



CCAMLR

Commission for the Conservation of Antarctic Marine Living Resources
Commission pour la conservation de la faune et la flore marines de l'Antarctique
Комиссия по сохранению морских живых ресурсов Антарктики
Comisión para la Conservación de los Recursos Vivos Marinos Antárticos

WG-EMM-15/39

21 June 2015

Original: English

WG-EMM

**Scientific background document in support of the development of a
CCAMLR MPA in the Weddell Sea (Antarctica) - Version 2015 - Part B:
Description of available spatial data**

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Introduction

Part B of the scientific background document informs on the data retrieval process within the Weddell Sea MPA (WSMPA) project. Chapter 1 describes the environmental data sets that were acquired for the evaluation of a MPA in the Weddell Sea planning area (see Table 1-1). These are satellite data mainly with a high temporal resolution. For example, satellite observations on daily sea ice concentration, derive from the Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-EOS) instrument on board the Aqua satellite, are available by several Internet web sites. Further oceanographic data were obtained e.g. from the global Finite Element Sea Ice-Ocean Model (FESOM; Timmermann et al. 2009). Chapter 2 provides a systematic overview of the current data situation regarding ecological data sets. In total, more than 20 ecological data sets on zooplankton, zoobenthos, fish, birds and mammals were acquired (see Tab. 2-1). 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.

Those data sets or parts of data sets that were acquired for our study, but were not incorporated into further analyses are marked grey in Table 1-1 and 2-1. Those data sets mostly (i) represent parameters that are already covered by other data sets, (ii) show an inappropriate spatial and/or temporal resolution or (iii) are not quantifiable. Most data sets are already presented in our background document SC-CAMLR-XXXIII/BG/02, which the Scientific Committee had welcomed and endorsed as a foundation reference document for the Weddell Sea MPA planning (SC-CAMLR-XXXIII, § 5.21). In addition, some newly acquired data sets are listed (e.g. observation on nest guarding fish).

1. Environmental parameters

1.1 Bathymetry & Geomorphology

Bathymetric data are provided by the first regional digital bathymetric model established in the International Bathymetric Chart of the Southern Ocean (IBCSO) programme and published by Arndt et al. (2013). 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 (multi-beam and single beam data) from many hydrographic offices, scientific institutions and data centres. The derivatives of the bathymetry (e.g. slope, hillshade, geomorphology) are derived from the IBCSO data set.

1.2 Sedimentology

A substantial data set on grain size derives 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 that are merged in now in a new compilation (G. Kuhn & K. Jerosch, AWI).

1.3 Oceanography

Data on temperature, salinity and currents (speed and direction of water movement) are 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 dynamic/thermodynamic ice model. For the simulations analysed here, FESOM was initialised on February, 1st 1980 with hydrographic data from the Polar Science Center Hydrographic Climatology (Steele et al. 2001) and forced with atmospheric reanalysis data such as wind speed, temperature, humidity, and cloudiness.

1.4 Sea ice

Three large data sets on sea ice were acquired (see Tab. 1-1):

(1) Satellite observations of daily sea ice concentration derive 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.

(2) Data on daily polynya distribution derive 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.

(3) Data on monthly sea ice thickness derive 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.

2. Ecological parameters

2.1 Chl-a concentration

Chlorophyll-a (chl-a) concentration values derive 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.

2.2 Pelagic ecosystem

Many data sets on zooplankton, mainly data on krill, were acquired (see Tab. 2-1). Studies focusing on zooplankton communities, including meso-, macro-zooplankton and micro-nekton, were identified as relevant data sources (e.g. Boysen-Ennen & Piatkowski 1988, Flores et al. 2014). These data sets are quite diverse taxonomically, and principal groups include salps, juvenile cephalopods or paralarvae, crustaceans (e.g. euphausiids, copepods) and fish (mainly mesopelagic species). Data on adult squid are extremely scarce particularly catch data refer to very few records (e.g. Nesis et al. 1998). Most data on the occurrence of squid are obtained from stomach analysis of birds and marine mammals (Piatkowski & Pütz 1994, Plötz et al. 1991).

Krill

The largest data set on adult Antarctic krill, *Euphausia superba*, consists of more than 700 stations sampled between 1928 and 2013 (see Tab. 2-1). 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).

Pelagic fish

Unpublished data are available on the distribution of oceanic pelagic fish (held by R. Knust, AWI). Moreover, we acquired data on mesopelagic fish, such as Antarctic silverfish (*Pleuragramma antarctica*), from the LAzarev Sea KRill Study (LAKRIS) project (e.g. Flores et al. 2014), and older studies e.g. from Boysen-Ennen & Piatkowski 1988 and Hubold et al. 1988 (see Tab. 2-1).

2.3 Benthic ecosystem

Zoobenthos – Shelf and slope

Three substantial zoobenthic data sets are listed in Table 2-1. Gutt et al. (2013) 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. 2013). 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, an unpublished quantitative macrobenthos data set (abundance, biomass) is held by D. Gerdes (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). A third zoobenthic data set (semi-quantitative data) was

digitised for the WSMMPA project based on *Polarstern* cruise reports and on unpublished data held by W. Arntz (AWI, retired). Additional data sources on macrofaunal communities are available e.g. from Galéron et al. (1992) and Voß (1988). Moreover, there is a considerable number of data sets referring to specific taxonomic groups - particularly polychaetes (e.g. Stiller 1995), molluscs (e.g. Hain 1990), and echinoderms (e.g. Gutt 1988, Piepenburg et al. 1997) - sampled along the Weddell Sea shelf and slope. So far more than 10 such smaller data sets, partly stored in the ANTABIF data portal (primarily as presence data) have been made available for the WSMMPA project.

Zoobenthos – Deep Sea

There is a considerable number of data sets on abyssal benthic deep-sea fauna in the Weddell Sea. Most of these data sets are based on ANDEEP I-III (ANtartic benthic DEEP-sea biodiversity: colonization history and recent community patterns) expeditions in 2002 and 2005 (Brandt & Hilbig 2004, Brandt & Ebbe 2007), and referring to specific taxonomic groups - particularly sponges (e.g. Janussen & Tendal 2007), polychaetes (e.g. Hilbig 2001, Schüller & Ebbe 2007, Schüller et al. 2009), molluscs (e.g. Linse et al. 2006, Schwabe et al. 2007), crustaceans (e.g. Brandt et al. 2007, De Broyer et al. 2006) and echinoderms (e.g. Bohn 2006).

Demersal fish

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. 2-1). Observations on nest guarding fishes (*Chaenodraco wilsoni*, *Neopagetopsis ionah*) derive from unpublished data held by Dieter Gerdes (AWI) and Tomas Lundäv (Swedish Institute for the Marine Environment).

Data from an exploratory long line fishery on *Dissostichus mawsoni* conducted by Russia in 2012/13 and 2013/14 have been submitted to the CCAMLR secretariat. They are still awaiting a thorough analysis by CCAMLR's Working Group on Fish Stock Assessment.

2.4 Birds

Seabirds

A few data sets exist on flying seabirds (i.e. petrels or Procellariiformes), their distribution and abundance patterns in the Weddell Sea. Two substantial seabird data sources derive from van Franeker et al. (1999) and Croxall et al. (1995) (see Tab. 2-1). The comprehensive databases give relevant information about Antarctic Petrel and Snow Petrel breeding colonies from Coats Land, Dronning Maud Land and the Antarctic Peninsula between 1905 and the early 90s. Those data were complemented by published data on flying seabirds with substantial breeding populations near the Weddell Sea MPA planning area, such as the Southern Fulmar (Creuwels et al. 2007) and the Southern Giant Petrel (Patterson et al. 2008).

Penguins

Data on emperor penguin population estimates are available 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.

2.5 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 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 2009; 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 WG-EMM-14/19, supplementary material, 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).

Whales

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 evaluated. 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 et al. 2014).

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

Parameter	Spatial and temporal resolution			Source (contact person, publication, web site)
	Spatial resolution	Period	Temporal resolution	
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	depending on local sedimentation rates: 1-1000 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 & K. Jerosch, AWI (compiled data set)
Water column properties				
Sea temperature (°C), salinity (PSU), currents, i.e. speed (m) and direction of water movement (°) - Model data (FESOM)	1.5° x 1.5° (horizontal) Surface & bottom value (vert.) Coastal polynia model 3 km – 50 km (horizontal)	1990 - 2009	Monthly	Timmermann et al. (2009) Haid and Timmermann (2013)
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 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 1-1 (contd.)

Parameter	Spatial and temporal resolution			Source (contact person, publication, web site)
	Spatial resolution	Period	Temporal resolution	
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) - Polynya distribution	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)	1.5° x 1.5° (horizontal) Coastal polynya model 3 km – 50 km (horizontal)	1990 - 2009	Monthly	Timmermann et al. (2009) Haid and Timmermann (2013)
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 2-1: List of ecological data sets for marine protected area evaluation in the Weddell Sea. Data sets or parts of data sets that were sighted, but were not incorporated into further analyses are grey-shaded.

Parameter	Sampling design and temporal resolution			Source (contact person, publication, web site)
	Sampling design	Period	Temporal resolution	
Chlorophyll-a				
Chlorophyll-a concentration (mg/m ³)	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/
Zooplankton				
Abundance data on adult Antarctic krill, <i>Euphausia superba</i> (N/m ² ; N/1000 m ³)	> 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), B. Krafft (Institute of Marine Research, Bergen; unpubl. data)
Abundance data on adult ice krill, <i>Euphausia crystallophias</i> (N/1000 m ³)	> 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/m ²)	> 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/1000m ³)	39 stations; RMT1, RMT8	1983	Snapshot in time	Boysen-Ennen & Piatkowski (1988)
Abundance data on macrozooplankton and micro-nekton (N/1000m ³)	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 2-1 (contd.)

Parameter	Sampling design and temporal resolution			Source (contact person, publication, web site)
	Sampling design	Period	Temporal resolution	
Zoobenthos				
Macrobenthic communities (descriptive)	± 90 data sets, Weddell Sea shelf	1956 - 2010	Summary data set, Snapshots in time	Gutt et al. (2013) and references therein in regards to results and data http://ipt.biodiversity.aq/resource.do?r=macrobenthos
Macrozoobenthos (N/m ² , g C/m ²)	Various German Antarctic expeditions; almost 300 samples	1984 - 2011	Different time intervals	Data originators: Dieter Gerdes (AWI); Ute Mühlenhardt-Siegel (DZMB); e.g. Gerdes et al. (1992)
Macrozoobenthos (semi-quantitative data)	Various German Antarctic expeditions (ANT VII/4, ANT VII/5, ANT IX/1-4, ANT XIII/3, ANT XV/3, ANT XVII/3, ANT XXI/2)	1989 - 2004	Different time intervals	<i>Polarstern</i> cruise reports and data originator W. Arntz (AWI, retired)
Considerable number on specific higher taxonomic groups (primarily abundance data)	Several <i>Polarstern</i> 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 1995), molluscs (e.g. Hain 1990, Linse et al. 2006), crustaceans (e.g. Brandt et al. 2007), echinoderms (e.g. Dahm 1996, Gutt 1988, Brey & Gutt 1991, Gutt 1991, Piepenburg et al. 1997)
Fish				
Mostly abundance and biomass data on demersal fish, but also pelagic fish	> 10 <i>Polarstern</i> 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 (TI) Drescher et al. (2012), Ekau et al. (2012 a, b), Hubold et al. (1988), 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
Nest guarding fish observations (<i>Chaenodraco wilsoni</i> , <i>Neopagetopsis ionah</i>)	German Antarctic expeditions ANT XXVII/3 and ANT XXIX/9	2011, 2014	Snapshots in time	Unpublished data held by D. Gerdes (AWI) and T. Lundäv (Swedish Institute for the Marine Environment)
Fishery operations (catch in kg); mainly <i>Dissostichus</i> spp. catches	Longline surveys	2005 - 2013	Summary data base (annual and bi-annual)	David Ramm, CCAMLR data manager; www.ccamlr.org

Table 2-1 (contd.)

Parameter	Sampling design and temporal resolution			Source (contact person, publication, web site)
	Sampling design	Period	Temporal resolution	
Birds				
Antarctic Petrel breeding localities	± 20 breeding localities, Coats Land and Dronning Maud Land	1971-1994	Summary data set, Snapshots in time	Van Franeker et al. (1999)
Snow Petrel breeding localities	± 60 breeding localities, Coats Land, Dronning Maud Land, Antarctic Peninsula	1905-1992	Summary data set, Snapshots in time	Croxall et al. (1995)
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/km ²)	flight campaigns	1992 - 2014	Different time intervals	Ackley et al. (2006), Bester et al. (1995, 2002), Bester & Odendaal (2000), Flores et al. (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
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 <i>Polarstern</i> cruises	2005 - ongoing	Snapshot in time	Burkhardt (2009 a-i, 2011, 2012 and unpublished data); Bombosch et al. (2014); http://www.pangaea.de/search?count=10&minlat=&minlon=&maxlat=&maxlon=&mindate=&maxdate=&env=All&q=elke+burkhardt+

References

- Ackley S, Bengtson J, Bester MN, Blix AS, Bornemann H, Boveng P, Boyd I, Cameron M, Nordøy E, Plötz J, Siniff D, Southwell C, Steinhage D, Stewart BS, Stirling J, Torres J, Yochem PK (2006) The International Antarctic Pack Ice Seals (APIS) Program. Multi-disciplinary research into the ecology and behavior of Antarctic pack ice seals. Summary Update. In: Bester MN, Stewart BS (eds). The Expert Group on Seals; Scientific Committee on Antarctic Research.
- Antonov JI, Seidov D, Boyer TP, Locarnini RA, Mishonov AV, Garcia HE, Baranova OK, Zweng MM, Johnson DR (2010) World Ocean Atlas 2009, Volume 2: Salinity. In: Levitus S (ed). NOAA Atlas NESDIS 69, U.S. Government Printing Office, Washington, D.C., 184 pp.
- Arndt JE, Schenke HW, Jakobsson M, Nitsche F, Buys G, Goleby B, Rebesco M, Bohoyo F, Hong JK, 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.
- Atkinson A, Siegel V, Pakhomov EA, 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 EA, Rothery P, Loeb V, Ross RM, Quetin LB, Schmidt K, Fretwell P, Murphy EJ, Tarling GA, Fleming AH (2008) Oceanic circumpolar habitats of Antarctic krill. *Marine Ecology Progress Series*, 362, 1-23.
- Atkinson A, Siegel V, Pakhomov EA, Jessopp MJ, Loeb V (2009) A re-appraisal of the total biomass and production of Antarctic krill. *Deep-Sea Research I*, 56, 727-740.
- Barron CN, Kara AB (2006) Satellite-based daily SSTs over the global ocean. *Geophysical Research Letters*, 3, L15603, doi:10.1029/2006GL026356.
- Bester MN, Erickson AW, Ferguson JWH (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 MN, Odendaal PN (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, 51-55.
- Bester MN, Ferguson JWH, Jonker FC (2002) Population densities of pack ice seals in the Lasarev Sea, Antarctica. *Antarctic Science*, 14, 123-127.
- Blix AS, Nordøy ES (2007) Ross seal (*Ommatophoca rossii*) annual distribution, diving behaviour, breeding and moulting, off Queen Maud Land, Antarctica. *Polar Biology*, 30, 1449-1458.
- Bohn JM (2006) The Crinoidea and Holothuroidea (Echinodermata) collected during the ANDEEP III expedition. In: Fahrbach E (ed). *The Expedition ANTARKTIS XXII-3 of RV 'Polarstern' in 2005. Reports on Polar and Marine Research*, 533, 184-187.
- Bombosch A, Zitterbart DP, van Opzeeland I, Frickenhaus S, Burkhardt E, Wisz MS, Boebel O (2014) Predictive habitat modelling of humpback (*Megaptera novaeangliae*) and Antarctic minke (*Balaenoptera bonaerensis*) whales in the Southern. *Deep-Sea Research I*, 91, 101-114.
- Boysen-Ennen E, Piatkowski U (1988) Meso- and macrozooplankton communities in the Weddell Sea, Antarctica. *Polar Biology*, 9, 17-35.
- Brandt A, Hilbig B (2004) ANDEEP (ANtarctic benthic DEEP-sea biodiversity: colonization history and recent community patterns) - a tribute to Howard L. Sanders. *Deep-Sea Research II*, 51 (14-16), 1457-1919.
- Brandt A, Ebbe B (2007) ANDEEP III ANtarctic benthic DEEP-sea biodiversity: colonisation history and recent community patterns. *Deep-Sea Research II*, 54 (16-17), 1645-1904.
- 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.
- 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.

- 729034; 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/PANGAEA.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
- Creuwels JCS, Poncet S, Hodum PJ, Van Franeker JA (2007) Distribution and abundance of the Southern Fulmar *Fulmarus glacialoides*. Polar Biology, 30, 1083-1097.
- Croxall JP, Steele WK, McInnes SJ, Prince PA (1995) Breeding distribution of the Snow Petrel *Pagodroma nivea*. Marine Ornithology, 23, 69-99.
- Dahm C (1996) Ecology and Population Dynamics of Antarctic Ophiuroids (Echinodermata) (Ökologie und Populationsdynamik antarktischer Ophiuroiden (Echinodermata)). Reports on Polar Research 194, 1 – 289.
- De Broyer C, Danis B, Hétérier V (2006) Biodiversity, phylogeny and trophodynamics of amphipod crustaceans of the Antarctic deep sea. In: Fahrbach E. (ed.) (2005) The Expedition ANTARKTIS XXII/3 of the Research Vessel "Polarstern" in 2005. Berichte zur Polar- und Meeresforschung, 533, 135-141.
- 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.
- 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.
- 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, 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 Part II, 58, 2509-2523; doi: 10.1016/j.dsr2.2011.06.007.
- Fevolden SE (1979) Investigations on krill (Euphausiacea) sampled during the Norwegian Antarctic Research Expedition 1976/77. Sarsia, 64, 189-198.
- Fevolden SE (1980) Krill off Bouvetoya and in the southern Weddell Sea with a description of larval stages of *Euphausia crystallorophias*. Sarsia, 65, 149–162.
- Flores H, Haas C, van Franeker JA, 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 BPV, Kruse S, Pakhomov EA, Siegel V, van Franeker JA, Strass V, Van de Putte AP, Meesters EHWG, Bathmann U (2014) Seasonal changes in the vertical distribution and community structure of Antarctic macrozooplankton and micronekton. Deep-Sea Research I, 84, 127-141.
- Forcada J, Trathan PN (2009) Penguin responses to climate change in the Southern Ocean. Global Change Biology, 15, 1618–1630, doi: 10.1111/j.1365-2486.2009.01909.x.

- Forcada J, Trathan P, Boveng PL, Boyd IL, Burns JM, Costa DP, Fedak M, Rogers TL, Southwell CJ (2012) Responses of Antarctic pack-ice seals to environmental change and increasing krill fishing. *Biological Conservation*, 149, 40-50.
- Fretwell PT, LaRue MA, Morin P, Kooyman GL, Wienecke B, Ratcliffe N, Fox AJ, Fleming AH, Porter C, Trathan PN (2012) An Emperor Penguin Population Estimate: The First Global, Synoptic Survey of a Species from Space. *PLoS ONE*, 7(4), e33751, doi:10.1371/journal.pone.0033751.
- Fretwell PT, Trathan PN, Wienecke B, Kooyman GL (2014) Emperor Penguins Breeding on Iceshelves. *PLoS ONE* 9(1), e85285, doi:10.1371/journal.pone.0085285.
- Galéron J, Herman RL, Arnaud PM, Arntz WE, Hain S, Klages M (1992) Macrofaunal communities on the continental shelf and slope of the southeastern Weddell Sea, Antarctica. *Polar Biology*, 12, 283-290.
- Garcia HE, Locarnini RA, Boyer TP, Antonov JI, Baranova OK, Zweng MM, Johnson DR (2010a) World Ocean Atlas 2009, Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation. In: Levitus S (ed.) NOAA Atlas NESDIS 70, U.S. Government Printing Office, Washington D.C., 344 pp.
- Garcia HE, Locarnini RA, Boyer TP, Antonov JI, Zweng MM, Baranova OK, Johnson DR (2010b) World Ocean Atlas 2009, Volume 4: Nutrients (phosphate, nitrate, silicate). In: Levitus S (ed.) NOAA Atlas NESDIS 71, U.S. Government Printing Office, Washington D.C., 398 pp.
- Gerdes D, Klages M, Arntz WE, Herman RL, 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.
- Gutt J (1988) On the distribution and ecology of sea cucumbers (Holothuroidea, Echinodermata) in the Weddell Sea (Antarctica). *Reports on Polar Research* 41, 1 – 87.
- Gutt J (1991) On the distribution and ecology of holothurians in the Weddell Sea (Antarctica). *Polar Biology*, 11, 145-155.
- Gutt J, Griffiths HJ, Jones CD (2013) Circum-polar overview and spatial heterogeneity of Antarctic macrobenthic communities. *Marine Biodiversity*, 43, 481-487.
- Haid V, Timmermann R (2013) Simulated heat flux and sea ice production at coastal polynyas in the southwestern Weddell Sea, *Journal of Geophysical Research*, 118(5), 2640-2652, doi:10.1002/jgrc.20133.
- 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.
- Hempel I, Hempel G (1982) Distribution of euphausiid larvae in the southern Weddell Sea. *Meeresforschung*, 29, 253-266.
- Hilbig B (2001) Deep-sea polychaetes in the Weddell Sea and Drake Passage: first quantitative results. *Polar Biology*, 24, 538-544.
- Hubold G, Hempel I, Meyer M (1988) Zooplankton communities in the southern Weddell Sea (Antarctica). *Polar Biology*, 8, 225-233.
- Hunewinkel T, Markus T, Heygster GC (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 BPV, Pakhomov EA, 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 BS, McIntyre T, Tosh CA, Bornemann H, Plötz J, Bester MN (2012) Inter-population differences in diving behaviour of adult male southern elephant seals (*Mirounga leonina*). *Polar Biology*, 35, 1759–1766.
- Janussen D, Tendal OS (2007) Diversity and distribution of Porifera in the bathyal and abyssal Weddell Sea and adjacent areas. *Deep-Sea Research II*, 54 (16/17), 1864-1875.

- 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 Atmospheric and Oceanic Technology*, 24, 1301–1308.
- 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.
- Linse K, Griffiths HJ, Barnes DKA, Clarke A (2006) Biodiversity and biogeography of Antarctic and Sub-Antarctic Mollusca. *Deep-Sea Research II*, 53, 985-1008.
- Locarnini RA, Mishonov AV, Antonov JI, Boyer TP, Garcia HE, Baranova OK, Zweng MM, Johnson DR (2010) World Ocean Atlas 2009, Volume 1: Temperature. In: Levitus S (ed) NOAA Atlas NESDIS 68, U.S. Government Printing Office, Washington, D.C., 184 pp.
- Makarov RR, Sysoeva MV (1985) Biology and Distribution of *Euphausia superba* in the Lazarev Sea and Adjacent Waters. *Hydrobiological Journal (Gidrobiologiceskij Zhurnal)*, 23, 95-99.
- Markus T, Burns BA (1995) A method to estimate subpixel scale coastal polynyas with satellite microwave data. *Journal of Geophysical Research*, 100, 16707–16 718.
- McIntyre T, Stansfield LS, Bornemann H, Plötz J, Bester MN (2013) Hydrographic influences on the summer dive behaviour of Weddell seals (*Leptonychotes weddellii*) in Atka Bay, Antarctica, *Polar Biology*, 36, 1693-1700.
- 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 WE (2005) Polychaete assemblages on the Magellan and Eddell Sea shelves: comparative ecological evaluation. *Marine Ecology Progress Series*, 297, 189-202.
- Nesis KN, Nigmatullin CM, Nikitina IV (1998) Spent females of deepwater squid *Galiteuthis glacialis* under the ice at the surface of the Weddell Sea (Antarctic). *Journal of Zoology*, 244, 185–200.
- Nordøy ES, Blix AS (2009) Movements and dive behaviour of two leopard seals (*Hydrurga leptonyx*) off Queen Maud Land, Antarctica. *Polar Biology*, 32, 263–270.
- Patterson DL, Woehler EJ, Croxall JP, Cooper J, Poncet S, Hunter S, Fraser WR (2008) Breeding distribution and population status of the Northern Giant Petrel *Macronektes halli* and Southern Giant Petrel *M. giganteus*. *Marine Ornithology*, 36, 115-124.
- 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, Pütz K (1994) Squid diet of emperor penguins (*Aptenodytes forsteri*) in the eastern Weddell Sea, Antarctica during late summer. *Antarctic Science*, 6, 241-247.
- 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.76 0099; doi:10.1594/PANGAEA.760100; doi:10.1594/PANGAEA.760 101.
- SC-CAMLR-XXXIII (2014) Report of the thirty-third meeting of the Scientific Committee. Hobart, Australia, 20-24 October, 397 pp.

- SC-CAMLR-XXXIII/BG/02 (2014) Scientific background document in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica) – Version 2014. Delegation of Germany, 110 pp.
- 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.
- Schüller M, Ebbe B, Wägele J-W (2009) Community structure and diversity of polychaetes (Annelida) in the deep Weddell Sea (Southern Ocean) and adjacent basins. *Marine Biodiversity* DOI 10.1007/s12526-009-0009-4.
- Schwabe E, Bohn JM, Engl W, Linse K, Schroedl M (2007) Rich and rare – first insights into species diversity and abundance of Antarctic abyssal Gastropoda (Mollusca) *Deep-Sea Research II*, 54, 1831-1847.
- Siegel V (1982) Investigations on krill (*Euphausia superba*) in the southern Weddell Sea. *Meeresforschung*, 29, 244-252.
- 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(8), 1151-1177.
- Siegel V, Reiß CS, Dietrich KS, Haraldsson M, Rohardt G (2013) Distribution and abundance of Antarctic krill (*Euphausia superba*) along the Antarctic Peninsula. *Deep-Sea Research I*, 177, 63-74.
- Southwell C, Bengtson J, Bester MN, 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.
- Spren 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.
- 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.
- 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 CA, Bornemann H, Ramdohr S, Schröder M, Martin T, Carlini A, Plötz J, Bester MN (2009) Adult male southern elephant seals from King George Island utilize the Weddell Sea. *Antarctic Science*, 21, 113-121.
- Van Franeker JA, Gavrilov M, Mehlum F, Veit RR, Woehler EJ (1999) Distribution and abundance of the Antarctic Petrel. *Waterbirds*, 22, 14-28.
- 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) Zoogeographie und Gemeinschaftsanalyse des Makrozoobenthos des Weddellmeeres (Antarktis). *Berichte zur Polarforschung*, 45, 145pp.
- 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.