Current abundance estimates of humpback and fin whales in the Antarctic Areas IIIE, IV, V and VIW (35^{o}E -145^{o}W)

KOJI MATSUOKA, TAKASHI HAKAMADA, HIROTO MURASE AND SHIGETOSHI NISHIWAKI

The Institute of Cetacean Research, 4-5, Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan
Contact e-mail: matsuoka@cetacean.jp

ABSTRACT

This paper reports current abundance estimates of humpback and fin whales in the Antarctic 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) in the waters south of 60^{o}S. Estimates were based on sighting data obtained by JARPA between 1989/90 and 2002/03 austral summer seasons and the DISTANCE analysis program. The following conditions and assumptions were applied to these analyses: 1) distance and angle were corrected by using the results of the distance and angle estimation experiments, 2) truncation distance was 2.4 n.miles, 3) effective search half width was obtained by fitting a hazard rate model, 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 for estimations of the effective search half-width (*ws*) and the mean school size (E(s)).

Abundance estimates of humpback whale in Areas IIIE, IV, V and VIW were 4,426 (CV=0.20), 32,519 (CV=0.11), 2,759(CV=0.16), 1,551 (CV=0.24), respectively. For the total research area estimate was 41,255 (CV=0.10) in 2001/02 + 2002/03 seasons. Because data in Areas IIIE and VIW were not obtained in the peak migration period, results in these Areas are underestimated. Instantaneous increase rates of humpback whale were estimated as 18.1% (CV=0.21) and 12.2% (CV=0.21) in Areas IV and V, respectively. Expansion of humpback whale distribution was observed in Area IV between the first half (1989/90-1996/97) and the second half of surveys (1997/97-2002/03). Abundance of fin whale in Areas IIIE, IV, V and VIW were 3,382 (CV=0.52), 7,642 (CV=0.26), 3,031(CV=0.33) and 474 (CV=0.32), respectively. For the total research area estimate was 14,529 (CV=0.20) in 2001/02 + 2002/03 seasons. Instantaneous increase rates for fin whales were 29.8% (CV=0.10) and 12.9% (CV=0.25) in Areas IV and V, respectively. Preliminary estimate of this species south of 30^{o}S between 35^{o}E and 145^{o}W based on JARPA data and Japanese Scouting Vessel data (JSV) was 68,000 (CV=0.21).

KEY WORDS: ANTARCTIC, ABUNDANCE ESTIMATE, HUMPBACK WHALE, FIN WHALE,

INTRODUCTION

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 (80-130E) 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, Western Australia 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 60S (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, Antarctic minke whale *(Balaenoptera bonaerensis*) was the dominantly sighted species through the surveys from 1987/88 to 2002/03 seasons. However, in Area IV, humpback whale (*Megaptera novaeangliae*) 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, fin whale (*Balaenoptera physalus*) was the sub-dominantly sighted species in 2000/01 season (Nishiwaki *et al*., 2001a). This paper reports abundance estimates and increasing rate of these species in each Area between 1989/90 and 2002/03 seasons using the DISTANCE analysis program.

SURVEYS AND DATA COLLECTION

JARPA DATA

Sighting surveys

Unique sighting procedures to collect unbiased sighting data have been introduced in the JARPA including (1) the trackline was designed in order to cover the strata uniformly, (2) the line transect sampling procedure sampled the schools proportionally according to the densities encountered, (3) all the schools sighted were recorded, (4) searches were conducted only in wind speed 20 knot or less for northern strata and 25 knot or less in the southern strata. Details of the sighting procedures were given in the Review of the sighting survey in the JARPA (Nishiwaki *et al*., 2001b).

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 (Fig. 1). Each Area (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 1990/2000 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 Antarctic minke distribution. There are no stratifications for Areas IIIE and VIW (Fig. 4a and 4b).

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*.

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 estimate

A = area of stratum

$E(s)$ = estimated mean school size

N = numbers of schools primary sightings

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) where

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

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

Correction of the estimated angle and distance

To correct biases of distance and angle estimation, distance and angle estimation 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 analyses. A restrictive approach is followed here than for minke whales since the small number of sightings available for humpback and fin whales dictates the need to include as many data as possible.

Truncation distance

The perpendicular distance distribution was truncated at 2.4 n.miles. 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 (Table 2).

Effective search half-width

Hazard rate model with no adjustment terms 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 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

To estimate instantaneous increasing rate, inverse-variance-weighted regression model is used. The formula is

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

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

RESULTS

Distributions

Fig.1. shows the research area of JARPA. Fig. 2a and Fig. 3a show that all sighting positions of humpback and fin whales sighted between 1989/90 and 2002/03 seasons including transit surveys.

Humpback whales

Humpback whales were concentrated between 90ºand 120ºE in northern and southern strata, and were widely dispersed in other part of Area IV (Fig. 2a). 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). Compare to distribution pattern between the first half of surveys (1989/90-1996/97) and late of surveys (1997/98-2002/03), concentration area of humpback whales was expanded to the southern strata year by year between 90E^o and 120^{o}E (Figs. 2b and 2c). In Area V, they were widely dispersed on the Pacific Antarctic Ridge except the Ross Sea (Fig. 2a). The primary sighting positions of humpback whales with the searching efforts between 1989/90 and 2002/03 seasons, which were used in present analyses for current abundance estimation, are shown in Fig. 4a.

Fin whales

Fin whales tended to be distributed in Area V rather than Area IV. They were widely dispersed and also rarely found within the Prydz Bay and the Ross Sea (Fig. 3a). Compare to distribution pattern between the first half of surveys (1989/90-1995/96) and late of surveys (1996/97-2002/03), 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 2002/03 seasons, which were used in the present analyses for current abundance estimation, are shown in Fig. 4b.

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

Fig. 5. shows monthly change of the density index (DI: whales / 100 n.miles) using all effort and number of sightings for humpback and fin whales in the research area between 1989/90 and 2002/03 seasons. The DI of humpback whales was increase from December to February and decrease in March. For fin whales, the DI increase from December to March.

Abundance estimates

Table 3a-3d (For humpback whale) and Tables 4a-4d (For fin whale) 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.6a and 6b show the perpendicular distance in nautical miles used in the present analyses.

Humpback whales

Current abundance of humpback whales in Areas IIIE, IV, V and VIW (south of 60^o S) were estimated as 4,426 (CV=0.20), 32,519 (CV=0.11) in 2001/02 season and 2,759 (CV=0.16), 1,551 (CV=0.24) in 2002/03 season, respectively (Table 3a-3d). Total abundance of this species from Area IIIE to Area VIW (35^oE-145^oW) was 41,255 (CV=0.10) in 2001/02 + 2002/03 seasons (Table 5).

Summary of abundance estimates of humpback whales are shown in Table 5. In Area IIIE, present 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 and 4,426 (CV=0.20) in 2001/02 seasons. In Area IV, present abundance estimates of 4,610 (CV=0.27) in 1989/90, 4,051 (CV=0.17) in 1991/92, 2,889 (CV=0.15) in 1993/94, 7,941 (CV=0.14) in 1995/96, 10,415 (CV=0.17) in 1997/98, 18,089 (CV=0.13) in 1999/2000 and 32,519 (CV=0.11) in 2001/02 seasons. In Area V, present abundance estimates of 694 (CV=0.32) in 1990/91, 4,514 (CV=0.64) in 1992/93, 2,865 (CV=0.28) in 1994/95, 1,345 (CV=0.28) in 1996/97, 12,001 (CV=0.27) in 1998/99, 4,752 (CV=0.23) in 2000/2001, 2,759 (CV=0.16) in 2002/03 seasons. In Area VIW, present 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.

Fin whales

Current abundance of fin whale in Areas IIIE, IV, V and VIW were estimated as 3,382 (CV=0.52), 7,642 (CV=0.26) in 2001/02 and 3,031(CV=0.33) and 474 (CV=0.32) in 2002/03, respectively (Table 4a-4d). Total abundance of this species from Area IIIE to Area VIW (35^oE-145^oW) was 14,529 (CV=0.20) in 2001/02 + 2002/03 seasons (Table 5).

Summary of abundance estimates of fin whales are shown in Table 5. In Area IIIE, present 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 seasons. In Area IV, present abundance estimates of 63 (CV=0.97) in 1989/90, 129 (CV=0.64) 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 and 7,642 (CV=0.26) in 2001/02 seasons. In Area V, present 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, 1,789 (CV=0.75) in 1998/99, 1,074 (CV=0.30) in 2000/2001 and 474 (CV=0.32) in 2002/03 seasons.

Instantaneous increase rate

Humpback whales

Increase rate of this species were estimated as 18.1% (CV=0.21) and 12.2% (CV=0.21) in Areas IV and V, respectively, between 1989/90 and 2002/03 seasons (Table 6, Fig. 7a and 7b). Combined increasing rate for Areas IV and V between 1989/90 and 2002/03 was 13.7 % (CV=0.29) (Fig. 9), and combined increase rate for from Areas IIIE to VIW between 1995/96 and 2002/03 (over 8 years) was 22.3 % (CV=0.13). Significant increases were observed in each Area (Table 6).

Fin whales

Increase rates for this species were estimated as 29.8% (CV=0.10) and 12.9% (CV=0.25) in Areas IV and V, respectively (Table 6, Fig. 8a and 8b). Increase rate in Area IV was very high, due to high abundance estimation in 2001/02 season. It was noted that in this season, large number of school of this species sighted in the northern part of Area IV, abnormally. Combined increasing rate for Areas IV and V between 1989/90 and 2002/03 (over 14 years) was 20.9 % (CV=0.11) (Fig. 9), and combined increase rate for from Areas IIIE to VIW between 1995/96 and 2002/03 (over 8 years) was 13.9 % (CV=0.10) (Table 6). Significant increases were observed in each Area.

DISCUSSIONS

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.

Increasing rate of humpback whales including effect of habitat expansion in Area IV

It is known in general that the observed rates of increase are much higher than the range of 0.01 to 0.04 which was often referred in the reports of the Scientific Committee to the International Whaling Commission as to "possible" or "likely" range of maximum net recruitment rates for baleen whales (Best, 1993). Bannister (1994) reported that the rate of increase of humpback whales off Shark Bay, Western Australia between 1963 and 1991 (over 29 years) was 10.9 % per annum. 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). Present estimation of increasing rate of 18.1 % (CV=0.21) was higher than previous estimations. Present abundance estimates in Area IV increased year by year especially after 1997/98 season (Fig. 7a). After 1997/98 season, humpback whales tended to be distributed in the southern strata year by year (Ishikawa *et al*., 2000 and 2002), (Figs. 2b and 2c in this paper). These distribution changes suggested that humpback whale populations are recovering and expanding their distributions in the feeding grounds year by year. It is reasonable to support a view that present estimation of increasing rate of 18.1 % (CV=0.21) might include two phenomena of their "observed rate of increase" and "effect of habitat expansions". Further analyses are required to interprete "increasing " more precisely in the feeding grounds.

Movement of humpback whale between Areas IV and V

In Areas IV and V, there are two stocks "Group IV" and "GroupV" suggested by mark recapture analyses and mtDNA analyses. Results of analyses of mtDNA, were consistent with those from mark recapture analyses in the past. Recent mtDNA analysis, however, showed that a same animal migrated to both Areas IV (eastern part) and V (western part) in different years (Pastene *et al*.., 2000). On the other hand, abundance estimates in Area V, showed large yearly fluctuations. It is suggested that animals from the Group V could move to a part of Area IV in austral summer in some years (Fig. 7a and 7b). Total abundance estimates (Areas IV + V) less fluctuated compare with the trend of Area IV (Fig.9).

Under- estimates of abundance of humpback whales in Areas 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. 5). 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.

Current abundance estimates of fin whales

There was no abundance estimation of fin whales by use of whale sightings for each Antarctic 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°S (Butterworth *et al*., 1994). Recent estimates of this species in the whole area south of 60°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 estimate of 14,529 (CV=0.20) in the half of Antarctic Areas (35°E-145°W) and significant increases will be the first value in these Areas. In addition, we preliminarily estimated abundance of this species in the south of 30°S between 35°E and 145°W, using current estimations and Japanese Scouting Vessel (JSV) data as 68,000 (CV=0.21) by same manner as Butterworth *et al*., 1994. Because they mainly distributed in the area north of 60°S (Kasamatsu, 1993), large yearly fluctuation in the area south of 60°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. Further surveys are necessary for improving the precision of the annual rate of increase in the feeding ground.

Under- estimates of abundance of fin whales in Areas IIIE and VIW

There were no estimations of this species by sighting surveys in these Areas. Present estimates between 1995/96 and 2001/02 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. 5). 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 the future.

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Table 1. Estimated observer bias in distance and angle estimation (JARPA) during 1989/90 to 2001/02.

	1989/90			1990/91			1991/92			1992/93		
platform	Vessel	distance	angle	Vessel	distance	angle	Vessel	distance	angle	Vessel	distance	angle
barrel	K01	n.s.	0.930	K01	n.s.	1.051	K01	0.930	n.s.	K01	n.s.	0.942
upper bridge		n.s.	0.872		0.953	1.064		n.s.	0.950		1.083	0.941
barrel	T18	n.s.	1.047	T18	n.s.	n.s.	T18	n.s.	n.s.	T18	n.s.	n.s.
upper bridge		n.s.	n.s.		n.s.	n.s.		0.960	n.s.		n.s.	n.s.
barrel	T25	1.099	n.s.	T25	0.882	n.s.	T25	n.s.	n.s.	T25	n.s.	1.056
upper bridge		1.075	n.s.		0.961	n.s.		1.070	n.s.		n.s.	1.082

	1993/94			1994/95			1995/96			1996/97		
platform	Vessel	distance	angle	Vessel	distance	angle	Vessel	distance	angle	Vessel	distance	angle
barrel	K01	0.863	n.s.	K01	n.s.	n.s.	K01	n.s.	n.s.	K01	0.822	n.s.
upper bridge		n.s.	n.s.		n.s.	0.933		n.s.	n.s.		0.844	n.s.
barrel	T18	n.s.	n.s.	T18	n.s.	n.s.	T18	n.s.	n.s.	T18	0.711	n.s.
upper bridge		n.s.	n.s.		0.934	n.s.		1.110	0.956		n.s.	n.s.
barrel	T25	n.s.	n.s.	T25	0.940	n.s.	T25	0.889	n.s.	T25	0.799	n.s.
upper bridge		n.s.	1.057		0.902	n.s.		0.905	1.040		0.773	1.036
							KS2	n.s.	0.905	KS2	0.789	0.951
								n.s.	0.898		0.662	1.050

	1997/98			1998/99			1999/2000			2000/2001		
platform	Vessel	distance	angle	Vessel	distance	angle	Vessel	distance	angle	Vessel	distance	angle
barrel	K01	0.842	n.s.	K01	0.902	n.s.	K01	n.s.	n.s.	K01	n.s.	1.051
upper bridge		0.746	n.s.		0.956	1.057		1.050	n.s.		n.s.	n.s.
barrel	T18	0.902	n.s.	T25	n.s.	1.053	T25	n.s.	1.081	T25	n.s.	n.s.
upper bridge		0.788	n.s.		n.s.	1.065		n.s.	n.s.		1.062	n.s.
barrel	T25	0.729	n.s.	YS1	0.923	n.s.	YS1	n.s.	n.s.	YS1	n.s.	n.s.
upper bridge		0.914	n.s.		0.968	n.s.		n.s.	n.s.		n.s.	n.s.
barrel	KS2	0.876	n.s.	KS2	0.928	0.950	KS2	n.s.	0.930	KS2	n.s.	n.s.
upper bridge		0.788	n.s.		n.s.	n.s.		n.s.	n.s.		n.s.	0.861

	2001/2002			2002/2003		
platform	Vessel	distance	angle	Vessel	distance	angle
barrel	K01	0.957	0.921	K01	1.073	n.s.
upper bridge		0.957	n.s.		n.s.	n.s.
barrel	T25	0.951	n.s.	YS1	1.051	1.037
upper bridge		0.960	n.s.		1.058	0.938
barrel	YS1	n.s.	n.s.	YS2	1.050	n.s.
upper bridge		n.s.	n.s.		n.s.	n.s.
barrel	KS2	n.s.	n.s.	KS2	n.s.	n.s.
upper bridge		n.s.	n.s.		n.s.	1.088

*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

	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

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

	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

Table. 3a. Abundance estimates of humpback whale in Area IV (south of 60°S) between 1989/90 and 2001/02. 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	NW	218,378	21.2	1987.6	1.067	0.297	0.937	0.210	1.804	0.056	1.027	2,244	0.32
	NE	213,661	20.0	1964.4	1.018	0.448	0.937	0.210	1.804	0.056	0.980	2,094	0.47
	SW	41,683	10.3	2518.3	0.409	0.392	0.937	0.210	1.804	0.056	0.394	164	0.41
	SE	40,371	1.0	1362.2	0.073	0.732	0.937	0.210	1.804	0.056	0.071	29	0.76
	PB	34,628	2.0	831.9	0.240	0.482	0.937	0.210	1.804	0.056	0.231	80	0.53
	Total	548,721	54.5	8664.4	0.629	0.215	0.937	0.210	1.804	0.056	**0.840**	**4,610**	**0.27**
1991/92	NW	219,773	42.0	2482.7	1.691	0.229	1.323	0.103	1.813	0.041	1.158	2,546	0.24
	NE	217,764	16.0	2173.9	0.736	0.300	1.323	0.103	1.813	0.041	0.504	1,098	0.31
	SW	34,259	19.2	2237.5	0.857	0.355	1.323	0.103	1.813	0.041	0.587	201	0.36
	SE	34,871	16.7	2281.7	0.732	0.383	1.323	0.103	1.813	0.041	0.501	175	0.39
	PB	27,733	1.0	607.5	0.165	0.730	1.323	0.103	1.813	0.041	0.113	31	0.74
	Total	534,400	94.9	9783.3	0.970	0.150	1.323	0.103	1.813	0.041	**0.758**	**4,051**	**0.17**
1993/94	NW	232,782	43.8	4160.7	1.053	0.192	1.315	0.093	1.670	0.041	0.668	1,556	0.20
	NE	171,281	28.3	3175.1	0.891	0.291	1.315	0.093	1.670	0.041	0.566	969	0.30
	SW	33,394	24.7	2377.7	1.038	0.333	1.315	0.093	1.670	0.041	0.659	220	0.34
	SE	30,908	7.0	2258.9	0.310	0.315	1.315	0.093	1.670	0.041	0.197	61	0.32
	PB	35,196	4.0	1077.0	0.371	0.688	1.315	0.093	1.670	0.041	0.236	83	0.69
	Total	503,561	107.8	13049.4	0.826	0.137	1.315	0.093	1.670	0.041	**0.574**	**2,889**	**0.15**
1995/96	NW	217,044	121.7	3530.5	3.447	0.171	1.325	0.062	1.747	0.027	2.272	4,931	0.17
	NE	228,383	46.0	2979.7	1.543	0.279	1.325	0.062	1.747	0.027	1.017	2,323	0.28
	SW	33,433	54.4	2851.2	1.907	0.318	1.325	0.062	1.747	0.027	1.257	420	0.32
	SE	29,932	27.6	2039.9	1.353	0.246	1.325	0.062	1.747	0.027	0.892	267	0.25
	PB	27,929	0.0	1321.8	-	-	-	-	-	-	-	0	-
	Total	536,721	249.6	12723.1	1.962	0.123	1.325	0.062	1.747	0.027	**1.480**	**7,941**	**0.14**
1997/98	NW	224,230	184.4	3367.2	5.478	0.202	1.725	0.044	1.760	0.020	2.794	6,265	0.20
	NE	224,567	101.6	3622.7	2.803	0.358	1.725	0.044	1.760	0.020	1.430	3,211	0.36
	SW	31,505	165.9	3432.5	4.833	0.158	1.725	0.044	1.760	0.020	2.465	777	0.16
	SE	41,450	23.9	3195.9	0.747	0.224	1.725	0.044	1.760	0.020	0.381	158	0.22
	PB	2,481	2.0	490.0	0.408	0.758	1.725	0.044	1.760	0.020	0.208	5	0.76
	Total	524,233	477.8	14108.3	3.386	0.122	1.725	0.044	1.760	0.020	**1.987**	**10,415**	**0.17**
1999/2000	NW	236,307	54.5	2825.3	1.930	0.193	0.886	0.099	1.735	0.021	1.890	4,466	0.20
	NE	229,576	158.9	3550.8	4.475	0.206	0.886	0.099	1.735	0.021	4.382	10,061	0.21
	SW	34,825	104.1	2336.7	4.455	0.249	0.886	0.099	1.735	0.021	4.363	1,519	0.25
	SE	33,129	165.0	2704.3	6.100	0.191	0.886	0.099	1.735	0.021	5.974	1,979	0.20
	PB	27,000	3.0	1244.7	0.241	0.610	0.886	0.099	1.735	0.021	0.236	64	0.62
	Total	560,837	485.4	12661.8	3.834	0.110	0.886	0.099	1.735	0.021	**3.225**	**18,089**	**0.13**
2001/02	NW	200,738	251.4	3043.6	8.260	0.190	1.246	0.033	1.823	0.016	6.042	12,129	0.19
	NE	223,108	237.2	3271.6	7.250	0.207	1.246	0.033	1.823	0.016	5.304	11,833	0.21
	SW	61,517	386.1	2321.8	16.628	0.176	1.246	0.033	1.823	0.016	12.165	7,483	0.18
	SE	66,790	63.4	2885.2	2.196	0.257	1.246	0.033	1.823	0.016	1.607	1,073	0.26
	PB	29,155	0.0	1033.7	-	-	-	-	-	-	-	0	-
	Total	581,308	938.0	12555.9	7.471	0.104	1.246	0.033	1.823	0.016	**5.594**	**32,519**	**0.11**

Table. 3b. Abundance estimates of humpback whale in Area V (south of 60°S) between 1990/91 and 2002/03 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**
1990/91	NW	232,898	1.0	2,726.8	0.037	1.10	1.186	0.19	1.399	0.09	0.022	50	1.12
	NE	347,440	1.0	2,498.9	0.040	0.82	1.186	0.19	1.399	0.09	0.024	82	0.85
	SW	62,355	21.7	1,635.0	1.328	0.37	1.186	0.19	1.399	0.09	0.783	488	0.39
	SE	208,511	1.0	1,670.0	0.060	0.96	1.186	0.19	1.399	0.09	0.035	74	0.98
	Total	851,204	24.7	8,530.7	0.290	0.33	1.186	0.19	1.399	0.09	**0.082**	**694**	**0.32**
1992/93	NW	332,682	5.0	2,299.3	0.217	1.43	0.605	0.26	2.000	0.08	0.359	1,195	1.44
	NE	290,526	9.0	1,661.5	0.542	0.86	0.605	0.26	2.000	0.08	0.895	2,600	0.88
	SW	43,572	5.0	1,907.4	0.262	0.49	0.605	0.26	2.000	0.08	0.433	189	0.53
	SE	180,745	4.0	2,256.3	0.177	0.64	0.605	0.26	2.000	0.08	0.293	529	0.67
	Total	847,525	23.0	8,124.5	0.283	0.48	0.605	0.26	2.000	0.08	**0.533**	**4,514**	**0.64**
1994/95	NW	194,879	14.0	3,229.4	0.433	0.75	1.683	0.08	1.818	0.06	0.234	456	0.75
	NE	303,617	26.1	2,554.1	1.022	0.41	1.683	0.08	1.818	0.06	0.552	1,677	0.42
	SW	40,116	41.6	2,469.0	1.687	0.20	1.683	0.08	1.818	0.06	0.911	366	0.21
	SE	175,421	5.0	1,293.0	0.386	0.52	1.683	0.08	1.818	0.06	0.209	366	0.52
	Total	714,033	86.7	9,545.5	0.909	0.20	1.683	0.08	1.818	0.06	**0.401**	**2,865**	**0.28**
1996/97	NW	305,819	1.0	2,784.6	0.036	1.68	1.510	0.16	1.601	0.07	0.019	58	1.69
	NE	363,668	14.0	3,133.4	0.446	0.36	1.510	0.16	1.601	0.07	0.236	859	0.37
	SW	40,130	16.6	3,124.4	0.531	0.38	1.510	0.16	1.601	0.07	0.281	113	0.40
	SE	208,224	6.0	2,098.5	0.286	0.50	1.510	0.16	1.601	0.07	0.152	316	0.51
	Total	917,841	37.5	11,140.9	0.337	0.23	1.510	0.16	1.601	0.07	**0.147**	**1,345**	**0.28**
1998/99	NW	321,375	11.8	1,830.6	0.644	0.51	0.664	0.23	1.707	0.05	0.828	2,662	0.54
	NE	311,050	21.7	1,226.9	1.767	0.39	0.664	0.23	1.707	0.05	2.272	7,066	0.41
	SW	45,455	30.5	2,333.5	1.309	0.43	0.664	0.23	1.707	0.05	1.682	765	0.45
	SE	52,553	34.9	1,561.0	2.233	0.15	0.664	0.23	1.707	0.05	2.871	1,509	0.19
	Total	730,433	98.9	6,952.0	1.422	0.18	0.664	0.23	1.707	0.05	**1.643**	**12,001**	**0.27**
2000/01	NW	249,712	43.2	3,751.9	1.153	0.39	1.318	0.16	1.751	0.04	0.766	1,913	0.40
	NE	334,377	43.0	3,941.1	1.092	0.29	1.318	0.16	1.751	0.04	0.726	2,426	0.31
	SW	64,854	30.2	3,152.9	0.958	0.22	1.318	0.16	1.751	0.04	0.637	413	0.25
	SE	105,458	0.0	3,320.2	-	-	-	-	-	-	-	0	-
	Total	754,401	116.5	14,166.1	0.822	0.19	1.318	0.16	1.751	0.04	**0.630**	**4,752**	**0.23**
2002/03	NW	257,084	12.0	2,777.2	0.432	0.39	1.649	0.09	1.630	0.05	0.214	549	0.40
	NE	338,026	57.5	5,077.1	1.132	0.18	1.649	0.09	1.630	0.05	0.560	1,892	0.19
	SW	65,671	18.8	2,209.8	0.852	0.33	1.649	0.09	1.630	0.05	0.421	277	0.34
	SE	58,424	3.0	2,111.9	0.142	0.49	1.649	0.09	1.630	0.05	0.070	41	0.49
	Total	719,205	91.3	12,176.0	0.750	0.14	1.649	0.09	1.630	0.05	**0.384**	**2,759**	**0.16**

Table. 3c. Abundance estimates of humpback whale in Area IIIE between 1995/96 and 2001/02 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**
1995/96	FIIIE	378,299	53.1	5,646.8	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	6,704.0	0.369	0.22	1.730	0.19	1.818	0.06	**0.194**	**539**	**0.25**
1999/2000	FIIIE	226,025	141.7	3,679.7	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	4,822.9	2.038	0.20	1.657	0.06	2.027	0.03	**1.247**	**4,426**	**0.20**

Table. 3d. Abundance estimates of humpback whale in Area VIW between 1996/97 and 2002/03 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**
1996/97	FVIW	137,886	62.5	6,464.2	0.967	0.16	1.229	0.15	1.768	0.05	**0.696**	**959**	**0.18**
1998/99	SVIW	316,727	5.0	1,114.5	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	4,383.6	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	5,950.2	0.808	0.22	1.132	0.17	1.402	0.06	**0.500**	**1,551**	**0.24**

Table. 4a. Abundance estimates of fin whale in Area IV (south of 60^{o}S) between 1989/90 and 2001/02. 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	NW	218,378	0.0	1,987.6	-	-	-	-	-	-	-	-	-
	NE	213,661	1.0	1,964.4	0.051	0.88	3.000	0.00	3.000	0.67	0.025	54	1.10
	SW	41,683	1.0	2,518.3	0.040	0.89	3.000	0.00	3.000	0.67	0.020	8	1.11
	SE	40,371	0.0	1,362.2	-	-	-	-	-	-	-	-	-
	PB	34,628	0.0	831.9	-	-	-	-	-	-	-	-	-
	Total	548,721	2.0	8,664.4	0.023	0.62	3.000	0.00	3.000	0.67	**0.011**	**63**	**0.97**
1991/92	NW	219,773	3.1	2,482.7	0.124	0.60	1.884	0.81	1.174	0.39	0.039	85	0.81
	NE	217,764	1.0	2,173.9	0.046	0.95	1.884	0.81	1.174	0.39	0.014	31	1.31
	SW	34,259	0.0	2,237.5	-	-	-	-	-	-	-	-	-
	SE	34,871	2.7	2,281.7	0.120	1.21	1.884	0.81	1.174	0.39	0.038	13	1.51
	PB	27,733	0.0	607.5	-	-	-	-	-	-	-	-	-
	Total	534,400	6.8	9,783.3	0.070	0.57	1.884	0.81	1.174	0.39	**0.024**	**129**	**0.64**
1993/94	NW	232,782	1.0	4,160.7	0.024	0.95	1.227	0.27	2.000	0.27	0.020	46	1.02
	NE	171,281	3.0	3,175.1	0.094	0.44	1.227	0.27	2.000	0.27	0.077	132	0.53
	SW	33,394	1.0	2,377.7	0.042	1.17	1.227	0.27	2.000	0.27	0.034	11	1.23
	SE	30,908	0.0	2,258.9	-	-	-	-	-	-	-	-	-
	PB	35,196	0.0	1,077.0	-	-	-	-	-	-	-	-	-
	Total	503,561	5.0	13,049.4	0.038	0.40	1.227	0.27	2.000	0.27	**0.038**	**189**	**0.45**
1995/96	NW	217,044	8.0	3,530.5	0.227	0.49	1.380	0.09	3.466	0.21	0.285	618	0.50
	NE	228,383	5.0	2,979.7	0.168	0.41	1.380	0.09	3.466	0.21	0.211	481	0.43
	SW	33,433	0.0	2,851.2	-	-	-	-	-	-	-	-	-
	SE	29,932	5.0	2,039.9	0.245	0.73	1.380	0.09	3.466	0.21	0.308	92	0.74
	PB	27,929	0.0	1,321.8	-	-	-	-	-	-	-	-	-
	Total	536,721	18.0	12,723.1	0.141	0.32	1.380	0.09	3.466	0.21	**0.222**	**1,191**	**0.32**
1997/98	NW	224,230	3.9	3,367.2	0.117	0.51	1.690	0.17	3.167	0.14	0.110	246	0.53
	NE	224,567	6.0	3,622.7	0.166	0.46	1.690	0.17	3.167	0.14	0.155	348	0.48
	SW	31,505	5.0	3,432.5	0.146	0.58	1.690	0.17	3.167	0.14	0.136	43	0.60
	SE	41,450	0.0	3,195.9	-	-	-	-	-	-	-	-	-
	PB	2,481	0.0	490.0	-	-	-	-	-	-	-	-	-
	Total	524,233	14.9	14,108.3	0.106	0.30	1.690	0.17	3.167	0.14	**0.122**	**637**	**0.34**
1999/2000	NW	236,307	1.5	2,825.3	0.052	0.69	1.455	0.15	3.740	0.13	0.067	157	0.70
	NE	229,576	8.0	3,550.8	0.225	0.27	1.455	0.15	3.740	0.13	0.290	665	0.29
	SW	34,825	4.0	2,336.7	0.171	0.60	1.455	0.15	3.740	0.13	0.220	77	0.61
	SE	33,129	0.0	2,704.3	-	-	-	-	-	-	-	-	-
	PB	27,000	9.5	1,244.7	0.760	1.10	1.455	0.15	3.740	0.13	0.977	264	1.11
	Total	560,837	22.9	12,661.8	0.181	0.48	1.455	0.15	3.740	0.13	**0.207**	**1,162**	**0.32**
2001/02	NW	200,738	24.0	3,043.6	0.787	0.42	1.367	0.11	5.024	0.10	1.447	2,906	0.42
	NE	223,108	15.0	3,271.6	0.458	0.60	1.367	0.11	5.024	0.10	0.842	1,879	0.60
	SW	61,517	56.9	2,321.8	2.452	0.39	1.367	0.11	5.024	0.10	4.507	2,772	0.40
	SE	66,790	2.0	2,885.2	0.069	0.72	1.367	0.11	5.024	0.10	0.127	85	0.73
	PB	29,155	0.0	1,033.7	-	-	-	-	-	-	-	-	-
	Total	581,308	97.9	12,555.9	0.780	0.27	1.367	0.11	5.024	0.10	**1.315**	**7,642**	**0.26**

Table. 4b. Abundance estimates of fin whale in Area V (south of 60°S) between 1990/91 and 2002/03 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**
1990/91	NW	232,898	2.0	2,726.8	0.073	0.65	1.309	0.24	1.455	0.14	0.041	95	0.68
	NE	347,440	7.0	2,498.9	0.280	0.32	1.309	0.24	1.455	0.14	0.156	541	0.36
	SW	62,355	1.0	1,635.0	0.061	1.15	1.309	0.24	1.455	0.14	0.034	21	1.19
	SE	208,511	1.0	1,670.0	0.060	1.10	1.309	0.24	1.455	0.14	0.033	69	1.14
	Total	851,204	11.0	8,530.7	0.129	0.27	1.309	0.24	1.455	0.14	**0.085**	**726**	**0.31**
1992/93	NW	332,682	2.0	2,299.3	0.087	0.47	1.019	0.38	1.833	0.13	0.078	260	0.62
	NE	290,526	6.5	1,661.5	0.392	0.42	1.019	0.38	1.833	0.13	0.352	1,023	0.48
	SW	43,572	2.0	1,907.4	0.105	0.61	1.019	0.38	1.833	0.13	0.094	41	0.67
	SE	180,745	1.0	2,256.3	0.044	1.36	1.019	0.38	1.833	0.13	0.040	72	1.42
	Total	847,525	11.5	8,124.5	0.142	0.30	1.019	0.38	1.833	0.13	**0.165**	**1,397**	**0.38**
1994/95	NW	194,879	8.0	3,229.4	0.248	0.49	1.356	0.24	3.604	0.12	0.329	641	0.52
	NE	303,617	24.4	2,554.1	0.955	0.50	1.356	0.24	3.604	0.12	1.269	3,852	0.53
	SW	40,116	11.0	2,469.0	0.445	0.35	1.356	0.24	3.604	0.12	0.591	237	0.39
	SE	175,421	8.9	1,293.0	0.688	0.62	1.356	0.24	3.604	0.12	0.914	1,603	0.67
	Total	714,033	52.3	9,545.5	0.548	0.27	1.356	0.24	3.604	0.12	**0.887**	**6,334**	**0.37**
1996/97	NW	305,819	3.0	2,784.6	0.108	0.53	1.107	0.20	2.216	0.14	0.108	330	0.55
	NE	363,668	7.0	3,133.4	0.223	0.41	1.107	0.20	2.216	0.14	0.224	813	0.45
	SW	40,130	4.0	3,124.4	0.128	0.86	1.107	0.20	2.216	0.14	0.128	51	0.87
	SE	208,224	1.0	2,098.5	0.048	0.61	1.107	0.20	2.216	0.14	0.048	99	0.66
	Total	917,841	15.0	11,140.9	0.135	0.32	1.107	0.20	2.216	0.14	**0.141**	**1,294**	**0.32**
1998/99	NW	321,375	7.9	1,830.6	0.432	0.85	1.351	0.16	3.402	0.15	0.544	1,748	0.86
	NE	311,050	6.0	1,226.9	0.489	0.34	1.351	0.16	3.402	0.15	0.616	1,916	0.38
	SW	45,455	3.0	2,333.5	0.129	0.54	1.351	0.16	3.402	0.15	0.162	74	0.56
	SE	52,553	21.7	1,561.0	1.387	0.35	1.351	0.16	3.402	0.15	1.747	918	0.37
	Total	730,433	38.6	6,952.0	0.555	0.27	1.351	0.16	3.402	0.15	**0.637**	**4,655**	**0.37**
2000/01	NW	249,712	43.9	3,751.9	1.171	0.30	1.441	0.08	3.111	0.19	1.264	3,157	0.32
	NE	334,377	8.0	3,941.1	0.203	0.73	1.441	0.08	3.111	0.19	0.219	733	0.75
	SW	64,854	39.6	3,152.9	1.255	0.33	1.441	0.08	3.111	0.19	1.355	879	0.35
	SE	105,458	1.0	3,320.2	0.030	2.43	1.441	0.08	3.111	0.19	0.033	34	2.44
	Total	754,401	92.5	14,166.1	0.653	0.21	1.441	0.08	3.111	0.19	**0.637**	**4,802**	**0.25**
2002/03	NW	257,084	25.0	2,777.2	0.900	0.40	1.383	0.13	2.798	0.14	0.911	2,341	0.41
	NE	338,026	4.0	5,077.1	0.079	0.42	1.383	0.13	2.798	0.14	0.080	269	0.44
	SW	65,671	14.0	2,209.8	0.634	0.53	1.383	0.13	2.798	0.14	0.641	421	0.56
	SE	58,424	0.0	2,111.9	-	-	-	-	-	-	-	-	-
	Total	719,205	43.0	12,176.0	0.353	0.29	1.383	0.13	2.798	0.14	**0.421**	**3,031**	**0.33**

Table. 4c. Abundance estimates of fin whale in Area IIIE between 1995/96 and 2001/02 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**
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**

Table. 4d. Abundance estimates of fin whale in Area VIW between 1996/97 and 2002/03 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**
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	316,727	5.0	1114.5	0.449	0.73	1.351	0.16	3.402	0.15	**0.565**	**1,789**	**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**

Table. 5. Summary of abundance estimates of humpback and fin whales for each season obtained in this paper between 1989/90 and 2002/03 season. Truncate is 2.4 n.miles. The g (0) is assumed to be 1. P: estimated population abundance (individuals). Above : humpback whale, below: fin whale.

Humpback	Seasons		Area IIIE	Area IV	Area V	Area VIW	Total
	1989/90 + 1990/91	P	-	4,610	694	-	5,304
		CV	-	0.27	0.32	-	0.23
	1991/92+ 1992/93	P	-	4,051	4,514	-	8,565
		CV	-	0.17	0.64	-	0.35
	1993/94+ 1994/95	P	-	2,889	2,865	-	5,754
		CV	-	0.15	0.28	-	0.16
	1995/96+ 1996/97	P	2,224	7,941	1,345	959	12,469
		CV	0.18	0.14	0.28	0.18	0.10
	1997/98+ 1998/99	P	539	10,415	12,001	1,827	24,782
		CV	0.25	0.17	0.27	0.69	0.16
	1999/00+ 2000/01	P	8,390	18,089	4,752	2,448	33,679
		CV	0.14	0.13	0.23	0.20	0.09
	2001/02+ 2002/03	P	4,426	32,519	2,759	1,551	41,255
		CV	0.20	0.11	0.16	0.24	0.09

Fin	Seasons	P CV	Area IIIE	Area IV	Area V	Area VIW	Total
	1989/90 + 1990/91	P	-	63	726	-	789
		CV	-	0.97	0.31	-	0.30
	1991/92+ 1992/93	P	-	129	1,397	-	1,526
		CV	-	0.64	0.38	-	0.35
	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	1,789	7,159
		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	7,642	3,031	474	14,529
		CV	0.52	0.26	0.33	0.32	0.20

Table. 6. Summary of estimated instantaneous increase rates for humpback and fin whales. Inverse-variance-weighted regression model is used in present analyses.

Species	Area	Seasons	estimate	CV	p-value	R^2
Humpback	IV	1989/90 - 2002/03 (over 14 years)	0.181	0.213	p<0.05	0.816
Humpback	V	1989/90 - 2002/03 (over 14 years)	0.122	0.213	p<0.05	0.816
Humpback	IV+V	1989/90 - 2002/03 (over 14 years)	0.137	0.278	p<0.05	0.722
Humpback	III+IV+V+VI	1995/96 - 2002/03 (over 8 years)	0.223	0.132	p<0.05	0.966
Fin	IV	1989/90 - 2002/03 (over 14 years)	0.298	0.098	p<0.05	0.954
Fin	V	1989/90 - 2002/03 (over 14 years)	0.129	0.252	p<0.05	0.760
Fin	IV+V	1989/90 - 2002/03 (over 14 years)	0.209	0.114	p<0.05	0.939
Fin	III+IV+V+VI	1995/96 - 2002/03 (over 8 years)	0.139	0.090	p<0.05	0.984

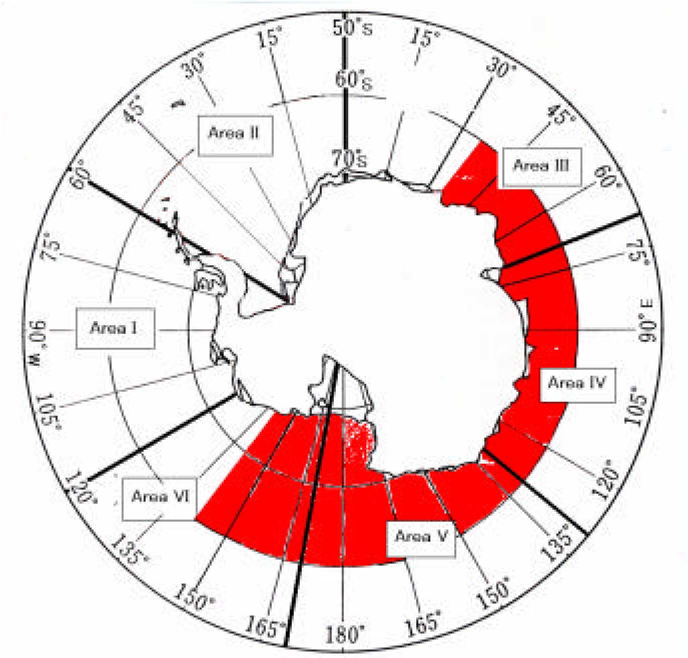

Fig.1. The IWC Antarctic Areas for the management of baleen whales (except Bryde's whale) and research Area of the JARPA surveys between 35°E and 145°W (colored). Areas III east (IIIE: 35 °E-70°E), IV(70° E-130° E), V (130°E-170°W) and VI west (VIW: 170°W -145°W).

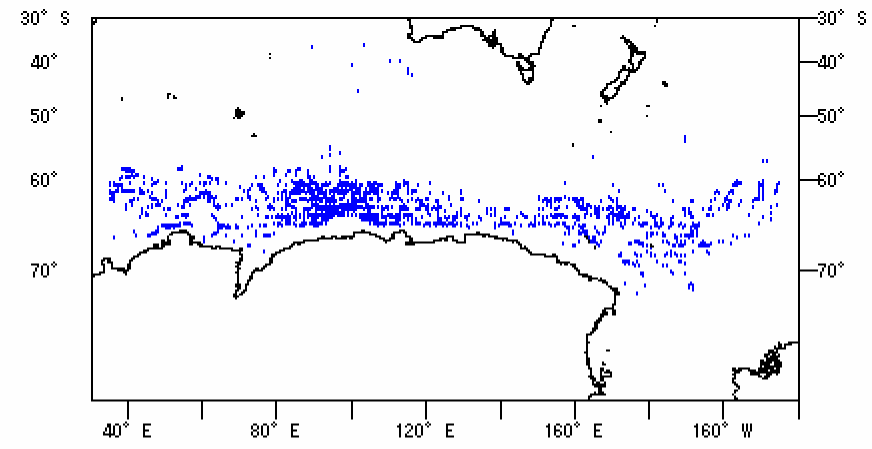

Fig.2a. Position of the primary sightings for humpback whales in JARPA surveys between 1989/90 and 2002/03 seasons including transit surveys.

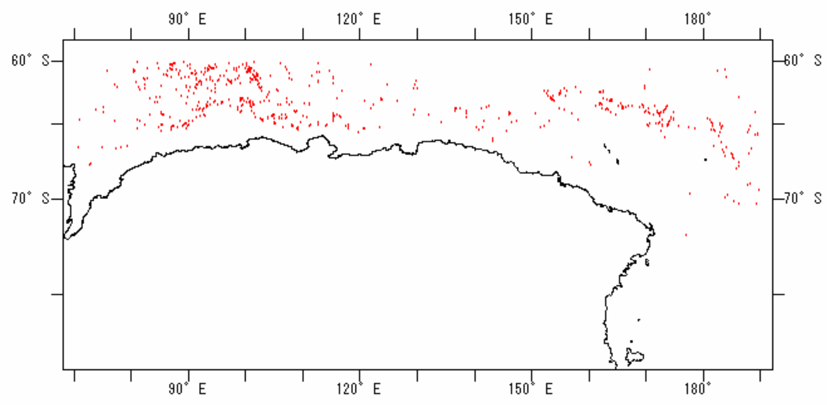

Fig.2b. Position of the primary sightings of humpback whales in the first half of JARPA in Areas IV and V between 1989/90 and 1996/97 surveys by three sighting and sampling vessels.

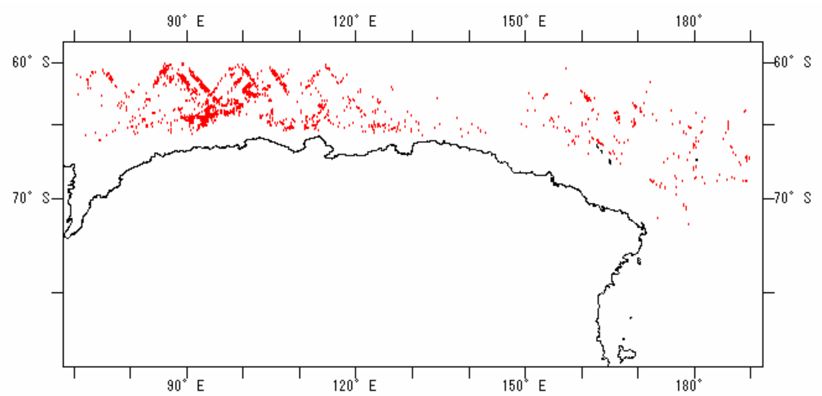

Fig.2c. Position of the primary sightings of humpback whales in the second half of JARPA in Areas IV and V between 1997/98 and 2002/03 seasons by three sighting and sampling vessels.

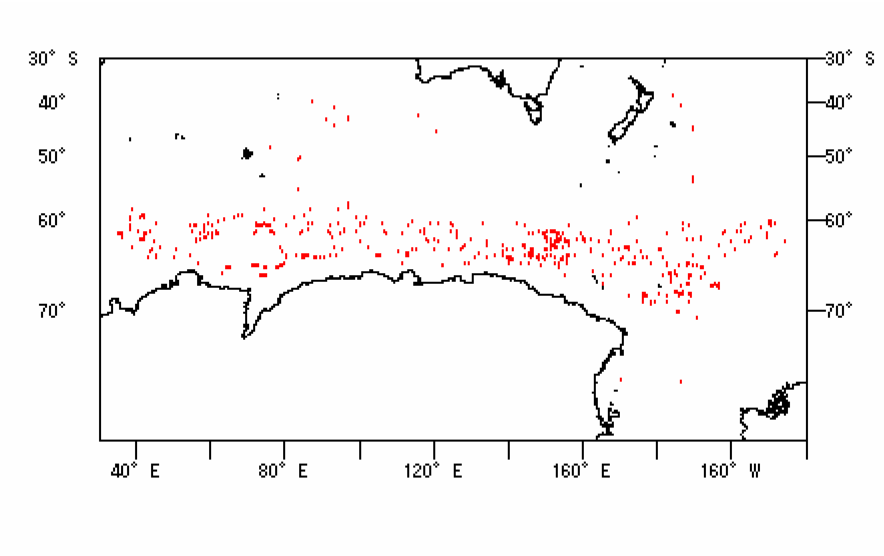

Fig.3a. Sighting position of the fin whales in JARPA surveys between 1989/90 and 2002/03 seasons including transit surveys.

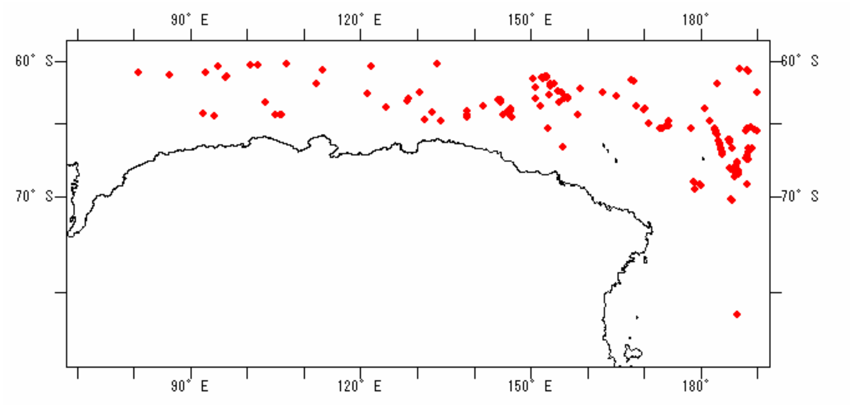

Fig.3b. Position of the primary sightings of fin whales in the first half of JARPA in Areas IV and V between 1989/90 and 1996/97 surveys by three sighting and sampling vessels.

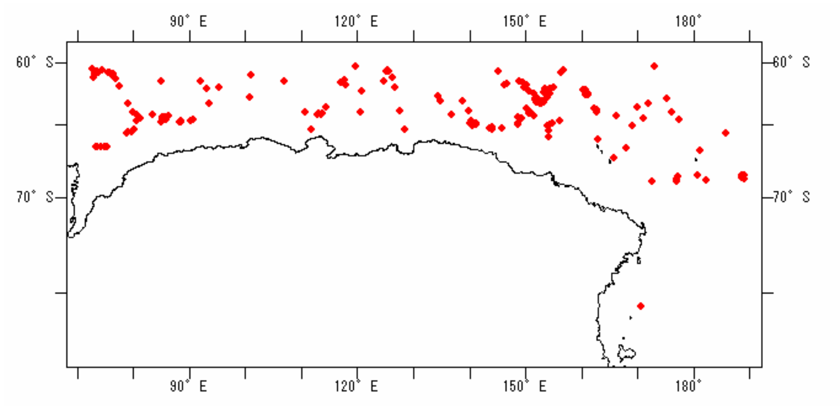

Fig.3c. Position of the primary sightings of fin whales in the second half of JARPA in Areas IV and V between 1997/98 and 2002/03 seasons including transit surveys by three sighting and sampling vessels .

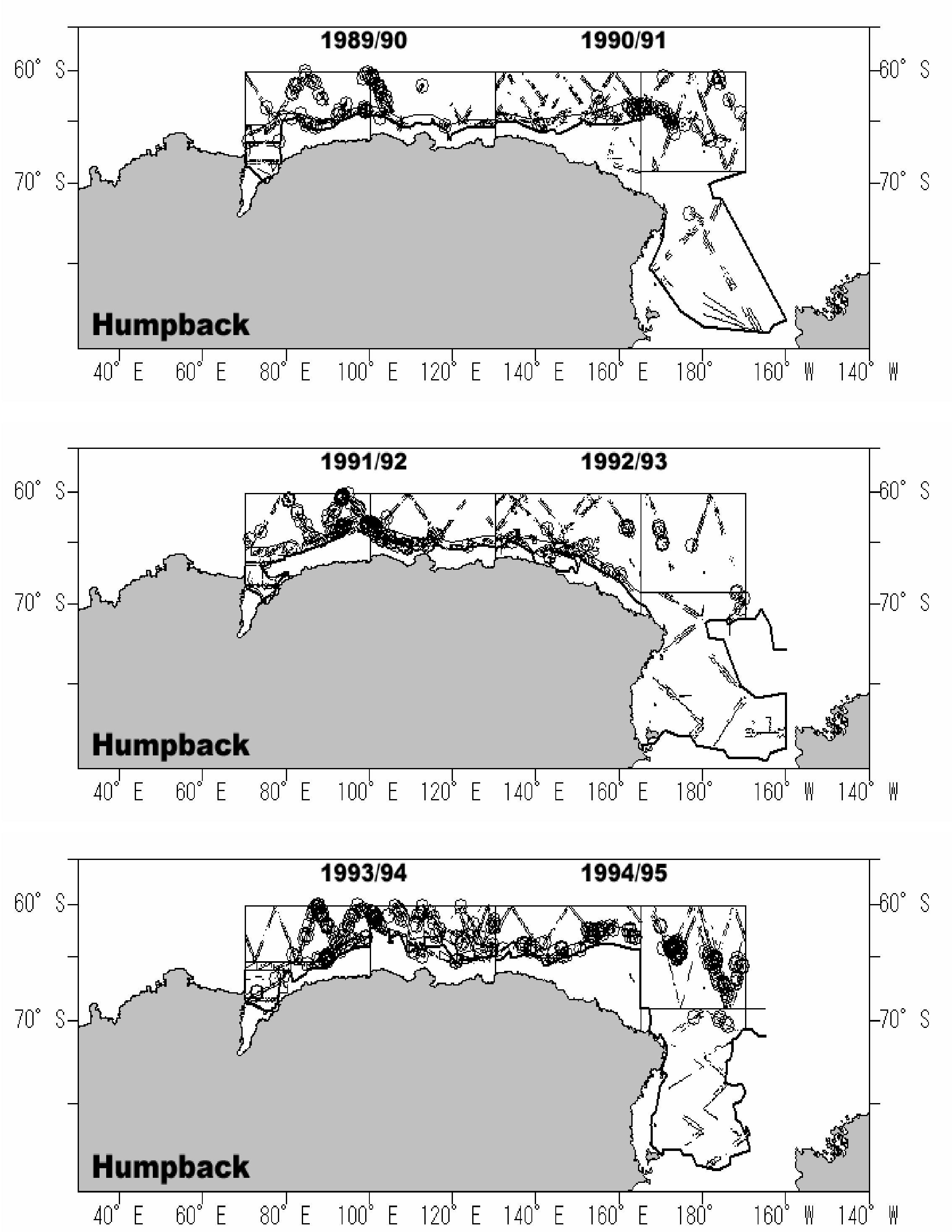

Fig. 4a. Distribution of the searching effort and position of the primary school sightings of humpback whales between 1989/90 and 2002/03 seasons which used in this analyses. Black line shows the on efforts. Bold line shows the estimated ice edge line. The circles show the primary schools of humpback whales sighted.

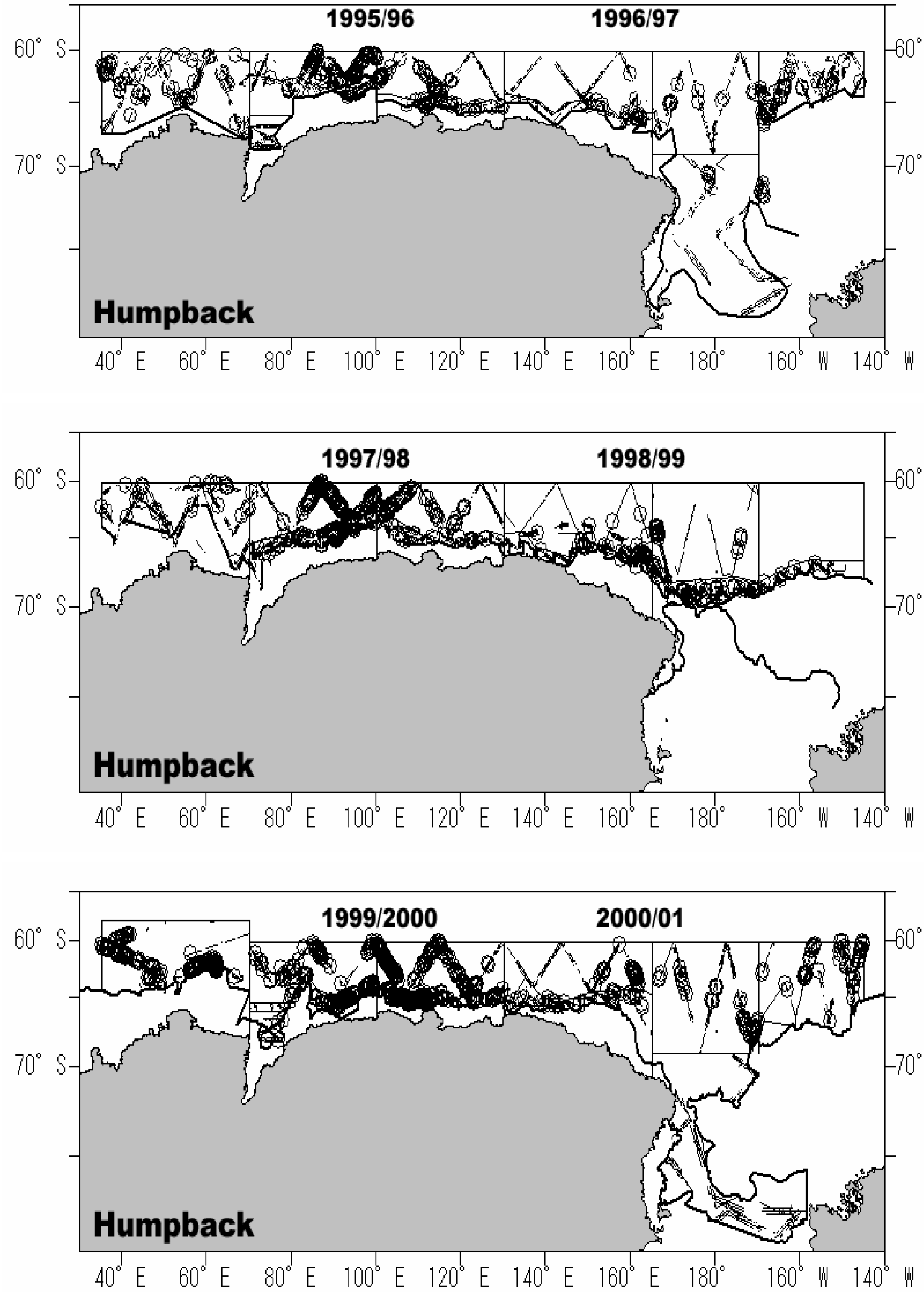

Fig. 4a. (Continued)

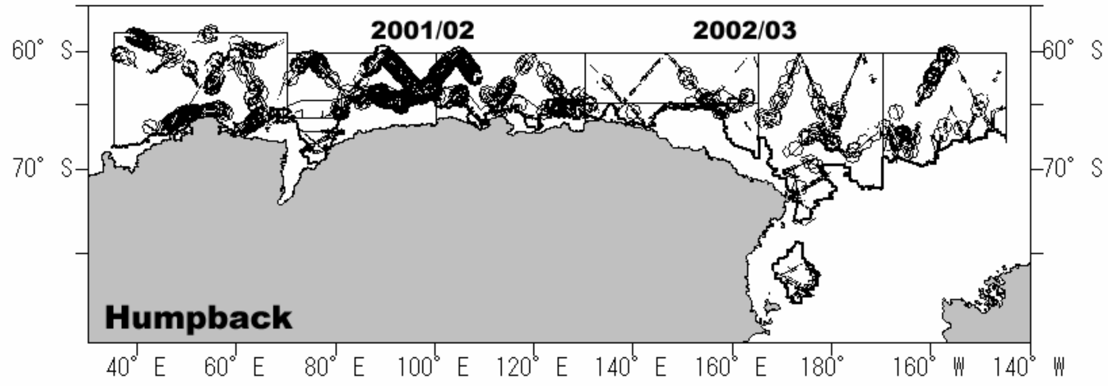

Fig. 4a. (Continued)

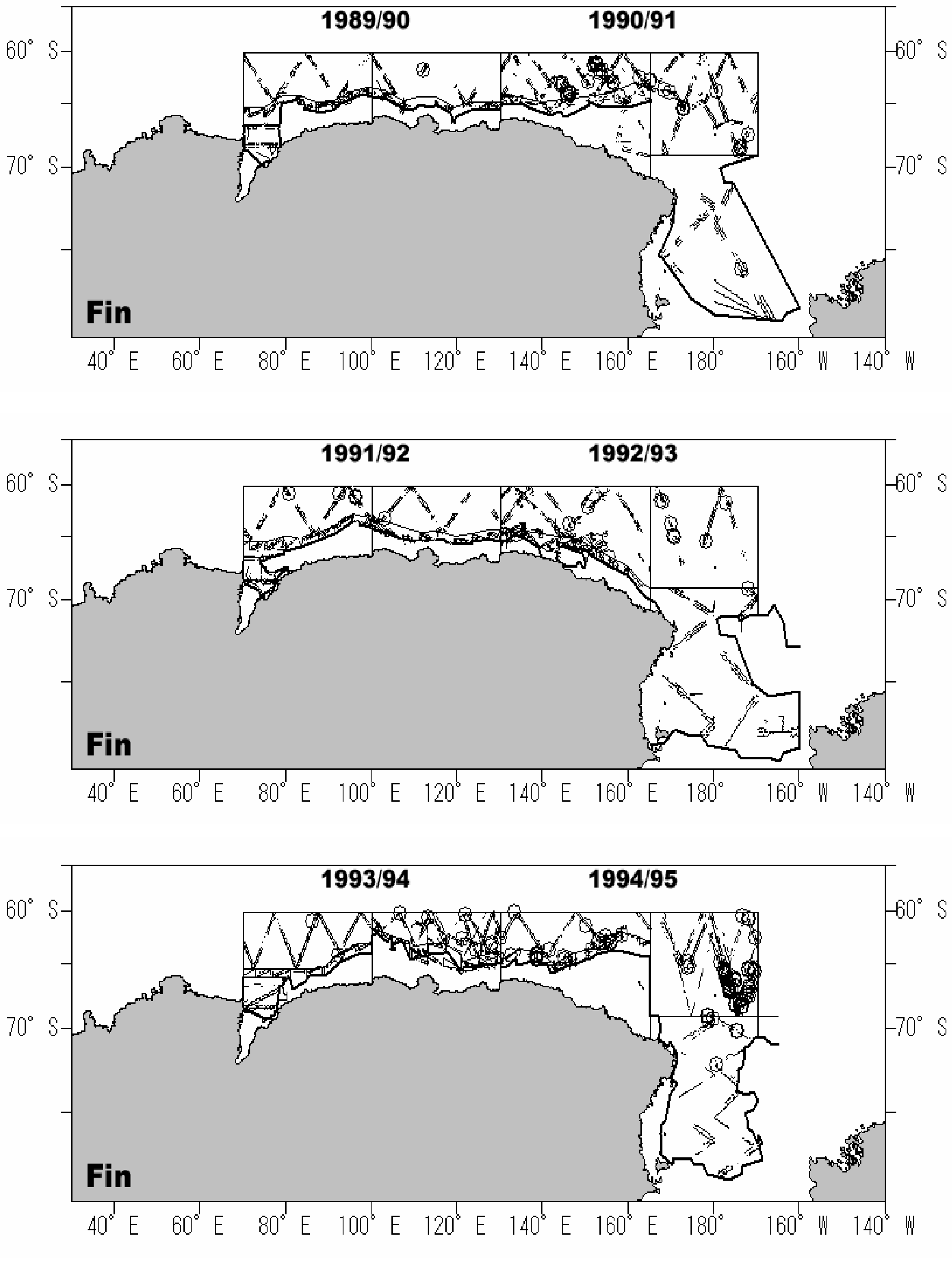

Fig. 4b. Distribution of the searching effort and sighting position of the primary school of fin whales between 1989/90 and 2002/03 seasons which used in this analyses. Black line shows the on efforts. Bold line shows the estimated ice edge line. The circles show the primary schools of fin whales sighted.

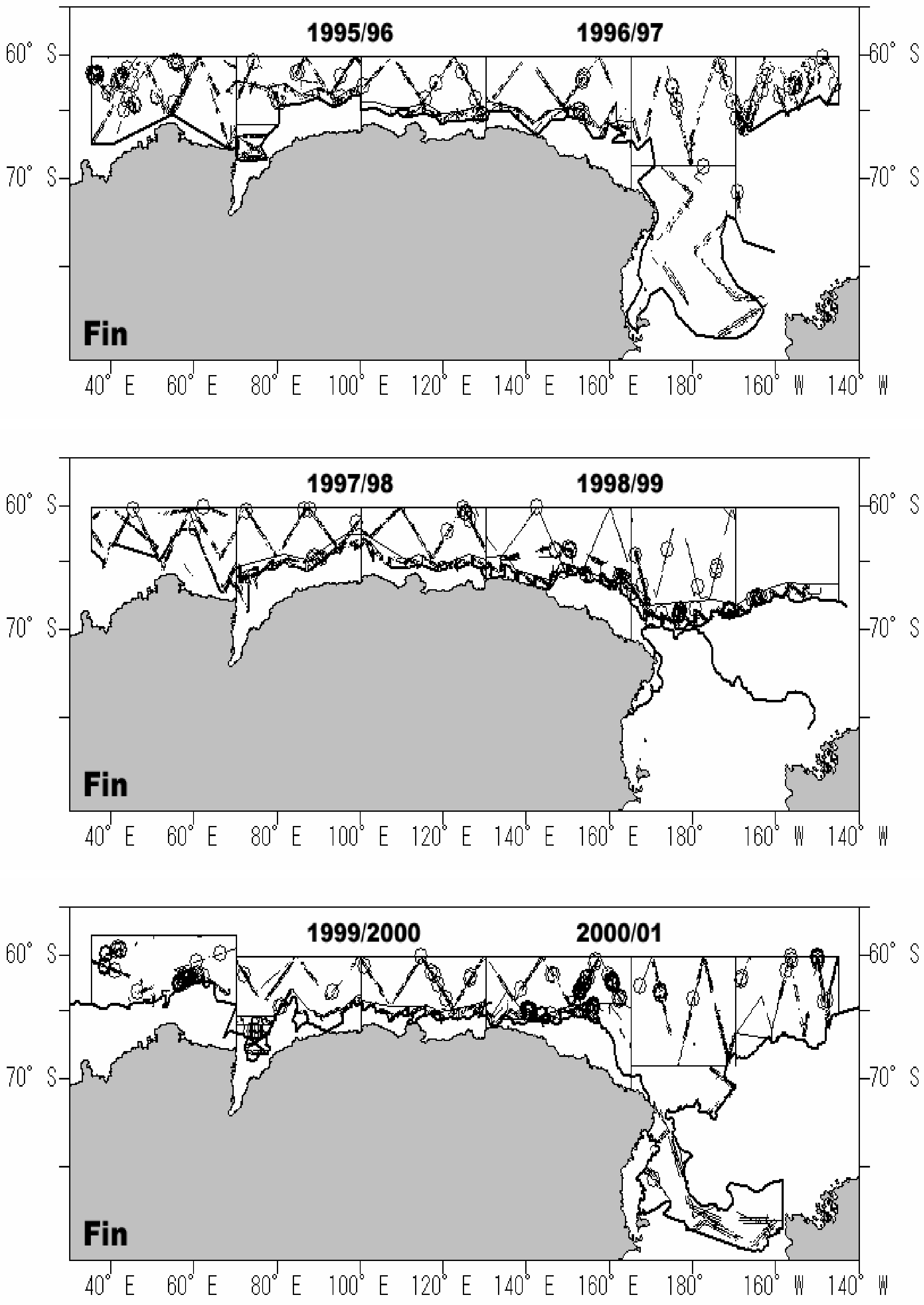

Fig. 4b. (Continued)

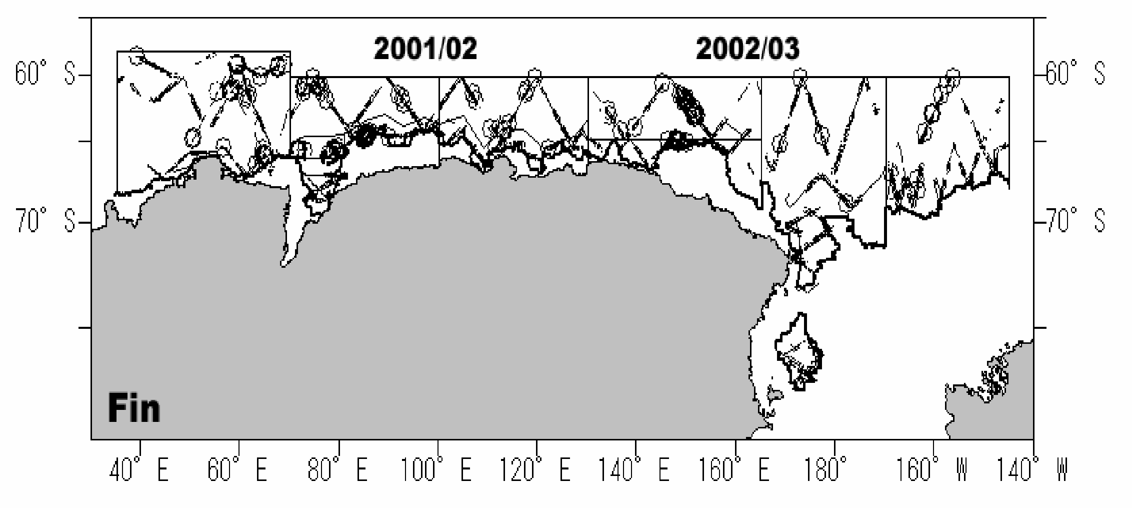

Fig. 4b. (Continued)

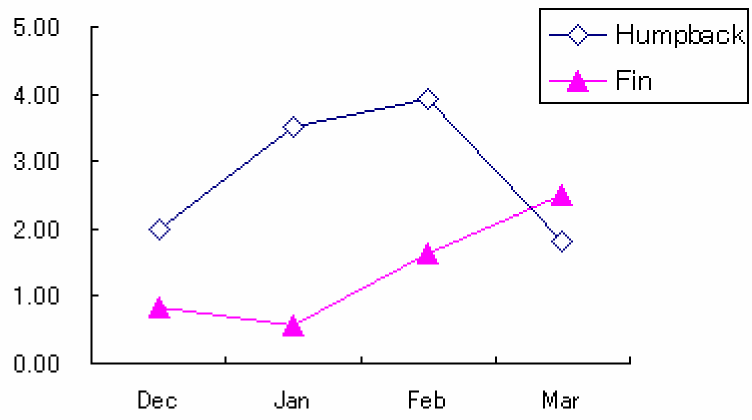

Fig. 5. Monthly change of the density index (DI: whales / 100 n.miles) for humpback and fin whales in the research area by JARPA sighting data between 1989/90 and 2002/03 seasons.

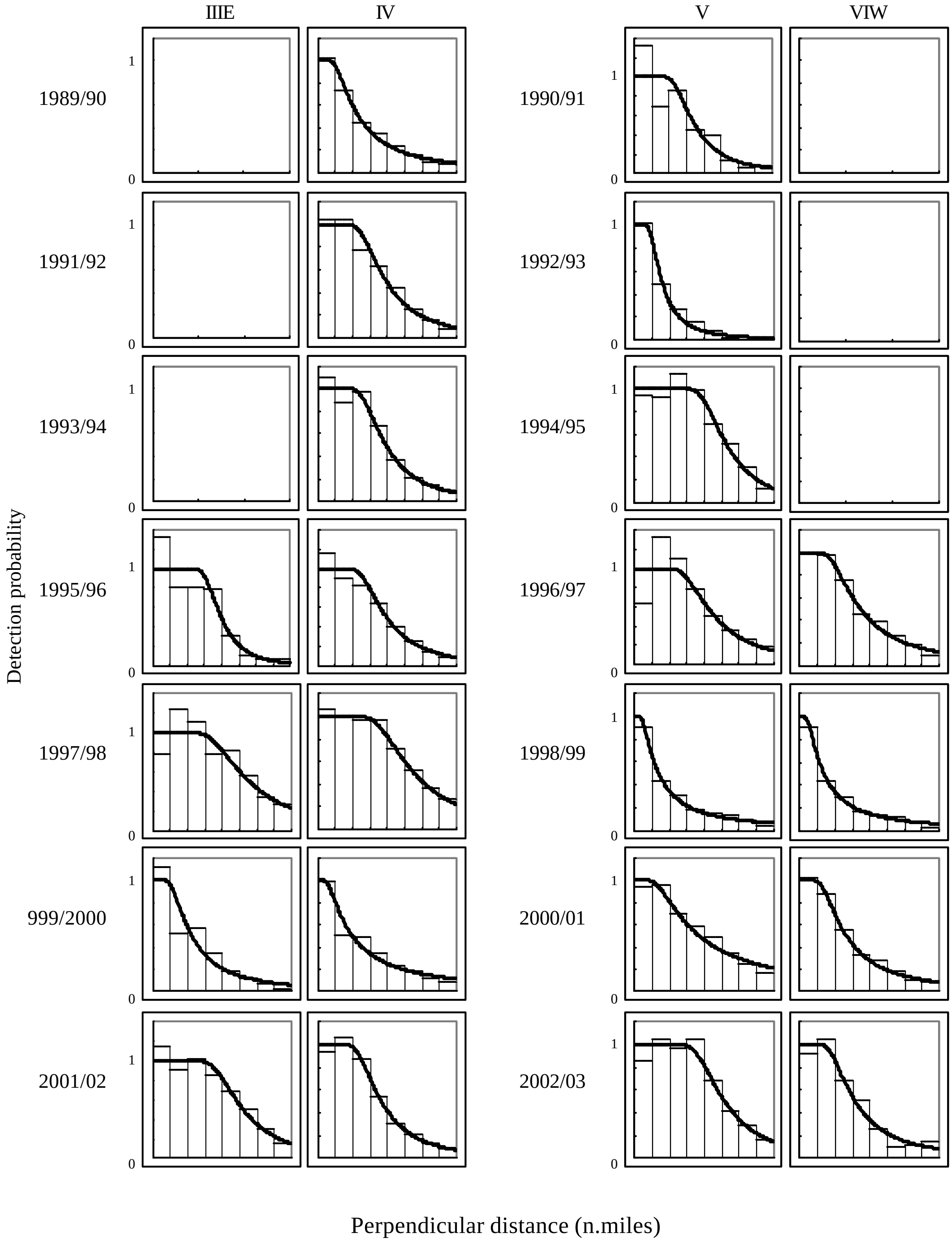

Fig. 6a. Detection probability function of humpback whale in Area IIIE, IV, V and VIW surveyed from 1989/90 to 2002/2003 seasons in relation to Table 3a, 3b, 3c and 3d.

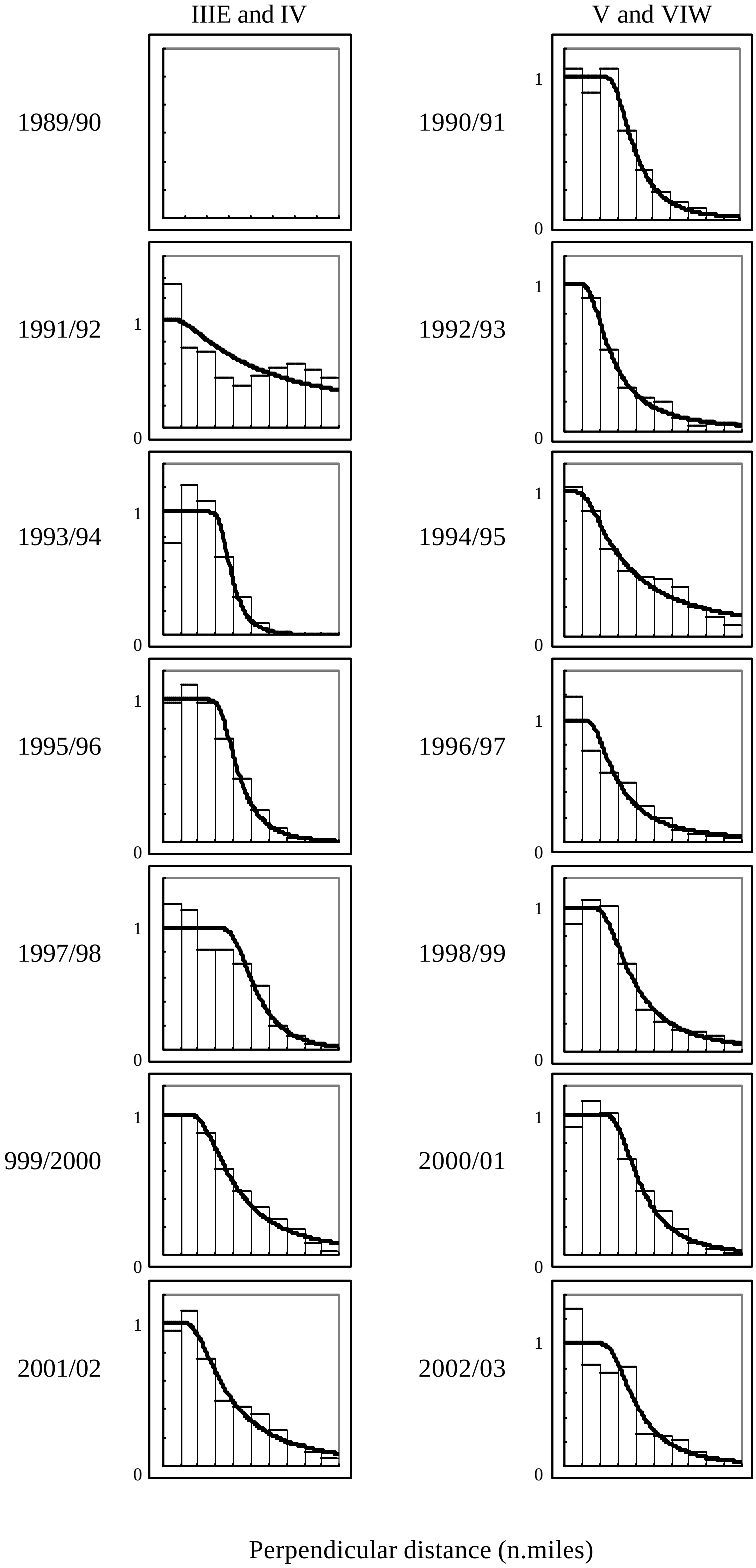

Fig. 6b. Detection probability function of Fin whale in Area IIIE, IV, V and VIW surveyed from 1989/90 to 2002/2003 seasons in relation to Table 4a, 4b, 4c and 4d.

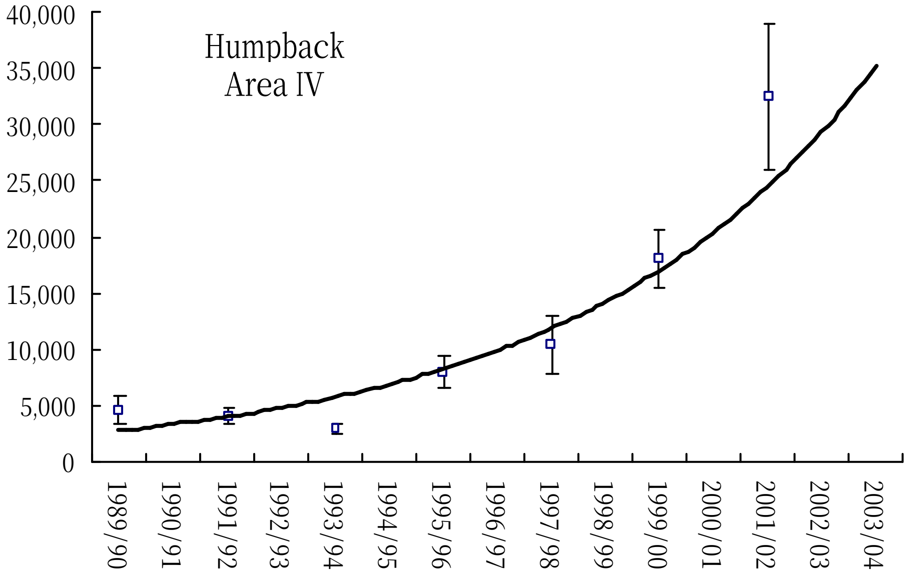

Fig. 7a. Abundance estimates of humpback whale in Area IV (south of 60°S) surveyed during January to February, between 1989/90 and 2001/2002 seasons (over 14 years). Vertical lines show standard errors.

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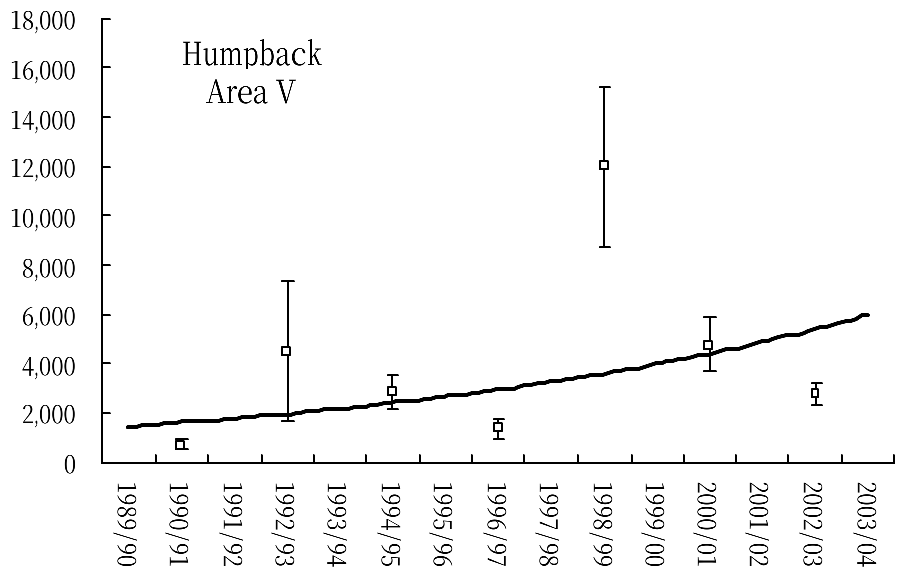

Fig. 7b. Abundance estimates of humpback whale in Area V (south of 60°S) surveyed during January to February, between 1990/91 and 2002/2003 seasons (over 14 years). Vertical lines show standard errors.

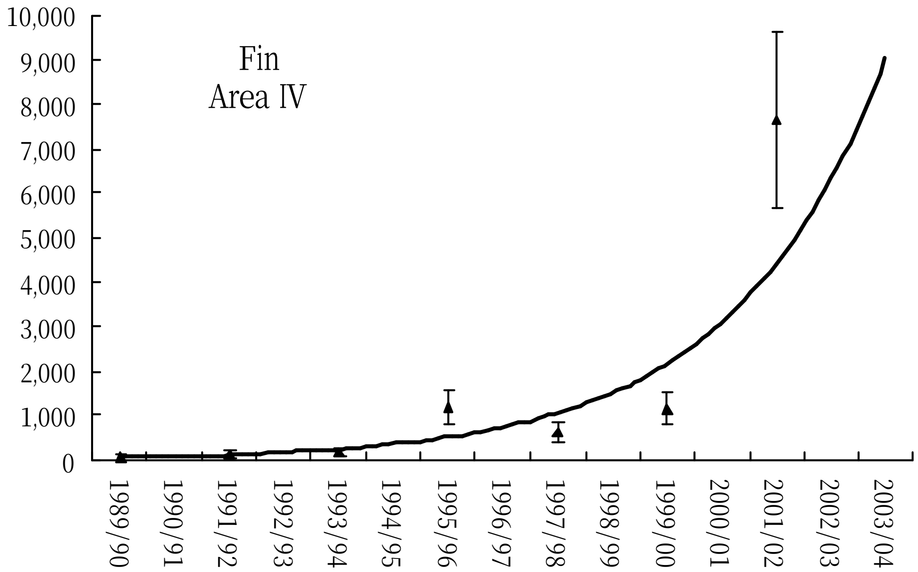

Fig. 8a. Abundance estimates of fin whale in Area IV (south of 60^{o}S) surveyed during January to February, between 1989/90 and 2001/2002 seasons (over 14 years). Vertical lines show standard errors.

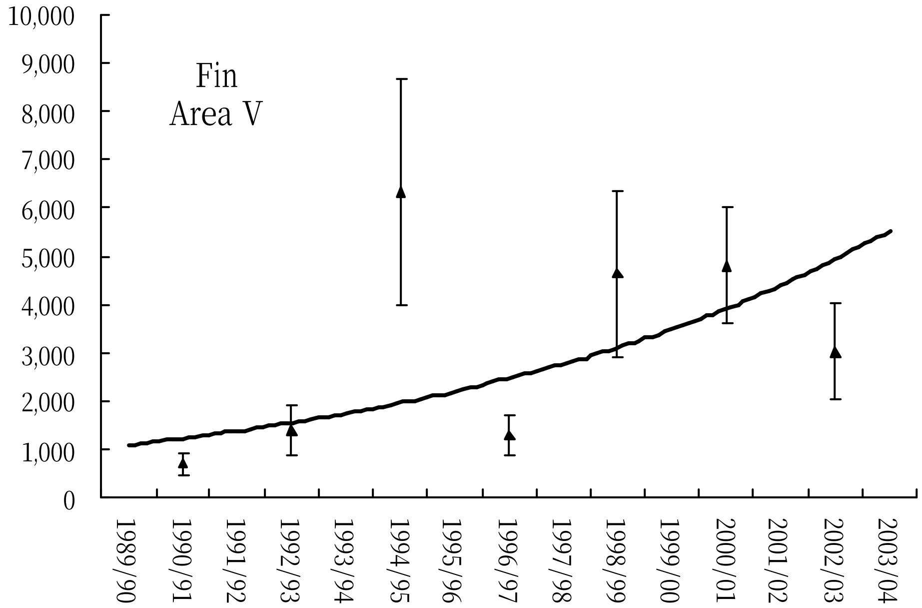

Fig. 8b. Abundance estimates of fin whale in Area V (south of 60^{o}S) surveyed during January to February, between 1990/91 and 2002/2003 seasons (over 14 years). Vertical lines show standard errors.

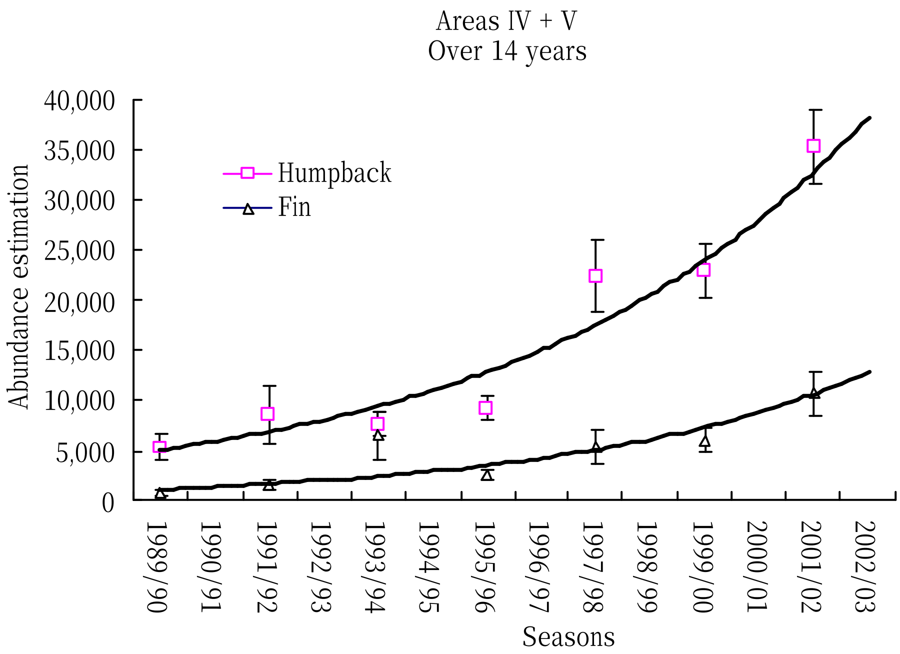

Fig. 9. Abundance estimates of humpback and fin whales in Areas IV and V (south of 60°S) between 1989/90 and 2002/2003 seasons (over 14 years) in relation to Table 5. Vertical lines show standard errors.

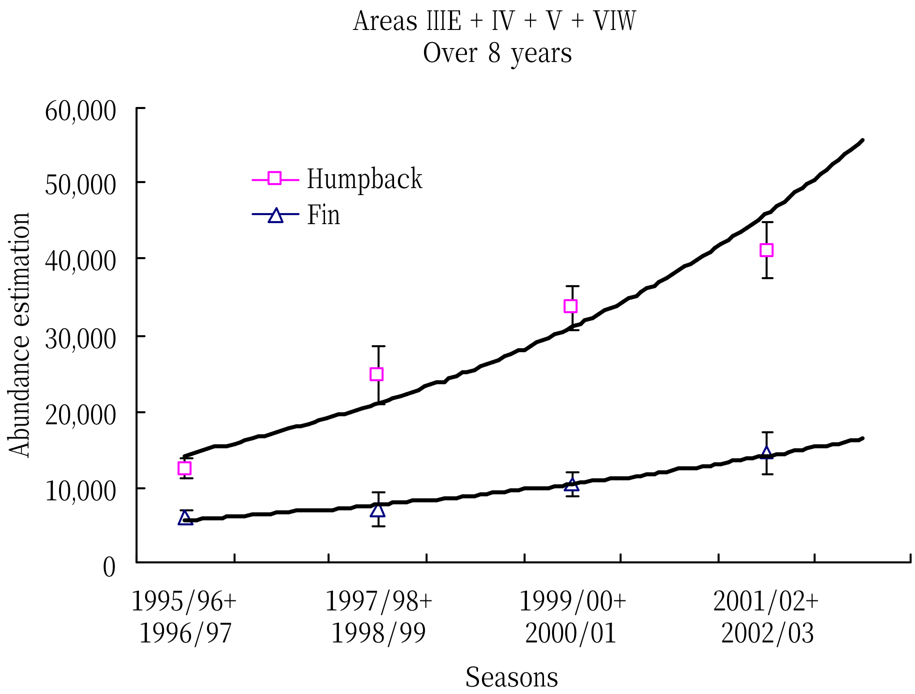

Fig. 10. Abundance estimates of humpback and fin whales in Areas III east, IV, V and VI west between 1995/96 and 2002/2003 seasons (over 8 years) in relation to Table 5. Vertical lines show standard errors.