SC/67A/SCSP/11

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Genta Yasunaga, Satoko Inoue, Hideyoshi Yoshida and Toshi Kitakado

INTERNATIONAL WHALING COMMISSION

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GENTA YASUNAGA[1], SATOKO INOUE[1], HIDEYOSHI YOSHIDA[2] AND TOSHI KITAKADO[3]

[1] *Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan*
[2] *National Research Institute of Far Seas Fisheries, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan*
[3] *Tokyo University of Marine Science and Technology, 5-7 Konan 4, Minato-ku, Tokyo 108-8477, Japan*

ABSTRACT

To refine the preliminary analyses regarding success proportions of biopsy and lethal sampling for sei, Bryde's and common minke whales based on the JARPNII data for 2014-2016 submitted to the Expert Panel review workshop for NEWREP-NP, the differences between the two approaches were assessed using a generalized linear model (GLM) for the response variable adjusting for potential covariates (sampling method, research year, Beaufort scale and visibility at experiment and sampling vessels) based on these data. The analyses show that the success proportions for biopsy sampling were significantly lower than for lethal sampling for all whale species. Explanatory variables in the best-fitting model for sei and Bryde's whales included only 'method', and that for common minke whale included 'method' and 'vessel', indicating that environmental covariates had no significant effect. In common minke whales, only two biopsy specimens could be sampled in 14 trials, suggesting biopsy sampling is not feasible for these whales in the coastal components of the program. On the other hand, it has been noted that experience and training can play an important role in the efficiency of biopsy sampling following introduction of the Larsen system for the 2015 JARPNII. For this system the shooters would benefit from more experience and training time. These results and conclusions support the preliminary analyses submitted to the Expert Panel workshop.

KEYWORDS: SCIENTIFIC PERMITS; COMMON MINKE WHALE; BRYDE'S WHALE; SEI WHALE; SURVEY VESSEL; BIOPSY SAMPLING

INTRODUCTION

The International Whaling Commission's Scientific Committee (IWC SC) convened an Expert Panel workshop to review the Proposed Research Plan for the New Scientific Whale Research Program in the western North Pacific (NEWREP-NP) in Tokyo from 30 January to 3 February 2017.

At this workshop, the proponents summarized results of the feasibility study on non-lethal techniques to evaluate whether the objectives of the research could be achieved by non-lethal methods based on data and samples collected from the JARPN II surveys for 2014-2016 (Yasunaga *et al.*, 2017). Biopsy sampling was possible for sei and Bryde's whales by sighting and sampling vessel in the offshore component of the program and for common minke whales by small-type catcher boat in the coastal components. However, given the main objective of JARPNII and available research resources, biopsy sampling is not feasible for common minke whale in the coastal components, whereas it is feasible for sei and Bryde's whales in the offshore component. In addition, the proponents submitted additional analyses to the Expert Panel in response to their request during the meeting; these suggested that success proportions for biopsy sampling for all three species were significantly lower than those for catches (IWC, 2017). In the report of the Expert Panel on NEWREP-NP, the Panel agreed with the proponents' conclusions that it is feasible to collect biopsy samples from all three species, and that it is more difficult to conduct biopsy sampling for common minke whales in the coastal waters than for sei and Bryde's whales in offshore waters. However, the Panel noted that the success of biopsy sampling for common minke whales might be dependent on other covariates. Given this, the Panel recommended that various factors such as

sea state, swell, visibility, experience of sampler, vessel and equipment be considered in assessing the efficiency of biopsy sampling of common minke whales.

The aim of this report is to refine the preliminary analyses submitted in the Expert Panel workshop. The success proportions for biopsy and lethal sampling are estimated by generalized linear models in the context of other potential covariates (research year, Beaufort scales and visibility at experiment, and vessel).

MATERIALS AND METHODS

Research area and platform

For the main objective of JARPNII (feeding ecology and ecosystem studies), the field survey involved two components: offshore and coastal (two localities: Sanriku and Kushiro). The offshore research area involved sub-areas 7, 8 and 9, as established by the IWC but excluding the EEZs of foreign countries, and the coastal research areas were located in the sub-area 7CN (Kushiro) and 7CS (Sanriku) established by the IWC (Figure 1). The coastal surveys were mainly conducted within a 30 nautical miles radius from the port in the respective area (the Kushiro port or the Ayukawa port), and limited within the maximum of 50 n. miles radius from the port. The biopsy and lethal sampling in offshore and coastal areas were conducted by the three sighting and sampling vessels (SSV1-3) and the four small-type catcher boats (SCB1-4). The surveys were conducted from April to October in the years 2014-2016 (Table 1).

Target sample size and effort

The target sample sizes for the biopsy and lethal sampling were 10 and 90 for sei whales and 25 and 25 for Bryde's whales in each year's research. Allocation of effort between lethal (90%) and non-lethal (10%) activities was set without the target sample sizes for the biopsy sampling for common minke whales (sample size for lethal sampling in each year and component: 51 animals).

Sampling devices of biopsy and lethal sampling

The improved Larsen system described by Larsen (1998) was used. The chamber was modified to 9mm, allowing the use of 9mm, 0.380 and 0.357 blank ammunition. It was fitted with a valve for adjusting the gas pressure entering the barrel from the chamber. The barrel consisted of a 48.5cm long aluminium cylinder that allowed the use of darts with 27mm diameter floats. The open sight was replaced by an electronic aiming device (red-dot-sight), which allowed faster aiming and thus faster shooting. The biopsy darts consisted of a carbon fibre shaft to which a polyethylene float was high-pressure moulded. The float also functioned as a stop to limit penetration into the tissue. In the float end of the dart, a threaded insert was used for attaching the screw-on biopsy tip. The biopsy tip was a stainless cylinder with a 9mm outer diameter, an internal diameter of 7mm and three internal barbs for sample retention. The length of the biopsy tip was normally between 20 and 50mm depending of which species was targeted, with 40mm the most commonly used for *balaenopterids*. The weight of the dart without a sampling tip was 32g (Larsen, 1998).

A whaling harpoon (SSV: 75mm in diameter; SCB: 50mm in diameter) with four flexible barbs is fired from a whaling cannon mounted on the forecastle of the SSVs and SCBs, and the top case of the harpoon in loaded with a penthrite cartridge and fuse (Ishikawa and Shigemune, 2005).

Data collection and definition

Experimental and environmental data such as time spent, sea state (the Beaufort scale), visibility and sea surface temperature were recorded by researchers during the experiments.

To compare the efficiency between biopsy and lethal sampling, 'success proportion' is defined as the following equation.

Success proportion = Number of sampled whales or biopsy samples / Number of targeted whales

where 'Number of sampled whales or biopsy samples' is the number of individual whales obtained or biopsy samples obtained, and 'Number of targeted whales' is the total number of individuals identified as the target species and chased for sampling by SSVs and SCBs.

Statistical analysis

The differences of success proportion for biopsy and lethal sampling for sei, Bryde's and common minke whales were assessed by a generalized linear model (GLM) as the response variable adjusting for covariates (sampling method, research year, Beaufort scale and visibility at experiment and sampling vessels) based on data from the JARPNII for 2014-2016. In this analysis, the binomial distribution was assumed for the response variable, outcome of sampling (failure = 0; success = 1). For explanatory variables, sampling method (lethal sampling = 0; biopsy sampling = 1), research year (sei and Bryde's whales: 2015 = 0; 2016 = 1, common minke whale: 2014 = 0; 2015 = 1; and 2016 = 2) and vessels (sei and Bryde's whales: SSV1 = 0; SSV2 = 1 and SSV3 = 2, common minke whale: SCB1 = 0; SCB2 =1; SCB3 = 2 and SCB4 = 3) were analysed as categorical variables, and sea condition (Beaufort scale classes from 0 to 7) and visibility (n.mile) at the time of the experiment as a numerical variables. Covariates within a given process were grouped together in a base set of linear models to describe individual processes (Table 1). The Bayesian information criterion (BIC) was used to select the best-fitting model (Schwarz 1978). A p value of less than 0.05 was considered to indicate statistical significance in all tests. In GLM analyses with the sampling methodologies as the explanatory variables, point estimates were estimated by prediction using the fitted model, and their standard errors were estimated approximately by the delta method.

RESULTS

Table 2 shows a summary of experiments of biopsy and lethal sampling during JARPNII for 2014-2016. Table 3 shows BICs for the each candidate model for sei, Bryde's and common minke whales. The best model with lowest BIC (Schwarz 1978) was Model 1 for sei and Bryde's whales and Model 5 for common minke whales. Table 4 shows estimated coefficients of each explanatory variable in the selected models. The coefficient estimates and p values for the explanatory variable indicated that the success proportions of biopsy sampling were lower than those of lethal sampling for all three species. Table 5 and Figure 2 shows the estimates and the standard errors of the success proportion of biopsy and lethal sampling for sei and Bryde's, and those for each vessel for common minke whales. Only two biopsy samples for common minke whales were collected in 14 trials in the coastal components for 2014-2016, so that the estimates of success proportions of biopsy sampling were much lower than those of lethal sampling.

DISCUSSION

In the GLM analyses, the selected explanatory variables in the best-fitting model for sei and Bryde's whales included only 'method'. The present analyses support the preliminary analyses presented at the Expert Panel workshop, because the estimates of success proportions (sei: Biopsy 0.571 ± 0.066, Lethal 0.905 ± 0.021; Bryde's: Biopsy 0.782 ± 0.047, Lethal 0.926 ± 0.036) for biopsy and lethal sampling in the present analyses were the approximately same as levels of those (sei: Biopsy 0.490 ± 0.050, Lethal 0.894 ± 0.018; Bryde's: Biopsy 0.694 ± 0.038, Lethal 0.926 ± 0.029) in the preliminary analyses (IWC, 2017). Furthermore, it is suggested that the Larsen system is one of the most efficient method for biopsy sampling, and relatively robust in any sea conditions (Nishiwaki *et al.*, 1990). It is used regularly during the IWC POWER surveys in the North Pacific so the shooters of the Larsen system were experienced crew members for the offshore component. Therefore, the success proportions would be affected only by methods for sei and Bryde's whales in the offshore area.

In the analysis for common minke whale, the best-fitting model included 'method' and 'vessel' as explanatory variables, because the estimate of success proportions for lethal sampling for the SCB2, 3 and 4 were higher than for the SCB1. Success proportions for biopsy sampling were significantly lower than lethal sampling; moreover only two biopsy specimens could be sampled in 14 trials, suggested biopsy sampling is not feasible for common mink whales in the coastal components. On the other hand, it has been noted that experience and training can play an important role in the efficiency of biopsy sampling in the coastal components, because the Larsen system was introduced in the 2014 Kushiro survey for the costal components. Here the shooters would benefit from more experience and training time.

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Table 1. Candidate model set for estimation of sampling success proportions in sei, Bryde's and common mike whales

Model	Candidate model components
Model 0	β_0 (intercept only)
Model 1	β_1Method
Model 2	$\beta_0 + \beta_1$Method + β_2Year
Model 3	$\beta_0 + \beta_1$Method + β_2Sea condition
Model 4	$\beta_0 + \beta_1$Method + β_2Visibility
Model 5	$\beta_0 + \beta_1$Method + β_2Vessel
Model 6	$\beta_0 + \beta_1$Method + β_2Year +β_3Sea condition
Model 7	$\beta_0 + \beta_1$Method + β_2Year +β_3Visibility
Model 8	$\beta_0 + \beta_1$Method + β_2Year +β_3Vessel
Model 9	$\beta_0 + \beta_1$Method + β_2Sea condition +β_3Visibility
Model 10	$\beta_0 + \beta_1$Method + β_2Sea condition +β_3Vessel
Model 11	β_0 +β_1Method + β_2Visibility + β_3Vessel
Model 12	β_0 +β_1Method + β_2Year +β_3Sea condition + β_4Visibility
Model 13	β_0 +β_1Method + β_2Year +β_3 Sea condition + β_4 Vessel
Model 14	β_0 +β_1Method + β_2Year +β_3 Visibility + β_4Vessel
Model 15	β_0 +β_1Method + β_3Sea condition + β_4Visibility + β_5Vessel
Model 16	β_0 +β_1Method + β_2Year +β_3Sea condition + β_4Visibility + β_5Vessel

Table 2. Success proportions, sampled whale numbers, target whale (experiment) numbers and average time of experiment in sei, Bryde's and common minke whales for a) biopsy and b) lethal sampling in the JARPNII surveys over 2014-2016

a) Biopsy sampling using Larsen system

Species	Component	Research year	Success proportion	Number of sampled whales	Number of targeted whales	Average of time of experiment (min.)
Sei whale	Offshore	2015	0.615	16	26	14.3
		2016	0.533	16	30	15.8
		2015-2016	0.571	32	56	15.0
Bryde's whale	Offshore	2015	0.786	33	42	16.0
		2016	0.778	28	36	18.9
		2015-2016	0.782	61	78	17.3
Common minke whale	Sanriku	2015	0.000	0	1	-
		2016	0.333	1	3	52.0
		2015-2016	0.250	1	4	52.0
	Kushiro	2014	0.500	1	2	33.0
		2015	0.000	0	7	-
		2016	0.000	0	1	-
		2014-2016	0.100	1	10	33.0

b) Lethal sampling

Species	Component	Research year	Success proportion	Number of sampled whales	Number of targeted whales	Average of time of experiment (min.)
Sei whale	Offshore	2015	0.891	90	101	14.1
		2016	0.918	90	98	16.2
		2015-2016	0.904	180	199	15.2
Bryde's whale	Offshore	2015	0.862	25	29	11.4
		2016	1.000	25	25	16.0
		2015-2016	0.926	50	54	13.7
Common minke whale	Sanriku	2014	0.638	30	47	27.7
		2015	0.576	19	33	20.2
		2016	0.640	16	25	38.9
		2014-2016	0.619	65	105	28.3
	Kushiro	2014	0.646	51	79	20.3
		2015	0.689	51	74	17.0
		2016	0.553	21	38	13.9
		2014-2016	0.644	123	191	17.8

Table 3. BICs for candidate models for sampling success proportions for sei, Bryde's and common minke whales

Model	sei whale	Bryde's whale	common minke whale
Model 0	236.9	120.6	419.5
Model 1	**213.0**	**120.1**	411.4
Model 2	218.5	124.3	422.3
Model 3	242.4	130.2	423.0
Model 4	218.0	123.6	413.9
Model 5	218.5	122.0	**407.7**
Model 6	247.9	134.8	433.8
Model 7	223.5	127.2	424.2
Model 8	224.0	126.0	418.9
Model 9	247.5	134.0	424.6
Model 10	247.9	134.3	421.2
Model 11	223.5	125.3	410.3
Model 12	253.1	138.3	433.7
Model 13	253.4	138.9	431.8
Model 14	229.1	128.9	421.2
Model 15	253.0	138.1	423.1
Model 16	258.6	142.3	432.6

Table 4. Results of generalized linear model analyses with estimates of success proportions for sampling by biopsy and lethal sampling for sei, Bryde's and common minke whales in relation to explanatory variables

a) Sei whale (Model 1)

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	2.2485	0.2412	9.323	$p < 0.05$
Method1	-1.9608	0.3621	-5.416	$p < 0.05$

Null deviance: 231.39 for 254 degrees of freedom; Residual deviance: 201.87 for 253 degrees of freedom

b) Bryde's whale (Model 1)

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	2.5257	0.5196	4.861	$p < 0.05$
Method1	-1.2481	0.5876	-2.124	$p < 0.05$

Null deviance: 115.67 for 131 degrees of freedom; Residual deviance: 110.31 for 130 degrees of freedom

c) Common minke whale (Model 5)

	Estimate	Std. Error	z value	Pr (>|z|)
Method0	-0.3842	0.2449	-1.569	0.117
Method1	-2.9965	0.8172	-3.667	$p < 0.05$
SCB2	1.2320	0.3551	3.470	$p < 0.05$
SCB3	1.4098	0.3392	4.156	$p < 0.05$
SCB4	1.0792	0.3569	3.024	$p < 0.05$

Null deviance: 429.75 for 310 degrees of freedom; Residual deviance: 378.98 for 305 degrees of freedom

Table 5. Estimates and standard errors of success proportions for biopsy and lethal sampling for sei, Bryde's and common minke whales

Species	Vessel	Lethal	Biopsy
Sei whale	-	0.905 ± 0.021	0.571 ± 0.066
Bryde's whale	-	0.926 ± 0.036	0.782 ± 0.047
Common minke whale	SCB1	0.405 ± 0.059	*
	SCB2	0.700 ± 0.054	*
	SCB3	0.736 ± 0.046	0.170 ± 0.110
	SCB4	0.667 ± 0.058	0.128 ± 0.089

*: Biopsy samples were not obtained.

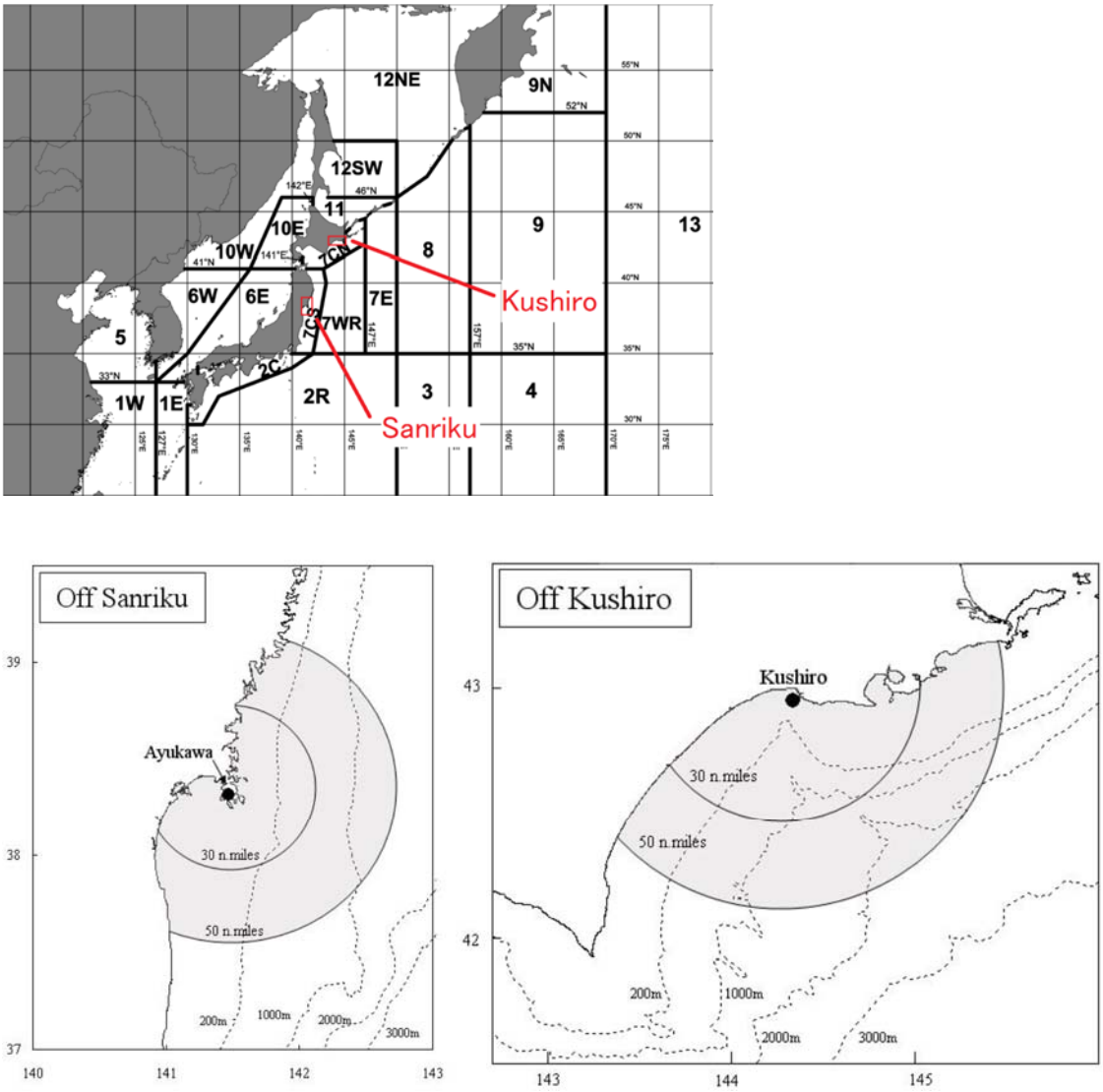

Figure 1. Research areas for the whale sampling surveys in the offshore (upper) and coastal (lower) component of JARPN II

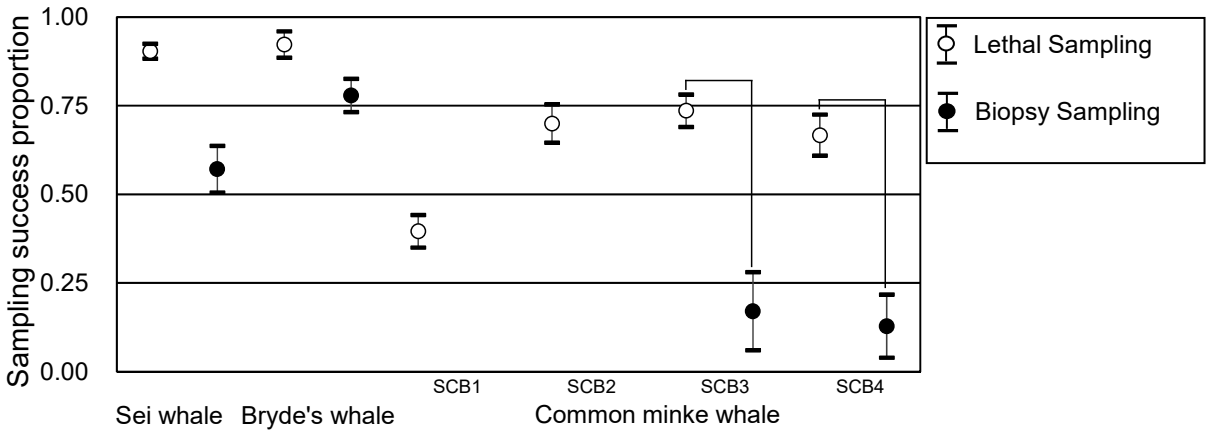

Figure 2. Comparison of estimates and standard errors for success proportions for lethal and biopsy sampling for sei, Bryde's and common minke whales