Cruise Report of the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) Area IV and Eastern Part of Area III in 1999/2000

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ABSTRACT

The thirteenth year of the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) was conducted in Area IV and eastern part of Area III (Area IIIE) from 5 December 1999 to 10 March 2000. One sighting vessel (SV), three sighting / sampling vessels (SSVs) and one research base ship were engaged in the research. The SV covered 4,963.2 n. miles, and made primary sightings of 491 schools / 1,771 individual minke whales. Three SSVs searched a total of 11,378.3 n. miles and sighted 1,016 schools / 4,810 individual minke whales as primary sightings. Minke whale was the most dominant species in every stratum except for the northern stratum in Area IIIE and occurred in extremely high density in the East-south stratum in Area IV. Humpback whale was the second dominant species and occurred in high density in both the Areas IV and IIIE. Distribution of humpback whales showed clear segregation from minke whales except for the East-south stratum in Area IV where both species were found most frequently. The sightings for each of three rorquals, minke, humpback and blue whale were higher than the past JARPA survey records. The recent increase of sightings of humpback whale strongly support recovery of the stock of this species. A total of 468 minke whales were targeted for sampling resulting in the catch of 439 individuals (109 from Area IIIE and 330 from Area IV). A "Feasibility Study of Modification of Sampling Method" was conducted in the East-south stratum and the target school for sampling was selected according to the predetermined interval for each school size. A total of 49 biopsy samples was obtained from humpback, blue and right whales by the SV and SSVs. The SSVs conducted an experiment of biopsy for randomly selected minke whales and obtained 10 samples. The SV conducted an oceanographic survey using a passive acoustic system, Electric Particle Counting and Sizing System (EPCS) and XCTD. One of the SSVs also conducted an oceanographic survey using EPCS and CTD. Information from National Ice Center revealed that there was few ice-free area south of the ice edge line in Area IV compared to the 1997/98 JARPA. Preliminary analysis of oceanographic survey data indicated that the course line of the research vessels passed above the continental slope of the Antarctica where was abundant in krill. These suggest possible reasons for the high density of baleen whales.

KEYWARDS: JARPA, CRUISE REPORT, MINKE WHALE

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INTRODUCTION

The Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) has been conducted every year since the 1987/88 season in compliance with Article VIII of the International Convention for the Regulation of Whaling. JARPA is authorized by the Japanese Government and planned and conducted by the Institute of Cetacean Research (ICR). After two seasons of feasibility research in 1987/88 and 1988/89, full-scale research started in the 1989/90 season. The program is designed to repeat surveys in the Antarctic Areas IV and V alternatively in each of the sixteen years of the research period. From the 1995/96 season, the survey area was expanded into a part of Areas III and VI to improve the stock structure study (Government of Japan, 1987, 1989, 1995). The original objective of the expansion to the eastern part of Area III in 1995/96 season was a feasibility study on stock identification to examine the hypothesis of the occurrence of more than one stock in Areas IV and V (Government of Japan, 1995). Initial study using commercial samples suggested that the core stock (C stock) was widely distributed in Areas IV and V and a different stock (W stock) occurred in the eastern part of Area III (Area IIIE) and western part of Area IV (Area IVW) in the early period of feeding season (Pastene *et al.*, 1996). However, the result of mitochondrial DNA analyses using the 1995/96 and 1997/98 samples was the reverse to what was anticipated, as the samples from Area IIIE and Area IVW in the early period were not W stock (Pastene and Goto, 1997, 1999). Although these results are consistent with the view that different stocks interact in the western part of Area IV, it seems their distribution pattern could change both within and between years. Further sampling in the expanded area was required to elucidate yearly variation of the stock distribution pattern.

The research plan of the 1999/2000 JARPA was submitted to 51st Annual Meeting of the International Whaling Commission and the Scientific Committee (IWC/ SC) meeting (Government of Japan, 1999). The objectives of the research were as follows;

1) Elucidation of the stock structure of the Southern Hemisphere minke whales to improve the stock management,
2) Estimation of biological parameters of the Southern Hemisphere minke whales to improve the stock management,
3) Elucidation of the role of whales in the Antarctic marine ecosystem through studies of whale feeding ecology,
4) Elucidation of the effect of environmental changes on cetaceans.

Although these objectives were the same as previous research, the present research was planned with special reference to elucidation of the W stock distribution pattern.

This paper reports on the thirteenth cruise of the JARPA, which was conducted from 5 December 1999 to 10 March 2000 in the Antarctic Area IV and Area IIIE.

RESEARCH METHODS

Research area

The research area in the present survey was composed of the eastern part of Area III (Area IIIE, 35° E – 70° E) and the entire Area IV (70° E - 130° E) south of 60° S (Fig. 1). The northern boundary of Area IIIE was expanded to 58° S to increase the number of samples apart from the ice edge in the early period of feeding season. Area IV was divided into two sectors, east and west, by the 100° E. They were further divided into two strata, a south stratum extending from the pack ice edge to a locus 45 n. miles from the ice edge, and a north stratum extending from the northern boundary of the south stratum to the 60° S. In the present research, as the north strata were surveyed prior to the south strata, the southern boundary of the north strata was set at the ice edge expecting a retreat of the ice edge at the time of the survey of the south strata. The southern boundary of the West-north stratum was fixed at 65° S (70° E - 80° E) and 64° 15' E (80° E - 100° E) in advance, which were estimated from the results of previous surveys. The southern boundary of the West-south stratum between 70° E and 80° E was fixed at 66° S and Prydz Bay was defined as the southern area of this boundary. The survey of each stratum in Area IV was conducted as follows; West-north, East-north, East-south, West-south and Prydz Bay. Area IIIE was also divided into two strata as the same manner of the Area IV for precise survey during the early Antarctic summer. The survey in Area IIIE in the second period was planned but not carried out because of delay of the survey schedule.

Research vessels

Three vessels, *Kyo Maru No.1* (K01; 812.08 GT), *Toshi Maru No.25* (T25; 739.92 GT) and *Yushin Maru* (YS1; 720 GT) were engaged in sighting and sampling surveys (the sighting / sampling vessels; SSVs). *Nisshin Maru* (NM; 7,575GT) served as a research base on which all biological examinations of collected samples were conducted. *Kyoshin Maru No.2* (KS2; 368 GT) was dedicated to sighting survey from which most of all experiments were conducted (the sighting vessel; SV).

Cruise track line and sighting and sampling method

Fig. 2 shows the track line of the main course. The method for establishment of the cruise track line in Area IV was same as the previous research (Nishiwaki *et al.* 1996, Ishikawa *et al.* 1998). In Area IIIE, two longitudinal zigzag lines were set in east and west of the northern stratum. A lateral zigzag line in the southern stratum was set in 6° longitudinal intervals in Area IIIE which was expanded from 4° longitudinal intervals in Area IV.

Sighting and sampling procedures were as in the previous JARPA surveys (Nishiwaki *et al.* 1996, 1997b, Ishikawa *et al.* 1998) with some modifications. The sighting survey using SSVs was conducted under limited closing mode (when a sighting of minke whale was made on the predetermined track line, the vessel approached the whale and species and school size were confirmed). SSVs followed parallel track lines 7 n. miles apart, at a standard speed of 11.5 knots. The sighting survey using SV was conducted under limited closing mode and passing mode (even if sighting was made on the predetermined track line, the vessel did not approach the whale directly and searching from the barrel was uninterrupted). The survey was operated under optimal research conditions (when the wind speed was below 25 knot in the south strata or 20 knot in the north strata and visibility was over 2 n. miles). In addition to the sightings of minke whales or whales suspected to be minke whales, the SV approached blue, right, humpback and pygmy right whales for conducting some experiments. The SSVs also approached blue whales and right whales for experiments. One ordinary form minke whale was sampled randomly from each primary sighted school within 3 n. miles of the track line. This sampling manner was changed during the Feasibility Study of Modification of Sampling Method (see the paragraph of Experiments). The dwarf form minke whale was not a target species for sampling.

Low and middle latitudinal sighting survey

During transit cruises, sighting surveys were conducted in the area between south of 30° S and north of 60° S except for areas within national EEZs. The results of these surveys are not mentioned in this report.

Experiments

Following experiments were conducted.

Sighting distance and angle experiment

This experiment was conducted in order to evaluate the accuracy of the information on sighting distance and sighting angle given by observers of the SV and SSVs in this cruise.

Photo-identification experiment

The following species were targeted for photographic record of natural markings during the surveys conducted from the SV; blue, humpback and right whales. Photographic records of blue whales and other species were also taken from the SSVs.

Biopsy sampling

The species targeted for photo-identification experiments as well as the pygmy right whale were also targeted for biopsy skin sampling using air guns developed by ICR. All collected sample were preserved at - 80° C.

Biopsy for randomly selected minke whales

The purpose of the experiment is to assess the possibility of collecting DNA samples from randomly selected minke whales by non-lethal method. SSVs tried to get biopsy sample using same protocol as that for the random sampling method adopted in JARPA. Both the air gun and the crossbow were used and performance and utility were compared.

Satellite tagging experiment

Attempts to attach satellite tags to some species were made from SV in order to elucidate migration routes.

Acoustics

SV conducted acoustic monitoring of blue whale and other baleen whale species using a retrievable sonobuoy system (System Giken Ltd., Japan) which consisted of a hydro-phone, battery and DAT recorder (Matsuoka *et al.*, 2000).

Oceanographic survey

SV conducted the following oceanographic survey; 1) hydro-acoustic survey using a passive acoustic system (EK500 38kHz, 120kHz, 200kHz, SIMRAD, Norway) to elucidate distribution and abundance of prey species of Antarctic whales, 2) consecutive measuring of water surface temperature, conductivity, surface chlorophyll, dissolved oxygen, surface particle and surface flow by Electric Particle Counting and Sizing System (EPCS), 3) XCTD survey and 4) marine debris recording in the research area. YS1 conducted CTD and EPCS survey. All marine debris found in the stomach of minke whales was recorded and collected on NM.

Feasibility Study of Modification of Sampling Method (S-experiment)

During the 49th IWC Scientific Committee meeting, modification of the sighting and sampling method of JARPA was proposed (Schweder, 1998). Japan decided to conduct a limited scale feasibility study on whether the modified method was workable or not (Government of Japan, 1999). The feasibility study (S-experiment) was conducted in the East-south stratum in Area IV. During the S-experiment period, all SSVs stayed at the point where the survey of the day was finished until next day. Different from the ordinal research manner, they never moved forward during night or in bad weather condition. Target school for sample was selected according to the predetermined interval for each school size. One or two individuals were collected from the targeted school. Two weeks were allocated for the S-experiment.

Biological research

Biological research on all whales caught was conducted on the research base ship (NM).

OUTLINE OF THE RESEARCH ACTIVITIES

An outline of the research activities conducted during the 1999 /2000 JARPA survey is as follows.

Event	Date	Vessels
Departure from Japan	9 November 1999	NM, SV and SSVs
Sighting survey in transit area.	24 November - 3 December 1999	SV and SSVs
Sighting and sampling survey in Area IIIE	5 December - 26 December 1999	SV and SSVs
Sighting and sampling survey in the West-north stratum in Area IV	27 December 1999 -11 January 2000 28 December 1999 -13 January 2000	SV SSVs
Sighting and sampling survey in the East-north stratum in Area IV	11 January - 26 January 2000 14 January - 27 January 2000	SV SSVs
Sighting and sampling survey in the East-south stratum in Area IV	28 January - 18 February 2000 28 January - 18 February 2000	SV SSVs
Sighting and sampling survey in the West-south stratum in Area IV	18 February - 29 February 2000 6 March - 9 March 2000 19 February - 1 March 2000 7 March - 9 March 2000	SV SSVs
Sighting and sampling survey in the Prydz Bay	1 March - 6 March 2000 2 March - 6 March 2000	SV SSVs*

Sighting survey in transit area.	12 March	- 18 March	2000	SV and SSVs*
Arrival at Japan	4 April			SSVs
	6 April			NM and SV

*SSVs were dedicated to sighting survey after sampling survey.

OBSTRUCTION FROM VIOLENT CONSERVATION GROUP

From 20 December to 16 January, a conservation group, Greenpeace attempted to obstruct the research activity. Contrary to their principle that was publicized, their attempted obstruction was violent and dangerous. On 21 December, Greenpeace's ship *Arctic Sunrise* caused a collision with NM which resulted from a reckless approach neglecting caution warnings from NM. Greenpeace activists attacked crews of SSVs with water spray from 25 December. They also broke and robbed equipment of NM and tried to invade NM 12 January. Although these violent attempts to obstruct the research had little effect on the research, Greenpeace's inflatable boats occasionally interrupted sighting survey of SSVs and a biopsy experiment on two humpback whales was interrupted on 30 December.

RESULTS

Searching effort

Table 1 shows the searching distances (n. miles) by each stratum. The SV covered 4,963.2 n. miles and the three SSVs covered an average of 3,792.8 n. miles each. Total searching distance of one SV and three SSVs was 16,341.5 n. miles (Area IIIE; 3,679.7, Area IV; 12,661.8). Total searching distance in Area IIIE was less than half of that searched in the previous JARPA in 1997/98 because of bad weather in northern part and cancellation of the second period survey. The SV conducted passing mode searching for six hours a day. During the S-experiment, the SV adopted closing mode all day. The ratio of passing mode was 35.0 % of total searching distance of the SV.

Species sighted

Tables 2a and 2b summarize the sightings made. Minke whale was the most dominant species followed by humpback whale in both Areas IIIE and IV. No dwarf minke whales were sighted in the whole research area. Total primary sightings of minke whales involved 1,507 schools / 6,581 individuals, whereas those of humpback whales involved 661 schools / 1,269 individuals. In Area IV, minke whale was extremely abundant in southern area, especially in the East-south stratum where a number of large group was observed. Primary sightings in Prydz Bay were mostly minke whale (79.7%). Distribution of minke whales in Area IIIE was also concentrated near the pack ice west of 56 ° E. Most of the minke whales sighted in the northern stratum were in the southern most part of the stratum and only a few minke whales were sighted off the ice edge in Area IIIE (Fig. 3). Distribution of humpback whales in Area IIIE was clearly separated from that of minke whales. Humpback whales were concentrated in the western part of the northern stratum and the southern stratum between 56 ° E - 62 ° E while few minke whales were sighted in this area. In Area IV, a similar segregation pattern for the two species was observed in the north strata, however, distribution of humpback whales in the south strata was concentrated between 90 ° E - 112 ° E where it overlapped with a high density area of minke whales. Humpback whales were seldom seen in the Prydz Bay (Fig. 4).

Table 3 shows density indices (DI; schools sighted / 100 n. miles searching distance) and mean school size (MSS) of minke whale and humpback whale in each stratum. Although the DI of minke whale was relatively low in the north strata, it increased dramatically in the south strata to a level 4.2 – 8.9 times higher than in the north strata. In the East-south stratum, MSS of minke whale was more than two times that of other south strata. On the other hand, the difference of DI and MSS between north and south strata for humpback whale was relatively small except for the Prydz Bay.

Fig. 5 shows the frequency rate for each school size in relation to the total school sighting number of minke and humpback whales. The most frequent school size of minke whale is one (0.41) and the frequency rate decreases inversely with school size. On the other hand, the most frequent school size of humpback whale is two (0.54) followed by one (0.32) and the schools of more than two are infrequent.

A total of 25 schools /53 individual blue whales and 66 schools / 356 individual fin whales were primarily sighted. A number of these two species were sighted with humpback whales between 56° E - 62° E in Area IIIE. Blue whales were observed relatively near the pack ice, whereas many fin whales were found off the ice edge in Area IIIE and the entrance of the Prydz Bay (Fig. 6).

Calves of blue (two cases), fin (three cases) and humpback whales (six cases) accompanying their mother were observed. Calves of blue whales accompanying mother were sighted only in Area IIIE (December). No calf-accompanying mothers of minke whales were observed in whole research area.

Killer whale was the most abundant toothed whale. It was frequently observed that a large group of killer whales surrounded minke whales and / or humpback whales in the south strata in Area IV. Southern bottlenose whale schools and sperm whale schools were the dominant schools of toothed whales sighted. Sightings of these species were relatively high in the West-north stratum in Area IV where the sightings of baleen whales were relatively low.

Sampling of minke whale

Out of 1,016 schools / 4,810 individual minke whales sighted by the SSVs, 468 individuals were targeted for sampling. A total of 439 individuals was collected (109 from Area IIIE, 330 from Area IV, see Fig. 7). Technical sampling efficiency (the rate of sampling for targeted individuals) was 0.94. Technical sampling efficiency in this season was high in every stratum (0.89 –1.00). Out of 31 cases of sampling failure, the most frequent reason was missing the whale before commencement of chase (eight cases). Sampling failure because of technical problems occurred four cases.

Special attention to reduce the time to death was given to all targeted and sampled whales. Explosive harpoons were used for all targeted whales as the primary killing method. The large caliber rifle was used as the secondary killing method when required.

Experiments

A sighting distance and angle experiment was performed on 4 January by the SV and SSVs. The results of this experiment will be used in calculating abundance estimates.

Table 4a summarizes the results of photo-ID, biopsy sampling and acoustic monitoring. A total of 125 individuals were photographed and 49 skin samples were collected by biopsy from humpback, blue, and right whales. Acoustic records were obtained for total of 19 hours and 38 minutes from seven cetacean species. Special attention was paid to record the sound of blue and right whales.

Table 4b summarizes the results of the oceanographic and hydro-acoustic surveys. XCTD and CTD surveys were conducted at 123 and 87 locations in all research areas respectively. EPCS surveys and hydro-acoustic surveys were also conducted in the all research areas.

The marine debris survey was carried out concomitant with the sighting survey of the SV in all research areas. A total of seven debris (five buoys, a plastic bottle and a plastic box) were confirmed. A plastic piece and a wood piece were found in the third compartment of the stomach of sampled minke whales. A plastic piece was also found inside the rectum of another sampled minke whale.

Nine trials of the satellite tagging experiment were performed for minke whales and humpback whales. Although the small harpoon for tagging hit the target in four cases, the connection between the device and the harpoon failed in these cases. These trials were therefore unsuccessful.

Biopsy for randomly selected minke whales was performed from 6 to 8 February after the catch limit of the day was reached. One SSV equipped with air gun and two SSVs with crossbow tried to get biopsy sample using the same protocol as that used for catching. During the experiment, weather and sea condition were extremely good (wind speed 0-5 knot and the Beaufort scale 1-2) and MSS of minke whale was high in 5.85 (3-15). Seven trials with the air gun and six trials with the crossbow were conducted and a total of 10 biopsy sample was collected. Sampling efficiency was 1.0 by the air gun and 0.5 by the crossbow. Average experiment time (chasing time) per school was 11 minutes by the air gun and 16 minutes by the crossbow. A questionnaire survey to crew of SSVs revealed following problems with the biopsy sampling method; 1) because of the short shooting range of biopsy devices, firing opportunity was limited and it was difficult to target a whale swimming fast compared with harpoon gun, 2) both air gun and crossbow were very weak in wind, 3) size of the target for a biopsy dart was much smaller than that of a harpoon because biopsy darts couldn't reach whale body under the water surface. Regarding the weather condition, the wind condition recommended for biopsy sampling was considered under nine knots for the crossbow and 12 knots for the air gun.

S-experiment was conducted from 28 January to 10 February in the East-south stratum in Area IV. During the experiment, 109 schools / 514 individual minke whale were primary sighted and 92 schools / 113 individuals were selected for the target according to the predetermined interval for each school size. Details of the experiment is reported in other document (Hakamada and Fujise, 2000).

Biological research

Table 5 summarizes data and samples collected. In Area IIIE, a female fetus with body length of 284.4 cm was collected on 8 December. In West-north stratum in Area IV, a male fetus with body length of 301.0 cm was collected on 6 January. This is the largest fetus obtained during past JARPA surveys.

A series of experiments aiming to improve in vitro fertilization and cryopreservation techniques of minke whale follicular oocytes were undertaken in the laboratory of NM by Dr. Masafumi Tetsuka, a guest scientist from the Obihiro University of Agriculture and Veterinary Medicine.

Products

All the whales collected were processed on NM after biological sampling was completed, according to the provisions of Article VIII of the Convention. A total of 1,849 tons of meat, blubber, viscera, etc. was produced.

Preliminary analyses of biological information

Sex ratio and reproductive status

Table 6 and Fig. 7 show the reproductive status of all samples by each stratum. Because histological examination has not been done yet, maturity of males was tentatively determined by the testis weight according to Kato (1986), i. e., testis over than 400g were determined to be mature while others were classified as immature. Maturity of females was determined by existence of corpus luteum or albicans on ovaries.

Mature females were dominant in the East-south stratum (43.8 %) and Prydz Bay (46.7 %), whereas mature males were dominant in the north strata (38.7 % and 50 %) , West-south stratum (48.6 %) in Area IV and Area IIIE. In Area IIIE, the ratio of immature females was the highest in all strata (32.1 %) and that of mature female was the lowest (10.0 %).

Length composition

Fig. 8 shows body length composition of minke whales collected in Areas IIE and IV. Table 7 shows mean body length of minke whales collected in each stratum. Maximum length of the sample was 9.45 m for male and 9.92 m for female. Minimum length was 4.71 m and 5.23 m, respectively. Mean body length in each sexual maturity class was not significantly different among strata except for immature males (ANOVA, p=0.14 - 0.64). In the West-north stratum, mean body length of immature males was lower than other strata.

DISCUSSION

The most characteristic result of the present survey is a large number of sightings of minke whales in Area IV. Total sightings of minke whales in the present survey is higher than that in past JARPA surveys being more than twice as many as that recorded in the past. In the previous survey in Area IV (1997/98 season), low density of minke whales and low maturity rate of females in the south strata was observed (Ishikawa *et al.* 1998). In the present survey, however, the density of minke whales was extremely high in the south strata with high maturity rate of females. On the other hand, in Area IIIE, maturity rate of females was lower than that in Area IV and high density area of minke whales was observed only in the southern area. Although the main purpose of the survey in Area IIIE was to collect samples off the ice edge in early season, it was not achieved. Since a similar distribution pattern was observed in the past two JARPA surveys in Area IIIE (Nishiwaki *et al.* 1996, Ishikawa *et al.* 1998), it seems that most of the minke whales in Area IIIE only distribute near the ice edge in the early period of the Antarctic summer.

In spite of the drastic change of minke whale density compared to the 1997/98 JARPA, total sighting number of other rorquals i. e. blue whales, fin whales and humpback whales was not decreased. On the contrary, total sighting number of blue and humpback whales was also higher than in the past JARPA surveys. Sightings of humpback whales in Area IV overwhelmed those of minke whales in the recent two major cetacean surveys, i. e. 1997/98 JARPA and 1998/99 SOWER (Ishikawa *et al.* 1998, Ensor *et al.* 1999). The DI calculated by a grid cell (latitudinal 1° × longitudinal 1°) for humpback whales in 1997/98 JARPA revealed concentrated distribution along the southern boundary of the Antarctic Circumpolar Current between 80° E and 120° E (Matsuoka *et al.* 2000b) and this is consistent with the distribution pattern observed in the present survey. Population recovery of humpback whale is suggested both in the Austral coastal water (Chaloupka *et al.* 1999) and Antarctic Areas IV and V (Nishiwaki *et al.*, 1997). Brandao *et al* (1999) calculated that the maximum possible rate of increase of humpback whales was over 10 % (yr-1). The results of the present survey also support the increase of the humpback whale population in the Antarctic Sea.

MSS of humpback whales is relatively stable in spite of change of DI in each stratum. Although the MSS of minke whales tends to increase with DI (1.20-7.65, see Table 3), the MSS of humpback whales is close to two in every stratum (1.64-2.23) and the school of two individuals was the most frequent schools of humpback whales sighted (Fig. 5). It is observed that humpback whales sometimes maintain socially related schools in the feeding ground over years (Martin, 1990). DNA analysis of individuals among the schools might help to elucidate social structure of the schools of humpback whales in the Antarctic Sea. Biopsy samples of individuals from same schools obtained in the present survey will be analyzed.

In the 1997/98 JARPA in which low density and low maturity rate of minke whale was characteristic, it was suggested that most of the mature females might migrate into ice-free areas where the research vessels could not enter because of the irregular shape of pack ice (Fig .9, Ishikawa *et al.* 1998). In the present research, few such areas were observed from information provided by the National Ice Center. Relatively straight ice edge line seems to be one of the possible reasons of large number of minke whales sighted in the south strata. High proportion of the mature females in the south strata compared with 1997/98 JARPA (East-south; 2.7→ 43.8, West-south; 9.3→ 37.2, Prydz Bay; 10.4→ 46.7) supported this idea. Preliminary analysis of data from the oceanographic and hydro-acoustic surveys reveals high levels of krill abundance in the waters where large number of rorquals were sighted. Fig. 10 shows krill distribution observed by a passive acoustic system of SV. It is suggested that the south strata where high density of krill and rorquals were observed coincides with continental slope of Antarctica (Murase *et al.* 2000). High krill density may therefore account for the high density of minke whales and other rorquals observed. Furthermore, sightings of minke whales also increased in the western part of Area V (next to the East-south in Area IV) in the 1998/99 JARPA which was conducted late in the Antarctic summer season (Nishiwaki *et al.* 1999). From these observations, it seems probable that the large number of sightings of rorquals resulted because the randomly selected track line of the research vessels was set along the continental slops where krill was abundant and /or the ice edge line was straight compared with the other years.

It is interesting that large fetuses were obtained in Area IIIE and the West-north stratum adjacent to Area IIIE. In past JARPA surveys, fetuses nearly birth length were only obtained in Area IIIE (two in 1995/96 and one in 1997/98 JARPA). The existence of parturient females around Area IIIE supports the idea that this area is geographically located closer to the breeding area of minke whales compared with the Area IV (Nishiwaki *et al.*, 1996). More data is required to confirm this.

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Table 1. Searching distances (n. miles) of one sighting vessel (SV) and three sighting/sampling vessels (SSVs) in each stratum.

Stratum	SV			SSVs	Total
	Passing Mode	Closing Mode	Total		
Area III					
Northern stratum	188.1	527.8	715.9	1385.4	2101.3
Southern stratum	21.3	301.1	322.4	1256.0	1578.4
Total	209.4	828.9	1038.3	2641.4	3679.7
Area IV					
East-North	345.5	698.2	1043.7	2507.1	3550.8
East-South	582.3	237.2	819.5	1884.8	2704.3
West-North	325.5	673.6	999.1	1826.2	2825.3
West-South	171.9	498.9	670.8	1665.9	2336.7
Prydz Bay	101.4	290.4	391.8	852.9	1244.7
Total	1526.6	2398.3	3924.9	8736.9	12661.8
Grand Total	1736.0	3227.2	4963.2	11378.3	16341.5

Table 2a. Summary of sightings (no. schools / no. individuals) conducted by SV and SSVs in Area IV.

	SV				SSVs			
	West sector		East sector		West sector		East sector	
Species	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Northern stratum								
Minke whale	6 / 7	5 / 5	58 / 78	9 / 13	54 / 65	2 / 2	104 / 136	4 / 4
Like minke whale	-	-	3 / 3	-	3 / 3	1 / 1	7 / 7	-
Blue whale	-	-	4 / 6	3 / 6	1 / 1	-	-	1 / 1
Fin whale	1 / 1	-	3 / 91	-	1 / 2	-	5 / 10	-
Right whale	-	-	-	-	-	-	1 / 1	-
Humpback whale	14 / 28	2 / 3	72 / 131	5 / 9	41 / 73	6 / 9	97 / 161	3 / 8
Unidentified baleen whale	-	-	1 / 5	1 / 1	4 / 6	1 / 1	5 / 7	-
Sperm whale	39 / 39	3 / 3	4 / 4	1 / 1	48 / 53	-	11 / 11	-
Southern bottlenose whale	15 / 29	3 / 5	15 / 21	1 / 1	25 / 44	6 / 8	10 / 15	-
Unidentified beaked whale	5 / 7	2 / 3	4 / 4	2 / 3	18 / 27	1 / 1	9 / 11	-
Killer whale	9 / 40	-	2 / 11	-	1 / 3	-	7 / 31	-
Long-finned pilot whale	-	-	-	-	1 / 20	1 / 100	-	-
Unidentified pilot whale	-	-	-	-	-	-	1 / 50	-
Unidentified whale	8 / 9	1 / 1	4 / 4	-	21 / 22	3 / 3	36 / 36	-
Southern stratum								
Minke whale	122 / 391	33 / 101	178 / 973	72 / 227	254 / 976	30 / 98	339 / 2983	52 / 405
Like minke whale	1 / 10	-	3 / 4	-	2 / 3	-	3 / 3	-
Blue whale	-	-	-	-	4 / 12	-	5 / 11	3 / 8
Fin whale	2 / 4	-	-	-	2 / 3	-	-	-
Right whale	-	-	2 / 2	-	-	-	-	1 / 1
Humpback whale	32 / 68	12 / 22	89 / 169	21 / 46	78 / 152	10 / 20	90 / 230	12 / 34
Unidentified baleen whale	3 / 3	3 / 4	5 / 7	11 / 28	6 / 7	-	4 / 8	-
Sperm whale	3 / 3	-	17 / 17	2 / 2	14 / 14	-	23 / 24	3 / 3
Arnoux's beaked whale	1 / 5	-	-	-	3 / 58	-	2 / 13	-
Southern bottlenose whale	2 / 3	-	16 / 34	-	3 / 11	-	8 / 14	-
Unidentified beaked whale	1 / 3	-	5 / 14	-	1 / 3	-	11 / 27	-
Killer whale	10 / 178	1 / 60	10 / 374	3 / 19	17 / 280	2 / 60	27 / 698	2 / 90
Hourglass dolphin	-	-	-	-	1 / 4	-	-	-
Unidentified whale	-	-	11 / 12	1 / 2	16 / 16	-	29 / 29	-
Prydz Bay								
Minke whale	57 / 184	7 / 19			143 / 398	9 / 29		
Like minke whale	1 / 1	2 / 4			1 / 1	-		
Fin whale	-	-			10 / 81	-		
Humpback whale	3 / 6	-			-	2 / 5		
Unidentified baleen whale	3 / 5	1 / 1			1 / 3	1 / 3		
Sperm whale	-	-			1 / 1	-		
Southern bottlenose whale	-	-			2 / 2	-		
Unidentified beaked whale	-	-			1 / 2	-		
Killer whale	10 / 197	-			9 / 160	1 / 2		
Unidentified whale	3 / 3	-			6 / 6	-		

Table 2b. Summary of sightings (no. schools / no. individuals) conducted by SV and SSVs in Area IIIE.

	SV				SSVs			
	Northern Stratum		Southern Stratum		Northern Stratum		Southern Stratum	
Speceis	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Minke whale	10 / 12	10 / 19	60 / 126	25 / 42	15 / 32	2 / 2	107 / 220	6 / 12
Like minke whale	3 / 4	-	1 / 1	-	-	-	2 / 2	-
Blue whale	5 / 9	2 / 4	1 / 4	4 / 8	/	1 / 3	5 / 10	3 / 6
Fin whale	7 / 36	2 / 5	7 / 22	3 / 6	12 / 34	2 / 7	16 / 72	6 / 13
Humpback whale	15 / 28	1 / 3	13 / 32	3 / 5	63 / 100	6 / 11	54 / 91	3 / 9
Unidentified baleen whale	3 / 7	3 / 4	7 / 22	2 / 4	40 / 107	5 / 5	31 / 58	1 / 2
Sperm whale	2 / 3	3 / 3	3 / 3	3 / 3	11 / 11	-	21 / 23	2 / 2
Arnoux's beaked whale	-	-	-	-	-	-	1 / 5	-
Southern bottlenose whale	5 / 8	-	10 / 23	1 / 2	15 / 20	1 / 1	13 / 29	-
Mesoplodon spp.	-	-	-	-	2 / 4	-	-	-
Unidentified beaked whale	12 / 22	1 / 2	-	-	14 / 19	-	29 / 49	-
Killer whale	4 / 23	1 / 2	-	-	2 / 13	-	1 / 3	-
Unidentified pilot whale	-	1 / 5	-	-	-	-	-	-
Unidentified whale	6 / 18	2 / 2	3 / 5	-	22 / 23	-	23 / 31	-

Table 3. Density indices (DI) and mean school size (MSS) of minke whale and humpback whale primary sightings by SV and SSVs.

	Minke whale						Humpback whale					
	SV		SSVs		Total		SV		SSVs		Total	
Stratum	DI	MSS	DI	MSS	DI	MSS	DI	MSS	DI	MSS	DI	MSS
Area III												
Northern stratum	1.40	1.20	1.08	2.13	1.19	1.76	2.10	1.87	4.55	1.59	3.71	1.64
Southern stratum	18.61	2.10	8.52	2.06	10.58	2.07	4.03	2.46	4.30	1.69	4.24	1.84
Total	6.74	1.97	4.62	2.07	5.22	2.03	2.70	2.14	4.43	1.63	3.94	1.73
Area IV												
East-North	5.56	1.34	4.15	1.31	4.56	1.32	6.90	1.82	3.87	1.66	4.76	1.73
East-South	21.72	5.47	17.99	8.80	19.12	7.65	10.86	1.90	4.78	2.56	6.62	2.23
West-North	0.60	1.17	2.96	1.20	2.12	1.20	1.40	2.00	2.25	1.78	1.95	1.84
West-South	18.19	3.20	15.25	3.84	16.09	3.64	4.77	2.13	4.68	1.95	4.71	2.00
Prydz Bay	14.55	3.23	16.77	2.78	16.07	2.91	0.77	2.00	0.00	0.00	0.24	2.00
Total	10.73	3.88	10.23	5.10	10.39	4.71	5.35	1.91	3.50	2.01	4.08	1.97
Grand Total	9.89	3.61	8.93	4.73	9.22	4.37	4.80	1.94	3.72	1.91	4.04	1.92

Table 4a. Summary of photo-ID, biopsy sampling and acoustic monitoring. B, HP, R, M, BW, SP, KW represent blue, humpback, right, minke, unidentified baleen, sperm and killer whales respectively.

	Photo-ID (no.of ind.)			Biopsy (no. of samples)			Acoustic Monitoring (minutes)						
Stratum	B	HP	R	B	HP	R	B	HP	R	M	BW	SP	KW
Area III East	17	13	-	1	10	-	416	-	-	-	-	84	-
Area IV													
East-North	3	24	1	1	10	1	144	104	-	-	-	-	-
East-South	11	21	2	2	13	2	-	-	128	74	64	-	-
West-North	1	15	-	-	7	-	-	84	-	-	-	-	-
West-South	12	5	-	-	2	-	-	40	-	-	-	-	40
Total	27	65	3	3	32	3	144	228	128	74	64	84	40
Grand total	44	78	3	4	42	3	560	228	128	74	64	84	40

Table 4b. Summary of oceanographic and hydro-acoustic survey.

	CTD	XCTD	EPCS (days)		Hydroacoustic
Stratum	(no. of stations)	(no. of stations)	YS1	KS2	survey (n.miles)
Area III East	22	13	22	23	1749
Area IV					
East-North	14	20	14	16	1256
East-South	19	23	22	22	1062
West-North	13	15	17	16	1118
West-South	14	29	14	12	916
Prydz Bay	5	23	5	-	428
Total	65	110	72	66	4780
Grand total	87	123	94	89	6529

Table 5. Summary of biological data and samples collected.

Samples and data	Number of whales		
	Male	Female	Total
-Data-			
Photographic record of external character	233	206	439
Body length and sex identification	233	206	439
Measurement of external body proportion	233	206	439
Body weight	233	206	439
Body weight by total weight of parts	39	31	70
Skull measurement (length and breadth)	221	193	414
Craniometric study	1	1	2
Standard measurement of blubber thickness (five points)	233	206	439
Detailed measurement of blubber thickness (fourteen points)	39	31	70
Mammary gland; lactation status and measurement	-	206	206
Breadth measurement of uterine horn	-	206	206
Testis and epididymis weight	233	-	233
Weight of stomach content in each compartment	229	205	434
Photographic record of fetus	50	46	104*
Fetal length and weight	50	45	103*
External measurements of fetus	50	46**	96
Number of ribs	232	206	438
-Sample-			
Diatom film record and sampling	233	206	439
Serum sample for physiological study	232	204	436
Earplug for age determination	233	205	438
Earplug for chemical analysis (one of the pair)	11	9	20
Tympanic bone for age determination	233	204	437
Largest baleen plate for age determination	56	73	129
Largest baleen plate for morphologic study	233	205	438
Vertebral epiphyses sample	233	206	439
Ovary	-	206	206
Histological sample of endometrium	-	206	206
Histological sample of mammary gland	-	206	206
Milk sample for chemical analysis	-	3	3
Histological sample of testis	233	-	233
Histological sample of epididymis	233	-	233
Testis and epididymis stamp smear for sperm detection	233	-	233
Skin, blubber, muscle, liver, kidney and heart tissues for genetic study	233	206	439
Muscle, liver and kidney tissues for heavy metal analysis	233	206	439
Blubber and liver tissues for organochlorine analysis	233	206	439
Muscle, liver and blubber tissues for lipid analysis	39	31	70
Stomach contents for food and feeding study	158	130	288
Stomach contents for heavy metal analysis	8	12	20
Stomach contents for organochlorine analysis	8	8	16
Stomach contents for lipid analysis	17	12	29
External parasites	46	48	94
Internal parasites	19	13	32
Fetus	1	1	10*
Skin, blubber, muscle, liver, kidney and heart tissues for genetic study (fetus)	38	32***	70
Adrenal glands for physiological study	5	6	11
Pancreas for histological study	7	6	13
Pancreas for physiological study	7	6	13
Various fat for pharmacological study	3	2	5
Muscle and skin tissues and whole brain for chemical study	1	0	1
Sperm for in-vitro fertilization (IVF)	13	-	13
Oocyte for in-vitro fertilization (IVF)	-	206	206
Fetal serum for culture	8	7	15
Uterine, oviducal and cervical tissues for histological study	-	16	16
Ovarian tissues for histological study	-	5	5
Pituitary gland for histological study	-	3	3
Granulosa cells for cell culture	-	23	23
Uterine epithelial cells for cell culture	-	3	3
Fetal fibroblast cells for cell culture	-	1	1
Follicular fluid for hormone assay	-	6	6
Fetal reproductive tract for histological study	38	33	71
Marine debris	2	1	3

* : including a fetus of unidentified sex.

** : since a fetus was damaged by harpoon, external measurement was partly done.

*** : including a fetus from which kidney and liver were not sampled.

Table 6. Reproductive status of minke whales collected. Numbers in parenthesis represent ratio of samples in each stratum (%). Maturity of males was tentatively defined by testis weight according to Kato (1986). "Resting" represents non-pregnant mature female without corpus luteum, "Preg+Lac" represents pregnant and lactating female and "Ovulating" represents female which had corpus luteum but fetus was not observed.

Stratum	Male			Female					
					Mature				
	Immature	Mature	Total	Immature	Pregnant	Resting	Preg.+Lac	Ovulating	Total
Area III East	24 (22.0)	39 (35.8)	63 (57.8)	35 (32.1)	8 (7.3)	0 (0.0)	2 (1.8)	1 (0.9)	46 (42.2)
Area IV									
East-North	21 (22.6)	36 (38.7)	57 (61.3)	23 (24.7)	13 (14.0)	0 (0.0)	0 (0.0)	0 (0.0)	36 (38.7)
East-South	12 (8.8)	45 (32.8)	57 (41.6)	20 (14.6)	56 (40.9)	0 (0.0)	1 (0.7)	3 (2.2)	80 (58.4)
West-North	6 (12.0)	25 (50.0)	31 (62.0)	11 (22.0)	7 (14.0)	0 (0.0)	1 (2.0)	0 (0.0)	19 (38.0)
West-South	1 (2.9)	17 (48.6)	18 (51.4)	4 (11.4)	12 (34.3)	1 (2.9)	0 (0.0)	0 (0.0)	17 (48.6)
Prydz Bay	2 (13.3)	5 (33.3)	7 (46.7)	1 (6.7)	6 (40.0)	0 (0.0)	0 (0.0)	1 (6.7)	8 (53.3)
Combined	42 (12.7)	128 (38.8)	170 (51.5)	59 (17.9)	94 (28.5)	1 (0.3)	2 (0.6)	4 (1.2)	160 (48.5)
Grand total	66 (15.0)	167 (38.0)	233 (53.0)	94 (21.4)	102 (23.2)	1 (0.2)	4 (0.9)	5 (1.1)	206 (46.9)

Table 7. Mean body length (m) with standard deviation and body length range of minke whales collected in each stratum. Maturity of males was defined as Table 6.

Stratum	Male			Female		
	Immature	Mature	Total	Immature	Mature	Total
Area III East	6.79 ± 0.70 (5.11 - 7.93)	8.46 ± 0.35 (7.27 - 9.39)	7.82 ± 0.96 (5.11 - 9.39)	6.48 ± 0.79 (5.26 - 8.12)	8.74 ± 0.40 (8.23 - 9.55)	7.02 ± 1.20 (5.26 - 9.55)
Area IV						
East-North	6.56 ± 0.94 (4.71 - 8.26)	8.55 ± 0.43 (7.72 - 9.45)	7.82 ± 1.17 (4.71 - 9.45)	6.50 ± 0.89 (5.41 - 8.51)	8.86 ± 0.32 (8.34 - 9.49)	7.35 ± 1.35 (5.41 - 9.49)
East-South	7.32 ± 0.86 (5.42 - 8.55)	8.53 ± 0.30 (7.86 - 9.34)	8.27 ± 0.69 (5.42 - 9.34)	6.98 ± 0.97 (5.23 - 8.11)	9.01 ± 0.43 (8.08 - 9.92)	8.50 ± 1.07 (5.23 - 9.92)
West-North	5.55 ± 0.40 (5.07 - 6.32)	8.50 ± 0.31 (7.90 - 9.20)	7.93 ± 1.21 (5.07 - 9.20)	6.18 ± 0.38 (5.53 - 6.87)	8.96 ± 0.34 (8.53 - 9.64)	7.35 ± 1.42 (5.53 - 9.64)
West-South	7.32 ± 0.00 (7.32 - 7.32)	8.43 ± 0.50 (7.48 - 9.23)	8.36 ± 0.55 (7.32 - 9.23)	7.04 ± 1.45 (5.35 - 8.80)	9.04 ± 0.32 (8.42 - 9.53)	8.57 ± 1.14 (5.35 - 9.53)
Prydz Bay	6.78 ± 0.94 (5.83 - 7.72)	8.69 ± 0.22 (8.42 - 9.00)	8.14 ± 1.02 (5.83 - 9.00)	7.24 ± 0.00 (7.24 - 7.24)	8.84 ± 0.24 (8.42 - 9.16)	8.64 ± 0.57 (7.24 - 9.16)
Combined	6.66 ± 1.02 (4.71 - 8.55)	8.52 ± 0.38 (7.48 - 9.45)	8.06 ± 1.00 (4.71 - 9.45)	6.65 ± 0.95 (5.23 - 8.80)	8.98 ± 0.39 (8.08 - 9.92)	8.12 ± 1.3 (5.23 - 9.92)
Grand total	6.71 ± 0.92 (4.71 - 8.55)	8.51 ± 0.37 (7.27 - 9.45)	8.00 ± 1.00 (4.71 - 9.45)	6.59 ± 0.9 (5.23 - 8.80)	8.96 ± 0.4 (8.08 - 9.92)	7.87 ± 1.36 (5.23 - 9.92)

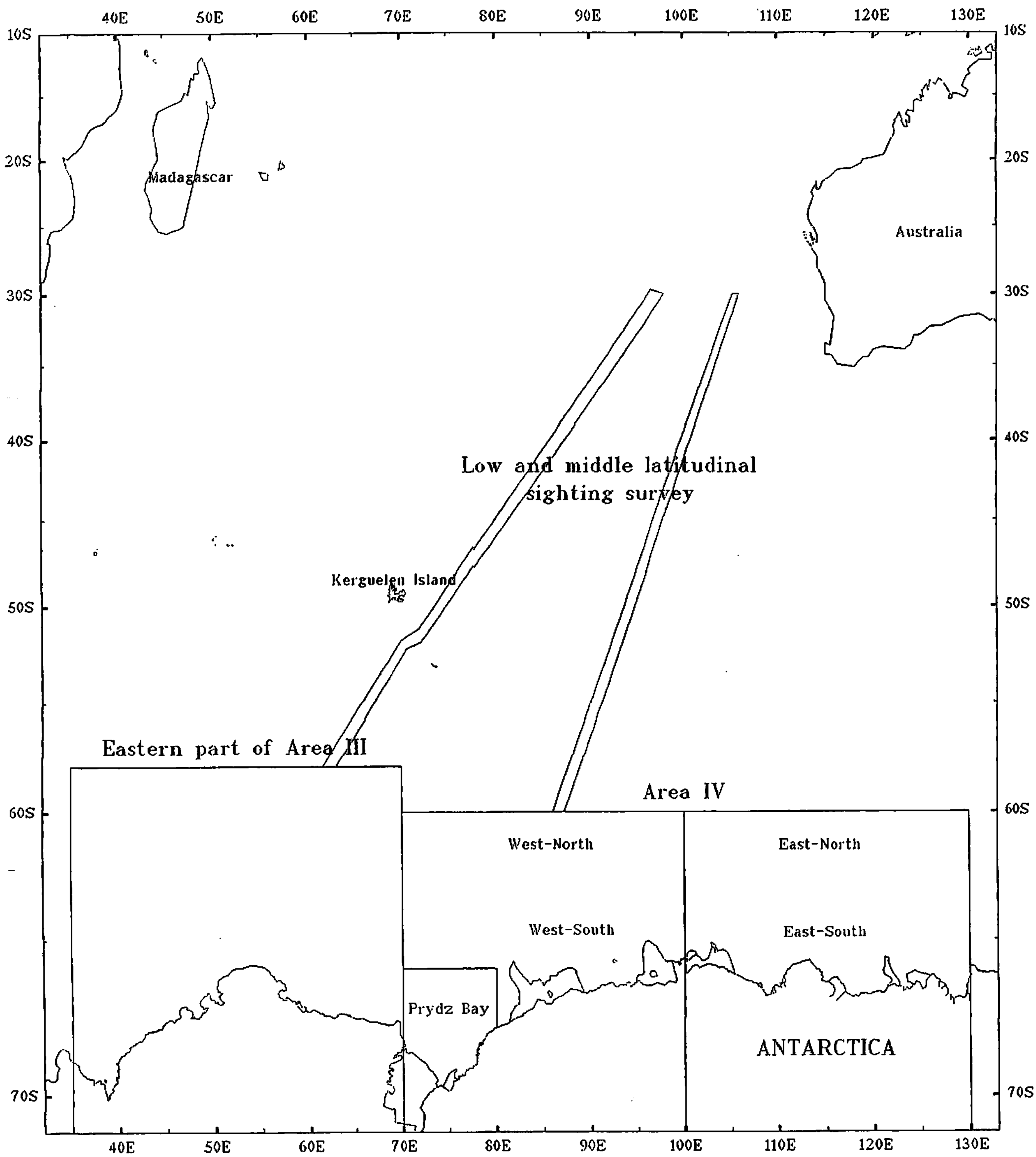

Fig. 1. Geographic location of research area of the 1999/2000 JARPA surveys and cruise tracks of sighting survey between research area and Japan.

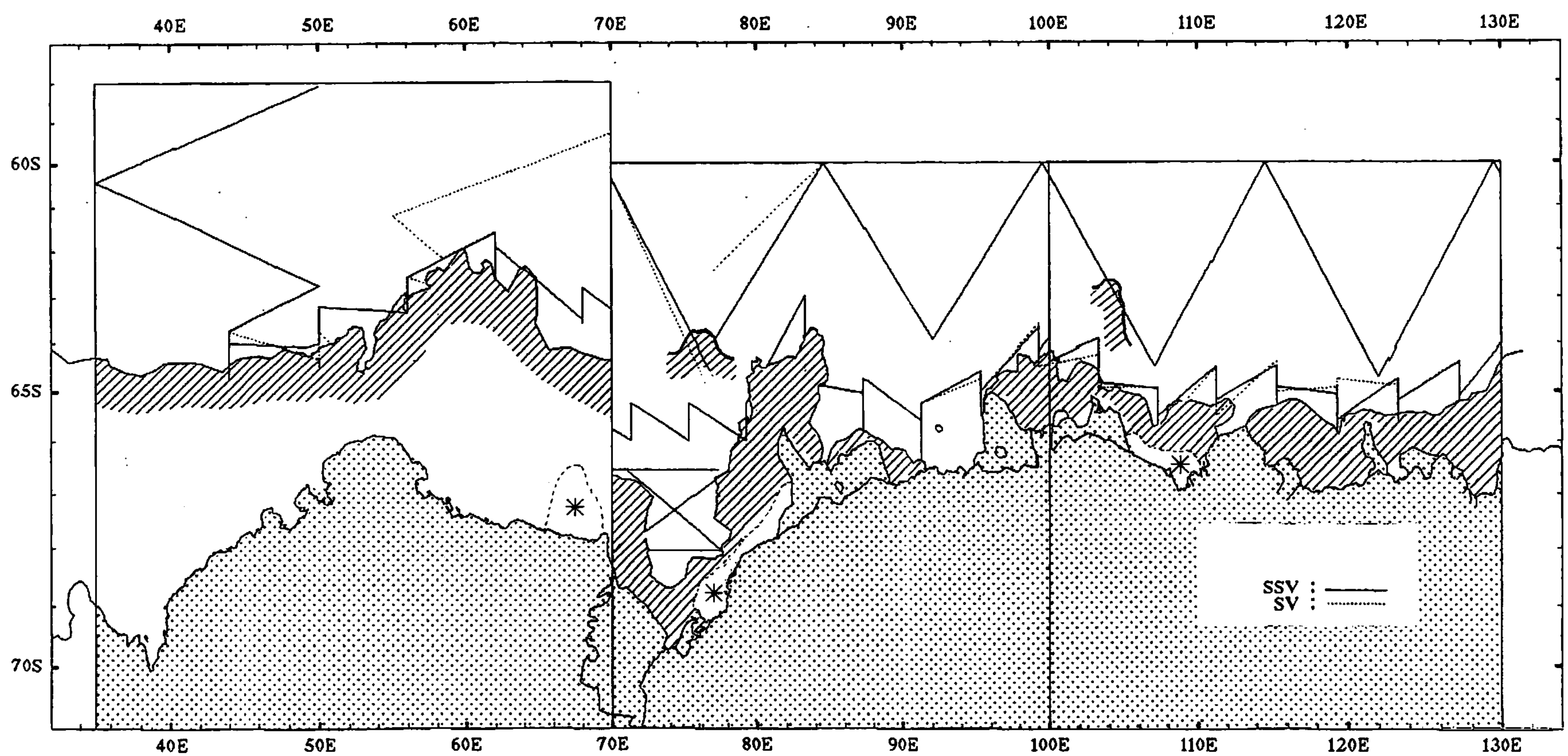

Fig. 2. Cruise track line of sighting vessel (SV, broken line) and sighting/ sampling vessels (SSVs, solid line) in 1999/2000 JARPA. Pack ice lines are estimated by observation of research vessels and the information from National Ice Center (NIC). Asterisks represent estimated ice free areas south of the ice edge.

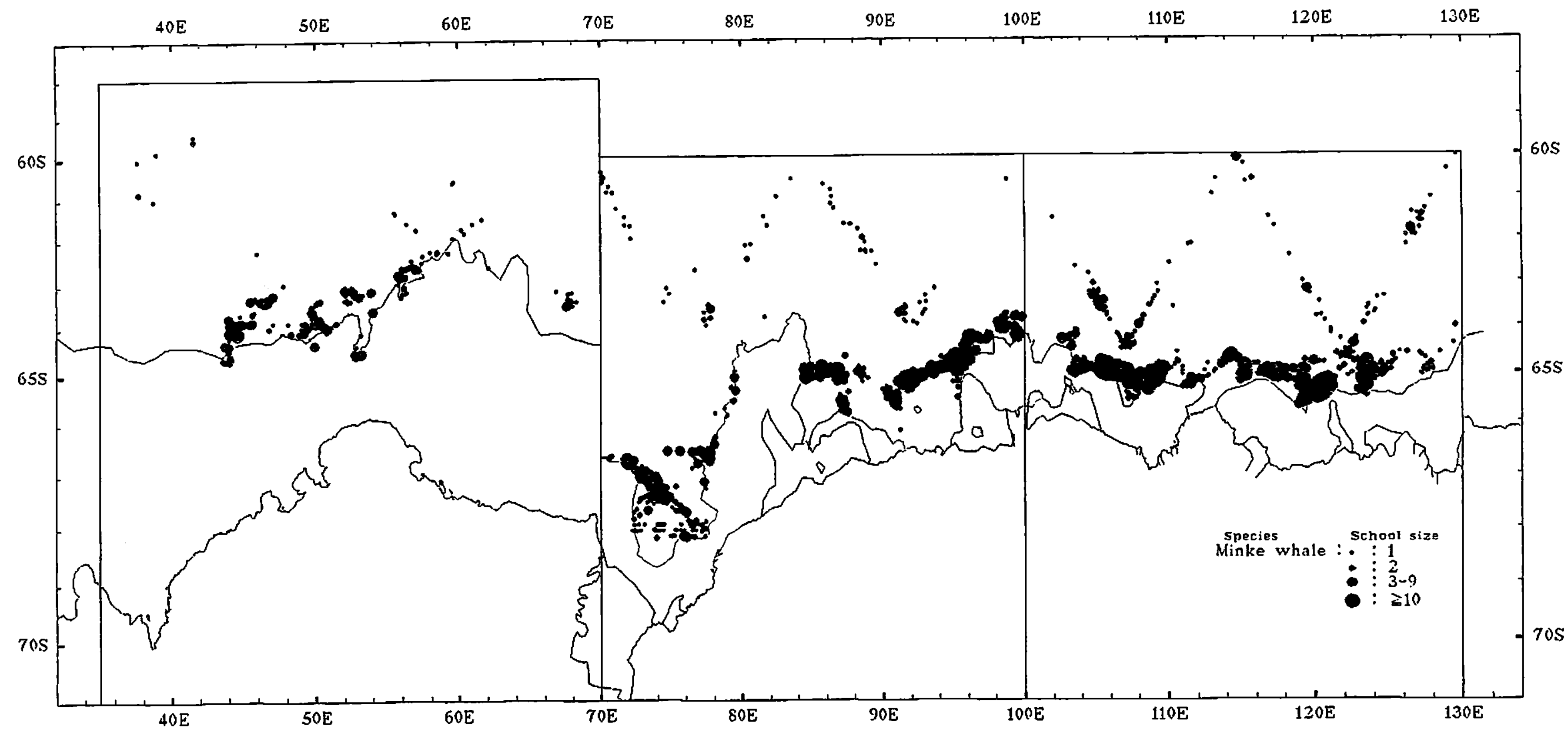

Fig. 3. Distribution of primary sightings of minke whales sighted by SV and SSVs in 1999/2000 JARPA.

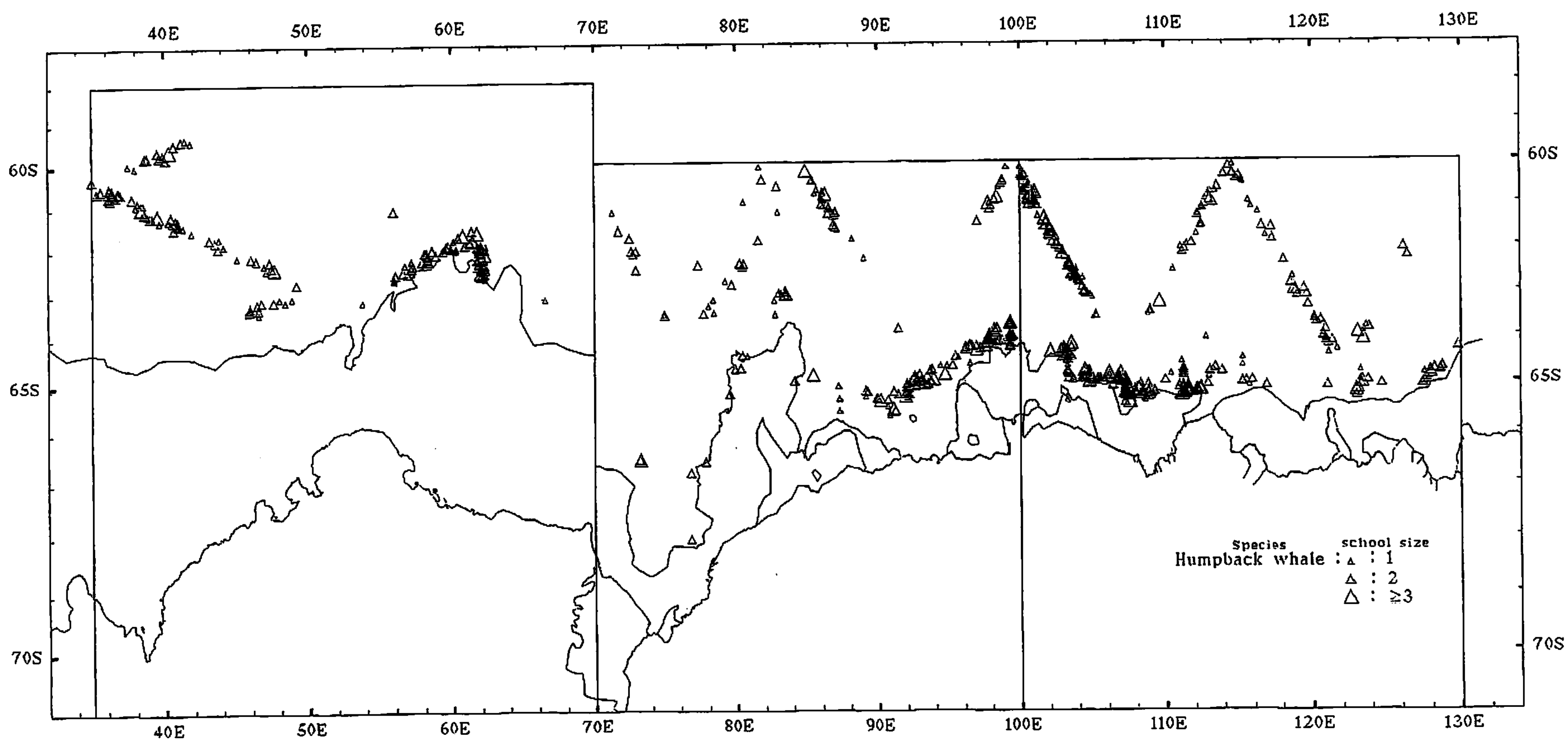

Fig. 4. Distribution of primary sightings of humpback whales sighted by SV and SSVs in 1999/2000 JARPA.

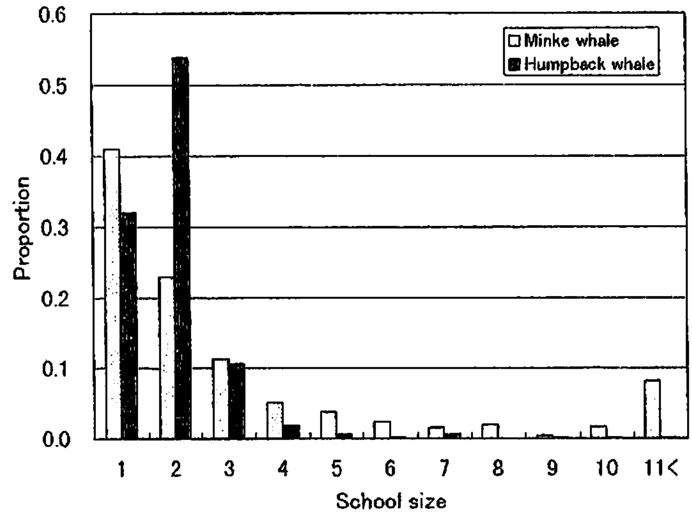

Fig. 5. The proportion of frequency of each school size to the total school sighting number. Dotted and cross striped lines represent minke whale and humpback whale, respectively.

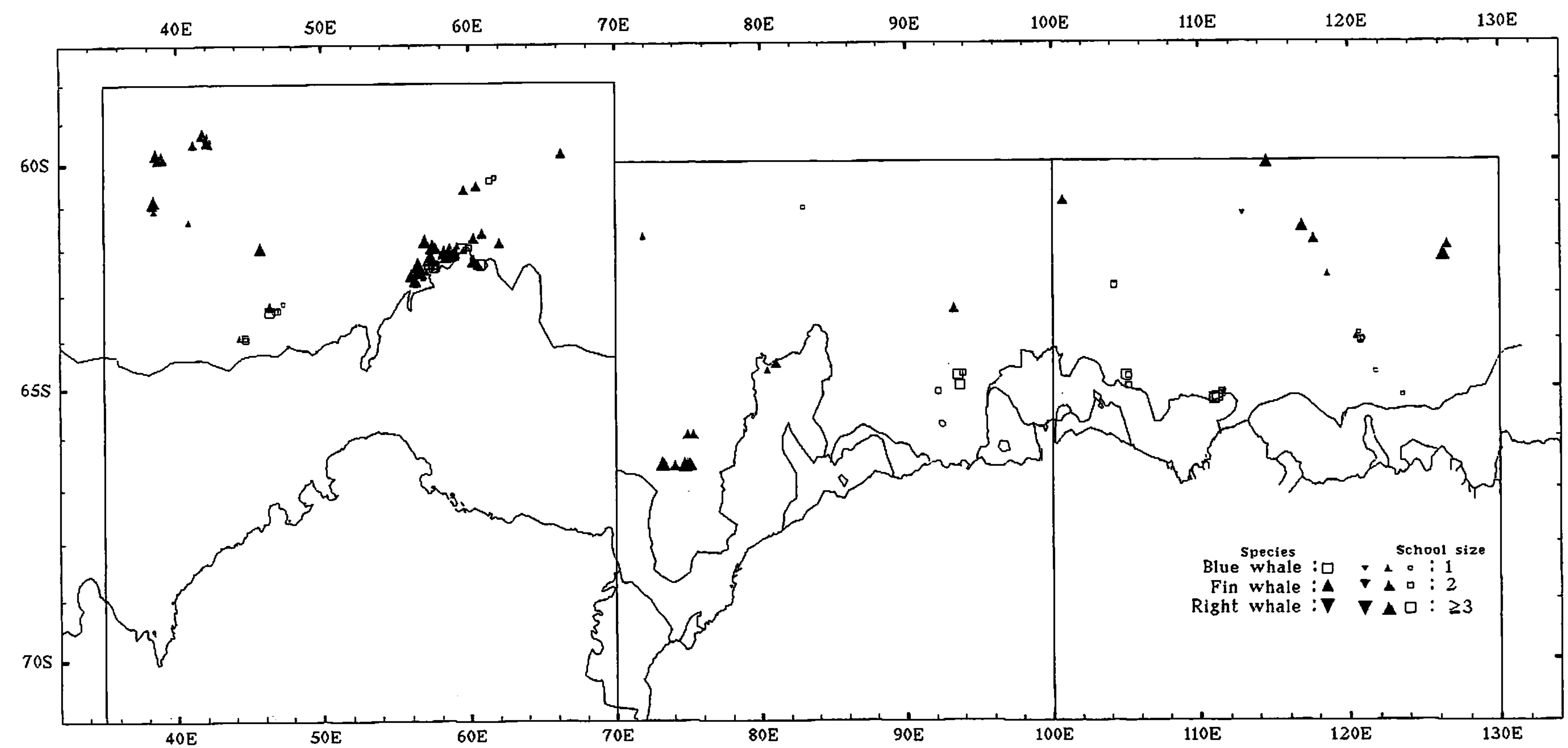

Fig. 6. Distribution of primary sightings of blue, fin and right whales sighted by SV and SSVs in 1999/2000 JARPA.

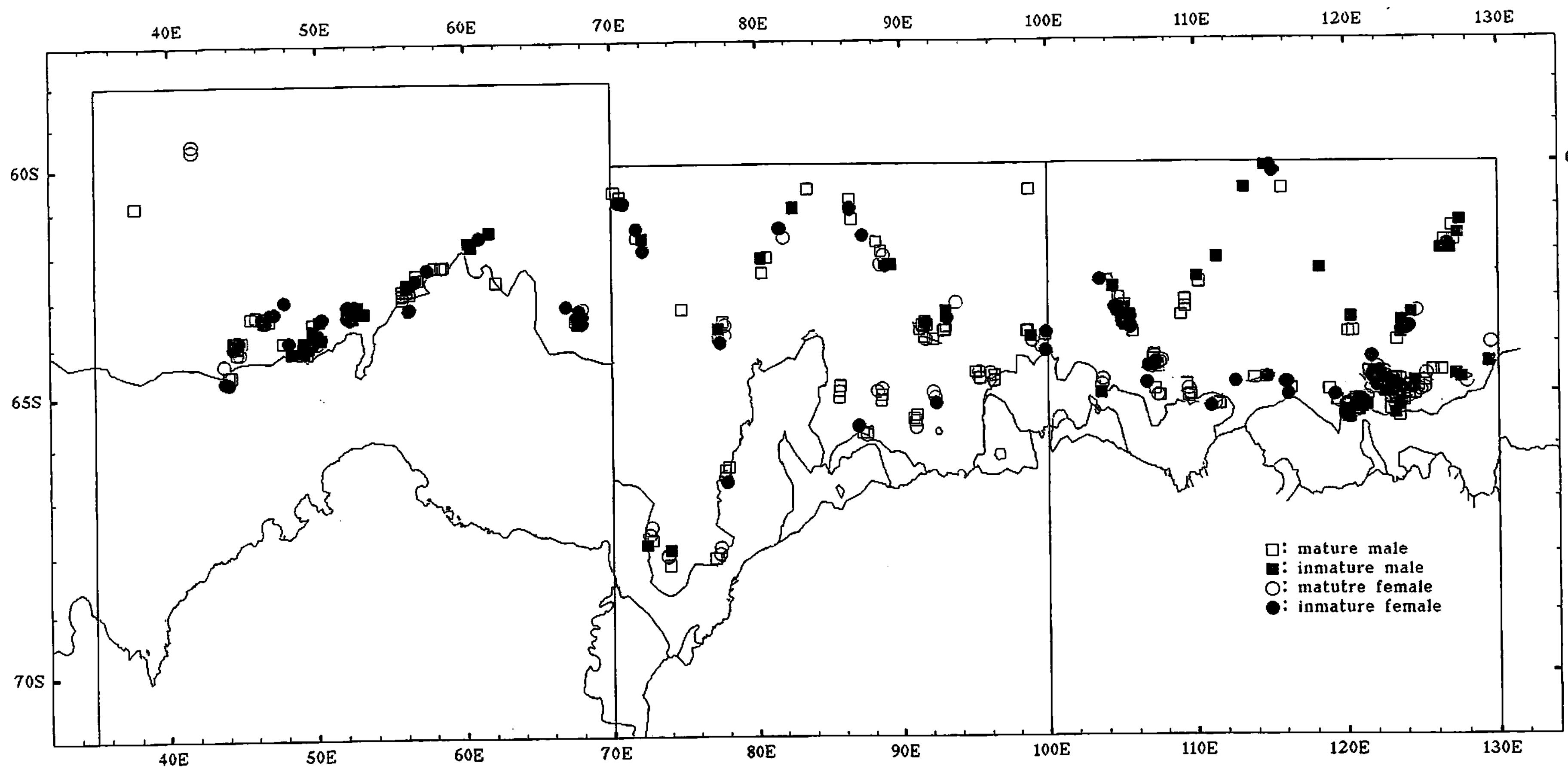

Fig. 7. Sighted position of sampled minke whales by sex and reproductive status in 1999/2000 JARPA.

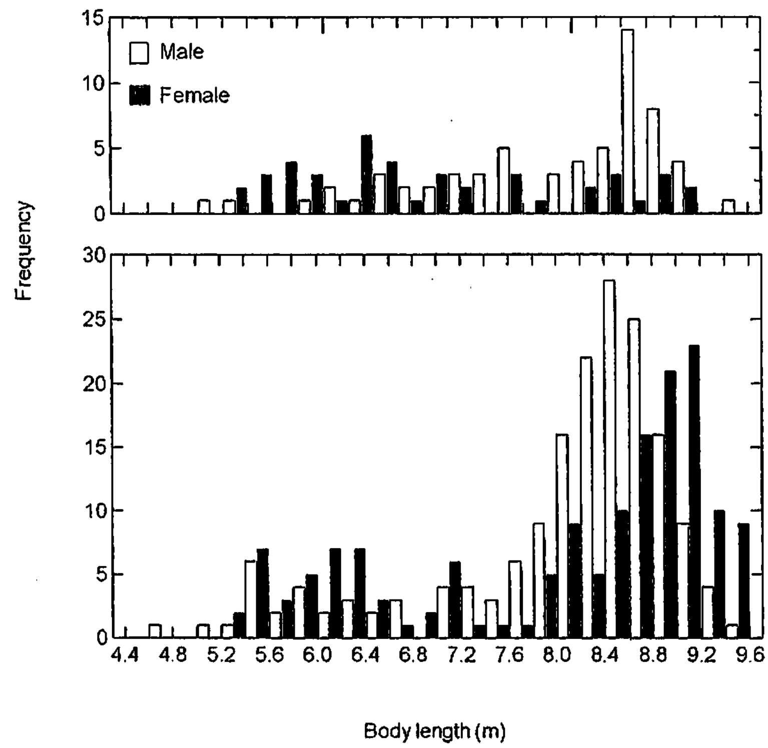

Fig. 8. Body length compositions (20 cm intervals) by sex and Area. Solid and hatched lines represent males and females, respectively. Upper: Area IIIE, lower: Area IV.

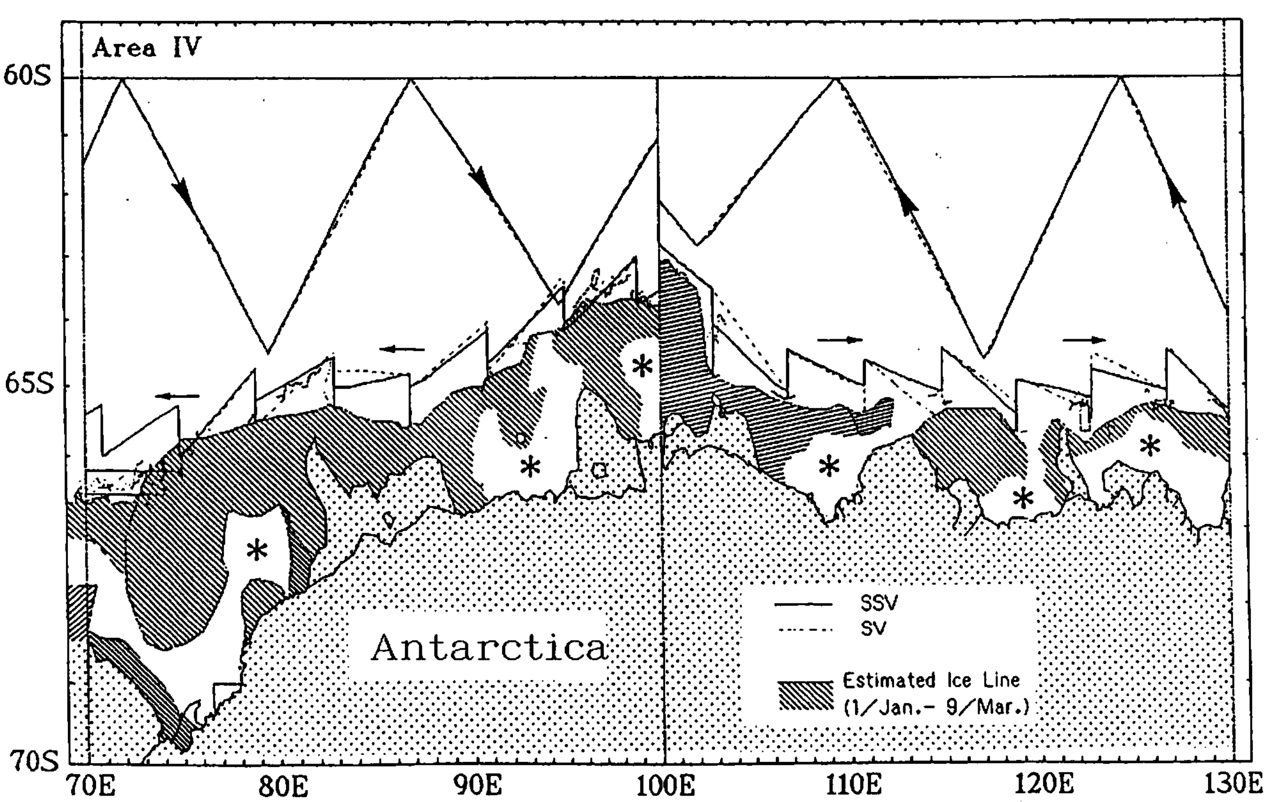

Fig. 9. Cruise track line of SV (broken line) and SSVs (solid line) and ice condition in Area IV during **1997/98 JARPA** (Ishikawa *et al.* 1998). Pack ice lines are estimated by observation of research vessels and the information from National Ice Center (NIC). Asterisks represent estimated ice free areas south of the ice edge.

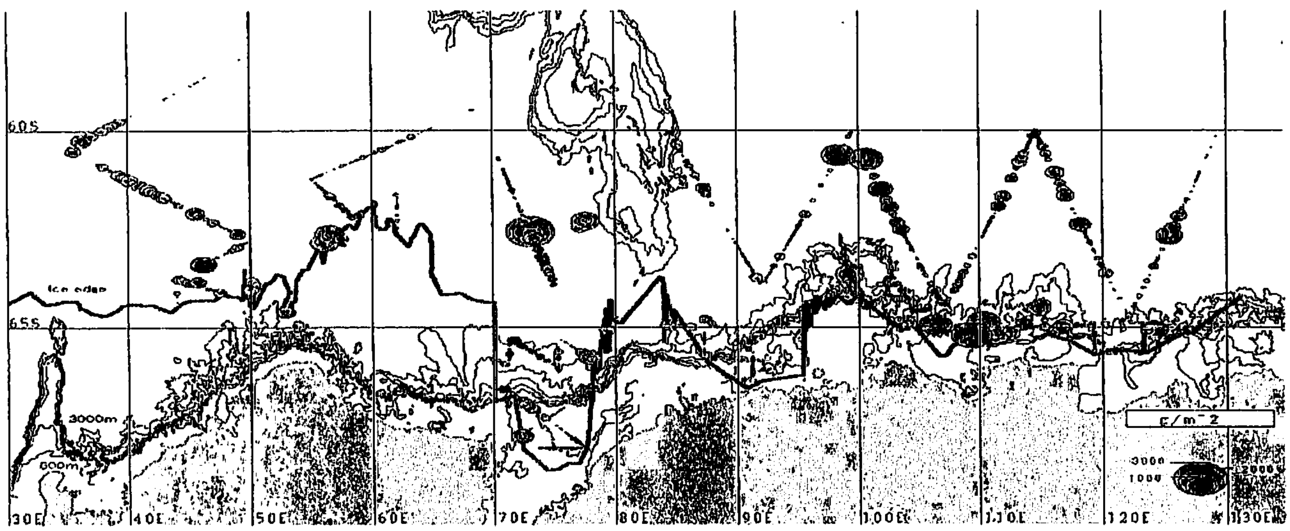

Fig. 10. Weight densities (g/m^2) per 1 n. mile integrated interval of krill observed by a passive acoustic system and continental slope. Bold line = ice edge line; thin lines = 500m interval isobath from 500m to 3000m depth. After Murase *et al.* (2000).