

An integrated compilation of data sources for the development of a marine protected area in the Weddell Sea

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Abstract. The Southern Ocean may contribute a considerable part to the proposed global network of Marine Protected Areas (MPAs) that should cover about 10% of the world oceans in 2020. In the Antarctic, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is responsible for this task, 20 and currently Germany leads a corresponding scientific evaluation of the wider Weddell Sea region. Compared to other marine regions within the Southern Ocean, the Weddell Sea is exceptionally well investigated. A tremendous amount of data and information has been produced over the last four decades. Here, we give a systematic overview of all data sources collected in the context of the Weddell Sea MPA planning process. The compilation of data sources comprises data produced by scientists / institutions from more than twenty countries 25 and were either available within our institutes, downloaded via data portals, or transcribed from the literature. It is the first compilation for this area that includes abiotic data, such as bathymetry and sea ice, and ecological data from zooplankton, zoobenthos, fish, birds and marine mammals. All data layer products based on this huge compilation of environmental and ecological data are available from the data publisher PANGAEA via the six persistent identifiers at <https://doi.org/10.1594/PANGAEA.899595> (Pehlke and Teschke, 2019), 30 <https://doi.org/10.1594/PANGAEA.899667> (Teschke et al., 2019a), <https://doi.org/10.1594/PANGAEA.899645> (Teschke et al., 2019b), <https://doi.org/10.1594/PANGAEA.899591> (Teschke et al., 2019c), <https://doi.org/10.1594/PANGAEA.899520> (Pehlke et al., 2019a) and <https://doi.org/10.1594/PANGAEA.899619> (Pehlke et al., 2019b). This compilation of data sources with the final data layer products will serve future research and monitoring well beyond the current MPA development 35 process.

1 Introduction

Marine Protected Areas (MPAs) have experienced a significant increase in number and coverage at a global scale during recent decades (e.g. Mora and Sale, 2011; McDermott et al., 2018; UNEP-WCMC and IUCN, 40 2019). The number of MPAs has increased almost 1.5 times since the 1990s and the total area protected is currently almost 30 million km². At the United Nations World Summit on Sustainable Development in 2002 the international community of states reached an agreement about the establishment of a representative network of MPAs for the purposes of long-term conservation of marine biodiversity by 2012 (A/CONF.199/20, 2002). The

- adopted *strategic plan for biodiversity 2011-2020* of the Convention on Biological Diversity aims at the conservation of at least 10 % of the coastal and offshore marine areas by 2020 based on a MPA network (CBD, 2010). The Southern Ocean may contribute a considerable proportion of this MPA network due to its size, and the uniqueness of the Antarctic environment renders its conservation the more urgent.
- 5 The Weddell Sea represents the southerly part of the Atlantic Sector of the Southern Ocean. About one quarter of the Weddell Sea's entire marine area covers the continental shelf along the eastern contour of the Antarctic Peninsula and the Antarctic continent up to 20°E as a non topographic delineation. The Weddell Sea is deserving protection in multiple respects. On the one hand, all arguments for the conservation of the Southern Ocean hold true for the Weddell Sea, too: An extreme environment mostly dominated by the seasonal dynamic of the sea ice
- 10 with an excellent adapted biota. The biodiversity is - particularly in the benthos - very high (e.g. Brey et al., 1994; Brandt et al., 2007), and there is a significant number of endemic species, i.e. unique to the Antarctic or even to the Weddell Sea (e.g. Arntz et al., 1994; Clarke and Johnston, 2003; Linse et al., 2006). Moreover, the Weddell Sea plays an important role for seabirds, penguins and marine mammals. Almost one third of the entire population of emperor penguins (Fretwell et al., 2012) and a major part of the circum-Antarctic population of
- 15 crabeater seals (*cf.* Bester and Odendaal, 2000; Southwell et al., 2012; Gurarie et al. 2017a, b) apparently occurs in the Weddell Sea. Sponge associations which are comparable to tropical reef systems in terms of their structural and functional complexity occur along the eastern Weddell Sea shelf (Barthel and Gutt, 1992), and on the broad shelf in the southern Weddell Sea a special benthic community - adapted to very cold water temperatures - seems to resident (Teschke et al., 2016).
- 20 The Weddell Sea is - despite being one of the most remote and inaccessible places on earth - relatively well investigated compared to other Antarctic regions. Since approximately 30 years the Weddell Sea is the geographical focus area of the German Antarctic research. In addition, there are manifold research activities of other nations. Consequently, we were able to compile a tremendous amount of environmental and ecological data to support the development of a Weddell Sea MPA (hereafter: WSMPA) under the Commission for the
- 25 Conservation of Antarctic Marine Living Ressources (CCAMLR). Here, we present a systematic overview of all environmental and ecological data sources collected for the development of a WSMPA and provide data layer products that are based on this data compilation.

2 Data description

2.1 Study site

- 30 The WSMPA Planning Area in which we acquired the environmental and ecological data is located between the Antarctic Peninsula and 20°E (Fig. 1). The northern border is at 64°S and the continental margin forms the southern border. This area is defined by CCAMLR's MPA Planning Domains in the CCAMLR Convention Area (SC-CAMLR-XXX, 2011) and by aiming at a bio-geographically homogeneous area, particularly on the shelf (Teschke et al., 2016). In addition to the WSMPA Planning Area (approx. 4.2 million km² in size) we compiled
- 35 data for a 200 km wide buffer area near the Antarctic Peninsula, which is part of an MPA initiative led by Argentina and Chile (CCAMLR-XXXVII/31, 2018). This buffer zone is adjacent northerly to the northern border of the WSMPA Planning Area and has the eastern and western boundaries at 30°W and 60°W, respectively. Some data (e.g. seal tracking data), extend beyond the WSMPA Planning Area (plus buffer) and

originate from adjacent regions of the Weddell Sea, such as the Bellinghausen Sea along the west side of the Antarctic Peninsula.

2.2 Data availability

All raw data sets of environmental and ecological parameters collected by the end of 2016 and further processed

5 as part of the WSMPA planning process are systematically described and the primary reference is mentioned, such as the data portal on which the data are freely available or the website of the institute/organisation on which the data can be requested on demand (see Table 1 and 2; see all data records in Fig. 2 and Fig. S1). For each individual raw data set in Tables 1 and 2, the accessibility status is indicated, i.e. it is immediately clear which data set is directly freely available and which data set must first be requested.

10 In addition, we offer data layer products that we developed on the basis of the raw data sets whose sources are described here. The methods used to process and analyse the data and to develop each data layer are described in detail in the Supplement. All data layer products with metadata description are freely available from the data publisher PANGAEA via the six persistent identifiers at <https://doi.org/10.1594/PANGAEA.899595> (Pehlke and Teschke, 2019), <https://doi.org/10.1594/PANGAEA.899667> (Teschke et al., 2019a),
15 <https://doi.org/10.1594/PANGAEA.899645> (Teschke et al., 2019b), <https://doi.org/10.1594/PANGAEA.899591> (Teschke et al., 2019c), <https://doi.org/10.1594/PANGAEA.899520> (Pehlke et al., 2019a) and
20 <https://doi.org/10.1594/PANGAEA.899619> (Pehlke et al., 2019b) (see Table 1 and 2). The data layers are available either as ArcMAP packages (as mxd file, containing a map document with all associated files) or as individual GIS files for those who use another GIS-software instead of the ESRI software (ArcMap). The shape and raster files, all with the same spheroid (WGS 1984) and projection (South Pole Lambert Azimuthal Equal Area, EPSG 102020), were processed in such a way that they can be easily used for the analysis of MPA scenarios or other geostatistical analyses in the Weddell Sea without direct access to the underlying raw data. For example, the shape and raster files could be stacked to identify hot- and coldspots of biodiversity, or certain layers could be used as explanatory variables in species distribution models.

25 2.3 Environmental data

2.3.1 IBCSO data

The bathymetric data used in the context of the WSMPA planning initiative originate from the first regional digital bathymetric model (DBM) established in the International Bathymetric Chart of the Southern Ocean (IBCSO) Version 1.0 programme (data request: April 2013) (Table 1; Fig. 3a). This chart model is based upon

30 bathymetric data of different origin, such as multi-beam and single beam data, digitized depths from nautical charts, predicted bathymetry, from many hydrographic offices, scientific institutions and data centres. The IBCSO Version 1.0 DBM has a horizontal resolution of 500 m x 500 m and a vertical resolution of 1 m based on a polar stereographic projection with true scale at 65° referenced to WGS84 ellipsoid (Arndt et al., 2013a, b).

2.3.2 AMSR-E sea ice maps

Daily high resolution sea ice maps of the Antarctic Ocean are provided by the PHAROS group (PHysical Analysis of RemOte Sensing images) at the Institute of Environmental Physics, University of Bremen, Germany. The sea ice raster maps, which were used in the context of the WSMPA planning initiative, are derived from satellite observations of daily sea ice concentration by the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-EOS) instrument on board the Aqua satellite. Daily AMSR-E sea ice concentration data (Jun 2002 - Oct 2011) were downloaded from IUP, University of Bremen (data request: 18-12-2013) (see Table 1; Fig. 3b). The ARTIST Sea Ice (ASI) concentration algorithm was used with a spatial resolution of 6.25 km x 6.25 km (Spreen et al., 2008) and a polar stereographic projection (EPSG: 3976).

10 2.3.3 FESOM data

Monthly mean values of seawater temperature, salinity and current velocity from 1990 to 2009 were derived from the Finite Element Sea Ice - Ocean Model (FESOM) (Table 1; Fig. 3c, d). The model run was initialised on January, 1st 1980 with hydrographic data from the Polar Science Center Hydrographic Climatology (Steele et al., 2001), and forced with NCEP daily atmospheric re-analysis data (Kalnay et al., 1996) for 1980 to 2009. For more information on FESOM and the atmospheric forcing data sets see e.g. Timmermann et al. (2009) and Haid and Timmermann (2013), respectively. The FESOM raster has a resolution of 0.18° (x) x 0.05° (y); in the vertical, two z-levels (i.e. sea surface and sea bottom) are used. The raster bases on WGS84 geographic coordinate system (EPSG: 4326).

20 IBCSO data, AMSR-E sea ice maps and FESOM data were used in a pelagic regionalisation analysis for the Weddell Sea. The respective data layer products are available at <https://doi.org/10.1594/PANGAEA.899595> ("Pelagic regionalisation - clustering approach"). The clustering approach to classify different pelagic provinces is described in the Supplement. In addition, the data sets were used as environmental variables in various geostatistical approaches to develop spatial distribution maps for (i) adult Antarctic krill (AMSR-E), (ii) ice krill (IBCSO, FESOM), (iii) echinoderms (FESOM), (iv) demersal fish (IBCSO, FESOM), (v) Antarctic toothfish (IBCSO), (vi) Antarctic petrel (IBCSO, AMSR-E, FESOM) and (vii) emperor penguins (AMSR-E). The methods used to develop the different spatial distribution maps are described in the Supplement and the PANGAEA link to the respective data layer products (incl. file names) is given in the corresponding subsection under "2.4 Ecological data".

30 2.3.4 SeaWiFS data

Near-surface chlorophyll a concentration values stem from the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) measurements on board of the OrbView-2 (formerly SeaStar) spacecraft (Table 1). The monthly aggregated data (1997 to 2010) were downloaded as level 3 standard mapped images (L3SMI) with a spatial resolution of 9 km x 9 km (data request: 09-09-2014).

2.3.5 WOA13 data

Data on dissolved oxygen, phosphate and nitrate were obtained from the World Ocean Atlas 2013 version 2 (WOA13 V2) (Garcia et al., 2014a, b) (Table 1). The data (1955 to 2012) were downloaded as monthly statistical means with a horizontal resolution of 1° (x) x 1° (y) and 57 and 37 vertical (z) levels between 0 to

- 5 1500 m and 0 to 500 m for dissolved oxygen and phosphate/nitrate, respectively. The data request was on 11-07-2013 (dissolved oxygen), 17-07-2013 (nitrate) and 18-07-2013 (phosphate), respectively.

2.3.6 Data on chemical sediment components

A data compilation on total organic carbon content and calcium carbonate and silicia in surface sediments were downloaded from the data archive PANGAEA (Seiter et al., 2004a, b, c, and references therein) (see Table 1).

- 10 10 Data on biogenic silica of the sediment surface were obtained from PANGAEA, too (Geibert et al., 2005 b).

The data described under 2.3.4 to 2.3.6 were used as explanatory variables in the Antarctic krill species distribution model (SDM) (SeaWiFS, WOA13, chemical sediment components) and in the demersal fish SDM (WOA13, chemical sediment components). The SDMs are described in detail in the Supplement and the
15 PANGAEA link to the respective data layer products (incl. file names) is given in the corresponding subsection under "2.4 Ecological data".

2.4 Ecological data

- 20 20 In the following, we describe the sources of raw data sets used in the WSMPA planning process and indicate which data layer product was developed on the basis of which raw data sets. In addition, the methods for processing and analysing the data and for developing each data layer are described in detail in the Supplement.

2.4.1 Zooplankton

Antarctic krill (adults)

- 25 25 The WSMPA data collection on adult Antarctic krill (*Euphausia superba*) originates from (i) historical UK data from "Discovery Expeditions" (1928-1939) and data collected during the SIBEX cruise by British Antarctic Survey, (ii) five South African data sets from the 1990s, (iii) four Soviet data sets from 1998 and 1990, (iv) Polish data (Witek et al., 1985) and (v) German data from location discovery cruises with MV "Polarstern" in 1979/80 and 1980/81 (Siegel, 1982), RV "Walther Herwig" cruises (1975/76, 1977/78) and the 2004 Lazarev
30 30 Sea Krill Survey (LAKRIS) (RV "Polarstern" cruise ANT-XXI/4) (Siegel, 2012). All the data are publicly available via the database KRILLBASE (doi.org/brg8) (Atkinson et al., 2017) (see Table S2 in the Supplement that provides a detailed list of data used from KRILLBASE). The data from KRILLBASE were complemented by abundance data on *E. superba*, which were collected (a) during the Norwegian Antarctic research expedition 1976/77 (MV "Polarstern"), (b) during two Soviet research cruises in 1977 and 1983, (c) in the context of the
35 35 Lazarev Sea Krill Survey as well as (d) during RV "Polarstern" cruises ANT-V/1-3, ANT-VII/4, ANT-XVIII/4 and ANT-XXIX/3 (Table 2). Furthermore, fisheries data on *E. superba* for the WSMPA Planning Area (i.e.

Statistical Subarea 48.5 and southern part of Subarea 48.6) stem from the CCAMLR database (<https://www.ccamlr.org>; data request: 03-10-2013) (Table 2).

All these data were used in a species distribution model (SDM) of adult Antarctic krill and ultimately led to a data layer product showing habitat suitability for adult Antarctic krill in the WSMPA Planning Area (see doi 5 10.1594/PANGAEA.899667; file name: "Adult Antarctic krill, *Euphausia superba* - habitat suitability prediction").

Antarctic krill (larvae)

Abundance data on Antarctic krill larvae stem from (a) the Antarctic research expeditions 1976/77 and 1979/80 10 with MV "Polarsirkel", (b) the First International BIOMASS Experiment survey (FIBEX), (c) the Lazarev Sea Krill Survey (LAKRIS) as well as (d) RV "Polarstern" cruise ANT-VII/4 and the combined RV "Polarstern" (ANT-VIII/2) and RV "Akademik Fedorov" cruises (see Table 2).

All data on Antarctic krill larvae were used for an interpolation approach and led to a map of the interpolated 15 abundances of krill larvae in the WSMPA Planning Area (see doi 10.1594/PANGAEA.899667; "Antarctic krill larvae, *Euphausia superba* - interpolated abundance").

Ice krill

Abundance data on adult ice krill (*Euphausia crystallorophias*) originate from pelagic trawl surveys during (a) 20 the German Antarctic research cruise 1975/76 with "Walther Herwig", (b) the "Pre-Site Survey" 1979/80 with MV "Polarsirkel", (c) the Lazarev Sea Krill Survey as well as (d) RV "Polarstern" cruises ANT-V/1-3, ANT-VII/4 and ANT-XXIX/3 (Table 2).

The abundance data on *E. crystallorophias* were used for an interpolation approach and led to a map showing the 25 interpolated abundances of ice krill (see doi 10.1594/PANGAEA.899667; "Ice krill, *Euphausia crystallorophias* - interpolated denisty"). In addition, the abundance data on *E. crystallorophias* were used for "ground truthing" of the potential ice krill habitat (doi 10.1594/PANGAEA.899667; "Ice krill, *Euphausia crystallorophias* – pot habitat").

All data about *E. superba* and *E. crystallorophias*, which were used additionally to KRILLBASE and the 30 CCAMLR database, are stored in the data warehouse of the Thuenen Institute of Sea Fisheries (<https://www.thuenen.de/de/sf>) and can be requested on demand.

2.4.2 Zoobenthos

Sponges

Abundance data and semi-quantitative data on sponges (higher taxonomic groups), which were compiled in the context of the WSMPA planning initiative, originate from zoobenthos data sets. The abundance data (Gerdes, 35 2014 a-p) and the semi-quantitative data set (Teschke and Brey, 2020) are publically available via PANGAEA (see Table 2).

Based on these data, we developed a map of the occurrence of sponges in the WSMPA Planning Area (doi 10.1594/PANGAEA.899645; "Sponges, Porifera - interpolated presence").

Echinoderms

The compiled data set on echinoderms consists of presence-absence data on species level for asteroids, abundance data on ophiuroid taxa as well as on holothurian taxa. The first two data sets are freely available in PANGAEA (Teschke and Brey, 2019a, b), the latter in the information system biodiversity.aq (Gutt et al., 2014). These data were used in a clustering approach to ultimately identify the potential habitat for echinoderms in the 5 WSMPA Planning Area by environmental proxies (doi 10.1594/PANGAEA.899645; "Special echinoderm assemblage - pot habitat").

2.4.3 Fish

Antarctic silverfish and demersal fish

The WSMPA data collection on Antarctic silverfish larvae (*Pleuragramma antarctica*) originates from 10 quantitative zooplankton data sets obtained during the RV "Polarstern" cruises ANT-I/2 and ANT-III/3 and during the Lazarev Sea Krill Survey (LAKRIS) (Table 2). The first mentioned data (ANT-I/2) are stored in the data warehouse of the Thuenen Institute of Sea Fisheries and can be requested on demand (<https://www.thuenen.de/de/sf>). Data on fish larvae from ANT-III/3 are available from Hubold et al. (1988), and the LAKRIS data can be requested from <https://www.awi.de/forschung/biowissenschaften/polare-biologische-ozeanographie>. 15

Abundance data on demersal fish and adult *P. antarctica* stem from benthic and pelagic trawl surveys from six "Polarstern" cruises between 1996 and 2011 (Table 2) and are published in PANGAEA (Balguerías and Knust, 2020; Knust and Schröder, 2020; Knust et al., 2020a-d). This data compilation was complemented by data on demersal fish and *P. antarctica* derived from trawl and dredge surveys published in PANGAEA (Drescher et., 20

2012; Ekau et al., 2012a, b; Hureau et al., 2012; Kock et al., 2012; Wöhrmann et al., 2012).

All abundance data on Antarctic silverfish (adults and larvae) were used for an interpolation approach and led to a map of the interpolated abundances of *P. antarctica* in the WSMPA Planning Area (doi 10.1594/PANGAEA.899591; "Antarctic silverfish, *Pleuragramma antarctica* - interpolated abundance").

All data on demersal fish were used in a SDM and led to a data layer product showing the habitat suitability for 25 demersal fish in the WSMPA Planning Area (see doi 10.1594/PANGAEA.899591; "Demersal fish - habitat suitability prediction").

Antarctic toothfish (adults)

Fishery data on the Antarctic toothfish (*Dissostichus mawsoni*) for the WSMPA Planning Area (i.e. Statistical 30 Subarea 48.5 and southern part of Subarea 48.6) were taken from the CCAMLR database (<https://www.ccamlr.org>; data request: 03-08-2016) (Table 2).

The data were used to determine the potential habitat of *D. mawsoni* in the WSMPA Planning Area (see doi 10.1594/PANGAEA.899591; "Adult toothfish, *Dissostichus mawsoni* - pot habitat").

35 Demersal fish nesting sites

Information about nesting sites of demersal fish was collected during the RV "Polarstern" cruises PS82 (Knust and Schröder, 2014) and PS96 (Piepenburg, 2016). The data collected during RV "Polarstern" cruises were supplemented by data from the literature (Daniels 1978, 1979; Jones and Near 2012). The map with the locations

of the nesting sites of demersal fish is available at PANGAEA (doi 10.1594/PANGAEA.899591; "Demersal fish - observation of nesting sites") and is also shown in the Supplement (see Fig. S12).

2.4.4 Flying and non-flying seabirds

Breeding and non-breeding Adélie penguins

5 Tracking data on breeding and non-breeding Adélie penguins (*Pygoscelis adeliae*) originate from (i) British Antarctic Survey (BAS) inventory data (ID 754, 764, 773, 779), (ii) a data set from BAS and Instituto Antártico Argentino (ID 753) and (iii) a data set from the US AMLR Program (NOAA) (ID 910) (see also Table 2). All the data are stored in the Birdlife International's Seabird Tracking Database (<http://www.seabirdtracking.org/>; data request: 20-10-2015). Adélie penguins breeding locations and estimated abundances of breeding pairs were
10 derived from Lynch and LaRue (2014).

The tracking data on *P. adeliae* were used to model the probability of breeding and non-breeding *P. adeliae* occurrence during foraging (doi 10.1594/PANGAEA.899520; "Breeding Adélie penguin, *Pygoscelis adeliae* - modelled foraging trips" and "Non-breeding Adélie penguin, *Pygoscelis adeliae* - modelled foraging trips"). The final data layer product for breeding *P. adeliae* also depict breeding locations and estimated abundances of
15 breeding pairs as well as buffer areas around each colony.

Breeding Emperor penguins

Data on Emperor penguin (*Aptenodytes forsteri*) colony locations and breeding population estimates were derived from Fretwell et al. (2012, 2014) (Table 2).

20 These data were used to develop a probability map of foraging areas for *A. forsteri* (doi 10.1594/PANGAEA.899520; "Breeding emperor penguin, *Aptenodytes forsteri* - modelled foraging areas").

Antarctic petrels

Information on breeding locations and estimated number of breeding pairs of the Antarctic petrel (*Thalassoica antarctica*) are published in van Franeker et al. (1999) (Table 2).

25 The information on breeding pairs and their colony locations is shown in the final data layer product next to modelled foraging habitats of *T. antarctica* (doi 10.1594/PANGAEA.899520; "Antarctic petrel, *Thalassoica antarctica* - modelled foraging areas").

2.4.5 Pinnipeds

30 Tracking data from pinnipeds were obtained from the MEOP data portal "Marine Mammals Exploring the Oceans Pole to Pole" available via <http://www.meop.net/> (data request: 14-11-2016) (see Table 2 for a detailed list of data used). Furthermore, the data from the MEOP data portal were complemented by tracking data sets on southern elephant seals (Tosh et al., 2009a, b; James et al., 2012a, b), Weddell seals (McIntyre et al., 2013a, b) and crabeater seals (Nachtsheim et al., 2016a, b) stored in PANGAEA.

35 All these tracking data were used to model the probability of seal occurrence during foraging (doi 10.1594/PANGAEA.899619; "Seal abundance - modelled prediction values").

Point data from pack-ice seals (unspecified taxa) based on aerial surveys are from Plötz et al. (2011a-e) and were downloaded from PANGAEA (Table 2). These data were sampled during five flight campaigns from 1996 to 2001 within the Antarctic Pack Ice Seals (APIS) programme. In addition, information on crabeater seal densities (predicted or observed) was derived from Bester et al. (1995 and 2002), Flores et al. (2008) and Forcada et al.

5 (2012; Table 2).

All the APIS point data and information on seal densities were used to develop a map showing the distribution patterns of seals in the WSMPA Planning Area (doi 10.1594/PANGAEA.899619; "Seal abundance - modelled and interpolated prediction values").

3 Outlook

This is the first compilation of data sources for the Antarctic Weddell Sea and adjacent seas, which considers data across the entire ecosystem: i.e., from abiotic data, such as bathymetry and sea ice, to ecological data ranging from zooplankton and zoobenthos to fish, birds and marine mammals. The effort to create such a compilation of data sources was directly coupled with the initiative to develop a WSMPA. However, our compilation of data sources will facilitate the future research on fauna, ecology and nature conservation in the Weddell Sea. Using our systematic overview of available data for the development of a specific data collection, future projects save the time-consuming multi-parameter data search from the scratch. In addition, our work serves to guide future studies aimed at closing data gaps in the wider Weddell Sea region and/or simply pointing to specific data sets that may be of particular interest to future generations (baseline is a particular issue). For example, some of the ecological data sets were collected in the 1980s and earlier, when the Weddell Sea was still almost pristine and hardly affected by any anthropogenic activities, so that these data sets are optimally suited to describe a reference state for assessing the effect of pressures on the Weddell Sea ecosystem. In addition, the ecological data - with a few exceptions - provide information on abundances of the respective taxa and are therefore better suited as an indicator for environmental changes than presence-absence data or presence data only. Ultimately, the compilation of data sources serves to motivate researchers to incorporate further data, both from existing "paper sources" and from future measurements, into existing data repositories and archives.

Subsequent work will focus on the development of an efficient and tailor-made management system for the storage of these complex and heterogeneous data and information of WSMPA data compilation and automated data mining, handling and analysis. This system will serve three purposes: (i) to better enable a more holistic and integrative approach towards ecosystem research in the Weddell Sea in general, (ii) to enable the management of the WSMPA to carry out the tasks of the Research and Monitoring Programme as a mandatory part of an MPA under CCAMLR when adopting the MPA, and (iii) to provide key stakeholders and the public with access to data, information and management measures related to the ecosystem of the Weddell Sea region in general and the WSMPA in particular. The CCAMLR MPA Information Repository (CMIR) currently being developed by the CCAMLR Secretariat will also be available in the future as a suitable storage location for metadata on CCAMLR MPAs in Antarctica.

Author contribution. KT collected all data together, described the metadata and led the writing of the paper. HP took over the technical part of the data acquisition (retrieval, storage, processing). VS collected and prepared the

data on zooplankton for further analyses within the WSMPA planning. HB and RK were significantly involved in the collection of the data on pinnipeds and fishes, respectively. TB collaborated in the paper writing.

Competing interests. The authors declare that they have no conflict of interests.

Acknowledgements. This work was financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Office for Agriculture and Food (BLE), grant number 2813HS009. In particular, we would like to thank all colleagues from all national and international scientific institutions who have supported us in providing data used to build up the data compilation for the wider Weddell Sea: i.e. from the Alfred Wegener Institute (Hauke Flores, Dieter Gerdes, Julian Gutt, Stefan Hain, Kerstin Jerosch, Dieter Piepenburg, Ralf Timmermann), British Antarctic Survey (Mike Dunn, Phil Trathan), CCAMLR Secretariat (Elanor Miller, Tim Jones, David Ramm), Helmholtz Centre Geesthacht (Verena Haid), Instituto Antártico Argentino (Enrique Marschoff, Mercedes Santos), National Oceanic and Atmospheric Administration (Jefferson Hinke, Wayne Trivelpiece), Royal Belgian Institute of Natural Sciences (Anton van de Putte), Stony Brook University (Heather Lynch), Thünen Institute of Sea Fisheries (Karl-Hermann Kock), University of Gothenburg (Tomas Lundälv), University of Padova (Emilio Riginella), University of St. Andrews (Lars Boehme), Wageningen University & Research (Jan van Franeker). The marine mammal data were collected and made freely available by the International MEOP Consortium and the national programs that contribute to it (<http://www.meop.net>). The seal tracking data ct96 and ct109 are collected by the Integrated Marine Observing System (IMOS). IMOS is a national collaborative research infrastructure, supported by the Australian Government. It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent. We thank two anonymous reviewers for careful reading and constructive comments on the manuscript.

Figures

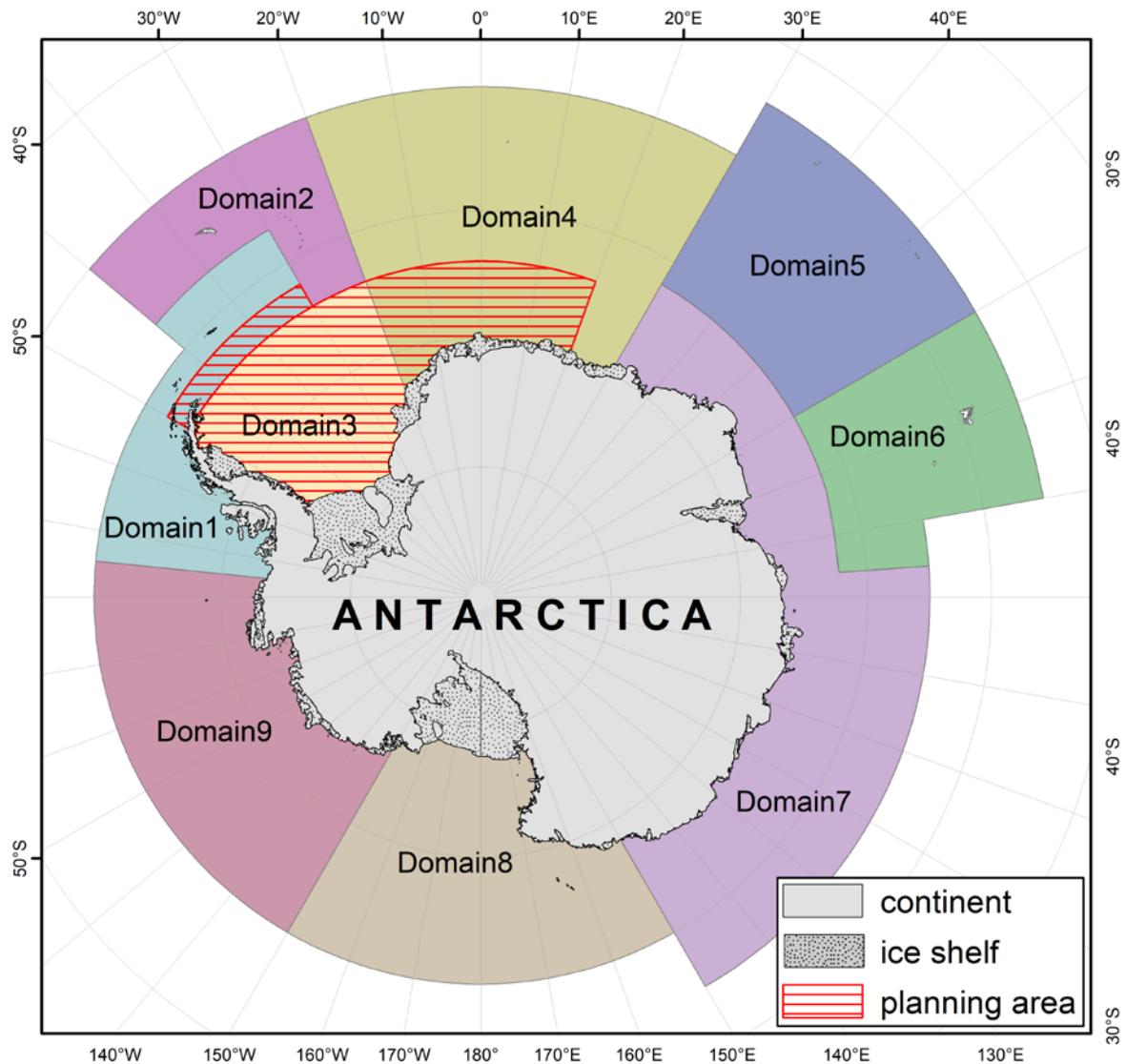


Figure 1. CCAMLR Convention Area with its Marine Protected Area (MPA) Planning Domains and the planning area (incl. 200 km wide buffer area near the Antarctic Peninsula) for the development of a MPA in the wider Weddell Sea (red shaded area). Domain 1: Western Peninsula - South Scotia Arc, Domain 2: North Scotia Arc, Domain 3: Weddell Sea, Domain 4: Bouvet Maud, Domain 5: Crozet - del Cano, Domain 6: Kerguelen Plateau, Domain 7: Eastern Antarctica, Domain 8: Ross Sea, Domain 9: Amundsen - Bellingshausen.

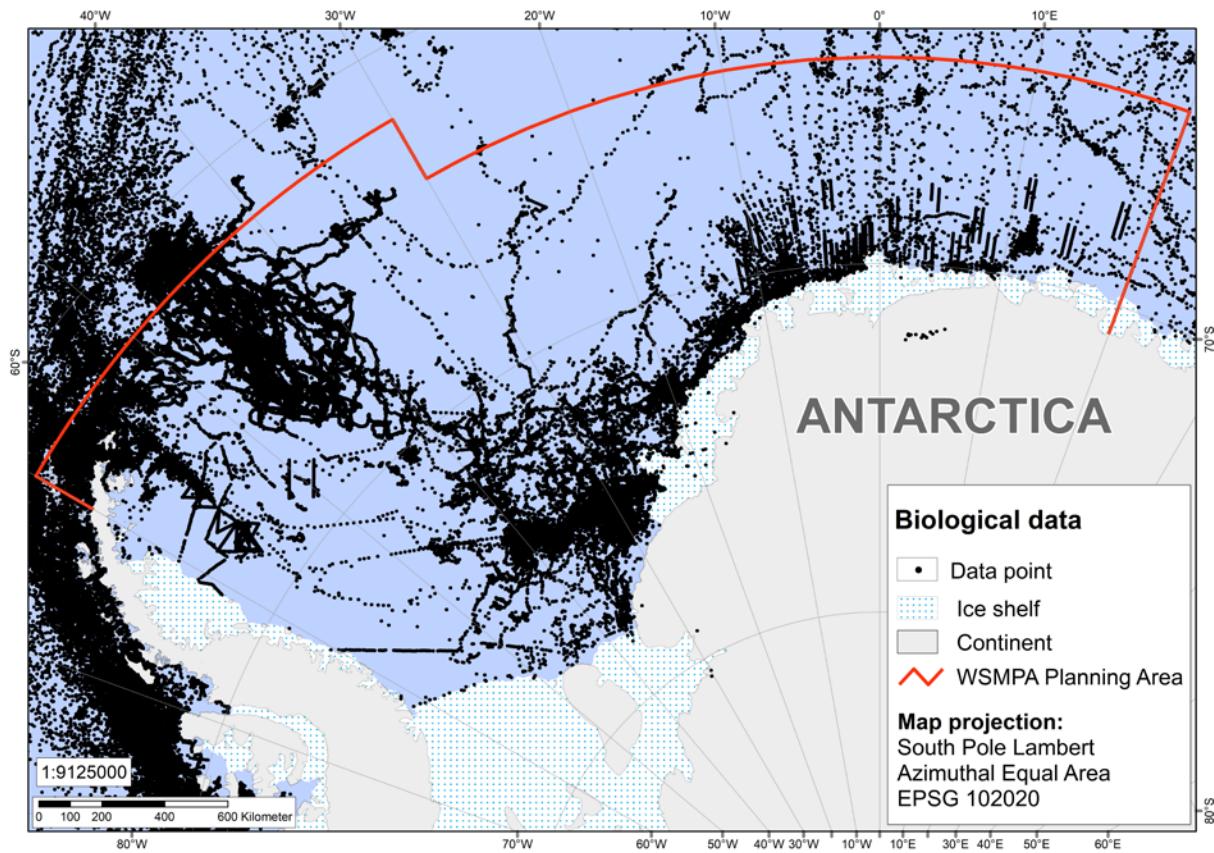
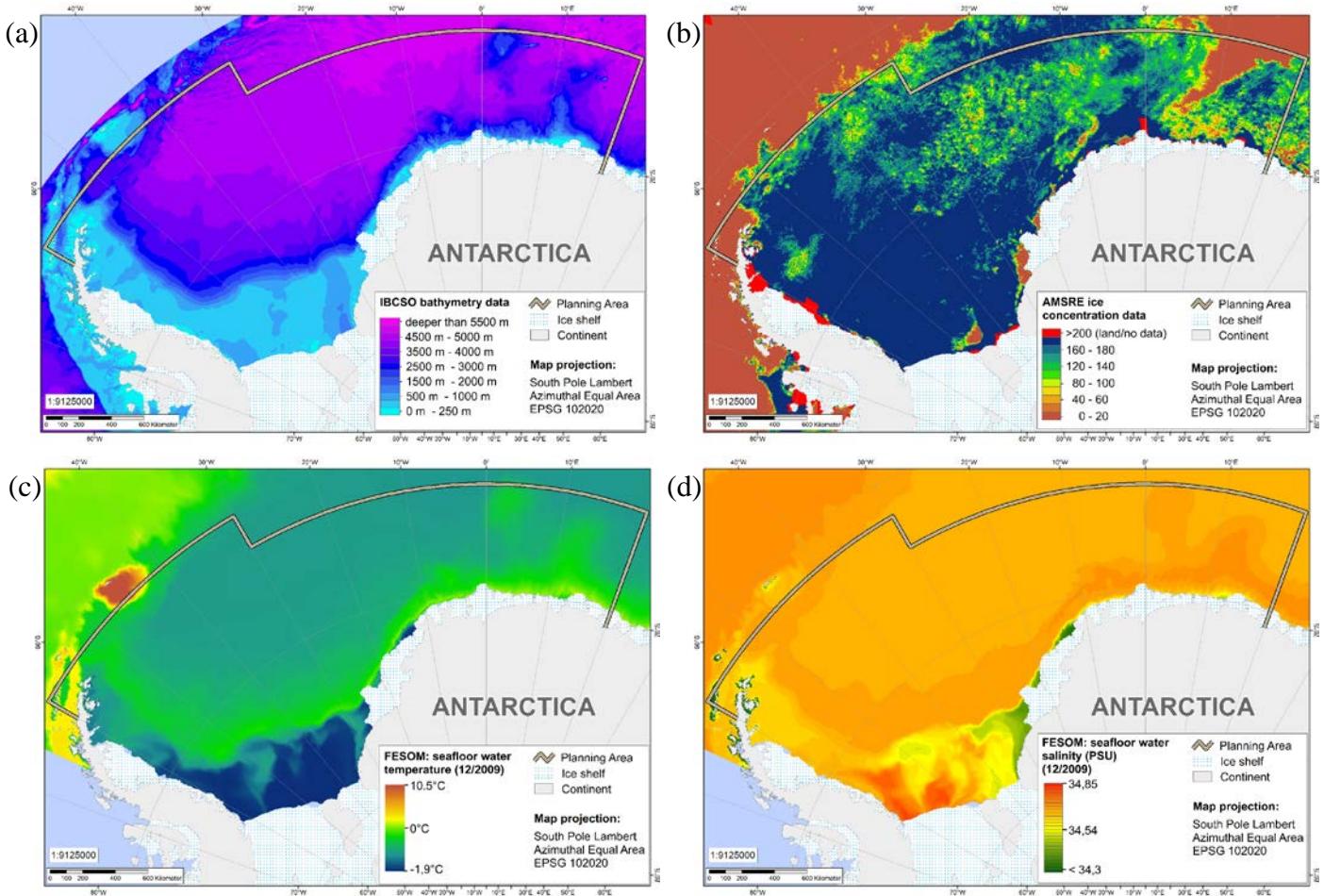


Figure 2. Distribution of all data recordings across the wider Weddell Sea region, which were compiled in the context of the WSMPA planning initiative. Figure S1 in the Supplement provides the distribution of data recordings per higher taxonomic group, i.e. zooplankton, zoobenthos, fishes, birds and pinnipeds.



5 **Figure 3.** Raster data sets of environmental parameters, which have been used as basic data in a regionalisation analysis of environmental provinces in the context of the WSMPA planning. IBCSO bathymetry (a), AMSR-E sea ice maps (exemplarily for 15 December 2009) (b), FESOM sea bottom temperature and salinity data (exemplarily for December 2009) (c, d).

Tables

Table 1. Data collection of environmental parameters compiled for the development of a marine protected area (MPA) in the wider Weddell Sea (Antarctica). For each raw data set, the name of the data source, the primary reference, such as the data portal or website on which the data are available, as well as examples of publications that have used the respective raw data set are listed. In addition, DOI links to the final WSMPA data layer products is provided, which includes the respective raw data set.

Content	Name	Reference to raw data	Availability of raw data	Reference to publications, which have used raw data (exemplarily)	DOI link to ArcMap packages
Depth	International Bathymetric Chart of the Southern Ocean (IBCSO) Version 1.0	Arndt et al. (2013b) doi:10.1594/PANGAEA.805736 [data request: April 2013]	freely available	Arndt et al. (2013a) Jerosch et al. (2016)	doi:10.1594/PANGAEA.899595 doi:10.1594/PANGAEA.899667 doi:10.1594/PANGAEA.899591
Sea ice concentration	Daily AMSR-E Sea Ice Maps	https://seacie.uni-bremen.de/data/ [data request: 18-12-2013]	freely available	Spreen et al. (2008)	doi:10.1594/PANGAEA.899595 doi:10.1594/PANGAEA.899667
Temperature, salinity, current velocity	Finite Element Sea Ice - Ocean Model (FESOM)	https://www.awi.de/forschung/klimawissen/klimadynamik [data delivery: 20-11-2013]	request necessary	Danilov et al. (2004) Timmermann et al. (2009) Haid & Timmerman (2013)	doi:10.1594/PANGAEA.899595 doi:10.1594/PANGAEA.899645 doi:10.1594/PANGAEA.899667 doi:10.1594/PANGAEA.899591
Dissolved oxygen, phosphate, nitrate	World Ocean Atlas 2013 version 2 (WOA13 V2)	https://www.nodc.noaa.gov/OC5/woa13/woa13data.html [data request: 11 to 18 July 2013]	freely available	Garcia et al. (2014a, b)	doi:10.1594/PANGAEA.899667 doi:10.1594/PANGAEA.899591
Total organic carbon content		Seiter et al. (2004b) doi:10.1594/PANGAEA.199835	freely available	Seiter et al. (2004a)	doi:10.1594/PANGAEA.899591
Calcium carbonate, silicia		Seiter et al. (2004c) doi:10.1594/PANGAEA.186024	freely available	Seiter et al. (2004a)	doi:10.1594/PANGAEA.899591
Biogenic silica		Geibert et al. (2005b) doi:10.1594/PANGAEA.230042	freely available	Geibert et al. (2005a)	doi:10.1594/PANGAEA.899591
Chlorophyll a concentration	Sea-Viewing Wide Field-of- View Sensor (SeaWiFS) measurements	https://oceandata.sci.gsfc.nasa.gov/SeaWiFS/ [data request: 09-09-2014]	registration necessary	Moore & Abbott (2000) Gregg & Casey (2004)	doi:10.1594/PANGAEA.899667

Table 2. Data collection of ecological parameters compiled for the development of a marine protected area (MPA) in the wider Weddell Sea (Antarctica). For each raw data set, the name of the data source, the primary reference, such as the data portal or website on which the data are available, as well as the respective cruise reports and/or examples of publications that have used the respective raw data set are listed. In addition, DOI links to the final WSMPA data layer products is provided, which includes the respective raw data set.

Content	Name	Reference to raw data	Availability of raw data	Cruise report	Reference to publications, which have used raw data (exemplarily)	DOI link to ArcMap packages
Zooplankton						
Adult Antarctic krill (abundances)	KRILLBASE (doi:brg8) See detailed list of data in Table S2 in Supplement	Atkinson et al. (2017)	request necessary		Atkinson et al. (2004) Atkinson et al. (2008) Piñones & Fedorov (2016) Atkinson et al. (2019)	doi:10.1594/PANGAEA.899667
Adult Antarctic krill (catch and effort)	Japanese, Norwegian and Soviet fisheries data	https://www.ccamlr.org/ [data request: 03-10-2013]	request necessary			doi:10.1594/PANGAEA.899667
Adult Antarctic krill (abundances)	Soviet cruises: RV Gzhiga 1977 and RV Volny Vetter 1983	https://www.thuenen.de/en/sf/	request necessary			doi:10.1594/PANGAEA.899667
Adult Antarctic krill (abundances)	ANT-XVIII/4	https://www.thuenen.de/en/sf/	request necessary	Fahrbach et al. (2003)		doi:10.1594/PANGAEA.899667
Adult Antarctic krill & ice krill (abundances)	MV Polarsirkel 1976/77	Fevolden (1979) doi:10.1080/00364827.1979	freely available			doi:10.1594/PANGAEA.899667
Adult Antarctic krill & ice krill (abundances)	Lazarev Sea Krill Survey (LAKRIS) data (ANT-XXI/4, ANT-XXIII/2, ANT-XXIII/6, ANT-XXIV/2)	https://www.thuenen.de/en/sf/	request necessary	Smetacek et al. (2005) Strass (2007) Bathmann (2008, 2010)	Siegel (2012)	doi:10.1594/PANGAEA.899667
Adult Antarctic krill & ice krill (abundances)	ANT-XXIX/3	https://www.thuenen.de/en/sf/	request necessary	Gutt (2013)	Siegel et al. (2013)	doi:10.1594/PANGAEA.899667
Adult Antarctic krill & ice krill (abundances)	ANT-V/3	https://www.thuenen.de/en/sf/	request necessary	Schnack-Schiel (1987)		doi:10.1594/PANGAEA.899667
Adult Antarctic krill & ice krill (abundances)	ANT-VII/4	https://www.thuenen.de/en/sf/	request necessary	Arntz et al. (1990)		doi:10.1594/PANGAEA.899667

Adult ice krill (abundances)	RV Walther Herwig 1975/76	https://www.thuenen.de/en/sf/	request necessary		doi:10.1594/PANGAEA.899667
Adult ice krill (abundances)	MV Polarsirkel 1979/80	https://www.thuenen.de/en/sf/	request necessary	Siegel (1982) Hempel et al. (1983)	doi:10.1594/PANGAEA.899667
Larval Antarctic krill (abundances)	MV Polarsirkel 1976/77	Fevolden (1979) doi:10.1080/00364827.1979	freely available		doi:10.1594/PANGAEA.899667
Larval Antarctic krill (abundances)	MV Polarsirkel 1979/80	https://www.thuenen.de/en/sf/	request necessary	Siegel (1982)	doi:10.1594/PANGAEA.899667
Larval Antarctic krill (abundances)	First International BIOMASS Experiment survey (FIBEX), RV “Walther Herwig” 1981	https://www.thuenen.de/en/sf/	request necessary	Trathan & Everson (1994) Siegel (2005)	doi:10.1594/PANGAEA.899667
Larval Antarctic krill (abundances)	ANT-VII/4	https://www.thuenen.de/en/sf/	request necessary	Arntz et al. (1990)	doi:10.1594/PANGAEA.899667
Larval Antarctic krill (abundances)	ANT-VIII/2 and RV Akademik Fedorov, 1989	https://www.thuenen.de/en/sf/	request necessary	Augstein et al. (1991)	Menshenina (1992)
Larval Antarctic krill (abundances)	Lazarev Sea Krill Survey (LAKRIS) data (ANT- XXI/4, ANT-XXIII/6)	https://www.thuenen.de/en/sf/	request necessary	Smetacek et al. (2005) Bathmann (2008)	Siegel (2012)

Zoobenthos

Sponges (abundances)	WH068/1 WH068/2 ANT-III/2 ANT-V/1 ANT-VI/3 ANT-VII/4 ANT-IX/3 ANT-X/3 ANT-XIII/3 ANT-XIII/4 ANT-XV/3 ANT-XVII/3 ANT-XIX/5 ANT-XXI/2 ANT-XXIII ANT-XXVII	Gerdes (2014a-p) doi:10.1594/PANGAEA.834061 doi:10.1594/PANGAEA.834065 doi:10.1594/PANGAEA.834009 doi:10.1594/PANGAEA.717708 doi:10.1594/PANGAEA.834017 doi:10.1594/PANGAEA.834021 doi:10.1594/PANGAEA.834013 doi:10.1594/PANGAEA.834025 doi:10.1594/PANGAEA.834029 doi:10.1594/PANGAEA.834033 doi:10.1594/PANGAEA.834041 doi:10.1594/PANGAEA.834074 doi:10.1594/PANGAEA.834069 doi:10.1594/PANGAEA.834049 doi:10.1594/PANGAEA.834053 doi:10.1594/PANGAEA.834057	freely available	- - Hempel (1985) Schnack-Schiel (1987) Fütterer (1988) Arntz et al. (1990) Bathmann et al. (1992) Spindler et al. (1993) Arntz & Gutt (1997) Fahrbach & Gerdes (1997) Arntz & Gutt (1999) Arntz & Brey (2001) Arntz & Brey (2003) Arntz & Brey (2005) Gutt (2008) Knust et al. (2012)	Gerdes et al. (1992) Gerdes et al. (2003)	doi:10.1594/PANGAEA.899645
Sponges (semi-quantitative data)	ANT-VII/4 ANT-IX/3 ANT-XIII/3 ANT-XV/3 ANT-XXI/2	Teschke & Brey (2020) doi:10.1594/PANGAEA.911801	freely available	Arntz et al. (1990) Bathmann et al. (1992) Arntz & Gutt (1997) Arntz & Gutt (1999) Arntz & Brey (2005)	Galéron et al. (1992)	doi:10.1594/PANGAEA.899645
Echinoderms - Asteroids (presence-absence)	ANT-I/2 ANT-II/4 ANT-V/3 ANT-VI/3 ANT-XV/3 ANT-XVII/3	Teschke & Brey (2019a) doi:10.1594/PANGAEA.898629	freely available	Drescher et al. (1983) Kohnen (1984) Schnack-Schiel (1987) Fütterer (1988) Arntz & Gutt (1999) Arntz & Brey (2001)	Voß (1988)	doi:10.1594/PANGAEA.899645
Echinoderms - Ophiuroids (abundances)	ANT-I/2 ANT-II/4 ANT-V/3 ANT-V/4 ANT-VI/3 ANT-VII/4 ANT-IX/3 ANT-X/3	Teschke & Brey (2019b) doi:10.1594/PANGAEA.898773	freely available	Drescher et al. (1983) Kohnen (1984) Schnack-Schiel (1987) Miller & Oerter (1990) Fütterer (1988) Arntz et al. (1990) Bathmann et al. (1992) Spindler et al. (1993)	Brey et al. (1994) Dahm (1996)	doi:10.1594/PANGAEA.899645

Echinoderms - Holothurians (abundances)	ANT-I/2 ANT-II/4 ANT-III/3	Gutt et al. (2014) doi:10.3897/zookeys.434.7622	freely available	Drescher et al. (1983) Kohnen (1984) Hempel (1985)	Gutt (1988) Piepenburg et al. (1997)	doi:10.1594/PANGAEA.899645
Fishes						
<i>Pleuragramma antarctica</i> & demersal fishes (abundances)	ANT-XIII/3 ANT-XV/3 ANT-XVII/3 ANT-XIX/5 ANT-XXI/2 ANT-XXVII/3	Balguerías & Knust (2020) doi:10.1594/PANGAEA.911965 Schröder & Knust (2020) doi:10.1594/PANGAEA.911966 Knust et al. (2020a) doi:10.1594/PANGAEA.911967 Knust et al. (2020b) doi:10.1594/PANGAEA.911968 Knust et al. (2020c) doi:10.1594/PANGAEA.911969 Knust et al. (2020d) doi:10.1594/PANGAEA.911970	freely available freely available freely available freely available freely available freely available	Arntz & Gutt (1997) Arntz & Gutt (1999) Arntz & Brey (2001) Arntz & Brey (2003) Arntz & Brey (2005) Knust et al. (2012)	Mintenbeck et al. (2012) Caccavo et al. (2018)	doi:10.1594/PANGAEA.899591
<i>Pleuragramma antarctica</i> & demersal fishes (abundances)	ANT-I/2 ANT-III/3 ANT-V/3 ANT-VII/4 ANT-IX/3 ANT-XXIII/8	Drescher et al. (2012) doi:10.1594/PANGAEA.786877 Ekau et al. (2012a) doi:10.1594/PANGAEA.786883 Ekau et al. (2012b) doi:10.1594/PANGAEA.786884 Hureau et al. (2012) doi:10.1594/PANGAEA.786886 Wöhrmann et al. (2012) doi:10.1594/PANGAEA.786887 Kock et al. (2012) doi:10.1594/PANGAEA.786888	freely available freely available freely available freely available freely available freely available	Drescher et al (1983) Hempel (1985) Schnack-Schiel (1987) Arntz et al. (1990) Bathmann et al. (1992) Gutt (2008)	Ekau (1988) Caccavo et al. (2018)	doi:10.1594/PANGAEA.899591
Fish larvae - <i>Pleuragramma antarctica</i> (abundances)	ANT-I/2	https://www.thuenen.de/en/sf/	request necessary	Drescher et al (1983)	Boysen-Ennen & Piatkowski (1988)	doi:10.1594/PANGAEA.899591
Fish larvae - <i>Pleuragramma antarctica</i> (abundances)	ANT-III/3	Hubold et al. (1988) doi:10.1007/BF00443454	freely available	Hempel (1985)		doi:10.1594/PANGAEA.899591
Fish larvae - <i>Pleuragramma antarctica</i> (abundances)	Lazarev Sea Krill Survey (LAKRIS) data: ANT- XXI/4, ANT-XXIII/6, ANT-XXIV/2	https://www.awi.de/forschung/biowis senschaften/polare-biologische- ozeanographie	request necessary	Smetacek et al. (2005) Bathmann (2008, 2010)	Flores et al. (2014)	doi:10.1594/PANGAEA.899591

Antarctic toothfish (catch per unit effort)	Japanese, Korean, Norwegian and South African fishing data	https://www.ccmlr.org/ [data request: 03-08-2016]	request necessary		doi:10.1594/PANGAEA.899591
Demersal fish nesting sites	PS82 (ANT-XXIX/9) PS96 (ANT-XXXI/2)	Knust & Schröder (2014) doi:10.2312/BzPM_0680_2014 Piepenburg (2016) doi:10.1594/PANGAEA.862097	freely available freely available	Schröder (2016) La Mesa et al. (2019)	doi:10.1594/PANGAEA.899591
Demersal fish nesting sites		Daniels (1978, 1979) doi:10.1111/j.1095- 8649.1978.tb04190.x doi:10.1126/science.205.4408.831 Jones & Near (2012) doi:10.1111/j.1095- 8649.2012.03282.x	freely available freely available		doi:10.1594/PANGAEA.899591
Birds					
Adélie penguin colonies (estimated abundances of breeding pairs)		Lynch & LaRue (2014) doi:10.1642/AUK-14-31.1	freely available		doi:10.1594/PANGAEA.899520
Breeding and non- breeding Adélie penguins (tracking data)	US AMLR Program (ID 910)	http://www.seabirdtracking.org/ [data request: 20-10-2015]	request necessary	Hinke et al. (2015)	doi:10.1594/PANGAEA.899520
Breeding and non- breeding Adélie penguins (tracking data)	BAS / Instituto Antártico Argentino data (ID 753)	http://www.seabirdtracking.org/ [data request: 20-10-2015]	request necessary	Warwick-Evans et al. (2019)	doi:10.1594/PANGAEA.899520
Breeding and non- breeding Adélie penguins (tracking data)	BAS Inventory (754, 773, 779)	http://www.seabirdtracking.org/ [data request: 20-10-2015]	request necessary	Dunn et al. (2011)	doi:10.1594/PANGAEA.899520
Breeding Adélie penguins (tracking data)	BAS Inventory (ID 764)	http://www.seabirdtracking.org/ [data request: 20-10-2015]	request necessary	Lynnes et al. (2002)	doi:10.1594/PANGAEA.899520
Emperor penguin colonies (populations estimates)		Fretwell et al. (2012) doi:10.1371/journal.pone.0033751 Fretwell et al. (2014) doi:10.1371/journal.pone.0085285	freely available freely available		doi:10.1594/PANGAEA.899520

Antarctic petrel Colonies (estimated number of breeding pairs)	Van Franeker et al. (1999) doi:10.2307/1521989	freely available		doi:10.1594/PANGAEA.899520	
Pinnipeds					
Seal taxa (tracking data)	Data from: Australia (ct109, ct96), Brazil (ct56, ct46, ct39, ct22), China (ct105), UK (ct1, ct8, ct27, ct27x, ct40, ct43, ct45, ct49, ct58, ct70), France (ct16, ct62, ft01, ft02, ft11, ft12), Germany (ct21, ct35, ct35b, ct44, ct54, ct68, ct87, ct99, ct102, ct113, wd06, wd07), Norway (ct34), South Africa (ct33, ct50, ct73), USA (ct9, ct14, ct25, ct29, ct37, ct48)	http://www.meop.net/ [data request: 14-11-2016]	registration necessary	Treasure et al. (2017) doi:10.1594/PANGAEA.899619 Nachtsheim et al. (2019) Boehme et al. (2016)	
Southern elephant seals (tracking data)	Tosh et al. (2009a) doi:10.1594/PANGAEA.692856 James et al. (2012a) doi:10.1594/PANGAEA.785852	freely available freely available	Tosh et al. (2009b) James et al. (2012b)	doi:10.1594/PANGAEA.899619	
Weddell seals (tracking data)	McIntyre et al. (2013a) doi:10.1594/PANGAEA.818467	freely available	McIntyre et al. (2013b)	doi:10.1594/PANGAEA.899619	
Crabeater seals (tracking data)	Nachtsheim et al. (2016a) doi:10.1594/PANGAEA.854842	freely available	Nachtsheim et al. (2016b)	doi:10.1594/PANGAEA.899619	
Pack-ice seals (aerial surveys)	Antarctic Pack Ice Seals (APIS) programme EMAGE-I to -V	Plötz et al. (2011a-e) doi:10.1594/PANGAEA.760097 doi:10.1594/PANGAEA.760098 doi:10.1594/PANGAEA.760099 doi:10.1594/PANGAEA.760100 doi:10.1594/PANGAEA.760101	freely available	Southwell et al. (2012) Gurarie et al. (2017a, b)	doi:10.1594/PANGAEA.899619

Crabeater seal densities (predicted or observed)	Bester et al. (1995, 2002) doi:10.1017/S0954102095000502 doi:10.1017/S0954102002000676	freely available	doi:10.1594/PANGAEA.899619
	Flores et al. (2008) doi:10.1016/j.dsr2.2007.12.024	freely available	
	Forcada et al. (2012) doi:10.1016/j.biocon.2012.02.002	freely available	

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