Examination of the effect of survey mode on abundance estimate for Southern Hemisphere humpback whales using JARPA Sighting data

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ABSTRACT

This paper examines whether abundance estimates for Southern Hemisphere humpback whales (*Megaptera Novaeagliae*) are biased due to the survey modes in JARPA. The result of the Generalised Linear Model (GLM) showed that there was no significant effect of "survey modes" on the abundance estimate for humpback whales and supported the estimates in Matsuoka *et al.* (2006).

KEY WORDS: SOUTHERN HEMISPHERE, HUMPBACK WHALE, INDEX OF ABUNDANCE

INTRODUCTION

In Matsuoka *et al*. (2006), on estimating abundance, sighting data in closing mode and passing mode were pooled, and also abundance estimate from Sighting and Sampling Vessels (SSV) data and those from dedicated Sighting Vessel (SV) are combined without using correction factors. This is due to that there was not substantial difference in abundance estimates between closing mode and passing mode and between SSV and SV, and that the sample size was so small to estimate mean school size and effective half search width for each "survey mode", in some years. At the last SC meeting, there was a question on this point (Childerhouse *et al.*, 2005). In this paper, we examined whether the significant difference in abundance estimates among 'survey modes' using generalised linear models.

MATERIALS AND METHODS

Survey modes

SSV conducted both sighting survey of whales and sampling of Antarctic minke whales (*Balaenoptera bonaerensis*). They sometime skipped sighting survey on the trackline due to time shortage by sampling activity especially until 1992/93. SV conducted sighting survey only and didn't take the minke whales. SV have been conducted sighting surveys in closing mode since 1991/92 (SVC) and conducted sighting surveys both in closing and passing modes since 1997/98 (SVP). SV doesn't skip sighting survey due to sampling activity. More details of survey procedure were described in Nishiwaki *et al*. (2005). Sampling was made for only minke whales in the sighting surveys in JARPA. In the case of detecting of humpback whale, closing was stopped just after its species was identified and survey vessels returned to trackline to resume sighting survey.

Abundance data

We used estimated encounter rates and their CVs in Matsuoka *et al.* (2006), which were shown in Table 1, to estimate abundance index and its CV described below. Unfortunately we can't use the estimate mean school size and effective half search width for each survey mode because sample size is too small to estimate those statistics for closing mode and passing mode separately in Area V. So we used abundance index defined as formula (1) and (2) instead of abundance estimate for each survey mode.

Model

Because we can't use the estimated mean school size and effective half width, we defined a relative abundance index p^* in Areas IV and V under the assumption that the estimated mean school size and effective half width don't vary by year and Area as follows:

$$p^* = \sum_{i=1}^{i\max} A_i \left(\frac{n}{l}\right)_i \qquad (1)$$

where A_i is Area in stratum i, $(n/l)_i$ is encounter rate in stratum i and $imax$ is the number of stratum in each Area (5 in Area IV and 4 in Area V). The variance of p^* is estimated by

$$\mathrm{var}(p^*) = \sum_{i=1}^{i\max} A_i^{\,2}\ \mathrm{var}\left(\frac{n}{l}\right)_i \qquad (2)$$

To examine the effect of the "survey modes", a GLM assuming log-normal error is applied.

$$\log(p^*(y,a)) = \log(p^*_{true}(y,a)) + MODE + \varepsilon \qquad (3)$$

where y is year, a is Area, p^* is observed abundance estimate, p^*_{true} is unbiased abundance index (i.e. free from survey mode effect) and $MODE$ is mode effect on abundance standardised to SVP. Intercept was included the estimated unbiased abundance index. In this formula, we deal all covariate as categorical one.

RESULTS AND DISCUSSIONS

Table 2 shows the result of the GLM in formula (3) with covariate of mode effect that is standardised to SVP. P-value of the coefficient of $R2$ (SVC/SVP) and $R3$ (SSV/SVP) are 0.359 and 0.131, respectively. Therefore, it means that there was no significant effect on the abundance estimate due to survey mode.

Further, mode effect on abundance standardised to SVC to examine the effect of sampling of minke whales on the humpback abundance. The ratio of SSV in abundance estimate standardised to SVP ($R1$) is 1.032. The probability that $R1$ isn't significantly different from 0 is 0.817. Fig. 1 showed the estimate of correction factors $R1$ and $R2$ and their 95% confidential intervals. $R1$ indicates the effect of sampling of the minke whales on the humpback abundance and $R2$ indicates the effect of closing $R2$. Point estimate of $R1$ is much closer to 1 than $R2$ and therefore the effect of sampling is smaller than the effect of closing. 95% Confidential Interval of both correction factors include 1. Both of the correction factors are not significantly different from 1.

There was a concern that the effect of skipping on the abundance (Childerhouse *et al.*, 2005). The correction factor $R2$ and $R3$ are more than 1. One possible interpretation is that this may be because distribution of minke and that of humpback are negatively correlated. If so, the effect of skipping on humpback whale abundance would be substantial. But this seems inconsistent with the estimate of correction factor $R1$ of 1.032 which support that the effect of skipping due to sampling the minke whales is small. Therefore, the correlation between the distribution of the humpback whales and that of the minke whales is considered to be so weak that the humpback abundance was not biased due to survey mode.

Matsuoka *et al*. (2006) estimated abundances for the humpback whales under the assumption that they were not biased significantly due to "survey modes". Our results supported that the estimates in Matsuoka *et al.* (2006).

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Table 1. Abundance data (the number of detected schools, effort, abundance index defined by furmula (1) and its CV) used in this analysis in Areas IV and V.

Area IV

	SSV				SV closing				SV passing			
year	n	effort	p^*	CV(p^*)	n	effort	p^*	CV(p^*)	n	effort	p^*	CV(p^*)
1989/90	54.5	8664.4	4789	0.250								
1991/92	81.4	7584.1	5960	0.169								
1993/94	76.7	7789.3	5320	0.154	29.9	5260.1	3232	0.332				
1995/96	189.7	9305.5	12547	0.153	60.4	3417.6	10420	0.282				
1997/98	379.7	10630.3	21529	0.178	73.3	2476.3	20191	0.451	31.0	1090.3	12574	0.736
1999/00	297.2	8736.9	16968	0.122	45.4	1526.6	16399	0.393	94.2	2398.3	18771	0.268
2001/02	687.3	8687.2	47041	0.121	64.0	1261.7	44948	0.367	184.9	3072.6	36877	0.271
2003/04	928.5	10253.5	54341	0.106	117.1	1177.9	64169	0.490	264.1	2918.1	41519	0.210

Area V

	SSV				SV closing				SV passing			
year	n	effort	p^*	CV(p^*)	n	effort	p^*	CV(p^*)	n	effort	p^*	CV(p^*)
1990/91	24.7	8530.7	1178	0.306								
1992/93	12.0	4428.8	2630	0.751	11.0	3695.7	2776	1.047				
1994/95	45.5	5821.4	4038	0.372	42.0	3724.1	7760	0.416				
1996/97	27.9	8140.7	3252	0.284	9.6	3000.2	948	0.677				
1998/99	65.4	4277.4	11938	0.360	10.7	1041.6	10231	0.502	15.8	1634.0	2322	0.524
2000/01	64.7	10191.5	5834	0.268	16.6	1745.9	14009	0.480	36.1	2950.0	9376	0.415
2002/03	62.6	8257.4	5275	0.188	5.5	1646.9	4347	0.681	22.9	2975.7	5064	0.256
2004/05	88.0	8896.2	13549	0.291	12.9	1151.1	31982	0.751	30.8	3319.9	11562	0.340

Table 2. Results of the GLM including covariate of mode effect standardised to SVP. Point estimates in this table are exponential of the coefficient of the model in formula (3). Note that abundance index estimated in this model is given as formula (1) and is not same as abundance estimate.

	Estimate	SE	t value	Pr(>|t|)
Area IV in 1989/90	3952	0.274	30.24	< 2e-16
Area IV in 1991/92	4918	0.205	41.42	< 2e-16
Area IV in 1993/94	4043	0.183	45.41	< 2e-16
Area IV in 1995/96	9998	0.180	51.21	< 2e-16
Area IV in 1997/98	17401	0.196	49.89	< 2e-16
Area IV in 1999/00	14671	0.146	65.69	< 2e-16
Area IV in 2001/02	38473	0.146	72.43	< 2e-16
Area IV in 2003/04	44494	0.133	80.30	< 2e-16
Area V in 1990/91	972	0.324	21.27	1.04E-14
Area V in 1992/93	2234	0.611	12.62	1.11E-10
Area V in 1994/95	4518	0.301	27.93	< 2e-16
Area V in 1996/97	2243	0.284	27.17	< 2e-16
Area V in 1998/99	6768	0.268	32.90	< 2e-16
Area V in 2000/01	6663	0.221	39.92	< 2e-16
Area V in 2002/03	4545	0.166	50.75	< 2e-16
Area V in 2004/05	12160	0.221	42.63	< 2e-16
R2 (=SVC/SVP)	1.174	0.171	0.94	0.359
R3 (=SSV/SVP)	1.212	0.122	1.58	0.131

Fig. 1. Point estimate of correction factors *R*1 (1.032) and *R*2 (1.174) derived from GLMs. Vertical lines indicate their 95% confidential interval.