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Influence of sea ice concentration on Antarctic minke whale abundance estimation in the Ross Sea

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ABSTRACT
The relationship between the sea ice condition and the abundance estimates of Antarctic minke whales in the Ross Sea was examined using the IDCR/SOWER and JARPA II survey data. For both IDCR/SOWER and JARPA II surveys in the Ross Sea, abundance estimates were high when small ice extended in the survey area. In contrast, the abundance estimates were low when the sighting surveys were limited due to large sea ice extent. Sea ice concentration anomalies in January from 1976 to 2008 were also examined. At the Ross Sea, the sea ice concentration anomaly during CPII (1986) was almost lowest in the past 30 years, indicating that during CPII the sighting survey was able to cover the research area thoroughly. In contrast, the sea ice concentration anomaly was high during CPIII (2004), indicating the sighting survey was unable to cover most, if not all, of the research area. All of the information indicated that the survey coverage differed markly between CPII and CPIII. Estimates of recent JARPA II in 2006/07 and 2008/09 seasons suggested large fluctuation in abundance estimates between 2 seasons. Magnitude of the fluctuation was four folds, possibly because of change in the sea ice extent, concentration and configurations in the Ross Sea. Recent sighting surveys conducted on the Japanese, German and Australian ice breakers and aerial surveys reported the existence of Antarctic minke whales in the sea ice areas. These observations suggest a relationship between abundance estimate and ice extent. Estimation of trend of abundance requires consideration of the effect of sea ice, particularly of year to year changes observed in sea ice extent; concentration and configurations.

KEY WORDS: ANTARCTIC, SURVEY-VESSEL, ABUNDANCE ESTIMATE, SEA ICE, ANTARCTIC MINKE WHALE

INTRODUCTION

In recent years, SC/IA sub-committee recommended that the issue of sea ice condition in research areas that appeared to influence abundance estimates of Antarctic minke whales should be examined using sea ice condition indices such as sea ice concentration ("Changes in the location of the ice-edge and the proportion of animals south of the ice-edge"; IWC, 2003, 2005; Branch, 2007). The sub-committee also concerns about estimation of the Antarctic minke whales abundance inside of sea ice. Some preliminary studies for this including spatial analysis have been presented (IWC, 2006, 2007, 2008).

It has been observed that Antarctic minke whales are concentrated along the ice edge. Similarly, Kasamatsu *et al*. (2000) reported a significant negative correlation between Antarctic minke whale encounter rates and distance from the sea ice edge. In addition to that, recent sighting and aerial surveys conducted by the Japanese, German, and

Australian ice breakers and airplanes that covered the areas where SOWER vessels were not able to enter due to sea ice reported existence of many Antarctic minke whales in such areas (Shimada and Murase, 2006, Shimada and Kato, 2007, Scheidat, 2007, Kelly *et al.*, 2008). Therefore, abundance of Antarctic minke whales estimated from the data that was unable to cover these areas should be underestimated.

Last year, we hypothesized that, as the abundance estimates from CPII and CPIII from a given statistical area were substantially different, the sea ice conditions should have been also quite different between the two. In fact, this relationship was clearly seen in Area II (Weddell Sea) and Area V (Ross Sea) where the shape of ice field varies substantially year by year due to changes in the sea ice and meteorological conditions. Abundance estimate was high at the year when the survey was able to cover the statistical area thoroughly, and was low when the survey was not able to do so due to the high ice concentration. Recent sighting survey conducted on the Japanese, German and Australian ice breaker and aerial survey reported existence of Antarctic minke whales in such areas. These observations strongly support this hypothesis and further qualitative analysis is required to accommodate the discrepancy (Matsuoka *et al.*, 2008).

This year, in this document, we focused the Ross Sea (south of 69°S) which Antarctic minke whale abundance estimates were showed large fluctuation between CPII and CPIII. Further, we also using recent JARPA II estimates (two seasons), which were also showed large fluctuations between two seasons.

MATERIAL AND METHODS

The IDCR/SOWER sighting survey data (the ice edge lines, the searching effort and the primary sightings) were provided by the IWC/ Database and Estimation Software System (DESS). To see the effect of change in sea ice concentration on abundance estimation of Antarctic minke whales in the Ross Sea, January sea ice concentration anomaly by each latitudinal sector from 69°S to the Antarctic continent from 1979 to 2008 was calculated using satellite derived monthly sea ice data, Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I (Comiso, 1999). Resolution of original data was 25 * 25 km grid in polar stereographic projection and sea ice concentration in each grid was available in the original data. Firstly mean sea ice concentration by each latitudinal sector from 69°S to the Antarctic continent in each year was calculated using original data. Secondary, anomaly from mean sea ice concentration values from 1979 to 2008 for respective latitudinal sector was calculated. The 2009 data was not available at this moment. The anomaly data were then plotted on time series contour plot. To clarify the effect of sea ice of abundance estimation of Antarctic minke whale, past papers (Murase and Shimada, 2004; Shimada and Murase, 2006) were revisited in this paper.

The JARPA II dedicated sighting survey data (the same as above) were also used in this paper. Abundance estimates of Antarctic minke whale in the Ross Sea in 2006/07 and 2008/09 seasons which assuming $g(0)$=1, were provided by one of the Authors (TH).

RESULTS AND DISCUSSIONS

The abundance estimates at Area V substantially differed between CPII and CPIII (Okamura and Kitakado, 2009). At the Area, the abundance estimates were high during CPII and low during CPIII. This could indicate a decrease of Antarctic minke whales over time or it could simply be due to operational difficulties on sea ice field. At this time, we go for the latter explanation because it is known that concentration and configuration of sea ice usually varies substantially year by year especially at the Ross Sea, resulting in changes in coverage area for the sighting survey followed by subsequent underestimation of Antarctic minke whales abundance. Antarctic minke whale abundance must be underestimated if sighting survey cannot cover all of the water in the research areas due to the higher sea ice concentration that prevent the research vessels but not Antarctic minke whales. As same as last year (Matsuoka *et al.*, 2008), we thus hypothesize that, if abundance estimates from CPII and CPIII from the same statistical area were substantially different, the sea ice condition should have been also quite different between the two.

Secondary, the sea ice condition during CPII to that during CPIII at the Ross Sea was carefully compared (Figures 1, 2 and 3). As a result, during CPIII, the ice edge was extended southwestward at the Ross Sea. There was an extensive sea ice area in the eastern part of the Ross Sea. The vessels could not survey this area and a narrower area of coverage by the CPIII. This ice condition should have resulted in substantial reduction in coverage for sighting survey followed by low abundance estimates during CPIII compared to CPII. In almost of this extensive sea ice area, sea ice concentrations were between 12% (light blue colored) and 50 % (light orange colored), which prevent the research vessels but not Antarctic minke whales.

Then the level of sea ice concentration anomalies in January from 1976 to 2008 was compared between CPII and CPIII (Figure 4). At the Ross Sea, the sea ice concentration anomaly during CPII (1986) was the lowest in the past 30 years, indicating that during CPII the sighting survey were able to cover the research area thoroughly. In contrast, the sea ice concentration anomaly was high during CPIII (2004), indicating the sighting survey was unable to cover most, if not all, of the research area. In fact, in 2002/03 season, SOWER vessels gave up the Ross Sea survey due to abnormal sea ice extent. All of the information indicated that at the Ross Sea, the areas covered by the sighting survey quite differed between CPII and CPIII.

For the JARPA II estimates, the large fluctuation of abundance estimates of Antarctic minke whales was observed in the two seasons (2006/07 and 2008/09 seasons) in the Ross Sea. Comparison of these estimates which assuming *g(0)*=1, were 19,400 (CV=0.176) in 2006/07 season and 87,643 (CV=0.166) in 2008/09 season, respectively (Hakamada, per.com, in prep.). The estimate showed large fluctuation in the magnitude of four folds possibly during 2 years. Influence of the sea ice concentration was thus clearly seen on abundance estimates of Antarctic minke whales during these seasons (Figures 5 and 6). As we hypothesized, at the Ross Sea, a negative relationship was detected as the abundance estimate was lower with higher sea ice concentration. Such phenomena were observed possibly because Antarctica land shape and ice shape was variable in the Ross Sea.

Resent sighting survey conducted on the Japanese, German, and Australian ice breakers in fact reported existence of many Antarctic minke whales within the ice edge areas (Shimada and Murase, 2006, Shimada and Kato, 2007, Scheidat, 2007). Spatial analysis also showed similar results (Murase *et al.*, 2005; IWC, 2006). These observations suggest a relationship between abundance estimate and ice extent. Further studies are necessary to investigate large impact of sea ice conditions on Antarctic minke whale abundance estimation especially in Area V (Ross Sea) such as case study of analysis by 10 degree longitudinal slices for small scale study area which already started in IA e-mail sea ice working group (Shimada and Burt, 2007).

It is concluded that estimation of trend of abundance requires consideration of the effect of sea ice, particularly of year to year changes observed in sea ice extent; concentration and configurations. This trend should only be interpreted as 2 abundance estimates at 2 different times under different sea ice extent, concentration and configuration.

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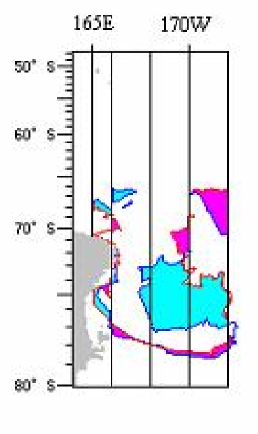

Figure 1. Ice edge anomaly between CPII and CPIII in the Ross Sea (south of 69°S between 165°E to 170°W (including west of 165°E and east of 170°W in the inner part of the Ross Sea). Grey color shows the Antarctica. Pink color shows extent sea ice north CPII than CPIII and blue color shows it extent north CPIII than CPII (Shimada and Murase, 2006). There are large unsurveyed areas in the Ross Sea.

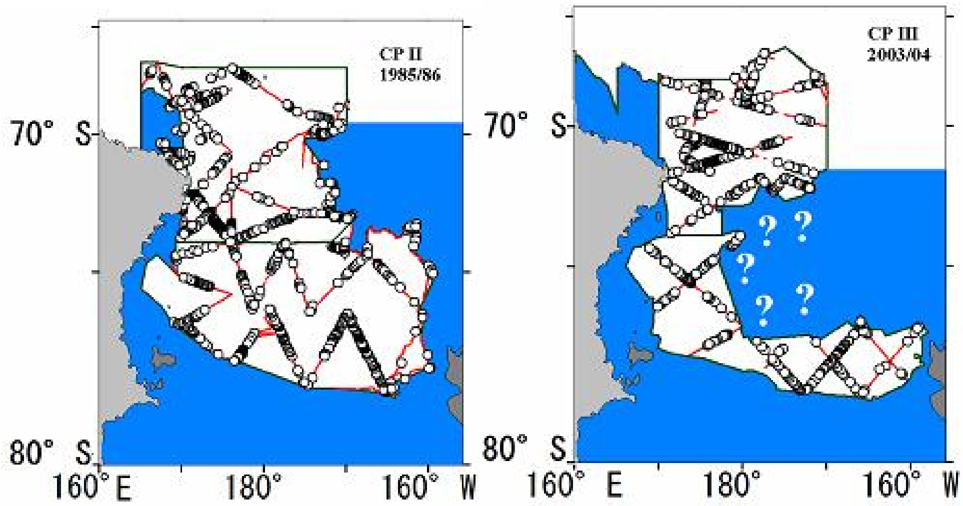

Figure. 2. Relationship between sea ice extent (without sea ice concentrations) and Antarctic minke whales in the Ross Sea using IDCR/SOWER CPII (left) and CPIII (right) data. Maps of sighting survey track lines, boundary lines of strata, primary sighting positions of Antarctic minke whale (open circle), and observed sea ice edge line by research vessels. Data were obtained from the IWC/DESS.

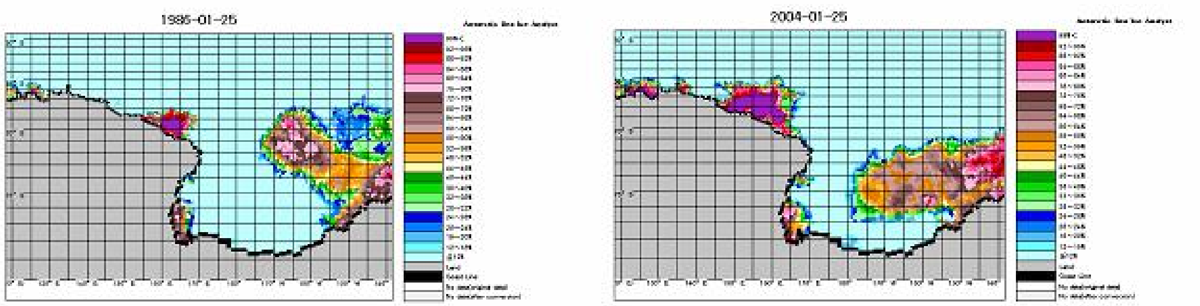

Figure 3. Sea ice concentration maps of CPII (left:1985/86) and CPIII (right: 2003/04).

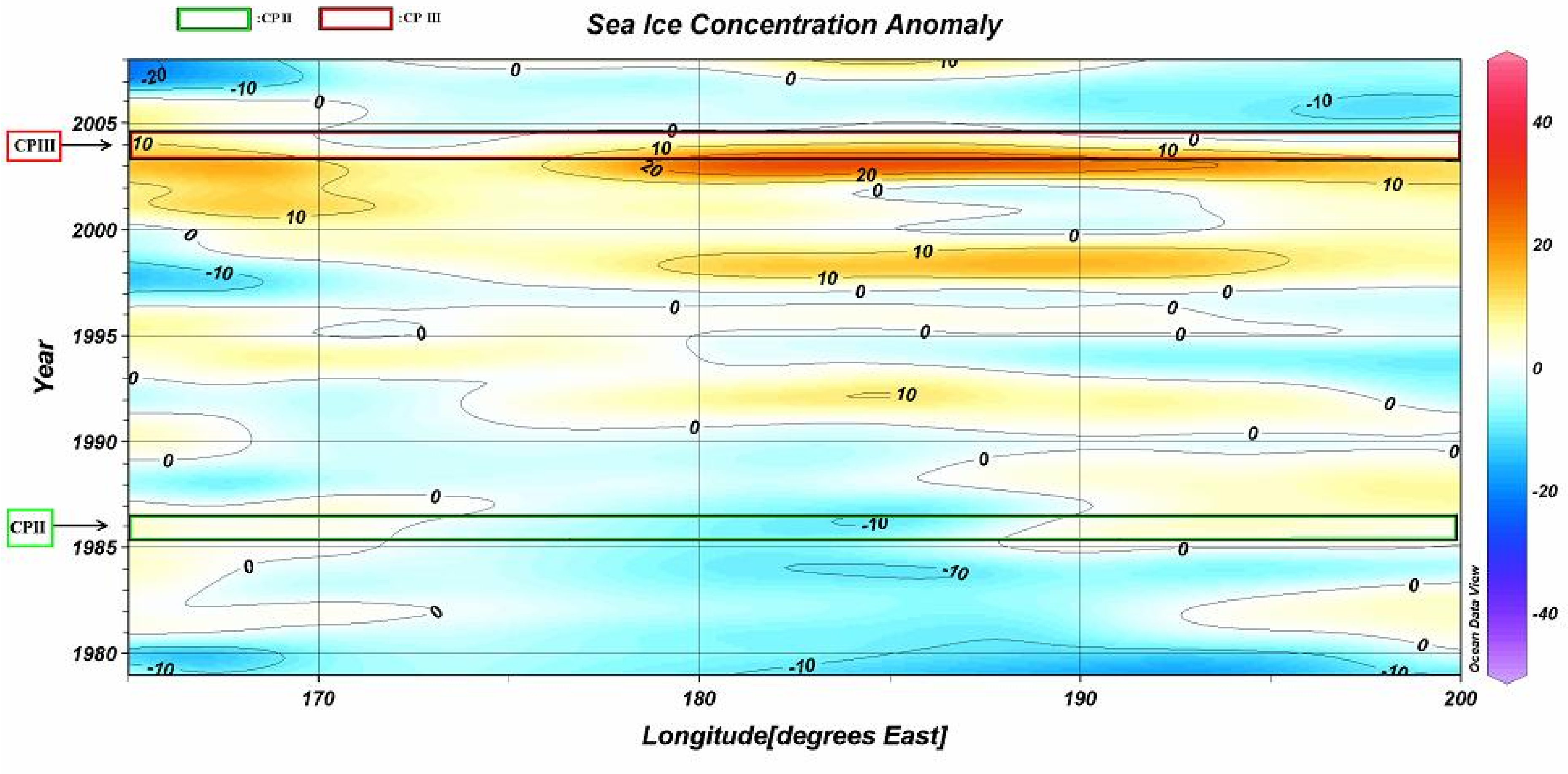

Figure 4. Sea ice concentration anomaly of the Ross Sea (south of 69°S) in January by longitude (from 1979 to 2008) with CPII (1986) and CPIII (2004) (colored squares). Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I (Comiso, 1999). In 2003, SOWER vessels gave up the Ross Sea survey due to abnormal sea ice extent.

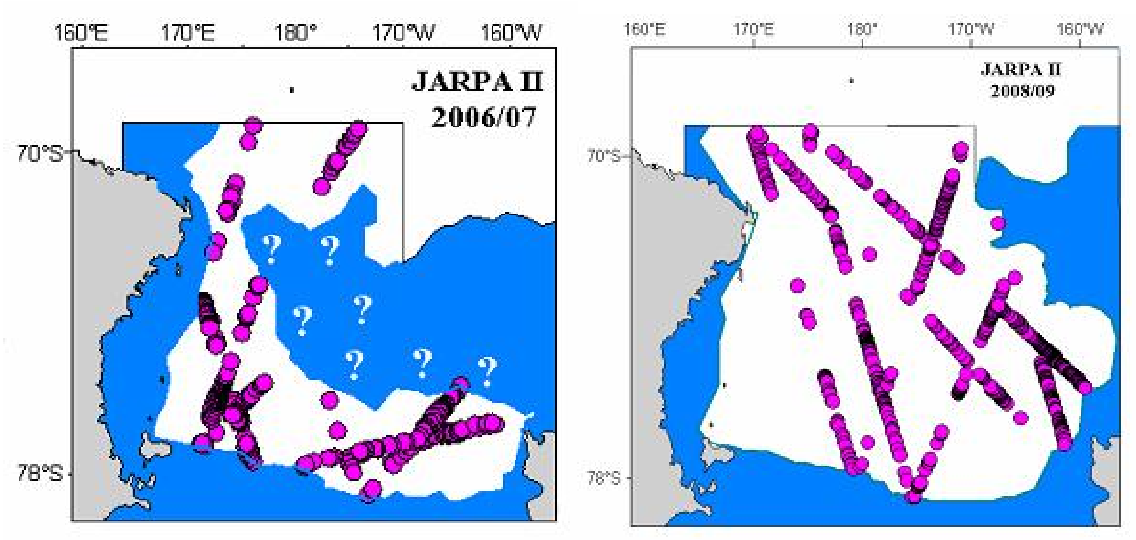

Figure 5. Relationship between sea ice extent (without sea ice concentrations) and Antarctic minke whales (open circle: primary sighting positions) in the Ross Sea using JARPA II 2006/07 (left) and 2008/09 (right) data. Ice edge lines were estimated by the research vessels and satellite data.

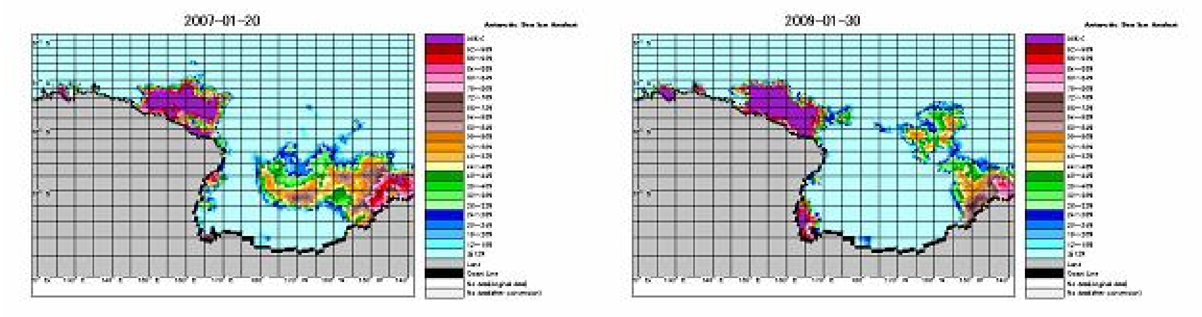

Figure 6. Sea ice concentration maps of JARPAII seasons (left:2006/07, right: 2008/09).