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Antarctic Pack Ice Seals and oceanographic features at the Filchner Outflow System, southern Weddell Sea

Rationale

The Filchner Outflow System is one of the most important areas for Antarctic deep water formation. Here the outflow of Ice Shelf Water (ISW) of the Filchner Ronne Ice Shelf interacts with Warm Deep Water (WDW) of the Weddell Gyre circulation, resulting in Weddell Sea Deep and Bottom Water production (WSDW, WSBW). Modified WDW is found on the shelf. The interaction around the sill of the Filchner Trough is thought to result in a physical oceanography "hotspot" that may also aggregate primary and secondary producers, leading to increased abundance of top predators.

Fixed wing aircraft survey

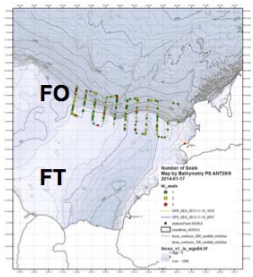

Fig. 2: ***All seals***

Filchner Outflow (FO)

Timing	*15. - 16.11.2013*
Aircraft	*POLAR 6*
Transects	*11*
Length	*132 km (70 nm)*
Spacing	*37 km (20 nm)*
Altitude	*200 m (600 ft)*
Velocity	*260 kmh⁻¹ (140 kts)*
Effort	*1,148 km (620 nm)*

Filchner Trough (FT)

Transects	*0*
Effort	*0 km (0 nm)*

Density *calculation by strip transect sampling*

Survey design

We conducted two aerial surveys to estimate density gradients and regional abundance of pack ice seals in the ice covered FOS. Transects flown by fixed wing aircraft (Fig. 2) and helicopter (Figs. 3 and 4) were placed perpendicular to the 1,000 m bathymetric contour, and extended if possible up to the 400 and 2,000 m bathymetric contours (Figs 3, 4). Helicopter transects in the northerly FO were superimposed on the transect grid flown by the fixed wing aircraft, though with less latitudinal extent and a doubling of the longitudinal density of transects to increase sampling intensity.

Helicopter survey

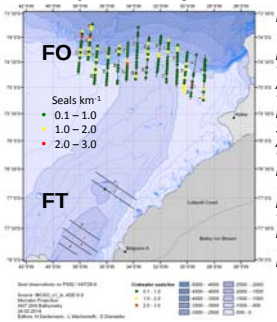

Fig. 3: ***Crabeater seals***

Filchner Outflow (FO)

Timing	*04.01. - 09.02.2014*
Aircraft	*POLARHELI 2*
Transects	*25*
Length	*56 km (30 nm)*
Spacing	*18.52 km (10 nm)*
Altitude	*60 m (200 ft)*
Velocity	*110 kmh⁻¹ (60 kts)*
Effort	*1,368 km (738 nm)*

Filchner Trough (FT)

Transects	*6*
Effort	*426 km (230 nm)*

Density *calculation by line transect sampling*

Oceanography

Seal counts were related to hydrographic features along the FOS (Fig. 1).

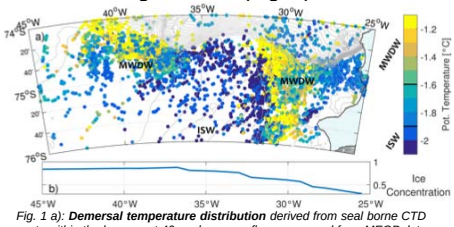

Fig. 1 a): ***Demersal temperature distribution*** *derived from seal borne CTD casts within the lowermost 40 m above sea floor processed from MEOP data (www.meop.net). The temperatures indicate the presence of very cold ice shelf water (ISW) within the Filchner Trough and of modified warm deep water (MWDW) further to the east and west on the shelf. The depth layer of MWDW coincides with preferred dive depths of Weddell seals instrumented with CTD-Satellite Relay Dive Loggers in synchrony with the seal survey.*

Fig. 1b): ***Latitudinal mean of sea ice concentrations*** *from the ERA-interim reanalysis (ECMWF) averaged between 2006 and 2016 indicate an increasing gradient from east to west along the FOS.*

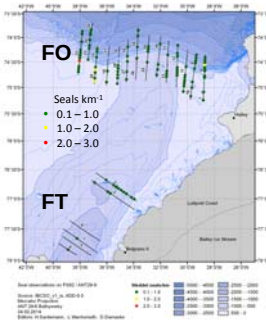

Fig. 4: ***Weddell seals***

Filchner Outflow (FO)

Timing	*04.01. - 09.02.2014*
Aircraft	*POLARHELI 2*
Transects	*25*
Length	*56 km (30 nm)*
Spacing	*18.52 km (10 nm)*
Altitude	*60 m (200 ft)*
Velocity	*110 kmh⁻¹ (60 kts)*
Effort	*1,368 km (738 nm)*

Filchner Trough (FT)

Transects	*6*
Effort	*426 km (230 nm)*

Density *calculation by line transect sampling*

Results

Fixed wing aircraft survey

265 seals were sighted on transect lines in the Filchner Outflow (**FO**) disregarding species composition. **Density estimate** for all seals were haulout corrected (0.8). **Gradients** are shown in Figs 5, 6.

- **ALL FO 0.5** seals km^{-2} (range 0.05 – 1.17)

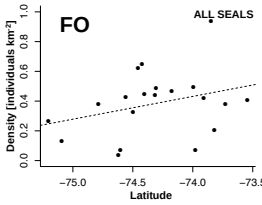

Fig. 5: ***Density across latitude*** *showed a weak correlation (β = 0.15 ± 0.11 SE; adjusted R^2 = 0.05, p = 0.18), possibly because we only surveyed a limited latitudinal gradient.*

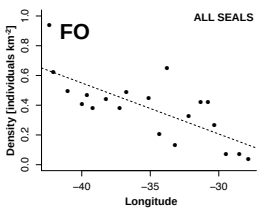

Fig. 6: ***Density across longitude*** *implied a significant longitudinal density gradient (β = - 0.034 ± 0.007 SE; adjusted R^2 = 0.51, p <0.001), from 0.04 seals km^{-2} (east) to 0.94 seals km^{-2} (west).*

Helicopter survey

754 crabeater (**CRA**) and 217 Weddell seals (**WED**) were counted. Filchner Outflow (**FO**) and Trough (**FT**) differed in **density estimates** (haulout corrected) and **gradients** (Figs 7, 8).

- **CRA FO 1.32** seals km^{-2} (1.09 – 1.61 95% CI)
- **WED FO 0.38** seals km^{-2} (0.21 – 0.68)
- **CRA FT 0.0078** s. km^{-2} (0.001- 0.06)
- **WED FT 0.14** seals km^{-2} (0.04 – 0.58)

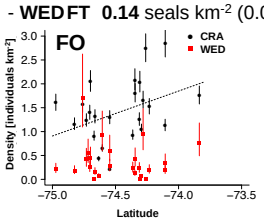

Fig. 7: ***CRA*** *density tended to be higher on transects with a more northerly mean latitude (β = 0.94 ± 0.46 SE, adjusted R^2 = 0.11, p = 0.05). No relationship existed between density and latitude for* ***WED****.*

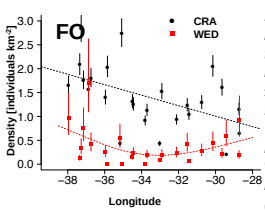

Fig. 8: ***CRA*** *density increased from east to west (linear regression; β = - 0.11 ± 0.04 SE, adjusted R^2 = 0.21, p = 0.01).* ***WED*** *density was higher on eastern and western transects and lower near FO centre (generalised additive model; adjusted R^2 = 0.21, p = 0.09).*

Conclusions

Fixed wing aircraft survey

- 265 seals were counted on transect lines during the fixed wing aircraft digital imaging survey in November 2013 with a higher encounter rate on transects located further to the west.

Helicopter survey

- Only crabeater (n = 754) and Weddell seals (n = 217) were encountered.
- Seal density differed latitudinal between survey regions, with only very few seals encountered in the more southerly FT.
- Density increased longitudinal from east to west along FO in January 2014 supporting the results of the fixed wing aircraft survey, but challenge the idea of a top predator (seals) hotspot at the sill of the Filchner Trough.

Oceanography

- Crabeater seal density along FO seems to coincide with ice concentration.
- Weddell seal density along FO seems to coincide with presence of MWDW near the bottom.

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All data are available via the Data Publisher for Earth & Environmental Science PANGAEA (www.pangaea.de):
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