

Southern Ocean Asteroidea: a proposed update for the Register of Antarctic Marine Species

Camille VE Moreau[‡], Antonio Aguera[‡], Quentin Jossart[‡], Bruno Danis[‡]

[‡] Université Libre de Bruxelles (ULB), 50 avenue F. Roosevelt 1050, Brussels, Belgium

Corresponding author:

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Abstract

Background

The Register of Antarctic Marine Species (RAMS, De Broyer et al. 2015) is the regional component of the World Register of Marine Species (WoRMS Editorial Board 2015) in the Southern Ocean. It has been operating for the last ten years, with a special effort devoted towards its completion after the International Polar Year (IPY) in 2007-2008, in the framework of the Census of Antarctic Marine Life (CAML, 2005 - 2010). Its objective is to offer free and open access to a complete register of all known species living in the Southern Ocean, building a workbench of the present taxonomic knowledge for that region. The Antarctic zone defined by this dynamic and community-based tool has been investigated with a particular interest. The Sub-Antarctic zone was a secondary objective during the establishment of the RAMS and is still lacking the impulse of the scientific community for some taxa.

New information

In the present study, more than 13,000 occurrences records of Asteroidea (Echinodermata) have been compiled within the RAMS area of interest and checked against the RAMS species list of sea stars, using WoRMS Taxon Match tool. Few mismatches (basonym mistakes : i.e. original name misspelled or incorrect) were found within the existing list and 97 unregistered species are actually occurring within the RAMS boundaries. After this update, the number of Asteroidea species was increased by around 50%, now reaching 295 accepted species.

Keywords

Asteroidea, Sea stars, Southern Ocean, RAMS, WoRMS, Register of Antarctic Marine Species, Biodiversity, Checklist

Introduction

The Register of Antarctic Marine Species, RAMS

RAMS is a collaborative and dynamic information system managing Southern Ocean marine taxon names and related information (De Broyer et al. 2015). The main objective of RAMS is to establish a benchmark of the present taxonomic knowledge of the Southern Ocean biodiversity (De Broyer and Danis 2011).

In a recent appraisal of RAMS, Jossart et al. (2015) underscored the number of 10,294 described species of which 8,297 are accepted marine species (*viz.* checked by taxonomic experts). Among these species, 537 (~6.5%) were reported as accepted species names for echinoderms and 198 (~2.4%) as accepted names for sea star species.

After 10 years of service, RAMS still displays several spatial gaps, especially with regards to species occurring in the sub-Antarctic zone, described as the area below the sub-Tropical front (Deacon 1984, Rintoul 2007) and North of the Polar Front.

In order to complete the taxonomic information for the class Asteroidea, we propose in this work an updated version of the checklist of Southern Ocean sea stars species occurring within the RAMS area of interest.

Materials and methods

Area of interest

As described in De Broyer and Danis (2011) the RAMS area of interest is extending from the coast of the Antarctic continent to the sub-Tropical front. Convenient operational limits have been defined (Table 1; Fig. 1), splitting the Southern Ocean into two zones: the Antarctic zone and the sub-Antarctic zone.

Data collection

More than 13,000 occurrences records were aggregated from different sources including global information systems such as the Ocean Biogeographic Information System ([OBIS](#)), the Global Biodiversity Information Facility ([GBIF](#)), initiatives such as the [Biogeographic Atlas of the Southern Ocean](#) (De Broyer et al. 2014), historic records mined

from the literature pertaining to the early exploration of the Southern Ocean (e.g. Sladen 1889), recently published checklists (e.g. Gutt et al. 2014) or unpublished cruise records. Only the specimens identified at a species level, regardless of their depth (shelf, slope, deep-sea) were kept for the preparation of this checklist.

The validity of each species name was controlled using the Taxa Match Tool available in RAMS (<http://www.marinespecies.org/rams/aphia.php?p=match>) and WoRMS (<http://www.marinespecies.org/aphia.php?p=match>) to ensure its validity and presence in the RAMS checklist.

Data resources

Complete checklist of Southern Ocean Asteroidea

The data underpinning the analyses reported in this paper are deposited at GBIF, the Global Biodiversity Information Facility, http://ipt.pensoft.net/resource?r=southern_ocean_asteroidea&v=1.1

Checklist of RAMS Asteroidea species

Abyssaster diadematus (Sladen, 1883)

Abyssaster planus (Sladen, 1883)

Acodontaster capitatus (Koehler, 1912)

Acodontaster conspicuus (Koehler, 1920)

Acodontaster elongatus (Sladen, 1889)

Acodontaster hodgsoni (Bell, 1908)

Acodontaster marginatus (Koehler, 1912)

Adelasterias papillosa (Koehler, 1906)

Allostichaster capensis (Perrier, 1875)

Anasterias antarctica (Lütken, 1857)

Anasterias asterinoides Perrier, 1875

Anasterias directa (Koehler, 1920)

Anasterias mawsoni (Koehler, 1920)

Anasterias pedicellaris Koehler, 1923

Anasterias perrieri (E. A. Smith, 1876)

Anasterias rupicola (Verrill, 1876)

Anasterias sphaerulata (Koehler, 1920)

Anasterias spirabilis (Bell, 1881)

Anasterias studeri Perrier, 1891

Anasterias suteri (deLoriol, 1894)

Anseropoda antarctica Fisher, 1940

Anteliaster australis Fisher, 1940

Anteliaster scaber (E. A. Smith, 1876)

Asterina fimbriata Perrier, 1875

Astropecten brasiliensis Müller & Troschel, 1842

Bathybiaster loripes Sladen, 1889

Belgicella racowitzana Ludwig, 1903

Benthopecten pedicifer (Sladen, 1885)

Caimanaster acutatus Clark, 1962

Calyptraster tenuissimus Bernasconi, 1966

Calyptraster vitreus Bernasconi, 1972

Ceramaster grenadensis (Perrier, 1881)

Ceramaster patagonicus (Sladen, 1889)

Cheiraster (Luidiaster) antarcticus (Koehler, 1907)

Cheiraster (Luidiaster) gerlachei Ludwig, 1903

Cheiraster (Luidiaster) hirsutus (Studer, 1884)

Cheiraster (Luidiaster) planeta (Sladen, 1889)

Chitonaster cataphractus Sladen, 1889

Chitonaster felli (H.E.S. Clark, 1971)

Chitonaster johannae Koehler, 1908

Chondraster elattosis H.L. Clark, 1923

Cladaster analogus Fisher, 1940

Cosmasterias lurida (Philippi, 1858)

Crossaster penicillatus Sladen, 1889

Cryptasterias brachiata Koehler, 1923

Cryptasterias turqueti (Koehler, 1906)

Ctenodiscus australis Lütken, 1871

Ctenodiscus procurator Sladen, 1889

Cuenotaster involutus (Koehler, 1912)

Cycethra frigida (Koehler, 1917)

Cycethra macquariensis Koehler, 1920

Cycethra verrucosa (Philippi, 1857)

Diplasterias brandti (Bell, 1881)

Diplasterias brucei (Koehler, 1908)

Diplasterias kerguelenensis (Koehler, 1917)

Diplasterias meridionalis (Perrier, 1875)

Diplasterias octoradiata (Studer, 1885)

Diplasterias radiata (Koehler, 1923)

Diplodontias singularis (Müller & Troschel, 1843)

Diplopteraster clarki Bernasconi, 1937

Diplopteraster peregrinator (Sladen, 1882)

Diplopteraster semireticulatus (Sladen, 1882)

Diplopteraster verrucosus (Sladen, 1882)

Dytaster felix Koehler, 1907

Echinaster smithi Ludwig, 1903

Eremicaster crassus (Sladen, 1883)

Eremicaster pacificus (Ludwig, 1905)

Eremicaster vicinus Ludwig, 1907

Freyastera tuberculata (Sladen, 1889)

Freyella attenuata Sladen, 1889

Freyella drygalskii Döderlein, 1927

Freyella formosa Korovchinsky, 1976

Freyella fragilissima Sladen, 1889

Freyella giardi Koehler, 1908

Freyella heroina Sladen, 1889

Freyella mutabila Korovchinsky, 1976

Ganeria attenuata Koehler, 1907

Ganeria falklandica Gray, 1847

Ganeria hahni Perrier, 1891

Gaussaster antarcticus (Sladen, 1889)

Glabraster antarctica (E. A. Smith, 1876)

Granaster nutrix (Studer, 1885)

Henricia diffidens (Koehler, 1923)

Henricia fisheri A.M. Clark, 1962

Henricia obesa (Sladen, 1889)

Henricia pagenstecheri (Studer, 1885)

Henricia parva Koehler, 1912

Henricia praestans (Sladen, 1889)

Henricia smilax (Koehler, 1920)

Henricia studeri Perrier, 1891

Hippasteria falklandica Fisher, 1940

Hippasteria phrygiana (Parelius, 1768)

Hymenaster caelatus Sladen, 1882

Hymenaster campanulatus Koehler, 1908

Hymenaster coccinatus Sladen, 1882

Hymenaster crucifer Sladen, 1882

Hymenaster densus Koehler, 1908

Hymenaster edax Koehler, 1908

Hymenaster formosus Sladen, 1882

Hymenaster fucatus Koehler, 1908

Hymenaster graniferus Sladen, 1882

Hymenaster latebrosus Sladen, 1882

Hymenaster pellucidus Thomson, 1873

Hymenaster perspicuus Ludwig, 1903

Hymenaster praecoquis Sladen, 1882

Hymenaster sacculatus Sladen, 1882

Hymenodiscus distincta (Sladen, 1889)

Hyphalaster inermis Sladen, 1883

Hyphalaster scotiae Koehler, 1907

Kampylaster incurvatus Koehler, 1920

Kenrickaster pedicellaris A.M. Clark, 1962

Labidiaster annulatus Sladen, 1889

Labidiaster radiosus Lütken, 1872

Leptychaster flexuosus (Koehler, 1920)

Leptychaster kerguelenensis E. A. Smith, 1876

Leptychaster magnificus (Koehler, 1912)

Leptychaster melchiorensis (Bernasconi, 1969)

Lethasterias australis Fisher, 1923

Lonchotaster tartareus Sladen, 1889

Lophaster densus Fisher, 1940

Lophaster gaini Koehler, 1912

Lophaster stellans Sladen, 1889

Lophaster tenuis Koehler, 1920

Luidia clathrata (Say, 1825)

Lysasterias adeliae (Koehler, 1920)

Lysasterias belgicae (Ludwig, 1903)

Lysasterias chirophora (Ludwig, 1903)

Lysasterias digitata A.M. Clark, 1962

Lysasterias hemiora Fisher, 1940

Lysasterias heteractis Fisher, 1940

Lysasterias joffrei (Koehler, 1920)

Lysasterias lactea (Ludwig, 1903)

Lysasterias perrieri (Studer, 1885)

Macroptychaster accrescens (Koehler, 1920)

Mediaster pedicellaris (Perrier, 1881)

Mirastrella biradialis Fisher, 1940

Neosmilaster georgianus (Studer, 1885)

Neosmilaster steineni (Studer, 1885)

Notasterias armata (Koehler, 1911)

Notasterias bongraini (Koehler, 1912)

Notasterias candicans (Ludwig, 1903)

Notasterias haswelli Koehler, 1920

Notasterias pedicellaris (Koehler, 1907)

Notasterias stolophora Fisher, 1940

Notioceramus anomalus Fisher, 1940

Novodinia novaezelandiae (H.E.S. Clark, 1962)

Odinella nutrix Fisher, 1940

Odontaster meridionalis (E. A. Smith, 1876)

Odontaster penicillatus (Philippi, 1870)

Odontaster pusillus Koehler, 1907

Odontaster validus Koehler, 1906

Paralophaster antarcticus (Koehler, 1912)

Paralophaster godfroyi (Koehler, 1912)

Paralophaster lorioli (Koehler, 1907)

Pectinaster filholi Perrier, 1885

Pedicellaster hypernotius Sladen, 1889

Pergamaster incertus (Bell, 1908)

Pergamaster triseriatus H.E.S. Clark, 1963

Peribolaster folliculatus Sladen, 1889

Peribolaster macleani Koehler, 1920

Perknaster antarcticus (Koehler, 1906)

Perknaster aurantiacus Koehler, 1912

Perknaster aurorae (Koehler, 1920)

Perknaster charcoti (Koehler, 1912)

Perknaster densus Sladen, 1889

Perknaster fuscus Sladen, 1889

Perknaster sladeni (Perrier, 1891)

Persephonaster facetus (Koehler, 1907)

Poraniopsis echinaster Perrier, 1891

Porcellanaster ceruleus Wyville Thomson, 1877

Psolidaster mordax Fisher, 1940

Pseudarchaster discus Sladen, 1889

Psilaster charcoti (Koehler, 1906)

Pteraster affinis Smith, 1876

Pteraster florifer Koehler, 1920

Pteraster gibber (Sladen, 1882)

Pteraster hirsutus (Sladen, 1882)

Pteraster koehleri A.M. Clark, 1962

Pteraster rugatus Sladen, 1882

Pteraster spinosissimus (Sladen, 1882)

Pteraster stellifer Sladen, 1882

Radiaster gracilis (H.L. Clark, 1916)

Remaster gourdoni Koehler, 1912

Rhopiella hirsuta (Koehler, 1920)

Saliasterias brachiata Koehler, 1920

Scotiaster inornatus Koehler, 1907

Smilasterias clarkailsa O'Loughlin & O'Hara, 1990

Smilasterias scalprifera (Sladen, 1889)

Smilasterias triremis (Sladen, 1889)

Solaster notophrynus Downey, 1971

Solaster regularis Sladen, 1889

Styracaster armatus Sladen, 1883

Styracaster chuni Ludwig, 1907

Styracaster horridus Sladen, 1883

Styracaster robustus Koehler, 1908

Tremaster mirabilis Verrill, 1880

Vemaster sudatlanticus Bernasconi, 1965

Zoroaster tenuis Sladen, 1889

Checklist of Proposed-RAMS Asteroidea species

Allostichaster farquhari McKnight, 2006

Allostichaster insignis (Farquhar, 1895)

Allostichaster polyplax (Muller & Troschel, 1844)

Anasterias laevigata (Hutton, 1879)

Anthenoides cristatus (Sladen, 1889)

Astromesites primigenius (Mortensen, 1925)

Astropecten polyacanthus Müller & Troschel, 1842

Astrostole scabra (Hutton, 1872)

Benthopecten munidae H.E.S. Clark, 1969

Benthopecten pikei H.E.S. Clark, 1969

Brisinga chathamica McKnight, 1973

Brisingenes multcostata (Verrill, 1894)

Ceramaster australis H.E.S. Clark, 2001

Cheiraster (Cheiraster) otagoensis Studer, 1883

Chitonaster trangae Mah, 2011

Clavaporania fitchorum Mah & Foltz, 2014

Coscinasterias calamaria (Gray, 1840)

Coscinasterias muricata Verrill, 1870

Cosmasterias dyscrita H.L. Clark, 1916

Crossaster campbellicus McKnight, 1973

Crossaster multispinus H.L. Clark, 1916

Diplodontias dilatatus (Perrier, 1875)

Diplodontias robustus (Fell, 1953)

Diplopteraster hurleyi McKnight, 1973

Dipsacaster magnificus (H.L. Clark, 1916)

Echinaster farquhari Benham, 1909

Eratosaster jenaе Mah, 2011

Freyastera benthophila (Sladen, 1889)

Freyella echinata Sladen, 1889

Freyellaster polycnema (Sladen, 1889)

Fromia monilis (Perrier, 1869)

Gilbertaster anacanthus Fisher, 1906

Henricia aucklandiae Mortensen, 1925

Henricia compacta (Sladen, 1889)

Henricia lukinsii (Farquhar, 1898)

Henricia ornata (Perrier, 1869)

Henricia ralphae Fell, 1958

Henricia simplex (Sladen, 1889)

Henricia spinulfera (E. A. Smith, 1876)

Hymenaster estcourti McKnight, 1973

Hymenaster nobilis Wyville Thomson, 1876

Hymenodiscus aotearoa (McKnight, 1973)

Hymenodiscus submembranacea (Döderlein, 1927)

Hyphalaster giganteus Macan, 1938

Lithosoma novaezealandiae McKnight, 1973

Luidia porteri A.H. Clark, 1917

Mediaster arcuatus (Sladen, 1889)

Mediaster dawsoni McKnight, 1973

Mediaster sladeni Benham, 1909

Meridiastra medius (O'Loughlin, Waters & Roy, 2003)

Meridiastra oriens (O'Loughlin, Waters & Roy, 2003)

Mimastrella cognata (Sladen, 1889)

Myxoderma qawashqari (Moyana & Larrain Prat, 1976)

Odontaster aucklandensis McKnight, 1973

Odontaster benhami (Mortensen, 1925)

Odontaster pearsei Janosik & Halanych, 2010

Odontaster roseus Janosik & Halanych, 2010

Odontohenricia anarea O'Hara, 1998

Odontohenricia endeavouri Rowe & Albertson, 1988

Ophidiaster confertus H.L. Clark, 1916

Paralophaster hyalinus H.E.S. Clark, 1970

Paranepanthia aucklandensis (Koehler, 1920)

Patiriella regularis (Verrill, 1867)

Paulasterias tyleri Mah et al. 2015

Pectinaster mimicus (Sladen, 1889)

Pentagonaster pulchellus Gray, 1840

Peribolaster lictor Fell, 1958

Perissasterias monacantha McKnight, 1973

Pillsburiaster aoteanus (McKnight, 1973)

Pillsburiaster inutilis McKnight, 2006

Plutonaster complexus H.E.S Clark & D.G. McKnight, 2000

Plutonaster fragilis H.E.S. Clark, 1970

Plutonaster hikurangi H.E.S Clark & D.G. McKnight, 2000

Plutonaster jonathani H.E.S Clark & D.G. McKnight, 2000

Plutonaster knoxi Fell, 1958

Plutonaster sirius A.H. Clark, 1917

Proserpinaster neozelanicus (Mortensen, 1925)

Psolidaster fisheri McKnight, 2006

Pseudarchaster garricki Fell, 1958

Pseudechinaster rubens H.E.S. Clark, 1962

Psilaster acuminatus Sladen, 1889

Pteraster bathami Fell, 1958

Pteraster robertsoni McKnight, 1973

Sclerasterias eustyla (Sladen, 1889)

Sclerasterias mollis (Hutton, 1872)

Smilasterias irregularis H.L. Clark, 1928

Solaster longoi Stampanato & Jangoux, 1993

Solaster torulatus Sladen, 1889

Sphaeriodiscus mirabilis A.M. Clark, 1976

Stichaster australis (Verrill, 1871)

Taranuiaster novaezealandiae McKnight, 1973

Tarsaster stoichodes Sladen, 1889

Zoroaster actinocles Fisher, 1919

Zoroaster alternicanthus McKnight, 2006

Zoroaster fulgens Thomson, 1873

Zoroaster macracantha H.L. Clark, 1916

Zoroaster spinulosus Fisher, 1906

Analysis

More than 13,000 occurrences records from 295 accepted species have been compiled within the extent of the RAMS area of interest. 198 of these species (67%) were already

in the RAMS database and 97 (33%) were new to the system. After this update, the number of Asteroidea species in RAMS will be increased by around 50%.

The seven Orders of the Class Asteroidea are represented in the Southern Ocean. The Valvatida are the most speciose with 8 families, 41 genus and 87 species followed by Forcipulatida (6 families, 30 genus, 78 species), Paxillosida (6 families, 22 genus, 43 species), Velatida (2 families, 6 genus, 37 species), Spinulosida (1 family, 4 genus, 20 species), Brisingida (2 families; 9 genus; 19 species) and Notomyotida (1 family, 4 genus, 2 subgenus, 11 species).

After a careful verification of the RAMS species list for Asteroidea we propose to address the following points. These issues have been taken into account in this paper:

- *Cheiraster (Barbadosaster) echinulatus* and *Stegnaster wesseli* are only described from Central America and should be removed from the RAMS list
- *Spoladaster veneris* is only described from Amsterdam and Saint-Paul Islands which are not part of the RAMS area of interest
- *Anthenoides peircei*, *Astropecten cingulatus*, *Cheiraster (Cheiraster) sepius*, *Peltaster placenta*, and *Psilaster herwigi* do not seem to be distributed in the RAMS area of interest
- *Echinaster (Othilia) brasiliensis* is only described from South America and should be removed of the RAMS list
- *Freyella mutabilia* was originally described as *Freyella mutabila* by Korovchinsky (1976)
- *Mimastrella cognata* and *Mirastrella cognata* are source of a problem. Both genus do exist but *Mimastrella cognata* and *Mirastrella biradialis* are the only described species. The genus name being nearly identical, it has lead to a mistake. *Mirastrella cognata* is an invalid name and should be deleted from RAMS and WoRMS systems

Moreover, we recommend the addition of species from our "Proposed-RAMS" checklist (i.e. species not registered in the RAMS list but present in the RAMS area of interest) to RAMS. None of these species are new to science but their austral distribution range was not properly documented (e.g. species from the Campbell Plateau are reported as New-Zealand species but are also present in the Southern Ocean, species from the French sub-Antarctic Islands, etc...). Interestingly, 22 of the 97 "non-RAMS" species are present in the Antarctic zone. Some have been described recently (e.g. *O. roseus* and *O. pearsei* described by Janosik and Halanych (2010); *C. trangae* described by Mah (2011) or *P. tyleri* described by Mah et al. 2015) but have not been added to the RAMS.

A final comment pertains to *Astropecten polyacanthus*, occurring in the RAMS Sub-Antarctic region in a location that is not actually South from the Sub-Tropical Front. This final observation shows that convenient boundaries should be used with care. However, only one species was concerned for a very wide area of interest. *A. polyacanthus*

presence in the RAMS checklist should be discussed by the editors from RAMS and WoRMS.

Discussion

This study highlights the fact that after ten years of effort, the work is still in progress for RAMS. The main objective of covering the Antarctic zone has generally been reached for the class Asterozoa but needs at this point to go through a major update by the editors. Regarding the asteroids, the secondary objective of covering the Sub-Antarctic zone lacked the impulse of the scientific community and we hope that the work presented here will fill the gaps as accurately as possible.

This approach may not bring the same results for all the taxa in the Southern Ocean. Indeed some charismatic fauna are very well known in the RAMS area of interest (e.g. marine mammals), however, we believe that the knowledge concerning the number of species present in the Southern Ocean waters might be significantly increased.

Only few mistakes were found in the existing RAMS list of Asterozoa and should be fixed soon after getting in contact with the editors. The new updated checklist of Asterozoa species will be available through the RAMS website (<http://www.marinespecies.org/rams>) in early 2016. A way to improve the general system, with the sea stars for model is also in development.

Recent work using genetics on *Odontaster* species (Janosik and Halanych 2010) highlights the fact that diversity might be higher than expected even in well-studied areas. There is also a lack of resources for identification and taxonomic work leading to redundant mistakes. In this context, the creation of a digital library, hotlinked with the RAMS and compiling original descriptions, literature materials and DNA barcoding informations for each species will bring the RAMS a step ahead and provide a vital tool for future taxonomic and biogeographic work. Perspectives also include an illustrative determination key using a polytomic approach and the creation of interactive Antarctic Field Guides (<http://afg.biodiversity.aq>) on the <http://www.biodiversity.aq> platform (Van de Putte et al. 2015) in order to help the scientific community with the identification process and to enhance data availability.

We believe that the homogenization of available data for all taxa will result in a better understanding of the Southern Ocean and its biogeography, especially in the Sub-Antarctic zone.

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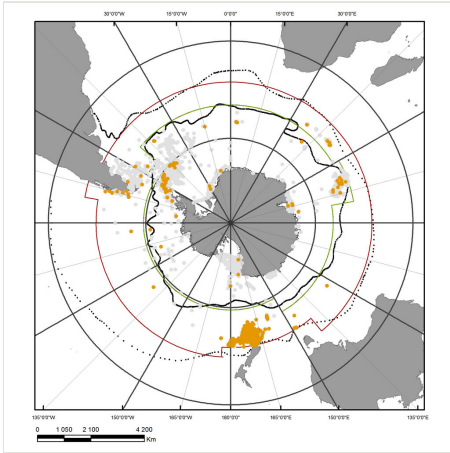


Figure 1.

Occurrences of RAMS (light grey dots) and Proposed-RAMS (orange dots) sea star species. The Antarctic zone is located below the green line and the Sub-Antarctic zone between the green and dark red lines. The Polar Front (black line) and the Sub-Tropical Front (dashed black line) are also shown.

Table 1.

RAMS area of interest. Operational northern limits in the different sector of the Southern Ocean for both the Antarctic zone and the sub-Antarctic zone.

Sector	Longitude range	Northern limit
Antarctic zone		
South Atlantic Sector	60°W-50°W	57°S
	50°W-30°E	50°S
Indian Sector	30°E-80°E	50°S
	80°E-150°E	55°S
South Pacific Sector	150°E-60°W	60°S
Sub-Antarctic zone		
Atlantic & Indian Sectors	60°W-140°E	43°S
South Pacific Sector	140°E-176°W	48°S
	176°W-80°W	45°S
	80°W-72°W	41°S