The Occurrence of Cetaceans along two Transects from 57° S to Atka Bay (70°29.6' S/07°57.6' W)

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Abstract

Following a successful pilot study in 2006 the German research vessel 'Polarstern' conducted a cetacean sighting survey in the Southern Ocean using helicopters near the Greenwich meridian from 12 to 27 December 2008. The cetacean survey was part of cruise leg ANT XXV/2 from 5 December 2008 to 5 January 2009. Two transects were covered: the first more westerly one started at 57°09.3' S/00°39.1' E and went to Atka Bay (70°29.6' S/07°57.6' W) whereas the second (return leg) followed a more easterly course from Atka Bay over Maud Rise to 57°03.1' S/12° 27.5' W. No observations could be conducted from 63 to 57°S on the return cruise due to fog (visibility < 300 m) and swell. Standard line transect survey protocols were followed when the helicopter flew pre-designed track lines. We were particularly interested in the distribution and abundance of minke whales in the pack-ice. Helicopter tracklines covered a total of 6321 km. Environmental information, including proportion ice coverage, was collected continuously. A total of 24 sightings of 28 minke whales were recorded with a maximum group size of 3. In addition 5 southern bottlenose whales and 1 killer whale were sighted inside the ice whereas several species were seen in open water north of 55°S. Helicopters can provide a useful means to collect sighting data for cetaceans. They cover long distances effectively and, in contrast to vessels, are particularly suitable of surveying areas of dense pack-ice.

Introduction

IDCR/SOWER (International Decade of Cetacean Research and Southern Ocean Whale Ecosystem Research) cruises to estimate whale abundance (primarily minke whales, *Balaenoptera bonaerensis*) have been conducted within the remit of the IWC since

1978/79 during three circumpolar cruises (CP I, II, and III). They extended from 60° S as far south as the northern limit of the pack-ice (e.g. Branch and Butterworth 2001; Ensor et al., 2007). Due to logistic constraints, IWC/SOWER cruises could not penetrate into the pack–ice. Therefore, they were not able to account for those whales that inhabit the pack-ice at the time of the survey. Furthermore, substantial changes made to survey and experimental design and equipment after CP I had finished in 1983/84, made CP I not as easily comparable as CP II and CP III (Branch and Butterworth, 2001).

Considerable differences in abundance estimates of minke whales in the Southern Ocean exist between those estimated from CP II and CP III. The abundance estimate from the third circum-Antarctic survey accounted for only 55 (closing mode) to 45% (IO mode) of the two first cruises (Branch and Butterworth, 2001). A large part of these differences still awaits reconciliation. Hypotheses have been brought forward to explain at least part of these differences (e.g. Branch, 2007; Okamura and Kitakato, 2007, 2008; Matsuoka et al., 2008). One hypothesis suggests that the differences are due to a large number of minke whales inhabiting sea ice-covered waters (Shimada and Kato, 2002a, b, 2003, 2005, 2007). The difficulty in testing or rejecting this hypothesis remains in the fact that the survey vessels currently being used for IDCR/SOWER cruises are unable to penetrate far enough into the ice to test this hypothesis and few cruises have been undertaken in the pack-ice (Thiele et al., 2002, 2004; Shimada and Kato, 2005; Scheidat et al., 2007) to test this hypothesis.

Previous studies (Plötz et al., 1991; Franeker, 1992; Scheidat et al., 2007) have demonstrated that helicopters provide a useful means to survey cetaceans in the pack-ice. We extended our effort in December 2008 when we conducted a second aerial survey from board the German research vessel ‘Polarstern’ en route from 57° S to Atka Bay and back to 57° S. The cruise was primarily an oceanographic cruise, and this determined the cruise track on which the cetacean observations piggybacked. We report here on preliminary results of cetacean observations in the course of this cruise with emphasis on abundance of minke whales in the pack-ice.

Material and Method

RV ‘Polarstern’ left Cape Town on 6 December 2008. The cetacean survey started at 57° S on 12 December and ended at 57° S on 27 December 2008. The cruise track of the outward voyage followed an almost straight line from 57° S to Neumayer in Atka Bay (70°29.6’ S/07°57.6 W, see Figure 2) with very few limited detours around particularly heavy ice fields which the vessel avoided to reduce fuel consumption (Figure 1a - c). The return voyage took place further to the east, with transects that included a series of CTD casts conducted on Maud Rise (Figure 2). The vessel returned to Cape Town in the morning of 5 January 2009. The cruise track as well as information on those portions of the cruise track covered by helicopter flights is provided in Figure 2. Speed of the ‘Polarstern’ was 6 –10 knots depending on the ice conditions.

The aerial survey followed standard line transect (distance sampling) methodology. Flying altitude was 600 feet; the helicopter’s speed was 80 knots. The first observer/data recorder occupied the port front seat of the helicopter and observed the area to the front while focusing on the transect line. The second observer was positioned behind the first observer and observed the port side of the helicopter, perpendicular to the cruise track (Scheidat et al., 2007). In contrast to 2006/07, a third observer was placed behind the pilot and observed the starboard side of the helicopter.

During each flight GPS position and information on ancillary environmental parameters were collected continuously using the software ‘VOR’. GPS positions were continuously recorded. Environmental data collected included the proportion of ice cover, sea state, cloud cover, glare, and glare intensity. A digital tape recorder provided an audio backup for later reference. The following information was recorded for each whale sighting: species, group (pod) size, group composition, inclination angle, behaviour, cue, swimming direction, dive, and possible reaction to the helicopter. When a sighting occurred abeam an inclinometer was used to record the vertical angle which was later converted into perpendicular distance from transect.

Results

Sea ice conditions

RV ‘Polarstern’ entered loose pack - ice at about 58° 20’ S late on 12 December 2008 and soon hit dense pack–ice concentrations (Figure 1a). The survey in 2008 was conducted almost 3 weeks later than the survey in 2006 (Scheidat et al., 2007). However, mean ice cover was almost 10% higher than in late November/early December 2006.

Dense pack–ice (ice coverage 60–90%) prevailed with limited areas of more open water between 62 and 64° S. However, some open water among the multi-annual and annual sea-ice was common. Freezing of leads during the day was restricted to areas closer to the continent (south of 65-66° S). The vessel reached the fast ice in the vicinity of Neumayer Station in the morning of 17 December 2008 after travelling more than 700 nm through the ice. Sea ice conditions and progressive opening of the polynya between 62° and 64° S are shown in Figure 1b during the time when the vessel was moored at the fast ice close to Neumayer Station.

The vessel left Neumayer Station in a north-easterly direction in the early morning of 20 December. The easternmost extent of Maud Rise was reached on 23 December. Ice coverage including both multi-annual and annual ice was 40–60%, attaining 60 – 80% in some limited areas. The conduct of a number of CTD casts and the recovery of 2 oceanographic moorings lasted until the morning of 26 December while the vessel moved progressively further north. RV ‘Polarstern’ continued her return journey to Cape Town on 26 December and left the pack-ice at 58°00’ S/12° 10’ W on 27 December 2008 in the afternoon. Figure 1c demonstrates that the polynya had opened further and the ice had largely receded from most parts of the north-eastern Weddell Sea by late December. However, the coarse scale of the ice charts is somewhat misleading. RV ‘Polarstern encountered large fields of annual ice of 30–50% coverage in some cases on its northward journey as far north as 58° 30’ S where the ice charts indicated little or no ice. No sighting observation could be conducted from 63 to 57° S due to poor visibility caused by dense fog (< 200m) and high sea swell (> 3m).

The average sea ice coverage per helicopter flight ranged from 19 to 86%. Mean ice cover in December 2008 was 51.7%.

Sightings

Twenty-two helicopter flights were conducted which covered 6321 km of trackline (Figure 2). A total of 24 minke whale groups were sighted, which consisted of 28 animals. Mean group size was 1.17, with a maximum group size of three animals. Most minke whales (61%) were initially detected by their body breaking the surface, 35% by their footprint on water and 4% spotting the body underneath the surface. None of the whales showed an obvious reaction to the passing or hovering helicopter.

Effort per survey flight ranged from 220km to 364km, with a corresponding flying time of 1.48 to 2.46 hours. Table 1 provides an overview of all sighting rates of minke whales during the 22 helicopter flights south of 57°S. No minke whales were seen north of the Marginal Ice Zone (MIZ). The highest sighting rate was recorded during survey H14 with 0.016 sightings per km.

The distribution of group sizes was similar to that reported in 2006/07 (Scheidat et al., 2007). Groups consisted primarily of solitary animals. Group sizes > 2 were rarely encountered (Figure 3).

Main behaviour of minke whales was directional swimming (65%), followed by slow swimming (18%), milling (4%) and feeding (4%). Feeding was supposed in one animal that made repeated shallow dives under the sea ice with an opened mouth.

In addition to minke whales two groups of southern bottlenose whales (*Hyperoodon planifrons*) consisting of 2 and 3 individuals were sighted north of the first survey track (Figure 2). An indiual killer whale (*Orcinus orca*) was observed in the coastal polynya close to the Antarctic continent (Figure 2).

Discussion

It has been demonstrated previously (Plötz et al., 1991; van Franeker, 1992; Scheidat et al., 2007) that helicopters provide a useful mean to survey the abundance of cetaceans and other marine mammals in the pack–ice. Helicopters provide several advantages to vessels in the pack – ice:

- Large areas can be surveyed in a comparatively short period of time of 2 - 3 hours;

- the design of track lines can be adapted close to the start of each survey flight to capture specific environmental features such as areas of high ice coverage or seamounts or to avoid adverse weather conditions locally;
- the flight can be discontinued at any time to position the helicopter in such a way that sightings can be properly identified, ID photographs can be taken, and group size can be estimated more precisely, and
- a generally low sea state in the ice allowed observations of whales down to 3–4 m water depth from above.

It is difficult to assess whether sighting rates obtained during our two surveys in 2006/07 (Scheidat et al., 2007) and 2008 (3 observers) by helicopter were directly comparable to sighting rates obtained from the bridge of RV 'Polarstern' (2 observers) during ANT XXI/4 (27 March to 6 May 2004) in the same area. In 2004, results obtained inside and outside the pack-ice combined (0.0160 whales per km) (McKay and Asmus, 2005) were slightly higher than ours obtained in the pack-ice only. Similar densities of minke whales in the close pack-ice were observed during shipboard surveys in the northern and central Weddell Sea in October-November 1988 (Joiris, 1991) and in the Ross Sea in May – June 1998 (van Dam and Kooyman, 2004).

Similar whale densities during previous surveys and our more recent observations might reflect a more general pattern of minke whale density in the retreating pack-ice of the eastern Weddell Sea. Minke whale density in the retreating pack–ice of the western Weddell Sea, albeit observed one month later was several-fold larger than in the eastern Weddell Sea (Scheidat et al., 2007) which illustrates the difficulty of extrapolating minke whale densities from limited observations to larger areas.

Minke whales were rarely sighted in front of the ice edge even when euphausiids were abundant and visible at the surface (see also Murase et al., 2002). Species diversity of the cetacean community changed remarkably with distance to the ice edge (Kasamatsu, 2000). Species diversity during IDCR cruises from the late 1970s to the late 1980s was lowest at the ice edge and increased until 200 nm from the ice edge when diversity started to decline again (Kasamatsu, 2000). Kasamatsu suggested that the MIZ as an area of high productivity attracts baleen whales.

It has been well established since the 1980s that (adult) minke whales inhabit the pack-ice year-round with a preference for areas of lighter ice cover (<50%) and leads and polynyas (Taylor, 1957; Naito, 1982; Ainley, 1985, 2007; Ensor, 1989; Ribic et al., 1991; Plötz et al., 1992; van Franeker, 1992; Aguayo – Lobo, 1994a, b; Kasamatsu et al., 1996, 1998a, b, 2000; Joiris, 1991, 2000; Thiele et al, 2000, 2002, 2004, 2005; Shimada and Kato, 2005; Scheidat et al., 2007).

Our understanding of the distribution pattern of minke whales in and outside the pack-ice, however, is limited. There is evidence from several studies now for a close relationship among sea-ice, cold water, and minke whale distribution and abundance: extension of sea-ice cover in the Ross Sea in 1994/95 covered the typically krill-rich slope region during summer (which also provides other abundant euphausiids such as *E. crystallorophias* and *Thysanoessa macrura*, the hyperiid *Themisto gaudichaudii*, and the Antarctic silverfish *Pleuragramma antarcticum* as secondary food items locally which were often observed together with abundant krill in the stomach contents, Bushuev, 1986; Ichii and Kato, 1991; Tanura and Konishi, 2006), and prevented minke whales to exploit this habitat in the usual manner. As a consequence, body fat condition of minke whales was poorer than in ‘normal’ years (Ichii and al., 1998).

Based on sightings obtained from mid-February to end of March, Ainley et al. (2007) found a significant inverse relationship between minke whale density and sea ice concentration in the Amundsen and Bellingshausen Seas, switching offshore to the MIZ once waters within the pack-ice began to freeze permanently. Kasamatsu et al. (2000) obtained evidence that lower sea surface temperature and sea floor type associated with the extent of sea-ice and cold water intrusions influenced the distribution and abundance of minke whales in the Bellingshausen Sea. Ichii (1990) speculated that the formation of krill concentrations induced by oceanographic fronts over the shelf break and banks is another important factor influencing the distribution and abundance of minke whales. Indications for a close relationship of whale distribution and oceanic fronts was also described by Tynan (1997) and Kasamatsu et al. (1998b). Tynan (1997), Kasamatsu et al., 1998b), and Ainley et al. (2007) suggested that neither sea-ice nor sea surface temperature alone are sufficient to explain minke whale abundance but that the complex dynamics of several processes were responsible in shaping the distribution and abundance of minke whales. Nicol et al. (2008) condensed these findings into a complex spatial structure in which baleen whales live in relation to their prey and environment at meso and micro-scales.

Sea-ice coverage, density and extent have undergone considerable changes in the Southern Ocean since first records exist from whaling in the early 1930s (de la Mare, 1997, 2002). Although it is still debatable whether sea-ice has retreated on a circum-Antarctic scale (Ackley et al., 2003) it is widely accepted that sea-ice has retreated regionally. This has particularly been the case regionally in the Atlantic Ocean sector and the neighbouring Antarctic Peninsula. These regions have seen considerable variability in sea-ice retreat and warming of the area (Antarctic Peninsula) (Cotté and Guinet, 2007). Ainley et al. (2007) stressed the need for further collection of information on minke whale density in and adjacent to the pack-ice.

One of the important processes shaping the use of habitat is food. Murase et al. (2002) found that minke whale concentrations were mostly observed along the ice edge over the continental slope in summer between 35° E and 145° W. They were rarely seen offshore even when krill was abundant. It remains questionable if the MIZ in summer (when the IDCR cruises took place) is the zone of highest krill biomass and thus the most favourable feeding ground for minke and other baleen whales. Considerable inter-annual variability in the distribution of krill biomass over large oceanic areas (and not concentrated along the MIZ) casts further doubts on the validity of this hypothesis (Atkinson et al., 2008). Regional krill abundance in summer appears to be positively correlated to the extent of sea-ice in the previous winter (Brierley et al., 1999; Hewitt et al., 2003). It is debatable, however, if such a simple cause-and-effect relationship exists between the extent of sea-ice and krill and whether climate change is having already an adverse effect on krill abundance (Atkinson et al., 2004; Nicol et al., 2008).

It seems that prey distribution may not be the only driver of habitat selection: the avoidance of inter-specific competition appears to be another reason for minke whales to prefer ice-laden habitats. Minke whales and humpback whales, for example, utilize different feeding areas possibly to avoid competition for food (Murase et al., 2002). Finer-scale analyses note that minke and humpback whales avoid competition by targeting different water depths and size classes of krill (Friedlaender et al, 2008). It remains debatable whether minke whales utilize the pack-ice to avoid predation by killer whales (Murase et al., 2002). Killer whales have been observed as deep into the pack-ice as minke whales (Gill and Thiele, 1997; Thiele and Gill, 1999; Scheidat et al., 2007). Attacks of killer whales on minke whales have also been observed in the pack-ice (Murase et al., 2002).

Oceanographic data from our cruise still await analysis. Unfortunately, time constraints did not allow sampling *E. superba* and other potential prey species in the course of the cruise. The food intake of minke whales was found to be several times higher in the closed pack-ice than in the outer and inner MIZ (Joiris, 1991) in spring (mid-October to mid-November) making this region potentially more attractive to minke whales while relying on feeding of krill under the sea-ice.

School size of minke whales consisted mostly of one individual and less often of two whales while larger schools were rarely encountered in the pack-ice both in 2006/07 and 2008. No schools of minke whales were detected in open water close to the pack-ice on the southward journey. No observations were possible on the northward journey due to poor visibility caused by dense fog (Figure 2). Similar school sizes were observed in autumn – winter in the Ross Sea (Ribic et al., 1991). Peak densities of minke whales have been found close to the ice edge in January (Kasamatsu, 1996). School size in open water close to the pack-ice tends to be larger. Individuals tend to find more members of their own species in their immediate vicinity than would be expected in a random distribution. Whale density in these patches approaches a constant value when optimum density is attained (Kasamatsu et al., 1998a).

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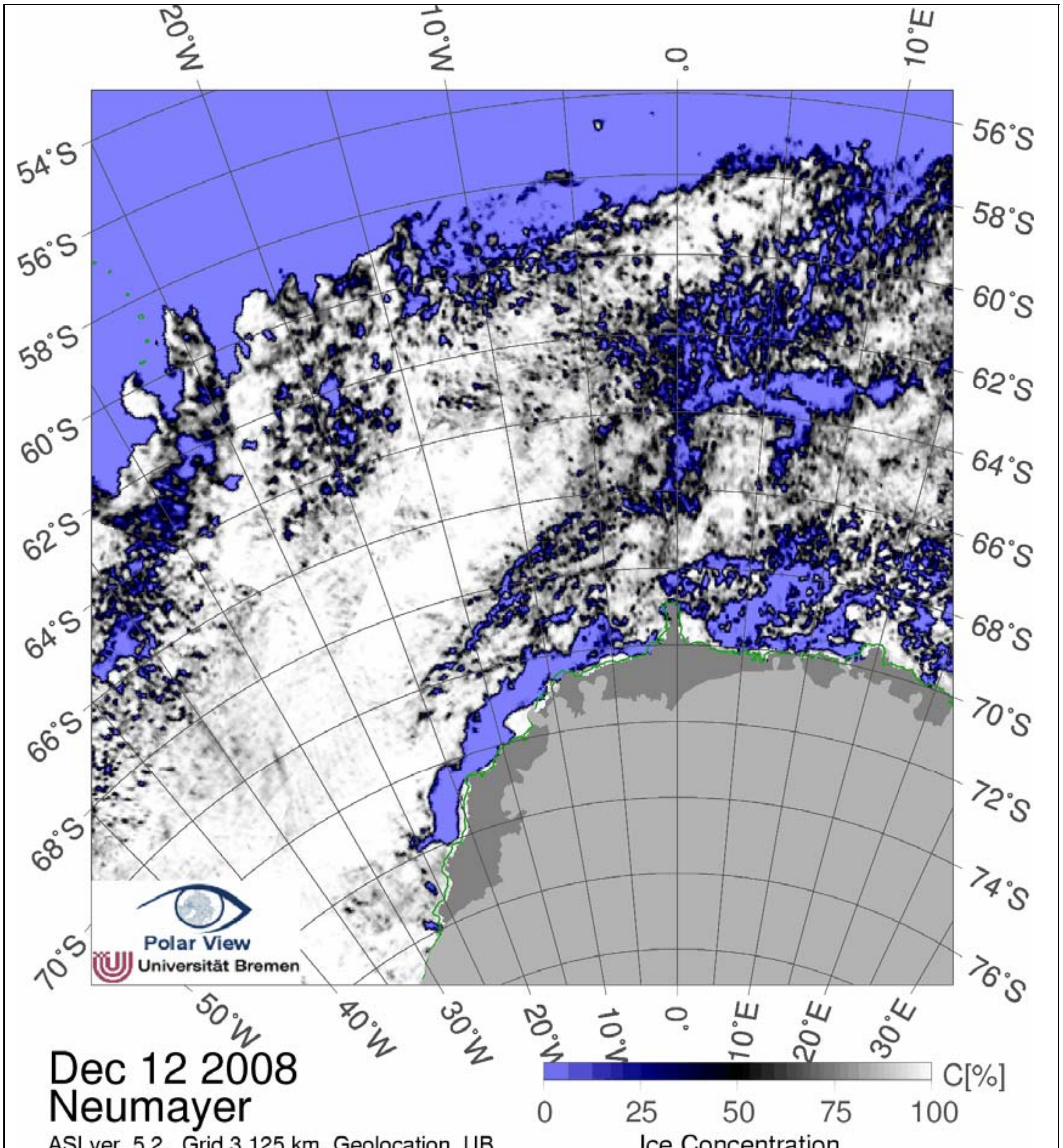

Fig. 1a: Ice situation on 12 December 2008 when RV 'Polarstern' entered the pack - ice Bay.

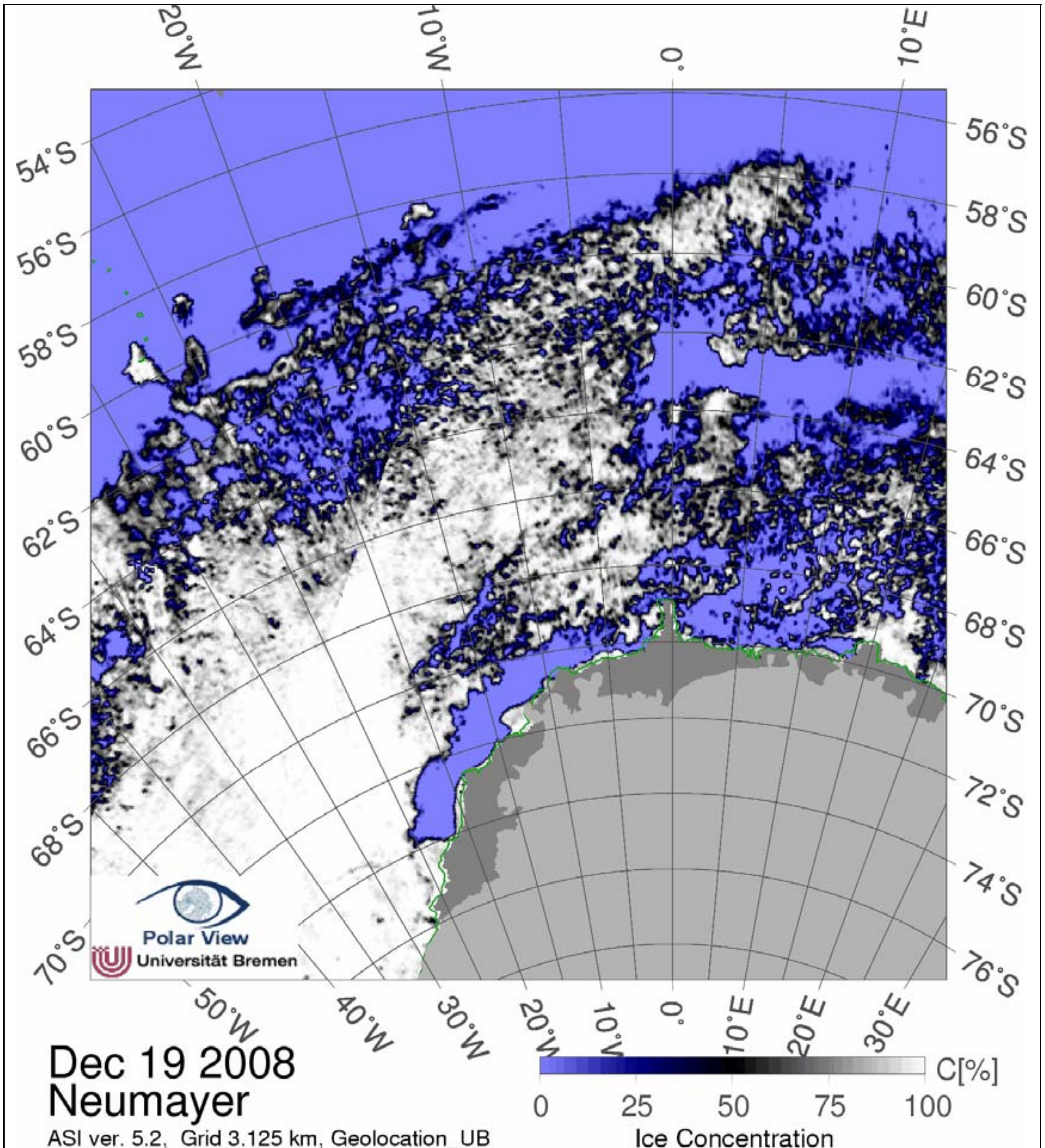

Fig. 1b: Ice situation on 19 December 2008 when RV 'Polarstern' was at Neumayer in Atka Bay.

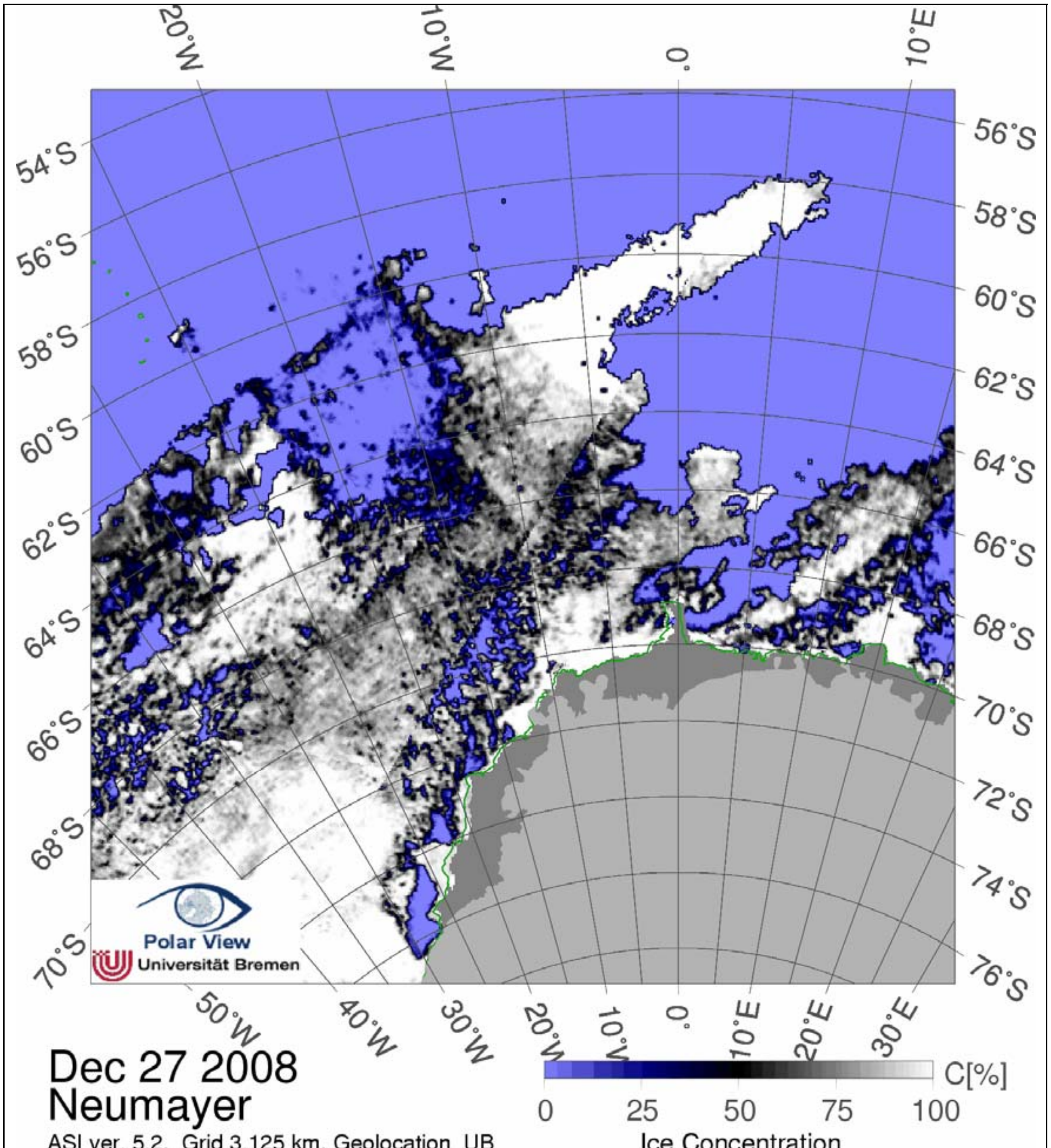

Fig. 1c: Ice situation on 27 December 2008 when RV ‘Polarstern’ left the pack - ice

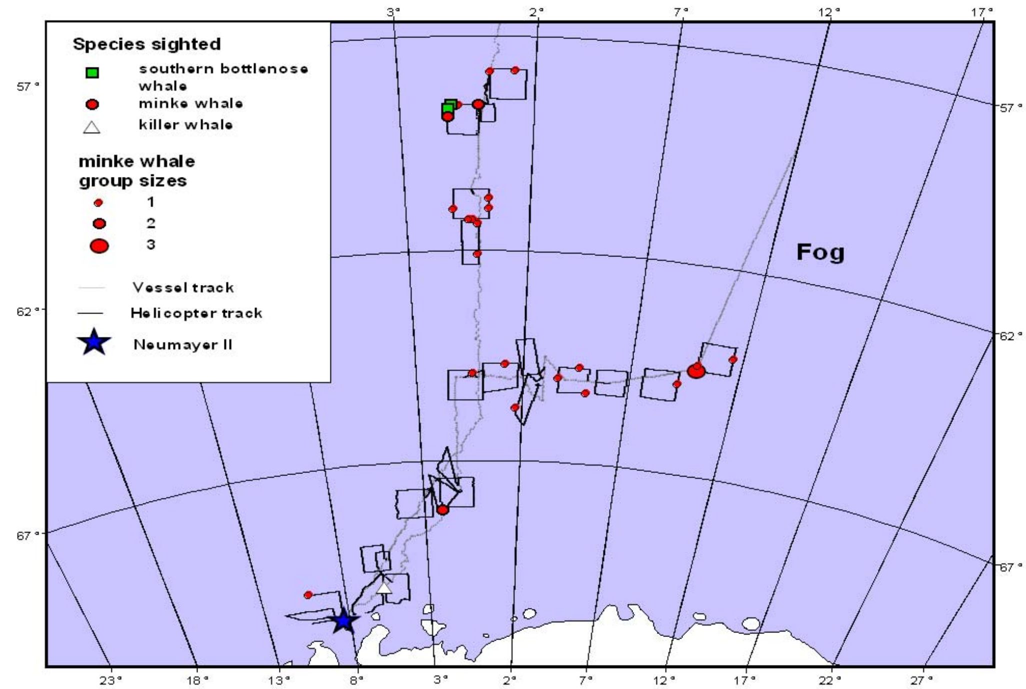

Figure 2: Sightings of cetaceans south of 57° S

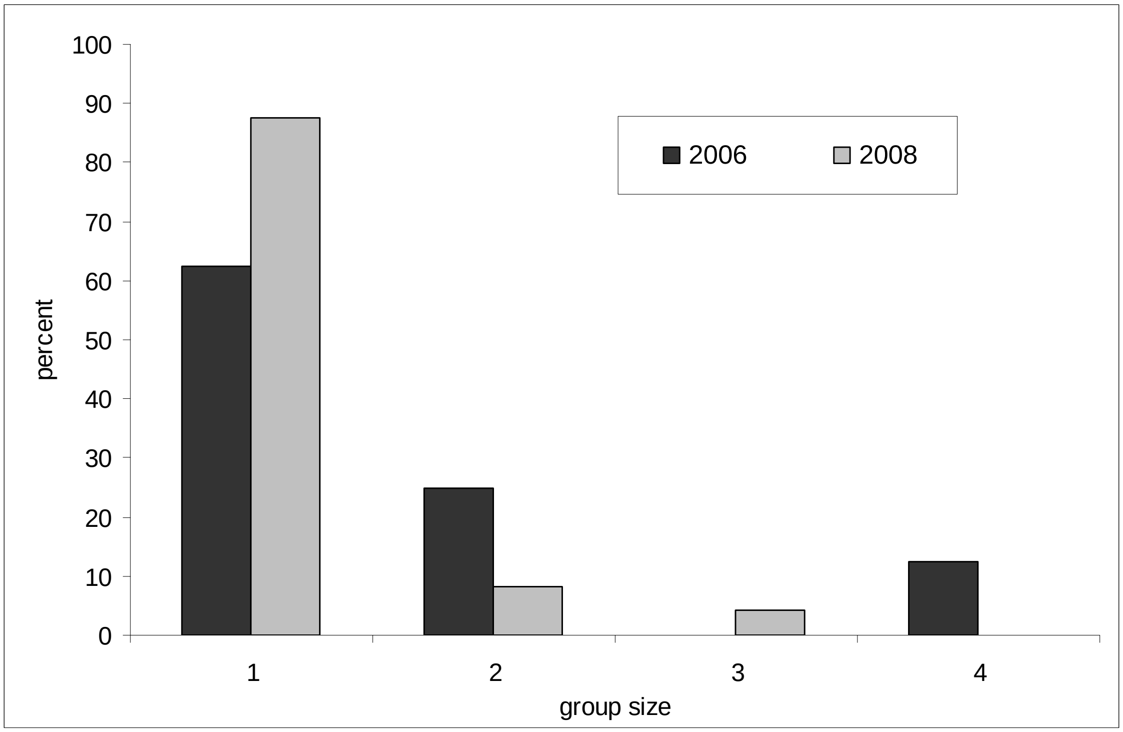

Figure 3: Distribution of group sizes in minke whales in 2006/07 (n=18) and 2008/09 (n=24) in the eastern Weddell Sea

Table 1: Overview of conducted helicopter surveys south of 57°.

Survey	km on effort	latitude	longitude	average ice coverage %	sightings of minke whales	number of minke whales	sightings / km	animals / km
H11	346	-58.25	0.98	29	2	2	0.006	0.006
H12	220	-58.76	0.32	59	0	0	0.000	0.000
H13	323	-59.03	-0.49	63	2	3	0.006	0.009
H14	316	-60.99	-0.28	62	5	5	0.016	0.016
H15	311	-61.86	-0.32	51	2	2	0.006	0.006
H16	303	-67.65	-1.15	82	0	0	0.000	0.000
H17	334	-67.87	-3.24	72	0	0	0.000	0.000
H18	321	-69.13	-5.63	73	0	0	0.000	0.000
H19	280	-69.82	-4.75	46	0	0	0.000	0.000
H20	214	-70.16	-8.55	36	1	1	0.005	0.005
H21	243	-70.29	-9.70	19	0	0	0.000	0.000
H22	248	-69.98	-6.18	38	0	0	0.000	0.000
H23	263	-67.69	-1.88	51	1	2	0.004	0.008
H24	276	-67.15	-1.46	86	0	0	0.000	0.000
H25	336	-65.14	-0.56	42	1	1	0.003	0.003
H26	279	-64.97	0.96	53	1	1	0.004	0.004
H27	308	-65.45	2.27	65	1	1	0.003	0.003
H28	289	-64.55	2.29	51	0	0	0.000	0.000
H29	221	-64.97	4.22	41	3	3	0.014	0.014
H30	282	-64.99	6.04	40	0	0	0.000	0.000
H31	299	-64.90	8.31	50	1	1	0.003	0.003
H32	309	-64.18	10.52	29	3	5	0.010	0.016