Revised estimate of g(0) for the North Pacific minke whale

HIROSHI OKAMURA[1], TOMIO MIYASHITA[1], and TOSHIHIDE KITAKADO[2]
[1]*National Research Institute of Far Seas Fisheries*
2-12-4 Fukuura, Kanazawa-ku, Yokohama-shi, Kanagawa 236-8648, Japan
[2]*Tokyo University of Marine Science and Technology*
5-7, Konan 4, Minato, Tokyo 108-8477, Japan
Contact e-mail: okamura@fra.affrc.go.jp

ABSTRACT
The abundance of common minke whales in the sub-area 10 and 11 was re-estimated using the IO passing mode sighting survey data in 2006 and 2007. The method provides the estimate of g(0) taking into account weather condition (Beaufort scale) as a covariate. However, by model selection using AIC, the weather condition was not significantly influential for the detection process. The latest estimate of g(0) for Top barrel & Upper bridge was 0.822. The resultant abundance estimates are 1,387 (2006JPN), 3,884 (2006RUS), 575 (2007OKH), and 659 (2007SJ).

INTRODUCTION

Japan conducted the IO passing mode sighting surveys in the sub-areas 10 and 11 in 2006 and 2007. Using the data from the 2006 survey, we provided a preliminary abundance estimate assuming g(0)<1 (Miyashita and Okamura 2007, Okamura et al. 2008). In this paper, we revised the estimate of g(0) by adding the 2007 data into the analysis. In addition, the covariate analysis with the weather condition was conducted in the similar way to the last year's analysis.

MATERIALS AND METHODS

Details on the sighting results are shown in Miyashita (2007, 2008, 2009). The survey areas were categorized into 2006JPN, 2006RUS, 2007OKH, and 2007SJ where 2007OKH corresponds to sub-area 11 and the others to sub-area 10. The research effort distance was 174.2 n.miles for 2006JPN, 1,157.2 n.miles for 2006RUS (excluding the ROS block which did not have any sighting for minke whales), 564.0 n.mile for 2007OKH, and 1051.4 n.miles for 2007SJ. The number of primary sightings was 3 schools for 2006JPN, 45 schools for 2006RUS, 23 schools for 2007OKH, and 16 schools for 2007SJ, respectively, when the sightings were truncated at the perpendicular distance of 1.5 n.miles. All the sighting data with the truncation distance of 1.5 n.miles were employed for the estimation of detection function, including g(0), and abundance without any stratification.

For the estimation of esw including g(0), a hazard probability model by Okamura and Kitakado (2009: OK method) was used. In the Russian and Japanese waters, minke whales consist of single animals in general. So, we do not need the complicated handling of school size distribution as in Okamura and Kitakado (2009). In addition, because the sample size is small for g(0) estimation, we can investigate only the effect of limited covariates. Unlike Antarctic minke whale surveys, this study has on-board identification of simultaneous and delayed duplicates. So, we adopted a considerably short time (15 seconds) as an error of recorded time. The detailed description of the model is given in Appendix.

Weather condition considered was Beaufort scale (0-2: good, 3-4: bad). The visibility was also a candidate for covariate. The survey, however, was conducted only when the visibility was better than 2 n.miles, and most of animals were sighted within 2 n.miles. The observation by naked eyes therefore seemed not to be affected by the visibility. Hence, the visibility was not taken into account in this analysis.

RESULTS AND DISCUSSION

The observed school size was almost 1 with a few sightings with the school size of 2 or 3. We therefore did not include the school size into detection function as a covariate. The school size was regressed using a traditional regression, log(s) ~ g(x), so that the coefficient of g(x) was not significant at 15% significance level. Thus, the simple expected value of school size was used for abundance estimation.

Table 1 shows the results on estimation of g(0) for models with and without the covariate. The estimates were given for Top, IO, and upper bridge as well as their combination. Diagnostic plots for detection functions including g(0) against the perpendicular distance were also provided for both cases in Figures 1 and 2. These figures indicated that the models were well-fitted. AIC indicated that the model without covariates outperformed the model with a weather covariate (delta-AIC = 1.75). This was also supported by little difference in g(0) estimates for between good and bad weather conditions. The estimates of g(0) were 0.754 (cv 0.33) for TOP barrel, 0.668 (cv 0.45) for IO platform, 0.447 (cv 0.77) for upper bridge, and 0.822 (cv 0.26) for Top barrel & upper bridge (Table 1). These estimates were higher than those of Okamura et al. (2008) probably because of the increase of proportion of duplicates in the 2007 data.

The resultant abundance estimates for both models were given in Table 2. The point estimates from the model without covariates were 1,387 for 2006JPN, 3,884 for 2006RUS, 575 for 2007OKH, and 659 for 2007SJ, whereas those from the model with a weather covariate were 1,365 for 2996JPN, 3,908 for 2006RUS, 570 for 2007OKH, and 647 for 2007SJ. Despite the higher g(0), both abundance estimates were slightly higher than those of Okamura et al. (2008). This is probably because of decrease of observed perpendicular distances. The difference between (x,y)- and (R,A)-Q functions was small in terms of abundance estimation, while the difference of AICs for the two models was considerable.

REFERENCES

Miyashita, T. 2007. Cruise report of the IO sighting survey in the northern Sea of Japan in 2006. SC/59/NPM3. 8pp.

Miyashita, T. and Okamura, H. 2007. Abundance estimate of common minke whales in the northern Sea of Japan including the Russian EEZ using IO sighting data in 2006. Document SC/59/NPM4. 10pp.

Miyashita, T. 2008. Abundance estimate of common minke whales using the Japanese sighting data in the Sea of Japan. Document SC/60/NPM5. 9pp.

Miyashita, T. et al. 2009. Abundance of the J-stock common minke whale using the Japanese

sighting data with g(0)=1. Document SC/61/NPM7.
Okamura, H., Miyashita, T., and Kitakado, T. 2008. Abundance estimation on common minke whales in the Russian waters of sub-area 10 using the IO sighting data in 2006. Document SC/60/NPM7, 7pp.
Okamura H. and Kitakado, T. 2009. Abundance estimates and diagnostics of Antarctic minke whales from the historical IDCR/SOWER survey data using the OK method. Document SC/61/IA6. 58pp.

Table 1. g(0)s for each platform and the combined platforms. A, B, and C denote Top, IO platform, and Upper bridge, respectively.

Without covariate of weather

	g0	CV
A	0.754	0.333
B	0.668	0.453
C	0.447	0.768
AUB	0.867	0.192
AUC	0.822	0.257
BUC	0.772	0.335
AUBUC	0.893	0.157

With covariate of weather

	$g0\|_{weather\ =\ good}$	CV	$g0\|_{weather\ =\ bad}$	CV
A	0.753	0.313	0.712	0.390
B	0.666	0.425	0.619	0.520
C	0.447	0.730	0.396	0.844
AUB	0.866	0.181	0.839	0.235
AUC	0.821	0.242	0.786	0.309
BUC	0.771	0.315	0.729	0.399
AUBUC	0.892	0.148	0.869	0.194

Table 2. Abundance estimates using the OK method with estimation of g(0). nL and nS denote the numbers of replicate lines and sighting, respectively.

without covariate

year	block	areasize (n.m^2)	effort (n.m)	nL	nS	density	abund	CV
2006	JPN	51763.7	174.2	3	3	0.027	1,387	0.72
2006	RCM	36496.3	776.1	14	19	0.038	1,390	0.55
2006	RCN	14205.7	252.5	7	23	0.142	2,014	0.56
2006	RCS	13210.0	128.6	3	3	0.036	480	0.90
2006	RUS_Total	63911.9	1157.2	24	45	0.061	3,884	0.43
2007	OKH	9064.0	564.0	11	23	0.063	575	0.49
2007	SJ	27822.5	1051.4	11	16	0.024	659	0.42

with covariate

year	block	areasize (n.m^2)	effort (n.m)	nL	nS	density	abund	CV
2006	JPN	51763.7	174.2	3	3	0.026	1,365	0.72
2006	RCM	36496.3	776.1	14	19	0.040	1,443	0.56
2006	RCN	14205.7	252.5	7	23	0.139	1,974	0.56
2006	RCS	13210.0	128.6	3	3	0.037	491	0.90
2006	RUS_Total	63911.9	1157.2	24	45	0.061	3,908	0.43
2007	OKH	9064.0	564.0	11	23	0.063	570	0.49
2007	SJ	27822.5	1051.4	11	16	0.023	647	0.42

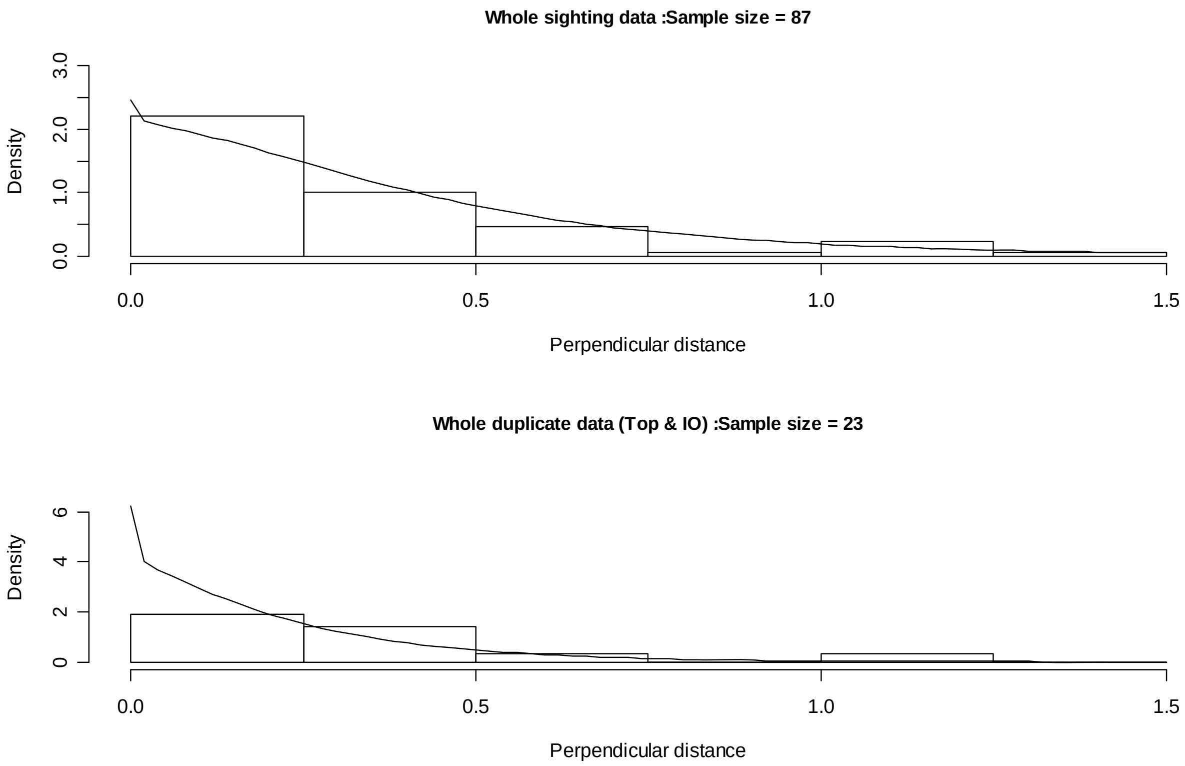

Fig. 1. Graphical diagnosis of the OK model without covariate of weather.

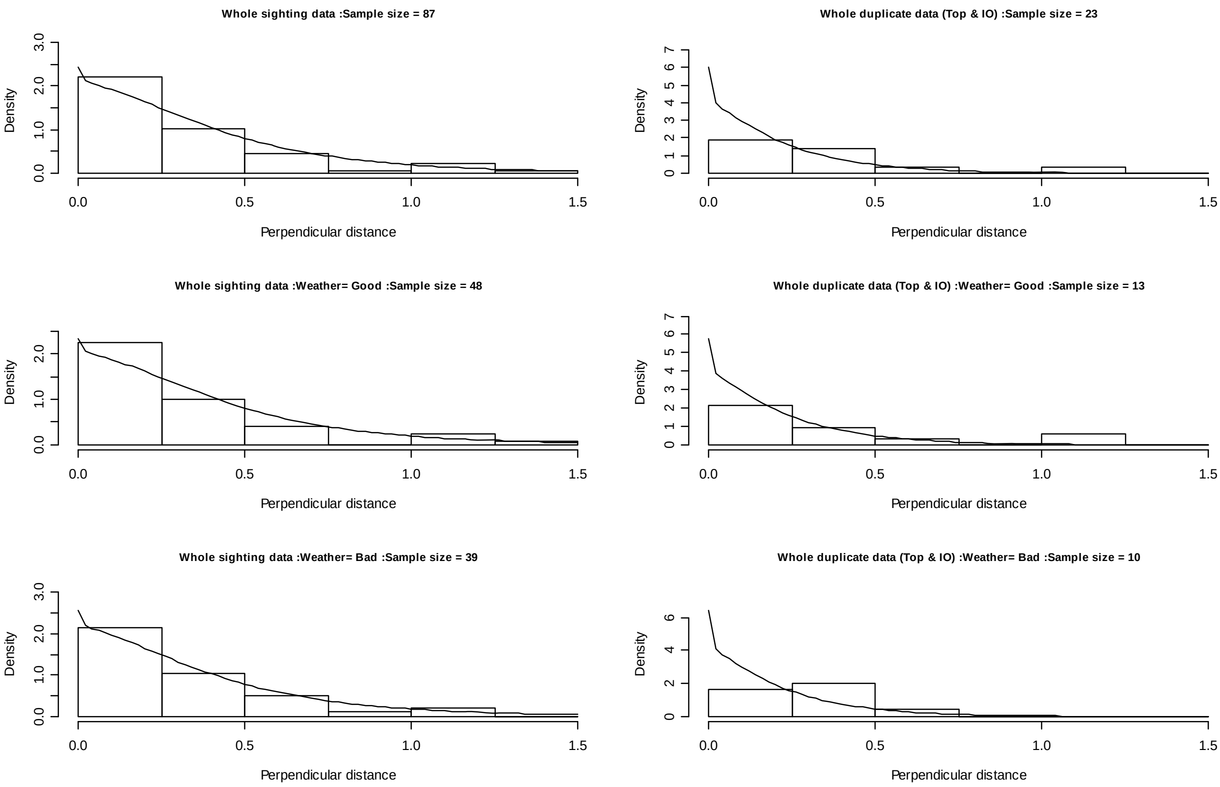

Fig. 2. Graphical diagnosis of the OK model with covariate of weather.

APPENDIX

A.1. The hazard probability model and the likelihood function

The detection probability density function of the animal positioned at the perpendicular distance x and the forward distance y assuming a Poisson surfacing pattern with the mean surfacing rate λ is

$$p(x,y) = \frac{\lambda}{v} Q(x,y) \exp\left\{ -\frac{\lambda}{v} \int_{y}^{\infty} Q(x,y')dy' \right\}, \tag{A.1}$$

We construct a likelihood function as follows:

$$P(x_i, y_i, u_i) = \frac{p(x_i, y_i, u_i)}{\text{esw}}, \tag{A.2}$$

where u_i is a type of detection pattern, p is a detection probability density function, and esw is

$$\text{esw} = \int_{0}^{x_{max}} \int_{0}^{\infty} \sum_{u}^{\text{all patterns}} p(x,y,u)dxdy. \tag{A.3}$$

The total likelihood function is then given by

$$L = \prod_{i=1}^{n} P(x_i, y_i, u_i). \tag{A.4}$$

We estimate parameters by maximizing the logarithm of the total likelihood function.

A.2. Abundance estimation

The population size is estimated with a Horvitz-Thompson-like estimator,

$$\hat{P} = \frac{A}{2L} \sum_{i=1}^{n} \frac{\text{E}(s)}{\hat{\text{esw}}_{A \cup B \cup C}(\eta_i)}, \tag{A.5}$$

where L is total survey distance, A is the size of survey area, η_i is a vector of covariates, and the numerator $\text{E}(s)$ is the mean observed school size.

An estimator for the unconditional asymptotic coefficient of variation of $\hat{P}$ is estimated using the method similar to standard line transect sampling, and then,

$$\hat{\text{CV}}(\hat{P}) = \sqrt{\hat{\text{CV}}(e\hat{s}w)^2 + \hat{\text{CV}}(\text{E}(s))^2 + \hat{\text{CV}}(n/L)^2}, \tag{A.6}$$

where θ is a vector of estimated parameters.

A.3. detection probability function of sighting cues

The hazard probability model is given by a logistic form,

$$Q(x,y) = \frac{1}{1 + \exp[(\tau_r R^{\gamma_r} + \tau_a A^{\gamma_a}) + \omega]} \tag{A.7}$$

where τ_r, τ_a, γ_r, and γ_a are scalar parameters with positive values. The parameter ω is related to several covariates with a log-link function as follows:

$\omega \sim$ Platform + Weather.

A.4. Specification of detection function for each sighting pattern

There are three platforms with two independent observers and one semi-independent observer. The detection pattern is therefore complicated by taking account of duplicate sightings. The probability density function for each sighting pattern is given below. The contribution to the likelihood function of detection with each sighting pattern is calculated by each probability density divided by $\mathrm{esw}_{A\cup B\cup C}$ which is given by

$$\begin{aligned}\mathrm{esw}_{A\cup B\cup C} = &\int_0^{x_{max}} \int_0^{\infty} \frac{\lambda}{v} Q_{A\cup B\cup C}(x,y) \\ &\times \exp\left\{-\frac{\lambda}{v}\int_y^{\infty} Q_{A\cup B\cup C}(x,y')dy'\right\} dxdy. \end{aligned} \tag{A.8}$$

1. A

$$\begin{aligned} p(x,y,A) = &\frac{\lambda}{v}\{Q_{A\cup B}(x,y) - Q_B(x,y)\} \exp\left\{-\frac{\lambda}{v}\int_0^{y} Q_B(x,y')dy'\right\} \\ &\times \exp\left[-\frac{\lambda}{v}\left\{\int_y^{\infty} Q_{A\cup B}(x,y')dy' + \int_{y+vT}^{\infty} Q_{A\cup B\cup C\setminus A\cup B}(x,y')dy'\right\}\right], \end{aligned} \tag{A.9}$$

where $T = 15/3600$.

2. B

Same as A except for exchanging the symbols A and B.

3. C

$$\begin{aligned} p(x,y,C) = &\frac{\lambda}{v}\{Q_{A\cup B\cup C}(x,y) - Q_{A\cup B}(x,y)\} \\ &\times \exp\left[-\frac{\lambda}{v}\left\{\int_0^{y} Q_{A\cup B}(x,y')dy' + \int_y^{\infty} Q_{A\cup B\cup C}(x,y')dy'\right\}\right]. \end{aligned} \tag{A.10}$$

4. $A \times B$

$$\begin{aligned} p(x,y,AB) = &\frac{\lambda}{v}\Bigg(Q_A(x,y)Q_B(x,y)\exp\left\{-\frac{\lambda}{v}\int_y^{\infty} Q_{A\cup B}(x,y')dy'\right\} \\ &+Q_A(x,y)\exp\left\{-\frac{\lambda}{v}\int_y^{\infty} Q_A(x,y')dy'\right\} \\ &\times\left[\exp\left\{-\frac{\lambda}{v}\int_{y+vT}^{\infty} Q_{A\cup B\setminus A}(x,y')dy'\right\} - \exp\left\{-\frac{\lambda}{v}\int_y^{\infty} Q_{A\cup B\setminus A}(x,y')dy'\right\}\right] \\ &+Q_B(x,y)\exp\left\{-\frac{\lambda}{v}\int_y^{\infty} Q_B(x,y')dy'\right\} \\ &\times\left[\exp\left\{-\frac{\lambda}{v}\int_{y+vT}^{\infty} Q_{A\cup B\setminus B}(x,y')dy'\right\} - \exp\left\{-\frac{\lambda}{v}\int_y^{\infty} Q_{A\cup B\setminus B}(x,y')dy'\right\}\right]\Bigg) \end{aligned} \tag{A.11}$$

where $T = 15/3600$.

5. $A \rightarrow B$

$$
\begin{aligned}
p(x,y,A\to B) &= \left(\frac{\lambda}{v}\right)^2 Q_B(x,y)\{Q_{A\cup B}(x,y+v\tau_{AB}) - Q_B(x,y+v\tau_{AB})\} \\
&\times \exp\left[-\frac{\lambda}{v}\left\{\int_{y+v\tau_{AB}}^{\infty} Q_{A\cup B\setminus B}(x,y')dy' + \int_{y}^{\infty} Q_B(x,y')dy'\right\}\right]
\end{aligned} \tag{A.12}
$$

where $\tau_{AB} > 15/3600$h.

6. $B \to A$

Same as $A \to B$ for exchanging the symbols A and B.

7. $C \to A$

$$
\begin{aligned}
p(x,y,C\to A) &= \left(\frac{\lambda}{v}\right)^2 \{Q_{A\cup B}(x,y) - Q_B(x,y)\} \\
&\times\{Q_{A\cup B\cup C}(x,y+v\tau_{CA}) - Q_{A\cup B}(x,y+v\tau_{CA})\} \\
&\times \exp\left\{-\frac{\lambda}{v}\int_{y+v\tau_{CA}}^{\infty} Q_{A\cup B\cup C\setminus A\cup B}(x,y')dy'\right\} \\
&\times \exp\left[-\frac{\lambda}{v}\left\{\int_{y}^{\infty} Q_{A\cup B}(x,y')dy' + \int_{0}^{y} Q_B(x,y')dy'\right\}\right]
\end{aligned} \tag{A.13}
$$

where $\tau_{CA} > 15/3600$h.

8. $C \to B$

Same as $C \to A$ for exchanging the symbols A and B.