Large whale distributions in relation to the southern boundary of the ACC in the Antarctic Areas IV and IIIE using JARPA 1997/98 data

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ABSTRACT

Further analyses of the relationship between whale distributions and the southern boundary of the Antarctic Circumpolar Current (ACC) in the Antarctic was conducted based on the density index of whale species (DI; individuals / 100 n.miles) by grid cell (grid size is 1° latitude x 1° longitude). longitudinal distributions of humpback, right, sperm and southern bottlenose whales were concentrated between 80° and 120° E.

Results of XCTD analyses in this area indicated a large meander of the southern boundary of the ACC that seemed to be moving north along the continent rise to 61° S and then slowly moving down to 63° S. It was considered that this area was a high productivity area formed by large-scale up welling with nutritious bottom waters due to the effect of the southern Kerguelen Plateau.

Further, in this large meander, humpback whale, which was the dominantly sighted species in this cruise, was concentrated along the southern boundary of the ACC. Minke whale, which was sub-dominantly sighted, was distributed along the ice-edge line. Right whales were sighted between 85° E and 120° E. Sperm and southern bottlenose whales were concentrated on the Antarctic continental slope.

Several whale species, especially humpback, right, minke, sperm and southern bottlenose whales used this area as their key feeding area, although it seemed that they were segregated from each other in their feeding habits.

INTRODUCTION

The Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) was conducted in eastern part of Area III (longitudinal 35° – 70° E) and Area IV (70° – 130° E) in the 1997/98 season (Ishikawa *et al.*, 1998). The research vessel *KS2* conducted the line transect sighting

survey and some experiments (photo-ID, biopsy sampling, XCTD etc.). In previous cruises from 1987/88 to 1996/97, the XBT (depth, water temperature) system was used (Naganobu, 1995). In order to investigate more oceanographic conditions and reduce the oceanographic survey hours during sighting surveys, it was recommended that the XCTD system be used instead of the XBT (Shimada *et al.*, 1997). This was the first attempt to use this system in the JARPA surveys. Preliminary analyses of this data were submitted to the 1999 IWC/SC meeting (Matsuoka *et al.*, 1999), which recommended further analyses of these data. In this paper, we further analyzed the density index (DI) of principal whale species, which were primary sighted by grid cell (grid size is 1° latitude x 1° longitude) using all JARPA-1997/98 sighting data. In addition, we examined the relationship between the southern boundary of the ACC and bottom topography, using geographical information system.

MATERIAL AND METHOD

Research area and research period

The research area was composed of the eastern part of Area III (Area III E, 35° - 70° E) and the entire Area IV (70° - 130° E) south of 60° S to ice-edge line (Fig.1). The research period of the XCTD oceanographic survey was from 17th December 1997 to 11th March 1998. Area IV was surveyed in January to February. Area III E was surveyed mainly in December and again in the beginning of March, before and after the survey of the Area IV.

Cruise track line, research vessel and sighting procedures

Cruise track line of this survey is shown in Fig.1. Construction of the cruise track line used the same method as the previous JARPA cruises (Nishiwaki *et al.*, 1997a) which is similar to the line transect procedure as used for IWC-SOWER cruises. Four research vessels, *Kyoshin-maru No.2* (KS2), *Kyo-maru No.*1, *Toshi-maru No.25 and Toshi-maru No.18* conducted the sighting survey, using closing mode at a research speed of 11.5 knots. The research vessels were operated under optimal research weather conditions (when the wind speed was below 25 knot near the ice-edge, or 20 knot in the off shore and visibility was over 2 n. miles). The searching distance, number of schools and individuals of whales sighted were recorded.

XCTD operation

The dedicated sighting vessel *KS2* conducted the XCTD oceanographic surveys using probes which enabled coverage from the surface to 1,000 meter in water depth (Mizuno and Watanabe, 1998) during searching effort (usually vessel was steaming at 11.5 knots). The XCTD stations were set

along the track line, which was continuous from northern strata to southern strata. Stations were set every one-degree latitude in the northern strata and every 10 minutes latitude in the southern strata in order to allow a even coverage of the major water-mass properties. A total of 93 XCTD profiles were measured in the research area (Fig.1).

XCTD data handling

The profile data were processed removing the sea surface (0-10 m) and sea bottom data. All profile data were divided into seven transects and considered for each location and period. Each of the seven profiles was processed for sectioned drawings of temperature and salinity. Temperature–Salinity diagrams of each transect was considered for each location and period.

Density Index of primary whales sighted

The density index (DI) by grid cell (grid size is 1° latitude x 1° longitude) for each species is calculated as the number of primary whales sighted per 100 n.miles of whale sightings using all 1997/98 JARPA sighting data. Blue, fin, right, humpback, minke, sperm, southern bottlenose and killer whales, which were mainly sighted in this cruise were examined.

Bottom topography

Bottom topography in the geographical information system was used in this analysis. The searching effort, oceanographic information and DI data were introduced to this system to compare the bottom topography.

RESULTS

Thermohaline Structure

In order to examin the large-scale oceanographic conditions; seven meridional temperature and salinity sections were constructed as shown in Fig. 2. In every section, the temperature minimum structure is commonly observed in the surface layer. The subsurface temperature minimum layer is thicker and colder in the coastal area. There is an obvious subsurface temperature front in the coastal side on several sections. The Antarctic Circumpolar Water exists north of the front. The front indicates the southern boundary of the Antarctic Circumpolar Current (ACC).

Meandering of the Southern boundary of the ACC

The southern boundary of the ACC was detected from each meridional section and the map of dynamic height. The southern boundary of the ACC appeared to 63° -64° S from off the Enderby

Land (50° E) to off the Wilks Land (130° E) and there was a large meander that seemed to be moving northward along the continent rise to 61° S and then slow-moving down to 63 ° S, between 80° and 120° E. A drastic meander of the southern boundary of the ACC was observed from 82° - 86° E which was caused by the existence of the southern Kerguelen Plateau.
Large scale up welling with nutritious bottom waters were observed in the transects IV-1, VI-1 and VII-1 (Fig. 2).

Whale distributions in relation to the southern boundary of ACC and bottom topography

Fig. 3 shows the searching effort of the research vessels in this cruise.

Baleen whales

Humpback whale was dominant sighted species in this cruise. The DI of this species was clearly high along the southern boundary of the ACC. In January to February, humpback whales were widely dispersed other parts of Area IV. In December in Area IIIE, humpback whales were distributed north of the southern boundary of the ACC. Minke whale was the sub-dominant species in this cruise. The DI of this species tended to be high along the ice-edge line. Minke whales were widely dispersed in other parts of Area IV. In December in Area IIIE, minke whales were distributed north of the southern boundary of the ACC (Fig. 4a). Distribution patterns of blue, fin and right whales were not clear due to few sightings, though right whales were sighted south of the southern boundary of the ACC between 85° E and 120° E in Area IV. In December in Area IIIE, blue and fin whales distributed north of the southern boundary of the ACC (Fig. 4b).

From the viewpoint of longitudinal distributions, humpback and right whales were concentrated between 80° and 120° E. Similar distribution patterns of these species were also observed in previous JARPA surveys (Nishiwaki *et al.*, 1997b).

Toothed whales

The DI of sperm and southern bottlenose whales tended to be high on the slope of the Antarctic continental slope or the southern Kerguelen Plateau. These species were also widely dispersed in other parts of the research area. The distribution pattern of killer whales was similar to minke whales, distributed south of the southern boundary of the ACC, especially near the ice-edge line. They were also widely dispersed in the research area (Fig. 4c). Long finned pilot whale and hourglass dolphin were mainly sighted north of the southern boundary of the ACC.

From the viewpoint of longitudinal distributions, sperm and southern bottlenose whales were concentrated between 80° and 120° E.

Segregation of whales between 80° and 120° E

Distribution of the DI of humpback and minke whales in the large meander, high-density area of humpback and minke whales shows segregation of these species along the southern boundary of the ACC and along the ice-edge line. On the other hand, both high-density areas of sperm and southern bottlenose whales were observed on the continental slope, although it seemed that sperm whales were concentrated in the more abrupt areas of the continental slope (Fig.5).

DISCUSSION

High productivity in the meander of the southern boundary of ACC

From the viewpoint of large scale whale distributions, humpback, right, sperm and bottlenose whales were concentrated between 80° and 120° E (south of 60 ° S) rather than other parts of the research area. This area was characterized by a large meander (rise to 61° S and slow-moving down to 63° S) of the southern boundary of the ACC which seemed to be formed by large scale up-welling with nutritious bottom waters resulting from the bottom shape of the southern Kerguelen Plateau.

It has been pointed out that high productivity of the waters around the Antarctic continent may be linked to the southern boundary of the ACC (Tynan, 1998). The BROKE, Australian Antarctic survey, indicated the possibility of the occurrence of large-scale upwelling between 80° and 100° E (Thiele and Gill, in press). In JARPA 1999/2000 cruise, high density of Euphausiid was reported between 100 ° and 120 ° E (Murase *et al.*, 2000).

Considering the above, the large meander of the southern boundary of the ACC between 80° and 120° E, was likely a high productivity area used by several whale species, especially humpback, right, minke, sperm and southern bottlenose whales as their key feeding area in January and February. Segregation of these species within this area may result their feeding habit.

Future studies

In JARPA 1999/2000 cruise, similar tendency of whale distributions were observed (Ishikawa *et al.*, 2000) and high density of Euphausiid was reported between 100 ° and 120 ° E using krill survey data. These results suggested that stationary high productivity waters exist between 80° and 120° E during January to February.

Further analyses are necessary to compare yearly and monthly variation of oceanographic conditions and whale distributions using 1997/98 and 1999/2000 data. Oceanographic surveys are also necessary to further elucidate the relationship between the distribution patterns of whales and their habitat.

ACKNOWLEDGEMENTS

We wish to express our gratitude to T. Nibe and K. Ohshima who contributed the oceanographic surveys. We also thank Captain Y. Maiya and his crew on the *Kyosin-Maru No.2* who contributed to the success of the JARPA cruise in 1997/98. We thank E. Hofmann, Center for Coastal Physical Oceanography and H. Hatanaka, National Research Institute of Fisheries Science for their valuable suggestions and comments. Dan Goodman of the ICR for critically reviewing the maniscript.

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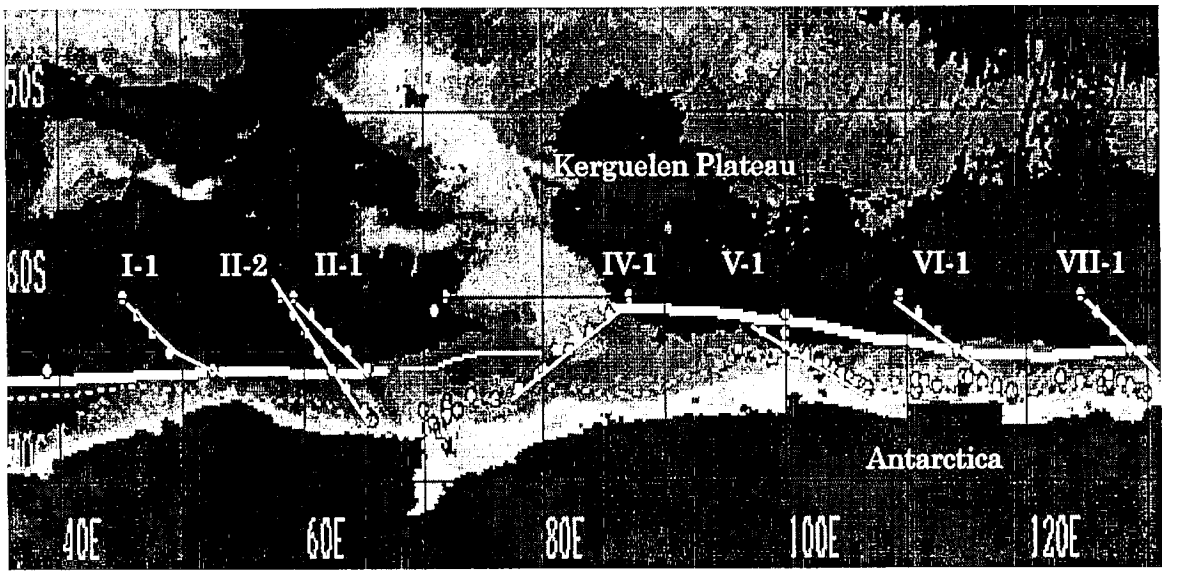
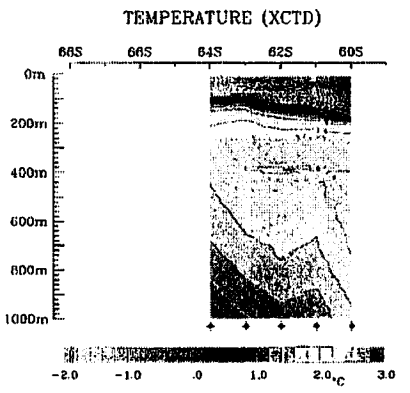
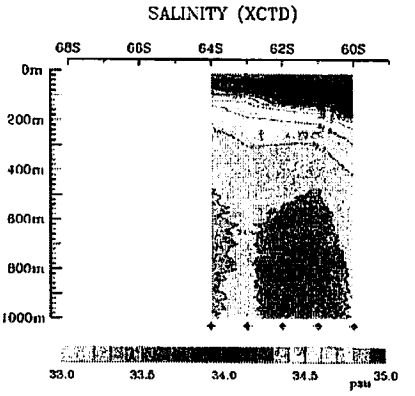


Fig. 1. The XCTD stations and each transect with bottom topography in the JARPA-1997/98 cruise by *Kyosin-Maru No.2*. Broken line shows the estimated ice edge line.

I-1





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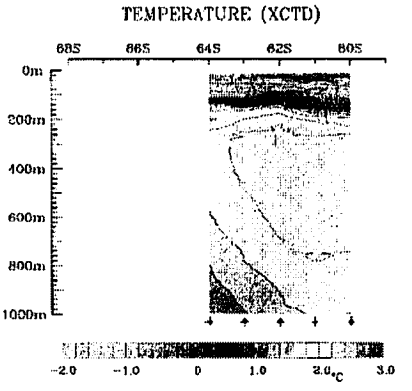

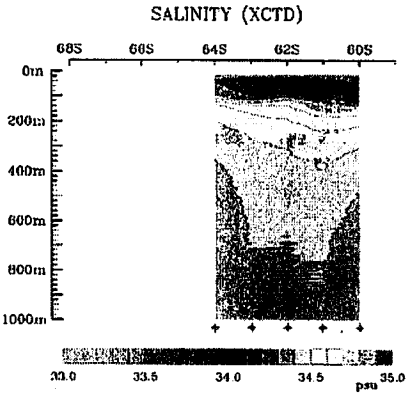

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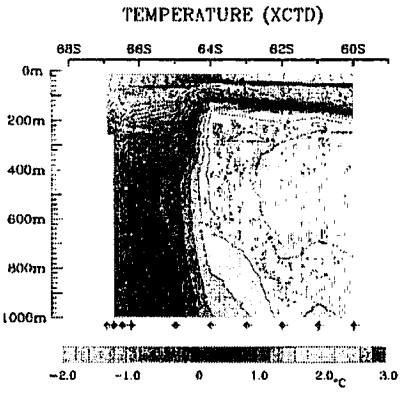

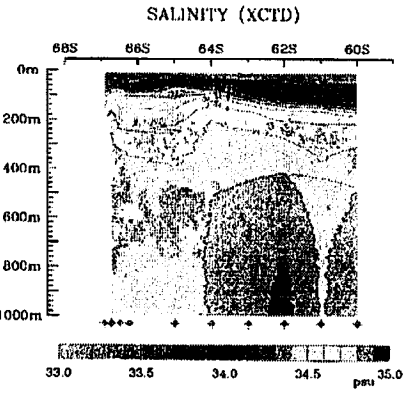

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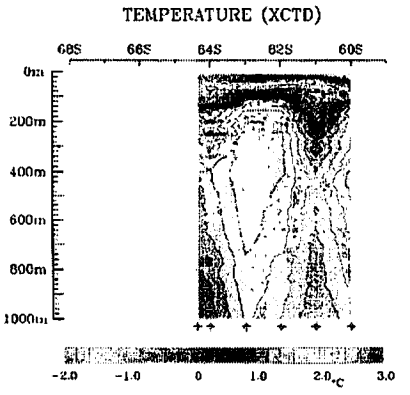


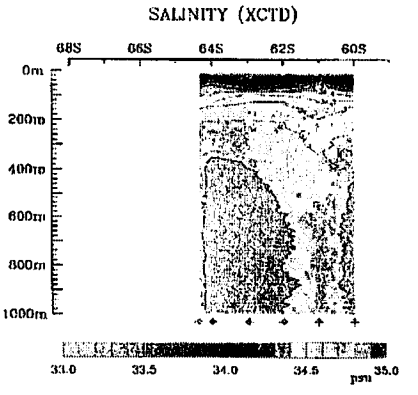
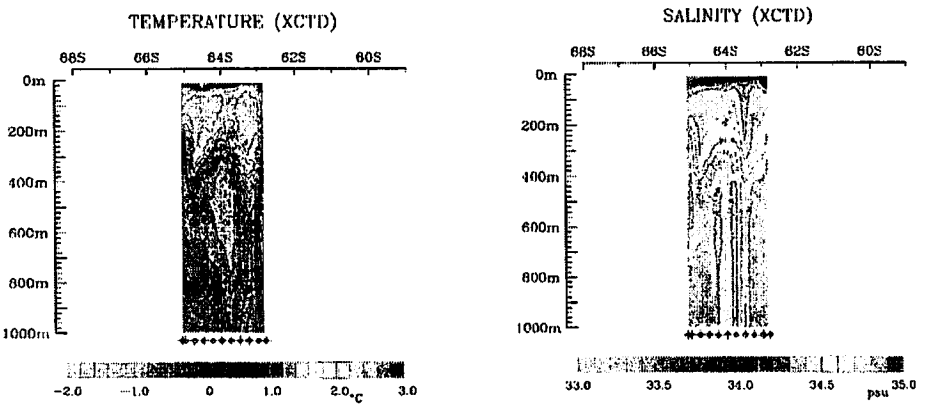


Fig. 2. Meridional temperature and salinity sections of each transect I-1 to VII-1.

V-1



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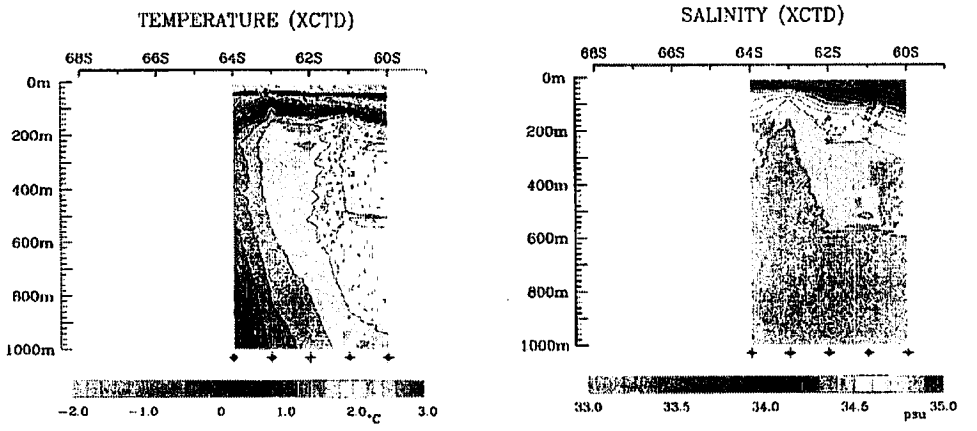


VII-1

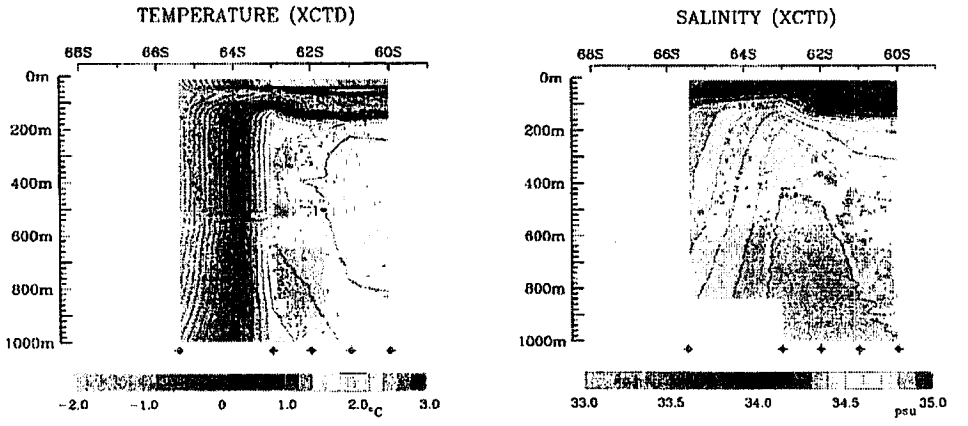


Fig. 2. (Continued).

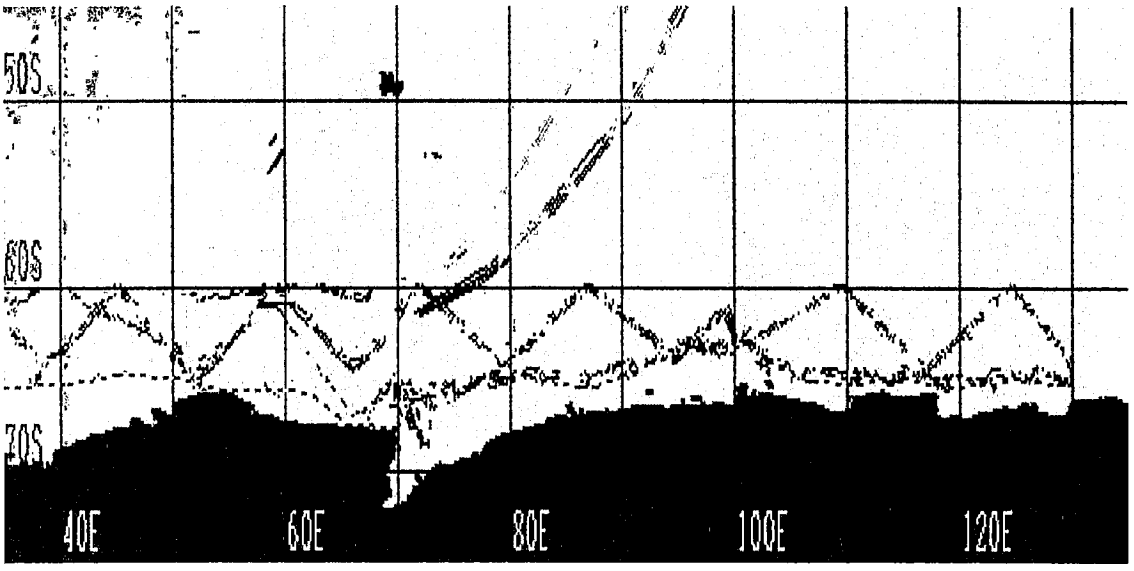
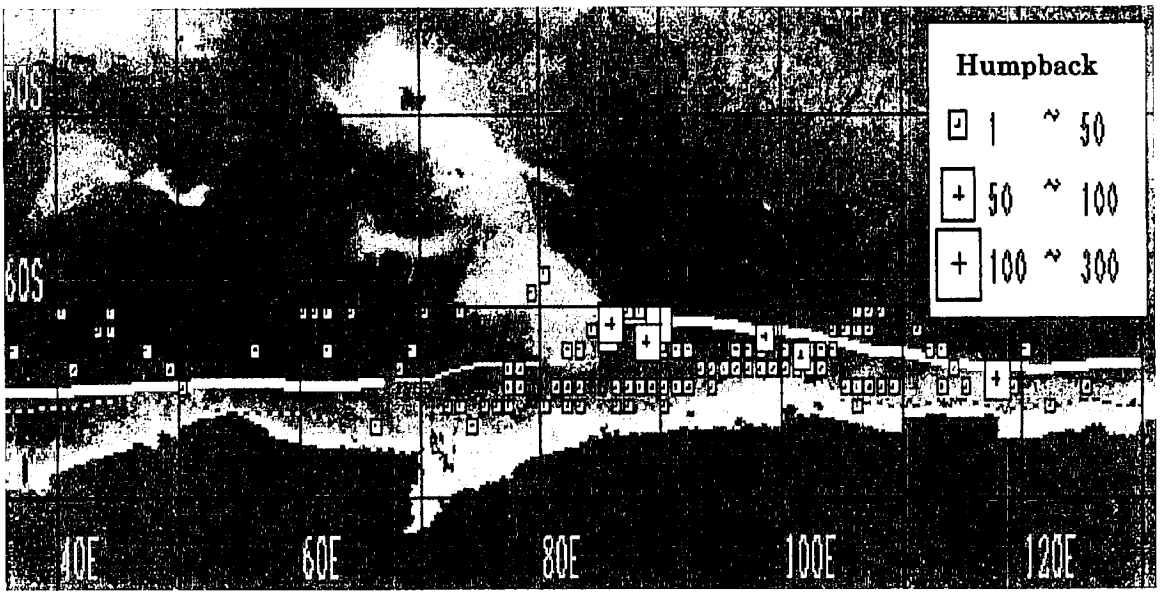


Fig. 3. The searching efforts of the research vessels, *Kyosin-Maru No.2, Kyo-Maru No.1, Toshi-Maru No.25 and Toshi-Maru No.18,* in the JARPA-1997/98 survey (Black line: on effort, white line: off effort). Broken line shows the estimated ice edge line.



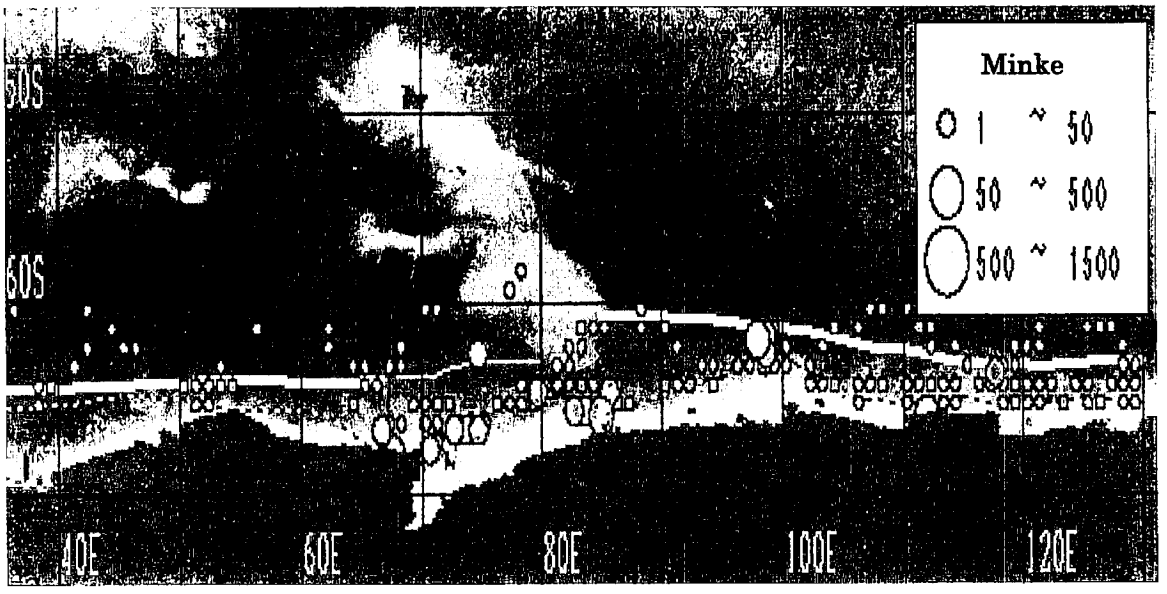


Fig. 4a. Relationship between the distribution of the Density Index (DI: individuals / 100 n.miles) and the southern boundary of the Antarctic Circumpolar Current (ACC; thick solid line) in the JARPA-1997/98 cruise. Broken line shows the estimated ice edge line. Top: humpback whale. Bottom: minke whale.

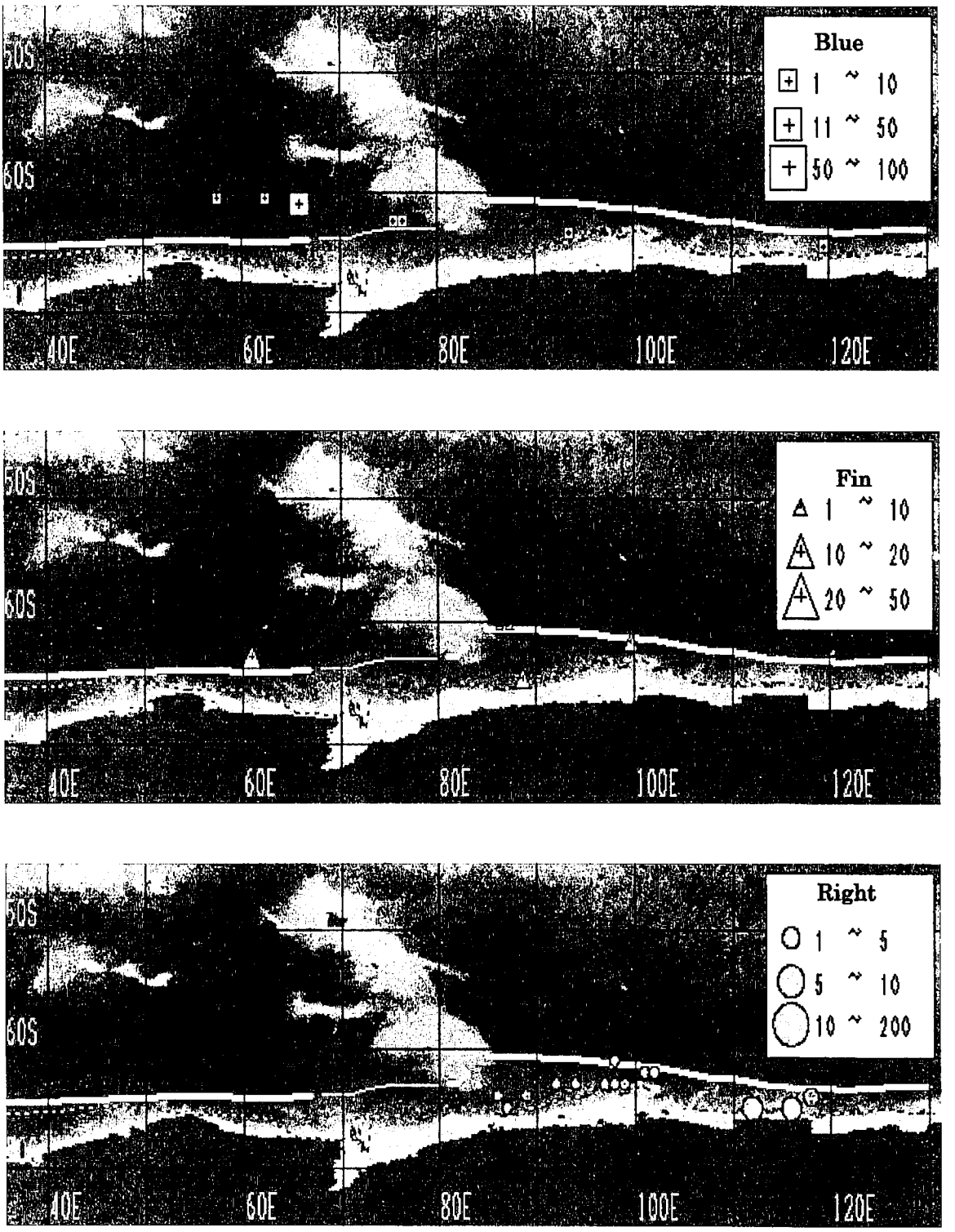


Fig. 4b (continued). Top: blue whale. Middle: fin whale. Bottom: right whale.

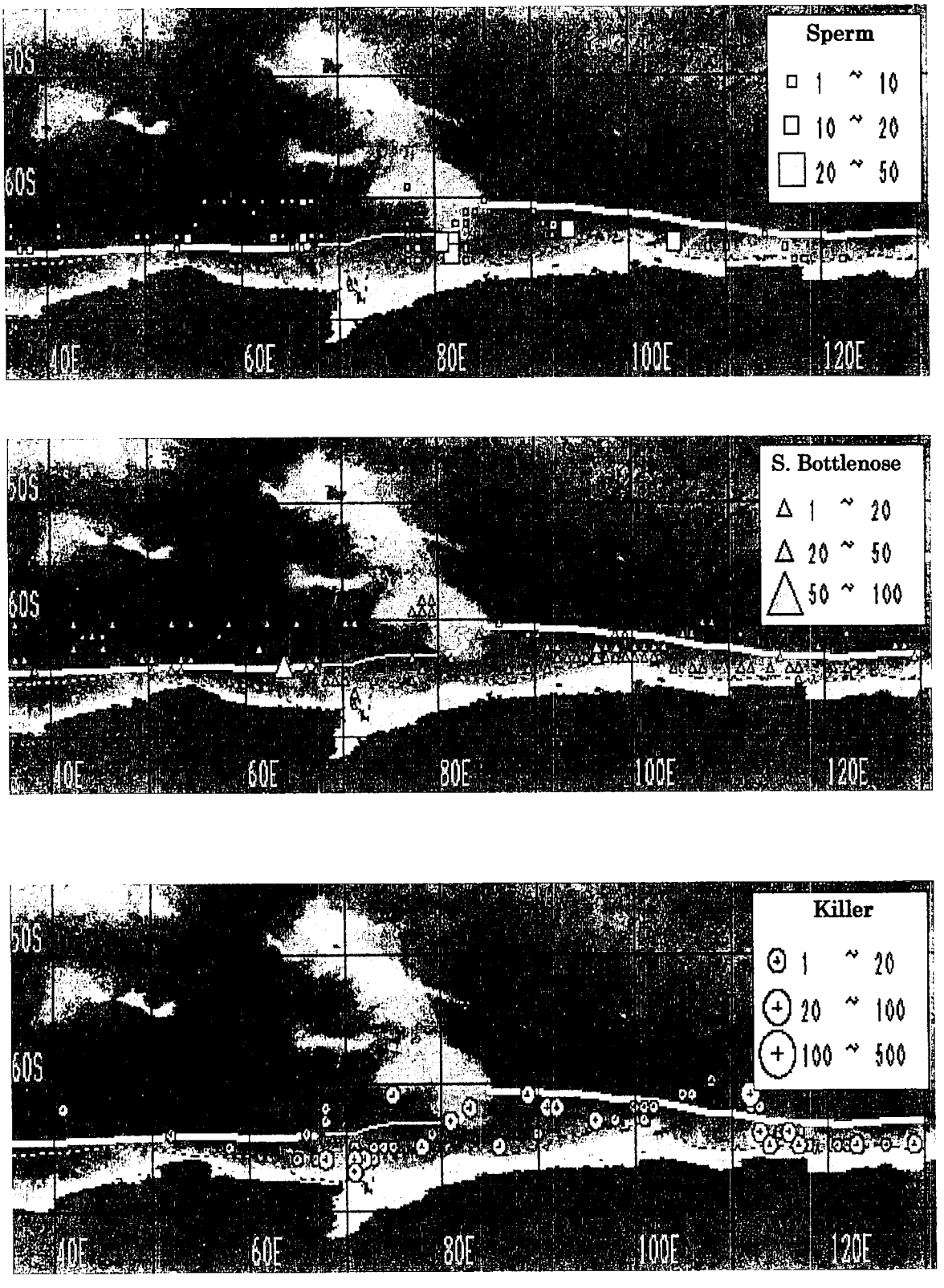


Fig. 4c (continued). Top: sperm whale. Middle: southern bottlenose whale. Bottom: killer whale.

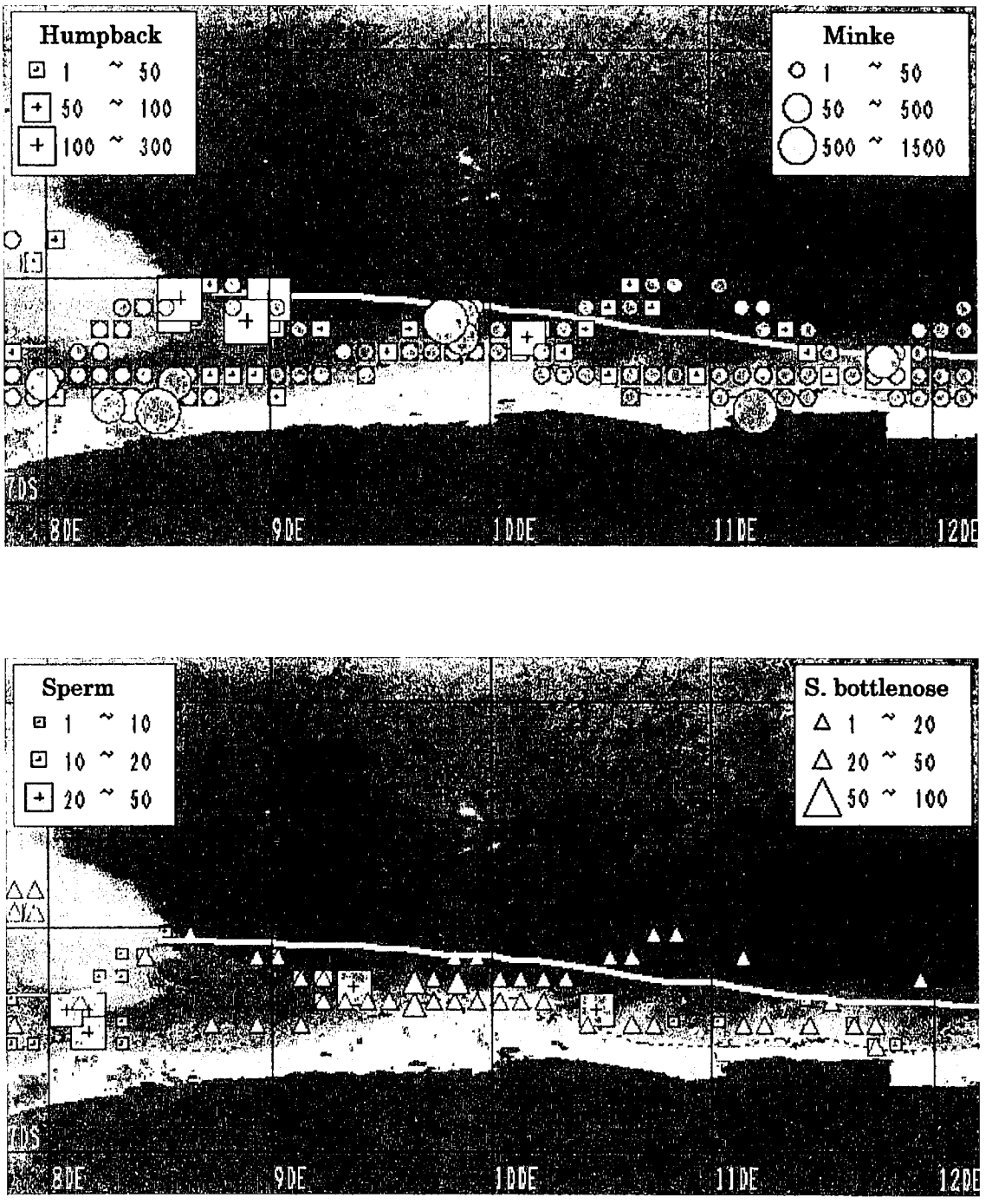


Fig. 5. Distribution of humpback, minke, sperm and southern bottlenose whales in the meander of the southern boundary of the Antarctic Circumpolar Current (ACC) between 80 –120 E with bottom topography in the JARPA-1997/98 cruise using the density Index (individuals / 100 n.miles) by grid cell (grid size is 1° latitude x 1° longitude) data. Thick solid line shows the southern boundary of the ACC. Broken line shows the estimated ice edge line. Top: humpback and minke whales. Bottom: sperm and southern bottlenose whales.