Current abundance and density trend of humpback and fin whales in the Antarctic Areas IV and V using JARPA data

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ABSTRACT

We report the results from an analysis of current abundance (south of 60 ° S) of humpback and fin whales and their annual rate of increase in the Antarctic Areas IV and V between the 1989/90 and 2000/01 seasons (over 12 years) by the DISTANCE analysis program. There was agreement that estimates from the elosing mode on IWC/IDCR-SOWER surveys and JARPA SV (dedicated sighting vessel) data could be used in the same way (IWC, 2000), based on the simulation results (Clarke et al., 2000). Current abundance of humpback whales in Area IV were estimated as 12,093 (CV=0.29) by SV and 11,960 (CV=0.14) by SSV (sighting and sampling vessels), respectively from 1999/2000 data. Humpback whales in Area V were estimated as 4,251 (CV=0.48) by SV and 3,477 (CV=0.31) by SSV, respectively from 2000/01 data. Fin whales in Area IV were estimated as 230 (CV=0.61) by SV and 1,523 (CV=0.64) by SSV, respectively, and in Area V they were estimated as 6,362 (CV=0.50) by SV and 4,330 (CV=0.40) by SSV, respectively. Following conditions were applied to this analyses; 1) using corrected distance and angle by the results of the distance and angle estimation experiments, 2) truncation distance was 2.4 n.miles, 3) effective search half width is obtained by fitting a hazard rate model, and 4) g (0) was assumed to be 1. Estimated densities (whales / 100 n.miles^2) of these species were also estimated in each Area based on the SSV data due to the long survey years (over 12 years). An estimated annual rate of increase for humpback whales in the feeding ground were 17.2% (CV=0.29) and 10.2% (CV=0.59) in Areas IV and V, respectively. For fin whales, 28.2 % (CV=0.31) and 10.3 % (CV=1.58) in Areas IV and V were estimated. Distribution patterns of these species were also reported.

INTRODUCTION

The Japanese Whale Research Program under special permit in the Antarctic (JARPA) has been carried out in a consistent way every other year in Areas IV from the 1987/88 to 2000/01 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 have been conducted since 1989/90 season. The sighting procedures followed the method used in the IWC/IDCR and SOWER cruises as much as possible. In Areas IV and V, minke whale was the dominantly sighted species in surveys from the 1987/88 to the 1995/96 seasons. In Area IV, humpback whale was the sub-dominantly sighted species in 1995/96, the dominant sighted species in 1997/98,and again the sub-dominantly sighted species in 1999/2000 and 2000/01 seasons (Ishikawa et al., 2000 and Nishiwaki et al., 2001a). Nishiwaki et al. (1997) reported

abundance estimation of humpback and fin whales using JARPA data between 1989/90 and 1995/96 season (over 7 years), although it was recommended that a reanalysis be carried out based on a more scientifically defensible procedure (IWC, 1999). Abundance estimation and density trend of humpback whale in Area IV from 1989/90 to 1999/2000 seasons using JARPA data were reported in the last year (Matsuoka et al., 2000). This paper reports further results from an analysis of abundance of humpback and fin whales and their annual rate of increase in Areas IV and V (south of 60 ° S) between 1989/90 and 2000/01 seasons (over 12 years) using the DISTANCE analysis program.

SURVEYS AND DATA COLLECTION

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 whole area uniformly, (2) the line transect procedure sampled the schools proportionally 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 60 ° S to the ice-edge in the Areas IV (70 ° E-130 ° E) and V (130 ° E-170 ° W) were covered. Each Area (IV and V) was divided into two sectors (western sector and eastern sector). Each sector also divided into two strata (southern and northern 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 (southren 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.

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 following trackline legs were systematically set on the ice-edge and on the locus of the 45n.miles from the ice-edge (southern stratum), and the 45 n.miles from the 60 ° S latitude line (northern stratum).

Research vessels

Kyosin-Maru No.2 has been used surveyed as the dedicated sighting vessel (SV) since 1995/96 survey. *Kyo-Maru No.1, Toshi-Maru No.25, Toshi-Maru No.18* operated as sighting and sampling vessel (SSV) for the surveys from 1989/90 to 1997/1998. *Yusin-Maru* operated as SSV for the 1998/1999 survey as the replacement of *Toshi-Maru No.18.*

METHODS

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 slope through the origin divided estimated distance. 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).

Abundance estimation

Methodology of abundance estimation used in this study was deseribed 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. To see more detail, please refer to, for example, Buckland et al. (1993) or Branch and Butterworth (2001).

Truncation

The perpendicular distance distribution is truncated at 2.4 n.miles. The truncated number of detection was substitute to formula (1).

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).

RESULTS

Distribution of searching efforts

Fig.1 shows the searching effort of SV in 1999/2000 and 200/01 cruises as an example of JARPA survey coverage. The searching effort uniformly covered Area IV and V. Coverage of the searching effort was equivalent to the IWC/SOWER cruise, which was planned a minimum 50 % coverage in the northern strata, and a minimum 80 % coverage in the southern strata. All searching efforts in JARPA surveys were reported (Nishiwaki et al., 2001b and Hakamada et al., 2001).

Distributions of whales

The primary sighting positions of humpback and fin whales, which were used in the present analyses, are shown in Figure 1, 9 and 10. Humpback whales were concentrated between 90° – 110° E in northern and southern strata, and were widely dispersed in other part of Area IV. It must be noted that there was a meander of the southern boundary of the Antarctic Circumpolar Current in these longitudinal area in 1997/98 season (Matsuoka et al., 2000). The meander might be related the distribution of humpback whales. They were widely dispersed except in the northern strata (130E-145E) and the Ross Sea in Area V.

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.

Abundance estimates

Abundance, total number of the primary sightings (n), areas (A), effort (L), n/L, effective search half width (ESW), estimated mean school size (MSS), estimated whale density (D: whales / 100 n.miles^2), abundance estimation (P) with CVs by each stratum are shown in Table2-5. Truncation distance was 2.4 n.miles and g (0) was assumed as 1 in this analysis. Result of the distance and angle estimation experiments in each season were included in these analyses. Fig.3 and 4 show the perpendicular distance in nautical miles used in the present analyses.

Humpback whales

Abundance estimates of this species (south of 60 S) were 12,093 (CV=0.28) in Area IV and 4,251 (CV=0.48) in Area V, respectively using SV data in 1999/2000 and 2000/01 seasons.

Fin whale

Abundance estimates of this species (south of 60 S) were 230 (CV=0.61) in Area IV and 6,362 (CV=0.50) in Area V, respectively using SV data in 1999/2000 and 2000/01 seasons.

Trend of the density estimations

Humpback whales

Densities (whales / 100 n.miles^2) of this species in Area IV were estimated as 0.826 (CV=0.32), 0.449 (CV=0.19), 0.513 (CV=0.19), 1.464 (CV=0.17), 2.641 (CV=0.18) and 2.133 (CV=0.14) using full-scale research SSV data for the research seasons between 1989/90 and 1999/2000 (Table 6). In the same way in Area V, densities of this species were estimated as 0.267 (CV=0.25), 0.253 (CV=0.75), 0.312 (CV=0.36), 0.255 (CV=0.37), 1.077 (CV=0.38) and 0.461 (CV=0.31) for the research seasons between 1990/91 and 2000/01 (Table 7). An estimated annual rate of increase in the feeding ground of humpback whales were 17.2 % (CV=0.29) and 10.2 % (CV=0.59) in Areas IV and V, respectively.

Fin whale

Densities of this species in Area IV were estimated as 0.014 (CV=1.00), 0.091 (CV=0.79), 0.031 (CV=0.83), 0.143 (CV=0.44), 0.128 (CV=0.48) and 0.272 (CV=0.64) using full-scale research SSV data for the research seasons between 1989/90 and 1999/2000 (Table 8). In the same way in Area V, densities of this species were estimated as 0.199 (CV=0.26), 0.124 (CV=0.43), 0.921 (CV=0.88), 0.037 (CV=0.67), 0.612 (CV=0.73) and 0.574 (CV=0.40) for the research seasons between 1990/91 and 2000/01 (Table 7). An estimated annual rate of increase in the feeding ground of fin whales were 28.2 % (CV=0.31) and 10.3 % (CV=1.58) in Areas IV and V, respectively.

DISCUSSIONS

Biases in abundance estimates

From the results of the simulation (Clarke et al., 2000), there was agreement that estimates from the closing mode on IWC/IDCR-SOWER surveys and JARPA SV data could be used in the same way (IWC, 2000). Present estimates of humpback and fin whales by SV data were reliable, as current abundance in the Antarctic of their feeding ground, although south of 60S was not their principal feeding ground.

On the other hand, for abundance estimates of minke whales using JARPA SSV data, it has been pointed out that "under-surveying in high density areas of minke whales " causes bias (IWC, 1998). Application of GAM-based analysis was suggested, if available, for correction of this bias for humpback whale analyses. However, one question is raised whether the abundance estimate of humpback whales using SSV data has bias like minke whales or not. If the density of humpback whales is independent of that of minke whales, the abundance estimate of humpback whales using SSV data may not have this kind of bias. The study on distributional correlation between humpback and minke whales recommended (IWC, 2001). Kasamatsu *et al.*, (1998), however reported that the density of humpback whales had no correlation with that of minke whales in the Antarctic using both IDCR/SOWER and JARPA data. Further, no correlation of two species is supported by the fact that the abundance estimate using SSV data (11,960 whales, CV=0.14) is not different substantially from that using SV data (12,093 whales, CV=0.29) in 1999/2000 season. This result suggested that correction using GAM-based analysis is not necessary for present humpback whale analyses.

Abundance estimates of humpback whale in Area IV

There are no information about abundance of humpback whales in the late of 1990's off Western Australia and Antarctic Area IV. Bannister (1994) reported a total population size of some 3,000 whales off Shark Bay, Western Australia, 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). Almost same number of abundance estimate was reported as 3,436 whales (CV=0.45) in the 1988/89 season using IWC/IDCR data in Area IV (Brown and Butterworth, 1999). These abundance estimations in early 1990's were similar in number. Present JARPA estimates for Area IV in 1999/2000 season are 12,093 (CV=0.29) and 11,960 (CV=0.14) whales are consistent as a rate of increasing has been assumed to be some 10 %. Analysis of the 1998/99 IWC/SOWER cruise data in Area IV and comparison with the JARPA estimates are useful for improvement of abundance estimations.

Abundance estimates of humpback whale in Area V

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). Present JARPA estimates for Area V in 1999/2000 season are 4,251 (CV=0.48) and 3,477 (CV=0.31) whales are consistent as a rate of increasing has been assumed to be some 10 %.

Increase of humpback whales

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. In Eastern Australia, rates of increase for this species were reported to be 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). Present annual rate of increase 17.2 % and 10.2 % per annum in Areas IV and V, respectively between 1989/1990 and 2000/01 (over 12 years) were close to previous estimates. Therefore the variances of the estimate of increase of the densities may be negatively biased. Further in general, the observed rates of increase are much higher than the range of 0.01 to 0.04 often referred to in 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). Further attention should be given to the existence of two stocks of this species in Area IV (the Group IV and the Group V), that pointed out from results of the mtDNA analyses using biopsy samples collected in Area IV (Pastene and Baker, 1997). DNA analysis showed that same animal migrated to both Area IV and V (Pastene et al., 2000). This also must be taken account when comparison of increasing rate between breeding and feeding grounds in the future.

Anyway, the number of survey year is still too short to detect precisely yearly trend.

Further surveys are necessary for improving the precision of the annual rate of increase in the feeding ground.

Abundance estimates of fin whales

There is no abundance estimation of this species in the Antarctic Areas IV and V. Estimate of this species based on IWC/IDCR and Japanese Scouting Vessels (JSV) was 18,000 (CV=0.47) in the area south of 30S (Butterworth et al., 1994). Estimates 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 (until 1997/98) circumpolar series, respectively in the area south of 60S (Branch and Butterworth, 2001). Present abundance and density estimates of this species (south of 60 S) indicated that there was a sharp yearly fluctuation in the area south of 60 S in Areas IV and V, because they mainly distributed in the area north of 60S. For that reason, the CV of an estimated annual rate of increase was not extremely precise in present analyses.

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Table 1. Estimated observer bias in distance and angle estimation during 1989/90 to 2000/01.

1989/90

Vessel	platform	distance	angle
K01	barrel	n.s.	0.938
	upper bridge	n.s.	n.s.
T18	barrel	n.s.	1.041
	upper bridge	n.s.	n.s.
T25	barrel	1.083	n.s.
	upper bridge	1.051	n.s.

1990/91

Vessel	platform	distance	angle
K01	barrel	n.s.	1.051
	upper bridge	0.953	1.064
T18	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	0.890	n.s.
	upper bridge	n.s.	n.s.

1991/92

Vessel	platform	distance	angle
K01	barrel	0.935	n.s.
	upper bridge	n.s.	n.s.
T18	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	1.063	n.s.
	upper bridge	1.055	n.s.

1992/93

Vessel	platform	distance	angle
K01	barrel	n.s.	n.s.
	upper bridge	1.083	0.958
T18	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	n.s.	1.130

1993/94

Vessel	platform	distance	angle
K01	barrel	0.846	n.s.
	upper bridge	n.s.	n.s.
T18	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.

1994/95

Vessel	platform	distance	angle
K01	barrel	n.s.	n.s.
	upper bridge	n.s.	0.960
T18	barrel	n.s.	n.s.
	upper bridge	0.946	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	0.923	n.s.

1995/96

Vessel	platform	distance	angle
K01	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T18	barrel	n.s.	n.s.
	upper bridge	1.079	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	0.948	1.035
KS2	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.

1996/97

Vessel	platform	distance	angle
K01	bridge	n.s.	n.s.
	upper bridge	n.s.	n.s.
T18	bridge	0.950	n.s.
	upper bridge	n.s.	n.s.
T25	bridge	n.s.	n.s.
	upper bridge	n.s.	n.s.
KS2	bridge	1.120	0.942
	upper bridge	1.155	1.053

1997/98

Vessel	platform	distanee	angle
K01	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T18	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	1.055	n.s.
	upper bridge	n.s.	n.s.

1998/99

Vessel	platform	distance	angle
K01	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	1.050
	upper bridge	1.054	1.065
YS1	barrel	0.931	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	0.939	0.960
	upper bridge	n.s.	n.s.

1999/2000

Vessel	platform	distance	angle
K01	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
YS1	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	n.s.	0.934
	upper bridge	n.s.	n.s.

2000/2001

Vessel	platform	distance	angle
K01	barrel	n.s.	1.038
	upper bridge	n.s.	n.s.
T25	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
YS1	barrel	n.s.	1.036
	upper bridge	1.057	n.s.
KS2	barrel	n.s.	n.s.
	upper bridge	n.s.	0.882

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

Table. 2. Abundance estimates of **humpback whale** in Area IV (south of 60S) using 1999/2000-SV data. Truncate is 2.4 n.miles. The g (0) is assumed to be I. n: number of primary schools, L: searching distance, esw: the effective search half width, MSS: mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated 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.)	P (ind.)	CV
1999/2000	NW	236,307	14	997.4	1.404	0.38	1.736	0.09	1.888	0.03	0.763	1,803	0.39
	NE	229,576	64	1045.4	6.122	0.41	1.736	0.09	1.888	0.03	3.328	7,640	0.42
	SW	34,825	28	637.3	4.393	0.39	1.736	0.09	1.888	0.03	2.388	832	0.40
	SE	33,129	78	819.5	9.518	0.34	1.736	0.09	1.888	0.03	5.174	1,714	0.35
	PB	27,000	3	425.3	0.705	0.65	1.736	0.09	1.888	0.03	0.383	104	0.66
	Total	560,837	187	3924.9	4.764	-	1.736	0.09	1.888	0.03	2.156	12,093	0.29

Table. 3. Abundance estimates of **humpback whale** in Area V (south of 60S) using 2000/01-SV data. 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, MSS: mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated 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.)	P (ind.)	CV
2000/01	NW	249,712	14	906.8	1.544	0.75	1.138	0.35	2.130	0.05	1.445	3,608	0.82
	NE	334,377	21	1236.3	1.699	0.48	1.138	0.35	2.130	0.05	1.590	5,315	0.59
	SW	64,854	19	885.2	2.146	0.29	1.138	0.35	2.130	0.05	2.009	1,303	0.45
	SE	105,458	0	946.3	0.000	-	1.138	0.35	2.130	0.05	-	0	-
	Total	754,401	54	3974.6	1.359	-	1.138	0.35	2.130	0.05	1.272	4,251	0.48

Table. 4. Abundance estimates of **fin whale** in Area IV (south of 60S) using 1999/2000-SV data. 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, MSS: mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated 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.)	P (ind.)	CV
1999/2000	NW	236,307	0	901.9	0.000	-	2.103	0.21	1.766	0.24	0.000	0	-
	NE	229,576	2	1045.4	0.191	0.58	2.103	0.21	1.766	0.24	0.080	184	0.66
	SW	34,825	2	637.3	0.314	1.16	2.103	0.21	1.766	0.24	0.132	46	1.20
	SE	33,129	0	819.5	0.000	-	2.103	0.21	1.766	0.24	0.000	0	-
	PB	27,000	0	425.3	0.000	-	2.103	0.21	1.766	0.24	0.000	0	-
	Total	560,837	4	3829.4	0.104	-	2.103	0.21	1.766	0.24	0.041	230	0.61

Table.5. Abundance estimates of **fin whale** in Area V (south of 60S) using 2000/01-SV data. 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, MSS: 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.)	P (ind.)	CV
2000/01	NW	249,712	12	906.8	1.323	0.57	1.010	0.26	2.222	0.08	1.456	3,635	0.63
	NE	334,377	7	1236.3	0.566	0.79	1.010	0.26	2.222	0.08	0.623	2,082	0.83
	SW	64,854	8	885.2	0.904	0.67	1.010	0.26	2.222	0.08	0.994	645	0.72
	SE	105,458	0	946.3	0.000	-	1.010	0.26	2.222	0.08	0.000	0	-
	Total	754,401	27	3974.6	0.679	-	1.010	0.26	2.222	0.08	0.843	6,362	0.50

Table. 6. Abundance estimates of **humpback whale** seasons in Area IV (south of 60S) using SSV data, between 1989/90 and 1999/2000. 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, MSS: 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.)	P (ind.)	CV
1989/90	NW	218,378	22	1987.6	1.107	0.29	0.973	0.21	1.804	0.06	1.026	2,241	0.36
	NE	213,661	20	1964.4	1.018	0.43	0.973	0.21	1.804	0.06	0.944	2,017	0.48
	SW	41,683	11	2518.3	0.436	0.38	0.973	0.21	1.804	0.06	0.404	168	0.44
	SE	40,371	1	1362.2	0.074	0.72	0.973	0.21	1.804	0.06	0.068	27	0.75
	PB	34,628	2	831.9	0.240	0.57	0.973	0.21	1.804	0.06	0.223	77	0.61
	Total	548,721	56	8664.4	0.646	–	0.973	0.21	1.804	0.06	**0.826**	**4,530**	**0.32**
1991/92	NW	219,773	42	2482.7	1.692	0.24	1.431	0.08	1.793	0.05	1.060	2,330	0.25
	NE	217,764	16	2173.9	0.736	0.29	1.431	0.08	1.793	0.05	0.461	1,004	0.31
	SW	34,259	14	1199.4	1.167	0.42	1.431	0.08	1.793	0.05	0.731	251	0.43
	SE	34,871	10	1357.7	0.737	0.54	1.431	0.08	1.793	0.05	0.462	161	0.55
	PB	27,733	0	370.4	0.000	–	–	–	–	–	–	0	–
	Total	534,400	82	7584.1	1.081	–	1.431	0.08	1.793	0.05	**0.449**	**3,746**	**0.19**
1993/94	NW	230,748	34	2530.3	1.344	0.22	1.694	0.10	1.608	0.05	0.721	1,664	0.25
	NE	161,376	18	1924.7	0.935	0.28	1.694	0.10	1.608	0.05	0.502	810	0.30
	SW	35,428	18	1352.9	1.331	0.38	1.694	0.10	1.608	0.05	0.714	253	0.39
	SE	40,813	6	1419.1	0.423	0.34	1.694	0.10	1.608	0.05	0.227	93	0.36
	PB	35,196	3	562.3	0.534	0.92	1.694	0.10	1.608	0.05	0.286	101	0.93
	Total	503,561	79	7789.3	1.014	–	1.694	0.10	1.608	0.05	**0.513**	**2,921**	**0.19**
1995/96	NW	217,044	102	2736.9	3.727	0.19	1.298	0.07	1.615	0.03	2.318	5,031	0.21
	NE	231,845	33	2123.5	1.554	0.30	1.298	0.07	1.615	0.03	0.967	2,241	0.31
	SW	29,610	36	2137.0	1.685	0.27	1.298	0.07	1.615	0.03	1.048	310	0.28
	SE	30,123	21	1461.5	1.437	0.32	1.298	0.07	1.615	0.03	0.894	269	0.33
	PB	27,929	0	846.6	0.000	–	–	–	–	–	–	0.000	–
	Total	536,551	192	9305.5	2.063		1.298	0.07	1.615	0.03	**1.464**	**7,851**	**0.17**
1997/98	NW	224,230	161	2616.3	6.154	0.22	1.469	0.04	1.745	0.02	3.665	8,194	0.22
	NE	224,567	88	2643.3	3.330	0.34	1.469	0.04	1.745	0.02	1.977	4,440	0.35
	SW	31,505	137	2568.0	5.335	0.17	1.469	0.04	1.745	0.02	3.168	998	0.18
	SE	41,450	20	2370.4	0.844	0.25	1.469	0.04	1.745	0.02	0.501	208	0.25
	PB	2,481	2	432.3	0.463	0.80	1.469	0.04	1.745	0.02	0.275	7	0.80
	Total	524,233	408	10630.3	3.838	–	1.469	0.04	1.745	0.02	**2.641**	**13,847**	**0.18**
1999/2000	NW	236,307	41	1826.2	2.245	0.22	1.321	0.06	1.849	0.03	1.571	3,713	0.23
	NE	229,576	95	2507.1	3.789	0.19	1.321	0.06	1.849	0.03	2.652	6,088	0.20
	SW	34,825	77	1665.9	4.622	0.30	1.321	0.06	1.849	0.03	3.235	1,126	0.31
	SE	33,129	84	1884.8	4.457	0.21	1.321	0.06	1.849	0.03	3.119	1,033	0.22
	PB	27,000	0	852.9	0.000	–	–	–	–	–	–	0	–
	Total	560,837	297	8736.9	3.399		1.321	0.06	1.849	0.03	**2.133**	**11,960**	**0.14**

Table. 7. Abundance estimates of **humpback whale** in Area V (south of 60S) using SSV data, between 1989/90 and 2000/01 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, MSS: 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.)	P (ind.)	CV
1990/91	NW	232,898	2	4382.2	0.046	0.63	0.931	0.17	1.420	0.05	0.035	81	0.65
	NE	347,440	7	4370.7	0.160	0.37	0.931	0.17	1.420	0.05	0.122	424	0.41
	SW	62,355	24	2707.1	0.887	0.34	0.931	0.17	1.420	0.05	0.676	422	0.38
	SE	208,511	27	3200.0	0.844	0.24	0.931	0.17	1.420	0.05	0.644	1,342	0.30
	Total	851,204	60	14660.0	0.409	-	0.931	0.17	1.420	0.05	0.267	2,269	0.25
1992/93	NW	332,682	5	1224.6	0.408	1.33	1.080	0.13	1.667	0.09	0.315	1,048	1.34
	NE	290,526	3	944.2	0.318	0.99	1.080	0.13	1.667	0.09	0.245	712	1.00
	SW	43,572	1	902.7	0.111	0.74	1.080	0.13	1.667	0.09	0.085	37	0.75
	SE	180,745	3	1205.6	0.249	0.70	1.080	0.13	1.667	0.09	0.192	347	0.72
	Total	847,525	12	4277.1	0.281	-	1.080	0.13	1.667	0.09	0.253	2,144	0.75
1994/95	NW	189,310	6	2062.5	0.291	1.03	1.603	0.10	1.830	0.09	0.166	314	1.03
	NE	303,617	11	1949.8	0.564	0.58	1.603	0.10	1.830	0.09	0.322	977	0.59
	SW	45,685	27	1584.3	1.704	0.27	1.603	0.10	1.830	0.09	0.972	444	0.30
	SE	175,421	3	606.6	0.495	0.74	1.603	0.10	1.830	0.09	0.282	495	0.76
	Total	714,033	47	6203.2	0.758	-	1.603	0.10	1.830	0.09	0.312	2,230	0.36
1996/97	NW	305,819	1	2073.0	0.048	1.55	1.282	0.26	1.677	0.07	0.032	97	1.58
	NE	363,668	15	2327.3	0.645	0.32	1.282	0.26	1.677	0.07	0.422	1,533	0.42
	SW	40,130	9	2432.0	0.370	0.54	1.282	0.26	1.677	0.07	0.242	97	0.60
	SE	208,224	6	1321.8	0.454	0.49	1.282	0.26	1.677	0.07	0.297	618	0.56
	Total	917,841	31	8154.1	0.380	-	1.282	0.26	1.677	0.07	0.255	2,345	0.37
1998/99	NW	321,375	3	833.6	0.360	0.69	1.207	0.16	1.560	0.05	0.233	748	0.71
	NE	311,050	17	574.1	2.961	0.44	1.207	0.16	1.560	0.05	1.914	5,953	0.48
	SW	45,455	16	1686.0	0.949	0.44	1.207	0.16	1.560	0.05	0.613	279	0.47
	SE	52,553	31	1183.7	2.619	0.15	1.207	0.16	1.560	0.05	1.693	890	0.22
	Total	730,433	67	4277.4	1.566	-	1.207	0.16	1.560	0.05	1.077	7,870	0.38
2000/01	NW	249,712	30	2845.1	1.055	0.44	1.412	0.15	1.652	0.06	0.167	1,540	0.47
	NE	334,377	24	2704.8	0.887	0.35	1.412	0.15	1.652	0.06	0.519	1,736	0.38
	SW	64,854	12	2267.7	0.529	0.34	1.412	0.15	1.652	0.06	0.310	201	0.38
	SE	105,458	0	2373.9	0.000	-	-	-	-	-	-	0	-
	Total	754,401	66	10191.5	0.648	-	1.412	0.15	1.652	0.06	0.461	3,477	0.31

Table. 8. Abundance estimates of **fin whale** seasons in Area IV (south of 60S) using SSV data, between 1989/90 and 1999/2000. 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, MSS: 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.)	P (ind.)	CV
1989/90	NW	218,378	0	1987.6	0.000	–	2.400	–	3.000	0.67	–	0	–
	NE	213,661	1	1964.4	0.051	0.43	2.400	–	3.000	0.67	0.032	68	1.08
	SW	41,683	1	2518.3	0.040	0.38	2.400	–	3.000	0.67	0.025	10	1.10
	SE	40,371	0	1266.3	0.000	–	2.400	–	3.000	0.67	–	0	–
	PB	34,628	0	831.9	0.000	–	2.400	–	3.000	0.67	–	0	–
	Total	548,721	2	8568.5	0.023	–	2.400	–	3.000	0.67	0.014	78	1.00
1991/92	NW	219,773	3	2482.7	0.121	0.65	2.400	0.01	5.286	0.63	0.133	292	0.90
	NE	217,764	1	2173.9	4.600	0.89	2.400	0.01	5.286	0.63	0.051	110	1.09
	SW	34,259	0	1199.4	0.000	–	–	–	–	–	–	0	–
	SE	34,871	3	1357.7	0.221	1.16	2.400	0.01	5.286	0.63	0.243	85	1.32
	PB	27,733	0	370.4	0.000	–	–	–	–	–	–	0	–
	Total	534,400	7	7584.1	0.092	–	2.400	0.01	5.286	0.63	0.091	488	0.79
1993/94	NW	230,748	0	2530.3	0.000	–	1.227	0.43	2.000	0.50	0.000	0	–
	NE	161,376	2	1924.7	0.104	0.54	1.227	0.43	2.000	0.50	0.085	137	0.85
	SW	35,428	1	1352.9	0.074	1.19	1.227	0.43	2.000	0.50	0.060	21	1.35
	SE	40,813	0	1419.1	0.000	–	–	–	–	–	–	0	–
	PB	35,196	0	562.3	0.000	–	–	–	–	–	–	0	–
	Total	503,561	3	7789.3	0.039	–	1.227	0.43	2.000	0.50	0.031	158	0.83
1995/96	NW	217,044	6	2736.9	0.219	0.58	1.364	0.20	2.417	0.11	0.194	422	0.62
	NE	231,845	3	2123.5	0.141	0.49	1.364	0.20	2.417	0.11	0.125	290	0.54
	SW	29,610	0	2137.0	0.000	–	–	–	–	–	–	0	–
	SE	30,123	3	1461.5	0.205	1.05	1.364	0.20	2.417	0.11	0.182	55	1.08
	PB	27,929	0	846.6	0.000	–	–	–	–	–	–	0	–
	Total	536,551	12	9305.5	0.129	–	1.364	0.20	2.417	0.11	0.143	767	0.44
1997/98	NW	224,230	1	2616.3	0.038	0.66	1.122	0.16	2.700	0.19	0.046	103	0.71
	NE	224,567	5	2643.3	0.189	0.52	1.122	0.16	2.700	0.19	0.228	511	0.58
	SW	31,505	4	2568.0	0.156	0.68	1.122	0.16	2.700	0.19	0.187	59	0.72
	SE	41,450	0	2370.4	0.000	–	–	–	–	–	–	0	–
	PB	2,481	0	432.3	0.000	–	–	–	–	–	–	0	–
	Total	524,233	10	10630.3	0.094	–	1.122	0.16	2.700	0.19	0.128	673	0.48
1999/2000	NW	236,307	0	1826.2	0.000	–	–	–	–	–	–	0	–
	NE	229,576	5	2507.1	0.199	0.32	1.400	0.24	5.438	0.44	0.387	889	0.59
	SW	34,825	2	1665.9	0.120	0.37	1.400	0.24	5.438	0.44	0.233	81	0.62
	SE	33,129	0	1884.8	0.000	–	–	–	–	–	–	0	–
	PB	27,000	9	852.9	1.055	0.96	1.400	0.24	5.438	0.44	2.05	553	1.09
	Total	560,837	16	8736.9	0.183	–	1.400	0.24	5.438	0.44	0.272	1,523	0.64

Table. 9. Abundance estimates of **fin whale** in Area V (south of 60S) using SSV data, between 1989/90 and 2000/01 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, MSS: 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.)	P (ind.)	CV
1990/91	NW	232,898	18	4382.2	0.411	0.29	1.092	0.13	2.030	0.11	0.382	890	0.34
	NE	347,440	7	4370.7	0.160	0.33	1.092	0.13	2.030	0.11	0.149	517	0.37
	SW	62,355	5	2707.1	0.185	0.45	1.092	0.13	2.030	0.11	0.172	107	0.48
	SE	208,511	3	3200.0	0.094	0.50	1.092	0.13	2.030	0.11	0.087	182	0.53
	Total	851,204	33	14660.0	0.225	-	1.092	0.13	2.030	0.11	0.199	1,696	0.26
1992/93	NW	332,682	2	1224.6	1.630	0.63	1.492	0.19	1.714	0.11	0.094	312	0.67
	NE	290,526	4	944.2	0.424	0.48	1.492	0.19	1.714	0.11	0.243	707	0.53
	SW	43,572	1	902.7	0.111	0.84	1.492	0.19	1.714	0.11	0.064	28	0.86
	SE	180,745	0	1205.6	0.000	-	-	-	-	-	-	0	-
	Total	847,525	7	4277.1	0.164	-	1.492	0.19	1.714	0.11	0.124	1,047	0.43
1994/95	NW	189,310	4	2062.5	0.194	0.64	0.674	0.80	1.830	0.18	0.492	931	1.04
	NE	303,617	13	1949.8	0.667	0.41	0.674	0.80	1.830	0.18	1.690	5,132	0.91
	SW	45,685	7	1584.3	0.442	0.47	0.674	0.80	1.830	0.18	1.120	512	0.94
	SE	175,421	0	606.6	0.000	-	-	-	1.830	0.18	-	0	-
	Total	714,033	24	6203.2	0.387	-	0.674	0.80	1.830	0.18	0.921	6,575	0.88
1996/97	NW	305,819	2	2073.0	0.096	0.63	1.431	0.18	1.500	0.15	0.051	155	0.67
	NE	363,668	2	2327.3	0.086	1.13	1.431	0.18	1.500	0.15	0.045	164	1.16
	SW	40,130	2	2432.0	0.082	0.79	1.431	0.18	1.500	0.15	0.043	17	0.82
	SE	208,224	0	1321.8	0.000	-	1.431	0.18	1.500	0.15	0.000	0	-
	Total	917,841	6	8154.1	0.074	-	1.431	0.18	1.500	0.15	0.037	336	0.67
1998/99	NW	321,375	4	833.6	0.480	1.37	1.112	0.18	3.068	0.21	0.662	2,127	1.40
	NE	311,050	2	574.1	0.348	0.54	1.112	0.18	3.068	0.21	0.480	1,494	0.60
	SW	45,455	3	1686.0	0.178	0.53	1.112	0.18	3.068	0.21	0.245	112	0.60
	SE	52,553	12	1183.7	0.010	0.43	1.112	0.18	3.068	0.21	1.398	735	0.51
	Total	730,433	21	4277.4	0.491	-	1.112	0.18	3.068	0.21	0.612	4,467	0.73
2000/01	NW	249,712	31	2845.1	1.090	0.36	1.614	0.07	3.703	0.27	1.250	3,121	0.46
	NE	334,377	1	2704.8	0.037	1.87	1.614	0.07	3.703	0.27	0.042	142	1.89
	SW	64,854	31	2267.7	1.367	0.38	1.614	0.07	3.703	0.27	1.568	1,017	0.47
	SE	105,458	1	2373.9	0.042	2.44	1.614	0.07	3.703	0.27	0.048	51	2.46
	Total	754,401	64	10191.5	0.628	-	1.614	0.07	3.703	0.27	0.574	4,330	0.40

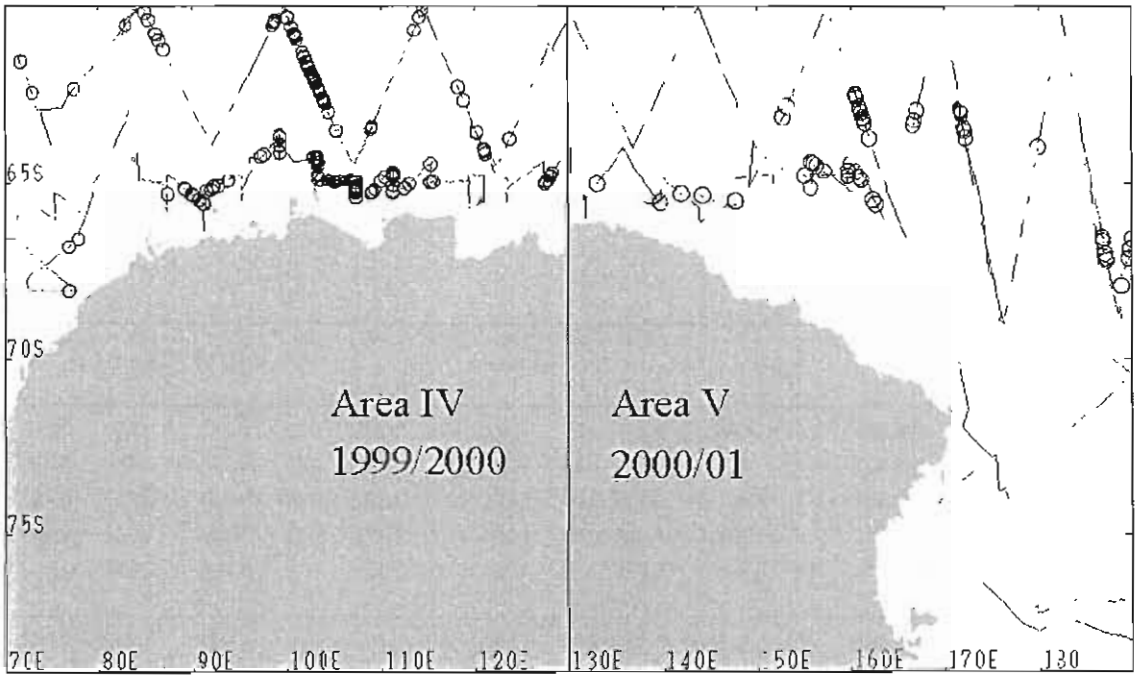

Fig. 1. Distribution of the searching effort and primary school sightings of **humpback whales** in the 1999/2000 and 2000/01 seasons by Kyosin-Maru No.2 (SV). Black line shows the on efforts. The circles show the primary schools of humpback whales.

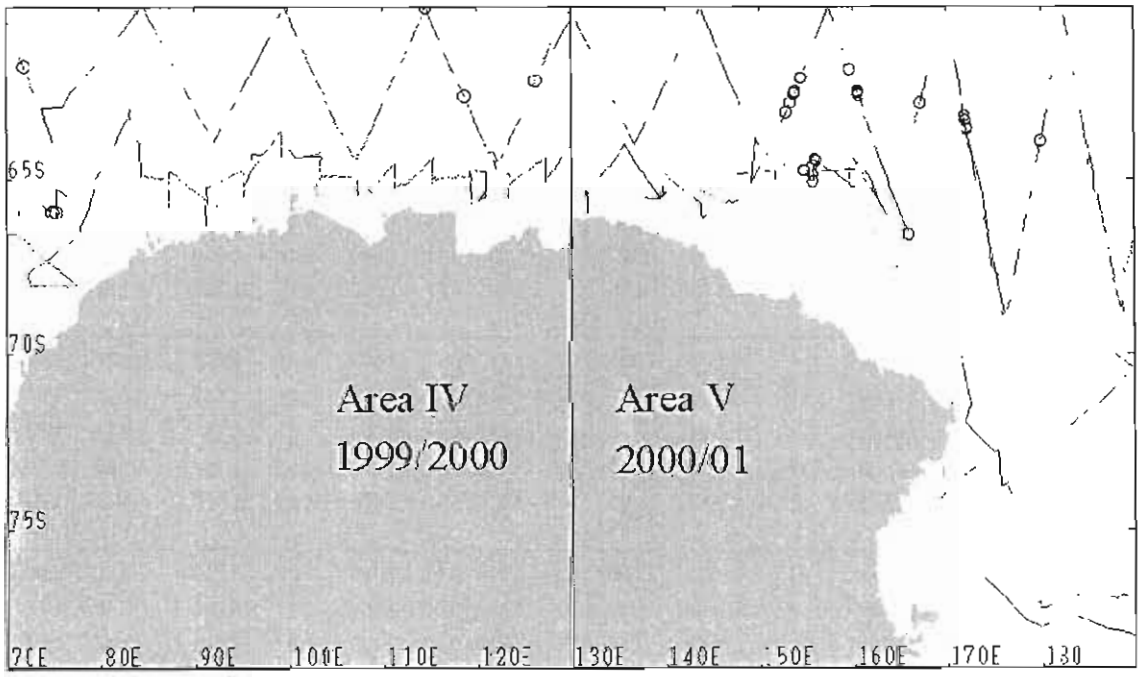

Fig. 2. Distribution of the searching effort and primary school sightings of **fin whales** in the 1999/2000 and 2000/01 seasons by Kyosin-Maru No.2 (SV). Black line shows the on efforts. The circles show the primary schools of fin whales.

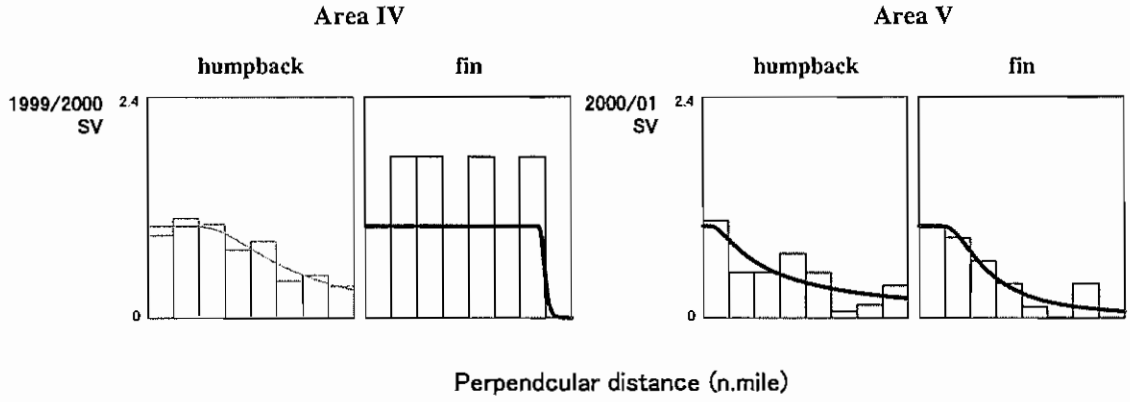

Fig.3. Probability plots by SV, using present abundance estimation of humpback and fin whales in Areas IV and V in 1999/2000 and 2000/01 seasons.

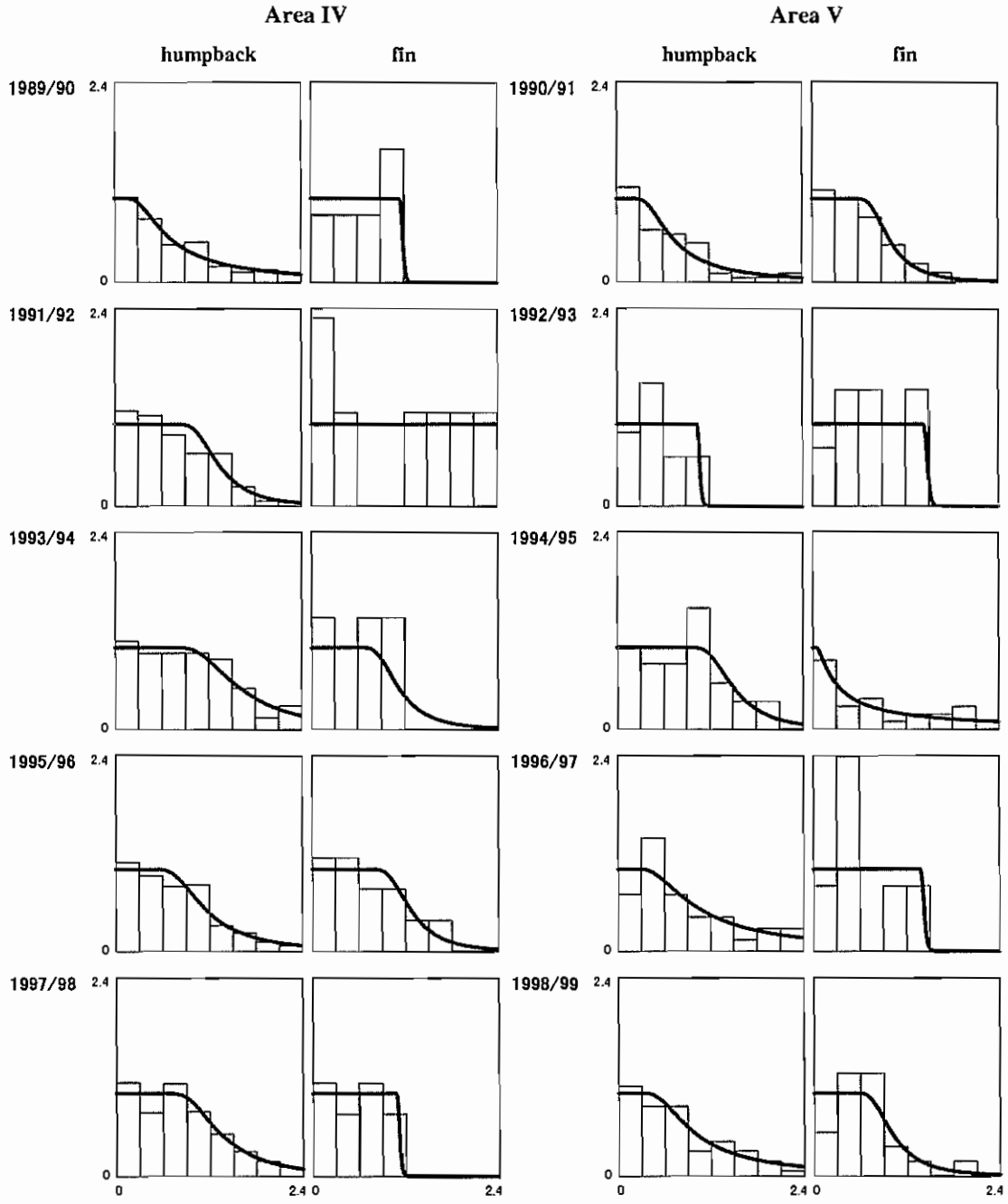

Fig. 4. Probability plots by SSV, using present abundance estimation of humpback and fin whales between 1989/90 to 2000/01 seasons.

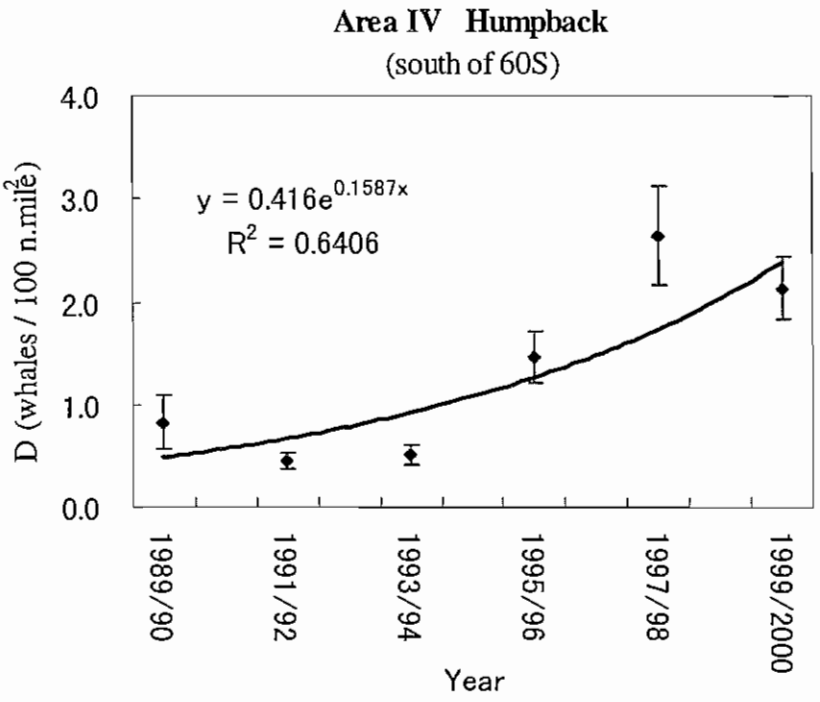

Fig. 5. Trend of density estimations (**D**: whales / 100 n.miles ^{2}) of **humpback whale** in Area IV (south of 60 S) surveyed during January to February, between 1989/90 and 1999/2000 seasons (over 11 years). Vertical lines show standard errors. Estimated annual rate of increase was 17.2 % as of present analyses.

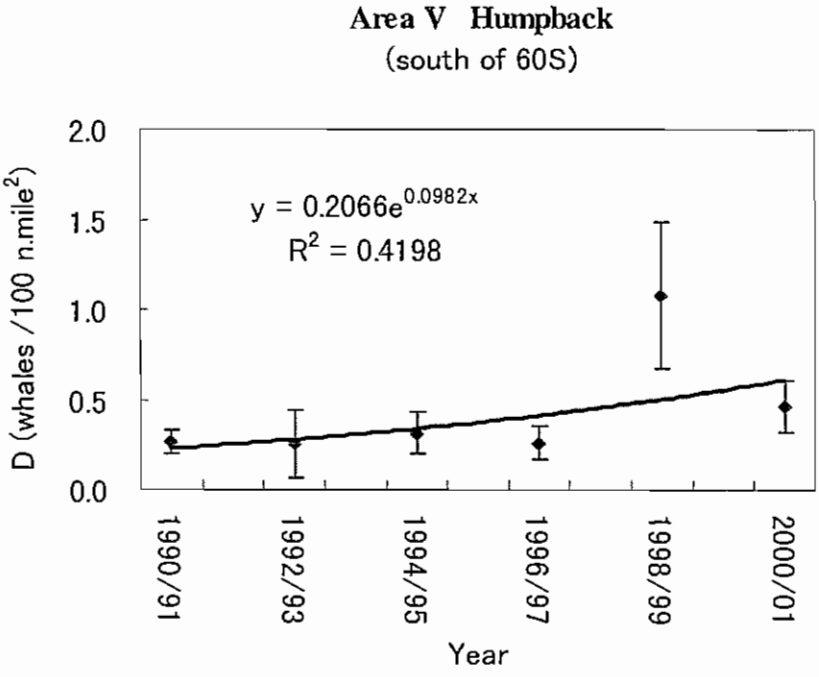

Fig. 6. Trend of density estimations (**D**: whales / 100 n.miles ^{2}) of **humpback whale** in Area IV (south of 60 S) surveyed during January to February, between 1989/90 and 1999/2000 seasons (over 11 years). Vertical lines show standard errors. Estimated annual rate of increase was 10.2 % as of present analyses.

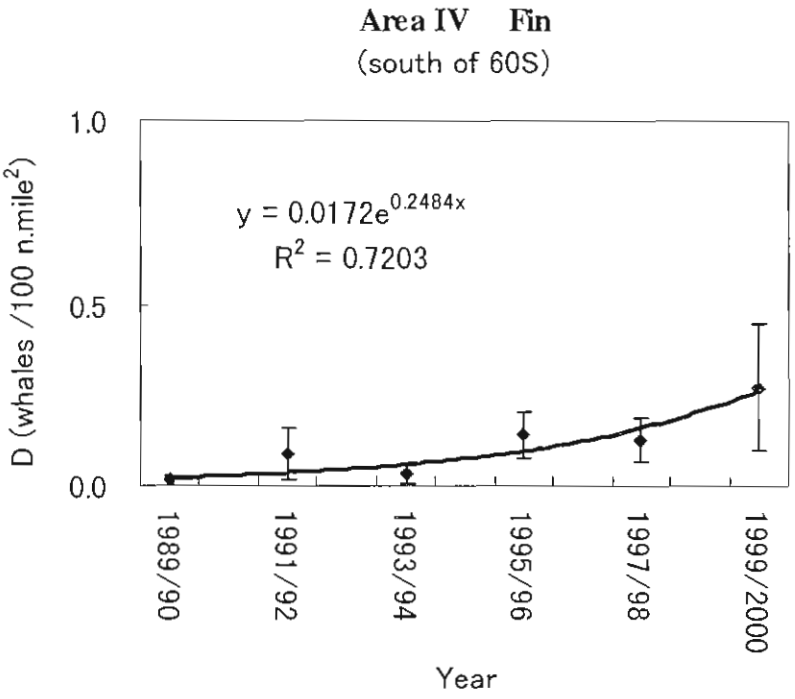

Fig. 7. Trend of density estimations (**D**: whales / 100 n.miles ^{2}) of **fin whale** in Area IV (south of 60 S) surveyed during January to February, between 1989/90 and 1999/2000 seasons (over 11 years). Vertical lines show standard errors. Estimated annual rate of increase was 28.2 % as of present analyses.

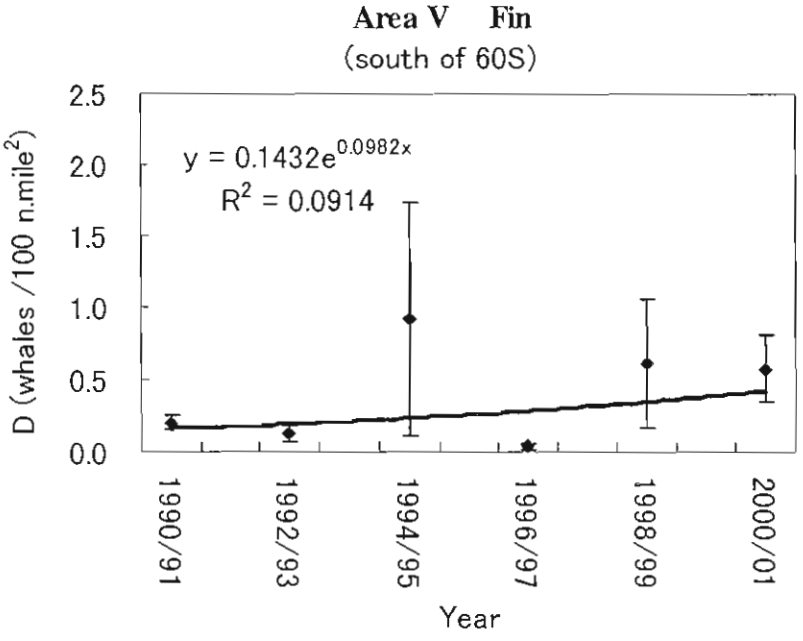

Fig. 8. Trend of density estimations (**D**: whales / 100 n.miles ^{2}) of **fin whale** in Area IV (south of 60 S) surveyed during January to February, between 1989/90 and 1999/2000 seasons (over 11 years). Vertical lines show standard errors. Estimated annual rate of increase was 10.3 % as of present analyses.

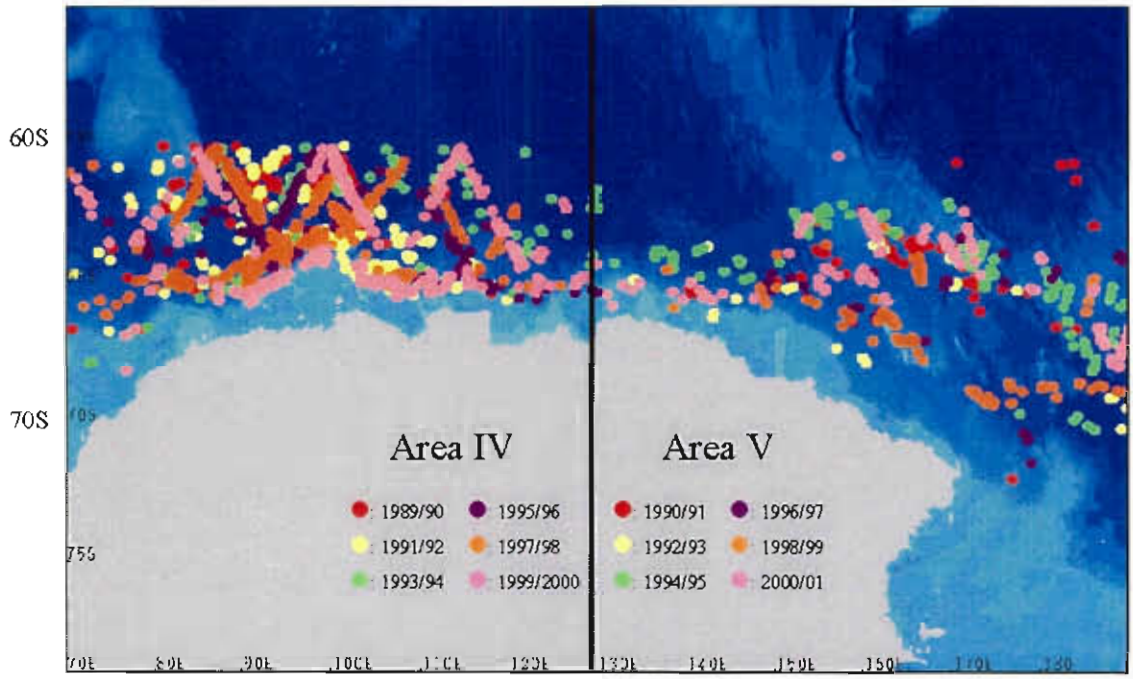

Figure 9. Sighting positions of the primary school of **humpback whales** in JARPA survey during 1989/90 to 2000/01.

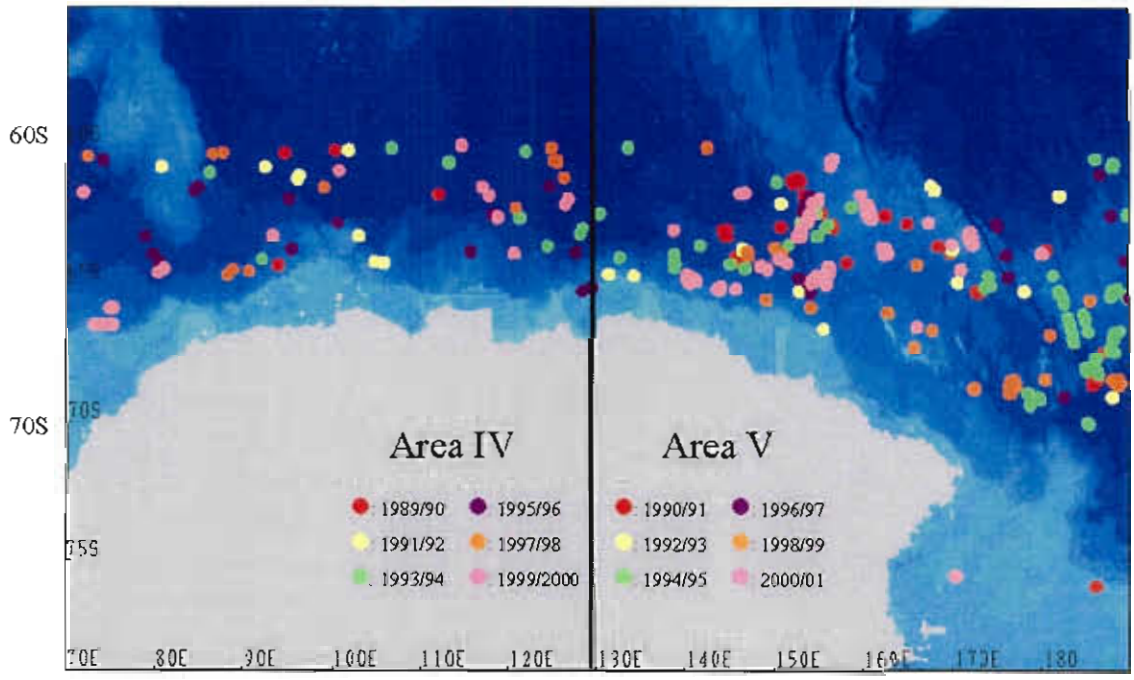

Figure 10. Sighting positions of the primary school of **fin whales** in JARPA survey during 1989/90 to 2000/01.