INCREASING TREND AND ABUNDANCE ESTIMATE OF SEI WHALES IN THE WESTERN NORTH PACIFIC

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ABSTRACT

During the 2002 and 2003 JARPNII surveys, dedicated sighting surveys were conducted in sub-areas 8 and 9 (excluding foreign EEZ) in August and September. The analytical program DISTANCE was used to estimate abundance of sei whales based on data collected in those surveys, resulting in the figure of 4,100 animals (CV=0.281). Japanese scouting vessel (JSV) data were used to estimate an extrapolation factor and then abundance estimate in the western North Pacific (north of 35^{o}N and west of 180^{o}) in recent years, was possible. Result of the estimation was 68,000 animals (CV=0.418, 95% CI: 31,000-148,000). There is a possibility that the extrapolation factor estimate has a low precision due to small number of JSV sightings. The present estimate is more than double of the former estimate of 28,400 and several explanations are given for this difference. Density index was higher in recent JARPN II surveys than in previous JSV surveys, which support the view of increasing trend in abundance for this population.

KEY WORDS: ABUNDANCE ESTIMATE, WESTERN NORTH PACIFIC, SEI WHALE

INTRODUCTION

From the sighting positions of sei whales during 1994-2001 JARPN and JARPNII feasibility surveys, it was suggested that sei whales distributes uniformly in sub-areas 7, 8 and 9. JSV data also suggest that sei whales distribute uniformly in the western North Pacific. Twenty-six years have passed since the ban of catch of this stock, and the recovering trend appears remarkable in recent years by the Japanese whale sighting surveys and the JARPN sighting surveys (Government of Japan, 2002). In 2002, the abundance in the western North Pacific (west of 180^{o}) was estimated as 28,400 animals (CV=0.414) by extrapolating from abundance estimate 4,905 (CV=0.405) from JARPN surveys (1997-2001) (Government of Japan, 2002).

To investigate abundance estimate in the western North Pacific further, dedicated sighting surveys in 2002 and 2003 were planned. Because sighting survey conducted during 1997 – 2001 did not cover the survey area fully, further sighting surveys were conducted in 2002 and 2003 in order to get a more accurate abundance estimate. These sighting surveys were conducted in sub-areas 8 and 9 by dedicated sighting vessels. Abundance was estimated from these surveys and extrapolated using the same method as Government of Japan (2002).

Figs. 2 and 3 suggest that sei whales distribute to the east of 170^{o}E as well as in sub-areas 8 and 9.

JSV data were used to extrapolate abundance by JARPNII because a) JSV surveys collected sighting data consistently for a long period and b) wide areas were covered by the surveys. JSV data cannot be used to estimate absolute abundance because there is no record of sighting distance data (e.g. radial distance and angle), but JSV data are useful to estimate relative abundance index (Miyashita *et al*., 1994). There were some previous studies using JSV data for extrapolation purpose (Butterworth et al., 1994; Miyashita *et al*., 2001; Minamikawa *et al*., 2002).

MATERIALS AND METHODS

Data

JARPNII sighting data

Fig. 1 shows the survey area covered by a dedicated sighting vessel in 2002 and 2003. The figure shows that effort was allocated uniformly in sub-areas 8 and 9, but there was insufficient effort in sub-area 7 due to time restriction. These surveys were conducted in August and September.

JSV data

JSV data in the waters comprised between 30oN and 60oN and east of 180o obtained from 1972 to 1988, were used. We did not use JSV data in the Okhotsk Sea and Bering Sea. We used only the data in August and September because differences of distribution pattern are suggested from JSV data, as shown in Figs. 2 and 3. Table 1 shows searching distance, number of sighted whales, area in JARPNII survey and whole of the western North Pacific excluding JARPNII survey area used in this study. The number of sighted whales and searching distance by JSV in 5^{o} square by month and by year were also used.

Abundance estimation

Abundance was estimated by using DISTANCE (Buckland *et al.,* 1993). The perpendicular distance distribution is truncated at 2.4 n. miles. Detection function was fitted to hazard-rate function with no adjustment terms;

$$f(x) = 1 - \exp\left\{-\left(\frac{x}{a}\right)^{-b}\right\} \qquad (1)$$

where, *x* is perpendicular distance and *a* and *b* are parameters. Abundance estimator is following formula;

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

where, *P* is abundance estimate, *A* is area size of survey area, *E*(*s*) is estimated mean school size, *n* is the number of primary sightings, w is effective searching half-width and *L* is searching distance. Only the sightings for which school size is confirmed are used for estimation. We used the method of estimation of mean school size described Buckland *et al*. (1993). Coefficient of Variance (CV) of the abundance is estimated by

$$\mathrm{CV}(P) = \sqrt{\{\mathrm{CV}(\frac{n}{L})\}^2 + \{\mathrm{CV}(E(s))\}^2 + \{\mathrm{CV}(w)\}^2} \qquad (3).$$

Assuming P is log-normally distributed, 95% confidential interval is (P/C, CP), where

$$C = \exp(Z_{0.025}\sqrt{\log_e[1+\{\mathrm{CV}(P)\}^2]}) \qquad (4)$$

and $Z_{0.025}$ is 2.5 percentile of standard normal distribution. For further details, see Buckland *et al*. (1993), for example.

Extrapolation to western North Pacific

Extrapolated abundance (P_E) for western North Pacific of this species, which weighted by the Japanese Scouting Vessel (JSV) data (sighting rate of 5°×5°square) collected in August and September during 1972 to 1988 (Fig. 3) were analyzed by the following formula;

$$P_E = P \times \Sigma / \Sigma^* \qquad (5),$$

where,

$$\Sigma = \sum_{i,j} (n/L)_{i,j} A_{i,j}$$ (sum over all squares in the west of 180°and the north of 30°N)

$$\Sigma^* = \sum_{i,j} (n/L)_{i,j} p_{i,j} A_{i,j}$$ (sum over only squares for which abundance estimate applied)

n : number of sei whales, L: searching distance n.miles,

$(n/L)_{i,j}$: sighting rate of 5°×5°square of latitudinal band i and longitudinal band j.

$A_{i,j}$: Area size of 5°×5°square of latitudinal band i and longitudinal band j

$p_{i,j}$: Proportion of area size of surveyed area during JARPNII survey within 5°×5°square of latitudinal band i and longitudinal band j

We estimate extrapolation factor (= Σ/Σ^*) from JSV data in August and September because sighting survey was conducted in August and September. CV of extrapolation factor is estimated by Jackknife method (Gray and Schucany, 1972; Miller, 1974) taking year as a sampling unit.

RESULTS

Abundance estimate in sub-areas 8 and 9

Abundance estimate in sub-areas 8 and 9 is 4,085 (CV=0.281) from 2002-2003 JARPNII dedicated survey (Table 2). Fig. 4 shows detection function for each survey. Comparing the former estimate (Table 4), CV is smaller by about 0.1 and therefore precision is increased. One of the reasons for this is because effort was designed to be uniformly allocated in the survey area.

Extrapolated abundance

Extrapolated abundance using JSV data in August and September is 67,642 (CV=0.418) (Table 3). The present estimate for CV of extrapolation factor (0.310) is much higher than the first estimate (0.071), because CV of extrapolation factor is high probably due to less effort in August (22,000 n. miles) and September (18,000 n. miles) than in June (70,000 n. miles) and July (52,000 n. miles).

DISCUSSION

Abundance estimate from JARPNII data

Though it may not be able to compare directly two estimates due to the difference of survey period, the present estimate of 4,085 (CV=0.281) is not significantly different from the first estimate of 4,909 (CV=0.405). The present abundance estimate might be underestimated due to lack of effort in sub-area 7.

It may be possible that summing abundance estimates in latitudinally different area surveyed in different year caused double counting of the population. CV of the abundance estimate may be underestimated, because additional variance is not taken into account.

Extrapolated abundance

From comparison between Figs. 2 and 3, it was suggested that density of sei whale is lower in sub-areas 8 and 9 than in to the east of 170°E in August and September, whereas there were similar level of sightings of sei whales in sub-areas 8 and 9 as well as to the east of 170°E in June and July. This may suggest seasonal change in distribution pattern of sei whales.

From Table 1, there were only 2 sightings in sub-areas 8 and 9 according to JSV data, though the searching distance amounted to 8,000 n. miles. There are two possible interpretations of this. One is that (1) main distribution area of sei whales shift north or east of sub-areas 8 and 9 and density in sub-areas 8 and 9 is low in August and September. Another is that (2) when the JSV data was collected, abundance estimate of 9,000 (IWC, 1975) was lower than that in recent years and the density in sub-areas 8 and 9 was low. In contrast, the population has been increasing and density in this area became higher, recently. In this survey, 103 whales were detected per 5,600 n. miles, but only 43 whales were detected per 40,000 n.miles according to 1972-88 JSV data. In other words, the present density index is 17 times as much as that of JSV. It’s reasonable to think that this change is due to multiple effects of seasonal migration and increase of the population. Sighting surveys to investigate seasonal migration patterns of sei whales and distribution outside of sub-areas 8 and 9 are necessary. Data from these sighting surveys could improve both the estimate and CV of extrapolation factor.

The present estimate is more than double of the former estimate of 28,400. There will be three possible reasons for this result. First, the extrapolation factor is biased due to small size of sightings in sub-area 8 and 9. Second, seasonal migration affects on the abundance estimate. JSV data support seasonal migration. Third, the population has been increasing up to now. This is supported by comparison of JSV data and JARPN data mentioned in above paragraph.

Estimated CV of extrapolation factor using Jackknife method using year as sampling unit may be underestimated, because the searching effort is more in 1970’s than in 1980’s. In fact, applying Jackknife method to only the data in 1970’s, estimated CV is 0.441, which is more than the estimated CV of 0.310 using all years. It is necessary to consider analysis method other than Jackknife method to estimate CV of extrapolation factor more precisely.

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REFFERENCE

Buckland, S.T., Anderson, D. R., Burham., K. P. and Lakke, J. L. 1993. DISTANCE sampling. Chapman and Hall, London. 446pp.

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

Gray, H. L. and Schucany, W. R. 1972. The generalized Jackkife Statistic. Marcel Dekker. New York. 308pp.

Government of Japan, 2002. Research Plan for Cetacean Studies in the Western North Pacific under Special Permit (JARPN II). Paper SC/54/O2 presented to the IWC Scientific Committee, April 2002 (unpublished). 45pp.

International Whaling Commission (IWC). 1975. 27th Report of the Commission. Report of the Scientific Committee. 52pp

Matsuoka, K., Hakamada, T.,Fujise Y., and Miyashita, T., 2000. Distribution pattern of minke whales based on sighting data during the JARPN 1994-1999. Paper SC/F2K/J16 presented to the IWC Scientific Committee Workshop to Review the Japanese Whale Research Programme under Special Permit for North Pacific Minke Whales (JARPN), Tokyo, 7-10 February 2000 (unpublished). 17pp.

Miller, R. G. 1974. The Jackkife – a review. *Biometrika*. 61:1-15.

Minamikawa, S., Miyashita, T. and Okamura, H. 2002. Further analysis on the JSV data of the Antarctic minke whale using GLMs. Paper SC/54/IA12 presented to the IWC Scientific Committee, April 2002. 11pp.

Miyashita, T. and Shigemune, H. and Kato, H. 1994. Outline of the sighting strategy of scouting vessels attached to Japanese whaling fleets. *Rep. int. Whal. Commn*. 44:273-6.

Miyashita, T., Kato, H. and Kasuya, T. (eds.). 1995. Worldwide Map of Cetacean Distribution Based on Japanese Sighting Data. National Research Institute of Far Seas Fisheries, Shimizu, Japan. 140pp.

Miyashita, T., Shono, H. and Okamura,.H. 2001. GLM analysis of the JSV data for the Antarctic minke whale. Paper SC/53/IA11 presented to IWC Scientific Committee, June 2001. 6pp.

Table 1. Searching distance and the numbers of sighted whales from JARPNII area and JSV data used in this study.

survey	the number of 5^ox5^osquare[*1]	searching distance (n. miles)	the number of sighted whales	area of survey region (n.miles^2)
JARPNII	13	5,587	103[*2]	671,429[*3]
JSV (JARPNII survey area)	13	8,003	2	671,429[*3]
JSV (outside of JARPNII survey area)	23	31,586	41	1,790,350[*4]

*1 If only a part of the square was surveyed, we counted it.
*2 the number of sighted schools multiplied by estimated mean school size
*3 excluding Russian EEZ
*4 excluding Okhotsk Sea and Bering Sea

Table 2. Sei whale abundance in sub-areas 8 and 9 from JARPNⅡ2002-2003 (in August and September)

sub-area	season	Area	n	L	n/L	CV	ESW	CV	E(s)	CV	D	P	CV
8 + 9S	2002	534,449	36	3054.5	0.012	0.279	1.563	0.101	1.72	0.075	0.0065	3,470	0.306
9N	2003	136,980	24	2532.9	0.009	0.575	1.352	0.390	1.28	0.086	0.0045	616	0.700
Total		671,429	60	5587.4	0.011						0.0061	**4,085**	**0.281**

Table 3. Estimate of extrapolated abundance using JSV data to western North Pacific (WNP) (north of 35^oN and west of 180^o)

	Estimate	CV
sub-areas 8 and 9	4,085	0.281
western North Pacific	67,642	0.418

Table 4. Sei whale abundance estimate in Government of Japan (2002)

Year	Month	sub-area	area size (n.miles2)	sub-area coverage	L (n.miles)	n	n/L	esw (n.miles)	mean school size	abundance	Extrapolated abundance by JSV data
1997+ 2001	June+ July	7,8,9	431,157	49.8%	12,530	122	0.010 (0.317)	0.913 (0.159)	1.38 (0.045)	4,909 (0.405)	28,400 (0.414)

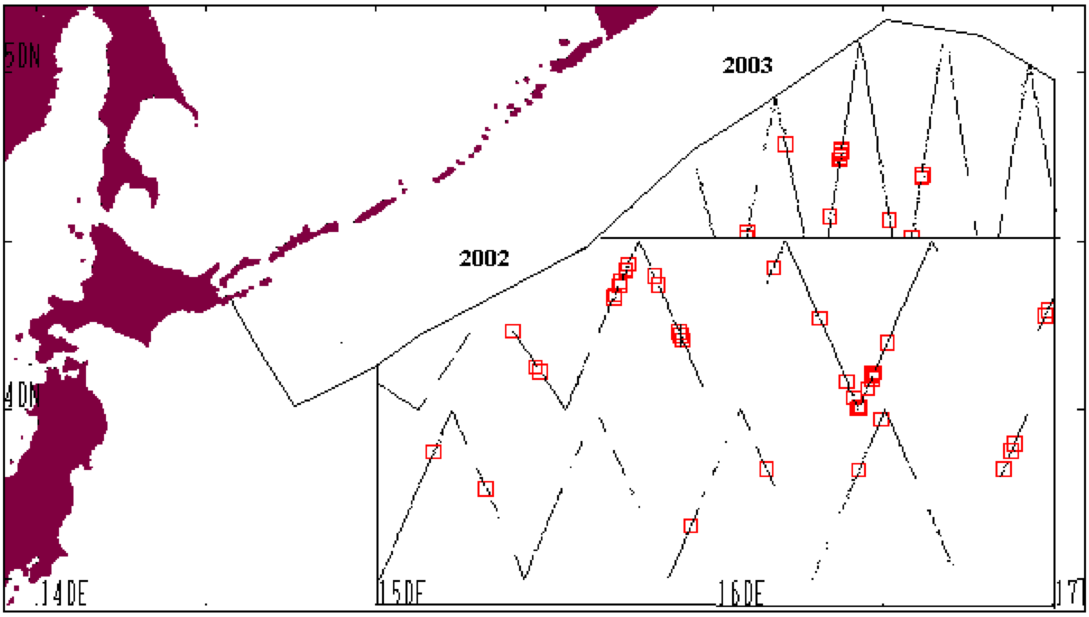


Fig.1. Research area, searching effort and primary sighting positions of sei whales in August and September of 2002 and 2003 JARPNII surveys.

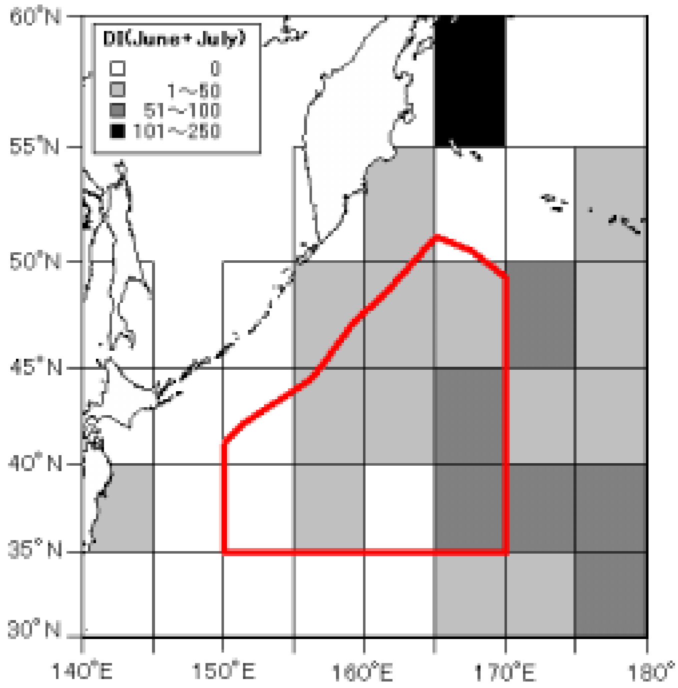
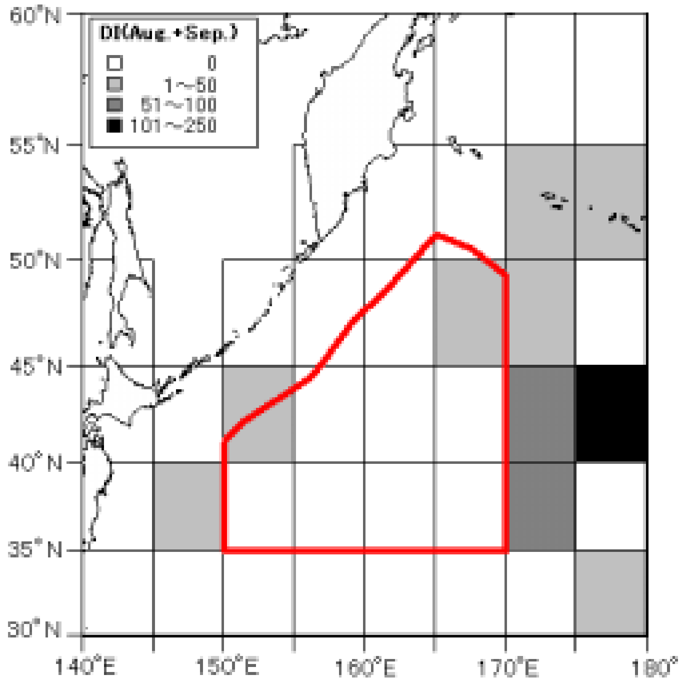


Fig. 2. Density indices (whales per 10,000 n. miles) of sei whales from JSV data in 1972-1988 in June and July. Bold lines indicate boundary of the 2002-2003 JARPNII survey area



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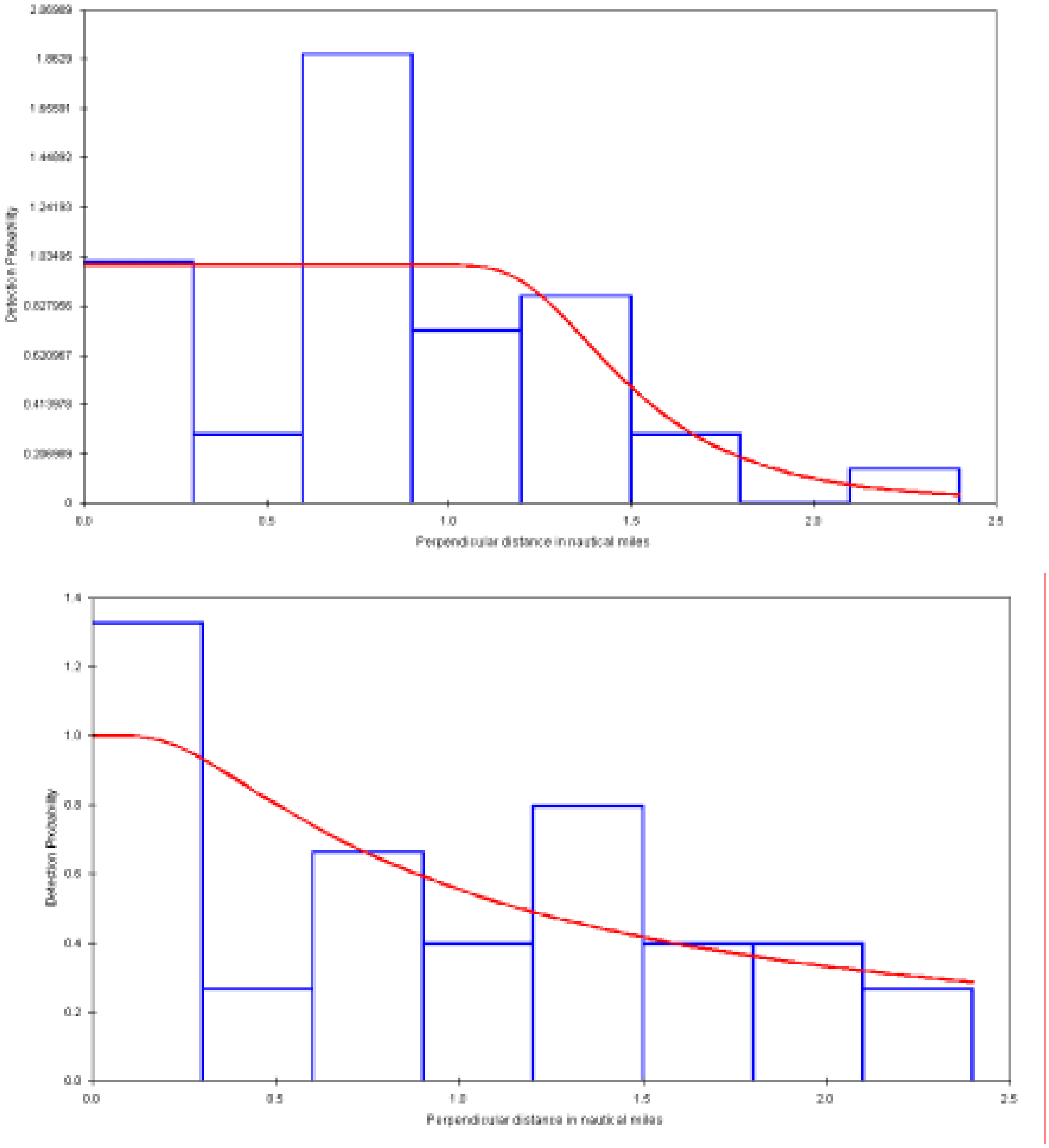

Fig. 4. Detection function of sei whales estimated from JARPNII 2002 and2003（upper panel：2002, lower panel：2003）.