Abundance estimate for western North Pacific minke whales based on JARPNII dedicated sighting survey data from 2008 to 2009

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ABSTRACT
Abundance estimate for common minke whales (*Balaenoptera acutorostrata*) in the western North Pacific are obtained for each management sub-area based on JARPN II 2008 and 2009 dedicated sighting survey data. Estimates were based on standard IWC SC methodology. Detection function with covariate such as year, sea state (Beaufort scale) and sub-area was considered. Abundance estimate in sub-area 9 is 1,840 (CV=0.576) in 2008. Abundance estimates in sub-areas 8 and 9 are 507 (CV=0.830) and 1,693 (CV=0.701), respectively in 2009. These estimates could be used for the simulating *CLA*. For sub-area 7CS, 7CN, 7WR and 7E in 2008 and 2009 and sub-area 8 in 2008 sighting data may not be suitable for abundance estimation for the simulating *CLA* because considerations of the survey coverage and survey timing.

INTRODUCTION
In 2008 and 2009, dedicated sighting survey was conducted in north of 35^{o}N and west of 170^{o}E. Cruise track was designed in accordance with original definition of sub-areas 7, 8 and 9 for western North Pacific common minke whales (*Balaenoptera acutorostrata*) (International Whaling Commission (IWC), 1994). Sub-areas used in present *Implementation review* (*IR*) were agreed at First Interssesional Meeting for the *Implementation Review* of the common minke whales in 2010 (IWC, 2011). Allocation of cruise track may not be suitable for abundance estimation in some sub-areas due to the modification to boundary for these sub-areas. At the second 'First Intersessional Workshop' for the *Implementation Review* of the common minke whales, it was agreed that it is also desirable for abundance estimates from each of these surveys to be presented for review at the 2012 Annual Meeting (IWC, 2012) in order to abundance estimates can be used in simulating *Catch limit Algorithm* (*CLA*) application. This paper provides abundance estimate of the minke whales by the sub-areas used in present *IR* based on JARPN II survey data during 2008-2009 that could be used in simulating *CLA* application.

MATERIALS AND METHODS
Survey area
Sighting data were collected by dedicated sighting vessels which operated independently from Sighting and Sampling vessels during JARPN II surveys. Survey was conducted in line transect method. Summary of both year surveys are shown in Table 1. Two dedicated sighting vessels conducted survey. Survey area was sub-areas 7CS, 7CN, 7WR, 7E, 8 and 9 in 2008. In 2009, survey area was same as in 2008 except that north of 45^{o}N in sub-area 9 was not included.

Survey procedure
Starting point of the cruise track was selected at random. Zigzag track lines were systematically allocated in each survey stratum uniformly. Survey procedures were following the RMP requirements and guidelines for sighting surveys (IWC, 1997; 2005; 2008). For more details on survey procedure are given in Hakamada *et al*. (2012)

Survey mode
In 2008, sighting survey was conducted in closing mode. In 2009, sighting survey was conducted in Closing and Passing with abeam closing mode. Because there are few very high density areas and common minke school size are nearly all 1, it can be assumed that difference in survey mode would not cause bias in abundance estimate and therefore we didn't estimate abundance for closing and passing

mode, separately.

Cruise track

Plot of cruise track and primary sightings in 2008 and 2009 are shown in Figures 1 and 2, respectively. From these figures, survey coverage was not good in coastal area and north of 40°N in sub-area 7. The figure also shows cruise track by two vessels. The cruse track was allocated so that they covered whole of the planned survey area only once and the two vessels surveyed along the cruise track independently.

Analysis procedure

Procedure conducted in this paper is similar to Hakamada and Kitakado (2011). It is assumed that $g(0)=1$. Detection function is considered covariates such as sea state (Beaufort scale), sub-area and year. In order to consider the effect of the covariates on estimated detection functions for JARPN II data, MCDS (Multiple Covariates Distance Sampling) module in DISTANCE ver. 6.0 is used. MCDS methods are based on a Horvitz-Thompson like estimator of abundance (Thomas *et al.*, 2010). Hazard-rate model is considered. Full model of the detection function is provided by

$$g(x) = 1 - \exp\left\{ -\left(x \big/ a\exp(Beaufort + Year + SA) \right)^{-b} \right\} \quad (1).$$

AIC is used to select the best model to estimate effective half search width (ESW). In fitting detection function, Beaufort scale ranges from 0 to 5 because sighting survey was not conducted when Beaufort scale was 6 or more. Beaufort scale is grouped into 2 groups. One group is 2 or less and another group is 3 or more.

Searching distance and the number of the primary sightings are stratified by the sub-areas used in present RMP/IST. The Horvitz-Thompson like estimator is applied for the abundance estimation, with consideration of the covariate effects. Detection function is modelled globally, and estimated separately in each sub-area, given the covariate values of the observations in the sub-area to estimate ESW for each sub-area.

RESULTS

Detection function considering covariates

Table 2 compares AIC for each model. Selected model is the hazard-rate model with Beaufort scale and Year as covariates. Estimated coefficients and their precision are shown in Table 3. Plot of detection function for each Beaufort group are shown in Figure 3. The estimated coefficients and shape of the detection functions reflect the fact that the schools are easier to detect as Beaufort scale is less. Estimated ESHW using the selected model are applied to estimate abundance estimates.

Abundance estimates

Table 4 shows abundance estimates by sub-areas during 2008-2009. For 2008, Abundance estimate in sub-area 9 is 1,840 (CV=0.576). For 2009, abundance estimates in sub-areas 8 and 9 are 507 (CV=0.830) and 1,693 (CV=0.701), respectively. CV of encounter rate was high probably because primary sightings were distributed in some concentrated area. North of 45°N in sub-area 9 was not surveyed in 2009, therefore abundance estimate for sub-area 9 in 2009 could be a minimum estimated.

DISCUSSION

Suitability of abundance estimate by sub-areas for simulating *CLA*

It is necessary to consider which abundance estimate can be used for *CLA* among abundance estimates obtained in this paper. Table 5 shows abundance estimates with the best model by sub-area and year using JARPN II data including some information on sighting surveys such as survey month, survey coverage, % of realized trackline and so on. Table 6 shows abundance estimates provided by Miyashita and Fujise (1997) including information on the sighting surveys.

Table 5 indicates that searching effort was allocated insufficiently in sub-areas 7CS and 7CN, respectively in 2008 and 2009 comparing to previous survey. As suggested Figures 1 and 2, northern part (north of 40°N) of sub-areas 7WR and 7E were not covered sufficiently in the both year.

From sighting information during JARPN II coastal component, it is suggested that high density of the minke whale distribution occur in sub-area 7CS in April, and in sub-area 7CN from September to October. Abundance estimate in sub-areas 7 and 8 was much less in July and August than those in May and June based on 2006 and 2007 JARPN II surveys (Hakamada *et al*., 2009), it was suggested that high density of the minke whales did not occur in those sub-areas in 2008 survey during July - August.

Therefore, abundance estimate in sub-areas 7CS, 7CN, 7WR, 7E and 8 for 2008 and 7CS, 7CN, 7WR and 7E for 2009 may not be suitable to use for simulating *CLA* application considering survey design and survey timing.

Underestimate of abundance

Abundance estimate examined in this paper are thought to be underestimate because it was assumed that $g(0)=1$ given that Okamura *et al* (2010) showed that g(0) for Top barrel & Upper bridge was 0.798 for common minke whales.

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Table 1. Summary of sighting survey in 2008 and 2009 JARPN II

year	vessels	period	survey mode	survey area
2008	KK1, KS2	5 Jul - 25 Aug	closing	7CS,7CN,7WR,7E,8,9
2009	KK1, YS1	23 May - 23 Jun	closing, passing	7CS,7CN,7WR,7E,8,9*

*: excluding north of 45N

Table 2. AIC for each model. The selected model is indicted by an asterisk.

covariates	AIC
Beaufort+Year+Sub-Area	797.4
Beaufort+Sub-Area	798.9
Beaufort+Year*	791.7
Year+Sub-Area	804.8
Sub-Area	802.6
Year	806.2
Beaufort	792.2
no covariate	799.2

Table 3. Estimates of coefficients and their standard errors (SE) for the selected model. The parameters *a* and *b* are those for Beaufort scale 3 or more.

	coefficient	SE
a	0.232	0.053
b	2.622	3.042
Beaufort0-2	0.519	0.170
Year2002	0.923	0.628
Year2003	-0.010	0.350
Year2004	0.241	0.388
Year2005	0.806	0.465
Year2006	0.611	0.360
Year2007	0.858	0.634
Year2008	0.110	0.489

Table 4. Abundance estimate for each sub-area in 2008 and 2009.

Year	sub-area	Area	n	L	n/L	CV	ESW	CV	$E(s)$	CV	D	P	CV
2008	9	499,235	8	2678.9	0.0030	0.468	0.405	0.335	1.00	0.000	0.004	1,840	0.576
2009	8	162,789	3	1084.5	0.0028	0.631	0.444	0.540	1.00	0.000	0.003	507	0.830
2009	9	362,113	7	2274.1	0.0031	0.586	0.423	0.356	1.29	0.143	0.005	1,693	0.701

Table 5. Abundance estimates with the best model by sub-area and year using JARPN II data including some information on sighting surveys.

sub-area	year	Aerial covarage	Timing	Area size (n.miles2)	effort (n.miles)	n	Encounter rate (/100 n.miles)	ESW (n.miles)	Mean school size	P	CV(P)	planned trackline	% of realised trackline	Conditioning
7CS	2003	62.6%	May	16,789	367	6	1.636 (1.092)	0.431 (0.179)	1.00 (-)	319	0.786	524	70.0%	No
	2004	100.0%	May	26,826	199	7	3.511 (1.451)	0.606 (0.171)	1.14 (0.14)	886	0.502	301	66.2%	Yes
	2006	100.0%	Jun - Jul	26,826	264	23	8.718 (9.001)	0.431 (0.263)	1.36 (0.11)	3,690	1.199	453	58.2%	Yes
	2007	100.0%	Jun - Jul	26,826	10	0	0 (-)	-	-	0	-	98	9.8%	No
	2008	100.0%	Aug	26,826	160	0	0 (-)	-	-	0	-	243	65.6%	
	2009	100.0%	May - Jun	26,826	153	0	0 (-)	-	-	0	-	270	56.8%	
7CN	2003	75.4%	May	18,281	247	3	1.214 (0.837)	0.604 (0.251)	1.00 (-)	184	0.805	562	43.9%	Yes
	2008	75.4%	Aug	18,281	19	0	0 (-)	-	-	0	-	172	11.1%	
	2009	75.4%	May	18,281	38	0	0 (-)	-	-	0	-	156	24.5%	
7WR	2002	30.5%	Aug	25,059	244	0	0 (-)	-	-	0	-	618	39.5%	No
	2003	54.2%	May - Jun	44,589	986	10	1.014 (0.348)	0.431 (0.263)	1.00 (-)	524	0.700	1,725	57.2%	Min
	2004	88.8%	May - Jun	72,991	789	7	0.887 (0.323)	0.484 (0.24)	1.29 (0.18)	863	0.648	1,558	50.7%	Yes
	2006	88.8%	Jun - Jul	72,991	411	0	0 (-)	-	-	0	-	519	79.2%	No
	2007	88.8%	Jun - Jul	72,991	465	3	0.645 (0.525)	0.431 (0.214)	1.00 (-)	546	0.953	764	60.8%	Yes
	2008	88.8%	Aug	72,991	395	0	0 (-)	-	-	0	-	777	50.8%	
	2009	88.8%	May - Jun	72,991	601	1	0.166 (0.144)	0.330 (0.310)	1.00 (-)	184	1.278	777	77.4%	
7E	2003	26.3%	May - Jun	22,166	535	6	1.121 (0.929)	0.642 (0.107)	1.33 (0.21)	257	0.866	610	87.7%	No
	2004	57.1%	May - Jun	48,208	390	3	0.77 (0.423)	0.422 (0.233)	1.00 (-)	440	0.779	683	57.1%	Yes
	2006	57.1%	May - Jun	48,208	225	2	0.888 (0.762)	0.423 (0.101)	1.00 (-)	506	0.891	517	43.5%	Yes
	2007	57.1%	Jun - Jul	48,208	360	0	0 (-)	-	-	0	-	480	74.9%	Yes
	2008	57.1%	Aug	48,208	313	0	0 (-)	-	-	0	-	546	57.3%	
	2009	57.1%	Jun	48,208	315	0	0 (-)	-	-	0	-	431	73.0%	
8	2002	65.0%	Jun - Jul	162,689	1,184	0	0 (-)	-	-	0	-	1,736	68.2%	Yes
	2003	13.1%	Jul	32,857	272	1	0.368 (0.304)	0.431 (0.214)	1.00 (-)	140	0.964	306	88.7%	No
	2004	40.5%	Jun	101,373	917	8	0.872 (0.404)	0.461 (0.139)	1.14 (0.14)	1,093	0.576	1,636	56.1%	Yes
	2005	65.0%	May - Jul	162,789	1,434	1	0.07 (0.046)	0.431 (0.152)	1.00 (-)	132	0.746	1,915	74.9%	Yes
	2006	65.0%	May - Jul	162,789	1,039	3	0.289 (0.152)	0.761 (0.324)	1.00 (-)	309	0.677	1,680	61.8%	Yes
	2007	65.0%	Jun - Jul	162,789	914	2	0.219 (0.208)	0.456 (0.161)	1.00 (-)	391	1.013	1,623	56.3%	Yes
	2008	65.0%	Jul-Aug	162,789	892	0	0 (-)	-	-	0	-	1,570	56.8%	
	2009	65.0%	May - Jun	162,789	1,085	3	0.277 (0.175)	0.440 (0.240)	1.00 (-)	507	0.830	1,560	69.5%	
9	2002	62.4%	Jun - Jul	358,530	1,866	3	0.161 (0.124)	0.31 (0.109)	2.00 (-)	1,859	0.847	3,504	53.3%	No
	2003	33.2%	Jul - Sep	190,676	2,533	40	1.579 (0.38)	0.609 (0.081)	1.03 (0.03)	2,546	0.276	3,619	70.0%	Min
	2004	42.6%	Jun-Jul	244,759	1,542	4	0.259 (0.157)	0.538 (0.192)	1.00 (-)	590	0.703	3,180	48.5%	No
	2005	63.0%	May -Aug	362,113	3,502	13	0.371 (0.214)	0.686 (0.208)	1.11 (0.11)	1,088	0.716	4,593	76.2%	No
	2006	86.9%	May - Aug	499,235	3,238	17	0.525 (0.146)	0.484 (0.24)	1.00 (-)	2,708	0.569	5,107	63.4%	No
	2007	86.9%	May - Jul	499,235	2,067	1	0.048 (0.049)	0.497 (0.172)	1.00 (-)	243	1.078	4,903	42.2%	No
	2008	86.9%	Jun - Aug	499,235	2,679	8	0.299 (0.14)	0.405 (0.136)	1.00 (-)	1,840	0.576	4,551	58.9%	
	2009	63.0%	May - Jun	362,113	2,274	7	0.308 (0.181)	0.423 (0.151)	1.29 (0.18)	1,693	0.701	3,341	68.1%	

Table 6. Abundance estimates in sub-area 9 by strata using JARPN data (Miyashita and Fujise, 1997) including some information on sighting surveys.

sub-area	year	Aerial covarage	Timing	Area size (n.miles2)	effort (n.miles)	n	Encounter rate (/100 n.miles)	ESW (n.miles)	Mean school size	P	CV(P)	planned trackline	% of realised trackline	Conditioning
9	1994 1st	42.5%	Jul - Aug	244,172	1,608	12	0.746 (0.228)	0.321 (0.091)	1.08 (0.08)	3,065	0.423	6,884	23.4%	No
	1994 2nd	32.9%	Aug - Sep	189,012	2,118	7	0.331 (0.185)	0.321 (0.091)	1.00 (-)	973	0.628	5,807	36.5%	No
	1995 1st	54.7%	Jun	314,082	2,907	12	0.413 (0.076)	0.481 (0.095)	1.00 (-)	1,348	0.272	5,035	57.7%	No
	1995 2nd	13.2%	Jul - Aug	75,635	791	10	1.264 (0.436)	0.481 (0.095)	1.00 (-)	994	0.396	3,119	25.4%	No
	1995 3rd	28.5%	Aug	163,610	1,706	4	0.234 (0.142)	0.481 (0.095)	1.00 (-)	399	0.636	2,470	69.1%	No

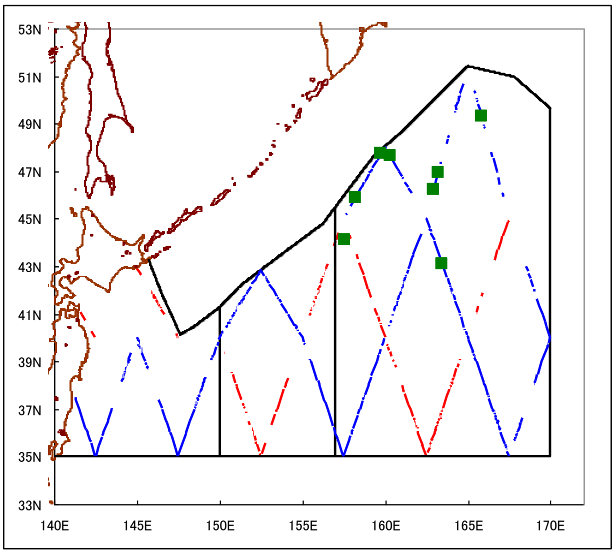

Figure 1. Plot of cruise track and primary sightings of the minke whales during the JARPN II surveys for 2008. Red line indicates cruise track by *Kaiko-Maru* (*KK1*). Blue line indicates cruise track by *Kyoshin-Maru No. 2*(*KS2*). Black bold line indicates boundary of planned survey areas. Green square indicates a primary sighting of the minke whales.

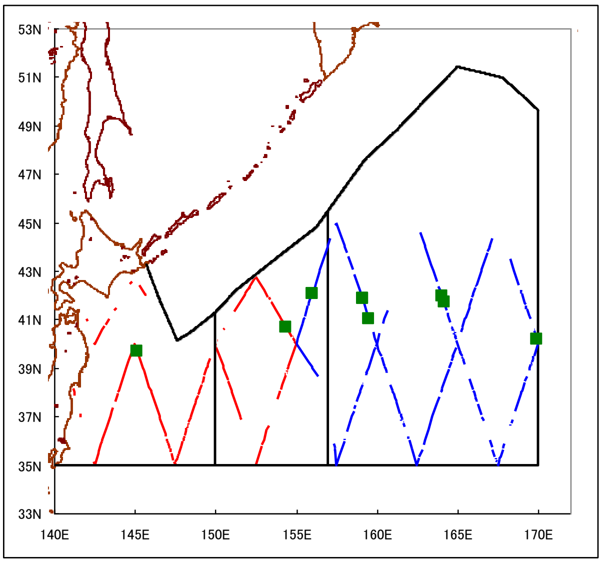

Figure 2. Plot of cruise track and primary sightings of the minke whales during the JARPN II surveys for 2009. Red line indicates cruise track by *Kaiko-Maru* (*KK1*). Blue line indicates cruise track by *Yushin-Maru No. 1*(*YS1*). Green squaere indicates a primary sighting of the minke whales.

B=0-2 B=3-5

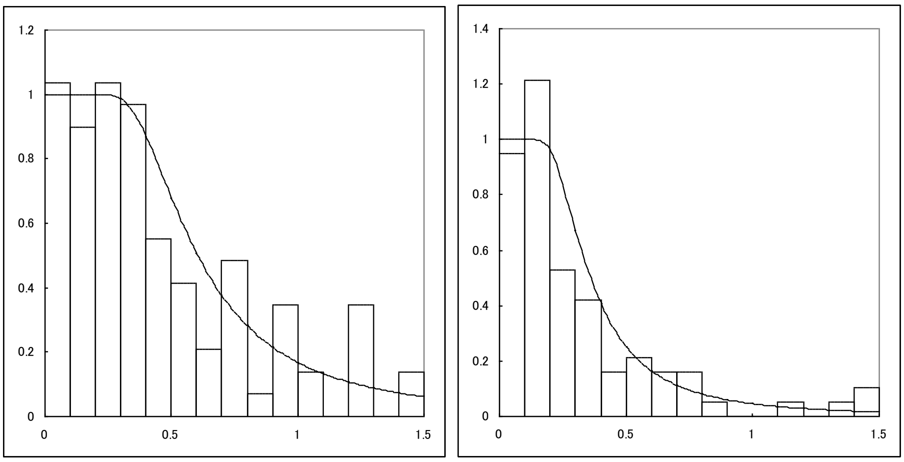

Figure 3. Plot of the selected detection function and distribution of the perpendicular distance of the primary sightings for Beaufort scale 0-2 and 3-5.