END	1								
Polycitor glareosus (Sluiter, 1906)	30–270	ANT-SAM	1		1			1			
Protoholozoa pedunculata Kott, 1969	750–5500	ANT-SAM	1	1		1		1			
Sigillina moebiusi (Hartmeyer, 1905)	240	HS	1								
Sycozoa anomala Millar, 1960	50–120	HS		1							
Sycozoa gaimardi (Herdman, 1886)	0–350	ANT-SAM	1			1		1			
Sycozoa georgiana (Michaelsen, 1907)	0–400	ANT-SAN	1			1			1		
Sycozoa sigillinoides Lesson, 1830	0–600	HS	1		1	1		1	1	1	1
Didemnum bentarti Varela & Ramos-Espla 2008	425	END	1								
Didemnum biglans (Sluiter, 1906)	30–1220	END	1	1	1	1					
Didemnum studeri Hartmeyer, 1911	0–700	HS		1		1		1	1	1	1
Didemnum subflavum (Herdman, 1886)	50	END							1		
Didemnum tenue (Herdman, 1886)	300–1100	ANT-SAM				1		1			
Diplosoma antarcticum Kott, 1969	150	END	1								
Diplosoma longinquum (Sluiter, 1912)	50–350	END	1			1					
Leptoclinides capensis Michaelsen,1934	0–25	ANT-SAF							1		
Leptoclinides kerguelensis Kott, 1954	50	END							1		
Polysyncraton mortenseni (Michaelsen, 1924)	120–680	AU-NZ									1
Polysincraton trivolutum (Millar, 1960)	50–950	ANT-SAM	1	1		1		1	1		
Trididemnum auriculatum Michaelsen, 1919	20–75	END						1			
Ciona antarctica Hartmeyer, 1911	100–500	END	1								
Mysterascidia symmetrica Monniot & Monniot, 1982	3500	END	1								
Tylobranchion speciosum Herdman, 1886	0–3000	ANT-SAM	1	1	1	1	1	1	1		
Dimeatus attenuatus Sanamyan, 2000	5500–6000	END		1							
Dimeatus mirus Monniot & Monniot, 1982	5000	END									
Cybacapsa gulosa Monniot &Monniot, 1983	550–800	END	1		1						
Kaikoja multitentaculata Vinogradova, 1975	4500–5500	END	1		1						
Megalodicopia rineharti (Monniot & Monniot, 1989)	700–4000	CM	1								
Octacnemus kottae Sanamyan & Sanamyan, 2002	3700–4000	END			1						
Polyoctacnemus patagoniensis (Metcalf, 1893)	1900	END						1			
Situla macdonaldi Monniot & Monniot, 1977	800	END							1		
Situla rebainsi Vinogradova, 1975	3700–5500	END	1		1						
Corella eumyota Traustedt,1882	0–850	CM	1	1		1		1		1	1
Xenobranchion insigne Arnback, 1950	–	END						1			
Adagnezia antarctica Kott, 1969	100	END								1	
Adagnezia charcoti Monniot & Monniot, 1973	500–5500	CM								1	
Adagnezia henriquei Monniot & Monniot, 1983	120	END						1			
Adagnezia weddelli Monniot & Monniot, 1994	1200	END	1								
Agnezia abyssa Sanamyan & Sanamyan, 2002	7500–8000	END			1						
Agnezia arnaudi Monniot & Monniot, 1974	0–200	ANT-SAN	1		1				1		
Agnezia biscoei Monniot & Monniot, 1983	30–200	HS	1	1							
Agnezia glaciata Michaelsen,1898	100	HS						1			
Agnezia tenue Monniot & Monniot, 1983	20	END						1			
Caenagnezia bocki Arnback, 1938	50–1000	END	1		1	1					
Caenagnezia schmitti Kott, 1969	50–1100	END	1								
Corynascidia cubare Monniot & Monniot, 1994	450	END	1								
Corynascidia lambertae Sanamyan & Sanamyan, 2002	1300	END	1								
Corynascidia suhmi Herdman, 1882	1200–6200	HS	1	1	1	1			1	1	1
Proagnezia depressa (Millar, 1955)	2500–6000	CM		1							
Ascidia bathybia Hartmeyer, 1922	3500–4200	END							1		
Ascidia challengeri Herdman,1882	0–700	HS	1	1		1			1		
Ascidia meridionalis Herdman,1880	10–1100	HS	1	1		1		1			
Ascidia translucida Herdman,1880	0–250	ANT-SAN				1			1		
Alloeocarpa affinis Bovien, 1921	100	NZ									1
Alloeocarpa bacca Arnback, 1929	20	END						1			
Alloeocarpa bigyna Monniot, 1978	0–220	ANT-SAM				1		1	1		
Alloeocarpa bridgesi Michaelsen, 1900	50–100	END						1			
Alloeocarpa incrustans (Herdman, 1886)	0–500	ANT-SAM				1		1			
Bathyoncus mirabilis Herdman, 1882	1000–6000	HS	1	1				1	1		
Bathystyeloides anfractus Monniot & Monniot, 1985	400–1200	HS									1

Species	Depth (meters)	Biogeographical Group	CONT	SOR	SSA	SGE	BOU	SAM	KE	MQ	NZI
Bathystyeloides enderbyanus Michaelsen, 1904	1000–5500	CM	1			1			1		
Bathystyeloides magnus Sanamyan & Sanamyan, 1999	2000–4500	HS								1	
Botrylloides leachii (Savigny, 1816)	20–175	CM									1
Cnemidocarpa acanthifera Monniot, 2011	815	END	1								
Cnemidocarpa barbata Vinogradova, 1962	200–3500	CM	1						1		
Cnemidocarpa bathypila Millar, 1955	2200–5300	CM	1								
Cnemidocarpa bythia (Herdman, 1881)	2200–7000	CM	1						1		
Cnemidocarpa digonas Monniot & Monniot, 1968	2200–5300	CM							1		
Cnemidocarpa drygalskii (Hartmeyer, 1911)	100–1500	ANT-SAM	1	1	1			1	1	1	
Cnemidocarpa effracta Monniot, 1978	200	END							1		
Cnemidocarpa eposi Moniot & Monniot, 1994	500	END	1								
Cnemidocarpa humilis (Heller, 1878)	0–50	HS									1
Cnemidocarpa minuta (Herman, 1881)	200–300	END							1		
Cnemidocarpa nordenskjoldi (Michaelsen, 1898)	0–500	ANT-SAM	1					1			
Cnemidocarpa ohlini (Michaelsen, 1898)	20–270	END						1			
Cnemidocarpa pfefferi (Michaelsen, 1898)	75–450	END	1	1		1					
Cnemidocarpa sericata (Herdman, 1888)	4000–5000	HS	1						1		
Cnemidocarpa univesica Monniot, 2011	800–110	END	1								
Cnemidocarpa verrucosa (Lesson, 1830)	0–400	ANT-SAM	1	1	1	1	1	1	1		
Cnemidocarpa victoriae Moniot & Monniot, 1983	70–350	END						1			
Dicarpa antarctica Moniot & Monniot, 1977	3200–4400	ANT-AU							1		
Dicarpa cornicula (Moniot, 1978)	200	END							1		
Dicarpa insinuosa (Sluiter, 1912)	30–620	END	1			1					
Dicarpa mysogyna Moniot & Monniot, 1982	2800	END		1							
Dicarpa tricostata (Millar, 1960)	35–450	END	1			1					
Gynandrocarpa misanthropos Monniot,1978	200	END							1		
Monandrocarpa abyssa Sanamyan & Sanamyan, 1999	2800–4400	ANT-SAN	1							1	
Oligocarpa megalorchis Hartmeyer, 1911	0–450	END							1	1	
Pelonaia quadrivena Monniot, 2011	50	END	1								
Polycarpa zeteta Millar, 1982	100–1100	END									1
Polyzoa minor Monniot, 1970	0–150	END							1		
Polyzoa opuntia Lesson,1830	0–430	HS			1	1	1	1	1	1	1
Styela crinita Moniot & Monniot, 1973	2000–5600	CM							1	1	
Styela glans Herdman, 1881	35–1700	HS	1						1		
Styela magalhaensis Michaelsen, 1898	15–540	SAM						1			
Styela mallei Monniot, 1978	–	END							1		
Styela materna Monniot & Monniot,1983	50–400	ANT-SAF			1	1					
Styela milleri Ritter ,1907	0–120	END						1			
Styela paessleri Michaelsen, 1898	85–120	SAM						1			
Styela schmitti simplex Van Name, 1945	150–4800	CM	1	1		1		1			
Styela squamosa Herdman, 1881	200	END							1		
Styela wandeli (Sluiter, 1911)	20–150	END	1	1		1					
Theodorella arenosa Michaelsen, 1922	30–450	ANT-NZ				1					
Bathypera hastaefera Vinogradova, 1962	300–2000	END	1								
Bathypera splendens Michaelsen, 1904	50–4700	ANT-SAM	1	1				1			
Boltenia elegans Herdman, 1881	–	END						1			
Culeolus anonymus Monniot & Monniot,1976	2500–6500	HS	1	1				1		1	
Culeolus antarcticus Vinogradova, 1962	1200–5600	HS	1	1	1			1			
Culeolus likae Sanamyan & Sanamyan, 2002	4600–5600	SAM						1			
Culeolus pinguis Monniot & Monniot,1982	2800	END	1								
Culeolus recumbens Herdman, 1881	700–2500	HS							1		1
Hemistyela hirta (Monniot & Monniot, 1977)	1400–4200	HS	1						1		
Pyura bouvetensis (Michaelsen, 1904)	25–2100	ANT-NZ	1	1		1	1				1
Pyura chilensis Molina, 1782	0	SAM						1			
Pyura discoveryi (Herdman, 1910)	0–650	END	1	1		1					
Pyura georgiana (Michaelsen, 1898)	15–600	END	1		1	1					
Pyura legumen (Lesson, 1830)	0–130	ANT-SAM				1		1			
Pyura lycoperdon Monniot & Monniot,1983	70–240	END	1								
Pyura multiruga Monniot & Monniot,1982	2300–2800	END	1								
Pyura obesa Sluiter, 1912	25–220	END	1	1							
Pyura paessleri (Michaelsen, 1900)	0–280	ANT-SAM				1		1			
Pyura pilosa Monniot & Monniot,1974	0–675	ANT-AU							1	1	
Pyura setosa (Sluiter, 1905)	15–650	END	1	1							
Pyura squamata Hartmeyer, 1911	250–2000	ANT-NZ	1	1		1			1		
Pyura stubenrauchi (Michaelsen, 1900)	40–100	SAM						1			
Pyura trita (Sluiter, 1900)	20–675	AU-NZ									1
Pyura tunica Kott, 1969	185	END	1								
Pyura tunica Kott, 1969	15–350	ANT-SAM	1		1			1	1		
Eugyroides kerguelenensis (Herdman, 1881)	20–850	END	1	1	1	1					
Eugyroides polyducta Monniot & Monniot,1983	50	END							1		

Species	Depth (meters)	Biogeographical Group	CONT	SOR	SSA	SGE	BOU	SAM	KE	MQ	NZI
Eugyroides septum (Monniot, 1978)	100	SAM						1			
Fungulus cinereus Herdman, 1882	2800–6000	ANT-SAM	1		1			1	1		
Fungulus perlucidus (Herdman, 1881)	3000–5700	HS			1			1	1	1	
Gamaster vallatum Monniot, 1978	100	END							1		
Minipera macquariensis Sanamyan & Sanamyan, 1999	5500	END								1	
Molgula coactilis Monniot & Monniot, 1977	3200	END							1		
Molgula delicata Monniot & Monniot, 1991	500–1200	HS									1
Molgula enodis (Sluiter, 1912)	20–125	ANT-NZ	1	1							1
Molgula estadosi Monniot & Monniot, 1983	75	END						1			
Molgula euplicata Herdman, 1923	40–650	END	1	1		1					
Molgula georgiana Michaelsen, 1900	0–200	ANT-SAN			1	1			1		
Molgula hodgsoni Herdman, 1910	50–600	END	1	1		1					
Molgula kerguelensis Kott, 1954	50	END							1		
Molgula longivascula Millar, 1982	0–200	ANT-SAN				1			1	1	
Molgula macquariensis Kott, 1954	0–200	END							1	1	
Molgula marioni Millar, 1960	100–500	ANT-SAM				1		1	1	1	
Molgula millari Kott, 1971	3000–4200	ANT-AU	1		1	1				1	
Molgula mortenseni (Michaelsen, 1922)	15–500	HS				1		1			1
Molgula novaeselandiae (Michaelsen, 1911)	–	ANT-NZ								1	
Molgula pedunculata Herdman, 1881	0–900	HS	1	1	1	1	1	1	1		
Molgula pigafettae Monniot & Monniot, 1983	75–275	END						1			
Molgula pulchra Michaelsen, 1900	0–450	ANT-SAM				1		1	1	1	
Molgula pyriformis Herdman, 1881	0-500	HS				1		1			
Molgula riddlei Monniot, 2011	816	END	1								
Molgula robini Millar, 1960	100–3700	END	1			1					
Molgula setigera Arnback, 1938	0–150	END						1			
Molgula sluiteri (Michaelsen, 1922)	0–100	ANT-NZ								1	
Molgula variazizi Monniot, 1978	200	END							1		
Molguloides bathybia (Hartmeyer, 1912)	–	END	1								
Molguloides coronatum Monniot, 1978	200	ANT-SAN	1						1		
Molguloides crinibus Monniot, 1978	200	END							1		
Molguloides cyclocarpa Monniot & Monniot, 1982	3000–6000	HS				1		1			
Molguloides glans Monniot, 1978	200–600	HS							1		1
Molguloides monocarpa (Millar, 1959)	200–4500	HS	1						1	1	
Molguloides sphaeroidea (Millar, 1970)	4500–6000	SAM						1			
Molguloides tenuis Kott, 1954	1300	END	1								
Pareugyroides arnbackae (Millar, 1960)	30–1100	END	1		1						
Pareugyroides galatheae (Millar, 1959)	1500–6000	HS	1		1	1		1	1	1	
Pareugyroides macquariensis Kott, 1954	0	END								1	
Paramolgula canioi Monniot & Monniot, 1983	200–500	END						1			
Paramolgula gregaria (Lesson, 1830)	0–250	HS				1		1			

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.

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.

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 interoperable databases, forming the Antarctic regional node of the Ocean Biogeographic 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.

The Editorial Team

Claude DE BROYER is a marine biologist at the Royal Belgian Institute of Natural Sciences in Brussels. His research interests cover structural and ecofunctional biodiversity and biogeography of crustaceans, and polar and deep sea benthic ecology. Active promoter of CAML and ANDEEP, he is the initiator of the SCAR Marine Biodiversity Information Network (SCAR-MarBIN). He took part to 19 polar expeditions.

Huw GRIFFITHS is a marine Biogeographer at the British Antarctic Survey. He created and manages SOMBASE, the Southern Ocean Mollusc Database. His interests include large-scale biogeographic and ecological patterns in space and time. His focus has been on molluscs, bryozoans, sponges and pycnogonids as model groups to investigate trends at high southern latitudes.

Cédric d'UDEKEM d'ACOZ is a research scientist at the Royal Belgian Institute of Natural Sciences, Brussels. His main research interests are systematics of amphipod crustaceans, especially of polar species and taxonomy of decapod crustaceans. He took part to 2 scientific expeditions to Antarctica on board of the *Polarstern* and to several sampling campaigns in Norway and Svalbard.

Bruno DANIS is an Associate Professor at the Université Libre de Bruxelles, where his research focuses on polar biodiversity. Former coordinator of the scarmarbin. be and antabif.be projects, he is a leading member of several international committees, such as OBIS or the SCAR Expert Group on Antarctic Biodiversity Informatics. He has published papers in various fields, including ecotoxicology, physiology, biodiversity informatics, polar biodiversity or information science.

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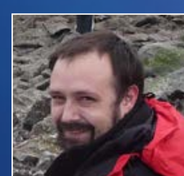
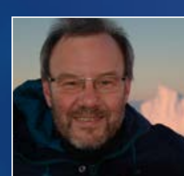
Ben RAYMOND is a computational ecologist and exploratory data analyst, working across a variety of Southern Ocean, Antarctic, and wider research projects. His areas of interest include ecosystem modelling, regionalisation and marine protected area selection, risk assessment, animal tracking, seabird ecology, complex systems, and remote sensed data analyses.



Anton VAN DE PUTTE works at the Royal Belgian Institute for Natural Sciences (Brussels, Belgium). He is an expert in the ecology and evolution of Antarctic fish and is currently the Science Officer for the Antarctic Biodiveristy Portal www. biodiversity.aq. This portal provides free and open access to Antarctic Marine and terrestrial biodiversity of the Antarctic and the Southern Ocean.

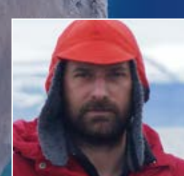
Bruno DAVID is CNRS director of research at the laboratory BIOGÉOSCIENCES, University of Burgundy. His works focus on evolution of living forms, with and more specifically on sea urchins. He authored a book and edited an extensive database on Antarctic echinoids. He is currently President of the scientific council of the Muséum National d'Histoire Naturelle (Paris), and Deputy Director at the CNRS Institute for Ecology and Environment.



Julian GUTT is a marine ecologist at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, and professor at the Oldenburg University, Germany. He participated in 13 scientific expeditions to the Antarctic and was twice chief scientist on board Polarstern. He is member of the SCAR committees ACCE and AnT-ERA (as chief officer). Main focii of his work are: biodiversity, ecosystem functioning and services, response of marine systems to climate change, non-invasive technologies, and outreach.

Graham HOSIE is Principal Research Scientist in zooplankton ecology at the Australian Antarctic Division. He founded the SCAR Southern Ocean Continuous Plankton Recorder Survey and is the Chief Officer of the SCAR Life Sciences Standing Scientific Group. His research interests include the ecology and biogeography of plankton species and communities, notably their response to environmental changes. He has participated in 17 marine science voyages to Antarctica.

Alexandra POST is a marine geoscientist, with expertise in benthic habitat mapping, sedimentology and geomorphic characterisation of the seafloor. She has worked at Geoscience Australia since 2002, with a primary focus on understanding seafloor processes and habitats on the East Antarctic margin. Most recently she has led work to understand the biophysical environment beneath the Amery Ice Shelf, and to characterise the habitats on the George V Shelf and slope following the successful CAML voyages in that region.



Yan ROPERT COUDERT spent 10 years at the Japanese National Institute of Polar Research, where he graduated as a Doctor in Polar Sciences in 2001. Since 2007, he is a permanent researcher at the CNRS in France and the director of a polar research programme (since 2011) that examines the ecological response of Adélie penguins to environmental changes. He is also the secretary of the Expert Group on Birds and Marine Mammals and of the Life Science Group of the Scientific Committee on Antarctic Research.