Preliminary estimation of North Pacific sei whale abundance derived from 2010 IWC/Japan Joint Cetacean Sighting Survey data

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ABSTRACT
Abundance of North Pacific sei whale (*Balaenoptera borealis*) was preliminary estimated using 2010 IWC/Japan Joint Cetacean Sighting Survey Cruise. Sensitivity analyses were also conducted. Abundance estimate in the central North Pacific (north of 40^{o}N, south of Aleutian Islands, between 170^{o}E and 170^{o}W) was 9,286 (CV=0.35) for reference case. Abundance estimate ranges between 8,528 and 9,188 in sensitivity analyses. Abundance estimates based on IWC/Japan Joint Cetacean Sighting Survey Cruise could be used for in-depth assessment of this species.

INTRODUCTION
In-depth assessment for North Pacific sei whale (*Balaenoptera borealis*) is planned to start at this meeting (IWC, 2011). In 2010, the plan of the cruise was agreed at the SC62 and IWC/Japan Joint Cetacean Sighting Cruise was conducted in North Pacific (Matsuoka *et al.*, 2011). The plan of the survey had been drawn up following guidelines agreed at the North Pacific programme intersessional meeting (IWC, 2011). This survey provided valuable data to estimate North Pacific sei whale abundance. This paper preliminary estimates abundance of the sei whale derived from this survey using the standard methodology (Branch and Butterworth, 2001a).

MATERIALS AND METHODS

Survey area and period
Sighting survey was conducted by dedicated sighting vessel *Kaiko-Maru* (KK1) in the period of 8 July – 25 August. Surveyed area was in the central North Pacific (north of 40^{o}N, south of Aleutian Islands, between 170^{o}E and 170^{o}W) and the survey area was divided into two strata by latitudinal line of 47^{o}N (Figures 1a and 1b). Area sizes of northern and southern strata were 238,637n.miles^2 and 365,244n.miles^2, respectively. They were calculated by Arc GIS (ver 9.31).

Searching effort
The searching effort was 490.46n.miles and 1325.74n.miles in northern and southern strata, respectively (Table 1). Plot for searching effort and the primary sightings of the sei whales are shown in Figure 2. Survey coverage is higher in southern stratum than in northern stratum.

Sighting records
Primary sightings from top (30 schools/56 individuals) and those from upper bridge (15 schools/33 schools) were used for this analysis. Because it is assumed that $g(0)$=1, those from IO platform was not used. Observed distance and angles were corrected using the Angle and Distance Experiment data (Branch and Butterworth 2001a).

Survey mode
Closing mode (36 schools/77 individuals) and passing mode (9 schools/12 individuals) were conducted in the survey. Sighting and effort data in both survey modes were pooled for abundance estimation because of limited sample size as in the case of IDCR/SOWER based abundance estimation for large baleen whales (Branch and Butterworth, 2001b; Branch 2008).

Abundance estimation
It was assumed that $g(0)$=1 to estimate abundance. The observed data of radial distance and angle are smeared using the method II of Buckland and Anganuzzi (1988). Detections are truncated at 3.0 n.miles. Abundance and

its CV were estimated by formula (1) and (2), respectively. DISTANCE ver 6.0 (Thomas *et al*., 2010) was used for abundance estimation.

$$N = \frac{AnE(s)}{2wL} \quad (1)$$

$$CV(N) = \sqrt{\left\{CV\left(\frac{n}{l}\right)\right\}^2 + \left\{CV(w)\right\}^2 + \left\{CV(E(s))\right\}^2} \quad (2)$$

where N is abundance estimate, A is area size of the surveyed area, n is the smeared number of schools detected within perpendicular distance of 3.0 n.miles, $E(s)$ is estimated mean school size, w is effective strip half width (ESW) and l is searching distance.

On estimation of CV for total abundance, we took into account that estimated ESW and mean school size for northern and southern strata are in common assuming that encounter rate in northern and southern strata aren't correlated. The CV was estimated by

$$CV(N) = \sqrt{\left\{\frac{\sum_i A_i^2 \operatorname{var}\left(\frac{n_i}{l_i}\right)}{\sum_i A_i^2 \left(\frac{n_i}{l_i}\right)^2}\right\} + \left\{CV(w)\right\}^2 + \left\{CV(E(s))\right\}^2} \quad (3)$$

where i is index for strata.

The smeared and truncated sightings data for schools were grouped into intervals of 0.3 n. miles to estimate the detection function. We consider the model Half-normal and Hazard rate models as a candidate model for detection function. Model was selected by AIC. We combined data in northern and southern strata to estimate ESW and mean school size because there were not sufficient detections in the northern stratum. Mean school size was estimated from the primary sightings whose school size was confirmed only in closing mode. Regression method in Buckland *et al*. (1993) was conducted to estimate mean school size.

Some sensitivity analyses were conducted as following.
1. Mean school size could differ between northern and southern strata.
2. Northern stratum was ignored because survey coverage in northern stratum is not high.
3. Width of perpendicular distance intervals was changed from 0.3 to 0.6.

Because school size is one for all the sightings in northern stratum, pooling data in northern and southern strata to estimate mean school size could cause over estimate of abundance. This is reason for conducting sensitivity 1. Sensitivity 3 was conducted to improve fit of the detection function.

RESULTS AND DISCUSSIONS

Sei whales were mainly distributed in southern stratum with some concentration areas but they also were distributed in northern stratum, too. Effect of school size on detection was not significant at 15% level (i.e. *p*-value was 0.30) therefore observed mean school size was used to estimate abundance (Table 2). Table 1 shows estimate of encounter rate, ESW, mean school size and their CVs. Abundance estimate in northern and southern strata were 1,394 (CV=0.53) and 7,893 (CV=0.34), respectively and total abundance estimate was 9,286 (CV=0.35) for reference case. Coverage is low in northern stratum due to bad weather condition. This could cause worse precision of abundance estimate in northern stratum. For sensitivity 1, abundance estimate in northern and southern strata were 707 (CV=0.52) and 8,128 (CV=0.38), respectively and total abundance estimate was 8,835 (CV=0.35). For sensitivity 2, abundance estimate was 8,528 (CV=0.35) in southern stratum. Abundance estimate would not change substantially among the sensitivities.

AIC for Half Normal model is smaller than that for Hazard rate model (Table 3) and therefore Half-Normal model was selected by AIC. Plot of the detection function was shown in Figure 3. The fit of the model seems good except interval of [0.3, 0.6]. For sensitivity, width of the interval for perpendicular distance was changed from 0.3 to 0.6. Abundance estimate were 1,380 (CV=0.53) and 7,808 (CV=0.38) in northern and southern strata, respectively. Total abundance estimate was 9,188 (CV=0.38). This sensitivity improved in fit of the detection function (Figure 4). Half Normal model was selected by AIC for the sensitivities, too. Detection function considering covariates such as Beaufort state and so on could be examined for further investigation by increasing the data collected in 2011 Cruise.

Kanda *et al*. (2009; 2011) indicated that the open water of the North Pacific was mainly occupied by the individuals from a single stock of the sei whales. The abundance estimate in western North Pacific (north of 35^{o}N and west of 170^{o}E, excluding foreign EEZ) was 5,406 (CV=0.300) in July-early September (Hakamada *et al*., 2009). Abundance estimate for North Pacific stock of sei whales could be estimated at least 14,000, assuming that there is a single stock of the sei whale in the North Pacific. The IWC/Japan joint cetacean sighting surveys will be conducted further eastern area in 2011, and better abundance estimate could be obtained in near future. These data and estimates could be used in the in-depth assessment of this species.

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REFERENCES
Branch, T. A. and Butterworth, D. S. 2001a. Southern Hemisphere minke whales: standardised abundance estimates from the 1978/79 to 1997/98 IDCR-SOWER surveys. *J. Cetacean Res. Manage.* 3:143-174.
Branch, T. A. and Butterworth, D. S. 2001b. Estmates of abundance south of 60^{o}S for cetacean species sighted frequently on the 1978/79 to 1997/98 IDCR-SOWER surveys. *J. Cetacean Res. Manage.* 3:251-270.
Branch, T. A. 2008. Humpback abundance south of 60°S from three complete circumpolar sets of surveys. *J. Cetacean Res. Manage. special issue* (in press)
Buckland S. T. and Anganuzzi A. A. 1988. Comparison of smearing methods in the analysis of minke sightings data from IWC/IDCR Antarctic cruises. *Rep. Int. Whal. Commn* 38: 257-63.
Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, reprinted 1999 by RUWPA, University of St Andrews. 446pp.
Hakamada, T., Matsuoka, K. and Miyashita, T. 2009. Distribution and the number of western North Pacific common minke, Bryde's, sei and sperm whales distributed in JARPN II Offshore component survey area. Paper SC/J09/JR15 presented to the Expert Workshop to review results of JARPN II. (unpublished) 18pp.
International Whaling Commission. 2010. Report of the intersessional meeting on the North Pacific Sighting Survey Programme. Paper SC/62/Rep3 presented to IWC Scientific Committee meeting, May, 2010 (unpublished) 9pp.
International Whaling Commission. 2011. Report of the Scientific Committee. *J. Cetacean Res. Manage.* (suppl.). xx-xx.
Kanda, N., Goto, M., Yoshida, H. and Pastene, L. A. 2009. Stock structure of sei whales in the North Pacific as revealed by microsatellite and mitochondrial DNA analyses. Paper SC/J09/JR32 presented to the Expert Workshop to review results of JARPN II. (unpublished) 14pp.
Kanda, N., Goto, M., Matsuoka, K., Yoshida, H. and Pastene, L. A. 2011. Preliminary microsatellite analysis of sei whales obtained from the North Pacific in 2010. Paper SC/63/IA12 presented to this meeting.
Matsuoka, K., Hakala, S., Kim, H. W., Aki, M. and Shinyashiki, Y. 2011. Cruise Report for 2010 IWC/Japan Joint Cetacean Sighting Survey Cruise in the North Pacific. Paper SC/63/O5 presented to this meeting (unpublished) 43pp.
Thomas, L., S.T. Buckland, E.A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R.B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

Table 1. Abundance estimates for the sei whales and their CV by strata. *A* was area size of the surveyed area, *n* is the smeared number of schools detected within perpendicular distance of 3.0 n.miles, *l* is searching distance, *ESW* is effective strip half width, *E*(*s*) is estimated mean school size, *D* is density (individual/n.miles^2), *P* is abundance estimate and CI is abbreviation for confidence interval.

a. Mean school size was estimated with pooling northern and southern strata (reference case).

Stratum	Area (n.miles^2)	n	l (n.miles)	n/l*100	CV	ESW (n.miles)	CV	E(s)	CV	D (ind./n.miles^2)	P (ind.)	CV	95% CI LL	95% CI UL
Northern	238,627	4.0	490.46	0.82	0.50	1.38	0.12	1.97	0.10	0.006	1,394	0.53	528	3,677
Southern	365,244	40.0	1,325.74	3.02	0.35	1.38	0.12	1.97	0.10	0.022	7,893	0.38	3,863	16,127

b. Mean school size was estimated separately for northern and southern strata (sensitivity 1).

Stratum	Area (n.miles^2)	n	l (n.miles)	n/l*100	CV	ESW (n.miles)	CV	E(s)	CV	D (ind./n.miles^2)	P (ind.)	CV	95% CI LL	95% CI UL
Northern	238,627	4.0	490.46	0.82	0.50	1.38	0.12	1.00	0.00	0.003	707	0.52	272	1,837
Southern	365,244	40.0	1,325.74	3.02	0.35	1.38	0.12	2.03	0.10	0.022	8,128	0.38	3,977	16,614

c. Using data in southern stratum only (sensitivity 2).

Stratum	Area (n.miles^2)	n	l (n.miles)	n/l*100	CV	ESW (n.miles)	CV	E(s)	CV	D (ind./n.miles^2)	P (ind.)	CV	95% CI LL	95% CI UL
Northern														
Southern	365,244	40.0	1,325.74	3.02	0.31	1.31	0.12	2.03	0.10	0.023	8,528	0.35	4,409	16,495

d. Width of intervals for perpendicular distance was doubled (sensitivity 3).

Stratum	Area (n.miles^2)	n	l (n.miles)	n/l*100	CV	ESW (n.miles)	CV	E(s)	CV	D (ind./n.miles^2)	P (ind.)	CV	95% CI LL	95% CI UL
Northern	238,627	4.0	490.46	0.82	0.50	1.39	0.12	1.97	0.10	0.006	1,380	0.53	522	3,644
Southern	365,244	40.0	1,325.74	3.02	0.35	1.39	0.12	1.97	0.10	0.021	7,808	0.38	3,815	15,981

Table 2. Results for regression of log of observed school size and detection probability for reference case.

slope	SE	student's-*t*	*p*-value
-0.063	0.287	-0.219	0.414

Table 3. AIC estimate for each model of detection functions for reference case.

model	AIC
Hazard rate	181.13
Half-normal	**177.90**

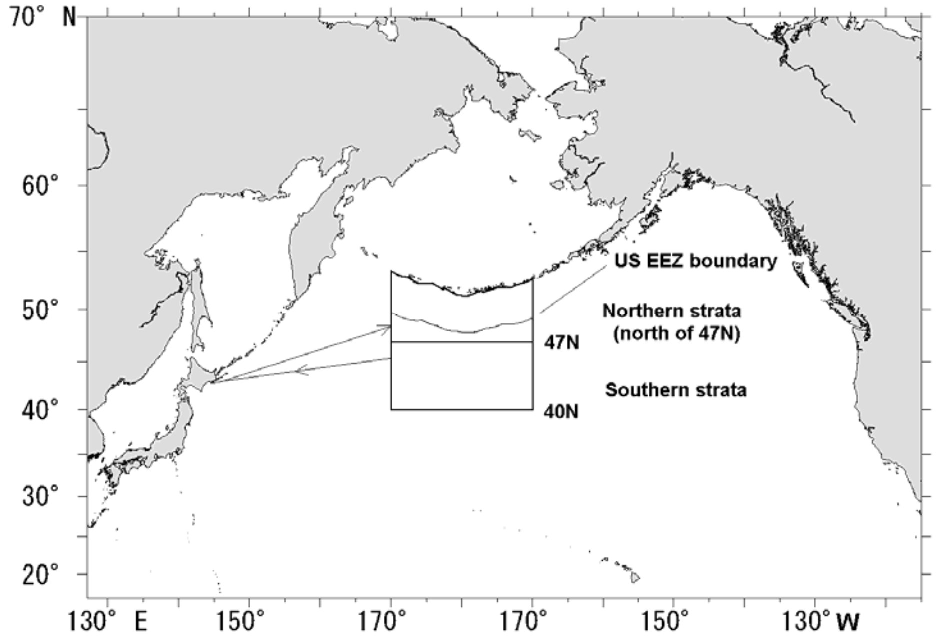

Figure 1a. Survey area of 2010 IWC/Japan Joint Cetacean Sighting Survey Cruise in the North Pacific.

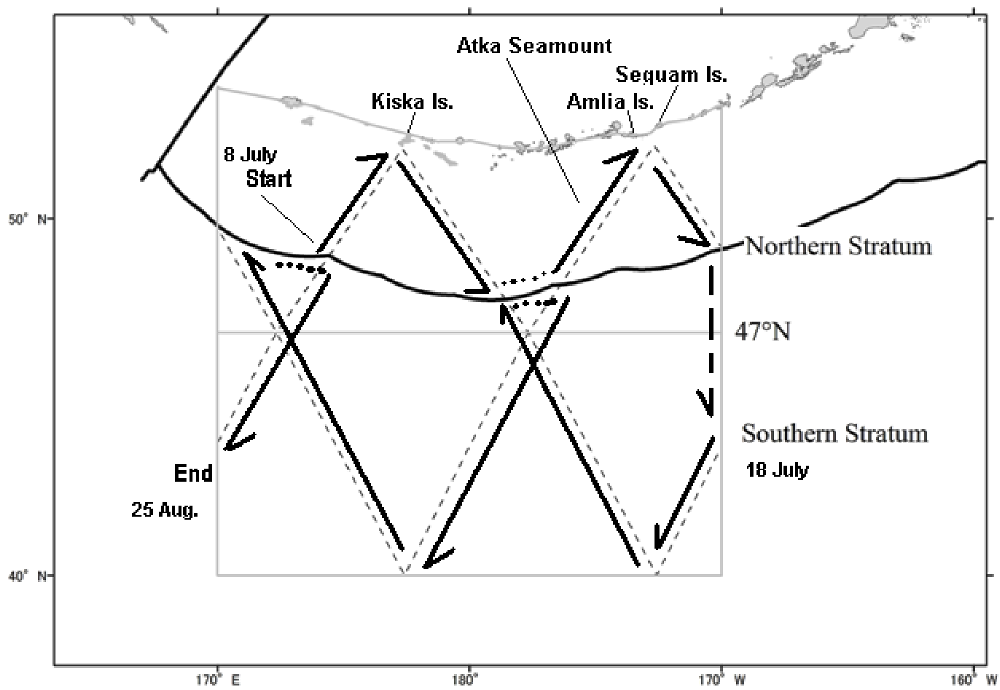

Figure 1b. Cruise tracklines design and strata for the survey. The survey area was divided into northern and southern strata by 47°N latitudinal line. Broken lines indicate cruise track. Bold arrows indicate survey order. bold dotted lines indicate transit in the research area.

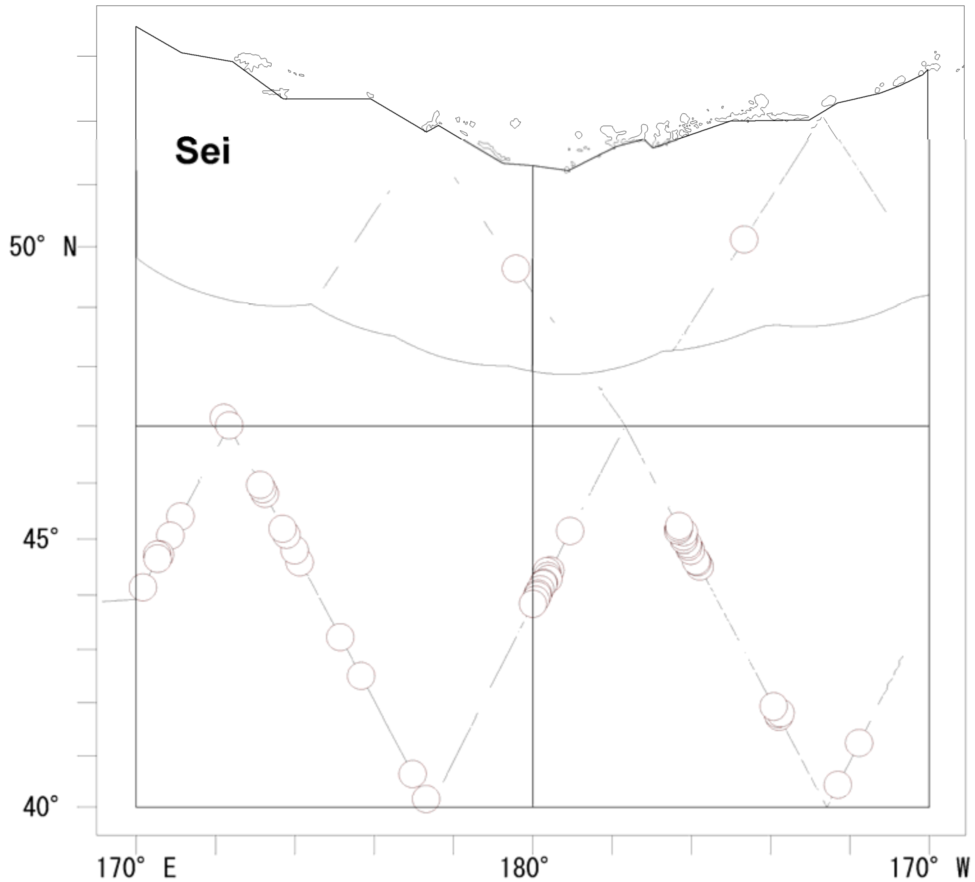

Figure 2. Plot of searching effort and primary sightings of the sei whales in the northern and southern strata. Open circle represents the primary sighting position.

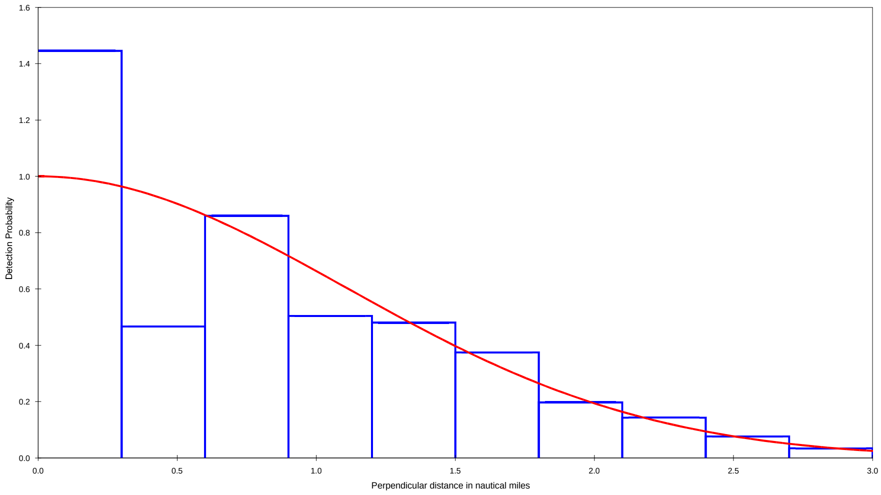

Fig. 3. Plot of the estimated detection function fitted to the number of schools as a function of perpendicular distance (n. miles) from the track line for reference case.

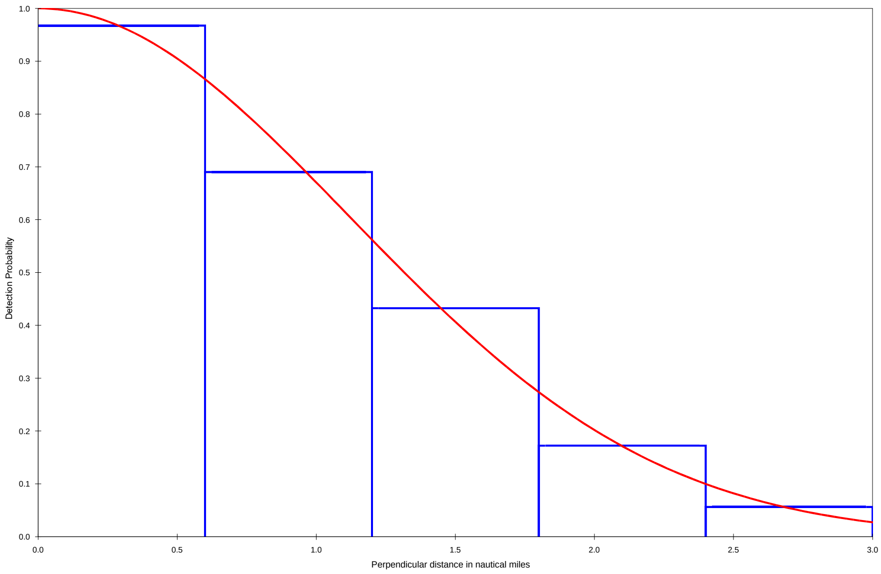

Figure 4. Plot of the estimated detection function fitted to the number of schools as a function of perpendicular distance (n. miles) from the track line for sensitivity 3.