Extrapolation of abundance to unsurveyed areas in sub-areas 8, 11 and 12NE for the western North Pacific common minke whales by using prediction with a linear model

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Abstract

This paper aims at providing extrapolated abundance estimates in sub-areas 8, 11, and 12NE, in which there were areas not covered in some surveys in a time series. The reason which we have to consider such an extrapolation is to eliminate bias in abundance trend information arising from results for a series of surveys with variable coverage. For this exercise, we applied data/results from surveys in those sub-areas to linear models with some different treatment specific to sub-areas. The resultant trends in estimates with the extrapolation in sub-area 8 and 11 did not differ so much from the original trend based on variable coverage while that in sub-area 12NE was quite large and not ignorable. For giving better information to the CLA calculation, the authors considered that those results would be worth using.

INTRODUCTION

During the discussion of the first Intersessional Workshop for the Implementation Review of western North Pacific common minke whales, the Workshop identified that the RMP specifications allow for appropriate statistical procedures to be used to extrapolate to areas not covered in some surveys in a time series, provided that they were covered in others. Sub-areas 8, 11, and 12NE are the subject matter. For example, as shown in Figure 1, the southern three blocks out of the four in the sub-area 8 were covered by all but 2004 surveys, and therefore the abundance for the uncovered most southern block in 2004 can be predicted by the argument above. This is also the case for the sub-areas 11 and 12NE (see Annex G of the Workshop report, IWC 2012).

The idea of this extrapolation process is originated from elimination of the bias in abundance trend information that would otherwise arise from results for a series of surveys with variable coverage. The extrapolation should be made with consideration of the additional variance. However, such extrapolation with estimation of additional variance was not possible in the case of surveys in sub-area 12NE because only one past survey has covered all blocks, thus the Workshop agreed to preclude the estimation of the additional variance associated with any extrapolation in that sub-area. The Workshop also agreed that the 2002 survey in sub-area 8 had resulted in a zero estimate of abundance and therefore an alternative distribution models to the conventional log-normal is employed for the estimation.

The Workshop agreed that review would be required by the Scientific Committee before these extrapolated abundance are considered acceptable as input to the CLA. Given this situation, the Workshop requested that a document presenting results for these extrapolations be presented for review at the 2012 Annual Meeting. This paper intends to meet this requirement.

MATERIALS and METHODS

We conducted an extrapolation of abundance in blocks of sub-areas which were partially covered by surveys using the survey results shown in Table 2. Detailed information on the surveys and underlying abundance estimation are given in the author's other papers etc (Hakamada and Kitakado 2012 for sub-area 8 and Buckland et al. (1990), Miyashita and Shimada (1994) and Miyashita and Okamura (2011) for sub-area 11 and 12NE).

For this analysis, the following linear model was intended to be used.

log(Abundance estimate)

= (annual trend) + log(area adjustment*block effect) + process error + sampling error

However, as explained in the introduction, situations differ among the sub-areas. Also, the coverage of 1990's survey in block B11-2 was quite poor and therefore one of the coauthor, Miyashita, decided not to use that estimate for this exercise. Hence, we made some treatments specific to situations as follows.

Sub-area 8

Abundance estimates in sub-area 8 in 2002 and other three estimates are zero, and therefore the log-linear model above cannot be applied directly. A special treatment using a Poisson school count data model with the following link function is used.

$\log(\mu)$= (annual trend) + log(2*L*esw) + esw_error + log(area adjustment*block effect) + process error

Although the effective strip widths in sub-area 8 inherently differ among the blocks/years, for the sake of convenience we assumed a fixed esw value with consideration of correlations between predictors (e.g. Kitakado *et al*. 2008).

Note that definition of boundary in sub-area 8 slightly changed over years. The new boundary definition is regarded as base blocks and area effects in previous years are adjusted by the ratio of defined areas (62,628/43,413=144% upward for block B8-2 and 38,745/57,936=66.9%downward for block B8-3).

An REML method is applied to estimate the variance in the process error (additional variance). The term for the annual trend is considered only if the test rejects its constancy.

Sub-areas 11 and 12NE

The additional variances for sub-areas 11 and 12NE were not estimated because of less replication of surveys.

log(Abundance estimate) = (annual trend) + log(block effect) + sampling error

Since the esw was assumed to be common within each year, sampling errors between blocks were taken into account for sub-area 11 in 1999 and for sub-area in 1990. Such correlations were also reflected in the CVs for the total abundance in sub-areas 11 and 12NE.

Remark that the mean school size was assumed to be 1 when extrapolation was made.

RESULTS AND DISCUSSION

For the three sub-areas, the year effects were not far from significant. For example, in sub-area 8, the annual rate of increase was estimated as 0.608, which was driven by a big change in estimates in B8-2 between 2002 and 2004 and not significant (SE=0.479). Therefore, extrapolation derived by no yearly change in abundance was considered appropriate for all the sub-areas. This was the case for sub-areas 11 (annual rate of increase =0.0280, SE=0.0901) and 12NE (annual rate of increase =-0.0069, SE=0.039).

Table 3 summarizes results of analysis. The resultant trends in estimates with the extrapolation in sub-area 8 and 11 did not differ so much from the original trend based on variable coverage while those in sub-area 12NE were quite large and not ignorable. For giving better information to the CLA calculation, the authors considered that those results would be worth using.

Remark that the results for sub-area 8 will be revised because the variance-covariance matrix given by one of authors should be re-assessed.

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Table 1. Summary of availability of block-wise abundance estimates for sub-area 8, 11 and 12NE. The survey coverage for B11-2 in 1990 was poor and deleted from the original list.

	2002	2004	2005	2006
B8-1 Russian EEZ	not surveyed at all and no extrapolation is made for this block			
B8-2 Northern block	X	X	X	X
B8-3 Southern block 1	X	X	X	X
B8-4 Southern block 2	X		X	X

	1990	1999	2003
B11-1 Western Block	X	X	X
B11-2 Estern Block		X	
B12NE-1 Western Block	X	X	X
B12NE-2 Estern Block	X		

Table 2. Summary of abundance estimates in blocks in sub-areas 8, 11 and 12NE.

Year	Block	A	n	L	n/L	CV(n/L)	ESW	CV(ESW)	E(s)	CV(E(s))	D	P	CV(P)
2002	B8-2	62,628	0	508.6	0.000	0.000	-	-	-	-	-	0	-
	B8-3	38,745	0	243.2	0.000	0.000	-	-	-	-	-	0	-
	B8-4	61,315	0	432.4	0.000	0.000	-	-	-	-	-	0	-
2004	B8-2	62,628	7	447.9	0.016	0.331	0.530	0.329	1.14	0.125	0.017	1,055	0.483
	B8-3	38,745	0	469.4	0.000	0.000						0	
	B8-4	61,315	-	-	-	-	-	-	-	-	-	-	-
2005	B8-2	43,413	0	357.8	0.000	0.000	-	-	-	-	-	0	-
	B8-3	57,936	1	626.9	0.002	1.096	0.696	0.798	1	0	0.001	66	1.356
	B8-4	61,315	0	448.8	0.000	0.000	-	-	-	-	-	0	-
2006	B8-2	43,413	1	267.47	0.004	1.161	0.585	0.800	1	0	0.003	139	1.410
	B8-3	57,936	1	470.9	0.002	0.930	0.585	0.800	1	0	0.002	105	1.227
	B8-4	61,315	1	300.72	0.003	1.220	0.910	0.644	1	0	0.002	112	1.379

Year	Block	A	n	L	n/L	CV(n/L)	ESW	CV(ESW)	E(s)	CV(E(s))	D	P	CV(P)
1990	B11-1	12,389	9	237.0	0.038	0.855	0.315	0.090	1.11	0.10	0.060	829	0.865
	B11-2	10,198	-	-	-	-	-	-	-	-	-	-	-
	B12NE-1	163,586	18	884.3	0.020	0.326	0.315	0.090	1.11	0.07	0.032	5,867	0.345
	B12NE-2	211,119	26	772.7	0.022	0.358	0.315	0.090	1.23	0.13	0.053	13,869	0.391
1999	B11-1	12,389	17	325.7	0.052	0.410	0.412	0.107	1.11	0.07	0.063	871	0.428
	B11-2	10,198	2	239.0	0.008	0.937	0.412	0.107	1	-	0.010	104	0.943
	B12NE-1	163,586	52	1984.4	0.026	0.230	0.412	0.107	1.09	0.04	0.031	5,670	0.257
	B12NE-2	211,119	-	-	-	-	-	-	-	-	-	-	-
2003	B11-1	12,389	19	182.5	0.104	0.867	0.541	0.109	1.16	0.09	0.096	1,383	0.878
	B11-2	10,198	-	-	-	-	-	-	-	-	-	-	-
	B12NE-1	163,586	36	1157.5	0.031	0.421	0.541	0.109	1.11	0.05	0.028	5,219	0.438
	B12NE-2	211,119	-	-	-	-	-	-	-	-	-	-	-

Table 3. Results of analyses using linear models. The results for sub-area 8 will be revised.

Sub-area 8		
Block effect	Estimate	SE
B8-2	4.467	0.822
B8-3	3.802	0.983
B8-4	3.494	1.239
additional sd (tau)	0.956	1.239
Predicted Abundance	Estimate	CV
B8-2	87.1	0.822
B8-3	44.8	0.983
B8-4	32.9	1.239
Total in 2004	Estimate	CV
Without extrapolation	1,055	0.483
With extrapolation	1,088	0.406

Sub-area 8	Estimate	CV	Correlation			
			2002	2004	2005	2006
2002	0	-				
2004	1088			1	0.083	0.143
2005	6635				1	0.053
2006	3557					1

Sub-area 11		
Block effect	Estimate	SE
B11-1	6.843	0.351
B11-2	4.638	0.943
Predicted Abundance	Estimate	CV
B11-1	937	0.351
B11-2	103	0.943
Total in 1990	Estimate	CV
Without extrapolation	829	0.865
With extrapolation	932	0.777
Total in 2003	Estimate	CV
Without extrapolation	1,383	0.878
With extrapolation	1,486	0.820

Sub-area 11	Estimate	CV	Correlation		
			1990	1999	2003
1990	932	0.777	1	0	0.011
1999	975	0.399		1	0
2003	1,486	0.820			1

Sub-area 12NE		
Block effect	Estimate	SE
B12-1	8.638	0.186
B12-2	9.538	0.390
Predicted Abundance	Estimate	CV
B12-1	5,641	0.186
B12-2	13,883	0.390
Total in 1999	Estimate	CV
Without extrapolation	5,670	0.257
With extrapolation	19,553	0.287
Total in 2003	Estimate	CV
Without extrapolation	5,219	0.438
With extrapolation	19,102	0.308

Sub-area 12NE	Estimate	CV	Correlation		
			1990	1999	2003
1990	19736	0.299	1	0	0
1999	19,553	0.287		1	0.89
2003	19,102	0.308			1

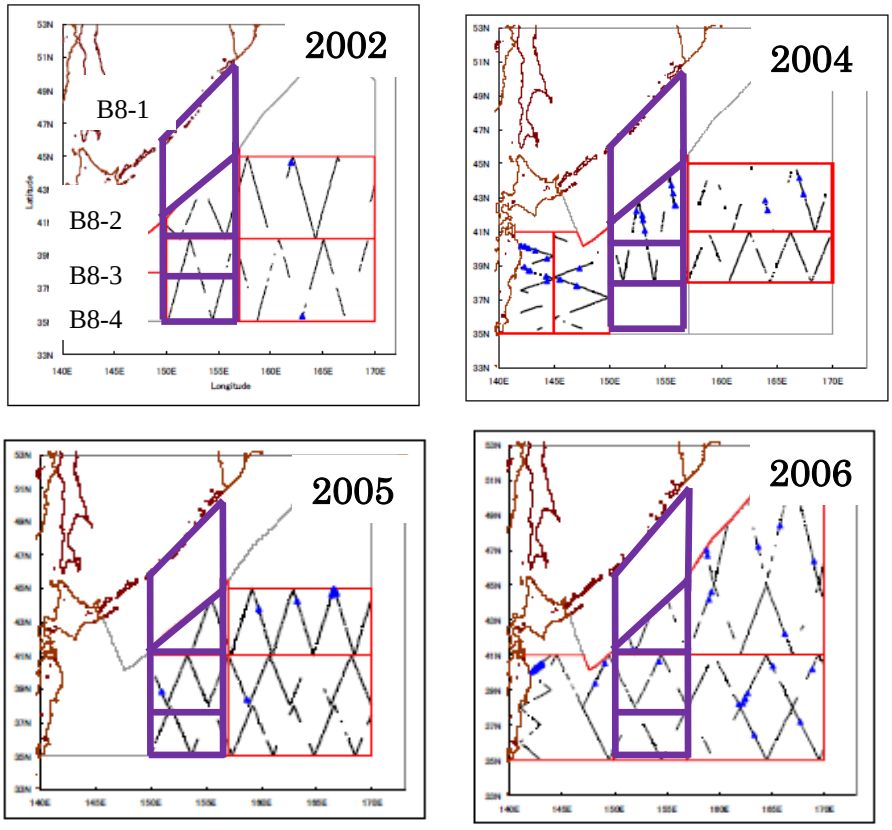

Figure 1. Four survey blocks (framed by bold lines) in sub-area 8. Block B8-1 was not converd by the four surveys. Abundance in Block 8-4 in 2004 is extrapolated.

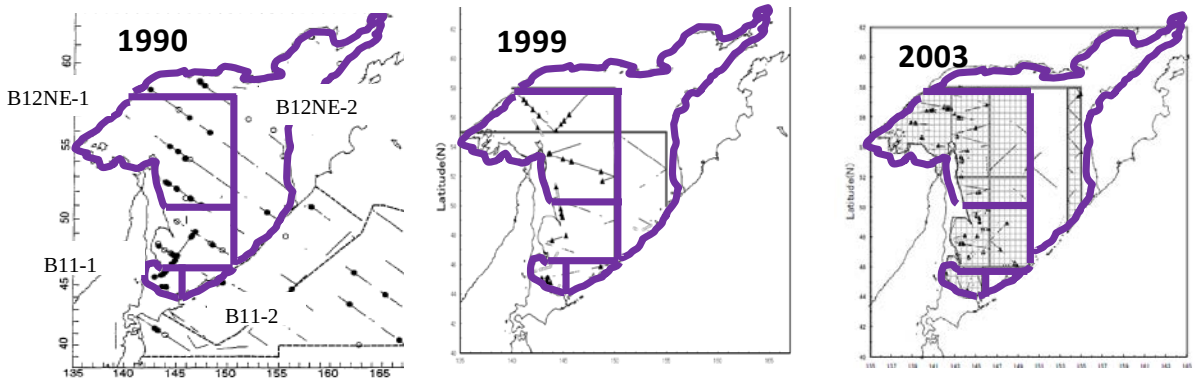

Figure 2. Two survey blocks (framed by bold lines) in each of sub-area 11 and 12NE. Abundance in block B11-2 in 1990 and 2003 and that in block B12-2 in 1999 and 2003 are extrapolated.