TEREP-ICR

TECHNICAL REPORTS OF THE INSTITUTE OF CETACEAN RESEARCH

No. 5

December 2021

TEREP-ICR is published annually by the Institute of Cetacean Research.
ISSN: 2433-6084

Citation

Entire issue:

Institute of Cetacean Research. 2021. *Technical Reports of the Institute of Cetacean Research (TEREP -ICR)* No. 5. The Institute of Cetacean Research, Tokyo, Japan, 94 pp.

Individual reports:

'Author Name'. 2021. 'Report title'. *Technical Reports of the Institute of Cetacean Research (TEREP-ICR)* No. 5: 'pp'-'pp'.

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Cover photo: A researcher operating a drone (Phantom 4 Pro DJI) during a dedicated sighting survey of whales in the Antarctic (top); checking the number of whales in a school of Antarctic minke whales from a drone (middle); view of the dorsal side of an Antarctic blue whale from a drone (bottom).

TECHNICAL REPORTS OF THE INSTITUTE OF CETACEAN RESEARCH

TEREP-ICR
No. 5

The Institute of Cetacean Research (ICR)
Tokyo, 2021

Foreword

It is a pleasure for me to introduce the fifth issue of the Technical Reports of the Institute of Cetacean Research (TEREP-ICR-5). Consistent with its stated objectives, TEREP-ICR describes and reports on the process, progress, and results of technical or scientific research, as well as the state of technical or scientific research programs conducted by the ICR, including those commenced recently as is the case of the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A).

The Covid-19 pandemic has markedly affected the ways of conducting scientific research at the ICR. Such consequences include field surveys, physical assistance to the office and laboratories, and the necessity for online domestic and international meetings. Despite such difficulties and inconveniences, and despite some limitations regarding international sighting surveys, the ICR has been able to safely and successfully conduct field surveys that were scheduled for 2021. In line with safety measures adopted by the government, ICR scientists combined working remotely from home and physically assisting laboratories, while engaging in online meetings with colleagues domestically and internationally. These efforts enabled the ICR to make progress on some priority and urgent works as well as advancing several research works during 2021 as shown in this issue of TEREP-ICR.

Similar to previous TEREP-ICR issues, TEREP-ICR-4 was widely distributed in Japan. However, distribution of the issue to foreign colleagues and institutions has not been possible due to Covid-19 pandemic restrictions. We do, however, plan to distribute TEREP-ICR-4 together with this issue (TEREP-ICR-5) to our international colleagues and institutions, if conditions allow for it. Notwithstanding the challenges imposed by the pandemic, TEREP-ICR is on course towards achieving its objectives. At the same time, it has been a good opportunity for our scientists to compile and summarize their research conducted over the years, as a precursor to submitting their works for peer review and publications.

I sincerely hope that this fifth issue of the TEREP-ICR will contribute further to an increased understanding among national and international scientific communities of the technical and research activities conducted by the ICR.

Dr. Yoshihiro Fujise
Director General
Institute of Cetacean Research
Tokyo, December 2021

Editorial

Welcome to the fifth issue of the Technical Reports of the Institute of Cetacean Research (TEREP-ICR-5).

This issue contains eight technical reports and one commentary article. In TEREP-ICR-5, we continue with the series of reports summarizing the research findings on whales and the ecosystem in the Indo-Pacific sector of the Antarctic.

This time, Pastene and colleagues focus on the studies on stock structure in large baleen whale species other than the Antarctic minke whale. These studies have been possible because the ICR holds one of largest collections of biopsy samples of baleen whales from the Antarctic region.

Results of three important dedicated sighting surveys are summarized in this issue: Isoda and colleagues summarize the results of the 2020/21 austral summer season survey of the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A); Katsumata and colleagues summarize the results of several surveys conducted in the North Pacific in 2019 and 2020; and Matsuoka and Murase summarize the results of the 2020 International Whaling Commission-Pacific Ocean Whale and Ecosystem Research (IWC-POWER) survey.

The basic concept of Density Surface Model (DSM) for estimating abundance of large whales is explained in a report by Hakamada.

Goto and colleagues summarize the biological and ecological knowledge acquired by ICR on the J stock common minke whales. Several biological and ecological studies of this stock have been possible by the genetic identification of individuals of this stock based on nuclear DNA markers.

Mogoe and colleagues report on the activities on stranding records by the ICR while Matsuoka and Yoshida outline the development and application of Unmanned Aerial Vehicles (UAVs) to the cetacean research by ICR.

In the commentary article, Pastene presents his view on the importance of international collaboration in the research of marine mammals, especially of baleen whale species.

TEREP-ICR-5 issue also include sections that outline the contribution of ICR scientists to international and national meetings in 2021, as well as their contribution in terms of peer-reviewed publications up to December 2021.

I trust that you will find this fifth issue informative and useful.

Dr. Luis A. Pastene
Editor, TEREP-ICR
Tokyo, December 2021

Contents

Technical Report (not peer reviewed)

What do we know about whales and ecosystem in the Indo-Pacific region of the Antarctic? Part 3: population genetic structure of large baleen whales other than Antarctic minke whales

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ABSTRACT

The Institute of Cetacean Research (ICR) conducted whale research under special scientific permit in the Antarctic starting from the austral summer season 1987/88. The research was conducted systematically under different research programs such as JARPA and JARPAII, and more recently, under NEWREP-A. These research programs employed both lethal and non-lethal methods. NEWREP-A ceased after the 2018/19 austral summer season as a consequence of Japan's decision to withdraw from the International Convention for the Regulation of Whaling. Japan's whale research continues in the Antarctic, using non-lethal methods only. This paper is a continuation of the series of reports on research contribution in the Antarctic by the ICR. This time, the topic is on stock structure of large baleen whale species other than Antarctic minke whales, in the Indo-Pacific sector of the Antarctic. Genetic analyses, which were based on the large biopsy sample collection of the ICR in the Antarctic, have provided important information on the stock structure and movement of baleen whales, including blue, fin, humpback and southern right whales in the Indo-Pacific sector.

INTRODUCTION

Japan conducted systematic research on whales and the Antarctic ecosystem for more than 30 years. The first research program was the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA), which was followed by JARPAII and subsequently by the New Scientific Whale Research Program in the Antarctic Ocean (NEWREP-A). The Institute of Cetacean Research (ICR) was the institution in charge of designing and implementing those research programs. Tamura *et al.* (2017) have provided details on the objectives, sampling and analytical methodology of the three research programs. Several international review workshops (e.g., IWC, 2015a) discussed and evaluated the large amount of data and results from these research programs.

As a consequence of Japan's change in whaling policy, the NEWREP-A ceased on 30 June 2019, the date of Japan's withdrawal from the International Convention for the Regulation of Whaling (ICRW). From the 2019/20 austral summer season, Japan started whale research in the Antarctic using non-lethal methods. The new research program is called the Japanese Abundance and Stock-structure Surveys in the Antarctic program (JASS-A) (see Isoda *et al.*, 2020).

At this point, it was considered important to summarize the knowledge on whales and the Antarctic ecosystem accumulated so far by Japan's whale research in the Antarctic. This paper is a continuation of the series of reports on research contribution in the Antarctic by the ICR. This time the topic is stock structure of large baleen whale species other than Antarctic minke whales, in the Indo-Pacific sector of the Antarctic. Genetic analyses have been possible based on the large biopsy sample collection of the ICR in the Antarctic, which is one of the largest in the world. Biopsy samples were obtained during the surveys of the JARPA/JARPAII and NEWREP-A but also during the surveys of the International Whaling Commission (IWC)'s International Decade for Cetacean Research (IDCR) and Southern Ocean Whale and Ecosystem Research (SOWER) programs.

This paper is not exhaustive of the information on stock structure in Antarctic large whales. More detailed results will be presented by species in future issues of TEREP-ICR.

COLLECTION OF GENETIC SAMPLES

Biopsy sampling systems

Genetic analyses have been carried out based on biopsy samples collected by different biopsy sampling systems during systematic sighting surveys. These systems, which

Table 1

Number of biopsy samples collected by the Institute of Cetacean Research in the Indo-Pacific sector of the Antarctic between 1993/94 and 2014/15 during JARPA and JARPAII surveys.

Season	Blue				Fin				Humpback				Southern right			A. minke			Total
	III	IV	V	VI	III	IV	V	VI	III	IV	V	VI	III	IV	V	III	IV	V	
1993/94	-	-	4	-	-	-	-	-	-	20	-	-	-	5	-	-	-	-	29
1994/95	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	8	20
1995/96	1	-	-	-	-	-	-	-	2	8	-	-	-	1	-	-	-	-	12
1996/97	-	-	-	1	-	-	-	-	-	-	5	15	-	-	-	-	-	-	21
1997/98	-	1	-	-	-	-	-	-	5	19	-	-	-	4	-	1	-	-	30
1998/99	-	-	2	-	-	-	3	-	-	-	22	1	-	-	-	-	-	-	28
1999/00	1	3	-	-	-	-	-	-	10	32	-	-	-	3	-	-	10	-	59
2000/01	-	-	3	-	-	-	9	-	-	-	14	22	-	-	-	-	-	-	48
2001/02	-	1	-	-	-	4	-	-	12	14	-	-	2	14	-	-	-	-	47
2002/03	-	-	-	-	-	-	6	-	-	-	10	-	-	-	2	-	-	1	19
2003/04	2	3	-	-	4	-	-	-	27	31	-	-	-	4	-	-	-	-	71
2004/05	-	-	-	-	-	-	-	2	-	-	28	8	-	-	1	-	-	-	39
2005/06	-	5	-	-	-	9	-	-	1	6	-	-	-	15	-	-	-	-	36
2006/06	-	-	1	1	-	-	3	-	-	-	11	2	-	-	-	-	-	-	18
2007/08	4	2	-	-	-	-	-	-	1	3	-	-	-	16	2	-	-	-	28
2008/09	-	-	-	-	-	-	-	-	-	-	13	1	-	-	-	-	-	-	14
2009/10	-	-	-	-	1	-	-	-	12	26	38	-	-	1	-	-	-	-	78
2011/12	-	-	-	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	4
2012/13	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	3
2014/15	-	3	-	-	-	9	-	-	-	10	-	-	-	39	-	-	-	-	61
Total	8	18	10	2	5	22	21	2	73	169	154	49	2	102	8	1	10	9	665

Figure 1. Biopsy sampling using the Larsen system (left) and a biopsy sample from a blue whale (right).

will be described in details in future TEREP-ICR issues, include the ICR air gun system (Kasamatsu *et al.*, 1991) used between 1992/93 and 2001/02, a crossbow system used between 2002/03 and 2013/14, and a Larsen system (Larsen, 1998) (Figure 1) used from 2014/15 to the present day.

Number of biopsy samples

Surveys conducted by the ICR in the Indo-Pacific sector of the Antarctic collected a total of 665 biopsy samples between 1993/94 and 2014/15, 38 from Antarctic blue whales, 50 from fin whales, 445 from humpback whales, 112 from southern right whales, and 20 from Antarctic minke whales (Table 1). All samples collected were preserved onboard at −20°C until they were used at the ICR genetic laboratory. An example of biopsy sample is shown in Figure 1.

OUTLINE OF THE LABORATORY WORK

The laboratory work for genetic analyses in all case studies involved the following steps: extractions of total genomic DNA, molecular sex determination, sequencing of a portion of the mitochondrial DNA (mtDNA) control region and genotyping with a set of microsatellite DNA (msDNA) loci. Technical details of the laboratory work can be found in Pastene and Goto (2016). A brief summary is presented here based on that study.

Sampled skin tissues were preserved frozen at −20°C until use. Total genomic DNA was extracted from 0.05 g of skin tissue using either the standard phenol-chloroform method or the Gentra Puregene kits (QIAGEN). Extracted DNA was stored in TE buffer (10 mM Tris-HCl, 1 mM EDTA, pH 8.0).

The SRY locus located on the Y chromosome was also used for sex determination following the method of Abe *et al.* (2001) with a slight modification. With the combination of loci of SRY and a microsatellite locus as a positive control, males show amplified products of both SRY and a microsatellite locus, while females show only a microsatellite locus.

An approximate 500 base pairs (bp) of the mtDNA control region were amplified by the polymerase chain reaction (PCR) using a set of primers available at the ICR. PCR products were purified using MicroSpin S-400HR columns (Pharmacia Biotech). Cycle sequencing was performed using BigDye terminator cycle sequence Kit (Applied Biosystems) and the PCR primers, following the protocols of the manufacturer. The cycle sequencing products were purified using AutoSeq G-50 spin Columns (Pharmacia Biotech). The labeled sequencing fragments were resolved using an ABI PRISM 377 or an ABI3500 Genetic Analyzers (Applied Biosystems) (Figure 2).

The samples were also genotyped at a number of msDNA loci, which varies between 14 and 17 depending on the species, in multiplex fluorescent PCRs. PCR products were electrophoresed on an ABI3500 DNA Analyzer (Applied Biosystems) (Figure 2), and allele sizes were determined using a 600 LIZ size standard (Applied Biosystems) and GeneMapper v. 4.0 (Applied Biosystems).

ANALYTICAL PROCEDURES

The analytical procedures for genetic analyses on stock structure are those used routinely in these kinds of studies, and they are mentioned briefly below, together with the progress in research.

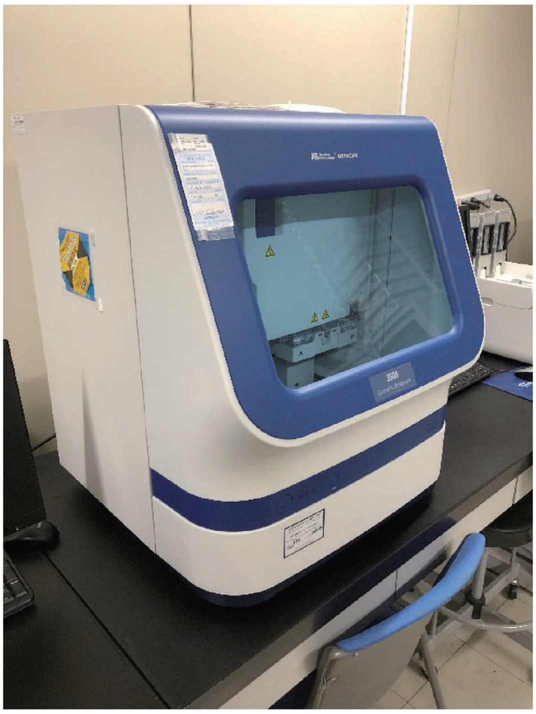

Figure 2. ABI3500 DNA Analyzer (Applied Biosystems) available at the ICR genetic laboratory.

PROGRESS IN RESEARCH

The summary of research progress on stock structure for some large whale species below are based on Pastene (in press).

Blue whales

ICR scientists have collaborated with foreign scientists in the study of population genetics of blue whales.

One example is the genetic study by LeDuc *et al.* (2007), who used samples from the Antarctic (n=30 from IDCR/SOWER cruises and n=17 from JARPA), Chile (n=16 from IDCR/ SOWER), the southern and western coasts of Australia (n=28 from IDCR/SOWER), around the Maldives (n=6 from IDCR/SOWER) and Peruvian and Ecuadorian waters (n=12 from US SWFSC research cruises). Analysis focused on investigating the pattern of genetic variation in Southern Hemisphere blue whales and the use of an assignment test to detect mixing on the feeding grounds. Genetic markers used were mtDNA control region sequences and seven microsatellite loci. Strong genetic differences were found among samples from the southeast Pacific Ocean, Indian Ocean and around the Antarctic continent. Genetic differentiation between the geographical ranges of the nominal sub-species (i.e., Antarctic vs pygmy blues in the Pacific and Indian Oceans) was not markedly greater than between populations of pygmy blue whales.

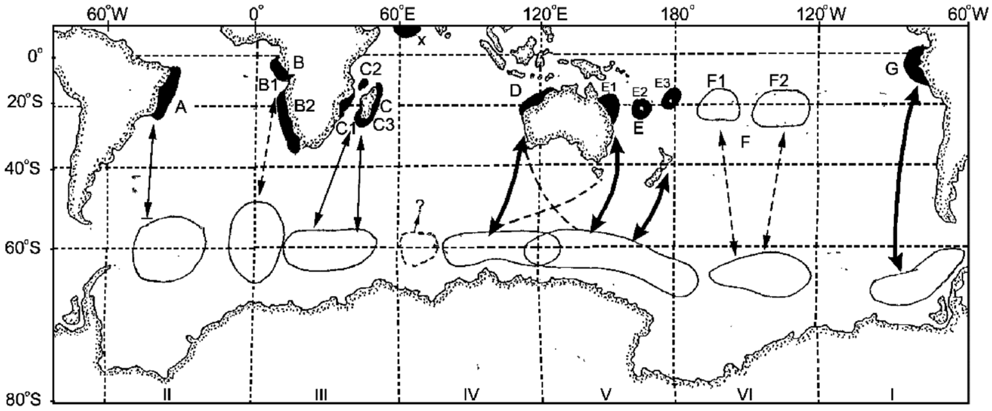

Figure 3. Hypothetical stock structure for Southern Hemisphere humpback whales. The areas and sub-areas identified reflect approximate, rather than necessarily exact, boundaries. A dotted line represents hypothetical connection, thin lines represent a small number of documented connections between areas while thick lines represent a large number of documented connections between areas (from IWC, 2005).

Fin whales

Genetic analyses on stock structure of fin whales in the Antarctic feeding grounds are very scarce. One of the few studies was conducted by Goto and Taguchi (2019).

These authors examined population genetic structure in IWC Management Areas III, IV, V and VIW based on mtDNA control region sequences (478 bp) and sixteen microsatellite loci. The analysis was based on biopsy samples collected by the JARPA and IDCR/SOWER cruises, and samples from takes during JARPAII. The analyses were conducted on the basis of three arbitrary sectors: POP1 (0°–70°E, n=39), POP2 (70°E–160°E, n=48) and POP3 (160°E–145°W, n=18). The study showed a high mtDNA diversity, which was comparable among groups. Genetic analyses based on heterogeneity test (mtDNA and msDNA) and STRUCTURE, PCA and test for Hardy Weinberg deviation (msDNA) failed to find evidences of stock structure in the research area. A phylogenetic analysis based on mtDNA haplotype showed no relationship between clusters and particular geographical group. The authors noted that the sample sizes were small and that the results could be due to a low power of the statistical analyses.

Humpback whales

The IWC Scientific Committee (SC) has described hypothetical stock structure and migratory corridors for Southern Hemisphere humpback whales based mainly on information such as Discovery marks, photo-identification, genetics and satellite tracks (IWC, 2005). Seven Breeding Stocks (BS) are recognised, 'A'–'G.' Some ('B,' 'C,' 'E' and 'F') were further subdivided into sub-stocks (Figure 3). The IWC SC completed the assessment of most stocks at its 2014 meeting (IWC, 2015b). For the assessment, the information on stock structure summarised below contributed to the interpretation of stock abundance and trend as well as for allocating historical catches to the various stocks.

Pastene *et al.* (2006) examined the population genetic structure in IWC Management Areas IIIE, IV, V and VI based on mtDNA control region sequences and six microsatellite loci. The analysis was based on biopsy samples collected by the JARPA and IDCR/SOWER cruises, namely: n=81 for Area IIIE (JARPA: 50; IDCR/SOWER: 31); n=172 for Area IV (JARPA: 126; IDCR/SOWER: 46); n=97 for Area V (JARPA: 90; IDCR/SOWER: 7); and n=61 for Area VI (JARPA: 44; IDCR/SOWER: 17). The analysis confirmed the high level of genetic diversity for both mtDNA and microsatellites. Both genetic markers suggested differentiation among these four Areas, with the differences being stronger for females than males. The authors did not reject the possibility of some mixing of populations on the borders of the Management Areas.

Kanda *et al.* (2014) examined the population genetic structure in IWC Management Areas IIIE, IV, V and VI based on genotypes from 14 microsatellite loci. The analysis was based on JARPA and IDCR/SOWER cruise samples: n=93 for Area IIIE (JARPA: 62; IDCR/SOWER: 31); n=218 for Area IV (JARPA: 172; IDCR/SOWER: 46); n=153 for Area V (JARPA: 146; IDCR/SOWER: 7); n=64 for Area VI (JARPA: 47; IDCR/SOWER: 17). Major genetic differences were attributed to samples from different Areas. Stronger differentiation was seen in females than in males. Despite the increase of the number of loci from six in the previous analysis to 14, the level of stock differentiation was still too low for analysis at the individual level.

Pastene *et al.* (2013) used biopsy samples obtained by JARPA/JARPAII and IDCR/SOWER surveys and mtDNA

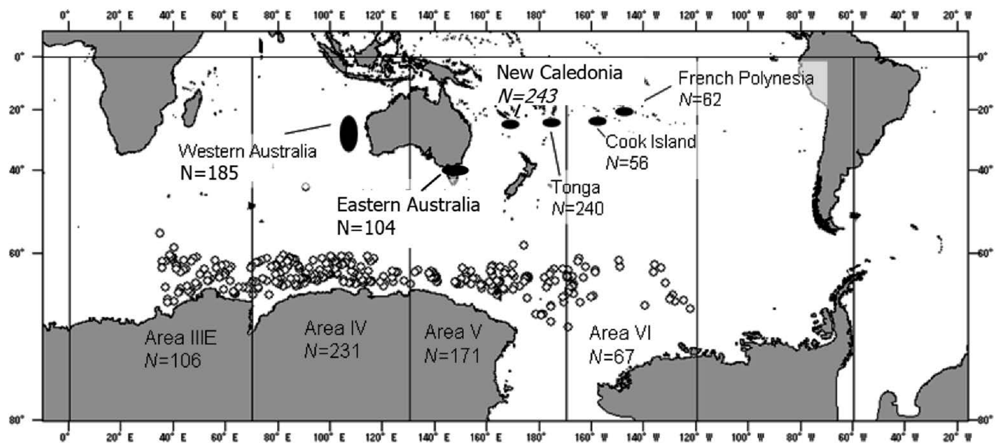

Figure 4. Geographical distribution of humpback whale samples from breeding and feeding grounds analyzed in Pastene *et al.* (2013).

control region sequences to study the distribution and mixing rates of breeding stocks BSD, BSE and BSF in Antarctic Areas IIIE–VI (Figure 4). Breeding ground samples were from Western Australia (*n*=185), Eastern Australia (*n*=104), New Caledonia (*n*=243), Tonga (*n*=240), Cook Islands (*n*=56) and French Polynesia (*n*=62). They were collected by several groups and research institutions and were provided for analysis under the IWC SC Data Availability Protocol. JARPA and IDCR/SOWER survey samples were provided as outlined above (Pastene *et al.*, 2006). According to one of the hypotheses on baseline populations, Western Australian whales were distributed mainly in Management Areas IVW (84.5% SE: 0.043; F_{ST}: 0.0015) and IVE (75.9% SE: 0.092; F_{ST}: −0.0015); whales from Eastern Australia in Area VW (64.7% SE: 0.074; F_{ST}: 0.0013); whales from New Caledonia in Area VE (83.9% SE: 0.011; F_{ST}: 0.0062), and whales from Tonga in Area VI (43.3% SE: 0.015; F_{ST}: 0.0010). Whales from Cook Islands and French Polynesia were not represented on feeding ground Areas IIIE–VI.

Southern right whales

Two genetic studies based on biopsy samples collected by the ICR have been conducted (Pastene *et al.*, 2018; *in-press*). These studies were based on 157 biopsy samples collected mainly in the Indian sector of the Antarctic. Both mtDNA control region sequencing (381 bp) and msDNA at 14 loci were used in the analyses. The mtDNA analysis suggested that whales in the Antarctic Indian sector in summer are closely related to the South West Australian breeding grounds (Pastene *et al.*, 2018). The msDNA revealed eight individual matches (four males and four females), which demonstrated that at least some males and females returned to the same feeding grounds over the years (Pastene *et al.*, in press). The matching occurred in an area where visual surveys showed aggregations of whales associated with high krill concentrations.

SUMMARY

The ICR, through its former whale research programs in the Antarctic (JARPA, JARPAII), collected a large number of biopsy samples from different baleen whale species. In fact, the set of biopsy samples from the Antarctic held by the ICR is the largest in the world. These samples were used in genetic analyses on phylogeny, stock structure and individual matching in some baleen whale species that are key components of the Antarctic ecosystem. Results of these analyses have been important for the assessment of these species conducted by the IWC SC. In the case of blue whales, the analyses contributed to understand the genetic differentiation between Antarctic and pygmy blue whales. The ICR started the genetic analysis of fin whales in the Antarctic feeding grounds. However it seems that the sample sizes are still small to allow the detection of stocks. The genetic analyses of biopsy samples of humpback whales contributed to understand the genetic diversity and degree of differentiation of the species in the feeding grounds of Areas IIIE-VI and the relationship between breeding and feeding grounds of several stocks. At least four stocks were confirmed in the Indo-Pacific sector of the Antarctic, which mix spatially in some sectors. In the case of southern right whales, genetic analysis suggested that whales in the Indo-Pacific sector of the Antarctic belong to the same stock as Western South Australia and that some whales return to the same feeding grounds over the years. More refined analyses will be conducted on these species with additional biopsy samples collected by NEWREP-A and the ongoing JASS-A program.

ACKNOWLEDGEMENTS

We thank the captain, crew members and researchers involved in the surveys of JARPA, JARPAII and IDCR/SOWER for their effort in collecting biopsy samples from different baleen whale species. The genetic analyses on stock structure summarized in this paper are based on those samples.

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Technical Report (not peer reviewed)

Results of the dedicated sighting survey under the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A) in the western part of Area III in the 2020/21 austral summer season

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ABSTRACT

The results of the sighting survey of the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A) in the 2020/21 austral summer season are reported. A dedicated sighting vessel was engaged in the line transect method survey in the eastern part of Antarctic Area III West (015°E–035°E) for 28 days, from 10 January to 6 February 2021. The total searching distance in the research area was 1,744.3 n.miles (3,230.4 km). Four baleen whale species and at least three toothed whale species were sighted in the research area. Other research activities such as biopsy sampling, photo-ID, satellite tagging and oceanographic observations were also conducted. The Antarctic Area III West (000°–035°E) was covered during the 2019/20 and 2020/21 JASS-A surveys.

INTRODUCTION

Long-term systematic surveys on whales and the ecosystem in the Antarctic such as the JARPA/JARPAII[1], NEWREP-A[2], and IDCR/SOWER[3] obtained important data to study the abundance and abundance trends of large whales as well the biology and role of whales in the Antarctic ecosystem. All these research programs have been terminated. The last NEWREP-A survey was carried out in the 2018/19 austral summer season.

The Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A) commenced in the 2019/20 austral summer season because it was considered important to continue with the whale and ecosystem surveys in the Indo-Pacific region of the Antarctic through dedicated sighting surveys and other non-lethal research techniques. JASS-A has two main research objectives, i) the study of the abundance and abundance trends of large whale species, and ii) the study of the distribution, movement and stock structure of large whale species. JASS-A also has several secondary research objectives related to oceanography, marine debris, whale biology, and study on the utility of Unmanned Aerial Vehicle (UAV). The JASS-A program was presented to the 2019 meeting of IWC SC[4] (GOJ, 2019a), the 2019 meeting of CCAMLR-EMM[5] (GOJ, 2019b), and the 2019 meeting of NAMMCO SC[6] (GOJ, 2019c).

The approach of JASS-A is systematic vessel-based sighting surveys utilizing the ʻline transect methodʼ. Surveys are designed and conducted following the protocols included in the ʻRequirements and Guidelines for Conducting Surveys and Analysing Data within the Revised Management Schemeʼ (IWC, 2012). Sighting protocols are the same as those used in the former IDCR/SOWER surveys (Matsuoka *et al.*, 2003). The JASS-A surveys are conducted alternatively in IWC Management Areas III, IV, V and VI by one or two specialized vessels, during a tentative period of eight austral summer seasons.

The first JASS-A survey was carried out in the 2019/20 austral summer season and covered the sector 000°–015°E of Area III. The second survey was carried out during the 2020/21 season and covered the sector 015°E–035°E of this Area. This paper presents a summary of the results of the 2020/21 JASS-A survey.

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[1] Japanese Whale Research Programs under Special Permit in the Antarctic, Phases I and II
[2] New Scientific Whale Research Program in the Antarctic Ocean
[3] International Decade for Cetacean Research/Southern Ocean Whale and Ecosystem Research
[4] International Whaling Commission-Scientific Committee
[5] Commission for the Conservation of Antarctic Marine Living Resources-Working Group on Ecosystem Monitoring and Management
[6] North Atlantic Marine Mammal Commission-Scientific Committee

SURVEY DESIGN

Research area

The research area of JASS-A is comprised by IWC Management Areas III, IV, V and VI, south of 60°S (Figure 1). The research area in the 2020/21 season covered by the survey was the eastern part of Antarctic Area III West (015°E–035°E), south of 60°S (Figure 1). The area was divided into northern and southern strata based on a line 45 n.miles from the ice-edge (Figure 2). In the northern and southern strata, the survey track lines consisted of a zigzag course changing direction at 5°00′ and 2°30′ longitudinal degree intervals in a 10 degrees longitudinal band, respectively (Figure 2). The starting point in this survey followed the last longitudinal point of the 2019/20 JASS-A survey (000°–015°E).

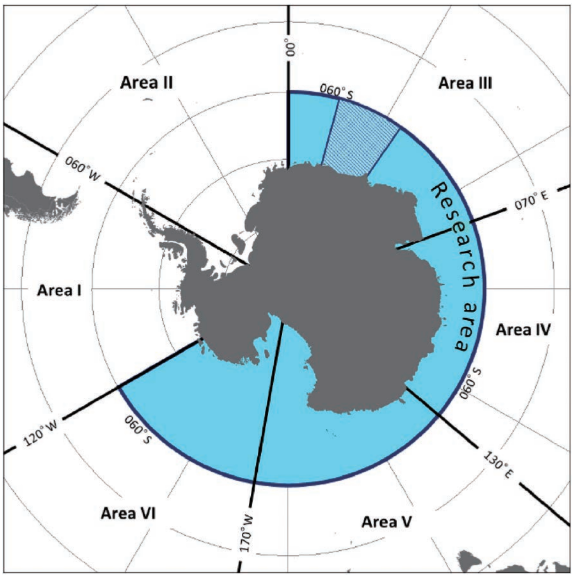

Figure 1. Research area of JASS-A. The shaded area (015°E–035°E) indicates the surveyed area in the 2020/21 austral summer season.

Research vessel

The dedicated sighting vessel *Yushin-Maru* No. 2 (*YS2*) was engaged in the survey. Its specifications are: gross tonnage 747GT, total length 69.6 m, top barrel platform (TOP) 19.5 m, Independent Observer Platform (IOP) 13.5 m, and upper bridge platform (UBP) 11.5 m (Figure 3). Three Japanese researchers participating in the survey had experience in conducting line transect surveys, biopsy sampling, photo-identification (photo-ID), satellite tagging, and oceanographic survey in the Antarctic through the previous JARPA/JARPAII and NEWREP-A programs.

Sighting procedures and mode

The sighting survey was conducted using (1) Passing with abeam Closing mode (NSP) and (2) Passing with Independent Observer (IO) mode. For NSP mode, there were two primary observers on the TOP. For IO mode, there were two primary observers on the TOP and one primary observer on

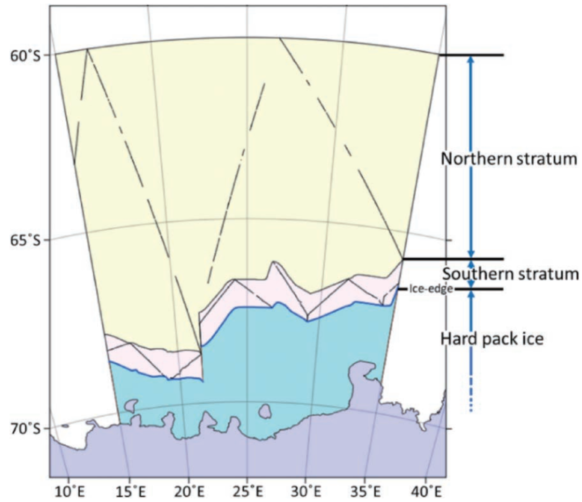

Figure 2. Research area (015°E–035°E) and searching efforts of the JASS-A survey in 2020/21. The research commenced at 60°00′S; 026°41′E and ended at 68°17′S; 015°00′E.

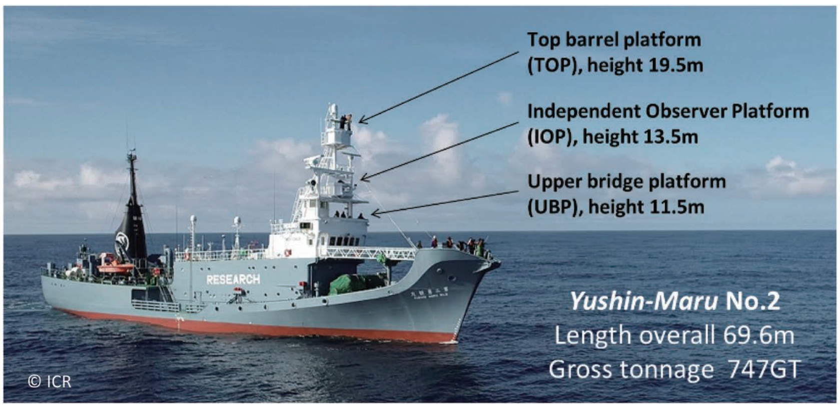

Figure 3. The dedicated sighting vessel *Yushin-Maru* No. 2 and its equipped three platforms.

the IOP. There was no open communication between the IOP and the TOP. Two primary observers were at the UBP, regardless of the research mode. The observers conducted searching for cetaceans by using angle board and binoculars with reticles (7x), which include the distance estimate scales. Sighting-information by these TOP and IOP observers was reported to researchers and observers on the UBP for data recording and tracking of cetaceans.

Sighting activities were classified into two principal types: 'On-effort' and 'Off-effort'. On-effort activities were times when full search effort was being executed and conditions (such as weather and sea state) were within acceptable conditions to conduct research. Off-effort activities were all activities that were not On-effort. All sightings recorded while the vessel was On-effort were classified as 'Primary sightings', and all other sightings were classified as 'Secondary sightings'.

Guidelines for species identification and determining group size were the same as those used during the IWC-SOWER surveys (Anon, 2008).

For details of the procedures used for sighting surveys and other research activities such as sighting distance and angle experiment, photo-ID, biopsy sampling, satellite tagging, oceanographic survey, marine debris observation, and survey using UAV see Isoda *et al.* (2021).

RESULTS OF THE SURVEY

Narrative of the survey

Table 1 shows the itinerary of the survey. The duration of this cruise was 109 days. The *YS2* departed Shiogama, Japan on 4 December 2020 arriving in Maputo, Republic of Mozambique on 2 January 2021. The *YS2* started the sighting survey in Antarctic Area III West at 60°00'S; 026°41'E on 10 January. The survey was completed at 68°17'S; 015°00'E on 6 February. The *YS2* arrived back in Maputo on 20 February and Japan on 22 March.

Research effort in the research area

Table 2 shows a summary of the effort spent during the survey. The *YS2* was engaged in the research for 28 days, from 10 January to 6 February 2021. The total searching effort was 1,744.3 n.miles (3,230.4 km); 887.3 n.miles in NSP mode for 84 hours 59 minutes and 857.0 n.miles in IO mode for 83 hours 27 minutes. In the northern stratum, the total searching effort was 1,097.7 n.miles (NSP: 528.3 n.miles; IO: 569.4 n.miles), and the searching effort coverage was 68%. In the southern stratum, the total searching effort was 646.6 n.miles (NSP: 359.0 n.miles; IO: 287.6 n.miles), and the searching effort coverage was 90%. Therefore, a good distribution of effort within both strata and survey mode was achieved. The total experimental time for photo-ID, biopsy sampling, tagging and distance and angle experiment was 31 hours 41 minutes.

Whale sightings in the research area

Four baleen whale species and at least three toothed whale species were sighted in the research area. The dominant whale species in the research area was the humpback whale (359 schools/697 individuals) followed by the fin whale (136/228). Sightings of other species were as follows; Antarctic minke whale (51/120), Antarctic blue whale (24/29), sperm whale (6/6), killer whale (4/13), southern bottlenose whale (6/16), and Ziphiidae (10/16) (Table 3).

Antarctic blue whales

Blue whales were found more frequently in the southern stratum (Figure 4) as found in previous surveys (Ensor *et al.*, 2005; Isoda *et al.*, 2020). Nine schools (13 individuals) were sighted in the vicinity of 67°10'S; 030°10'E.

Table 1
Narrative of the 2020/21 JASS-A dedicated sighting survey.

Date (y/m/d)	Event
2020/11/20	Planning meeting at Tokyo, Japan
2020/12/03	Pre-cruise meeting at Shiogama, Japan
2020/12/04	*YS2* departed Shiogama, Japan
2020/12/20	Transit survey started at 10°11'S; 089°26'E
2021/01/02	*YS2* arrive in Maputo, Mozambique
2021/01/10	Transit survey finished and survey started in the research area at 60°00'S; 026°41'E
2021/02/06	Survey completed in the research area (28 days) and transit survey start at 68°17'S; 015°00'E
2021/02/20	*YS2* arrive in Maputo, Mozambique
2021/03/04	Transit survey completed at 10°30'S; 085°20'E
2021/03/22	*YS2* arrived in Japan and post cruise meeting carried out in Shiogama, Japan

Table 2
Summary of searching effort (time and distance) and time (hours) spent during the 2020/21 JASS-A survey.

Survey Sections	Date and time		Searching effort (distance [n.miles] and time [hours:minutes])				Experiments time	
	Start	End	NSP		IO		Photo-ID, Biopsy, tagging experiment	Estimated angle and distance training/ experiment
Transit survey (10°S-Entering MZ EEZ)	2020/12/20 06:10	2020/12/31 17:20	519.7	45:03	—	—	00:29	—
Transit survey (Leaving SA EEZ-60°S)	2021/01/04 12:00	2021/01/10 08:30	283.0	24:17	—	—	00:33	—
Research area (Area IIIW 015°E-035°E)	2021/01/10 08:47	2021/02/06 14:30	887.3	84:59	857.0	83:27	25:08	06:33
Transit survey (015°E-Entering SA EEZ)	2021/02/06 14:30	2021/02/17 11:51	474.8	41:38	—	—	04:17	—
Transit survey (Leaving MZ EEZ-10°S)	2021/02/22 11:32	2021/03/04 16:35	593.4	50:02	—	—	—	—
Total	2020/12/20 06:10	2021/03/04 16:35	2,758.2	245:59	857.0	83:27	30:27	06:33

Table 3
Number of sightings in the research area, by stratum and species.

Species	Eastern part of Area IIIW (015°E–035°E)								Sub-total				Total	
	Southern stratum				Northern stratum									
	Primary		Secondary		Primary		Secondary		Primary		Secondary			
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Antarctic blue whale	21	25	1	1	2	3	0	0	23	28	1	1	24	29
Fin whale	14	17	0	0	117	201	5	10	131	218	5	10	136	228
Like fin	0	0	0	0	2	2	0	0	2	2	0	0	2	2
Antarctic minke whale	23	42	12	57	13	18	3	3	36	60	15	60	51	120
Like minke	0	0	0	0	1	1	0	0	1	1	0	0	1	1
Humpback whale	96	128	4	7	256	559	3	3	352	687	7	10	359	697
Like humpback	0	0	0	0	1	1	0	0	1	1	0	0	1	1
Baleen whales	4	4	0	0	4	4	0	0	8	8	0	0	8	8
Sperm whale	1	1	0	0	5	5	0	0	6	6	0	0	6	6
Killer whale (Undetermined ecotypes)	2	7	0	0	2	6	0	0	4	13	0	0	4	13
Southern bottlenose whale	0	0	0	0	6	16	0	0	6	16	0	0	6	16
Ziphiidae	2	2	0	0	8	14	0	0	10	16	0	0	10	16
Unidentified whales	2	2	1	1	4	4	0	0	6	6	1	1	7	7

Fin whales

Fin whales were mainly distributed in the northern stratum (Figure 4). In a previous survey, this species was hardly observed in this area (Ensor *et al.*, 2005). This difference could be due to an increase in the abundance of this species, as suggested previously (Matsuoka and Hakamada, 2014).

Antarctic minke whales

Antarctic minke whales were mainly sighted in the western part of the research area, in the southern stratum (near the ice-edge). They were infrequently sighted in the southern stratum in the eastern part of the research area and in the northern stratum (Figure 4). In previous surveys, this species was more frequently sighted in the

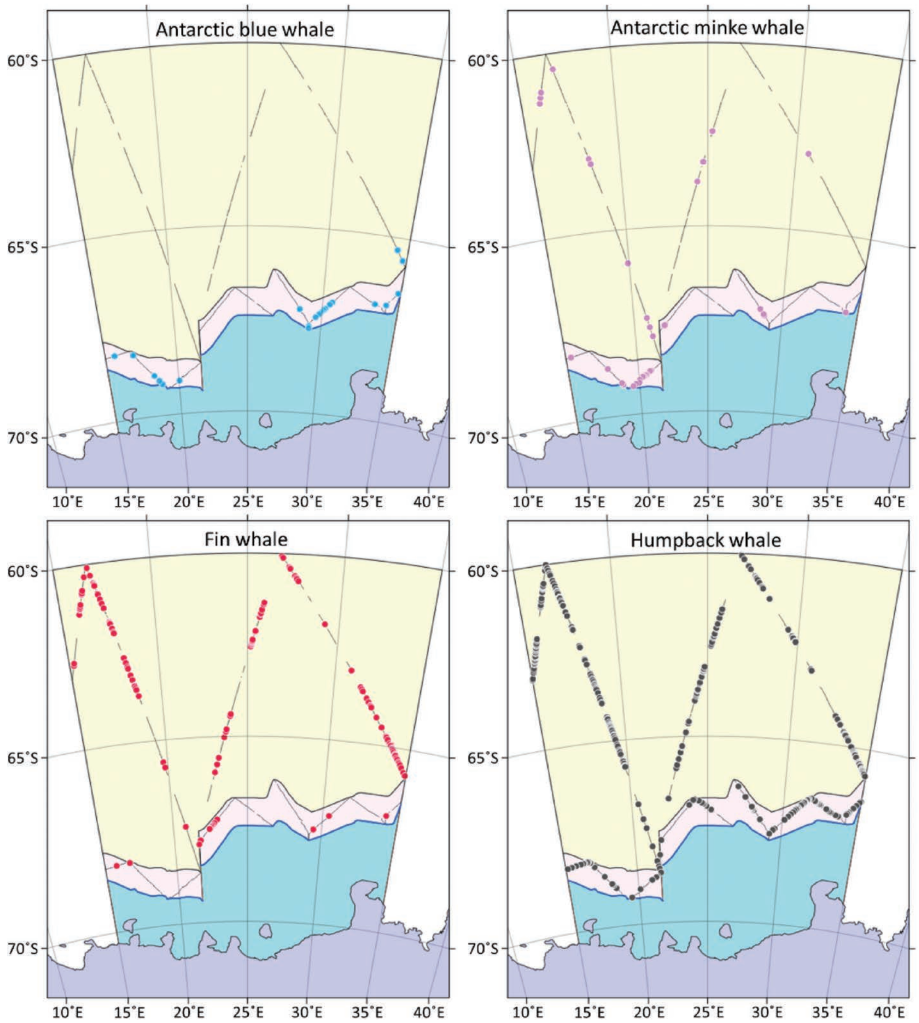

Figure 4. Position of primary sightings of Antarctic blue, fin, Antarctic minke, and humpback whales.

southern stratum in the western side of Area IIIW (Ensor *et al.*, 2005; Bando *et al.*, 2019).

Humpback whales

Humpback whales were sighted frequently across the entire research area (Figure 4) which is a different pattern from previous surveys (Ensor *et al.*, 2005). This observation could be due to an increase in abundance and distribution of this species in the research area as suggested previously (Hakamada and Matsuoka, 2014).

Duplicate sightings

Duplicates sightings were those sightings made by both the IOP and TOP barrel observers during the IO mode survey. These data will be used to estimate *g*(0), which in turn is used to adjust estimates of abundance. Duplicates were recorded for a total of 127 sightings (involving several whale species) in this survey.

Other research activities

Table 4 shows a summary of different research activities.

Sighting distance and angle experiment

The sighting distance and angle experiment was conducted in order to evaluate the accuracy of sighting distance and angle provided by primary observers. The results of this experiment will be used for the calculation of abundance estimates. A training for this experiment was conducted on 13 January. The actual experiments comprising 128 trials were successfully completed on 1 February.

Photo-ID

Photo-ID data is used for matching exercise to investigate distribution and movement of those large whales (Figure 5). A total of 20 Antarctic blue, 41 humpback and 1 killer whales were successfully photo-identified during the entire survey. These data will be registered with the Institute of Cetacean Research (ICR) catalogue and submission of photographs be made to relevant international

Table 4
Summary of experiments during the 2020/21 JASS-A survey.

Experiments	Results and descriptions
Sighting distance and angle experiment	128 trials completed by 1 February
Photo-ID	Obtained from 20 Antarctic blue, 41 humpback and 1 killer whales
Biopsy sampling	Collected from 8 Antarctic blue, 15 fin, 14 Antarctic minke, 16 humpback and 1 Bryde's whales
Satellite tagging	Deployed on 7 fin and 10 Antarctic minke whales
Data logger tagging	Deployed on 2 humpback whales
Oceanographic survey	99 XCTD casts
Marine debris observation	No debris was observed in the research area
UAV	Aerial images collected from 10 Antarctic blue, 7 fin and 2 humpback whales

Figure 5. Examples of photo-ID of humpback whales during the 2020/21 JASS-A survey, ventral side of the flukes (left) and left side of dorsal fin (right).

Figure 6. Biopsy sampling of blue whale using a Larsen system during the 2020/21 JASS-A survey (left and middle); skin/blubber samples of a blue whale obtained by biopsy sampling (right).

catalogues (e.g. Matsuoka and Pastene, 2014).

Biopsy sampling for large whales
Biopsy samples are used for studies on stock structure of large whale based on genetic analyses and for other feasibility studies included among the specific objectives of the JASS-A. A total of 54 biopsy samples were collected from eight Antarctic blue, 15 fin, 14 Antarctic minke, 16 humpback and 1 Bryde's whales, using the Larsen system (Larsen, 1998) for the entire survey (Figure 6). Biopsy samples were stored at −20°C.

Satellite tagging
Satellite tagging is used for the study of movement, distribution and stock structure of whales. The satellite-monitored tags (SPOT6, Wildlife Computers, Redmond, Washington, USA) were deployed with the Air Rocket Transmitter System (ARTS) (LK-ARTS, Skutvik, Norway). The detail of deployment system and protocols, and research results to date were described in Konishi *et al.* (2020). In the research area, seven and ten satellite tags were deployed on fin and Antarctic minke whales respectively.

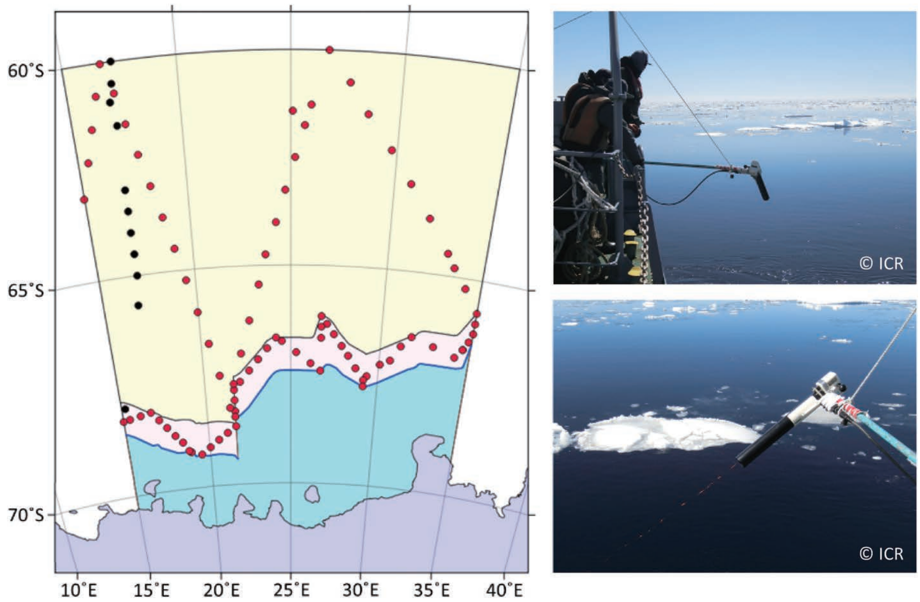

Figure 7. Oceanographic observation stations (XCTD casting points); Red circle: research area; black circle: transit (left). Oceanographic observation using XCTD (upper-right); XCTD launcher with the probe launched (lower-right).

Feasibility study on data logger (TDR) tagging

The feasibility study of data logger tagging was conducted in order to obtain information on dive-time of large whales using the satellite-linked Time-Depth Recorder (TDR) tags (SPLASH 10-F, Wildlife Computers, Redmond, Washington, USA). The tags were successfully deployed on two humpback whales and the data (position, time and depth) were collected in both cases. This experiment will be further refined in the next field surveys to obtain data of mean dive-time and diving behaviour of the animal, which are key parameters for abundance estimation considering availability bias.

Oceanographic survey

Oceanographic observations are important to understand the relationship of whales and the physical environment. The vertical distribution of water temperature and salinity were recorded from sea surface to 1,850 m water depth using XCTD system (eXpendable Conductivity, Temperature and Depth, Tsurumi-Seiki Co., Ltd., Yokohama, Japan) at 99 stations along the survey track lines (Figure 7). Oceanographic data will be analysed to study the oceanographic structure of the research area and the relationship with whale distribution.

Marine debris observation

Studies on marine debris in the Antarctic are very scarce. However, it is important to continue with this kind of survey to monitor future trends in the occurrence of marine debris. No marine debris objects were observed in the research area during the survey.

Feasibility study on the utility of UAV

This technique will be used to determine the number of individuals in the schools, information highly relevant for abundance estimation. It will be used also in photogrammetry studies. Aerial images were collected in a total of ten Antarctic blue, seven fin and two humpback whales using small UAV, DJI phantom 4 Pro, (Figures 8 and 9) (video clips can be accessed at https://www.youtube.com/channel/UCz3c9IIMiQPVeryAogmJIig). These data will be registered with the photo-ID catalogue of ICR.

Sighting survey in the transit areas

Sighting survey was conducted between south of 10°S and the research area, excluding areas of the foreign countries EEZs. The searching effort was 802.7 n.miles and total sightings included fin (8/13), Bryde's (1/1), Antarctic minke (1/1), and humpback (3/6) whales. Biopsy samples were collected from Bryde's (sighted position 27°17′S; 039°29′E) and Antarctic minke (sighted position 29°01S; 050°09′E) whales (Figure 10). During the transit survey from the Antarctic research area to 10°S, the searching effort was 1068.2 n.miles and the total sightings included fin (9/16), Antarctic minke (1/1), humpback (22/36), and sperm (3/3) whales. During the transit in the research area, biopsy samples were collected from three fin and five humpback whales and satellite tags were attached on two fin whales. Further biopsy samples were collected from two fin whales (a school comprising five whales) at 43°49′S; 19°12′E and one humpback whale at 38°58′S; 26°55′E.

Figure 8. UAV in flight obtaining overhead images of Antarctic blue (left) and humpback (right) whales during the 2020/21 JASS-A survey.

Figure 9. Examples of aerial image of Antarctic blue whales captured by UAV during the 2020/21 JASS-A survey.

Figure 10. Bryde's whale sighted at 27°17'S; 039°29'E on 31 December 2020 (left) and Antarctic minke whale sighted at 29°01'S; 050°09'E on 29 December 2020 (right) on sighting survey in the transit area.

HIGHLIGHTS OF THE SURVEY

The 2019/20 and 2020/21 JASS-A surveys covered the full Antarctic Area III West (000°–035°E) and succeeded in collecting sighting data necessary for estimation of cetacean abundance in this Area. In addition, several other data necessary for understanding stock structure, movement and the environment of whales were collected during the survey. The data collected through the JASS-A will be analysed in conjunction with the data collected by the previous JARPA/JARPA, NEWREP-A and IDCR/SOWER surveys in the same region so that the analyses can be based on a long and consistent data set.

ACKNOWLEDGEMENTS

We thank the captain, crew members and researchers who participated in the 2020/21 JASS-A survey for their effort in the collection of data and samples. Thanks also to the Fisheries Agency of Japan for the funding and logistic support for the JASS-A program including fuel supply, ICR colleagues for logistic support and useful suggestions for the fieldwork, the steering group of JASS-A for their guidance in the design and implementation of the research, and Kenji Konishi (ICR) for planning and assisting the satellite tagging. We are grateful to Luis A. Pastene (ICR) for assistance in preparing this report. Finally, we acknowledge all of those who helped in the course of

conducting the survey in a very difficult situation complicated by COVID-19.

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Technical Reports of the Institute of Cetacean Research (2021) pp. 16–32

Technical Report (not peer reviewed)

Results of the Japanese dedicated cetacean sighting surveys in the western North Pacific in 2019 and 2020

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ABSTRACT

Vessel-based sighting surveys were conducted in 2019/2020 by Japan to examine the distribution and abundance of large whales in the western North Pacific. The research area, set between 25°N–45°N and 128°E–150°E, was covered between 10 May 2019 and 18 March 2020 involving four seasons: early summer, late summer, autumn and winter. Previous surveys in autumn and winter were very scarce. The research vessels *Yushin-Maru*, *Yushin-Maru* No. 2, *Yushin-Maru* No. 3 and *Kaiyo-Maru* No. 7 were engaged in the current surveys. A total of 9,415.9 n.miles was searched in the research area. The coverage of the planned track lines on effort was 94% in the early summer, 86% in the late summer, 75% in the autumn and 70% in the winter surveys. In total, seven large whale species, including blue (7 schools/8 individuals), fin (50/80), sei (44/66), Bryde′s (159/202), common minke (39/45), humpback (80/123) and sperm (168/438) whales were sighted over the entire research period. Photo-ID images were collected from blue (8 individuals), humpback (26 individuals), and killer (7 individuals) whales. Biopsy skin samples were collected from blue (n=5), fin (n=7), sei (n=5), common minke (n=1), humpback (n=3), and killer (n=1) whales using a Larsen system. Satellite tags were attached on fin (n=6), sei (n=14) and Bryde′s (n=1) whales. Data collected during these surveys will be used in studies on abundance, distribution, movement and stock structure of several species. This information is essential for appropriate management and conservation of cetacean species in the western North Pacific.

INTRODUCTION

Dedicated cetacean sighting surveys in the western North Pacific have been conducted in the summer season since 1995 as a part of the former Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN/JARPNII) and the New Scientific Whale Research Program in the western North Pacific (NEWREP-NP). Those surveys were based on the survey guidelines and procedures of the International Whaling Commission/Southern Ocean Whale and Ecosystem Research (IWC/SOWER) (Anon, 2008). Based on the collected data the distribution patterns of large whales such as blue, fin, sei, Bryde′s, common minke, humpback, North Pacific right and sperm whales, and abundance estimates of common minke, sei and Bryde′s whales were investigated and reported to the IWC SC (IWC, 2001; 2010; 2016).

The National Research Institute of Far Seas Fisheries (NRIFSF) has also conducted dedicated sighting surveys for cetaceans in the North Pacific since the 1980s (Buckland *et al.*, 1992; Miyashita *et al.*, 1995., Kanaji *et al.*, 2012). In 2019 and after completing the JARPN/JARPNII and NEWREP-NP, the Government of Japan decided to continue the sighting surveys in the North Pacific (IWC, 2019) based on the rationale that the collection of sighting data to estimate abundance and biopsy/photo-identification data to examine stock structure have contributed, in the past, to the work on management and conservation of large whales by the IWC SC (IWC, 2016).

This paper reports the results of the Japanese dedicated sighting surveys conducted during May 2019 to March 2020 involving four seasons: early summer, late summer, autumn and winter.

SURVEY DESIGN

Research season and area

In 2019/20, in addition to the usual summer season survey, sighting surveys were also conducted in autumn (October–November) and winter (February–March) seasons. The objective of the extra surveys was to provide basic information on distribution and abundance of large whales from seasons which have been poorly documented. Therefore, surveys in 2019/20 were conducted in four seasons: early summer, late summer, autumn and

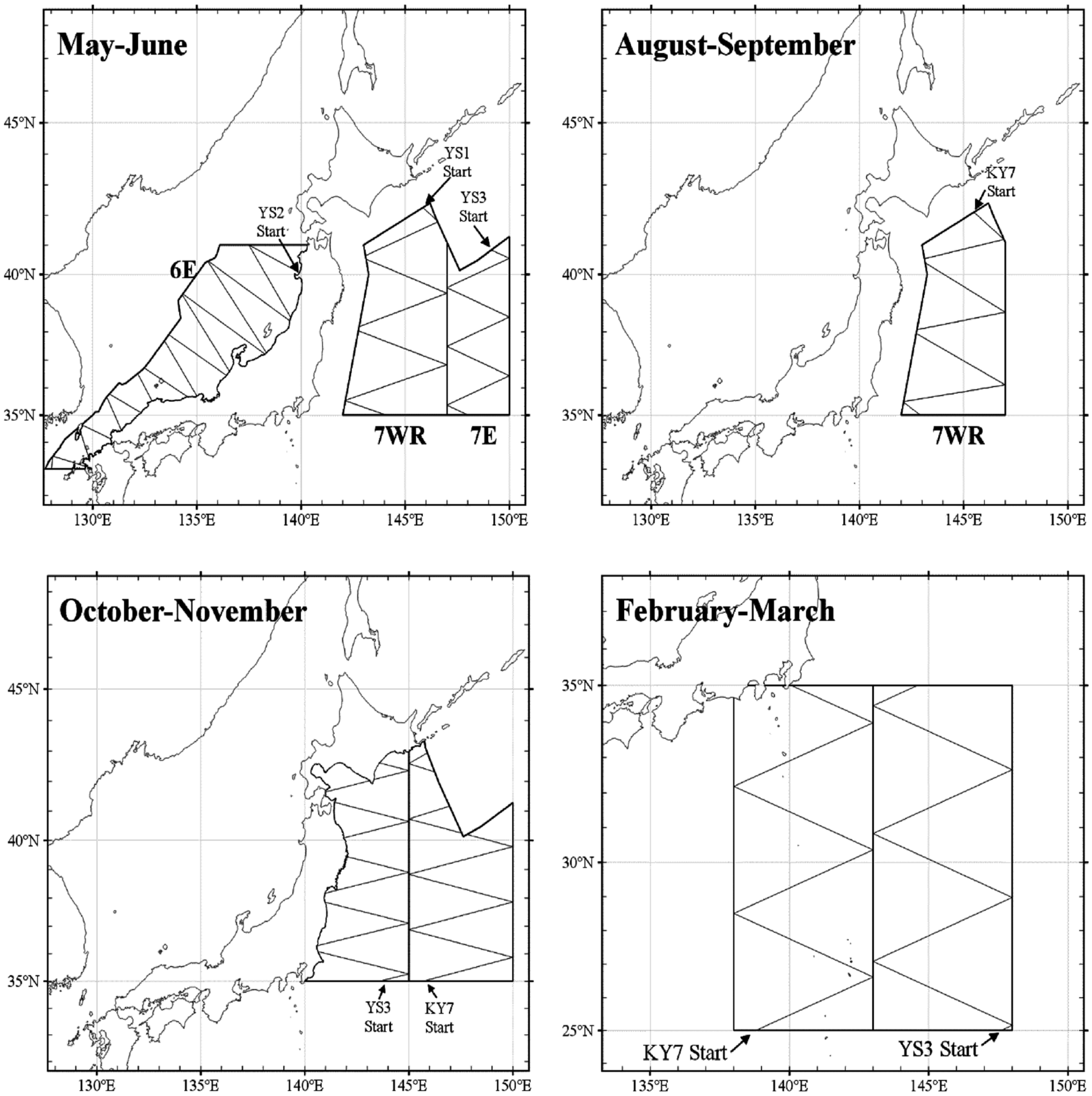

Figure 1. The research area and pre-determined track lines in each season. Upper left: early summer survey (May–June 2019). Upper right: late summer survey (August–September 2019). Lower left: autumn survey (October–November 2019). Lower right: winter survey (February–March 2020).

winter. Figure 1 illustrates the research areas covered in each season.

In early summer (May to June 2019), the research area was set up between 33°N–45°N and 128°E–150°E (for convenience, we name the sub-areas as 6E, 7WR, and 7E from the west).

In late summer (August to September 2019), the research area was set up between 35°N–45°N and 142°E–147°E.

In the autumn season (October to November 2019), the research area was set up between 35°N–45°N and 140°E–150°E. This research area was divided into 'Western part' and 'Eastern part.'

Finally, in the winter season (February to March 2020), the research area was set up between 25°N–35°N and 138°E–148°E and the research area was divided into 'Western' and 'Eastern' parts.

Research vessels

The surveys in 2019/20 were conducted by the research vessels *Yushin-Maru* (*YS1*), *Yushin-Maru* No. 2 (*YS2*), *Yushin-Maru* No. 3 (*YS3*) and *Kaiyo-Maru* No. 7 (*KY7*). The vessels were equipped with a top barrel platform (TOP), independent observer barrel platform (IOP) and upper bridge (Figure 2).

Track line design

The survey blocks and pre-determined track lines are shown in Figure 1. The start point of each track line was decided randomly using the Distance program ver. 7.0

Figure 2. The dedicated sighting vessel that participated in the 2019/20 surveys: *Yushin-Maru* (*YS1*) (upper left), *Yushin-Maru* No. 2 (*YS2*) (upper right), *Yushin-Maru* No. 3 (*YS3*) (lower left), *Kaiyo-Maru* No. 7 (*KY7*) (lower right).

(Thomas *et al.*, 2010), and the number of the lines (width in the longitude) was decided by the research schedule, based on the IWC survey guidelines (IWC, 2012).

Sighting procedure and mode

The sighting survey was conducted using (1) Normal Passing mode (NSP) and (2) Passing with Independent Observer mode (IO) in order to estimate abundance with estimated *g*(0) for large cetaceans. Both survey modes followed the protocol endorsed for the SOWER surveys (e.g. Matsuoka *et al.*, 2003).

For NSP mode, there were two primary observers in the top barrel (TOP) and the captain and helmsman were in the upper bridge. All primary observers conducted searching for cetaceans by using angle board and scaled binoculars (7×).

For IO mode, there were two primary observers on the TOP and the independent observer platform (IOP), respectively. These observers on TOP and IOP also conducted searching for cetaceans by angle board and scaled binoculars (7×). There was no open communication between the IOP and the TOP. The observers and researchers on the upper bridge communicated to the TOP (or IOP) independently, with the top-men only clarifying information and without distracting the top-men from their normal search procedure. These primary observers reported sighting-information to researchers and other observers on the upper bridge for data recording. For small cetaceans, sightings from the TOP and the upper bridge were recorded.

The survey effort began 60 minutes after sunrise and ended 60 minutes before sunset, with a maximum of 12 hours per day (maximum 06:00–19:00, including 30 minutes for lunch and supper, when surveying in IO mode) when the weather conditions were acceptable for observations: visibility better than 2.0 n.miles and wind speed less than 17 knots in the early and late summer, 21 knots in the autumn and winter season. The searching speed was planned to be 10.5 to 11.5 knots with slight adjustment to avoid vibration of the vessel.

Distance and angle experiments were conducted in the middle of the survey period, using a buoy with a reflector that resembles a blow. The experiment to evaluate measurement error was conducted late in the survey following the protocol of the IWC/SOWER and IWC-POWER surveys (IWC, 2012). The Estimated Angle and Distance Training Exercise were also conducted early in the surveys. During the exercise, the observers familiarized themselves with distance estimates from the TOP and Upper Bridge.

Experiments

For each survey, when large cetaceans such as blue and humpback whales were encountered, photo-ID images were obtained using Canon EOS 7D Mark II (with 100–400 mm lens) from the bow or upper deck. Further, biopsy skin sampling using the Larsen sampling system

(Larsen, 1998) was conducted in early summer, late summer and autumn season survey when blue, fin, sei and humpback whales were sighted. In the early summer, autumn and winter season surveys, a satellite tagging experiment using LK-ARTS was also conducted when fin, sei and common minke whales were sighted. These data collected in different seasons will assist the interpretation of stock structure hypotheses and abundance estimations for these species.

RESULTS OF THE SURVEY

Narrative of the surveys

Early summer 2019

The *YS1* and *YS3* departed Shimonoseki, Yamaguchi prefecture, Japan on 10 May, and the *YS2* departed Shiogama, Miyagi prefecture, Japan, on 11 May. The *YS1* started the survey in sub-area 7WR on 13 May and completed it on 4 June. The *YS2* started the survey in sub-area 6E on 13 May and completed it on 14 June. The YS3 started the survey in sub-area 7E on 14 May and completed it on 2 June. Each vessel surveyed a pre-determined track line from north to south of each stratum, taking into account the seasonal migration of baleen whales to avoid double counting (Figure 1). The *YS1* and *YS3* arrived in Shimonoseki on 8 June, and the *YS2* arrived in Shiogama on 26 June.

Late summer 2019

The *KY7* departed Hachinohe, Aomori prefecture, Japan, on 16 August. The vessel started the survey in sub-area 7WR on 19 August and completed it on 21 September. The vessel arrived in Misaki, Kanagawa prefecture, Japan, on 26 September. The vessel surveyed a pre-determined track line from north to south (Figure 1).

Autumn in 2019

The *YS3* departed Daiba, Tokyo, Japan, and started the survey in the western part of the research area on 8 October. The *KY7* departed Misaki on 10 October and started the survey in the eastern part of the research area on 16 October. The *YS3* completed the survey on 10 November and arrived in Shimonoseki on 15 November. The *KY7* completed the survey on 17 November and arrived in Hachinohe on 20 November. Both vessels surveyed a pre-determined track line from south to north in each stratum (Figure 1).

Winter 2020

The *KY7* departed Shimizu, Shizuoka prefecture, Japan, on 6 February and started the survey in the western part of the research area on 11 February. The *YS3* departed Shimonoseki on 12 February and started the survey in the eastern part of the research area on 16 February. The *KY7* and *YS3* completed the survey on 13 March and arrived in Shiogama on 16 March and Shimonoseki on 17 March, respectively. Both vessels surveyed a pre-determined track line from south to north in each stratum (Figure 1).

The Estimated Angle and Distance Experiments were

Table 1

Summary of the searching effort by each season and area.

Season	Research area	Vessel	Research period	Planned cruise track (n.miles)	Searching effort NSP (n.miles)	Searching effort IO (n.miles)	Searching effort Total (n.miles)	Coverage of effort (%)
Early summer (May–Jun.)	6E	*YS2*	2019/5/13–6/14	2,021.1	959.4	932.4	1,891.8	94
	7WR	*YS1*	2019/5/13–6/4	1,177.2	566.5	580.1	1,146.6	97
	7E	*YS3*	2019/5/14–6/2	871.8	397.2	408.2	805.4	92
	Sub total	—	2019/5/13–6/14	4,070.1	1,923.2	1,920.7	3,843.8	94
Late summer (Aug.–Sep.)	7WR	*KY7*	2019/8/19–9/21	1,193.0	511.9	518.9	1,030.7	86
Autumn (Oct.–Nov.)	Western	*YS3*	2019/10/8–11/10	1,597.8	635.9	647.4	1,283.3	80
	Eastern	*KY7*	2019/10/16–11/17	1,611.0	578.1	557.8	1,135.8	71
	Sub total	—	2019/10/8–11/17	3,208.8	1,213.9	1,205.1	2,419.1	75
Winter (Feb.–Mar.)	Western	*KY7*	2020/2/11–3/13	1,505.1	450.7	414.3	865.0	58
	Eastern	*YS3*	2020/2/16–3/13	1,522.9	663.7	593.5	1,257.3	83
	Sub total	—	2020/2/11–3/13	3,028.0	1,114.4	1,007.8	2,122.2	70
Total	—	—	—	11,499.9	4,763.4	4,652.5	9,415.9	82

Table 2a
Numbers of sightings of large whales in early summer (May–June), by each sub-area.

Season	Species	6E		7WR		7E		Total	
		Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Early summer (May–Jun.)	Blue whale	0	0	0	0	4	5	4	5
	Fin whale	12	21	5	7	6	9	23	37
	Sei whale	0	0	1	2	7	11	8	13
	Bryde's whale	0	0	16	19	32	42	48	61
	Like Bryde's	0	0	0	0	4	4	4	4
	Common minke whale	37	43	1	1	0	0	38	44
	Like minke	0	0	1	1	0	0	1	1
	Humpback whale	1	1	21	29	15	21	37	51
	Sperm whale	0	0	66	165	21	63	87	228
	Unidentified large baleen whale	0	0	1	1	5	5	6	6
	Unidentified large cetacean	1	1	1	1	0	0	2	2

Table 2b
Numbers of sightings of small cetaceans in early summer (May–June), by each sub-area.

Season	Species	6E		7WR		7E		Total	
		Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Early summer (May–Jun.)	Cuvier's beaked whale	1	4	0	0	0	0	1	4
	Unidentified Ziphiidae	22	39	6	13	10	20	38	72
	Unidentified *Mesoplodon*	2	4	0	0	2	2	4	6
	Common dolphin	1	200	3	48	9	435	13	683
	Risso's dolphin	5	56	17	143	2	13	24	212
	Pacific white-sided dolphin	8	421	2	170	12	316	22	907
	Dalli type Dall's porpoise	1	4	2	10	1	5	4	19
	Truei type Dall's porpoise	1	1	0	0	2	8	3	9
	Unid. type Dall's porpoise	9	30	4	12	5	51	18	93

conducted on 27 May by *YS1 and YS3*, on 2 June by *YS2* and on 5 September by *KY7*. In winter, the Estimated Angle and Distance Experiments were conducted again on 7 March by *KY7* and *YS3* because there was a change of observers. The results of this experiment will be used in the calculation of abundance estimates.

Research effort in each season and research area

A summary of the searching effort and coverage in each season and research area is shown in Table 1. A total of 9,415.9 n.miles (17,438.2 km) were searched in the whole research area and during all seasons. In early summer, the total searching effort was 3,843.8 n.miles (7,118.7 km), and the coverage exceeded 90% due to continued stable weather conditions. In late summer, the searching effort was 1,030.7 n.miles (1,908.9 km), and the coverage was 86.4%. The percentage dropped slightly in late summer because the survey was interrupted three times in September to avoid typhoons. In the autumn season, the total searching effort was 2,419.1 n.miles (4,480.2 km), and the coverage was relatively low (75.4%) because the available survey hours of the day were only about eight hours due to times of the sunrise and sunset, and also because typhoons were still active around Japan in October. In the winter season, the total searching effort was 2,122.2 n.miles (3,930.3 km), and the coverage was 70.1%. In the western part, the coverage was low (57.5%) because time was lost on a number of occasions in avoiding stormy weather.

Sightings

Sightings were summarized by each season (Tables 2a to 5b). The sighting location of each species in each season

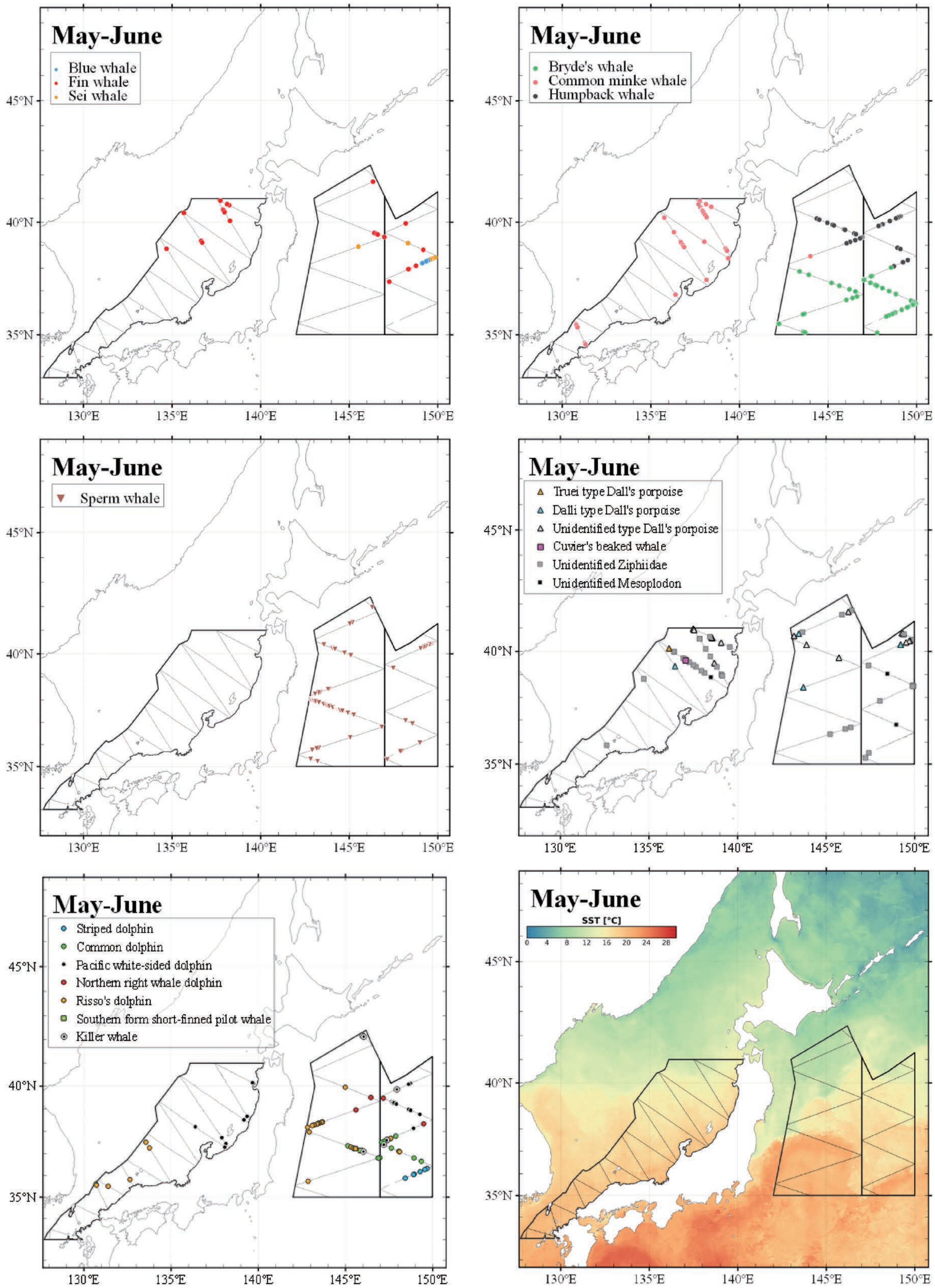

Figure 3. The sighting locations of large and small cetaceans during the early summer (May–June 2019) and information on SST in that season (original data of SST: Ocean color web, from https://oceancolor.gsfc.nasa.gov/).

is shown in Figures 3, 4, 5 and 6, together with sea surface temperature (SST).

Early summer (May–June)

Blue whale

Four schools (five individuals including a mother and calf pair) were sighted between 38°20′N, 149°27′E and 38°06′N, 148°46′E in sub-area 7E (Table 2a, Figure 3). One blue whale formed a mixed school with a fin whale. The range of SST at the sighting positions was 14.5–15.2°C. All five individuals were photographed, and biopsy samples were collected from four individuals.

Fin whale

Fin whales were sighted in each research area (Table 2a, Figure 3). In sub-area 6E, 12 schools (21 individuals including 2 mother and calf pairs) were sighted. Observed mean school size was 1.75. The range of SST in the sighting positions was 10.0–16.3°C. In sub-areas 7WR and 7E, 11 schools (16 individuals) were sighted. Observed mean school size was 1.45. The range of SST at the sighting positions was 8.4–20.5°C.

Sei whale

Sei whales were sighted in sub-areas 7WR and 7E (Table 2a, Figure 3). A total of eight schools (13 individuals including 2 mother and calf pairs) were sighted. Observed mean school of size was 1.63. The range of SST at the sighting positions was 14.1–16.4°C.

Bryde′s whale

A total of 48 schools (61 individuals including 10 mother and calf pairs) were sighted in sub-areas 7WR and 7E (Table 2a, Figure 3). Because the survey was conducted at the beginning of the migration season of this species, they were only sighted in the southern part of sub-areas 7WR and 7E. The observed mean school size was 1.27. The range of the SST at the sighting positions was 15.6–24.2°C.

Common minke whale

This species was the most frequently sighted species in sub-area 6E (37 schools and 43 individuals including 2 mother and calf pairs) (Table 2a, Figure 3). The range of SST at the sighting positions was 10.1–21.9°C, and the observed mean school size was 1.16. In sub-area 7WR, one school (one individual) was sighted. The SST at the sighting position was 16.5°C and the estimated body length was 7.8 m. A picture of a common minke whale is shown in Figure 7.

Humpback whale

Humpback whales were sighted frequently in sub-areas 7WR and 7E (36 schools and 50 individuals) (Table 2a, Figure 3). No mother and calf pair was sighted. They were mainly sighted in the northern part of sub-areas 7WR and 7E. Observed mean school size was 1.38. The range of SST at the sighting positions was 8.6–18.8°C. In sub-area 6E, one individual was sighted. The SST at the sighting position was 10.4°C and the estimated body length was 12.2 m. This individual was photographed and a biopsy sample was obtained.

Sperm whale

A total of 87 schools (228 individuals) of this species were sighted (Table 2a, Figure 3) in the North Pacific sector. A high-density area of sperm whales was observed in the western part of sub-area 7WR. This high-density area was formed across the Japan Trench. The observed mean school size was 2.62. Because the opportunity to approach the schools was limited, there was little information on body length and calves. The range of SST at the sighting positions was 6.8–24.1°C.

Small cetaceans

The species sighted are shown in Table 2b and their distribution in Figure 3. In this season, one species was identified in the family Ziphiidae, three species were identified in the family Delphinidae and one species was identified in the family Phocoenidae. The most common species sighted were Risso's dolphin (24/212), followed by Pacific white-sided dolphin (22/907). There were many sightings of the family Ziphiidae, but it was difficult to identify the species because of their elusive behavior.

Late summer (August–September)

Blue whale

One individual of estimated body length of 24.5 m. was sighted at 40°54′N, 145°13′E (Table 3a, Figure 4). The SST in the sighting position was 22.8°C This individual was photographed and a biopsy sample was obtained (Figure 8).

Fin whale

Two schools (two individuals) were sighted north of 40°N (Table 3a, Figure 4). The estimated body lengths were 20.8 m and 22.8 m. The range of SST at the sighting positions was 22.5–22.8°C.

Sei whale

This species was not sighted in the research area. However, one individual of 14.2 m in body length was sighted during the transit survey between Hachinohe and the starting point of the research area. The SST at the sighting position was 21.5°C.

Bryde′s whale

A total of 67 schools (92 individuals include 8 mother and calf pairs) were sighted. In comparison with the distribution of Bryde′s whales in early summer, these were widely distributed except the southern part of the research area (Table 3a, Figure 4). In general, Bryde′s whales were widely distributed in summer (from July to September) in the western North Pacific, north of 35°N, based on the previous dedicated sighting surveys (Shimada, 2004, Pastene *et al.*, 2009, Hakamada *et al.*, 2017). The observed mean school size was 1.37. The range of the SST at the

Table 3a
Numbers of sightings of large whales in late summer (August–September).

Season	Species	7WR	
		Sch.	Ind.
Late summer (Aug.–Sep.)	Blue whale	1	1
	Fin whale	2	2
	Sei whale	1	1
	Bryde's whale	67	92
	Like Bryde's	5	5
	Like Sei/Bryde's	1	1
	Sperm whale	30	91
	Unidentified large baleen whale	4	5
	Unidentified large cetacean	1	1

Table 3b
Numbers of sightings of small cetaceans in late summer (August–September).

Season	Species	7WR	
		Sch.	Ind.
Late summer (Aug.–Sep.)	Baird's beaked whale	1	2
	Cuvier's beaked whale	1	2
	Unidentified *Mesoplodon* spp.	2	10
	Unidentified Ziphiidae	12	26
	Common dolphin	14	961
	Northern form short-finned pilot whale	1	20
	Risso's dolphin	2	37
	Melon-headed whale	1	96
	Striped dolphin	8	278

sighting positions was 22.0–27.0°C.

<u>Common minke whale</u>

This species was not sighted in the late summer season.

<u>Humpback whale</u>

Humpback whales were not sighted in the research area. It was considered that humpback whales had migrated to the northern area.

<u>Sperm whale</u>

A total of 30 schools (91 individuals) of this species were sighted in the research area (Table 3a, Figure 4). The observed mean school size was 3.09. The range of the estimated body length was 9.1–12.2 m. The range of SST at the sighting positions was 6.8–24.1°C.

<u>Small cetaceans</u>

The species sighted are shown in Table 3b and their distribution in Figure 4. In this season, two species were identified in the family Ziphiidae and five species were identified in the family Delphinidae. The most common species sighted were common dolphins (14/961), followed by striped dolphins (8/278). In comparison with the results of the early summer (May–June), the distribution of the common, Risso's and striped dolphins extended north of 40°N, and the Pacific white-sided dolphin, which was distributed around 40°N in the early summer season, was not sighted in this season. The SST map shows a temperature around 24°C, even near 40°N (Figure 4), suggesting that the distribution of these dolphins is shifting northward as the water temperature rises.

Autumn (October–November)

<u>Blue whale</u>

Two schools (two individuals) with body lengths of 24.3 m and 25.3 m were sighted in the western part (Table 4a, Figure 5). The SST at the sighting positions was 16.7°C and 17.2°C, respectively. These two individuals were photographed.

<u>Fin whale</u>

A total of 22 schools (38 individuals) were sighted in the research area. In this season, fin whales were mainly sighted north of 40°N (Table 4a, Figure 5). The observed mean school size was 1.73. A school of three fin whales sighted at 42°23′N, 145°56′E on 13 November was chased by a solitary adult male killer whale (Figure 9).

<u>Sei whale</u>

A total of 28 schools (38 individuals) were sighted north of 40°N in the research area. Sei whales were concentrated in the northern coastal part of the research area (Table 4a, Figure 5). The observed mean school size was 1.36. The range of the SST at the sighting positions was 9.1–18.1°C.

<u>Bryde's whale</u>

A total of 37 schools (42 individuals including 1 mother and calf pair) were sighted. In this season, Bryde's whales were mainly sighted in the western part of the research area (Table 4a, Figure 5). The observed mean school size was 1.14. Range of the SST in the sighting positions was 16.8–24.3°C.

<u>Common minke whale</u>

One school (one individual) of body length estimated to be 7.2 m was sighted in the most northern part of the western part of the research area (Table 4a, Figure 5). The SST at the sighting position was 11.3°C.

<u>Humpback whale</u>

A total of 26 schools (42 individuals) of this species was sighted. Sightings were concentrated between 41°N and

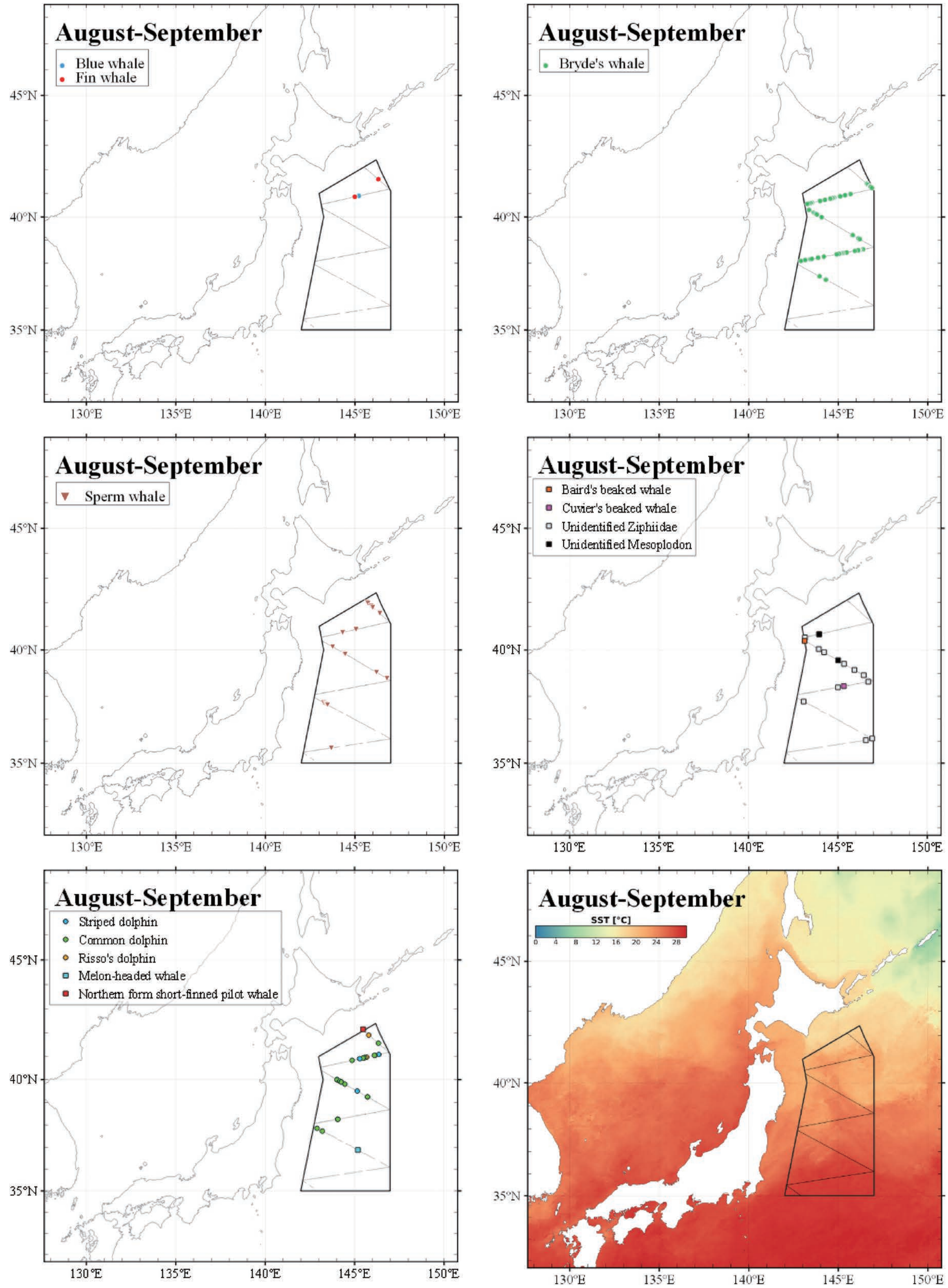

Figure 4. The sighting locations of large and small cetaceans during the late summer (August–September 2019) and information on SST in that season (original data of SST: Ocean color web, from https://oceancolor.gsfc.nasa.gov/).

42°N in the research area (Table 4a, Figure 5). The observed mean school size was 1.62. The range of SST at the sighting position was 8.8–18.8°C. More than half of the schools (65%) were sighted in waters with SST of 11°C.

Sperm whale

A total of 41 schools (107 individuals) of this species were

Table 4a
Numbers of sightings of large whales in autumn (October–November) by each area.

Season	Species	Western part		Eastern part		Total	
		Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Autumn (Oct.–Nov.)	Blue whale	2	2	0	0	2	2
	Fin whale	10	15	12	23	22	38
	Like fin	0	0	1	2	1	2
	Sei whale	10	11	18	27	28	38
	Bryde's whale	35	39	2	3	37	42
	Common minke whale	0	0	1	1	1	1
	Humpback whale	16	27	10	15	26	42
	Sperm whale	26	52	15	55	41	107
	Unidentified large baleen whale	8	8	1	1	9	9

Table 4b
Numbers of sightings of small cetaceans in autumn (October–November), by each area.

Season	Species	Western part		Eastern part		Total	
		Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Autumn (Oct.–Nov.)	Baird's beaked whale	3	29	0	0	3	29
	Unidentified Ziphiidae	9	23	4	8	13	31
	Common dolphin	2	70	11	416	13	486
	Southern form short-finned pilot whale	1	4	0	0	1	4
	Risso's dolphin	2	4	0	0	2	4
	Pacific white-sided dolphin	0	0	1	5	1	5
	Killer whale	0	0	3	3	3	3
	Spotted dolphin	0	0	3	75	3	75
	Striped dolphin	1	100	19	537	20	637
	Harbour porpoise	1	4	0	0	1	4
	Dalli type Dall's porpoise	1	15	0	0	1	15
	Truei type Dall's porpoise	2	12	1	25	3	37

sighted (Table 4a, Figure 5). Sightings were concentrated south of 38°N in the research area. The observed mean school size was 2.61. The range of SST at the sighting positions was 11.9–26.7°C.

Small cetaceans

The species sighted are shown in Table 4b and their distribution in Figure 5. In this season, one species was identified in the family Ziphiidae, and seven species were identified in the family Delphinidae and two species were identified in the family Phocoenidae. The most common species sighted were striped dolphins (20/637), followed by common dolphins (13/486). Compared with the late summer (August–September) results, the distribution of the common and striped dolphins shifted to the south and were mainly sighted between 37°N–39°N. The SSTs are decreasing from the north during this season, suggesting that the distribution of these dolphins is moving south as water temperature changes.

Winter (February–March)

Blue whale

This species was not sighted in the winter season.

Fin whale

Three schools (three individuals) were sighted east of 147°E (Table 5a, Figure 6). The range of SST at the sighting positions was 17.3–23.4°C. All four groups were solitary, including one group sighted at 27°47′N, 138°07′E during the transit survey.

Sei whale

A total of 7 schools (14 individuals including 3 mother and

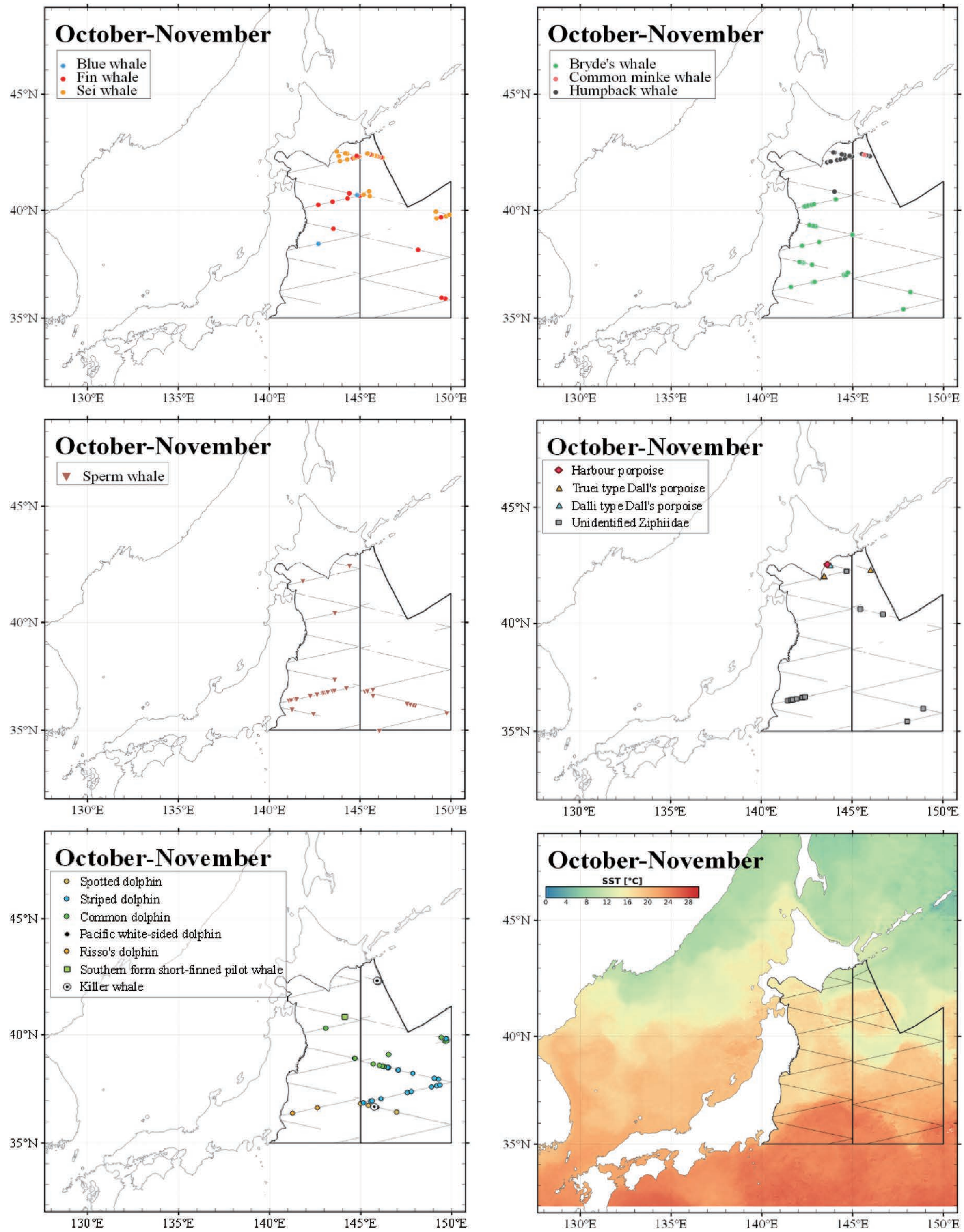

Figure 5. The sighting locations of large and small cetaceans during the autumn (October–November 2019) and information on SST in that season (original data of SST: Ocean color web, from https://oceancolor.gsfc.nasa.gov/).

calf pairs) were sighted in the eastern part of the research area (Table 5a, Figure 6). The range of SST at the sighting positions was 17.4–21.9°C. Sightings occurred only in the eastern part, and the ratio of mother and calf pairs (3/7) was higher than in the other seasons. These data would be useful to identify the breeding ground of sei whales in the North Pacific.

Bryde′s whale

A total of seven schools (seven individuals) were sighted in the research area (Table 5a, Figure 6). The range of

Table 5a
Numbers of sightings of large whales in winter (February–March).

Season	Species	Western part		Eastern part		Total	
		Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Winter (Feb.–Mar.)	Fin whale	0	0	3	3	3	3
	Sei whale	0	0	7	14	7	14
	Like sei	0	0	1	1	1	1
	Bryde's whale	4	4	3	3	7	7
	Humpback whale	13	23	4	7	17	30
	Sperm whale	2	4	8	8	10	12
	Unidentified large baleen whale	1	1	0	0	1	1

Table 5b
Numbers of sightings of small cetaceans in winter (February–March).

Season	Species	Western part		Eastern part		Total	
		Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Winter (Feb.–Mar.)	Unidentified Ziphiidae	6	10	1	3	7	13
	Common dolphin	1	40	0	0	1	40
	Southern form short-finned pilot whale	2	106	0	0	2	106
	Risso's dolphin	3	20	1	4	4	24
	Killer whale	0	0	1	10	1	10
	Spotted dolphin	1	22	0	0	1	22
	Striped dolphin	1	35	3	270	4	305
	Rough toothed dolphin	1	4	0	0	1	4

SST at the sighting positions was 17.2–22.6°C. All eight groups were solitary. One group was sighted at 26°35′N, 144°52′E during the transit survey.

Common minke whale

This species was not sighted in the winter season.

Humpback whale

A total of 17 schools (30 individuals, including 3 mother and calf pairs) were sighted (Table 5a, Figure 6). Eight of all schools (13 individuals) were sighted in the waters around 27°N, 142°E on 23 February. This area was reported as breeding ground of humpback whales in the western North Pacific (Darling and Mori, 1993). The range of SST at the sighting positions was 17.4–23.6°C. The observed mean school size was 1.76.

Sperm whale

A total of 10 schools (12 individuals) were sighted (Table 5a, Figure 6). The range of SST at the sighting positions was 17.9–22.9°C and the observed mean school size was 1.20. The school size was comparatively smaller than in the other seasons. When the *KY7* entered Suruga Bay on 27 and 28 February in order to shelter from stormy weather, the vessel encountered 11 schools (52 individuals) of sperm whales (secondary sightings). In Suruga Bay, sperm whales were distributed in waters at the center of a submarine canyon (Figure 6). The range of SST at the sighting positions in Suruga Bay was 17.0–18.2°C. The observed mean school size was 4.72.

Small cetaceans

The species sighted are shown in Table 5b and their distribution in Figure 6. No species was identified in the family Ziphiidae because of their elusive behavior. Seven species were identified in the family Delphinidae. Striped (4/305) and Risso's (4/24) dolphins were the most commonly sighted dolphin species.

Duplicate sightings

Duplicate sighting data will be used for analysis of $g(0)$ to accounti for perception bias. A total of 594 re-sightings were recorded during IO mode throughout the whole season involving several species.

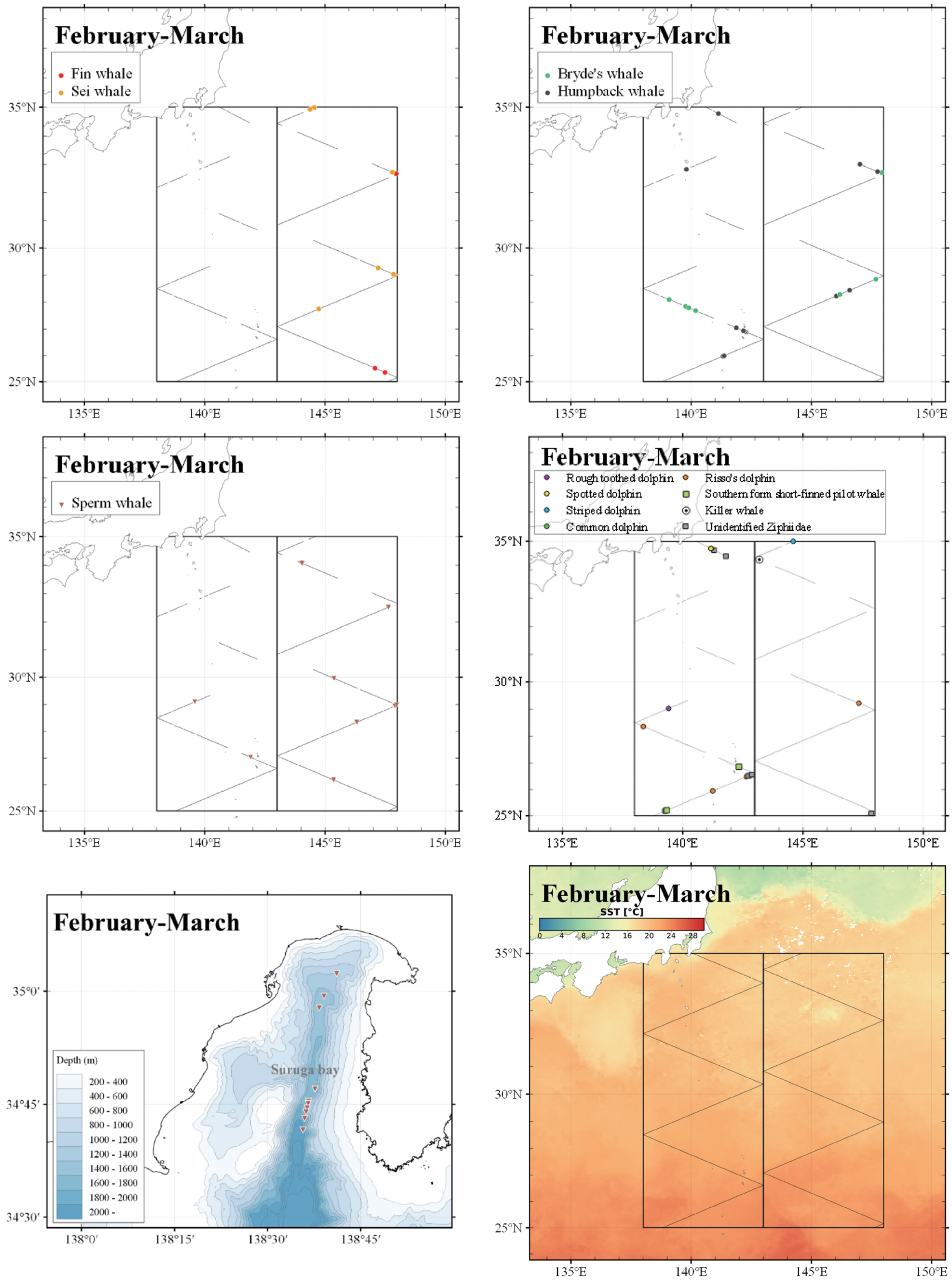

Figure 6. The sighting locations of large and small cetaceans during the winter (February–March 2020) and information on SST in that season (original data of SST: Ocean color web, from https://oceancolor.gsfc.nasa.gov/). Lower left: the sighting locations of sperm whales in Suruga Bay (secondary sightings).

Experiments

Photo-ID

Photo-IDs will be used for investigation of movement, stock structure and site fidelity of cetaceans, and to estimate abundance using the mark-recapture method. Photographs were taken of blue (n=8), humpback (n=26)

Figure 7. A common minke whale surfacing. The white flipper band can be seen below the sea surface.

Table 6
Number of individuals photographed, by each season and sub-area.

Species	Early summer (May–Jun.)			Late summer (Aug.–Sep.)	Autumn (Oct.–Nov.)		Winter (Feb.–Mar.)		Total
	6E	7WR	7E	7WR	Western part	Eastern part	Western part	Eastern part	
Blue whale	0	0	5	1	2	0	0	0	8
Humpback whale	1	0	4	0	5	2	6	8	26
Killer whale	0	2	5	0	0	0	0	0	7
Total	1	2	14	1	7	2	6	8	41

Figure 8. Blow and body of a blue whale.

and killer (*n*=7) whales throughout the whole season (Table 6). Some small cetaceans were also photographed. All photographs were stored in the Institute of Cetacean Research (ICR) catalogues.

Biopsy sampling
These samples will be used in genetic analyses on stock structure and studies to evaluate the utility of non-lethal techniques for whale biological research. A total of 22 biopsy samples were collected from blue (*n*=5), fin (*n*=7), sei (*n*=5), common minke (*n*=1), humpback (*n*=3) and killer (*n*=1) whales (Table 7). All samples were stored at the ICR laboratory.

Satellite tagging
Tracking data obtained from satellite tags will contribute to the elucidation of the movement of whales in each season and the timing of the start of migration between low latitude breeding areas and high latitude feeding areas. Satellite tags were successfully attached on fin (*n*=6), sei (*n*=14) and Bryde's (*n*=1) whales (Table 8).

HIGHLIGHTS OF THE SURVEY

The sighting surveys conducted in 2019/20 were completed successfully. They provided unique data obtained not only in summer, but also in autumn and winter seasons for which information on cetacean distribution and abundance have been very scarce. Some main characteristics of the surveys are summarized below.

A large number of common minke and fin whales were sighted in May–June in the southern part of the Sea of Japan. These data are unique and will be analyzed in combination with available sighting data from the northern

Figure 9. One adult male killer whale chasing a school of three fin whales. Clipped from a video taken from a distance.

Table 7
Number of biopsy samples collected, by each season and research area. The biopsy sampling was conducted in early summer (all areas), late summer (7WR) and autumn (eastern part).

Species	Early summer (May–Jun.)			Late summer (Aug.–Sep.)	Autumn (Oct.–Nov.)	Total
	6E	7WR	7E	7WR	Eastern part	
Blue whale	0	0	4	1	0	5
Fin whale	0	1	3	0	3	7
Sei whale	0	0	2	0	3	5
Common minke whale	1	0	0	0	0	1
Humpback whale	1	0	2	0	0	3
Killer whale	0	1	0	0	0	1
Total	2	2	11	1	6	22

Table 8
Number of individuals attached with satellite tags, by each season and sub-area. The tagging was conducted in early summer (6E and 7E), autumn (whole area) and winter (eastern part).

Species	Early summer (May–Jun.)		Autumn (Oct.–Nov.)		Winter (Feb.–Mar.)	Total
	6E	7E	Western part	Eastern part	Eastern part	
Fin whale	1	1	3	1	0	6
Sei whale	0	2	4	3	5	14
Bryde's whale	0	0	0	0	1	1
Total	1	4	7	4	6	22

part of the Sea of Japan obtained in 2018. The purpose will be to estimate common minke whale abundance in the Sea of Japan, an area where recent information on abundance is scarce.

A large number of Bryde's, humpback and sperm whales were sighted in May–June in the northern part of the Pacific side of Japan. No common minke whales were sighted during this season in this area which suggests that most common minke whales are likely to have already moved north into the Russian EEZ.

The survey in August–September covered the northern part of the Pacific side of Japan, and provided important summer sighting data for Bryde's whales, which will be used for the abundance estimation of this species. It was also confirmed that blue, fin and sperm whales were also distributed in this area, though in small numbers.

A large number of sei and fin whales were sighted in October–November in the coastal area. This area had never been surveyed in this season. These species were sighted north of latitude 40°N. A large number of Bryde's whales and a small number of blue whales were sighted south of 40°N in this season. In addition, it was confirmed

Figure 10. Breaching of a Baird's beaked whale. The long, stout beak and the prominent melon-shaped head identify this species.

that sperm whales are still distributed south of 38°N in this season.

During the February–March survey in the waters around Ogasawara Islands, several fin and sei whales were sighted possibly before their migration to the north. Of particular value are the satellite tags attached on some of these whales. In addition, Bryde's whales and humpback whales were sighted possibly before their migration to the north. Several schools of sperm whales were sighted in the central part of Suruga Bay in waters of 1,000 m depth.

As with the previous surveys, the 2019/20 surveys collected data on small cetaceans in the same way as large whales. The analyses of these data will provide valuable information on the distribution and abundance of small cetaceans in different seasons.

ACKNOWLEDGEMENTS

The authors acknowledge the Government of Japan for its assistance in providing the research permits and funding for these cruises. We also thank the captains Hidenori Kasai, Chikamasa Okoshi, Nobuo Abe, Yasuaki Sasaki, Ryoji Kita and their officers and crew of the *Yushin-Maru, Yushin-Maru* No. 2, *Yushin-Maru* No. 3 and *Kaiyo-Maru* No. 7 for their hard work and dedication that led to the successful execution of these surveys. We express our deep gratitude to Takashi Hakamada and Megumi Takahashi (ICR) for their assistance in the survey design and logistical support. We thank Yoshihiro Fujise and the staff of the ICR, Kyodo Senpaku Co. Ltd. and Kaiyo Engineering Co. Ltd., for their assistance and support for these cruises. We thank Luis A. Pastene (ICR) for his assistance in preparing this report.

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Technical Reports of the Institute of Cetacean Research (2021) pp. 33–42

Technical Report (not peer reviewed)

Results of the IWC-Pacific Ocean Whale and Ecosystem Research (IWC-POWER) dedicated sighting survey in 2020

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ABSTRACT

This paper outlines the main results of the 2020 dedicated sighting survey of the International Whaling Commission-Pacific Ocean Whale and Ecosystem Research (IWC-POWER). The IWC-POWER surveys are designed and implemented by the IWC Scientific Committee (SC), in special partnership with the Government of Japan. The long-term objective of the IWC-POWER is to ʻprovide information to allow determination of the status of populations (and thus stock structure is inherently important) of large whales that are found in the North Pacific waters and provide the necessary scientific background for appropriate conservation and management actions.ʼ To fulfill this objective, the IWC-POWER originally identified short and medium-term activities and priorities. The IWC-POWER is close to successfully completing its first-phase (2010–2021) related to the short-term priorities. It has also updated the medium-term priorities for this second phase. The 2020 survey was conducted successfully between 11 July and 24 September in the central North Pacific by the Japanese R/V *Yushin-Maru* No. 2. The following whale species were sighted during the entire survey: blue (22 schools /31 individuals), fin (29/32), sei (131/181), Brydeʼs (6/8), common minke (3/3), humpback (7/8), sperm (56/90) and killer (18/71) whales. Photo-identification data were collected from 26 blue, 3 humpback and 17 killer whales. A total of 65 biopsy samples were collected from 13 blue, 9 fin, 38 sei, 1 Brydeʼs, 2 humpback and 2 killer whales. A total of 67 objects of marine debris were observed and recorded. Data collected during this survey will be used mainly for abundance estimation and stock structure purposes.

INTRODUCTION

The International Whaling Commission-Pacific Ocean Whale and Ecosystem Research (IWC-POWER) program is an international research effort in the North Pacific coordinated by the IWC and designed by the IWC Scientific Committee (SC) in special partnership with the Government of Japan. Scientists from the Institute of Cetacean Research (ICR) participate regularly in the IWC-POWER program, both in designing and implementing the surveys. The IWC-POWER surveys in the North Pacific follow the series of IWC International Decade for Cetacean Research/Southern Ocean Whale and Ecosystem Research (IDCR/SOWER) surveys that have been conducted in the Antarctic since 1978.

The long-term objective of the IWC-POWER is to ʻprovide information to allow determination of the status of populations (and thus stock structure is inherently important) of large whales that are found in the North Pacific waters and provide the necessary scientific background for appropriate conservation and management actions.ʼ The first survey of this program was conducted in 2010 and the most recent one in 2020 (IWC, 2021).

The IWC SC is close to completing the first phase of the IWC-POWER, which is related to its short-term priorities. The IWC SC is preparing for the second phase related to medium-term priorities, based on the results of the first phase (see Matsuoka, 2020).

The objective of this document is to summarize the results of the 2020 IWC-POWER survey (Murase *et al.*, 2021). For a general background of the IWC-POWER including objectives, research area, and general methodology, see Matsuoka (2020).

RESULTS OF THE 2020 IWC-POWER SURVEY

The main results of the 2020 IWC-POWER survey are summarized here based on Murase *et al.* (2021).

Table 1
The 2020 IWC-POWER survey itinerary.

Date	Event
10 July 2020	Pre cruise meeting at Shiogama, Japan
11 July	Vessel departs Shiogama
18 July	Vessel arrives in the research area and starts the first part of the research
12 August	Vessel completes research and starts transit survey to Kushiro, Japan
17 August	Vessel arrives in Kushiro for replacement of researchers
19 August	Mid-cruise meeting at Kushiro
20 August	Vessel departs Kushiro
26 August	Vessel arrives research area and starts second part of the research
17 September	Vessel completes research and starts transit to Shiogama
24 September	Vessel arrives in Shiogama
25 September	Post-cruise meeting at Shiogama

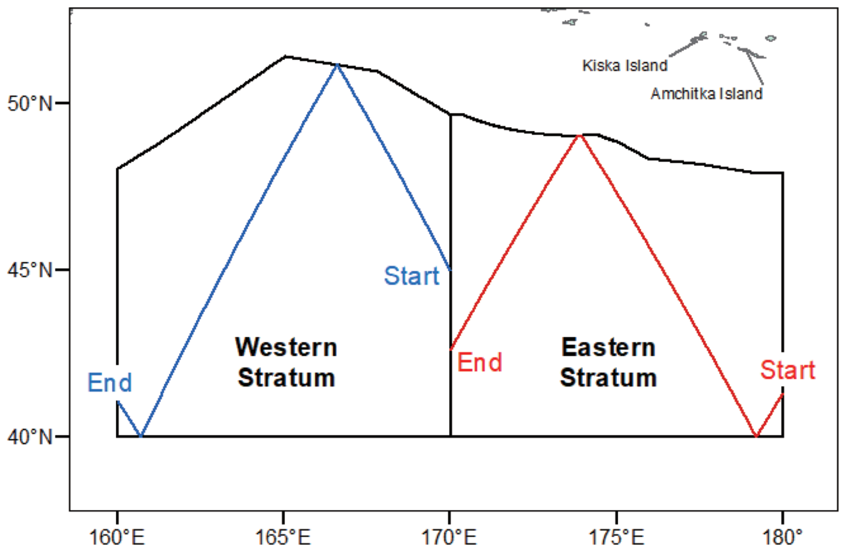

Figure 1. Research area and survey track lines with start and end points for the 2020 IWC-POWER survey.

Itinerary

The survey was conducted between 11 July and 24 September 2020 by the Japanese R/V *Yushin-Maru* No. 2. The itinerary is shown in Table 1.

Research area

The research area was between 160°E and 180° (Figure 1).

Research vessel and scientific personnel

The R/V *Yushin-Maru* No. 2 was used for this survey. The vessel is shown in Figure 2 and its specifications in Table 2.

Four international researchers were nominated by the IWC SC for this survey:

Koji Matsuoka (Japan)—cruise leader/chief scientist, sighting, photo-ID, 1st half
Hiroto Murase (Japan)—cruise leader/chief scientist, sighting, 2nd half
Isamu Yoshimura (Japan)—sighting data, marine debris and biopsy sample managements, 1st half
Taiki Katsumata (Japan)—sighting, photo-ID data management, biopsy sample management, whole cruise
Souya Fujii (Japan)—sighting, biopsy sample management, marine debris, 2nd half

Searching effort

A total of 981.7 n.miles (NSP: 491.1 n.miles, IO: 490.7 n.

Figure 2. Photography of the R/V *Yushin-Maru* No. 2.

Table 2
Specifications of the R/V *Yushin-Maru* No. 2.

Call sign	JPPV
Length overall [m]	69.61
Molded breadth [m]	11.5
Gross tonnage (GT)	747
Barrel height [m]	19.5
IO barrel height [m]	13.5
Upper bridge height [m]	11.5
Bow height [m]	6.5
Engine power [PS/kW]	5303/3900

miles) and 921.2 n.miles (NSP: 450.9 n.miles, IO: 470.3 n.miles) of the original track line were surveyed in the western and eastern strata, respectively. Survey track line coverage in the entire research area was 84.0% (1,903.0 of the planned distance of 2,264.9 n.miles), with a total of 942.0 n.miles in NSP and 961.0 n.miles in IO. A total of 521.3 n.miles was surveyed during transit surveys between the port and the research area. The effort spent in sighting and several experiments is shown in Table 3.

Summary of the sightings

During the entire survey, blue (22 schools /31 individuals), fin (29/32), sei (131/181), Bryde's (6/8), common minke (3/3), humpback (7/8), sperm (56/90) and killer (18/71) whales were observed. Several dolphin species were also sighted (Table 4). These data will be used to estimate abundance of several species.

Geographical distribution

Blue whale (Balaenoptera musculus)

Blue whales were the third most frequently encountered baleen whale species throughout the survey. They were mainly distributed in the northern part of the western stratum. No blue whales were observed in the eastern

Table 3
Summary of the searching effort (time and distance), experimental time (hours) and the area code during the 2020 survey. R.A.: research area.

Area	Area Code	Leg No.	Start	End	NSP		IO		NSP+IO		Photo-ID, Biopsy	Estimated angle and distance training/ experi-ment
		Start End	Date Time	Date Time	Time	Dist. (n.m.)	Time	Dist. (n.m.)	Time	Dist. (n.m.)	Time	Time
Shiogama to R.A. (Leg 001)	1 High Sea	001 —	12 Jul. 6:00	18 Jul. 8:52	10:13:51	120.14	14:16:00	167.5	24:29:51	287.64	1:19:35	0:00:00
Eastern stratum (Leg 201–217)	83 High Sea	201 217	18 Jul. 8:52	12 Aug. 13:54	40:10:17	450.9	41:53:28	470.34	82:03:45	921.24	18:14:19	3:17:12
R.A. to Kushiro (Leg 002)	1 High Sea	002 —	12 Aug. 13:54	16 Aug. 12:00	0:00:00	0.00	0:00:00	0.00	0:00:00	0.00	0:00:00	0:00:00
Kushiro to R.A. (Leg 003)	2 High Sea	003 —	21 Aug. 6:00	26 Aug. 7:21	20:04:53	233.68	0:00:00	0.00	20:04:53	233.68	1:04:09	7:19:58
Western stratum (Leg 101–118)	82 High Sea	101 118	26 Aug. 7:21	17 Sep. 7:33	43:12:57	491.06	43:22:42	490.67	86:35:39	981.73	24:30:59	0:00:00
R.A. to Shiogama (Leg 004)	2 High Sea	004 —	17 Sep. 7:33	22 Sep. 12:00	0:00:00	0.00	0:00:00	0.00	0:00:00	0.00	0:00:00	0:00:00
Total			12 Jul. 6:00	22 Sep. 12:00	113:41:58	1,295.78	99:32:10	1,128.51	213:14:08	2,424.29	45:09:02	10:37:10

Table 4

Number of sightings for all species observed in the research area during the 2020 IWC-POWER survey (original track lines and transit track lines), by effort mode. NSP: Normal Passing with abeam closing mode; IO: Independent Observer mode, OE: Top down (TD) and drifting (DR). Numbers of Individuals include the number of calves.

Species	Research area			Research area			Research area			Transit			Total		
	NSP			IO			OE			NSP					
	Sch.	Ind.	Calf	Sch.	Ind.	Calf	Sch.	Ind.	Calf	Sch.	Ind.	Calf	Sch.	Ind.	Calf
Blue whale	10	15	1	11	15	0	1	1	0	0	0	0	22	31	1
Fin whale	15	16	1	10	12	1	0	0	0	4	4	0	29	32	2
Like fin	0	0	0	2	2	0	0	0	0	0	0	0	2	2	0
Sei whale	50	65	1	51	68	2	4	5	1	26	43	0	131	181	7
Like sei	5	5	0	7	7	0	0	0	0	0	0	0	12	12	0
Bryde's whale	2	3	1	1	1	0	0	0	0	3	4	1	6	8	2
Like Bryde's	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0
Common minke whale	2	2	0	1	1	0	0	0	0	0	0	0	3	3	0
Humpback whale	1	1	0	6	7	0	0	0	0	0	0	0	7	8	0
Sperm whale	14	25	0	25	25	0	1	1	0	16	39	1	56	90	1
Killer whale	9	30	2	5	25	0	0	0	0	4	16	2	18	71	4
Mesoplodon spp.	2	4	0	1	3	0	0	0	0	1	2	1	4	9	1
Ziphiidae	1	2	0	2	5	0	0	0	0	1	1	0	4	8	0
Risso's dolphin	1	43	1	2	85	1	0	0	0	0	0	0	3	128	2
Striped dolphin	0	0	0	2	121	3	0	0	0	2	205	12	4	326	15
Common dolphin	8	326	15	4	229	21	0	0	0	28	1,032	43	40	1,587	79
Pacific white-sided dolphin	4	113	3	4	176	10	0	0	0	1	85	8	9	374	21
Northen right whale dolphin	0	0	0	3	197	0	0	0	0	0	0	0	3	197	0
Dalli type Dall's porpoise	7	38	0	6	42	0	0	0	0	2	20	0	15	100	0
Unid. type Dall's porpoise	4	24	0	4	14	0	0	0	0	9	50	0	17	88	0
Unid. Pilot whale	1	18	0	0	0	0	0	0	0	0	0	0	1	18	0
Unid. Dolphin	0	0	0	3	93	0	0	0	0	1	28	0	4	121	0
Unid. Cetacean	3	6	0	1	4	0	0	0	0	0	0	0	4	10	0
Unid. large baleen whale	4	4	0	12	15	0	0	0	0	2	3	0	18	22	0

stratum. In the research area a total of 22 schools (31 individuals, including 1 mother and calf pair) were sighted (Figure 3). Surface temperatures of the sighting positions ranged between 10.4°C and 18.0°C.

Fin whale (Balaenoptera physalus)

Fin whales were the second most frequently encountered baleen whale species in the research area, and they were widely distributed throughout both the western and eastern strata. Fin whales were mainly distributed north of 45°N of the research area but some aggregations were also observed to the south (Figure 4). A total of 25 schools (28 individuals) were observed in the research area, including two mother and calf pairs. A total of 2 schools (2 individuals) of 'Like fin' were recorded; these appeared to be fin whale blows but the white right lower jaw could not be confirmed. Surface temperatures of the sighting positions ranged between 9.3°C to 21.2°C.

Sei whale (Balaenoptera borealis)

Sei whales were the most frequently encountered baleen whale species in the research area, and they were

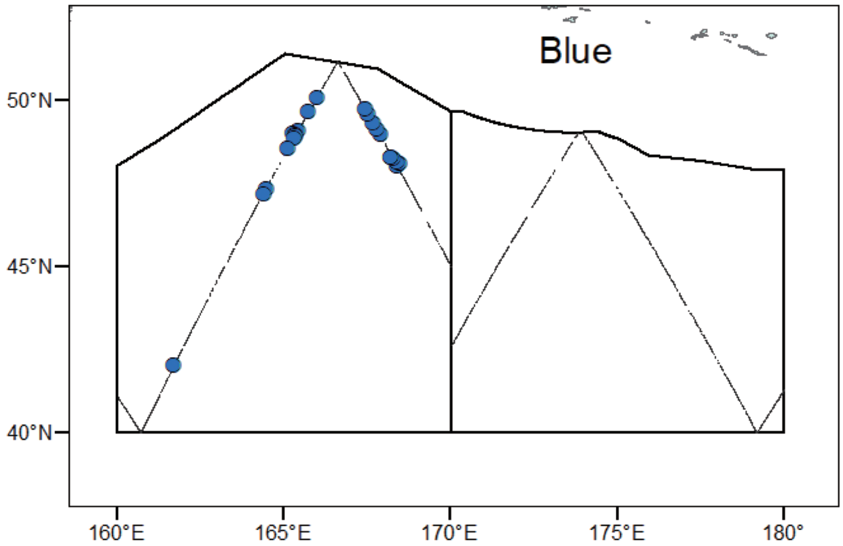

Figure 3. The searching effort (thin line) and sighting positions (blue circles) of blue whales during the 2020 IWC-POWER survey.

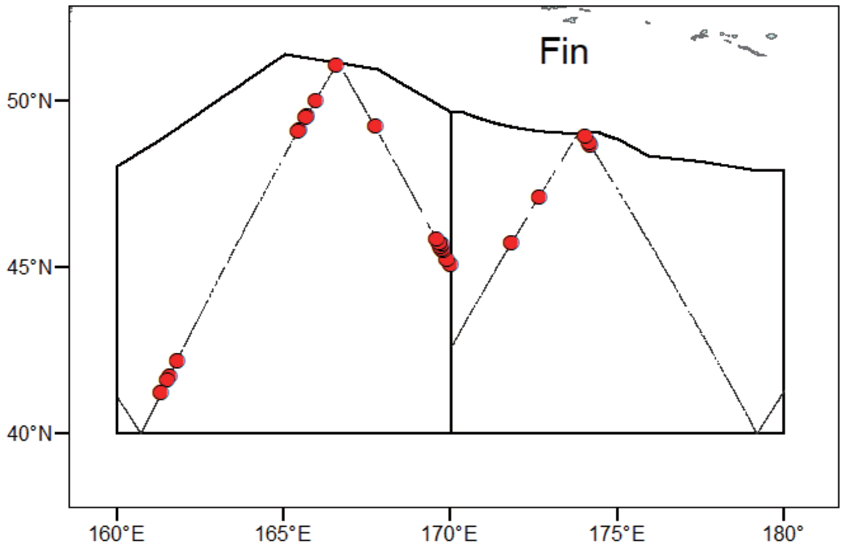

Figure 4. The searching effort (thin line) and sighting positions (red circles) of fin whales during the 2020 IWC-POWER survey.

widely distributed throughout both the western and eastern strata (Figure 5). In the research area a total of 105 schools (138 individuals, including 7 mother and calf pairs) were sighted (Table 4). Observed mean school size was 1.38. Surface temperatures of the sighting positions ranged between 8.9°C to 17.8°C. A total of 12 schools and 12 individuals of 'Like sei' were recorded; these appeared to be sei whale blows or body but the rostral ridge of the head could not be confirmed.

Bryde's whale (Balaenoptera edeni brydei)

Bryde's whales were distributed south of 45°N of the research area (Figure 6). In the research area a total of 3 schools (4 individuals, including 1 mother and calf pair) were sighted in the research area (Table 4). Observed mean school size was 1.33. A total of 1 school and 1 individual of 'Like Bryde's' were recorded; these appeared to be Bryde's whale blows or body but the three ridges in the head could not be confirmed by. Surface temperatures of the sighting positions ranged between 12.5°C and 18.4°C.

Common minke whale (Balaenoptera acutorostrata)

Common minke whales were the least frequently sighted baleen whale species in the research area. They were sighted only in the northern part of the western stratum (Figure 7). In the research area a total of 3 schools (3 individuals) were observed (Table 4). Surface tempera-

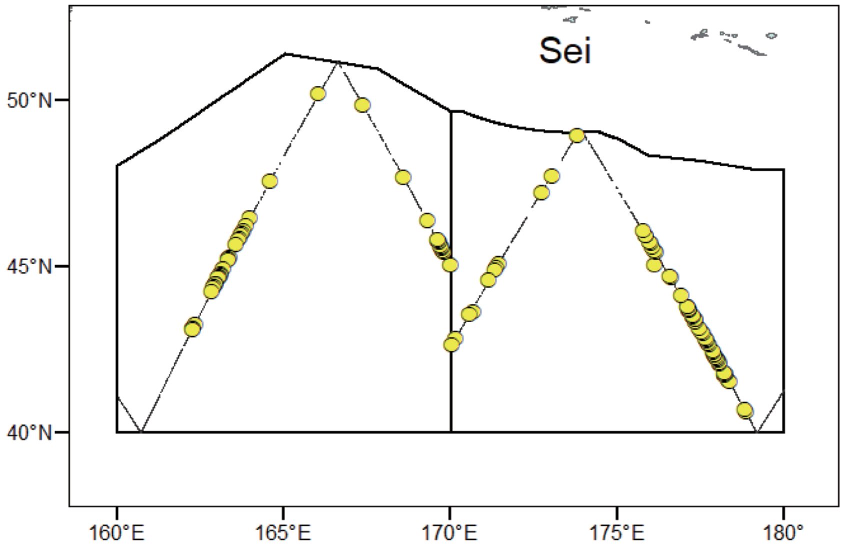

Figure 5. The searching effort (thin line) and sighting positions (yellow circles) of sei whales during the 2020 IWC-POWER survey.

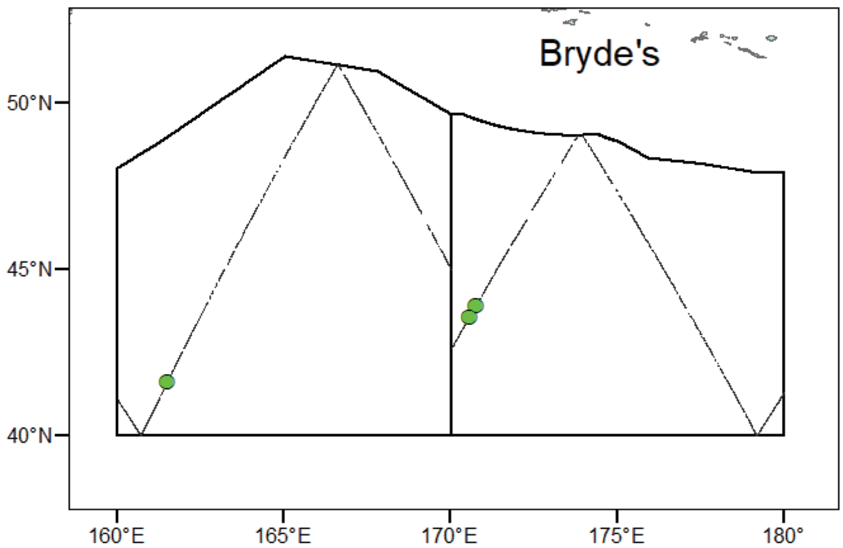

Figure 6. The searching effort (thin line) and sighting positions (yellow circles) of Bryde's whales during the 2020 IWC-POWER survey.

tures of the sighting positions ranged between 10.4°C to 14.2°C. During this survey, sea states averaged 4–5 on the Beaufort scale, which is considered to be unsuitable for sightings of common minke whales.

Humpback whale (Megaptera novaeangliae)
Humpback whales were distributed close to the northern boundary of the research area (Figure 8). In the research area a total of 7 schools (8 individuals) were sighted (Table 4). Surface temperatures of the sighting positions ranged between 9.4°C and 10.8°C.

Sperm whale (Physeter macrocephalus)
Sperm whales were widely distributed throughout the research area (Figure 9). In the research area a total of 40 schools (51 individuals) was sighted (Table 4). Surface temperatures of the sighting positions ranged between 8.9°C to 18.1°C.

Killer whale (Orcinus Orca)
Killer whales were mainly sighted in the northern part of the research area (Figure 10). In the research area a total of 14 schools (55 individuals, including 2 mother and calf pairs) were sighted (Table 4). Surface temperatures of the sighting positions ranged between 9.0°C to 17.8°C.

Identification of duplicated sightings
A total of 153 resightings were made during IO Mode

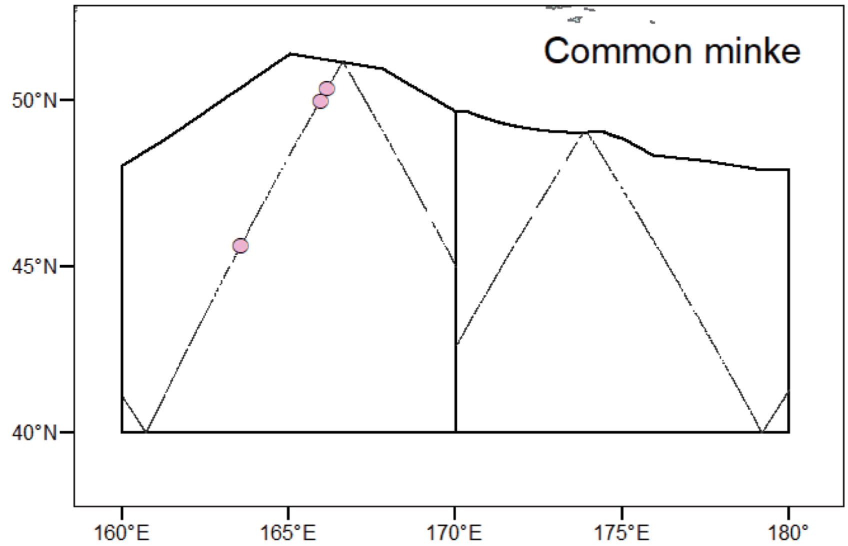

Figure 7. The searching effort (thin line) and sighting positions (pink circles) of common minke whales during the 2020 IWC-POWER survey.

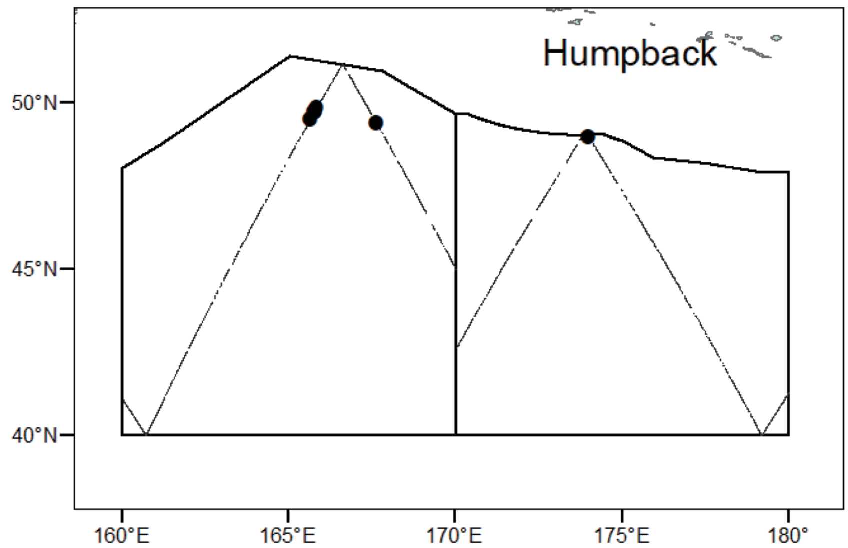

Figure 8. The searching effort (thin line) and sighting positions (black circles) of humpback whales during the 2020 IWC-POWER survey.

involving several baleen whale species. These data will be used to estimate *g*(0), which in turn will be used to adjust abundance estimates.

Photo-ID experiments

Photo-ID data were obtained for a total of 47 whales: blue (26 individuals), fin (1), humpback (3) and killer (17) whales (Table 5). Images collected during the survey were uploaded to the IWC master photographic database in Adobe Lightroom (LR) (Anon, 2020). Preliminary coding was completed for all cetacean images (4,054), including the allocation of species name, sighting number, school size and biopsy effort. Photo-ID data will be used to study movement, distribution and stock structure of the species involved.

Biopsy sampling

Biopsy samples were collected using the Larsen sampling system from 65 individual whales: 13 blue, 9 fin, 38 sei, 1 Bryde′s, 2 humpback, and 2 killer whales (Table 6, Figure 11a). All biopsy samples (Figure 11b) were catalogued and stored on the vessel in cryo-vials frozen at a temperature of −30°C. These samples will be used for molecular genetics analyses on stock identification.

Marine macro debris observation

During the survey, a total of 67 marine macro debris objects were observed. These included 15 single fishing

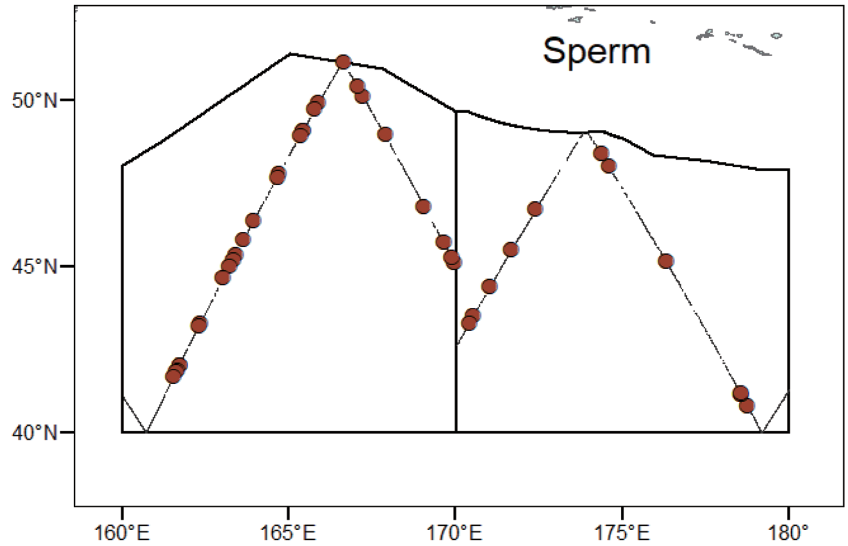

Figure 9. The searching effort (thin line) and sighting positions (red triangles) of sperm whales during the 2020 IWC-POWER survey.

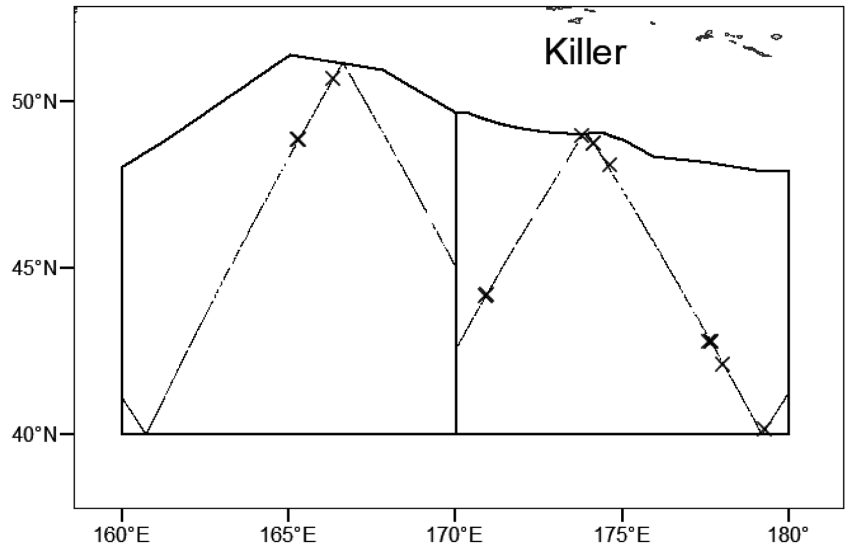

Figure 10. The searching effort (thin line) and sighting positions (black cross) of killer whales during the 2020 IWC-POWER survey.

Table 5
Summary of the Photo-ID'd experiments, by each species conducted during the 2020 IWC-POWER survey. R.A.: research area.

Photo-ID.	Blue	Fin	Humpback	Killer	Total
Transit from Japan to Eastern Stratum (R.A.) (High Sea, area code 1)	0	0	0	0	0
Eastern Stratum (High Sea, area code 83)	0	1	1	14	16
Transit from Eastern Stratum (R.A.) to Kushiro (High Sea, area code 1)	0	0	0	0	0
Transit from Kushiro to Western Stratum (R.A.) (High Sea, area code 2)	0	0	0	2	2
Western Stratum (All High Sea, area code 82)	26	0	2	1	29
Transit from Western Stratum (R.A.) to Japan (All High Sea, area code 2)	0	0	0	0	0
Total	**26**	**1**	**3**	**17**	**47**

Table 6
Summary of the number of species-specific biopsy samples collected during the 2020 IWC-POWER survey. R.A.: research area.

Biopsy samples	Blue	Fin	Sei	Bryde's	Humpback	Killer	Total
Transit from Japan to Eastern Stratum (R.A.) (All High Sea, area code 1)	0	0	5	0	0	0	5
Eastern Stratum (All High Sea, area code 83)	0	0	27	1	0	0	28
Transit from Eastern Stratum (R.A.) to Kushiro (High Sea, area code 1)	0	0	0	0	0	0	0
Transit from Kushiro to Western Stratum (R.A.) (High Sea, area code 2)	0	1	2	0	0	0	3
Western Stratum (All High Sea, area code 82)	13	8	4	0	2	2	29
Transit from Western Stratum (R.A.) to Japan (All High Sea, area code 2)	0	0	0	0	0	0	0
Total	**13**	**9**	**38**	**1**	**2**	**2**	**65**

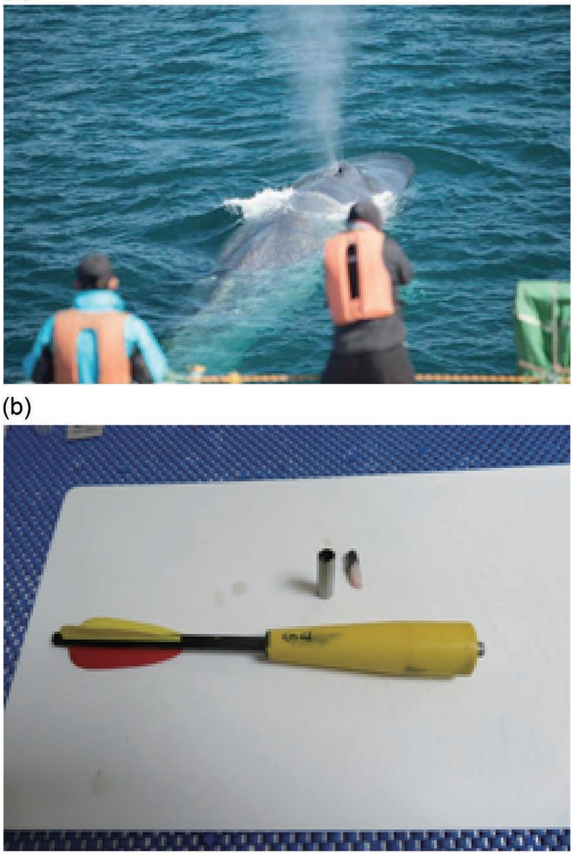

Figure 11. (a) Biopsy sampling of blue whale during the 2020 IWC POWER survey using the Larsen sampling system. (b) Dart and tip and fin whale skin sample (black skin and blubber) collected by the Larsen system.

floats, 10 styrofoam pieces (less than 1 square meter) and 8 plastic bottles (clear, 500–2,000 mL). All items were recorded 'on effort' (i.e., during the first 15 minutes of each hour).

HIGHLIGHTS OF THE SURVEY

It is concluded that the 2020 IWC-POWER survey was completed successfully by a group of international scien-

Figure 12. Researchers and crew of the 2020 IWC-POWER survey with the *Yushin-Maru* No. 2 in the background. The picture was taken during a mid-cruise meeting in Kushiro.

tists (Figure 12) and that valuable data were collected for several cetacean species. Such data will allow studies on distribution, abundance and stock structure in this particular area of the North Pacific.

There are two aspects of this survey that should be highlighted. The first aspect is the hot spot of blue whales detected southeast off Kamchatka Peninsula as shown in Figure 3. Many blue whales (21 schools/ 31 individuals) were sighted in the northern part of the western side of the research area (north of 45°N). This hot spot was also reported during the JARPN/JARPNII and NEWREP-NP surveys (e.g., Matsuoka and Hakamada, 2019). Photo-ID data and biopsy samples obtained from different research programs will allow studies on stock structure for this particular spot.

The second aspect is the continuous distribution of sei whales in the sector comprised between 160°E and 180° detected in this survey (Figure 5). In past surveys only a limited sighting effort was spent in the sector 170°E–180°, so the continuous distribution in this sector confirmed in this survey is an important piece of information to assist the interpretation of stock structure of the species.

With the completion of this survey, the waters north of 40°N between 160°E and 135°W have been covered since 2010, with the only exception being the Russian EEZ. From 2021, it is anticipated that the IWC-POWER program will move toward its second phase, which will be designed after examining in details the results from the first phase.

ACKNOWLEDGEMENTS

We thank the Governments of the United States and Japan for their assistance in obtaining research permits and for funding. We thank Greg Donovan and the IWC Secretariat for their technical and logistical support during the preparation for this survey. We also thank all international researchers, captain and crew of the *Yushin-Maru* No. 2 for their hard work and dedication. We appreciate the valuable advice of the Steering Group and the Technical Advisory Group. Takashi Hakamada, Megumi Takahashi, Taiki Katsumata (ICR) as well Isamu Yoshimura (Kyodo Senpaku Co. Ltd.) made logistical arrangements in preparation of this survey. Finally, we thank Luis A. Pastene (ICR) for his assistance in preparing this document.

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Technical Reports of the Institute of Cetacean Research (2021) pp. 43–48

Technical Report (not peer reviewed)

An outline of the Density Surface Model for estimating abundance of baleen whales undertaken by the Institute of Cetacean Research

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ABSTRACT

The Institute of Cetacean Research (ICR) is starting the use of the Density Surface Model (DSM), a model-based approach, to estimate abundance of large baleen whales. This is an alternative approach to the design-based approach used so far for the same purpose. This paper explains the concepts of DSM, and outlines the potential utility of this approach for the work on whale abundance undertaken by the ICR.

INTRODUCTION

The Institute of Cetacean Research (ICR) conducts regular sighting surveys of large whales with the aim of estimating abundance in oceanic regions of interest. The basic sighting procedures for this purpose were described in Hakamada and Matsuoka (2017). Abundance has been estimated routinely by the 'design-based approach,' using the distance sampling method (Thomas *et al.*, 2010). Conventionally, abundance is estimated by equation (1) (Buckland *et al.*, 1993; 2001).

$$\frac{An\mathrm{E}(s)}{2wL} \tag{1}$$

where,
A is Area size of the survey area,
n is the number of detected whale schools,
E(*s*) is the expected mean school size,
w is the effective half search width (esw), and
L is the searching distance.

The validity of the abundance estimator based on equation (1) relies on the assumption of a randomized survey design (Hedley and Buckland, 2004; Miller *et al.*, 2013). In the case that this assumption is violated, an abundance estimator not requiring a randomized design is necessary.

Distribution of whales may be driven by environmental covariates such as sea surface temperature (SST), depth and salinity, each of which could vary in space. Relationships between environmental covariates and distribution of specific species is one of the interesting topics to investigate. Spatial modelling of the whale distribution can be constructed as a function of environmental covariates if dependency of the covariates on density of whales is substantial. Such constructed spatial modelling can be used to predict distribution in areas where the environmental covariates are available. Investigation of environmental covariates related to the distribution of the species can be conducted by selecting covariates using statistical criterion.

The two aims of spatial modelling are i) estimation of overall abundance in the area of interest ('model-based approach'), and ii) investigation of the relationship between density/abundance and environmental covariates (Miller *et al.*, 2013). Unlike conventional distance sampling ('design-based approach'), abundance estimates obtained by spatial modelling do not rely on the survey design. Spatial modelling can be applied to data obtained from different sources: platforms of opportunity such as ferries, fishing boats, incomplete surveys due to bad weather or accident, and surveys that were designed neither randomly nor systematically.

There are many kinds of spatial modelling. Density Surface Model (DSM) (Miller *et al.*, 2013) is one of them, and its use is starting to be utilized at the ICR. The objective of this paper is to explain the basic concepts of DSM based on Generalized Additive Model (GAM) (Wood, 2006) in the context of abundance estimates of large baleen whales. A secondary objective of this paper is to outline the future applications of the DSM in the work on whale abundance by the ICR.

GENERALIZED ADDITIVE MODEL (GAM)

DSM is expressed using the statistical model GAM. GAM allows the assumption that distribution of response variables is an 'exponential family.' A distribution belongs to the exponential family if its probability density function or probability mass function can be expressed by the formula

$$f(\theta, y) = \exp\left[\frac{\{y\theta - b(\theta)\}}{a(\phi)} + c(y,\phi)\right] \quad (2)$$

where a, b and c are arbitrary functions, ϕ is an arbitrary scale parameter and θ is known as the canonical parameter of the distribution (Wood, 2006). Properties and examples of exponential families are provided in McCullagh and Nelder (1989) and Wood (2006). In this context, GAM can model variables that follow not only normal distribution but also Poisson, binomial, and other distribution types. For example, the number of counts, probability, presence/absence can be used as a response variable in GAM. A formula of GAM can be written as:

$$\mathrm{E}(y) = g^{-1}(f_1(x_1) + \cdots + f_k(x_k)) \quad (3)$$

where,
y is the response variable,
E(y) is the expectation of y,
g^{-1} is the inverse of link function g,
$f_j(x_j)$ is a smooth function of x_j.

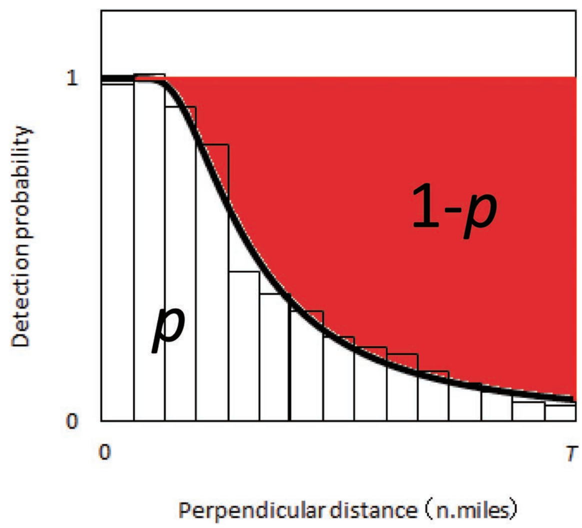

Figure 1. Histogram of relative frequency of detections by intervals of perpendicular distance and plot of detection function (bold curve). The red zone represents the proportion of animal detections missed as compared to the animals in the surveyed area within T n.miles from the track line, where T is truncation distance. Example of the histogram and the detection function models are taken from Hakamada *et al.* (2013).

A spline is a special function defined piecewise by polynomials, and is usually used as a smooth function in the GAM. When $f_j(x_j)$ is a linear function with respect to x_j, equation (3) becomes a Generalized Linear Model (GLM) (McCullagh and Nelder, 1989). In this sense, GAM can be regarded as an extension of GLM.

BASIC CONCEPT FOR THE CONSTRUCTION OF DENSITY SURFACE MODEL (DSM)

There are four steps in constructing a DSM from line transect survey data.

1. Fitting detection function with perpendicular distance data and other covariates that would affect detectability of whale schools.
2. Fitting count models in each grid with environmental covariates data.
3. Prediction of abundance in each grid in the study area using the models constructed above.
4. Summation of the predicted abundance in the grid over the area of interest.

The abundance estimate in the study area is obtained as follows.

Step 1

The detection function represents the relationship between the detection probability and the perpendicular distance. It is assumed that the detection probability decreases as the perpendicular distance increases. Figure 1 shows a histogram of relative frequency of detection by perpendicular distance and estimated detection function. T is the truncation distance (i.e., detections of perpendicular distance more than T are excluded from the analysis). Among the animals within T n.miles from the track line, the zone below the detection function represents animals actually detected. The red zone represents the animals missed. The detection function predicts probability for each detection. The proportion of the former is p, the detection probability and proportion of the latter is 1-p. By dividing the number of the detections by the detection probability p, the number of whales that fail to be detected can be taken into account (i.e., red zone in Figure 1).

The detection function derived from Multi Covariate Distance Sampling (MCDS) can be used in this method. The advantage of using MCDS is that the effect of covariates on sighting conditions, such as Beaufort scale, wind speed, and visibility, on the detection function can be assessed. As mentioned later, the detection function with assumption $g(0)<1$ can be used in this method.

Step 2

Figure 2 illustrates the division into grids to construct count models. As shown in the figure, the track line sur-

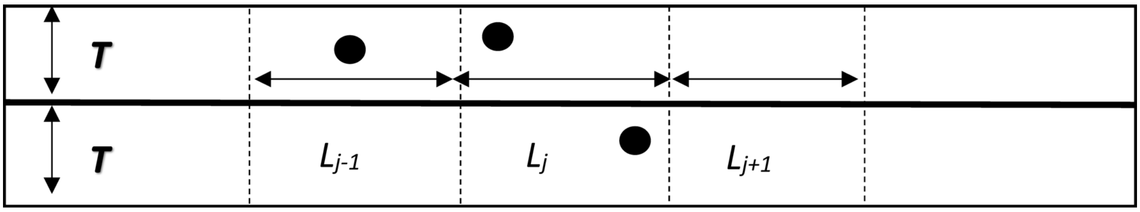

Figure 2. Illustration of the division of track line into grids to construct count models. Black circle indicates a detected whale school. Bold line indicates the track line surveyed. T is truncation distance. L_j is the length of the track line surveyed in the j th grid. Area size of the j th grid is $A_j=2L_jT$.

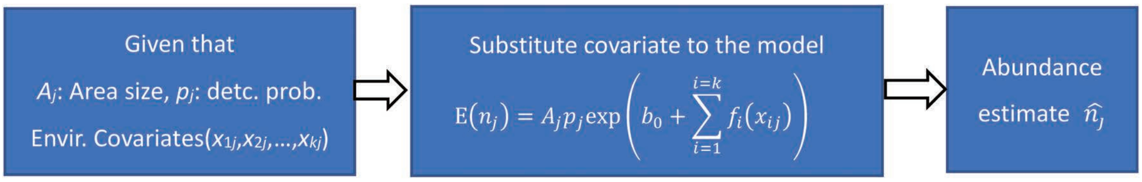

Figure 3. Scheme to predict abundance estimate in each grid.

veyed were divided into several sections.

The j th grid has a width of $2T$ and length of L_j. L_j is not necessarily constant. The area size of the j th grid is $A_j=2L_jT$. The area size should be chosen, such that it is small enough to ensure that density in the grid can be regarded as almost uniform. The number of the detected school in the j th grid is n_j. The count model has covariates that could change in response to space and other factors (e.g., longitude, latitude, SST, depth, salinity) as explanatory variables and the number of counts per unit area size as a response variable.

For simplicity, it is assumed that the values of the explanatory variables x_js are available for any position in the area of interest. When fitting the model, explanatory variables in the grid are usually obtained by averaging all observed values in the grid. One example of the count model can be expressed by:

$$E(n_j) = A_j p_j \exp\left(b_0 + \sum_{i=1}^{i=k} f_i(x_{ij})\right) \qquad (4)$$

where,

$E(n_j)$ is the expected the number of the detection in the grid j,

A_j is the area size of the grid j as an offset,

p_j is the averaged detection probability for detected schools in the j th grid derived from the detection function constructed in step 1,

b_0 is intercept,

k is the number of the explanatory variables, and

$f_i(x_{ij})$ is the i th smooth function of the i th covariate x_{ij} at the j th grid.

When the detection function has covariates on sighting condition derived by MCDS, it can be considered that p_j may be different among the grids.

Step 3

The grids for prediction of abundance are defined in order to cover the study area of interest. The shape of the grid is usually almost a square. The size of the grid should be small enough so that density can be regarded as almost uniform. These grids are different from those defined in Step 2.

The expected numbers of detection (abundance estimate) in the grid can be predicted by using equation (4), if A_j, p_j and x_{ij} for all i are available (Figure 3). A_j is the area size of the grid j and is clearly available. p_j can be predicted in all the grids if one of the two following conditions are satisfied. The first is that the covariate of the detection function derived in Step 1 is only the perpendicular distance (in this case, p_j is constant for all grids). The second is that the detection function has covariates on sighting conditions and the value of the covariates are available for all the grids. The explanatory variables in the grid are usually obtained by averaging all observed values in the grid. Thus, abundance estimate in all the grids can be predicted.

Step 4

The predicted abundance estimate in each grid are totaled to obtain the abundance estimate for the whole area of interest. When the shape of the area of interest is complex, only a part of the grid belongs to the area for some of the grids at the edge of the area. In such case, equation 4 can be applied to the intersect of the grid and the area.

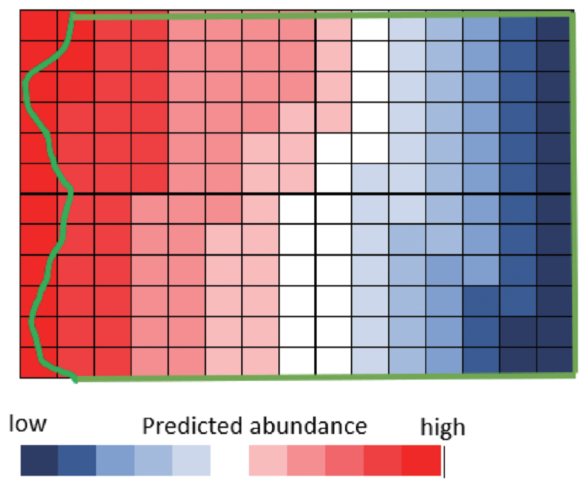

Figure 4. Illustrative example of a map for the predicted abundance in each grid. Strong red indicates high density and strong blue indicates low density. Green line indicates the boundary of the area of interest.

Figure 4 is an illustrative map for the predicted abundance in each grid. In this case, the model shows a tendency whereby the predicted abundance is getting higher from the right to the left. For some of the grids, the whole of the grid is not included in the area of interest. Prediction can be conducted using the data in the intersect of the grid and the area. One of the advantages of predicting abundance by the grids is that it is easy to calculate the abundance estimate for any subset of the surveyed area by summing the predicted abundance over the grids in the subset.

Further aspects on DSM

One and two stage approaches

Explanation in the previous section is based on the two-stage approach, which means fitting DSM and detection model at each stage. A one-stage approach means fitting both models simultaneously (Royle *et al.*, 2004). The disadvantage of the one-stage approach is that the computation to estimate and check is more difficult than in the two-stage approach, because both steps must be conducted at once. The disadvantage of a two-stage approach is that to estimate uncertainty for the abundance estimate, the uncertainties in the detection function and the spatial model must be combined appropriately (Miller *et al.*, 2013).

Distribution of response variable

In the case of count models, Poisson distribution is usually assumed as the distribution of the count. In many cases, there is a high proportion of the grids with zero count (i.e., there is no sightings in the grid), because the numbers of grids constructed in Step 2 is larger than the numbers of animals detected. Alternative distributions of count are, for example, quasi-Poisson, negative binomial and Tweedie distribution (Tweedie, 1984), which deal with the higher proportion of zero data. The latest version of R library dsm, which is software that can conduct DSM, can deal with quasi-Poisson, negative binomial and Tweedie distribution as the distribution of a response variable (Miller *et al.*, 2021).

Variance estimation

In previous studies on abundance estimates derived from DSM, the variance was estimated using parametric bootstrap (Hedley et al., 1999; Hedley and Buckland 2004). When the detection function model and the count model are independent, the variance of the abundance can be approximated as the sum of variance due to detection function and variance due to count model using delta method (Seber, 1982). When the detection function and the count model are not independent, the approximation by the delta method cannot be applied to estimate the variance of abundance. In this case, variance propagation can be applied to estimate the variance of the abundance. Details of the variance propagation are provided in Bravington *et al.* (2021).

Evaluation of extrapolation using DSM

When applying DSM to areas outside of the reference data (i.e., data used to construct the model), attention should be paid to the extrapolation of DSM (Miller *et al.*, 2013). For example, when the DSM that has SST as a covariate is fitted using data from warm waters in a temperate zone, predictions for cold waters in the sub-arctic by the model are unlikely to be reliable due to difference in the range of SST. Bouchet *et al* (2020a) reviewed several quantitative extrapolation diagnostics and recommended to use two of them, principally, the percentage of data nearby, %N (King and Zeng, 2007) and the Extrapolation Detection, ExDet (Mesgaran *et al.*, 2014), as standard tools for assessing extrapolation in abundance models. %N is a metric that represents how close the data for extrapolation and the reference data are. The higher the %N is, the more reliable the extrapolation is. ExDet is a metric that characterizes both univariate and combinatorial extrapolation and provides geographical distribution of the most influential covariate among the covariates (Bouchet *et al.*, 2020a). Assessment of extrapolation using the two metrics can be implemented by dsmextra library of R (Bouchet *et al.*, 2020b).

POTENTIAL UTILITY OF THE DSM FOR THE WORK ON WHALE ABUNDANCE BY THE INSTITUTE OF CETACEAN RESEARCH

The model-based approach can be applied to the case of Antarctic minke whales and common minke whales in the western North Pacific. These are two of the target species for abundance research by the ICR.

In the case of Antarctic minke whales, the abundance estimation in polynyas is problematic. The pack ice prevents the research vessels entering the polynyas. The shape of the polynyas is often complex and narrow, therefore a random and/or systematic survey design cannot be realized even if platforms other than the vessel (e.g., drone) are used for the survey. In such cases, the data obtained can be used to estimate abundance based on DSM.

The common minke whales in the western North Pacific are distributed in the Okhotsk Sea, the western North Pacific Ocean and the Sea of Japan. Some areas of the distribution of this species cannot be surveyed, because they are in the Exclusive Economic Zone (EEZ) of third countries, from which permits are difficult to obtain. This situation results in underestimation of the abundance because not all areas of distribution of the species or stock are covered. If some environmental data in the unsurveyed areas are available, extrapolation by model-based approach can be applied. This study would be ambitious and challenging, because it is difficult to obtain reliable DSM given that the ranges of environmental covariates in areas where the DSM was extrapolated would be expected to be different from the reference data (i.e., the data used to construct the model). However, the reliability of the extrapolation can be evaluated using the indices mentioned above. By assessing conditions under which models are likely to fail or succeed in extrapolation through this exercise, a better understanding of distribution patterns and their underlying drivers for this species may be obtained (Yates *et al.*, 2018).

The latest version of R library dsm can deal with detection function derived from mark-recapture distance sampling (MRDS) that allows $g(0)<1$ (Miller *et al.*, 2021). Concept and example of such detection function derived from the MRDS are provided in Takahashi (2019). From this update, DSM derives abundance estimates that consider $g(0)$ estimate. This is particularly relevant for species that cannot be detected due to their behavior and whose distribution is driven by environmental covariates varying in space. DSM that allows $g(0)<1$ can be applied to whales, such as common minke whales and Antarctic minke whales, whose $g(0)$ estimates have been shown to be less than 1 in previous studies (Okamura *et al.*, 2010; Okamura and Kitakado, 2012).

ACKNOWLEDGEMENTS

I thank Luis A. Pastene (ICR) for his assistance in preparing this manuscript.

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Technical Reports of the Institute of Cetacean Research (2021) pp. 49–57

Technical Report (not peer reviewed)

Review of biological information of the J stock common minke whale based on genetically identified individuals

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ABSTRACT

The findings from a review of the biological and ecological information of the J stock common minke whale held at the Institute of Cetacean Research are summarized in this paper. Information reviewed included spatial/temporal distribution, morphology, morphometrics, reproductive characteristics, feeding ecology, environmental pollutants, and ecological markers, based on the individuals of this stock identified by genetic markers. Results of this review confirm biological and ecological differentiation of the J stock within the North Pacific common minke whale, and corroborate the view that this stock should be managed independently.

INTRODUCTION

In the western North Pacific, at least two biological stocks of common minke whales *Balaenoptera acutorostrata* are known to exist: the Okhotsk Sea-West Pacific (O stock) and the Sea of Japan-Yellow Sea-East China Sea (J stock) (Omura and Sakiura, 1956; Ohsumi, 1977; 1983). The two stocks are differentiated in morphological and reproductive characteristics (Omura and Sakiura, 1956; Ohsumi, 1977; Kato, 1992), as well in genetics (Wada and Numachi, 1991 for allozymes; Goto and Pastene, 1997 for mtDNA; and Kanda *et al.*, 2009a; b for microsatellites), suggesting their reproductive isolation. The International Whaling Commission (IWC) had proposed some boundaries for these stocks (Donovan, 1991).

Previous genetic studies showed that both stocks mix with each other spatially and temporally in the southern part of the Okhotsk Sea (northern Hokkaido) (Wada, 1991; Pastene *et al.*, 1998). Since then, a substantial number of genetic samples of western North Pacific common minke whales became available, and modern and more powerful genetic markers have been applied to those samples in recent years. The application of such markers to the new samples enabled finer studies on stock structure of this species in this ocean basin (Pastene *et al.*, 2016a; b).

In recent years microsatellite DNA data from a substantial number of genetic samples of common minke whales in the western North Pacific have been used in genetic analyses for individual assignment, for example, by using the program STRUCTURE (Pritchard *et al.*, 2000). Genetic individual identification has allowed the study of several biological and ecological aspects separately for both J and O stocks common minke whales. The objective of this document was to review the biological and ecological information accumulated on the J stock based on these approaches.

INDIVIDUAL IDENTIFICATION BASED ON MICROSATELLITE DNA ANALYSES

Microsatellite DNA data and the program STRUCTURE version 2.0 (Pritchard *et al.*, 2000) were used to determine the most likely number of genetically distinct stocks present in the samples of common minke whales in the western North Pacific. The program is a model-based clustering method for inferring stock structure (K, the number of stocks in the model) using multilocus genotype data with and without information on sampling locations. Individual assignment was conducted for the most plausible K using the estimated individual proportion of membership probability. The ancestry model used for the simulation was the admixture model, which assumes individuals may have mixed ancestry. The allele frequency model used was the correlated allele frequencies model, which assumes frequencies in the different stocks are likely to be similar due to migration or shared ancestry.

Further details of the genetic analyses on individual identification of common minke whales can be found in Goto *et al.* (2017).

BIOLOGICAL AND ECOLOGICAL CHARACTERIZATION OF THE J STOCK

Several biological and ecological studies have been conducted based on genetically-identified J stock individuals.

Table 1

Summary of different biological and ecological studies of the J stock common minke whales including focal points, samples used and key references. JARPN: Japanese Whale Research Program under Special Permit in the western North Pacific; JARPNII: JARPN Phase II; NEWREP-NP: New Scientific Whale Research Program in the western North Pacific.

Focal points	Samples/Years/Sources	References
Distribution and movement		
Spatial distribution	*n*=4,275 (1994 to 2014), JARPN/JARPNII; bycatch	Goto *et al.* (2017)
Temporal distribution	*n*=2,522 (2001 to 2014), JARPNII; bycatch	Goto *et al.* (2017)
Distance from the coastal line	*n*=986 (1994 to 2007), JARPN/JARPNII; bycatch	Kanda *et al.* (2010)
Morphology and morphometry		
Flipper color pattern	*n*=220 (2012 and 2013), JARPNII	Nakamura *et al.* (2016)
Fluke color pattern	*n*=164 (2007), JARPNII	Nagatsuka (2008; 2010)
Morphometry	*n*=500 (2000 to 2007), JARPN/JARPNII	Hakamada and Bando (2009)
Reproduction		
Conception date	*n*=107 (1994 to 2007), JARPN/JARPNII	Bando *et al.* (2010a)
Feeding ecology		
Stomach contents	*n*=742 (1996 to 2018), JARPN/JARPNII; NEWREP-NP	Present study
Ecological markers		
Total Hg levels	*n*=59 (2012 and 2013), JARPNII	Yasunaga and Fujise (2016)
Cookie cutter shark scar	*n*=1,037 (2002 to 2007), JARPN/JARPNII	Bando *et al.* (2010b)

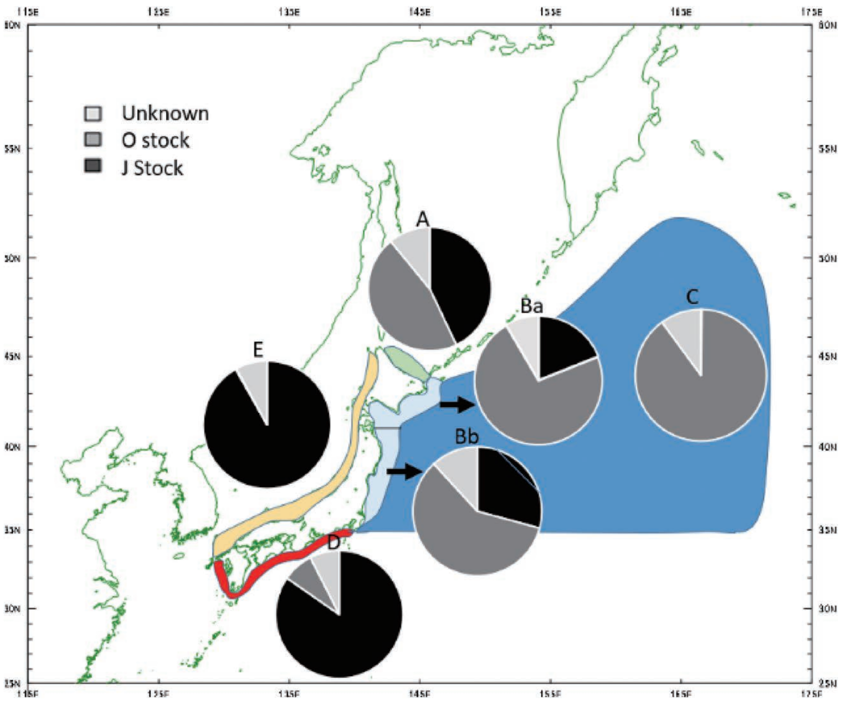

Figure 1. Spatial occurrence of O and J stocks common minke whales in waters around Japan based on genetic individual identification (modified after Goto *et al.*, 2017).

Description of the results of the main focal points are presented in this section (Table 1).

Distribution and movement

Spatial distribution along the Japanese coast

As shown in Figure 1, almost all of the individuals collected from the Sea of Japan side belong to the J stock, whereas almost all of the individuals from the offshore North Pacific belong to the O stock. The southern part of the Pacific side of Japan was mainly occupied by the J stock. Northern Hokkaido and the northern part of the Pacific side of Japan represent areas where both stocks overlap geographically.

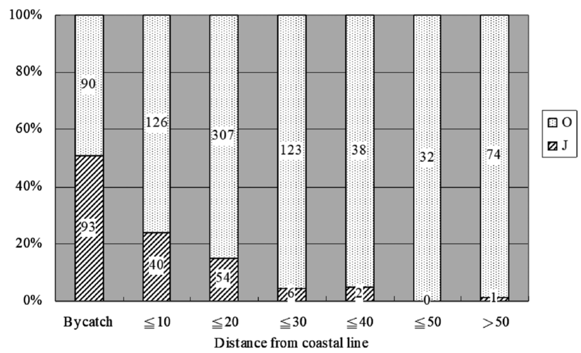

Figure 2. Proportion of the minke whales assigned to the J and O stocks collected from sub-area 7W by the distance from the Japanese coastal line (after Kanda *et al.*, 2010).

Temporal distribution along the Pacific coast of Japan

In the southern part of the Pacific side of Japan, the J stock was predominant throughout the year (around 80% in proportion). In the Northern part of the Pacific side of Japan, the proportion of the J stock increased in autumn/winter and decreased in spring/summer. Conversely, the proportion of O stock decreased in autumn/winter and increased in spring/summer. The fact that the J stock is distributed in the southern part of the Pacific side of Japan throughout the year suggests that the Kuroshio Current—one of the strongest west-boundary currents of the subtropical gyre—is serving as the stock boundary between O and J stocks (Goto *et al.*, 2017).

Distance from the coastal line

In terms of the distance from the Japanese coastal line in the North Pacific side e.g., sub-area 7W (sub-areas Ba and Bb in Figure 1), the proportion of the common minke whales was different between the J and O stocks (Figure 2). The proportion of the J stock whales decreased from coastal areas towards offshore areas. Such a clinal distribution supports the mixing of the two stocks in sub-area 7W.

Migratory routes

The migratory routes to feeding areas of adult and juvenile J stock animals are schematically shown in Figure 3. Migratory routes to breeding areas are assumed to be the reverse in the case of adults. Adult animals were assumed to migrate northward and southward for feeding and breeding, respectively, through the central corridor of the Sea of Japan. The northward migration limit was not clear at this stage because there were no genetic samples available from the central and northern parts of the Okhotsk Sea. In the case of juveniles, it was assumed that they were making short northward and southward

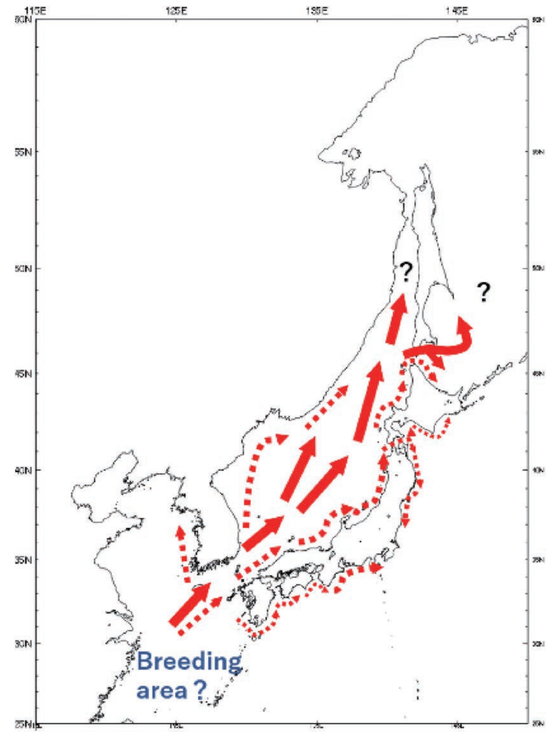

Figure 3. Assumed feeding migration route of J stock animals (modified after Hatanaka and Miyashita, 1997 and Goto *et al.*, 2010). Solid line: mature, dotted line: immature.

migrations along the coastal area for feeding because bycatch juvenile animals were observed throughout the year on the Japanese coast.

Morphology and morphometry

Morphology

Nakamura *et al.* (2016) studied the unique white patch on the flipper of whales sampled by JARPNII during 2012 and 2013 to elucidate stock differences. They focused on the morphological differences in the size and pattern of the white patch on the flipper of each whale. The length of the white patch along the anterior (ventral) margin of the flipper tends to be proportionally smaller in the J stock. The pattern of the boundary area of the white patch named as the 'Grayish Accessary Layer (GAL)' was remarkably different between the two stocks (Figure 4). Among animals with 'no GAL' type, 94% were J stock. Conversely, 96% of the animals with GAL expanding over the half the flipper width were O stock.

Fluke color pattern

Nagatsuka (2008) found that common minke whales had different black and white patterns on the underside of their flukes. She then separated the sampled whales into three different fluke color types (Figure 5). Differences

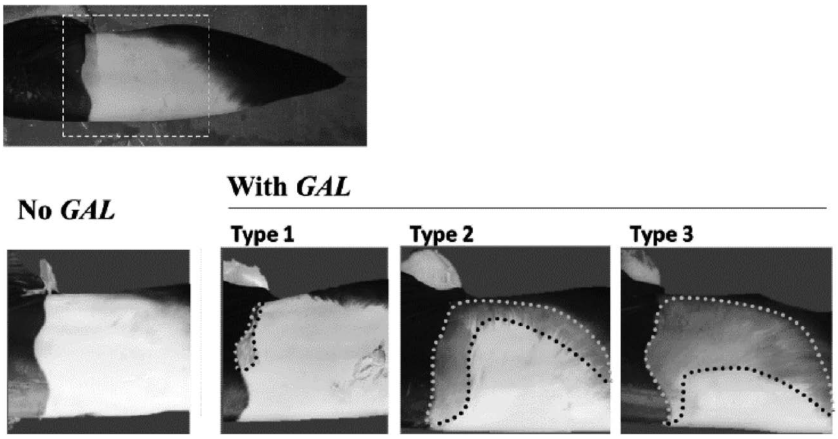

Figure 4. Characteristics of the white patch along the ventral part of the flipper in common minke whales from the western North Pacific. The pictures show the basis for the classification based on the *GAL* types (*GAL*: surrounded by dotted line) (after Nakamura *et al.*, 2016).

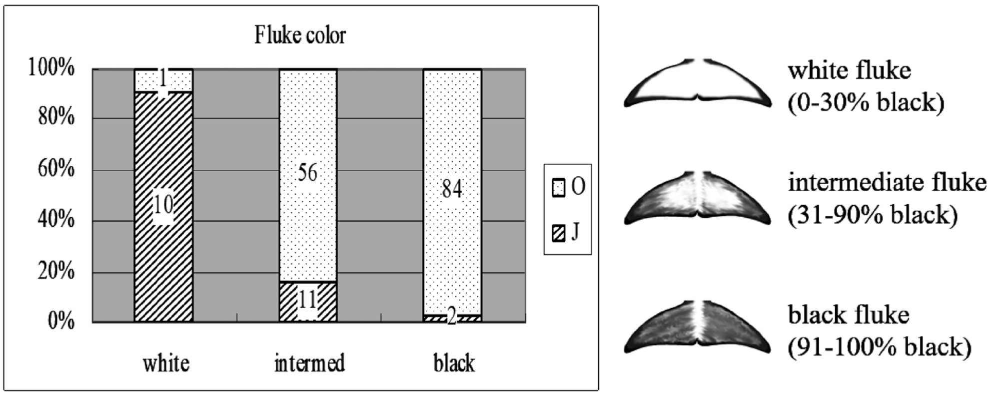

Figure 5. Proportion of the minke whales assigned to J and O stock collected from sub-area 7W by the fluke color pattern, and diagram of the fluke color pattern (after Kanda *et al.*, 2010).

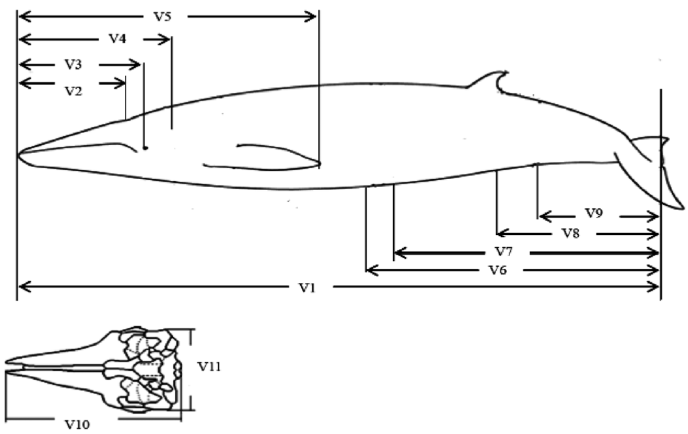

Figure 6. External measurements of western North Pacific common minke whales examined for comparative stock analyses (after Hakamada and Bando, 2009). Measurements V3, V4, V7, V10 and V11 showed significant differences in morphometrics between J and O stocks.

in the frequencies of these three types were observed between the individuals assigned genetically as J and O stocks sampled during the 2007 JARPNII coastal and offshore surveys (Nagatsuka, 2010). The frequencies of the three types were recalculated for the samples collected only from sub-area 7W (Figure 5). The frequencies were different between the individuals assigned to J and O stocks ($p<0.001$).

Morphometry

Hakamada and Fujise (2000) examined the difference between the J and O stocks, using the external measurement data obtained during the 1994–1999 JARPN surveys. Significant differences were observed between the two stocks, especially that J animals exhibited shorter lower body than O stock animals. Hakamada and Bando (2009) examined morphometric data of common minke whales sampled by JARPNII to investigate the differences between J and O stocks (Figure 6). Analysis of covariance (ANCOVA) using body length as a covariate was used to test if there were significant differences in morphometric measurements among the groups compared. Measurements V3, V4, V7, V10 and V11 showed significant differences in morphometrics between J and O stocks.

Reproduction

Conception date

Bando *et al.* (2010a) examined the distribution of conception dates of J and O stock animals collected from the coastal area of western North Pacific (sub-area 7W) and the Okhotsk Sea (sub-area 11) during 1994–2007 JARPN/JARPNII surveys (Figure 7). In sub-area 7W the conception date of the J stock was in August (n=1) and January (n=2); in sub-area 11 they were distributed between October and March (n=8). These results suggested that the

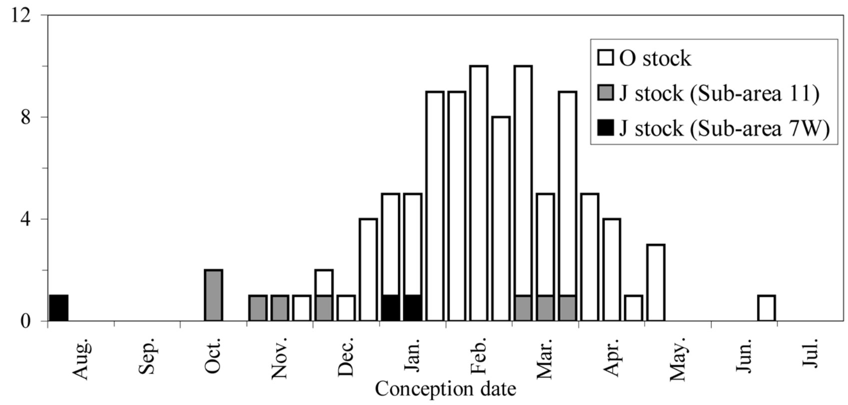

Figure 7. Seasonal distribution of conception dates of the J and O stock common minke whales in ten-day periods (after Bando *et al.*, 2010a).

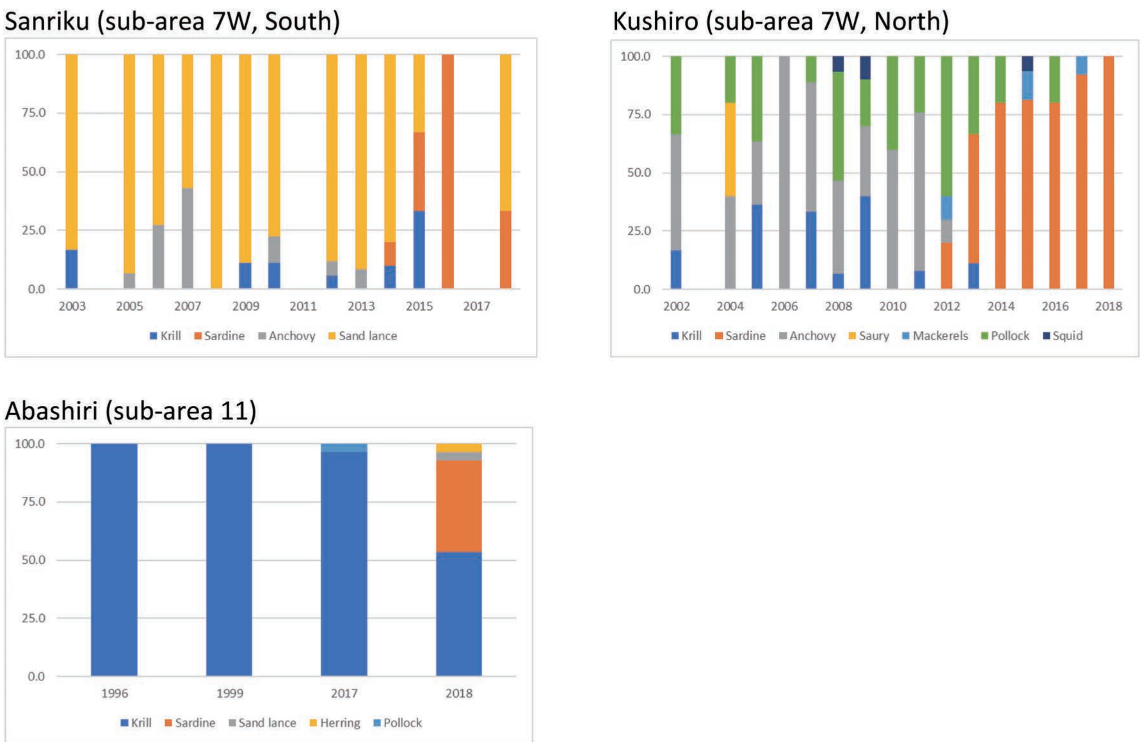

Figure 8. Yearly and geographical change of main prey species of J stock common minke whales.

conception period of the J stock extends from autumn to winter. However, the sample sizes are too small to reach a definitive conclusion.

Feeding ecology

The feeding ecology of common minke whales around Japan has been examined in previous published papers (Kasamatsu and Tanaka, 1992; Tamura and Fujise, 2002; Konishi *et al.*, 2009). However, there have been few published papers specifically on the feeding habits of J stock common minke whales. Results of the analyses of genetically identified J stock individuals showed that these whales fed on various prey species such as Pacific krill *(Euphausia pacifica)*, Japanese sandlance *(Ammodytes personatus)*, Japanese anchovy *(Engraulis japonicus)*, Pacific saury *(Cololabis saira)*, walleye pollock *(Gadus chalcogrammus)*, and Japanese common squid *(Todarodes pacificus)*, and that the main prey species changed both yearly and geographically (Figure 8). These results suggested that J stock common minke whales appear to be an opportunistic feeder, changing their prey species in response to prey availability.

Environmental pollutant (total Hg levels)

Yasunaga and Fujise (2016) compared the accumulation patterns of total Hg concentrations in muscle and liver between J and O stocks of common minke whales. The analyses were based on 35 O stock and 24 J stock immature animals taken from sub-area 7W in the 2012 and 2013 JARPNII surveys (Figure 9). Multiple linear regression analyses in total Hg concentrations of the whales adjusted for confounders (age index, sex, blubber thickness and year) showed no discernible effect between the two stocks. Results suggested that there is no stock-dependent difference of total Hg and that there is no exposure risk among the common minke whales from the coastal waters of Japan.

Ecological markers

Cookie cutter shark scar

Bando *et al.* (2010b) investigated cookie cutter shark-

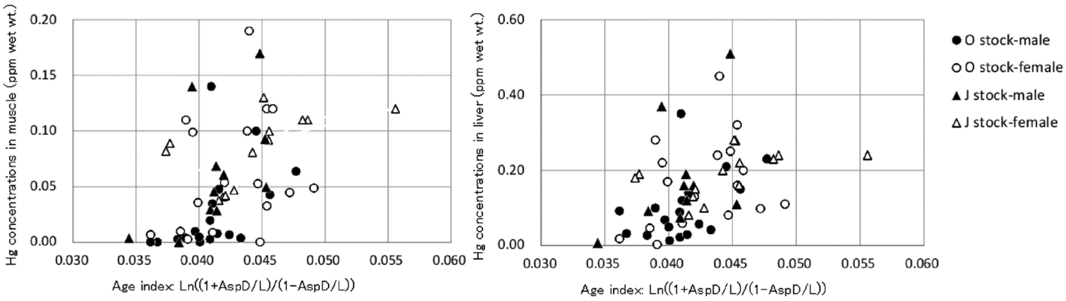

Figure 9. Relationship between Hg concentrations (ppm wet wt.) in muscle in relation to age (left) and Hg concentration in liver in relationship to age (right) in common minke whales from sub-area 7W (after Yasunaga and Fujise, 2016).

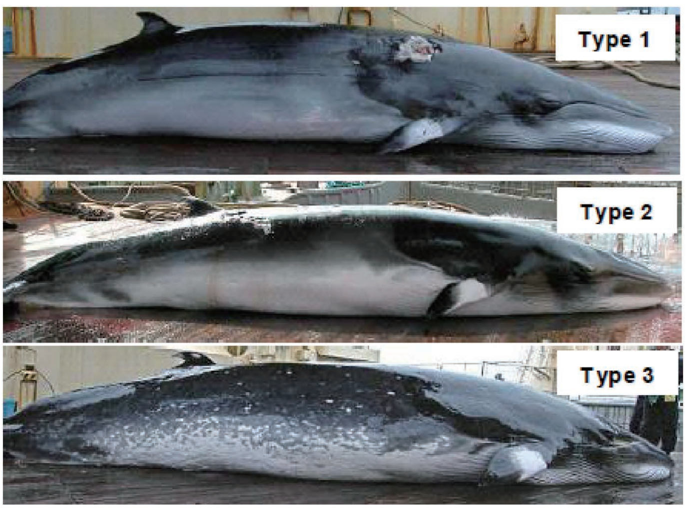

Figure 10. Three types of cookie cutter shark-induced scars in common minke whales. J stock animals had fewer scars than O stock animals.

Table 2
Types of cookie cutter shark-induced scars in common minke whales in the coastal areas of western North Pacific off sub-area 7W (North: off Hokkaido, South: off Sanriku) and Pacific offshore area (sub-areas 8 and 9) (modified from Bando *et al.*, 2010b).

Sub-area	Type of scar	Microsatellite DNA		
		O	?	J
7W North	Type 1 None	0	2	17
	Type 2 1–20 scars	14	5	31
	Type 3 more than 20 scars	291	31	5
	Total	305	38	53
7W South	Type 1 None	0	3	19
	Type 2 1–20 scars	10	5	22
	Type 3 more than 20 scars	213	25	2
	Total	223	33	43
8	Type 1 None	0	0	0
	Type 2 1–20 scars	3	1	0
	Type 3 more than 20 scars	95	11	0
	Total	98	12	0
9	Type 1 None	0	0	0
	Type 2 1–20 scars	4	1	0
	Type 3 more than 20 scars	203	23	1
	Total	207	24	1

induced scars as an ecological marker to determine stock structure in western North Pacific common minke whales collected by JARPNII surveys during 2002–2007. Three types of common minke whales were identified from the density of scars (Figure 10). Prevalence of scars differed clearly between J and O stock animals. However, this ecological marker cannot be considered as an absolute marker to differentiate the two stocks as evidenced in Table 2. J stock animals had fewer scars than O stock animals. In both stocks, prevalence increased with body length, and almost all animals of more than 7 m in body length had scars. Nevertheless, these results were consistent with the occurrence of the two stocks J and O, the former with fewer scars distributing in coastal areas while the latter with more scars distributing in both coastal and offshore areas.

SUMMARY

Table 3 shows a summary of the biological and ecological characteristics of J stock individuals. The individual identification by the genetic markers has been very useful in looking for stock characterization and differences in several traits, such as distribution and movement, morphology and morphometry, reproduction, feeding ecology and environmental pollutant, as presented in this paper. Except for feeding ecology and environmental pollutant (total Hg levels), these traits indicate that J stock individuals are biologically and ecologically distinguished from O

Table 3
Summary of the studies on biological and ecological characteristics of the genetically identified individuals of J stock common minke whales reviewed in this study.

Focal point	Characteristic
Spatial distribution	Whales occupy the Sea of Japan side and the southern part of the Pacific side of Japan; they overlapped geographically with O stock in northern Hokkaido and the northern part of the Pacific side of Japan.
Temporal distribution	Whales are predominant throughout the year in the southern part of the Pacific side of Japan. Their proportion increases in autumn/winter and decreases in spring/summer in the Northern part of the Pacific side of Japan.
Distance from the coastal line	Their proportion decreases from coastal areas towards offshore.
Flipper color pattern	Characterized for almost no GLA in their flippers in comparison with the O stock (Figure 4).
Fluke color pattern	Characterized by a higher proportion of white color in flukes in comparison with the O stock (Figure 5).
Morphometry	Characterized by short lower body in comparison with the O stock.
Conception date	Most likely extends from autumn to winter.
Feeding ecology	Feed on various prey species such as krill, schooling pelagic fishes, and Japanese common squid. They appear to be an opportunistic feeder changing their prey species in response to prey availability in their feeding ground.
Environmental pollutant (total Hg levels)	Levels are similar to those of the O stock animals in the coastal waters of Japan. Levels suggest that the health risk is low.
Cookie cutter shark scar	Fewer scars in comparison with the O stock (Figure 10).

stock individuals. The J stock can be defined as a group of individuals sharing a common gene pool maintained by random mating and should therefore be managed independently.

ACKNOWLEDGEMENTS

We thank Luis A. Pastene (ICR) for his assistance in preparing this document.

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Technical Report (not peer reviewed)

Stranding record activities at the Institute of Cetacean Research

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ABSTRACT

The Institute of Cetacean Research (ICR) has been engaged in collecting and analyzing cetacean stranding records along the coast of Japan for a number of years. Stranding records are reported to the ICR voluntarily by the general public as well as staff from local governments, universities, aquariums and museums. In this document, the stranding record activities of the ICR are described briefly. A total of 4,275 individual records involving toothed and baleen whales were made during 1996–2015. Of these, 297 related to baleen whale species and 3,943 to toothed whale species. In 35 cases the species could not be determined due to insufficient morphological information or evidence from genetic analysis. When possible, samples and data have been collected from stranded cetaceans and used in different studies.

INTRODUCTION

Cetaceans can become stranded along the coast line due to a variety of reasons. They can be stranded alive or found dead after drifting to the shore. A mass stranding is defined as two or more individuals (excluding parent-calf pairs) stranded in the same location at the same time (Geraci and Lounsbury, 2005). This kind of stranding is common in a few species of toothed whales that strand in groups of 15 to 100 or more (Geraci and Lounsbury, 2005). There are records of at least 19 species of toothed whales and four species of baleen whales related to mass stranding events (Martin *et al.*, 1990). While mass stranding is generally rare in baleen whales, one exception is the mass stranding of sei whales that occurred in the Chilean Central Patagonia region in early 2015 (Häussermann *et al.*, 2017).

As a review study by Sergeant (1982) shows, there are a variety of possible reasons for stranding. Cetaceans can drift to the shore as a result of natural death. In many cases, calves separate from their parents and become stranded. In other cases, animals can be stranded due to weakness or diseases. Some of the diseases are caused by virus (Hinshaw *et al.*, 1986; Groch *et al.*, 2020), bacteria (Guzmán-Verri *et al.*, 2012), or parasite infections (Bowater *et al.*, 2003). In addition, whales may become lost due to the influence of wind, tide, or ocean currents and become beached or drift into harbors. In some cases, whales have been stranded because of man-made causes, such as entanglement or ship strike. The mass stranding of beaked whales has been related to mid-frequency active sonar (Piantadosi and Thalmann, 2004; Bernaldo de Quirós *et al.*, 2019). Further, some mass stranding events have been related to the geomagnetic field.

Cetacean stranding provides biologists with a wide range of information. This includes genetic samples for addressing taxonomic questions (Wada *et al.*, 2003; Yamada *et al.*, 2019; Rosel *et al.*, 2021), and biological samples for pathological (Hinshaw *et al.*, 1986; Bowater *et al.*, 2003; Guzmán-Verri *et al.*, 2012) and environmental pollutant studies (Law *et al.*, 2012; Bowater *et al.*, 2003; Garcia-Cegarra *et al.*, 2021). Also, data and samples have been used in population studies (Peltier *et al.*, 2012; 2013). Necropsies provide information to ascertain possible causes of death. A recent study based on stranding investigated microplastics ingestion (Burkhardt-Holm and N'Guyen, 2019). Analyses of stranding data allow the assessment of the impact of human activities on cetaceans (e.g., fishing gear entanglement, ship strikes, etc.).

In this document, the stranding record activities of the Institute of Cetacean Research (ICR) are described briefly.

STRANDING RECORD HELD AT THE ICR

Network

ICR has been collecting whale stranding records along the coast of Japan for a number of years. Stranding events can be reported by volunteers from the general public, local governments, universities, aquariums and museums. There is an established protocol and as well as a data sheet form available for providing stranding information to the ICR.

Protocol for data recording and species identification

The objective of this protocol is to facilitate and standardize the collection of data and samples from stranded animals. Such samples and data can be useful in understanding the reasons for the stranding as well as being useful in different research activities. The data sheet in Appendix 1 is a key part of the protocol, and show the basic items on data and samples to be collected. This form should be completed for each stranding event. Collection of samples are avoided when animals are found alive or when there are any safety concerns (Ishikawa and Ogino, 2001).

The collection of genetic samples is important because subsequent genetic analyses allow the confirmation of the species identity of the stranded animal. Furthermore, such genetic samples can be added to a larger collection of samples at the ICR, contributing to other studies a such as taxonomy and stock structure of the species involved.

Database

The basic information of stranding events recorded in the form in Appendix 1 is stored electronically in an Excel file. When the exact location in terms of latitude and longitude is not provided, geographic coordinates are assigned using geocoding from the address submitted. Only the cases where the species identity has been confirmed are added to the Excel file. The Excel file is updated annually and is upload to the ICR site https://www.icrwhale.org/zasho2.html (accessed 2021-09-30).

Sample storage

Samples for genetics analysis are kept in 99% ethanol in a sealed bottle that is pre-labeled and stored at room temperature (Figure 1). Other types of samples are kept in a frozen state.

NUMBER OF STRANDING EVENTS

Between 1996 and 2015 a total of 4,275 cetacean individuals were recorded in the ICR database related to stranding events (Table 1). Most of the cases corresponded to toothed whales.

EXAMPLES OF STRANDING RECORDS

The first example is on a large baleen whale found stranded on 1 April 2003 at Hitachi City, on the Pacific coast of Ibaraki prefecture, Japan (36°39'N, 140°42'E). Local authorities towed the carcass (via sea) to a sandy shore area within the Kawajiri Harbor, where the whale was buried. Prior to burial, however, biological research was conducted by staff of the Ibaraki Prefectural Oarai Aquarium, Ibaraki Nature Museum, National Museum

Figure 1. Storage samples for genetics analysis.

Table 1
Number of stranded cetaceans recorded in the ICR database during 1996–2015.

Suborder	Family	Events	Individuals	Genetic samples (percentage of individuals)
Mysticeti (Baleen whales)	Balaenidae	7	7	6 (85.7)
	Balaenopteridae	264	264	115 (43.6)
	Eschrichtiidae	4	4	2 (50.0)
	Unknown 1)	22	22	6 (27.3)
Odontoceti (Toothed whales)	Delphinidae	577	1,357	86 (6.3)
	Kogiidae	143	156	24 (15.4)
	Phocoenidae	1,763	1,777	161 (9.1)
	Physeteridae	123	139	27 (19.4)
	Ziphiidae	259	265	75 (28.3)
	Unknown 1)	235	249	15 (6.0)
Unknown 1)		35	35	1 (2.9)

1) The cetacean could not be identified to the family level because extreme decomposition and/or lack of genetic samples.

of Nature Science and ICR. The procedure followed the protocol and the Stranding Recording Form (Appendix 1) was used to take photographs and collect biological tissue samples (Figure 2).

The whale was morphologically identified as a male North Pacific right whale with a body length of 12.95 m and body weight of approximately 33,000 kg. Three years after its burial, the carcass was cleaned, and the skeleton, together with relevant information, were displayed for educational purpose at the Ibaraki Prefectural Oarai Aquarium in January 2006.

The second example is that of a whale found stranded on 14 May 2015 in a decomposed state in the city of Takahagi (Figure 3). Ibaraki Prefectural Oarai Aquarium investigated the carcass and completed the sheet in Appendix 1, which was sent to ICR together with a skin sample for genetic analysis. The length of the whale was 4.6 m. Due to the advanced state of decomposition, only subsequent mitochondrial DNA (mtDNA) analyses were able to identify the animal as a North Pacific common minke whale.

Genetic analyses on stock structure have been conducted based on genetic samples from stranded whales. For example, Pastene *et al.* (in review) used mtDNA analyses for investigating the stock structure of western and eastern North Pacific right whales. The western samples included a number of stranded whales along the Japanese coast. Results of the analyses were consistent with the hypothesis that separate populations inhabit the eastern and western North Pacific Ocean respectively.

As shown in these cases, genetic samples from stranded animals make valuable contributions to the genetic analyses for species identification/confirmation, and to studies on stock structure.

Figure 2. Investigation of a stranded North Pacific right whale.

Figure 3. A stranded baleen whale. Subsequent genetic analyses identified the animal as a North Pacific common minke whale.

ACKNOWLEDGEMENTS

We thank Tsutomu Tamura (ICR) for his comments pertaining to this manuscript. We also express our gratitude to those working on stranding records and the contributors of information. Thanks also to Luis A. Pastene (ICR) for his assistance in preparing this manuscript.

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Appendix 1.

Stranding Reporting Form

* This form is designed to record one whale per sheet.
To record multiple individuals at the same time, please use separate sheets.

OBSERVER NAME ______________________________

AFFILIATION ______________________________

ADDRESS ______________________________ TEL______________

STRANDING TYPE 1. Beached / Drifting at sea 2. Bycatch 3. Entering river or harbor______________
* Please fill in the applicable number.

COMMON NAME ______________________________ No. of Whales______________

____
* If you have determined the species, please describe the distinctive features.

SEX 1. Male 2. Female 3. Unknown______________
* Please fill in the applicable number.

DATE Year_________ Month_________ Day_________ Hour_________
1.Sighting 2. Observation______________
1. Alive 2. Dead 3. Unknown______________
* Please fill in the applicable number.

LOCATION ______________________________

STRANDING SITUATION ______________________________
* Please provide any additional information on the situation when the animal was found.
In case of death, please describe the condition of the corpse.

ANIMAL INFORMATION
Body length (Measurement 1 on the reverse side. Measurement method used) ______________
Body weight (Measurement method used) ______________
External features ______________
1. Body color 2. Baleen plate/ tooth 3. Snout (Shape of the tip of the head) 4. Dorsal fin
5. Notch of flukes (Presence / Absence of the notch; reverse side of the page)
6. Throat / Ventral grooves (reverse side of the page) 7. Color pattern of flipper 8. Other features

PHOTOGRAPHS TAKEN
1. Full body 2. Head 3. External genital organs 4. Other ______________
* Please fill in the applicable number. If possible, attach any photographs.

SAMPLES COLLECTED ______________________________ * Yes / No

Detail (Organ / Storage / Owner) ______________________________

REMARKS ______________________________

CARCASS DISPOSAL ______________________________

MORPHOLOGICAL MEASUREMENTS

* Please use this side as an aid when the observer makes measurements.
The ownership of the measurement data belongs to the measurer and the Institute of Cetacean Research. If the data recorded by the Institute of Cetacean Research are used by other researchers, the consent of the measurer must also be obtained.

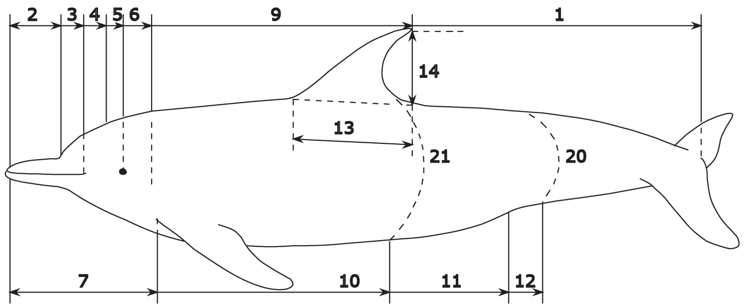
1. Tip of snout – Notch of flukes	_____	12. Tip of snout – Notch of flukes	_____
2. – Base of beak	_____	13. Dorsal fin, length of base	_____
3. – Angle of gape	_____	14. Dorsal fin, vertical height	_____
4. – Blowhole	_____	15. Flipper, boundary length of lower border	_____
5. – Center of eye	_____	16. Flipper, boundary length of posterior	_____
6. – Center of ear	_____	17. Flipper, maximum width	_____
7. – Base of flipper	_____	18. Width of flukes	_____
8. – End of ventral grooves	_____	19. Flukes, width at insertion	_____
9. – Posterior tips of dorsal fin	_____	20. Girth of buttock, half	_____
10. – Umbilicus	_____	21. Girth of abdomen, half	_____
11. – Center of reproductive aperture	_____	22. Baleen plate / Tooth, maximum height	_____
		23. Baleen plate / Tooth, maximum width	_____

* Please indicate all length measurements in centimeters. Please measure parallel to the body axis.

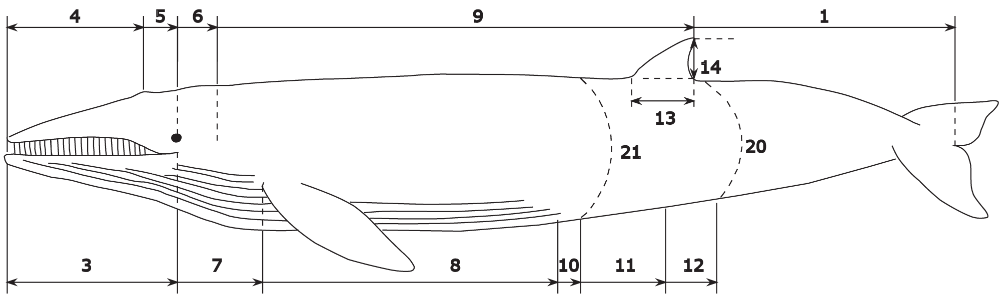
24. # Tooth Upper left _________ Upper right _________ Lower left _________ Lower right _________
25. Body weight _______________

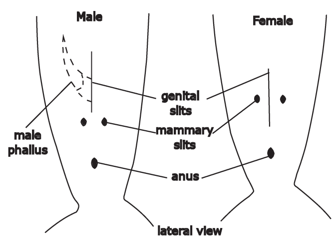
* Be aware of the possibility of an impacted tooth.

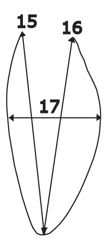
Toothed whales, dolphins, and porpoises

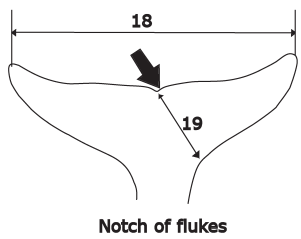


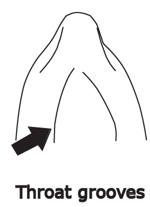
Baleen whales











Technical Report-Note (not peer reviewed)

Development of an Unmanned Aerial Vehicle (UAV) and utility for the research work of the Institute of Cetacean Research

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The usage of drones is increasing for the observation and research of wild animals including the cetaceans. Drones are replacing helicopters and small airplanes which require airfield for departure and arrival. The key characteristics of drones are their small sizes and maneuverability. Furthermore, they can be operated from the platform of vessels. This increases their utility in difficult environments that are often encountered in cetacean research activities. Whale research using drones has already begun (e.g., Hodgson *et al.*, 2017), and they are used for various observation purposes in the polar regions (e.g., Funaki *et al.*, 2014).

The Institute of Cetacean Research (ICR) has acquired some commercially-available drones, e.g., the Phantom 4 Pro (DJI), with the aim of studying whales. Also the ICR has started the development of its own Unmanned Aerial Vehicles (UAVs). This technical note describes this development, and summarizes the application of UAVs in the context of the research work on cetaceans by the Institute.

UAV development at the ICR

Since 2019, the ICR has been working on the development of new whale research methods for cetaceans using small UAVs. It has developed a Vertical Take-off and Landing (VTOL) type UAV, specifically to operate from a cetacean research vessel. Flight tests in open seas from several oceanic regions, including the Antarctic Ocean, have been conducted to examine the performances of the UAVs. From such tests, and to ensure good performance, several important factors were identified. Among these factors were strong winds at open sea, hull swaying, magnetic disturbance and radio wave interference,

Table 1
Specification of the newly-developed VTOL-UAV in 2021.

Name	Prototype ASUKA Mk 4
Overall length	1,920 mm
Wing length	2,500 mm
Overall height	620 mm
Body weight	12.44 kg
Cruising range	Approx. 100 km (51 km in Level 3 flight mode)
Maximum speed	160 km/h
Payload	5 kg maximum
Seaworthiness	Normal operation at 20 kt wind speed, level flight maintained at 40 kt wind speed

Figure 1. Photograph of the VTOL ASUKA aircraft (Prototype ASUKA Mk 4) developed in 2021.

and geomagnetic deviation in the polar regions. The new UAV 'ASUKA,' a VTOL type, was designed to minimize all such detrimental factors. The main data of the ASUKA are shown in Table 1 and the UAV itself is shown in Figure 1.

Figure 2 is a conceptual image of the operation of VTOL-ASUKA from the platform of a cetacean research vessel in the Antarctic. No airfield is required as the UAV can depart and return using the platform of a cetacean research vessel conducting routine line transect surveys. Flight operations can be conducted in shallow waters and ice bound seas where research vessels are unable to enter.

UAV performance during a finless porpoise survey

The ASUKA was used in a survey for finless porpoise (*Neophocaena phocaenoides*) in Mikawa Bay, Aichi prefecture in March 2021. The UAV departed and arrived using the platform of the research vessel and conducted a total of six aerial visual surveys (total distance: 71.2 km). It succeeded in detecting and identifying three finless porpoise pods (four individuals). The sighting rate was 0.56 individuals/10 km. Figure 3 shows the ASUKA operating during the finless porpoise survey in Mikawa Bay on 29 March 2021.

In March 2021, ASUKA achieved an autonomous flight distance of 51 km in the North Pacific Ocean (Figure 4, left), which is considered a Japanese record for UAVs (a domestic record for flight distance under the conditions of Level 3 flight (unmanned area with no visual line of sight and no assistants) as specified in the 'Roadmap for the Industrial Revolution in the Sky' promoted by Japan.

Figure 4 (right) shows the track lines of the UAV during the finless porpoise survey in Mikawa Bay on 29 March 2021. Figure 5 shows finless porpoise detected and identified by the ASUKA's camera.

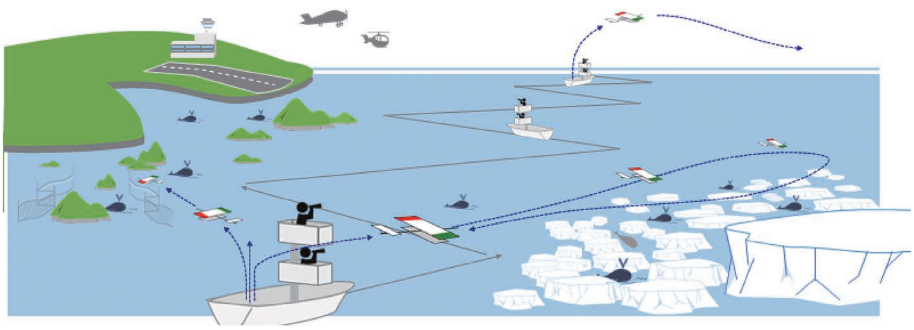

Figure 2. Conceptual image of the operation of VTOL-ASUKA from the platform of a vessel. Unlike small airplanes and helicopters, ASUKA do not require an airfield, and can operate over shallow waters as well as in polynyas in the Antarctic where the vessels cannot operate. In coastal areas, ASUKA can provide information on the presence of fishing nets.

Figure 3. VTOL-ASUKA undertaking vertical take-off from the research vessel (left) and launch landing on the vessel in strong winds (right) during a survey in Mikawa Bay on 29 March 2021.

Figure 4. Long-distance (51 km) survey trial (left) and track lines of the survey (right) by ASUKA during the finless porpoise survey in Mikawa Bay on 29 March 2021.

Figure 5. Photographs of finless porpoise taken during a flight at an altitude of 50 meters by ASUKA's camera (using zoom) during the finless porpoise survey in Mikawa Bay on 29 March 2021.

Japan 2021 Drone Exposition

The ASUKA was introduced at the Japan 2021 Drone Exposition for the Commercial Unmanned Aircrafts Systems (UAS) Market, together with its results from aerial cetacean surveys. The exposition was held between 14 and 16 June 2021 at the Makuhari Messe (Chiba City, Japan), and was organized by Japan UAS Industrial Development Association (JUIDA). During the event, ASUKA attracted the attention of many engineers as an aircraft capable of taking off and landing from vessels. During the Exposition, useful information was obtained regarding, for example, the development of technology for mounting biopsy equipment as well as surveys on marine debris and red tide. Such advances will be useful for research on cetaceans.

Further improvement

Further performance development of ASUKA continues to be focused on aspects related to shooting equipment and image processing technology. The efforts will also be focused on increasing the duration of surveys (distances) by the creation of a lightweight vehicle with a large capacity battery. The idea is to further develop and implement an UAV capable of carrying out research on marine mammals under stringent conditions, while ensuring that disturbance to the animals is minimal.

Application to the study of cetaceans at the ICR

The ICR regularly conducts vessel-based dedicated cetacean surveys. In general, UAVs operated from the platform of the vessels will increase and improve the observational capacity during the surveys. For example, the use of UAVs will allow the survey of cetaceans even in circumstances where vessel movement is inhibited, such as the polynyas in the Antarctic.

The use of UAVs will also complement the observations of researchers on board regarding species identity, number of animals in a school and behavior of the sighted cetaceans. UAVs can also obtain data for photogrammetry studies, which are important for taxonomical or stock structure studies.

Additionally, the use of UAVs will enable the collection of environmental data from above when operating over shallow waters, as well as the detection of areas where fishing gears are installed. That is, it is anticipated that the use of drones will enhance information collection from a wider range of oceanographic conditions and sea areas, thus providing more precise findings from research activities.

ACKNOWLEDGEMENTS

We thank the Fisheries Agency of Japan for research permit and funding for the development and implementation of UAVs. We also thank Yoshihiro Fujise, Takashi Hakamada, Megumi Takahashi, Taiki Katsumata and Masato Hayashi (ICR) for their logistical support. Our gratitude to all engineers who were involved in the development work. Finally, our thanks to Luis A. Pastene (ICR) for his assistance in the preparation of this manuscript.

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Commentary

The views expressed here are those of the author and do not necessarily reflect the views of the Institute of Cetacean Research

Importance of international collaboration in the study of cetaceans: experiences of the Institute of Cetacean Research

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The Institute of Cetacean Research (ICR) is an institute focused on the studies of cetaceans. This includes the baleen whale species, which have been the target of several studies by the ICR. Baleen whales are particularly difficult to study, because they are migratory animals and their habitat is mainly oceanic. They move seasonally between low latitude breeding areas and high latitude feeding areas. International research collaboration on cetaceans, particularly on baleen whales, is relevant and important for several reasons. In this article, these are explained and illustrated by use of case studies at the ICR.

International research collaboration facilitates the access to samples and information from wider areas

The study on some research topics of cetaceans requires samples and information not only from wider areas within an oceanic basin, but also globally. For example, the studies on taxonomy, stock structure, abundance and the impact of cetaceans on the marine ecosystem fall into this category. The ICR has succeeded in addressing some important scientific questions related to such topics, especially regarding baleen whales. This has been achieved often through international research collaborations.

The taxonomy of some baleen whale species is yet to be settled, and the elucidation of their taxonomical status requires studies based on samples collected worldwide. The ICR has collaborated with international colleagues in studies on the taxonomy of blue, right, Bryde′s and minke whales. Here, I explain briefly the collaborative study on minke whale taxonomy. Two species of the minke whale are recognized, the Antarctic minke whale *(Balaenoptera bonaerensis)*, which is restricted to the Southern Hemisphere, and the common minke whale (*B. acutorostrata)*, which is distributed globally. Furthermore, three sub-species of the common minke whale are recognized, one in the North Pacific (*B. a. scammoni)*, one in the North Atlantic *(B. a. acutorostrata)*, and one in the Southern Hemisphere (dwarf or diminutive minke whale). The latter is an un-named sub-species of the common minke whale. In order to elucidate the taxonomical status of the dwarf minke whale, international research collaboration was carried out between ICR scientists and scientists from regions where dwarf minke whales are distributed in the Southern Hemisphere, specifically scientists from several research institutes in Chile and Brazil. The last published work based on mitochondrial DNA (mtDNA) and microsatellite DNA (msDNA) indicated significant genetic differences between western South Pacific and western South Atlantic dwarf minke whales, suggesting that the taxonomical status of common minke whales in the Southern Hemisphere should be revised (Milmann *et al.*, 2021).

Within an oceanic basin, a species of baleen whales is composed of stocks, which are demographically independent units. The identification of such units, through genetic and non-genetic analyses, is very important, because conservation and management policies should be based on these units. International collaboration by ICR has been important in investigating the number and distribution of stocks in some baleen whale species distributed through the entire North Pacific Ocean. In the case of North Pacific right whales, genetic analyses based on mtDNA were conducted to investigate the stock structure of this species in this oceanic basin. The analyses were facilitated by the collaboration between Japanese scientists who contributed genetic data from the western sector of the North Pacific Ocean, and US scientists who contributed genetic data from the eastern sector. Results of the study confirmed that at least two stocks occur in the North Pacific Ocean, one in the western side and the other in the eastern side (Pastene *et al.*, in review). This is key information for developing conservation policies for this depleted species.

Other examples include the genetic analyses on stock structure of sei and Bryde′s whales in the North Pacific Ocean, carried out with genetic samples from different sources. Genetic samples from the western North Pacific Ocean were collected by ICR scientists during the former whale research programs conducted under the IWC special permit (JARPN, JARPNII and NEWREP-NP), and biopsy samples were also obtained during Japanese dedicated sighting surveys. Genetic samples from the central and eastern North Pacific Ocean were mainly biopsy samples collected during dedicated sighting surveys of the International Whaling Commission Scientific Committee (IWC SC) POWER (Pacific Ocean Whale and Ecosystem Research). This is a collaborative research program between Japan and the IWC. Genetic analyses based on mtDNA and msDNA suggested two stocks of Bryde's whales in the central-western North Pacific Ocean with spatially overlapping distribution, and one stock of sei whales in the whole of the North Pacific Ocean. International research collaboration enabled large areas in the North Pacific Ocean to be covered, and the results of the genetic analyses on the stock structure of these two species were important for the work on assessment and management carried out by the IWC SC. The analyses presented in IWC (2018) is one example of this kind of research.

Abundance estimates of sei and Bryde's whales as well of other species in large areas of the North Pacific Ocean have also benefited from the Japan-IWC international research collaboration through the POWER surveys (see IWC, 2020).

The research of the impact of baleen whales on the marine ecosystem also requires samples and information from wider areas within an oceanic basin. Once again, international collaboration plays an important role. Qualitative and quantitative analyses of prey consumption by whales are commonly used to investigate the impact of whales on the ecosystem. Estimates of prey consumption by marine mammals in the North Pacific Marine Science Organization (PICES) region, which cover the entire North Pacific Ocean, were made in collaboration between the ICR and scientists from research organizations in Canada (Tamura *et al.*, 2019). This collaborative research was an important contribution to the 5-year PICES project titled 'Climate and Trophic Ecology of Marine Birds and Mammals.'

International research collaboration facilitates the access to, and interchange of, field, laboratory and analytical techniques

Research groups from different institutes have different levels of expertise on field, laboratory and analytical techniques used for different scientific purposes. In science, the development and improvement of such techniques progress rapidly. In such an environment, it is clear that collaboration among institutes will facilitate access, interchange and use of new techniques among collaborating laboratories.

It should be noted that access to, and interchange of, new field, laboratory and analytical techniques are not restricted to cetaceans nor solely to international collaboration. Collaboration among research institutes within one country, irrespective of target species, could also contribute in achieving the same purpose.

Below are some cases of ICR's international collaborations that have resulted in the interchange of new techniques.

New techniques acquired by ICR as a result of international research collaboration

Survey design and analytical techniques for abundance estimates

Abundance estimates of whale species is essential for defining policies on conservation and management. Given the importance of this topic, and to ensure the design and implementation of sighting surveys as well as analyses of the data are in line with the guidelines adopted by the IWC SC, scientists of ICR have received technical and scientific advice from experts of several international research institutes and universities. These have included organizations in South Africa and Scotland, and also the IWC POWER program (IWC, 2020).

Kinship analysis

This technique was acquired by ICR following collaboration with a university in Germany regarding the North Pacific common minke whale stock structure. Kinship information based on the analyses of genetic data is very important in addressing questions on ecology, stock structure and abundance estimates.

Ecological markers

The occurrence of external and internal parasites in whales can be used as ecological markers to resolve, among others, questions on stock structure. ICR scientists have benefited from a recent collaboration with scientists from a university in Spain to investigate the use of parasites as ecological markers for Antarctic minke whales. As a result, techniques for the identification and analyses of parasites were acquired by ICR.

Satellite tracking

Satellite tracking of whales is a useful tool to study movement, stock structure and behavior of whales. ICR scientists are using this technique to study such aspects in whales from both the Antarctic and North Pacific Oceans.

The technique used by ICR scientists has improved considerably, thanks to the international collaboration with experts from an institute in Norway. More recently, Japan and the North Atlantic Marine Mammal Commission (NAMMCO) commenced a collaborative project to develop miniature tags (MINTAG project) to be used on fast swimming whale species in the North Atlantic, the North Pacific and other oceans.

Krill surveys

ICR scientists have collaborated with specialists from the Convention for the Conservation of Marine Living Resources in the Antarctic (CCAMLR) regarding the design and implementation of krill surveys using dedicated sighting vessels for cetaceans as a platform. The advice from visiting CCAMLR specialists resulted in an improved data collection method in estimating the abundance and distribution of krill.

Statistical models

ICR scientists have benefited from an international collaboration with Norwegian scientists in developing and applying statistical models to study yearly trends of biological characteristics of whales. In particular, these statistical models were applied in a study on the trend of blubber thickness and stomach-content weight in Antarctic minke whales, in order to assess yearly change in body conditions of this species. See Cunen *et al.* (2021) for the latest application of the statistical models that address this research topic.

Technical assistance of ICR to scientists from foreign countries

ICR scientists have participated in programs of collaboration that included the transfer of new survey, laboratory and analytical techniques to colleagues from foreign countries.

Some examples include the collaborative programs with scientists from Caribbean and western African countries. To learn sighting surveys techniques for the purposes of abundance estimation and genetic analyses on stock structure, scientists from St. Lucia and St. Vincent and the Grenadines in the Caribbean, as well as from the Republic of Guinea and other countries from western Africa have visited ICR. At the same time, some ICR scientists have visited those countries to participate in field works and hold lectures on relevant research topics.

Other examples include research collaborations with Brazilian and Mexican scientists on population genetic analyses pertaining to large whales. As a result of such collaboration, foreign colleagues increased their knowledge on genetic techniques available at the ICR (laboratory and analytical), which in turn, allowed them to apply such techniques in their respective countries.

Final remarks

Based on just some of ICR's experiences outlined above, it is clear that international collaboration is important for the studies of cetaceans, including the difficult group of baleen whales. International research collaboration on topics such as stock structure, abundance, and impact of cetacean on the ecosystem is important because such collaboration enables coverage of wider areas of the distribution of species and stocks. It is also important for access to, and interchange of, laboratory, field and analytical techniques among research institutes from different regions and countries.

Despite the advances and benefits of internet communications, research activities of many research organizations in the world are still not well known to many people, and even to a large part of the scientific community. The ICR is not an exception in this respect. International research collaboration, with interchange of scientists between laboratories on specific scientific projects, will facilitate the mutual understanding of objectives and activities of the research institutes involved.

Further, international research collaboration will allow the interchange of ideas and modes of working among scientists from different countries. This should facilitate the understanding of the different cultures involved. Ignoring such differences may result in misunderstandings or miscommunication during scientific debates among scientists from different countries.

Responding to and appropriately addressing scientific questions on baleen whales are indispensable for their conservation and management. International collaboration contributes greatly to this end, as evidenced by the results of several cases at the ICR. Therefore, the ICR should continue to seek and engage in international collaboration on research topics relevant for the conservation and management of cetaceans.

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National meetings

Participation of scientists from the Institute of Cetacean Research in National Meetings in 2021

The 2021 meeting of the Japanese Society of Fisheries Science (JSFS)

The Japanese Society of Fisheries Science (JSFS) was established in 1932. It is a non-profit, registered society dedicated to the promotion of all aspects of fisheries science. The society fulfills its global commitment by promoting science, striving to achieve sustainable development in the field of fisheries, while recognizing the crucial need to preserve the natural aquatic resources. It also strives to forge relationships with the fishing industry, comprising both capture and culture fisheries. The main events organized by the society are the biannual meetings held in spring and autumn in one of the main cities of Japan. This forum is where members present their research activities, exchange information, and foster collaborative research in areas of common interest.

The 2021 spring meeting of the JSFS was held online from 26 to 29 March. Two scientists from the Institute of Cetacean Research (ICR) (Tamura and Wada) participated in the meeting. They presented the study entitled 'Results of krill sampling by IKMT and Maruchi nets in the Antarctic Ocean during the 2017/18 and 2018/19 austral summer seasons.' Tamura was also a co-author of another study presented at the meeting entitled 'Proposal of criteria for distinguishing sand lance using the acoustic data in Sendai Bay.'

The 2021 meeting of the Japanese Society of Fisheries Oceanography (JSFO)

The Japanese Society of Fisheries Oceanography (JSFO) was established in 1962. Its aim is to identify scientific issues of local fisheries, and to promote studies in cooperation with local scientists and fishers in order to address such issues. Recent field research activities in JSFO include, for example, the study on the relationship between marine organism distribution and oceanographic conditions, acoustic assessment of fish abundance, oceanographic approach using satellite image, population dynamics and modeling approaches. The research activities of the JSFO are within the framework of the fisheries oceanography definition, which is 'the study of oceanic processes affecting marine ecosystems and the relationship of these ecosystems to the abundance and availability of fish.'

The 50th Symposium on North Pacific Studies was held on 13 March as part of the 2021 meeting of the JSFO. Tamura, Konishi, Isoda and Kato from the ICR participated in the meeting and presented their study 'The feeding habits and prey consumption by common minke whales around Hokkaido.'

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International meetings

Participation of scientists from the Institute of Cetacean Research in International Meetings in 2021

Annual meeting of the International Whaling Commission Scientific Committee (IWC SC)

The International Whaling Commission (IWC) is an international body set up by the terms of the International Convention for the Regulation of Whaling (ICRW), which was signed in Washington, D.C., United States, on 2 December 1946, to ʻprovide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry.ʼ One of the important subsidiary bodies of the IWC is its Scientific Committee (SC), which meets annually.

Originally, the 2021 meeting of the IWC SC was planned for Bled, Slovenia, between 27 April and 9 May (SC68C). The in-person meeting was cancelled due to the Covid-19 pandemic. Instead, the meeting was carried out through a series of virtual sessions between 27 April and 14 May. A total of twelve scientists from the Institute of Cetacean Research (ICR) participated in the meeting as observers from Japan (Fujise, Kato, Pastene, Tamura, Matsuoka, Hakamada, Taguchi, Konishi, Goto, Isoda, Takahashi and Katsumata). They presented a total of 10 documents: six documents at the Standing Working Group on Abundance Estimates, Stock Status and International Cruises (ASI), one document at the Working Group on Stock Definition and DNA testing (SDDNA), one document at the Sub-Committee on Conservation Management Plans (CMP) and two general documents (O: PICES Observer Report and Japanʼs Scientific Progress Reports).

The report of the IWC SC meeting can be found on the website of the IWC (https://iwc.int/home).

ICR scientists also participated in the meeting of the ʻIWC-POWER Technical Advisory Group (TAG)ʼ and the ʻPlanning Meeting for the 2021 IWC-POWER Cruise,ʼ held online from 9 to 10 November, 2020. Another online meeting was held on 21 April 2021 to discuss the effect of the Covid-19 pandemic on the logistical aspects of the 2021 IWC-POWER survey. Kato, Matsuoka and Takahashi from the ICR participated in these meetings. The report of these meetings can be found on the website of the IWC (https://iwc.int/home).

Annual meeting of the Convention on the Conservation of Antarctic Marine Living Resources-Working Group on Ecosystem Monitoring and Management (CCAMLR-EMM)

The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) is part of the Antarctic Treaty System. The Convention was opened for signature on 1 August 1980 and entered into force on 7 April 1982, thereby establishing the Commission for the Conservation of Antarctic Marine Living Resources. Its goal is to preserve marine life and environmental integrity in and near Antarctica. It was established in large part in response to concerns that an increase in krill catches in the Southern Ocean could have a serious impact on populations of other marine life, which are dependent upon krill for food. The CCAMLR has a Scientific Committee and several Working Groups. One of these is the Working Group on Ecosystem Monitoring and Management (EMM), which meets annually.

The in-person meeting of the EMM Working Group was cancelled due to the Covid-19 pandemic. Instead, an online meeting was held between 5 and 12 July, 2021. The main items on the meeting agenda were: Krill Management including risk analyses, Spatial Management and Climate Change. Under the risk analyses approach, several papers on distribution, abundance and prey consumption of whales in western Antarctic were presented. Three scientists from the ICR participated in the meeting (Pastene, Isoda and Katsumata).

The report of the e-mail group discussion can be found on the website of the CCAMLR (https://www.ccamlr.org/).

Annual meeting of the North Atlantic Marine Mammal Commission (NAMMCO) Scientific Committee (SC)

The North Atlantic Marine Mammal Commission (NAMMCO) is an international body for cooperation on the conservation, management and study of marine mammals in the North Atlantic. The NAMMCO Agreement was signed in Nuuk, Greenland on 9 April 1992 by Norway, Iceland, Greenland and the Faroe Islands, and entered into force on 8 July 1992. The agreement focuses on modern approaches to the study of the marine eco-

Scientists from the ICR participating in the online meeting of the NAMMCO Scientific Committee (25–29 January 2021).

system as a whole, and to better understanding the role of marine mammals in the ecosystem. NAMMCO has a Scientific Committee (SC), which meets annually.

The 2020 NAMMCO SC meeting was held online between 25 and 29 January 2021. The in-person meeting was cancelled due to the Covid-19 pandemic. Four scientists from ICR participated in the meeting (Pastene, Konishi, Inoue and Takahashi) as observers from Japan. They presented the following documents: the 2019–2020 Japan progress report on large cetacean research, the 2018–2019 Japan progress report on small cetacean research, and the 2019–2020 report on satellite tagging experiments at the Institute of Cetacean Research. The report of the meeting can be found in the website of NAMMCO (https://nammco.no/).

NAMMCO-Japan MINTAG project meeting

NAMMCO and Japan have agreed on a collaborative project to develop a new satellite tag suited for use on fast-swimming baleen whales which are of most interest to NAMMCO countries and Japan. The project is called ʻMiniature Tagʼ or MINTAG project. The project started in 2021 and will run for five years. The project is divided into phases: development phase, testing phase, deployment-data collection-analyses phase, and publication-final reporting- workshop phase. The project is led by a Steering Group composed of scientists from NAMMCO countries and Japan, the Secretariat of NAMMCO and the Fisheries Agency of Japan (FAJ).

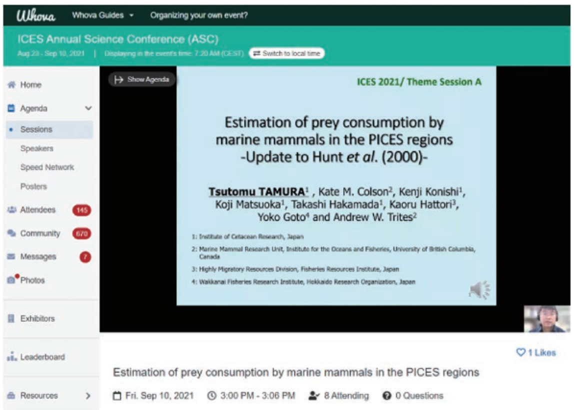
The first organizational meeting of the MINTAG Steering Group was held online on 4 August 2021. The main topics of the meeting were the tender material for tags, web blog and the schedule for the project. Two scientists from the Institute of Cetacean Research (Pastene and Konishi), and one member from the FAJ (Moronuki) participated in the meeting as members of the Steering Group.

Annual meeting of the North Pacific Marine Science Organization (PICES)

The North Pacific Marine Science Organization (PICES) is an intergovernmental science organization established in 1992. It aims to promote and coordinate marine scientific research in the North Pacific Ocean and its adjacent seas, and to provide a mechanism for information and data exchange among scientists in its member countries. Its present members are Canada, Japan, People's Republic of China, Republic of Korea, the Russian Federation, and the United States of America.

The 2021 meeting of the PICES was originally planned for Qingdao, China. The in-person meeting was cancelled due to the Covid-19 pandemic. Instead, the meeting was held online between 18 and 29 October. The business meeting of the Marine Bird and Mammals (S-MBM) section was held on 30 September. One scientist from ICR participated in the meeting (Tamura) introducing the observer report of IWC/SC meeting. The report of the PICES meeting can be found in the website of PICES (https://meetings.pices.int/).

The Annual Science Conference of the International Council for the Exploration of the Sea (ICES) was held online between 6 and 10 September 2021. The joint ICES/PICES session on top predators, food webs, and ecosystem-based fisheries management was held on 10 September. One scientist from ICR participated in this session (Tamura). He presented the study titled ʻEstimation of prey consumption by marine mammals in the PICES regions —Update to Hunt *et al.* (2000)—ʼ.



A scientist from the ICR giving a presentation at the joint ICES/ PICES session of the online ICES Annual Science Conference.

48th Annual Symposium of the European Association for Aquatic Mammals

The 48th Annual Symposium of the European Association for Aquatic Mammals was held online between 11 and 13 March 2021. The study titled 'Epibiotic macrofauna of Antarctic minke whale, *Balaenoptera bonaerensis* Burmeister, 1867, in the Southern Ocean,' co-authored by Ten, Konishi, Nakai, Raga, Pastene and Aznar, was presented at the symposium as an oral presentation.

Conference 2021/UK&Ireland Regional Student Chapter

This conference, organized by the Sea Mammal Research Unit, University of St. Andrews, was held online between 23 and 25 June 2021. The study titled 'The epibiont *Xenobalanus globicipitis* as a multifaceted indicator of cetacean biology: a review,' co-authored by Ten, Konishi, Raga, Fernandez, Pastene and Aznar, was presented at the conference as a poster presentation.

XXIV Biennial of the Real Sociedad Española de Historia Natural

This biennial was held between 8 and 10 September 2021 in Valencia, Spain. The study titled '*Xenobalanus globicipitis*: un crustaceo epibionte possible indicador de migraciones de ballenas,' co-authored by Ten, Konishi, Nakai, Raga, Pastene and Aznar, was presented at the biennial as an oral presentation.

Peer-reviewed publications

List of peer-reviewed publications based on the Institute of Cetacean Research (ICR)'s surveys up to 2021

This section presents a list of peer-reviewed publications based on data collected by surveys conducted under former special scientific permit programs (JARPA/JARPAII/NEWREP-A and JARPN/JARPNII/NEWREP-NP), including both lethal and non-lethal techniques. Peer-reviewed publications based on these surveys are focused mainly on topics related to assessment and management of large whales. However samples and data collected by the surveys have also been useful to carry out studies of a more academic-oriented nature. Publications based on such studies are also listed here.

This section also includes a list of peer-reviewed publications resulting from other surveys and research activities, different from special scientific permit surveys.

Publications having as a first author a non-ICR scientist commonly followed a data request or collaboration research agreement with ICR. In a few cases, external scientists used published data from ICR surveys in their analyses and publications, without a formal agreement with ICR. These cases are indicated by an asterisk (*).

JARPA/JARPAII/NEWREP-A surveys

1989 (2)

Kato, H., Hiroyama, H., Fujise, Y. and Ono, K. 1989. Preliminary report of the 1987/88 Japanese feasibility study of the special permit proposal for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 39: 235–248.

Nakamura, T., Ohnishi, S. and Matsumiya, Y. 1989. A Bayesian cohort model for catch-at-age data obtained from research takes of whales. *Rep. int. Whal. Commn* 39: 375–382.

1990 (8)

Butterworth, D.S. and Punt, A.E. 1990. Some preliminary examinations of the potential information content of age-structure data from Antarctic minke whale research catches. *Rep. int. Whal. Commn* 40: 301–315.

Ichii, T. 1990. Distribution of Antarctic krill concentrations exploited by Japanese krill trawlers and minke whales. *Proc. NIPR Symp. Polar Biol* 3: 36–56.

Itoh, S., Takenaga, F. and Tsuyuki, H. 1990. Studies on lipids of the Antarctic minke whale. I. The fatty acid compositions of the minke whale blubber oils caught on 1987/88 season. *Yukagaku* 39 (7): 486–490 (in Japanese).

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