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Technical Report

What do we know about whales and ecosystem in the western North Pacific Ocean? Part 2: summary of results on abundance estimates in baleen whale species

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ABSTRACT

The Institute of Cetacean Research (ICR) has been conducting whale sighting surveys in the western North Pacific Ocean for more than 25 years. The main purpose of these surveys is the collection of sighting data required for abundance estimation of baleen whale species in this oceanic basin. Results of the analyses of the data collected have revealed the pattern of distribution and abundance estimates of each whale species in different years and in different periods within a year. Abundance estimates have been used for management purposes (e.g. calculation of catch limits for sustainable commercial whaling) in the case of some species. This paper presents a brief outline of the survey design and analytical procedures used, and of the main results obtained so far.

INTRODUCTION

Information regarding the distribution and abundance of whale species is essential in understanding the role and impact of whales in the ecosystem. Abundance is also an important piece of information required for establishing policy of management of whales. For example, a time series of estimates of absolute abundance derived from sighting surveys is required under the Revised Management Procedure (RMP) for setting safe catch limits of commercial whaling. The RMP is the management procedure developed by the International Whaling Commission's Scientific Committee (IWC SC) for baleen whale species.

One of the most common approaches for collecting sighting data for abundance estimation purposes is the vessel-based survey using the Line Transect (LT) method. Japan through the Institute of Cetacean Research (ICR) has conducted systematic research on whales in the western North Pacific for more than 25 years. The first one was the Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN, 1994–1999), which was followed by the second phase of this program (JARPNII, 2000–2016). Subsequently, the New Scientific Whale Research Program in the western North Pacific (NEWREP-NP) was designed and implemented between 2017–2019. All these three research programs (JARPN, JARPNII, NEWREP-NP) had an important sighting survey component based on the LT method. Abundance estimates based on sighting data collected by this survey component have been crucial in the context of some of the objectives of those programs, e.g. the estimation of prey consumption by whale species. As noted above, abundance estimates are key information for calculating catch limit for commercial whaling on some species.

The objective of this paper is to presents a brief outline of the survey design and analytical procedures used by the ICR sighting surveys in the western North Pacific, and to present the main results obtained so far.

RESEARCH AREA

The research area for the sighting surveys comprises the Pacific side of Japan, north of 35°N, the Sea of Japan, and Okhotsk Sea (see Figure 1). Each of these research areas were divided into smaller strata, and the surveys were conducted in spring (mainly May to June) and summer (mainly August to September) seasons to investigate whale distribution and abundance in each season.

VESSEL USED

Specialized vessels which have three observation platforms were used in the surveys (Figure 2). Observers collected whale sighting data from the platforms using binoculars in the time period between sunrise and sunset.

SURVEY METHODOLOGY

Sighting surveys were conducted by the LT method. The survey protocols followed the IWC SC's Requirements and Guidelines for Conducting Surveys and Analyzing Data within the Revised Management Scheme (IWC, 2012a). Under the LT method, vessels move on pre-determined zigzag track lines, which cover the entire or a part of a management area (Figure 3A). The start point is randomly selected for each survey. The design of track lines does not follow physical features such as isobaths which may be correlated with whale distribution and their migration.

Observers search for whales from each platform on the research vessels. When a whale school is detected, the distance between observers and whales and the angle from the track line to whales were recorded (Figure 3B) together with the position of the research vessel and time of the sighting.

ANALYTICAL PROCEDURES

Abundance estimation using sighting data is made using distance sampling calculation (Buckland *et al.*, 2001). The methodology involves two main components. The first component involves fitting the detection function to sighting data. Initially it is assumed that whales are uniformly distributed and that they have the same probability to be detected. However, searching activity is affected by environmental factors (e.g. glare, fog, sea state), and whales occurring far from the vessel are more difficult to detect (Figure 4). Therefore, detection function (e.g. Half-normal function and Hazard-rate function) should be examined, and the best model is selected using the Akaike Information Criterion (AIC) values.

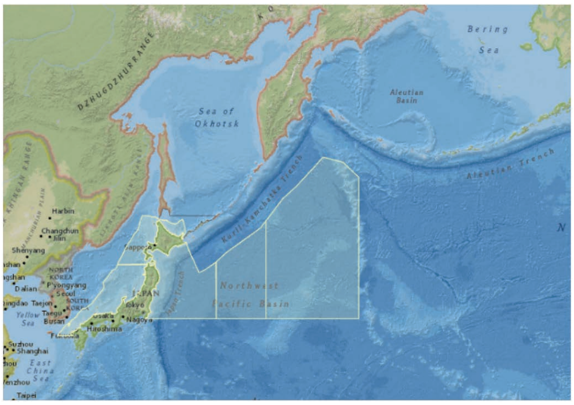

Figure 1. Research area on the Pacific side of Japan, southern Okhotsk Sea and Sea of Japan, covered by Japanese sighting surveys.

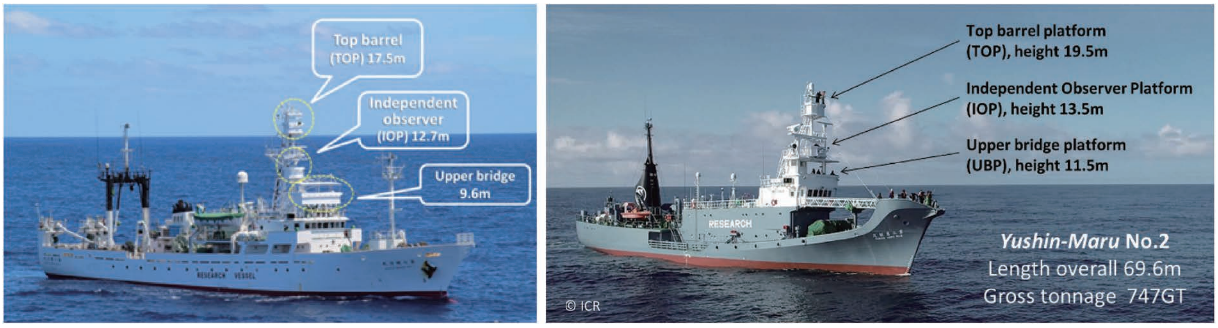

Figure 2. Specialized research vessels used for sighting surveys (left: *Kaiyo-Maru* No.7, right: *Yushin-Maru* No.2). The figures show the observation platforms (taken from Takahashi [2020] and Isoda *et al.* [2021]).

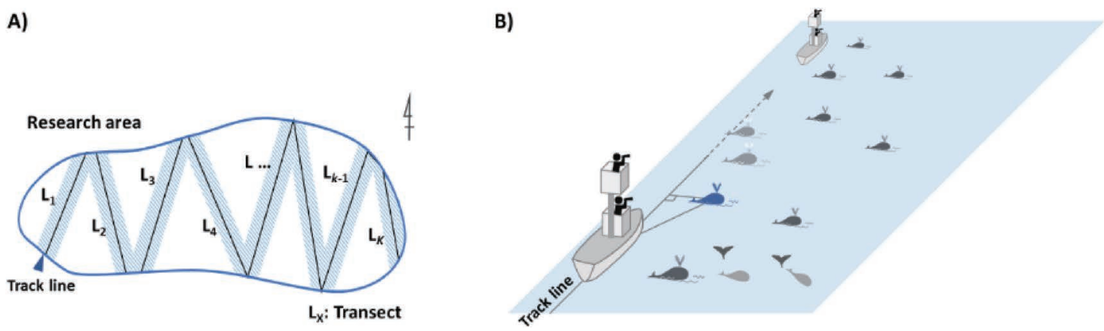

Figure 3. Diagrams showing the zigzag track lines for a research area under the LT survey (A); and the whale observation from different platforms (B).

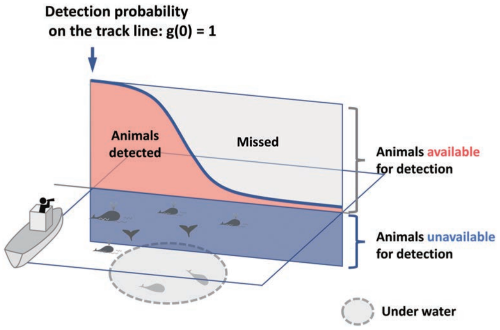

Figure 4. Diagram showing the detection probability assuming $g(0)=1$. The probability of detection decreases with distance from the vessel.

$$\text{Half-normal: } f(x,\mathbf{z}) = \exp\left(-\frac{x^2}{2\sigma^2}\right)$$

$$\text{Hazard-rate: } f(x,\mathbf{z}) = 1 - \exp\left[\left(\frac{-x}{a\sigma}\right)^{-b}\right],$$

where x is perpendicular distance, $\boldsymbol{z}$ is vector of several covariates; and σ represents scale parameter for incorporating the covariates in the detection function and a and b are parameters of each key function.

The second component is for estimating abundance using the detection probability derived from the detection function. The Horvitz–Thompson-like estimator is one of the most frequently used methods. The principle of the estimator is that the total number of whales present are estimated from the proportion of the abundance in the area surveyed (the covered area) to the entire survey area. To do this the abundance in the area surveyed is calculated using the detection probability. The detection function models are denoted *f*(*x*; _) where x is perpendicular distance (from the track line to whales) and $\boldsymbol{\theta}$ is a vector of parameters of the key function to be estimated.

$$\hat{N}_{covered} = \sum_{i=1}^{n} \frac{s_i}{\int_0^w \frac{1}{w} f(\widehat{x, \mathbf{z}_i; \boldsymbol{\theta}})dx},$$

where w is truncation distance from the track line, s_i is size of i^{th} detected cluster ($I=1, \cdots, n$).

Then, it is scaled up to the full study area by multiplying it by the ratio of covered area to study area. Here, $A/2wL$ represents proportion of entire research area to area searched:

$$\hat{N} = \frac{A}{2wL}\widehat{N_{covered}}$$

In reality, because of diving behavior, not all animals are available for detection even when they are near the vessel and/or on the track line. Therefore, this bias should also be considered in the abundance estimation process. This bias is known as availability bias and is different from perception bias caused by human error under different environmental conditions.

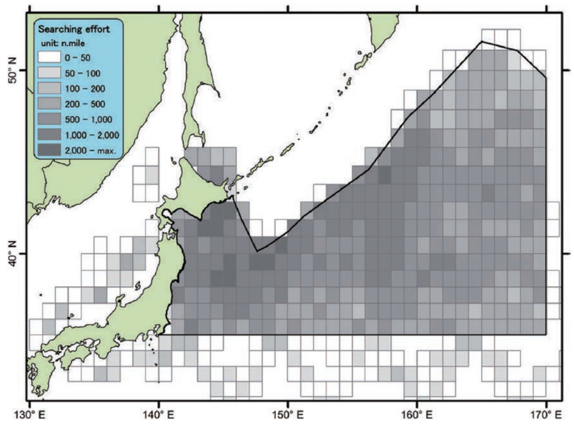

Figure 5. The searching effort by each Lat. 1°×Long. 1° grid square covered by JARPN and JARPNII surveys during 1994 to 2014 (Matsuoka and Hakamada, 2019). The gray scale shows the degree of searching effort.

RESULTS ON DISTRIBUTION AND ABUNDANCE

Figure 5 shows the main research area and the total primary searching effort by each Lat. 1°×Long. 1° grid square during 1994 to 2014 under JARPN and JARPNII surveys.

Table 1 shows the abundance estimates for each whale species. The numbers of whales distributed in the JARPNII survey area were estimated in the early and late seasons (see Hakamada and Matsuoka, 2016a; 2016b).

Blue whales

The main distribution area for blue whales moved northward from 35°N–40°N to north of 40°N during the spring (May to June) to summer (August to September) seasons (Matsuoka *et al.*, 2016) (Figure 6). In the late 20th century, they had never been observed in this area in June, but this could have been caused by the difference in regulations of the whaling operations for coastal and offshore whaling. In the late season, blue whales were more frequently sighted north of 40°N (Figure 6), and the abundance estimate was 958 animals (CV=0.461) (Table 1).

Fin whales

Fin whales were observed mainly in the Pacific side of Japan but also occurred in the Okhotsk Sea and Sea of Japan (Matsuoka *et al.*, 2016). The main distribution area was north of 37°N, and the highest density area was north of 45°N. Fin whales were widely distributed across the western North Pacific in the spring season, but they

Table 1
Abundance estimates for several large baleen whale species. All estimates assumed $g(0)=1$, except for common minke whales in which $g(0)=0.798$ (CV=0.134).

Species	Spring season		Summer season	References
	2009	2011+2012	2008	
Blue whale	38 (0.977)	161 (0.474)	958 (0.461)	Hakamada and Matsuoka (2016b)
Fin whale	413 (0.569)	1,369 (0.295)	3,958 (0.425)	Hakamada and Matsuoka (2016b)
Sei whale	4,734 (0.177)	2,988 (0.304)	5,086 (0.378)	Hakamada and Matsuoka (2016a)
Bryde's whale	2,957 (0.394)	1,851 (0.413)	13,306 (0.251)	Hakamada and Matsuoka (2016a)
Humpback whale	1,136 (0.438)	1,921 (0.318)	392 (0.877)	Hakamada and Matsuoka (2016b)
North Pacific right whale	0 (—)	1,147 (0.434)	416 (0.653)	Hakamada and Matsuoka (2016b)
Common minke whale	3,629 (0.586)	2,122 (0.371)	3,080 (0.677)	Hakamada and Matsuoka (2016a)

Spring season: May to June, Summer season: August to September.

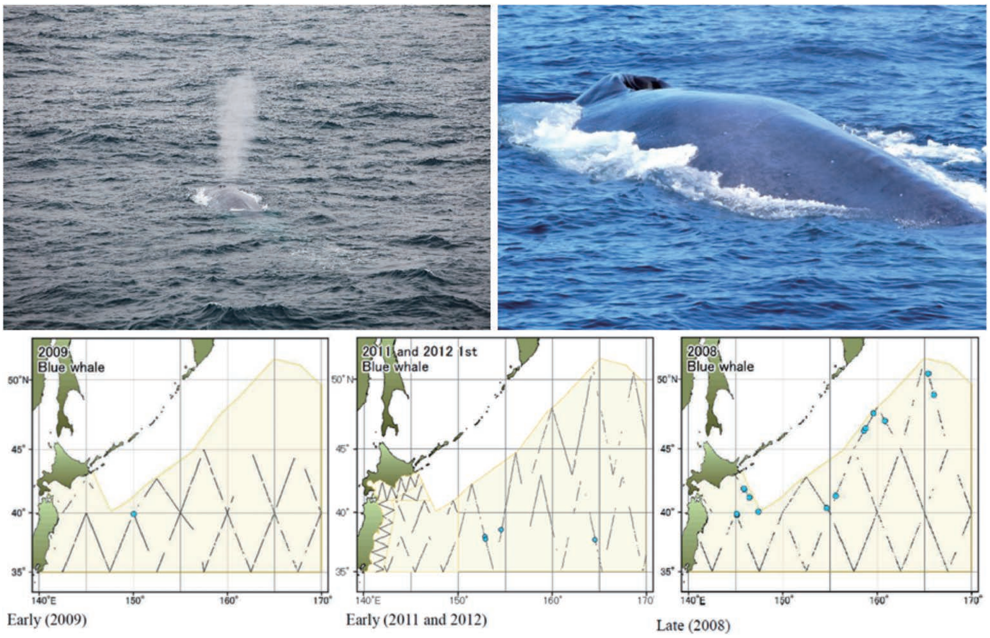

Figure 6. Blue whales observed during the surveys (top). Sighting positions of blue whales (blue circles) on the track lines, by survey period (bottom).

were more frequently sighted north of 40°N in the summer season (Figure 7), and the abundance was estimated at 3,958 animals (CV=0.425) in this season (Table 1).

Humpback whales

The main distribution area of humpback whales was north of 37°N from May to September (Matsuoka *et al.*, 2016). The highest density area was observed north of 35°N (west of 158°E) and north of 45°N (east of 158°E). They moved northward from 37°N to 43°N in the inshore area of Japan during May to June, and to further north of 45°N during July to August (Figure 8). The abundance estimates were 1,136 (CV=0.438) to 1,921 (CV=0.318) in the early seasons. Despite the surveys covering the entire western North Pacific in the summer season, sightings of this species were not frequent in this season (Table 1).

North Pacific right whales

During the survey programs, 48 schools (68 individuals) were observed north of 37°N from May to September (Matsuoka *et al.*, 2016) (Figure 9). The total abundance was estimated to be 1,147 animals (CV=0.434) based on the JARPNII data in the spring season of 2011/12 (Table 1).

Sei whales

The main distribution area of sei whales shifted northward during spring to summer seasons (Murase *et al.*, 2016; Figure 10). The abundance estimate in the summer season was higher than that in the spring season

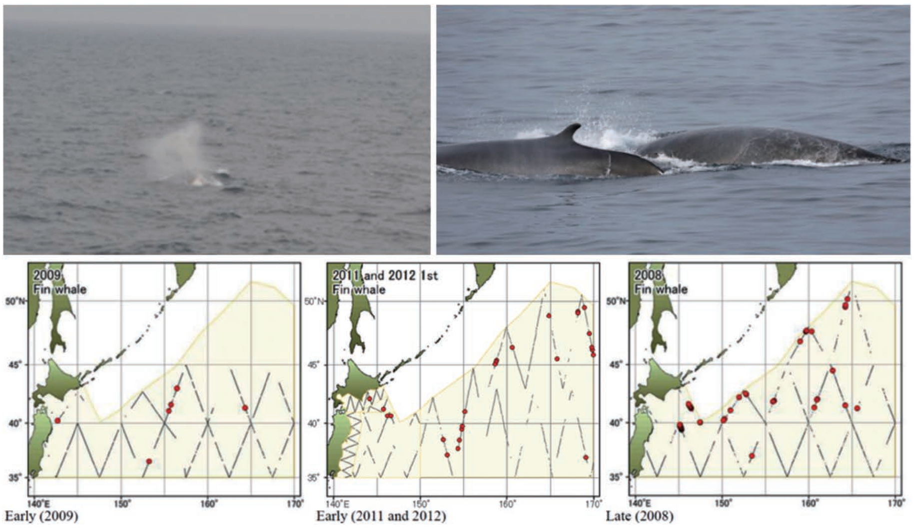

Figure 7. Fin whales observed during the surveys (top). Sighting positions of fin whales (red circles) on the track lines, by survey period (bottom).

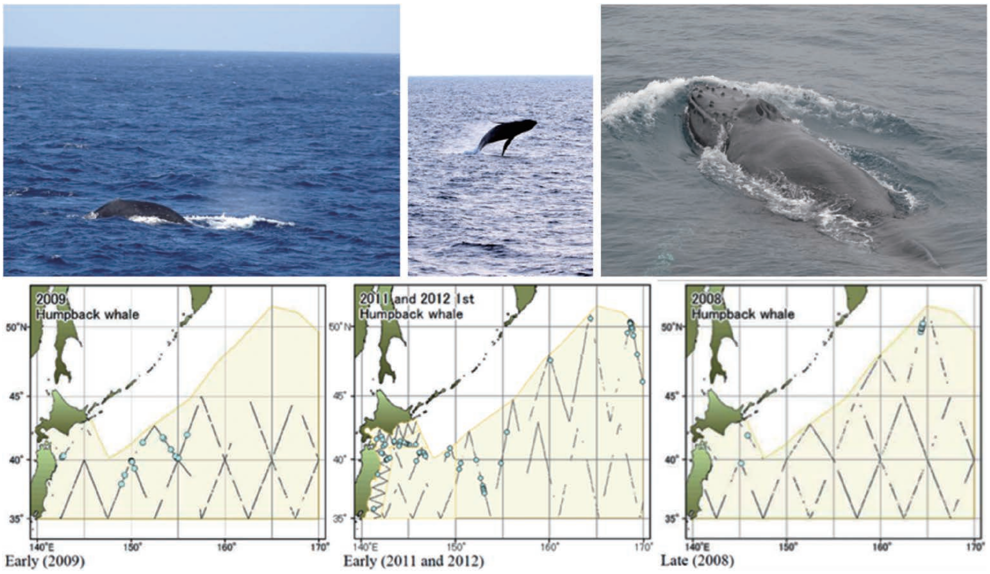

Figure 8. Humpback whales observed during the surveys (top). Sighting positions of humpback whales (light blue circles) on the track lines, by survey period (bottom).

(Table 1). The estimates should be considered as a part of the total stock number of this species (see Taguchi *et al.*, this issue).

Bryde′s whales

The main distribution of Bryde′s whale shifted northward during the spring to summer season (Hakamada *et al.*, 2009). Their distribution was in lower latitudes compared to other large baleen whale species (Figure 9). Table 1 shows the abundance estimates for Bryde′s whales in the spring and summer (July to September) seasons in this JARPNII area.

Common minke whales

Common minke whales are known to migrate further north of the JARPNII survey area through early season to late season (Hakamada *et al.*, 2009) (Figure 12). Common minke whales distribute primarily in the Sea of Okhotsk and in the waters east of the Kamchatka Peninsula and the Kuril Islands in August and September (Buckland *et al*, 1992; Miyashita, 2019). The estimated numbers distributed in the survey area were 3,629 (CV=0.586) and 2,122 (CV=0.371) in the spring season and 3,080 (CV=0.677) in the summer season (Table 1).

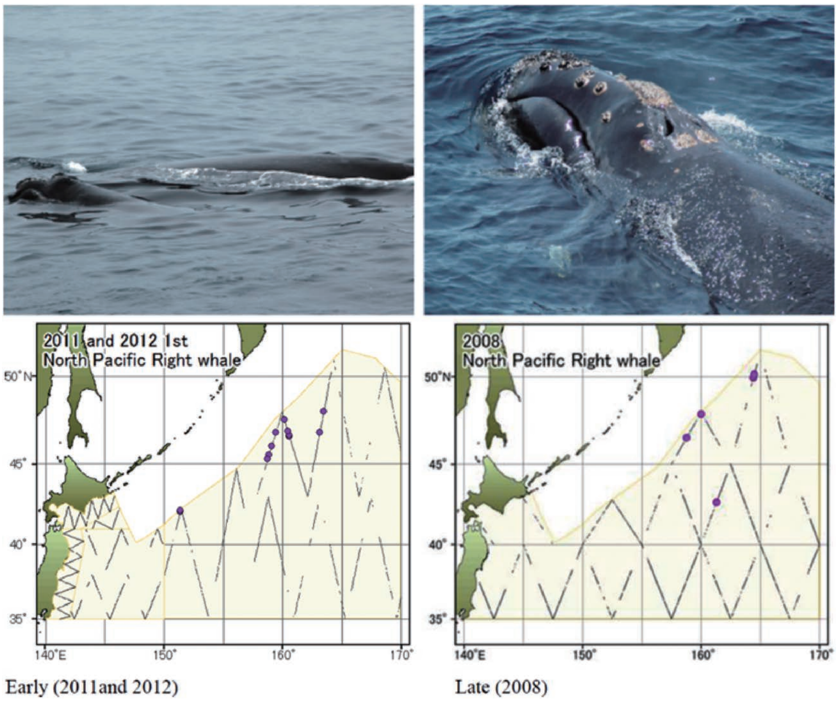

Figure 9. North Pacific right whales observed during the surveys (top). Sighting positions of North Pacific right whales (purple circles) on the track lines, by survey period (bottom).

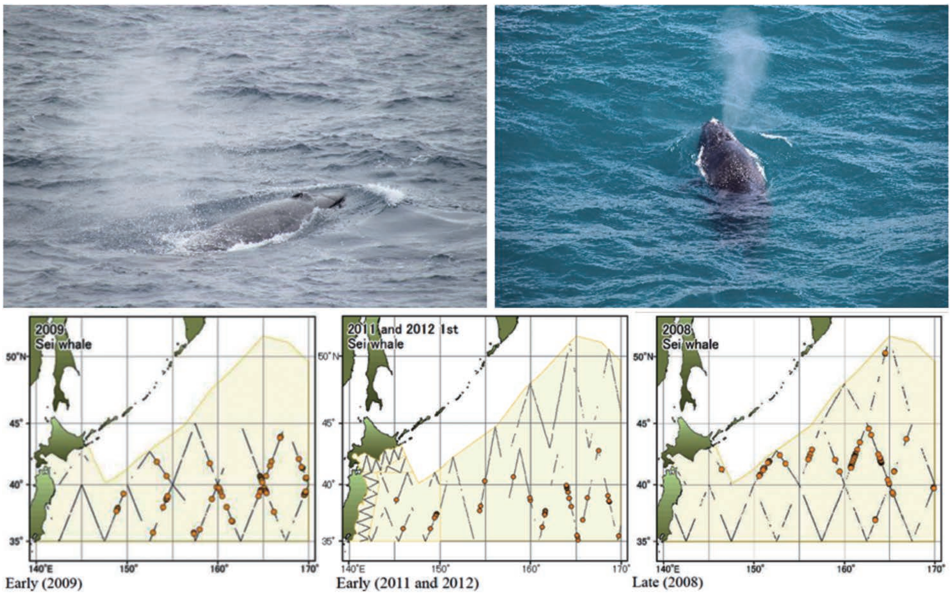

Figure 10. Sei whales observed during the surveys (top). Sighting positions of sei whales (orange circles) on the track lines, by survey period (bottom).

USE OF THE ABUNDANCE ESTIMATES FOR MANAGEMENT PURPOSES

Japan resumed commercial whaling of North Pacific sei, Bryde's and western North Pacific common minke whales in July 2019. Catch limits for each species were set in line with the RMP (IWC, 2012b). The core component of the RMP is the Catch Limit Algorithm (CLA) (Aldrin and Huseby, 2007; Aldrin *et al.*, 2008), which is a feedback control algorithm that sets baleen whale harvest levels based on catch histories and a time series of estimates of absolute abundance derived from sighting surveys. *Implementation Simulation Trials* (*ISTs*) are conducted to assess uncertainties for several parameters in the case of multi-stock scenarios.

Abundance estimates from ICR sighting surveys have been fundamental in the process of applying the CLA and *ISTs* to the three North Pacific baleen whale species.

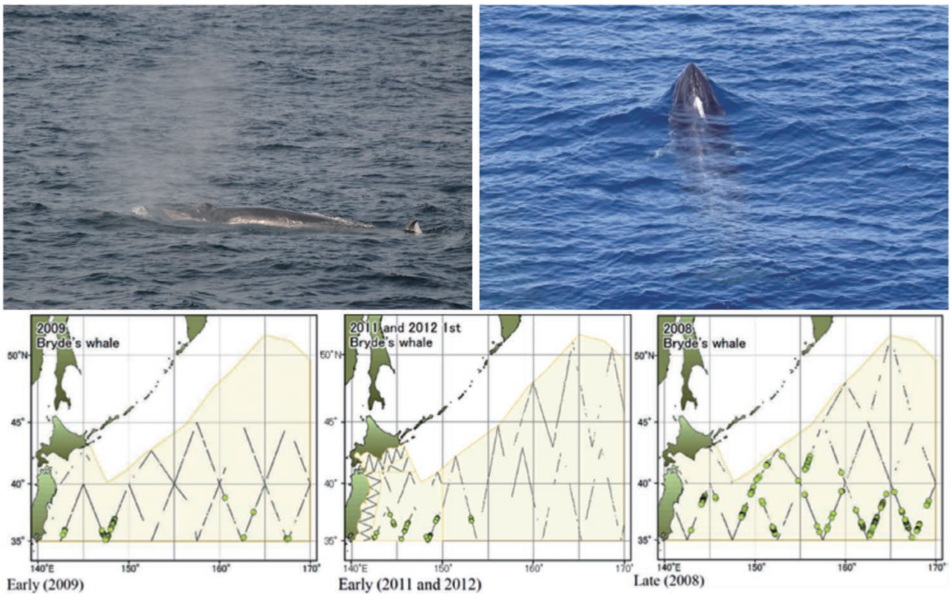

Figure 11. Bryde′s whales observed during the surveys (top). Sighting positions of Bryde′s whales (green circles) on the track lines, by survey period (bottom).

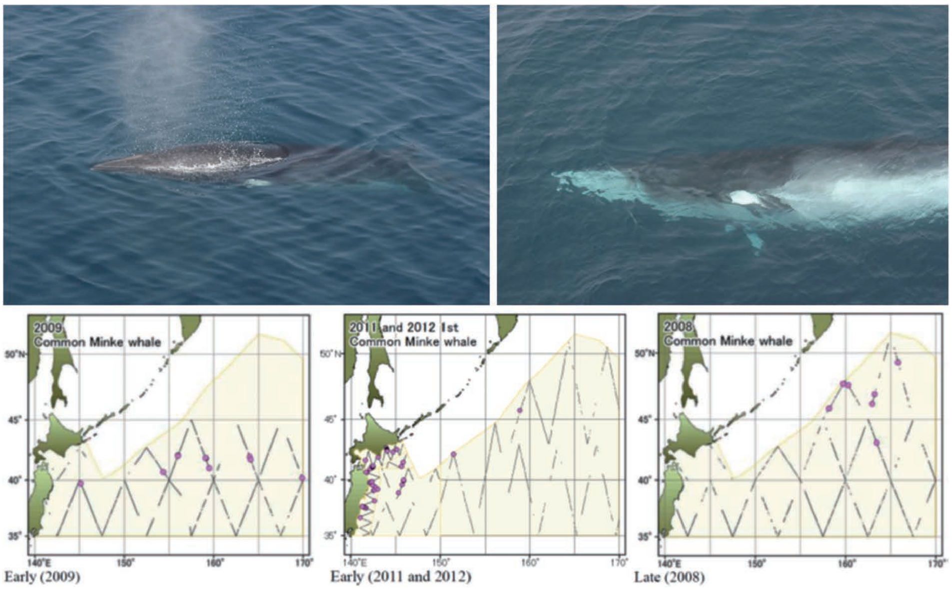

Figure 12. Common minke whales observed during the surveys (top). Sighting positions of common minke whales (purple circles) on the track lines, by survey period (bottom).

For species like the sei and Bryde′s whales, total stock abundances have been obtained by combining the ICR estimates in the western North Pacific with estimates from other surveys in the central and eastern North Pacific.

See details of the process for catch limit calculation in Japan′s RMP Team (2019).

FINAL REMARKS

The ICR has conducted sighting surveys for more than 25 years, in collaboration with other institutions, using a systematic survey procedure. The surveys revealed the distribution and abundance of several large baleen whale species in the western North Pacific Ocean. Moreover, abundance estimates from the ICR surveys contributed to the process for calculating catch limits for sustainable commercial whaling of sei, Bryde′s and common minke whales. There are several aspects that could improve the abundance estimates in the future. Among them are the estimates of *g*(0) for all species, evaluation of additional variance for multi-year surveys and the use of model-based approaches.

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