# Revised abundance estimate of western North Pacific common minke whales based on JARPN II sighting data.

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**ABSTRACT**
In order to access the status of common minke whale (*Balaenoptera acutorostrata*) stocks in the western North Pacific, it was required to estimate the number of these whales in the JARPN II survey area as a part of the whale stocks. Considering the migration pattern of these whales in the area revealed by our sighting survey data, abundance was estimated separately for the early and late seasons. The estimates for the common minke whales were 6,395 (CV=0.717) in the early and 2,872 (CV=0.458) in the late seasons assuming that g(0)=0.798 (SE=0.134) (Okamura *et al*., 2010). It is important to note that these estimates should not be used for assessment because the estimated figures represent only a part of the whole population considered.

**INTRODUCTION**
JARPN II survey area is Sub-areas 7, 8 and 9 excluding foreign EEZ Because the common minke whales migrate to north for feeding in spring and summer, the number of whales distributed in JARPN II survey area could be differ among the month. It is considered that more common minke whales pass through these areas in spring than in summer. But previous abundance estimates in these area was not taken migration into account. In this paper, migration/staying of the common minke whales was investigated and estimate abundance taking migration into account.

**MATERIALS AND METHODS**
Dedicated sighting survey was conducted in JARPN II survey from 2006 and 2007. Timing of survey and surveying order of strata was changed substantially year by year in order to know how the number of distributed whales changed and how whales moved seasonally (for more details, see Kiwada *et al*., 2009). During 2006-2007 the whole survey area was planned to be covered at once. In 2006, the survey was conducted from south to north. In 2007, the survey was conducted from north to south. More details of the sighting survey procedure are explained in Kiwada *et al*., (2009). Stratification of the JARPN II survey area is shown in Fig. 1. Sub-areas 8 and 9 are stratified at 41ºN latitudinal line. Distributions of trackline surveyed and primary sightings of the common minke whales are shown in Fig. 2.

Based on sighting data obtained during these surveys, the number of the whales distributed in the JARPN II survey area and their CVs was estimated from the following formulae;

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

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

where *N* was the number of the whales distributed, *A* was area size of the surveyed area, *E*(*s*) was estimated mean school size, *w* was effective strip half width and *l* was searching distance. In case that data were pooled over the two surveys to estimate *w* and *E*(*s*), CV of the estimated *N* was estimated from

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

where *i* was an index of strata. *n* was the number of strata whose data were pooled. In this calculation, it was assumed that

$$\operatorname{cov}\left(\frac{n_i}{l_i}, \frac{n_j}{l_j}\right) = 0 \quad (i \neq j) \quad (4).$$

The whale numbers were estimated using the program DISTANCE ver. 5.0 (Thomas *et al*., 2006) *g*(0) was assumed to be 0.798 with SE=0.134 (Okamura *et al,* 2010) for Top barrel and Upper bridge for the minke whales.

## RESULTS

### Distribution and movement of the common minke whales

As discussed later, the common minke whales mainly distribute in southern part of the survey area (south of 41ºN) in early season (May – June) and migrate to north of 41ºN in late season (July – September). In 2006, the southern part of the area was surveyed in early season and the northern part of the area was surveyed in later season. Therefore, our survey vessels likely followed migrating common minke whales. This survey process should have caused the highest estimate observed for the common minke in 2006. In 2007, northern part of the area was surveyed when the whales had not migrated there yet and southern part was surveyed in late season after the whales migrated out to north.

Fig. 3 shows monthly searching effort by latitude. Because there was not enough searching effort in April and October, we used data from May to September. Fig 4 shows Density Index (DI: the number of the sightings per 100 n.minles) by latitude during the 1994-2007 JARPN and JARPN II (Matsuoka *et al*., 2009). Fig 4 suggested that the minke whales were distributed south of 41°N in May and June and north of 41°N in July and August.

**Estimation of the numbers of whales distributed**

Table 1 shows the number of minke whales distributed in survey areas in 2006 and 2007, respectively. Because sighting surveys were conducted from May to August, these figures could be affected by the migration pattern suggested by Fig. 4. Considering above changes in distribution and the migration of the minke whales, data set were selected so as to include sighting data in the peak migration area in the early (May and June) and late (from July and August) seasons, respectively, but not to combine the both data set to avoid double counting due to migration. The area of low coverage was not selected. The selected data set were obtained and listed in Table 2. The estimated number of whales distributed in JARPN II survey area in the early and late season can be obtained using these data. Table 3 shows the estimated number of whales distributed in the JARPN II survey area in the early and late season. Coverage of the survey area for each of the sub-areas 7, 8 and 9 was 85.3%, 100% and 100%, respectively. The estimated numbers divided by these coverage. The estimates for the common minke whales were 6,395 (CV=0.717) in the early and 2,872 (CV=0.458) in the late seasons. Fig. 5 shows distributions of primary sightings used for the estimation of the common minke whales in the early and late seasons, respectively. The main distribution area of the common minke whales moves to north of JARPN II survey area. This figure likely well reflects the distribution pattern suggested by Fig. 4. Fig. 6 shows the detection probability functions for the common minke whales. The detection probability functions seemed to fit the relative frequency of the distribution of perpendicular distance of the detections.

## DISCUSSIONS

The estimated numbers of the common minke whales distributed in the survey area in the late season was less than that in the early season. This can be interpreted that the minke whales migrate to further north of the JARPN II survey area. In fact, the common minke whales mainly distribute in the Sea of Okhotsk and in the waters east of the Kamchatka Peninsula and the Kuril Islands in August and September (Buckland *et al*, 1992; Miyashita, 2010).

As discussed above paragraph, the distributed whales in the JARPN II survey area were a part of the whole stock. In order to obtain abundance estimates appropriate for assessment of whale stocks, we also need the information of the common minke abundance outside of the JARPN II survey area.

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Table 1. The estimated number of the common minke whales during JARPN II surveys in 2006 and 2007 assuming $g(0)=1$.

2006

| straum | latitude | period | | Area | n | L | n/L | CV | ESW | CV | E(s) | CV | D | P | CV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA7 | 35-41N | 5/17-5/19, | early | 173,679 | 23.2 | 1135.80 | 0.0205 | 0.821 | 0.605 | 0.266 | 1.16 | 0.046 | 0.020 | 3,416 | 0.864 |
| SA8S | 35-38N, 38-41N | 5/19-5/25, | early | 119,251 | 2.0 | 771.58 | 0.0026 | 0.642 | 0.605 | 0.266 | 1.16 | 0.046 | 0.002 | 297 | 0.697 |
| SA8N | 41N+ | 7/11-7/17 | late | 43,413 | 1.0 | 267.46 | 0.0037 | 0.599 | 0.605 | 0.266 | 1.16 | 0.046 | 0.004 | 156 | 0.657 |
| SA9S | 35-38N, 38-41N | 5/27-6/5, 6/7-6/18 | early | 221,466 | 7.7 | 1497.10 | 0.0052 | 0.367 | 0.605 | 0.266 | 1.16 | 0.046 | 0.005 | 1,101 | 0.456 |
| SA9N | 41N+ | 7/17-8/26 | late | 277,711 | 8.0 | 1741.30 | 0.0046 | 0.511 | 0.605 | 0.266 | 1.16 | 0.046 | 0.004 | 1,227 | 0.578 |

2007

| straum | latitude | period | | Area | n | L | n/L | CV | ESW | CV | E(s) | CV | D | P | CV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA7 | 38-41N, 35-41N | 6/22-6/27, 7/25-7/30 | late | 173,679 | 3.0 | 795.46 | 0.004 | 0.489 | 0.605 | 0.266 | 1.16 | 0.046 | 0.004 | 630 | 0.559 |
| SA8S | 38-41N, 35-38N | 6/27-7/2, 7/20-7/24 | late | 119,251 | 0.0 | 625.84 | 0.000 | 0.000 | 0.605 | 0.266 | 1.16 | 0.046 | 0.000 | 0 | 0.270 |
| SA8N | 41N+ | 6/10-6/15 | early | 43,413 | 2.0 | 288.05 | 0.007 | 0.657 | 0.605 | 0.266 | 1.16 | 0.046 | 0.007 | 290 | 0.710 |
| SA9S | 38-41N, 35-38N | 7/2-7/10, 7/10-7/20 | late | 221,466 | 1.0 | 761.21 | 0.001 | 0.963 | 0.605 | 0.266 | 1.16 | 0.046 | 0.001 | 280 | 1.000 |
| SA9N | 41N+ | 5/16-6/10 | early | 277,711 | 0.0 | 1305.90 | 0.000 | 0.000 | 0.605 | 0.266 | 1.16 | 0.046 | 0.000 | 0 | 0.270 |

Table 2. Sighting data used for the estimated number of whales distributed in early and late season.

| period | SA 7 | SA 8 | SA 9 |
|---|---|---|---|
| early (May-June) | 2006 [*1] | South of 41°N in 2006 and North of 41°N in 2007 | South of 41°N in 2006 and North of 41°N in 2007 |
| late (July-August) | 2007 [*2] | North of 41°N in 2006 and South of 41°N in 2007 | North of 41°N in 2006 and South of 41°N in 2007 |

*1：Survey period in SA7 included several days in early July in 2006.

*2：Survey period in SA7 included several days in late June in 2007.

Table 3.The estimated number of the whales distributed in JARPN II survey area in early and late season. $g(0)$ is assumed to be 0.798 with its SE=0.134 (Okamura *et al*,2010). The figure in SA7 was divided by coverage for sub-area 7 (85.4%).

| period | SA7 | | SA8N | | SA8S | | SA9N | | SA9S | | total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | CV | P | CV | P | CV | P | CV | P | CV | P | CV |
| early | 4,280 | 0.880 | 363 | 0.730 | 372 | 0.717 | 0 | 0.000 | 1,379 | 0.485 | 6,395 | 0.717 |
| late | 789 | 0.584 | 196 | 0.678 | 0 | 0.000 | 1,537 | 0.602 | 350 | 1.014 | 2,872 | 0.458 |

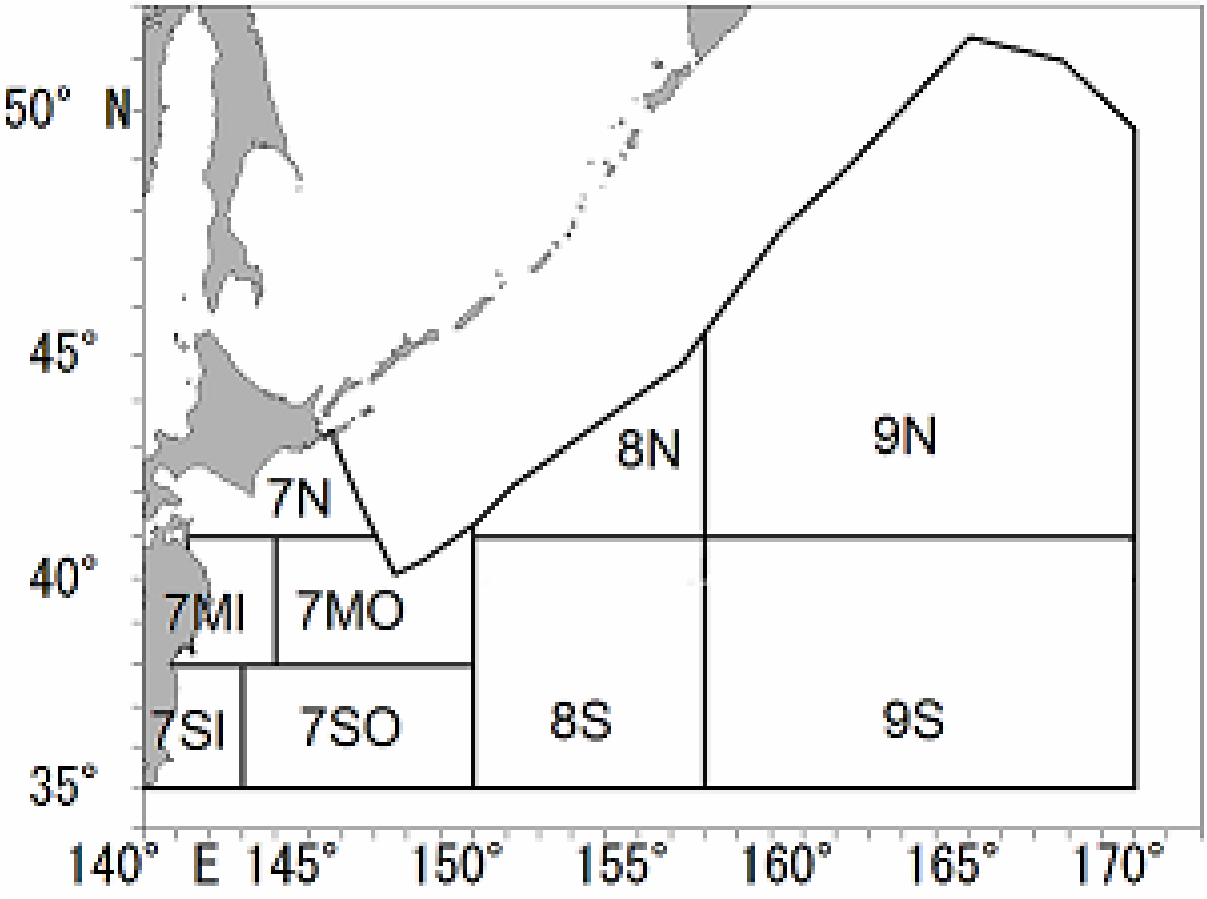

Fig. 1. JARPN II survey area and its stratification.

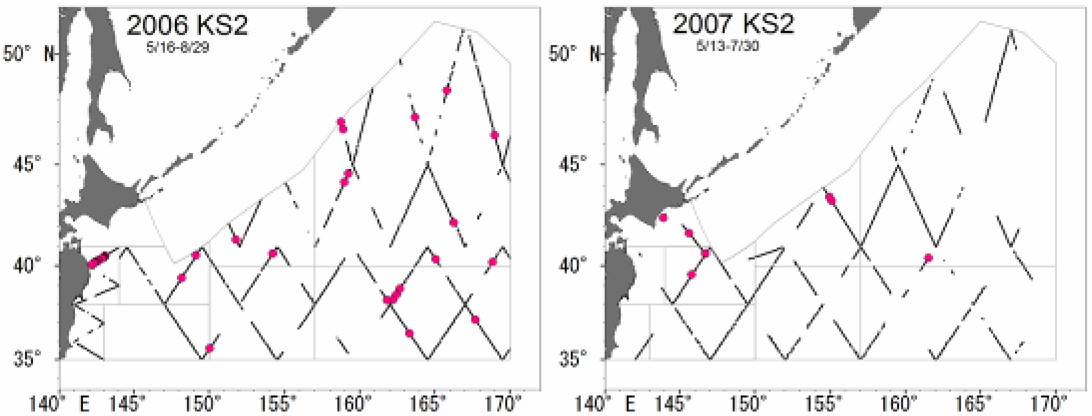

Fig. 2. Distribution of the effort and primary sightings of western North Pacific common minke whales by dedicated sighting vessel during JARPN II 2006 and 2007.

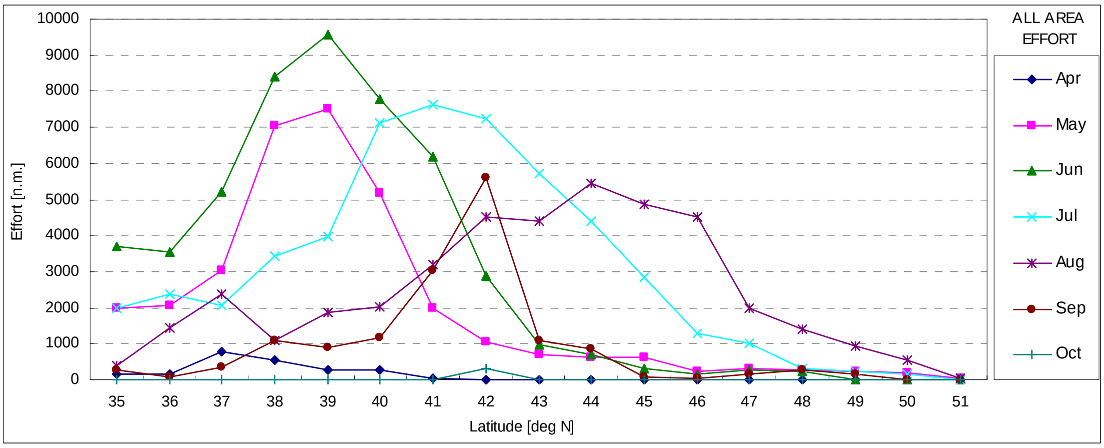


Fig. 3. Effort by latitude from April to October during 1994-2007.

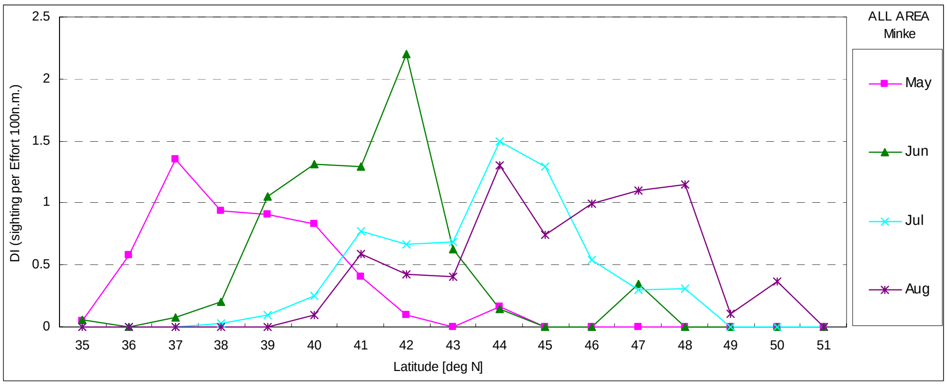


Fig.4. DI (whale/100n.mile) by latitude from May to September during 1994-2007 for the common minke whales.

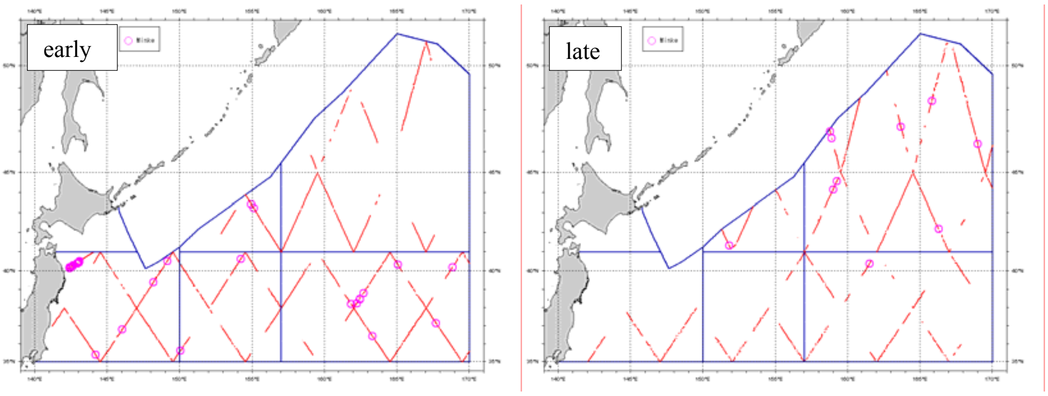


Fig.5. Distribution of primary sightings of the common minke whales in early and late seasons. Left panels are figures in early season and right ones are in late season.

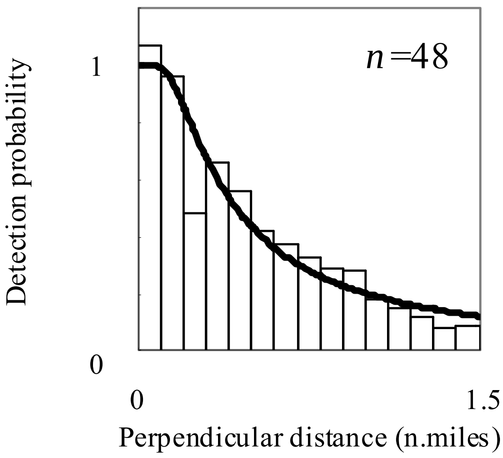


Fig. 6. Plot of detection probability functions for the common minke whales. *n* is the number of the primary sightings during JARPN II 2006 and 2007 to estimate the detection probability functions.