To be completed by the Secretariat:		
	Document No.:	WG-EMM-14/19
	Date submitted:	20 June 2014
	Original Language:	English
To be completed by the author:		
	Meeting:	WG-EMM-14
	Agenda Item No(s):	3.1

Title **Progress report on the scientific data compilation and analyses in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica)**

Author(s) K. Teschke[1], K. Jerosch[1], H. Pehlke[1] and T. Brey[1]
on behalf of the German Weddell Sea MPA project team, with contributions from the participants at the International Expert Workshop on the Weddell Sea MPA project (7-9 April 2014, Bremerhaven)

Address(s) [1]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

Name and email address of person submitting paper: Katharina.Teschke@awi.de

Published or accepted for publication elsewhere? Yes [ ] No [x]

If published or in press, give details:

To be considered for publication in *CCAMLR Science*?[1] Yes [ ] No [x]

[1] By indicating that the paper is to be considered for publication in *CCAMLR Science*, the authors have agreed that the paper can be considered by the Editorial Board of the journal and that, if the paper is accepted for peer review, it is the responsibility of the authors to ensure that permission to publish data and cite unpublished working group papers has been received.

Abstract

This progress report represents a follow up of WG-EMM-13/22 (WG-EMM, Jul 2013, Bremerhaven) and SC-CAMLR-XXXII/BG/07 (SC-CAMLR-XXXII, Oct 2013, Hobart). The authors intend to update the Working Group on Ecosystem Monitoring and Management on the actual state of our project, particularly on the proceeds of the data acquisition process and the preliminary scientific analysis. In addition, we present the report of the International Expert Workshop on the Weddell Sea MPA project (7-9 April 2014, Bremerhaven) as supplementary paper. The main objectives of this document are *(i)* to provide an updated summary of the data identification and acquisition process, *(ii)* to set out the preliminary scientific analysis which was worked out so far, *(iii)* to present on the report of the International Expert Workshop on the Weddell Sea MPA project (7-9 April 2014, Bremerhaven), and *(iv)* to give an update on the further process.

Abstract

This progress report represents a follow up of WG-EMM-13/22 (WG-EMM, Jul 2013, Bremerhaven) and SC-CAMLR-XXXII/BG/07 (SC-CAMLR-XXXII, Oct 2013, Hobart). The authors intend to update the Working Group on Ecosystem Monitoring and Management on the actual state of our project, particularly on the proceeds of the data acquisition process and the preliminary scientific analysis. In addition, we present the report of the International Expert Workshop on the Weddell Sea MPA project (7-9 April 2014, Bremerhaven) as supplementary paper. The main objectives of this document are *(i)* to provide an updated summary of the data identification and acquisition process, *(ii)* to set out the preliminary scientific analysis which was worked out so far, *(iii)* to present on the report of the International Expert Workshop on the Weddell Sea MPA project (7-9 April 2014, Bremerhaven), and *(iv)* to give an update on the further process.

Contents

1. The background of the MPA Weddell Sea project

In recent years, CCAMLR Member States have undertaken substantial efforts to designate marine protected areas (MPAs) in the Southern Ocean in order to provide better protection to Antarctic wildlife. Important milestones were:

- *(i)* the designation of the South Orkney Islands southern shelf area as a MPA by CCAMLR in 2009 (Conservation Measure 91-03),
- *(ii)* the adoption of a general framework for the establishment of CCAMLR MPAs in 2011 (Conservation Measure 91-04) and
- *(iii)* the definition of nine MPA planning domains in the CCAMLR area in 2011.

MPA planning for six domains is underway and proposals for MPAs in the Ross Sea and in East Antarctica are currently being discussed by CCAMLR. For three domains, particular CCAMLR Member States were asked to take the lead in MPA planning.

At the CCAMLR meeting in 2012, the Commission welcomed the offer of Germany to take the lead in developing a MPA proposal in Planning Domain 3 (Weddell Sea). Subsequently, the German Federal Ministry of Food and Agriculture (BMEL) tasked the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) to compile and analyse data considered to be relevant for identifying potential conservation areas and measures in the Weddell Sea. This project started mid-April 2013 under the lead of Prof. Dr. Thomas Brey.

This progress report follows WG-EMM-13/22 (WG-EMM Jul 2013, Bremerhaven) and SC-CAMLR-XXXII/BG/07, which was submitted to SC-CAMLR-XXXII, Hobart (Oct 2013). We intend to update the Working Group on Ecosystem Monitoring and Management on the actual state of our project, particularly on the proceeds of the data acquisition process and the preliminary scientific analysis. In addition, we present the report of the International Expert Workshop on the Weddell Sea MPA project (7-9 April 2014, Bremerhaven) as supplementary paper. The workshop discussion centered around environmental and biological data sets currently available for a Weddell Sea MPA evaluation, and the preliminary results of the analyses done so far by the AWI.

The main objectives of this document are:

1. to provide an updated summary of the data identification and acquisition process;
2. to set out the preliminary scientific analysis which was worked out so far;
3. to present on the report of the International Expert Workshop on the Weddell Sea MPA project (7-9 April 2014, Bremerhaven);
4. to give an update on the further process.

2. Description of the Weddell Sea MPA planning area

2.1. Boundaries of the planning area

The Scientific Committee noted that the progress report on the scientific data compilation and analyses carried out by Germany in support of the development of a CCAMLR MPA in the Weddell Sea (SC-CAMLR-XXXII/BG/07) described the boundaries of the planning area, which in addition to MPA Planning Domain 3, includes the southern parts of Planning Domain 4 (south of 64°S from 20°W to 20°E; see Fig. 1; SC-CAMLR-XXXII, paragraph 5.23). **Please note** that these boundaries do **not** resemble the boundaries of any proposed Weddell Sea MPA. The extension of the planning area ensures that the specific oceanographic and ecological conditions as well as the biological communities of the Weddell Gyre system as a whole can be considered as one entity in the data compilation and analyses.

2.2. The Weddell Sea ecosystem

The Weddell Sea with an area of approximately 2.8 million km² is the largest of the 14 marginal seas of the Southern Ocean. Water depths in the Weddell Sea range from about 100 m at the edge of the ice shelf and 5000 m in the Weddell Sea abyssal plain. Compared to the continental shelf of oceans north of the Southern Ocean, the Weddell Sea shelf is deep with depths of 400 –500 m (Laws 1985), and thus the shelf break is located approx. two to four times deeper than in other oceans which usually lies at 200 m (Knox 2007). Those depths arise from the extraordinary weight of the Antarctic ice cap, which depresses the Antarctic continent by approx. 200 m (Smetacek & Nicol 2005). Prominent bathymetric features of the Weddell Sea are the relative narrow, complex structured shelf and steep slope in the eastern Weddell Sea, and the broad shelf in the southern Weddell Sea that extends up to several 100 km from the coast and is cut through by the deeper Filchner Trench (Schenke et al. 1998; see Fig. 2).

The Weddell Sea plays an important role for driving global thermohaline circulation ("global ocean conveyor belt") and ventilating the global abyssal ocean, as a considerable part of the Antarctic Bottom Water is generated in the Weddell Sea (Knox 2007, Fahrbach et al. 2009). The formation of those dense water masses in the Weddell Sea is facilitated by the large-scale cyclonic Weddell Gyre (see Fig. 1). Its global relevance has made the Weddell Gyre the subject of much scientific attention in the past, including studies of temporal variation in either the gyre itself or the surrounding ocean-ice-atmosphere system and the climate impact on it (Fahrbach et al. 2004, McKee et al. 2011).

Probably the most pronounced feature of the Weddell Sea is the sea ice and its extreme seasonal variability (see Fig. 3). Sea ice in the Weddell Sea expands from late March onwards, and retreats from late October. Each summer, sea ice cover with more than 75 % shrinks to a minimum of approx. 1.420.000 km² (Feb - Mar), representing approx. one third of its maximum winter extent in September (approx. 4.480.000 km², i.e. ~ 98 % of total planning area). Perennial sea ice occurs in the western Weddell Sea and covers approx. 595.000 km² (~ 13 % of total planning area).

Regarding the unique nature of Antarctic marine biota, the shelves and slopes of the eastern and south-eastern part of the Weddell Sea constitute particular examples of diverse marine communities. Here, in some areas biodiversity is comparable to tropical regions (Brey et al. 1994), and there is a significant number of endemic species, i.e. unique to the Antarctic or even to the Weddell Sea (Arntz et al. 1994, Clarke & Johnston 2003, Mühlenhardt-Siegel 2011). For example, the Weddell Sea region with approx. 20 % endemism for molluscs has higher levels of endemism than the adjacent region of the Antarctic Peninsula (Linse et al. 2006). Moreover, unique biocoenoses occur in the eastern Weddell Sea, such as the structurally and ecologically complex sponge associations (Barthel & Gutt 1992). Considerable physical impact along the south-eastern Weddell Sea shelf, mainly caused by icebergs scouring, leads to diverse benthic communities with the coexistence of successional stages at regional scales (Gerdes et al. 2003, Gutt & Piepenburg 2003, Knust et al. 2003). Regarding Weddell Sea plankton communities, there is an open water oceanic, eastern shelf and a south eastern/southern shelf community which differ distinctly in the occurrence of Antarctic krill and ice krill (Siegel 1982, Boysen-Ennen & Piatkowski 1988). In addition, a pelagic community, which has very different characteristics to the rest of the Weddell Sea shelf, dominated by amphipods and ice krill, rather than copepods and Antarctic krill occurs at the Filchner Trough border (south of 74-75°S).

Whereas the coasts along the Antarctic Peninsula are one of the world`s fastest warming regions and winter sea ice duration in those regions is shortening (Parkinson 2002), climatic conditions remained relatively stable in the eastern and south-eastern Weddell Sea. Although, projections until the end of this century show considerable warming along the eastern coast of the Weddell Sea (Hellmer et al. 2012), this geographic region is likely to play an important role in providing refugia for ice-dependent key ecosystem components, such as penguins, in the near future. Accordingly, in response to a presentation by the United Kingdom regarding the likely impact of climate change upon emperor penguins (*Aptenodytes forsteri*), the recent 36th ATCM meeting in Brussels, Belgium (20-29 May 2013) endorsed the monitoring of emperor penguin colonies to identify potential climate change refugia (WP010 2013).

In summary, the Weddell Sea constitutes a unique region in the Southern Ocean in terms of ocean and ice dynamics as well as regarding marine biota, their adaption to short-term environmental variation, and their likely response to long-term climate change.

3. Data sets, data layers and preliminary scientific analysis

This chapter intends to update WG-EMM on the data retrieval process. Table 1 and 2 provide a systematic overview of the current data situation. Complete data sets or parts of it which were already acquired for our study, but were not incorporated into further analyses so far are marked grey. Both tables are based on data already presented in our document SC-CAMLR-XXXII/BG/07 (SC-CAMLR-XXXII), but include additional data sets which were discussed at the International Expert Workshop on the Weddell Sea MPA project and beyond.

Furthermore, we would also like to inform WG-EMM on the data layers and the preliminary scientific analysis that were carried out so far and were mostly presented and discussed at the International Expert Workshop on the Weddell Sea MPA project.

For all environmental and ecological data layers WGS 84 / NSIDC Sea Ice Polar Stereographic South (EPSG-Code: 3967; http://nsidc.org/data/atlas/epsg_3976.html) are used. Where data layers included missing data, "empty" pixels were flagged in using the abbreviation NA (not available) and were not used for the subsequent calculations. Data processing, such as transformation of data formats, statistical analysis and figure compilation was mainly performed using the R software (version 3.0.2; R Core Team 2013) and the ESRI`s GIS desktop software suite (ESRI 2011).

3.1. Environmental parameters

More than ten large environmental data sets are listed at the moment (see Tab. 1). These are satellite data mainly with a high temporal resolution. For example, satellite observations on daily sea ice concentration, derived from the Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-EOS) instrument on board the Aqua satellite, are available by several Internet web sites (see Tab. 1). Further oceanographic data were obtained from a high-resolution oceanographic model, the Finite Element Sea Ice-Ocean Model (FESOM; Timmermann et al. 2009).

3.1.1. Bathymetry & Geomorphology

Bathymetric data are derived from the first regional digital bathymetric model established by the International Bathymetric Chart of the Southern Ocean (IBCSO) programme and published by Arndt et al. (2013; Fig. 2). The bathymetric model Version 1.0 has a horizontal resolution of 500 m x 500 m and a vertical resolution of 1 m. This chart model is based on satellite data and in situ data (e.g. multi-beam data) from hydrographic offices, scientific institutions and data centres. The continental shelf break was defined as the 1000 m isobath. This was the best suited definition to distinguish between continental shelf to slope and deep sea regions although the slope in some areas starts at a slightly shallower depth.

Based on the digital bathymetric model, i.e. on the depth or bathymetric raster, *(i)* the slope, or the measure of steepness, *(ii)* the terrain ruggedness, the variation on three-dimensional orientation of grid cells within a neighbourhood, and *(iii)* the bathymetric position index (BPI) at broad and fine scale were calculated with the Benthic Terrain Modeler (BTM) Version 3.0 extension for ArcGIS™ (Wright et al. 2005). The slope values describe the gradient or the maximum change from each cell to its neighbour cell and are given in degree units. The BPI compares the elevation of each cell to the mean elevation of the neighbourhood cells, and thus is a measure of relative elevation in the overall "seascape". The broad and fine scale BPI were standardised to avoid spatial auto-correlation.

To define a classification scheme in terms of the bathymetric derivatives the BTM requires a classification table. A modified version of the classification table of Erdey-Heydorn (2008) and Wienberg et al. (2013) appeared to be most appropriate, by using a fine scale radius of 0 - 5 km and a broad scale radius of 0 - 125 km (Jerosch et al. in prep. a). The spatial resolution of the bathymetric derivatives corresponds to the bathymetric data resolution.

The following data layers were generated:

(1) Depth
(2) Slope
(3) Ruggedness
(4) Broad scale bathymetric position index
(5) Fine scale bathymetric position index
(6) Geomorphology derived from data layer (1)-(2) and (4)-(5) is shown in Figure 4.

Briefly, our benthic regionalisation approach used 17 geomorphological units to describe the structures at the sea bottom (see Fig. 4). Our findings reflect the geomorphology of the Weddell Sea described by Douglass et al. (2011; WS-MPA-11/23) quite well.

3.1.2. Sedimentology

A substantial data set on grain size was derived from the scientific data information system PANGAEA, an ICSU World Data Centre, hosted by the AWI and the Centre for Marine Environmental Science, University Bremen (doi:10.1594/PANGAEA.730459, doi:10.1594/ PANGAEA.55955). These data are published by Petschick et al. (1996) and Diekmann & Kuhn (1999). The sediment samples were taken with large box corer, multi- or mini-corer during several *Polarstern* cruises (1983-1997). This data set was complemented by unpublished data of G. Kuhn, AWI.

In total more than 400 grain size samples were standardised from absolute content values of gravel, sand, silt and clay to percentages. The data density of the grain size data restricted the ground truthing to six parcelled-out areas (see Fig. 5): (1) South Orkney Plateau, (2) Central Weddell Sea, (3) Ronne Ice Shelf Bank, (4) Filchner Trough, (5) Explora Escarpment, (6) Lazarev Sea, according to IBCSO (Arndt et al. 2013). Sediment texture maps were interpolated from the grain size data relying on other variables more densely available: bathymetry, geomorphology, distance to shelf ice and speed. Three different interpolation methods were applied in ArcGIS™ geo-statistical analyst extension and were evaluated: Ordinary Kriging, collocated Cokriging and Empirical Bayesian Kriging. Due to limited overall data density, this task was successfully accomplished for areas 4, 5 and 6 only (see Fig. 5) according to sediment classification schemes published by Folk (1954), Shepard (1954) and Flemming (2000) (Jerosch et al. in prep. b). In those areas at the continental shelf and slope gravelly mud and gravelly muddy sand predominate. Please note that areas potentially characterised by hard substrate are not represented in Figure 5.

3.1.3. Water column properties

Data on water column properties, i.e. temperature, salinity and currents (speed and direction of water movement), were derived from the coupled Finite Element Sea Ice Ocean Model (FESOM; Timmermann et al. 2009). FESOM combines a hydrostatic, primitive-equation ocean model with a (thermo-) dynamic ice model. FESOM was initialised on February, 1st 1980 with climatological data, such as temperature, humidity and latent heat flux, from the Polar Science Center Hydrographic Climatology (Steele et al. 2001).

Haid (2013) showed that FESOM is able to predict Weddell Sea hydrodynamics with high accuracy. Here, we used FESOM data covering the period 1990-2009 with a spatial resolution of 0.18 m x 0.05 m. For each water column property, data layers for the sea surface and the sea bottom were established. For more details of the model see Haid (2013) and Haid & Timmermann (2013).

Speed was calculated by sqrt (u^2 + v^2) where *u* is the zonal current with current values from west to east being positive and those from east to west being negative, and *v* is the meridional current with currents from south to north (positive values) or those from north to south (negative values). Direction (absolute value *abs* in degree *deg* from 0° to 360°) was calculated by arcsin [u/(sqrt (u^2 + v^2))] where *u* is the zonal current and *v* is the meridional current.

3.1.4. Chlorophyll-a concentration

Chlorophyll-a (chl-a) concentration values were derived from the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) measurements. The data were downloaded via the NASA's OceanColor website (http://oceancolor.gsfc.nasa.gov/) as monthly level 3 standard mapped images with a spatial resolution of 9 km x 9 km.

Data gaps naturally occur in the monthly chl-a data set caused by clouds, ice and low incident light. There are little or no SeaWiFS data in our planning area (south of 64°S) during austral winter owing to the short day length and the inability of SeaWiFS to produce accurate chl-a estimates at very high solar angles (Moore & Abbott 2000). The high sea ice concentration in most parts of the Weddell Sea hampers the measurement of surface chl-a concentration data, too. Thus, only austral summer (Nov - Mar) chl-a data were considered. Mean and standard deviation were calculated for each grid cell of both raw and log-transformed chl-a concentration data of 14 austral summers (Nov 1997 - Mar 2010).

Here, chl-a is used as a proxy measure of phytoplankton biomass (e.g. Moore & Abbott 2000). Furthermore, several studies showed a positive relationship between chl-a concentration and the occurrence of zooplankton species (e.g. Atkinson et al. 2004) or mammals (e.g. Thiele et al. 2000, Širović & Hildebrand 2011) in the Southern Ocean.

Overall, raw and log-transformed data produced the same basic picture in terms of chl-a concentration, and thus the raw data are mapped (see Fig. 6). Mean chl-a concentration is low in most parts of the planning area despite the available nitrate and phosphate in surface waters (typically < 0.5 mg/m^3). Phytoplankton blooms with chl-a concentration values exceeding 1-3 mg/m^3 particularly occur in three areas: *(i)* near Larsen C Ice Shelf, *(ii)* offshore Ronne Ice Shelf and *(iii)* east of Filchner Trough, near Brunt Ice Shelf. Our findings reflect well the chl-a distribution published in Moore & Abbott (2000). High standard deviations are seen near Larsen C Ice Shelf and in the western part offshore Ronne Ice Shelf reflecting considerable intra- and interannual variation and/or outliers, e.g. due to measurement errors.

3.1.5. Sea ice

Three large data sets were used to describe the overall picture of sea ice dynamics in the Weddell Sea and to detect areas with high sea ice dynamic at different temporal scales. To this end, approximately 100 data layers in terms of dynamic sea ice behaviour were generated. For example, almost 30 data layers were generated to evaluate the inter- and intra-annual variation in open water areas (here: ≤ 15% ice cover).

Satellite data of daily sea ice concentration

Satellite observations of daily sea ice concentration were derived from the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-EOS) instrument on board the Aqua satellite. High resolution AMSR-E 89 GHz sea ice concentration maps (Jun 2002 – Oct 2011) were downloaded from the Institute of Environmental Physics, University of Bremen (http://www.iup.uni-bremen.de/). The ARTIST Sea Ice (ASI) concentration algorithm was used with a spatial resolution of 6.25 km x 6.25 km (Kaleschke et al. 2001, Spreen et al. 2008). We restrained from using AMSR2 data (available since Aug 2012) on board the new `Shizuku` satellite as a thorough calibration of the AMSR2/ASI data has not been accomplished yet.

Areas of above-average number of days with sea ice cover ≤ 70 % were used as an indication for polynya formation or sea ice edge retreat. Those open water areas have an important ecological role during particular times of year. For example, the lack of sea ice cover in early summer promotes an earlier onset of the phytoplankton bloom, which in turn pushes secondary production (e.g. Arrigo & van Dijken 2003).

The relative number of days, for which a given pixel had ice cover ≤ 70 %, was calculated for the austral summer (Dec - Mar) from 2002 to 2010. Data on daily sea ice concentration were reclassified, i.e. a value of 1 was assigned to each pixel with ice cover less than 70 %, whereas pixels with ice cover > 70 % were set to N/A (not available).

The data layer regarding relative number of days with sea ice cover ≤ 70 % was incorporated into the pelagic regionalisation analysis, and the results are described in paragraph 3.2.

Daily winter-time polynya distribution

Data on daily polynya distribution were derived from the Special Sensor Microwave / Imager (SSM/I). The data were downloaded from the Integrated Climate Data Center (ICDC) of the University of Hamburg (http://icdc.zmaw.de/polynya_ant.html; Kern et al. 2007, Kern 2012). Here, polynyas are defined as areas of open water and/or thin (< 20 cm) sea ice in regions of typically thick sea ice (> 20 cm). A basic algorithm, described by Markus & Burns (1995) and Hunewinkel et al. (1998), was used with a spatial resolution of 5 km x 5 km. Data on daily polynya distribution focus on coastal polynyas and temporally cover the austral winter (May - Sept) for a period from 1992 to 2008.

Polynyas are considered to be important areas for higher trophic levels. For example, they constitute major access points to open water for emperor penguins (Zimmer et al. 2008) and are crucial for marine mammals for breathing (e.g. Gill & Thiele 1997), in particular during winter where almost the whole planning area in the Weddell Sea is covered by ice.

Therefore, the relationship between coastal winter polynyas and colonies of emperor and Adélie penguins in the Weddell Sea were evaluated (see results in paragraph 3.3.4).

FESOM data

Data on monthly sea ice thickness were derived from the coupled Finite Element Sea Ice Ocean Model (FESOM; Timmermann et al. 2009). For analysis, we only used data on ice thickness from the 20 year time period (1990-2009) with a spatial resolution of 6.90 km x 8.65 km.

The model had been shown to be able to reproduce real polynya dynamics very well in space and time. For example, Haid & Timmermann (2013) showed that a certain polynya exhibited similar size and ice concentration values in the FESOM simulation and in satellite observations derived from the Special Sensor Microwave / Imager (SSM/I). For more details of the model see Haid (2013) and Haid & Timmermann (2013).

The data on sea ice thickness derived from the FESOM model are not directly incorporated into further scientific analysis so far, but were used as additional background information to support the distribution pattern of summer and winter polynyas in the Weddell Sea. The relative number of days with sea ice thickness ≤ 20 cm per month (Jan – Dec) out of 20 years (1990-2009) was calculated. Data on monthly sea ice thickness were reclassified, i.e. a value of 1 was assigned to each pixel with ice thickness ≤ 20 cm, whereas pixels with ice thickness ≥ 20 cm were set to N/A (not available). We followed this procedure as those data will potentially be compared and intersected with ordinal data on coastal winter polynyas from the ICDC (University Hamburg), and we refrained from calculating means from categorial data on winter polynya distribution.

3.1.6. Distance variables

The distance layers were calculated on the base of the Euclidean distance using the GRASS GIS package ‘v.distance’ (Soimasuo et al. 1994; first two layer) and ArcGIS™ (third layer). Shapefiles of the coast line and the shelf ice were provided by Boris Dorschel, AWI. The raster distance to ice shelf has a spatial resolution of 8.02 x 8.02 km. The raster distance to coast line has a spatial resolution of 0.92 km x 0.92 km.

Three data layers were generated:

(1) Distance to the nearest land from each pixel in the planning area

(2) Distance to the continental shelf break (defined as the 1000 m depth contour) with distances from land to shelf break being positive and those from offshore to shelf break being negative

(3) Distance to the shelf ice.

Distance variables, such as distance to the shelf break, were calculated as proxies for factors affecting species distribution patterns (e.g. affecting dispersal or active habitat selection by mobile organisms). For example, distance to the shelf break seems to be an important factor influencing the distribution pattern of many species, such as krill (Atkinson et al. 2008), crabeater seals (Southwell et al. 2012 and references therein) or minke whales (Ainley et al. 2007).

3.2. Pelagic regionalisation

Each data layer, which was incorporated into the pelagic regionalisation analysis, was generated with a raster of 6.25 x 6.25 km². That raster size forms the basis of the AMSR-E 89 GHz sea ice concentration maps. The pelagic regionalisation analysis focuses on the austral summer (Dec – Mar), and used the following parameters:

(1) Sea ice concentration
   1. AMSR-E 89 GHz sea ice concentration maps were used (see paragraph 3.1.5.).
   2. Data on sea ice concentration were log-transformed.
   3. The relative number of days for which a given grid cell had ice cover ≤ 70 % was calculated from 2002 to 2011.
   4. Weighting factor: 1.

(2) Bathymetry
   1. Bathymetric data by IBSCO were used (see paragraph 3.1.1.).
   2. For each grid cell mean and standard deviation of depth and 'depth range' - expressed as the difference between maximum and minimum depth in each grid - was calculated.
   3. Data on depth and depth range were log-transformed.
   4. Each parameter, i.e. depth and depth range, was weighted with 0.5.

(3) Sea water temperature and salinity
   1. FESOM model data were used (see paragraph 3.1.3.).
   2. Data on temperature and salinity were log-transformed.
   3. For each grid cell mean and standard deviation of temperature and salinity at the sea surface and the sea bottom was calculated from a 20 year time period (1990-2009).
   4. Each parameter, i.e. *(i)* temperature at the sea surface, *(ii)* temperature at the sea bottom, *(iii)* salinity at the sea surface and *(iv)* salinity at the sea bottom was weighted with 0.25.

The chosen parameters for the pelagic regionalisation analysis are major structuring components of the pelagic Weddell Sea ecosystem. Furthermore, these parameters overlap with the variables which were incorporated in a circumpolar pelagic regionalisation of the Southern Ocean by Raymond (2011; WG-MPA-11/6).

For clustering we applied the K-means clustering algorithm of Hartigan & Wong (1979). In general, the goal of K-means algorithm is to find the best division of n entities in k groups, so that the total distance between the group's members and its corresponding centroid, representative of the group, is minimized. To determine the optimal number of clusters we used the 'clusGap' function from the R-package 'cluster' (Maechler et al. 2014). The first local maximum in the gap statistic was used to define the optimal number of cluster 'firstSEmax'. Due to the large amount of data, the 'clusGap' analysis could not be applied to the complete data matrix (119,862 samples times 7 variables). Therefore, the matrix was reduced to 4,000 samples x 7 variables by a permutation approach (number of permutations: 150). Finally, the median of the 150 values for optimal number of clusters were used for the K-means cluster analysis.

The result of the pelagic regionalisation approach is shown in Figure 7. 'Coastal polynyas I' (blue-shaded area) denominates areas with a very high probability of ice-free days and high variation in sea surface temperature. Those areas occur along the south-eastern and eastern edge of the ice shelf (from Brunt Ice Shelf to eastern part of Fimbul Ice Shelf) and at the northern border of the Weddell Sea planning area near Larsen C Ice Shelf. Sea ice thickness data (FESOM model) support those results as they show relatively low sea ice thickness (< 20-30 cm) in about the same areas (i.e. from Riiser-Larsen Ice Shelf to Jelbart Ice Shelf and near Larsen C Ice Shelf; results not shown). 'Coastal polynyas II' (red-shaded area) show a high probability of occurrence of polynyas along the edge of the ice shelf. 'Coastal polynyas III' (green-shaded area) denominates areas with an above-average proportion of ice-free days, but significantly less compared to 'Coastal polynyas I and II'. Those areas occur along the south-eastern and eastern edge of the ice shelf (from Filchner Ice Shelf to eastern part of Fimbul Ice Shelf), at the northern border of the planning area near Larsen C Ice Shelf, and near Ronne Ice Shelf. The 'transition zone' (olive-shaded area) is characterised by an average probability of ice-free days and moderate depths (approx. 2000 - 3500 m). 'Deepwater I, II and III' (pink-, orange- and light green-shaded area) are all characterised by above-average water depth. While 'Deepwater I and II' exhibit depths between approx. 3500 m and 5000 m, 'Deepwater III' covers the areas below 4000 m. 'Deepwater I and II' differ in their depth range with 'Deepwater I' covering significantly shallower areas. This coincides well with the benthic regionalisation approach (see paragraph 3.1.1.; Fig. 4) that shows distinct canyon structures (alternation of crests, slopes and troughs) at the south-eastern and eastern continental slope. The 'Ice-covered area' (yellow-shaded) on the continental shelf and in deep waters in the south-western Weddell Sea is characterised by the occurrence of perennial sea ice.

3.3. Ecological parameters

So far, more than 20 ecological data sets on zooplankton, zoobenthos, fish, birds and mammals were acquired (see Tab. 2). These data sets consist of point or areal data mainly, are snapshots in time and are stored in data portals, such as AntaBIF/biodiversity.aq (primarily contains presence/absence data) or PANGAEA.

3.3.1. Zooplankton

Many data sets on zooplankton, mainly data on krill, were acquired so far (see Tab. 2). The largest data set on adult Antarctic krill, *Euphausia superba*, consists of more than 700 stations sampled between 1928 and 2013. Next to some snapshot studies from research operations in the 1970s and 1980s (Fevolden 1979; Makarov & Sysoeva 1985; Siegel 1982), most historical abundance data on krill (until 2004) are available in the data base krillbase (http://www.iced.ac.uk/science/krillbase.htm) and are published in e.g. Atkinson et al. (2004, 2008 and 2009) and Siegel (1982). More recent data on krill (2004 to 2008) are published in Siegel (2012) and are complemented by unpublished data from B. Krafft (Institute of Marine Research; Bergen, Norway). Haul-by-haul krill catch data from commercial operations are stored as a summary data base by CCAMLR. Moreover, we acquired data on ice krill, *Euphausia crystallorophias* (Siegel 1982 and 2012; Siegel et al. 2013). Studies focusing on zooplankton communities, including meso-, macro-zooplankton and micro-nekton, were identified as potentially relevant data sources (e.g. Hunt et al. 2011, Flores et al. 2014) and were partly acquired so far (Boysen-Ennen & Piatkowski 1988, Siegel 2012, unpublished data from Norway, contact: B. Krafft). These data sets are quite diverse taxonomically, and principal groups include salps, cephalopods, crustaceans (e.g. euphausiids, copepods) and fish (mainly mesopelagic species). For additional data that may be relevant and are in the progress of being analysed, please see the workshop report (paragraph 8.).

Preliminary results detecting hotspots for abundance on adult Antarctic krill, *Euphausia superba*, are shown in Figure 8. The data layer on the distribution pattern of krill was derived from KRILLBASE data (Atkinson et al. 2004, 2008, 2009; Siegel 1982), and from published data (Fevolden 1979; Makarov & Sysoeva 1985; Siegel 2012; Siegel et al. 2013) as well as from unpublished data (Volker Siegel, Thünen Institute, Hamburg).

Although data on Antarctic krill differ in sampling depth, proportion of day vs. night hauls and time of year of sampling, we created a krill density distribution layer from un-standardised data. Atkinson et al. (2008) compared the circumpolar krill distribution based on raw, un-standardised data and standardised krill densities. Overall, Atkinson et al. (2008) obtained the same basic picture, despite higher overall Krill densities after standardisation procedures.

Inverse distance weighted (IDW) interpolation was used in the ArcGIS™ spatial analyst tool; see Burrough & McDonnell (1988) and Lu & Wong (2008) for more details. IDW was performed using log-transformed data, and the interpolated data were finally expressed as mean krill densities (individuals/m²) +/- the n-fold of the standard deviation per grid cell (6.25 x 6.25 km²).

Hotspots of adult Antarctic krill abundance are located *(i)* at the northern border of the Weddell Sea planning area near Larsen C Ice Shelf and to the east of it, *(ii)* in open water at 25°W, *(iii)* at the continental slope at 15°W (similar latitude as Quarisen Ice Shelf), *(iv)* in open water at the northern border of the Weddell Sea planning area near the Greenwich meridian, *(v)* near Maud Rise sea mount (66°S, 3°E), and *(vi)* on the continental shelf near Fimbul Ice Shelf; see Fig. 8). Our results coincide quite well with the distribution patterns of Antarctic krill reported in e.g. Atkinson et al. (2008), Siegel (1982) and Boysen-Ennen & Piatkowski (1988).

Further efforts to detect biodiversity and abundance hotspots for other pelagic key species (e.g. ice krill) were discussed at the International Expert Workshop (see workshop report; paragraph 8.), and corresponding analyses are in progress.

3.3.2. Zoobenthos

Two substantial zoobenthic data sets are listed in Table 2. Gutt et al. (2013a) provide a comprehensive data set on the geographical distribution of Antarctic macrobenthic communities. This descriptive data set, consisting of approx. 90 individual data sets, has a temporal coverage from 1956 to 2010 and covers almost the entire Southern Ocean (Gutt et al. 2013b). Although the data show a considerable patchiness at regional scale, the south-eastern Weddell Sea is covered well, and thus the data set provides unique geo-referenced biological basic information. Furthermore, a large quantitative macrobenthos data (abundance, biomass) set exists at AWI. Macrobenthic samples were taken during 10 *Polarstern* cruises in the south-eastern and eastern Weddell Sea shelf area from 1984 to 2011 (e.g. Gerdes et al. 1992). In addition, there is a considerable number of data sets referring to specific taxonomic groups - particularly polychaetes (e.g. Montiel et al. 2005, Schüller & Ebbe 2007, Stiller 1996), molluscs (e.g. Hain 1990), crustaceans (e.g. Brandt et al. 2007) and echinoderms (e.g. Piepenburg et al. 1997, Brey & Gutt 1991, Gutt 1991) - mainly sampled along the Weddell Sea shelf, but also in deeper waters. In total more than 20 such smaller data sets, partly stored in the ANTABIF data portal (primarily as presence data), and on macrofaunal communities (e.g. Galéron et al. 1992, Voß 1988, Linse et al. 2007) were checked (not listed in Tab. 2).

Macrozoobenthic taxonomic richness at the level of higher taxonomic groups was calculated from the data set held by D. Gerdes (AWI) and U. Mühlenhardt-Siegel (Thünen Institute). The number of higher taxonomic zoobenthic groups per spatial grid cell (1° of latitude by 1° of longitude) was counted. The residuals resulting from a regression between number of samples (x) and number of higher taxonomic groups (per spatial cell, y) were used to reduce bias caused by regionally varying sampling efforts. Here, we applied the Ugland T-S curve (Ugland et al. 2003), which accounts for the degree of environmental heterogeneity (e.g., depth or sediment properties) and the size of the whole area by partitioning the dataset of the sampled areaheld by into several subsets.

Cluster of grid cells with an above-average taxonomic richness are located *(i)* near Brunt Ice Shelf, *(ii)* at Ekstrøm to Jelbart Ice Shelfs, and *(iii)* at Fimbul Ice Shelf (see Fig. 9). Rich macrozoobenthic communities, classified by functional traits after Gutt (2007) and Turner et al. (2009), occur near Larsen C Ice Shelf and also near Brunt Ice Shelf (see more details in Gutt et al. 2013a). Here, the dominant community types are seep communities and sessile suspension feeder communities dominated by sponges, respectively.

Analyses of macrozoobenthic abundance, biomass, production and further characteristics are in progress. Objectives are to identify areas with important ecosystem functions (e.g., nursery grounds or strongly structured habitats; more details see workshop report; paragraph 8.). Different interpolation models will be applied where possible.

3.3.3. Fish

There are substantial data available on the Weddell Sea fish fauna. During various *Polarstern* cruises between 1983 and 2011 the demersal fish fauna was sampled particularly along the Weddell Sea shelf, but also in deeper waters (see Drescher et al. 2012, Ekau et al. 2012 a, b, Hureau et al. 2012, Kock et al. 2012, Wöhrmann et al. 2012 and unpublished data held by R. Knust, AWI; Tab. 2). Furthermore, information is available on the distribution of oceanic pelagic fish (unpublished data held by R. Knust, AWI). Data from long line fishery operations, mainly *Dissostichus* spp. catches, are stored as a summary data base by CCAMLR, and were already acquired. An additional data source, which was identified by the International Expert Workshop on the Weddell Sea MPA project, focuses on *Pleuragramma* from e.g. Hubold (1984, 1992) and Piatkowski (1987). Data on mesopelagic fish which derived e.g. from the LAzarev Sea KRIll Study (LAKRIS) project were already described in paragraph 3.3.1. Data on spawning grounds would be useful for the MPA Weddell Sea evaluation, and the International Expert Workshop noted that there is information for some specific spawning areas (approx. 1400 m - 1600 m; see more details see workshop report; paragraph 8.); however, the data were not acquired so far.

The International Expert Workshop identified the following key topics regarding Antarctic fish: *(i)* biodiversity, *(ii)* biomass of the most abundant species, *(iii)* important areas for specific life cycle stages and *(iv)* relevant trophic interactions. The subsequent data preparation and analysis will show if the data are actually appropriate for creating corresponding data layers.

3.3.4. Birds

Currently there is a lack of data on flying seabirds (i.e. fulmarine petrels, such as Antarctic Petrel and Snow Petrel), in particular on their breeding colonies and their distribution patterns in the Weddell Sea. A few data sets exist (mainly shipboard observations; little tracking data) at German and international research institutes, and their principal investigators have already been, or will be, contacted in a timely manner.

Data on emperor penguin population estimates were derived from Fretwell et al. (2012, 2014). This data set was complemented by unpublished data on Adélie penguin colonies from Heather Lynch, Stony Brook University, USA.

Within the boundaries of the proposed planning area there are two Adélie colonies situated near the tip of the Antarctic Peninsula with a total estimated abundance of 35,098 breeding pairs (95th percentile confidence intervals: 13,670 - 57,934 breeding pairs; see Fig. 10). Furthermore, there are 15 Emperor penguin breeding colonies in the Weddell Sea with a total estimated abundance of approx. 78,000 breeding pairs, representing approx. 25 % of the world`s population (Fretwell et al. 2012, 2014; Ainley et al. 2010). The penguin colonies` proximity to persistent or recurrent coastal winter polynyas is shown in Figure 10. Recurrent polynyas occur in the west of the planning area at the northern border of Larsen C Ice Shelf and along the south-eastern and eastern ice shelf particularly near *(i)* Brunt Ice Shelf, *(ii)* Riiser-Larsen Ice Shelf, *(iii)* Ekstrøm to Jelbart Ice Shelf, and *(iv)* the eastern part of Fimbul Ice Shelf.

Subsequent analyses will focus on the evaluation of foraging ranges of Emperor penguins.

3.3.5. Marine Mammals

Pinnipeds

A pinniped survey within the Antarctic Pack Ice Seals (APIS) programme, which was developed and executed by members of the Scientific Committee on Antarctic Research (SCAR) Group of Specialists on Seals and their national programmes, was carried out along the eastern coast of the Weddell Sea from 1996 to 2001 (Ackley et al. 2006; Plötz et al. 2011a-e; Southwell et al. 2012). During five fixed-wing aircraft flight campaigns, which covered an area of more than 80,000 km of aerial transects, approx. 2,300 seals were counted in total. An additional APIS survey, based on helicopter flights from aboard RV *Polarstern* in 1998 - a year with unusually low sea ice coverage - covered the area from 7°W to 45°W with 15 transects (Bester & Odendaal 1999,2000). Moreover, pack-ice seal line-transect data were collected during an aerial survey, conducted as the UK contribution to the APIS programme, in the western part of the Weddell Sea (Forcada & Trathan 2008; Forcada et al. 2012). A methodologically congruent “pre-APIS”-helicopter survey was carried out more easterly in the Weddell Sea (0° - 5° W) by Bester et al. (1995). Post-APIS-helicopter surveys from aboard RV *Polarstern* were flown in 2004 / 2005 (ANT-XXII/2), and were concentrated north of 69°S (Flores et al. 2008). Most recent photographic and video footage were taken during the research survey of the AWI aircraft *Polar 6* in November 2013, and additional species specific helicopter based counts were carried during RV *Polarstern*'s ANT-XXIX/9 2013/2014 research mission, both in the southern Weddell Sea. The most recent data are currently in analyses. Acoustic data, i.e. year-round records of the presence of pinnipeds since 2005, derive from the coastal Perennial Acoustic Observatory in the Antarctic Ocean (PALAOA) near Neumayer Station, and additionally from several oceanographic moorings distributed along the Greenwich meridian and throughout the Weddell Sea (Van Opzeeland 2010). However, the International Expert Workshop noted that there is limited information available particularly on elephant seal abundance and migration patterns (more details see workshop report; paragraph 8.). Few tracking data sets are available on southern elephant seals (Tosh et al. 2009; James et al. 2012), Ross seals (Blix & Nordøy 2007), leopard seals (Nordøy & Blix 2009), and Weddell seals (McIntyre et al. 2013).

Figure 11 presents a preliminary map of pinniped distribution in the Weddell Sea. The modelled abundance data on crabeater seals (see Fig. 11), Weddell seals and leopard seals (results are not shown) were derived from Forcada et al. (2012). The seal densities (unspecified taxa) in the south-eastern/eastern part of the Weddell Sea based on data from the APIS programme (Plötz et al. 2011a-e).

Absolute seal density (individuals/km²) was calculated with the count method for line transect data (Bester et al. 1995, Bester & Odendaal 2000, Hedley & Buckland 2004). We used un-standardised data for the density calculations as the data set from Plötz et al. (2011a-e) based on video material, and thus at least observer related factors potentially influencing the probability of animal detection are not relevant to consider. In contrast, Forcada et al. (2012) considered several factors potentially influencing the probability of animal detection for their density estimations (e.g. probability of detection for perpendicular sighting distances). To estimate the absolute seal density, we applied inverse distance weighted interpolation in ArcGIS™ spatial analyst tool to the data from PANGAEA, while a more sophisticated approach, i.e. a combination of different generalized additive models, was used in Forcada et al. (2012).

Absolute seal density (i.e. > 15 individuals/km²) is highest near the edge of Riiser-Larsen Ice Shelf to Quarisen Ice Shelf (see Fig. 11). The greater part of the western Weddell Sea is characterised by relatively low crabeater seal densities (1-2 individuals/km²). However, crabeater seals are the most abundant pinniped species in the western Weddell Sea compared to leopard seals and Weddell seals with highest estimated densities of ≤ 0.02 individuals/km² and ≤ 0.5 individuals/km², respectively (see Forcada et al. 2012).

We plan to verify the modelled seal densities in the eastern part of the Weddell Sea MPA planning area by different approaches regarding data standardisation procedure and modelling techniques. In addition, subsequent analyses will particularly focus on the evaluation of mating areas of pinnipeds based on acoustic data from the AWI (see Tab. 2).

Cetaceans

The presence of cetaceans is also recorded year-round since 2005 by PALAOA, and additionally by several oceanographic moorings distributed along the Greenwich meridian and throughout the Weddell Sea (Van Opzeeland 2010). Regarding cetacean sightings, two data sets were sighted so far. Since 2005, the AWI systematically and continuously logs all sightings of cetaceans near RV *Polarstern* in the Southern Ocean (Marine Mammal Perimeter Surveillance, MAPS). By means of the MAPS project more than 1300 individuals from nine cetacean taxa were identified in the Weddell Sea from 2005 to date (Burkhardt 2009a-i, 2011, 2012). Those data were used to build a habitat suitability model of humpback and Antarctic minke whales in the Southern Ocean (see Bombosch 2013). Furthermore, quantitative cetacean sightings, surveyed during five *Polarstern* cruises from 2006 to 2013, could serve as a basis for estimating local cetacean densities in the Weddell Sea (unpublished data held by H. Feindt-Herr, Institute for Terrestrial and Aquatic Wildlife Research, Hannover).

Habitat suitability models of humpback and Antarctic minke whales indicates (see Bombosch 2013) that favourable habitat conditions for humpback whales exist in open waters near Larsen C Ice Shelf and in the eastern part of the planning area throughout January and February. Suitable minke whale habitats are consistently predicted within sea ice covered areas. Throughout November and early December, favourable conditions for minke whales span wide areas of the Weddell Sea (exceptions are e.g., areas directly along the ice shelf edge). Suitable habitats start to shrink rapidly by mid-December and concentrate towards coastal areas for the following months. By mid-March, habitat suitability reaches its spatial minimum and starts extending again until the end of April. Highly favourable conditions for minke whales throughout the season are predicted for an area around 70°S and 40°W.

4. Future work

Future work within the MPA Weddell Sea project will concentrate on the data identification and acquisition process and the scientific data analysis. While effort put into data identification and acquisition will continuously decrease, we will focus more and more on the scientific data analysis (incl. planning analyses such as Marxan).

The International Expert Workshop has also been useful in identifying the scope of future work, which leads to a revision of the initial project timeline as set out in SC-CAMLR-XXXII/BG/07 (Hobart, Oct 2013).

Following the presentation of this working paper at WG-EMM-14, the next step will be the development of a preliminary background paper to be submitted to the Scientific Committee (October 2014). This document will be similarly structured as this status report, and will draw on experts' expertise to provide a description of the Weddell Sea ecosystem. It will describe the available data, specify those data used in the analyses and provide details of all the analyses undertaken. Furthermore, future steps regarding outstanding information collection, data analysis and development of modules for a MPA proposal will be outlined.

It is intended to adjust the working plan following the responses of WG-EMM-14 and SC-CAMLR-14 with the aim of having a proposal in 2015.

5. Tables

Table 1: List of environmental data sets for marine protected area evaluation in the Weddell Sea. Complete data sets or parts of it which were sighted, but were not incorporated into further analyses so far are grey-shaded.

	Spatial and temporal resolution			
Parameter	**Spatial resolution**	**Period**	**Temporal resolution**	**Source (contact person, publication, web site)**
Bathymetry				
Bathymetry (m)	500 x 500 m	not applicable	not applicable	Arndt et al. (2013); www.ibcso.org
Sedimentology				
Grain size, i.e. gravel, sand, silt, clay (%)	> 400 samples were taken with large box corer, multi- or mini-corer	1983 - 1997	time interval: 1-3 years	Petschick et al. (1996) http://doi.pangaea.de/10.1594/PANGAEA.55955 Diekmann & Kuhn (1999) http://doi.pangaea.de/10.1594/PANGAEA.730459 G. Kuhn, AWI (unpublished data)
Water column properties				
Sea temperature (°C), salinity (PSU), currents, i.e. speed (m) and direction of water movement (°) - Model data (FESOM)	0.18 km x 0.05 km (horizontal) Surface and bottom value (vertical)	1990 - 2009	Monthly	Timmermann et al. (2009)
Sea surface temperature (°C)	1/8° x 1/8° (MODAS) 1/12° x 1/12° (HYCOM)	1993 - ongoing	daily	Barron & Kara (2006) MODAS: http://www7320.nrlssc.navy.mil/modas/ HYCOM: http://www7320.nrlssc.navy.mil/GLBhycom1-12/skill.html
Sea surface height (cm)	1/3° x 1/3°	1992 - ongoing	daily	Archiving, Validation & Interpretation of Satellite Oceanographic data (Aviso) http://www.aviso.oceanobs.com/en/
Sea temperature (°C), Salinity (PSS), Dissolved oxygen (ml l^{-1}), inorganic nutrients (µM)	1° x 1°	1955 - 2006	Monthly, seasonal, annual	Locarnini et al. (2010), Antonov et al. (2010), Garcia et al. (2010a,b), http://www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html

Table 1 (contd.)

	Spatial and temporal resolution			
Parameter	**Spatial resolution**	**Period**	**Temporal resolution**	**Source (contact person, publication, web site)**
Chlorophyll-a				
Chlorophyll-a concentration (mg/m³)	0.83 km x 0.83 km	1997 - 2010	daily	National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Ocean Data Processing System (ODPS) http://oceandata.sci.gsfc.nasa.gov/SeaWiFS/L3SMI/
Sea ice dynamic				
Sea ice concentration (%)	6.25 km x 6.25 km	Jun 2002 - Oct 2011; Aug 2012 - ongoing	daily	Kaleschke et al. (2001), Spreen et al. (2008) Institute of Environmental Physics, University of Bremen: http://www.iup.uni-bremen.de/seaice/amsr/ Integrated Climate Data Center (ICDC), University of Hamburg: http://www.icdc.zmaw.de/seaiceconcentration_asi_amsre.html
Sea ice thickness (cm)	5 km x 5 km	1992 - 2008	Daily (May-Sept)	Markus & Burns (1995), Hunewinkel et al. (1998), Kern et al. (2007), Kern (2012) Integrated Climate Data Center (ICDC), University of Hamburg: http://icdc.zmaw.de/polynya_ant.html
Sea ice thickness (cm) - Model data (FESOM)	6.90 km x 8.65 km	1990 - 2009	Monthly	Timmermann et al. 2009
Frontal areas				
Weddell system	8 repeat hydrographic sections, moored instruments and profiling floats on 0°	1984 - 2008	Different time intervals	Fahrbach et al. (1995, 2004, 2007, 2011) Data are available at e.g. http://www.pangaea.de/
Weddell Gyre	206 ice-compatible vertically profiling floats	1999 - 2010	Snapshot in time	Klatt et al. (2007)

Table 2: List of ecological data sets for marine protected area evaluation in the Weddell Sea. Complete data sets or parts of it which were sighted, but were not incorporated into further analyses so far are grey-shaded.

	Sampling design and temporal resolution			
Parameter	**Sampling design**	**Period**	**Temporal resolution**	**Source (contact person, publication, web site)**
Zooplankton				
Abundance data on adult Antarctic krill, *Euphausia superba* (N/m²; N/1000 m³)	> 700 stations; e.g. IKMT, RMT nets	1928 - 1997 1977 - 1983 2001 - 2013	Different time intervals	Krillbase: http://www.iced.ac.uk/science/krillbase.htm Atkinson et al. (2004, 2008, 2009); Siegel (1982) Fevolden (1979), Makarov & Sysoeva (1985); Siegel (1982, unpublished data) Siegel (2012, unpublished data), Siegel et al. (2013)
Abundance data on adult Antarctic krill, *Euphausia superba* (N/m²)	21 stations; macroplankton trawl	2008	Snapshot in time	Unpublished data (contact: Bjoern Krafft, Institute of Marine Research, Bergen)
Abundance data on adult ice krill, *Euphausia crystallorophias* (N/1000 m³)	> 400 stations; RMT nets	1976 - 1989 2004 - 2013	Different time intervals	Siegel (1982, unpublished data) Siegel (2012), Siegel et al. (2013)
Abundance data on Antarctic krill larvae and ice krill larvae (N/m²)	> 300 stations; e.g. Juday, RMT1, Bongo nets	1977 - 1989 2004, 2006	Different time intervals	Fevolden (1979, 1980), Hempel & Hempel (1982), Menshenina (1992), Siegel (2005, unpublished data) Siegel (2012)
Krill data from commercial operations (catch in kg)	Bottom and midwater trawls	1974 - 2009	Different time intervals	David Ramm, CCAMLR data manager; www.ccamlr.org
Abundance data on meso- and macrozooplankton (N/1000m³)	39 stations; RMT1, RMT8	1983	Snapshot in time	Boysen-Ennen & Piatkowski (1988)
Abundance data on macrozooplankton and micro-nekton (N/1000m³)	RMT, SUIT nets along 3-4 transects; station spacing 20-30 nm, approx. 50-80 stations per expedition	2004 - 2008	Different time intervals	Hunt et al. (2011), Flores et al. (2014)

Table 2 (contd.)

	Sampling design and temporal resolution			
Parameter	**Sampling design**	**Period**	**Temporal resolution**	**Source (contact person, publication, web site)**
Zoobenthos				
Macrobenthic communities (descriptive)	approx. 90 data sets, Weddell Sea shelf	1956 - 2010	Summary data set, Snapshots in time	Gutt et al. (2013a, b) and references therein in regards to results and data http://ipt.biodiversity.aq/resource.do?r=macrobenthos
Macrozoobenthos (N/m², g C/m²)	Various German Antarctic expeditions; almost 300 samples	1984 - 2011	Different time intervals	Data originators: Dieter Gerdes (AWI); Ute Mühlenhardt-Siegel (vTI); e.g. Gerdes et al. (1992)
Considerable number on specific higher taxonomic groups (primarily abundance data)	Several *Polarstern* cruises; mainly sampled along the Weddell Sea shelf, but also in deeper waters	1983 - 2005	Snapshots in time	Polychaetes (e.g. Montiel et al. 2005, Schüller & Ebbe 2007, Stiller 1996), molluscs (e.g. Hain 1990), crustaceans (e.g. Brandt et al. 2007), echinoderms (e.g. Piepenburg et al. 1997, Brey & Gutt 1991, Gutt 1991)
Fish				
Mostly abundance and biomass data on demersal fish, but also pelagic fish	> 10 Polarstern cruises, > 300 hauls, mostly Weddell Sea shelf, but also deeper waters	1983 - 2011	Different time intervals	Contact: Julian Gutt (AWI), Rainer Knust (AWI), Karl-Hermann Kock (vTI) Drescher et al. (2012), Ekau et al. (2012 a, b), Hureau et al. (2012), Kock et al. (2012), Wöhrmann et al. (2012) and unpublished data held by R. Knust, AWI doi:10.1594/PANGAEA.786877, doi:10.1594/PANGAEA.786883, doi:10.1594/PANGAEA.786884, doi:10.1594/PANGAEA.786886, doi:10.1594/PANGAEA.786888, doi:10.1594/PANGAEA.786887 Regarding data on *Pleuragramma*: e.g. Hubold (1984, 1992), Piatkowski (1987)
Fishery operations (catch in kg); mainly *Dissostichus* spp. catches	Longline surveys	2005 - 2013	Summary data base (annual and bi-annual)	David Ramm, CCAMLR data manager; www.ccamlr.org
Birds				
Adélie penguin breeding colonies	high resolution (0.6 m) satellite imagery with spectral analysis, Antarctic Peninsula	2000s	Snapshot in time	H. Lynch, Stony Brook University, USA (unpublished data)
Emperor penguin breeding colonies	High resolution satellite imagery	2009 (Sept-Dec); 2012	Snapshot in time	Fretwell et al. (2012, 2014)
Mammals				
Pinniped line-transect data (N/Km²)	flight campaigns	1992 - 2014	Different time intervals	Bester et al. (1995), Bester & Odendaal (1999, 2000), Ackley et al. (2006), Flores et al. (2008), Forcada & Trathan (2008), Plötz et al. (2011 a-e; http://www.pangaea.de), Forcada et al. (2012), Southwell et al. (2012), and unpublished data held by H. Bornemann, AWI

Table 2 (contd.)

	Sampling design and temporal resolution			
Parameter	**Sampling design**	**Period**	**Temporal resolution**	**Source (contact person, publication, web site)**
Mammals				
Tracking data on pinnipeds	Tagging of up to 15 individuals of southern elephant seals, Ross seals, leopard seals and Weddell seals, respectively	1999-2008	Snapshots in time, different tracking times	Blix & Nordøy 2007; Nordøy & Blix 2009; Tosh et al. 2009, doi:10.1594/PANGAEA.692856; James et al. 2012, doi:10.1594/PANGAEA.785852; McIntyre et al. 2013
Acoustic data on pinniped and cetacean presence	oceanographic moorings	2006-2012	Daily, different starting times for single recorders	Kindermann (2013), doi:10.1594/PANGAEA.773610 Van Opzeeland (2010)
Opportunistic cetacean sightings	15 *Polarstern* cruises	2005 - ongoing	Snapshot in time	Burkhardt (2009 a-i, 2011, 2012 and unpublished data); Bombosch (2013) http://www.pangaea.de/search?count=10&minlat=&minlon=&maxlat=&maxlon=&mindate=&maxdate=&env=All&q=elke+burkhardt+
Quantitative cetacean sightings (N/km²)	5 *Polarstern* cruises	2006 - 2013	Time interval: 1-2 years	Helena Feindt-Herr, Institute for Terrrestrial and Aquatic Widlife Research, University of Veterinary Medicine Hannover

6. Literature

Ackley, S., Bengtson, J., Bester, M. N., Blix, A. S., Bornemann, H., Boveng, P., Boyd, I., Cameron, M., Nordøy, E., Plötz, J., Siniff, D., Southwell, C., Steinhage, D., Stewart, B.S., Stirling, J., Torres, J., Yochem, P.K. (2006): The International Antarctic Pack Ice Seals (APIS) Program. Multi-disciplinary Research into the Ecology and Behavior of Antarctic Pack Ice Seals. Summary Update. The Expert Group on Seals (EGS); Scientific Committee on Antarctic Research (SCAR). Marthan N. Bester, D.Sc., Chief Officer, Brent S. Stewart, Ph.D., J.D., Secretary (eds.).

Ainley, D.G., Dugger, K.M., Toniolo, V., Gaffney I. (2007) Cetacean occurrence patterns in the Amundsen and southern Bellingshausen sea sector, Southern Ocean. Marine Mammal Science 23: 730-730.

Ainley, D., Russell, J., Jenouvrier, S., Woehler, E., Lyver, P., Fraser, W.R., Kooyman, G.L. (2010) Antarctic penguin response to habitat change as Earth's troposphere reaches 2°C above preindustrial levels. Ecological Monographs 80, 49–66.

Antonov, J.I., Seidov, D., Boyer, T.P., Locarnini, R.A., Mishonov, A.V., Garcia, H.E., Baranova, O.K., Zweng, M.M., Johnson, D.R. (2010) World Ocean Atlas 2009, Volume 2: Salinity. S. Levitus, Ed. NOAA Atlas NESDIS 69, U.S. Government Printing Office, Washington, D.C., 184 pp.

Arndt, J.E., Schenke, H.W., Jakobsson, M., Nitsche, F., Buys, G., Goleby, B., Rebesco, M., Bohoyo, F., Hong, J.K., Black, J., Greku, R., Udintsev, G., Barrios, F., Reynoso-Peralta, W., Morishita, T., Wigley, R. (2013) The International Bathymetric Chart of the Southern Ocean (IBCSO) Version 1.0 - A new bathymetric compilation covering circum-Antarctic waters. Geophysical Research Letters, doi: 10.1002/grl.50413

Arntz, W., Brey, T., Gallardo, V.A. (1994) Antarctic Zoobenthos. Oceanography and Marine Biology Annual Review 32, 241-304.

Arrigo, K.R., van Dijken, G.L. (2003) Phytoplankton dynamics within 37 Antarctic coastal polynya systems. Journal of Geophysical Research 108, No. 3271, doi:10.1029/2002JC0017 39.

Atkinson, A., Siegel, V., Pakhomov, E.A., Rothery, P. (2004) Longterm decline in krill stock and increase in salps within the Southern Ocean. Nature 432: 100-103.

Atkinson, A., Siegel, V., Pakhomov, E.A., Rothery, P., Loeb, V., Ross, R.M., Quetin, L.B., Schmidt, K., Fretwell, P., Murphy, E.J., Tarling, G.A., Fleming, A.H. (2008) Oceanic circumpolar habitats of Antarctic krill. Marine Ecology Progress Series 362: 1-23.

Atkinson, A., Siegel, V., Pakhomov, E.A., Jessopp, M.J., Loeb, V. (2009) A re-appraisal of the total biomass and production of Antarctic krill. Deep-Sea Research I 56: 727-740.

Barron, C.N., Kara, A.B. (2006) Satellite-based daily SSTs over the global ocean. Geophysical Research Letters 3, L15603, doi:10.1029/2006GL026356.

Barthel, D., Gutt, J. (1992): Sponge associations in the eastern Weddell Sea. Antarctic Science 4, 137–150.

Bester, M.N., Erickson, A.W., Ferguson, J.W.H. (1995) Seasonal change in the distribution and density of seals in the pack ice off Princess Martha Coast, Antarctica. Antarctic Science 7, 357–364.

Bester, M.N., Odendaal, P.N. (1999) Abundance and distribution of Antarctic pack ice seals in the Weddell Sea. In: Arntz, W.E., Gutt, J. (eds) The Expedition ANTARKTIS XV/3 (EASIZ II) of "Polarstern" in 1998. Berichte zur Polarforschung 301: 102-107.

Bester, M.N., Odendaal, P.N. (2000) Abundance and distribution of Antarctic pack ice seals in the Weddell Sea. In: Davison, W., Howard-Williams, C., Broady, P. (eds) Antarctic Ecosystems: Models for Wider Ecological Understanding, Caxton Press, Christchurch, pp 51-55.

Blix. A.S., Nordøy, E.S. (2007) Ross seal (*Ommatophoca rossii*) annual distribution, diving behaviour, breeding and moulting, off Queen Maud Land, Antarctica. Polar Biology 30: 1449-1458.

Bombosch, A. (2013) Modelling habitat suitability of humpback and Antarctic minke whale feeding grounds in the southern ocean. PhD thesis, University of Bremen, Germany, 173 pp.

Boysen-Ennen, E., Piatkowski, U. (1988) Meso- and macrozooplankton communities in the Weddell Sea, Antarctica. Polar Biology 9: 17-35.

Brandt, A., Brix, S., Brökeland, W., Choudhury, M., Kaiser, S., Malyutina, M. (2007) Deep-sea isopod biodiversity, abundance, and endemism in the Atlantic sector of the Southern Ocean – Results from the ANDEEP I-III expeditions. Deep-Sea Research II 54, 1760-1775.

Brey T., Gutt J. (1991) The genus *Sterechinus* (Echinodermata: Echinoidea) on the Weddell Sea shelf and slope (Antarctica): distribution, abundance and biomass. Polar Biology 11, 227-232.

Brey, T., Klages, M., Dahm, C., Gorny, M., Gutt, J., Hain, S., Stiller, M., Arntz, W.E., Wägele, J.-W., Zimmermann, A. (1994) Antarctic Benthic Diversity. Nature 368, 297.

Burkhardt, E. (2009a-i) Whale sightings during POLARSTERN cruise ANT-XXII/3. Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Bremerhaven, doi:10.1594/PANGAEA.729027; doi:10.1594/PANGAEA.729030; doi:10.1594/PANGAEA.7290 34; doi:10.1594/PANGAEA.729035; doi:10.1594/PANGAEA.729036; doi:10.1594/PANGAEA. 729037; doi:10.1594/PANGAEA.729040; doi:10.1594/PANGAEA.729041; doi:10.1594/PANGA EA.728270.

Burkhardt, E. (2011) Whale sightings during POLARSTERN cruise ANT-XXVII/2. Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Bremerhaven, doi:10.1594/PANGAEA.760340

Burkhardt, E. (2012) Whale sightings during POLARSTERN cruise ANT-XXVII/3. Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Bremerhaven, doi:10.1594/PANGAEA.783806

Burrough, P.A., McDonnell, R.A. (1988) Principals of geographical information systems. Oxford University pRess, 333 pp.

Clarke, A., Johnston, N.M. (2003) Antarctic marine benthic diversity. Oceanography and Marine Biology, 41, 47-114.

Diekmann, B., Kuhn, G. (1999) Provenance and dispersal of glacial-marine surface sediments in the Weddell Sea and adjoining areas, Antarctica: ice-rafting versus current transport. Marine Geology, 158(1-4): 209-231.

Douglass, L.L., Turner, J., Grantham, H.S., Kaiser, S., Nicoll, R., Post, A., Brandt, A., Beaver, D. (2011) A hierarchical classification of benthic biodiversity and assessment of protected areas in the Southern

Ocean. WS-MPA-11/23, 28 pp.

Drescher, E., Hubold, G., Piatkowski, U., Plötz, J., Voß, J., Kock, K.-H., Gutt, J. (2012) Counts of fish species from trawl and dredge samples in the eastern Weddell Sea and at the Antarctic Peninsula during POLARSTERN cruise ANT-I/2. doi:10.1594/PANGAEA.786877.

Ekau, W., Hubold, G., Kock, K.-H., Gutt, J. (2012a) Counts of fish species from trawl and dredge samples in the eastern Weddell Sea and at the Antarctic Peninsula during POLARSTERN cruise ANT-III/3. doi:10.1594/PANGAEA.786883.

Ekau, W., Hubold, G. Wöhrmann, A., Kock, K.-H., Gutt, J. (2012b) Counts of fish species from trawl and dredge samples in the eastern Weddell Sea and at the Antarctic Peninsula during POLARSTERN cruise ANT-V/3. doi:10.1594/PANGAEA.786884.

Erdey-Heydorn, M.D. (2008) An ArcGIS Seabed Characterization Toolbox Developed for Investigating Benthic Habitats. Marine Geodesy 31: 318-358.

ESRI (2011) ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Fahrbach, E., Rohardt, G., Scheele, N., Schröder, M., Strass, V., Wisotzki, A. (1995) Formation and discharge of deep and bottom water in the northwestern Weddell Sea. Journal of Marine Research 53, 515–538.

Fahrbach, E., Hoppema, M., Rohardt, G., Schröder, M., Wisotzki, A. (2004) Decadal-scale variations of water mass properties in the deep Weddell Sea. Ocean Dynamics 54, 77–91.

Fahrbach, E., Rohardt, G., Sieger, R. (2007) 25 Years of *Polarstern* hydrography (1982–2007). WDC-MARE Reports 5, Alfred Wegener Institute, Bremerhaven, 94 pp.

Fahrbach E., Beszczynska-Möller A., Rohardt G. (2009) Polar oceans - an oceanographic overview. In: Hempel G., Hempel I. (eds). Biological studies in polar oceans: exploration of life in icy waters. Wirtschaftsverlag NW, Bremerhaven, 17-36.

Fahrbach, E., Hoppema, M., Rohardt, G., Boebel, O., Klatt, O., Wisotzki, A. (2011) Warming of deep and abyssal water masses along the Greenwich meridian on decadal time scales: The Weddell gyre as a heat buffer. Deep-Sea Research II 58, 2509–2523.

Fevolden, S.E. (1979) Investigations on krill (Euphausiacea) sampled during the Norwegian Antarctic Research Expedition 1976-77. Sarsia 64, 189-198.

Fevolden, S.E. (1980) Krill off Bouvetoya and in the southern Weddell Sea with a description of larval stages of *Euphausia crystallorophias*. Sarsia 65 (2), 149-162.

Flemming, B.W. (2000) A revised textural classification of gravel - free muddy sediments on the basis of ternary diagrams. Continental Shelf Research 20 (10-11): 1125–1137.

Flores, H., Haas, C., van Franeker, J.A., Meesters, E. (2008) Density of pack-ice seals and penguins in the western Weddell Sea in relation to ice thickness and ocean depth. Deep Sea Research II 55 (8), 1068-1074.

Flores, H., Hunt, B., Peter, V., Kruse, S., Pakhomov, E.A., Siegel, V., van Franeker, J.A., Strass, V.H., van de Putte, A.P., Meesters, E.H., Bathmann, U. (2014) Seasonal changes in the vertical distribution and community structure of Antartic macrozooplankton and micronekton. Deep-Sea Research I 84, 127-141.

Folk, R.L. (1954) The distinction between grain size and mineral composition in sedimentary rock nomenclature. Journal of Geology 62(4): 344–359.

Forcada, J., Trathan, P.N., Boveng, P.L., Boyd, I.L., Burns, J.M., Costa, D.P., Fedak, M., Rogers, T.L., Southwell, C.J. (2012). Responses of Antarctic pack-ice seals to environmental change and increasing krill fishing. Biological Conservation 149, 40-50.

Fretwell, P.T., LaRue, M.A., Morin, P., Kooyman, G.L., Wienecke, B., Ratcliffe, N., Fox, A.J., Fleming, A.H., Porter, C., Trathan, P.N. (2012) An emperor penguin population estimate: the first global, synoptic survey of a species from space. PLoS ONE 7(4): doi: 10.1371/annotation/32c246eb-3b73-4410-a44c-b41ddae11fc5.

Fretwell, P.T., Trathan, P.N., Wienecke, B., Kooyman, G.L. (2014) Emperor Penguins Breeding on Iceshelves. PLoS ONE 9(1): e85285. doi:10.1371/journal.pone.0085285.

Galéron, J., Herman, R.L., Arnaud, P.M., Arntz, W., Hain, S., Klages, M. (1992) Macrofaunal communties on the continental shelf and slope of the southeastern Weddell Sea, Antarctica. Polar biology 12, 283-290.

Garcia, H.E., Locarnini, R.A., Boyer, T.P., Antonov, J.I., Baranova, O.K., Zweng, M.M., Johnson, D.R. (2010a) World Ocean Atlas 2009, Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation. S. Levitus, Ed. NOAA Atlas NESDIS 70, U.S. Government Printing Office, Washington, D.C., 344 pp.

Garcia, H.E., Locarnini, R.A., Boyer, T.P., Antonov, J.I., Zweng, M.M., Baranova, O.K., Johnson, D.R. (2010b) World Ocean Atlas 2009, Volume 4: Nutrients (phosphate, nitrate, silicate). S. Levitus, Ed. NOAA Atlas NESDIS 71, U.S. Government Printing Office, Washington, D.C., 398 pp.

Gerdes, D., Klages, M., Arntz, W., Herman, R., Galéron, J., Hain, S. (1992) Quantitative investigations on macrobenthos communities of the southeastern Weddell Sea shelf based on multibox corer samples. Polar Biology 12, 291-301.

Gerdes, D., Hilbig, B., Montiel, A. (2003) Impact of iceberg scouring on macrobenthic communities in the high-Antarctic Weddell Sea. Polar Biology 26, 295–301.

Gutt, J. (1991): On the distribution and ecology of holothurians in the Weddell Sea (Antarctica). Polar Biology 11, 145-155.

Gutt, J., Piepenburg, D. (2003) Scale-dependent impact on diversity of Antarctic benthos caused by grounding of icebergs. Marine Ecology Progress Series 253, 77-83.

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

Gutt, J., Griffiths, H.J., Jones, C.D. (2013a) Circumpolar overview and spatial heterogeneity of Antarctic macrobenthic communities. Marine Biodiversity, doi:10.1007/s12526-013-0152-9.

Gutt, J., Barnes, D.K.L., Lockhart, S., van de Putte, A. (2013b) Antarctic macrobenthic communities: a compilation of circumpolar information. Nature Conservation 4, 1-13.

Haid, V. (2013) Coastal polynyas in the southwestern Weddell Sea: Surface fluxes, sea ice production and water mass modification. Dissertation, University Bremen, 160 pp, http://elib.suub.uni-bremen.de/edocs/00103445-1.pdf

Haid, V., Timmermann, R. (2013) Simulated heat flux and sea ice production at coastal polynyas in the southwestern Weddell Sea. Journal of Geophysical Research: Oceans 118: 2640-2652.

Hain, S. (1990) The benthic seashells (Gastropoda and Bivalvia) of the Weddell Sea, Antarctica (in German). Reports on Polar Research, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research 70, 180 pp.

Hartigan, J.A., Wong, M.A. (1979) A K-means clustering algorithm. Applied Statistics 28: 100–108.

Hedley, S.L., Buckland, S.T. (2004) Spatial models for line transect sampling. Journal of Agricultural, Biological, and Environmental Statistics 9, 181–199.

Hellmer, H.H., Kauker, F., Timmermann, R., Determann, J., Rae, J. (2012) Twenty-first-century warming of a large Antarctic ice-shelf cavity by a redirected coastal current. Nature 485 (7397), 225-228. doi: 10.1038/nature11064.

Hempel, G., Hempel, I. (1982) Distribution of euphausiid larvae in the southern Weddell Sea. Meeresforschung 29, 253-266.

Hubold, G. (1984) Spatial distribution of *Pleuragramma antarcticum* (Pisces: Nototheniidae) near the Filchner- and Larsen ice shelves (Weddell sea/Antarctica). Polar Biology 3 (4), 231-236.

Hubold, G. (1992). Zur Ökologie der Fische im Weddellmeer. Reports on Polar Research, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research 103, 157 pp.

Hunewinkel, T., Markus, T., Heygster, G.C. (1998) Improved Determination of the sea ice edge with SSM/I data for small-scale analyses. IEEE Transactions on Geoscience and Remote Sensing 36 (5): 1795-1808.

Hunt, B.P.V., Pakhomov, E.A., Siegel, V., Strass, V., Cisewski, B., Bathmann, U. (2011) The seasonal cycle of the Lazarev Sea macrozooplankton community and a potential shift to top-down trophic control in winter. Deep Sea Research Part II 58: 1662-1676.

Hureau, J.-C., Balguerias, E., Duhamel, G., Kock, K.-H., Ozouf-Costaz, C., White, M., Gutt, J. (2012) Counts and mass of fish species from trawl and dredge samples in the eastern Weddell Sea during POLARSTERN cruise ANT-VII/4. doi:10.1594/PANGAEA.786886.

James, B.S., McIntyre, T., Tosh, C.A., Bornemann, H., Plötz, J., Bester, M.N. (2012) Inter-population differences in diving behaviour of adult male southern elephant seals (*Mirounga leonina*). Polar Biology 35: 1759–1766.

Jerosch, K., Dorschel, B., Krajnik, I., Kuhn, G. (in prep. a) A geomorphological seabed classification for the Weddell Sea and the adjacent Southern Ocean consolidated with surficial grain size data.

Jerosch, K., Krajnik, I., Martinez, R., Dorschel, B., Kuhn, G. (in prep. b) Geostatistical sediment texture analysis of the Weddell Sea and the adjacent Southern Ocean on the basis of ternary grain size diagrams.

Gill, P.C., Thiele, D. (1997) A winter sighting of killer whales (*Orcinus orca*) in Antarctic sea ice. Polar Biology 17: 401-404.

Kaleschke, L., Lupkes ,C., Vihma, T., Haarpaintner, J., Bochert, A., Hartmann, J., Heygster, G. (2001) SSM/I sea ice remote sensing for mesoscale ocean-atmosphere interaction analysis. Canadian Journal of Remote Sensing 27: 526-537.

Kern, S., Spreen, G., Kleschke, L., de la Rosa, S., Heygster, G. (2007) Polynya Signature Simulation Method polynya area in comparison to AMSR-E 89 GHz sea-ice concentrations in the Ross Sea and off the Adelie Coast, Antarctica, for 2002–05: first results. Annals of Glaciology 46, 1-10.

Kern, S. (2012) Antarctic daily winter-time polynya distribution from SSM/I brightness temperature data http://icdc.zmaw.de/polynya_ant.html, 2014, Integrated Climate Data Center (ICDC), CEN, University of Hamburg, Hamburg, Germany, Digital Media.

Kindermann, L. (2013) Acoustic records of the underwater soundscape at PALAOA with links to audio stream files, 2005-2011. Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Bremerhaven, doi:10.1594/PANGAEA.773610.

Klatt, O., Boebel, O., Fahrbach, E. (2007) A profiling float's sense of ice. Journal of Atmosperic and Oceanic Technology 24, 1301–1308.

Knox, G.A. (2007) Biology of the Southern Ocean, CRC press, 621pp.

Knust, R., Arntz, W.E., Boche, M., Brey, T., Gerdes, D., Mintenbeck, K., Schröder, A., Starmans, A., Teixidó, N. (2003) Iceberg scouring on the eastern Weddell Sea shelf (Antarctica): a benthic system shaped by physical disturbances? In: Huskes, A.L., Gieskes, W.W., Rozema, J., Schorno, R.M., van der Vies, S.M., Wolff, W.J. (eds). Proceedings of the 8th SCAR Biology Symposium, Amsterdam: Antarctic biology in a global context. Backhuys Publishers, Leiden, 96–101.

Kock, K.-H., Busch, M., Holst, M., Klimpel, S., Pietschok, D., Pshenichnov, L., Riehl, R., Schöling, S., Gutt, J. (2012) Counts and mass of fish species from trawl samples in the western Weddell Sea during POLARSTERN cruise ANT-XXIII/8. doi:10.1594/PANGAEA.786888.

Laws, R.M. (1985) The ecology of the Southern Ocean. American Scientist 73, 26-40.

Linse, K., Griffiths, H., Barnes, D., Clarke, A. (2006) Biodiversity and biogeography of Antarctic and sub-Antarctic mollusca. Deep Sea Research Part II: Topical Studies in Oceanography 53, 985-1008.

Linse K, Brandt, A, Bohn J, Danis B, De Broyer C, Heterier V, Hilbig B, Janussen D, J. López González PJ, Schüller M, Schwabe E, Thomson MRA (2007) Macro- and megabenthic communities in the abyssal Weddell Sea (Southern Ocean). Deep-Sea Research II 54, 1848–1863.

Locarnini, R.A., Mishonov, A.V., Antonov, J.I., Boyer, T.P., Garcia, H.E., Baranova, O.K., Zweng, M.M., Johnson, D.R. (2010) World Ocean Atlas 2009, Volume 1: Temperature. S. Levitus, Ed. NOAA Atlas NESDIS 68, U.S. Government Printing Office, Washington, D.C., 184 pp.

Lu, G.Y., Wong, D.W. (2008) An adaptive inverse-distance weighting spatial interpolation technique. Computer & Geoscience, 34 (9), 1044-1055.

Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., Hornik, K. (2014) Cluster: cluster analysis basics and extensions. R package version 1.15.2.

Makarov, R.R., Sysoeva, M.V. (1985) Biology and Distribution of *Euphausia superba* in the Lazarev Sea and Adjacent Waters. Hydrobiological Journal (Gidrobiologiceskij Zhurnal), Kiev 23, 95-99.

Markus, T., Burns, B.A. (1995) A method to estimate subpixel scale coastal polynyas with satellite microwave data. Journal of Geophysical Research 100, 16707–16 718.

McIntyre, T., Stansfield, L.S., Bornemann, H., Plötz, J., Bester, M.N. (2013). Hydrographic influences on the summer dive behaviour of Weddell seals (*Leptonychotes weddellii*) in Atka Bay, Antarctica, Polar Biology 36: 1693-1700.
McKee, D.C., Yuan, X., Gordon, A.L., Huber, B.A., Dong, Z. (2011) Climate impact on interannual variability of Weddell Sea Bottom Water. Journal of Geophysical Research, 116, C05020, doi:10.1029/2010JC006484.

Menshenina, L. (1992) Distribution of euphausiid larvae in the Weddell Gyre in September-October 1989. Proceedings of the National Institute of Polar Research Symposium on Polar Biology (Tokyo) 5, 44-54.

Montiel, A., Gerdes, D., Hilbig, B, Arntz, W.E. (2005) Polychaete assemblages on the Magellan and Eddell Sea shelves: comparative ecological evaluation. Marine Ecology Progress Series 297, 189-202.

Moore, J.K., Abbott, M.R. (2000) Phytoplankton chlorophyll distributions and primary production in the Southern Ocean. Journal of Geophysical Research 105: 709-722.

Mühlenhardt-Siegel, U. (2011) Cumacean (Peracarida, Crustacea) endemism and faunal overlap in Antarctic deep-sea basins. Deep Sea Research II 58, 68-73.

Nordøy, E.S., Blix. A.S. (2009) Movements and dive behaviour of two leopard seals (*Hydrurga leptonyx*) off Queen Maud Land, Antarctica. Polar Biology 32: 263–270.

Parkinson, C.L. (2002) Trends in the length of the Southern Ocean sea-ice season, 1979–99. Annals of Glaciology 34, 435-440.

Petschick, R., Kuhn, G., Gingele, F. (1996) Clay mineral distribution in surface sediments of the South Atlantic: sources, transport, and relation to oceanography. Marine Geology 130(3-4): 203-229.

Piatkowski, U. (1987) Zoogeographical investigations and community analyses on antarctic macroplankton (in German). Reports on Polar Research, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research 34, 150 pp.

Piepenburg, D., Voß, J., Gutt, J. (1997) Assemblages of sea stars (Echinodermata: Asteroidea) and brittle stars (Echinodermata: Ophiuroidea) in the Weddell Sea (Antarctica) and off Northeast Greenland (Arctic): a comparison of diversity and abundance. Polar Biology 17, 305-322.

Plötz, J., Steinhage, D., Bornemann, H. (2011a-e): Seal census raw data during campaign EMAGE-I to EMAGE-V, doi:10.1594/PANGAEA.760097; doi:10.1594/PANGAEA.760098; doi:10.1594/PANGAEA.760099; doi:10.1594/PANGAEA.760100; doi:10.1594/PANGAEA.760 101.

Raymond, B. (2011) A circumpolar pelagic regionalisation of the Southern Ocean. WS-MPA-11/6.

R Core Team (2013) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

SC-CAMLR-XXXII (2013) Report of the thirty-second meeting of the Scientific Committee. Hobart, Australia, 21-25 October 2013, 342 pp.

Schenke, H.W., Dijkstra, S., Niederjasper, F., Schöne, T., Hinze, H., Hoppman, B. (1998) The new bathymetric charts of the Weddell Sea: AWI BCWS. In: Jacobs S.S., Weiss R.F. (eds). Ocean, Ice, and Atmosphere: Interactions at the Antarctic Continental Margin, Volume 75. AGU, Washington, DC, 371-380.

Schüller, M., Ebbe, B. (2007) Global distributional patterns of selected deep-sea Polychaeta (Annelida) from the Southern Ocean. Deep-Sea Research II 54, 1737-1751.
Shepard, F.P. (1954) Nomenclature based on sand-silt-clay ratios. Journal of Sedimentary Petrology 24, 151–158.

Siegel, V. (1982) Investigations on krill (*Euphausia superba*) in the southern Weddell Sea. Meeresforschung 29: 244-252.

Siegel, V. (2005) Distribution and population dynamics of *Euphausia superba*: Summary of recent findings. Polar Biology 29: 1-22.

Siegel, V. (2012) Krill stocks in high latitudes of the Antarctic Lazarev Sea: seasonal and interannual variation in distribution, abundance and demography. Polar Biology 35: 1151-1177.

Siegel, V., Reiß, C.S., Dietrich, K.S., Haraldsson, M., Rohardt, G. (2013) Distribution and abundance of Antarctic krill *(Euphausia superba)* along the Antarctic Peninsula. Deep-Sea Research I 177, 63-74.

Širović, A., Hildebrand, J.A. (2011) Using passive acoustics to model blue whale habitat off the Western Antarctic Peninsula. Deep Sea Research Part II: Topical Studies in Oceanography 58: 1719-1728.

Soimasuo, J., Neteler, M., Blazek, R., Landa, M., Metz, M. (1994) GRASS GIS package 'v.distance', http://grass.osgeo.org/grass70/manuals/v.distance.html.

Smetacek, V., Nicol, S. (2005) Polar ocean ecosystems in a changing world. Nature 437, 362-368.

Southwell, C., Bengtson, J., Bester, M.N., Shytte Blix, A., Bornemann, H., Boveng, P., Cameron, M., Forcada, J., Laake, J., Nordøy, E., Plötz, J., Rogers, T., Steinhage, D., Stewart, B., Trathan, P. (2012) A review of data on abundance, trends in abundance, habitat use and diet of ice-breeding seals in the Southern Ocean. CCAMLR Science 19, 26 pp.

Spreen, G., Kaleschke, L., Heygster, G. (2008) Sea ice remote sensing using AMSR-E 89-GHz channels. Journal of Geophysical Research-Oceans 113: C02S03, doi:10.1029/ 2005JC003384.

Steele, M., Morley, R., Ermold, W. (2001) PHC: A global ocean hydrography with a high quality Arctic Ocean, Journal of Climate 14, 2079–2087.

Steinhage, D., Stewart, B.S., Trathan, P. (2012) A review of data on abundance, trends in abundance, habitat use and diet of ice-breeding seals in the Southern Ocean. CCAMLR Science 19(49), hdl:10013/epic.40419.d001.

Stiller, M. (1995) Distribution and lifestyle of Aphroditidae und Polynoidae (Polychaeta) in the eastern Weddell Sea and in the Lazarev Sea (Antarctica). PhD. thesis, University Bremen.

Teschke, K., Dorschel, B., Gutt, J., Hain, S., Hellmer, H., Jerosch, K., Knust, R., Kock, K.H., Schlüter, M., Siegel, V., Brey, T. (2013) Proposal for the establishment of a marine CCAMLR MPA in the Weddell Sea (Antarctica) – First conceptual outline. WG-EMM-13/22, 17 pp.

Teschke, K., Bornemann, H., Bombosch, A., Brtnik, P., Burkhardt, E., Dorschel, B., Feindt- Herr, H., Gerdes, D., Gutt, J., Hain, S., Herata, H., Jerosch, K., Knust, R., Kock, K.H., Pehlke, H., Schlüter, M., Schwarzbach, W., Siegel, V., Strass, V., van Opzeeland, I., von Nordheim, H., Brey, T. (2013) Progress report on the scientific data compilation and analyses in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica). SC-CAMLR-XXXII/BG/07, 29 pp.

Thiele, D., Chester, E.T., Gill, P.C. (2000) Cetacean distribution off Eastern Antarctica (80-150 degrees E) during the Austral summer of 1995/1996. Deep-Sea Research II 47: 2543-2572.

Timmermann, R., Danilov, S., Schröter, J., Böning, C., Sidorenko, D., Rollenhagen, K. (2009) Ocean circulation and sea ice distribution in a finite element global sea ice-ocean model. Ocean Modelling 27: 114–129.

Tosh, C.A., Bornemann, H., Ramdohr, S., Schröder, M., Martin, T., Carlini, A., Plötz, J., Bester., M.N. (2009) Adult male southern elephant seals from King George Island utilize the Weddell Sea, Antarctic Science 21: 113-121.

Turner, J., Bindschadler, R., Convey, P., di Prisco, G., Fahrbach, E., Gutt, J., Hodgson, D., Mayewsky, P., Summerhayes, C. (2009) Antarctic climate change and the environment. SCAR, Scott Polar Research Institute, Cambridge.

Ugland, K.I., Gray, J.S., Ellingsen, K.E. (2003) The species accumulation curve and estimation of species richness. Journal of Animal Ecology 72, 888-897.

Van Opzeeland, I. (2010) Acoustic ecology of marine mammals in polar oceans, Reports on Polar and Marine Research, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research, 619, 332 pp.

Voß, J. (1988) Zoogeography and community analysis of macrozoobenthos of the Weddell Sea (Antarctica). Reports on Polar Research, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research 45, 145 pp.

Wienberg, C., Wintersteller, P., Beuck, L., Hebbeln, D. (2013) Coral Patch seamount (NE Atlantic) – a sedimentological and megafaunal reconnaissance based on video and hydroacoustic surveys. Biogeosciences 10: 3421-3443.

Wöhrmann, A., Zimmermann, C., Kock, K.-H., Gutt, J. (2012) Counts of fish species from trawl and dredge samples in the eastern Weddell and Lazarev Seas during POLARSTERN cruise ANT-IX/3. doi:10.1594/PANGAEA.786887.

Working paper (WP) 010 (2013) Identification of potential climate change refugia for emperor penguins: a science-based approach. XXXVI Antarctic Treaty Consultative Meeting, Brussels 2013, Agenda item: CEP 9f, CEP 10c, submitted by United Kingdom, 9 pp.

Wright, D.J., Lundblad, E.R., Larkin, E.M., Rinehart, R.W., Murphy, J., Cary-Kothera, L., Draganov, K. (2005) ArcGIS Benthic Terrain Modeler [a collection of tools used with bathymetric data sets to examine the deepwater benthic environment], Oregon State University, Davey Jones' Locker Seafloor Mapping/Marine GIS Laboratory and NOAA Coastal Services Center.

Zimmer, I., Wilson, R.P., Gilbert, C., Beaulieu, M., Ancel, A., Plötz, J. (2008) Foraging movements of emperor penguins at Pointe Géologie, Antarctica. Polar Biology 31: 229–243.

7. Figures

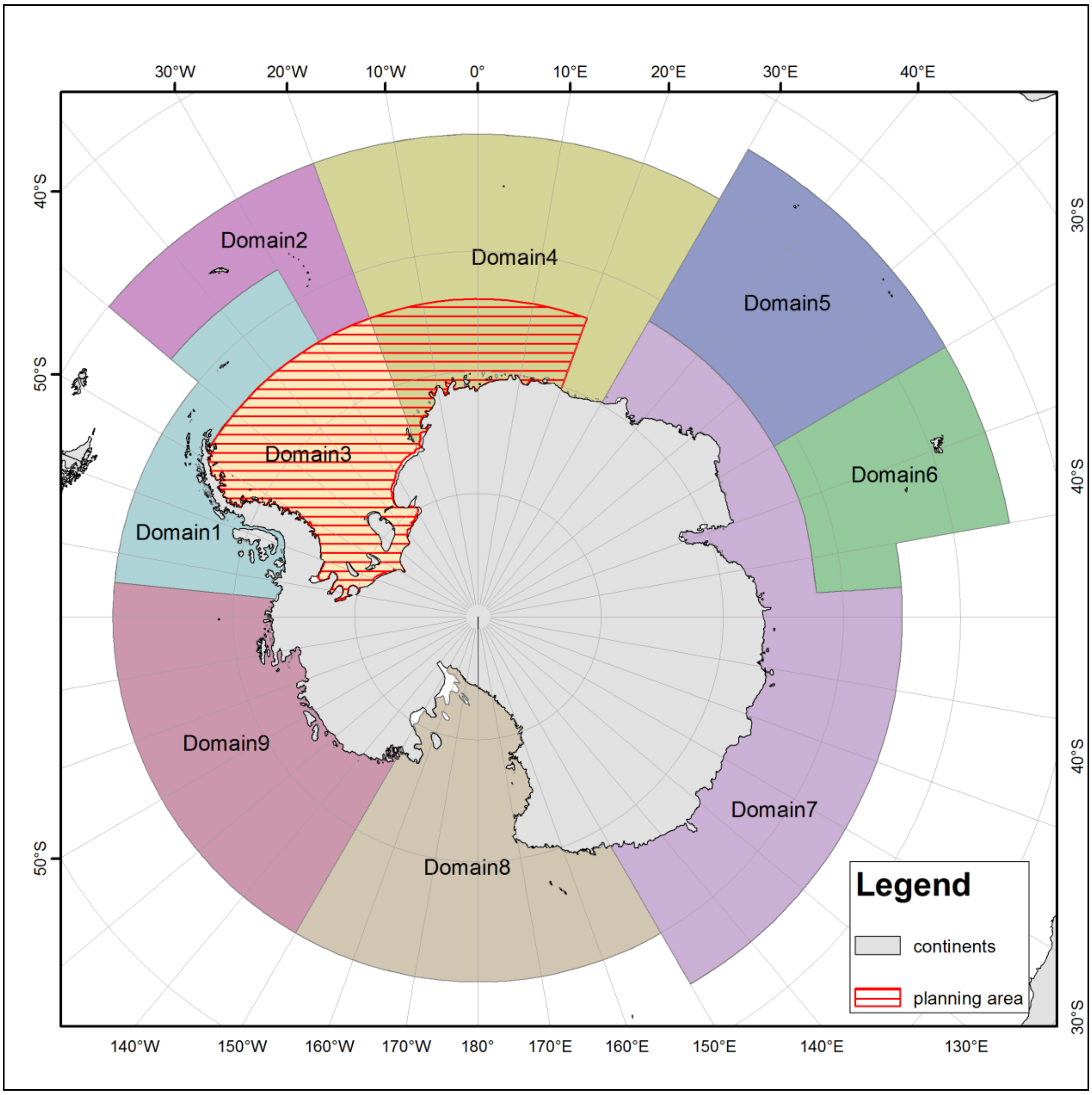

Figure 1 CCAMLR MPA Planning Domains and the proposed planning area for the evaluation of a Weddell Sea MPA (red shaded area). Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA. Domain 1: Western Peninsula - South Scotia Arc, 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.

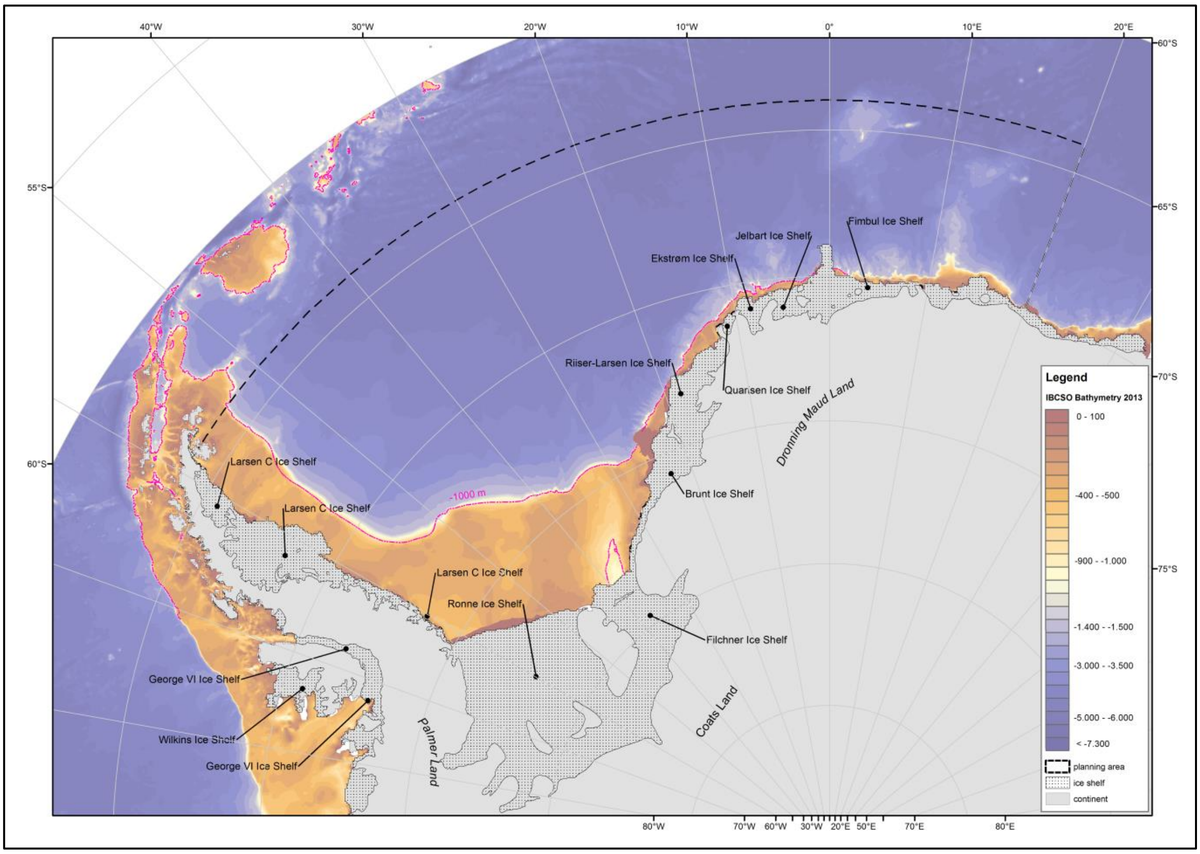

Figure 2 Bathymetry (in m) in the proposed planning area for the evaluation of a Weddell Sea MPA (black dashed box). Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA. The bathymetric chart of the Southern Ocean (IBCSO) is published by Arndt et al. (2013). The ice shelves are labelled and shown in grey.

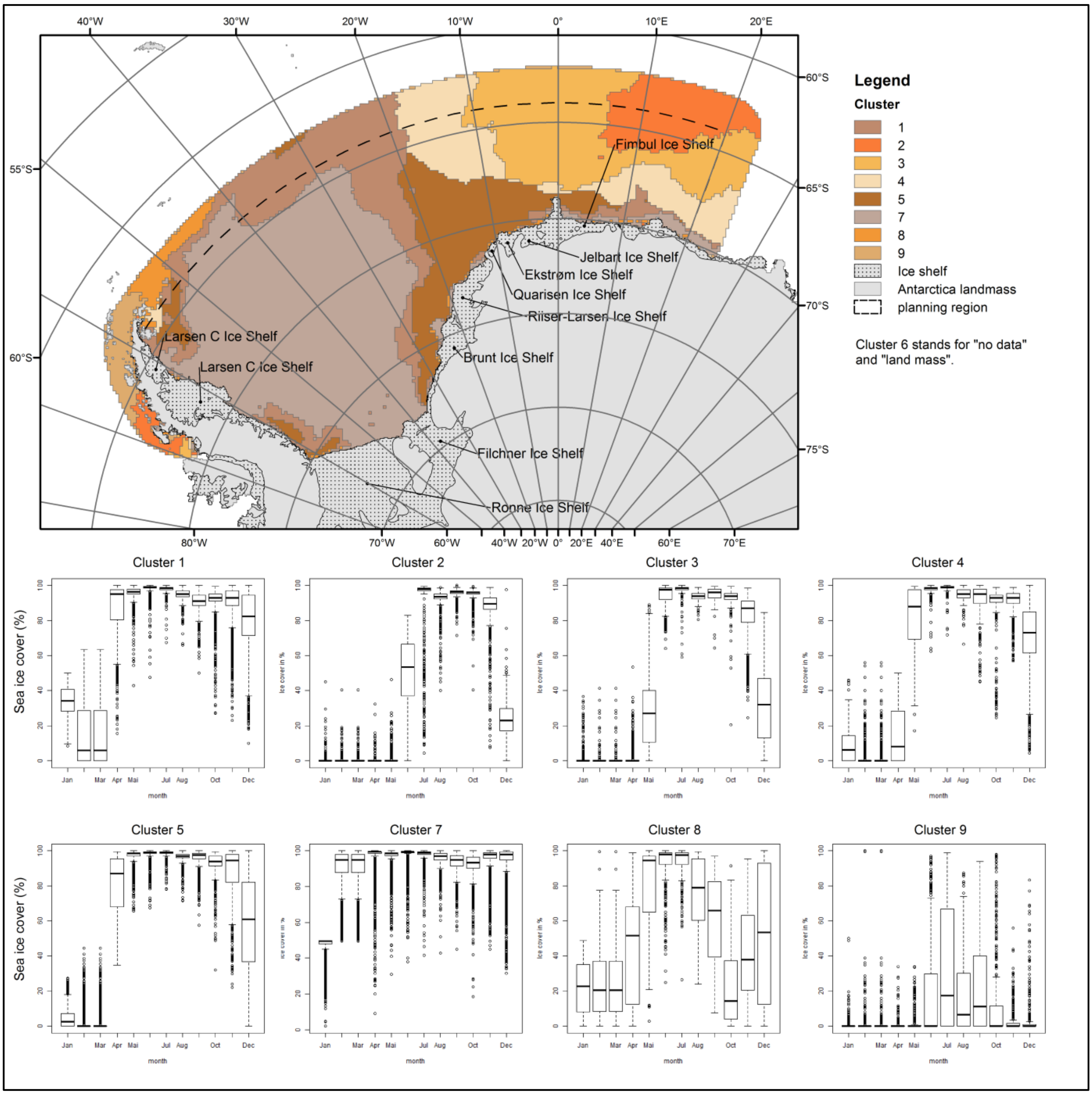

Figure 3 Overall picture on sea ice dynamics in the Weddell Sea. Cluster analysis based on daily data on sea ice concentration out of 10 years (2002-2011). Data were downloaded from the Institute of Environmental Physics, University of Bremen and are published in Spreen et al. (2008). Black dashed box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

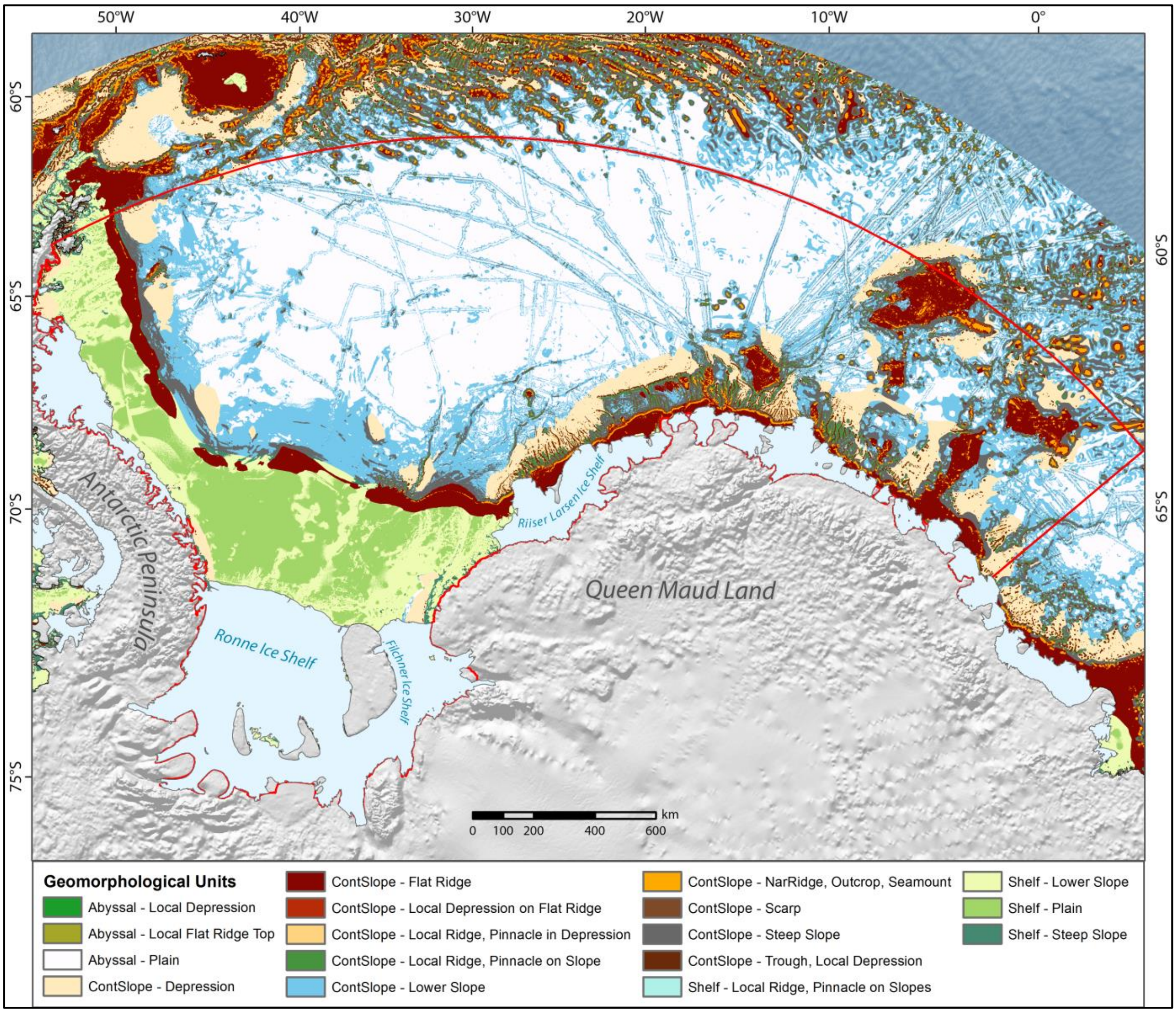

Figure 4 Geomorphology of the Weddell Sea which derived from bathymetry (IBCSO; Arndt et al. 2013) and its bathymetric derivatives, i.e. slope and bathymetric position index (Jerosch et al. in prep. a). Red box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

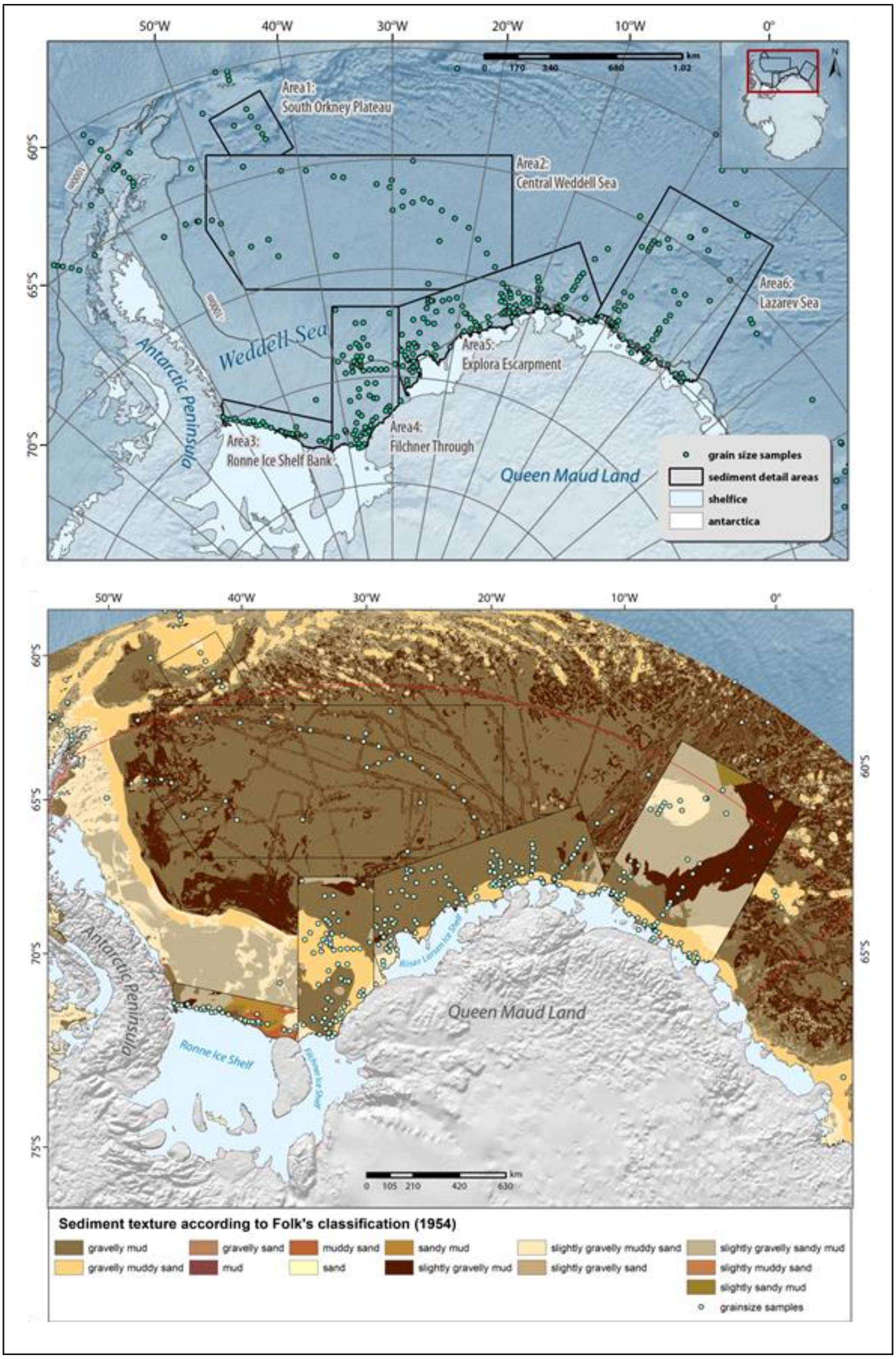

Figure 5 Above: Data density of the grain size data restricted the ground truthing to six parcelled-out areas: (1) South Orkney Plateau, (2) Central Weddell Sea, (3) Ronne Ice Shelf Bank, (4) Filchner Trough, (5) Explora Escarpment, (6) Lazarev Sea according to IBCSO (Arndt et al. 2013). Sediment grain size data are shown as green dots. Data were downloaded from PANGAEA and are published in Petschick et al. (1996) and Diekmann and Kuhn (1999), and were completed by unpublished data held by G. Kuhn, AWI. Below: Sediment texture according to Folk`s classification (1954). Interpolation methods were successfully applied for area 4, 5 and 6 due to data density (Jerosch et al. in prep. b).

Red box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

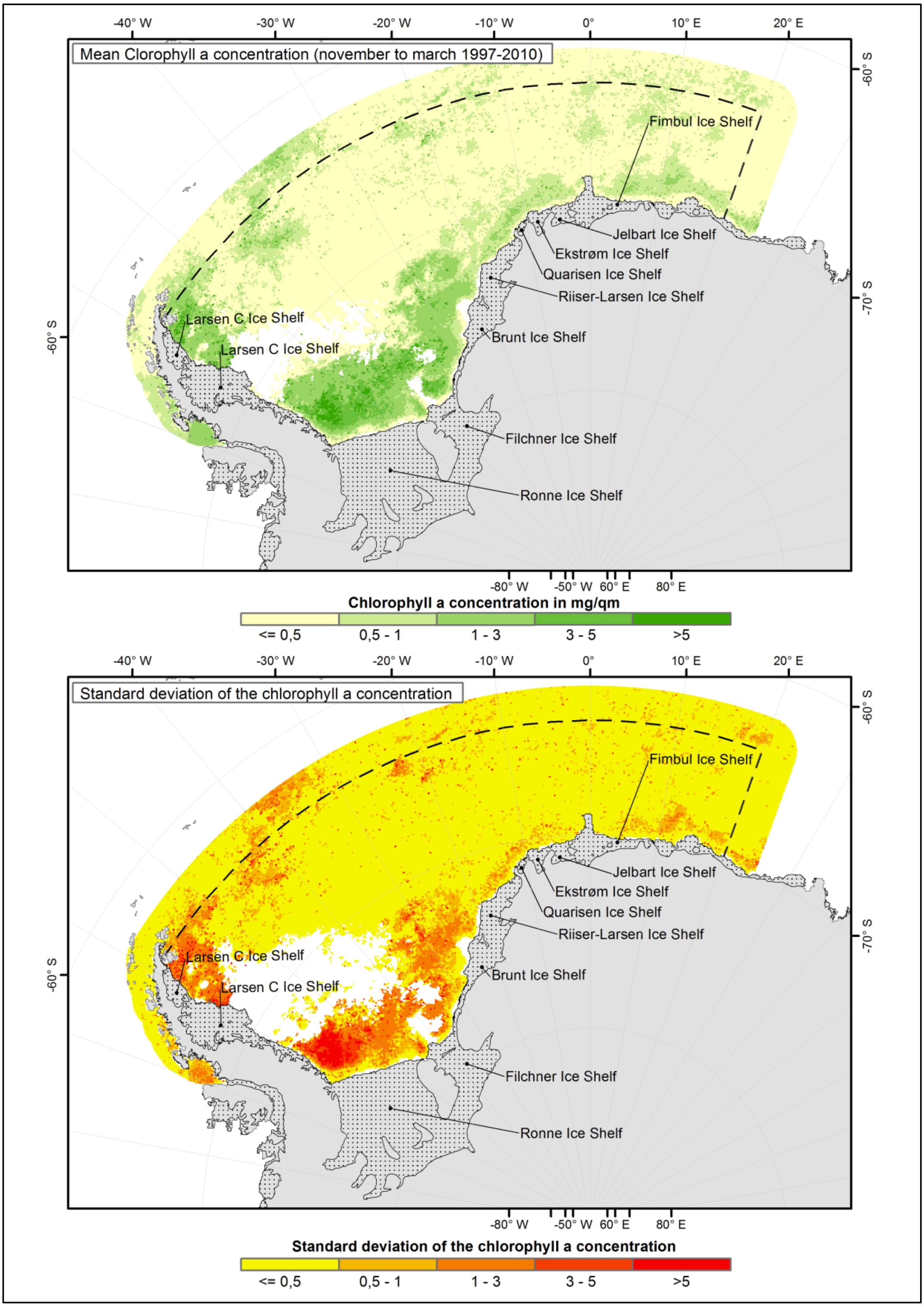

Figure 6 Mean value (above) and standard deviation (below) of data on chlorophyll-a concentration (in mg/m³) out of 14 austral spring and summer (Nov-Mar), 1997-2010. Areas in white had no valid chlorophyll data because of heavy sea ice or persistent cloud cover. Monthly data were downloaded via the NASA's OceanColor website. Black dashed box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

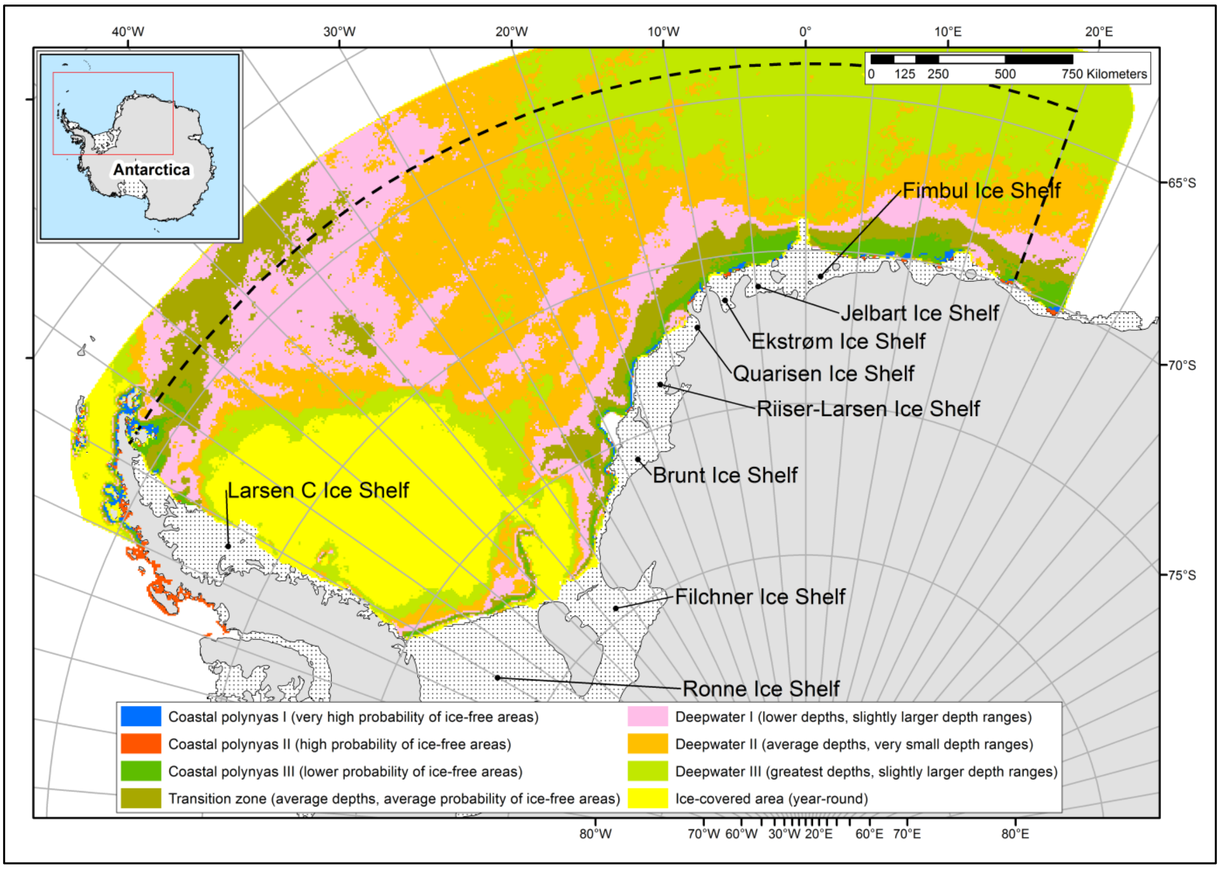

Figure 7 Pelagic regionalisation analysis based on *(i)* AMSR-E 89 GHz sea ice concentration data (Spreen et al. 2008), *(ii)* bathymetric data (i.e. depth and 'depth range') by IBSCO (Arndt et al. 2012), and *(iii)* FESOM model data on sea water temperature and salinity at the sea surface and the sea bottom (Timmermann et al. 2009). For more details on the pelagic regionalisation analysis see paragraph 3.2. Black dashed box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

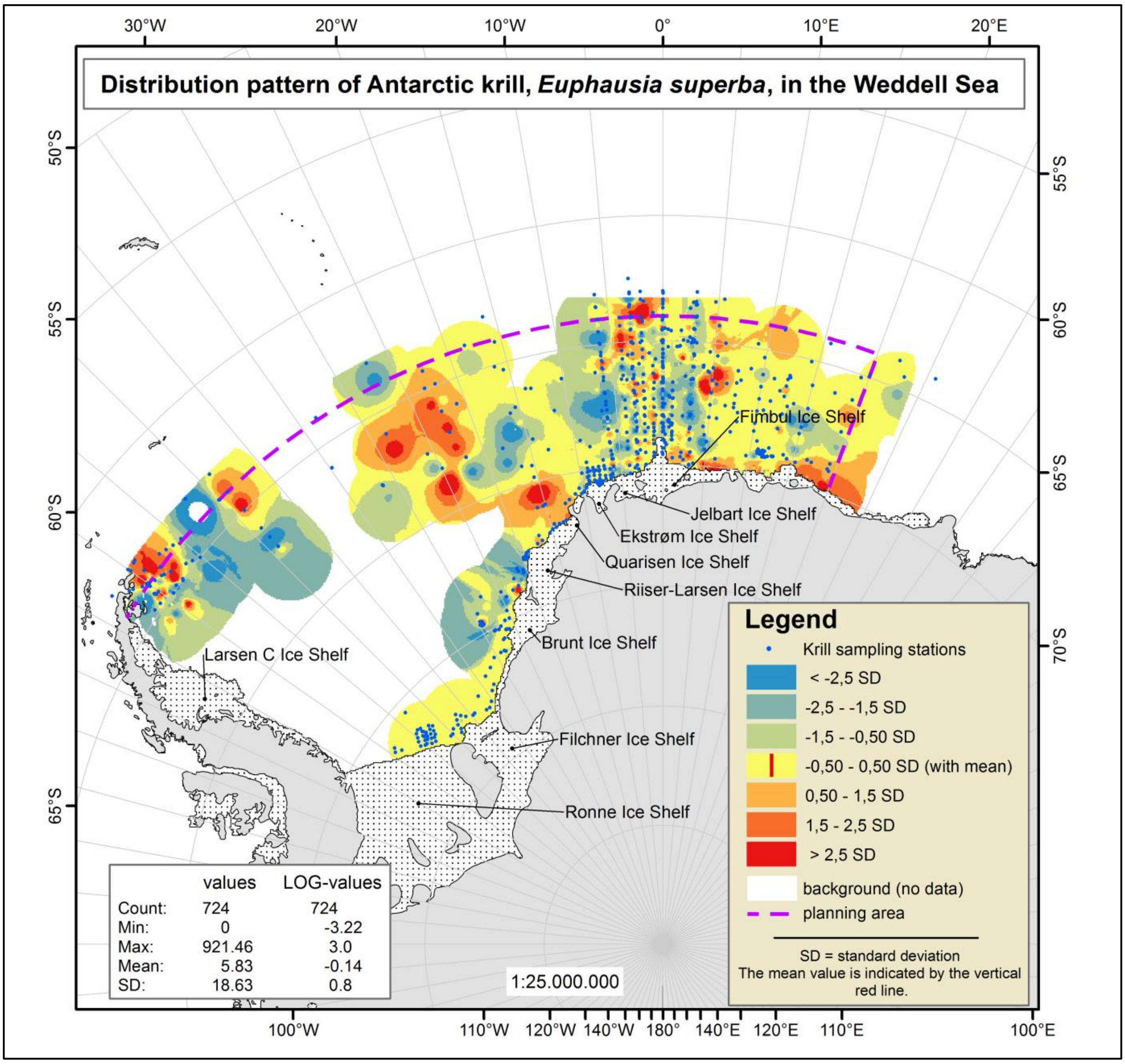

Figure 8 Distribution pattern of Antarctic krill, *Euphausia superba*, in the Weddell Sea based on un-standardised, log-transformed data from KRILLBASE (Atkinson et al. 2004, 2008, 2009; Siegel 1982) and (un-) published data held by Volker Siegel, Thünen Institute, Hamburg (e.g. Siegel 2012; Siegel et al. 2013). The interpolated data are plotted as mean krill densities (individuals/m²) +/- n-fold of standard deviation per grid cell (6.25 x 6.25 km²). Blue dots show the distribution of sampling effort. For white coloured grid cells no arithmetic means were calculated; here, less than three stations were sampled. Purple dashed box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

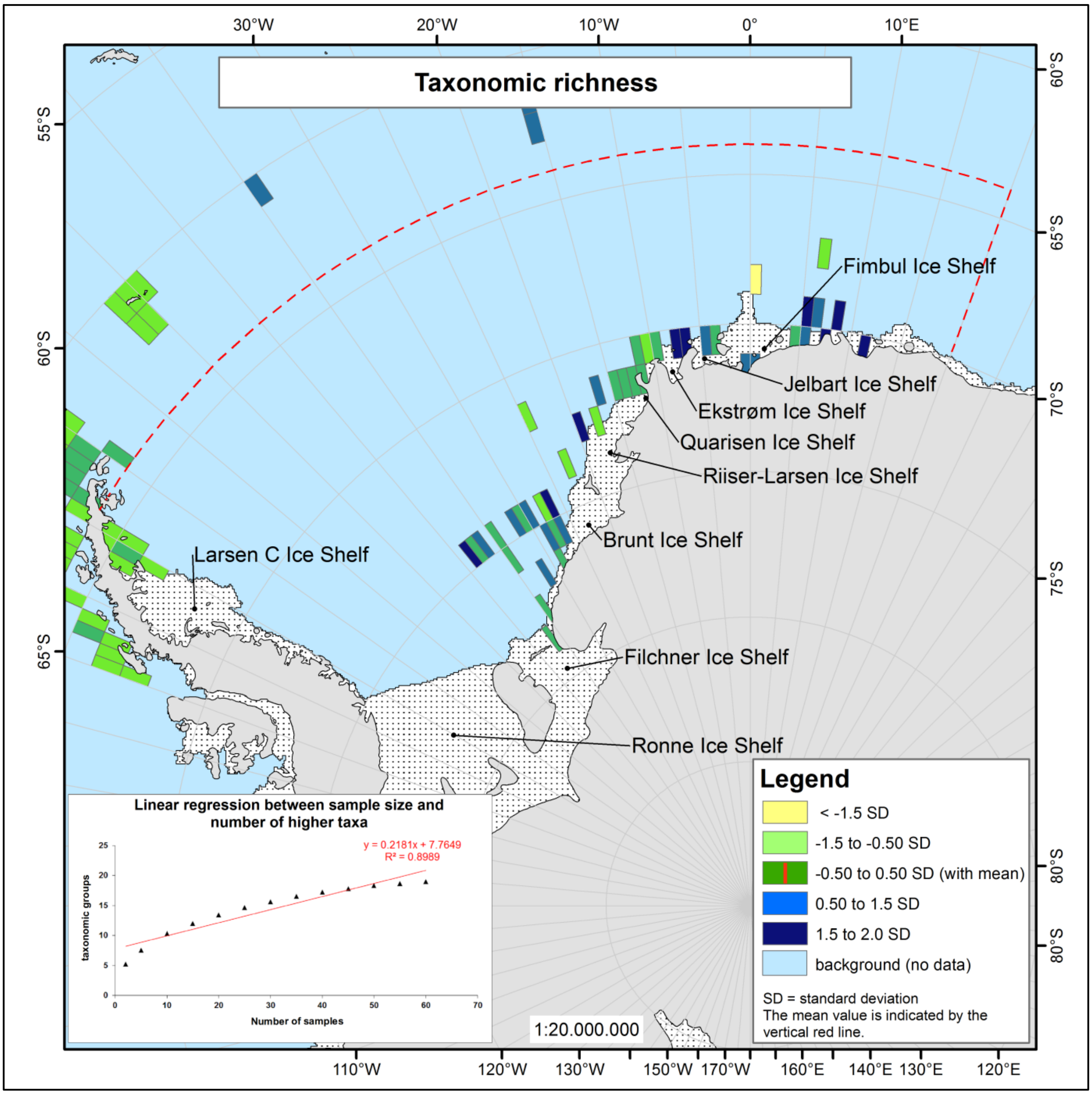

Figure 9 Distribution pattern of richness of higher taxonomic macrozoobenthic groups based on a data set held by D. Gerdes (AWI) and U. Mühlenhardt-Siegel (Thünen Institute). The data are plotted as un-transformed number of higher taxonomic groups, expressed as residuals of the expected number of higher taxonomic groups at a given number of records, +/- n-fold of standard deviation per grid cell (1° of latitude by 1° of longitude). Red dashed box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

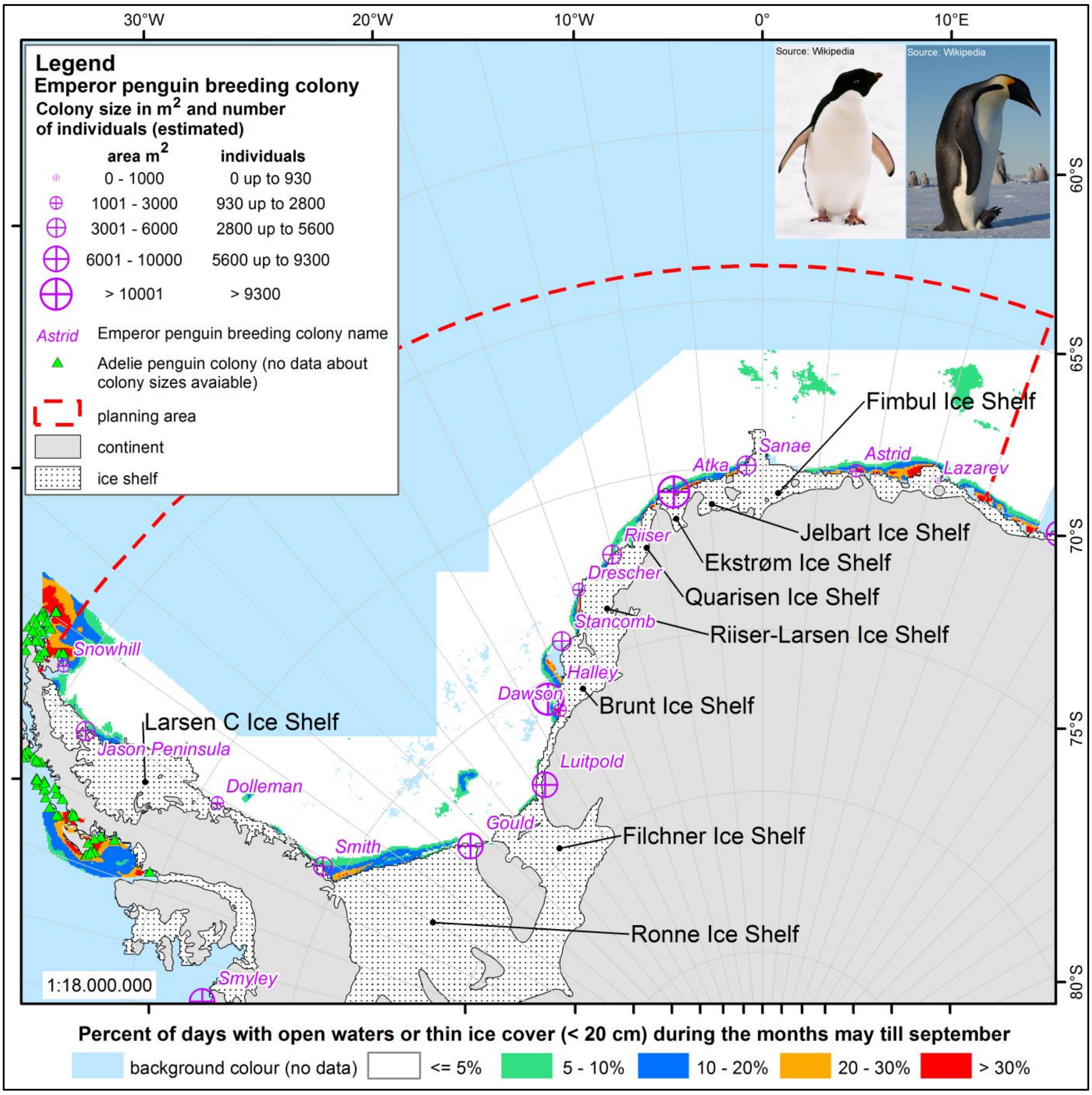

Figure 10 Relative number of days with sea ice thickness < 20 cm in coastal areas in austral winter (May-Sept) based on daily data (1992-2008). For blue coloured areas no data exist. Data availability: Integrated Climate Data Center, University of Hamburg (Kern et al. 2007, Kern 2012). Spatial distribution patterns of Adélie penguin colonies (see green triangle; unpublished data held by H. Lynch, Stony Brook University, USA) and emperor penguin population estimates (see cross hairs; Fretwell et al. 2012, 2014). Red dashed box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

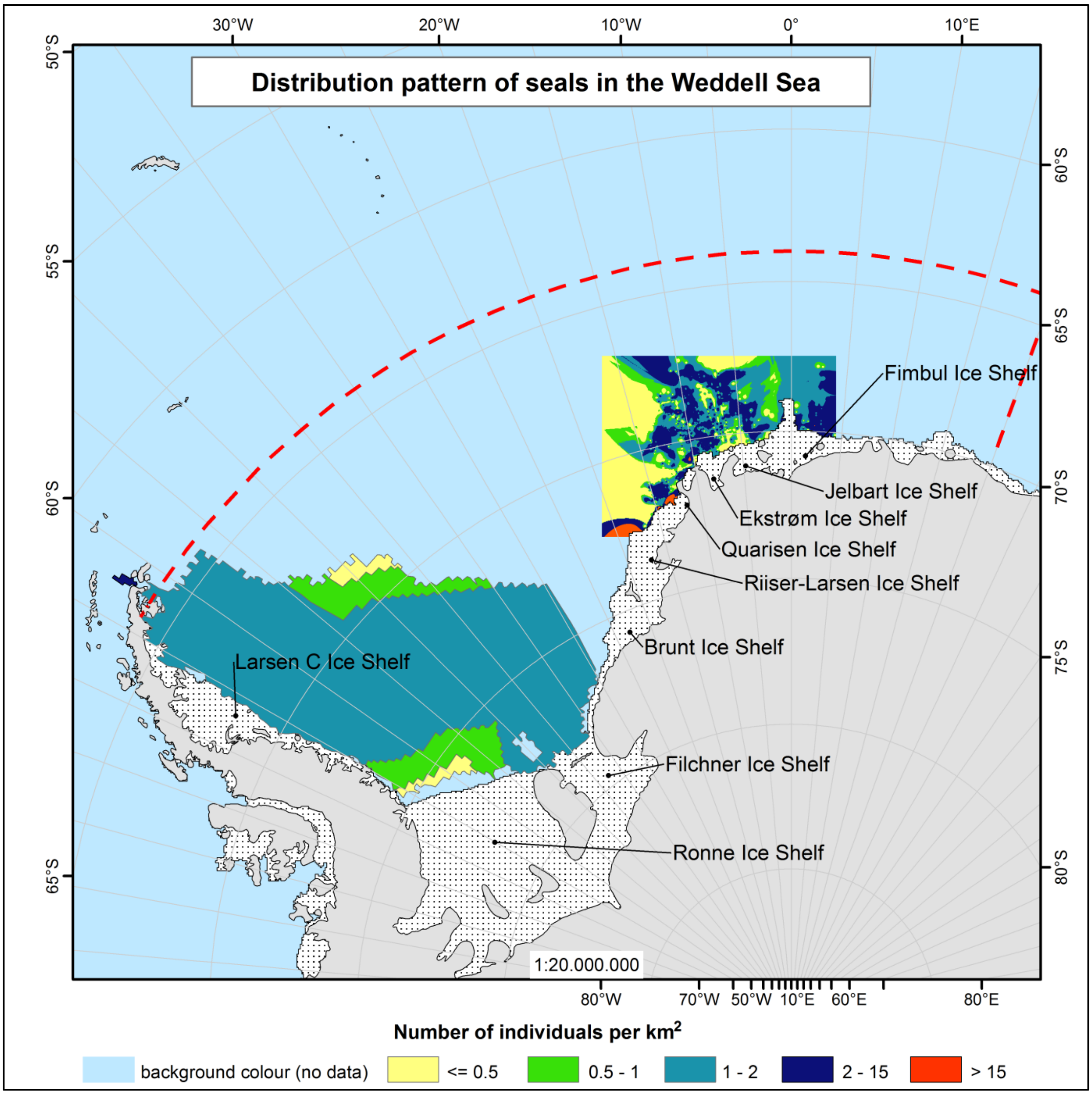

Figure 11 Distribution pattern of seals in the Weddell Sea. Abundance data on crabeater seals in the western part of the Weddell Sea planning area were derived from Forcada et al. (2012), un-transformed abundance data on seals (unspecified taxa) in the south-eastern/eastern part of the Weddell Sea based on data from PANGAEA (Plötz et al. 2011a-e). The un-transformed, interpolated data are plotted as absolute seal densities (individuals/km²). Purple dashed box: Planning area for the evaluation of a Weddell Sea MPA. Please note that the boundaries of the proposed planning area do not resemble the boundaries of any proposed Weddell Sea MPA.

8. Supplement

8.1. Report of the International Expert Workshop

Report of the International Expert Workshop
The Scientific Foundation of a CCAMLR Marine Protected Area in the Weddell Sea
Bremerhaven, Germany, April 7 – 9, 2014

Monday, April 7th

INTRODUCTION – OPENING OF THE MEETING

1.1. The workshop was convened by Prof. T. Brey (Germany). A List of Participants is included in this report as Attachment A.

1.2. The Workshop opened with a welcome by Dr Hain (Alfred Wegner Institute for Polar and Marine Research, AWI), encouraging openness and scientific debate during the meeting. Participants were encouraged to speak following Chatham House rules and sign an agreement on the data sharing rules for the meeting.

1.3. A Provisional Agenda had been prepared by the Convener and the time table is included as Attachment B.

1.4. This report was prepared by R. Driscoll (USA), Dr V. Siegel and R. Lahl (Germany), Dr P. Trathan and Dr S. Grant (UK) and Prof. P. Koubbi (France) in consultation with workshop participants.

AIMS

1.5. The workshop had been endorsed by the CCAMLR Scientific Committee at its 2013 meetings (SC-CAMLR XXXII § 5.23). The workshop aimed to review the scientific data currently available for a Weddell Sea MPA evaluation, and the preliminary results of the analyses done so far by the AWI.

PRESENTATIONS

2.1. The first of five presentations was given by Dr K. Teschke (Germany) titled, "Already acquired data sets for the evaluation of the Weddell Sea MPA". She gave an insight into the data identification and acquisition process. More than ten large environmental data sets are already acquired. These data sets mainly include satellite data, having a high temporal resolution and are freely available via Internet web sites (e.g. satellite observations on daily sea ice concentration). Further environmental data sets (e.g. water temperature, salinity, currents) were derived from the coupled Finite Element Sea Ice Ocean Model (Timmermann et al. 2009[1]). Data sets

[1] Timmermann, R., Danilov, S., Schröter, J., Böning, C., Sidorenko, D., Rollenhagen, K. (2009) Ocean circulation and sea ice distribution in a finite element global sea ice-ocean model. Ocean Modelling 27: 114–129.

describing the sea bottom of the Weddell Sea are based on satellite data and *in situ* data (e.g. multi-beam data). So far, more than 15 ecological data sets on zooplankton, zoobenthos, fish and mammals have been acquired, which are mainly snapshots in time and are available via data portals, such as ANTABIF and PANGAEA. At the moment, there is a particular lack of data on bird breeding colonies (e.g. fulmarine petrels), data on higher taxonomic resolution of sponges and data on mesozooplankton communities in the Weddell Sea. Regarding those taxonomic groups their principal investigators have already been, or will be, contacted in a timely manner.

2.2. During the presentation Dr Teschke noted that cetacean data had not been considered during the planning of the workshop as the management of cetaceans fall under the jurisdiction of the International Whaling commission.

2.3. Following the presentation, several members of the workshop noted the importance of including cetacean data in the planning of a MPA and their inclusion may reveal important ecological issues; thus including cetacean data would constitute using the best available science for fulfilling CCAMLR’s objectives. Other members reiterated that although cetacean data may be of value, their management falls outside the jurisdiction of CCAMLR.

2.4. The Workshop agreed that cetacean data should be included during the early stages of spatial planning, but that a decision to what extent this information could be used in later decisions should be deferred to a later date.

2.5. The workshop noted that ecological processes and changes to those processes which potentially influencing primary productivity should be included in the MPA planning process if possible, specifically citing the example of changing offshore polynyas due to climate change.

2.6. Some Workshop members noted the use of the Weddell Sea oceanographic model provided by the AWI as a way to explore potential ecological processes, but that polynyas are highly variable and trends may be difficult to see. Other members noted that exploring polynya changes may be outside the purview of MPA planning. The workshop also noted that, besides polynyas, frontal and upwelling areas are also important for ecological/biological processes, and that this information should also be included in the MPA planning process if possible.

2.7. The second presentation was given by Dr K. Linse (UK) titled, “An overview of BASO data for the Weddell Sea – A focus on benthic data sets”. The presentation introduced the SCAR Biogeographic Atlas of the Southern Ocean (BASO) which holds marine occurrence data on marine benthic and pelagic invertebrates, macroalgae, fish, birds and marine mammals. The BASO database is largely composed of public data available through AntaBIF, and validated by the expert that contributed to the BASO; other data were obtained from CCAMLR and other groups are not publicly available. The dataset includes 1.07 million occurrence records of 9064 validated species and 434000 distinct sampling stations from the Southern Ocean and adjacent areas. For this workshop a subset for the wider Weddell Sea area was selected, holding data for over 1000 benthic and over 50 pelagic species. Analysis of the sampling depth shows that for the benthic and pelagic realms most samples are taken on the shelf or in the first hundred meters of the water column, data from the bathyal are sparse and from the abyssal rare.

2.8. Benthic data in the Weddell Sea were mostly collected along the coastline of the eastern Weddell Sea and on the eastern tip of the Antarctic Peninsula. To date species counts per sample effort are highest in the Kapp Norvegia area and are biased towards taxonomic reporting. Occurrence and abundance data on the molluscan classes, Gastropoda and Bivalvia, were shown as examples.

2.9. Dr Linse also noted that under-reporting of the number of species from cruises is likely due to differences, in both effort and focus, on identification between cruises.

2.10. Workshop members were interested in the ability to build an index of effort to estimate the extent of under-reporting species numbers. Workshop members indicated that this is difficult and that comparisons can only be made between taxonomic groups in terms of diversity when entire groups are as fully identified as possible and that, even if gear is standardized, the individual effort of scientists or their study interest varies affecting the data.

2.11. The Workshop noted that biodiversity may be hidden in several ways. Morphologically similar species may be genetically separate species and that physically small taxonomic groups, the example given being bivalves and gastropods, are likely under-sampled by the large mesh trawls commonly used.

2.12. The workshop noted that the existing AntaBIF/biodiversity.aq data portal contains primarily presence/absence data and discussed the current work to add in abundance and effort data where available. A decision if this data should be used in further work of the Weddell Sea MPA was not taken.

2.13. The workshop noted that the biodiversity in the Weddell Sea was likely very high and on par with coral reefs or the Galapagos Islands.

2.14. The third presentation was given by Dr A. van de Putte (Belgium) titled, "An overview of BASO data for the Weddell Sea – A focus on plankton and higher predators". The presentation discussed the background of SCAR-MarBIN and biodiversity.aq. Biodiversity.aq is an ecosystem data service with facilities ranging from data publication to data discovery as well as providing specific contexts to present Antarctic biodiversity data. Details were provided on the data flows for data.biodiversity.aq and the SCAR Biogeographic Atlas of the Southern Ocean. Some additional datasets were presented such as the LAKRIS zooplankton data. Finally, a number of datasets which were recently published using ipt.biodiversity.aq were discussed.

2.15. The Workshop noted the benefits of the SCAR Biogeographic Atlas of the Southern Ocean to the workshop. The workshop further noted that the scale of the atlas allows to compare the Weddell Sea to other regions around the Southern Ocean and can be used to identify pelagic and benthic hotspots.

2.16. The fourth presentation was given by Dr T. Zuo (China) titled, "Information on Chinese studies in CCAMLR subarea 48 and some thoughts on the Weddell Sea MPA planning and process". Dr T. Zuo reviewed the historical Antarctic studies by China in the past thirty years. The Chinese studies in CCAMLR Area 48 can be divided into three phases roughly according to their research regions. During the first phase between 1984 and1987, interdisciplinary research was carried out around the South Shetland Islands. After 1988, China changed research priorities into long-term environmental monitoring of the local zone around the Great Wall Station of China at Fildes Peninsula (Subarea 48.1). Lastly, scientific observations north of the Weddell Sea have been performed in the course of Chinese circumpolar expeditions. In addition, studies on krill resources have been done on aboard krill fishing vessels in recent years.

With regard to the Weddell Sea MPA planning, Dr Zuo suggested the international expert workshop:

- to evaluate the present status of living resources in the Weddell Sea, including the potential threat
- to identify the objectives of the MPA candidate before planning and
- to standardise the data analysis methods or approach, depending on the

objectives or targets; identify the criteria or indices to enable progress of potential MPA to be gauged.

2.17. During the presentation Dr Zuo reminded that during SC-CAMLR-XXXI (2012), many candidates put forward that CCAMLR MPAs shall not be considered as an appreciate tool to protect the under-ice ecosystem, as those areas are currently well protected by the shelf ice itself (WG-EMM-12/34; SC-CAMLR-XXXI Meeting Report, Annex 6, paragraph 3.26 to 3.27).

2.18. The workshop noted that there is little data available on under ice shelf benthos. It was also noted that the purpose of WG-EMM-12/34 was to evaluate changes in biodiversity in the absence of direct human impacts following the loss of ice shelves due to climate change. The workshop noted that such monitoring would constitute a medium to long term goal for monitoring in the area. It was noted that UNCLOS states that the absence of data is not a reason to avoid the creation and implementation of management plans. The workshop also noted that although under ice shelf biodiversity may not be taken into account during the planning of the Weddell Sea MPA due to a lack of data, it should be considered in potential monitoring schemes for an MPA.

2.19. The fifth presentation was given by Dr L. Pshenichov (Ukraine) titled, "Ukrainian data input to the Weddell Sea MPA evaluation". He reported on fishing operations in the Southern Ocean which were conducted annually between 1971 and 1991 on board fishing vessels of the USSR exploration fleet. In the regions of the Indian and Atlantic Ocean Sectors adjacent to the Weddell Sea, the work of the exploratory vessels was carried out with two principle aims:

- search for aggregations of the commercial fish species in the shelf and continental slope areas, using bottom and mid-water trawls (approximately 40 cruises and 4,000 trawl sets)
- search and study of the Antarctic krill (*Euphausia superba*) in the areas of the continental slope and off the coast south of 60°S (68 cruises, over 5,000 trawl sets).

All the data of those cruises were submitted to the CCAMLR Secretariat in standard CCAMLR forms and are available according to CCAMLR rules of data access.

2.20. Dr Pshenichov also presented work on the importance of ice scour in creating ideal icefish egg laying habitat. He assumed that quasi-stationary fish aggregations within the shelf and continental slope have similar biological parameters around the whole Antarctic (circumpolar biological consistency) and it was suggested that peculiarities of the life cycle of commercial fish species may to a certain extent be extrapolated to unexplored slope and shelf areas of the Weddell Sea.

2.21. Dr Pshenichov briefly reviewed the results of the research and the proposal to form a Marine Protected Area (MPA) in the vicinity of the Islands of Argentina (western coast of the Antarctic Peninsula). The main principles of the establishment of a MPA in this small area are based on:

- the preliminary long-term investigation in the area of the suggested MPA.
- the idea that the MPA should not affect fishing operations of the marine living resources currently and potentially in future.

2.22. Dr Pshenichov noted that the South Orkney Island area MPA does not have a clear management plan. He mentioned that exploratory trawling in the Weddell Sea is active and that expansions of scientific trawling could provide valuable data.
Other Workshop members noted the amount of time needed to develop an agreed MPA Research and Monitoring Plan and a Management Plan; they also advised the Workshop that the development of such Plans are already underway for the South Orkney Islands and that CCAMLR Member states are encouraged to participate in the process via the CCAMLR website.

2.23. The Workshop agreed that all data, specifically fish data, would be of interest to the workshop and that funding may be available to digitize the Ukraine data. It was noted that these data are not currently available.

EVALUATION OF DATA SETS

3.1. The Workshop discussed available data sets and identified data gaps in 4 separate subgroups; benthic, pelagic, fish and marine mammal/seabirds. Results of the subgroup discussions were then presented in the plenary.

3.2. The benthic subgroup identified two types of data sets available to MPA planning. This first was classified as easily available data and are located in, specifically, the biodiversity.aq portal. The second type of data consists mainly of presence/absence data from the deep sea. It was noted that deep sea and shelf data should not be combined as they are distinctly different ecosystems but should be considered broadly related. Other easily available data noted, but not in the biodiversity.aq portal, were those for abundance data on sea stars, brittle stars and sea urchins, and biomass data on several higher taxonomic groups (from sponges to tunicates). The subgroup acknowledged that conservations objectives would likely be based on a community approach and identified initial objectives such as habitat heterogeneity, richness, biomass and ecosystem function. Ecosystem functions included e.g. energy transfer, nursery grounds and other kinds of symbiosis.

3.3. During discussion, the workshop elaborated on the resolution and presentation of benthic data putting forth 1X1 degree grid and that other presentations of the data, such as using iso-lines, could be technically limiting.

3.4. The Workshop identified an additional data source on pelagic fish from Norway which can be added to the existing krill data. Hydro-acoustic data are also available from this survey, however, it was determined that the little hydro-acoustic data that exists would represent only a small snapshot and may not be representative and other acoustic data has not been collected in the area under consideration. The Workshop clarified that the Ukrainian data is outside of the Weddell Sea planning area, however, there is historic krill fishing data that was already obtained from the CCAMLR data base. Weaknesses in the data sets were identified specifically in mesopelagic data such as myctophid or squid abundance. The Workshop explored the important parameters of the data that should be used concluding that abundance data on individual species and indices on richness and biodiversity would be useful. However, it was noted that biomass data could also be useful in the future in the monitoring of any proposed MPA. Specific species and groups were identified as particularly important, including but not limited to Antarctic krill *Euphausia superba, E. superba* larvae, ice krill *E. crystallorophias*, pelagic fish/fish larvae, squid, and *Salpa thompsoni*. The Workshop reviewed the available environmental data and noted that it was already well developed for its purpose. Additionally, it was agreed that environmental data should not serve as the basis for determining an MPA but be used as background information or as proxy for the biological/ecological variables. The Workshop noted the importance of including key ecosystem process for the pelagic environment but also realized that their inclusion may be limited by the available information and data on those processes.

3.5. The Workshop identified four key topics for Antarctic fish on which the subsequent scientific work should be focus on: *(i)* biodiversity of fish, *(ii)* biomass of the most abundant fish, *(iii)* important areas to life cycles, and *(iv)* relevant trophic interactions. The subsequent data preparation and analysis will show if the data are actually appropriate in order to work out data layers/target areas for those key topics. Additionally, it was agreed that a regionalisation of relevant environmental data may be used as background information for the distribution pattern of Antarctic fish. The subgroup identified fish data from the AWI, Russian and Japanese from exploratory long line fisheries via CCAMLR. Moreover, the workshop noted that additional data sources on pelagic fish exist, such as data sets on *Pleuragramma* from Hubold and Piatkowski (1980s) and data from more recent studies (2004-2008) which were part of the LAzarev Sea KRIll Study (LAKRIS) project. Furthermore, additional data on spawning grounds is sparse but would be useful.

3.6. The Workshop noted that although there are shipboard observations of seabirds there is little tracking data available. In addition, at sea observation data can be hard to interpret due to methodological caveats such as ship following. The Workshop also noted that there is limited data on pack ice seals and Elephant seals and very little tracking data available. The group noted that penguin colony locations are well known and foraging ranges should be included in MPA planning as well. Also there maybe need for temporal protection of penguins especially during key points during the reproductive cycle.

3.7. Members of the workshop also reiterated that inclusion of cetacean data would fulfill requirements to use the best available science. Other workshop members again noted that cetacean data could be included as a data layer for reference but not be included in the decision making process (see also paragraphs 2.2. to 2.4.). Additionally, it was discussed that cetacean data should be included at least in the background paper which will be developed for submission to the Scientific Committee (October 2014) and provide i.a. a description of the Weddell Sea ecosystem.

3.8. The workshop discussed the inclusion of upwelling information in the planning of the MPA. This was determined to be technically possible within the working oceanographic model provided by the AWI but further discussion was needed as to whether it should be included as a separate data layer, since polynyas already reflect the presence of upwelling phenomena.

Tuesday, April 8th

SYSTEMATIC CONSERVATION PLANNING

4.1. Dr S. Grant provided a presentation concerning the application of systematic conservation planning (SCP) and its use in relation to the process of designing MPAs; she presented various examples from other MPA planning projects and explored a number of considerations in relation to the Weddell Sea workshop. Dr Grant emphasised that SCP is a planning approach that can help balance competing demands for ecosystem goods and services by setting clear and transparent objectives. It aims to deliver defined and agreed protection objectives, but with minimal cost in terms of constraints and effects upon rational use. SCP relies upon spatially resolved data that describe constituent biodiversity and ecosystem processes as well as human activities.

4.2. The participants noted that the Weddell Sea workshop has data available to fulfil a number of the steps in the SCP process:

1. Define the planning area. This is already defined in SC-CAMLR-XXII/BG/07.
2. Compile relevant spatial data
3. Set conservation objectives, highlighting how these relate to CM 91-04 (particularly paragraph 2) which themselves are in accord with the CBD COP9 ANNEX I DECISION IX/20 or the scientific criteria for Ecologically and Biologically Significant Areas (EBSA).
4. Review existing protected areas and how these contribute to the achievement of the conservation objectives.

5. Identify target areas to define specific features or locations that would require protection to meet the conservation objectives. These areas may be further defined in proportional terms.
6. Identify candidate conservation areas to achieve the defined objectives.

4.3. It was noted that there are currently no defined scientific criteria for the implementation of the abstract principles of the SCP process (i.e. comprehensiveness, adequacy, representativeness, efficiency).

4.4. Dr Grant also described the software package Marxan, which is a decision support tool that can be used for identifying and testing different spatial solutions to meet conservation objectives, using the available spatial data and defined targets for protection. Use of Marxan can also include consideration of cost layers such as fisheries.

4.5. The workshop discussed how to evaluate datasets and parameters that will be relevant to the MPA planning process in the Weddell Sea. For example, it considered the need for contiguous coverage of spatial data, the spatial resolution of available data, and the geographic scale of MPA planning. The workshop noted that these are all important issues and may limit the use of existing data in some analyses such as Marxan.

4.6. One key point discussed, was how to include both benthic and pelagic domains. For the South Orkney Islands Southern Shelf MPA (CM 91-03), a pelagic analysis with Marxan was used whereas for the benthos, other means were considered. It was noted that two or more separate analyses could be undertaken, depending on the defined objectives and the nature of the available data.

4.7. The workshop discussed how to identify conservation objectives and set specific target percentages for protection, including how different target levels of protection may influence outcomes. The workshop noted that it may be useful to explore the use of different target levels of protection in a sensitivity analysis. In other applications of Marxan, commonly used target levels for representative protection were set on lower proportions of each bioregion or habitat, while higher proportions were given for rare or unique features, or those which are spatially well-defined, such as seamounts. The workshop noted that a handbook is available that describes best practices using Marxan[2].

4.8. The workshop recognised that Marxan does not provide a single final result; rather, it provides different options which all include protection for potentially representative areas. This is why Marxan is considered as a decision support tool – it offers options, but decisions need to be made as part of the SCP process.

4.9. The workshop noted that there are alternative software tools that can be used in the design of protected areas, as well as Marxan.

4.10. The workshop asked the subgroups (benthos, pelagic, fish and birds and mammals) to try to consider how the available data might be used to identify potential target areas for protection.

[2] Ardron, J.A., Possingham, H.P., and Klein, C.J. (eds). 2010. Marxan Good Practices Handbook, Version 2. Pacific Marine Analysis and Research Association, Victoria, BC, Canada. 165 pages. www.pacmara.org.

AVAILABLE DATA LAYERS

5.1. Dr K. Teschke presented a preliminary scientific analysis of the accumulated 300 environmental and ecological data layers available for the Weddell Sea. These layers currently include geomorphology, sedimentology, Chlorophyll a concentration, sea-ice dynamics, penguin colonies in relation to sea-ice, Antarctic krill, macrobenthos communities, and pinniped populations. Other data layers are in progress; these include layers for Antarctic krill larvae, adult crystal krill and larvae, flying seabird colonies, diversity of zooplankton and biodiversity and biomass of fish.

5.2. The workshop noted the quality and quantity of the data layers presented, recognising that this reflected considerable research effort; it recognised that the data available were a superb resource that will facilitate the SCP process for the Weddell Sea.

5.3. The workshop noted that the existing data layers have different geographic extents and different spatial resolution, with the grid cell size for each geographic layer reflecting the spatial resolution of the underlying scientific studies. The workshop suggested that a common grid should be chosen to facilitate the next step in the SCP during which decision support software, such as Marxan, will be necessary.

5.4. The workshop noted that each data layer must be converted to a common grid but that each cell in the grid does not have to have the same dimensions. For example, the grid cells may be different near the coast compared with offshore; this would be useful as the resolution of data is generally better over the continental shelves.

5.5. The workshop noted that there were a very large number of data layers that were available and which could potentially be included in the SCP process. However, a number of participants cautioned that care should be taken when considering which data layers to use within decision support software tools such as Marxan. This was because a number of datasets may reflect similar ecological properties and consequently some features may be inadvertently over emphasised if multiple datasets were included that were ecologically similar. For the South Orkney Islands Southern Shelf MPA, the pelagic analysis included 6 data layers describing 15 separate features (SC-CAMLR-XXVIII/14).

5.6. Some participants suggested that environmental layers might not be as useful to include as biological layers. However, others recalled that environmental layers had proven to be very valuable in the development of bioregionalisation products (e.g. Raymond 2011[3]). The workshop therefore asked the subgroups (benthos, pelagic, fish and bird and mammals) to try to determine what kind of data layers are needed to reflect the different species and ecosystem processes.

5.7. The workshop recognised that in order to set conservation objectives and to set target levels for protection, it could follow one of two approaches. Thus, it could achieve these by reviewing the available data, or it could achieve them by starting from a theoretical perspective. The workshop noted that both approaches had merit, but that eventually data would be necessary to support the conservation objectives and that it would be necessary to identify the quality of datasets and how these can be combined.

[3] Raymond, B. 2011 A circumpolar pelagic regionalisation of the Southern Ocean. CCAMLR, Hobart, Australia, Paper WS-MPA-11/6.

Wednesday, April 9th

GENERAL MPA CONSIDERATIONS

6.1. Prof. A. Rogers (UK) gave a presentation entitled "Southern Ocean management: the broader picture". The Southern Ocean makes up approximately 10% of the world's oceans and is characterised by a unique biota adapted to life at low temperatures. Southern Ocean ecosystems are responsible for a range of ecosystem services, from the provision of seafood to important roles in thermohaline circulation and global biogeochemical cycling. The aim of management of the Southern Ocean must be to maintain a healthy marine ecosystem which is partially reflected in the Convention for Conservation of Antarctic Marine Living Resources (CCAMLR). To date CCAMLR has focused on single species management of fisheries with associated monitoring of dependent species and a precautionary approach to exploitation. International obligations in the management of marine ecosystems extend back to the United Nations Convention of the Law of the Sea (UNCLOS) and its' implementing agreements, specifically the 1995 UN Fish Stocks Agreements. These both require that fisheries are managed sustainably but also have specific provisions with respect to protection of species within the wider ecosystem and specifically biodiversity. Subsequently, the Convention on Biological Diversity (CBD), addresses biodiversity with the latest Aichi targets requiring spatial protection of at least 10% of the world's oceans by 2020. In the absence of a legal framework for the establishment of marine protected areas on the high seas spatial management of human activities has still progressed. This has included action by Regional Fisheries Management Organisations (RFMOs) and regional seas organisations such as Oslo-Paris Convention (OSPAR) to close areas that host vulnerable marine ecosystems from deep-sea bottom fishing. The International Maritime Organisation (IMO) has also established Particularly Sensitive Sea areas where shipping operations are subject to special controls mainly for the protection of biodiversity hotspots. The CBD is currently undergoing a process to identify marine areas in requirement of protection as a result of their uniqueness, ecological importance or vulnerability, so called Ecologically and Biologically Significant Areas (EBSAs). Antarctica is notably absent from the EBSA process to date, although an EBSA workshop has been suggested that would cover the whole Southern Ocean including Antarctica. The workshop for the Southern Indian Ocean has identified areas around Crozet, Prince Edward Islands and the Del Cano Rise as EBSAs. Threats to Antarctic marine ecosystems are discussed, including the results of past exploitation (as this adds complexity to interpreting current change), the ecosystem impacts of current fisheries and also the future effects of climate change. These emphasise the need for a more comprehensive approach to ecosystem-based management, including the development of a network of marine protected areas.

6.2. Following the presentation, it was noted that there is now a cohesive body of international law and agreements focused on the goal of maintaining healthy ecosystems, which are in broad agreement on the value of MPAs as an important mechanism to achieve this goal, and committed to the development of MPAs in terms of areal targets.

6.3. It was noted that it is important to consider threats during the development of MPAs, but the workshop agreed that these may include threats from climate change as well as fishing. CCAMLR has been relatively successful in managing the direct threats of fishing on target species however other potential threats might include cascading effects on foodwebs, disturbance to habitats, and alteration of target populations in terms of size structure or recruitment potential. Threats should be considered in a broader context, to include not only target species but all ecosystem services. The cumulative effect of a number of different threats may be particularly relevant, although it was agreed that understanding of such effects is currently limited.

6.4. In addition to conservation objectives, it was noted that MPAs can be designated to achieve other objectives including those relating to scientific research and monitoring, where the level or type of threat may be different.

6.5. The need to apply a precautionary approach in the development of MPAs was discussed. Many agreed that MPA designation should be undertaken with consideration of the longer-term future, when there may be greater pressure to exploit living resources from an increased population and demand for food, and when stocks elsewhere may be less healthy. Damage to ecosystems can occur rapidly when fishing activity starts up before management is put in place. The precautionary approach is therefore an important principle, especially given the complexity of modeling the effects of potential cumulative threats.

DISCUSSION OF DATA LAYERS/TARGET AREAS IN RELATION TO CM 91-04 OBJECTIVES

BENTHIC SYSTEM

7.1. The subgroup noted that conservations objectives would likely be based on a community approach and identified initial objectives such as habitat heterogeneity, richness, biomass and ecosystem function. Ecosystem functions included e.g. nursery grounds and other kinds of symbiosis.

7.2. The workshop noted that an important objective is to protect representative examples of macrozoobenthic hot and cold spots in terms of richness, abundance, biomass and productivity. However, it was noted that subsequent analyses focusing on abundance, biomass and productivity are likely to be limited to only a few areas in the Weddell Sea and/or taxa where data are available.

7.3. Two key ecosystem processes were identified which may be of particular relevance: *(i)* architecturing/habitat forming by sponges (e.g. glass sponges, *Cinachyra*, *Mycale*), octocorals or erect bryozoans and *(ii)* bulldozing/bioturbating by ophiurids (excl. filter feeders, scavengers etc.), asteroids, irregular sea urchins, deposit feeding holothurians. Those processes may be only relevant if the specific species are abundant and/or occur with high biomass.

7.4. All sessile species (excl. fast growers, such as *Mycale*, solitary ascidians, *Homaxinella*) and all slow growers (e.g. brachiopods, shelled molluscs, asteroids) were noted as vulnerable to impact by bottom contact fishing.

7.5. Areas of high habitat heterogeneity (i.e. beta-diversity/species or assemblage turn-over) were mentioned as potential areas to maintain resilience since these areas could act as efficient source for recolonisation.

PELAGIC SYSTEM

8.1. The workshop agreed that further analyses should be undertaken to detect hotspots for pelagic biodiversity and abundance, focusing on key species including *Euphausia superba* (both adults and larvae), *E. crystallorophias, Pleuragramma*, salps, squid, mesopelagic fish and pteropods, as well as larvae of commercial fish species. Indices of species richness could be derived from existing datasets. The subsequent data preparation and analysis will show if the data are actually appropriate in order to propose targeted conservation actions. Additionally, the workshop agreed that information based on models (e.g. kriging), identifying potential areas for krill and other pelagic species, should be included in the MPA planning process if possible.

8.2. Two areas were identified which may be of particular relevance: i) the area around Maud Rise is a unique system influenced by the Weddell Gyre, with high productivity for krill, and ii) the shelf close to Neumayer station is an area of high diversity, based on data from the Biogeographic Atlas of the Southern Ocean.

8.3. *E. superba* is a key component of the foodweb, and it was agreed that adult/post-larval populations are of particular interest. It was noted that predators may switch to other euphausid species in areas where *E. superba* is less abundant. Squid were also noted as important prey species, although data are very scarce.

8.4. Salps are sometimes found in low densities in the Weddell Sea, but are generally distributed further to the north. They are not considered to be a key component in terms of Weddell Sea processes, but will nevertheless be included in further analyses. Pteropods may be of relevance as an indicator for ocean acidification; some data are available but this requires further work.

8.5. It was agreed that identifying pelagic reference areas or vulnerable pelagic areas is likely to be difficult because of the highly mobile and dynamic nature of the system.

8.6. The workshop agreed that pelagic processes such as those associated with the carbon cycle should be taken into account as background information depending on data availability. It was noted that the contribution of the pelagic system to ecosystem services such as carbon sequestration should also be highlighted.

8.7. The Filchner Trough border (south of 74-75°S) has very different characteristics to the rest of the Weddell Sea shelf, with a pelagic community dominated by amphipods and ice krill, rather than copepods and Antarctic krill. In discussing potential target areas to study the function of local ecosystems, it was noted that features such as the carbon system in this area may be important in maintaining a locally distinct ecosystem.

8.8. The workshop discussed whether the Weddell Sea could act as a refuge area from climate change. This is difficult to answer because of a lack of predictive models for this region and the very specific influence of characteristics of the Weddell Gyre.

FISH

9.1. The workshop agreed that an important objective is to conserve areas of high fish biodiversity. However, it was noted that further analyses are required, and that these are likely to be limited to the shelf area where data are available. There is good information for shelf areas down to 600m, but few data for deeper areas except for some specific spawning areas around 1400m to 1600m.

9.2. It was agreed that these known spawning areas are important conservation targets. Several species spawn at 1200m to 1600m, and would therefore be vulnerable to fishing at these depths. Future work beyond the MPA Weddell Sea project to develop environmental envelope models would also be useful to predict the location of spawning areas. This could be used as the basis for a precautionary approach to protecting such areas, as well as guiding future research and monitoring.

9.3. It was noted that spawning characteristics vary between species. For example, *Chaenodraco wilsoni* nests are found over a wide area in unstructured habitat, whereas other species such as

Trematomus spp. spawn in structured habitat with holes, hills etc. Further information and separate analyses are required to determine the needs of individual species.

9.4. The workshop discussed whether any key fish species for the Weddell Sea region could be identified. The workshop noted following fish as potential key species for the Weddell Sea: (i) *Chaenodraco wilsoni*, (ii) *Pleuragramma antarctica* and (iii) *Dissostichus* spp. *Chaenodraco wilsoni* is more abundant than most others, based on biomass estimates. *Pleuragramma antarctica* is also important as a forage fish for top predators such as emperor penguins. There is limited information on its distribution however important areas for protection are likely to be adjacent to penguin colonies. The Filchner Trough is a spawning ground for *C. wilsoni*, other icefish spp. and *Pleuragramma. Dissostichus* spp. was mentioned as top predator.

9.5. It was agreed that reference areas for fishing would also be valuable. E.g. fish communities on the continental slope are currently subject to research fisheries, and reference areas to these would therefore provide an important comparison.

BIRDS AND MAMMALS

10.1. It was noted that data on predators are very sparse. However, it was agreed that several generic issues may be useful in considering conservation objectives for upper trophic levels, including:

i) Spatially constrained and predictable areas for mammals and birds at different life history stages;
ii) Protection for a percentage distribution of the range of central place foragers (penguins and flighted birds, but also some seals) during the breeding season.
iii) Distribution of prey species (see also pelagic section above), and the availability of prey to central place foragers. Foraging distributions could also be protected under representative objectives, unless prey is aggregated in a particular area, for example upwelling areas at the head of fjords.
iv) Winter feeding grounds are particularly important for capital breeders, but also seals and penguins. Polynyas, marginal ice zones and frontal areas are typical foraging habitats at all times of year.
v) Migration routes, for example baleen whales following the ice edge into the Weddell Sea, and north again in autumn.

10.2. It was noted that good information is available on the location of penguin colonies from remote sensing. For emperor penguins, important ecological features around colonies could be identified, and modelling of foraging areas may be possible and important. However, there are no available predator tracking data to identify specific target areas based on foraging distributions.

10.3. Adélie penguins occur at only a few sites in the north of the Weddell Sea region. Their post-breeding foraging distribution is different to that for this species elsewhere. For example, colonies on the South Orkney Islands (at Laurie Island, Powell Island and Signy Island) all use the existing South Orkneys MPA, whereas birds from Hope Bay and the northern Peninsula moult near their colonies, and this is therefore a unique habitat which should be taken in consideration for the MPA process.

10.4. Seamounts are important for pelagic as well as benthic taxa. Maud Rise is a particular area of interest, and other seamounts are also likely to be critical for upper trophic levels.

10.5. Although data are sparse, it is predicted that the Weddell Sea may lose one-third of its sea ice cover over next century, mostly during winter. This has implications for the protection of areas to maintain resilience to climate change, for predators as well as other taxa.

10.6. It was noted that data on cetaceans (humpbacks and minkes) may also be relevant for consideration, although these were not available during the workshop, and are limited to summer only (see also paragraphs 2.2. to 2.4. and 3.7.).

CONCLUDING DISCUSSION

11.1. Following the discussion of conservation objectives and target areas specifically relevant to the four subitems, it was agreed that no additional objectives had been identified beyond those specified in CM 91-04. However, the workshop agreed that objectives could be sub-divided to reflect regionally-specific conservation goals, or defined separately for benthic and pelagic systems.

11.2. In reviewing the information presented during the workshop, some members of the workshop noted that the level of knowledge is relatively good for the Weddell Sea in comparison to other parts of the Southern Ocean, and that data are available to support the protection of some important features. However, it was agreed that data quality and quantity is unevenly distributed in space, and across different biological units, and there remains a lack of data and understanding in many areas (e.g. areas covered by sea ice). Any future MPA could therefore be inter alia a tool to focus further research.

11.3. CCAMLR requires that priorities for research and monitoring should be identified as part of an MPA proposal, however the workshop suggested that a Weddell Sea proposal could exceed this requirement and include more detail on future scientific work in the region, focusing on medium- to long-term aspects. It was also noted that the needs of rational use should be accommodated in this research.

11.4. The Weddell Sea is unique in terms of its oceanography and biology. This type of large gyre system and major contribution to deep ocean water formation does not exist anywhere else in the world. It has high levels of biodiversity and endemism, and is a key region for protection in the Southern Ocean. The workshop emphasised that this must be highlighted in background information presented to CCAMLR.

11.5. The workshop noted that it is important to consider how a MPA could be used to conserve and manage an area more generally, in addition to simply protecting special areas. There was a discussion on whether a MPA should focus on just one, major conservation objective, or if several objectives might be relevant. It was noted that the key objectives for this planning domain include: i) ensuring the Weddell Sea ecosystem is protected to an appropriate degree as the Weddell Sea represents one of only a few candidate MPAs in high latitudes in the Southern Ocean, ii) protecting a refuge area, and iii) protecting a threatened area. It was felt that all of these objectives have relevance for this region.

FUTURE WORK

12.1. It was agreed that good progress had been made during the workshop in terms of establishing collaborative contacts and identifying relevant datasets. However, a significant amount of further work is still required to analyse existing data. There may also be a need to approach relevant individuals or groups separately, to obtain any remaining unavailable datasets.

12.2. Expert knowledge will be needed for the identification of important areas for conservation, especially in the case of data that may not be suitable for other types of planning analyses such as Marxan. The workshop particularly underlined the importance of transparency in terms of analyses and the definition of conservation objectives.

12.3. The workshop has also been useful in identifying the scope of future work so that the project timeline can be revised. The timeline for future work is likely to be longer than previously set out in SC-CAMLR-XXXII/BG/07, with the possibility of a proposal in 2015 rather than in 2014.

12.4. It was suggested that another workshop would be valuable, particularly to address the policy and management aspects of a proposal. However, the conveners noted that further funding would be needed to be secured to progress the project beyond December 2014. The potential development of further work will be considered by the responsible ministry, following the responses of WG-EMM (July 2014) and SC-CAMLR (October 2014).

12.5. A progress report will be submitted to WG-EMM with the final workshop report as supplementary paper. A preliminary background paper will also be developed for submission to the Scientific Committee (October 2014). This document will be structured according to the parameters discussed during the workshop (e.g. fish, benthos, penguins etc.), and will draw on participants' expertise to provide a description of the Weddell Sea ecosystem. It will also describe the available data, specify those data used in the analyses, and provide details of all the analyses undertaken.

12.6. For future work it was agreed that the mailing list will be used to circulate documents. There may also be the option to use an online discussion group on the CCAMLR website for updates.

CLOSING REMARKS

13.1. The workshop agreed that the protection of biodiversity was the key issue identified by all four subgroups. The priority for the next stages of the project should therefore be scientific work to identify areas of importance for biodiversity. Questions relating to MPA design and management (e.g. whether there should be one large, or several smaller, MPAs) should not influence this work. The design of a MPA is a separate step, which must also include other considerations such as threat analysis, the requirements for research and monitoring or the degree to which it contributes to the effectiveness of an appropriate network of MPAs.

13.2. The workshop has demonstrated that there are sufficient data and grounds for establishing an MPA under at least three of the objectives defined in CM 91-04:

i) the protection of representative examples of marine ecosystems, biodiversity and habitats at an appropriate scale to maintain their viability and integrity in the long term;

ii) the protection of key ecosystem processes, habitats and species, including populations and life-history stages;

iii) the establishment of scientific reference areas for monitoring natural variability and long-term change or for monitoring the effects of harvesting and other human activities on Antarctic marine living resources and the ecosystems of which they form part.

13.3. Some members of the workshop suggested that a 'living MPA' could be established, with the designation in the first instance of areas that have a high level of available data and certainty in terms of their protection requirements. The MPA might then be extended in the future, following further research and monitoring, with the full engagement of the CCAMLR community. While this was mentioned at the end of the workshop there was not enough time to discuss this idea.

13.4. The conveners thanked the participants for their valuable input to the workshop, and expressed their hope that all would remain engaged in the development of further work towards a MPA in the Weddell Sea region.

13.5. The participants responded by thanking the hosts for all of their hard work to convene a very successful and productive meeting, and for their hospitality in Bremerhaven. All of the participants looked forward to the continuation of this project into the future.

8.2. Attachment A – List of participants

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR UND MEERESFORSCHUNG

International Expert Workshop
The scientific foundation of a CCAMLR marine protected area in the Weddell Sea
Bremerhaven
April 7 – 9, 2014

Participants

NAME	INSTITUTE	SIGNATURE	Adhere to workshop data rules
Karl-Hermann Kock	Inst. f. Seefischerei	[illegible]	✓
Katharina Teschke	AWI	[illegible]	✓
Hendrik Pehlke	AWI	[illegible]	✓
Rebecca Lahl	AWI	[illegible]	✓
Thomas Brey	AWI	[illegible]	✓
TAO ZUO	YSFRI	TAO ZUO	✓
Yang Lei	CAA	Yang Lei	✓
Leonid Pshenichnov	YugNIRO	[illegible]	✓
Andrey Petrov	VNIRO	[illegible]	✓
Viacheslav Bizikov	VNIRO	[illegible]	✓
Valery Lukin	AARI	[illegible]	✓
Andy Lowther	Norsk Polarinstitutt	[illegible]	✓

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

	NAME	INSTITUTE	SIGNATURE	Adhere to work-shop data rules
13	Lena Teuber	University of Bremen	L. Teuber	✓
	Heike Herata	Umweltbundesamt	[illegible]	✓
	Tomas Lundälv	Swedish Institute for the Marine Environment	[illegible]	✓
	Taro Ichii	Fishery Research Agency of JAPAN	Taro Ichii	✓
	Chika Fukugama	Fisheries Agency of Japan	fukugama	✓
	Mitsutaka Makino	Fisheries Research Agency. Japan	牧野光琢	✓
	Peter Seifert	Projektträger Jülich	[illegible]	✓
20	Tim Davies	MRAG	TkDavies	✓
	JINON YOON	KOREA OVERSEAS Fisheries Cooperation Institute	[illegible]	✓
	JONG HEE LEE	National Fisheries Research & Development Institute	이종희	✓
	KOUBBI Philippe	Sorbonne Université U.P.M.C	[illegible]	✓
	MARINO VACCHI	ISMAR - CNR ITALY	Marino Vacchi	✓
	Anton Van de Putte	Royal Belgian Institute for natural sciences	[illegible]	✓
	Ryan Driscoll	San Diego State University	[illegible]	✓
27	Volker Siegel	Inst. f. Seefischerei Hamburg	Volker Siegel	✓

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR
UND MEERESFORSCHUNG

	NAME	INSTITUTE	SIGNATURE	Adhere to workshop data rules
2[illegible]	Stefan Hain	AWI		yes!
	Nicole Meyer	AWI		yes
	Esther Winterhoff	BMEL		~
	Andrea HEYN	BMBF	A. Heyn	Yes!
	Holger Auel	BreMarE Uni Bremen	H. Auel	✓
	Wiebke Schwarzbach	UBA	W. Schwarzbach	✓
	Phil Trathan	BAS	Phil Trathan	ok
35	Kirsten Liess	BAS	K. Liess	yes
	ALEX ROGERS	UNIVERSITY OF OXFORD		Yes.
	SUSIE GRANT	BAS		Yes
	Ilse Van Opzeeland	AWI		yes.
	Bjørn Krafft	IMR	Bjørn Krafft	yes
40	Patricia Brtnik	DHM		yes
	Alexander Liebschner	BfN	A. Liebschner	yes

8.2. Attachment B – Time Table

Time	SUNDAY, April 6th	MONDAY, April 7th	TUESDAY, April 8th	WEDNESDAY, April 9th
	Themes	***Data sets, data layers & conservation targets***		
	Host	Karl-Hermann Kock	Stefan Hain	Thomas Brey
09:00		**Workshop opening** • Short introduction of attendees • Programme and schedule • Organisational issues	**Opening** **S. Grant** *Systematic conservation planning*	**Opening** **A. Rogers** *Southern Ocean Management: the broader picture*
09:30		**K. Teschke** *Already acquired data sets for the evaluation of the Weddell Sea MPA*	**K. Teschke** *Preliminary data layers and their conservation targets – Definition & prioritisation*	Presentation by each subgroup
10:00		**COFFEEBREAK**	**COFFEEBREAK**	**COFFEEBREAK**
10:30		**K. Linse** *An overview of BASO data for the Weddell Sea - A focus on benthic data sets*	**Working in subgroups** Data layers - Identification of relevant data layers, significant gaps in the data layers etc.	Presentation by each subgroup
10:50		**A. van de Putte** *An overview of BASO data for the Weddell Sea – A focus on plankton and higher predators*		***Plenary discussion*** • Further work required • Conservation target priorities • etc.
11:10		**T. Zuo** *Information on Chineses studies in CCAMLR subarea 48 and some thoughts on the Weddell Sea MPA planning process*		
11:30		**L. Pshenichnov** *Ukrainian data input to the Weddell Sea MPA evaluation*		
12:00		**LUNCH**	**LUNCH**	**LUNCH**
13:30		**Working in subgroups** Data sets – data relevance, missing data etc.	**Working in subgroups** Conservation targets –definition and prioritisation of relevant conservation targets	Summarise workshop results
14:30				Photo shoot
15:30		**COFFEEBREAK**	**COFFEEBREAK**	**COFFEEBREAK**
16:00		Presentation by each subgroup	**Working in subgroups** Conservation targets - definition and prioritisation	Farewell
16:30		**Plenary discussion**	**Plenary discussion**	
17:00		**T. Lundälv** *Slideshow and film about Weddell Sea benthic ecosystems*	**Day closure**	**Day closure**
18:00	**Ice breaker at Deutsches Auswanderer-haus**	**Day closure**		
18:30			Guided tour – AWI (Building D)	
19:30			**Dinner at Seute Deern**	