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.

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ABSTRACT

An Antarctic baleen whale management area, Area II (0°-60°W), was surveyed in 1986/87 as second circumpolar survey (CPII) and, in 1996/97 and 1997/98 as third circumpolar survey (CPIII). Whole area of Area II was covered in 1986/87. In CPIII, the area was separated into two 30 degree sectors at 30°W. The sector between 0° and 30°W was surveyed in 1996/97 and the rest (30°W-60°W) was surveyed in 1997/98. Sea ice extent in the southeastern Weddell Sea was unusually large in the summer of 1996/97. Unusual extensive sea ice free area, polynya, adjacent to southeastern side of Antarctic Peninsula was observed in the 1997/98. No such a large polynya was observed during satellite observation period (1979-2002). The survey vessels could not conduct survey in the polynya because sea ice prevented the access to there. The area of the polynya was estimated as 78,615 n.mile^2 using satellite derived data. It was 25.6% of the total survey area in 1997/98. Abundance estimates in Area II (closing mode) in CPII and CPIII were 142,837 and 46,414 individuals, respectively (Branch and Butterworth, 2001). Abundance estimates in CPIII increased to 86,264 individuals after adding estimates in the polynya. Abundance estimate in the 1997/98 would be underestimated because of presence of the large polynya. Although it is difficult to estimate the impact of sea ice configuration change on the abundance estimation exactly, the effect of the large polynya on the abundance estimate should be evaluated further.

KEYWORD: ANTARCTIC MINKE WHALE; SEA ICE; POLYNYA; ABUNDANCE ESTIMATE; ANTARCTIC

INTRODUCTION

The International Whaling Commission (IWC) has conducted the Antarctic minke whale abundance assessment cruises since 1978/79 in the Antarctic in austral summer (Matsuoka *et al.* 2003, for review). The name of the cruises were called as the International Decade of Cetacean Research programme (IDCR) from 1978/79 to 1995/96 and then changed to the Southern Ocean Whale and Ecosystem Research programme (SOWER) from 1996/97 2003/04. The cruises covered three circumpolar surveys. Abundance estimation was made using each circumpolar data set; 1978/79-1983/84 (first circumpolar, CPI), 1984/85-1990/91 (second circumpolar, CPII) and 1991/92-1997/98 (third circumpolar, CPIII). Though the abundance estimate of the third circumpolar set has not been completed, noticeable abundance decline from CPII (766,000) to CPIII (268,000) (Branch and Butterworth 2001) brought question whether the decline is true or apparent. Several hypotheses that might affect the apparent abundance change were pointed out (IWC 2003(b)). One of the factors is proportion of Antarctic minke whales population south of the ice edge where survey vessels can not enter.

The 1996/97 SOWER was conducted in eastern half (0°-30°W) of Area II. It was reported that amount of sea ice in the southeastern Weddell Sea was unusually large (Hegseth and Von Quillfeldt 2001). The 1997/98 SOWER was conducted in western half (30°W-60°W) of Area II. Though the large sea ice free area, polynya, was observed adjacent to southeastern side of Antarctic Peninsula during the cruise, the vessels could not conducted survey in the area because sea ice prevented the vessels accessing (Ensor *et al.* 1998). The polynya was called as the Ronne Polynya and it had largest extent in 25 years satellite observation periods (Ackley *et al.* 2001). Shimda *et al.* (2001) tentatively estimate the abundance of Antarctic minke whales in the pack ice in this region but the study was not considered the polynya specifically. In this paper, abundance estimation of Antarctic minke whale in the polynya was carried out. The implications of unusual sea ice conditions in CPIII for the interpretation of the abundance difference between CPII and CPIII in Area II were discussed.

MATERIALS AND METHODS

Cetacean survey data

IWC divided southern ocean into six areas for the management of baleen whales (Donovan, 1992). Area II is set between 0° and 60°W (Fig. 1). Sighting survey for the abundance estimation of Antarctic minke whale was conducted in austral summer. CPII survey was conducted from December 28, 1986 to February 4, 1987. Full longitudinal coverage was made in 1986/87 cruise. In CPIII, Area II was divided into two at 30°W. Eastern half (0°-30°W) was surveyed in 1996/97 cruise (January 16-February 14, 1997) whereas western half (30°W-60°W) was survey in 1997/98 cruise (January 18-February 14, 1998). Latitudinal coverage was south of 60°S to ice edge except 0-°20°W of CPII where the

northern limit was set at 61°S-63°S. Sighting trackline data, positions of sighted Antarctic minke whale and ice edge data stored in the IWC Database-Estimation Software System (DESS) version 3.0 (Strindberg and Burt, 2000) were used. The ice edge is defined by a level of ice cover that prevents the survey from being conducted at normal survey speed (11.5 knots) (IWC, 2003(a)). The ice edge was obtained by the dedicated ice edge survey vessel in CPII whereas it was estimated using the sea ice chart published by the National Ice Center (US) except around the waypoints. Because the sea ice chart was published weekly, the estimated ice edge using it lacked precision of CPII though the data were comparable (Ensor *et al.*, 1997; Ensor *et al.*, 1998). To estimate Antarctic minke whale abundance in the polynya, estimated density of whale (per n.mile^2, D_w) in Branch and Butterworth (2001) was used. The extrapolation method which was applied to unsurveyed northern areas in Brach and Butterworth (2001) was used. The both closing and IO mode density data were used. Survey area (n.mile^2) described in the paper was also referred.

Satellite sea ice data

Satellite derived daily sea ice data, Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I (Comiso, 1999) from 1978 to 2002 was used to map the see ice concentration and extent south of the ice edge. Sea ice observation using the satellite passive microwave sensors was started with the launch of Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus-7 in 1978. The sensor was changed to Special Sensor Microwave/Imager (SSM/I) in 1987 and the data collection is still on going. The daily satellite data corresponding to midday of the surveyed period in each 5-10 latitudinal and longitudinal degree sectors were integrated into a map using geographic information system (GIS), Marine Explorer (Environmental Simulation Laboratory Co. LTD, Japan). Because the most of the ice edge was estimated using the weekly charts in CPIII, they were referred to determine the appropriate date of the satellite data. The area of the polnya was calculated using the map. The polynya was defined as 0% sea ice concentration area south of the ice edge in this paper. Monthly mean sea ice satellite data in January from 1979 to 2002 were used to investigate long term sea ice configuration change in Area II.

Satellite chlorophyll-a concentration data

To see the chlorophyll-a concentration in Area II in January 1998, The SeaWiFS (Sea-viewing Wide Field-of-view Sensor) Level-3 monthly averaged chlorophyll-a concentration image (provided by the SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE) was used. Because the SeaWiFS image is available after September, 1997, there is no satellite chlorophyll-a concentration image for the 1986/87 and 1996/97 cruise.

RESULTS

Monthly averaged sea ice extent image in the Area II in January from 1979 to 2002 was shown in Fig. 2. No large polynya was observed during the satellite observation period except 1998.

Sighting survey trackline, sighting positions of Antarctic minke whale, ice edge line defined by the survey vessels and satellite derived sea ice concentration data in CPII and CPIII were overlaid in Fig. 3 and Fig. 4, respectively. Positions of ice edge defined by the satellite and the vessel had good agreement though there was some discrepancy between them. The sea ice extent in the southern part of the 1996/97 cruise was larger than that in the 1986/87 cruise. In 1997/98 cruise there was a large polynya which were not observed in the 1986/87 cruise. The area of the polynya was estimated as 78,615 n.mile^2. The total survey area in the 1997/98 was 306,981 n.mile^2. The area of the polynya was 25.6% of the total survey area. The abundance estimates in the polynya using the density estimates from adjacent southern stratum (ES1 and ES2 in Fig. 5) were shown in Table 1. The range of the estimates were from 5,417 to 39,850 individuals. Abundance estimates of CPII and CPIII in Area II in Branch and Butterworth (2001) was summarized in Table 2. CPIII abundance in closing and IO mode was 32% and 20% of CPII, respectively. After including the abundance estimates in the polynya in the estimates in Table 2, the ratio was reduced (Table 3).

SeaWiFS image suggested that higher chlorophyll-a concentration was occurred in the polynya region in January 1998 (Fig. 5). The chlorophyll-a concentration in the survey area was low relative to the polynya.

DISCUSSION

Southern portion of the 1996/97 survey area (0°-30°W) had larger amount of sea ice than the 1986/87 survey. Because the heavy sea ice condition in this area limited the growth season of the phytoplankton, biomass of the phytoplankton was low in this area in the summer of 1997 (Hegseth and Von Quillfeldt 2001). Antarctic krill (*Euphausia superba*), the dominant prey species of Antarctic minke whale (Ichiii and Kato 1991), feed predominantly on the phytoplankton (Miller and Hampton 1989). If the biomass of the phytoplankton was low, growth and sexual development of Anarchistic krill was negatively affected. In the case of the food scarcity, Antarctic minke whales could change the feeding area in response to it. The western Weddell Sea was also covered with high concentration of sea ice in the 1996/97 survey. Because Antarctic minke whales were move across the IWC baleen whale management area boundary (Wada 1984), some proportion of the population in Area II could move to adjacent area, such as Area III. Migration behavior in response to the food availability could affect the change in apparent abundance estimation between CPII and CPIII.

In contrast, there was a large polynya in the 1997/98 survey. SeeWiFS satellite image suggested that the primary production in the polynya was high. The size of the polynya increased from November and reached maximum

(300,000 km^2 = 87,466 $n.mile^2$) about on 1 March (Ackley *et al.* 2001). The prolonged open water period in the polynya could enhance the primary production. Coastal polynya is observed in the Ross Sea region during spring (Zwally *et al.* 2001). High density of Antarctic minke whales was also observed in this region (Kasamatsu *et al.* 1998). SeaWiFS data indicated that high values of chlorophyll were occurred in the Ross Sea region (Moore and Abbott, 2000). In the heavy sea ice coverage year because of the presence of ice berg, the primary production in this area decreased (Arrigo *et al.* 2002).

Abundance estimate in the 1997/98 would be underestimated because of presence of the large polynya. The effect of the polynya on the CPIII abundance estimates in Area II must be taken account though it is difficult to estimate Antarctic minke whale in the south of the ice edge where the sighting vessels can not conduct the survey (IWC 2002). Without considering the effect of the large polynya, the direct comparison of abundance estimates between CPII and CPIII is invalid.

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Table 1. Abundance estimates in the polynya observed in 1997/98 cruise. Density estimates in Table 1 of Branch and Butterworth (2001) was used.

Survey mode	Stratum	Density (ind/n.mile2)	Area of Polynya (n.mile2)	P (ind.)
Closing	ES1	0.0689	78,615	5,417
	ES2	0.5069		39,850
Passing	ES1	0.1292		10,157
	ES2	0.0819		6,439

Table 2. Abundance difference between CPII and CPIII reported in Table 6 of Branch and Butterworth (2001).

Survey mode	P (ind)				Ratio
	CPII	(Year)	CPIII	(Year)	(CPIII/CPII)
Closing	142,837	1986/87	46,414	1996/97 &	32%
IO	159,596		32,259	1997/98	20%

Table 3. Abundance difference between CPII and CPIII after including abundance estimates in the polynya in 1997/98.

Survey mode	P (ind)			Ratio
	CPII	CPIII(corrected)	(Stratum)	(CPIII/CPII)
Closing	110,984	51,831	ES1	47%
		86,264	ES2	78%
IO	128,680	42,416	ES1	33%
		38,698	ES2	30%

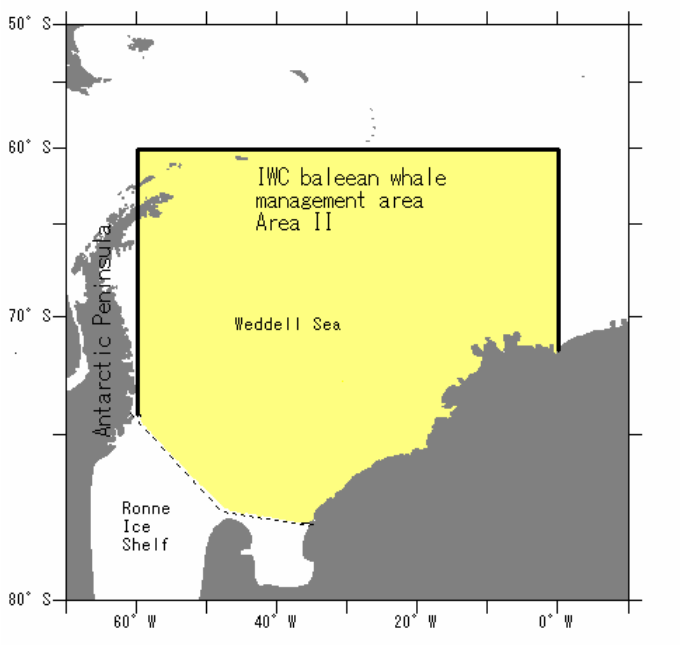

Fig. 1. Schematic map of survey area, Area II.

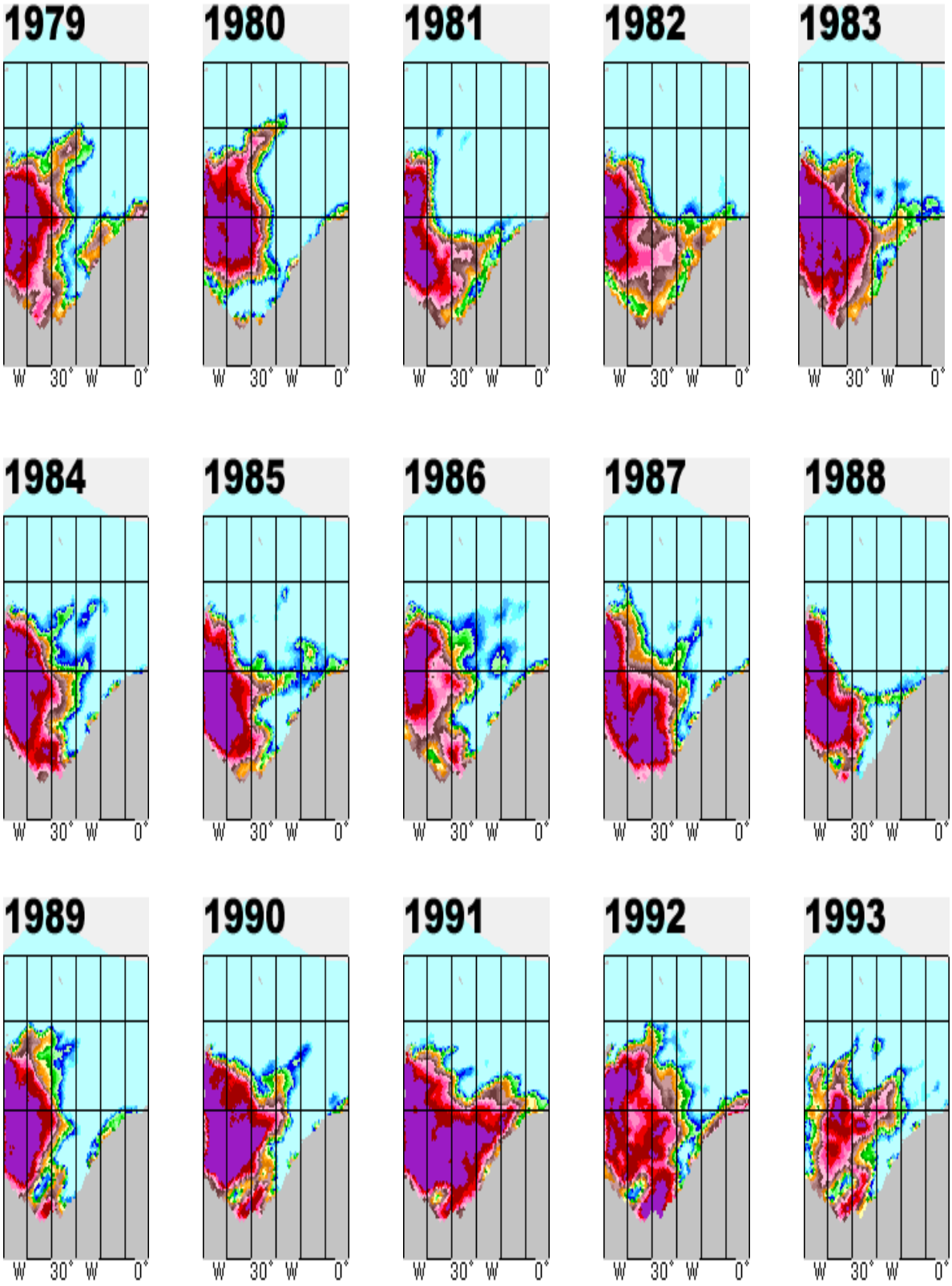

Fig. 2. January monthly mean sea ice concentration images in Area II from 1979 to 2002.

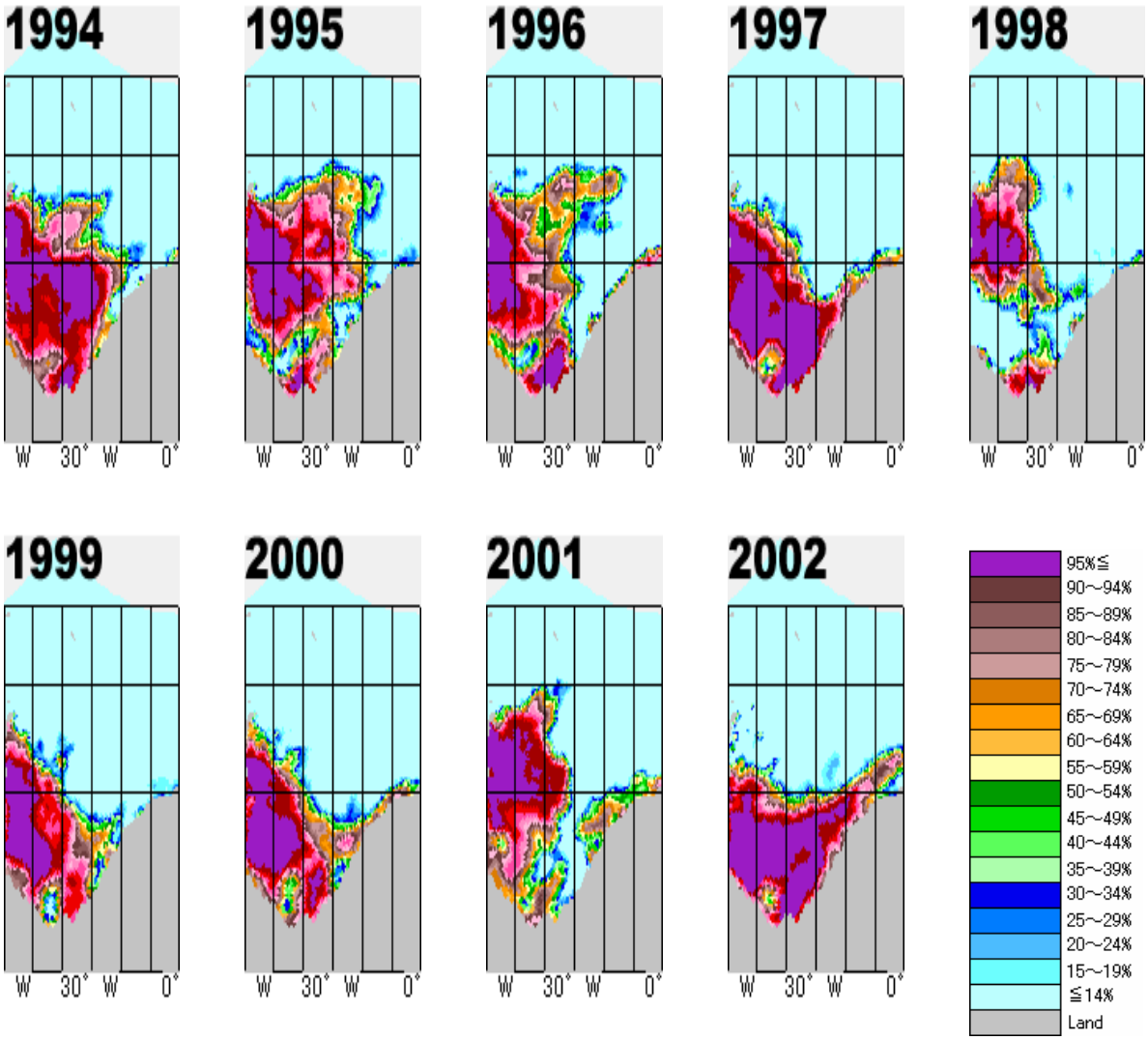

Fig. 2. (Continued)

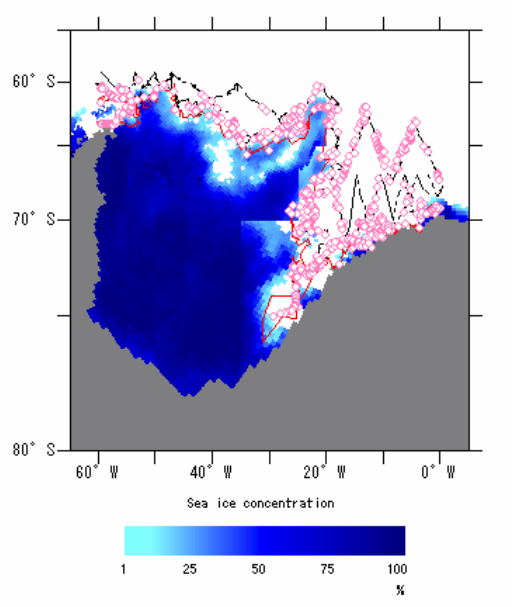

Fig. 3. Sighting survey trackline (black line), sighting positions of Antarctic minke whale (pink open circle), ice edge line (red line) defined by the survey vessels and satellite derived sea ice concentration in the 1986/87 CPII Area II cruise.

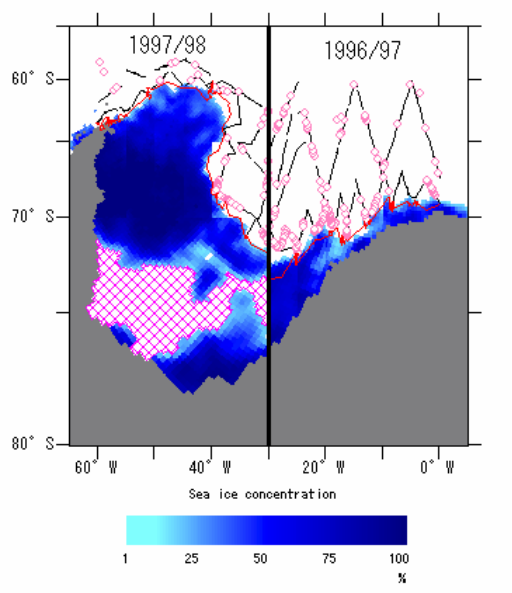

Fig. 4. Sighting survey trackline (black line), sighting positions of Antarctic minke whale (pink open circle), ice edge line (red line) defined by the survey vessels and satellite derived sea ice concentration in the 1996/97 (0°-30°W) and 1997/98 (30°W-60°W) CPIII Area II cruise. Pink hatched area was defined as the Ronne Polynya in this study.

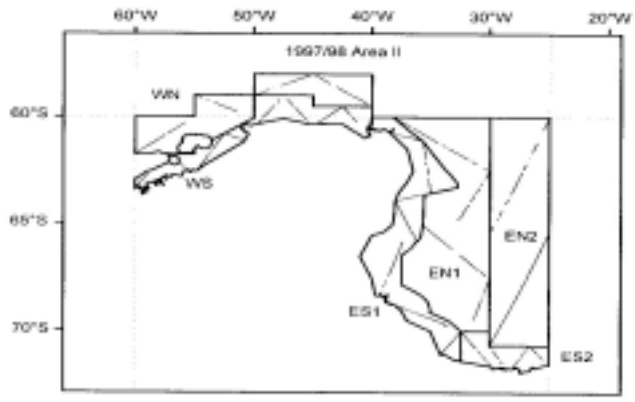

Fig. 5. Strata surveyed in the 1997/98 cruises (from Branch and Butterworth, 2001).

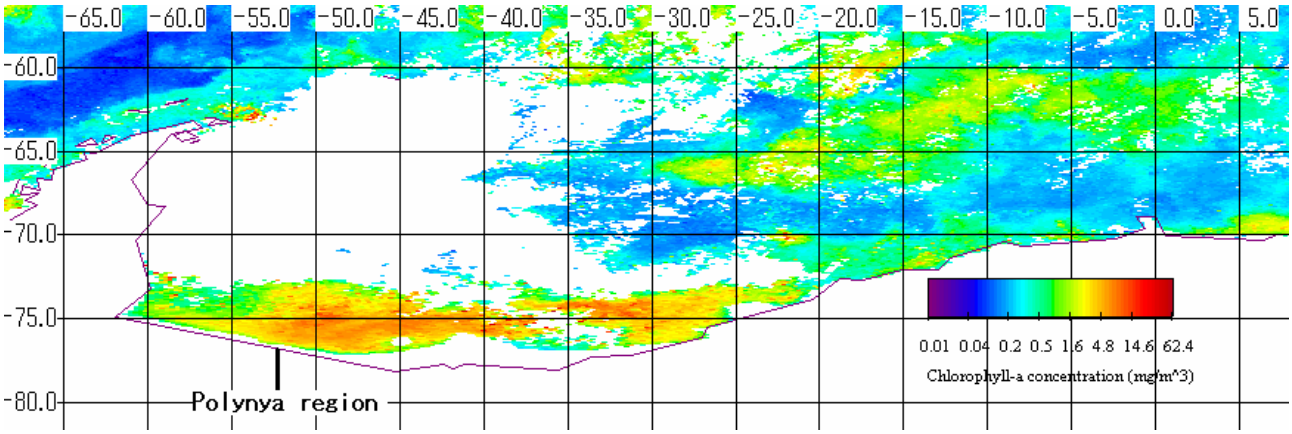

Fig. 6. Chlorophyll-a concentration in Area II in January, 1998.