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Influence of sea ice concentration in the research area on IDCR-SOWER abundance estimation

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ABSTRACT
We examined the relationship between the sea ice condition using “sea ice concentration” as an index that observed during IDCR-SOWER surveys, and the abundance of Antarctic minke whales estimated using the model of Okamura and Kitakado (2008). An operation of sighting survey and abundance of Antarctic minke whales appears to be influenced by the changes in the sea ice condition because the sighting survey cannot cover all of water in research areas due to higher sea ice concentration and formation of a polynya. We thus hypothesized that, if the abundance estimates from CPII and CPIII from a given research area were substantially different, the sea ice condition 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 condition. Abundance estimate was high at the year when the survey was able to approach and cover waters adjacent to the continental shelf and continental slope 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.

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 sea ice. Some preliminary studies for this including spatial analysis have been presented (IWC, 2006, 2007).

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). Therefore, abundance of Antarctic minke whales estimated from the data that was unable to cover these areas should be underestimated.

In this document, in order to illustrate influence of sea ice condition on abundance of Antarctic minke whales estimated from the historical IDCR-SOWER survey data, we examined the relationship between the sea ice condition, "sea ice concentration" observed during IDCR-SOWER surveys as indices, and abundance of Antarctic minke whales estimated using the model described by Okamura and Kitakado, (2008).

MATERIAL AND METHODS

To see the effect of change in sea ice concentration on abundance estimation of Antarctic minke whales by the IWC baleen whale management area (Areas I-VI), January sea ice concentration anomaly by each latitudinal sector from 60°S to the Antarctic continent from 1979 to 2006 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 60°S to the Antarctic continent in each year was calculated using original data. Secondary, anomaly from mean sea ice concentration values from 1979 to 2006 for respective latitudinal sector was calculated. The anomaly data were then plotted on time series contour plot.

January mean sea ice concentration by each IWC baleen whale management Area (I-VI) at the year of IDCR/SOWER survey was also calculated as an index of sea condition. The calculated January mean sea ice concentration by each Area was plotted against estimated abundance of Antarctic minke whale based on the OK method.

To clarify the effect of sea ice of abundance estimation of Antarctic minke whale, past papers (Murase and Shimada, 2004; Murase, *et al.*, 2005; Shimada and Murase, 2006) were revisited in this paper.

RESULTS AND DISCUSSIONS

Abundance estimates (with confidential intervals) of Antarctic minke whales during CPII and CPIII were plotted for each of the six research areas covered by IDCR/SOWER sighting survey (Fig. 1). The abundance estimates at Areas II and V substantially differed between CPII and CPIII, especially in Area V. At the both Areas, 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 shape of ice field usually varies substantially year by year due to sea ice condition especially at Areas II and V, resulting in changes in coverage area for sighting survey followed by subsequent underestimation of Antarctic minke whales abundance. Antarctic minke whale abundance should be underestimated if sighting survey cannot cover all of the water in the research areas due to the higher sea ice concentration and the formation of polynya that prevent the research vessels (but not Antarctic minke whales) from approaching the waters adjacent to shore line. We thus hypothesize that, if abundance estimates from CPII and CPIII from the same research area were substantially different, the sea ice condition should have been also quite different between the two.

We carefully compared the sea ice condition during CPII to that during CPIII at the research area (Fig. 2, 3a and 3b). During CPIII, a huge polynya was formed at Area II (Weddell Sea) and the ice edge was extended southwestward at Area V (Ross Sea). This ice condition should have resulted in substantial reduction in coverage for sighting survey (Figs. 3a and 3b) followed by low abundance estimates during CPIII compared to CPII. Fig. 3a shows an unusually extensive sea ice free area, polynia, adjacent to the southeastern side of the Antarctic Peninsula observed in the CPIII-Area IIW. Such large polynia were not observed via satellite during the rest of the observation period (1979-2002). The vessels could not survey within the polynia because the sea ice prevented access to the polynia (IWC, 2006). Similarly, Fig. 3b shows a narrower area of coverage by the sighting survey during CPIII due to extension of ice edge in the Ross Sea.

We then looked into the level of sea ice concentration as an index for sea ice condition. We depicted sea ice concentration anomalies in January from 1976 to 2006 (Fig. 4). Under the high level of ice concentration, research vessels are restricted to narrow water. At Area V (Ross Sea), the sea ice concentration anomaly during CPII 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, indicating the sighting survey was unable to cover most, if not all, of the research area. At Area II (Weddell Sea), the sea ice concentration anomaly was high during CPIII. All of the information indicated that at Areas II and V the areas covered by the sighting survey quite differed between CPII and CPIII.

Influence of the sea ice concentration was thus clearly seen on abundance estimates of Antarctic minke whales during CPII and CPIII (Fig. 5). As we hypothesized, at Area V, a negative relationship was detected as the abundance estimate was lower with higher sea ice concentration. Magnitude negative influence was observed in Area V. Contrast to Area V, no such relationship between the ice condition and abundance estimates was observed at the Areas III, IV, and VI where Antarctica land shape and ice shape was not variable. Such relationship was not also detected in Area II. We think, however, that in Area II abundance estimate during CPIII was mainly influenced by the formation of the huge polynya.

Resent sighting survey conducted on the Japanese, German, and Australian ice breakers and IDCR-SOWER aerial survey in fact reported existence of many Antarctic minke whales in such areas (Shimada and Murase, 2006, Shimada and Kato, 2007, Scheidat, 2007). Spatial analysis also showed similar results (Fig. 5; Murase *et al.*, 2005; IWC, 2006). These observations support our hypothesis.

Further studies are necessary to investigate large impact of sea ice conditions on Antarctic minke whale abundance estimation especially in Areas II (Weddell Sea) and 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.

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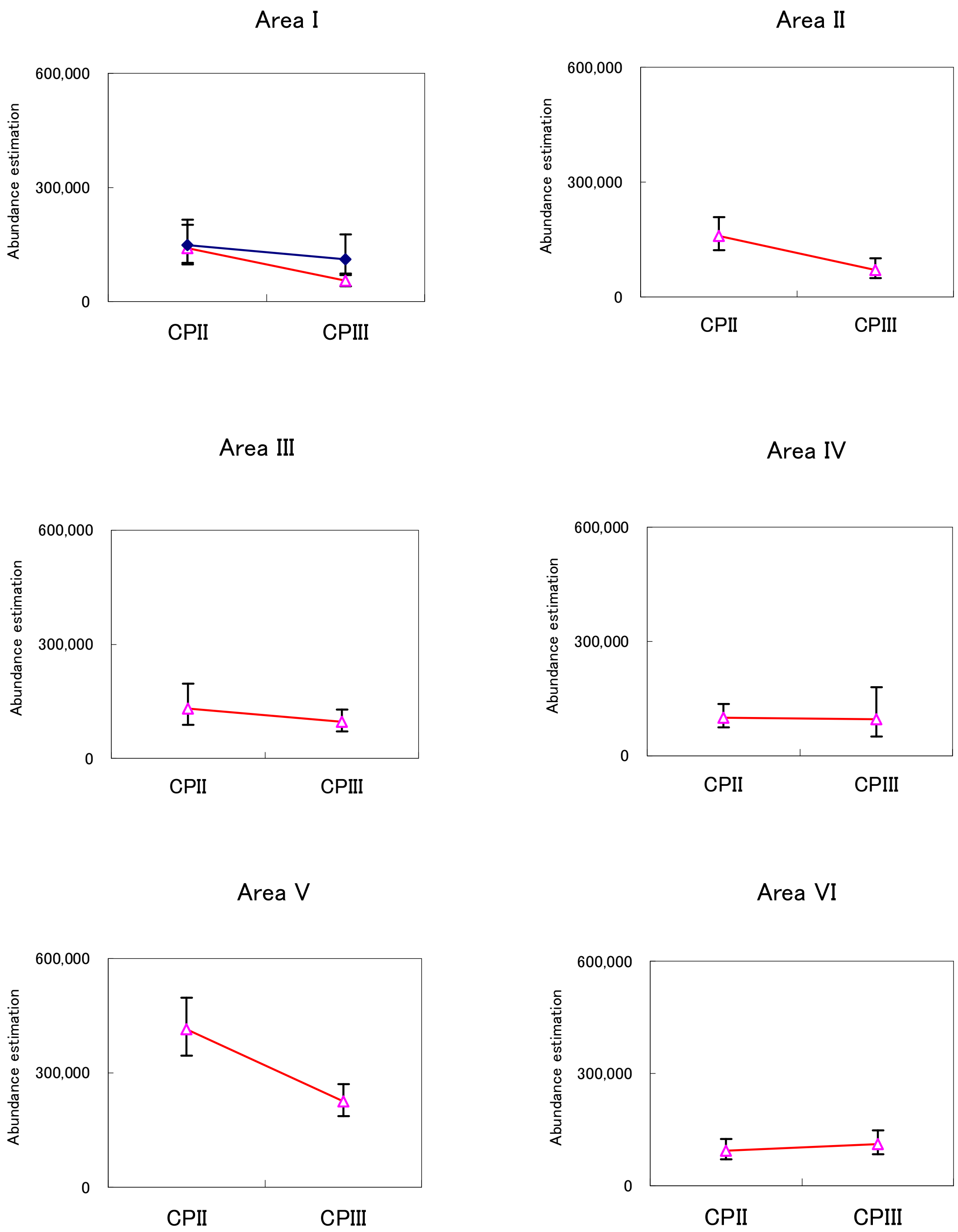

Figure 1. Abundance estimates of Antarctic minke whales between CPII and CPIII with 95 % confidence intervals by OK method with CNB (Okamura and Kitakado, 2008). In Area I, triangle indicated the "survey once (1994+2000+2001)" and black circle indicated abundance combined "1994+2001".

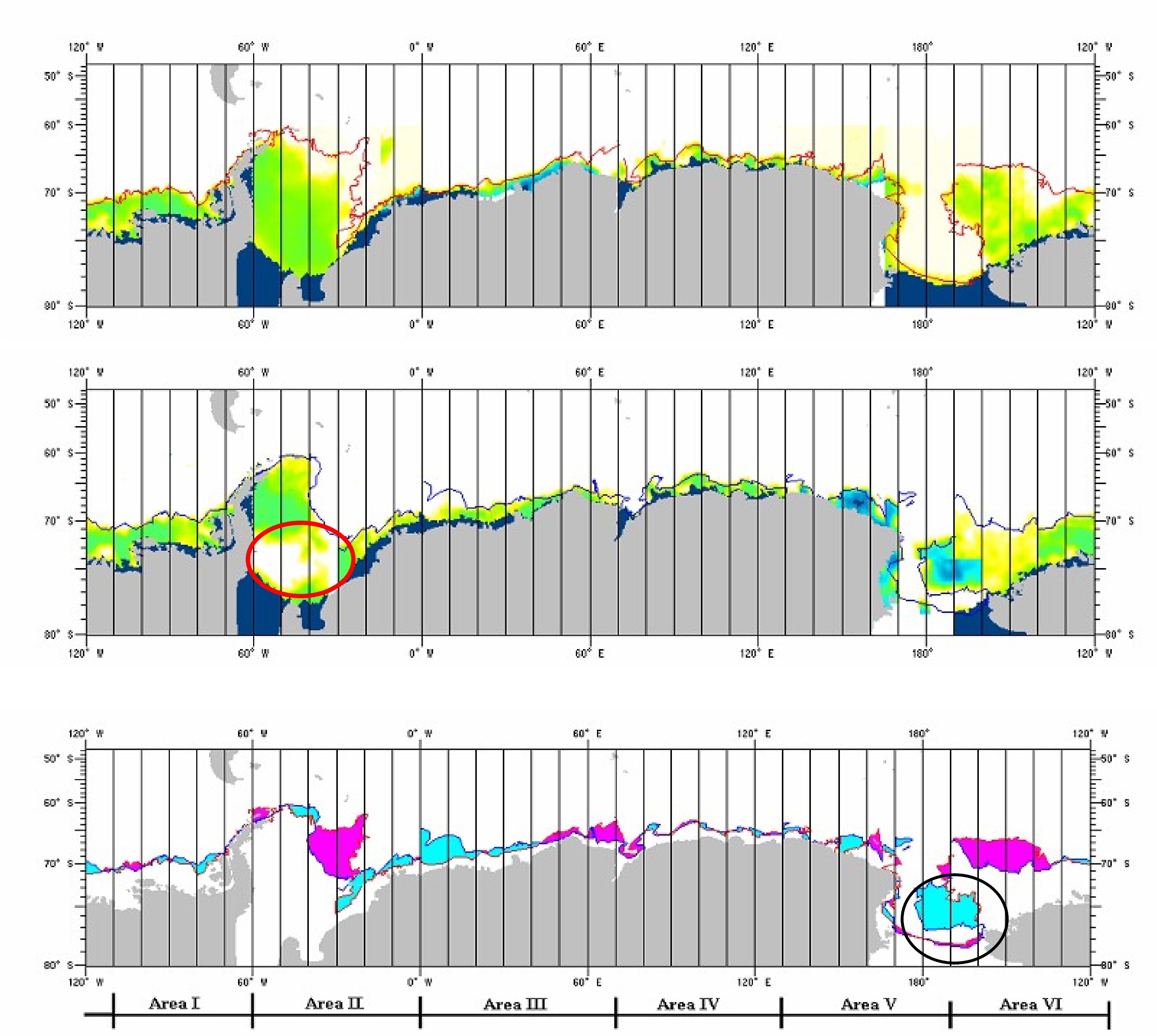

Figure 2. Top and middle figure shows Ice edge estimated by SOWER vessels and ice concentration from satellite information in CPII and CPIII, respectively. Bottom figure shows ice edge anomaly between CPII and CPIII. Pink color shows extent sea ice north CPII than CPIII and blue color shows it extent north CPIII than CPII (Shimada and Murase, 2006). We focused huge polynia in Area II (middle figure, red circle) and large unsurveyed areas in Area V (bottom figure, black circle).

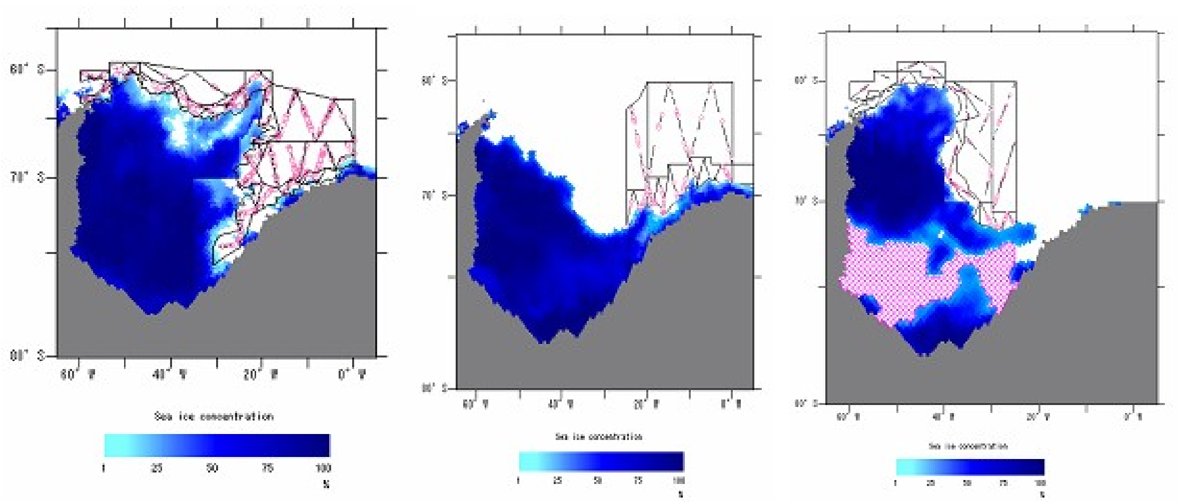

Fig. 3a. Relationship between sea ice extent and Antarctic minke whales in Area II (Weddell Sea). Maps of sighting survey track lines, boundary lines of strata, sighting positions of Antarctic minke whale (open circle), and satellite derived sea ice concentrations in CPII (left) and CPIII (middle and right) in Area II. Hatched area in CPIII was the Ronne Polynia (Murase *et al*., 2005).

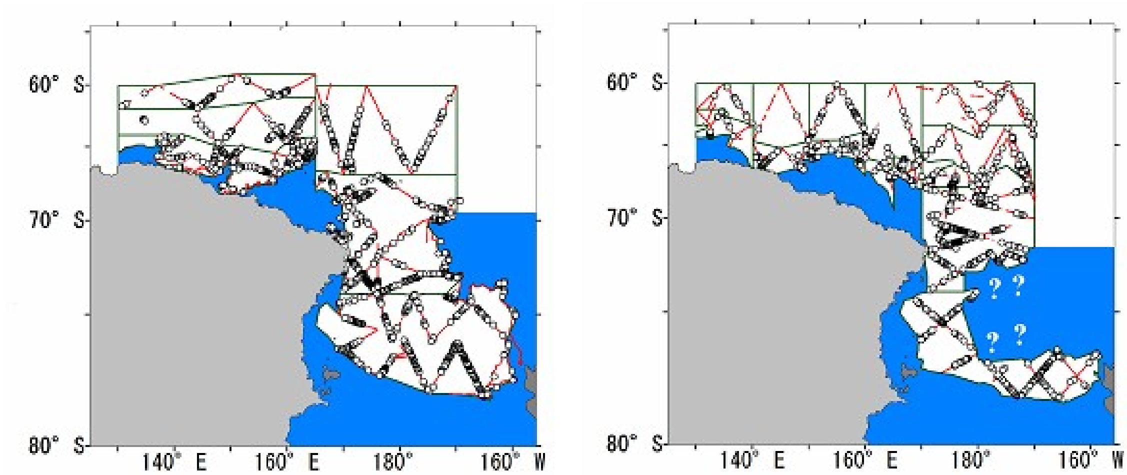

Fig. 3b. Relationship between sea ice extent (without sea ice concentrations) and Antarctic minke whales in Area V (Ross Sea). Maps of sighting survey track lines, boundary lines of strata, primary sighting positions of Antarctic minke whale (open circle), and observed sea ice edge line by research vessels in CPII (left) and CPIII (left and right) in Area V. Data were obtained from the IWC/DESS.

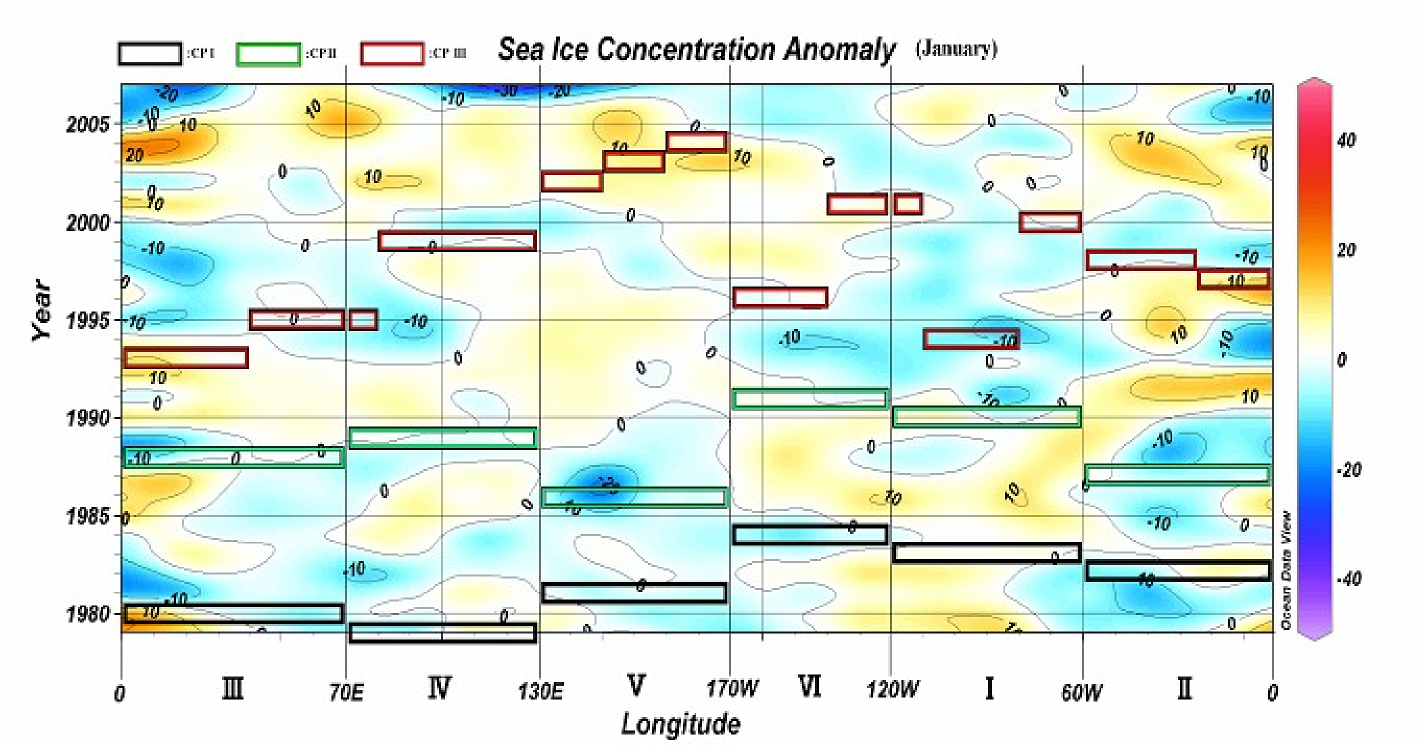

Figure 4. Sea ice concentration anomaly (south of 60S) in January by longitude (from 1979 to 2006) with IDCR/SOWER survey year (colored squares). Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I (Comiso, 1999).

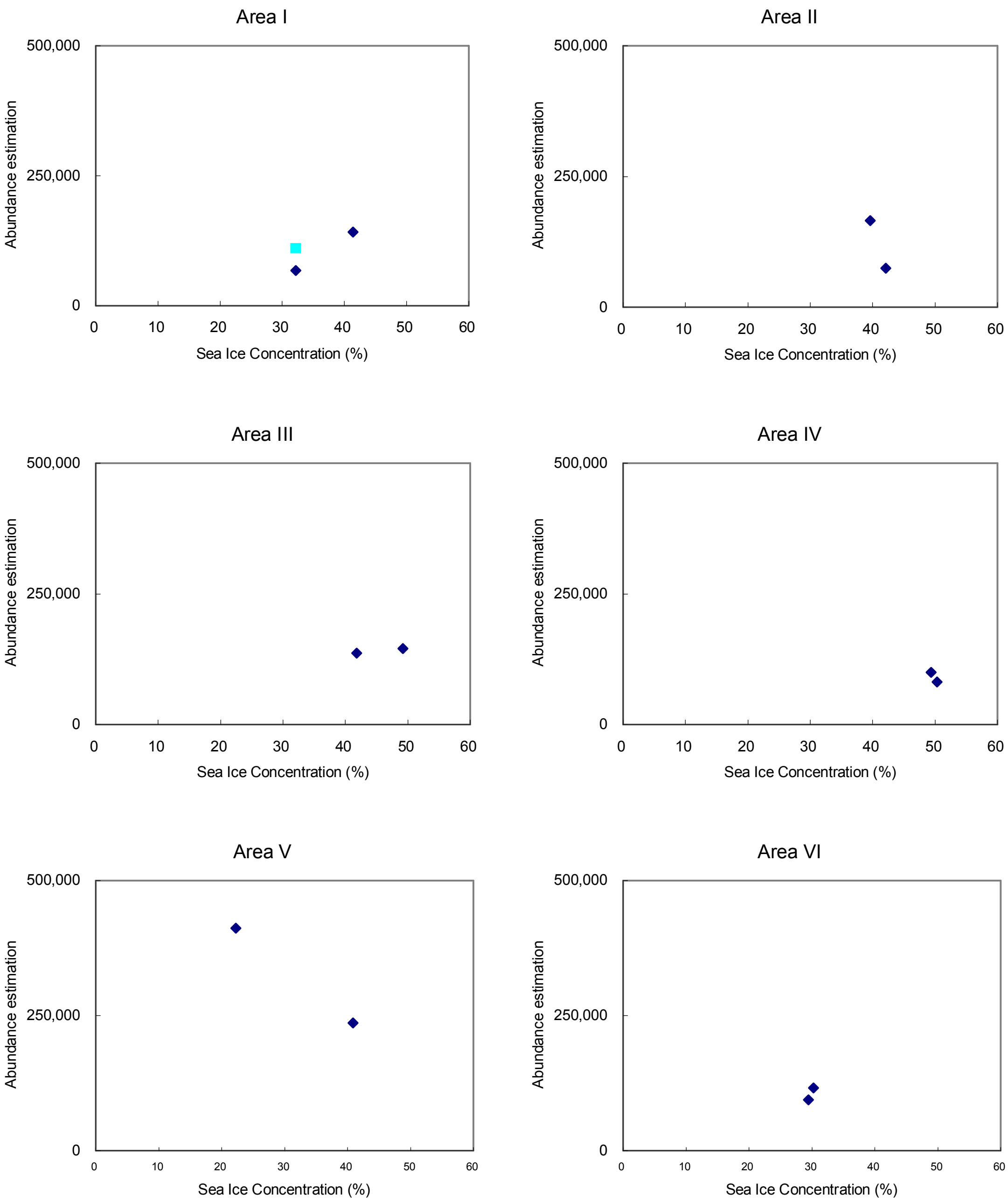

Figure 5. Sea ice concentration of south of 60S in January from 1979-2006 with IDCR-SOWER survey year. Data set was from National Snow and Ice Data Center (NSIDC). IDCR/SOWER abundance estimates were obtained from Okamura and Kitakado (2008). Square (blue) in Area I: 1994+2001.