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Distribution and abundance of humpback, fin and blue whales in the Antarctic Areas IIIE,IV,V and VIW (35°E -145°W)

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ABSTRACT

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 (35°E-70°E), IV(70°E-130°E), V (130°E-170°W) and VIW (170°W-145°W) in the waters south of 60 °S. The Density Index (no. whales / 100 n.miles, by lat. 1°x long. 2° square) was analysed for distribution pattern of each species. These estimates were based on JARPA sighting data between 1989/90 and 2003/04 seasons (for 15 years) using the DISTANCE analysis program.

Current abundance of humpback whales were estimated 7,889 (CV=0.10) and 31,750 (CV=0.11) in Areas IIIE, IV in 2003/04, and 2,735 (CV=0.16), 1,551 (CV=0.24) in Areas V and VIW in 2002/03 season, respectively. Abundances of humpback whales were increased in each Area. Current abundance of fin in each Area were 5,183 (CV=0.31), 1,388 (CV=0.28) in 2003/04 and 3,031 (CV=0.33), 474 (CV=0.32) in 2002/03 seasons, respectively. Increases of fin whale abundance were observed in Areas IIIE and IV. Abundance of blue whale (south of 60°S, 35°E-145°W) was 900 (CI: 500-1,600) in 1999/2000 + 2000/01 seasons and 500 whales (CI: 300-1,000) in 2001/02 + 2002/03 seasons.

A “shift in baleen whale dominance” event from Antarctic minke (Balaenoptera bonaerensis) to humpback whales, was observed in Area IV since 1997/98 season. In 1989/90 season, biomass of Antarctic minke was higher (382,000 tons) than humpback whales (128,000 tons), and after 15 years, the biomass of humpback (841,000 tons) increased twice than that of Antarctic minke (335,000 tons). Habitat expansion of humpback and fin whales were also observed in Area IV from the first half (1989/90-1996/97) to the later half of surveys (1997/98 -2002/04). At this morment, abundance of Antarctic minke whales is stable in Area IV, however, increases of abundance and habitat expansion of humpback and fin whales, may be caused by competition with Antarctic minke whales. Yearly change in some biological fetures also suggest this “Event”. Further monitoring survey will be required for the baleen whale population management in the Antarctic Ocean.

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

INTRODUCTION

In 1904, commercial whaling began in the Antarctic. Initially, the whaling mainly targeted humpback whale that are slow swimmers. Later, the target species were shifted to the blue, fin, sei and Antarctic minke whales one after anothers with reduction of the target whale stocks. Whaling of humpback, blue and fin in the Antarctic were banned in 1963, 1964, 1974, respectively.

Abundance of humpback whales off Western Australia were reported in the late of 1990's and early 2000's. Bannister (1994) reported a total population size of some 3,000 whales off Shark Bay, Western Australia, based on the results from comparison of the 1991 sighting rate with those from a 1963 commercial aerial spotter. A preliminary estimate of humpback whales off Western Australia using mark-recapture analyses of photo-identified individuals was 3,878 (SD=1,672) whales in the 1991-92 period (Jenner and Jenner ,1994). These abundance estimations off Western Australia from 1980's to early 1990's were similar in number. In the late of 1990's, analyses from coastal aerial survey, 8,000-14,000 whales was estimated off Western Australia (Bannister and Hedley, 2001). Abundance estimate from catch data of humpback whales was also reported as 8,000 whales in 1999 (Findlay et al., 2000). Abundance estimate using IWC/SOWER data for the part of Area IV (80^{o}-130^{o}E) in 1998/99 was estimated as 17,300 (CV=0.17) whales (Matsuoka et al., 2003b). Bannister (1994) reported that the rate of increase of humpback whales off Shark Bay between 1963 and 1991 (over 29 years) was 10.9 % per annum. On the other hand, there are several reports on abundance estimates of humpback whales in the late 1990's off Eastern Australia and Antarctic Area V. Estimate of East Australian humpback whales using land-based survey was 3,185 (s.e.=208) whales in the 1996 (Brown et al., 1997). The estimate in the Antarctic Area V in 1991/92 season using IWC/IDCR data was 2,104 whales (CV=0.52) (Brown and Butterworth, 1999).

In Eastern Australia, rates of increase for this species were reported as 9.7 % (Paterson and Paterson, 1989) and 14.4 % (Bryden et al., 1991). Yearly trend (encounter rate) of humpback whales in the Antarctic Area IV was 8.9 % between the 1987/88 and the 1993/94 season (Matsuoka and Ohsumi, 1995). Estimate of rate of increase for East Australian humpback whales using land-based survey was 12.3 % (CV=0.07) over the period 1981-1996 (Brown et al.,1997).

There was no abundance estimation of fin whales by use of whale sightings data in the Antarctic Areas IIIE, IV, V and VIW. Estimate of this species based on IWC/IDCR and Japanese Scouting Vessels (JSV) was reported as 18,000 (CV=0.47) in the whole area south of 30S (Butterworth et al., 1994). Recent estimates in the whole Antarctic based on the IWC/IDCR and SOWER of this species were 2,100 (CV=0.36), 2,100 (CV=0.45) and 5,500 (CV=0.53) in first, second and third (not completed, until 1997/98) circumpolar series, respectively in the area south of 60^{o}S (Branch and Butterworth, 2001).

The Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) was designed as large-scale and long-term monitoring line transect surveys. It has been carried out in a consistent way every other year in Areas IV and V since 1987/88 season during the austral summer seasons. After a season of feasibility research (1987/88 in Area IV and 1988/89 in Area V), a full-scale research has been conducted since 1989/90 season. In addition, additional surveys were conducted once a year on alternately in the eastern part of Area III (IIIE) and the western part of Area VI (VIW) to investigate the stock of Antarctic minke whales from 1995/96 season. The sighting procedures followed the method used in the IWC/IDCR (International Decade for Cetacean Research) and SOWER (Southern Ocean Whale and Ecosystem Research) cruises as much as possible. In the research Areas, the Antarctic minke whale was the dominantly sighted species through the surveys from 1987/88 to 2002/03 seasons. However, in Area IV, the humpback whale was the sub-dominantly sighted species in 1995/96, the dominant sighted species in 1997/98, and again the sub-dominantly sighted species in 1999/2000 and 2001/02 seasons (Ishikawa et al., 2000 and 2002). In Area V, the fin whale was the sub-dominantly sighted species in

2000/01 season (Nishiwaki et al., 2001a). This paper reports distribution and abundance estimates of these species in each Area between 1989/90 and 2002/03 seasons.

SURVEYS AND DATA COLLECTION

JARPA DATA

Sighting surveys

Unique sighting procedures to collect unbiased sighting data have been introduced in the JARPA including 1) distance and angle were corrected by using the results of the distance and angle estimation experiments, 2) sighting rate was obtained on each day, 3) effective search half width was obtained by fitting a hazard rate or half normal models, 4) smearing parameter was obtained by the Buckland and Anganuzzi method II, 5) g (0) was assumed to be 1, and 6) sighting data were pooled by each season and each stratum as much as possible for estimations 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., 2005).

Research area covered

The area from south of 60^{o}S to the ice-edge in the Areas IIIE (35^{o}E-70^{o}E), IV (70^{o}E-130^{o}E), V (130^{o}E-170^{o}W) and VIW (170^{o}W -145^{o}W) were covered (Fig. 1a). 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^{o}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^{o}S and the Ross Sea defined as south of 69^{o}S. An exception, in the 1999/2000 and 2001/02 seasons, northern boundary of the research area was set as 58^{o}S in the Area III east from view point of the strategy for Antarctic minke distribution. There are no stratifications for Areas IIIE and VIW. Distribution of the searching efforts in JARPA1987/88-2003/04 seasons. Including middle latitude transit sighting survey, is shown in Fig. 1b.

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^{o}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.

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;

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

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

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

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, inverse-variance-weighted regression model is used. The formula is

$$\mathrm{P} = \beta \exp(\alpha \mathrm{y})$$

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

Extrapolated abundance for the Indian Ocean stock of fin whales

Extrapolated abundance (P) for the Indian Ocean stock of this species which weighted by the Japanese Scouting Vessel (JSV) data (sighting rate of 5°×5°square) collected in January and February during 1965 to1987 were preliminary analyzed following formula;

$$\mathrm{P} = \text{abundance estimates for a part of sub-area } \times \Sigma / \Sigma^*,$$

where

$$\Sigma = \sum_{i,j} (n/L)_{i,j} A_{i,j} \quad \text{(sum over all squares from 35°E to 130°E and the south of 40°S)}$$

$$\Sigma^* = \sum_{i,j} (n/L)_{i,j} A_{i,j} \quad \text{(sum over only squares for which abundance estimate applied)}$$

n : number of sei whales, L: searching distance n.miles,

$(n/L)_{i,j}$: sighting rate of 5°×5°square of latitudinal band i and longitudinal band j.

$A_{i,j}$: Area size of 5°×5°square of latitudinal band i and longitudinal band j

RESULTS

Distributions

Fig.1a. shows the research area of JARPA. Fig.1b. shows distribution of the search effort. The research area was covered uniformly during 1987/88 to 2003/04 seasons. Figs. 1c, 1d, 1e and 1f show the map of the Density Index (number of primary sightings of whales / 100 n.mile) of humpback, fin, blue and Antarctic minke whales during JARPA -1987/88-2003/04 seasons by Lat.1°× Long.2°square, including transit surveys (for information as Antarctic minke whales) .

Humpback whales

Humpback whales were widely distributed in Areas IV and V. They were concentrated between 90ºand 120ºE in northern and southern strata where are eastern side of the Kerguren Plateau, and were widely dispersed in other part of Area IV (Fig. 2a). In Area IV, it must be noted that there was a meander of the southern boundary of the Antarctic Circumpolar Current in these longitudinal area and high density areas of this species were observed along this boundary in 1997/98 season (Matsuoka et al., 2003a).

To compare to distribution pattern between the first half of surveys (1989/90-1996/97) and late of surveys (1997/98-2003/04), concentration area of humpback whales was expanded to the southern and to the eastern strata year by year between 90^{o}Eand 120^{o}E (Figs. 2b and 2c). Average of the latitude was 60°30'S in the first half of JARPA, and was 62^{o}30'S in the later half of the JARPA (Fig. 2c).

In Area V, they were distributed clearly along the Pacific Antarctic ridge where the southern boundary of the Antarctic Circumpolar Current was observed (Fig. 2a). The primary sighting positions of humpback whales with the searching efforts between 1989/90 and 2003/04 seasons, which were used in present analyses for current abundance estimation, are shown in Fig. 5a.

Fin whales

Fin whales tended to be distributed more in Area V rather than Area IV. 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 area of this species were the western side of the Balleny Islnds (Fig. 3a). To compare distribution pattern between the first half of surveys (1989/90-1995/96) and late of surveys (1996/97-2003/04), fin whales appeared in the western part of Area IV in recent years (Figs. 3b and 3c). The primary sighting positions of fin whales with the searching effort in between 1989/90 and 2003/04 seasons, which were used in the present analyses for current abundance estimation, are shown in Fig. 5b.

Blue whales

In the research area, blue whales were rarely encounterd through the surveys and they were widely distributed in the research area. They were usually found in Area IIIE and Area VE (Fig. 4a). In Area IV, number of sightings of this species were increased gradually in the later half JARPA (Figs. 4b and 4c). The primary sighting positions of blue whales with the searching effort in between 1989/90 and 2003/04 seasons, which were used in the present analyses for current abundance estimation, are shown in Fig. 5c.

Monthly change in the density index (DI: whales / 100 n.miles)

Fig. 6. shows monthly change in the density index (DI: whales / 100 n.miles) using JARPA efforts and number of primary sightings of humpback and fin whales in the research area (south of 60°S) between 1989/90 and 2003/04 seasons. The DI of humpback whales increase from December to February and decrease in March. For fin whales, the DI was rather stable from December to March.

Abundance estimates

Tables 3a-3d (humpback whale), Tables 4a-4d (fin whale) and Tables 5a-5d (blue) show abundance, 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. Figs.7a and 7b show the perpendicular distance in nautical miles used in the present analyses.

Humpback whales

Current abundance of humpback whales in Areas IIIE and IV in 2003/04, V and VIW (south of 60^o S) in 2002/03 were estimated as 7,889 (CV=0.10), 31,750 (CV=0.11), 2,735 (CV=0.16), 1,551 (CV=0.24) , respectively (Tables 3a-3d).

Summary of abundance estimates of humpback whales are shown in Table 6. In Area IIIE, abundance estimates of 2,224 (CV=0.18) in 1995/96, 539 (CV=0.25) in 1997/98, 8,390 (CV=0.14) in 1999/2000, 4,426 (CV=0.20) in 2001/02 and 7,889 (CV=0.10) in 2003/04 seasons. In Area IV, abundance estimates of 5,230 (CV=0.30) in 1989/90, 5,350 (CV=0.19) in 1991/92, 2,740 (CV=0.15) in 1993/94, 8,850 (CV=0.14) in 1995/96, 10,874 (CV=0.17) in 1997/98, 16,211 (CV=0.15) in 1999/2000, 33,010 (CV=0.11) in 2001/02 and 31,750 (CV=0.11) in 2003/04 seasons. In Area V, abundance estimates of 1,354 (CV=0.20) in 1990/91, 3,837 (CV=0.63) in 1992/93, 3,565 (CV=0.31) in 1994/95, 1,543 (CV=0.28) in 1996/97, 8,301 (CV=0.31) in 1998/99, 4,720 (CV=0.22) in 2000/2001, 2,735 (CV=0.16) in 2002/03 seasons. In Area VIW, abundance estimates of 959 (CV=0.18) in 1996/97, 1,827 (CV=0.69) in 1998/99, 2,448 (CV=0.20) in 2000/2001 and 1,551 (CV=0.24) in 2002/03 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. Present estimates between 1995/96 and 2001/02 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. 6). 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

Summary of abundance estimates of fin whales are shown in Table 6. In Area IIIE, abundance estimates of 3,113 (CV=0.24) in 1995/96, 78 (CV=0.58) in 1997/98, 3,315 (CV=0.28) in 1999/2000 and 3,382 (CV=0.52) in 2001/02 and 5,185 (CV=0.31) in 2003/04 seasons. In Area IV, abundance estimates of 102 (CV=0.84) in 1989/90, 338 (CV=0.50) in 1991/92, 189 (CV=0.45) in 1993/94, 1,191 (CV=0.32) in 1995/96, 637 (CV=0.34) in 1997/98, 1,162 (CV=0.32) in 1999/2000, 7,285 (CV=0.28) in 2001/02, 1,388 (CV=0.28) in 2003/04 seasons. In Area V, abundance estimates of 726 (CV=0.31) in 1990/91, 1,397 (CV=0.38) in 1992/93, 6,334 (CV=0.37) in 1994/95, 1,294 (CV=0.32) in 1996/97, 4,655 (CV=0.37) in 1998/99, 4,802 (CV=0.25) in 2000/2001, 3,031 (CV=0.33) in 2002/03 seasons. In Area VIW, present abundance estimates of 420 (CV=0.26) in 1996/97, 194 (CV=0.75) in 1998/99, 1,074 (CV=0.30) in 2000/2001 and 474 (CV=0.32) in 2002/03 seasons. For Areas IIIE and VIW, there were no estimations of this species by sighting surveys. Present estimates between 1995/96 and 2003/04 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. 6). The index of this species suggested that current estimations of these Areas were under-estimated.

In this paper, we also estimate for the stock abundance in the research area. For the Indian Ocean Stock (Pastene et al, 2005) of this species in the south of 60°S was estimated as 4,000 (CV=0.20) in 1995/96, 1,000 (CV=0.31) in 1997/98, 4,000 (CV=0.22) in 1999/2000 11,000 (CV=0.24) in 2001/02 and 7,000 (CV=0.26) in 2003/04, respectively between 35°E and 130°E (Table 4e). Because they are mainly distributed in the area north of 60°S (Kasamatsu, 1993), large yearly fluctuation in the area south of 60°S in Areas IIIE and IV might be attributable to such distribution.

For the whole Indian Ocean Stock abundance estimation, it is possible to extrapotrate current abundance to the north of 60°S using Japanese scouting vessel (JSV) data (Miyashita et al, 1995), because this species also distributed in areas more north of 60°S. The abundance in January and February with consideration of seasonal distribution changes of this species were estimated to be 21,000 whales (CV=0.27) for this stock (south of 40°S, 35°E-130°E), from the results of the JARPA-2003/04 data.

Blue whales

Abundance of this species (south of 60°S, 35°E-145°W) was 900 (CI: 500-1,600) in 1999/2000 + 2000/01 seasons and 500 whales (CI: 300-1,000) in 2001/02 + 2002/03 seasons (Table 6). Only for this species, the CI are not included the process error caused by year to year combined estimates. They are still less than 1,000 (biomass: less than 8,000 tons) 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 using the IWC catch data, IWC/IDCR=SOWER abundance and JARPA sighting rate data (Branch et al., 2004). Present estimates of this species less than 1,000 in the half of Antarctic IWC management Areas is reasonable compared to recent result. They are so far from recovering. Anyway, the number of survey years is still too short to detect precise yearly trend (Fig. 11).

Instantaneous increase rate

Humpback whales

Observed rates of increase in this species were estimated as 16.2% (CV=0.20) and 6.4% (CV=0.71) in Areas IV and V, respectively, between 1989/90 and 2003/04 seasons. Increase rate in Area IV was very high, due to high abundance estimation in 2001/02 season. Excluding this season, increasing rate was 14.8±7.0%. Significant increases were observed in Area IV (Table 7).

Fin whales

For the Indian Ocean stock between 1995/96 and 2003/04 (over 9 years), increasing rate was estimated as 17.8% (CV=0.88), and for the Pacific Ocean stock between 1996/97 and 2002/03 (over 7 years) was estimated as 14.0% (CV=1.01). For combined whole research area (from IIIE to VIW) between 1995/96 and 2002/03 (over 8 years), increase rate was significant as 14.2 %±1.9%.

DISCUSSIONS

Habitat expansion of humpback whales in Area IV

Present abundance estimates in Area IV increased year by year especially after 1997/98 season (Fig. 8). After 1997/98 season, humpback whales tended to be distributed in the southern and eastern strata year by year (Ishikawa et al., 2000 and 2002), (Figs. 2b and 2c). These distribution changes suggested that humpback whale populations are recovering and expanding their distributions to the south and east in the feeding grounds year by year. Further, according to oceanographic research, the southern boundary of the Antarctic Circumpolar Current (SB-ACC) in the research area was moved to south year by year from 1997/98 to 2001/02 (Watanabe et al, 2005). It is known that distribution of humpback whales related to the SB-ACC (Matsuoka et al, 2003a), it is reasonable to support a view that habitat change from north of 60°S to the south related to the SB-ACC moved to the southern region. It is also reasonable to support a view that present estimation of increasing rate of 16.2% might include two phenomena of their “real rate of increase” and “effect of habitat expansions”. Further enviromental analyses such as satellight information and oceanographic data are required to interprete “habitat expansion ” more precisely in the feeding grounds.

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

Present estimates in the feeding grounds were generally high compare to recent estimations in the breeding grounds (see the Introduction). 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.

Current abundance estimates of fin whales

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: not completed, CV=0.53) in first, second and third circumpolar series, respectively (Branch and Butterworth, 2001).

Present JARPA estimate of 14,000 (CV=0.20) in the half of Antarctic Areas (35^{o}E -145^{o}W) and significant increases will be the first value in these Areas. In addition, for the Indian Ocean stock, we preliminarily estimated abundance of this species in the south of 40^{o}S between 35^{o}E and 130^{o},E using current estimations and Japanese Scouting Vessel (JSV) data as 21,000 (CV=0.27) from the results of the JARPA-2003/04 data, by same manner as Butterworth et al., 1994. Because they mainly distributed in the area north of 60^{o}S (Kasamatsu, 1993), large yearly fluctuation in the area south of 60^{o}S in Areas IV and V might be attributable to such distribution pattern. Anyway, the number of survey years is still too short to detect precise yearly trend.

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. 10). In 1989/90 season, biomass of Antarctic minke was higher (382,000 tons) than humpback whales (128,000 ton), and after 15 years in 2003/04 season, biomass of humpback (841,000 tons) was twice than Antarctic minke (335,000 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 and Tamura, 2005), 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, 2005). It is also reasonable to support a view that increase and habitat expansion of humpback and fin whales in Area IV, may be cause competition with Antarctic minke. Further mornitaring survey was required in order to understanding Antarctic ecosystem and for the baleen whale management in the Antarctic Ocean.

Future studies

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 recentry in these breeding areas. On the otherhand, the information on the present status of pelagic species, such as blue, fin and sei whales were limitted. 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 15 years in Areas IV and V. The number of survey years is still too short to detect precise yearly trend for whales population. JARPA continues providing more useful information about recovering of whale stocks for the management including blue whales. Further monitoring survey was required for the baleen whale management in the Antarctic Ocean.

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Table 1. Estimated observer bias in distance and angle estimation (JARPA) during 1989/90 to 2003/04 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	-	-
	upper bridge	-	-
YS1	barrel	-	-
	upper bridge	-	-
YS2	barrel	-	-
	upper bridge	-	-
KS2	barrel	-	-
	upper bridge	-	-

*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	-	-	-	-

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	-	-

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	218,378	21.2	1,987.6	1.067	0.297	0.996	0.226	2.000	0.093	1.071	2,339	0.33
	NE	213,661	20.0	1,964.4	1.018	0.448	0.727	0.426	1.750	0.082	1.225	2,618	0.52
	SW	41,683	10.4	2,518.3	0.411	0.391	0.937	0.201	1.804	0.056	0.396	165	0.41
	SE	40,371	1.0	1,362.2	0.073	0.732	0.937	0.201	1.804	0.056	0.071	29	0.76
	PB	34,628	2.0	831.9	0.240	0.482	1.139	0.129	1.526	0.059	0.231	80	0.53
	Total	548,721	54.6	8,664.4	0.630	0.215					**0.953**	**5,230**	**0.301**
1991/92	NW	219,773	41.7	2,482.7	1.680	0.231	1.052	0.202	1.929	0.062	1.540	3,384	0.26
	NE	217,764	16.0	2,173.9	0.736	0.300	1.005	0.143	1.803	0.049	0.661	1,438	0.32
	SW	34,259	19.7	2,237.5	0.880	0.350	1.379	0.172	1.680	0.082	0.536	184	0.37
	SE	34,871	17.0	2,281.7	0.745	0.378	0.746	0.327	1.870	0.051	0.905	316	0.42
	PB	27,733	1.0	607.5	0.165	0.730	1.379	0.172	1.680	0.082	0.100	28	0.75
	Total	534,400	95.4	9,783.3	0.975	0.150					**1.001**	**5,350**	**0.190**
1993/94	NW	232,782	43.7	4,160.7	1.050	0.191	1.220	0.122	1.614	0.068	0.695	1,618	0.21
	NE	171,281	30.5	3,175.1	0.960	0.290	1.874	0.171	1.774	0.079	0.454	778	0.31
	SW	33,394	24.8	2,377.7	1.043	0.338	1.381	0.157	1.571	0.070	1.075	198	0.35
	SE	30,908	7.0	2,258.9	0.310	0.315	1.381	0.157	1.571	0.070	1.075	72	0.33
	PB	35,196	4.0	1,077.0	0.371	0.688	1.381	0.157	1.571	0.070	1.075	74	0.70
	Total	503,561	110.0	13,049.4	0.843	0.138					**0.544**	**2,740**	**0.154**
1995/96	NW	217,044	122.2	3,530.5	3.461	0.171	1.126	0.070	1.543	0.037	2.372	5,149	0.18
	NE	228,383	45.8	2,979.7	1.537	0.280	1.076	0.119	1.826	0.079	1.304	2,979	0.29
	SW	33,433	54.5	2,851.2	1.911	0.318	1.468	0.118	1.909	0.050	1.243	416	0.32
	SE	29,932	27.6	2,039.9	1.353	0.246	1.248	0.154	1.893	0.087	1.026	307	0.27
	PB	27,929	0.0	1,321.8	–	–	–	–	–	–	–	0	–
	Total	536,721	250.1	12,723.1	1.966	0.123					**1.649**	**8,850**	**0.142**
1997/98	NW	224,230	191.6	3,367.2	5.690	0.200	1.829	0.071	1.870	0.035	2.908	6,522	0.20
	NE	224,567	107.2	3,622.7	2.959	0.367	1.681	0.085	1.658	0.040	1.459	3,277	0.37
	SW	31,505	171.3	3,432.5	4.991	0.157	1.533	0.064	1.767	0.030	2.876	906	0.16
	SE	41,450	25.2	3,195.9	0.789	0.218	1.549	0.168	1.555	0.090	0.396	164	0.24
	PB	2,481	2.0	490.0	0.408	0.758	1.533	0.064	1.767	0.030	0.235	6	0.76
	Total	524,233	497.3	14,108.3	3.525	0.123					**2.074**	**10,874**	**0.166**
1999/2000	NW	236,307	54.7	2,825.3	1.936	0.193	1.347	0.113	1.532	0.066	1.101	2,601	0.20
	NE	229,576	160.7	3,550.8	4.525	0.208	0.828	0.170	1.538	0.032	4.203	9,648	0.23
	SW	34,825	106.3	2,336.7	4.549	0.245	0.579	0.222	1.710	0.039	6.718	2,339	0.27
	SE	33,129	165.1	2,704.3	6.105	0.191	1.447	0.068	2.183	0.054	4.607	1,526	0.20
	PB	27,000	3.0	1,244.7	0.241	0.610	0.579	0.222	1.710	0.039	0.356	96	0.65
	Total	560,837	489.8	12,661.8	3.868	0.110					**2.890**	**16,211**	**0.146**
2001/02	NW	200,738	252.2	3,043.6	8.286	0.191	1.259	0.071	1.941	0.035	6.389	12,825	0.20
	NE	223,108	238.2	3,271.6	7.281	0.206	1.286	0.061	1.754	0.032	4.966	11,079	0.21
	SW	61,517	386.8	2,321.8	16.658	0.176	1.201	0.053	1.870	0.027	12.969	7,978	0.18
	SE	66,790	63.5	2,885.2	2.201	0.257	1.090	0.097	1.672	0.057	1.688	1,127	0.26
	PB	29,155	0.0	1,033.7	–	–	–	–	–	–	–	0	–
	Total	581,308	940.7	12,555.9	7.492	0.104					**5.679**	**33,010**	**0.112**
2003/04	NW	279,634	241.2	3,236.6	7.452	0.249	1.334	0.051	1.680	0.026	4.692	12,827	0.25
	NE	247,970	278.9	3,738.5	7.460	0.137	1.495	0.050	1.666	0.025	4.157	10,385	0.14
	SW	46,122	389.3	2,275.2	17.111	0.112	1.417	0.063	1.886	0.021	11.387	5,252	0.12
	SE	51,093	448.2	3,633.2	12.336	0.139	1.489	0.039	1.643	0.019	6.806	3,195	0.14
	PB	34,940	2.0	508.5	0.393	1.294	1.417	0.063	1.886	0.021	0.262	91	1.30
	Total	659,759	1359.6	13,392.0	10.152	0.077					**4.812**	**31,750**	**0.114**

Table. 3b. Abundance estimates of humpback whale in Area V (south of 60^{o}S) between 1990/91 and 2002/03 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	232,898	1.0	2726.8	0.037	1.10	1.189	0.16	1.303	0.09	0.020	47	1.11
	NE	347,440	6.0	1871.8	0.321	0.37	1.027	0.14	1.546	0.07	0.241	437	0.38
	SW	62,355	21.7	1635.0	1.328	0.37	1.189	0.16	1.303	0.09	0.728	454	0.39
	SE	208,511	25.6	1529.8	1.673	0.21	1.027	0.14	1.546	0.07	1.260	417	0.23
	Total	851,204	54.3	7763.4	0.700	0.18					**0.159**	**1,354**	**0.20**
1992/93	NW	332,682	5.0	2299.3	0.217	1.43	0.712	0.16	2.000	0.08	0.305	1,016	1.43
	NE	290,526	9.0	1661.5	0.542	0.86	0.712	0.16	2.000	0.08	0.761	2,210	0.87
	SW	43,572	5.0	1907.4	0.262	0.49	0.712	0.16	2.000	0.08	0.368	160	0.51
	SE	180,745	4.0	2256.3	0.177	0.64	0.712	0.16	2.000	0.08	0.249	450	0.65
	Total	847,525	23.0	8124.5	0.283	0.48					**0.453**	**3,837**	**0.63**
1994/95	NW	194,879	14.0	3229.4	0.433	0.75	1.793	0.08	1.658	0.06	0.200	390	0.75
	NE	303,617	26.1	2554.1	1.022	0.41	1.320	0.15	2.000	0.12	0.774	2,351	0.43
	SW	40,116	41.6	2469.0	1.687	0.20	1.793	0.08	1.658	0.06	0.780	313	0.21
	SE	175,421	5.0	1293.0	0.386	0.52	1.320	0.15	2.000	0.12	0.293	513	0.53
	Total	714,033	86.7	9545.5	0.909	0.20					**0.500**	**3,567**	**0.31**
1996/97	NW	305,819	1.0	2784.6	0.036	1.68	1.520	0.19	1.632	0.12	0.019	59	1.69
	NE	363,668	14.0	3133.4	0.446	0.36	1.381	0.19	1.700	0.06	0.274	997	0.38
	SW	40,130	17.5	3124.4	0.560	0.37	1.520	0.19	1.632	0.12	0.301	121	0.39
	SE	208,224	6.0	2098.5	0.286	0.50	1.381	0.19	1.700	0.06	0.176	366	0.52
	Total	917,841	38.5	11140.9	0.345	0.23					**0.168**	**1,543**	**0.28**
1998/99	NW	321,375	12.0	1830.6	0.656	0.53	0.639	0.42	1.684	0.08	0.864	2,776	0.62
	NE	311,050	21.9	1226.9	1.785	0.39	0.575	0.56	0.773	0.07	1.200	3,732	0.49
	SW	45,455	30.8	2333.5	1.320	0.43	0.639	0.42	1.684	0.08	1.739	791	0.50
	SE	52,553	34.9	1561.0	2.233	0.15	1.046	0.13	1.787	0.08	1.907	1,002	0.17
	Total	730,433	99.6	6952.0	1.432	0.18					**1.136**	**8,301**	**0.31**
2000/01	NW	249,712	43.2	3751.9	1.153	0.39	1.368	0.13	1.762	0.07	0.742	1,854	0.40
	NE	334,377	44.3	3941.1	1.124	0.29	1.668	0.13	1.956	0.07	0.659	2,204	0.30
	SW	64,854	30.5	3152.9	0.968	0.22	0.780	0.42	1.645	0.07	1.021	662	0.36
	SE	105,458	0.0	3320.2	−	−	−	−	−	−	−	−	−
	Total	754,401	118.1	14166.1	0.833	0.19					**0.626**	**4,720**	**0.22**
2002/03	NW	257,084	12.0	2777.2	0.432	0.39	1.291	0.13	1.548	0.09	0.259	666	0.40
	NE	338,026	58.0	5077.1	1.142	0.18	1.902	0.09	1.672	0.05	0.502	1,697	0.19
	SW	65,671	18.8	2209.8	0.852	0.33	1.291	0.13	1.548	0.09	0.511	335	0.34
	SE	58,424	3.0	2111.9	0.142	0.49	1.902	0.09	1.672	0.05	0.062	36	0.49
	Total	719,205	91.8	12176.0	0.754	0.14					**0.380**	**2,735**	**0.16**
2004/05	NW	−	−	−	−	−	−	−	−	−	−	−	−
	NE	−	−	−	−	−	−	−	−	−	−	−	−
	SW	−	−	−	−	−	−	−	−	−	−	−	−
	SE	−	−	−	−	−	−	−	−	−	−	−	−
	Total	−	−	−	−	−	−	−	−	−	−	−	−

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	378,299	53.1	5646.8	0.940	0.17	1.286	0.09	1.608	0.06	**0.588**	**2,224**	**0.18**
1997/98	FIIIE	277,996	24.7	6704.0	0.369	0.22	1.730	0.19	1.818	0.06	**0.194**	**539**	**0.25**
1999/2000	FIIIE	226,025	141.7	3679.7	3.851	0.12	0.880	0.12	1.697	0.03	**3.712**	**8,390**	**0.14**
2001/02	FIIIE	354,965	98.3	4822.9	2.038	0.20	1.657	0.06	2.027	0.03	**1.247**	**4,426**	**0.20**
2003/04	FIIIE	324,032	194.0	4844.9	4.004	0.10	1.437	0.06	1.747	0.03	**2.435**	**7,889**	**0.10**

Table. 3d. Abundance estimates of humpback whale in Area VIW between 1996/97 and 2002/03 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	137,886	62.5	6464.2	0.967	0.16	1.229	0.15	1.768	0.05	**0.696**	**959**	**0.18**
1998/99	SVIW	316,727	5.0	1114.5	0.449	0.67	0.664	0.23	1.707	0.05	**0.577**	**1,827**	**0.69**
2000/01	FVIW	290,908	48.7	4383.6	1.111	0.16	1.012	0.20	1.533	0.06	**0.842**	**2,448**	**0.20**
2002/03	FVIW	309,998	48.1	5950.2	0.808	0.22	1.132	0.17	1.402	0.06	**0.500**	**1,551**	**0.24**
2004/05	FVIW	−	−	−	−	−	−	−	−	−	−	−	−

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	218,378	0.0	1987.6	–	–	–	–	–	–	–	–	–
	NE	213,661	1.0	1964.4	0.051	0.88	1.227	0.27	2.000	0.27	0.041	89	0.96
	SW	41,683	1.0	2518.3	0.040	0.89	1.227	0.27	2.000	0.27	0.032	13	0.96
	SE	40,371	0.0	1362.2	–	–	–	–	–	–	–	–	–
	PB	34,628	0.0	831.9	–	–	–	–	–	–	–	–	–
	Total	548,721	2.0	8664.4	0.023	0.62					**0.019**	**102**	**0.84**
1991/92	NW	219,773	3.1	2482.7	0.124	0.60	1.227	0.27	2.000	0.27	0.101	222	0.64
	NE	217,764	1.0	2173.9	0.046	0.95	1.227	0.27	2.000	0.27	0.037	82	1.02
	SW	34,259	0.0	2237.5	–	–	–	–	–	–	–	–	–
	SE	34,871	2.7	2281.7	0.120	1.21	1.227	0.27	2.000	0.27	0.098	34	1.27
	PB	27,733	0.0	607.5	–	–	–	–	–	–	–	–	–
	Total	534,400	6.8	9783.3	0.070	0.57					**0.063**	**338**	**0.50**
1993/94	NW	232,782	1.0	4160.7	0.024	0.95	1.227	0.27	2.000	0.27	0.020	46	1.02
	NE	171,281	3.0	3175.1	0.094	0.44	1.227	0.27	2.000	0.27	0.077	132	0.53
	SW	33,394	1.0	2377.7	0.042	1.17	1.227	0.27	2.000	0.27	0.034	11	1.23
	SE	30,908	0.0	2258.9	–	–	–	–	–	–	–	–	–
	PB	35,196	0.0	1077.0	–	–	–	–	–	–	–	–	–
	Total	503,561	5.0	13049.4	0.038	0.40					**0.038**	**189**	**0.45**
1995/96	NW	217,044	8.0	3530.5	0.227	0.49	1.380	0.09	3.466	0.21	0.285	618	0.50
	NE	228,383	5.0	2979.7	0.168	0.41	1.380	0.09	3.466	0.21	0.211	481	0.43
	SW	33,433	0.0	2851.2	–	–	–	–	–	–	–	–	–
	SE	29,932	5.0	2039.9	0.245	0.73	1.380	0.09	3.466	0.21	0.308	92	0.74
	PB	27,929	0.0	1321.8	–	–	–	–	–	–	–	–	–
	Total	536,721	18.0	12723.1	0.141	0.32					**0.222**	**1,191**	**0.32**
1997/98	NW	224,230	3.9	3367.2	0.117	0.51	1.690	0.17	3.167	0.14	0.110	246	0.53
	NE	224,567	6.0	3622.7	0.166	0.46	1.690	0.17	3.167	0.14	0.155	348	0.48
	SW	31,505	5.0	3432.5	0.146	0.58	1.690	0.17	3.167	0.14	0.136	43	0.60
	SE	41,450	0.0	3195.9	–	–	–	–	–	–	–	–	–
	PB	2,481	0.0	490.0	–	–	–	–	–	–	–	–	–
	Total	524,233	14.9	14108.3	0.106	0.30					**0.122**	**637**	**0.34**
1999/2000	NW	236,307	1.5	2825.3	0.052	0.69	1.455	0.15	3.740	0.13	0.067	157	0.70
	NE	229,576	8.0	3550.8	0.225	0.27	1.455	0.15	3.740	0.13	0.290	665	0.29
	SW	34,825	4.0	2336.7	0.171	0.60	1.455	0.15	3.740	0.13	0.220	77	0.61
	SE	33,129	0.0	2704.3	–	–	–	–	–	–	–	–	–
	PB	27,000	9.5	1244.7	0.760	1.10	1.455	0.15	3.740	0.13	0.977	264	1.11
	Total	560,837	22.9	12661.8	0.181	0.48					**0.207**	**1,162**	**0.32**
2001/02	NW	200,738	22.0	3043.6	0.723	0.45	0.944	0.29	2.409	0.10	0.922	1,851	0.48
	NE	223,108	14.0	3271.6	0.428	0.55	0.864	0.19	3.125	0.47	0.774	1,727	0.61
	SW	61,517	55.5	2321.8	2.389	0.39	1.338	0.21	6.598	0.13	5.891	3,624	0.42
	SE	66,790	2.0	2885.2	0.069	0.72	0.864	0.19	3.125	0.47	0.125	84	0.81
	PB	29,155	0.0	1033.7	–	–	–	–	–	–	–	–	–
	Total	581,308	93.5	12555.9	0.744	0.27					**1.253**	**7,285**	**0.28**
2003/04	NW	279,634	8.0	3236.6	0.247	0.35	1.473	0.13	3.126	0.10	0.262	733	0.36
	NE	247,970	9.0	3738.5	0.241	0.44	1.473	0.13	3.126	0.10	0.255	633	0.46
	SW	46,122	1.0	2275.2	0.044	0.48	1.473	0.13	3.126	0.10	0.047	22	0.51
	SE	51,093	0.0	3633.2	–	–	–	–	–	–	–	–	–
	PB	34,940	0.0	508.5	–	–	–	–	–	–	–	–	–
	Total	659,759	18.0	13392.0	0.134	0.27					**0.210**	**1,388**	**0.28**

Table. 4b. Abundance estimates of fin whale in Area V (south of 60°S) between 1990/91 and 2002/03 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	232,898	2.0	2726.8	0.073	0.65	1.309	0.24	1.455	0.14	0.041	95	0.68
	NE	347,440	7.0	2498.9	0.280	0.32	1.309	0.24	1.455	0.14	0.156	541	0.36
	SW	62,355	1.0	1635.0	0.061	1.15	1.309	0.24	1.455	0.14	0.034	21	1.19
	SE	208,511	1.0	1670.0	0.060	1.10	1.309	0.24	1.455	0.14	0.033	69	1.14
	Total	851,204	11.0	8530.7	0.129	0.27					**0.085**	**726**	**0.31**
1992/93	NW	332,682	2.0	2299.3	0.087	0.47	1.019	0.38	1.833	0.13	0.078	260	0.62
	NE	290,526	6.5	1661.5	0.392	0.42	1.019	0.38	1.833	0.13	0.352	1,023	0.48
	SW	43,572	2.0	1907.4	0.105	0.61	1.019	0.38	1.833	0.13	0.094	41	0.67
	SE	180,745	1.0	2256.3	0.044	1.36	1.019	0.38	1.833	0.13	0.040	72	1.42
	Total	847,525	11.5	8124.5	0.142	0.30					**0.165**	**1,397**	**0.38**
1994/95	NW	194,879	8.0	3229.4	0.248	0.49	1.356	0.24	3.604	0.12	0.329	641	0.52
	NE	303,617	24.4	2554.1	0.955	0.50	1.356	0.24	3.604	0.12	1.269	3,852	0.53
	SW	40,116	11.0	2469.0	0.445	0.35	1.356	0.24	3.604	0.12	0.591	237	0.39
	SE	175,421	8.9	1293.0	0.688	0.62	1.356	0.24	3.604	0.12	0.914	1,603	0.67
	Total	714,033	52.3	9545.5	0.548	0.27					**0.887**	**6,334**	**0.37**
1996/97	NW	305,819	3.0	2784.6	0.108	0.53	1.107	0.20	2.216	0.14	0.108	330	0.55
	NE	363,668	7.0	3133.4	0.223	0.41	1.107	0.20	2.216	0.14	0.224	813	0.45
	SW	40,130	4.0	3124.4	0.128	0.86	1.107	0.20	2.216	0.14	0.128	51	0.87
	SE	208,224	1.0	2098.5	0.048	0.61	1.107	0.20	2.216	0.14	0.048	99	0.66
	Total	917,841	15.0	11140.9	0.135	0.32					**0.141**	**1,294**	**0.32**
1998/99	NW	321,375	7.9	1830.6	0.432	0.85	1.351	0.16	3.402	0.15	0.544	1,748	0.86
	NE	311,050	6.0	1226.9	0.489	0.34	1.351	0.16	3.402	0.15	0.616	1,916	0.38
	SW	45,455	3.0	2333.5	0.129	0.54	1.351	0.16	3.402	0.15	0.162	74	0.56
	SE	52,553	21.7	1561.0	1.387	0.35	1.351	0.16	3.402	0.15	1.747	918	0.37
	Total	730,433	38.6	6952.0	0.555	0.27					**0.637**	**4,655**	**0.37**
2000/01	NW	249,712	43.9	3751.9	1.171	0.30	1.441	0.08	3.111	0.19	1.264	3,157	0.32
	NE	334,377	8.0	3941.1	0.203	0.73	1.441	0.08	3.111	0.19	0.219	733	0.75
	SW	64,854	39.6	3152.9	1.255	0.33	1.441	0.08	3.111	0.19	1.355	879	0.35
	SE	105,458	1.0	3320.2	0.030	2.43	1.441	0.08	3.111	0.19	0.033	34	2.44
	Total	754,401	92.5	14166.1	0.653	0.21					**0.637**	**4,802**	**0.25**
2002/03	NW	257,084	25.0	2777.2	0.900	0.40	1.383	0.13	2.798	0.14	0.911	2,341	0.41
	NE	338,026	4.0	5077.1	0.079	0.42	1.383	0.13	2.798	0.14	0.080	269	0.44
	SW	65,671	14.0	2209.8	0.634	0.53	1.383	0.13	2.798	0.14	0.641	421	0.56
	SE	58,424	0.0	2111.9	–	–	–	–	–	–	–	–	–
	Total	719,205	43.0	12176.0	0.353	0.29					**0.421**	**3,031**	**0.33**
2004/05	NW	–	–	–	–	–	–	–	–	–	–	–	–
	NE	–	–	–	–	–	–	–	–	–	–	–	–
	SW	–	–	–	–	–	–	–	–	–	–	–	–
	SE	–	–	–	–	–	–	–	–	–	–	–	–
	Total	–	–	–	–	–	–	–	–	–	–	–	–

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	378,299	37.0	5646.8	0.655	0.21	1.380	0.09	3.466	0.21	**0.823**	**3,113**	**0.24**
1997/98	FIIIE	277,996	2.0	6704.0	0.030	0.56	1.690	0.17	3.167	0.14	**0.028**	**78**	**0.58**
1999/2000	FIIIE	226,025	42.0	3679.7	1.141	0.26	1.455	0.15	3.740	0.13	**1.467**	**3,315**	**0.28**
2001/02	FIIIE	354,965	25.0	4822.9	0.518	0.52	1.367	0.11	5.024	0.10	**0.953**	**3,382**	**0.52**
2003/04	FIIIE	324,032	88.9	5895.4	1.508	0.30	1.473	0.13	3.126	0.10	**1.600**	**5,185**	**0.31**

Table. 4d. Abundance estimates of fin whale in Area VIW between 1996/97 and 2002/03 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	137,886	19.7	6464.2	0.304	0.22	1.107	0.20	2.216	0.14	**0.305**	**420**	**0.26**
1998/99	SVIW	34,364	5.0	1114.5	0.449	0.73	1.351	0.16	3.402	0.15	**0.565**	**194**	**0.75**
2000/01	FVIW	290,908	15.0	4383.6	0.342	0.27	1.441	0.08	3.111	0.19	**0.369**	**1,074**	**0.30**
2002/03	FVIW	309,998	9.0	5950.2	0.151	0.31	1.383	0.13	2.798	0.14	**0.153**	**474**	**0.32**
2004/05	FVIW	–	–	–	–	–	–	–	–	–	–	–	–

Table. 4e. Abundance estimates of fin whale (south of 60°S; Indian Ocean stock; Pastene et al, 2005) between 1995/96 and 2003/04 seasons. P: estimated population abundance (individuals).

Season	P (ind.)	CV	95% CI LL	95% CI UL	Biomass (ton)
1995/96	4,305	0.197	2,938	6,308	206,629
1997/98	715	0.307	397	1,289	34,326
1999/2000	4,478	0.221	2,920	6,865	214,929
2001/02	10,668	0.255	6,522	17,448	512,052
2003/04	6,573	0.256	4,015	10,761	315,512

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	548,721	4.0	8664.4	0.046	0.479	1.581	0.107	1.727	0.039	0.012	65	0.484
1991/92	Total	534,400	2.0	9783.3	0.020	1.075	1.581	0.107	1.727	0.039	0.003	17	1.081
1993/94	Total	503,561	4.0	13049.4	0.031	0.657	1.581	0.107	1.727	0.039	0.013	64	0.621
1995/96	Total	536,721	1.0	12723.1	0.008	0.931	1.581	0.107	1.727	0.039	–	6	0.938
1997/98	Total	524,233	5.0	14108.3	0.035	0.533	1.581	0.107	1.727	0.039	0.029	153	0.605
1999/2000	Total	560,837	13.0	12661.8	0.103	0.366	1.581	0.107	1.727	0.039	0.039	218	0.397
2001/02	Total	581,308	10.0	12555.9	0.080	0.391	1.581	0.107	1.727	0.039	0.051	295	0.436
2003/04	Total	659,759	6.0	13392.0	0.045	0.438	1.581	0.107	1.727	0.039	0.014	92	0.718

Table. 5b. Abundance estimates of blue whale in Area V between 1990/91 and 2002/03 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	851,204	3.0	8530.7	0.035	1.01	1.581	0.11	1.727	0.04	0.024	205	1.01
1992/93	Total	847,525	4.0	8124.5	0.049	0.56	1.581	0.11	1.727	0.04	0.027	231	0.67
1994/95	Total	714,033	9.0	9545.5	0.094	0.37	1.581	0.11	1.727	0.04	0.039	275	0.64
1996/97	Total	917,841	1.0	11140.9	0.009	0.74	1.581	0.11	1.727	0.04	0.001	7	0.75
1998/99	Total	730,433	4.0	6952.0	0.058	1.27	1.581	0.11	1.727	0.04	0.030	221	2.07
2000/01	Total	754,401	7.7	14166.1	0.054	0.55	1.581	0.11	1.727	0.04	0.039	294	0.49
2002/03	Total	719,205	3.9	12176.0	0.032	0.52	1.581	0.11	1.727	0.04	0.020	142	0.53
2004/05	Total	–	–	–	–	–	–	–	–	–	–	–	–

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	378,299	8.0	5646.8	0.142	0.43	1.581	0.11	1.727	0.04	0.077	293	0.43
1997/98	FIIIE	277,996	10.9	6704.0	0.163	0.48	1.581	0.11	1.727	0.04	0.089	248	0.49
1999/2000	FIIIE	226,025	10.5	3679.7	0.285	0.58	1.581	0.11	1.727	0.04	0.156	352	0.59
2001/02	FIIIE	354,965	2.0	4822.9	0.041	0.62	1.581	0.11	1.727	0.04	0.023	80	0.62
2003/04	FIIIE	324,032	16.0	5241.3	0.305	0.33	1.581	0.11	1.727	0.04	0.167	540	0.34

Table. 5d. Abundance estimates of blue whale in Area VIW between 1996/97 and 2002/03 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	137,886	5.0	6464.2	0.077	0.44	1.581	0.11	1.727	0.04	0.042	58	0.45
1998/99	SVIW	316,727	0.0	1114.5	0.000	–	–	–	–	–	–	–	–
2000/01	FVIW	290,908	0.0	4383.6	0.000	–	–	–	–	–	–	–	–
2002/03	FVIW	309,998	1.0	5950.2	0.017	0.93	1.581	0.11	1.727	0.04	0.009	28	0.94
2004/05	FVIW	–	–	–	–	–	–	–	–	–	–	–	–

Table. 6. Summary of abundance estimates of humpback, fin and blue whales for each season between 1989/90 and 2003/04 seasons. Above : humpback whale, middle: fin whale, bottom; blue whale.

Humpback	Seasons		Area IIIE	Area IV	Area V	Area VIW	Total
	1989/90 + 1990/91	P	−	5,230	1,354	−	6,584
		CV	−	0.30	0.20	−	0.24
	1991/92+ 1992/93	P	−	5,350	3,837	−	9,187
		CV	−	0.19	0.63	−	0.29
	1993/94+ 1994/95	P	−	2,740	3,565	−	6,305
		CV	−	0.15	0.31	−	0.19
	1995/96+ 1996/97	P	2,224	8,850	1,543	959	13,576
		CV	0.18	0.14	0.28	0.18	0.10
	1997/98+ 1998/99	P	539	10,874	8,301	1,827	21,541
		CV	0.25	0.17	0.31	0.69	0.16
	1999/00+ 2000/01	P	8,390	16,211	4,720	2,448	31,769
		CV	0.14	0.15	0.22	0.20	0.09
	2001/02+ 2002/03	P	4,426	33,010	2,735	1,551	41,722
		CV	0.20	0.11	0.16	0.24	0.09
	2003/04+ 2004/05	P	7,889	31,750	−	−	39,639
		CV	0.10	0.11	−	−	0.09

Fin	Seasons	P CV	Area IIIE	Area IV	Area V	Area VIW	Total
	1989/90 + 1990/91	P	−	102	726	−	828
		CV	−	0.84	0.31	−	0.29
	1991/92+ 1992/93	P	−	338	1,397	−	1,735
		CV	−	0.50	0.38	−	0.32
	1993/94+ 1994/95	P	−	189	6,334	−	6,523
		CV	−	0.45	0.37	−	0.36
	1995/96+ 1996/97	P	3,113	1,191	1,294	420	6,018
		CV	0.24	0.32	0.32	0.26	0.16
	1997/98+ 1998/99	P	78	637	4,655	194	5,564
		CV	0.58	0.34	0.37	0.75	0.31
	1999/00+ 2000/01	P	3,315	1,162	4,802	1,074	10,353
		CV	0.28	0.32	0.25	0.30	0.15
	2001/02+ 2002/03	P	3,382	7,285	3,031	474	14,172
		CV	0.52	0.28	0.33	0.32	0.20
	2003/04+ 2004/05	P	5,185	1,388	−	−	6,573
		CV	0.31	0.28	−	−	0.26

Blue	Seasons	P CV	Area IIIE	Area IV	Area V	Area VIW	Total
	1989/90 + 1990/91	P	−	65	205	−	270
		CV	−	0.48	1.01	−	0.78
	1991/92+ 1992/93	P	−	17	231	−	248
		CV	−	1.08	0.67	−	0.63
	1993/94+ 1994/95	P	−	64	275	−	339
		CV	−	0.62	0.64	−	0.53
	1995/96+ 1996/97	P	293	6	7	58	364
		CV	0.43	0.94	0.75	0.45	0.35
	1997/98+ 1998/99	P	248	153	221	0	622
		CV	0.49	0.61	2.07	−	0.78
	1999/00+ 2000/01	P	352	218	294	0	864
		CV	0.59	0.40	0.49	−	0.31
	2001/02+ 2002/03	P	80	295	142	28	545
		CV	0.62	0.44	0.53	0.94	0.29
	2003/04+ 2004/05	P	540	92	−	−	632
		CV	0.34	0.72	−	−	0.31

Table. 7. Increasing rate of humpback and fin whales abundance in the Antarctic feeding ground (south of 60^{o}S) by each Area. *: exclude 2001/02 season.

Species	Area	Seasons	estimate	CV	p-value	R^2
Humpback	IV	1989/90 - 2003/04 (over 15 years)	0.162	0.201	p<0.05	0.816
Humpback	IV	1989/90 - 2003/04 (over 15 years)*	0.148	0.243	p<0.05	0.78
Humpback	V	1990/91 - 2001/02 (over 13 years)	0.064	0.711	0.218	0.284
Fin	IIIE+IV	1995/96 - 2003/04 (over 9 years)	0.178	0.880	0.338	0.301
Fin	V+VIW	1996/97 - 2002/03 (over 7 years)	0.140	1.009	0.426	0.329
Fin	III+IV+V+VI	1995/96 - 2002/03 (over 8 years)	0.142	0.069	p<0.05	0.991

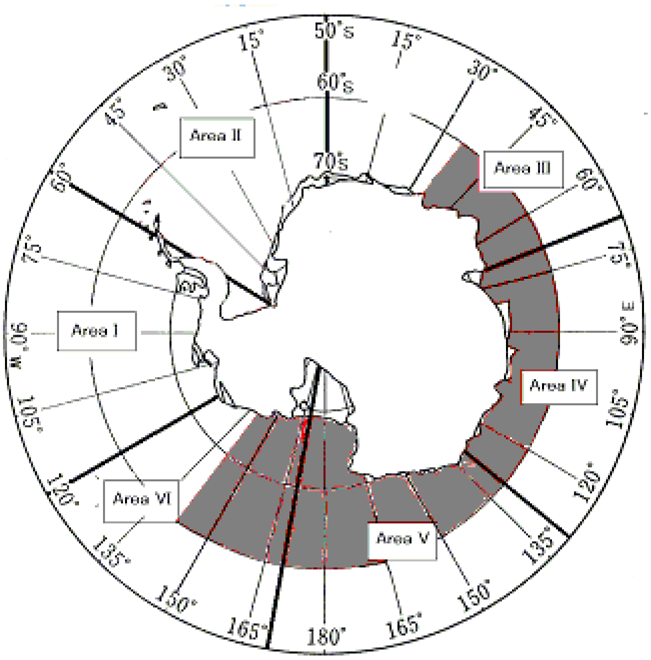


Fig.1a. The IWC Antarctic Areas for the management of baleen whales (except Bryde's whale) and research Area of the JARPA surveys between 35°E and 145°W (colored). Areas III east (IIIE: 35 °E-70°E), IV(70°E-130°E), V (130°E-170°W) and VI west (VIW: 170°W -145°W).

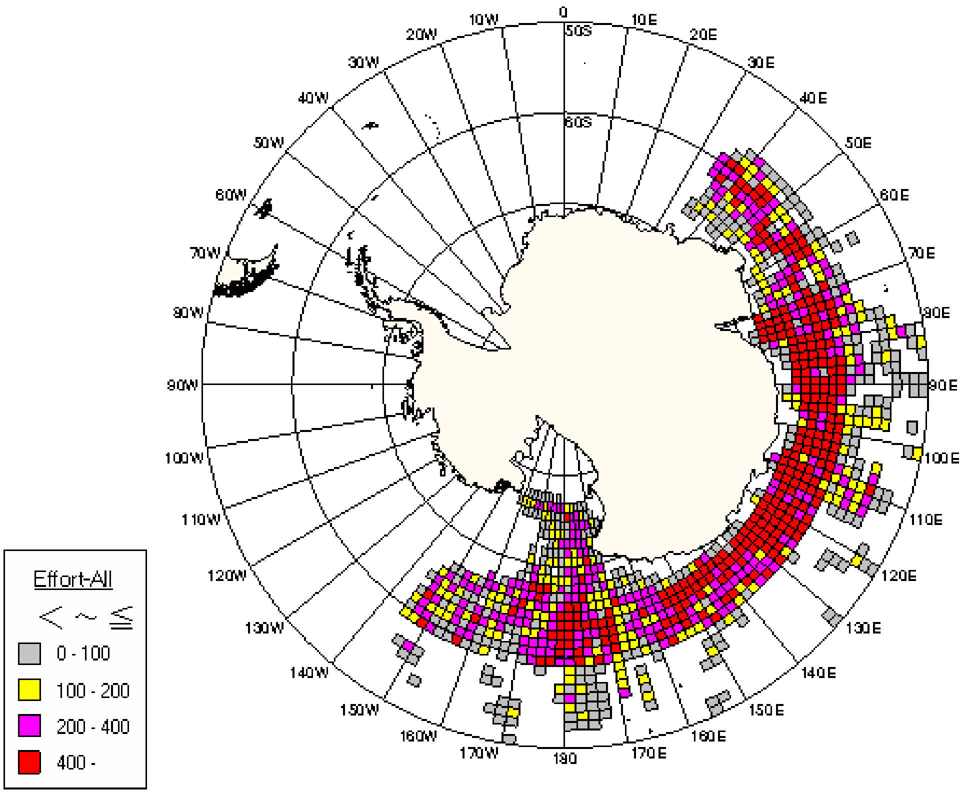


Fig.1b. Map of the the searching efforts by by Lat.1°× Long.2°square in the JARPA1987/88-2003/04 seasons, including middle latitude transit sighting survey. Research area was covered uniformly.

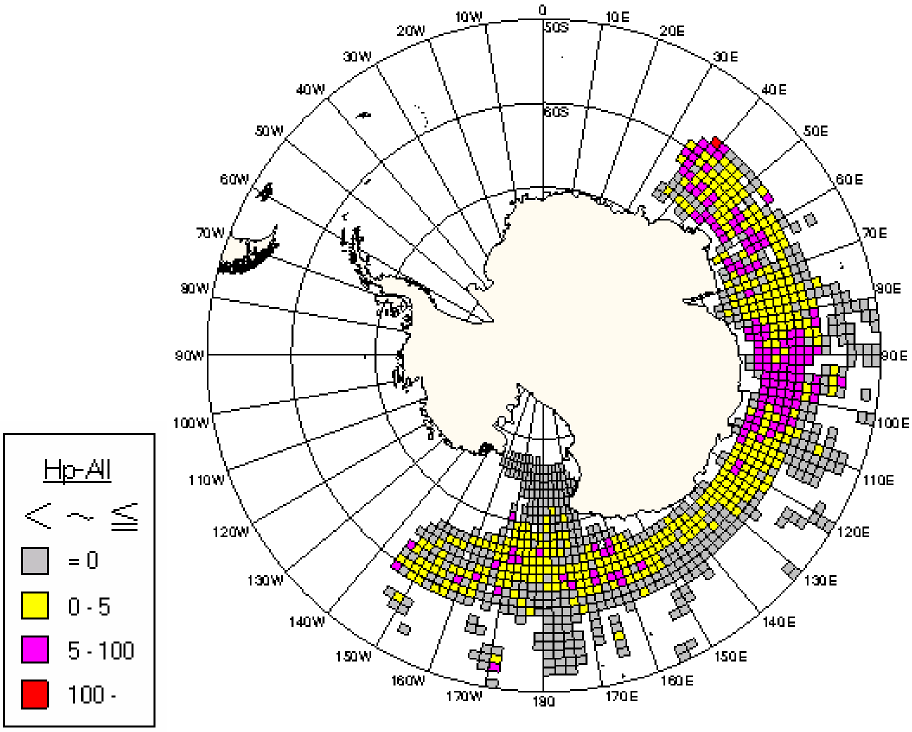


Fig.1c. Map of the Density Index (number of primary sightings of whales / 100 n.mile) of humpback whales during JARPA -1987/88-2003/04 seasons by Lat.1°× Long.2°square.

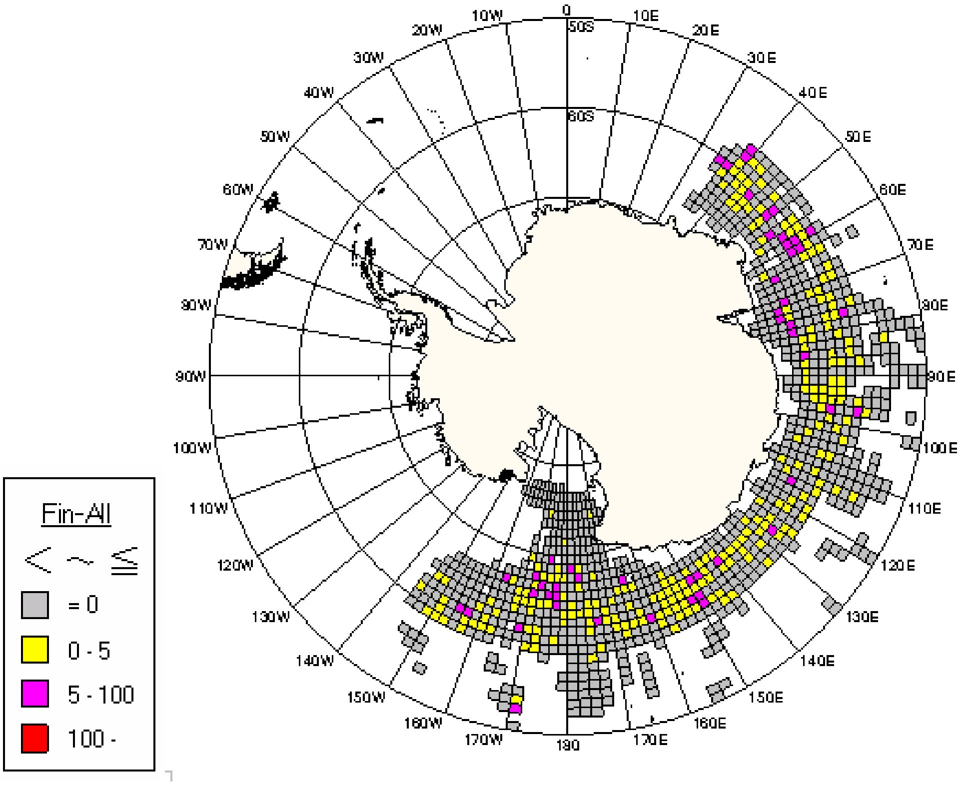


Fig.1d. Map of the Density Index (number of primary sightings of whales / 100 n.mile) of fin whales during JARPA -1987/88-2003/04 seasons by Lat.1°× Long.2°square.

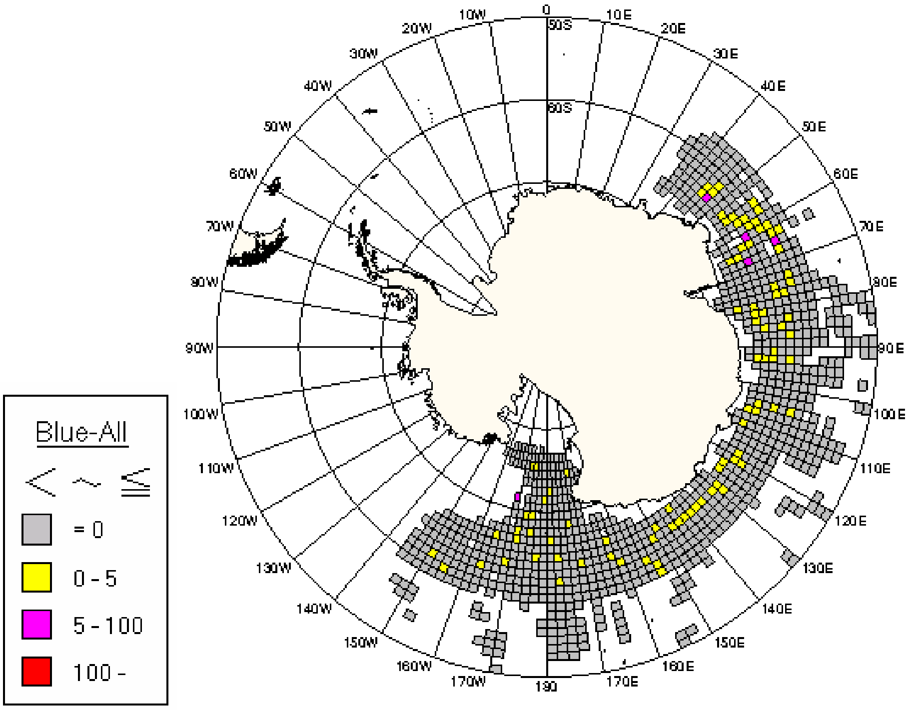


Fig.1e. Map of the Density Index (number of primary sightings of whales / 100 n.mile) of blue whales during JARPA -1987/88-2003/04 seasons by Lat.1°× Long.2°square.

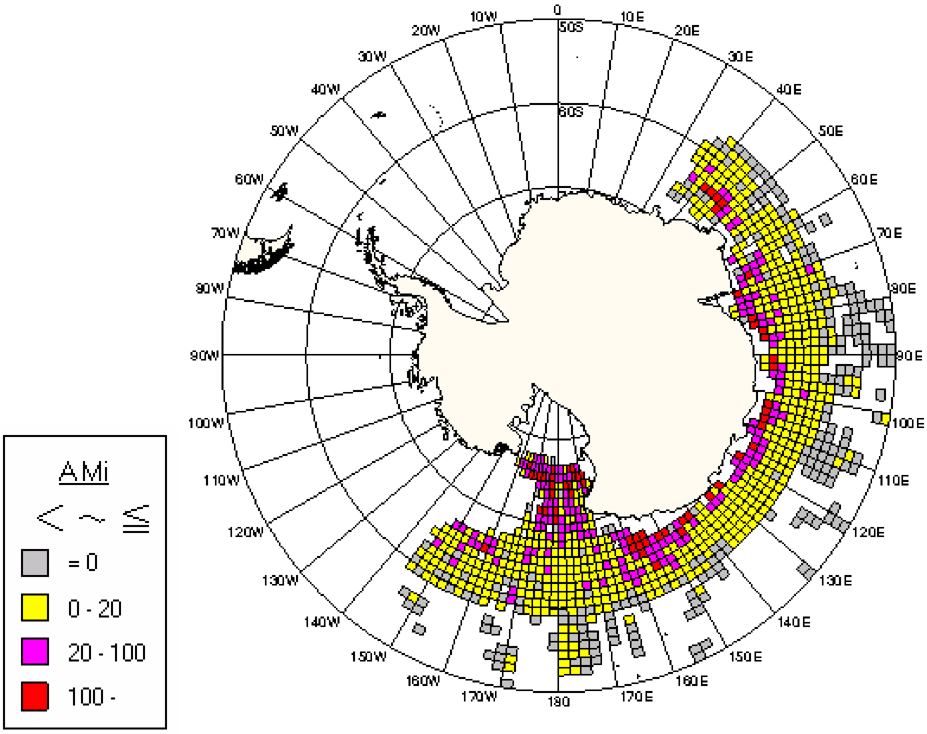


Fig.1b. Map of the Density Index (number of primary sightings of whales / 100 n.mile) of Antarctic minke whales during JARPA -1987/88-2003/04 seasons by Lat.1°× Long.2°square.

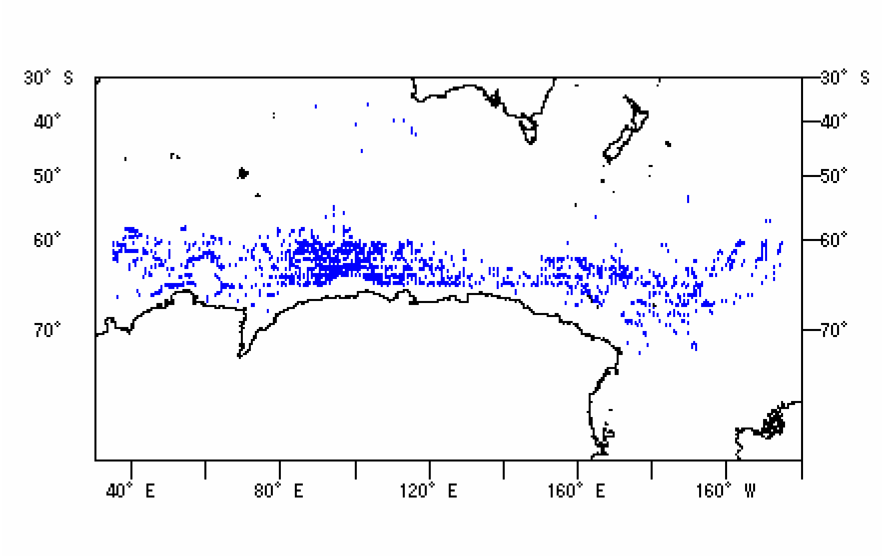


Fig.2a. Position of the primary sightings for humpback whales in JARPA surveys between 1989/90 and 2003/04 seasons including transit surveys.

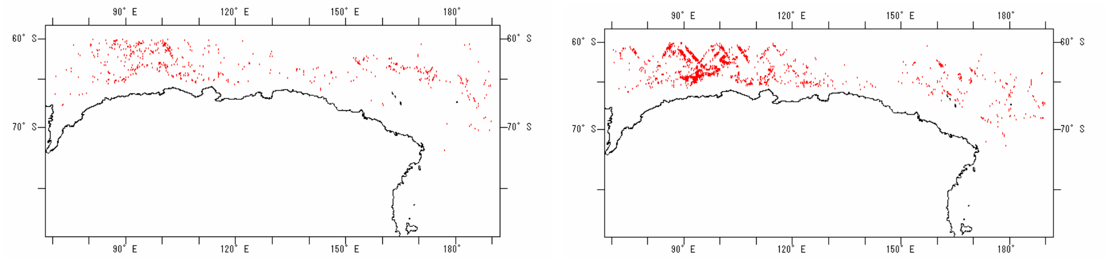


Fig.2b. Position of the primary sightings of humpback whales in the first half of JARPA in Areas IV and V between 1989/90 and 1996/97 surveys by three sighting and sampling vessels (Left). Position of the primary sightings of humpback whales in the later half of JARPA in Areas IV and V between 1997/98 and 2003/04 seasons by three sighting and sampling vessels (Right).

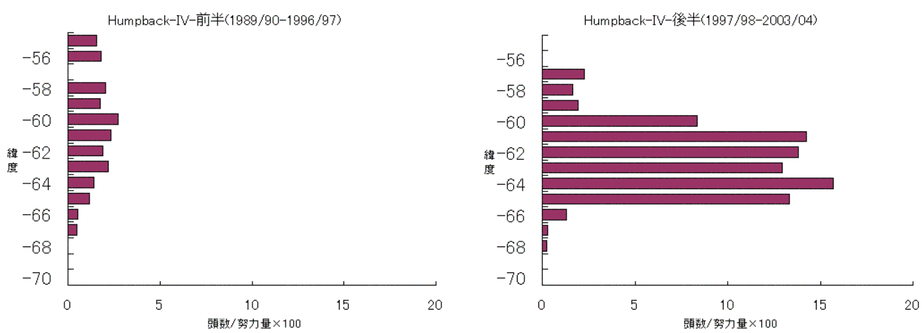


Fig.2c. Comparison of the latitudinal density Index (number of primary sightings of whales / 100 n.mile) between the first half of JARPA (Left: 1989/90-1996/97) and the later half of JARPA (Right: 1997/98-2003/04). Average of the latitude was 6030’S in the half of surveys, and was 6230’S in the second half of the surveys.

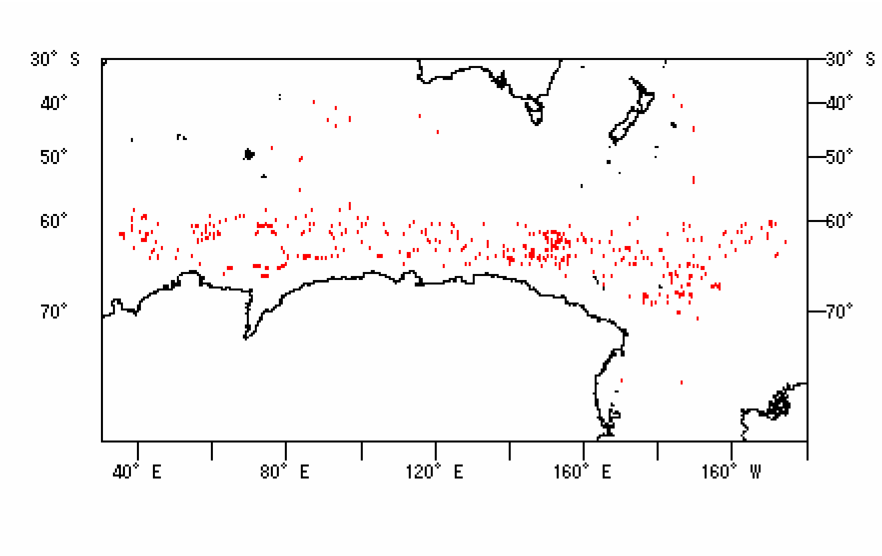


Fig.3a. Sighting position of the fin whales in JARPA surveys between 1989/90 and 2003/04 seasons including transit surveys.

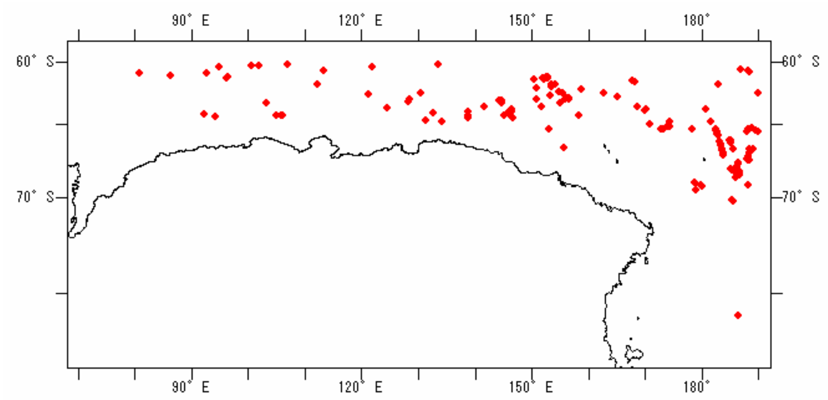


Fig.3b. Position of the primary sightings of fin whales in the first half of JARPA in Areas IV and V between 1989/90 and 1996/97 surveys by three sighting and sampling vessels .

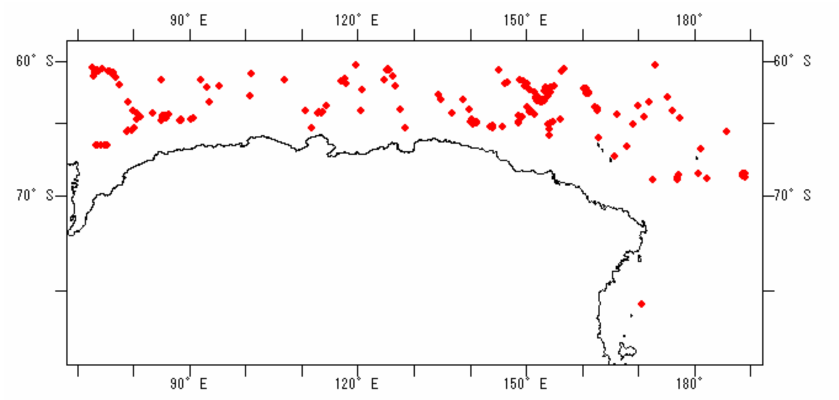


Fig.3c. Position of the primary sightings of fin whales in the second half of JARPA in Areas IV and V between 1997/98 and 2003/04 seasons including transit surveys by three sighting and sampling vessels .

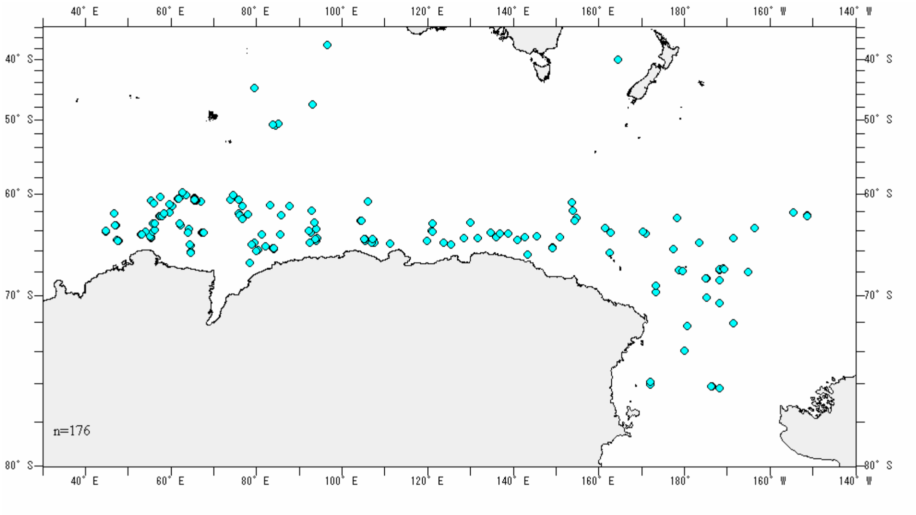


Fig.4a. Sighting position of the blue whales in JARPA surveys between 1989/90 and 2003/04 seasons including transit surveys.

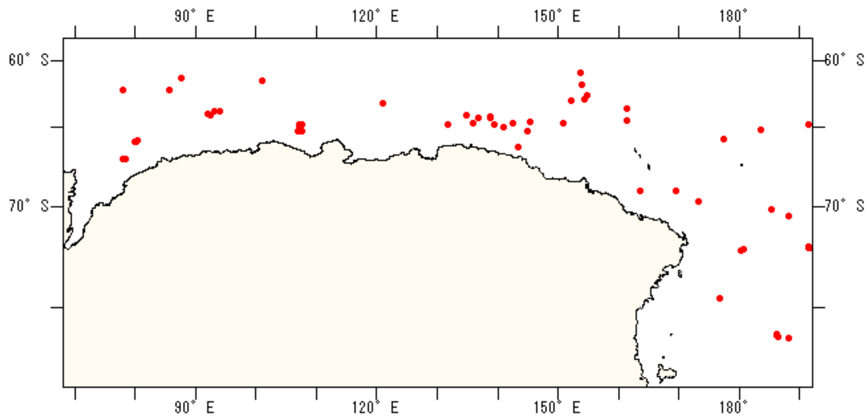


Fig.4b. Position of the primary sightings of blue whales in the first half of JARPA in Areas IV and V between 1989/90 and 1996/97 surveys by three sighting and sampling vessels .

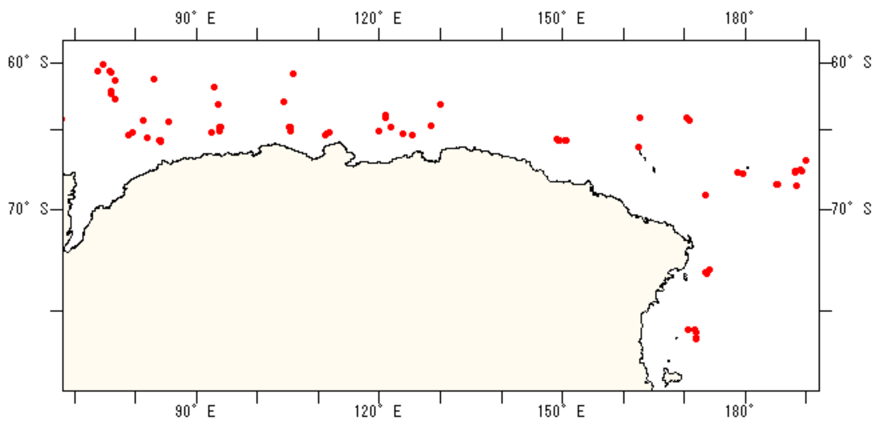


Fig.4c. Position of the primary sightings of blue whales in the second half of JARPA in Areas IV and V between 1997/98 and 2003/04 seasons including transit surveys by three sighting and sampling vessels .

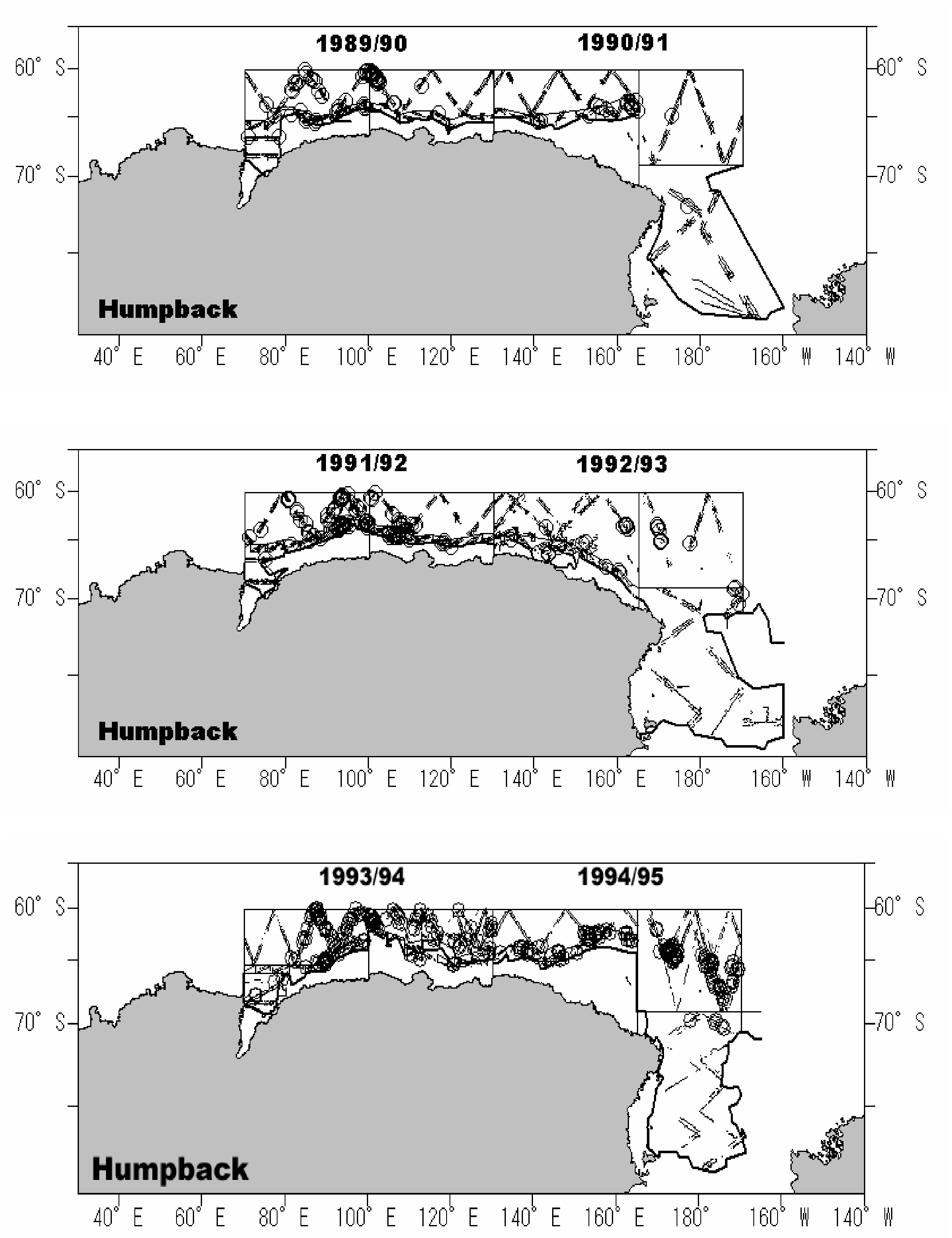


Fig. 5a. Distribution of the searching effort and position of the primary school sightings of humpback whales between 1989/90 and 2003/04 seasons which used in this analyses. Black line shows the on efforts. Bold line shows the estimated ice edge line. The circles show the primary schools of humpback whales sighted.

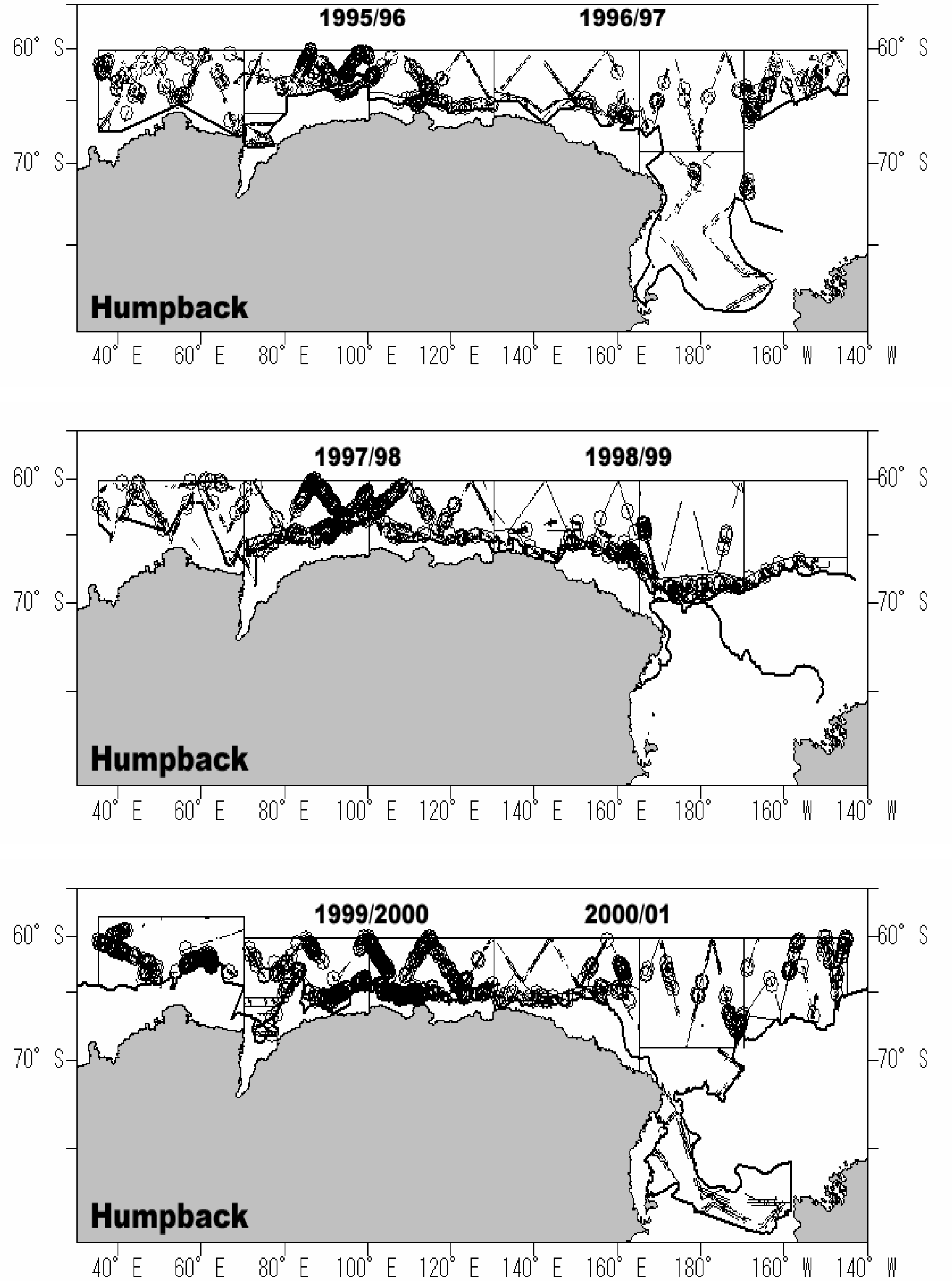


Fig. 5a. (Continued)

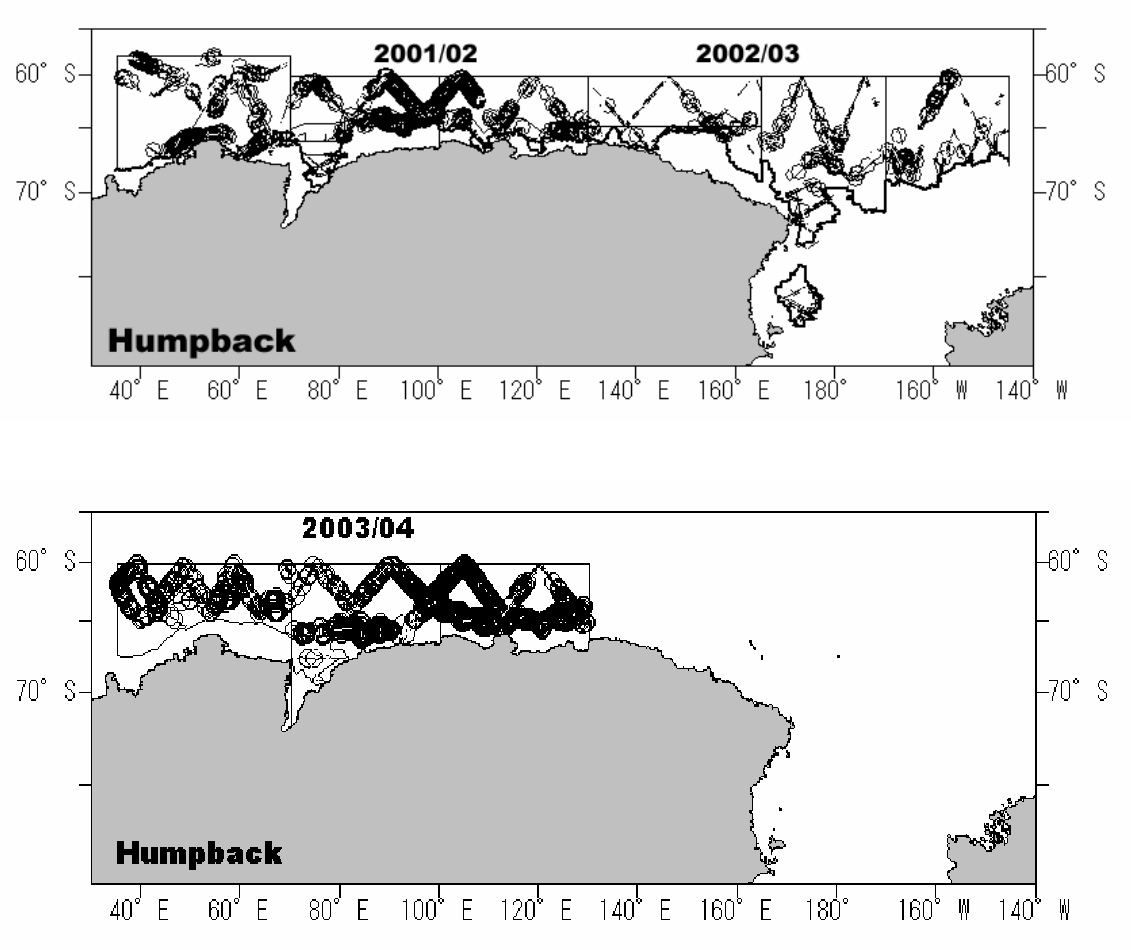


Fig. 5a. (Continued)

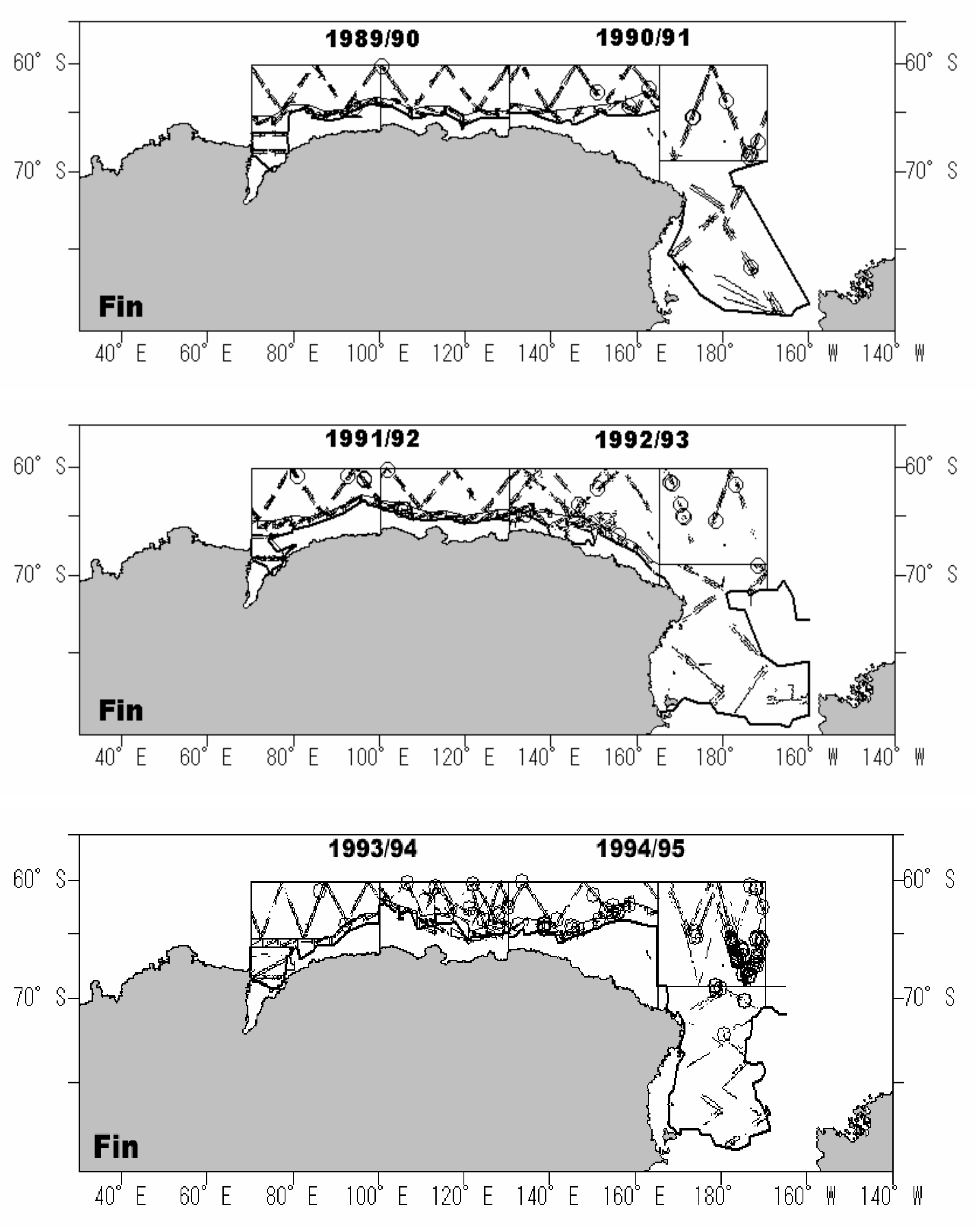
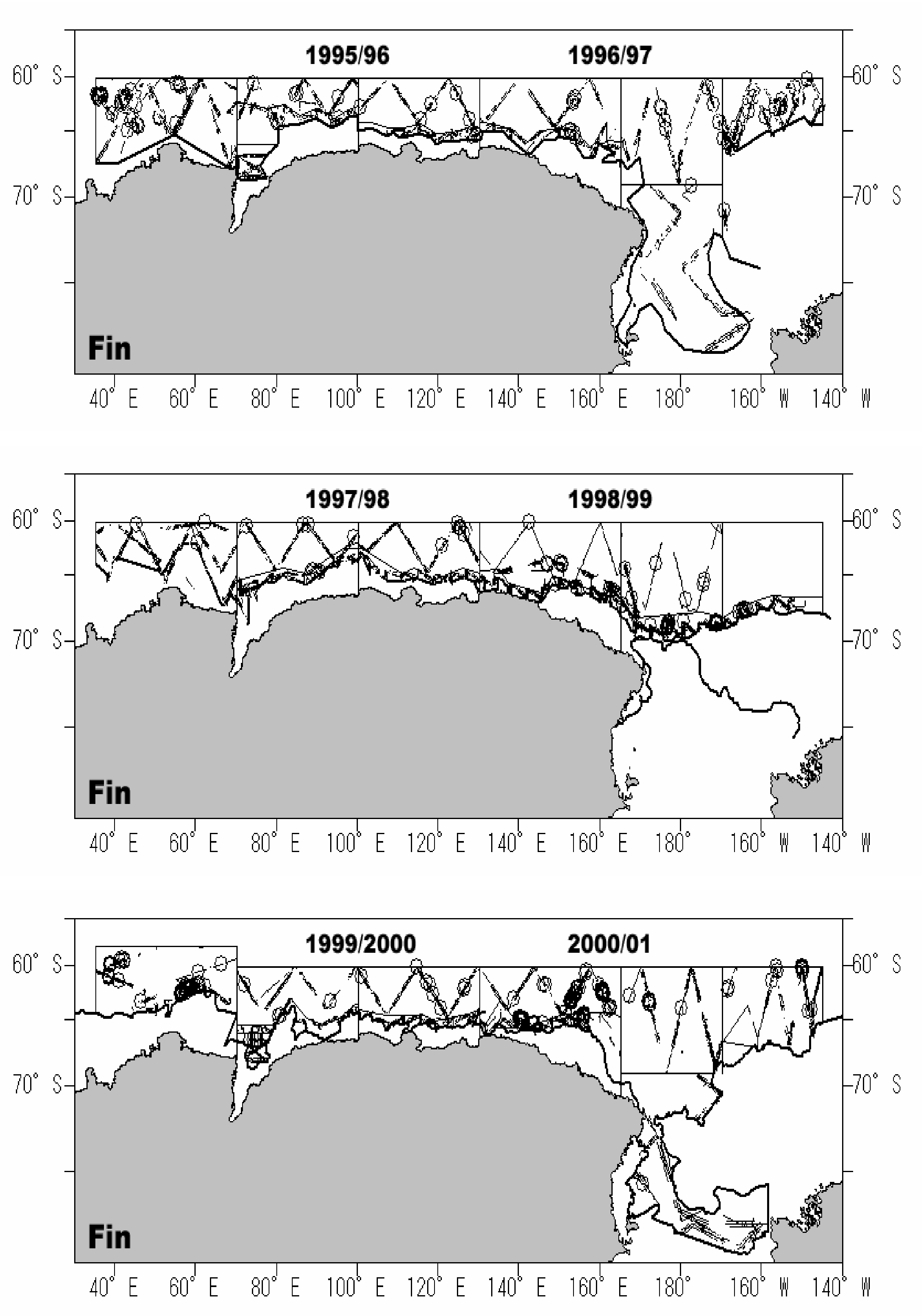


Fig. 5b. Distribution of the searching effort and sighting position of the primary school of fin whales between 1989/90 and 2003/04 seasons which used in this analyses. Black line shows the on efforts. Bold line shows the estimated ice edge line. The circles show the primary schools of fin whales sighted.



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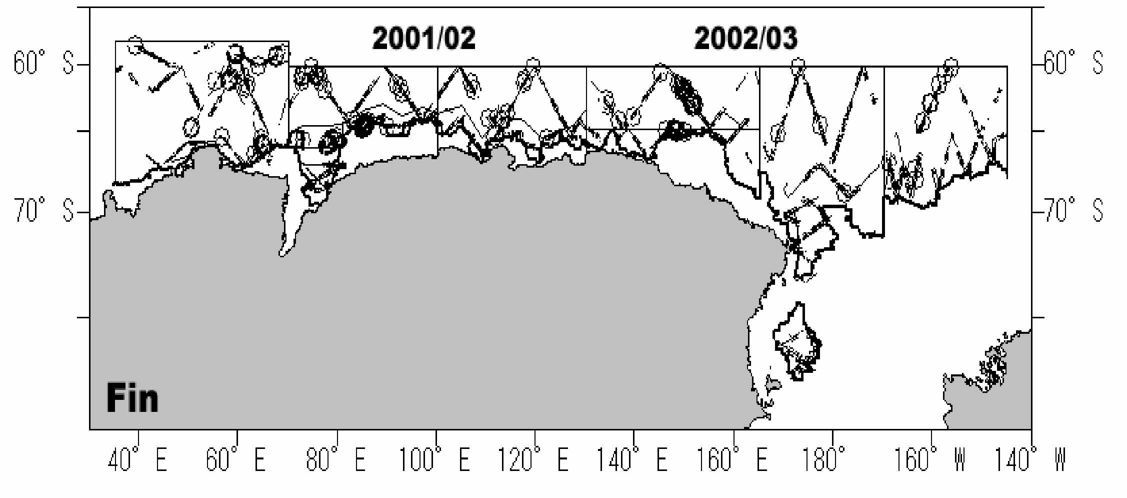

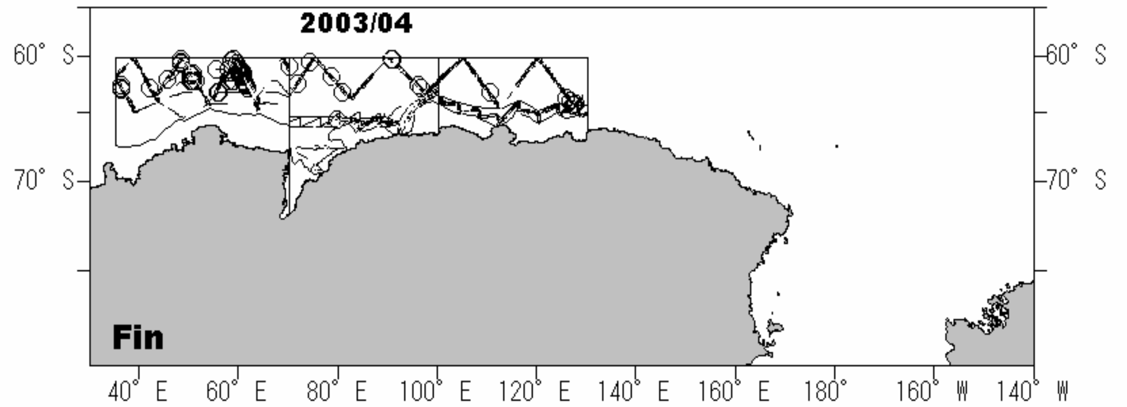

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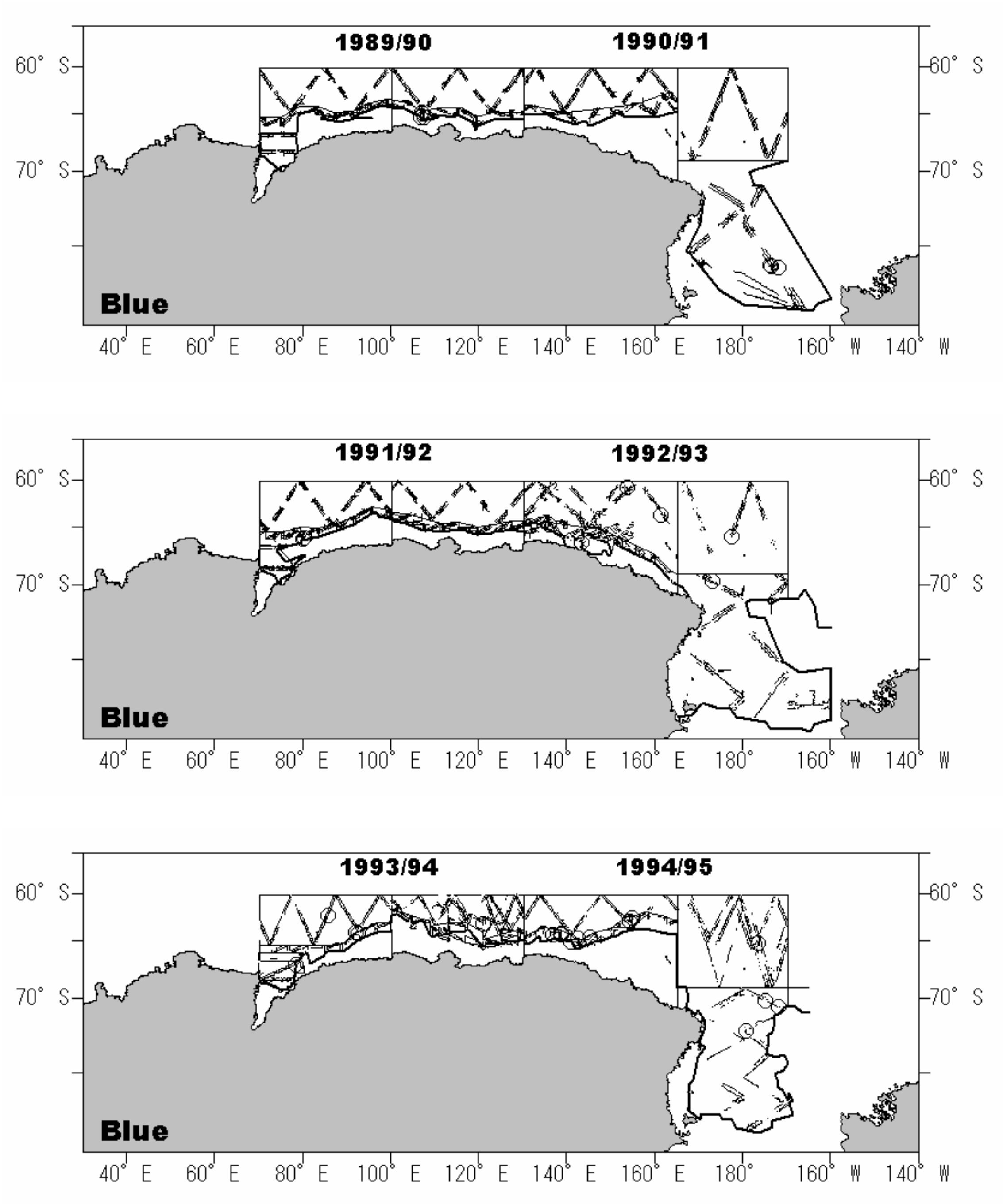
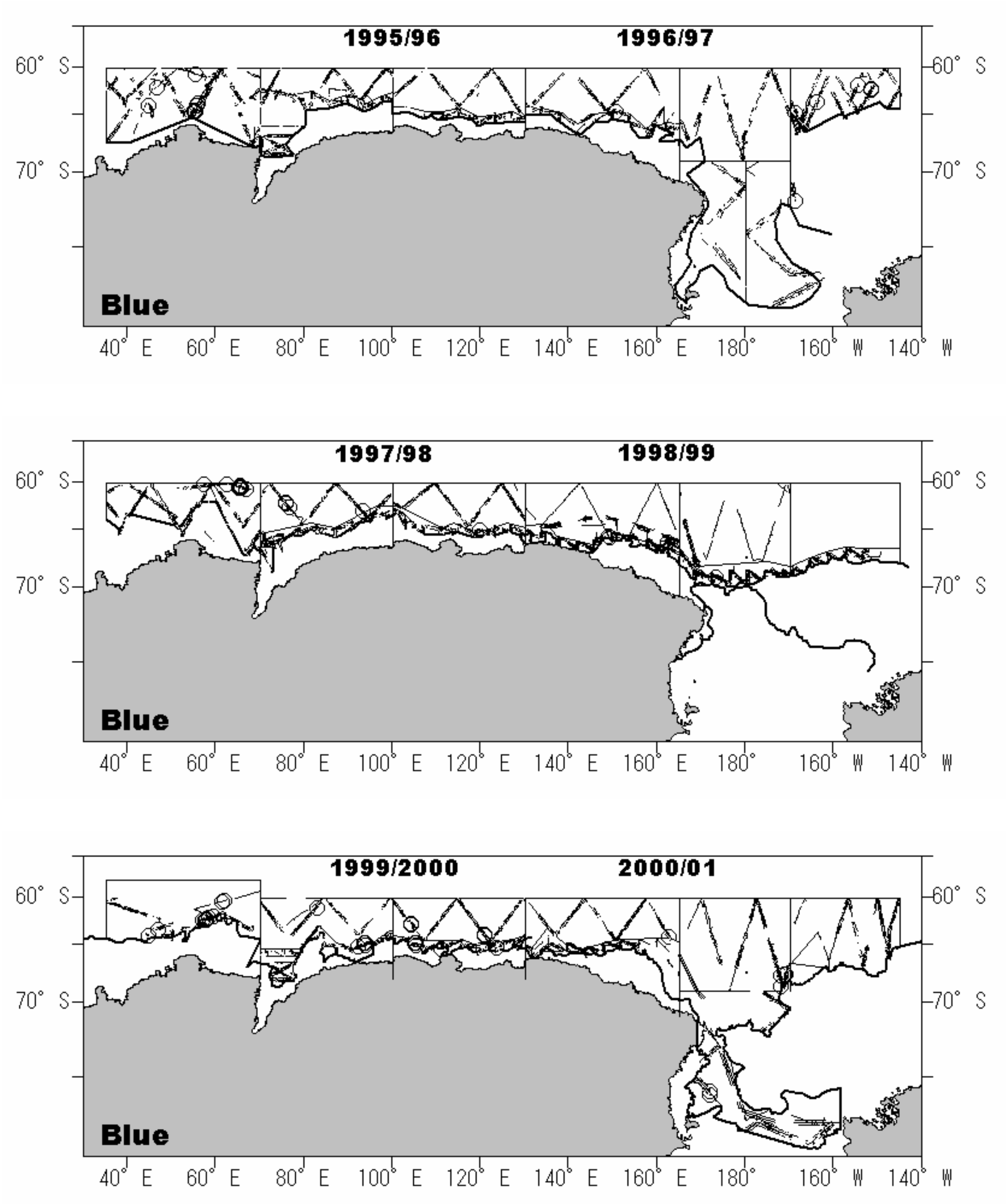


Fig. 5c. Distribution of the searching effort and sighting position of the primary school of blue whales between 1989/90 and 2003/04 seasons which used in this analyses. Black line shows the on efforts. Bold line shows the estimated ice edge line. The circles show the primary schools of fin whales sighted.



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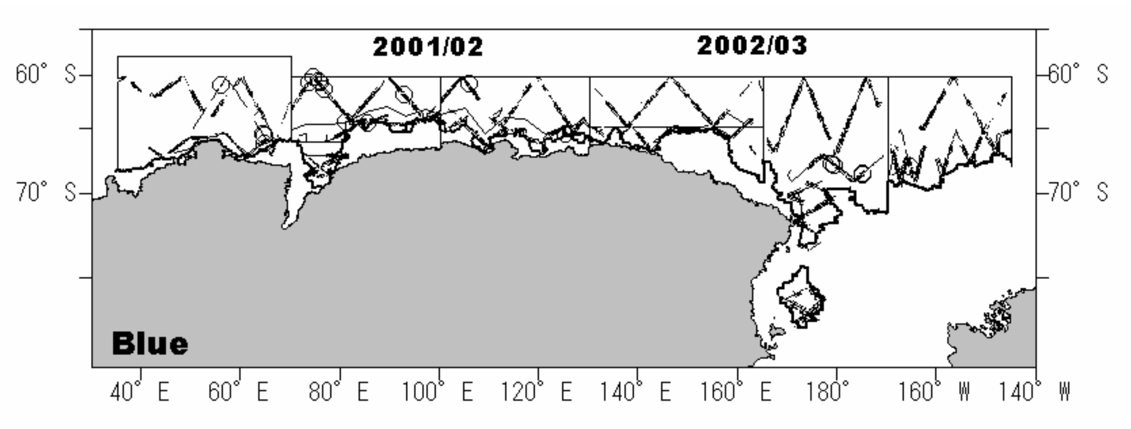

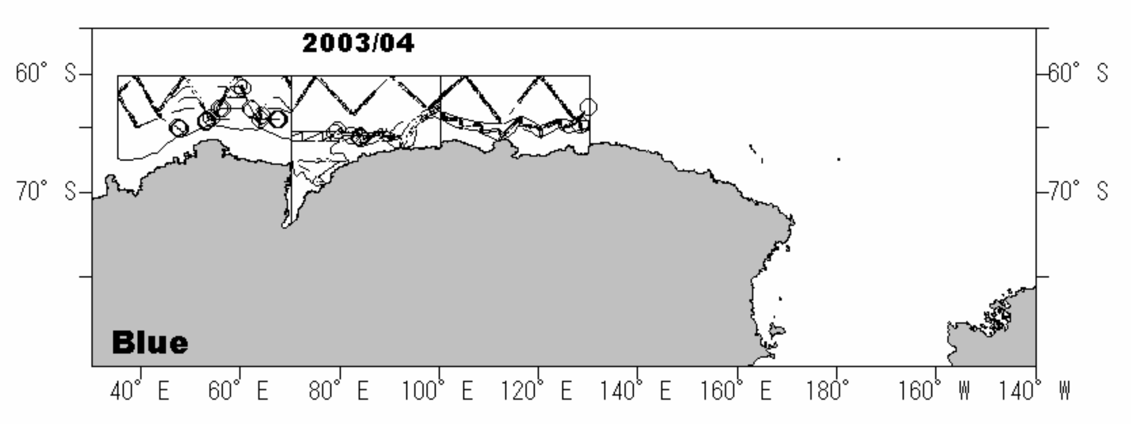

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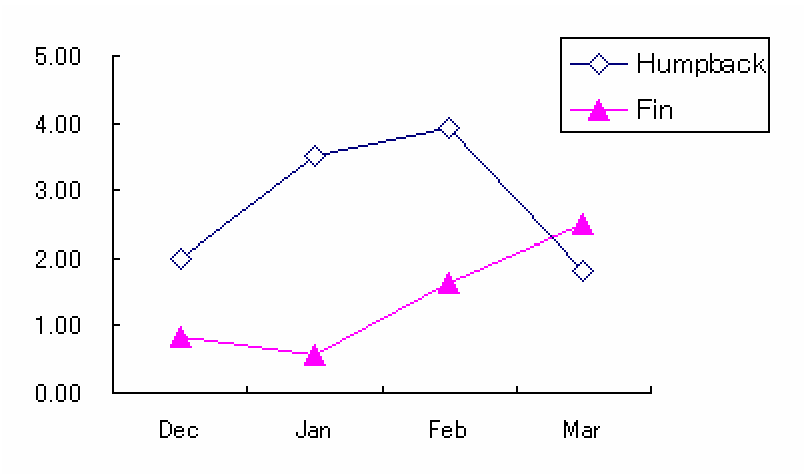

Fig. 6. Monthly change of the density index (DI: whales / 100 n.miles) for humpback and fin whales in the research area by JARPA sighting data between 1989/90 and 2002/03 seasons.

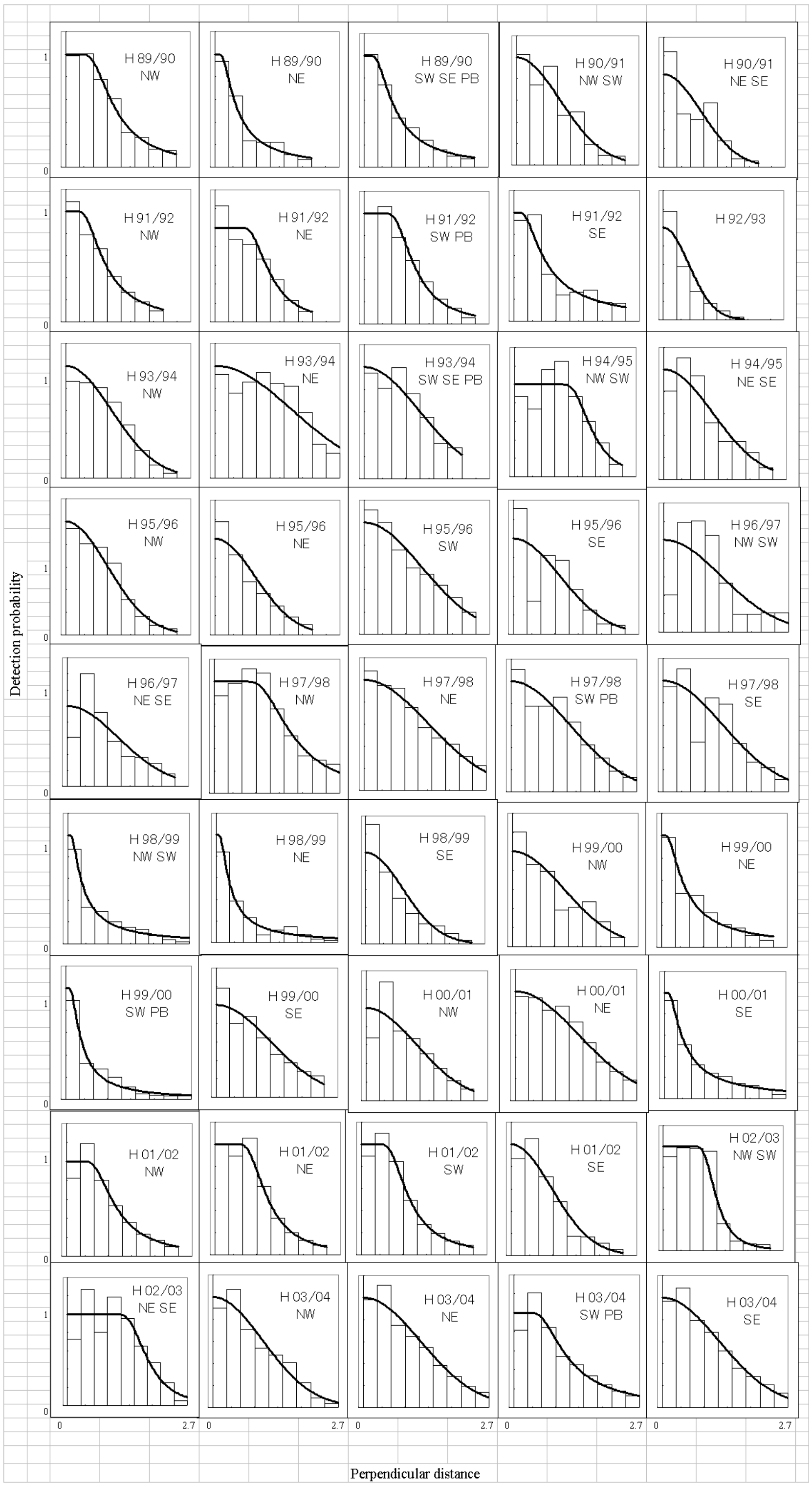

Fig. 7a. Detection probability function of humpback whale in Area IIIE, IV, V and VIW surveyed from 1989/90 to 2003/2004 seasons in relation to Table 3a, 3b, 3c and 3d.

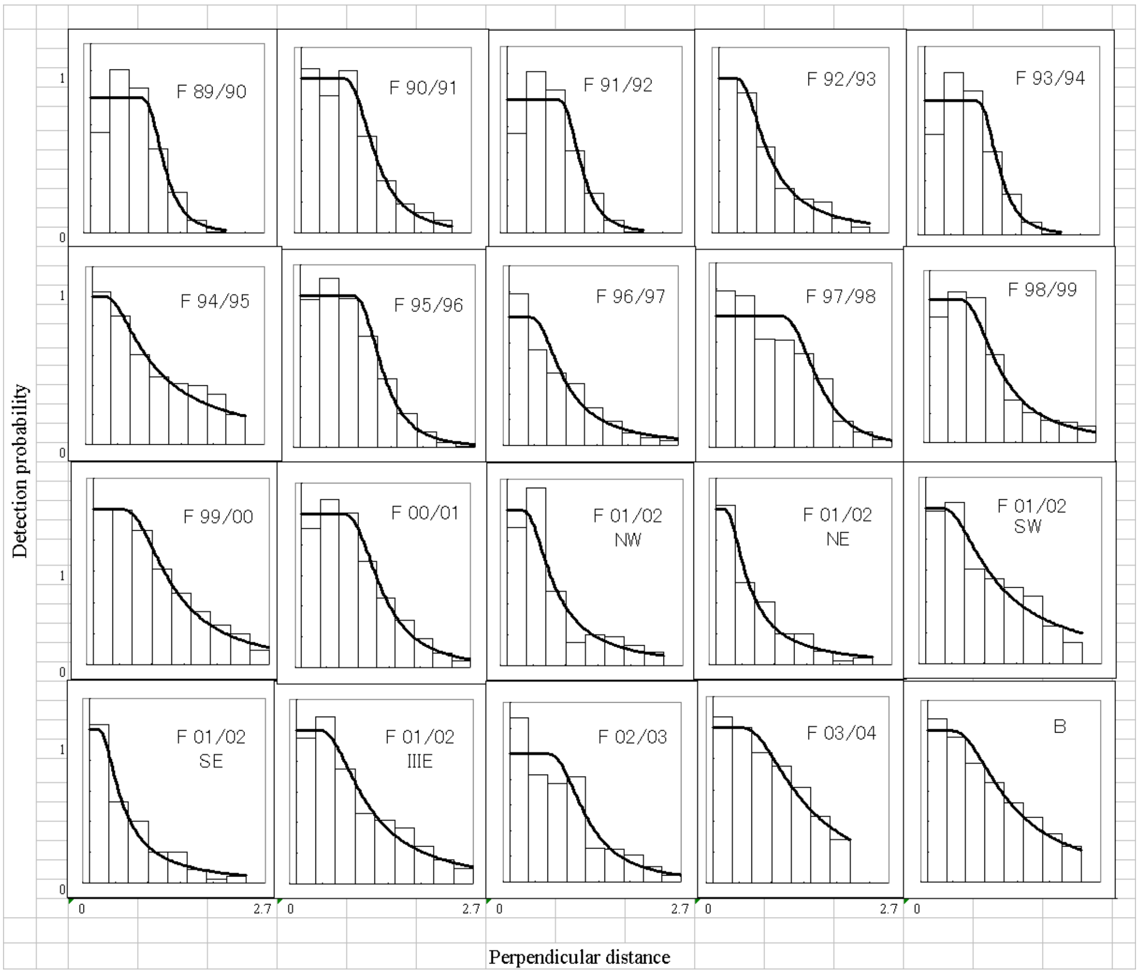

Fig. 7b. Detection probability function of Fin whale in Area IIIE, IV, V and VIW surveyed from 1989/90 to 2003/2004 seasons.

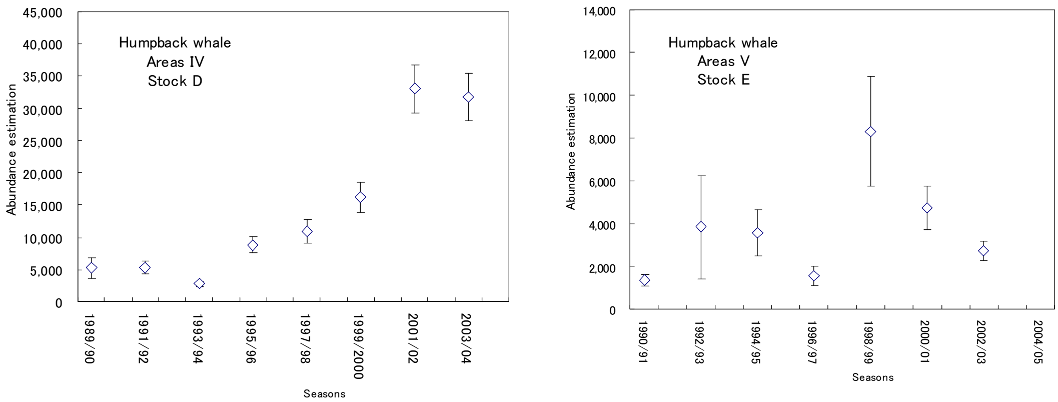

Fig. 8. Abundance estimates of humpback whale in Areas IV and V (south of 60°S) surveyed during January to February, between 1989/90 and 2003/2004 seasons (over 15 years). Vertical lines show standard errors.

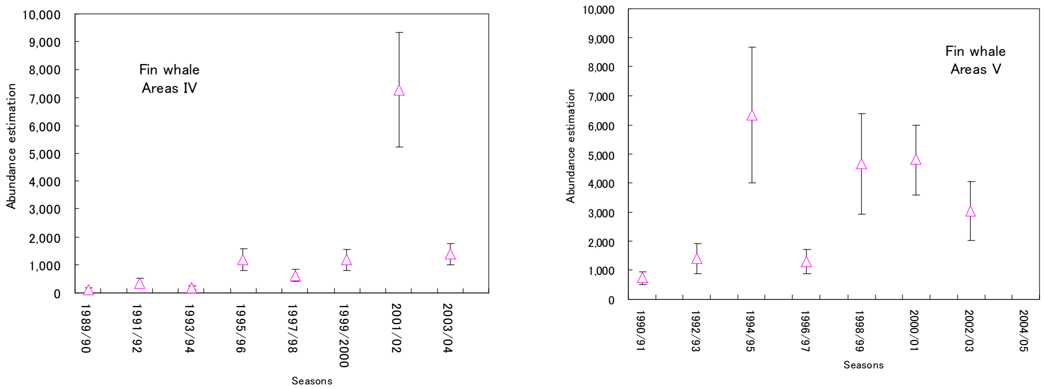

Fig. 9a. Abundance estimates of fin whale in Areas IV and V (south of 60°S) surveyed during January to February, between 1989/90 and 2003/2004 seasons (over 15 years). Vertical lines show standard errors.

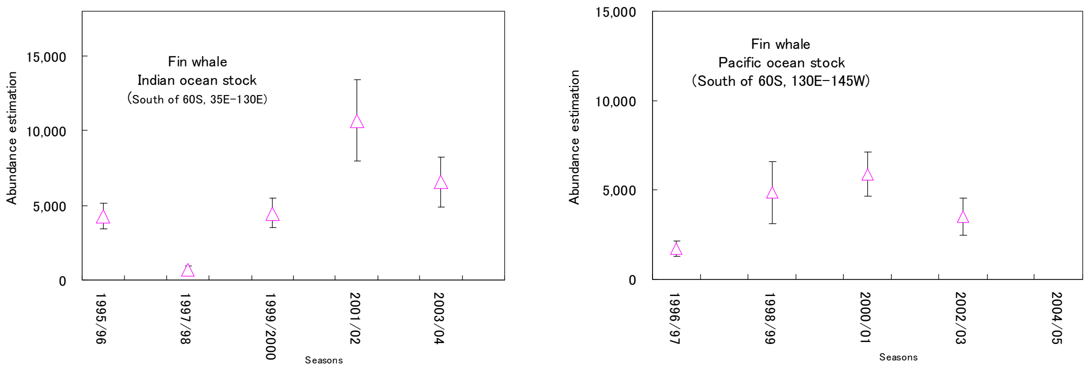

Fig. 9b. Abundance estimates of fin whale in Areas IV and V (south of 60°S) surveyed during January to February, between 1989/90 and 2003/2004 seasons (over 15 years). Vertical lines show standard errors.

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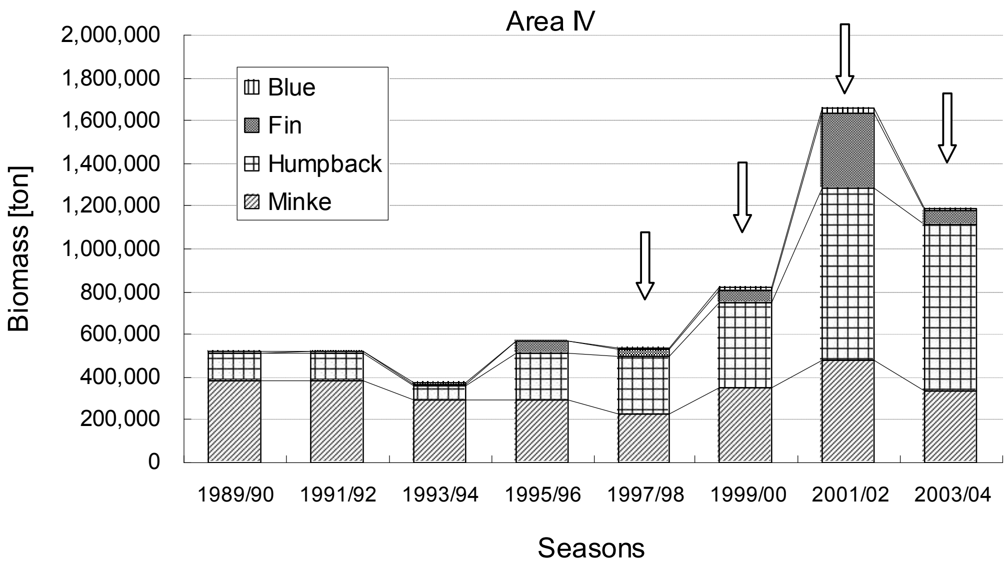

Fig. 10a. Biomass of Antarctic minke, humpback, fin and blue whales in Area IV (south of 60°S) surveyed during January to February, between 1989/90 and 2003/2004 seasons (over 15 years). Abundance of Antarctic minke were estimated by Hakamada et al, (2005). A "shift in baleen whale dominance" was observed since 1997/98 season (arrows).

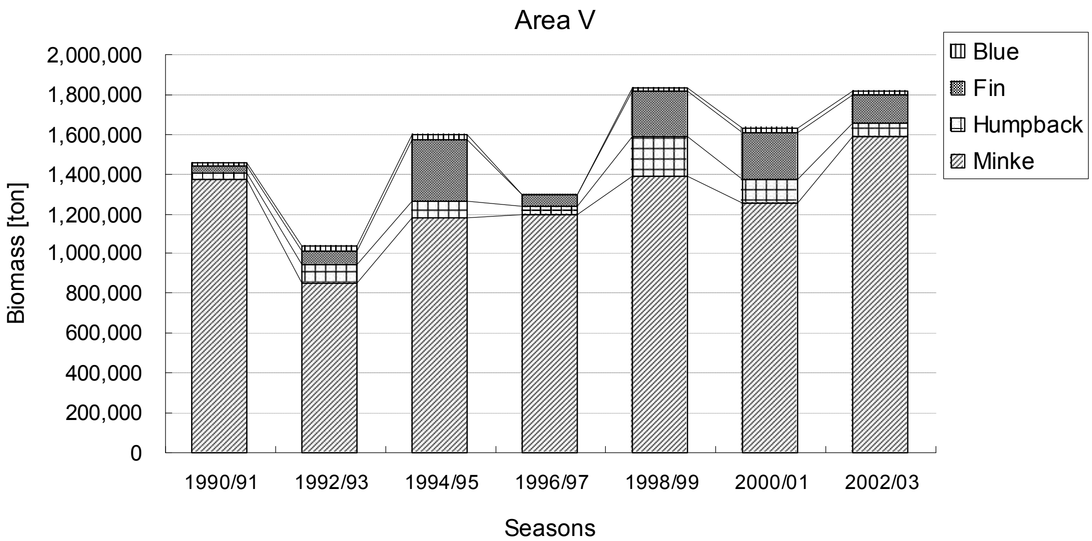

Fig. 10b. Biomass of Antarctic minke, humpback, fin and blue whales in Area V (south of 60°S) surveyed during January to February, between 1990/91 and 2002/2003 seasons (over 13 years). Abundance of Antarctic minke were estimated by Hakamada et al, (2005).

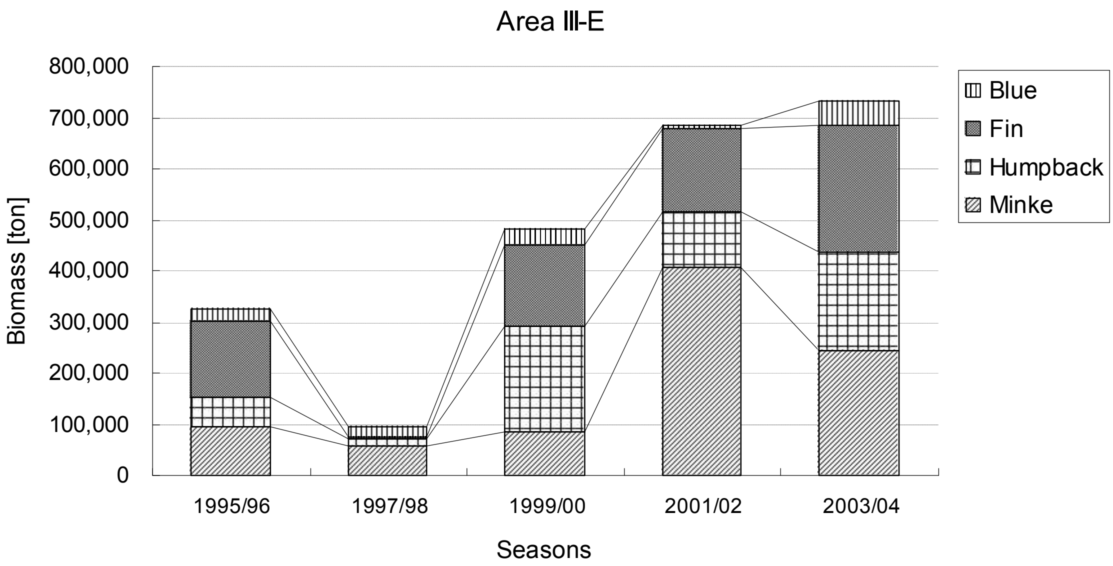

Fig. 10c. Biomass of Antarctic minke, humpback, fin and blue whales in Area IIIE (south of 60°S) surveyed during January to February, between 1995/96 and 2003/2004 seasons (over 15 years). Abundance of Antarctic minke were estimated by Hakamada et al, (2005).

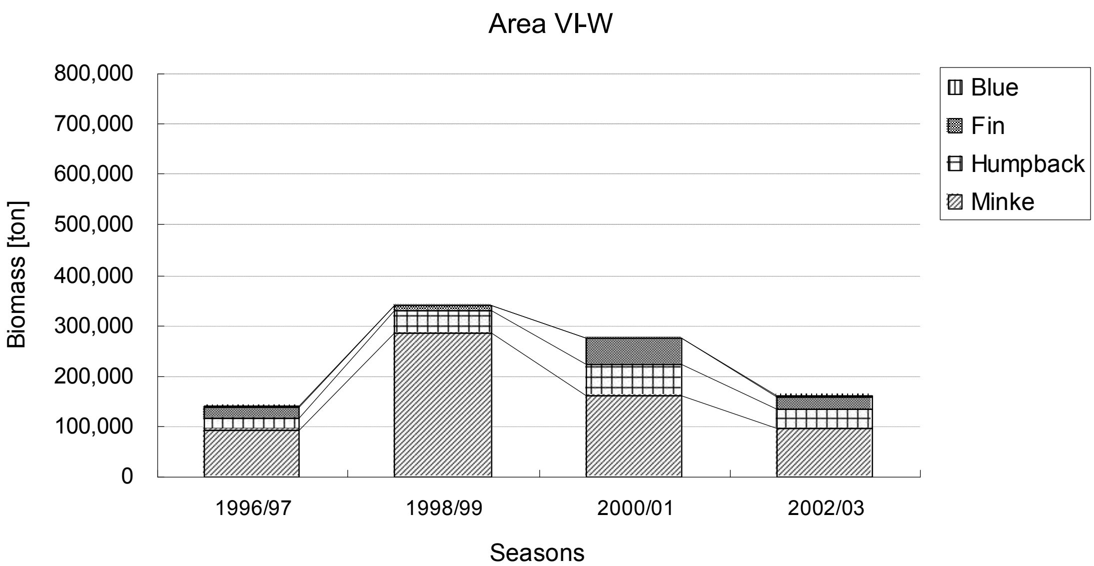

Fig. 10d. Biomass of Antarctic minke, humpback, fin and blue whales in Area VIW (south of 60°S) surveyed during January to February, between 1996/97 and 2002/2003 seasons (over 7 years). Abundance of Antarctic minke were estimated by Hakamada et al, (2005).

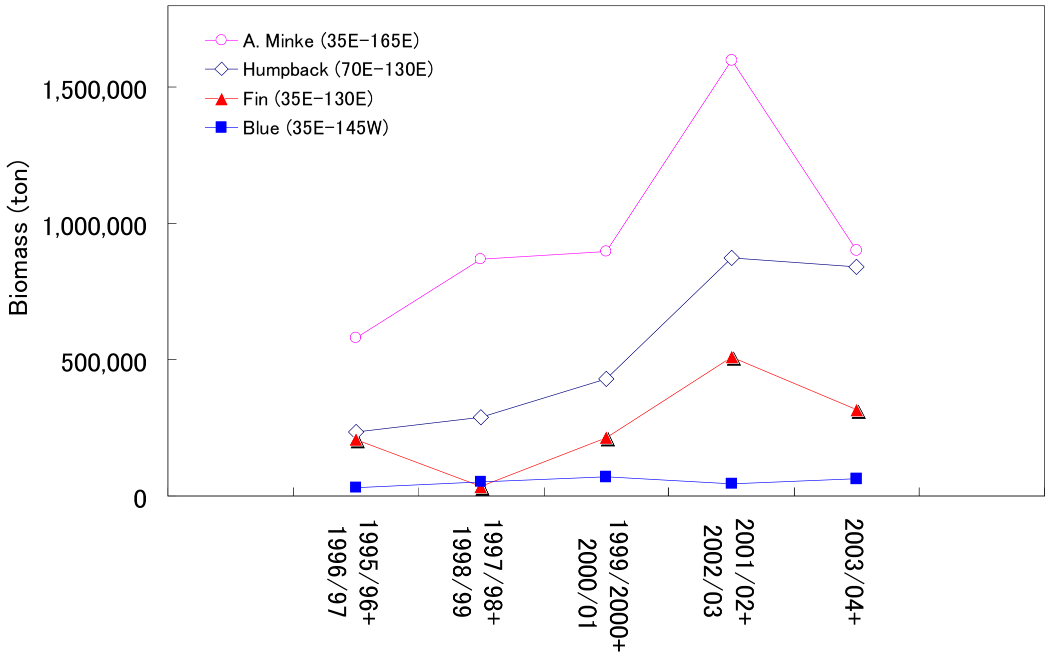

Figure 11. Biomass of Antarctic minke (I-stock), humpback (D-stock), fin (Indian Ocean stock) and blue whales during JARPA 1995/96-2003/04. Average of biomass between 1995/96 and 2002/03 seasons were used as 2004/05 season for Antarctic minke and blue whales.