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Current abundance and density trend of density of humpback whales in the Antarctic Area IV using JARPA data

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ABSTRACT

Current abundance of humpback whales in the Antarctic Area IV (longitude 70°-130° E and latitude south of 60° S) was estimated using JARPA 1999/2000 data. In this survey, estimates using data from the SV and SSV were 12,664 (CV=0.28) and 11,138 (CV=0.29) whales respectively.
Densities (whales / 100 n.miles ^{2}) of this species in Area IV also estimated for each survey conducted from 1989/90 to 1999/2000 seasons as follows: 1989/90, 0.801 (CV=0.32), 1991/92, 0.855 (CV=0.20), 1993/94, 0.772 (CV=0.19), 1995/96, 1.590 (CV=0.17), 1997/98, 2.686 (CV=0.18) and 1999/2000, 1.983 (CV=0.13). Annual increase rate of these estimations over 11 was 13.4 %, and this increase is statistically significant.

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 1999/2000 seasons. After the 1987/88 season of feasibility research in Area IV, a full-scale research started in the 1989/90 season. The sighting surveys have used the same procedures as that used by the IDCR/SOWER as much as possible. These whale sighting surveys were conducted during the Austral summer season.
In Area IV, minke whale was the dominantly sighted species in surveys from the 1987/88 to the 1995/96 season. Humpback whale was the sub-dominantly sighted species in 1995/96, the dominantly sighted species in 1997/98,and again the sub-dominantly sighted species in 1999/2000 season (Ishikawa et al., 2000).

Nishiwaki et al. (1997a) reported abundance estimation of humpback whales using JARPA data between the 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). This paper reports results from an analysis of abundance of humpback whales and their annual rate of increase in Area IV (longitude between 70° E-130° E and latitude south of 60° S) between the 1989/90 and 1999/2000 seasons (over 11 years) using the DISTANCE analysis program.

SURVEYS AND DATA COLLECTION

Sighting surveys

Unique sighting procedures to collect unbiased 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., 1997b).

Research area covered

The area from 60° S to the ice-edge in the Areas IV(70° E-130° E) was covered. The research area was divided into two strata: 60° S latitude line to the line of 45 n.miles from the ice-edge, and ice-edge to 45 n.miles from the ice-edge line.

Design of the trackline

The sawtooth type trackline was adopted 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 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 operated as the dedicated sighting vessel (SV) for the 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 1999/2000. *Yusin-Maru* operated as SSV for the 1999/2000 survey in Area IV.

METHODS

Abundance estimates

The number of schools (N) in the research area is estimated by the following formula given by Burnham, Anderson and Laake (1980);

$$N = (n.\, f\,(0).\, A) / (2.\, L)$$

where n is number of primary sightings, A is area, f(0) is the probability density function of the perpendicular distances evaluated at the origin, L is searching distance (n.mile). The model of the probability density function of the perpendicular distances is selected out of Hazard-rate function and Half-normal function by AIC. The population size (P) is thus estimated as

$$P = N.\ \bar{s}$$

where s is the expected mean school size.
The coefficient of variation of P is estimated as;

$$CV^2(P) = CV^2(n / L) + CV^2(\bar{s})$$

where CV is coefficient of variation.

Assuming N to be log normal, a 95 % confidence interval of N is by (Burnham, Anderson, White, Brownie and Pollock, 1987),

$$(N/C,\ N.C)$$

where

$$C = \exp\left(1.96\,(\log_e(1 + CV^2(N)))^{1/2}\right)$$

The probability to detect on the track line was assumed to be 100 % in this analysis. All estimating procedures were carried out using the program DISTANCE (Buckland, Anderson, Burnham and Laake, 1993).

RESULTS

Distribution of searching effort and humpback whales

Fig.1 shows the searching effort of SV and SSV in 1999/2000 cruise. The searching effort uniformly covered Area IV (Fig.1). Coverage of the searching effort was equivalent to IWC/SOWER cruise, which planned a minimum 50 % coverage in the northern strata, and a minimum 80 % coverage in the southern strata. Humpback whales were concentrated between 90° – 110° E in northern and southern stratum, and were widely dispersed in other part of the Area IV. The primary sightings of humpback whales, which were used in the present analyses, are shown in Figure 1.

Abundance estimates in Area IV

Abundance estimate for this species in Area IV (south of 60 S) was 12,664 (CV=0.28) using SV data for the 1999/2000season. Abundance, total number of the primary sightings, areas, effort, n/L, ESW, MSS, D, P with CV by each stratum are shown in Table1. Truncate was 2.4 n.miles and g (0) was assumed as 1 in this analysis. Fig.2 and 3 show the perpendicular distance in nautical miles used in the present analyses.

Trend of the density estimations

Densities (whales / 100 n.miles^2) of humpback whale in Area IV were estimated as 0.801 (CV=0.32), 0.855 (CV=0.20), 0.772 (CV=0.19), 1.590 (CV=0.17), 2.686 (CV=0.18) and 1.983 (CV=0.13) using full-scale research SSV data between for the research seasons between 1989/90 and 1999/2000. Table 2 shows the density estimation (south of 60° S) for each season with CV. Truncate was 2.4 n.miles and g (0) was assumed to be 1 in this analysis. The trend of increase of these estimations was 13.4 % annually (CV = 0.29) over 11 years (Fig.4). The increase for humpback whales is statistically significant.

DISCUSSION

Current abundance estimations

There are no 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 3,878 (SD=1,672) whales in the 1991-92 period was reported by Jenner and Jenner (1994). These estimates for the early 1990's are similar.Also similar was the estimate of abundance of humpback whales in the Antarctic Area IV in the 1988/89 season using IWC/IDCR data 3,436 whales (CV=0.45) (Brown and Butterworth,

1999). Results of the mtDNA analyses using biopsy samples collected in Area IV indicate that two stocks (the Group IV and the Group V) exist (Pastene and Baker, 1997).

Present JARPA estimates for Area IV in that 1999/2000 season are 12,664 (CV=0.28) and 11,138 (CV=0.29) whales are consistent as a rate of increasing has been assumed to be some 10 % (reported below). Analysis of the 1998/99 IWC/SOWER cruise data in Area IV and comparison with the JARPA estimates are recommended for improvement of abundance estimations.

Biases in abundance estimates

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 this 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.

Kasamatsu *et al.*, (1998) reported that using SSV data the density of humpback whales has no correlation with that of minke whales in the Antarctic (Fig 6). Therefore, the abundance estimate of humpback whales might not likely have this kind of bias. This is supported by the fact that the abundance estimate using SSV data (11,138 whales, CV=0.29) is not different substantially from that using SV data (12,664 whales, CV=0.28) in 1999/2000 JARPA. This result suggested that correction using GAM-based analysis is not necessary for present humpback whale analyses.

Increase of the densities in Area IV

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).

Our estimate calculated from densities in Antarctic Area IV was 13.4 % per annum between 1989/1990 and 1999/2000 (over 11 years). Process errors (Punt *et al.*, 1996) were not taken into account in this study, 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 surveys are necessary for improving the precision of the estimate of annual rate

of increase in the feeding ground of the Antarctic.

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Table. 1. Current abundance estimates of humpback whale in 1999/2000 season using SV data in Area IV (south of 60S). 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).

Stratum	area (n.mile ^{2})	n	L (n.mile)	n / L $*10^2$	CV	esw (n.mile)	CV	MSS	CV	D (ind.)	P (ind.)	CV
NW	236,307	14	999.1	1.401	0.38	1.628	0.07	2.00	2.00	0.861	2,033	0.43
NE	229,576	65	1,043.7	6.228	0.42	1.628	0.07	1.75	0.05	3.354	7,699	0.42
SW	34,825	29	670.8	4.323	0.37	1.628	0.07	2.17	0.06	2.884	1,004	0.38
SE	33,129	78	819.5	9.518	0.34	1.628	0.07	1.86	0.04	5.433	1,800	0.35
PB	27,000	3	391.8	0.766	0.61	1.628	0.07	2.00	0.00	0.470	127	0.61
Total	560,837	189	3,924.9	4.815		1.628	0.07			2.258	12,664	0.28

Table. 2. Current abundance estimates of humpback whale between 1989/90 and 1999/2000 seasons in Area IV (south of 60S) using SSV 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	MSS	CV	D (ind.)	P (ind.)	CV
1989/90	NW	232,782	22	1,987.6	1.107	0.28	1.014	0.21	2.00	0.09	1.091	2,383	0.37
	NE	171,281	19	1,964.4	0.967	0.44	1.014	0.21	1.74	0.09	0.828	1,769	0.49
	SW	33,394	11	2,518.3	0.437	0.38	1.014	0.21	1.64	0.12	0.352	147	0.45
	SE	30,908	1	1,362.2	0.073	0.72	1.014	0.21	1.00		0.036	14	0.75
	PB	35,196	2	831.9	0.240	0.57	1.014	0.21	1.50	0.33	0.178	62	0.69
	Total	503,561	55	8,664.4	0.635		1.014	0.21			**0.801**	**4,375**	**0.32**
1991/92	NW	217,044	42	2,482.7	1.692	0.24	1.287	0.10	1.93	0.06	1.268	2,786	0.26
	NE	228,383	16	2,173.9	0.736	0.30	1.287	0.10	1.69	0.10	0.483	1,051	0.33
	SW	33,433	19	1,199.4	1.584	0.42	1.287	0.10	1.68	0.10	1.037	355	0.44
	SE	29,932	18	1,357.7	1.326	0.33	1.287	0.10	1.78	0.09	0.916	319	0.36
	PB	27,929	1	370.4	0.270	1.61	1.287	0.10	2.00	0.00	0.210	58	1.60
	Total	536,721	96	7,584.1	1.266		1.287	0.10			**0.855**	**4,569**	**0.20**
1993/94	NW	232,782	34	2,493.3	1.364	0.22	1.162	0.09	1.62	0.07	0.953	2,199	0.25
	NE	171,281	17	1,924.7	0.883	0.29	1.162	0.09	1.81	0.11	0.688	1,110	0.33
	SW	33,394	18	1,352.9	1.331	0.38	1.162	0.09	1.45	0.10	0.830	294	0.40
	SE	30,908	6	1,419.1	0.423	0.34	1.162	0.09	2.56	0.31	0.466	190	0.47
	PB	35,196	3	599.3	0.501	0.91	1.162	0.09	1.27	0.26	0.274	97	0.95
	Total	503,561	78	7,789.3	1.001		1.162	0.09			**0.772**	**3,889**	**0.19**
1995/96	NW	217,044	102	2,736.9	3.727	0.19	1.175	0.06	1.44	0.04	2.285	4,960	0.20
	NE	228,383	33	2,123.5	1.554	0.30	1.175	0.06	1.89	0.09	1.250	2,897	0.32
	SW	33,433	36	2,125.1	1.694	0.27	1.175	0.06	1.73	0.06	1.247	369	0.28
	SE	29,932	20	1,530.7	1.307	0.32	1.175	0.06	1.82	0.10	1.010	304	0.34
	PB	27,929	0	846.6			1.175	0.06			–	–	–
	Total	536,721	191	9,362.8	2.040		1.175	0.06			**1.590**	**8,531**	**0.17**
1997/98	NW	224,230	161	2,616.3	6.154	0.22	1.469	0.04	1.83	0.04	3.835	8,599	0.23
	NE	224,567	88	2,643.3	3.329	0.34	1.469	0.04	1.70	0.04	1.923	4,318	0.35
	SW	31,505	137	2,645.4	5.179	0.17	1.469	0.04	1.74	0.03	3.061	964	0.18
	SE	41,450	20	2,370.4	0.844	0.25	1.469	0.04	1.50	0.11	0.431	179	0.27
	PB	2,481	2	354.9	0.564	0.68	1.469	0.04	1.50	0.33	0.288	7	0.76
	Total	524,233	408	10,630.3	3.838		1.469	0.04			2.684	14,068	0.18
1999/2000	NW	236,307	41	1,812.0	2.263	0.22	1.244	0.05	1.44	0.08	1.311	3,097	0.24
	NE	229,576	95	2,490.0	3.815	0.19	1.244	0.05	1.59	0.04	2.440	5,601	0.20
	SW	34,825	76	1,646.0	4.617	0.30	1.244	0.05	1.78	0.05	3.311	1,153	0.30
	SE	33,129	81	1,862.0	4.350	0.21	1.244	0.05	2.22	0.05	3.883	1,287	0.23
	PB	27,000	0	845.0			1.244	0.05			–	0	–
	Total	560,837	293	8,655.0	3.385		1.244	0.05			**1.983**	**11,138**	**0.13**

Table. 3. Yearly change of the density estimation (whales / 100 n.miles ^{2}) of humpback whales in Area IV (south of 60 S) between 1989/90 and 1999/2000 seasons.

Season	Number of vessel	n (school)	L (n.mile)	n/L	esw (n.mile)	CV	P (whale)	D (whales / 100 n.miles)	CV
1989/90	3	55	8,664.4	0.635	1.014	0.21	4,375	0.801	0.32
1991/92	3	96	7,584.1	1.266	1.287	0.10	4,569	0.855	0.20
1993/94	3	78	7,789.3	1.001	1.162	0.09	3,889	0.772	0.19
1995/96	3	191	9,362.8	2.040	1.175	0.06	8,531	1.59	0.17
1997/98	3	408	10,630.3	3.838	1.469	0.04	14,068	2.684	0.18
1999/00	3	293	8,655.0	3.385	1.244	0.05	11,138	1.983	0.13

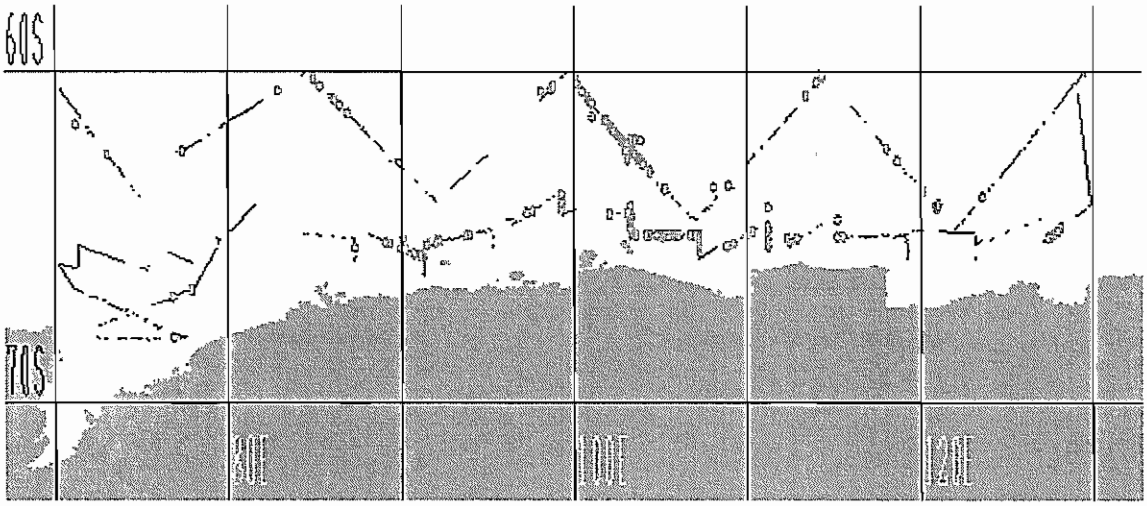

Fig. 1. Distribution of the searching effort and primary school sightings of humpback whales in the 1999/2000 season by Kyosin-Maru No.2 (SV). Black and white lines show the on and off efforts. The circles show the primary schools of humpback whales.

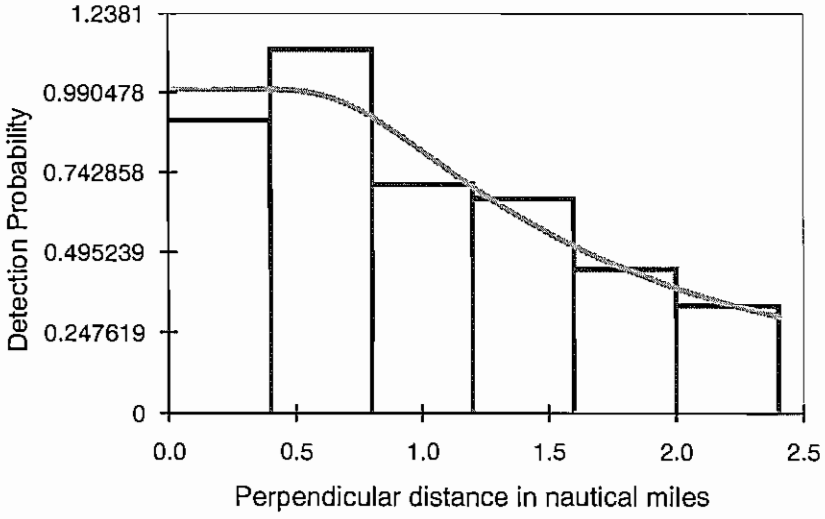

Fig.2. Probability plots by SV, using present abundance estimation of humpback whales in

1999/2000 season.

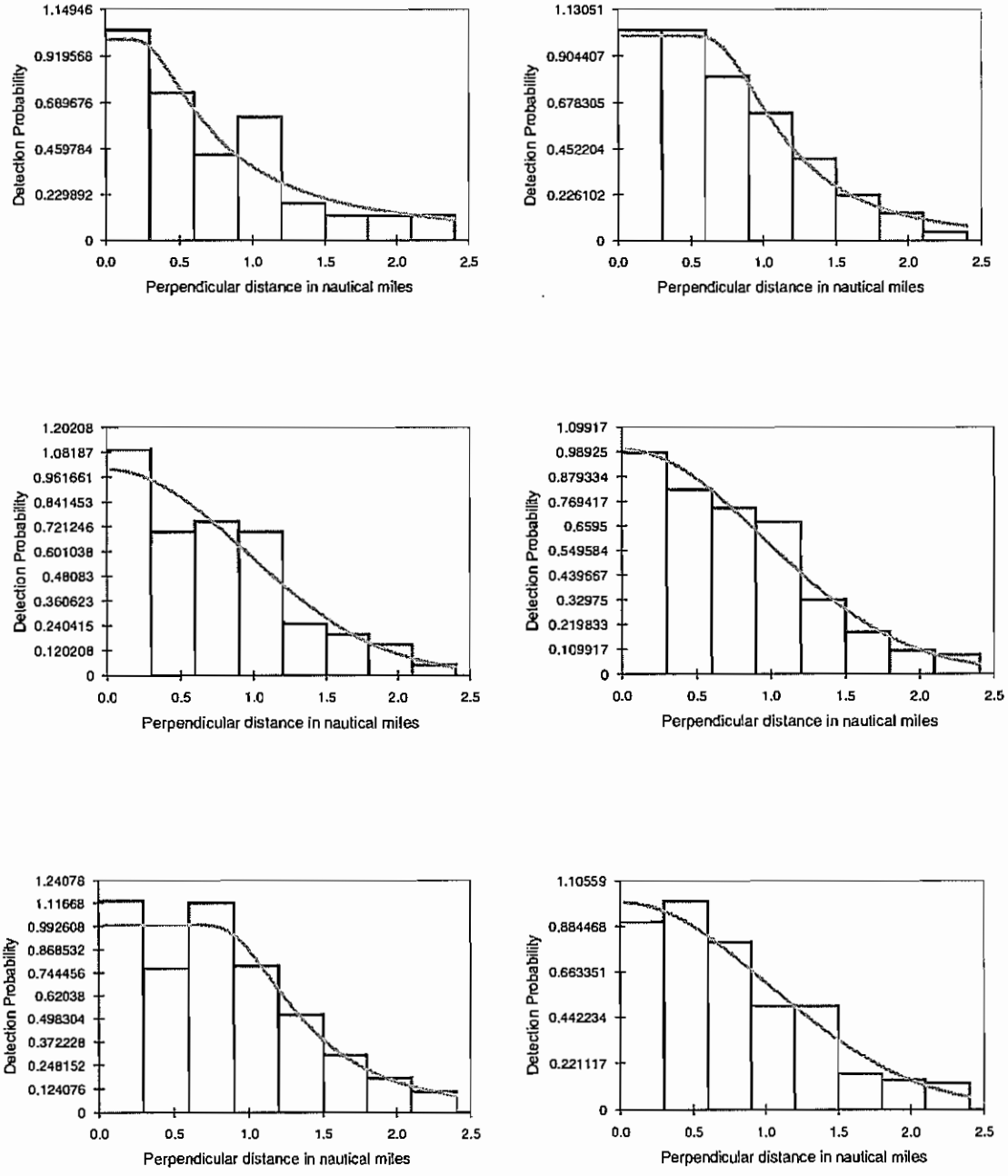

Fig. 4. Probability plots by SSV, using present abundance estimation of humpback whales between 1989/90 to 1999/2000 seasons. Top left: 1989/90, top right: 1991/92. Middle left: 1993/94, middle right: 1995/96. Bottom left: 1997/98, bottom right: 1999/2000 season.

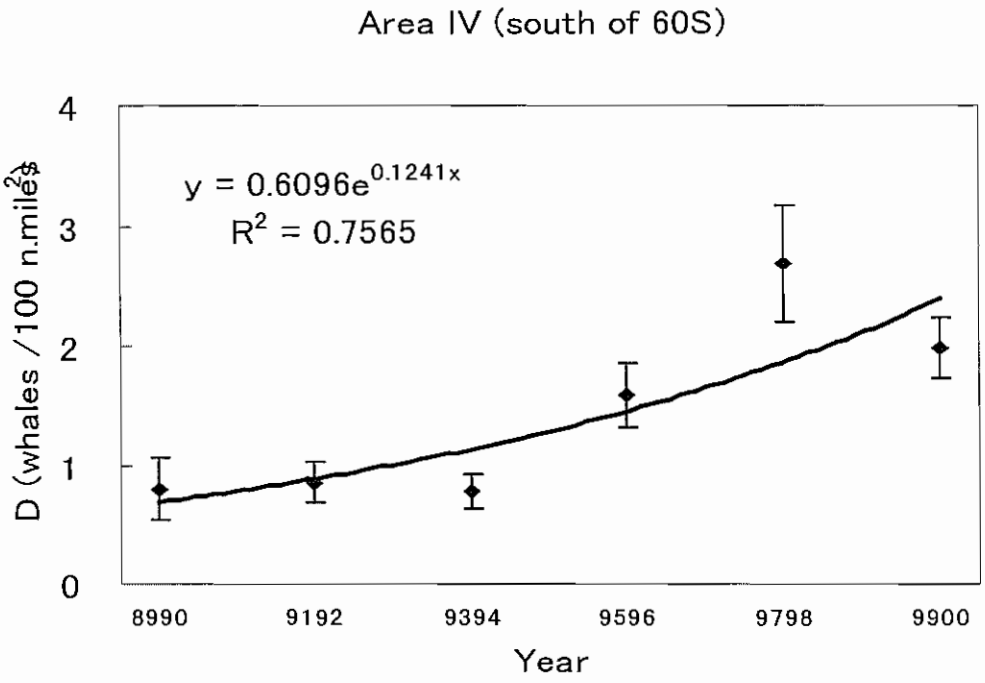

Fig. 5. Trend of density estimations (**D**: whales / 100 n.miles ^{2}) of humpback whale in Area IV (south of 60 S) surveyed during January to February, between 1989/90 and 1999/2000 seasons (over 11 years). Vertical lines show standard errors. Increasing rate was 13.4 % as of present analyses. Process errors were not taken into account in this study, therefore the variances of the abundance estimates may be negatively biased (See the DISCUSSION).

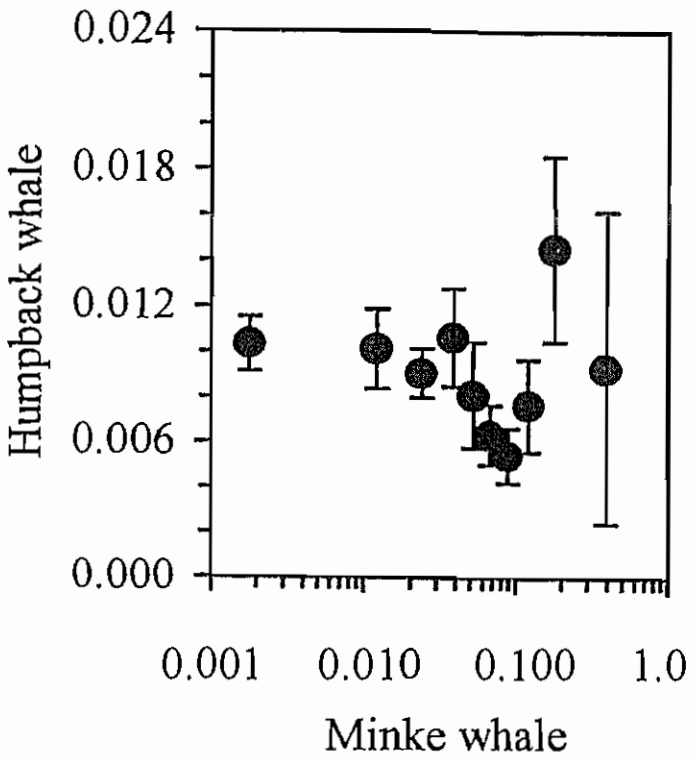

Fig.6. Interspecific relationship in density (encounter rate: whales / 100 n.miles) between minke whales and humpback whales in the Antarctic (south of 60 S) using JARPA SSV data. Vertical lines show standard errors. Humpback whales distribute independently from the minke whales (Kasamatsu *et al.*, 1998).