Estimates of abundance and abundance trend of the blue, fin and southern right whales in the Antarctic Areas IIIE-VIW, south of 60°S, based on JARPA and JARPAII sighting data (1989/90-2008/09)

KOJI MATSUOKA AND TAKASHI HAKAMADA

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

ABSTRACT

Antarctic sighting surveys from the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) and JARPAII in the 1989/90–2008/09 seasons were analyzed to obtain abundance estimates for blue (*Balaenoptera musculus intermedia*), fin (*B. physalus*) and southern right (*Eubalaena australis*) whales south of 60°S. Surveys were conducted following consistent procedures during these years, alternating between Areas III-East + IV (35°E–130°E) and Areas V + VI-West (130°E to 145°W), mainly in January and February. Blue whales were encountered through the surveys, and they were widely distributed without apparent aggregation. Fin whales were widely dispersed in the research area and tended to be distributed more in Area V rather than Area IV. Southern right whales were only distributed in Area IV. Abundance estimates were obtained using standard line transect analysis methods by the program Distance under assumption of g(0) =1. The annual rates of increase were estimated using a regression model based on suggestions of the IWC/SC.

Species	Area	Start - Latest seasons	Start season		Latest season		Abundance trend	95%CILL	95%CIUL
			Abundance	CV	Abundance	CV			
Blue whale	IIIE+IV+V+VIW	1995/96 - 2008/09	300	0.308	1,223	0.345	0.082	0.039	0.125
Fin whale (Indian Ocean stock)	IIIE+IV	1995/96 - 2007/08	3,087	0.191	2,610	0.285	0.089	-0.145	0.324
Fin whale (Western South Pacific stock)	V+VIW	1996/97 - 2008/09	1,879	0.226	14,981	0.298	0.120	0.026	0.215
Southern right whale	IV	1989/90 - 2007/08	42	1.305	1,557	0.303	0.059	-0.164	0.281

These abundance estimates are more detailed per Area compared to those of the IDCR/SOWER estimates which have only circumpolar estimates for blue and fin whales. These are also the first estimates for southern right whale in the Antarctic. These trends intervals included the biologically possible rates of increase for these species. Changes in whale species composition were also confirmed in Area IV. It was regrettable that the last two JARPAII sighting surveys in the first period had to be cancelled due to unscrupulous, obstructive actions by an anti-whaling group.

KEYWORDS: ANTARCTIC, SURVEY VESSEL, DISTRIBUTION, ABUNDANCE ESTIMATE, BLUE WHALE, FIN WHALE, SOUTHERN RIGHT WHALE,

INTRODUCTION

Some of the main sources of sighting data for abundance estimates of large whales in the Antarctic are the JARPA (Japanese Whale Research Program under Special Permit in the Antarctic) and its second phase, JARPAII. The International Whaling Commission Scientific Committee (IWC SC) have provided several recommendations to improve abundance estimates based on JARPA sighting survey data. Most of the recommendations were offered during the JARPA review meeting carried out in 2006 (IWC, 2008).

Most of the recommendations were followed and abundance estimates were obtained and published for the Antarctic humpback (Matsuoka *et al*., 2011) and minke (Hakamada *et al*., in press) whales.

The main objective of this paper is to estimate abundance and abundance trend of of blue, fin and southern right whales in Antarctic Areas IIIE, IV, V and VIW based on JARPA and JARPAII sighting data. The analyses take into consideration previous recommendations from the IWC SC.

To facilitate the understanding of the estimation procedures and the interpretation of results, some details of the JARPA and JARPAII survey procedures and their consistency through the time are provided below, with further details set out in Appendix 1 of Hakamada *et al*. (2014a). One of the features of JARPA and JARPAII is that, unlike the IDCR (International Decade for Cetacean Research)-SOWER (Southern Ocean Whale and Ecosystem Research) programmes (Matsuoka *et al*., 2003a), surveys have been repeated in the same area and in the same months every second season over a long period. Present abundance estimates are more detailed per Area compared to those of the IDCR/SOWER estimates which have only circumpolar based estimates for blue and fin whales. Therefore, the JARPA surveys facilitate both estimation of trends and the extent of inter-year variability in local abundance.

SIGHTING SURVEYS AND DATA COLLECTION

JARPA AND JARPAII DATA

Sighting surveys

The collection procedures and analyses of sighting data that have been used in JARPA are very similar to those used in IWC/IDCR-SOWER cruises and include: 1) distance and angle are corrected by using the results of the distance and angle estimation experiments, 2) sighting rate is obtained every day, 3) effective search half width is obtained by fitting a hazard rate or half normal models, 4) smearing parameters are obtained by the Buckland and Anganuzzi method II, 5) g (0) is assumed to be 1, and 6) sighting data are pooled each season and for each stratum as much as possible for reliable estimation of the effective search half-width (ws) and the mean school size (*E(s)*). Details of the sighting procedures were given in the Review of the sighting survey in the JARPA and JARPAII (Nishiwaki *et al*., 2006, 2014).

Research area covered

The area 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. Both Areas IV and V were divided into two sectors (western sector and eastern sector). Each sector was also divided into two strata (northern and southern strata), along 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 for the Prydz Bay and the Ross Sea regions. The Prydz Bay is defined as south of 66^{o}S, and the Ross Sea is defined as south of 69^{o}S. There are no stratifications for Areas IIIE and VIW in JARPA. In JARPAII, there are stratifications for Areas IIIE and VIW which are the same as in Area IV (Figure 2d and 2e).

Design of the trackline

In the southern strata, the sawtooth type trackline was applied to provide for a wider area of coverage in JARPA. The starting point of the sawtooth trackline was randomly selected at 1 n.mile intervals on the longitudinal lines. The trackline legs were systematically set on the ice-edge and at the locus of 45n.miles from the ice-edge in the southern stratum, and 45 n.miles from the 60^{o}S latitude line in the northern stratum. A zig-zag type trackline was systematically applied in a similar way in IDCR/SOWER surveys in JARPAII for southern and northern stratum (Nishiwaki *et al.*, 2014).

Research vessels

Kyo-Maru No.1, Toshi-Maru No.25, Toshi-Maru No.18 were operated for the surveys from 1989/90 to 1997/1998. *Kyosin-Maru No.2* has been engaged since the 1995/96 survey. *Yusin-Maru* operated in the 1998/1999 survey as the replacement of *Toshi-Maru No.18*. *Yusin-Maru No.2* operated in the 2001/2002 survey as the replacement of *Toshi-Maru No.25*. *Yusin-Maru No.3* operated in the 2007/2008 survey as the replacement of *Kyo-Maru No.1*. *Kaiko-Maru* had been engaged from 2005/06 to 2008/09 surveys (see Appendix of Hakamada *et al*., 2014a).

Size of research area

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

METHODS

Abundance estimation

The methodology of abundance estimation used in this study was described by Burt and Stahl (2000) which is the standard methodology adopted by the IWC. The program DISTANCE (Buckland *et al*., 1993) was used for abundance estimation. The 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 = number of schools that were primary sighted

W = effective search half-width for schools
L = search effort

The CV of P is calculated as follows:

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

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

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

where,
$Z_{0.025}$ represents 2.5-percentage point of the 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 for biases of distance and angle estimation, an experiment was conducted on each vessel every year. Bias was estimated for each platform (Table 1). Linear regression models with a standard error proportional to true (radar) distance were conducted to detect significant bias of an estimated distance at 5% level. In order to correct for 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 an estimated angle at 5% level. In order to correct for significant biases, the estimated slope through the origin divided the 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 were obtained from SSV and SV modes for Antarctic minke whale analyses in JARPA. In JARPAII, only SV data was used for this analysis. A more restrictive approach is followed for minke whales since the small number of sightings available for blue, fin and southern right whales dictates the need to include as much data as possible.

Truncation distance
The perpendicular distance distribution was truncated at 3.0 n.miles for blue, 2.7 n.miles for fin, and 3.0 n.miles for southern right whales, respectively. The truncated number of detection was substituted 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
The hazard rate model with no adjustment terms or half normal models that were 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 the 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, the mean of the observed school size was substituted to formula (1).

Estimation of increasing rate in the feeding ground
To estimate the instantaneous increasing rate, a regression model is used. The formula is

$$P = \beta \exp(\alpha y) \qquad (4)$$

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

Un-surveyed area due to canceled survey

There were several un-surveyed areas in Area IIIE (2005/06) and Area V (2006/07) due to obstructive actions by an anti-whaling group. Percentages of these un-surveyed areas were 58.6% in Area IIIE and 39.2% in Area V, respectively. Estimates of these un-surveyed areas were corrected using whale density of the neighboring strata as done in previous analyses (Matsuoka *et al*., 2011).

Sensitivity tests

Alternative estimates of effective search half-width

The base case selects between the hazard rate and half-normal models for the detection function for cruise-stratum/set-of-strata combination. For sensitivity tests, either all forms are set to half-normal or all to hazard rate.

Un-surveyed areas and incomplete coverage

For the un-surveyed areas, the approach followed to check sensitivity was as follows. For the base case estimates of abundance, the extrapolated density for the (nearly) un-surveyed portion of a stratum is taken to be the same as that in the surveyed portion of the stratum in the same season. As an alternative to this, the densities in these two portions of the stratum on other cruises were evaluated (in the case analysis, these amounts considering the ratio of sighting rates as values of other inputs to the calculation of density are common), and this was used instead to extrapolate the density in the surveyed area to that of the (nearly) un-surveyed portion for the season in question. The following un-surveyed areas were corrected using density in parenthesis:

Area IIIE: 2005/06, NE and SE over 35^{o} E - 55^{o}E (calculated using 2007/08 density)
Area VW: 2006/07 NW and SW over 130E^{o} - 158^{o}E (calculated using 2008/09 density)

RESULTS

Distributions of effort and whale sightings

Searching efforts

Figure 1a shows the IWC Areas and research area of JARPA and JARPAII. Figure 1b shows distribution of the search effort. The research area was covered uniformly during 1987/88 to 2008/09 seasons. Figures 2a-2e show the primary searching effort and associated primary sighting positions of blue, fin and southern right whales in each Area together with the ice edge during JARPA and JARPA II surveys.

Abundance estimates

Tables 3a and 4a (blue whale), Tables 3b and 4b (fin whale) and Tables 3c and 4c (southern right whale) show abundance estimates (P) south of 60^{o}S, total number of the primary sightings (n), area size (A) n.miles^2, effort (L) n.miles, n/L, effective search half width (esw) n.miles, estimated mean school size ($E(s)$), estimated whale density (D: whales / 100 n.miles^2), abundance estimation (P) with CVs by each stratum. Figures 3a to 3c show the detection probability function in nautical miles used in the analyses.

Blue whales

Abundance of this species (south of 60°S, 35°E-145°W) was 664 (CV=0.328) in 2005/06 + 2006/07 seasons and 1,223 whales (CV=0.345) in 2007/08 + 2008/09 seasons. Only for this species, the CV does not include the process error caused by year to year combined estimates (Table 4a).

Fin whales

There were no estimations of this species for each Area. Present estimates between 1995/96 and 2008/09 were new for this species. In this paper, we also estimate abundance for each stock in the research area. The Indian Ocean Stock (Pastene *et al*, 2005) of this species south of 60°S was estimated as 3,087 (CV=0.191) in 1995/96, and 2,610 (CV=0.285) in 2007/08, respectively between 35^{o}E and 130^{o}E (Table 4b). Because they are mainly distributed in the area north of 60°S (e.g. Miyashita *et al*., 1995), these estimates were under-estimated and large yearly fluctuation in the area south of 60°S in Areas IIIE and IV might be attributable to such distribution.

Southern right whales

For the Antarctic Areas, there were no abundance estimations of this species by sighting surveys. This species were only sighted in Areas IV and V, but mostly in Area IV. They were distributed in the southern stratum rather than northern stratum (Figure 2a). Present estimates between 1989/90 and 2007/08 were new for this species (Table 3c and 4c). In Area IV, abundance estimates ranged from 6 (CV=0.761) in 2003/04 to 1,557 (CV=0.303) in 2007/08 seasons. Because they also are mainly distributed in the area north of 60°S, these estimates were under-estimated and large yearly fluctuation in the area south of 60°S in Areas IV might be attributable to such distribution.

Abundance trends

Blue whales

Figure 4a shows the abundance estimates for the whole area plotted against the survey season. An increasing trend in abundance is evident for this area, more clearly so compared to the former results. For the species, the abundance trend was 8.2 % (95%CI: 3.9%, 12.5%) between 1995/96 and 2008/09 for combined Areas IIIE+ IV+V+VIW (Table 5).

Fin whales

Figures 4b and 4c show the abundance estimates of this species in Areas IIIE+IV and V+VIW, respectively which are plotted against the survey season. An increasing trend in abundance is evident for these areas, more clearly so compared to the latter results. For the Indian Ocean stock between 1995/96 and 2007/08 seasons, the abundance trend was estimated as 8.9% ((95%CI: -0.145%, 32.4%), and the Pacific Ocean stock between 1996/97 and 2008/09 was estimated as 12.0% (95%CI: 2.6%, 21.5%). The latter estimate is clearly significantly positive; the former trend for Areas IIIE+IV is not as clear as that for Areas V+VIW (Table 5).

Southern right whales

Figure 4d shows the abundance estimates in Area IV plotted against the survey season. An increasing trend in abundance is evident for this area. The abundance trend was 5.9 % (95%CI: -16.4%, 28.1%) between 1989/90 and 2007/08, which is not significant (Table 5).

Sensitivity tests

Alternative estimates of effective search half-width

The effects on abundance estimates at the Area level, and also on annual rates of increase, compared to the base case for these and the following two sets of sensitivity tests are shown in Tables 6a -6d. There are occasional instances of a large difference, but viewed overall, the average change in the abundance estimates from the base case never exceeds 5%, and any alteration to the rate of increase estimate is below 1%.

Poor coverage corrections

The effects on abundance estimates at the Area level, and also on annual rates of increase, compared to the base case for these and the following one set of sensitivity tests for the canceled areas of the 2005/06 season in Area IIIE and the 2006/07 season in Area VIW are shown in Tables 6a -6d, except southern right whales. There are occasional instances of a large difference, but viewed overall, the average change in the abundance estimates from the base case is between -17% and 65%, and any alteration to the rate of increase estimate is between -1.4% and 3%.

Calculation for biomass

Tables 7a and 7b show the estimated biomass (tons) of each species in each Area using abundance estimates and the mean body mass data (Hakamada and Matsuoka, 2014a and 2014b). Average body weights used for this calculation were 6.5, 30.0, 55.0, 100.0 and 57.0 tons for Antarctic minke, humpback, fin, blue and southern right whales, respectively (Trites and Pauly, 1998).

DISCUSSION

Blue whale abundance estimates

Two subspecies of blue whales exist in Southern Hemisphere: the Antarctic (or true) blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*) (Rice, 1998). The former attains greater maximum lengths, is longer at sexual maturity and has proportionately longer tail stock (Ichihara, 1966; Mackintosh & Wheeler, 1929). A complete review of spatial and seasonal distribution, densities and movements of blue whales is provided by Branch *et al*. (2007b). This study indicated that there is little evidence that pygmy blue whales migrate into high latitudes of the Antarctic. Less than 1% of the records south of 52^{o}S (Branch *et al*., 2007b) were of this subspecies. For this reason, pygmy blue whales are not further considered in this study. In the research area, blue whales were encountered through the surveys, and they were widely distributed without apparent aggregation. They were usually found in the southern stratum including the Ross Sea (Figures 2a to 2d).

There was no abundance estimation of blue whales by use of whale sightings for each IWC management Area. The pre-exploitation abundance of Antarctic blue whales was estimated to be 239,000 (95% Bayesian interval 202,000-311,000), and the population was at about 1% (1700 individuals, 95% Bayesian interval 860–2,900) of its original abundance in 1996 (Branch *et al.*, 2004). Recent estimates of Antarctic blue whale population size are available from the IDCR/SOWER cruises for the whole Antarctic Ocean (Branch, 2007a) and for each Area from the JARPA cruises (Matsuoka *et al*., 2006). The most current circumpolar abundance estimate was 2,249 (95% CI = 1,140-4,400) in 1997 (Branch, 2007a). The current estimate of 1,223 (95% CI = 654-2,288) from the 2007/08 + 2008/09 seasons was similar to half of the circumpolar estimate. The estimated trends indicate that the population increased at 7.3%/year (95% CI = 1.4–11.4%/year) in the Antarctic Ocean south of 60^{o}S in the period 1978/79-2000/01 (Branch *et al*., 2004) and 7.4%/year (95% CI = 1.2–46.6%) for Areas IV and V combined in the period 1989/90-2004/05 (Matsuoka *et al*., 2006). Updated estimates of this paper in the period 1995/96-2008/09 in the Areas IIIE+IV+V+VIW was 8.2%/year (95% CI = 3.9–12.5%) which were the first estimates for the Area based estimations completed with good precision compared to the circumpolar based estimates from the IDCR/SOWER cruises. Fortunately, signs of recovery are now evident for this species from both the IDCR-SOWER and JARPAII surveys. There is a need for the continued monitoring of the abundance and abundance trends of this species, especially because they provide an excellent opportunity to improve our understanding of the dynamics of baleen whale populations recovering from low levels.

Fin whale abundance estimates

There was no abundance estimation of fin whales by whale sighting for any of the IWC management Areas. An estimate of this species based on IWC/IDCR and Japanese Scouting Vessels (JSV) was 18,000 (CV=0.47) in the whole area south of 30^{o}S (Butterworth *et al*., 1994). Recent estimates of this species in the whole area south of 60^{o}S based on the IWC/IDCR and SOWER were 2,100 (1978/79-1983/84, CV=0.36), 2,100 (1985/86-1990/91, CV=0.45) and 5,500 (1991/92-1997/98: circumpolar not completed, CV=0.53) in first, second and third circumpolar series, respectively (Branch and Butterworth, 2001).

The JARPAII estimate of 17,600 from the latest two seasons for half of the Antarctic Areas (35^{o}E -145^{o}W) south of 60^{o}S and significant increases in Areas V+VIW will be the first value in these Areas. Taking into account the survey year and Area difference, an updated estimate is reasonable for this species. Because they are mainly distributed in the area north of 60^{o}S (Mackintosh, 1966), 17,600 whales is an underestimate, and large yearly fluctuation in the area south of 60^{o}S might be attributable to such distribution pattern. During JSV period, fin whales rarely found south of 60^{o}S; however, they found more and more south of 60^{o}S during JARPA and JARPAII periods.

Southern right whale abundance estimates

There was no abundance estimation of southern right whales in the Antarctic through IDCR/SOWER analyses. The most recent annual trend estimate for calving right whales wintering off the southern Australian coast, 1993-2006, was 8.10% (95% CI, 4.48-11.83%). The population estimate for the same area was 2,400 in 2006 (Bannister, 2008). A current estimate in Area IV south of 60^{o}S of 1,557 individuals (95% CI, 871-2,783) in the 2007/08 season and an abundance trend of 5.9%/year (95%CI, -16.4%, 28.1%) seemed reasonable, and it is the first value of an abundance estimate for this species in the Antarctic. The abundance trend was not significant for this species because they were mainly distributed in the area north of 60^{o}S. Such annual trend estimates of this species were possible influenced by oceanographic changes (Naganobu *et al*., 2014, Watanabe *et al*., 2014).

Changes in whale species composition in Area IV

A “Shift in baleen whale dominance” from Antarctic minke to humpback whales was observed in Area IV since the 1997/98 season (Matsuoka *et al*., 2005b, 2006). This event was also confirmed between 2005/06 and 2008/09 seasons in this paper (Figure 5a). In the 1989/90 season, the biomass of Antarctic minke was higher (222,000 tons) than humpback whales (165,000 tons), and after 19 years in the 2007/08 season, the biomass of the humpback (901,000 tons) was 8 times that of the Antarctic minke (112,000 tons). The compositions of blue and fin whale were not changed in Area IV. However, in the 1989/90 season, the biomass of the fin whale was 5,700 tons, and after 19 years in the 2007/08 season, the biomass of the fin whale was 91,000 tons or over 16 times the earlier measurement. The distribution shift of humpback whales was also statistically confirmed in Area IV using a quantitative approach (Murase *et al*., 2014).

Importance of monitoring whale populations

Blue, fin and southern right whales were heavily exploited during the past century and most of the stocks in the Southern Hemisphere were substantially depleted. In the Antarctic Ocean, catches of southern right, humpback, blue, fin and sei whales were prohibited in 1932, 1963, 1964, 1976 and 1978, respectively. Eighty years have passed already since the southern right whale has been protected, and more than 50 years have passed since the humpback whale and blue whale have been protected. In the coastal waters of South America, South Africa and along the east and west coasts of Australia, significant recovery of southern right whales and humpback whales has been reported recently in these breeding areas. On the other hand, the information on the present status of pelagic species, such as blue, fin and sei whales was limited. The IWC/IDCR-SOWER cruises, however not sufficient enough for monitoring the ecosystem, have covered the same area every year for 6 years. In this situation, JARPA and JARPAII have been monitoring baleen whale species populations by the large-scale and long-term line transect survey for over 26 years in Areas IV and V. The number of survey years is still short to detect precise yearly trends for whale populations. JARPAII continues to provide more useful information about the recovery of whale stocks including blue whales.

ACKNOWLEDGEMENTS
We wish to express our gratitude to Doug Butterworth and an advisory group member of the IWC/SC for their constructive suggestions to improve a previous version of this paper. Our gratitude also goes to Luis A. Pastene and Toshihide Kitakado for their help in the preparation of this paper. We would like to thank all of the researchers, captains, officers and crew members participating in the JARPA and JARPAII surveys in the Antarctic. We also would like to thank Seiji Ohsumi, Hiroshi Hatanaka, Yoshihiro Fujise, Tomio Miyashita, Hidehiro Kato and Shigetoshi Nishiwaki for their useful comments to this paper and also Satoshi Suzuki for his help drawing the several figures.

REFERENCES
Bannister, J.L. 2008. Population trend in right whales off southeastern Australia 1993-2007. *IWC Paper SC/60/BRG14*, 13pp.

Branch, T. A., and Butterworth, D., S., 2001. Estimates of abundance south of 60°S for cetacean species sighted frequently on the 1978/79 to 1997/98 IWC/IDCR-SOWER sighting surveys. *J. Cetacean. Res. Manage*. 3(3):251-270.

Branch, T.A., Matsuoka, K. and Miyashita, T., 2004. Evidence for increases in Antarctic blue whales based on bayesian modelling. *MARINE MAMMAL SCIENCE* 20 (4): 726-754.

Branch, T.A. 2007a. Abundance of Antarctic blue whales south of 60°S from three complete circumpolar sets of surveys. *Journal of Cetacean Research and Management,* 9(3), 87-96.

Branch, T.A. *et al*., 2007b. Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. *Mammal Rev*., 37(2), 116-175.

Buckland, S.T. and Anganuzzi, A.A. 1988. Comparison of smearing method in the analysis of minke sightings data from IWC/IDCR Antarctic cruise. *Rep. Int. Whal. Commn* 38: 257- 63.

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. *Distance sampling: Estimating Abundance of Biological Populations.* Chapman & Hall, London, UK. 446 pp.

Burt, M., L. and Stahl, D, 2000. Minke whale abundance estimation from the 1997-98 IWC-SOWER Antarctic cruise in Area II. Paper SC/52/IA13 submitted to the IWC Scientific Committee, 2000 (unpublished). 17pp.

Butterworth, D., S. Borchers, S., Chalis, J. B., Decker, De. and Kasamatsu, F. 1994. Estimates of abundance for southern hemisphere blue, fin, sei, humpback, sperm, killer and pilot whales from the 1978/79 to 1990/91 IWC/IDCR sighting survey cruise, with extrapolation to the area south of 30°S for the first five species based on Japanese scouting vessel data. Paper SC/46/SH24 submitted to the IWC Scientific Committee, 1994 (unpublished).129pp.

Hakamada, T., Matsuoka, K., Nishiwaki, S. and Kitakado, T., 2013. (inpress). Abundance estimates and trends for Antarctic minke whales (*Balaenoptera bonaerensis*) in the Antarctic Areas IV and V for the period 1989/90-2004/05. *J. CETACEAN RES. MANAGE*. X:xxx-xxx.

Hakamada, T. and Matsuoka, K.. 2014a. Estimates of abundance and abundance trend of the Antarctic minke whale in Areas IIIE-VIW, south of 60ºS, based on JARPA and JARPAII sighting data (1989/90-2008/09). SC/F14/J3. xxpp. (this meeting)

Hakamada, T, and Matsuoka, K. 2014b. Estimates of abundance and abundance trend of the humpback whale in Areas IIIE-VIW, south of 60ºS, based on JARPA and JARPAII sighting data (1989/90-2008/09). SC/F14/J4. Xxpp. (this meeting)

Ichihara, T. (Ed).1966. *The pygmy blue whale, Balaenoptera musculus brevicauda, a new subspecies from the Antarctic, In: Kenneth S. Norris, Whales, dolphins, and porpoises p. 79-113*. Berkeley, CA: University of California Press. 789 pp.

International Whaling Commission. 2008. Report of the Intersessional Workshop to Review Data and Results from Special Permit Research on Minke Whales in the Antarctic, Tokyo 4-8 December 2006. *J. Cetacean. Res. Manage. (Suppl.),* 10:411-445.

Mackintosh, N.A., & Wheeler, J.F.G. 1929. Southern blue and fin whales. *Discovery Reports*, 1, 257-540.

Mackintosh, N. A. 1966. Distribution of southern blue and fin whales. Pages 125-144 in K. S. Norris, editor. Whales, dolphins, and porpoises. University of California Press, Berkeley, CA.

Matsuoka, K., Ensor, P. Hakamada, T. Shimada, H. Nishiwaki, S. Kasamatsu, F. and Kato, H. 2003a. Overview of minke whale sightings surveys conducted on IWC/IDCR and SOWER Antarctic cruises from 1978/79 to 2000/01. *J. CETACEAN RES. MANAGE*. 5:173-201.

Matsuoka, K., Hakamada, T., Kiwada, H., Murase, H. and Nishiwaki, S. 2005b. Abundance increases of large baleen whales in the Antarctic based on the sighting survey during Japanese Whale Research Program (JARPA). *Glob. Environ. Res.*, 9(2): 105–115.

Matsuoka, K., T. Hakamada, H. Kiwada, H. Murase and S. Nishiwaki. 2006. Distributions and standardized abundance estimates for humpback, fin and blue whales in the Antarctic Areas IIIE, IV, V and VIW (35^{o}E -145^{o}W), south of 60^{o}S. IWC paper SC/D06/J7 presented to the IWC workshop on JARPA review. (unpublished). 33pp. [Available from the Office of this Journal].

Matsuoka, K., Hakamada,T., Kiwada, H. Murase H. and Nishiwaki, S. 2011. Abundance estimates and trends for humpback whales (*Megaptera novaeanglie*) in the Antarctic Areas IV and V based on JARPA sighting data. *J. CETACEAN RES. MANAGE*. (*SPECIAL ISSUE*) 3:75-94.

Miyashita, T., Kato, H. and Kasuya, T., 1995. Worldwide Map of Cetacean Distribution based on Japanese Sighting Data (Volume 1).pp43-56.

Murase, H., Matsuoka, K., Hakamada, T. and Kitakado, T., 2014. Preliminary analysis of changes in spatial distribution of Antarctic minke and humpback whales in Area IV during the period of JARPA and JARPAII from 1989 to 2006. SC/F14/J20 (this meeting).

Naganobu, M., Matsuoka, K. Murase, H. and Kutsuwada, K. 2014. Consideration on the Kerguelen-Davis Oscillation Index (KDOI) influencing variability on environmental ecosystem in the Prydz Bay Region, east Antarctic: data exploration. IWC paper SC/F14/ J21. ppxx. [Available from the Office of this Journal].

Nishiwaki, S., Ishikawa, H. and Fujise, Y., 2006. Review of general methodology and survey procedure under the JARPA. IWC Paper SC/ D06/ J2. 47pp..

Nishiwaki, S., *et al.*, 2014. Review of general methodology and survey procedure under the JARPAII. IWC Paper SC/F14/J2. xxpp. (this meeting).

Pastene, L., A., Goto, M., Kanda, N. and Nishiwaki, S, 2005. Genetic analyses on stock identification in the Antarctic humpback and fin whales based on samples collected under the JARPA. Paper JA/ J05/ JR 16. 13pp.

Rice, D.W. (ed.). 1998. *Marine mammals of the world: systematics and distribution*. Lawrence, KS: Society for Marine Mammalogy. 231 pp.

Trites, A. W. and Pauly, D. 1998. Estimating mean body masses of marine mammals from maximum body length. *Can. J. Zool.* 76:886-896.

Watanabe, T., Yabuki, T., Suga, T., Hanawa, K., Matsuoka, K. and Kiwada, H, 2014. Results of oceanographic analyses conducted under JARPA and JARPAII and possible evidence of environmental changes. Paper SC/F14/J20. (this meeting)

Table 1. Estimated observer bias in distance and angle estimation (JARPAII) during 2005/06 to 2008/09 seasons.

Season	Vessel	Platform			
		Barrel		Upper bridge	
		Distance	Angle	Distance	Angle
2005/06	KS2	1.043	0.914	n.s.	n.s.
	KK1	1.049	n.s.	n.s.	n.s.
2006/07	KS2	n.s.	n.s.	n.s.	n.s.
	KK1	n.s.	n.s.	n.s.	n.s.
2007/08	KS2	n.s.	0.961	n.s.	0.950
	KK1	n.s.	n.s.	0.839	n.s.
2008/09	KS2	n.s.	0.918	n.s.	n.s.
	KK1	1.055	0.963	n.s.	0.949

*n.s. indicates not significant at 5% level.

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

Blue whale*

	Areas IIIE and IV	
	angle	distance
2005/06	5.915	0.167
2006/07	5.915	0.167
2007/08	5.915	0.167
2008/09	5.915	0.167

	Areas V and VIW	
	angle	distance
2005/06	5.915	0.167
2006/07	5.915	0.167
2007/08	5.915	0.167
2008/09	5.915	0.167

Fin whale

	Areas IIIE and IV	
	angle	distance
2005/06	6.400	0.155
2006/07	8.372	0.400
2007/08	7.826	0.333
2008/09	5.379	0.140

	Areas V and VIW	
	angle	distance
2005/06	6.400	0.155
2006/07	8.372	0.400
2007/08	7.826	0.333
2008/09	5.379	0.140

S. right whale*

	Areas IV	
	angle	distance
2005/06	5.846	0.138
2006/07	5.846	0.138
2007/08	5.846	0.138
2008/09	5.846	0.138

Table 3a. Abundance estimates of the blue whale by strata in the JARPAII period. Data in closing and passing mode were analyzed together. n: number of schools sighted on primary effort, *L:* searching distance, esw: the effective search half width (normal form of a character: estimated by the Hazard rate model, Italics form: by the half normal model), *E(s)*: mean school size, *D*: estimated density (individuals / 100 n.miles ^{2}), *P*: estimated abundance. * data is not included for Tables 4a, 5, 6a and 7b.

Season	Stratum		Area (n.miles2)	*n*	L (n.miles)	*n/L**100	CV	esw (n.miles)	CV	E(*s*)	CV	*D* (ind.)	*P* (ind.)	CV	
2005/2006	IIIE	NE	332,409	1.0	674.21	0.148	0.636	*1.741*	*0.116*	1.711	0.085	0.001	242	0.652	
		SE	51,635	3.0	674.99	0.440	0.680	*1.741*	*0.116*	1.711	0.085	0.002	112	0.695	
	IIIE : sub total		384,043	4.0	1,349.20	0.294	-	-	-	-	-	0.001	354	0.506	
	IV	NW	228,919	1.0	1,131.40	0.088	0.849	*1.741*	*0.116*	1.711	0.085	0.000	99	0.861	
		NE	213,660	0.0	1,450.30	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
		SW	47,117	2.0	859.42	0.233	0.767	*1.741*	*0.116*	1.711	0.085	0.001	54	0.780	
		SE	37,228	2.0	865.48	0.231	0.755	*1.741*	*0.116*	1.711	0.085	0.001	42	0.768	
		PB	31,689	0.0	381.06	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
	IV : sub total		558,613	5.0	4,687.66	0.107	-	-	-	-	-	0.000	196	0.527	
	IIIE+IV : sub total			-	-	-	-	-	-	-	-	-	549	0.389	
	V	NW	238,068	1.0	613.77	0.163	0.752	*1.741*	*0.116*	1.711	0.085	0.001	191	0.766	
		NE	12,433	0.0	96.94	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
		SW	49,999	3.0	652.64	0.460	0.444	*1.741*	*0.116*	1.711	0.085	0.002	113	0.466	
		SE	34,914	0.0	153.84	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
	V : sub total		335,414	4.0	1,517.19	0.264	-	-	-	-	-	0.001	303	0.521	*
	Year Total		1,278,070	13.0	7,554.05	0.172	-	-	-	-	-	0.001	853	0.326	*
2006/2007	V	NW	351,072	0.0	97.25	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
		NE	340,889	0.0	2,107.70	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
		SW	38,198	0.0	136.24	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
		Ross	139,575	1.0	2,272.90	0.044	0.976	*1.741*	*0.116*	1.711	0.085	0.000	30	0.987	
	V : sub total		869,734	1.0	4,614.09	0.022	-	-	-	-	-	0.000	30	0.987	
	VI	SW	31,008	4.0	721.24	0.555	1.451	*1.741*	*0.116*	1.711	0.085	0.003	84	1.458	
		NW	220,818	0.0	756.37	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
	VI : sub total		251,826	4.0	1,477.61	0.271	-	-	-	-	-	0.000	84	1.458	
	Year Total		1,121,561	5.0	6,091.70	0.082	-	-	-	-	-	0.000	115	1.109	
2007/2008	III	NE	228,382	1.0	931.41	0.107	0.840	*1.741*	*0.116*	1.711	0.085	0.001	120	0.852	
		SE	50,431	19.6	1,126.20	1.737	0.651	*1.741*	*0.116*	1.711	0.085	0.009	430	0.666	
	III : sub total		278,813	20.6	2,057.61	0.999						0.002	551	0.559	
	IV	NW	213,311	2.0	958.89	0.209	0.608	*1.741*	*0.116*	1.711	0.085	0.001	219	0.625	
		NE	216,236	0.0	1,332.40	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
		SW	39,787	1.0	847.54	0.118	1.099	*1.741*	*0.116*	1.711	0.085	0.001	23	1.108	
		SE	36,277	0.0	819.76	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
		PB	---	-	-	-	-	-	-	-	-	-	-	-	
	IV : sub total		505,611	3.0	3,958.59	0.076	-	-	-	-	-	0.000	242	0.578	
	IIIE+IV : sub total			-	-	-	-	-	-	-	-	-	792	0.437	
	V	NW	275,376	3.0	1,148.10	0.261	0.549	*1.741*	*0.116*	1.711	0.085	0.001	353	0.567	
		SW	43,609	0.0	864.87	0.000	0.322	*1.741*	*0.116*	1.711	0.085	0.000	0	-	
	V : sub total		318,985	3.0	2,012.97	0.149	-	-	-	-	-	0.001	353	0.567	*
	Year Total		1,103,409	26.6	8,029.17	0.331	-	-	-	-	-	0.001	1,146	0.362	*
2008/2009	V	NW	224,275	0.0	1,144.70	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	0.144	
		NE	324,889	0.0	1,369.50	0.000	0.000	*1.741*	*0.116*	1.711	0.085	0.000	0	0.144	
		SW	64,901	0.9	638.13	0.145	1.386	*1.741*	*0.116*	1.711	0.085	0.001	46	1.393	
		Ross	277,209	7.0	2,757.80	0.254	0.459	*1.741*	*0.116*	1.711	0.085	0.001	346	0.481	
	V : sub total		891,274	7.9	5,910.13	0.134	-	-	-	-	-	0.000	392	0.460	
	VI	NW	166,610	0.0	721.57	0.000	0.398	*1.741*	*0.116*	1.711	0.085	0.000	0	0.423	
		SW	76,255	1.0	990.09	0.101	1.617	*1.741*	*0.116*	1.711	0.085	0.000	38	1.623	
	VI : sub total		242,865	1.0	1,711.66	0.058	-	-	-	-	-	0.000	38	1.623	
	Year Total		1,134,139	8.9	7,621.79	0.117	-	-	-	-	-	0.000	430	0.447	

Table 3b. Abundance estimates of the fin whales by strata in the JARPAII period. Data in closing and passing mode were analyzed together. n: number of schools sighted on primary effort, *L:* searching distance, esw: the effective search half width (normal form of a character: estimated by the Hazard rate model, Italics form: by the half normal model), *E(s)*: mean school size, *D*: estimated density (individuals / 100 n.miles ^{2}), *P*: estimated abundance. * data is not included for Tables 4b, 5, 6b, 6c and 7b.

Season	Stratum		Area	*n*	L	*n*/*L**100	CV	esw	CV	E(*s*)	CV	*D*	*P*	CV	
			(n.miles2)		(n.miles)			(n.miles)				(ind.)	(ind.)		
2005/2006	IIIE	NE	332,409	11.7	674.21	1.732	0.336	*1.633*	*0.078*	2.793	0.065	0.015	4,921	0.351	
		SE	51,635	0.0	674.99	0.000	0.000	*1.633*	*0.078*	2.793	0.065	0.000	0	-	
	IIIE : sub total		384,043	11.7	1,349.20	0.865	-	-	-	-	-	0.013	4,921	0.351	
	IV	NW	228,919	12.9	1,131.40	1.143	0.197	*1.633*	*0.078*	2.793	0.065	0.010	2,237	0.221	
		NE	213,660	12.8	1,450.30	0.881	0.516	*1.633*	*0.078*	2.793	0.065	0.008	1,610	0.526	
		SW	47,117	26.6	859.42	3.093	0.472	*1.633*	*0.078*	2.793	0.065	0.026	1,246	0.483	
		SE	37,228	32.0	865.48	3.695	0.654	*1.633*	*0.078*	2.793	0.065	0.032	1,176	0.662	
		PB	31,689	0.0	381.06	0.000	0.000	*1.633*	*0.078*	2.793	0.065	0.000	0	-	
	IV : sub total		558,613	84.3	4,687.66	1.798	-	-	-	-	-	0.011	6,269	0.238	
	IIIE+IV : sub total			-	-	-	-	-	-	-	-	-	11,190	0.216	
	V	NW	238,068	2.0	613.77	0.326	0.960	*1.633*	*0.078*	2.793	0.065	0.003	663	0.965	
		NE	12,433	0.0	96.94	0.000	0.000	*1.633*	*0.078*	2.793	0.065	0.000	0	-	
		SW	49,999	27.0	652.64	4.137	0.673	*1.633*	*0.078*	2.793	0.065	0.035	1,768	0.680	
		SE	34,914	0.0	153.84	0.000	0.000	*1.633*	*0.078*	2.793	0.065	0.000	0	-	
	V : sub total		335,414	29.0	1,517.19	1.911	-	-	-	-	-	0.007	2,432	0.564	*
	Year Total		1,278,070	124.9	7,554.05	1.654	-	-	-	-	-	0.011	13,622	0.211	*
2006/2007	V	NW	351,072	0.0	97.25	0.000	0.339	*1.577*	*0.206*	5.389	0.416	0.000	0	-	
		NE	340,889	10.2	2,107.70	0.485	0.549	*1.577*	*0.206*	5.389	0.416	0.008	2,822	0.719	
		SW	38,198	0.0	136.24	0.000	0.305	*1.577*	*0.206*	5.389	0.416	0.000	0	-	
		Ross	139,575	0.0	2,272.90	0.000	0.000	*1.577*	*0.206*	5.389	0.416	0.000	0	-	
	V : sub total		869,734	10.2	4,614.09	0.221	-	-	-	-	-	0.003	2,822	0.719	
	VI	SW	31,008	0.0	721.24	0.000	0.638	*1.577*	*0.206*	5.389	0.416	0.000	0	-	
		NW	220,818	7.0	756.37	0.921	0.622	*1.577*	*0.206*	5.389	0.416	0.016	3,475	0.776	
	VI : sub total		251,826	7.0	1,477.61	0.471	-	-	-	-	-	0.014	3,475	0.776	
	Year Total		1,121,561	17.2	6,091.70	0.282	-	-	-	-	-	0.006	6,298	0.628	
2007/2008	IIIE	NE	228,382	4.0	931.41	0.429	0.340	*1.579*	*0.138*	2.333	0.092	0.003	725	0.379	
		SE	50,431	7.0	1,126.20	0.622	0.844	*1.579*	*0.138*	2.333	0.092	0.005	232	0.861	
	IIIE : sub total		278,813	11.0	2,057.61	0.535						0.003	956	0.369	
	IV	NW	213,311	8.4	958.89	0.876	0.355	*1.579*	*0.138*	2.333	0.092	0.006	1,380	0.392	
		NE	216,236	2.0	1,332.40	0.150	0.646	*1.579*	*0.138*	2.333	0.092	0.001	240	0.667	
		SW	39,787	1.0	847.54	0.118	0.712	*1.579*	*0.138*	2.333	0.092	0.001	35	0.731	
		SE	36,277	0.0	819.76	0.000	0.415	*1.579*	*0.138*	2.333	0.092	0.000	0	-	
		PB	---	-	-	-	-	-	-	-	-	-	-	-	
	IV : sub total		505,611	11.4	3,958.59	0.288	-	-	-	-	-	0.003	1,654	0.353	
	IIIE+IV : sub total			-	-	-	-	-	-	-	-	-	2,610	0.285	
	V	NW	275,376	15.7	1,148.10	1.365	0.593	*1.579*	*0.138*	2.333	0.092	0.010	2,777	0.616	
		SW	43,609	0.0	864.87	0.000	0.322	*1.579*	*0.138*	2.333	0.092	0.000	0	-	
	V : sub total		318,985	15.7	2,012.97	0.778	-	-	-	-	-	0.009	2,777	0.616	*
	Year Total		1,103,409	38.1	8,029.17	0.474	-	-	-	-	-	0.005	5,387	0.366	*
2008/2009	V	NW	224,275	9.0	1,144.70	0.786	0.401	*1.544*	*0.100*	3.958	0.215	0.010	2,260	0.466	
		NE	324,889	17.9	1,369.50	1.309	0.298	*1.544*	*0.100*	3.958	0.215	0.017	5,449	0.381	
		SW	64,901	18.0	638.13	2.821	0.460	*1.544*	*0.100*	3.958	0.215	0.036	2,346	0.517	
		Ross	277,209	0.0	2,757.80	0.000	0.000	*1.544*	*0.100*	3.958	0.215	0.000	0	-	
	V : sub total		891,274	44.9	5,910.13	0.760	-	-	-	-	-	0.011	10,056	0.319	
	VI	SW	76,255	13.9	990.09	1.406	0.629	*1.544*	*0.100*	3.958	0.215	0.018	1,374	0.672	
		NW	166,610	12.0	721.57	1.663	0.398	*1.544*	*0.100*	3.958	0.215	0.021	3,551	0.463	
	VI : sub total		242,865	25.9	1,711.66	1.514	-	-	-	-	-	0.020	4,925	0.412	
	Year Total		1,134,139	70.8	7,621.79	0.929	-	-	-	-	-	0.013	14,981	0.298	

Table 3c. Abundance estimates of southern right whale by strata in the JARPAII period. Data in closing and passing mode were analyzed together. n: number of schools sighted on primary effort, *L:* searching distance, esw: the effective search half width (normal form of a character: estimated by the Hazard rate model, Italics form: by the half normal model), *E(s)*: mean school size, *D*: estimated density (individuals / 100 n.miles ^{2}), *P*: estimated abundance.

Season	Stratum	Area	*n*	L	*n/L**100	CV	esw	CV	E(*s*)	CV	*D*	*P*	CV
		(n.miles2)		(n.miles)			(n.miles)				(ind.)	(ind.)	
1989/90	NW	222,563	1.0	1,987.6	0.001	1.302	*1.454*	*0.079*	1.1	0.028	0.000	42	1.305
	NE	219,245	0.0	1,964.4	-	-	-	-	-	-	-	-	-
	SW	35,878	0.0	2,518.3	-	-	-	-	-	-	-	-	-
	SE	41,143	0.0	1,362.2	-	-	-	-	-	-	-	-	-
	PB	36,488	0.0	831.9	-	-	-	-	-	-	-	-	-
	total	555,317	0.0	8,664.4	-	-	-	-	-	-	-	**42**	1.305
1991/92	NW	219,713	6.0	2,482.7	0.002	0.478	*1.454*	*0.079*	1.1	0.028	0.001	201	0.485
	NE	216,299	0.0	2,173.9	-	-	-	-	-	-	-	-	-
	SW	37,191	0.0	2,237.5	-	-	-	-	-	-	-	-	-
	SE	39,732	0.0	2,281.7	-	-	-	-	-	-	-	-	-
	PB	36,569	0.0	607.5	-	-	-	-	-	-	-	-	-
	total	549,504	6.0	9,783.3	-	-	-	-	-	-	-	**201**	0.485
1993/94	NW	233,289	3.0	4,160.7	0.001	0.629	*1.454*	*0.079*	1.1	0.028	0.000	64	0.635
	NE	163,982	5.0	3,175.1	0.002	0.578	*1.454*	*0.079*	1.1	0.028	0.001	97	0.584
	SW	39,755	0.0	2,377.7	-	-	-	-	-	-	-	-	-
	SE	41,353	0.0	2,258.9	-	-	-	-	-	-	-	-	-
	PB	34,506	0.0	1,077.0	-	-	-	-	-	-	-	-	-
	total	512,885	8.0	13,049.4	-	-	-	-	-	-	-	**161**	0.437
1995/96	NW	149,107	0.0	3,530.5	-	-	-	-	-	-	-	-	-
	NE	230,473	5.0	2,979.7	0.002	0.509	*1.454*	*0.079*	1.1	0.028	0.001	146	0.516
	SW	89,825	0.0	2,851.2	-	-	-	-	-	-	-	-	-
	SE	33,980	3.0	2,039.9	0.001	0.569	*1.454*	*0.079*	1.1	0.028	0.001	19	0.575
	PB	25,970	0.0	1,321.8	-	-	-	-	-	-	-	-	-
	total	529,354	8.0	12,723.1	-	-	-	-	-	-	-	**165**	0.463
1997/98	NW	217,645	2.0	3,367.2	0.001	0.879	*1.454*	*0.079*	1.1	0.028	0.000	49	0.882
	NE	219,602	10.0	3,622.7	0.003	0.475	*1.454*	*0.079*	1.1	0.028	0.001	229	0.482
	SW	31,615	18.7	3,432.5	0.005	0.227	*1.454*	*0.079*	1.1	0.028	0.002	65	0.242
	SE	34,374	3.0	3,195.9	0.001	0.498	*1.454*	*0.079*	1.1	0.028	0.000	12	0.505
	PB	4,407	0.0	490.0	-	-	-	-	-	-	-	-	-
	total	507,643	33.7	14,108.3	-	-	-	-	-	-	-	**356**	0.343
1999/00	NW	229,368	0.0	2,825.3	-	-	-	-	-	-	-	-	-
	NE	226,272	1.0	3,550.8	0.000	0.968	*1.454*	*0.079*	1.1	0.028	0.000	24	0.972
	SW	44,862	0.0	2,336.7	-	-	-	-	-	-	-	-	-
	SE	34,175	2.0	2,704.3	0.001	1.184	*1.454*	*0.079*	1.1	0.028	0.000	10	1.187
	PB	21,288	0.0	1,244.7	-	-	-	-	-	-	-	-	-
	total	555,964	3.0	12,661.8	-	-	-	-	-	-	-	**34**	0.775
2001/02	NW	222,449	0.0	3,043.6	-	-	-	-	-	-	-	-	-
	NE	244,921	1.0	3,271.6	0.000	1.008	*1.454*	*0.079*	1.1	0.028	0.000	28	1.011
	SW	32,199	0.0	2,321.8	-	-	-	-	-	-	-	-	-
	SE	35,955	0.0	2,885.2	-	-	-	-	-	-	-	-	-
	PB	28,472	0.0	1,033.7	-	-	-	-	-	-	-	-	-
	total	563,995	1.0	12,555.9	-	-	-	-	-	-	-	**28**	1.011
2003/04	NW	243,849	0.0	3,236.6	-	-	-	-	-	-	-	-	-
	NE	218,072	0.0	3,738.5	-	-	-	-	-	-	-	-	-
	SW	38,976	1.0	2,275.2	0.000	0.756	*1.454*	*0.079*	1.1	0.028	0.000	6	0.761
	SE	38,952	0.0	3,633.2	-	-	-	-	-	-	-	-	-
	PB	37,537	0.0	508.5	-	-	-	-	-	-	-	-	-
	total	577,386	1.0	13,392.0	-	-	-	-	-	-	-	**6**	0.761
2005/06	NW	228,919	0.0	1,131.4	-	-	-	-	-	-	-	-	-
	NE	213,660	7.0	1,450.3	0.005	0.448	*1.565*	*0.0915*	1.382	0.061	0.002	455	0.461
	SW	47,117	4.0	859.4	0.005	0.656	*1.565*	*0.0915*	1.382	0.061	0.002	97	0.665
	SE	37,228	17.0	865.5	0.020	0.484	*1.565*	*0.0915*	1.382	0.061	0.009	323	0.496
	PB	31,689	1.0	381.1	0.003	1.117	*1.565*	*0.0915*	1.382	0.061	0.001	37	1.122
	total	558,613	29.0	4,687.7	-	-	-	-	-	-	-	**912**	0.314
2007/08	NW	213,311	1.0	958.9	0.001	1.086	*1.565*	*0.0915*	1.382	0.061	0.000	98	1.092
	NE	216,236	3.0	1,332.4	0.002	0.562	*1.565*	*0.0915*	1.382	0.061	0.001	215	0.573
	SW	39,787	24.2	847.5	0.029	0.676	*1.565*	*0.0915*	1.382	0.061	0.013	502	0.685
	SE	36,277	38.0	819.8	0.046	0.308	*1.565*	*0.0915*	1.382	0.061	0.020	741	0.327
	PB	-	-	-	-	-	-	-	-	-	-	-	-
	total	505,611	66.2	3,958.6	-	-	-	-	-	-	-	**1,557**	0.303

Table 4a. Abundance estimates of the blue whales for Areas IIIE, IV, V and VIW south of 60^{o}S during the JARPA and JARPA II period. Abundance estimates in the JARPA period are referred from Matsuoka *et al*, (2006).

Season	Area IIIE		Area IV		Season	Area V		Area VIW	
	P	CV(P)	P	CV(P)		P	CV(P)	P	CV(P)
1989/90	-	-	65	0.481	1990/91	183	1.010	-	-
1991/92	-	-	18	1.078	1992/93	257	0.639	-	-
1993/94	-	-	66	0.615	1994/95	270	0.633	-	-
1995/96	192	0.430	8	0.934	1996/97	10	0.749	90	0.447
1997/98	234	0.480	145	0.604	1998/99	206	2.147	-	-
1999/00	546	0.580	225	0.385	2000/01	317	0.498	-	-
2001/02	80	0.620	300	0.460	2002/03	143	0.526	28	0.932
2003/04	546	0.340	78	0.734	2004/05	489	0.746	152	0.377
2005/06	354	0.506	196	0.527	2006/07	30	0.987	84	1.458
2007/08	551	0.559	242	0.578	2008/09	392	0.460	38	1.623

Table 4b. Abundance estimates of the fin whales for Areas IIIE+IV combined and Area V +VIW combined south of 60^{o}S during the JARPA and JARPA II period. Abundance estimates in the JARPA period are referred from Matsuoka *et al*, (2006).

Areas IIIE and IV combined (Indian Ocean stock)

Season	P	CV	95%CI LL	95%CI UL
1995/96	3,087	0.191	2,130	4,473
1997/98	698	0.307	387	1,258
1999/2000	6,764	0.240	4,250	10,765
2001/02	9,250	0.266	5,536	15,455
2003/04	6,514	0.261	3,937	10,779
2005/06	11,190	0.216	5,453	12,259
2007/08	2,610	0.285	1,510	4,511

Areas V and VIW combined (Western South Pacific stock)

Season	P	CV	95%CI LL	95%CI UL
1996/97	1,879	0.226	1,212	2,911
1998/99	4,423	0.379	2,157	9,069
2000/01	6,392	0.211	4,249	9,616
2002/03	3,705	0.285	2,144	6,402
2004/05	5,241	0.381	2,547	10,784
2006/07	6,298	0.628	2,035	19,488
2008/09	14,981	0.298	8,452	26,552

Table 4c. Abundance estimates of southern right whale for Area IV south of 60°S during the JARPA and JARPA II period.

Season	P	CV	95%CI LL	95%CI UL
1989/90	42	1.305	6	299
1991/92	201	0.485	82	494
1993/94	161	0.437	71	365
1995/96	165	0.463	70	392
1997/98	356	0.343	185	683
1999/00	34	0.775	9	129
2001/02	28	1.011	5	147
2003/04	6	0.761	2	24
2005/06	912	0.314	500	1,661
2007/08	1,557	0.303	871	2,783

Table 5. Abundance trends estimate for blue, fin and southern right whales. CILL: confidence interval lower limit. CIUL: confidence interval upper limit.

Species	Area	Start - Latest seasons	Start season		Latest season		Abundance trend	95%CILL	95%CIUL
			Abundance	CV	Abundance	CV			
Blue whale	IIIE+IV+V+VIW	1995/96 - 2008/09	300	0.308	1,223	0.345	0.082	0.039	0.125
Fin whale (Indian Ocean stock)	IIIE+IV	1995/96 - 2007/08	3,087	0.191	2,610	0.285	0.089	-0.145	0.324
Fin whale (W. S. Pacific stock)	V+VIW	1996/97 - 2008/09	1,879	0.226	14,981	0.298	0.120	0.026	0.215
Southern right whale	IV	1989/90 - 2007/08	42	1.305	1,557	0.303	0.059	-0.164	0.281

Table 6a. Abundance estimates of blue whales for base case and sensitivities.

Season		1995/96	1997/98	1999/00	2001/02	2003/04	2005/06	2007/08	Average % of change	Abundance trend (%)	Change from base case (%)
Base case		300	585	1,088	551	1,268	664	1,222	-	8.2	-
		-	-	-	-	-	-	-	-	-	-
Hazard rate model		-	-	-	-	-	617	1,135	-	7.6	-0.6
		-	-	-	-	-	-7%	-7%	-7%	-	-
Half-normal model		-	-	-	-	-	664	1,222	-	9.0	0.0
		-	-	-	-	-	0%	0%	0%	-	-
Poor coverage corrections*		-	-	-	-	-	926	1,222	-	9.4	1.2
		-	-	-	-	-	39%	0%	20%	-	-

1): Estimates between 1995/96 and 2003/04 are from Matsuoka *et al*., 2006.
2): 2005/05 is included 2005/06+2006/07 estimates.
3): 2007/08 is included 2007/08+2008/09 estimates.
*: 2005/06 in Area IIIE, 2006/07 in Area VW.

Table 6b. Abundance estimates of fin (Indian Ocean stock) whales for base case and sensitivities.

Season		1995/96	1997/98	1999/00	2001/02	2003/04	2005/06	2007/08	Average % of change	Abundance trend (%)	Change from base case (%)
Base case		3,087	698	6,764	9,250	6,514	11,190	2,610	-	8.9	-
		-	-	-	-	-	-	-	-	-	-
Hazard rate model							11,482	2,376	-	8.5	-0.4
		-	-	-	-	-	3%	-9%	-3%	-	-
Half-normal model		-	-	-	-	-	11,190	2,610	-	8.9	0.0
		-	-	-	-	-	0%	0%	0%	-	-
Poor coverage corrections*		-	-	-	-	-	7,489	2,610	-	7.5	-1.4
		-	-	-	-	-	-33%	0%	-17%	-	-

1): Estimates between 1995/96 and 2003/04 are from Matsuoka *et al*., 2006.
*: 2005/06 in Area IIIE, 2006/07 in Area VW.

Table 6c. Abundance estimates of fin (Western South Pacific stock) whales for base case and sensitivities.

Season		1996/97	1998/99	2000/01	2002/03	2004/05	2006/07	2008/09	Average % of change	Abundance trend (%)	Change from base case (%)
Base case		1,879	4,423	6,392	3,705	5,241	6,298	14,981	-	12.0	-
		-	-	-	-	-	-	-	-	-	-
Hazard rate model		-	-	-	-	-	8,861	13,315	-	12.6	0.6
		-	-	-	-	-	41%	-11%	15%	-	-
Half-normal model		-	-	-	-	-	6,298	14,981	-	12.0	0.0
		-	-	-	-	-	0%	0%	0%	-	-
Poor coverage corrections*		-	-	-	-	-	14,485	14,981	-	15.0	3.0
		-	-	-	-	-	130%	0%	65%	-	-

1): Estimates between 1996/97 and 2004/05 are from Matsuoka *et al*., 2006.
*: 2005/06 in Area IIIE, 2006/07 in Area VW.

Table 6d. Abundance estimates of southern right whales in Area IV for base case and sensitivities.

Season	1989/90	1991/92	1993/94	1995/96	1997/98	1999/00	2001/02	2003/04	2005/06	2007/08	Average % of change	Abundance trend (%)	Change from base case (%)
Base case	42	201	161	165	356	34	28	6	912	1,557	-	5.9	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
Hazard rate model	43	203	163	167	359	34	29	7	908	1,550	-	5.9	0.0
	2%	1%	1%	1%	1%	0%	4%	17%	0%	0%	3%	-	-
Half-normal model	42	201	161	165	356	34	28	6	912	1,557	-	5.9	0.0
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-	-

Table 7a. Biomass of Antarctic minke, humpback, fin, blue and southern right whales in Area IV (south of 60^{o}S),

between 1989/90 and 2007/2008 seasons (over 19 years). Abundance of Antarctic minke and humpback whales was estimated by Hakamada *et al*, (2014a and 2014b).

AREA IV	Seasons	A. Minke	Humpback	Fin	Blue	S. Right	Total
	1989/90	194,955	159,750	5,717	6,500	2,394	369,315
	1991/92	210,717	162,240	18,981	1,800	11,457	405,195
	1993/94	179,387	82,410	10,323	6,600	9,177	287,897
	1995/96	214,305	241,980	56,666	800	9,405	523,156
	1997/98	107,653	319,710	34,632	14,500	20,292	496,787
	1999/00	292,143	502,530	86,858	22,500	1,938	905,968
	2001/02	200,246	934,020	325,286	30,000	1,596	1,491,147
	2003/04	214,305	833,490	68,043	7,800	342	1,123,980
	2005/06	414,661	778,740	347,930	35,400	51,984	1,628,715
	2007/08	98,072	872,010	91,797	55,100	88,749	1,205,728
	Total	2,126,443	4,886,880	1,046,231	181,000	197,334	8,437,887

Table 7b. Biomass of Antarctic minke, humpback, fin, blue and southern right whales in Area V (south of 60^{o}S), between 1990/91 and 2008/2009 seasons (over 19 years). Abundance of Antarctic minke and humpback whales was estimated by Hakamada *et al*, (2014a and 2014b). Average body weights used for this biomass calculation were 7.4, 31.0, 55.0 and 100.0 tons for Antarctic minke, humpback, fin and blue whales, respectively.

AREA V	Seasons	A. Minke	Humpback	Fin	Blue	Total
	1990/91	654,849	51,420	40,626	18,300	765,195
	1992/93	429,956	131,640	90,077	25,700	677,372
	1994/95	659,380	118,290	385,004	27,000	1,189,673
	1996/97	640,900	44,220	67,932	1,000	754,052
	1998/99	617,136	239,670	236,375	20,600	1,113,781
	2000/01	736,528	153,900	295,316	31,700	1,217,444
	2002/03	811,285	86,190	178,155	14,300	1,089,930
	2004/05	468,319	280,260	252,858	48,900	1,050,337
	2006/07	406,075	493,140	156,621	3,000	1,058,836
	2008/09	707,532	416,820	91,797	39,200	1,255,349
	Total	6,131,957	2,015,550	1,794,759	229,700	10,171,966

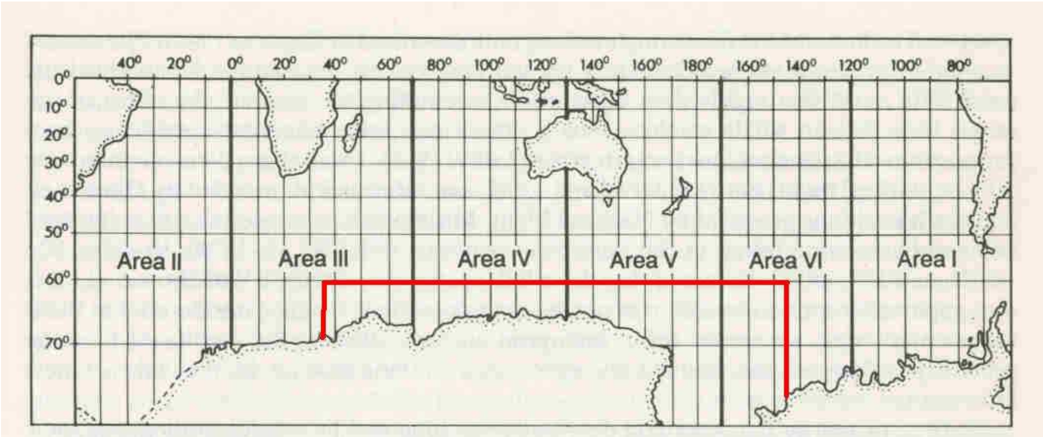

Figure 1a. The IWC Antarctic Areas for the management of baleen whales (except Bryde's whale) and research Area of the JARPA and JARPAII surveys between 35°E and 145°W (colored). Area III east (IIIE: 35 °E-70°E), Area IV(70°E-130°E), Area V (130°E-170°W) and Area VI west (VIW: 170°W -145°W).

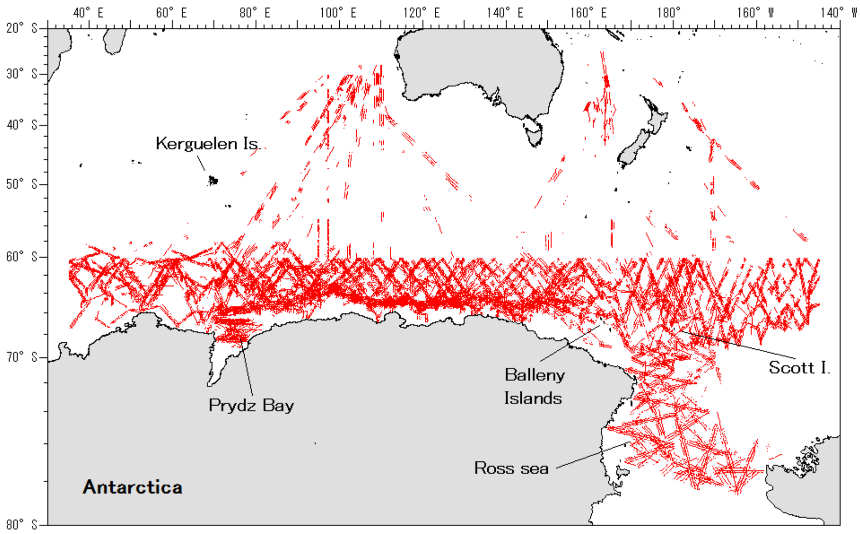

Figure 1b. Map of the searching efforts (red line) in the JARPA1987/88-2004/05 and JARPAII 2005/06-2008/09 seasons, including middle latitude transit sighting survey.

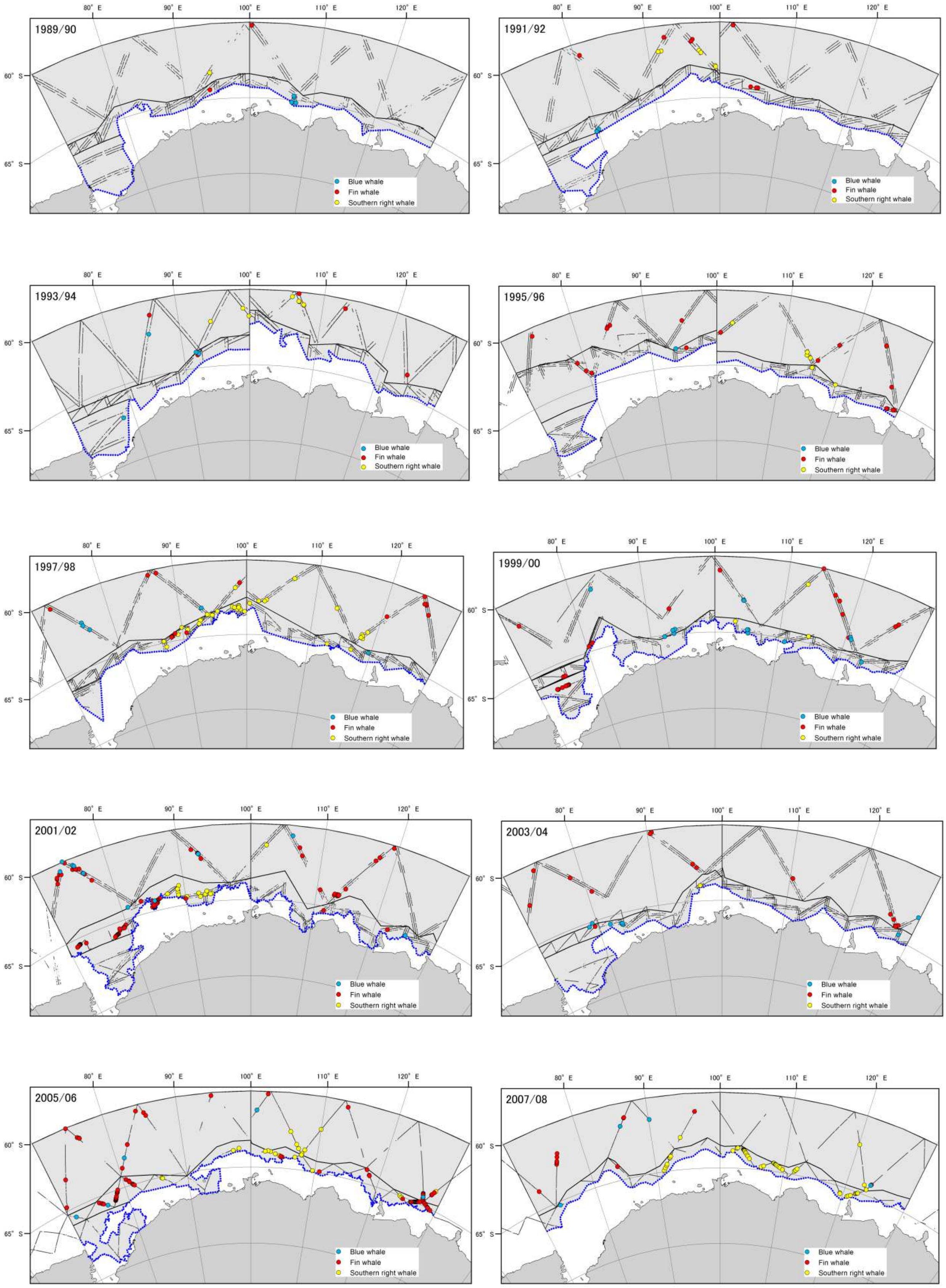

Figure 2a. Primary searching effort (thin lines) and associated primary sightings of blue (blue circle), fin (red) and southern right (yellow) whales in Area IV (70°E-130°E) together with the ice edge (dotted blue line) during JARPA and JARPA II surveys.

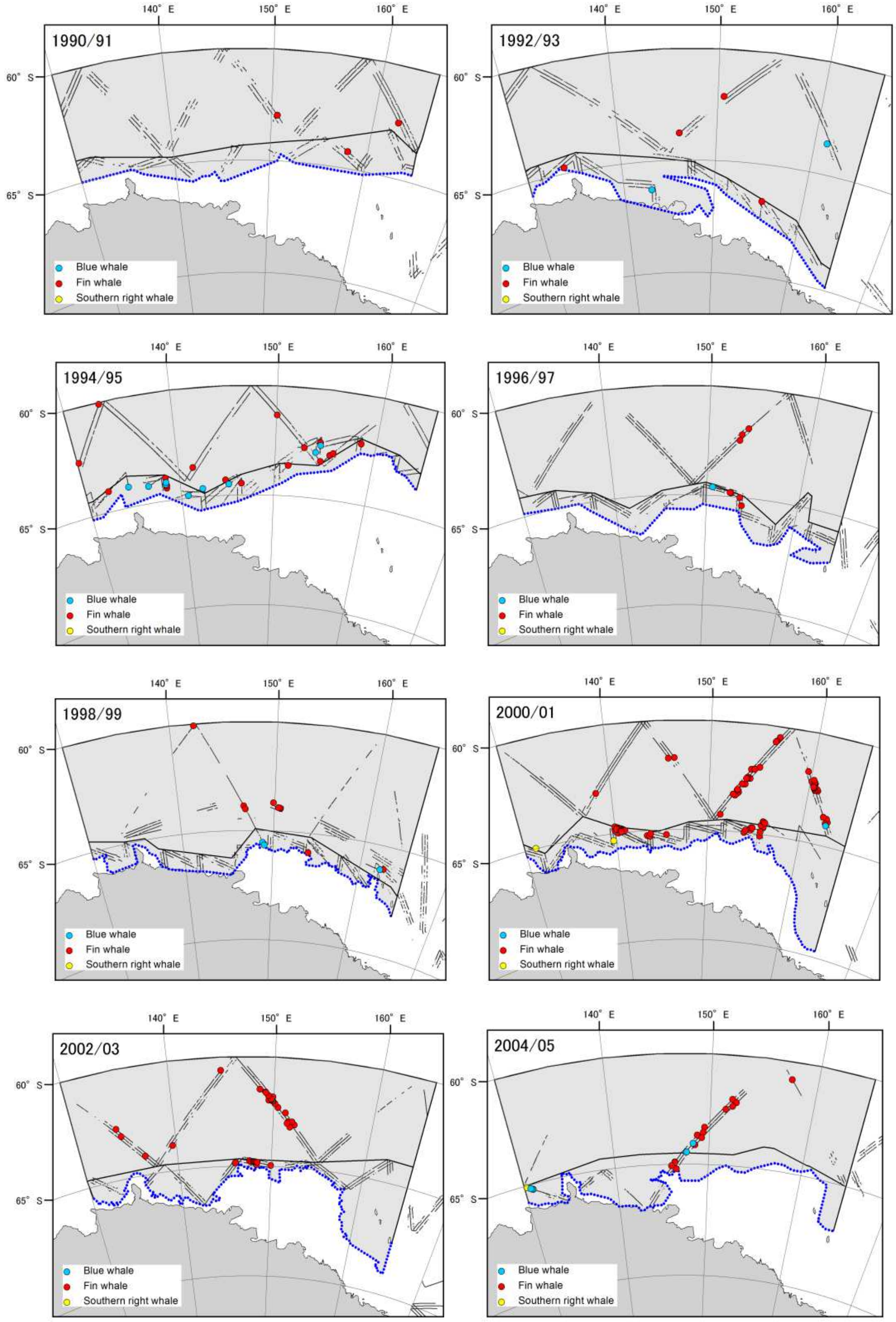

Figure 2b. Primary searching effort (thin lines) and associated primary sightings of blue (blue circle), fin (red) and southern right (yellow) whales in Area VW (130°E-165°E) together with the ice edge (dotted blue line) during JARPA surveys.

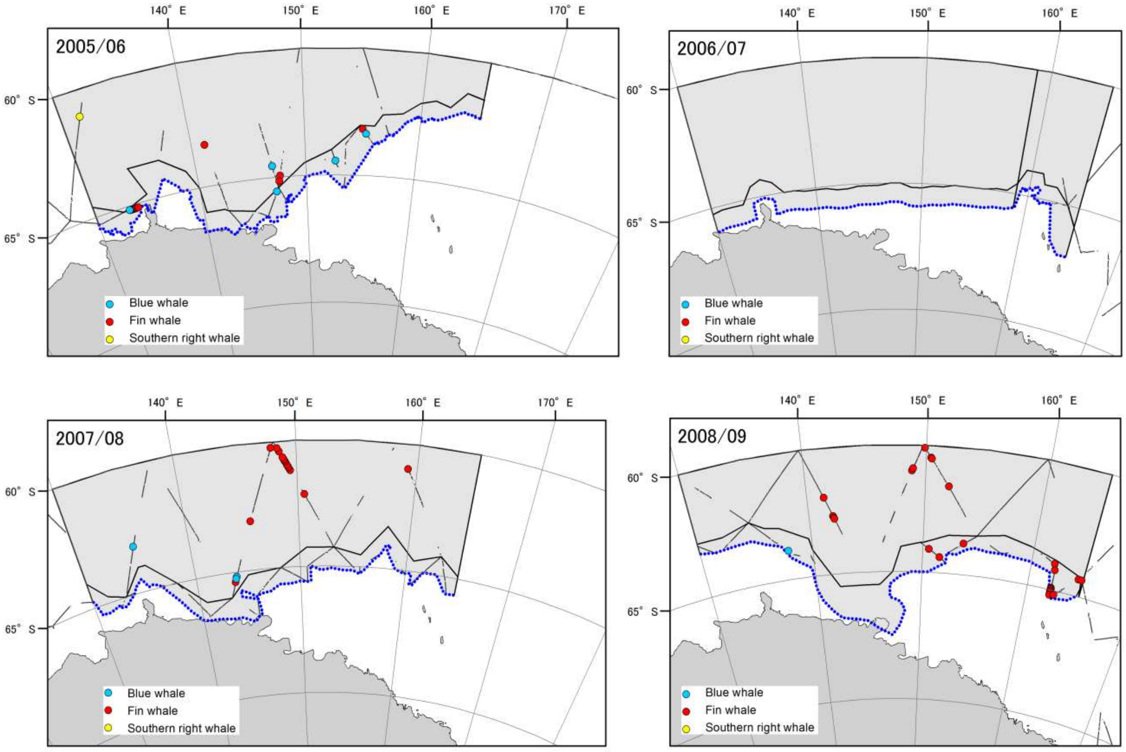

Figure 2c. Primary searching effort (thin lines) and associated primary sightings of blue (blue circle), fin (red) and southern right (yellow) whales in Area VW (130^{o}E-165^{o}E) together with the ice edge (dotted blue line) during JARPA II surveys.

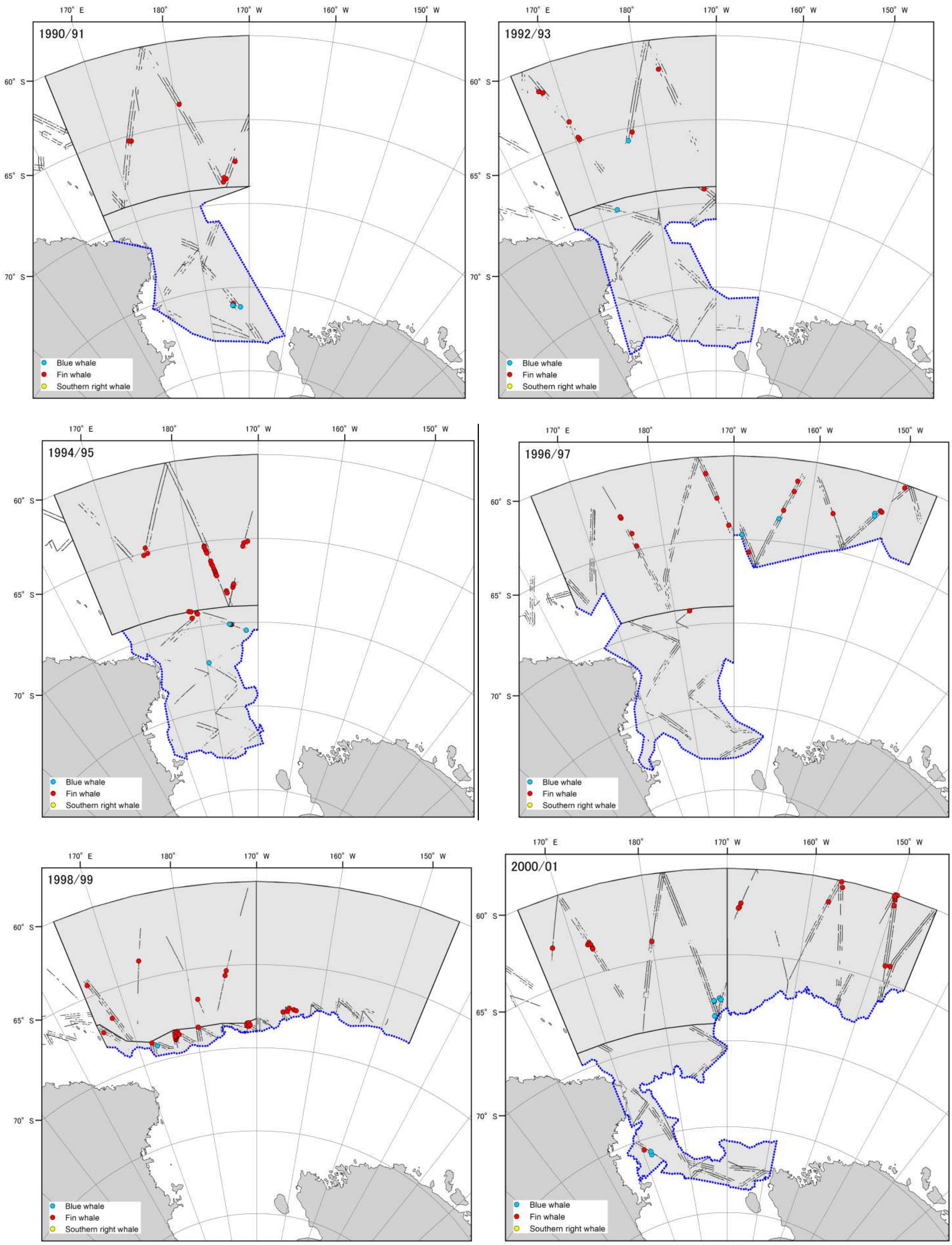

Figure 2d. Primary searching effort (thin lines) and associated primary sightings of blue (blue circle), fin (red) and southern right (yellow) whales in Areas VE and VIW (165°E-145°W) together with the ice edge (dotted blue line) during JARPA and JARPAII surveys.

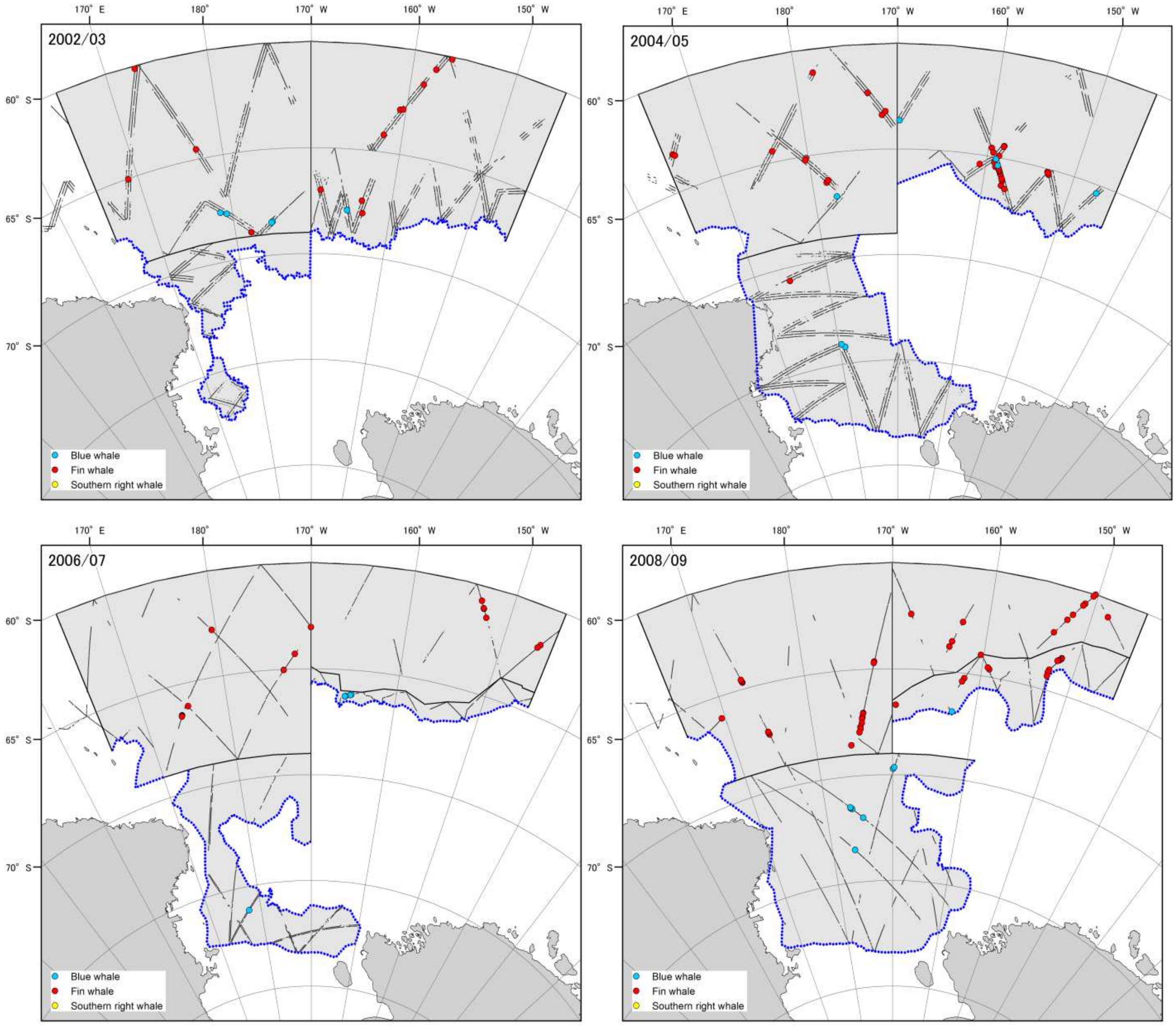

Figure 2d. (Continued).

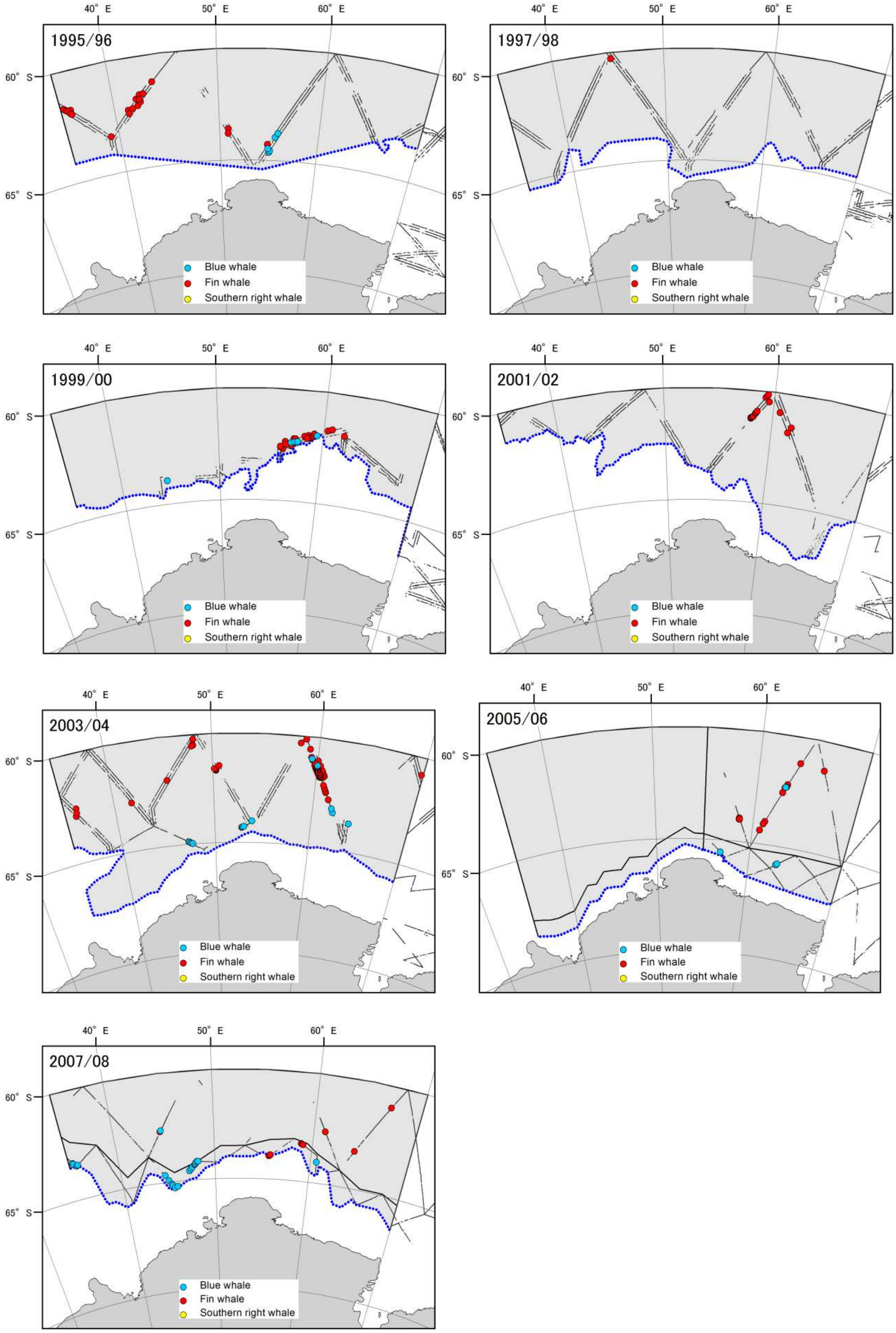

Figure 2e. Primary searching effort (thin lines) and associated primary sightings of blue (blue circle), fin (red) and southern right (yellow) whales in Area IIIE (35°E-70°E) together with the ice edge (dotted blue line) during JARPA and JARPAII surveys.

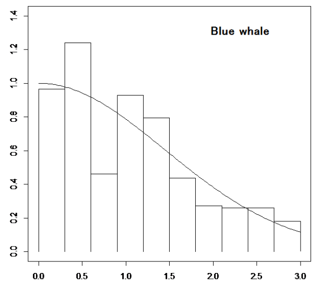

Figure 3a. Detection probability function of blue whales for the JARPA and JARPAII surveys.

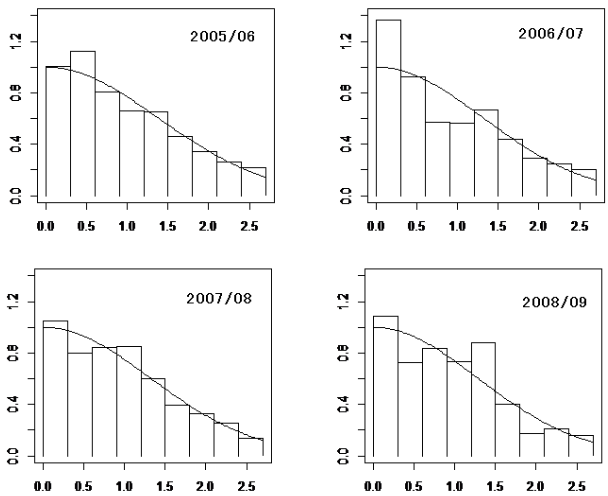

Figure 3b. Detection probability function of fin whales for the JARPAII surveys.

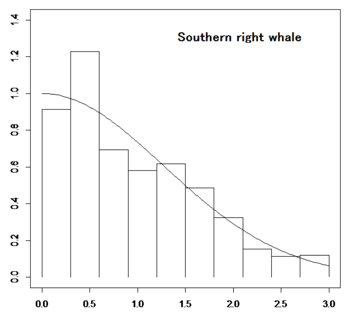

Figure 3c. Detection probability function of southern right whales for the JARPA and JARPAII surveys.

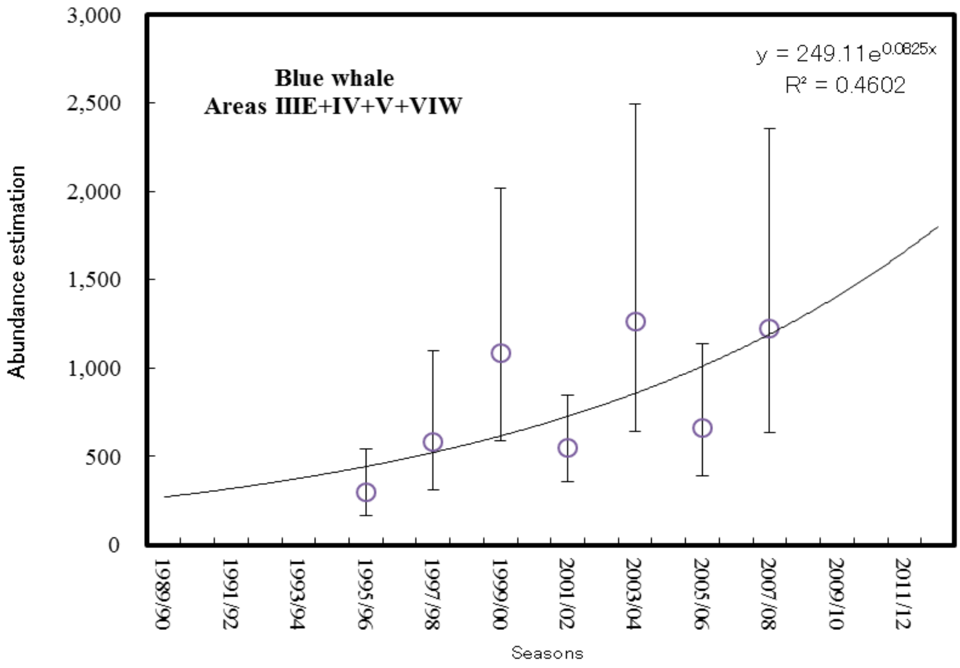

Figure 4a. Abundance estimates of blue whale in Areas IIIE, IV, V and VIW (south of 60^{o}S). Vertical lines show 95％ confidential intervals.

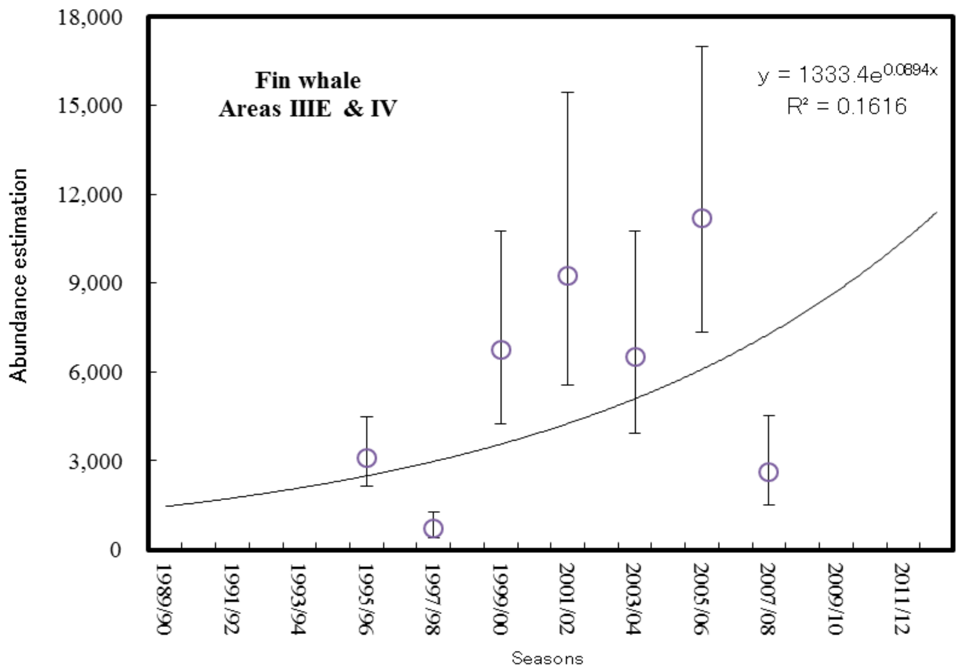

Figure 4b. Abundance estimates of fin whale in Areas IIIE & IV (south of 60^{o}S). Vertical lines show 95％ confidential intervals.

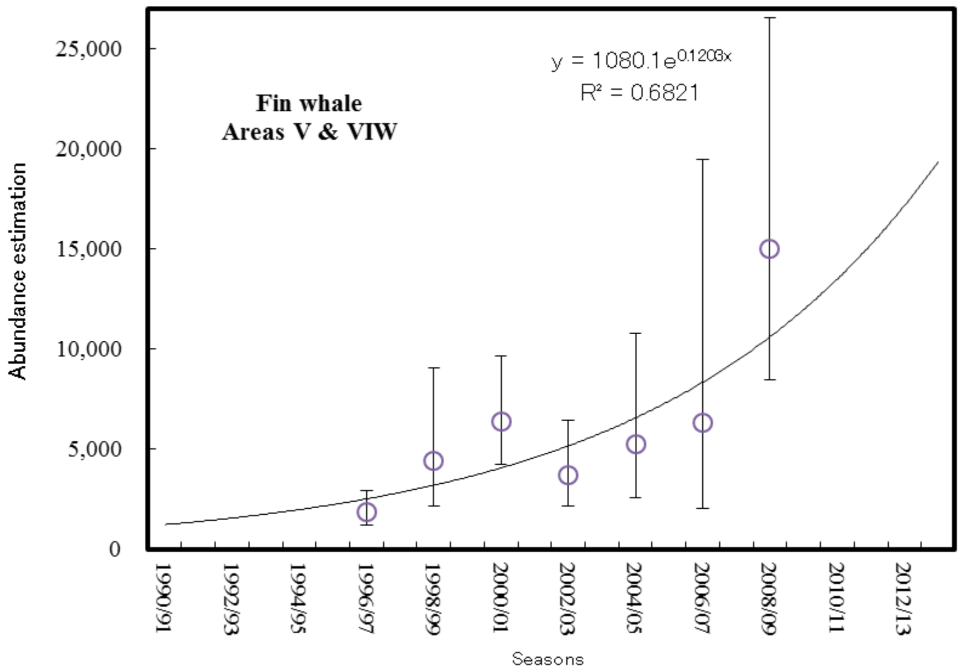

Figure 4c. Abundance estimates of fin whale in Areas V & VIW (south of 60°S). Vertical lines show 95% confidential intervals.

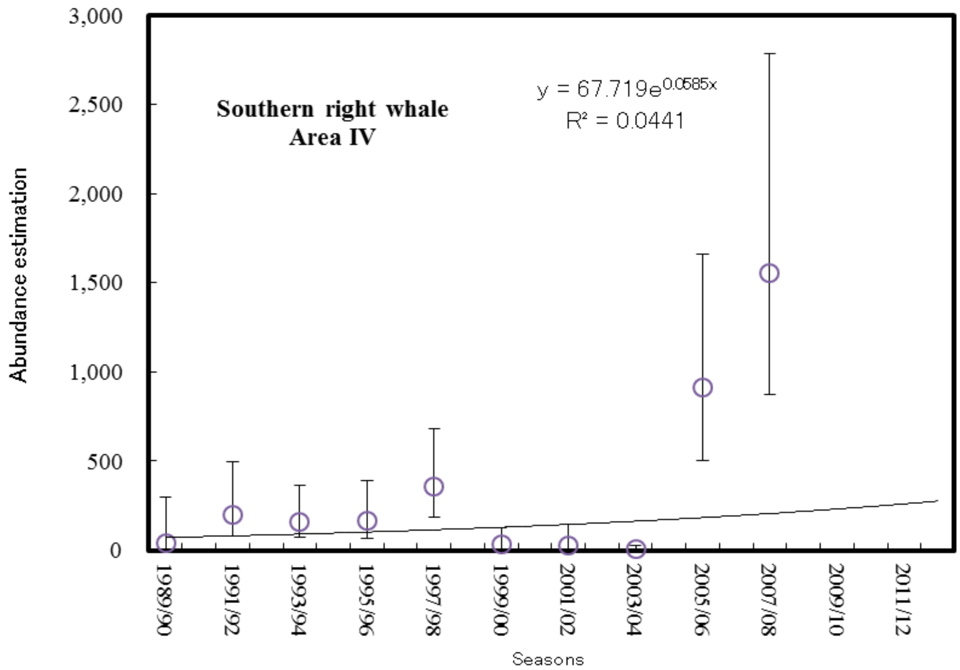

Figure 4d. Abundance estimates of southern right whale in Areas IV (south of 60°S). Vertical lines show 95% confidential intervals.

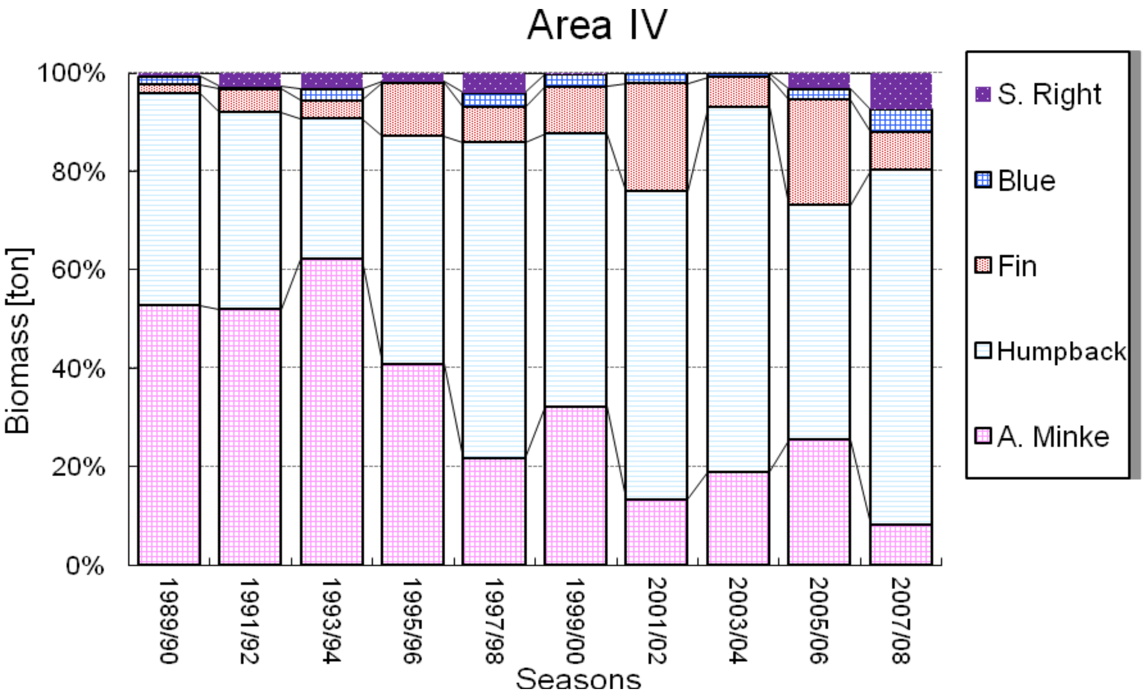

Figure 5a. Estimated biomass of blue, fin, humpback, Antarctic minke and southern right whales in Area IV (south of 60°S) between 1989/90 and 2007/08 seasons. Abundance of Antarctic minke and humpback whales was from Hakamada *et al*, (2014a and 2014b).

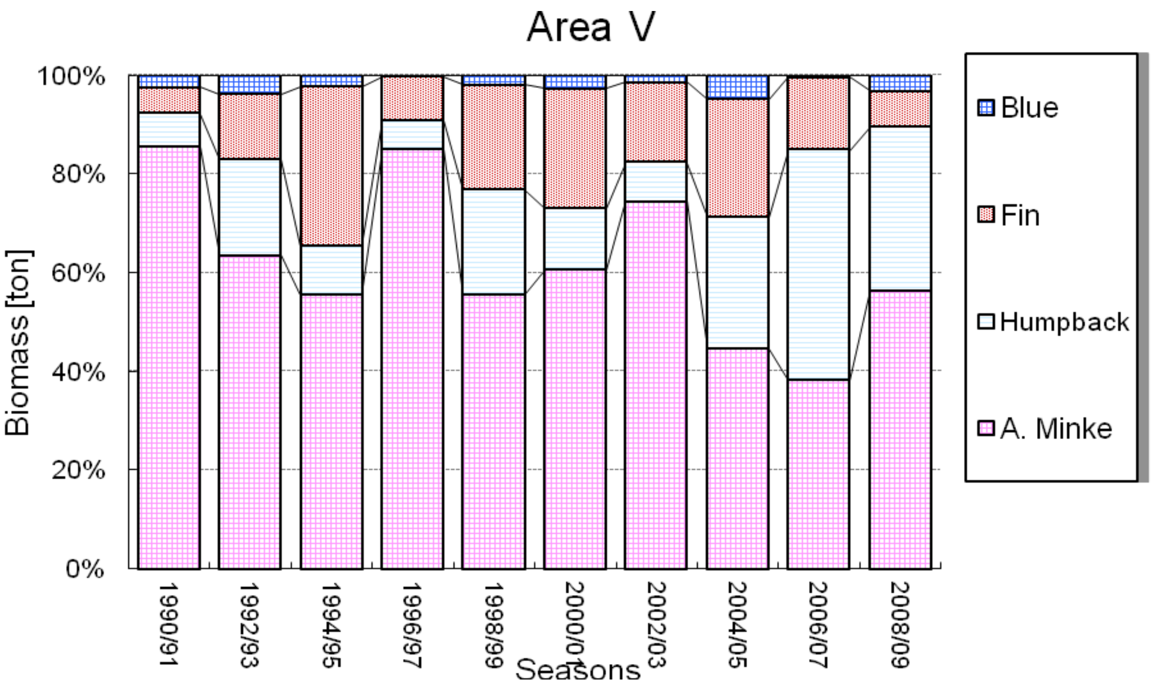

Figure 5b. Estimated biomass of blue, fin, humpback and Antarctic minke whales in Area V (south of 60°S) between 1990/91 and 2008/09 seasons. Abundance of Antarctic minke and humpback whales was from Hakamada *et al*, (2014a and 2014b).