Current distribution, abundance and density trend of humpback whales in the Antarctic Areas IV and V

KOJI MATSUOKA, TAKASHI HAKAMADA, HIROTO MURASE AND SHIGETOSHI NISHIWAKI

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

ABSTRACT

This paper reports current distribution, abundance (south of 60°S) and annual rate of increase of humpback whales in the Antarctic Areas IV (70°E-130°E) and V (130°E-170°W) between the 1988/89 and 2001/02 austral summer seasons (over 14 years). Data used were from JARPA (1987/89 - 2001/02 surveys) and IWC/IDCR-SOWER (Area IV: 1988/89 and 1998/99 surveys). The DISTANCE analysis program was used to estimate abundance. Humpback whales were widely distributed in Areas IV and V. The main concentration area was observed between 90°E and 110°E in both northern and southern strata. Abundance in Areas IV and V were estimated as 29,856 (CV=0.27) in 2001/02 and 4,251 (CV=0.48) in 2000/01, respectively. The following conditions and assumptions were applied to these analyses: 1) distance and angle were corrected by using the results of the distance and angle estimation experiments, 2) truncation distance was 2.4 n.miles, 3) effective search half width was obtained by fitting a hazard rate model, and 4) g (0) was assumed to be 1. Estimated densities (whales / 100 n.miles^2) were also estimated in Area IV (over 14 years) and Area V (over 11years). Annual rates of increase for humpback whales were estimated as 12.5% (CV=0.58) and 10.3% (CV=0.59) in Areas IV and V, respectively.

KEY WORDS: HUMPBACK WHALE, ANTARCTIC, DISTRIBUTION, ABUNDANCE ESTIMATE, TRENDS

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 and V from the 1987/88 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 (International Decade Cetacean Research) and SOWER (Southern Ocean Whale and Ecosystem Research) cruises as much as possible. In Areas IV and V, Antarctic minke whale (*Balaenoptera bonaerensis*) was the dominantly sighted species in surveys from the 1987/88 to the 1995/96 seasons. In Area IV, humpback whale (*Megaptera novaeangliae*) was the sub-dominantly sighted species in 1995/96, the dominant sighted species in 1997/98, and again the sub-dominantly sighted species in 2001/2002 and 2000/01 seasons (Ishikawa et al., 2002 and Nishiwaki et al., 2001a). Nishiwaki et al. (1997) reported abundance estimation of humpback 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. Abundance estimation and density trend of humpback whale in

Area IV from 1989/90 to 1999/2000 seasons using JARPA data were reported in recent years (Matsuoka et al., 2000a). This paper reports further results of abundance estimates and their annual rate of increase of this species in each Area (south of 60°S) between 1989/90 and 2001/02 seasons (over 14 years) using the DISTANCE analysis program.

SURVEYS AND DATA COLLECTION

JARPA DATA

Sighting surveys

Unique sighting procedures to collect unbiased sighting data have been introduced in the JARPA including (1) the trackline was designed in order to cover the 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. The SSV (Sighting and sampling vessel) have been engaged continuously from the 1987/88 cruise and the SV (Dedicated sighting vessel) have been engaged from 1992/93 cruise continuously. Data from the SV and the SSV were treated separately. Details of the sighting procedures were given in the Review of the sighting survey in the JARPA (Nishiwaki *et* al., 2001b).

Research area covered

The area from south of 60°S to the ice-edge in the Areas 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 trackline legs were systematically set on the ice-edge and on the locus of the 45n.miles from the ice-edge in southern stratum, and the 45 n.miles from the 60°S latitude line in northern stratum.

Research vessels

Kyosin-Maru No.2 has been used 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. Yusin-Maru No.2* operated as SSV from the 2001/2002 survey as the replacement of *Toshi-Maru No.25.*

IWC/IDCR-SOWER DATA

We used IWC cruise data which collected in 1988/89 and 1998/99 cruises in Area IV (south of 60°S). The 1998/99 cruise covered in the part of Area IV (80°-130°E). *Shonan-Maru* and *Shonan-Maru No.2* engaged

these cruises. These data already validated and coded to the IWC/DESS (Database-Estimation System Software, Stringburg and Burt, 2000). Details of the survey method and data collection of IWC cruise were reviewed from 1978/79 to 2000/01 (Matsuoka et al, 2000b).

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 distance was divided by the estimated slope through the origin. Linear regression models with constant variance were conducted to detect significant bias of estimated angle at 5% level. In order to correct significant biases, the estimated slope through the origin divided estimated angle (Burt and Stahl, 2000).

Abundance estimation

Methodology of abundance estimation used in this study was described by Burt and Stahl (2000) which is the standard methodology adopted by IWC. The program DISTANCE (Buckland et al., 1993) was used for abundance estimation. Following formula was used for abundance estimation.

$$P = \frac{AE(s)n}{2wL} \qquad (1)$$

Where

P = abundance estimate

A = area of stratum

$E(s)$ = estimated mean school size

N = numbers of schools primary sightings

W = effective search half-width for schools

L = search effort

The CV of P is calculated as follows

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

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

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

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

Truncation

The perpendicular distance distribution was 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

Distributions of humpback whales

The primary sighting positions of humpback whales with the searching effort of SV in 2001/2002 and 2000/2001 cruises, which were used in the present analyses for current abundance estimation, are shown in Fig.1.

Humpback whales were concentrated between 90°and 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., 2003). The meander might be related to the distribution of humpback whales. In Area V, they were widely dispersed except in the northern strata (130 °E-145° E) and the Ross Sea.

Fig.2 shows distribution of humpback whales in Areas IV and V in 1998/99 season. This season, Areas IV and V surveyed at the same time by SOWER and JARPA in Area IV and V, respectively. There was a blank area between 130°E and 140°E where there is no humpback whale sightings. It seems that this is the boundary between the Group IV and Group V in the Antarctic in this 1998/99 season. These large-scale surveys between 80°E and 170°W were useful for humpback whale distribution in the Antarctic to detect the stock boundary of humpback whales.

Current abundance estimates in Areas IV and V

Current abundance of humpback whales in Areas IV and V (south of 60° S) were estimated as 29,856 (CV=0.27) in 2001/02 season and 4,251 (CV=0.48) in 2000/01 season using JARPA SV data, respectively (Table 2 and 3). 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 this analyses.

Trend of the density estimations

Densities (whales / 100 n.miles^2) of this species in Area IV between 1988/89 and 2001/02 were estimated

using JARPA-SV full-scale research data and IDCR-SOWER data. Densities from IDCR/SOWER data were 1.574 (CV=0.73) in 1988/89 and 4.464 (CV=0.17) in Area IV (Table 4, and Fig. 5). However, it should be noted that the SOWER-1998/99 cruise had not covered between 70°E and 80°E.

In the Area V, densities of this species were estimated for the research seasons between 1990/91 and 2000/01 (Table 5 and Fig. 6). An estimated annual rate of increase in the feeding ground of humpback whales were 12.5 % (CV=0.58) and 10.3 % (CV=0.59) in Areas IV and V, respectively.

DISCUSSIONS

Abundance estimates of humpback whale in Area IV

There were some information about abundance of humpback whales off Western Australia in the late of 1990's and early 2000's. Bannister (1994) reported a total population size of some 3,000 whales off Shark Bay, Western Australia, based on the results from comparison of the 1991 sighting rate with those from a 1963 commercial aerial spotter. A preliminary estimate of humpback whales off Western Australia using mark-recapture analyses of photo-identified individuals was 3,878 (SD=1,672) whales in the 1991-92 period (Jenner and Jenner ,1994). These abundance estimations off Western Australia from 1980's to early 1990's were similar in number. In the late of 1990's, analyses from coastal aerial survey, 8,000-14,000 whales was estimated off Western Australia (Bannister and Hedley, 2001). Abundance estimate from catches and increase rate was also reported as 8,000 (Findlay et al., 2000).

In the Antarctic feeding ground, generally higher abundance was estimated than off Western Australia, because some portion of individuals could not return to their breeding ground surveyed area as it suggested in the North Atlantic humpback whale study (Smith et al., 1999). Present abundance estimates of 7,443 (CV=0.73) in 1988/89, 17,300 (CV=0.17) in 1998/99 and 29,856 (CV=0.27) in 2001/02 may be plausible assuming that a rate of increasing has been some 10 %, although there were some yearly fluctuations.

To interpret these results, further attention should be given to the distribution and movement of biological stocks. Results of analyses of mtDNA in these Areas were consistent with those from mark recapture analyses in the past. Two stocks distributed in these Areas but DNA analysis showed that a same animal migrated to both Areas IV (eastern part) and V (western part) in different years (Pastene et al., 2000). Then animal from the Group V could move to part of Area IV in summer. Although it seemed that there is discontinuity area around 130°-140°E in 1998/99 season (Fig.2). These results also must be taken account when comparison of abundance between breeding and feeding grounds in the future.

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 abundance estimates of 4,251 (CV=0.48) whales for Area V in 2000/01 are in the plausible range assuming that a rate of increasing has been some 10 %. Inclusion of both analyses of the SOWER data in Area V in 2000/01 and 2002/03 will be useful for the improvement of abundance estimations for this Area.

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). The increasing rate between 1982 and 1994 was reported as 10.15±4.6 % from the aerial survey off Western Australia (Bannister and Hedley, 2001). Present annual rates of increase between 1988/1989 and 2001/02 (over 14 years) were 12.5 % and 10.3 % (over 11 years) per annum in Areas IV and V, respectively. However, it should be noted that 12.5 % in Area IV including JARPA and IDCR-SOWER data. The duration of survey year is still too short to detect yearly trend precisely. Further surveys are necessary for improving the precision of the annual rate of increase in the feeding ground.

ACKNOWLEDGEMENTS

The sighting data used in this study were obtained during the JARPA surveys. We wish to express our gratitude to all researchers and crewmembers who contributed to those surveys in the Antarctic. We also thank to Drs. Seiji Ohsumi, The Institute of Cetacean research, Hiroshi Hatanaka, Fisheries Research Agency), Shigeyuki Kawahara and Tomio Miyashita, National Research Institute of Far Seas Fisheries and Marques Fernanda for their valuable suggestions and comments. We also thank to Atsushi Wada for his data proceedings.

REFERENCES

Bannister, J. L., 1994. Continued increase in humpback whales off western Australia. Rep. Int. Whal. Commn 44: 309- 310.

Bannister, J. L. and Hedley, S. L. 2001. Southern hemisphere Group IV humpback whales: their status from recent aerial survey. Mem. Qld. Mus. 47(2):587-598.

Branch, T. A., and Butterworth, D., S., 2001. Estimates of abundance south of 60S 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.

Brown, R. M. Field, M., S., Clarke, E., D., Butterworth, D. S. and Bryden, M., M., 1997. Estimates of abundance and rate of increase for east Australian humpback whales from the 1996 land-bases survey at Point Lookout, North Stradbroke Island, Queensland. Paper SC/49/SH35 submitted to the IWC Scientific Committee, May 1997 (unpublished). 15pp.

Brown, R. M. and Butterworth, D. S., 1999. Estimates of abundance for Southern Hemisphere humpback and blue whales from the IWC/IDCR-SOWER sighting survey cruises. Paper SC/51/CAWS35 submitted

to the IWC Scientific Committee, May 1999 (unpublished).

Bryden, M. M., G. P. Kirkwood and R. W. Slade, 1991. Humpback whales, Area V. An increase in numbers off Australia's east coast. Antarctic ecosystems. Ecological change and conservation. Springer-Verlag Press. 427 pp: 271-277.

Buckland, Anderson, Burnham and Laake, 1993. Distance sampling, 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.

Findlay. K. P., Cunningham, C. L. and Butterworth, D. S. 2000. A first step towards a preliminary assessment of southern hemisphere humpback whale. Paper SC/52/IA5 presented to the IWC Scientific Committee, 2000. (unpublished). 29pp.

Ishikawa, H., Otani, S., Mogoe, T., Kiwada, H., Tohyama, D., Yoshida, T., Hayashi, T., Nagamine, M., Fukutome, K., Konagai, T., Fujihira, T., Sasaki, T., Ishihara, T., and Mori, M. 2002. Cruise Report of the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) Area IV and Eastern Part of Area III in 2001/2002. Paper SC/54/O18 presented to the IWC Scientific Committee, May 2002 (unpublished). 20pp.

Jenner, K. C. S. and Jenner, M-N. 1994. A preliminary population estimate of the group IV breeding stock of humpback whales off Western Australia. *Rep. Int. Whal. Commn* 44: 303-307.

Matsuoka, K. and Ohsumi, S., 1995. Yearly trend in population density of large baleen whales in the Antarctic Areas IV and V in recent years. Paper SC/47/SH9 submitted to the IWC Scientific Committee, 1995 (unpublished). 25pp.

Matsuoka, K., Hakamada, T. and Nishiwaki, S., 2000a. Current abundance and density trend of humpback whales in the Antarctic Area IV using JARPA data. Paper SC/52/IA2 presented to the IWC Scientific Committee, 2000. (unpublished). 14pp.

Matsuoka, K., Ensor, P., Hakamada, T., Shimada, H., Nishiwaki, S., Kasamatsu, F. and Kato, H. 2000b. Overview of the minke whale sighting survey in IWC/IDCR and SOWER Antarctic cruises from 1978/79 to 2000/01. Paper SC/55/ForInfomation 20. Submitted to *Journal of Cetacean Research and Management.*

Matsuoka, K., Watanabe, T., Ichi, T., Shimada, H. and Nishiwaki, S., 2003. Large whale distributions (south of 60S, 35E-130E) in relation to the southern boundary of the ACC. *Antarctic Biology in a Global Context,* pp26-30. Edited by A. H. L. Huiske, W.W.C. Gieskes, J. Rozema, R.M.L. Schrno, S.M. van der Vies & W.J. Wolff. Backhuys Publishers, Leiden, The Netherlands.

Nishiwaki, S., Matsuoka, K., Hakamada, T. and Kasamatsu, F., 1997. Tenporal change of distribution and abundance estimates on large baleen whales in Areas IV and V in the Antarctic. Paper SC/M97/19 submitted to the IWC International working Group to Review to Data and Results from Special Permit Research on Minke whales in the Antarctic, May 1997(unpublished). 20pp.

Nishiwaki, S., Ishikawa, H., Narita, H., Otani, S., Kiwada, H., Kariya, T., Yoshimura, I., Takamatsu, T., Teraoka, T., Shiozaki, M., Abe, N., Okamura, S., Yasui, K. and Mori, M., 2001a. Cruise report of the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) Area V and Western Part of Area VI in 2000/2001. Paper SC/53/O11 presented to the IWC Scientific Committee, (unpublished). 21pp.

Nishiwaki, S., Matsuoka, K., Murase, H. and Hakamada, T.,2001b. Review of the sighting procedure in the JARPA. Paper SC/53/IA7 presented to the IWC Scientific Committee, (unpublished). 25pp.

Pastene, L., A., Goto, M., Abe, H., Nishiwaki, S. and Pallsboll, P., 2000. Genetic diversity of humpback whales in the Antarctic feeding ground examined by mitochondria DNA and microsatellite. Paper SC/52/IA4 presented to the IWC Scientific Committee, 2000. (unpublished). 16pp.

Paterson, R. and Paterson, P., 1989. The status of the recovering stock of humpback whales Magaptera novaeangliae in east Australian waters. Biological Conservation 47: 33-48.

Smith, T. D, Allen, J., Clapham, P. J., Hammond, P. S., Katona, S., Larsen, F., Lien, J., Mattila, D., Palsbøll, P. J., Sigurjónesson, J., Stevick, P. T. and Øien, N. 1999. An ocean-basin-wide mark-recapture study of the North Atlantic humpback whale (*Megaptera Novaeangliae*). Mar. Mamm. Sci. 15: 1-32.

Strindberg, S. and Burt, L. 2000. IWC Database-Estimation System Software (DESS) User Manual, May 2000. Research Unit for Wildlife Population Assessment, Mathematical Institute, University of St Andrews. 300pp.

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

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	distance	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

2001/2002

Vessel	platform	distance	angle
K01	barrel	0.957	0.921
	upper bridge	0.957	n.s.
T25	barrel	0.951	n.s.
	upper bridge	0.960	n.s.
YS1	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.
KS2	barrel	n.s.	n.s.
	upper bridge	n.s.	n.s.

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

Table. 2. Abundance estimates of humpback whale in Area IV (south of 60°S) using JARPA-2001/2002-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
2001/2002	NW	200,738	57.0	696.7	8.181	0.46	1.056	0.05	1.678	0.07	6.503	13,054	0.47
	NE	223,108	58.0	1021.5	5.678	0.49	1.056	0.05	1.383	0.05	3.720	8,299	0.50
	SW	61,517	127.0	945.8	13.428	0.35	1.056	0.05	2.018	0.06	12.836	7,896	0.35
	SE	66,790	11.0	833.6	1.320	0.49	1.056	0.05	1.455	0.17	0.909	607	0.53
	PB	29,155	0.0	465.6	0.000	-	-	-	-	-	-	-	-
	Total	581,308	253	3963	6.384	-	1.056	0.05	1.455	0.17	5.136	29,856	0.27

Table. 3. Abundance estimates of humpback whale in Area V (south of 60°S) using JARPA-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 humpback whale in Area IV (south of 60°S) using JARPA SV data and IWC/IDCR (1988/89) and SOWER (1998/99) data between 1988/89 and 2001/02. Truncate is 2.4 n.miles. The g (0) is assumed to be 1. n: number of primary schools, L: searching distance, esw: the effective search half width, MSS: mean school size, D: estimated density (individuals / 100 n.miles ^{2}), P: estimated population abundance (individuals). The 1998/99 cruise had not covered in Area IV between 70°E and 80°E.

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
1988/89	NW	156,617	29.3	1,431.9	2.044	0.570	0.604	0.71	2.215	0.17	3.599	5,636	0.958
	NE	181,166	2.0	1,116.3	0.179	0.699	0.604	0.71	2.215	0.17	0.315	571	0.671
	SW	58,693	5.0	483.5	1.034	0.324	0.604	0.71	2.215	0.17	1.821	1,069	0.467
	SE	52,441	1.0	554.3	0.180	0.932	0.604	0.71	2.215	0.17	0.318	167	0.478
	PBN	17,486	0.0	627.7	0.000	–	–	–	–	–	0.000	0	0.000
	PBS	6,520	0.0	231.9	0.000	–	–	–	–	–	0.000	0	0.000
	Total	472,923	37	4446	0.838	–	0.604	0.71	2.215	0.17	1.574	7,443	0.73
1993/94	NW	232,782	10.0	1667.4	0.600	0.40	1.447	0.15	1.833	0.08	0.380	885	0.43
	NE	171,281	11.0	1250.4	0.880	0.61	1.447	0.15	1.833	0.08	0.557	955	0.63
	SW	33,394	7.0	1024.8	0.683	0.75	1.447	0.15	1.833	0.08	0.433	145	0.77
	SE	30,908	1.0	839.8	0.119	0.73	1.447	0.15	1.833	0.08	0.075	23	0.75
	PB	35,196	1.0	477.7	0.209	0.77	1.447	0.15	1.833	0.08	0.133	47	0.79
	Total	503,561	30.0	5260.1	0.570	–	1.447	0.15	1.833	0.08	0.408	2,054	0.37
1995/96	NW	217,044	22.0	793.6	2.772	0.35	0.983	0.20	2.159	0.04	3.045	6,610	0.40
	NE	228,383	13.0	856.2	1.518	0.60	0.983	0.20	2.159	0.04	1.668	3,809	0.63
	SW	33,433	21.0	714.2	2.940	0.68	0.983	0.20	2.159	0.04	3.230	1,080	0.71
	SE	29,932	7.0	578.4	1.210	0.35	0.983	0.20	2.159	0.04	1.330	398	0.40
	PB	27,929	0.0	475.2	0.000	–	0.983	0.20	2.159	0.04	0.000	0.000	–
	Total	536,721	63.0	3417.6	1.843	–	0.983	0.20	2.159	0.04	2.217	11,897	0.35
1997/98	NW	224,230	37.0	750.9	4.927	0.47	1.482	0.12	1.848	0.04	3.071	6,887	0.48
	NE	224,567	26.0	979.4	2.655	1.04	1.482	0.12	1.848	0.04	1.655	3,716	1.05
	SW	31,505	38.0	787.1	4.828	0.33	1.482	0.12	1.848	0.04	3.009	948	0.35
	SE	41,450	6.0	825.5	0.727	0.43	1.482	0.12	1.848	0.04	0.453	188	0.45
	PB	2,481	0.0	135.1	0.000	–	–	–	–	–	0.000	0	–
	Total	524,233	107	3,478	3.076	–	1.482	0.12	1.848	0.04	2.240	11,739	0.45
1998/99	NW	105,396	100.4	637.2	0.158	0.192	1.564	0.07	2.046	0.06	10.302	10,858	0.21
	NE	169,387	44.5	1136.1	0.039	0.414	1.564	0.07	2.046	0.06	2.561	4,338	0.42
	SW	42,605	46.9	850.0	0.055	0.253	1.564	0.07	2.046	0.06	3.608	1,537	0.27
	SE	70,193	16.0	1294.1	0.012	0.193	1.564	0.07	2.046	0.06	0.808	567	0.21
	PB	–	–	–	–	–	–	–	–	–	–	–	–
	Total	387,581	208	3,917	5.305	–	1.564	0.07	2.046	0.06	4.464	17,300	0.17
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	3925	4.764	–	1.736	0.09	1.888	0.03	2.156	12,093	0.29
2001/2002	NW	200,738	57.0	696.7	8.181	0.46	1.056	0.05	1.678	0.07	6.503	13,054	0.47
	NE	223,108	58.0	1021.5	5.678	0.49	1.056	0.05	1.383	0.05	3.720	8,299	0.50
	SW	61,517	127.0	945.8	13.428	0.35	1.056	0.05	2.018	0.06	12.836	7,896	0.35
	SE	66,790	11.0	833.6	1.320	0.49	1.056	0.05	1.455	0.17	0.909	607	0.53
	PB	29,155	0.0	465.6	0.000	–	–	–	–	–	–	–	–
	Total	581,308	253	3963	6.384	–	1.056	0.05	1.455	0.17	5.136	29,856	0.27

Table. 5. Abundance estimates of humpback whale in Area V (south of 60°S) using JARPA-SSV data, between 1990/91 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

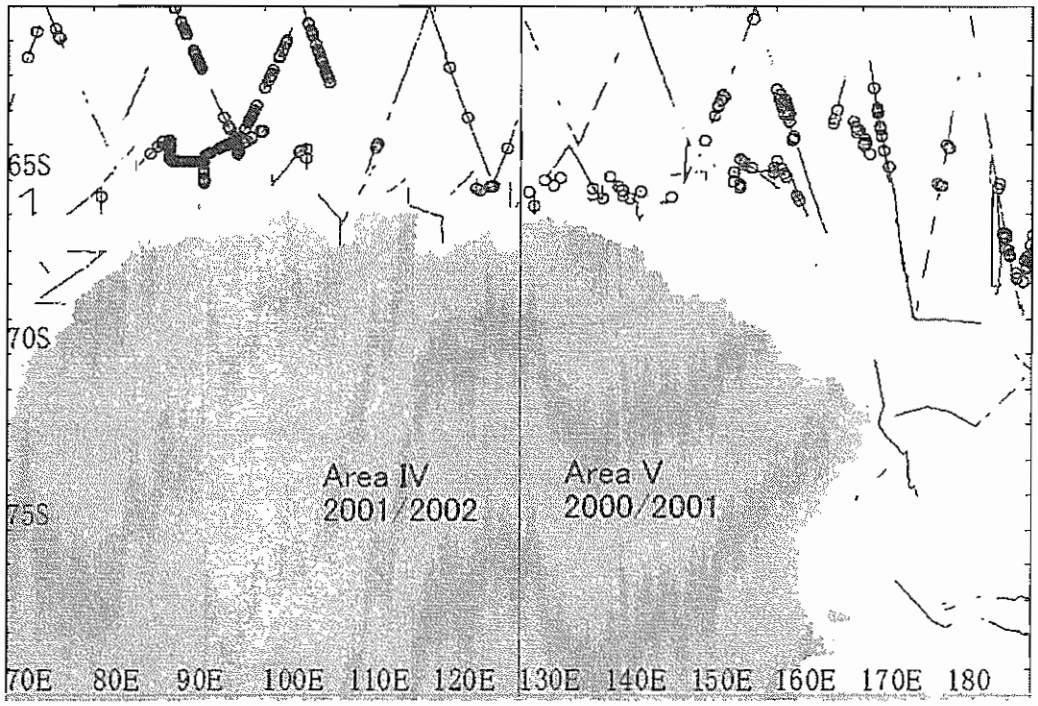

Fig. 1. Distribution of the searching effort and primary school sightings of humpback whales in the 2001/02 and 2000/01 seasons by *Kyosin-Maru No.2* (SV). Black line shows the on efforts. The circles show the primary schools of humpback whales sighted.

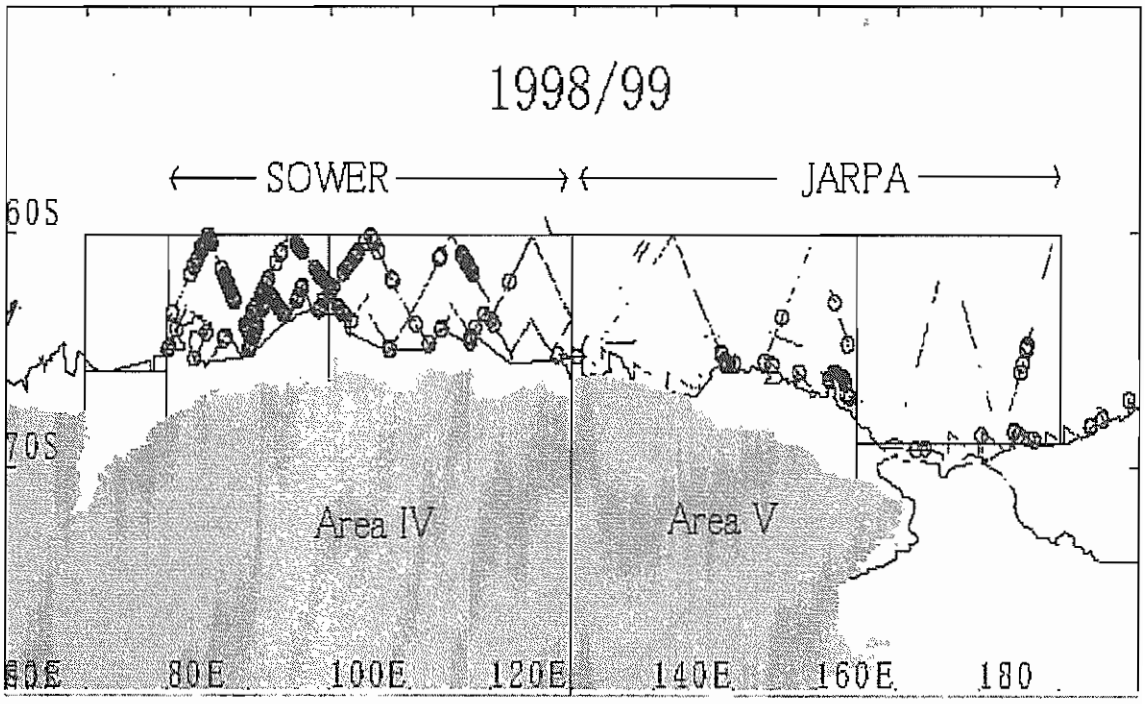

Fig. 2. Distribution of the searching effort and primary school sightings of humpback whales in the Antarctic Areas IV and V in 1998/99 season by IWC/SOWER and JARPA. This season, SOWER covered the Area IV except between 70E-80E. Black line shows the on efforts. The circles show the primary schools of humpback whales sighted. Dotted line shows estimated ice edge line.

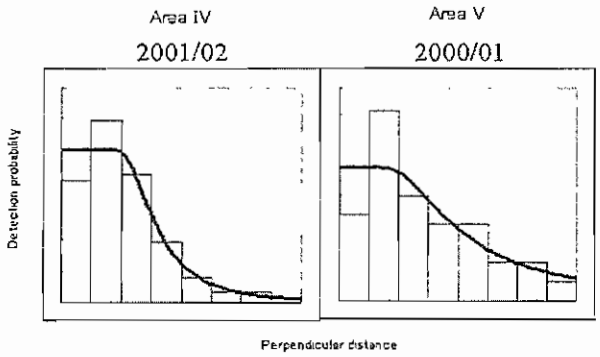

Fig.3. Probability plots by JARPA-SV data for the current abundance estimations of humpback whales in Areas IV and V in 2001/02 and 2000/01 seasons.

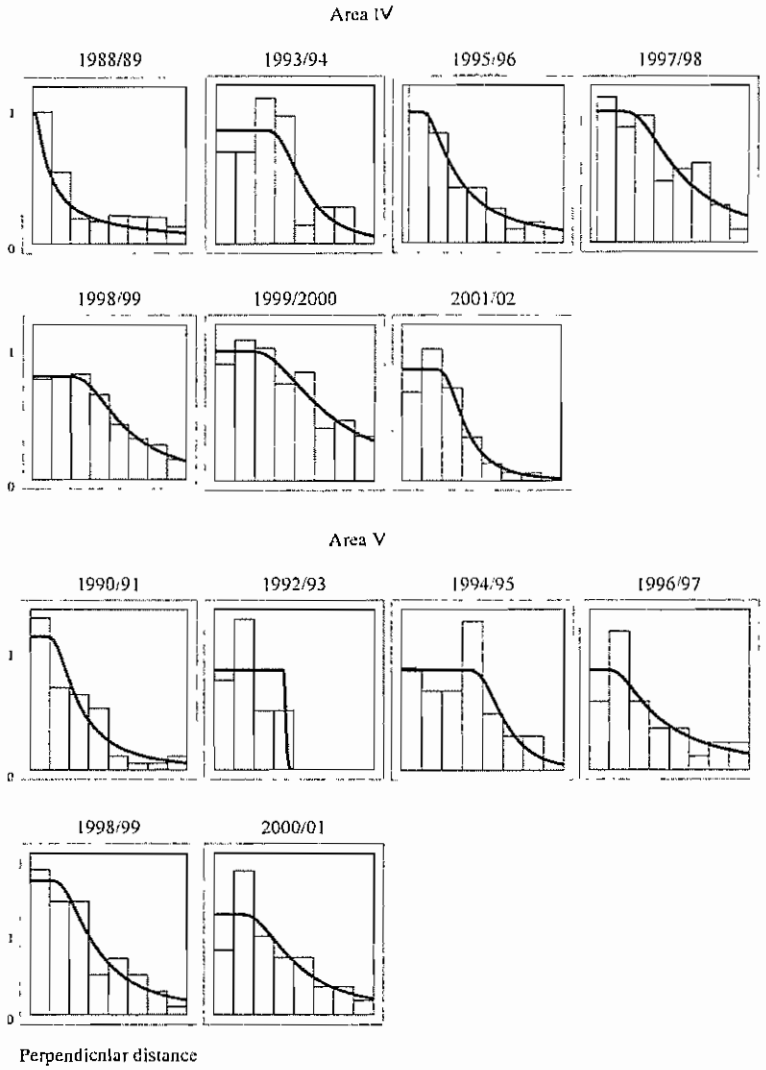

Fig. 4. Probability plots used for abundance estimations of humpback whales between 1988/89 to 2001/02 seasons in relation to Table 4 and 5.

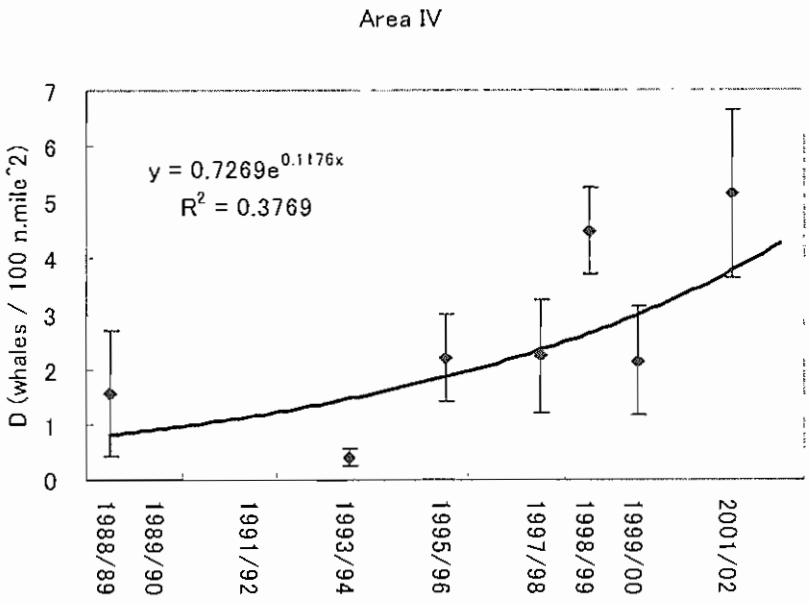

Fig. 5. Trend of density estimations (**D**: whales / 100 n.miles ^{2}) of humpback whale in Area IV (south of 60°S) surveyed during January to February, between 1988/89 and 2001/2002 seasons (over 14 years). Vertical lines show standard errors. Estimated annual rate of increase was 12.5 % as of present analyses.

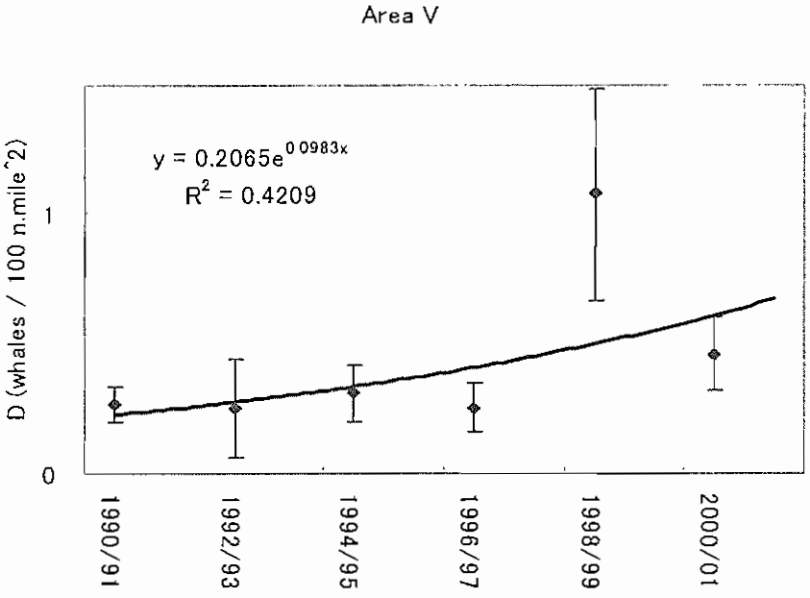

Fig. 6. Trend of density estimations (**D**: whales / 100 n.miles ^{2}) of humpback whale in Area V (south of 60 °S) surveyed during January to February, between 1990/91 and 2000/2001 seasons (over 11 years). Vertical lines show standard errors. Estimated annual rate of increase was 10.3 % as of present analyses.