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The number of western North Pacific common minke, Brydes and sei whales distributed in JARPNII Offshore survey area

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ABSTRACT
In order to examine the impact of large whales, such as common minke (*Balaenoptera acutorostrata*), Bryde's (*Balaenoptera edeni*) and sei whales (*Balaenoptera borealis*) on Japanese fisheries through estimating the amount of prey consumed by these whales or using ecosystem models, it was required to estimate the number of these whales in the JARPNII survey area (east of Japanese coast, west of 170ºE, north of 35ºN, south of Russian and US EEZ). Considering the migration pattern of these whales in the area suggested by previous analysis, the number of the whales needed to be estimated separately for the early and late seasons for each of the whale species. The estimates were 3,629 (in 2009) and 2,122 (in 2011 and 2012) in the early and 3,080 (in 2008) in the late season for the common minke assuming g(0) = 0.789, 2,957 (in 2009) and 1,851 (in 2011 and 2012) in the early and 13,306 (in 2008) in the late season for the Bryde's whales, 4,734 (in 2009) and 2,988 (in 2011 and 2012) in the early and 5,086 (in 2008) in the late season for the sei whales, assuming g(0)=1. It is important to note that these estimates should not be used for assessment because the estimated figures represent only a part of the population considered.

INDTRODUCTION

Elucidation of feeding ecology and ecosystem studies is one of the main objectives of the JARPNII. It is important to estimate prey consumption and to develop ecosystem models. The number of whales distributed in study area can be used for prey consumption estimates and ecosystem modelling. From the previous results, prey species are different between the early (May – June) and late (July – September) season (Tamura *et al*., 2009). For this reason, the number of whales distributed are estimated in the early and late seasons, respectively. At the JARPNII review meeting in 2009, the number of the common minke, Bryde's and sei whales in the early and the late season were estimated using JARPNII sighting surveys during 2002-2007 (Hakamada *et al*., 2009), which were used to estimate prey consumption and input for ecosystem models (Tamura *et al*., 2009; Mori *et al*., 2009).

This paper updates the number of the common minke, Bryde's and sei whales distributed in the JARPNII survey area (i.e. east of Japanese coast, west of 170ºE, north of 35ºN, south of Russian and US EEZ) in the early and late seasons using JARPNII dedicated sighting survey data obtained during 2008-2014.

MATERIALS AND METHODS

Data used in this study

Dedicated sighting surveys were conducted during 2008-2014. Among the surveys, survey data that covered the JARPNII survey area were used for this analysis. Survey periods and vessels used for these surveys are shown in Table 1. The numbers of whales distributed in the JARPNII survey area were estimated in the early and late seasons. Considering the survey period and survey area, there are three data sets to estimate the number of the whales distributed in the JARPNII survey area. For the early season, the numbers were estimated for the 2009 survey, and 2011 and 2012 1st surveys combined. For the late season, the numbers were estimated for the 2008 survey. Figures 1-3 shows plots of primary effort and sightings for the common minke, Bryde's and sei whales in the early and late seasons.

Abundance estimation
Analytical procedure are similar to Hakamada and Matsuoka (2015) as follows.

For this analysis it is assumed that g(0)=0.798 with CV=0.134 (Okamura *et al*., 2010) for the minke whales and that g(0)=1 for the Bryde's and sei whales. Detections are truncated at 1.5 n.miles for the common minke whale and 3.0 n.miles for the Bryde's and the sei whales. Abundance and its CV were estimated based on a Horvitz-Thompson like estimator of abundance expressed by formula (1) and (2), respectively.

$$P = \frac{A}{2WL}\sum_{i=1}^{n}\frac{s_i}{p_i(z_i)} = \frac{A}{2L}\sum_{i=1}^{n}s_i\hat{f}(0\,|\,\mathbf{z}_i) \qquad (1)$$

where P is abundance estimate, A is area size of the surveyed area, W is truncation distance (1.5 n.miles for the common minke whales and 3.0 n.miles for Bryde's and sei whales), L is searching effort, n is the number of schools detected within perpendicular distance of W, s_i is school size of ith detection, $p_i(z_i)$ is the probability that school i is detected given that it is within the perpendicular distance W and given the covariate z_i. $f(0|z_i)$ is conditional probability density function of distance 0 given covariates z_i

$$\mathrm{var}(P) = \left(\frac{A}{2WL}\right)^2\left\{\frac{1}{L(K-1)}\sum_{k=1}^{K}l_k\left(\frac{P_{Ck}}{l_k}-\frac{P_C}{L}\right)^2+\sum_{j=1}^{r}\sum_{m=1}^{r}\frac{\partial P_C}{\partial\theta_j}\frac{\partial P_C}{\partial\theta_m}H_{jm}^{-1}(\theta)\right\} \qquad (2)$$

where K is the number of transect, l_k is searching distance in kth transect, P_{Ck} is abundance estimate in covered region (within W n.miles from track line surveyed) in kth transect, P_C is abundance estimate in the covered region, $H_{jm}^{-1}(\theta)$ is the jmth element of inverse of Hessian matrix of detection function for covariate θ.

Multiple Covariate Distance Sampling (MCDS) Engine in DISTANCE program was used (Thomas *et al*., 2010). Given discussions at the IA sub-committee on detection function (IWC, 2015), Half Normal and Hazard Rate models were considered as candidate models for the detection function. Full model of the two detection functions were provided by

$$g(x) = 1-\exp\left\{-\left(x \big/ a\exp(Size+Beaufort+Year)\right)^{-b}\right\} \qquad (3)$$

$$g(x) = \exp\left[-x^2 \big/ 2a^2\exp\{2(Size+Beaufort+Year)\}\right] \qquad (4)$$

where x is perpendicular distance, a and b ($b \geqq 1$) are parameter, *Size* is observed school size, *Beaufort* is categorical variable for Beaufort sea state (good: 0-3, bad: 4-5) and *Year* is categorical variable for year. To estimate detection function, all primary sightings occurred during 2008-2014 were used.

AIC was used to select the best model to estimate detection probability of $1/Wf(0|z_i)$.

Smearing was not conducted on running MCDS because MCDS doesn't deal with smearing. Perpendicular distance was not binned on fitting detection function because selection of cut point could affect results of model selection and coefficient estimates of detection function.

Sensitivity analysis
Effect of including/excluding covariates in the detection function such as Beaufort sea state, school size and year were examined. If the difference in AIC of detection function is not substantially different

among the models, weighted average by Akaile weight (Buckland *et al*, 1997; Burnham and Anderson, 2002) were estimated.

Averaged abundance

Average of abundance estimates base case and in sensitivity analysis were also estimated. By using Akaike weight, weight is larger as model is better. Akaike weights are defined as follows;

$$w_i = \frac{\exp\left(-\Delta \mathrm{AIC}_i/2\right)}{\sum_{j=1}^{16}\exp\left(-\Delta \mathrm{AIC}_\mathrm{j}/2\right)} \quad (5)$$

The weighted average of the abundance estimates P_w and their standard errors were estimated by equations as follows.

$$P_w = \sum_{i=1}^{16} w_i P_i \quad (6)$$

$$\mathrm{CV}(P_w) = \frac{\sqrt{\sum_{i=1} w_i^2\ \mathrm{var}(P_i) + 2\sum_{i\neq j} w_i w_j\ \mathrm{cov}\left(P_i, P_j\right)}}{P_w} \quad (7)$$

where

$$\Delta \mathrm{AIC}_i = \mathrm{AIC}_i - \mathrm{AIC}_{\min} \quad (8)$$

RESULTS

The number of the whales distributed in JARPNII survey area

Table 2 shows AIC for each model of the detection functions for the common minke, the Bryde's and the sei whales. For the common minke, AIC is closer to the best model for Hazard rate model than Half normal models regardless of covariates selected. For the Bryde's and sei whales, AIC is different among the covariates selected rather than formula of detection function (i.e. Hazard rate or Half normal). Figure 4 shows plots of the selected detection function for the common minke, Bryde's and sei whales. Figure 5 shows qq-plot of the detection function for the common minke, Bryde's and sei whales. These figures suggests the fit of the detection function good. Table 3 shows the estimated number of whales by strata for the common, Bryde's and sei whales. Table 4 shows abundance estimates in the early season for common minke, Bryde's and sei whales. The estimated number of the whales distributed in early season were estimated for 2008 and 2011+ the 1st survey in 2012 combined in each stratum. Table 5 shows the estimated number of the whales distributed in the late season for common minke, Bryde's and sei whales. The estimated numbers in the late season were estimated for 2009.

Sensitivity analysis

Table 6 shows the number of the whales in Tables 4 and 5 would change when applying detection functions other than the best model. For comparison, the estimated number applying the best detection function is also included in the table. The estimated number is different by the selection of functional form of the detection function for the common minke whales. The estimated number is different by the selection of the covariate rather than the functional form of the detection function for Bryde's and sei whales. Table 7 shows weighted average using Akaike weight. The CV is an under estimate because variances of AIC are not taken into account. For Bryde's and sei whales, the estimated numbers seemed to be robust for the selection of the detection function. For the common minke, the estimated number is less robust than Bryde's and sei whales. This may because the numbers of the primary sightings to fit the detection function for the common minke is less than Bryde's and sei whales.

DISCUSSIONS

It is important to note that these estimates should not be used for assessment because the estimated figures represent only a part of the population considered. To estimate total abundance, it is necessary to consider the number of the whales outside of JARPNII area. For the common minke whles, it is necessary to include the estimated numbers in Okhotsk Sea. For Bryde's whales, it is necessary to include the estimated numbers in area in the south of 35ºN and that in the east of 170ºE. For sei whales, it is necessary to include the estimated numbers in area in the east of 170ºE.

The number of primary sighting of the common minke and Bryde's whales in Areas 8 and 9 in 2011 were less than those in 2009 while the numbers of blue, fin, humpback and North Pacific right whales in 2011 were more than those in 2009 (Hakamada and Matsuoka, 2016: SC/F16/J13). This may be due to the distribution pattern of these whales rather than an indication that the stock size of these species has changed.

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Table 1. Summary information on dedicated sighting survey under JARPNII.

Year	Vessels	Period	Survey area	IWC oversight
2008	KK1, KS2	2Jul.-29Aug.	SA7, 8, 9	N
2009	KK1, YS1	23May-23Jun.	SA7, 8, 9	N
2011	YS1, YS2,YS3	5May-5Jun.	SA8,9	Y
2012 1st	YS3	18May-29Jun.	SA7CS,7CN,7WR,7E	Y

Table 2. AIC for each model of detection functions for base case. For selected model, AIC is written by bold letters. HR: Hazard Rate and HN: Half Normal.

Common minke whale

Model	HR	HN
School size+Beaufort+Year	**15.2**	27.6
School size+Beaufort	16.3	21.5
School size+Year	17.3	29.8
Beaufort+Year	16.6	22.7
School size	17.0	29.3
Beaufort	18.1	23.1
Year	18.3	24.5
No covariate	15.4	28.5

Bryde's whale

Model	HR	HN
School size+Beaufort+Year	1039.9	**1038.9**
School size+Beaufort	1046.7	1046.1
School size+Year	1040.8	1042.8
Beaufort+Year	1050.5	1049.6
School size	1050.8	1054.3
Beaufort	1055.2	1054.2
Year	1051.5	1051.1
No covariate	1059.1	1059.4

Sei whale

Model	HR	HN
School size+Beaufort+Year	455.6	454.5
School size+Beaufort	453.9	453.4
School size+Year	454.4	453.3
Beaufort+Year	463.9	464.3
School size	452.7	**452.0**
Beaufort	462.0	463.4
Year	463.9	463.0
No covariate	462.1	461.7

Table 3. Abundance estimates for the common minke, Bryde's and sei whales and their CV's for each stratum based on 2008, 2009, 2011 and 2012 JARPNII cruises for the best model of detection function. It was assumed that g(0)=1 for the three species. *A* is area size of the surveyed area, n_s and n_w are the number of schools detected and the number of individuals detected within perpendicular distance of 1.5 n.miles for the common minke and 3.0 n.miles for the Bryde's and sei whales, *L* is searching distance, *P* is abundance estimate and CI is abbreviation for confidence interval.

Common minke whale

Year	Stratum	*A*	*L*	n_s	n_w	$n_w/L*100$	CV(n_w/L)	***P***	CV(P)	95%LL	95%UL
2008	7	166,306	886.5	-	-	-	-	-	-	-	-
2008	8	162,789	1193.6	-	-	-	-	-	-	-	-
2008	9	499,235	3067.0	9	9	0.293	0.425	**2,458**	0.664	739	8,182
2009	7	166,306	1036.5	1	1	0.096	0.871	**215**	0.942	34	1,338
2009	8	162,789	1084.5	3	3	0.277	0.631	**602**	0.725	143	2,545
2009	9	362,113	2274.1	7	9	0.396	0.572	**2,079**	0.688	572	7,553
2011	8	162,789	1101.5	1	1	0.091	0.945	**121**	0.966	10	1,428
2011	9N	208,660	1496.4	1	1	0.067	1.027	**115**	1.047	13	998
2011	9S	290,575	1492.8	-	-	-	-	-	-	-	-
2012	7CS	26,826	850.9	17	19	1.270	0.287	**537**	0.346	269	1,070
2012	7CN	16,171	649.2	17	23	1.541	0.501	**542**	0.601	164	1,790
2012	7WRN	6,874	175.7	2	2	0.235	0.913	**64**	0.935	3	1,471
2012	7WRS	66,117	750.1	3	4	0.616	0.906	**314**	0.934	50	1,961
2012	7E	48,208	302.3	-	-	-	-	-	-	-	-

Bryde's whale

Year	Stratum	*A*	*L*	n_s	n_w	$n_w/L*100$	CV(n_w/L)	***P***	CV(P)	95%LL	95%UL
2008	7	166,306	886.5	37	56	6.317	0.492	**3,394**	0.486	1,050	10,974
2008	8	162,789	1193.6	44	76	6.367	0.554	**2,733**	0.467	1,056	7,075
2008	9	499,235	3067.0	101	146	4.760	0.368	**7,179**	0.358	3,517	14,654
2009	7	166,306	1036.5	40	55	5.306	0.499	**2,595**	0.445	921	7,308
2009	8	162,789	1084.5	-	-	-	-	-	-	-	-
2009	9	362,113	2274.1	6	6	0.264	0.430	**363**	0.441	144	914
2011	8	162,789	1101.5	3	6	0.545	0.945	**201**	0.947	16	2,528
2011	9N	208,660	1496.4	-	-	-	-	-	-	-	-
2011	9S	290,575	1492.8	-	-	-	-	-	-	-	-
2012	7CS	26,826	850.9	-	-	-	-	-	-	-	-
2012	7CN	16,171	649.2	-	-	-	-	-	-	-	-
2012	7WRN	6,874	175.7	-	-	-	-	-	-	-	-
2012	7WRS	66,117	750.1	16	19	2.533	0.505	**464**	0.499	153	1,404
2012	7E	48,208	302.3	19	30	9.924	0.589	**1,186**	0.590	213	6,619

Sei whale

Year	Stratum	*A*	*L*	n_s	n_w	$n_w/L*100$	CV(n_w/L)	***P***	CV(P)	95%LL	95%UL
2008	7	166,306	886.5	1	1	0.113	1.128	**60**	1.130	6	611
2008	8	162,789	1193.6	16	26	2.178	0.637	**908**	0.635	261	3,158
2008	9	499,235	3067.0	51	108	3.521	0.446	**4,119**	0.444	1,721	9,854
2009	7	166,306	1036.5	6	8	0.772	0.936	**364**	0.938	52	2,536
2009	8	162,789	1084.5	9	16	1.475	0.666	**614**	0.683	136	2,768
2009	9	362,113	2274.1	51	95	4.177	0.182	**3,756**	0.182	2,551	5,530
2011	8	162,789	1101.5	3	6	0.545	0.848	**215**	0.852	21	2,204
2011	9N	208,660	1496.4	-	-	-	-	-	-	-	-
2011	9S	290,575	1492.8	27	42	2.813	0.382	**2,174**	0.376	904	5,231
2012	7CS	26,826	850.9	-	-	-	-	-	-	-	-
2012	7CN	16,171	649.2	-	-	-	-	-	-	-	-
2012	7WRN	6,874	175.7	-	-	-	-	-	-	-	-
2012	7WRS	66,117	750.1	2	2	0.267	0.520	**56**	0.525	18	178
2012	7E	48,208	302.3	9	12	3.970	0.738	**543**	0.740	67	4,390

Table 4. Abundance estimate for the common minke, Bryde's and sei whales in JARPNII survey area (i.e. sub-areas 7, 8 and 9 excluding foreign EEZ) in early season for 2009 and 2011+1st survey in 2012 combined. It is assumed that g(0)=0.798 (CV=0.134) for the common minke whale and g(0)=1 for Bryde's, sei and sperm whales.

Early	Common minke		Bryde's		Sei	
	P	CV(P)	***P***	CV(P)	***P***	CV(P)
2009	**3,629**	0.586	**2,957**	0.394	**4,734**	0.177
2011+2012_1st	**2,122**	0.371	**1,851**	0.413	**2,988**	0.304

Table 5. Abundance estimate for coomon minke, Bryde's, sei and sperm whales in the JARPNII survey area in late season for 2008. It is assumed that g(0)=0.798 (CV=0.134) for the common minke whale and g(0)=1 for Bryde's, sei and sperm whales.

Late	Common minke		Bryde's		Sei	
	P	CV(P)	***P***	CV(P)	***P***	CV(P)
2008	**3,080**	0.677	**13,306**	0.251	**5,086**	0.378

Table 6. Abundance estimate for the common minke, Bryde's and sei whales in JARPNII survey area in early and late seasons for sensitivity test (i.e. applying alternative detection function other than the best model). Bold letter indicates that the estimate is based on the best model. It is assumed that g(0)=0.798 with CV=0.134 (Okamura *et al.*, 2010) for the common minke whale and g(0)=1 for Bryde's and sei whales.

Common minke whale

Early (2009)

Model	Covariates	P	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	**3,629**	**0.586**	Half Normal	S+B+Y	1,904	0.467
	S+B	2,510	0.496		S+B	1,636	0.454
	S+Y	4,214	0.594		S+Y	2,216	0.460
	B+Y	3,484	0.576		B+Y	1,958	0.468
	S	2,898	0.503		S	1,706	0.453
	B	2,456	0.488		B	1,655	0.457
	Y	4,009	0.583		Y	2,285	0.460
	None	2,812	0.493		None	1,734	0.456

Early (2011+2012_1st)

Model	Covariates	P	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	**2,122**	**0.371**	Half Normal	S+B+Y	1,584	0.301
	S+B	2,435	0.365		S+B	1,649	0.296
	S+Y	2,172	0.379		S+Y	1,482	0.309
	B+Y	2,040	0.351		B+Y	1,595	0.304
	S	2,707	0.386		S	1,568	0.304
	B	2,354	0.344		B	1,675	0.299
	Y	2,088	0.359		Y	1,494	0.313
	None	2,600	0.362		None	1,603	0.309

Late (2008)

Model	Covariates	**P**	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	**3,080**	**0.677**	Half Normal	S+B+Y	2,447	0.615
	S+B	2,352	0.660		S+B	2,271	0.640
	S+Y	2,859	0.581		S+Y	1,638	0.455
	B+Y	3,094	0.672		B+Y	2,454	0.614
	S	1,988	0.494		S	1,278	0.451
	B	2,380	0.655		B	2,256	0.643
	Y	2,874	0.579		Y	1,638	0.455
	None	2,015	0.489		None	1,243	0.451

Bryde's whale

Early (2009)

Model	Covariates	**P**	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	3,306	0.387	Half Normal	S+B+Y	**2,957**	**0.394**
	S+B	2,939	0.380		S+B	2,713	0.394
	S+Y	3,394	0.410		S+Y	3,062	0.417
	B+Y	2,684	0.566		B+Y	3,080	0.436
	S	3,026	0.412		S	2,770	0.423
	B	3,122	0.420		B	2,830	0.429
	Y	3,629	0.459		Y	3,186	0.454
	None	3,230	0.457		None	2,895	0.453

Early (2011+2012_1st)

Model	Covariates	**P**	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	1,833	0.415	Half Normal	S+B+Y	**1,851**	**0.413**
	S+B	2,284	0.412		S+B	2,144	0.412
	S+Y	1,704	0.408		S+Y	1,758	0.410
	B+Y	2,131	0.437		B+Y	2,018	0.427
	S	2,133	0.402		S	2,031	0.407
	B	2,682	0.436		B	2,318	0.426
	Y	1,922	0.424		Y	1,379	0.580
	None	2,426	0.421		None	2,175	0.418

Late (2008)

Model	Covariates	**P**	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	14,566	0.253	Half Normal	S+B+Y	**13,306**	**0.251**
	S+B	13,143	0.251		S+B	12,430	0.252
	S+Y	14,357	0.254		S+Y	13,353	0.254
	B+Y	17,099	0.273		B+Y	14,627	0.263
	S	12,853	0.252		S	12,209	0.255
	B	15,479	0.270		B	13,619	0.262
	Y	16,561	0.273		Y	14,538	0.265
	None	14,744	0.270		None	13,214	0.264

(Table 6 continued.)

Sei whale

Early (2009)

Model	Covariates	**P**	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	5,305	0.216	Half Normal	S+B+Y	4,516	0.181
	S+B	5,025	0.199		S+B	4,664	0.178
	S+Y	5,405	0.214		S+Y	4,608	0.180
	B+Y	5,515	0.230		B+Y	4,768	0.188
	S	5,143	0.198		S	**4,734**	**0.177**
	B	5,363	0.215		B	4,995	0.183
	Y	5,723	0.230		Y	4,889	0.185
	None	5,570	0.215		None	5,047	0.180

Early (2011+2012_1st)

Model	Covariates	**P**	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	3,277	0.336	Half Normal	S+B+Y	3,283	0.308
	S+B	3,466	0.306		S+B	3,035	0.297
	S+Y	3,140	0.342		S+Y	3,188	0.314
	B+Y	3,384	0.338		B+Y	3,348	0.316
	S	3,332	0.314		S	**2,988**	**0.304**
	B	3,516	0.309		B	3,030	0.304
	Y	3,166	0.350		Y	3,219	0.322
	None	3,302	0.323		None	2,992	0.309

Late (2008)

Model	Covariates	**P**	CV(P)	Model	Covariates	P	CV(P)
Hazard Rate	S+B+Y	5,822	0.394	Half Normal	S+B+Y	4,955	0.381
	S+B	5,536	0.388		S+B	5,091	0.380
	S+Y	5,725	0.386		S+Y	4,966	0.379
	B+Y	6,743	0.425		B+Y	5,534	0.393
	S	5,477	0.381		S	**5,086**	**0.378**
	B	6,541	0.418		B	5,755	0.390
	Y	6,483	0.405		Y	5,539	0.388
	None	6,311	0.399		None	5,718	0.386

(Table 6 continued.)

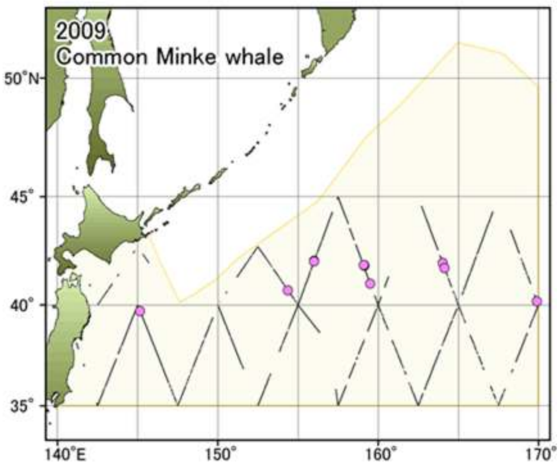
Table 7. Weighted average of the abundance estimates in Table 6 by Akaike weight for sensitivity.

Early

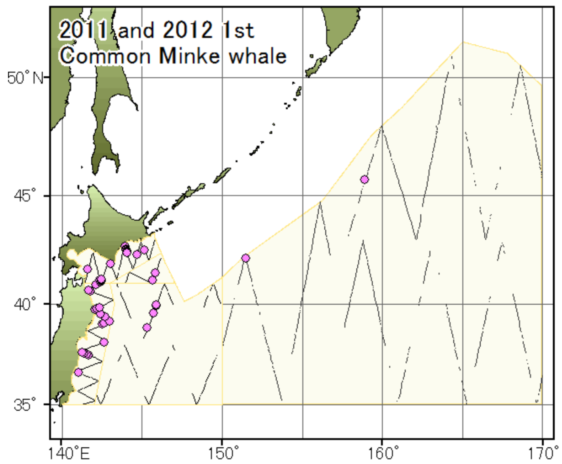
Early	Common minke			Bryde's			Sei		
	P	CV(P)	Change from base case	P	CV(P)	Change from base case	P	CV(P)	Change from base case
2009	3,179	0.471	-12.4%	3,137	0.418	6.1%	4,874	0.184	2.9%
2011+2012_1st	2,314	0.312	9.1%	1,822	0.412	-1.5%	3,177	0.313	5.9%

Late

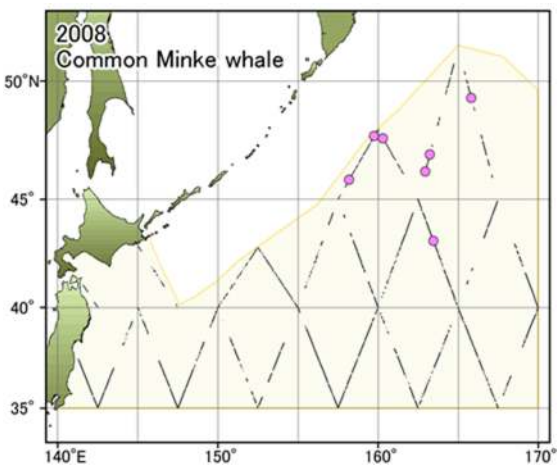
Late	Common minke			Bryde's			Sei		
	P	CV(P)	Change from base case	P	CV(P)	Change from base case	P	CV(P)	Change from base case
2008	2,570	0.482	-16.6%	13,851	0.255	4.1%	5,264	0.378	3.4%



Early (2009)

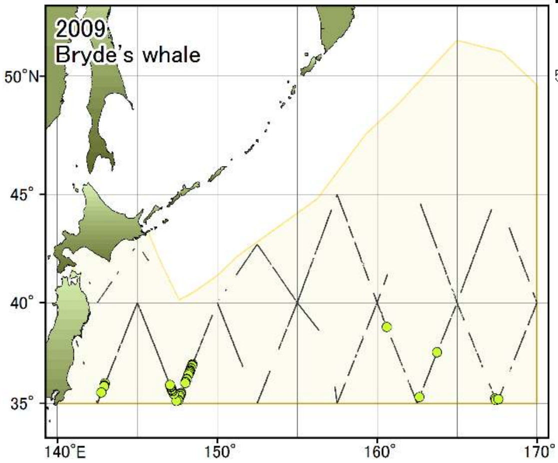


Early (2011 and 2012)

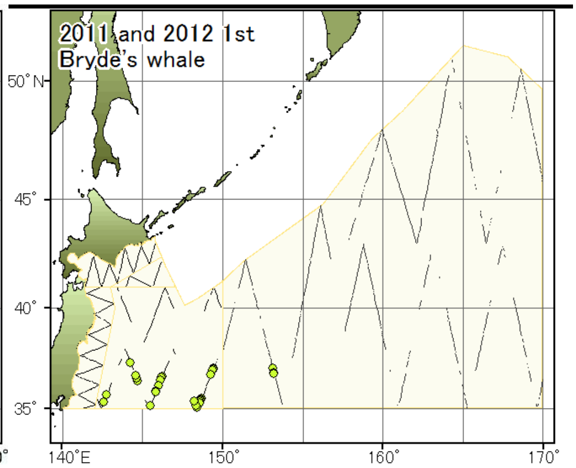


Late (2008)

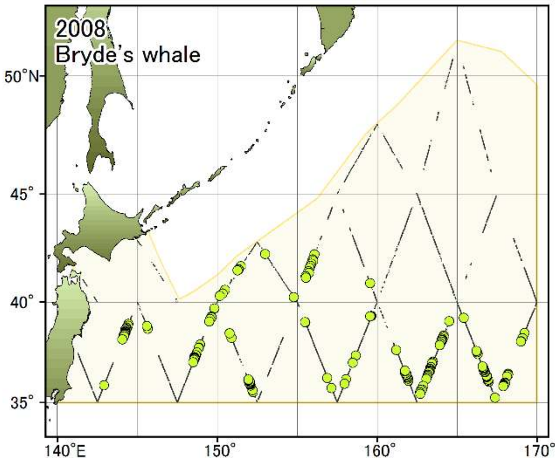
Figure 1. Plot of actually surveyed track line (black lines) and position of the common Minke whales (pink circles) for JARPNII surveys in early and late seasons.



Early (2009)

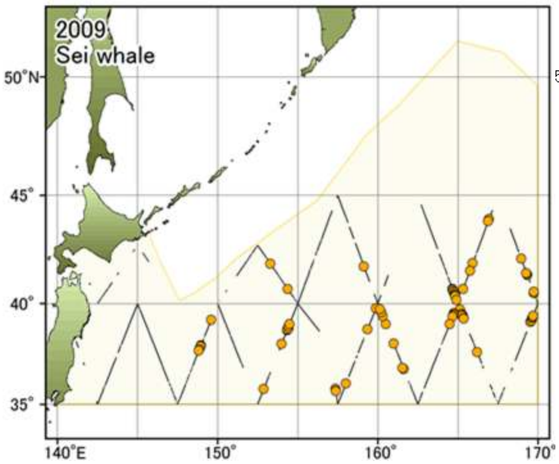


Early (2011 and 2012)

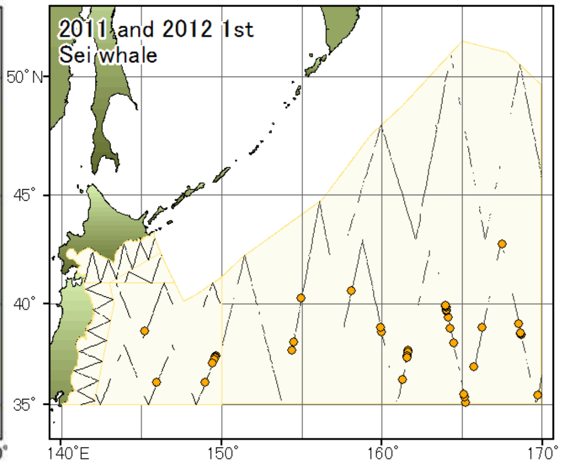


Late (2008)

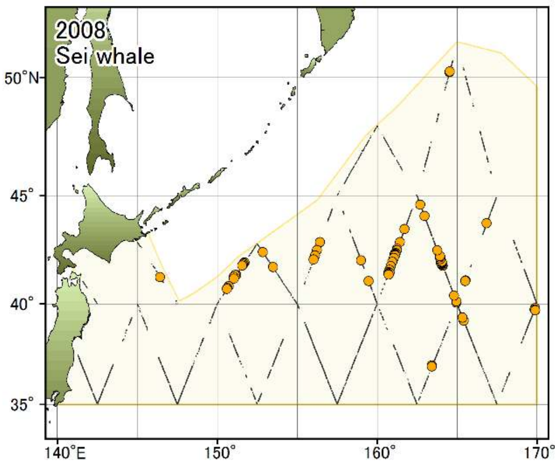
Figure 2. Plot of actually surveyed track line (black lines) and position of the Bryde's whales (yellow green circles) for JARPNII surveys in early and late season.



Early (2009)

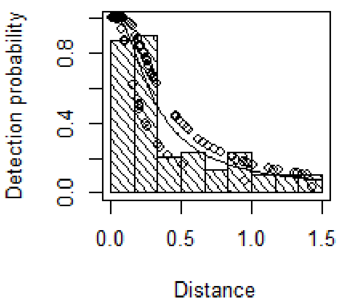


Early (2011 and 2012)

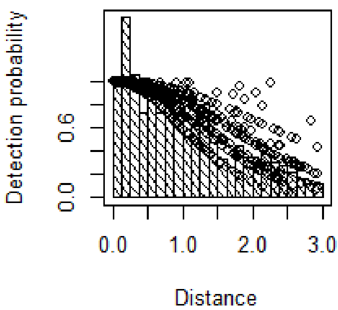


Late (2008)

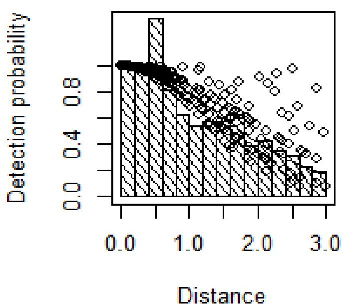
Figure 3. Plot of actually surveyed track line (black lines) and position of the Sei whales (orange circles) for JARPNII surveys in 2008, 2009, 2011 and 2012 (1st survey).



Common minke whale

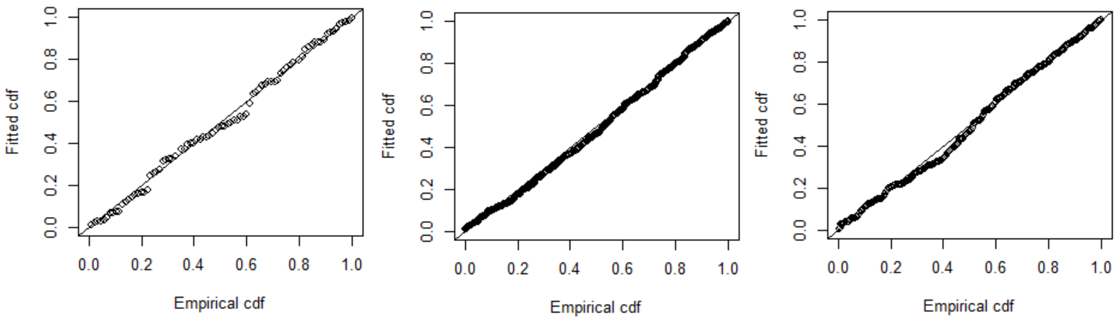


Bryde's whale



Sei whale

Figure 4. Plot of the estimated detection function fitted to the number of schools as a function of perpendicular distance (n. miles) from the track line for the best model. Left panel is the plot for the common minke, middle panel is for Bryde's whale and right panel is for sei whale.



Common minke whale Bryde’s whale Sei whale

Figure 5. QQ-plot of the estimated detection functions. Left panel is the plot for the common minke, middle panel is for Bryde’s whale and right panel is for sei whale.