Progress of preparation of sea ice data to investigate the relationship between sea ice characteristics and Antarctic minke whale abundance estimates

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ABSTRACT

Investigation on the relationship between sea ice characteristics and Antarctic minke whale abundance estimates has been treated as one of the important works to identify reasons of difference of the estimates between CPII and CPIII. An intersessional working group on the sea ice and abundance estimate was reestablished in 61st IWC/SC. Terms of references of the group is 1) create the timing of the ice melt index for the entire time series of CPII and CPIII; then 2) investigate the relationship between abundance estimates and sea ice characteristics by modelling the abundance estimates using this index and other sea ice characteristics, and possibly including interactions between the sea ice characteristics. The latter task includes estimation of the abundance in the south of ice edge in each 10° longitudinal sector. As a task of the group, an effort is being made to import satellite sea ice data to a GIS software. Data in Area II are being imported as a case study. Realization of sea ice characteristics in the south of ice edge at daily basis is difficult in geographically complex regions such as the Weddell Sea in Area II because surveys were conducted following retreating ice in these regions. In such cases, one of the solutions could be use of average sea ice data during the survey periods. The work of the group is expected to be completed by 63rd IWC/SC. However, limited resources slow down the progress. We would like to request budget to complete data preparation. Consideration of effect of other environmental variables (e.g. bathymetric depth and sea surface temperate) on abundance estimates has been also recommended by IWC/SC in addition to sea ice. Such environmental variables can also be imported to the GIS to integrate these data into one data set for the purpose of statistical analysis. Preparation of these environmental variables will be medium term task of the group.

INTRODUCTION

The International Whaling Commission (IWC) has conducted sighting surveys for assessing the abundance of the Antarctic minke whale (*Balaenoptera bonaerensis*) since 1978/79 in the Antarctic in austral summer. The names of the cruises were firstly the International Decade of Cetacean Research programme (IDCR, from 1978/79 to 1995/96) and then the Southern Ocean Whale and Ecosystem Research programme (SOWER, from 1996/97 to 2009/2010). These cruises covered three circumpolar surveys for the purpose of comprehensive assessments (Matsuoka et al., 2003): 1978/79-1983/84 (first circumpolar, CPI), 1984/85-1990/91 (second circumpolar, CPII) and 1991/92-2003/2004 (third circumpolar, CPIII). Abundance estimates based on the IWC standard method revealed that an appreciable difference of abundance between CPII and CPIII (Branch and Butterworth, 2001; Branch,

2006). The reasons of the difference have been investigated by the Scientific Committee of the IWC (IWC/SC) since 2001 (IWC, 2002a) but conclusion has not been reached. Change in sea ice characteristics such as its extent and configuration has been considered as one of the influential factors on the appreciable difference (IWC, 2002b; IWC, 2003). Many papers were submitted to IWC/SC to demonstrate possible effect of sea ice on abundance estimate and propose solutions for it. These works are listed in Table 1 by subjects: 1) sighting survey in ice field, 2) sea ice trend, 3) effect of sea extent on abundance, 4) effect of timing of ice melting, 5) abundance estimation within ice field and 6) spatial analysis. Each paper aimed at establishing confidence of scientists that sea ice characteristics affect the Antarctic minke whale abundance estimates. However, the magnitude of the effect on abundance estimates is still to be investigated. Givn this circumstance, the sea ice and abundance estimate intersessional working group was reestablished in IWC/SC 61 to continue the work. Terms of references of the group is 1) create the timing of the ice melt index for the entire time series of CPII and CPIII; then 2) investigate the relationship between abundance estimates and sea ice characteristics by modelling the abundance estimates using this index and other sea ice characteristics, and possibly including interactions between the sea ice characteristics. The latter task includes estimation of the abundance in the south of ice edge in each 10° longitudinal sector. The work of the group is expected to be completed by IWC/SC 63. This paper presents the progress of the task of the group.

PROGRESS OF DATA PREPARATION

As a task of the group, an effort is being made to import satellite sea ice data to a GIS software so that analysts can extract the data at specific locations easily. Data associated with sighting surveys (boundary, effort and sighting) are also being imported. A widely used GIS software, ArcGIS 9 (Version 9.3.1) is being used to facilitate data sharing among analysts as much as possible in the future. Data in Area II are being imported as a case study. Specifically, following data are being imported;

Coast line of Antarctica (1:10,000,000):

Antarctic Digital Database version 3 provided by the Scientific Committtee on Antarctic Research (SCAR).

Satellite sea ice data:

Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I (Comiso 1999) provided by National Snow and Ice Data Center (NSIDC).

Stratum boundary:

Point data (latitude and longitude) extracted from DESS version 3.3 is converted to polygon files by GIS.

Sighting data:

Sighting data of Antarctic minke whales extracted from DESS version 3.3.

Effort data:

Effort data extracted from DESS version 3.3 are divided into 5 km segments. The segmented data are imported to GIS.

Days after sea ice melting:

Days after sea ice melting corresponding to each sighting and effort segment

Days covered by sea ice:

Days covered by sea ice corresponding to each sighting and effort segment. The days with more than 15 % sea ice concentrations are counted up to 355 days preceding surveyed date.

Some examples of imported data are shown in Figs. 1-3.

SEA ICE CHARACTERISTICS IN GEOGRAPHICALLY COMPLEX REGIONS

Generally, IDCR/SOWER surveys proceeded to longitudinal directions as shown in Fig. 2. Realization of sea ice conditions in the south of ice edge on a daily basis is straightforward in these cases. However, such realization in geographically complex regions such as the Weddell Sea in Area II and the Ross Sea in Area V is difficult because surveys proceeded following retreating ice to the south in addition to longitudinal directions as shown in Fig. 1 and Fig. 3.

Moreover, extreme sea ice conditions encountered in CPII and CPIII in Area II added more difficulty. CPII in Area II (1986/87) were conducted from late December to early February. Because sea ice melts rapidly in Area II from late December to early January in general, CPII was conducted in unstable sea ice conditions (Fig. 1). CPIII in Area II (1996/97 and 1997/98) was conducted from late January to mid February when sea ice conditions are stable in general. However, unusual large polynya existed in 1997/98. Such polnya has not been observed by satellites since 1978 except 1998. Survey was not conducted in the polynya. Because both CPII and CPIII in Area II were conducted in extreme sea ice conditions, it is quite difficult to compare abundance estimates directly.

Preparation of sea ice data for estimation of the abundance in the south of ice edge in each 10° longitudinal sector is one of the tasks of the intersessional working group. Preparation of reasonable sea ice data is required to accomplish the task even if it is difficult. We propose that use of average sea ice data during the survey periods in geographically complex regions as in the cases of CPII and CPIII in Area II.

WORK PLAN

Above mentioned data will be prepare for all management area. Priority of the preparation will be given to CPII and CPIII. However, it is expected that completion of the preparation is difficult given current resources. To overcome the situation, we would like to request following budget for data preparation.

£5,000	salary of temporary workers to data preparation (about 60 days)

Once the data preparation of CPII and CPIII is completed we will prepare data of CPI.

Consideration of effect of other environmental variables (e.g. bathymetric depth and sea surface temperate) on abundance estimates has been also recommended by IWC/SC in addition to sea ice. Such environmental variables can also be imported to the GIS to integrate these data into one data set for the purpose of statistical analysis. Preparation of these environmental will be medium term task of the intersessional working group.

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Matsuoka, K., Ensor, P., Hakamada, T., Shimada, H., Nishiwaki, S., Kasamatsu, F. and Kato, H. 2003. Overview of minke whale sightings surveys conducted on IWC/IDCR SOWER Antarctic cruises from 1978/79 to 2000/01. *J. Cetacean Res. Manage.* 5: 173-201.

Table 1. List of papers of the relationship between sea ice characteristics and Antarctic minke whale abundance estimates. The papers submitted to IWC/SC since 2001 are listed by subject.

Subject	Submitted papers
Sighting survey in ice field (Area II, Germany)	Scheidat, M., Kock, K. H., Friedlaender, A., Lehnert, L. and Williams, R. 2007. Using helicopters to survey Antarctic minke whale abundance in the ice. Paper SC/59/IA20, presented to the 59th IWC Scientific Committee, May 2007 (unpublished). 10pp. Kock, K. H., Scheidat, M., Boebel, O., Bräger, S., Herr, H., Lehnert, K., Lehnert, L. S., Verdaat, H. and Williams, R. 2009. The occurrence of cetaceans along two transects from 57°S to Atka Bay (70° 29.6'S/07°57.6'W). Paper SC/61/IA11 presented to the 61st IWC Scientific Committee, May 2009 (unpublished). 19pp.
Sighting survey in ice field (Area IV, Australia)	Thiele, D., Chester, E. and Friedlaender, A. 2002. Antarctic sea-ice habitat for minke whales (*Balaenoptera acutorostrata* sp.). Results of a line transect survey in East Antarctica. Paper SC/54/IA6 presented to the 54th IWC Scientific Committee, April 2002 (unpublished). 14pp Hedley, S., Bravington, M., Gales, N., Kelly, N. and Peel, D. 2007. Aerial survey for minke whales off eastern Antarctica. Paper SC/59/IA2, presented to the 59th IWC Scientific Committee, May 2007 (unpublished). 47pp. Kelly, N., Peel, D., Pike, D., Bravington, M. and Gales, N. 2008. Aerial survey of minke whales off East Antarctica: report on 2007/08 test survey and future plan. Paper SC/60/IA4 presented to the 60th IWC Scientific Committee, May 2008 (unpublished). 8pp. Kelly, N., Peel, D., Bravington, M. and Gales, N. 2009. A planned aerial survey for minke whales in east Antarctica during summer 2009/10. Paper SC/61/IA4 presented to the 61st IWC Scientific Committee, May 2009 (unpublished). 5pp. Kelly, N., Peel, D., Pike, D., Bravington, M. and Gales, N. 2009. An aerial survey for Antarctic minke whales in sea ice off east Antarctica: a pilot study. Paper SC/61/IA3 presented to the 61st IWC Scientific Committee, May 2009 (unpublished). 14pp.
Sighting survey in ice field (Area IV, Japan)	Shimada, H. and Kato, A. 2004. Survey plan to explore minke whale abundance within ice field by the ice breaker, Shirase. Paper SC/56/IA12, presented to the 56th IWC Scientific Committee, June 2004 (unpublished). 4pp. Shimada, H. and Kato, A. 2005. Preliminary report on a sighting survey of Antarctic minke whale within ice field conducted by the Ice Breaker, Shirase in 2004/2005. Paper SC/57/IA7, presented to the 57th IWC Scientific Committee, May 2005 (unpublished). 14pp. Shimada, H. and Kato, A. 2006. Tentative population assessment of the Antarctic minke whale within ice field using sighting data on the ice breaker, Shirase in 2004/2005. Paper SC/58/IA11, presented to the 58th IWC Scientific Committee, May 2006 (unpublished). 10pp. Shimada, H. and Kato, A. 2007. Population assessment of the Antarctic minke whale within and out of ice field using a sighting daata on the Ice Breaker and the IWC SOWER vessels in 2004/2005. Paper SC/59/IA16, presented to the 59th IWC Scientific Committee, May 2007 (unpublished). 8pp.
Sighting survey in ice field (Area VI and I, USA)	Ainley, D. G., Dugger, K. M., Toniolo, V. and Gaffney, I. 2007. Cetacean occurrence patterns in the amundsen and southern ballingshausen sea sector,southern ocean. Mar. Mamm. Sci. 23: 287-305. (SC/59/For Information 7)

Table 1 (continue)

Subject	Submitted papers
Sea ice trend	Murase, H. and Shimada, H. 2004. Possible impact due to variability of sea ice condition on Antarctic minke whale abundance estimation in the Antarctic from 1978 to 2002. Paper SC/56/IA10, presented to the 56th IWC Scientific Committee, June 2004 (unpublished). 15pp. Murase, H. 2010. January sea ice trends during period of three IWC IDCR/SOWER circumpolar surveys (1978-2004). Paper SC/62/IA5, presented to the 62nd IWC Scientific Committee, May 2010 (unpublished). 15pp.
Effect of sea ice extent on abundance	Shimada, H. and Murase, H. 2006. Relationship between minke whale abundance and pack ice extent. Paper SC/58/IA12, presented to the 57th IWC Scientific Committee,May 2006 (unpublished). 7pp. Matsuoka, K., Kiwada, H. and Hakamada, T. 2006. The relationships between sea ice extension and trends in sighting parameters of Antarctic minke whales based on IDCR-SOWER data from CPII to CPIII. Paper SC/58/IA17, presented to the 57th IWC Scientific Committee, June 2006 (unpublished). 7pp. Matsuoka, K., Nishiwaki, S., Murase, H., Kanda, N., Kumagai, S. and Hatanaka, H. 2008. Influence of sea ice concentration in the research area on IDCR-SOWER abundance estimation. Paper SC/60/IA12 presented to the 60th IWC Scientific Committee, May 2008 (unpublished). 9pp. Matsuoka, K., Hakamada, T., Kimura, K. and Okada, Y. 2009. Influence of sea ice concentration on Antarctic minke whale abundance estimation in the Ross Sea. Paper SC/61/IA16 presented to the 61st IWC Scientific Committee, May 2009 (unpublished). 7pp.
Effect of timing of sea ice melting	Murase, H. and Ensor, P. 2009. Preliminary examination of the effect of timing of ice melting on the density of Antarctic minke whales - a new environmental index. Paper SC/61/IA17 presented to the 61st IWC Scientific Committee, May 2009 (unpublished). 9pp.
Abudance estimation within ice field (circumpolar by management area)	Shimada, H., Segawa, K. and Murase, H. 2001. Tentative trial for estimation of Antarctic minke whale abundance within pack ice region incorporating IDCR/SOWER data with meteorological satellites data. Paper SC/53/IA14 presented to the 52th IWC Scientific Committee, June 2000 (unpublished). 6pp. Shimada, H., Segawa, K. and Murase, H. 2002. A preliminary trial: estimation of the Antarcitc minke whale abundance within the sea ice area incorporating IDCR/SOWER data with meteorological satellites data. Paper SC/54/IA19 presented to the 54th IWC Scientific Committee, April 2002 (unpublished). 6pp.
Abudance estimation within ice field (circumpolar by 10° longitudinal sector)	Shimada, H. and Burt, M. 2007. Relationship between minke whale abundance and pack ice extent examined by 10° longitudinal slices. Paper SC/59/IA26, presented to the 59th IWC Scientific Committee, May 2007 (unpublished). 5pp.
Abudance estimation within ice field (Area II)	Murase, H. and Shimada, H. 2004. Alternative estimation of Antarctic minke whale abundance taking account of possible animals in the unsurveyed large polynya: A case study in Area II in 1997/98. Paper SC/56/IA14, presented to the 56th IWC Scientific Committee, June 2004 (unpublished). 13pp. Murase, H., Shimada, H. and Kitakado, T. 2005. Alternative estimation of Antarctic minke whale abundance taking account of possible animals in the unsurveyed large polynya using GAM-based spatial analysis: A case study in Area II in 1997/98 IWC/SOWER. Paper SC/57/IA6, presented to the 57th IWC Scientific Committee, May 2005 (unpublished). 13pp.
Abudance estimation within ice field (Area IV)	Shimada, H. and Murase, H. 2002. Some analysis on sea ice condition in relation to changes in the Antarctic minke whale distribution pattern in the Antarctic Area IV. Paper SC/54/IA18 presented to the 54th IWC Scientific Committee, April 2002 (unpublished). 8pp Shimada, H. and Murase, H. 2003. Further examination of sea ice condition in relation to changes in the Antarctic minke whale distribution pattern in the Antarctic Area IV. Paper SC/55/IA7 presented to the 55th IWC Scientific Committee, May 2003. (unpublished). 3pp.
Spatial analysis	Murase, H., Kitakado, T., Matsuoka, K., Nishiwaki, S. and Naganobu, M. 2007. Exploration of GAM based abundance estimation method of Antarctic minke whales to take into account environmental effects: A case study in the Ross Sea. aper SC/59/IA12 presented to the 59th IWC Scientific Committee, May 2007 (unpublished). 13pp. Beekmans, B. W. P. M., Forcada, J., Murphy, E. J. and Bathmann, U. V. 2008. Antarctic minke whale (*Balaenoptera bonaerensis*) density distributions in the Southern Ocean: a preliminary analysis. Paper SC/60/IA15 presented to the 60th IWC Scientific Committee, May 2008 (unpublished). 19pp.

CPII (1986/87) in Area II (60°W-0°)

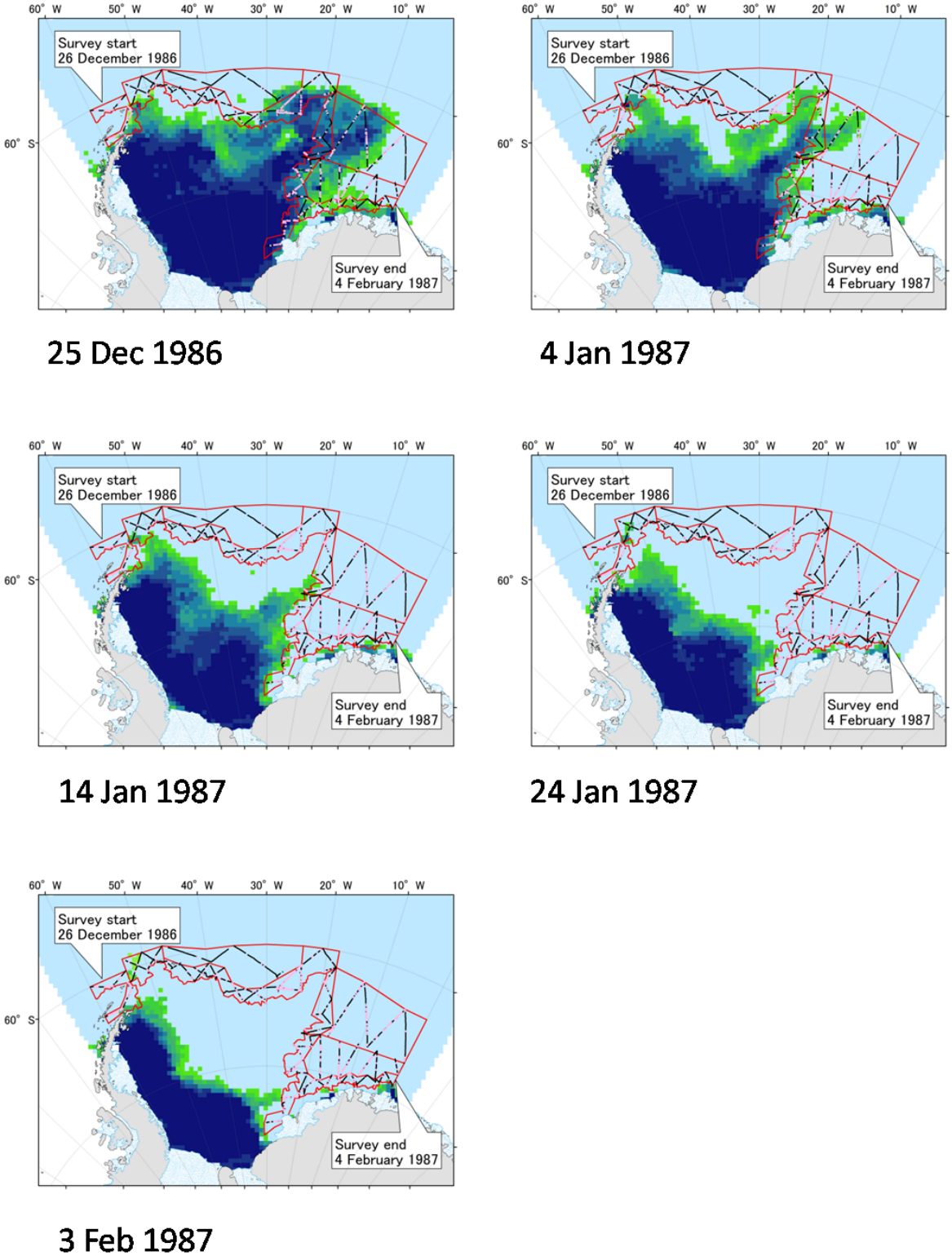

Fig. 1. Change in sea ice characteristics in Area II in CPII (1986/87). Daily sea ice characteristics during the survey periods at intervals of 10 day are shown. The survey was conducted from 26 December 1986 to 4 February 1987. The survey proceeded from west to east.

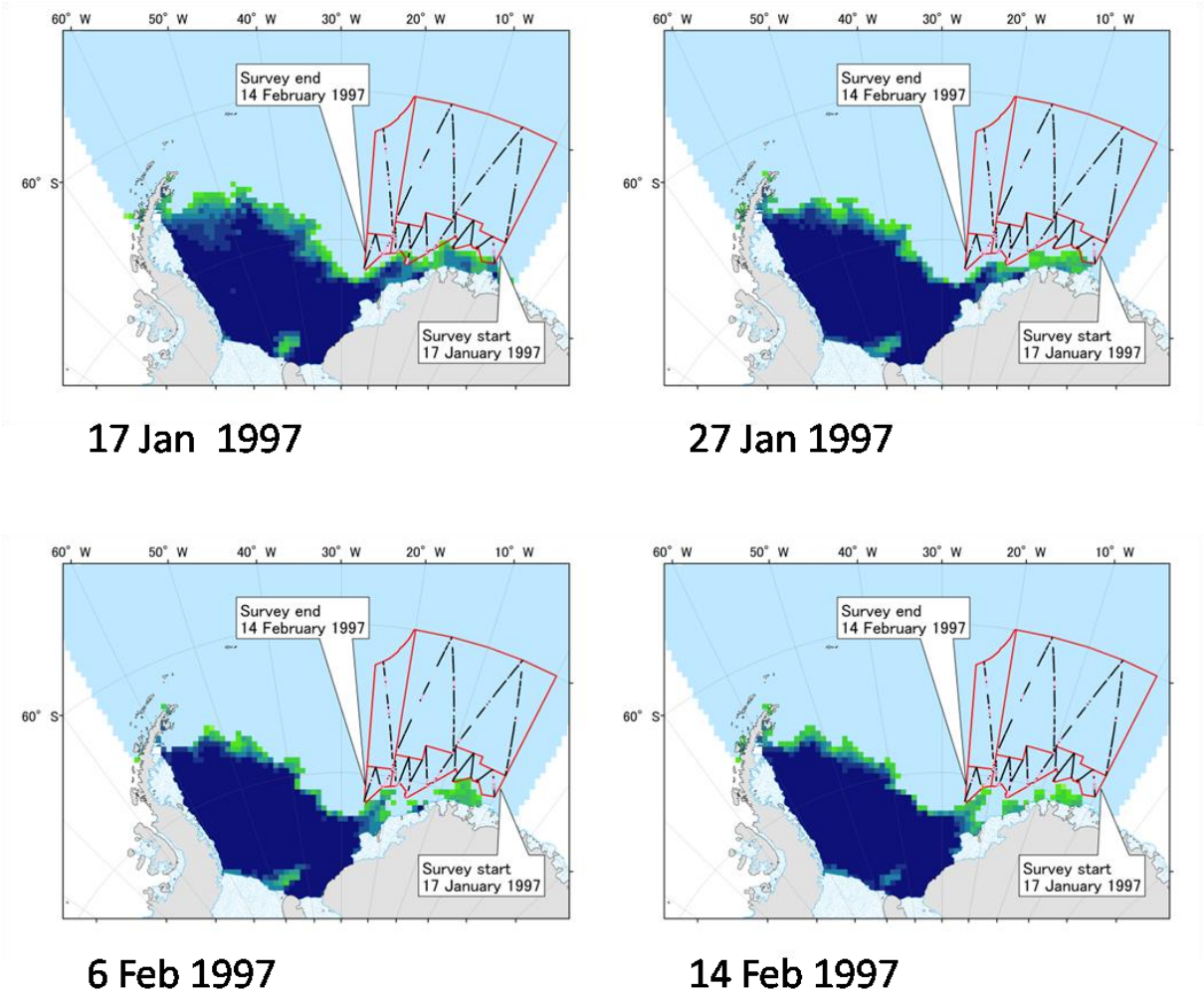

Fig. 2. Change in sea ice characteristics in Area II in CPIII (1996/97). Daily sea ice characteristics during the survey periods at intervals of 10 day are shown. Eastern half of Area II was surveyed in 1996/97. The survey was conducted from 14 January 1997 to 14 February 1997. The survey proceeded from east to west.

CPIII (1997/98) in Area II (60°W-25°W)

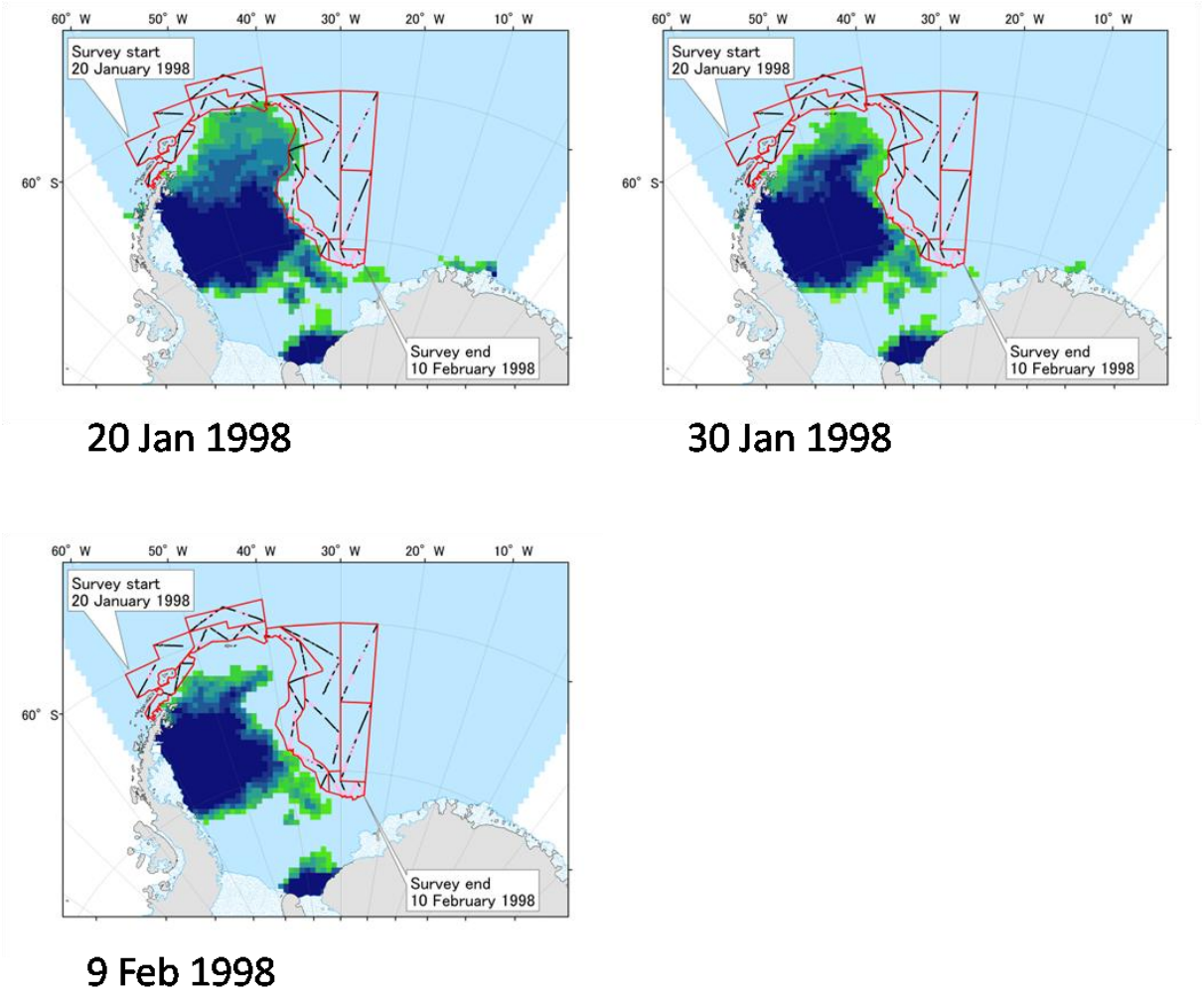

Fig. 3. Change in sea ice characteristics in Area II in CPIII (1997/98). Daily sea ice characteristics during the survey periods at intervals of 10 day are shown. Western half of Area II was surveyed in 1997/98. The survey was conducted from 20 January 1998 to 10 February 1998. The survey proceeded from west to east.