Distributions and standardized abundance estimates for humpback, fin and blue whales in the Antarctic Areas IIIE, IV, V and VIW (35°E -145°W), south of 60°S

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ABSTRACT
The sighting component of the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) was designed as a large-scale and long-term monitoring exercise using line-transect surveys. It was carried out in a broadly consistent way every other year in Areas IV and V between 1987/88 and 2004/05 austral summer seasons. The most important aspect is that sighting surveys are repeated in the same area in the same month (mainly January and February) for 18 years. For the whole period a total search distance on primary effort of 293,811 n.miles was achieved during 6,188 ship-days. The sighting survey procedures were very similar to those used IWC/IDCR-SOWER surveys. This paper reports current distributions and abundance estimates of humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*) and blue (*Balaenoptera musculus intermedia*) whales in the Antarctic Areas IIIE, IV, V and VIW, south of 60°S. Analyses were conducted using the DISTANCE program taking into account the suggestions offered in recent IWC/SC meetings to correct minute biases in estimates. The greatest concentration of humpback whales occurred recently east of the Kerguelen Plateau, between 80°-120°E and latitudinal and longitudinal expansions of this area was observed. In general, fin whales are more occurred in Area V than Area IV. However, in recent year they have been observed frequently in the western part of Area IV. High density areas were observed in the western sides of the Balleny Islands and Kerguelen Plateau. Blue whales were widely distributed in the research area without gaps. The eight full-scaled surveys in each Areas IV and V provided estimates of abundance for these species with good precision because the number of sightings was sufficient. Estimates in 2003/04 and 2004/05 seasons were 27,783 (CV=0.12) and 9,342 (CV=0.34) in Areas IV and V, respectively for humpback whale, 6,514 (CV=0.27) and 5,241 (CV=0.38) for the Indian Ocean and Western South Pacific Stocks of fin whale, respectively, although they mainly distributed in the area north of 60°S, 1,265 (CV=0.33) for the whole research area of blue whale. JARPA estimates for humpback whale are comparable to those of IDCR-SOWER. Similar to IDCR-SOWER estimates, high rates of increase were obtained for humpback whale in both Areas. A "shift in baleen whale dominance" from Antarctic minke (*Balaenoptera bonaerensis*) to humpback whale was observed in Area IV since 1997/98 survey.

KEY WORDS: ANTARCTIC, SURVEY VESSEL, DISTRIBUTION, ABUNDANCE ESTIMATE, HUMPBACK WHALE, FIN WHALE, BLUE WHALE

INTRODUCTION
The primary reason for the sighting surveys was their contribution to the main objective of the JARPA (Japanese Whale Research Program under Special Permit in the Antarctic) which was estimation of biological parameters to improve the stock management of Antarctic minke whales. In addition, sighting data contribute greatly to the RMP and the associated implementation process and in-depth assessment for Antarctic minke whales. Whales are heterogeneously distributed in the Antarctic spatially or other ways. Information from the past commercial whaling have demonstrated that larger animals of Antarctic minke

whales (mainly pregnant females) are concentrated in waters near pack ice -edge, while it was not well known about distribution of immature animals from the data of the commercial whaling. In order to obtain unbiased and reliable biological parameters, required for the management of the whale population, the Government of Japan put forward a research plan in 1987 that included the taking of Antarctic minke whales under a special permit. The principal object of the program is to obtain information on unbiased biological parameters including age composition through systematic random sampling carried out in combination with systematic sighting surveys. The surveys should be designed randomly to collect sample from the whole research area uniformly to make unbiased estimation of population characteristics and abundance.

The JARPA was large-scale and long-term monitoring exercise using line-transect surveys. It has been carried out in a broadly consistent way every other year in Areas IV and V since 1987/88 survey during the austral summer seasons. At the start of JARPA, two feasibility surveys were conducted in 1987/88 and 1988/89 in the Areas IV and V, respectively. Based on the results of feasibility surveys, full scaled survey had started in Area IV from 1989/90 (Kishino *et al*, 1991). The most important aspect of JARPA is that observation is repeated in the same area in the same season. During the 18-years history of the program a total search distance on primary effort of 293,811 n.miles had been achieved during 6,188 ship-days in the Antarctic. This effort is much larger than previous Antarctic research program such as the Discovery II (1933-39; 32,000 n.miles (Mackintosh and Brown, 1956)) and IDCR-SOWER (1978/79-2000/01; 105,967 n.miles (Matsuoka *et al*, 2003a)). JARPA provides more frequent repetition of surveys of the same localities than the IWC/IDCR (International Decade for Cetacean Research) and SOWER (Southern Ocean Whale and Ecosystem Research) program would facilitate estimation of the extent of inter-year variability in local abundance, which would in turn lead to improved results from the consolidation exercise.

The sighting procedures of JARPA followed the method used in the IDCR and SOWER cruises as much as possible. Large amounts of data in the feeding grounds on Southern Hemisphere whale species are accumulating, and some analyses have been done (IWC, 1998). After the JARPA review meeting in 1997, JARPA have been continued to provide valuable information such as trends in abundance of Antarctic minke, humpback, fin and blue whales in the Antarctic between 1989/90 and 2004/05 surveys (Kasamatsu *et al*., 2000, Government of Japan, 2005, Matsuoka *et al*., 2005, IWC, 2006a, Hakamada et al., 2006, Mori and Butterworth, 2006). In addition, there were some suggestions about JARPA estimates which rose in recent IWC/SC meetings and workshop. For examples, clearer description of survey methodology, effect of survey mode (SSV and SV, Closing and Passing), bias related to the un-surveyed area, sensitivity test to check over estimation, etc. We have corresponded seriously taking into account of useful suggestions to obtain unbiased estimates through recent IWC/SC meetings. As a result, in the St. Kitts SC meeting, it was noted a reasonable agreement between SOWER and JARPA abundance humpback whale estimates in Areas IV and V. In both Areas high rates of increase have been estimated using JARPA data similar to those obtained from IDCR-SOWER surveys (IWC, 2006b). This paper review the latest results from sighting survey for other baleen whales sighted frequently through the surveys.

SIGHTING SURVEYS AND DATA COLLECTION

JARPA DATA

Sighting surveys

The procedures to collect and analyses sighting data that have been used in JARPA are very similar to there used for IWC/IDCR-SOWER cruises and include: 1) distance and angle are corrected by using the results of the distance and angle estimation experiments, 2) sighting rate is obtained on each day, 3) effective search half width is obtained by fitting a hazard rate or half normal models, 4) smearing parameters are obtained by the Buckland and Anganuzzi method II, 5) g (0) is assumed to be 1, and 6) sighting data are pooled by each season and each stratum as much as possible for reliable estimation of the effective search half-width (ws) and the mean school size (E(s)). Details of the sighting procedures were given in the Review of the sighting survey in the JARPA (Nishiwaki *et al*., 2006).

Research area covered

The area from south of 60°S to the ice-edge in the Areas IIIE (35°E-70°E), IV (70°E-130°E), V (130°E-170°W) and VIW (170°W-145°W) were covered (Figs. 1a, 1b). Each Area of IV and V was divided into two sectors (western sector and eastern sector). Each sector also divided into two strata (northern and southern strata), the 60°S latitude line to the line of 45 n.miles from the ice-edge (northern stratum), and ice-edge to 45 n.miles from the ice-edge line (southern stratum) except the Prydz Bay and the Ross Sea regions. The Prydz Bay defined as south of 66°S and the Ross Sea defined as south of 69°S. An exception, in the 1999/2000 and 2001/02 seasons, northern boundary of the research area was set as 58°S in the Area III east from view point of the strategy for investigating Antarctic minke distribution. There are no stratifications for Areas IIIE and VIW. Distribution of the searching efforts in JARPA1987/88-2004/05 seasons, including middle latitude transit sighting survey, is shown in Fig. 2.

Design of the trackline

The sawtooth type trackline was applied to provide for a wider area of coverage. The starting point of the sawtooth trackline was randomly selected from 1 n.mile intervals on the longitudinal lines. The trackline legs were systematically set on the ice-edge and on the locus of the 45n.miles from the ice-edge in southern stratum, and the 45 n.miles from the 60°S latitude line in northern stratum.

Research vessels

Kyo-Maru No.1, *Toshi-Maru No.25*, *Toshi-Maru No.18* operated for the surveys from 1989/90 to 1997/1998. *Kyosin-Maru No.2* has been engaged since 1995/96 survey. *Yusin-Maru* operated for the 1998/1999 survey as the replacement of *Toshi-Maru No.18*. *Yusin-Maru No.2* operated from the 2001/2002 survey as the replacement of *Toshi-Maru No.25*.

Size of research area

Area size of each survey was calculated using the Marine Explore Geographical Information System version 4 (Environment Simulation Laboratory Co, Ltd, Japan).

METHODS

Abundance estimation

Methodology of abundance estimation used in this study was described by Burt and Stahl (2000) which is the standard methodology adopted by IWC. The program DISTANCE (Buckland *et al*., 1993) was used for abundance estimation. Following formula was used for abundance estimation.

$$P = \frac{AE(s)n}{2wL} \qquad (1)$$

where,

P = abundance in numbers

A = area of stratum

E(s) = estimated mean school size

N = numbers of schools primary sighted
W = effective search half-width for schools
L = search effort

The CV of P is calculated as follows;

$$\mathrm{CV}(P) = \sqrt{\{\mathrm{CV}(\frac{n}{L})\}^2 + \{\mathrm{CV}(E(s))\}^2 + \{\mathrm{CV}(w)\}^2} \qquad (2)$$

Assuming abundance is log-normally distributed, 95% confidential interval of the abundance estimate was calculated as (P/C, CP);

$$C = \exp(Z_{0.025}\sqrt{\log_e[1+\{\mathrm{CV}(P)\}^2]}) \qquad (3)$$

where,
$Z_{0.025}$ represents 2.5-percentage point of standard normal distribution. Details of the analyses methods were described by Buckland *et al*.. (1993) or Branch and Butterworth (2001).

Correction of the estimated angle and distance
To correct biases of distance and angle estimation, an experiment was conducted on each vessel in each year. Bias was estimated for each platform (Table 1). Linear regression models with standard error proportional to true (radar) distance were conducted to detect significant bias of estimated distance at 5% level. In order to correct significant biases, the estimated distance was divided by the estimated slope through the origin. Linear regression models with constant variance were conducted to detect significant bias of estimated angle at 5% level. In order to correct significant biases, the estimated slope through the origin divided estimated angle (Burt and Stahl, 2000).

Survey modes
The Sighting and Sampling Vessel (SSV) and the dedicated Sighting Vessel (SV) modes are grouped in these analyses, although separate estimates are obtained from SSV and SV modes for Antarctic minke whale analyses. A restrictive approach is followed here than for minke whales since the small number of sightings available for humpback, fin and blue whales dictates the need to include as many data as possible.

Truncation distance
The perpendicular distance distribution was truncated at 2.7 n.miles in principle. The truncated number of detection was substitute to formula (1).

Smearing parameters
The truncated sightings data are smeared before their use in the estimation of the effective search half-width (*ws*) and the mean school size E(s). Radial distance and angle data are conventionally smeared using Method II of Buckland and Anganuzzi (1988) and then grouped into intervals of 0.3 n.miles for estimating *ws* values. For minke whales, smearing parameters are normally estimated separately for each stratum from the data. However, due to the lower numbers of sightings for the species in this paper, some pooling is necessary to apply the Buckland and Anganuzzi method. Smearing parameters are thus obtained from pooled sightings (irrespective of whether school size was confirmed or not) separately for each Area and survey year (Table 2).

Effective search half-width

Hazard rate model with no adjustment terms or half normal models that automatically selected by the AIC. was used as a detection function model. It was assumed that *g(0)* is 1 (i.e. Probability of detection on the track is 1.). Effective search half-width was estimated for each stratum.

Mean school size

Regression of log of school size on $g(x)$ described by Buckland *et al*. (1993) was used to estimate mean school size. If the regression coefficient was not significant at 15% level, mean of observed school size was substituted to formula (1).

Estimation of increasing rate in the feeding ground

To estimate instantaneous increasing rate, regression model is used. The formula is

$$P = b\ \exp(ay) \qquad (4)$$

where, P is abundance, y is year, a and b are parameters. It is assumed that abundance are log-normally distributed. We estimate a as instantaneous increasing rate.

The effect of survey mode

The effects on abundance estimate were examined taking the comments made at the 58th IWC/SC meeting into account. Linear model in following formula is applied with inverse-variance-weighted of log of abundance estimates as Hakamada *et al* (2006).

$$\log(p(y,a)) = \log(p_{true}(y,a)) + MODE + e \qquad (5)$$

where y is year, a is Area, p is observed abundance estimate, p_{true} is unbiased abundance (i.e. free from survey mode effect) and *MODE* is mode effect on abundance standardised to SVP. Intercept was included the estimated unbiased abundance index.

Unsurveyed small area between southern and northern strata due to survey timings

In case that surveying northern strata was earlier than surveying southern strata, southern boundary of northern strata was defined as 45 n.miles of north from ice edge when northern strata were surveyed and northern boundary of southern strata was defined as 45 n.miles of north from ice edge when southern strata were surveyed. If ice edge moved to south substantially, unsurveyed area was occurred between northern and southern boundary. It was recommended that consideration be given to other treatments of apparently unsurveyed areas within strata when converting density estimates to abundance. To cover the recommendation, treatment of such unsurveyed area was reconsidered. Such unsurveyed area should be included as northern strata because they are north of 45 n.mile line from ice edge. Area size of each stratum was recalculated and therefore abundance estimate was recalculated.

RESULTS

Distributions

Searching efforts

Fig.1a and 1b. show the research area of JARPA. Fig.2. shows distribution of the search effort. The research area was covered uniformly during 1987/88 to 2004/05 seasons. Fig. 3. shows monthly change in the density index (DI: whales / 100 n.miles) using JARPA efforts and number of primary sightings of humpback, fin and blue whales in the research area (south of 60°S) between 1989/90 and 2004/05 seasons.

Humpback whales

The DI of humpback whales increased from December to February and decrease in March in the research area (Fig.3). Humpback whales were widely distributed in Areas IV and V. They were concentrated between 90°and 120°E in northern and southern strata where are eastern side of the Kerguren Plateau, and were widely dispersed in other part of Area IV (Fig. 4a). In Area IV, it must be noted that there was a meander of the southern boundary of the Antarctic Circumpolar Current (SB-ACC) in these longitudinal area and high density areas of this species were observed along this boundary in 1997/98 season (Matsuoka *et al*., 2003a). Same tendency also observed the IWC catch database and the JSV data (Fig.10). To compare to distribution pattern between the first half of JARPA (1989/90-1996/97) and late of JARPA (1997/98-2004/05), concentration area of humpback whales was expanded to the southern and to the eastern strata year by year between 90°E and 120°E (Fig. 5). Distribution pattern of humpback whales were similar to that of krill in Area IV and V (Fig.4d), In Area V, they were distributed clearly along the Pacific Antarctic ridge where the southern boundary of the Antarctic Circumpolar Current was observed (Fig. 4a).

Fin whales

The DI of fin whales increased slowly from January to March in the research area (Fig.3). Fin whales tended to be distributed more in Area V rather than Area IV along the SB-ACC. They were widely dispersed in Areas IIIE, IV, V and VIW, and also rarely found within the Prydz Bay and the Ross Sea. High density areas of this species were the western side of the Balleny Islands (Fig. 4b). To compare distribution pattern between the first half of JARPA (1989/90-1995/96) and late of JARPA (1996/97-2003/04), fin whales appeared in the western part of Area IV in recent years (Fig. 6). This distribution pattern was similar to krill distribution in the research area. They previously distributed in both north and south of 60°S (Fig.11).

Blue whales

For blue whales, the DI was rather stable from December to March (Fig.3). In the research area, blue whales were encountered through the surveys and they were widely distributed without apparent aggregation. They were usually found in Area IIIE and around the Scott Island in Area VE (Fig. 4c).

Abundance estimates

Tables 3a-3d (humpback whale), Tables 4a-4e (fin whale) and Tables 5a-5d (blue whale) show abundance estimates south of 60°S, total number of the primary sightings (n), areas (A), effort (L), n/L, effective search half width (esw), estimated mean school size (E(s)), estimated whale density (D: whales / 100 n.miles^2), abundance estimation (P) with CVs by each stratum. Fig. 7 show the perpendicular distance in nautical miles used in the present analyses.

Humpback whales

In Area IIIE, abundance estimates of 1,378 (CV=0.19) in 1995/96, 671 (CV=0.36) in 1997/98, 12,081 (CV=0.13) in 1999/2000, 4,791 (CV=0.20) in 2001/02 and 8,045 (CV=0.10) in 2003/04 seasons. In Area IV, abundance estimates of 5,325 (CV=0.30) in 1989/90, 5,408 (CV=0.19) in 1991/92, 2,747 (CV=0.15) in 1993/94, 8,066 (CV=0.14) in 1995/96, 10,657 (CV=0.17) in 1997/98, 16,751 (CV=0.14) in 1999/2000, 31,134 (CV=0.12) in 2001/02 and 27,783 (CV=0.12) in 2003/04 seasons. In Area V, abundance estimates of 1,714 (CV=0.18) in 1990/91, 4,388 (CV=0.62) in 1992/93, 3,943 (CV=0.31) in 1994/95, 1,474 (CV=0.27) in 1996/97, 7,989 (CV=0.33) in 1998/99, 5,130 (CV=0.21) in 2000/2001, 2,873 (CV=0.16) in 2002/03, 9,342 (CV=0.34) in 2004/05 seasons. In Area VIW, abundance estimates of 1,493 (CV=0.18) in 1996/97, 171

(CV=0.72) in 1998/99, 2,440 (CV=0.20) in 2000/2001 and 1,614 (CV=0.24) in 2002/03, 9,342 (CV=0.34) in 2004/05 seasons. For abundance estimates in Area IIIE and VIW, there were no estimations of this species and little is known about abundance estimations in these Areas. Updated estimates between 1995/96 and 2004/05 were the first values in these Areas by sighting surveys, although these Areas surveyed mainly in December. Further attention should be given to the monthly change of density index (DI) (Fig. 3). The index of this species suggested that current estimations of these Areas were under-estimated. Further surveys between January and February should be required in future survey.

Fin whales

In Area IIIE, abundance estimates south of 60^{o}S were 2,066 (CV=0.24) in 1995/96, 74 (CV=0.58) in 1997/98, 5,199 (CV=0.28) in 1999/2000 and 3,389 (CV=0.52) in 2001/02 and 5,288 (CV=0.32) in 2003/04 seasons. In Area IV, abundance estimates of 103 (CV=0.85) in 1989/90, 342 (CV=0.59) in 1991/92, 186 (CV=0.45) in 1993/94, 1,021 (CV=0.31) in 1995/96, 624 (CV=0.34) in 1997/98, 1,565 (CV=0.49) in 1999/2000, 5,861 (CV=0.29) in 2001/02, 1,226 (CV=0.28) in 2003/04 seasons. In Area V, abundance estimates of 732 (CV=0.30) in 1990/91, 1,623 (CV=0.38) in 1992/93, 6,937 (CV=0.37) in 1994/95, 1,224 (CV=0.32) in 1996/97, 4,259 (CV=0.39) in 1998/99, 5,321 (CV=0.25) in 2000/2001, 3,210 (CV=0.32) in 2002/03, 4,556 (CV=0.44) in 2004/05 seasons. In Area VIW, present abundance estimates of 655 (CV=0.26) in 1996/97, 164 (CV=0.74) in 1998/99, 1,071 (CV=0.30) in 2000/2001 and 495 (CV=0.32) in 2002/03, 685 (CV=0.30) in 2004/05 seasons. For Areas IIIE and VIW, there were no estimations of this species by sighting surveys. Present estimates between 1995/96 and 2004/05 were new ones of this species, although these Areas had mainly surveyed in December. Further attention should be given to the monthly change of density index (DI) (Fig. 3). The index of this species suggested that current estimations of these Areas were under-estimated. In this paper, we also estimate abundance for each stock in the research area. For the Indian Ocean Stock (Pastene *et al*, 2006) of this species in the south of 60°S was estimated as 3,087 (CV=0.20) in 1995/96, 698 (CV=0.31) in 1997/98, 6,764 (CV=0.24) in 1999/2000 9,250 (CV=0.27) in 2001/02 and 6,514 (CV=0.26) in 2003/04, respectively between 35^{o}E and 130^{o}E (Table 4e). Because they are mainly distributed in the area north of 60°S (Fig. 11), these estimates were under-estimated and large yearly fluctuation in the area south of 60°S in Areas IIIE and IV might be attributable to such distribution.

Blue whales

Abundance of this species (south of 60°S, 35°E-145°W) was 545 (CV=0.30) in 2001/2002 + 2002/03 seasons and 1,265 whales (CV=0.33) in 2003/04 + 2004/05 seasons. Only for this species, the CV are not included the process error caused by year to year combined estimates. They are still low level in the JARPA research area.

Instantaneous increase rate

Humpback whales

Observed rates of increase in this species were estimated as 15.5 % (CV=0.21) and 7.3% (CV=0.64) in Areas IV and V, respectively, between 1989/90 and 2004/05 seasons. In addition, as pointed out in the SC meeting, in comparison with IDCR/SOWER estimates in Area IV, estimates were low in 1993/94 and high in 2001/02 season (IWC, 2006c). Excluding these seasons, increasing rate was 12.4 % (CV=0.10). In the same way in Area V, increasing rate was 9.7 % (CV=0.31). Significant increases were observed both cases in Area IV and latter case in Area V.

Fin whales

For the Indian Ocean stock between 1995/96 and 2003/04 seasons, increasing rate was estimated as 16.0% (CV=0.78), and for the Pacific Ocean stock between 1996/97 and 2004/05 was estimated as 12.8%

(CV=0.60). For combined Areas IV and V significant increase rate was observed as 10.2 % (CV=0.27) between 1995/96 and 2004/05.

<u>Blue whales</u>

For the species, increase rate was 7.4 % (CV=1.19) between 1989/90 and 2004/05 for combined Areas IV and V. Excluding anomalously low in 1995/96+1996/97 season, significant increase rate was observed as 5.7 % (CV=0.17) between 1995/96 and 2004/05.

Examination for the effect of including tracklines those look like along with ice edge (Sensitivity tests for humpback whales)

At the 58th IWC/SC meeting, the Committee recommends that as a sensitivity analysis, calculations be repeated including only the perpendicular transects, or at least exclude segments that appeared to track the contours of the ice edge, to investigate implications for bias and precision. Some of tracklines not parallel to longitudinal line could lead overestimate of abundance because they are nearly paralell to the ice edge in strata where saw-tooth type tracklines were designed (e.g. SW and SE strata in Area IV). To examine the effect, sensitivity analyses of abundance estimation were conducted for two data sets. One is excluding tracklines those look like along with ice edge (Option B). Another is excluding all tracklines not parallel to longitudinal lines (Option C). We used sighting data in SW and SE in Area IV from 1997/98 to 2003/04 because there were not enough sightings to conduct this analysis in other cases.

To test the significance of the effect, t-tests for mean of (P_B/P) and (P_C/P) were conducted where P is abundance estimate using all tracklines, P_B is abundance estimate under Option B and P_C is abundance estimate under Option C. As shown in Table 6a, the means of P_B/P and P_C/P are not significantly different from 0 for all cases. It was indicated that there is no significant effect of the tracklines on humpback abundance. Therefore, including tracklines those look like nearly parallel to ice edge didn’t cause the substantial bias and therefore, we don’t remove such tracklines from data to estimate unbiased abundance.

The effect of survey mode for humpback whales

As shown in Table 6b, there is no significant effect of survey mode on humpback abundance. Though the effect was not significant, corrected abundance by the factor standardised to SVP were used to estimate an abundance trend as a sensitivity test for the humpback abundance trend. But the estimated abundance trend is similar to those using abundance series derived from IWC standard methodology. It was shown that the effect of survey mode on abundance trend was not substantial and increasing trends detected in Areas IV and V are not artificial one due to survey mode.

DISCUSSIONS

Appropriateness of abundance estimates with good precisions by the standardized method

Results of examinations for the “mode effect (SSV and SV, Closing and Passing) and “sensitivity test in the southern stratum” confirmed that present standardized abundance estimates was appropriate for humpback whales. These results indicated that JARPA estimates are comparable to IWC/SOWER estimates in both Areas IV and V (IWC, 2006a), for example, 4,164 whales (CV=0.53) in IDCR (1988/89) vs. 5,325 (CV=0.30) in JARPA (1989/90), and 17,938 (CV=0.18) in SOWER (1998/99) vs. 16,751 (CV=0.14) in JARPA (1999/2000) (Fig.8). There are some analyses models (e.g. spatial models) proposed in resent SC meetings, however, they are not practicable in model fitting for large whales at this moment, especially IWC/IDCR-SOWER surveys. It is reasonable to support that present standardized estimates are adequate with good precisions. In that respect, JARPA contributed for the baleen whales in-depth assessment and investigation of the Antarctic ecosystems.

Humpback whale in Area IV increased than Area V

Previously, there were two greatest hot spot of humpback whales in the JARPA research area according to IWC catch database and the JSV data. One was observed south of 58°S between 80°E and 120°E. Another one was observed around south of 60°S between 150°E and 160°W (Fig.10). In recent years, according to fig.10, humpback whales were concentrated between 80°E and 120°E rather than between 150°E and 160°W during JARPA period. These patterns supported that humpback whales in Area IV have increased rapidly rather than Area V (IWC, 2006a), although around 10 % increasing rate of the breeding ground in the both coast of Australia were reported (Banister and Hedley, 2001, Noad, *et al*., 2006).

Habitat expansion of humpback whales in Area IV

Updated abundance estimates in Area IV increased year by year especially after 1997/98 season. After this season, humpback whales tended to be distributed in the southern and eastern strata year by year. These distribution changes suggested that humpback whale populations are recovering and expanding their distributions to the south and east in the feeding grounds. Humpback whales were observed not only northern strata but also in southern strata such as even near ice-edge on the continental shelf (200m-1000m) (Fig.5). High density area of Chl-*a* was observed in whole Area IV in January 1999/2000 and was observed only southern strata in 2001/02. These distribution changes may relate to Chl-*a* and krill distributions. Southward distribution change was also observed in the southern strata especially western sector (SW) in 1999/2000 and 2001/02 seasons (Murase *et al*., 2006). Same distribution pattern was also observed in 2005/06 IWC/SOWER survey in Area III (Ensor *et al*., 2006). Further statistical analyses for estimating distribution patterns of this expansion such as GAM-based method are required and some analyses are preliminarily progressing. Further studies are also required to investigate interspecific relationships in density among whale species such as Antarctic minke whales on the continental shelf by statistical analyses.

High rates of increase south of 60°S related to southward of SB-ACC

It was indicated that distribution of humpback whales related to the southern boundary of the Antarctic Circumpolar Current (SB-ACC) in Area IV (Matsuoka *et al*, 2003b). Humpback distributions of the IWC catch database and JSV database also indicated this relation in circumpolar base (Fig.10). Further, according to JARPA oceanographic research, the SB-ACC in the research area was moved to south year by year from 1997/98 to 2001/02, and moved to north in 2003/04 season (Watanabe *et al*, 2006). This trend is as same as humpback abundance trend in south of 60°S during same periods (Fig. 8). Based on this relation, it is reasonable to suppose a hypothesis that high increase rates of humpback whales south of 60°S related to the SB-ACC moved to the southern region in recent seasons. It is also reasonable to support a view that present significant increasing rate of 12.4 % might include two phenomena of their "real rate of increase around 10 %" and few % of "effect of the year to year variation of their distribution pattern such as movement of SB-ACC including east and west movements of whales". This hypothesis is also applied for fin whales in Area IV. Further environmental analyses such as satellite information, oceanographic data and krill data (Naganobu *et al*., 2006, Murase *et al*., 2006, Nicol *et al*., 2000, Nicol, 2006) are required to interpret "habitat expansion" more precisely in the feeding grounds.

Larger abundance estimates of humpback whales in feeding ground than in breeding grounds

Updated estimates in the feeding grounds were generally high compare to recent estimations in the breeding grounds (Banister and Hedley, 2001, Noad, *et al*., 2006). Recent studies in the Western Antarctic Peninsula humpback wintering study (McKay *et al*., 2004) and the North Atlantic humpback whale study (Smith *et al*., 1999) suggested that some portion of individuals could not return to their breeding ground. Because all the portion do not always return to the breeding ground every year, abundance estimates in breeding area could be lower than those in feeding ground. In addition, as another reason of this difference, because all breeding areas were not surveyed at this moment, abundance estimates in breeding area could be lower than those in feeding ground. In the Hobart Workshop in 2006, it was concluded that question of a possible sex-bias in the breeding ground animals are still remain (IWC, 2006a). This bias issue suggests that survey of breeding grounds were not covered completely. On the other hands, JARPA estimates, previously considered much higher than IDCR/SOWER, are now comparable in Area IV and V (Fig. 8), and in addition the IDCR/SOWER surveys in these two areas showed high rates of increase similar to those from JARPA (IWC, 2006a). These similarities suggested that JARPA estimates are appropriate.

Fin whales increased in south of 60^{o}S

Fin whales were widely distributed from middle latitude to south of 60^{o}S in all longitude. They concentrated in Area III (between 10°E-60°E), in Area IV (between 80°E-110°E), AreaV (between 140°E-170°E) and Area VI (between 170°W-150°W) (Machintosh, 1966, Mizroch *et al*., 1984). Present distribution pattern of IWC catch database (1913-1973) and JSV data (1965/66-1987/88) (Miyashita *et al*., 1995) also indicated this pattern. During JSV period, fin whales rarely found in south of 60^{o}S, however they found more and more in south of 60^{o}S during JARPA period (1987/88-2004/05) (Fig.11).

First value of fin whale abundance estimates in good precision

There was no abundance estimation of fin whales by use of whale sightings for each IWC management Area. Estimate of this species based on IWC/IDCR and Japanese Scouting Vessels (JSV) was 18,000 (CV=0.47) in the whole area south of 30^{o}S (Butterworth *et al*., 1994). Recent estimates of this species in the whole area south of 60^{o}S based on the IWC/IDCR and SOWER were 2,100 (1978/79-1983/84, CV=0.36), 2,100 (1985/86-1990/91, CV=0.45) and 5,500 (1991/92-1997/98: circumpolar not completed, CV=0.53) in first, second and third circumpolar series, respectively (Branch and Butterworth, 2001). Updated JARPA estimate of 12,000 (CV=0.22) in recent two seasons for the half of Antarctic Areas (35^{o}E -145^{o}W) south of 60^{o}S and significant increases will be the first value in these Areas. Taking into account of survey year and Area difference, updated estimate is reasonable for this species. Because they mainly distributed in the area north of 60^{o}S (Fig. 11), 12,000 whales was under estimated and large yearly fluctuation in the area south of 60^{o}S in Areas IV and V might be attributable to such distribution pattern.

Blue whale are so far from recover

Blue whales were encountered through the surveys and they were widely distributed with no gaps. They were usually found in Area IIIE and around the Scott Island in Area VE. These information are useful for their distributions from the end of the 20th century to the beginning of 21 century as their distribution study such as Kato *et al*. (1995), Branch *et al* (2006). Abundance of this species (south of 60°S, 35°E-145°W) was 545 (CV=0.30) in 2001/2002 + 2002/03 seasons and 1,265 whales (CV=0.33) in 2003/04 + 2004/05 seasons. For this species, the CV are not included the process error caused by year to year combined estimates. They are still less than 1,300 in the JARPA research area. Initially, there were as many as 200,000 blue whales in the whole Antarctic by logistic model, and now were estimated as 1,700 (860-2,900) in 1996 with 7.8 % increasing rate (Branch *et al*., 2004). Present estimates in 2004 for this species less than 1,300 with 6.0% increasing rate in the half of Antarctic IWC management Areas is reasonable compared to result in 1996. They are so far from recovering.

A "Shift in baleen whale dominance" event from Antarctic minke to humpback whales in Area IV

A "Shift in baleen whale dominance" event from Antarctic minke to humpback whales was observed in Area IV since 1997/98 season (Fig. 9a). In 1989/90 season, biomass of Antarctic minke was higher (337,000 tons) than humpback whales (130,000 ton), and after 15 years in 2003/04 season, biomass of humpback (681,000 tons) was twice of Antarctic minke (312,000 tons). Increase of fin whale was observed in Areas IIIE and IV. In 1989/90 season, biomass of fin was 5,000 tons, and after 15 years in 2003/04 season, biomass of fin was 67,000 tons as over 10 times (20 % of Antarctic minke biomass). Abundance of Antarctic minke whales is stable in Areas IV and V, however, the decrease in blubber thickness in Area IV was observed (Konishi *et al*., 2006), and the decreasing pattern in stomach content weights of matured minke whales was also observed in Area IV since 1987/88 season using JARPA biological data (Tamura and Konishi, 2006). It is also reasonable to support a hypothesis that increase and habitat expansion of humpback and fin whales in Area IV may be caused competition with Antarctic minke whales. It is further necessary to investigate relationship between oceanographic conditions and whale distribution shifts such as effect of the Regime Shift in the Global Sea-Surface temperatures in relation to El Nino-Southern Oscillation Events. Further monitoring survey was required in order to understanding Antarctic ecosystem and for the baleen whale management in the Antarctic Ocean and investigating Antarctic Marine Ecosystems.

High productivity around the meander of the SB-ACC

Humpback and fin whales were widely distributed in all longitude along the SB-ACC and previously overlapped each other (Fig.10 and 11). Hot spots of these species were and observed along the meander of the SB-ACC. The position of the SB-ACC is mainly determined by bottom topography such as the Kerguelen Plateau the Pacific-Antarctic ridge. The SB-ACC meandered largely around 80°E-120°E, 150°E-180° and 180°-120°W. These areas were characterized by a large meander of the SB-ACC which seemed to be formed by large scale up-welling resulting from the bottom shape. Results of JARPA observations also suggest these distribution patterns. High density areas of krill were reported around the meander of the SB-ACC (Fig. 4d). Humpback and fin whales used these areas as their key feeding area.

Importance of monitoring whale population

In the Antarctic Ocean, catch of southern right, humpback, blue, fin and sei whales was prohibited in 1932, 1963, 1964, 1976 and 1978, respectively. Seventy years passed already since southern right whale has been protected, and more than 40 years have passed since humpback whale and blue whale have been protected. In coastal waters of South America, South Africa and east and west coast of Australia, significant recovery of southern right whale and humpback whales are reported recently in these breeding areas. On the other hand, the information on the present status of pelagic species, such as blue, fin and sei whales were limited. The IWC/IDCR-SOWER cruises, however not sufficient enough for the monitoring of ecosystem, as survey covers the same area once in every over 6 years. In this situation, JARPA have been monitoring for baleen whale species population by the large-scaled and long-term line transect survey for over 18 years in Areas IV and V. The number of survey years is still too short to detect precise yearly trend for whale's population. JARPA continues providing more useful information about recovering of whale stocks for the management including blue whales. Further monitoring surveys including co-operation studies including middle latitude and breeding grounds data was required for the baleen whale management in the Antarctic Ocean and investigation of Antarctic marine ecosystems.

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Table 1. Estimated observer bias in distance and angle estimation (JARPA) during 1989/90 to 2004/05 seasons.

1989/90

Vessel	platform	distance	angle
K01	barrel	n.s.	0.930
	upper bridge	n.s.	0.872
T18	barrel	n.s.	1.047
	upper bridge	n.s.	n.s.
T25	barrel	1.099	n.s.
	upper bridge	1.075	n.s.

1990/91

Vessel	platform	distance	angle
K01	barrel	n.s.	1.051
	upper bridge	0.953	1.064
T18	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	0.882	n.s.
	upper bridge	0.961	n.s.

1991/92

Vessel	platform	distance	angle
K01	barrel	0.930	n.s.
	upper bridge	n.s.	0.950
T18	barrel	n.s.	n.s.
	upper bridge	0.960	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	1.070	n.s.

1992/93

Vessel	platform	distance	angle
K01	barrel	n.s.	0.942
	upper bridge	1.083	0.941
T18	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	1.056
	upper bridge	n.s.	1.082

1993/94

Vessel	platform	distance	angle
K01	barrel	0.863	n.s.
	upper bridge	n.s.	n.s.
T18	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	n.s.	1.057

1994/95

Vessel	platform	distance	angle
K01	barrel	n.s.	n.s.
	upper bridge	n.s.	0.933
T18	barrel	n.s.	n.s.
	upper bridge	0.934	n.s.
T25	barrel	0.940	n.s.
	upper bridge	0.902	n.s.

1995/96

Vessel	platform	distance	angle
K01	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T18	barrel	n.s.	n.s.
	upper bridge	1.110	0.956
T25	barrel	0.889	n.s.
	upper bridge	0.905	1.040
KS2	barrel	n.s.	0.905
	upper bridge	n.s.	0.898

1996/97

Vessel	platform	distance	angle
K01	barrel	0.822	n.s.
	upper bridge	0.844	n.s.
T18	barrel	0.711	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	0.799	n.s.
	upper bridge	0.773	1.036
KS2	barrel	0.789	0.951
	upper bridge	0.662	1.050

1997/98

Vessel	platform	distance	angle
K01	barrel	0.842	n.s.
	upper bridge	0.746	n.s.
T18	barrel	0.902	n.s.
	upper bridge	0.788	n.s.
T25	barrel	0.729	n.s.
	upper bridge	0.914	n.s.
KS2	barrel	0.876	n.s.
	upper bridge	0.788	n.s.

1998/99

Vessel	platform	distance	angle
K01	barrel	0.902	n.s.
	upper bridge	0.956	1.057
T25	barrel	n.s.	1.053
	upper bridge	n.s.	1.065
YS1	barrel	0.923	n.s.
	upper bridge	0.968	n.s.
KS2	barrel	0.928	0.950
	upper bridge	n.s.	n.s.

1999/2000

Vessel	platform	distance	angle
K01	barrel	n.s.	n.s.
	upper bridge	1.050	n.s.
T25	barrel	n.s.	1.081
	upper bridge	n.s.	n.s.
YS1	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	n.s.	0.930
	upper bridge	n.s.	n.s.

2000/2001

Vessel	platform	distance	angle
K01	barrel	n.s.	1.051
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	1.062	n.s.
YS1	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	n.s.	n.s.
	upper bridge	n.s.	0.861

2001/2002

Vessel	platform	distance	angle
K01	barrel	0.957	0.921
	upper bridge	0.957	n.s.
T25	barrel	0.951	n.s.
	upper bridge	0.960	n.s.
YS1	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.

2002/2003

Vessel	platform	distance	angle
K01	barrel	1.073	n.s.
	upper bridge	n.s.	n.s.
YS1	barrel	1.051	1.037
	upper bridge	1.058	0.938
YS2	barrel	1.050	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	n.s.	n.s.
	upper bridge	n.s.	1.088

2003/2004

Vessel	platform	distance	angle
K01	barrel	0.957	0.921
	upper bridge	0.957	n.s.
YS1	barrel	0.951	n.s.
	upper bridge	0.960	n.s.
YS2	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.

2004/2005

Vessel	platform	distance	angle
K01	barrel	1.113	1.096
	upper bridge	1.044	n.s.
YS1	barrel	1.029	0.939
	upper bridge	1.024	0.919
YS2	barrel	1.102	1.061
	upper bridge	n.s.	n.s.
KS2	barrel	1.084	0.966
	upper bridge	1.064	n.s.

*n.s. indicates no significant at 5% level.

Table 2. Smearing parameters used in this analysis. *,**These parameters were estimated from entire data set, because number of sightings was small.

Humpback

	Area IIIE		Area IV	
	angle	distance	angle	distance
1989/90	-	-	4.9775	0.308
1991/92	-	-	6.589	0.266
1993/94	-	-	5.821	0.356
1995/96	6.445	0.227	5.742	0.273
1997/98	5.085	0.444	5.612	0.231
1999/2000	6.000	0.263	6.769	0.233
2001/02	4.142	0.219	5.289	0.233
2003/04	6.889	0.186	7.180	0.188

	Area V		Area VIW	
	angle	distance	angle	distance
1990/91	3.963	0.257	-	-
1992/93	4.616	0.396	-	-
1994/95	6.411	0.206	-	-
1996/97	7.732	0.214	6.000	0.260
1998/99	8.710*	0.281**	8.710*	0.281**
2000/01	6.559	0.307	3.948	0.212
2002/03	4.106	0.174	3.084	0.170
2004/05	6.486	0.250	12.857	0.400

Fin

	Areas IIIE and IV	
	angle	distance
1989/90	7.500	0.667
1991/92	5.000	0.667
1993/94	9.737	0.500
1995/96	7.059	0.326
1997/98	3.871	0.667
1999/2000	7.554	0.299
2001/02	4.639	0.215
2003/04	4.639	0.215

	Areas V and VIW	
	angle	distance
1990/91	8.630	0.300
1992/93	4.616	0.333
1994/95	5.037	0.284
1996/97	7.037	0.327
1998/99	6.000	0.323
2000/01	5.728	0.216
2002/03	3.818	0.153
2004/05	3.429	0.229

Blue

	Areas IIIE and IV	
	angle	distance
1989/90	11.437	0.216
1991/92	11.437	0.216
1993/94	11.437	0.216
1995/96	11.437	0.216
1997/98	11.437	0.216
1999/2000	11.437	0.216
2001/02	11.437	0.216
2003/04	11.437	0.216

	Areas V and VIW	
	angle	distance
1990/91	11.437	0.216
1992/93	11.437	0.216
1994/95	11.437	0.216
1996/97	11.437	0.216
1998/99	11.437	0.216
2000/01	11.437	0.216
2002/03	11.437	0.216
2004/05	11.437	0.216

Table. 3a. Abundance estimates of humpback whale in Area IV (south of 60°S) between 1989/90 and 2003/04. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1989/90	NW	222,563	21.2	1,987.6	1.067	0.297	0.996	0.226	2.000	0.093	1.071	2,383	0.331
	NE	219,245	20.0	1,964.4	1.018	0.448	0.727	0.426	1.750	0.082	1.225	2,687	0.522
	SW	35,878	10.4	2,518.3	0.411	0.391	0.937	0.201	1.804	0.056	0.396	142	0.412
	SE	41,143	1.0	1,362.2	0.073	0.732	0.937	0.201	1.804	0.056	0.071	29	0.761
	PB	36,488	2.0	831.9	0.240	0.482	0.937	0.201	1.804	0.056	0.231	84	0.526
	Total	555,317	54.6	8,664.4	0.630	0.215	-	-	-	-	**0.959**	**5,325**	**0.302**
1991/92	NW	219,713	41.7	2,482.7	1.680	0.231	1.052	0.202	1.929	0.062	1.540	3,383	0.265
	NE	216,299	16.0	2,173.9	0.736	0.300	1.005	0.143	1.803	0.049	0.661	1,429	0.317
	SW	37,191	19.7	2,237.5	0.880	0.350	1.379	0.172	1.680	0.082	0.536	199	0.368
	SE	39,732	17.0	2,281.7	0.745	0.378	0.746	0.327	1.870	0.051	0.905	360	0.424
	PB	36,569	1.0	607.5	0.165	0.730	1.379	0.172	1.680	0.082	0.100	37	0.755
	Total	549,504	95.4	9,783.3	0.975	0.150	-	-	-	-	**0.984**	**5,408**	**0.188**
1993/94	NW	233,289	43.7	4,160.7	1.050	0.191	1.220	0.122	1.614	0.068	0.694	1,619	0.208
	NE	163,982	30.5	3,175.1	0.960	0.290	1.874	0.171	1.774	0.079	0.454	744	0.310
	SW	39,755	24.8	2,377.7	1.043	0.338	1.381	0.157	1.571	0.070	0.597	237	0.354
	SE	41,353	7.0	2,258.9	0.310	0.315	1.381	0.157	1.571	0.070	0.179	74	0.334
	PB	34,506	4.0	1,077.0	0.371	0.688	1.381	0.157	1.571	0.070	0.211	73	0.701
	Total	512,885	110.0	13,049.4	0.843	0.138	-	-	-	-	**0.536**	**2,747**	**0.153**
1995/96	NW	149,107	122.2	3,530.5	3.461	0.171	1.126	0.070	1.543	0.037	2.347	3,611	0.176
	NE	230,473	45.8	2,979.7	1.537	0.280	1.076	0.119	1.826	0.079	1.304	3,007	0.289
	SW	89,825	54.5	2,851.2	1.911	0.318	1.468	0.118	1.909	0.050	1.293	1,100	0.336
	SE	33,980	27.6	2,039.9	1.353	0.246	1.248	0.154	1.893	0.087	1.029	348	0.267
	PB	25,970	0.0	1,321.8	-	-	-	-	-	-	-	0	-
	Total	529,354	250.1	12,723.1	1.966	0.123	-	-	-	-	**1.524**	**8,066**	**0.142**
1997/98	NW	217,645	191.6	3,367.2	5.690	0.200	1.829	0.071	1.870	0.035	2.924	6,365	0.204
	NE	219,602	107.2	3,622.7	2.959	0.367	1.681	0.085	1.658	0.040	1.465	3,217	0.369
	SW	31,615	171.3	3,432.5	4.991	0.157	1.533	0.064	1.767	0.030	2.944	931	0.161
	SE	34,374	25.2	3,195.9	0.789	0.218	1.549	0.168	1.555	0.090	0.395	136	0.239
	PB	4,407	2.0	490.0	0.408	0.758	1.533	0.064	1.767	0.030	0.204	9	0.761
	Total	507,643	497.3	14,108.3	3.525	0.123	-	-	-	-	**2.099**	**10,657**	**0.166**
1999/2000	NW	229,368	54.7	2,825.3	1.936	0.193	1.347	0.113	1.532	0.066	1.098	2,519	0.204
	NE	226,272	160.7	3,550.8	4.525	0.208	0.828	0.170	1.538	0.032	4.203	9,510	0.228
	SW	44,862	106.3	2,336.7	4.549	0.245	0.579	0.222	1.710	0.039	6.839	3,068	0.274
	SE	34,175	165.1	2,704.3	6.105	0.191	1.447	0.068	2.183	0.054	4.613	1,576	0.195
	PB	21,288	3.0	1,244.7	0.241	0.610	0.579	0.222	1.710	0.039	0.369	78	0.651
	Total	555,964	489.8	12,661.8	3.868	0.110	-	-	-	-	**3.013**	**16,751**	**0.143**
2001/02	NW	222,449	252.2	3,043.6	8.286	0.191	1.259	0.071	1.941	0.035	6.371	14,171	0.196
	NE	244,921	238.2	3,271.6	7.281	0.206	1.286	0.061	1.754	0.032	4.937	12,093	0.209
	SW	32,199	386.8	2,321.8	16.658	0.176	1.201	0.053	1.870	0.027	13.164	4,239	0.178
	SE	35,955	63.5	2,885.2	2.201	0.257	1.090	0.097	1.672	0.057	1.755	631	0.266
	PB	28,472	0.0	1,033.7	-	-	-	-	-	-	-	0	-
	Total	563,995	940.7	12,555.9	7.492	0.104	-	-	-	-	**5.520**	**31,134**	**0.123**
2003/04	NW	243,849	241.2	3,236.6	7.452	0.249	1.334	0.051	1.680	0.026	4.728	11,529	0.248
	NE	218,072	278.9	3,738.5	7.460	0.137	1.495	0.050	1.666	0.025	4.152	9,053	0.140
	SW	38,976	389.3	2,275.2	17.111	0.112	1.417	0.063	1.886	0.021	11.315	4,410	0.117
	SE	38,952	448.2	3,633.2	12.336	0.139	1.489	0.039	1.643	0.019	6.911	2,692	0.134
	PB	37,537	2.0	508.5	0.393	1.294	1.417	0.063	1.886	0.021	0.261	98	1.296
	Total	577,386	1359.6	13,392.0	10.152	0.077	-	-	-	-	**4.812**	**27,783**	**0.115**

Table. 3b. Abundance estimates of humpback whale in Area V (south of 60^{o}S) between 1990/91 and 2004/05 seasons. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^{2}	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^{2}**	**P (ind.)**	**CV**
1990/91	NW	239,688	1.0	2726.8	0.037	1.096	1.189	0.163	1.303	0.087	0.020	48	1.111
	NE	181,382	6.0	1871.8	0.321	0.366	1.027	0.138	1.546	0.070	0.241	438	0.382
	SW	64,431	21.7	1635.0	1.328	0.369	1.189	0.163	1.303	0.087	0.728	469	0.387
	SE	60,266	25.6	1529.8	1.673	0.210	1.027	0.138	1.546	0.070	1.260	759	0.230
	Total	545,767	54.3	7763.4	0.700	0.183	-	-	-	-	**0.314**	**1,714**	**0.179**
1992/93	NW	325,648	5.0	2299.3	0.217	1.428	0.712	0.156	2.000	0.083	0.305	993	1.435
	NE	348,822	9.0	1661.5	0.542	0.858	0.712	0.156	2.000	0.083	0.761	2,654	0.868
	SW	59,450	5.0	1907.4	0.262	0.485	0.712	0.156	2.000	0.083	0.367	218	0.506
	SE	210,194	4.0	2256.3	0.177	0.644	0.712	0.156	2.000	0.083	0.249	523	0.653
	Total	944,113	23.0	8124.5	0.283	0.482	-	-	-	-	**0.465**	**4,388**	**0.623**
1994/95	NW	209,990	14.0	3229.4	0.433	0.747	1.793	0.083	1.658	0.055	0.200	420	0.749
	NE	348,822	26.1	2554.1	1.022	0.411	1.320	0.147	2.000	0.115	0.774	2,701	0.430
	SW	39,911	41.6	2,469.0	1.687	0.200	1.793	0.083	1.658	0.055	0.789	315	0.210
	SE	173,180	5.0	1,293.0	0.386	0.519	1.320	0.147	2.000	0.115	0.293	507	0.531
	Total	771,903	86.7	9,545.5	0.909	0.200	-	-	-	-	**0.511**	**3,943**	**0.313**
1996/97	NW	288,197	1.0	2,784.6	0.036	1.679	1.520	0.194	1.632	0.117	0.019	55	1.694
	NE	337,779	14.0	3,133.4	0.446	0.356	1.381	0.190	1.700	0.062	0.274	926	0.375
	SW	53,960	17.5	3,124.4	0.560	0.369	1.520	0.194	1.632	0.117	0.286	162	0.394
	SE	187,983	6.0	2,098.5	0.286	0.500	1.381	0.190	1.700	0.062	0.176	331	0.515
	Total	867,919	38.5	11,140.9	0.345	0.230	-	-	-	-	**0.170**	**1,474**	**0.274**
1998/99	NW	314,778	12.0	1,830.6	0.656	0.529	0.639	0.419	1.684	0.078	0.863	2,719	0.623
	NE	327,490	21.9	1,226.9	1.785	0.386	0.575	0.560	0.773	0.074	1.201	3,926	0.491
	SW	48,333	30.8	2,333.5	1.320	0.431	0.639	0.419	1.684	0.078	1.740	841	0.500
	SE	25,709	34.9	1,561.0	2.233	0.145	1.046	0.128	1.787	0.082	1.892	504	0.167
	Total	716,310	99.6	6,952.0	1.432	0.178	-	-	-	-	**1.115**	**7,989**	**0.326**
2000/01	NW	271,595	43.2	3,751.9	1.153	0.389	1.368	0.128	1.762	0.074	0.741	2,019	0.396
	NE	348,535	44.3	3,941.1	1.124	0.293	1.668	0.132	1.956	0.071	0.659	2,297	0.305
	SW	79,594	30.5	3,152.9	0.968	0.224	0.780	0.418	1.645	0.072	1.035	815	0.362
	SE	148,828	0.0	3,320.2	-	-	-	-	-	-	-	-	-
	Total	848,552	118.1	14,166.1	0.833	0.189	-	-	-	-	**0.605**	**5,130**	**0.215**
2002/03	NW	266,687	12.0	2,777.2	0.432	0.393	1.291	0.126	1.548	0.094	0.259	691	0.404
	NE	345,003	58.0	5,077.1	1.142	0.181	1.902	0.087	1.672	0.050	0.502	1,732	0.188
	SW	79,376	18.8	2,209.8	0.852	0.331	1.291	0.126	1.548	0.094	0.510	406	0.342
	SE	69,872	3.0	2,111.9	0.142	0.489	1.902	0.087	1.672	0.050	0.062	44	0.493
	Total	760,938	91.8	12,176.0	0.754	0.144	-	-	-	-	**0.378**	**2,873**	**0.157**
2004/05	NW	278,281	19.5	970.0	2.015	0.780	1.688	0.199	2.050	0.075	1.223	3,405	0.791
	NE	336,130	85.8	3,381.8	2.537	0.196	1.295	0.080	1.583	0.460	1.551	5,214	0.309
	SW	51,373	16.0	856.7	1.873	0.235	1.437	0.232	1.686	0.099	1.099	564	0.270
	SE	212,181	10.0	8,158.7	0.123	0.575	1.295	0.080	1.583	0.460	0.075	159	0.629
	Total	877,965	131.4	13,367.2	-	-	-	-	-	-	**1.064**	**9,342**	**0.337**

Table. 3c. Abundance estimates of humpback whale in Area IIIE between 1995/96 and 2003/04 seasons. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1995/96	FIIIE	250,272	54.0	5,646.8	0.956	0.174	1.291	0.108	1.480	0.063	**0.546**	**1,378**	**0.19**
1997/98	FIIIE	267,522	26.0	6,704.0	0.388	0.211	1.480	0.172	1.923	0.493	**0.251**	**671**	**0.36**
1999/2000	FIIIE	354,053	141.0	3,679.7	3.832	0.122	0.946	0.065	1.681	0.030	**3.412**	**12,081**	**0.13**
2001/02	FIIIE	355,694	102.0	4,822.9	2.115	0.198	1.320	0.078	1.681	0.042	**1.347**	**4,791**	**0.20**
2003/04	FIIIE	330,467	194.0	4,844.9	4.004	0.096	1.437	0.059	1.747	0.030	**2.435**	**8,045**	**0.10**

Table. 3d. Abundance estimates of humpback whale in Area VIW between 1996/97 and 2004/05 seasons. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1996/97	FVIW	215,064	62.5	6,464.2	0.967	0.164	1.229	0.154	1.768	0.045	**0.697**	**1,493**	**0.185**
1998/99	SVIW	29,908	5.0	1,114.5	0.449	0.672	0.664	0.233	1.707	0.046	**0.543**	**171**	**0.721**
2000/01	FVIW	289,954	48.7	4,383.6	1.111	0.163	1.012	0.203	1.533	0.056	**0.842**	**2,440**	**0.196**
2002/03	FVIW	318,055	48.1	5,950.2	0.808	0.216	1.132	0.174	1.402	0.058	**0.493**	**1,614**	**0.235**
2004/05	FVIW	278,538	35.8	3,954.7	0.905	0.233	0.823	0.460	1.460	0.078	**0.803**	**2,237**	**0.353**

Table. 4a. Abundance estimates of fin whale in Area IV (south of 60°S) between 1989/90 and 2003/04. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1989/90	NW	222,563	0.0	1,987.6	-	-	-	-	-	-	-	-	-
	NE	219,245	1.0	1,964.4	0.051	0.88	1.227	0.27	2.000	0.27	0.041	91	0.96
	SW	35,878	1.0	2,518.3	0.040	0.89	1.227	0.27	2.000	0.27	0.032	12	0.96
	SE	41,143	0.0	1,362.2	-	-	-	-	-	-	-	-	-
	PB	36,488	0.0	831.9	-	-	-	-	-	-	-	-	-
	Total	555,317	2.0	8,664.4	0.023	0.62	-	-	-	-	**0.019**	**103**	**0.85**
1991/92	NW	219,713	3.1	2,482.7	0.124	0.60	1.884	0.81	1.174	0.39	0.101	222	0.81
	NE	216,299	1.0	2,173.9	0.046	0.95	1.884	0.81	1.174	0.39	0.037	81	1.02
	SW	37,191	0.0	2,237.5	-	-	-	-	-	-	-	-	-
	SE	39,732	2.7	2,281.7	0.120	1.21	1.884	0.81	1.174	0.39	0.098	39	1.27
	PB	36,569	0.0	607.5	-	-	-	-	-	-	-	-	-
	Total	549,504	6.8	9,783.3	0.070	0.57	-	-	-	-	**0.062**	**342**	**0.59**
1993/94	NW	233,289	1.0	4,160.7	0.024	0.95	1.227	0.27	2.000	0.27	0.020	46	1.02
	NE	163,982	3.0	3,175.1	0.094	0.44	1.227	0.27	2.000	0.27	0.077	126	0.53
	SW	39,755	1.0	2,377.7	0.042	1.17	1.227	0.27	2.000	0.27	0.035	14	1.23
	SE	41,353	0.0	2,258.9	-	-	-	-	-	-	-	-	-
	PB	34,506	0.0	1,077.0	-	-	-	-	-	-	-	-	-
	Total	512,885	5.0	13,049.4	0.038	0.40	-	-	-	-	**0.036**	**186**	**0.45**
1995/96	NW	149,107	8.0	3,530.5	0.227	0.49	1.380	0.09	3.466	0.21	0.289	431	0.51
	NE	230,473	5.0	2,979.7	0.168	0.41	1.380	0.09	3.466	0.21	0.211	486	0.43
	SW	85,078	0.0	2,851.2	-	-	-	-	-	-	-	-	-
	SE	33,980	5.0	2,039.9	0.245	0.73	1.380	0.09	3.466	0.21	0.308	104	0.74
	PB	25,970	0.0	1,321.8	-	-	-	-	-	-	-	-	-
	Total	524,608	18.0	12,723.1	0.141	0.32	-	-	-	-	**0.195**	**1,021**	**0.31**
1997/98	NW	217,645	3.9	3,367.2	0.117	0.51	1.690	0.17	3.167	0.14	0.109	238	0.53
	NE	219,602	6.0	3,622.7	0.166	0.46	1.690	0.17	3.167	0.14	0.156	342	0.48
	SW	31,615	5.0	3,432.5	0.146	0.58	1.690	0.17	3.167	0.14	0.140	44	0.60
	SE	34,374	0.0	3,195.9	-	-	-	-	-	-	-	-	-
	PB	4,407	0.0	490.0	-	-	-	-	-	-	-	-	-
	Total	507,643	14.9	14,108.3	0.106	0.30	-	-	-	-	**0.123**	**624**	**0.34**
1999/2000	NW	229,368	1.5	2,825.3	0.052	0.69	1.455	0.15	3.740	0.13	0.067	153	0.70
	NE	226,272	8.0	3,550.8	0.225	0.27	1.455	0.15	3.740	0.13	0.290	655	0.29
	SW	44,862	4.0	2,336.7	0.171	0.60	1.455	0.15	3.740	0.13	0.220	99	0.59
	SE	34,175	0.0	2,704.3	-	-	-	-	-	-	-	-	-
	PB	21,288	9.5	1,244.7	0.760	1.10	1.455	0.15	3.740	0.13	3.207	658	1.11
	Total	555,965	22.9	12,661.8	0.181	0.48	-	-	-	-	**0.281**	**1,565**	**0.49**
2001/02	NW	222,449	22.0	3,043.6	0.723	0.45	0.944	0.29	2.409	0.10	0.922	2,051	0.48
	NE	244,921	14.0	3,271.6	0.428	0.55	0.864	0.19	3.125	0.47	0.769	1,883	0.61
	SW	32,199	55.5	2,321.8	2.389	0.39	1.338	0.21	6.598	0.13	5.844	1,882	0.43
	SE	35,955	2.0	2,885.2	0.069	0.72	0.864	0.19	3.125	0.47	0.125	45	0.81
	PB	28,472	0.0	1,033.7	-	-	-	-	-	-	-	-	-
	Total	563,996	93.5	12,555.9	0.745	0.27	-	-	-	-	**1.039**	**5,861**	**0.29**
2003/04	NW	243,849	8.0	3,236.6	0.247	0.35	1.473	0.13	3.126	0.10	0.267	650	0.36
	NE	218,072	9.0	3,738.5	0.241	0.44	1.473	0.13	3.126	0.10	0.256	558	0.46
	SW	38,976	1.0	2,275.2	0.044	0.48	1.473	0.13	3.126	0.10	0.047	18	0.51
	SE	38,952	0.0	3,633.2	-	-	-	-	-	-	-	-	-
	PB	37,537	0.0	508.5	-	-	-	-	-	-	-	-	-
	Total	577,386	18.0	13,392.0	0.134	0.27	-	-	-	-	**0.212**	**1,226**	**0.28**

Table. 4b. Abundance estimates of fin whale in Area V (south of 60^{o}S) between 1990/91 and 2004/05 seasons. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1990/91	NW	239,688	2.0	2726.8	0.073	0.65	1.309	0.24	1.455	0.14	0.041	98	0.68
	NE	348,822	7.0	2498.9	0.280	0.32	1.309	0.24	1.455	0.14	0.156	543	0.36
	SW	64,431	1.0	1635.0	0.061	1.15	1.309	0.24	1.455	0.14	0.034	22	1.19
	SE	188,136	1.0	1670.0	0.060	1.10	1.309	0.24	1.455	0.14	0.033	69	1.14
	Total	841,077	11.0	8530.7	0.129	0.27	-	-	-	-	**0.087**	**732**	**0.30**
1992/93	NW	325,648	2.0	2299.3	0.087	0.47	1.019	0.38	1.833	0.13	0.078	254	0.62
	NE	348,822	6.5	1661.5	0.392	0.42	1.019	0.38	1.833	0.13	0.352	1,229	0.48
	SW	59,450	2.0	1907.4	0.105	0.61	1.019	0.38	1.833	0.13	0.094	56	0.67
	SE	210,194	1.0	2256.3	0.044	1.36	1.019	0.38	1.833	0.13	0.040	84	1.42
	Total	944,113	11.5	8124.5	0.142	0.30	-	-	-	-	**0.172**	**1,623**	**0.38**
1994/95	NW	209,990	8.0	3229.4	0.248	0.49	1.356	0.24	3.604	0.12	0.329	691	0.52
	NE	348,822	24.4	2554.1	0.955	0.50	1.356	0.24	3.604	0.12	1.269	4,426	0.53
	SW	39,911	11.0	2469.0	0.445	0.35	1.356	0.24	3.604	0.12	0.598	238	0.39
	SE	173,180	8.9	1293.0	0.688	0.62	1.356	0.24	3.604	0.12	0.914	1,582	0.67
	Total	771,903	52.3	9545.5	0.548	0.27	-	-	-	-	**0.899**	**6,937**	**0.37**
1996/97	NW	288,197	3.0	2784.6	0.108	0.53	1.107	0.20	2.216	0.14	0.107	310	0.55
	NE	337,779	7.0	3133.4	0.223	0.41	1.107	0.20	2.216	0.14	0.224	755	0.45
	SW	53,960	4.0	3124.4	0.128	0.86	1.107	0.20	2.216	0.14	0.128	69	0.85
	SE	187,983	1.0	2098.5	0.048	0.61	1.107	0.20	2.216	0.14	0.048	90	0.66
	Total	867,919	15.0	11140.9	0.135	0.32	-	-	-	-	**0.141**	**1,224**	**0.32**
1998/99	NW	314,778	7.9	1830.6	0.432	0.85	1.351	0.16	3.402	0.15	0.544	1,712	0.87
	NE	327,490	6.0	1226.9	0.489	0.34	1.351	0.16	3.402	0.15	0.616	2,018	0.38
	SW	48,333	3.0	2333.5	0.129	0.54	1.351	0.16	3.402	0.15	0.162	78	0.56
	SE	25,709	21.7	1561.0	1.387	0.35	1.351	0.16	3.402	0.15	1.754	451	0.37
	Total	716,310	38.6	6952.0	0.555	0.27	-	-	-	-	**0.595**	**4,259**	**0.39**
2000/01	NW	271,595	43.9	3751.9	1.171	0.30	1.441	0.08	3.111	0.19	1.266	3,438	0.32
	NE	348,535	8.0	3941.1	0.203	0.73	1.441	0.08	3.111	0.19	0.219	764	0.75
	SW	79,594	39.6	3152.9	1.255	0.33	1.441	0.08	3.111	0.19	1.345	1,071	0.35
	SE	148,828	1.0	3320.2	0.030	2.43	1.441	0.08	3.111	0.19	0.033	48	2.44
	Total	848,552	92.5	14166.1	0.653	0.21	-	-	-	-	**0.627**	**5,321**	**0.25**
2002/03	NW	266,687	25.0	2777.2	0.900	0.40	1.383	0.13	2.798	0.14	0.911	2,428	0.41
	NE	345,003	4.0	5077.1	0.079	0.42	1.383	0.13	2.798	0.14	0.080	275	0.44
	SW	79,376	14.0	2209.8	0.634	0.53	1.383	0.13	2.798	0.14	0.639	507	0.56
	SE	69,872	0.0	2111.9	-	-	-	-	-	-	-	-	-
	Total	760,938	43.0	12176.0	0.353	0.29	-	-	-	-	**0.422**	**3,210**	**0.32**
2004/05	NW	278,281	7.8	970.0	0.805	1.02	1.070	0.11	1.726	0.06	0.649	1,807	1.03
	NE	336,130	30.0	3,381.8	0.887	0.28	1.070	0.11	1.726	0.06	0.715	2,405	0.29
	SW	51,373	5.0	856.7	0.579	0.28	1.070	0.11	1.726	0.06	0.466	239	0.30
	SE	212,181	5.0	8,158.7	0.061	0.74	1.070	0.11	1.726	0.06	0.049	105	0.75
	Total	877,965	47.8	13367.2	0.358	0.26	-	-	-	-	**0.519**	**4,556**	**0.44**

Table. 4c. Abundance estimates of fin whale in Area IIIE between 1995/96 and 2003/04 seasons. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1995/96	FIIIE	250,272	37.0	5646.8	0.655	0.21	1.380	0.09	3.466	0.21	**0.825**	**2,066**	**0.24**
1997/98	FIIIE	267,522	2.0	6704.0	0.030	0.56	1.690	0.17	3.167	0.14	**0.028**	**74**	**0.58**
1999/2000	FIIIE	354,053	42.0	3679.7	1.141	0.26	1.455	0.15	3.740	0.13	**1.468**	**5,199**	**0.28**
2001/02	FIIIE	355,694	25.0	4822.9	0.518	0.52	1.367	0.11	5.024	0.10	**0.953**	**3,389**	**0.52**
2003/04	FIIIE	330,467	88.9	5895.4	1.508	0.30	1.473	0.13	3.126	0.10	**1.600**	**5,288**	**0.32**

Table. 4d. Abundance estimates of fin whale in Area VIW between 1996/97 and 2004/05 seasons. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1996/97	FVIW	215,064	19.7	6464.2	0.304	0.22	1.107	0.20	2.216	0.14	**0.304**	**655**	**0.26**
1998/99	SVIW	29,908	5.0	1114.5	0.449	0.73	1.351	0.16	3.402	0.15	**0.548**	**164**	**0.74**
2000/01	FVIW	289,954	15.0	4383.6	0.342	0.27	1.441	0.08	3.111	0.19	**0.369**	**1,071**	**0.30**
2002/03	FVIW	318,055	9.0	5950.2	0.151	0.31	1.383	0.13	2.798	0.14	**0.156**	**495**	**0.32**
2004/05	FVIW	278,538	13.0	3,955	0.329	0.27	0.823	0.23	1.231	0.10	**0.246**	**685**	**0.30**

Table. 4e. Abundance estimates south of 60^{o}S for fin whale (top: Indian Ocean Stock, bottom: Western South Pacific Stock) between 1995/96 and 2004/05 seasons. P: estimated population abundance (individuals).

Season	P (ind.)	CV	95% CI LL	95% CI UL
1995/96	3,087	0.191	2,130	4,473
1997/98	698	0.307	387	1,258
1999/2000	6,764	0.240	4,250	10,765
2001/02	9,250	0.266	5,536	15,455
2003/04	6,514	0.261	3,937	10,779

Season	P (ind.)	CV	95% CI LL	95% CI UL
1996/97	1,879	0.226	1,212	2,911
1998/99	4,423	0.379	2,157	9,069
2000/01	6,392	0.211	4,249	9,616
2002/03	3,705	0.285	2,144	6,402
2004/05	5,241	0.381	2,547	10,784

Table. 5a. Abundance estimates of blue whale in Area IV between 1989/90 and 2003/04 seasons. Truncate is 2.4 n.miles. The g (0) is assumed to be 1. n: number of primary schools, L: searching distance, esw: the effective search half width, E(s): mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals).

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1989/90	Total	555,317	4.0	8,664.4	0.046	0.479	1.521	0.069	1.644	0.042	**0.012**	**65**	**0.481**
1991/92	Total	549,504	2.0	9,783.3	0.020	1.075	1.521	0.069	1.644	0.042	**0.003**	**18**	**1.078**
1993/94	Total	512,885	4.0	13,049.4	0.031	0.657	1.521	0.069	1.644	0.042	**0.013**	**66**	**0.615**
1995/96	Total	529,354	1.0	12,723.1	0.008	0.931	1.521	0.069	1.644	0.042	**0.001**	**8**	**0.934**
1997/98	Total	507,643	5.0	14,108.3	0.035	0.533	1.521	0.069	1.644	0.042	**0.029**	**145**	**0.604**
1999/2000	Total	555,964	13.0	12,661.8	0.103	0.366	1.521	0.069	1.644	0.042	**0.041**	**225**	**0.385**
2001/02	Total	563,996	10.0	12,555.9	0.080	0.391	1.521	0.069	1.644	0.042	**0.053**	**300**	**0.460**
2003/04	Total	577,386	6.0	13,392.0	0.045	0.438	1.521	0.069	1.644	0.042	**0.013**	**78**	**0.734**

Table. 5b. Abundance estimates of blue whale in Area V between 1990/91 and 2004/05 seasons.

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1990/91	Total	545,767	3.0	7903.6	0.038	1.008	1.521	0.069	1.644	0.042	**0.033**	**183**	**1.010**
1992/93	Total	944,113	4.0	8124.5	0.049	0.557	1.521	0.069	1.644	0.042	**0.027**	**257**	**0.639**
1994/95	Total	771,903	9.0	9,545.5	0.094	0.372	1.521	0.069	1.644	0.042	**0.035**	**270**	**0.633**
1996/97	Total	867,919	1.0	11,140.9	0.009	0.744	1.521	0.069	1.644	0.042	**0.001**	**10**	**0.749**
1998/99	Total	716,310	4.0	6,952.0	0.058	1.273	1.521	0.069	1.644	0.042	**0.029**	**206**	**2.147**
2000/01	Total	848,552	7.7	14,166.1	0.054	0.549	1.521	0.069	1.644	0.042	**0.037**	**317**	**0.498**
2002/03	Total	760,938	3.9	12,176.0	0.032	0.524	1.521	0.069	1.644	0.042	**0.019**	**143**	**0.526**
2004/05	Total	877,965	8.0	13,367.2	0.060	0.419	1.521	0.069	1.644	0.042	**0.056**	**489**	**0.746**

Table. 5c. Abundance estimates of blue whale in Area IIIE between 1995/96 and 2003/04 seasons.

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1995/96	FIIIE	250,272	8.0	5,646.8	0.142	0.428	1.521	0.069	1.644	0.042	**0.076**	**192**	**0.43**
1997/98	FIIIE	267,522	10.9	6,704.0	0.163	0.481	1.521	0.069	1.644	0.042	**0.088**	**234**	**0.48**
1999/2000	FIIIE	354,053	10.5	3,679.7	0.285	0.582	1.521	0.069	1.644	0.042	**0.154**	**546**	**0.58**
2001/02	FIIIE	355,694	2.0	4,822.9	0.041	0.617	1.521	0.069	1.644	0.042	**0.022**	**80**	**0.62**
2003/04	FIIIE	330,467	16.0	5,241.3	0.305	0.333	1.521	0.069	1.644	0.042	**0.165**	**546**	**0.34**

Table. 5d. Abundance estimates of blue whale in Area VIW between 1996/97 and 2004/05 seasons.

Season	Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L * 10^2	CV	esw (n.mile)	CV	E (S)	CV	**D (ind.) * 10^2**	**P (ind.)**	**CV**
1996/97	FVIW	215,064	5.0	6,464.2	0.077	0.443	1.521	0.069	1.644	0.042	**0.042**	**90**	**0.447**
1998/99	SVIW	29,908	0.0	1,114.5	0.000	-	-	-	-	-	**-**	**-**	**-**
2000/01	FVIW	289,954	0.0	4,383.6	0.000	-	-	-	-	-	**-**	**-**	**-**
2002/03	FVIW	318,055	1.0	5,950.2	0.017	0.928	1.521	0.069	1.644	0.042	**0.009**	**28**	**0.932**
2004/05	FVIW	278,538	4.0	3,954.7	0.101	0.373	1.521	0.069	1.644	0.042	**0.055**	**152**	**0.377**

Table 6a. Results of mean P_B/P and P_C/P and their 95% confidential intervals. n is number of samples of P_B/P and P_C/P.

P_B/P (excluding tracklines nearly close to ice edge)

	n	mean	sd	95%CILL	95%CLUL
whole data	**24**	**1.068**	**0.695**	**0.774**	**1.361**
SSV	8	0.934	0.302	0.681	1.187
SVC	8	1.264	1.153	0.300	2.228
SVP	8	1.004	0.309	0.746	1.263
SW in Area IV	12	1.112	0.895	0.543	1.680
SE in Area IV	12	1.023	0.453	0.736	1.311

P_C/P (excluding tracklines not parallel to longitudinal line)

	n	mean	sd	95%CILL	95%CLUL
whole data	**24**	**0.975**	**0.684**	**0.687**	**1.264**
SSV	8	0.980	0.585	0.491	1.470
SVC	8	0.860	0.935	0.078	1.642
SVP	8	1.086	0.537	0.637	1.535
SW in Area IV	12	0.751	0.524	0.418	1.084
SE in Area IV	12	1.200	0.770	0.711	1.689

Table 6b. Result of examination of mode effects. The estimated coefficients of formula (5), their CVs and *p* values.

	Estimate	CV	*t* value	*p* value
Area IV in 1989/90	3,784	0.266	30.92	< 2e-16
Area IV in 1991/92	3,456	0.254	29.80	< 2e-16
Area IV in 1993/94	2,071	0.240	32.15	< 2e-16
Area IV in 1995/96	6,701	0.213	15.68	6.12E-12
Area IV in 1997/98	8,548	0.117	31.88	< 2e-16
Area IV in 1999/00	9,452	0.193	23.54	5.67E-15
Area IV in 2001/02	29,401	0.151	41.46	< 2e-16
Area IV in 2003/04	24,964	0.121	23.71	5E-15
Area V in 1990/91	1,420	0.244	77.50	< 2e-16
Area V in 1992/93	2,926	0.509	23.58	5.50E-15
Area V in 1994/95	3,154	0.342	47.41	< 2e-16
Area V in 1996/97	1,136	0.297	24.12	3.73E-15
Area V in 1998/99	8,536	0.384	68.19	< 2e-16
Area V in 2000/01	5,249	0.355	40.67	< 2e-16
Area V in 2002/03	2,390	0.191	83.61	< 2e-16
Area V in 2004/05	7,736	0.296	30.25	< 2e-16
$R2$ (=SVC/SVP)	1.242	0.172	1.26	0.223
$R3$ (=SSV/SVP)	1.207	0.126	1.49	0.153

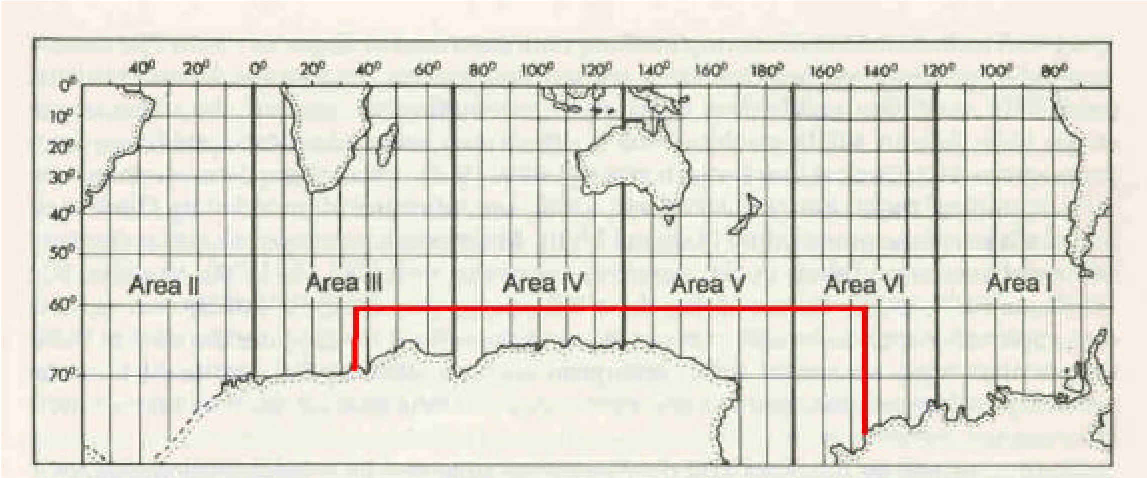


Fig.1a. The IWC Antarctic Areas for the management of baleen whales (except Bryde's whale) and research Area of the JARPA surveys between 35°E and 145°W (colored). Areas III east (IIIE: 35°E-70°E), IV(70°E-130°E), V (130°E-170°W) and VI west (VIW: 170°W -145°W).

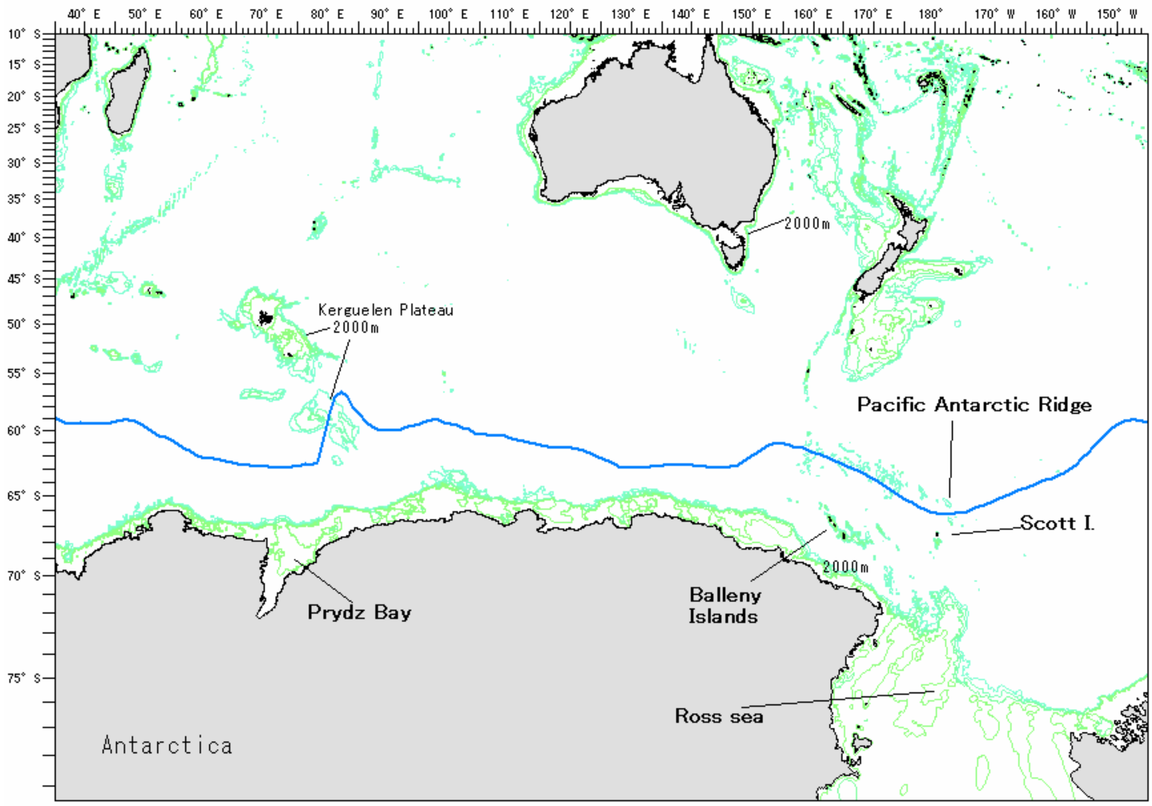


Fig.1b. Geographical map of the research area with bottom topography including middle latitude transit sighting survey area. Bold line show the observed Southern boundary of the Antarctic Circumpolar Current (Watanabe *et al*., 2006).

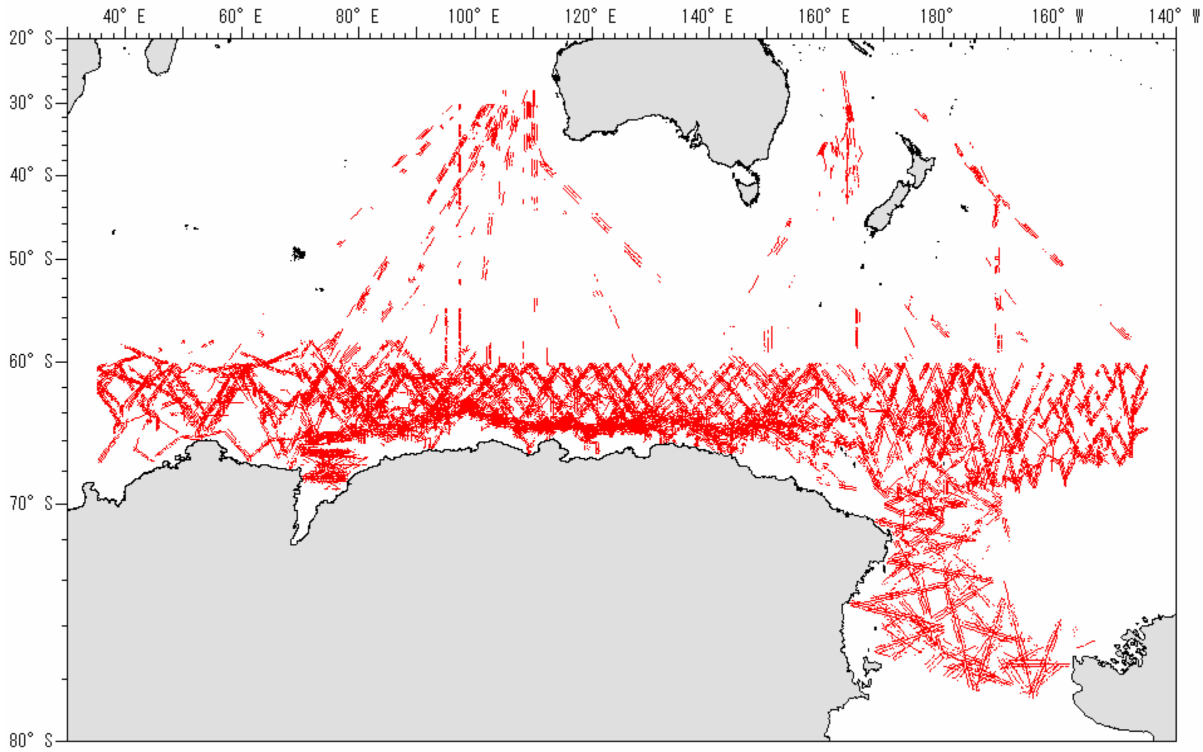


Fig.2. Map of the searching efforts in the JARPA1987/88-2004/05 seasons, including middle latitude transit sighting survey. Research area was covered uniformly.

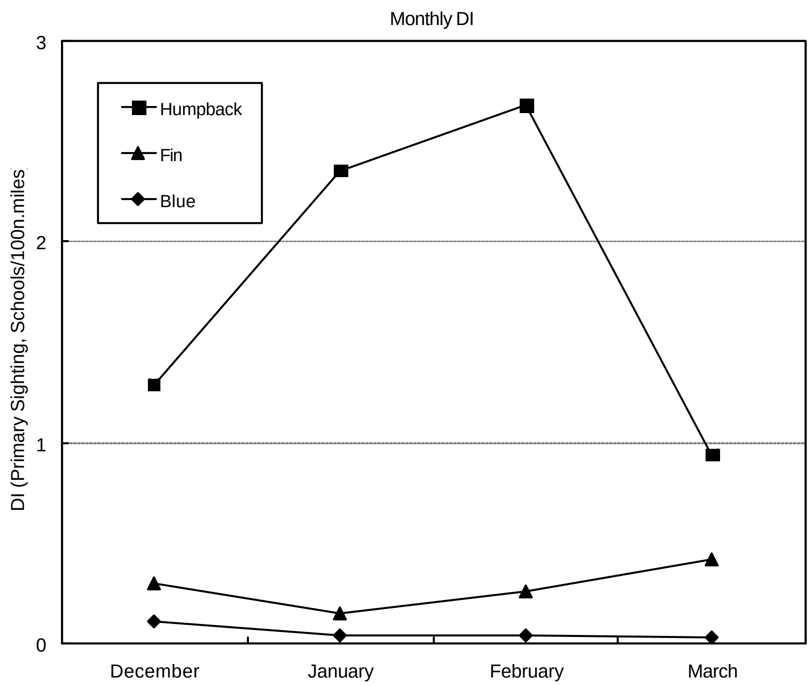
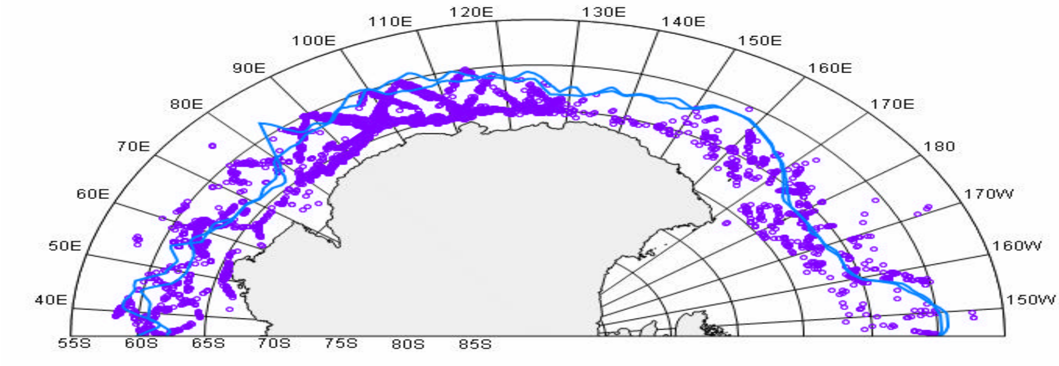
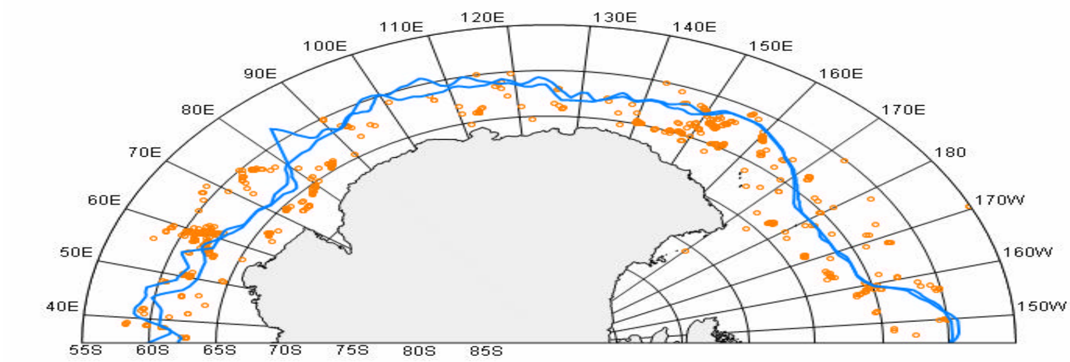


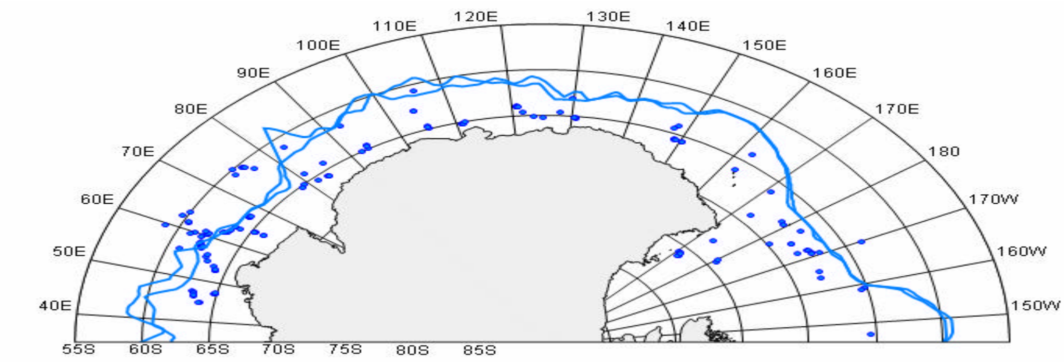
Fig. 3. Monthly change of the density index (DI: schools / 100 n.miles) for humpback and fin whales in the research area by JARPA sighting data between 1989/90 and 2002/03 seasons.



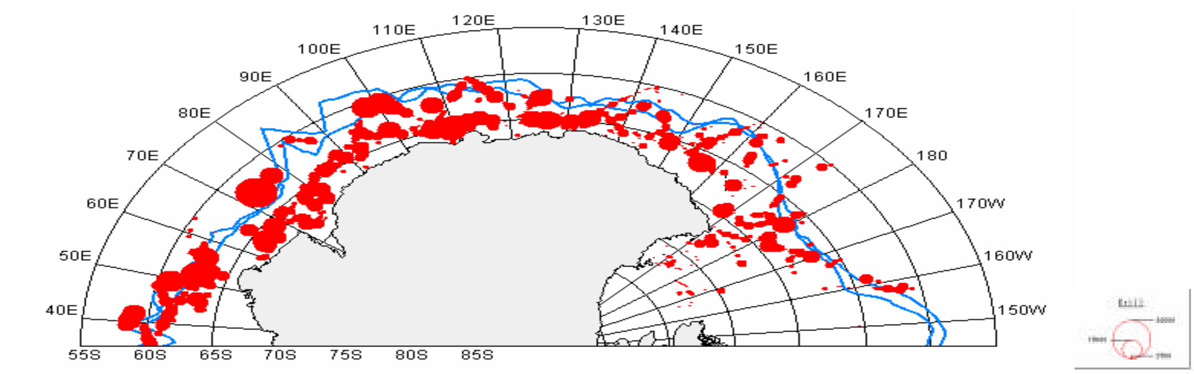
Humpback (a)



Fin (b)



Blue (c)



(d)

Fig.4 Distribution of blue, fin, humpback (primary sightings) and krill (SA) south of 60^{o}S in JARPA research area, austral summer between 1998/99 and 2004/05 seasons. Densities were shown as mean backscattering area per square n.miles of survey transect (Murase *et al*., 2006). Bold line show the observed Southern boundary of the Antarctic Circumpolar Current in 1997/98 and 1999/2000 seasons.

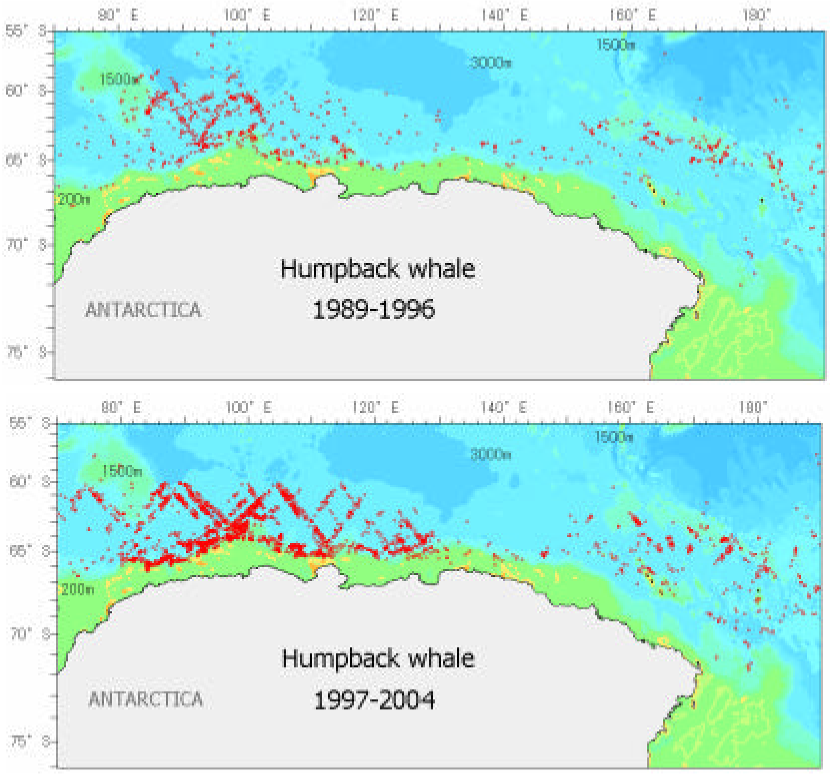


Fig.5. Position of the primary sightings of humpback whales of JARPA in Areas IV and V between 1989/90 and 2004/05 surveys by three sighting and sampling vessels (Left: first half, Right: second half).

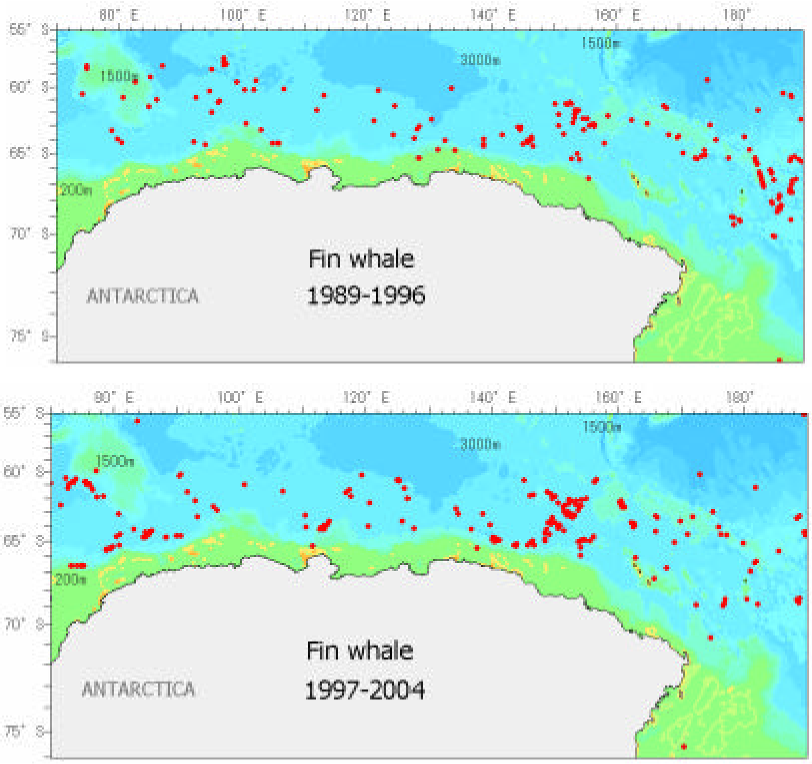


Fig.6. Position of the primary sightings of fin whales of JARPA in Areas IV and V between 1989/90 and 2004/05 surveys by three sighting and sampling vessels (Left: first half, Right: second half).

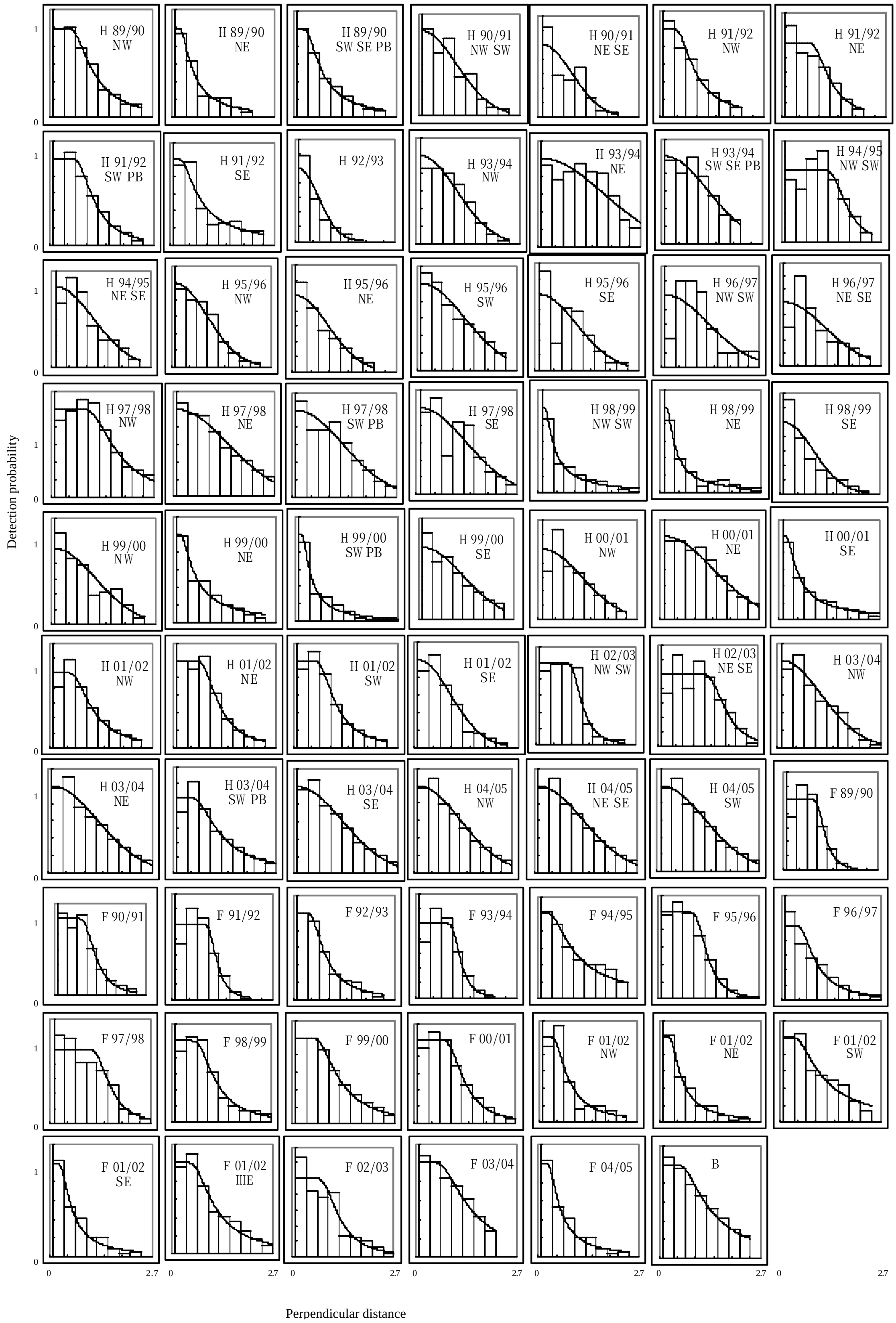
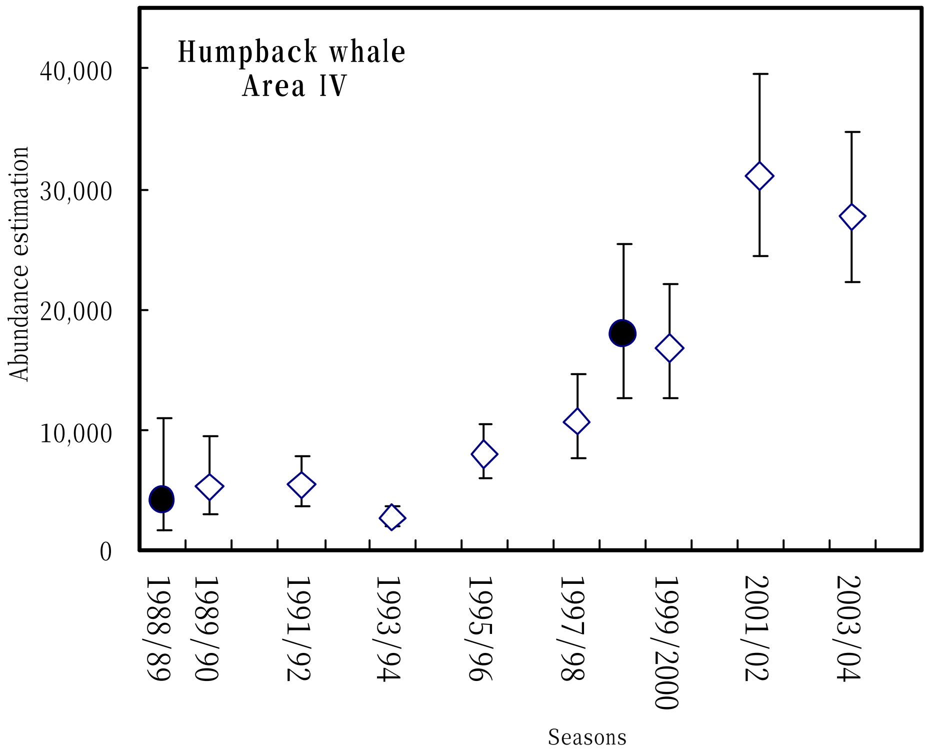


Fig. 7. Detection probability function of humpback (H), fin (F) and blue (B) whales in 1989/90 to 2004/05 seasons.



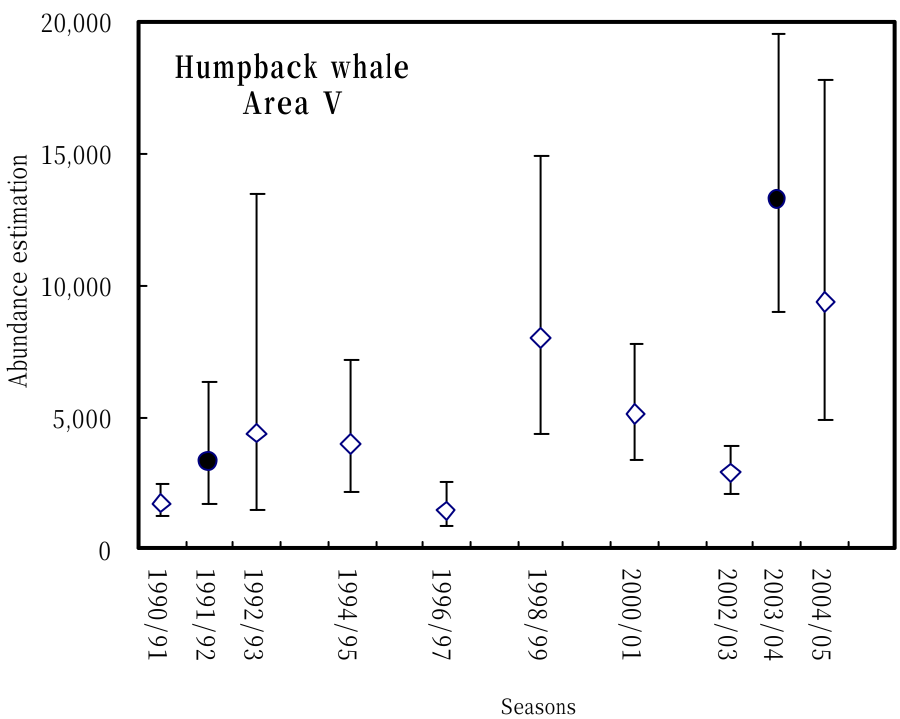


Fig. 8. Abundance estimates of humpback whale in Areas IV and V (south of 60°S) surveyed during January to February, between 1988/89 and 2004/05 seasons, including IDCR-SOWER (filled circles). Vertical lines show 95% confidential intervals. SOWER estimates were obtained from Branch (2006).

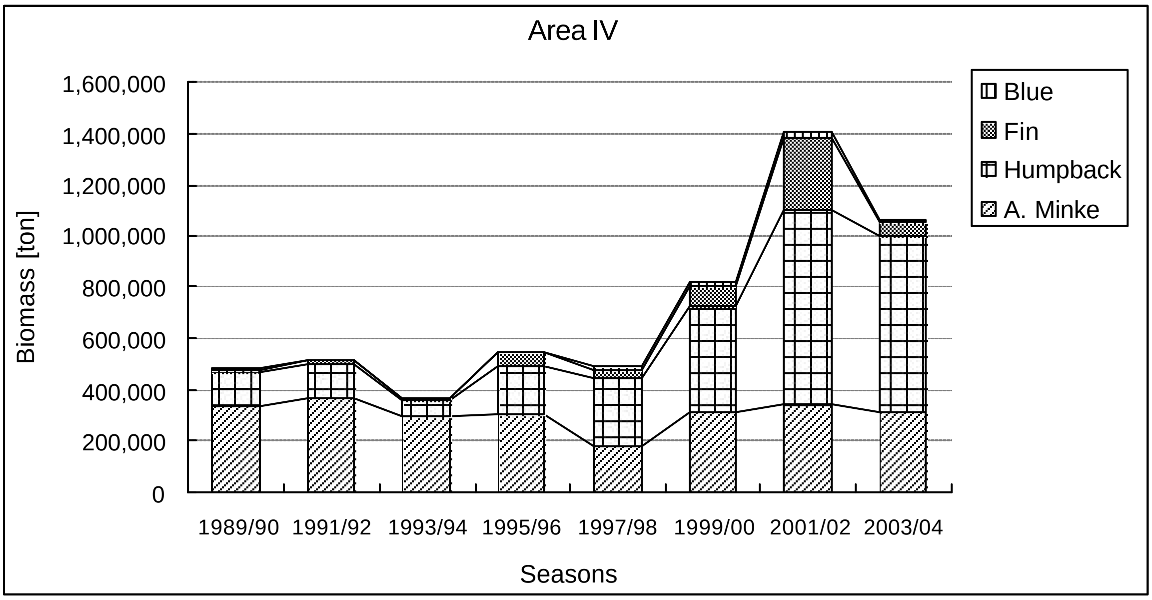


Fig. 9a. Biomass of Antarctic minke, humpback, fin and blue whales in Area IV (south of 60°S) surveyed during January to February, between 1989/90 and 2003/04 seasons. Abundance of Antarctic minke were estimated by Hakamada *et al*, (2006).

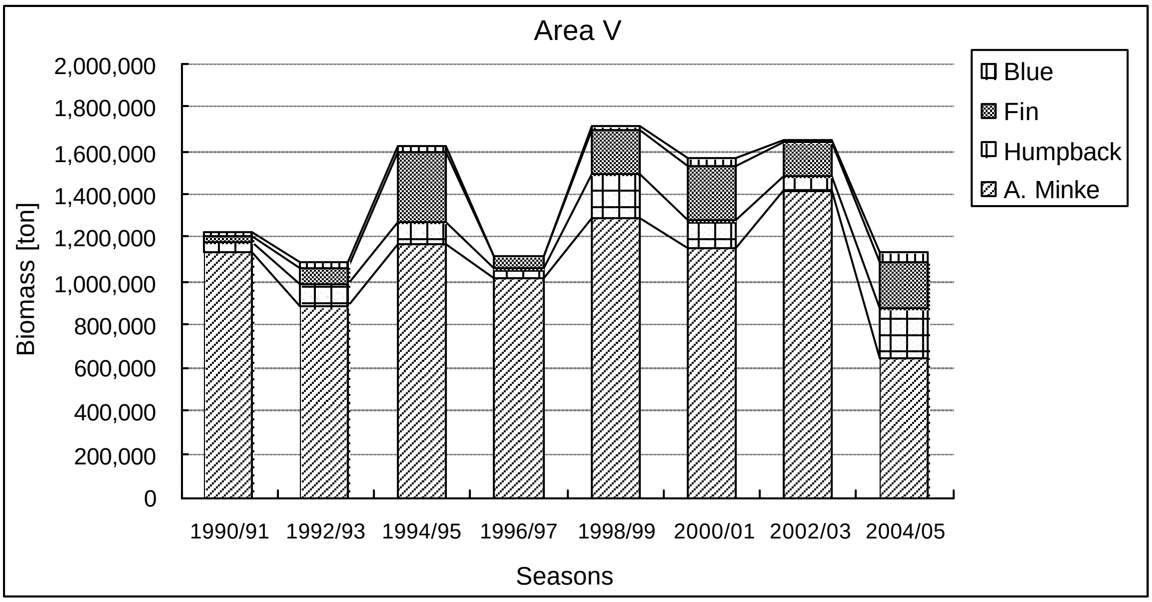


Fig. 9b. Biomass of Antarctic minke, humpback, fin and blue whales in Area V (south of 60°S) surveyed during January to February, between 1990/91 and 2004/05 seasons. Abundance of Antarctic minke were estimated by Hakamada *et al*, (2006).

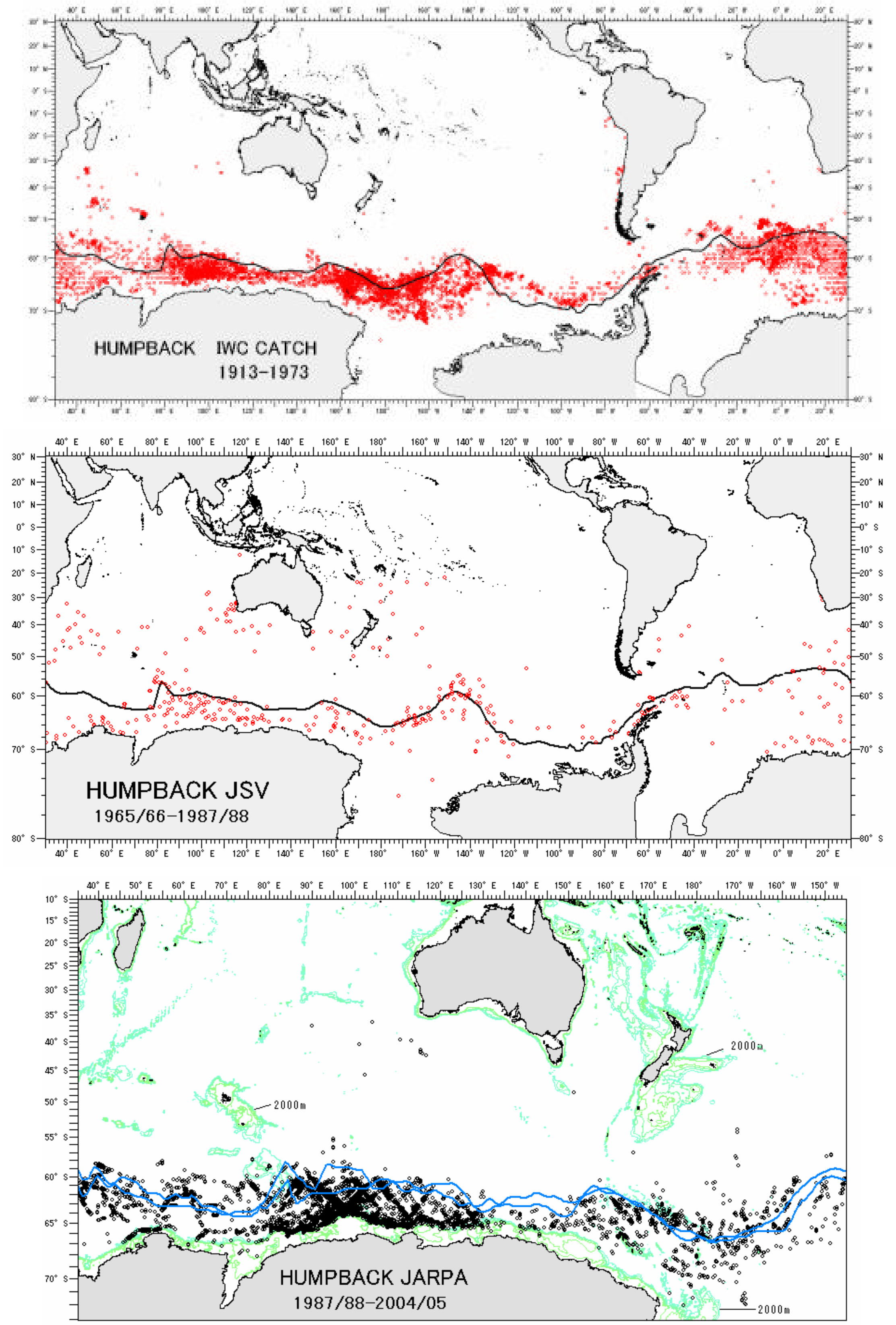


Fig.10. Distributions of humpback whales during December to March (Top: IWC catch database, noon positions (NP) of the caught day with Southern Boundary of Antarctic Circumpolar Current (SBACC) (Oris *et al*., 1995), Middle: JSV data, NP of the sighted day, Bottom: JARPA, the primary sightings with bottom topography. Bold line show the observed SBACC in 1997/98 and 1999/2000 seasons).

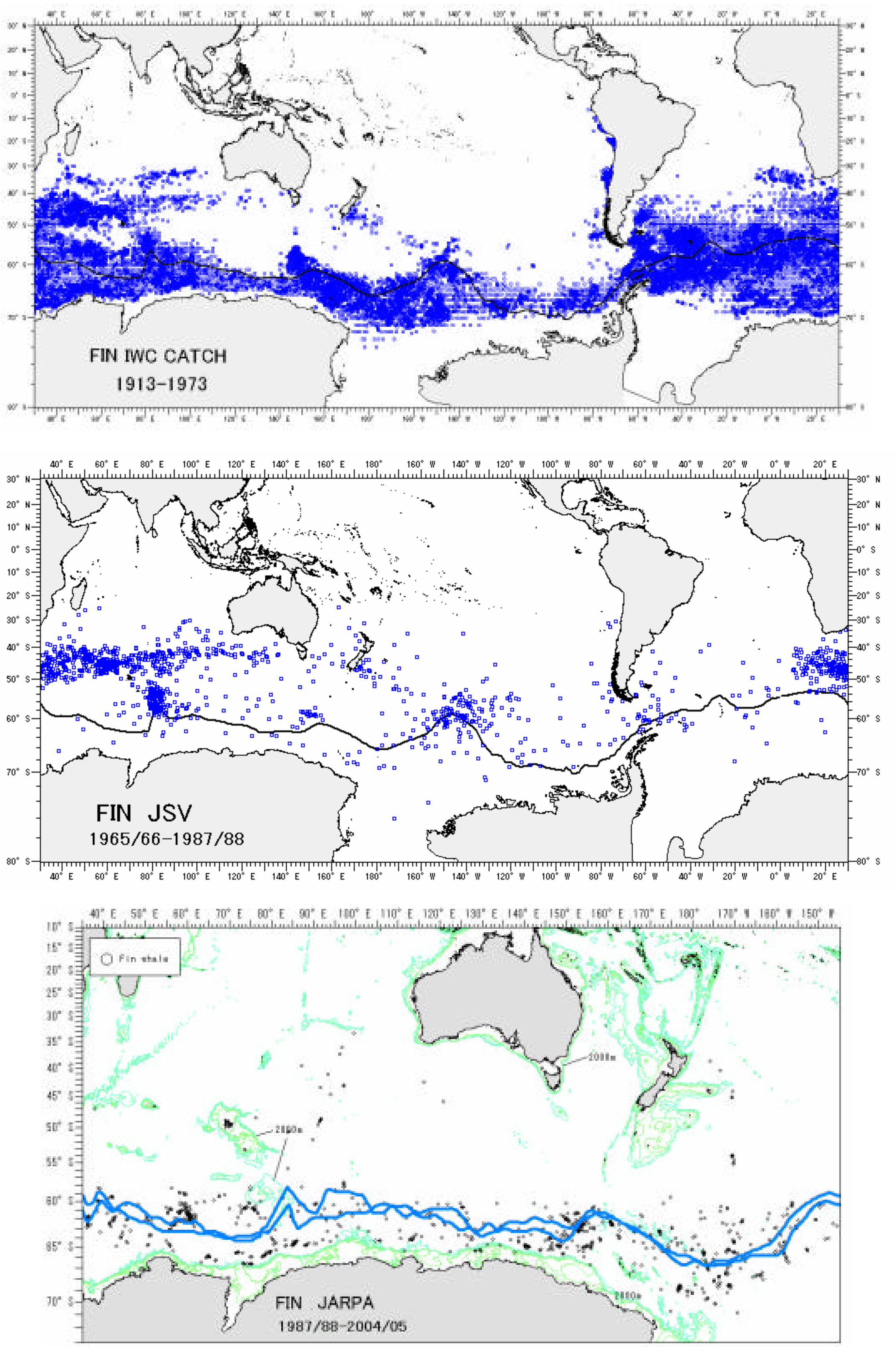


Fig.11. Distributions of fin whales during December to March (Top: IWC catch database, noon positions (NP) of the caught day with Southern Boundary of Antarctic Circumpolar Current (SBACC) (Oris *et al*., 1995), Middle: JSV data, NP of the sighted day, Bottom: JARPA, sighting position of the primary sightings with bottom topography. Bold line show the observed SBACC in 1997/98 and 1999/2000 seasons).

Appendix

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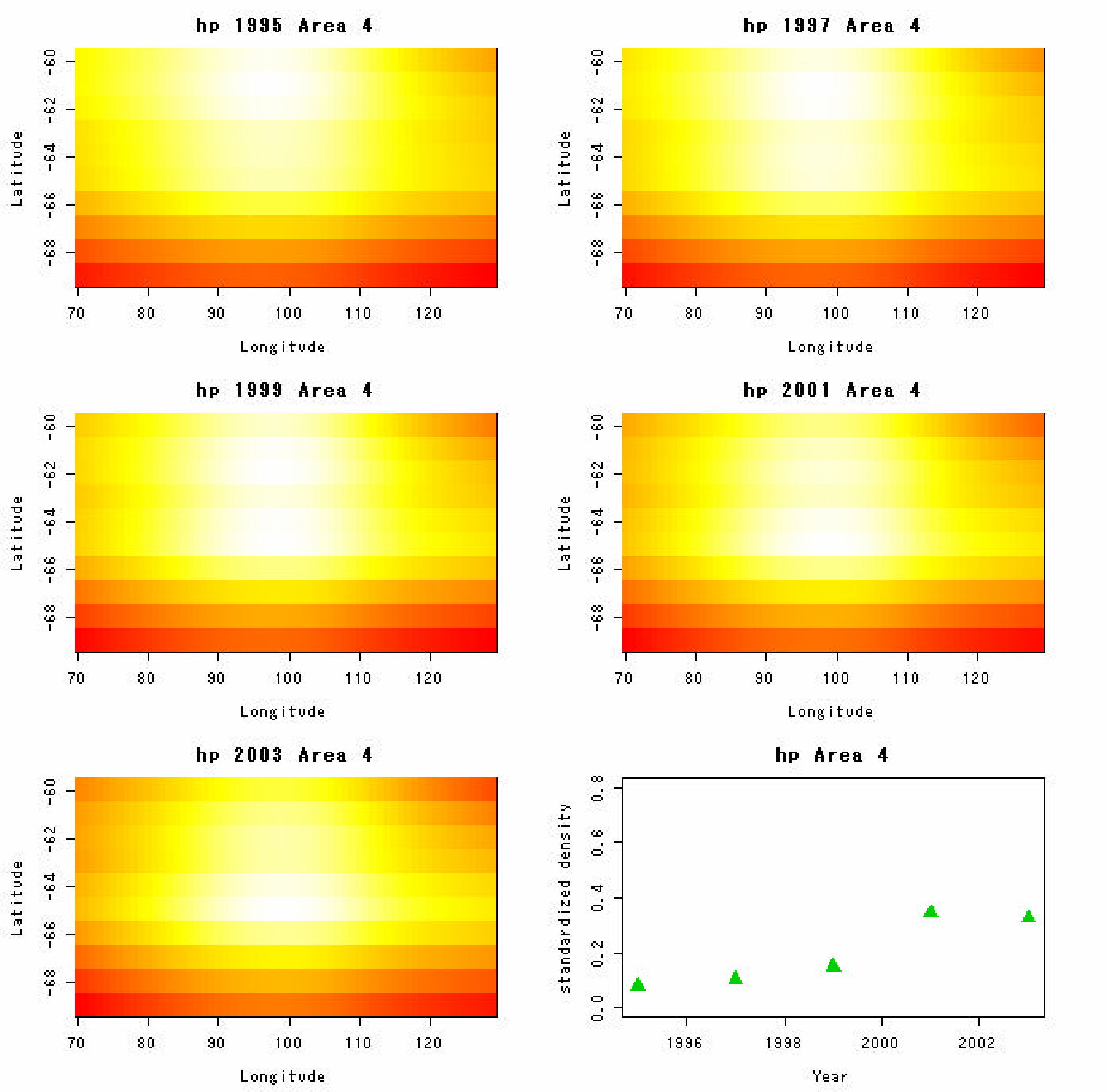

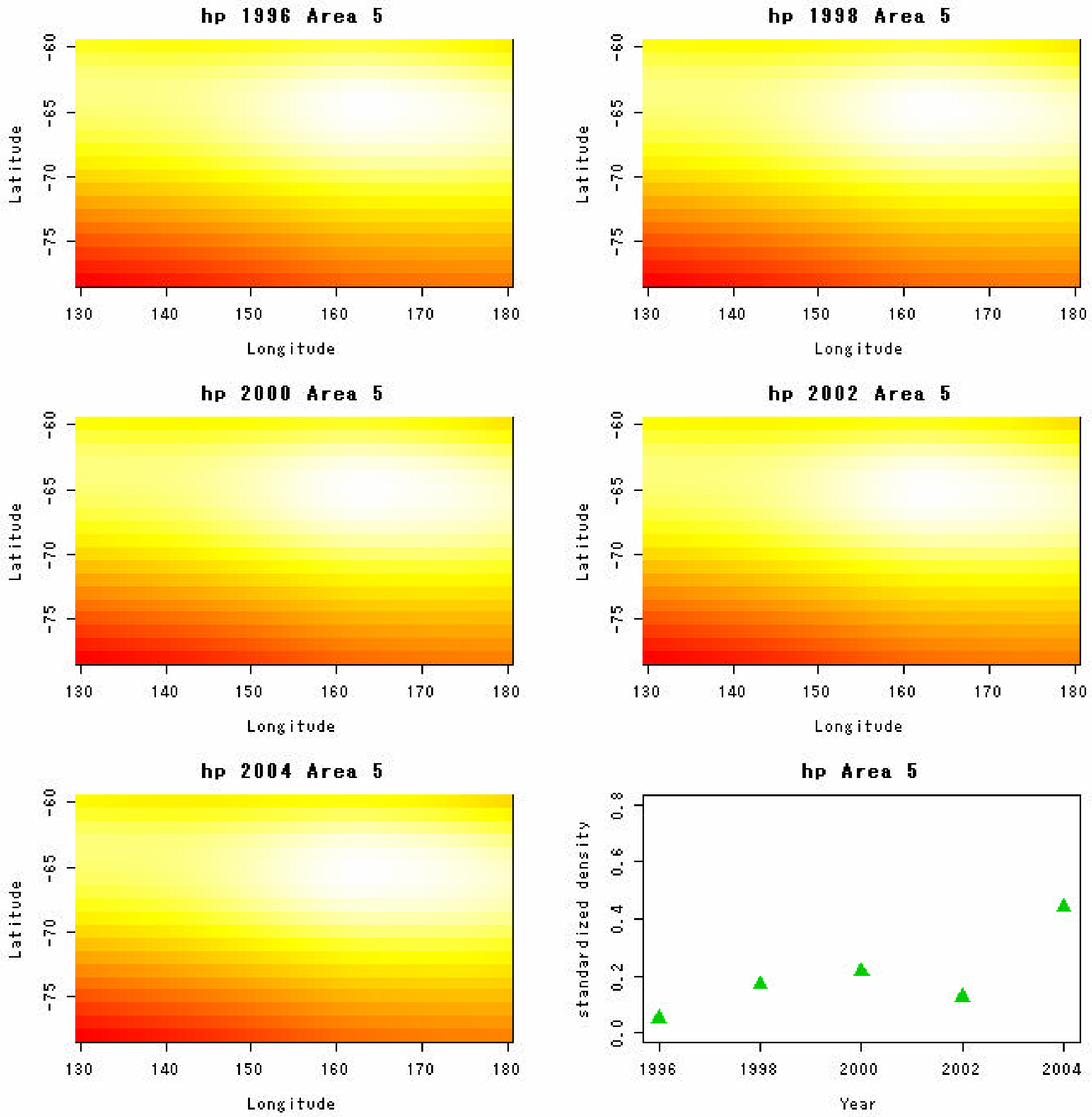
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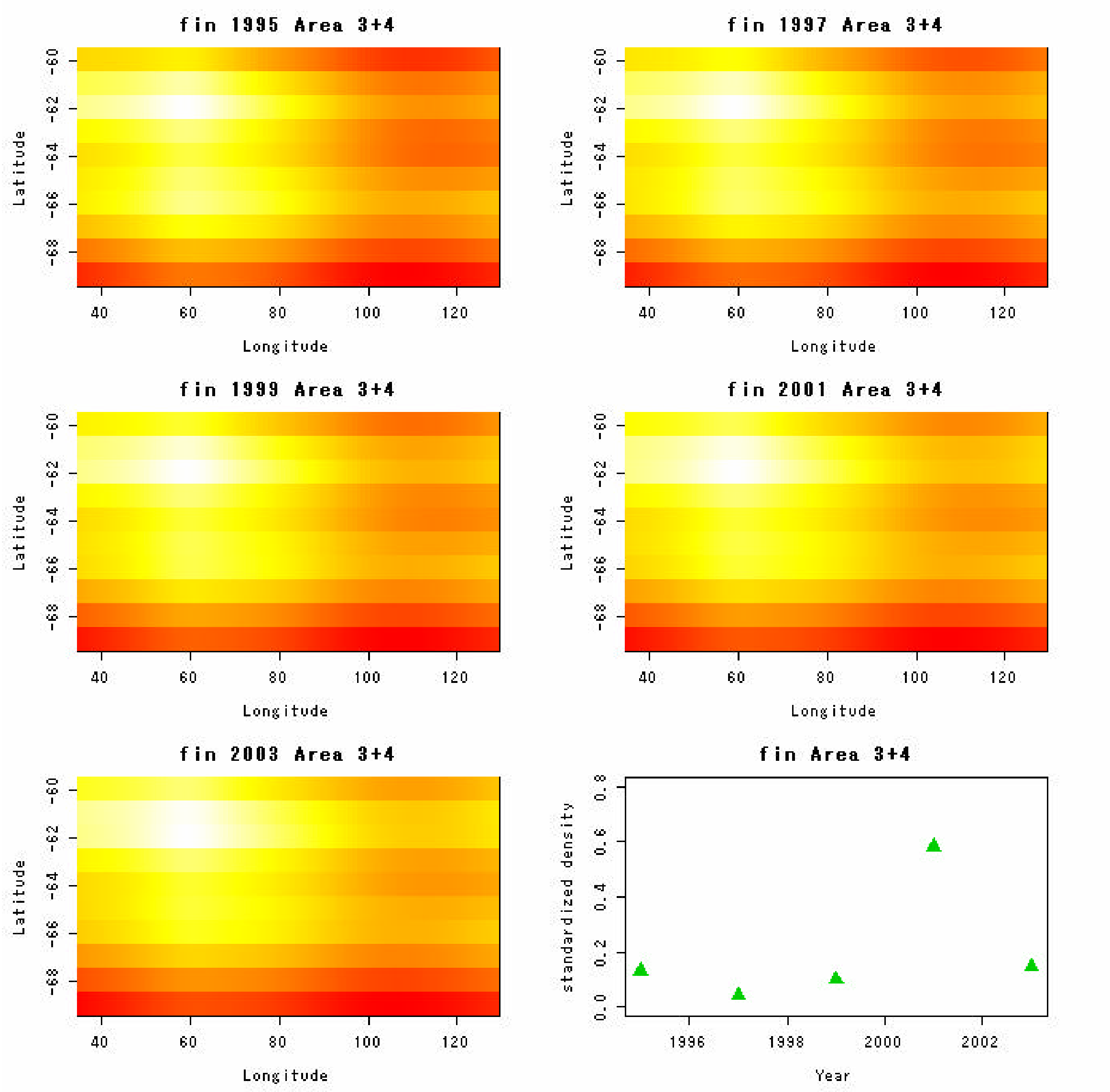
hp 1998 Area 5
hp 2000 Area 5
hp 2002 Area 5
hp 2004 Area 5
hp Area 5
Latitude
Longitude
standardized density
Year
-60
-65
-70
-75
130
140
150
160
170
180
0.0
0.2
0.4
0.6
0.8
1996
1998
2000
2002
2004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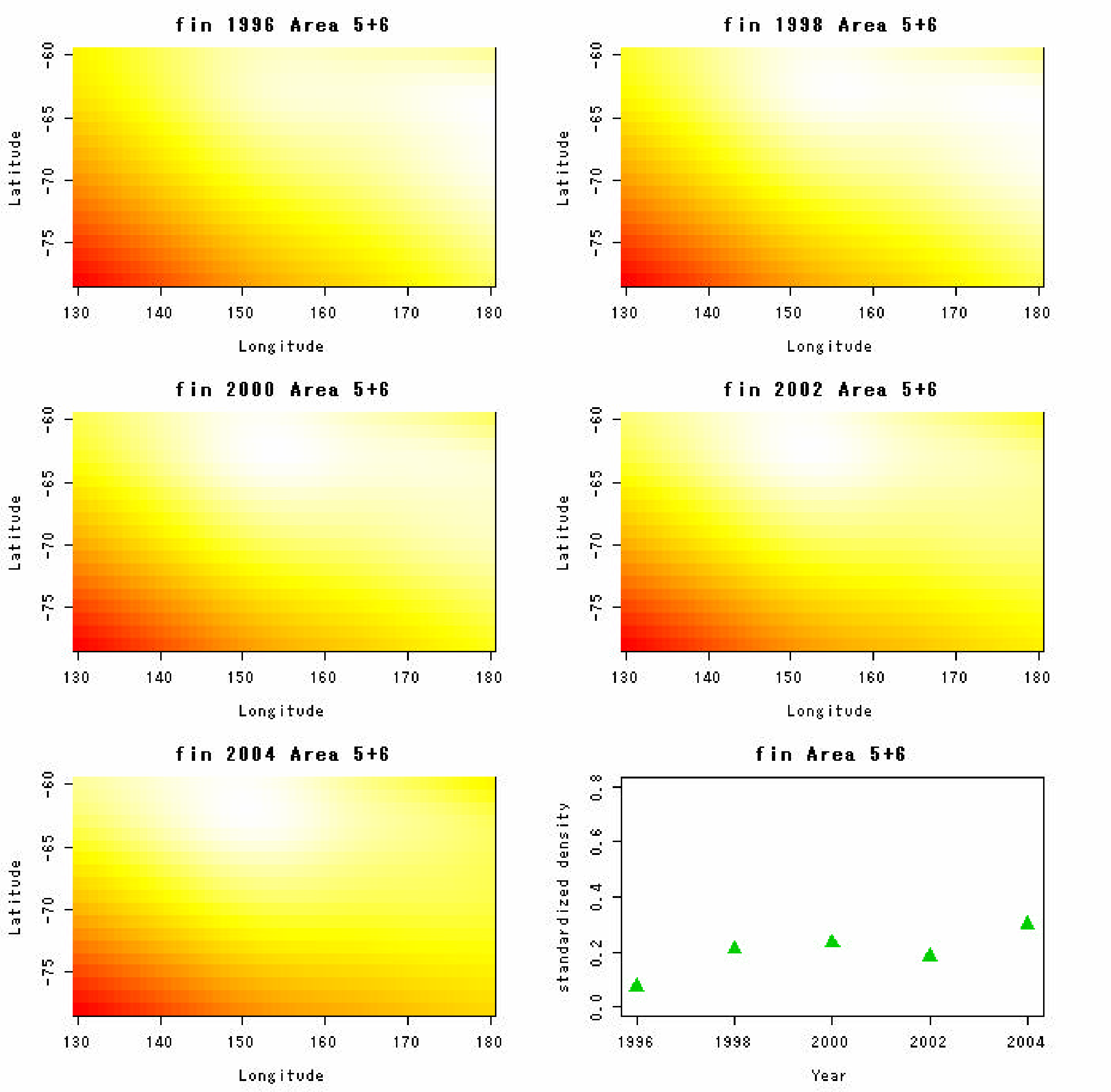
fin 1997 Area 3+4
fin 1999 Area 3+4
fin 2001 Area 3+4
fin 2003 Area 3+4
fin Area 3+4
Latitude
Longitude
-60
-62
-64
-66
-68
40
60
80
100
120
standardized density
0.0
0.2
0.4
0.6
0.8
1996
1998
2000
2002
Year


fin 1996 Area 5+6
fin 1998 Area 5+6
fin 2000 Area 5+6
fin 2002 Area 5+6
fin 2004 Area 5+6
fin Area 5+6
Latitude
-60
-65
-70
-75
Longitude
130
140
150
160
170
180
standardized density
0.0
0.2
0.4
0.6
0.8
Year
1996
1998
2000
2002
2004