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Cover photo: A specialized multi-platform observation vessel in the Antarctic. This kind of vessel is used by the Institute of Cetacean Research for dedicated sighting surveys in both Antarctic and North Pacific (top). Satellite tagging (LIMPET-type SPLASH10-F-333 fired with an Aerial Remote Tag System) on an Antarctic minke whale. The tag can be observed on the right side of the body (middle). Concurrent biopsy sampling (using a crossbow) and satellite-tag deployment (LIMPET-type SPLASH10-F-333 fired with a crossbow) of a fin whale in the southern Okhotsk Sea. The tag can be observed on the right side of the dorsal fin (bottom). These satellite-linked tags can transmit information on the diving profile of the whales via ARGOS system.

Foreword

It is a pleasure for me to introduce the seventh issue of the Technical Reports of the Institute of Cetacean Research (TEREP-ICR-7). As stated previously, TEREP-ICR describes and reports on the process, progress, and results of technical or scientific research on whales and their environment, as well as the field activities and state of current research surveys conducted by the ICR, both in the central-western North Pacific and the Antarctic.

The strict sanitary measures taken previously in response to the Covid-19 pandemic have been relaxed in 2023, which can be considered as the post-pandemic year. This relaxation of sanitary measures has facilitated enormously the implementation of the several research activities by the ICR, including preparation and implementation of sighting surveys and participation in national and international scientific meetings, which are now being conducted in-person or in a combination of in-person and online approaches. During 2023 the ICR has been able to conduct field surveys, laboratory works and analyses, write papers and participates safely and successfully in national and international meetings. These efforts enabled the ICR to make significant contribution to whale science during 2023 as shown in this issue of TEREP-ICR.

Similar as in previous TEREP-ICR issues, TEREP-ICR-6 was widely distributed in Japan and in foreign countries and I feel TEREP-ICR is on course towards achieving its objectives. At the same time, TEREP-ICR 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 publication in peer-review journals.

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

Dr. Yoshihiro Fujise
Director General
Institute of Cetacean Research
Tokyo, December 2023

Editorial

Welcome to the seventh issue of the Technical Reports of the Institute of Cetacean Research (TEREP-ICR-7).

This issue contains eight technical reports and one commentary article. In TEREP-ICR-7, we completed the series of reports summarizing the research findings on whales and the ecosystem in the western North Pacific Ocean. Yasunaga and Fujise (Part 4) focused on the studies on chemical pollution in large baleen whale species and their prey. Tamura and colleagues (Part 5) summarized the results of large whale's ecology, including feeding habits and ecosystem modelling.

Results of three important dedicated sighting surveys were presented in this issue: Isoda and colleagues summarized the results of the 2022/23 austral summer season survey of the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A) conducted in a Pacific sector of the Antarctic; Kim and colleagues summarized the results of sighting surveys conducted in the western North Pacific in 2022; and Katsumata and Matsuoka summarized the results of the 2022 International Whaling Commission-Pacific Ocean Whale and Ecosystem Research (IWC-POWER) survey conducted south of the western Aleutian Islands.

Inoue and colleagues presented an update of the study on age at sexual maturity trends in the Antarctic minke whale and interpreted the results in the context of other biological and ecological results for this species and hypotheses on Antarctic marine ecosystem changes. Katsumata and colleagues examined the utility of data logger for obtaining diving time data of Antarctic minke whales for the estimation of availability bias during dedicated sighting surveys. Finally, Konishi and Kleivane used the data logger techniques for studying the feeding ecology of fin whales in the southern Okhotsk Sea.

In the commentary article, Pastene presented his view on the current and future utility of data and samples from former Japanese whale research programs under special scientific permit.

TEREP-ICR-7 issue also included sections that outline the contribution of ICR scientists to international and national meetings in 2023, as well as their contribution in terms of peer-reviewed publications up to December 2023.

We trust that you will find this seventh TEREP-ICR issue informative and useful.

Dr. Luis A. Pastene
Dr. Satoko Inoue
Editorial Team, TEREP-ICR
Tokyo, December 2023

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Technical Reports

Commentary

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Technical Report (not peer reviewed)

What do we know about whales and the ecosystem in the western North Pacific Ocean? Part 4: Summary of results on chemical pollution

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ABSTRACT

Three baleen whale species, common minke, sei and Bryde′s whales were surveyed during the former Japanese whale research under special scientific permit programs in the western North Pacific Ocean. They were conducted from 1994 to 2019. The Institute of Cetacean Research collected and analyzed samples in order to investigate the concentration of chemical pollutants and the effect of those pollutants on the health of the whales. This paper summarizes the results found for mercury (Hg), Persistent Organic Pollutants (POPs) and radioisotope concentrations in the whales collected during the research programs. Whales are suited as biological indicators of environmental conditions because they are long-living animals with the ability to migrate long-distances. In particular, the former JARPNII research program investigated pollutant concentrations of the sampled baleen and toothed whales in relation to their sex and maturity. In addition, JARPNII investigated pollution concentrations in prey species collected from the stomach contents of whales as well as those in samples of seawater and air obtained from the research area at the time of survey. The results from direct examinations of different types of biotic and abiotic sources revealed very important information in furthering our understanding of the bioaccumulation process through the marine food chain.

INTRODUCTION

Pollutants such as Persistent Organic Pollutants (POPs) and mercury (Hg) are generally released from land and transported to coastal and pelagic waters in run-offs as well as by atmospheric dissemination and other ways. Higher trophic animals such as cetaceans generally accumulate POPs through the marine food web (Sanpera *et al.*, 1993; Borrell and Reijnders, 1999). The monitoring of pollutants concentrations in the marine environment through the examination of biological tissues of marine mammals is important, since marine mammals can serve as biological indicators of environmental conditions. Large cetaceans may be particularly useful as they are long-living animals migrating long distances.

In 1995, the International Whaling Commission (IWC) decided to ′give priority to research on the effects of environmental changes on cetaceans …′ (IWC Resolution 1995/10), and its Scientific Committee (SC) decided to treat the adverse effects of pollutants in cetaceans as one of its highest priority issues.

Japan′s whale research programs under special permit in the western North Pacific were conducted for approximately 25 years, from 1994 and 2019. The main target species of the programs were the common minke (*Balaenoptera acutorostrata*), Bryde′s (*B. edeni*) and sei (*B. borealis*) whales. During the surveys, the Institute of Cetacean Research (ICR) collected and analyzed samples in order to investigate the concentration of chemical pollutants and the effect of those pollutants on the health of the whales.

At this point, it was considered important to summarize the knowledge on whales and their environment accumulated so far by Japan′s whale research in the western North Pacific. The objective of this paper is to summarize the most relevant outputs of pollutant studies based on samples and data collected during the former whale research programs under special permit in the western North Pacific.

SUMMARY OF POLLUTANT MONITORING IN THREE BALEEN WHALE SPECIES

The ICR uses a cold-vapor atomic absorption spectrometry, ELISA, UPLC-MS/MS and UPLC-FDA for measurements of pollution and biomarker concentrations in whales (Figure 1).

Table 1 shows the measurement systems and the standard procedures used at the ICR in recent chemical pollutant studies of North Pacific baleen whales. Results on chemical pollutants in whales presented in this paper are based on those systems and procedures.

Laboratory and analytical procedures to determine pollutant concentrations in baleen whales have been described in previous documents (Yasunaga *et al.*, 2016; Yasunaga and Fujise, 2016a; b). Details of the procedures are not repeated here for the sake of brevity. The main results are presented in this section for three baleen whale species, by type of chemical pollutant.

Mercury (Hg)

It is known that Hg is mainly released on land as elemental Hg from natural sources such as volcanic activities and anthropogenic sources, e.g. thermal power plants. Once released, elemental Hg is transported to the pelagic ocean and pelagic surface water (Fitzgerald *et al.*, 1998). In the pelagic ocean, elemental Hg is converted into methyl Hg and bioconcentrated at moderate levels in animals of high trophic level, such as cetaceans, through the food chain (Knauer and Martin, 1972). Therefore, in predicting changes in Hg concentrations in baleen whales and their environment, factors such as food habitat of whales and biological information such as sex, age and pregnancy, are important.

Yasunaga *et al.* (2016) examined temporal changes in Hg concentrations (including all chemical forms of Hg such as methyl Hg and inorganic Hg, i.e. total Hg) of baleen whales using muscle samples of mature males of common minke whales for the period 1994–2014, sei whales for the period 2002–2014 and Bryde's whales for the period 2002–2014 from the western North Pacific. The research areas surveyed are shown in Figure 2. The

Figure 1. UPLC-MS/MS and FDA system at the environmental chemistry laboratory of the Institute of Cetacean Research.

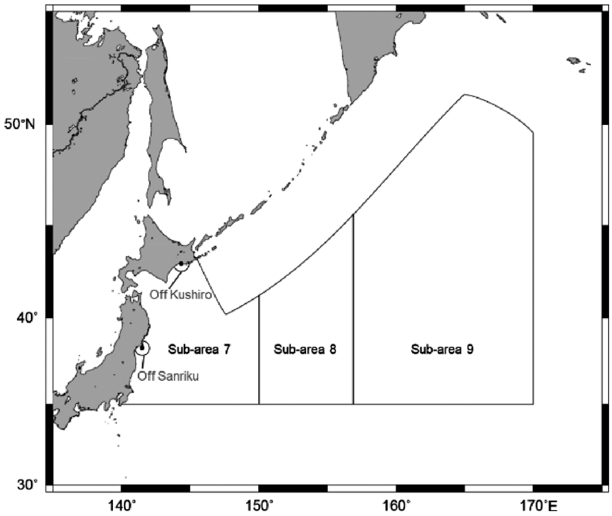


Figure 2. Sub-areas surveyed by the former Japanese whale research program under special permit. Sub-areas are based on IWC (1994), and they have been used by the IWC for the management of common minke whales.

Table 1

Measurement systems and the standard procedures used at the Institute of Cetacean Research in the recent chemical pollutant studies of North Pacific baleen whales.

Substances	Total Hg	Total PCB	Legacy POPs for determination of each isomer	Radioisotopes (the I131, Cs134 and Cs137)
Measurement systems	Direct Thermal Decomposition-Gold Amalgamation-CVAAS	Analytical method of PCBs using GC-ECD with a packed colomun	A sample decomposed with alkaline solution and extracted with hexane are measured by GC/MS-SIM	Containers were placed in 0.04-mm thick polyethylene bags and a germanium semiconductor detector
Standard procedures	Provisional regulation levels of Hg in fisheries by Ministry of Health and Welfare Japan (1972)	The public analytical method of Japan by Ministry of Welfare Japan (1973)	Analytical Manual for endocrine disrupter chemicals by Japan Environmental Agency (1998)	The analytical manual for radioactive materials in foods in emergency by Ministry of Health, Labour and Welfare (2002)

reason for using only mature males was to exclude the effects of pregnancy in case of females and growth, and to be less susceptible to age-related Hg accumulation (Braune *et al.*, 2015).

Concentrations of Hg through the trophic chain

To understand the bioaccumulation process, it is necessary to examine Hg concentrations not only in whales but also in their prey species. Figure 3 shows the relationships between Hg concentrations in common minke, sei and Bryde's whales in the western North Pacific, and those in their main prey species (two zooplanktons and six pelagic fish species) during the period 1995–2007. The Hg concentrations were in the order of:

Common minke whales (0.22±0.07 ppm wet wt.)>sei whales (0.052±0.009)≒Bryde's whales (0.046±0.008).

The Hg concentrations in krill and copepods ranged from <0.001–0.013 and 0.003–0.010 ppm dry wt., respectively. Mercury concentrations in the pelagic fishes were in the order of:

Pacific pomfret (0.232±0.027)>walleye pollock (0.045)=Pacific saury (0.039±0.016)=Japanese anchovy (adult) (0.037±0.025)>Japanese anchovy (larval fish) (0.005±0.003).

It is known that common minke whales selectively feed on relatively higher trophic organisms, mainly pelagic fish such as Pacific saury and Japanese anchovy (Tamura and Fujise, 2002). This is different from sei and Bryde's whales which feed mainly on krill and copepod (Tamura and Fujise, 2002; Tamura *et al.*, 2009). Differences in feeding habitat among whale species and trophic levels of prey would be one of the reasons for higher Hg concentrations in common minke whales than in sei and Bryde's whales. The Hg concentrations in common minke whales from offshore, however, would be affected by changes in the food habitat during the research period.

Temporal trend in Hg concentrations

To examine yearly changes of Hg in common minke, sei and Bryde's whales in the western North Pacific, multiple linear regression analyses were carried out including adjustment for confounders, i.e. sampling years, sampling longitude, sampling latitude, sampling date, body length, blubber thickness and main prey item.

Results indicated that Hg concentrations observed in the muscle of common minke whales off Kushiro and Sanriku (part of sub-area 7) and sub-area 8, and Bryde's whales in sub-areas 8 and 9 were relatively stable in the western North Pacific during the research periods.

On the other hand, the association of Hg concentrations with sampling year was statistically significant in common minke whales from sub-areas 7 and 9, and sei whales from sub-area 9. A slight flexion point of yearly trends of Hg was observed in 2008 for common minke whales from sub-area 9, and in 2012 for sei whales from sub-area 9 (Figure 4). The results of multiple linear regression analyses showed that the main prey items (sub-area 7=walleye pollock, sub-aera 9=Pacific pomfret and Pacific saury) were associated with Hg concentrations in common minke whales. This association was not observed in the case of sei whales. Hg concentrations in sei whales, having sardine and saury in their stomachs, were slightly lower than those in common minke whales from sub-area 9. Therefore, Hg concentrations of sei whales from sub-area 9 may be less affected by Hg in the food items (Figure 4).

Thus, the yearly trend of Hg in sea surface water and the baleen whales from the North Pacific remain stable for the research period. This is also supported by the

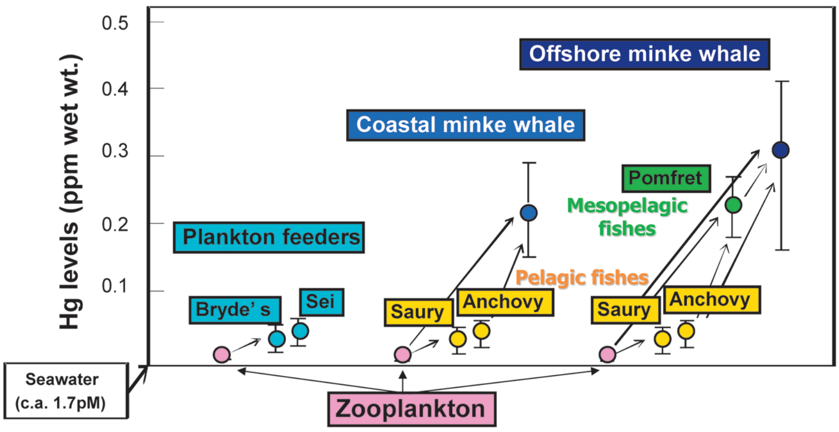
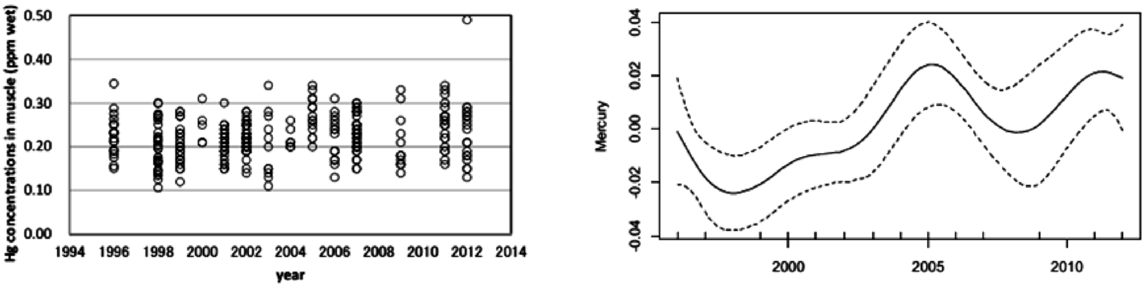
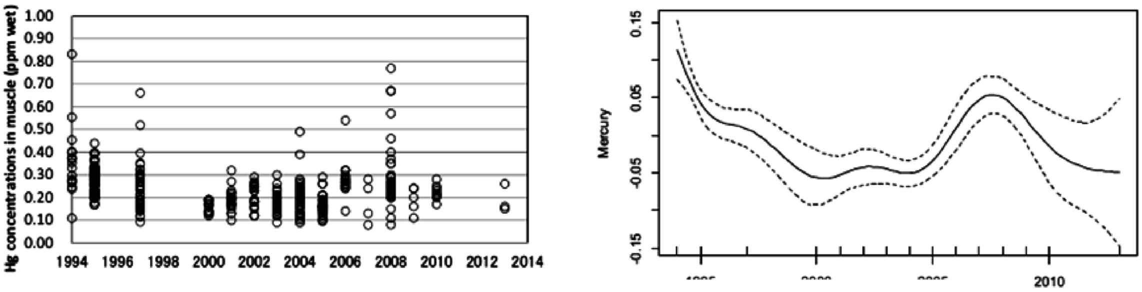


Figure 3. Relationships between Hg concentrations in muscle tissues of common minke, sei and Bryde's whales in the western North Pacific, and those in their prey species.

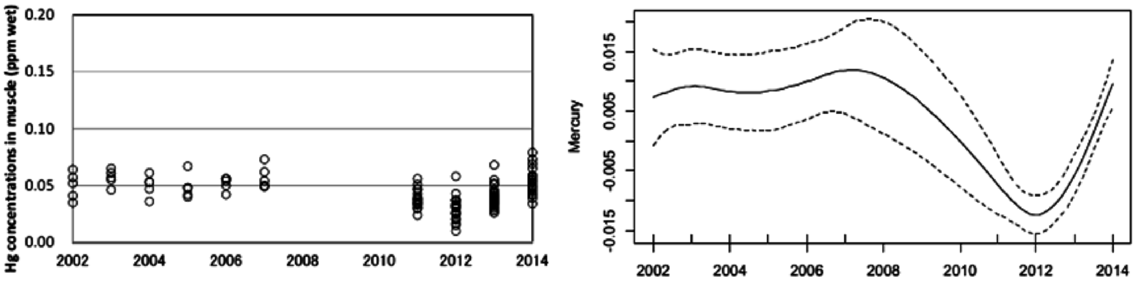
a) Mature male common minke whales, sub-area 7



b) Mature male common minke whales, sub-area 9



c) Mature male sei whales, sub-area 9



d) Mature male Bryde's whales, sub-area 8, 9

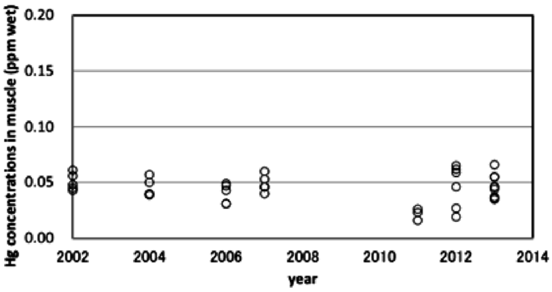


Figure 4. Simple plots (left sides) and smoothing plots using the GAM (right sides) of Hg concentrations in muscle tissues of common minke whales in sub-areas 7 (a: 1996–2012) and 9 (b: 1994–2013), sei whales in sub-area 9 (c: 2002–2014) and Bryde′s whales in sub-areas 8 and 9 during research years.

results of monitoring studies on Hg concentrations from 1980s in the nearby waters (Laurier *et al.*, 2004; Sunderland *et al.*, 2009).

POPs

POPs are organic compounds that are resistant to environmental degradation that occur through chemical and biological processes. Therefore, they have the potential to be transported over long distances. The manufacturing, use and import/export of the specified compounds have been strictly restricted since the adoption of the Stockholm Convention on POPs by the United Nations Environment Programme in 2001 (Hagen and Walls, 2005). Among them, polychlorinated biphenyls (PCBs), dichlorodiphenyl-trichloroethanes (DDTs), hexachlorocyclohexanes (HCHs), hexachlorobenzene (HCB) and chlordanes (CHLs) are commonly called ′legacy POPs′ (French *et al.*, 2006). These legacy POPs had been produced and used in large quantities worldwide in the middle of last century. However, they remain a major environmental

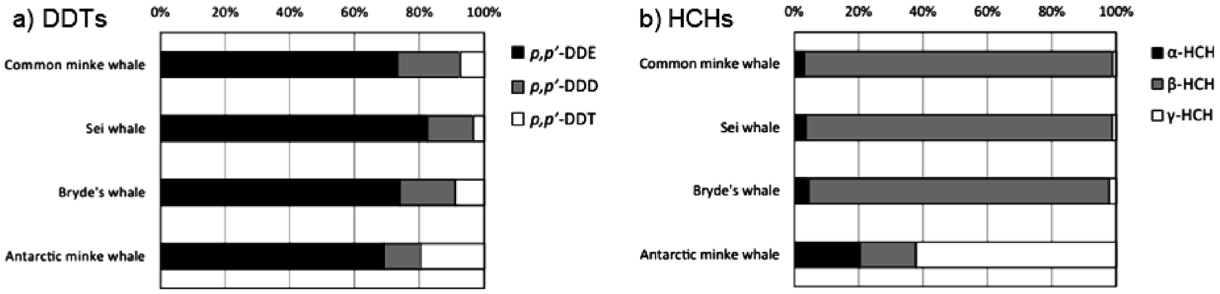


Figure 5. Compositions of a) DDTs and b) HCHs in the blubber of common minke, sei, Bryde′s whales from the western North Pacific and Antarctic minke whales.

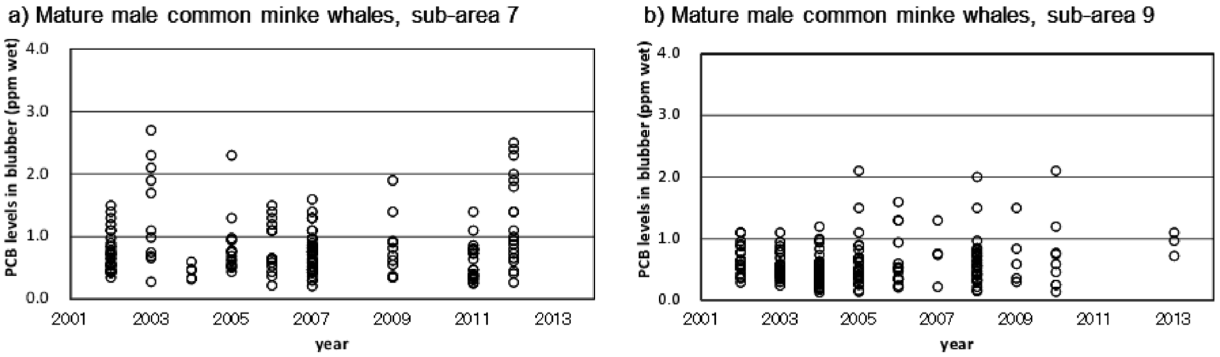


Figure 6. Simple plots of PCB concentrations in blubber of common minke whales (mature males) in sub-areas 7 (coastal) and 9 (offshore).

challenge for human health and risk to wildlife due to their toxicity and persistency.

Accumulation features

Yasunaga and Fujise (2020) examined accumulation features of PCB congeners and DDT, HCH, HCB and CHL isomers in the blubber of common minke, sei and Bryde′s whales from the western North Pacific. DDT and HCH, the main components contained in pesticide products released into the environment, were hardly present in the samples. Concentration levels of five mature males of common minke, sei and Bryde′s whales taken by the JARPNII in 2011 were compared with those in Antarctic minke whales. Results showed that, among the legacy POPs, concentration levels of PCBs were the highest in the whales from the western North Pacific, whereas in Antarctic minke whales from the Antarctic Ocean, the levels were lower than those of HCB and DDTs.

The average percentage of *p,p′*-DDT (which is primarily released into the environment) in the three whale species from the western North Pacific was lower than that of Antarctic minke whales (Figure 5). The *p,p′*-DDT has been used to control malaria (De Jager *et al.*, 2006), and is metabolized into *p,p′*-DDE in the animal body and the environment over a long period of time (Okonkwo *et al.*, 2008). The percentage of *β*-HCH accounted for over 90% of total HCHs in common minke, sei and Bryde′s whales from the western North Pacific, whereas the percentage of *γ*-HCH was the dominant isomer of total HCHs in Antarctic minke whales (Figure 5). Technical HCH, called Lindane, had been released into the environment. Almost all of those consisted of *γ*-HCH from the 1950s and 1970s (Walker *et al.*, 1999). However, in Australia, it was used after that period (Tanabe *et al.*, 1982). These results suggest that in the western North Pacific, a great deal of time had passed from the release of DDTs and HCHs into the environment.

Yearly trend

Yasunaga and Fujise (2016a) examined yearly changes of PCBs in the western North Pacific. Multiple linear regression analysis was carried out, including adjustment for confounders, i.e. sampling years, sampling longitude, latitude, sampling date, body length, blubber thickness and main prey species. Results indicated no significant correlations between year and food items in all areas. It was suggested that PCB concentrations in minke whales from the western North Pacific were stable during 2002–2014. Results for common minke whales in coastal and offshore waters are shown in Figure 6.

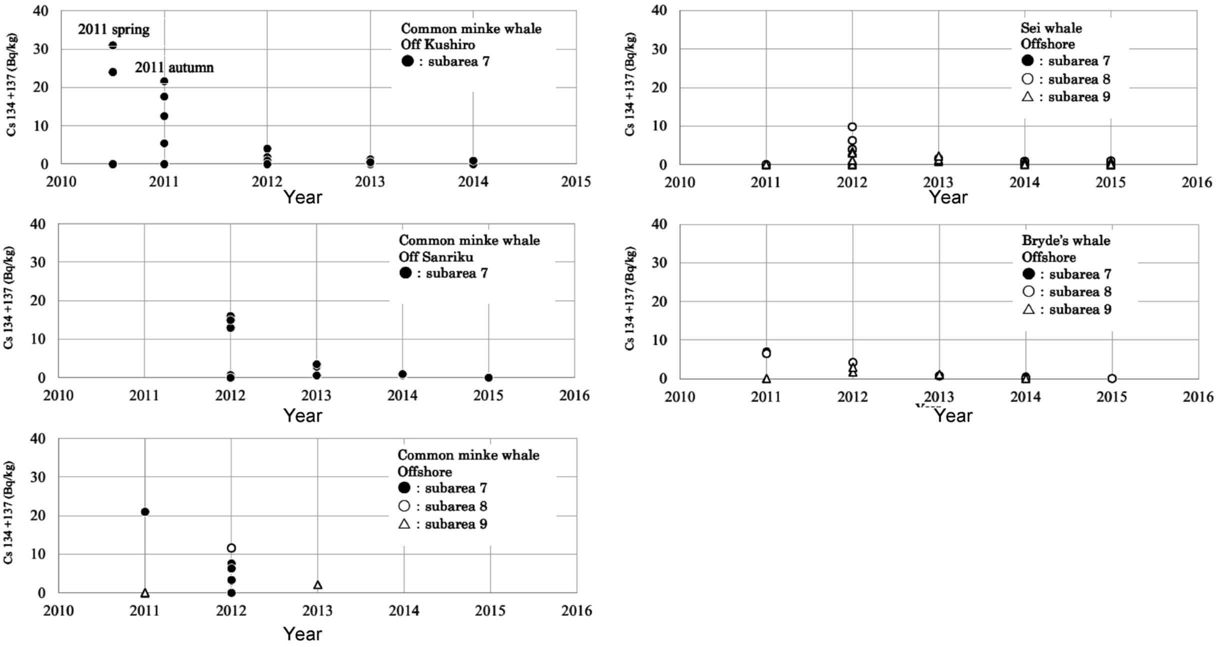


Figure 7. Concentrations of Cs 134+137 in muscle of common minke, sei and Bryde′s whales taken from the western North Pacific from 2011 to 2015.

Radio Isotope

On 11 March 2011, the Great East Japan Earthquake and the tsunami that followed destroyed the nuclear power plant in Fukushima. This accident led to the release of large amounts of radioactive materials into the environment.

To monitor the impact of this incident on large whales in the western North Pacific, Yasunaga and Fujise (2016b) investigated the I131, Cs134 and Cs137 concentrations in muscle samples of 53 common minke, 16 Bryde′s, 32 sei and 3 sperm whales sampled in the period 2011–2015. Results are shown in Figure 7. Iodine131 was not detected in Bryde′s, sei and sperm whales, with the exception of two common minke whales taken from Kushiro in 2012. The ranges of Cs134 + Cs137 concentrations in common minke, sei, Bryde′s and sperm whales were ND (not detected)-31, ND-9.8, ND-7.1 and ND-0.59 Bq/kg wet wt., respectively. The radioisotope concentrations in all four whale species examined have been decreasing since 2011.

CONCLUDING REMARKS

It is important to monitor the concentrations of different chemical pollutants in whale tissues and their environment, and the possible effect of such pollutants on whales. The ICR has contributed to this monitoring by analyzing samples and data collected over a long period in the western North Pacific, not only from whales but also from their prey species and their environment. Biological data available from the whales are important for the interpretation of the concentrations of chemical pollutants found. The results from the direct analyses of samples from biotic and abiotic sources revealed very important information in furthering our understanding of the bioaccumulation process through the marine food chain.

The Minamata Convention on Mercury is a global treaty which aims to protect human health and the environment from the adverse effects of mercury. The monitoring of the marine environment using bioindicators from marine mammals is encouraged by the Convention as one of the recommended actions in the Hg reduction plans (UNEP, 2019). Thus, the findings from this study are expected to contribute directly to such monitoring programs.

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Technical Report (not peer reviewed)

What do we know about whales and the ecosystem in the western North Pacific Ocean? Part 5: Summary of results on whale′s ecology including feeding habitat and ecosystem modelling

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ABSTRACT

The Institute of Cetacean Research has conducted whale research under special scientific permit in the western North Pacific since 1994. The research was conducted systematically under different research programs such as JARPN and JARPNII, and finally, under the NEWREP-NP. These research programs employed both lethal and non-lethal methods to study different aspects of the biology and ecology of large whales in the western North Pacific. NEWREP-NP ceased after the 2019 summer season following Japan′s decision to withdraw from the International Convention for the Regulation of Whaling and to start commercial whaling within its Exclusive Economic Zone. This paper summarizes the most relevant ecological research outputs from the Japanese whaling under special scientific permit in the western North Pacific.

INTRODUCTION

Japan conducted systematic research on whales and the ecosystem in the western North Pacific for more than 30 years (1994–2019). The first research program was the Japanese Whale Research Program under Special Permit in the North Pacific (JARPN: 1994–1999), which was followed by JARPNII (2000–2016) and subsequently by the New Scientific Whale Research Program in the North Pacific (NEWREP-NP: 2017–2019). The Institute of Cetacean Research (ICR) was the institution in charge of designing and implementing those research programs. Tamura *et al.* (2017) provided details on the objectives, sampling and analytical methodology of these research programs. Several international review workshops (e.g. IWC, 2001; 2016) discussed and evaluated the large amount of data and results from those research programs.

Following the change in Japan′s whaling policy, NEWREP-NP ceased from 30 June 2019, the date of Japan′s withdrawal from the International Convention for the Regulation of Whaling (ICRW). At this point, it was considered important to summarize the knowledge on whales and the western North Pacific ecosystem accumulated so far by the Japanese whale research in the North Pacific Ocean.

The objective of this paper is to summarize the most relevant ecological research outputs from the Japanese whaling under special scientific permit in the western North Pacific.

SURVEYS, DATA AND SAMPLES

Surveys were conducted in the western North Pacific, in the sub-areas used by the International Whaling Commission (IWC) for the management of common minke whales (*Balaenoptera acutorostrata*) (Figure 1). The research area on the Pacific side of Japan (e.g. Sanriku and Kushiro) can be considered as Japan′s richest fishing grounds and

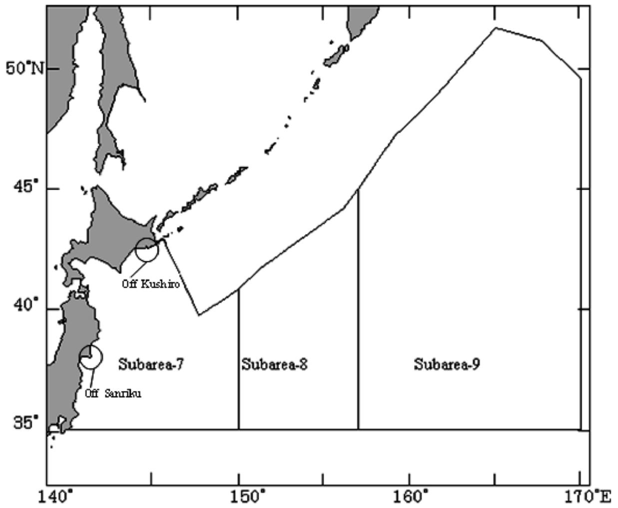


Figure 1. Sub-areas in the western North Pacific used by the IWC for management purposes of the common minke whale. These sub-areas were used for the Japanese whale surveys under special scientific permit.

provided an ideal area to study the interaction between cetaceans and fisheries. This area can be considered as a 'hot-spot' area for cetacean/fisheries interaction.

Survey and sampling methodologies of the Japanese whale research programs in the North Pacific Ocean regarding feeding ecology research were described in Tamura *et al.* (2016). A list of relevant data and samples collected by the Japanese whale research programs in the North Pacific Ocean is available in Tamura *et al.* (2016).

ABUNDANCE ESTIMATES OF LARGE BALEEN WHALES

Apart from its application for assessment and management, abundance estimate information is highly important for evaluating the impact of prey consumption by whales on the ecosystem. Abundance estimates are obtained by analyzing sighting data collected during dedicated sighting surveys. From the results of the feeding ecology studies, prey species of whales are different between the early (May–June) and late (July–September) seasons. For this reason, the abundances were estimated for the early and late seasons. Table 1 shows the abundance estimates for each whale species studied in the western North Pacific. Prey consumption of whales were estimated for the coastal areas of Sanriku and Kushiro as well for the offshore waters of sub-areas 7, 8 and 9. In the latter, abundance was estimated for the early and late seasons as explained above (Table 1). With this information, individual prey consumption can be extrapolated to obtain the amount of consumption by the total number of whales in the area.

DISTRIBUTION OF LARGE WHALES

Analyses of seasonal and spatial distribution of common minke, sei (*B. borealis*) and Bryde's (*B. edeni*) whales in the sub-areas of Figure 1 using Generalized Additive Models (GAM) indicated that all species shifted their distribution toward the north as the season progressed from spring to summer. However, the extent of the shift was different among whale species. While spatial segregation occurred among the three baleen whale species, some overlaps occurred. Given this, the extent of direct interaction among whale species could be minimal although indirect interaction could occur as they share the same prey species (Figure 2) (Murase *et al.*, 2016a).

OVERVIEW OF OCEANOGRAPHY, PREY SPECIES DISTRIBUTION AND BIOMASS AND PREY PREFERENCE STUDIES

Oceanography

Oceanographic surveys are important in understanding the pattern of distribution of prey species of whales. The northern part of the survey area is under the influence of the Oyashio (a subarctic western boundary current with cold, low-salinity water) whereas the southern part is under the influence of the Kuroshio and its extension (the subtropical western boundary current with warm, high-salinity water). The area between the Oyashio and the Kuroshio is called the Kuroshio–Oyashio or subarctic-subtropical transition (interferential) zone (Figure 3).

Oceanographic conditions in the research area were examined using FRA-ROMs data. This is an ocean forecast system developed by Fisheries Research Agency (FRA) based on Regional Ocean Modeling System (ROMS). Annual mean PDO index from 1900 to 2015 was calculated using monthly data available from "http://research.jisao.washington.edu/pdo/" [accessed on 6 October 2015]. Negative values of annual mean PDO index were dominant in the period from 2000 to 2013 (Figure 4). It can be considered that JARPNII surveys from 2000 to 2013 were conducted in the negative phase of PDO index.

Prey distribution and prey preference

Prey distribution and prey preferences of common minke, Bryde's and sei whales at meso-scale were estimated using data from the cooperative surveys of cetacean sampling and prey of cetaceans (using echosounder and several trawl nets). The surveys were conducted as a part of the offshore component of JARPNII in the western North Pacific from 2002 to 2007 (Figure 5).

For example, in the post-stratified block 1 in 2007, prey distribution, sighting positions and stomach contents of sampled common minke, Bryde's and sei whale, water temperature at 100 m and 200 m are shown in Figure 6. All blocks were examined for prey preference of whales.

The standardized form of Manly's selection index called Manly's α, also known as Chesson's index, was used for estimating prey preference. Table 2 showed the average Manly's α of three baleen whale species in the JARPNII offshore component survey area in summer seasons from 2002 to 2007. As a result, common minke whales showed preference for Japanese anchovy and Pacific saury while they avoided krill. Bryde's whales showed preference for Japanese anchovy while they also avoided krill. Sei whales showed preference for copepods and Japanese

Table 1

Abundance estimates for several large baleen whale species based on dedicated sighting surveys in coastal and offshore waters (from Tamura *et al.*, 2019).

Area: Coastal Sanriku
Species: Common minke whale

Period	Numbers	CV	95% CI LL	95% CI UL
2005	401	0.321	217	741
2006	216	0.407	101	466
2012	124	0.385	121	521

Area: Coastal Kushiro
Species: Common minke whale

Period	Numbers	CV	95% CI LL	95% CI UL
2002	551	0.350	283	1,073
2003	888	0.406	413	1,908
2004	338	0.352	173	660
2005	290	0.350	149	564
2006	221	0.351	113	431
2007	130	0.553	47	358
2012	433	0.542	160	1,171

Area: Offshore sub area 7
Species: Common minke whale

Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2000–2007	4,969	0.934	1,052	23,457
2008–2014	269	0.951	56	1,297
Late				
2000–2007	665	0.667	203	2,182
2008–2014	—	—		

Species: Bryde's whale

Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2000–2007	804	1.593	89	7,280
2008–2016	2,595	0.445	1,128	5,967
Late				
2000–2007	3,090	0.456	1,318	7,245
2008–2016	3,394	0.486	1,376	8,369

Species: Sei whale

Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2002–2007	668	0.529	253	1,768
2008–2016	364	0.938	77	1,729
Late				
2002–2007	241	1.148	40	1,452
2008–2016	60	1.130	10	353

Area: Offshore sub area 8
Species: Common minke whale

Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2000–2007	769	0.636	245	2,411
2008–2014	755	0.738	207	2,747
Late				
2000–2007	226	0.746	61	832
2008–2014	—	—		

Species: Bryde's whale

Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2000–2007	535	1.296	76	3,742
2008–2016	—	—		
Late				
2000–2007	2,918	0.466	1,224	6,958
2008–2016	2,733	0.467	1,145	6,526

Species: Sei whale

Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2002–2007	2,341	0.334	1,237	4,431
2008–2016	614	0.683	182	2,064
Late				
2002–2007	1,400	0.541	518	3,780
2008–2016	908	0.635	290	2,840

Area: Offshore sub area 9
Species: Common minke whale

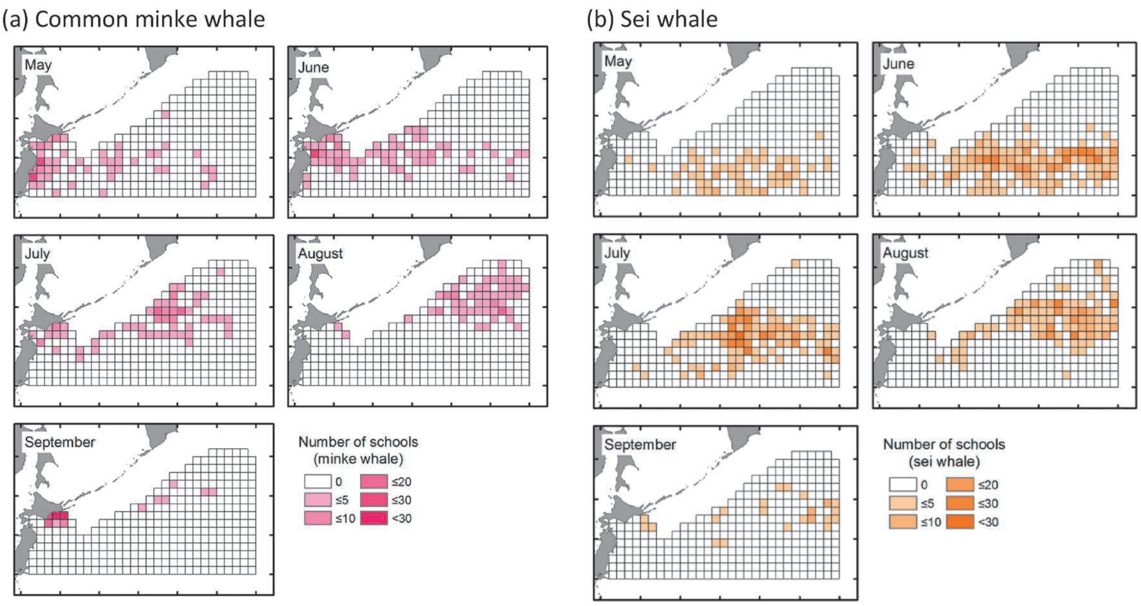
Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2000–2007	1,600	0.577	560	4,574
2008–2014	2,605	0.701	754	9,000
Late				
2000–2007	2,085	0.618	684	6,362
2008–2014	3,080	0.677	924	10,266

Species: Bryde′s whale

Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2000–2007	338	0.732	93	1,220
2008–2016	363	0.441	159	828
Late				
2000–2007	3,790	0.582	1,315	10,920
2008–2016	7,179	0.358	3,636	14,173

Species: Sei whale

Period	Numbers	CV	95% CI LL	95% CI UL
Early				
2002–2007	4,735	0.371	2,340	9,579
2008–2016	3,756	0.182	2,636	5,353
Late				
2002–2007	3,765	0.352	1,928	7,352
2008–2016	4,119	0.444	1,793	9,460



(c) Bryde's whale

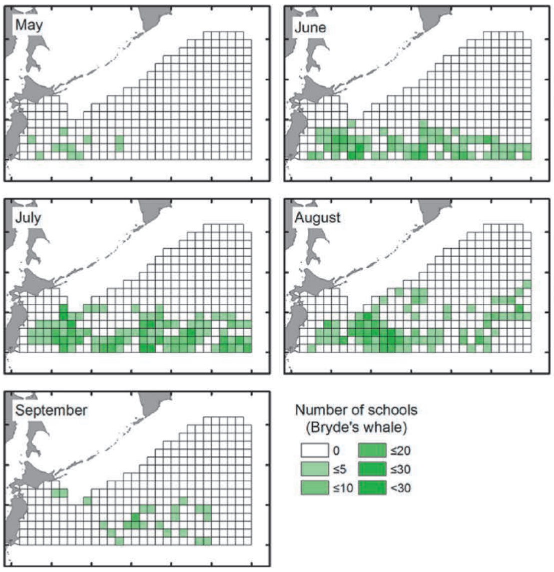


Figure 2. Number of sighted schools of common minke (a), sei (b) and Bryde's (c) whales in 1×1 longitude and latitude grids from May to September. Total numbers from 2002 to 2013 are shown (from Murase *et al.*, 2016a).

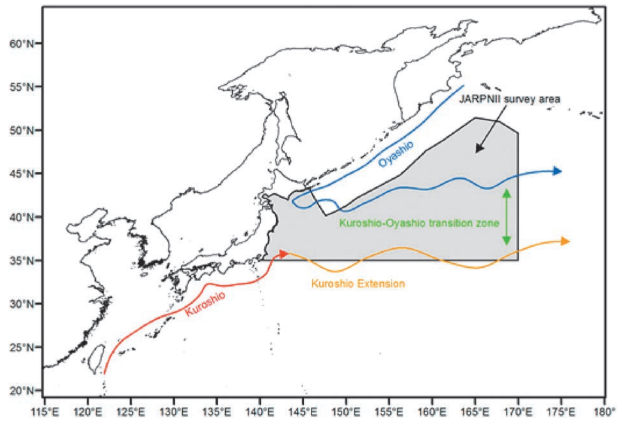


Figure 3. Schematic map of oceanographic structure in the survey area (from Okazaki *et al.*, 2016).

anchovy while they avoided krill and Pacific saury.

Overview of Prey Biomass Studies

In Japan, fish abundance and biomass for species such as Japanese anchovy, Japanese sardine, mackerels and walleye pollock have basically been estimated by cohort analysis. Estimation of the biomass of prey species using a quantitative echosounder in JARPNII were also used.

In offshore waters, basin-scale distribution pattern and biomass estimation of Japanese anchovy, which was one of the main prey species, were examined using a quantitative echosounder between 2004 and 2007. Taking account of the spatial coverage of the survey each year, the most reliable biomass estimate of Japanese anchovy for this region was 3.4 million tons (CV=0.22) (Murase *et al.*, 2012). As an example, Figure 7 shows the distribution of Japanese anchovy in 2006 using a quantitative echosounder.

In coastal waters off Sanriku, the prey surveys were included in the coastal component of JARPNII. The survey area for prey species was divided into ten blocks (A–J) based on bottom depth (20, 40, 100 and 200 m) and prefectural boundary (between Miyagi and Fukushima prefecture) (Figure 8). The biomass of sand lance and Japanese anchovy were examined using a quantitative echosounder between 2005 and 2009. The biomass estimations of sand lance were between 2,827 tons and 28,340 tons. The biomass estimations of Japanese anchovy were between 0.20 and 9,060 tons, respectively (Table 3) (Murase *et al.*, 2009b; Wada *et al.*, 2016).

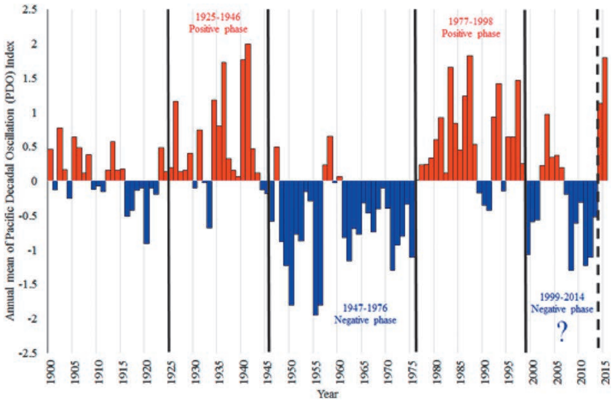


Figure 4. Annual mean of Pacific Decadal Oscillation (PDO) index from 1900 to 2015. Monthly PDO data available from "http://research.jisao.washington.edu/pdo/" (accessed on 6 October 2015) are used to calculate annual mean. Climate regime shift indicated in several published papers are also shown in the figure (see Okazaki *et al.*, 2016).

FEEDING ECOLOGY OF LARGE BALEEN WHALES

Sampling and treatment of stomach contents

Baleen whales have a four chambered stomach system. The stomach contents remain in the forestomach (first stomach) and fundus (second stomach). For the analyses, and after capture, the stomach contents were removed from each compartment and weighed to the nearest 0.1 kg on the ship's flensing deck.

The analysis of prey consumption was based on data collected from the forestomach and fundus. A sub-sample (1–5 kg) of stomach contents was removed and frozen and/or fixed with 10% formalin water for later analyses. The stomach contents were transferred to a system consisting of three sieves (20 mm, 5 mm and 1 mm), which were applied in the Norwegian scientific research to filter off liquid from the rest of the material (Haug *et al.*, 1995). In the laboratory, prey species in the sub-samples were identified to the lowest possible

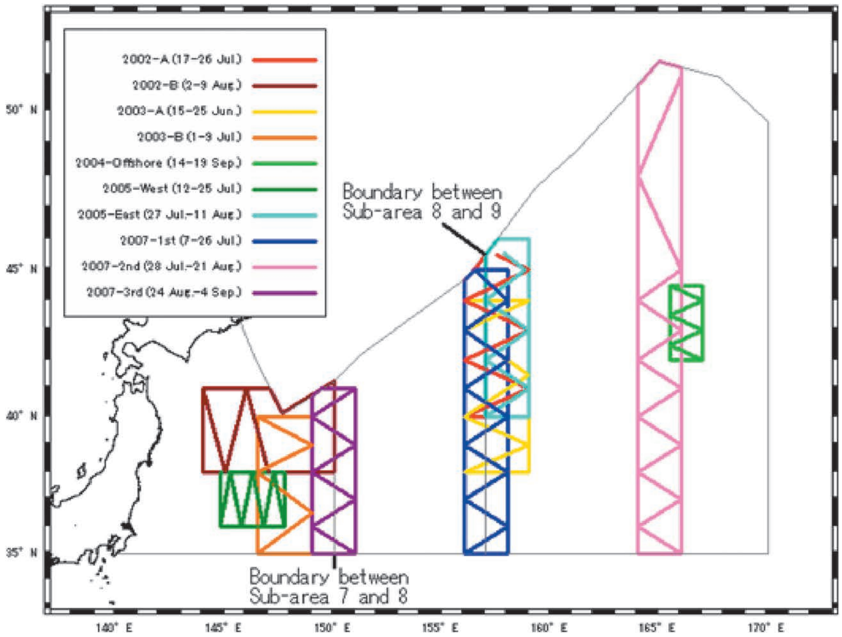


Figure 5. Pre-defined survey blocks for the cooperative whale and prey surveys in JARPNII offshore component from 2002 to 2007. Each color represents boundary of surveyed blocks. These blocks were post-stratified based on observed oceanographic conditions. Zigzag lines within each block represent planned track lines of prey surveys (from Murase *et al.*, 2009a).

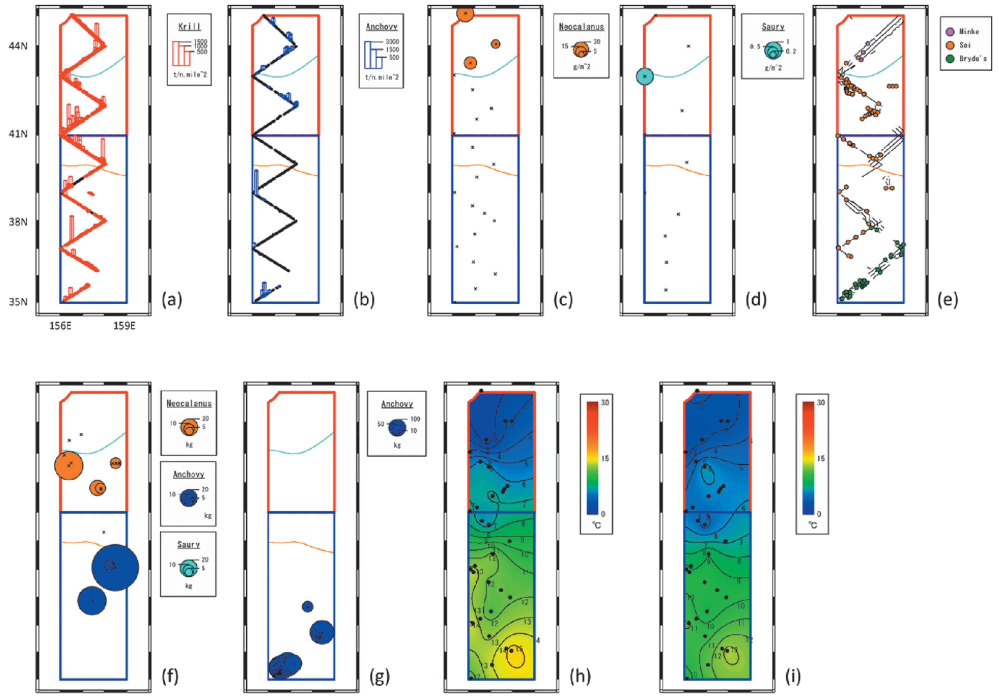


Figure 6. Maps in block 1 in 2007: Distribution patterns of krill (a), Japanese anchovy (b), copepods (*Neocalanus* spp. (Copepodite stage 5)) (c) and Pacific saury (d). Sighting effort and sighting positions of common minke, Bryde's and sei whales (e). Sampled positions and stomach contents of common minke (f) and sei (g) whales. Water temperature at 100 m (h) and 200 m (i) water depth. Encircled areas by red and blue lines are the post-stratified area, E–N and E–S, respectively. Light blue and orange lines in maps (a)–(g) represent 4°C and 10°C isotherm at 100 m water depth, respectively (from Murase *et al.*, 2009a).

Table 2

Estimated average values of Manly's α of common minke, Bryde's and sei whales α in the JARPNII offshore component survey area in summer from 2002 to 2007 using the log-likelihood function based on a multinomial distribution (from Murase *et al.*, 2009a).

Species	Copepods		Krill		Japanese anchovy		Pacific saury	
	Manly's α	SE	Manly's α	SE	Manly's α	SE	Manly's α	SE
Common minke whale	—	—	0.05	0.03	0.36	0.19	0.59	0.17
Bryde's whale	—	—	0.05	0.04	0.95	0.04	—	—
Sei whale	0.41	0.10	0.13	0.04	0.25	0.10	0.20	0.08

taxonomic level. The total weight of each prey species in the stomach contents were estimated by using the values obtained from the sub-sample and the total weight of stomach contents (see details in Tamura *et al.*, 2019).

Data analyses

An estimate of the daily prey consumption by whales requires the use of some additional biological and morphometric data. For example, body length of the whales was measured to the nearest 1 cm from the tip of the upper jaw to the deepest part of the fluke notch in a straight line. Body weight was measured to the nearest 50 kg using large weighing machine. Furthermore, energy requirements are different for sexual maturity classes, and therefore, estimations of the daily prey consumption took into consideration information on sexual maturity. Sexual maturity of each whale was defined by either testis weight or examination of ovaries.

The daily amount of prey consumption consumed is estimated using theoretical energy requirement formulae. The total seasonal prey consumption by whales was estimated using the information on abundance in Table 1, sexual maturity composition, daily prey consumption and a seasonal feeding period of 150 days. The uncertainties associated with the relevant parameters were treated by Monte Carlo simulations (see details in Tamura *et al.*, 2019).

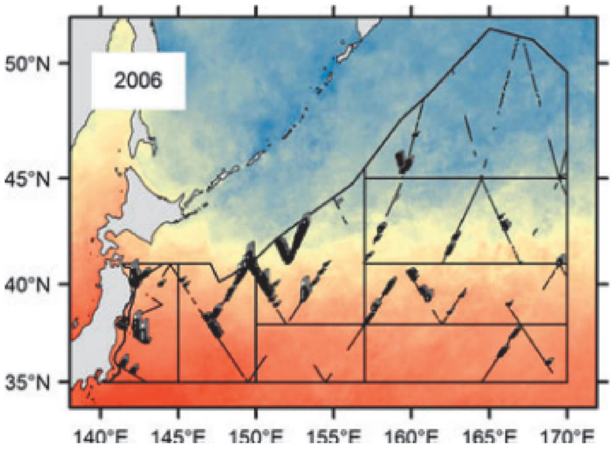


Figure 7. Distribution patterns of Japanese anchovy in 2006. *Bars* Relative densities of anchovy. *Thin black lines* Surveyed track lines. Seasonal composite surface seawater temperature (SST) data in the summer, derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the satellite, Aqua, are also shown (from Murase *et al.*, 2012).

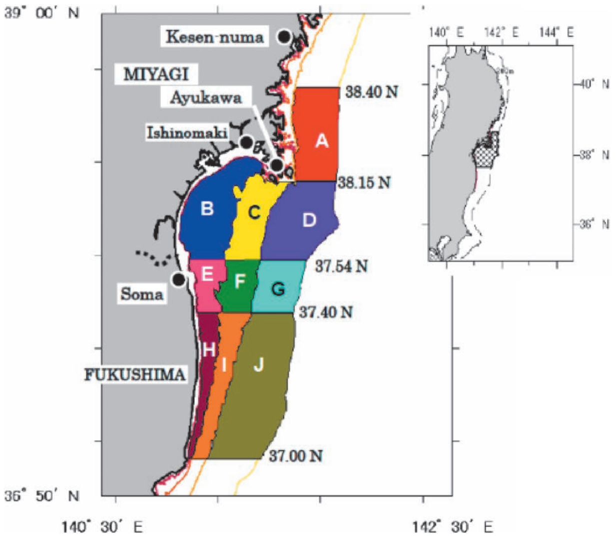


Figure 8. Ten blocks (A–J) surveyed for whales′ prey species in Sanriku since 2005 (from Wada *et al.*, 2016).

Table 3

Biomasses of sand lance and Japanese anchovy in B, C, E and F blocks (surveyed in 2005 and 2006) and B, C blocks (surveyed in 2008 and 2009). See Figure 8 for surveyed blocks (from Wada *et al.*, 2016).

Year	Sandlance (tons)	Japanese anchovy (tons)
2005	7,610	1,320
2006	28,340	9,060
2008	9,310	0.2
2009	2,827	0.6

Table 4

Prey species of common minke, Bryde′s and sei whales in the western North Pacific during May and September in the years 1994–2022.

Prey species/Whale species	Common minke	Sei	Bryde′s
Main prey species			
Copepoda			
Neocalanus cristatus	✔	✔	
N. plumchrus		✔	
Krill			
Euphausia pacifica	✔	✔	✔
E. similis		✔	✔
E. gibboides			✔
Thysanoessa gregaria	✔	✔	✔
T. inermis	✔		
T. inspinata	✔		
T. longipes	✔		
Nematoscelis difficilis			✔
Pisces			
Japanese anchovy	✔	✔	✔
Japanese sardine	✔	✔	
Pacific saury	✔	✔	
Chub mackerel	✔	✔	✔
Spotted mackerel		✔	✔
Walleye pollocke	✔		
Japanese pomfret	✔		
Pink salmon	✔		
Chum salmon	✔		
Atka mackerel	✔		
Sand lance	✔		
Vinciguerria nimbaria			✔
Auxis rochei			✔
Squids			
Japanese common squid	✔		✔
Minimal armhook squid	✔		
Minor prey species			
Pisces			
Paralepis atlantica	✔		
Arothron firmamentum			✔
Decapterus russelli			✔
Diaphus theta			✔
Tarletonbeania taylori			✔
Starry toado			✔
Nemichthys scolopaceus			✔
Lestidiops jayakari			✔
Squids			
Japanese common squid		✔	

Summary of results for three baleen whale species

Prey species in stomach

Common minke whales (1994–2022)

A total of eighteen preys, including one species of copepod, five species of krill, ten species of fishes and two species of squids were identified in 3,036 stomachs of common minke whales (Table 4).

Sei whales (2002–2022)

A total of eleven preys, including two species of copepods, three species of krill, five species of fishes and one species squid were identified in 1,722 stomachs of sei whales (Table 4).

Bryde's whales (2000–2022)

A total of eighteen preys, including five species of krill, twelve species of fishes and one species squid were identified in 1,478 stomachs of Bryde's whales (Table 4).

Geographical and yearly changes of main prey species in the offshore area

Common minke whales (1994–2019)

Prey composition in the stomach of common minke whales is shown for each season (early [May–June] and late [July–September]), sub-area and year in Figure 9. The composition of main prey species is highly variable between years.

In sub-area 7, Japanese anchovy has been an important prey in both seasons since 1994. After 2017, Japanese sardine and mackerels have become important preys.

In sub-area 8, krill and Japanese anchovy have been important preys since 1994. After 2017, Japanese sardine has been an important prey in the early season. In late season Pacific saury has been an important prey since

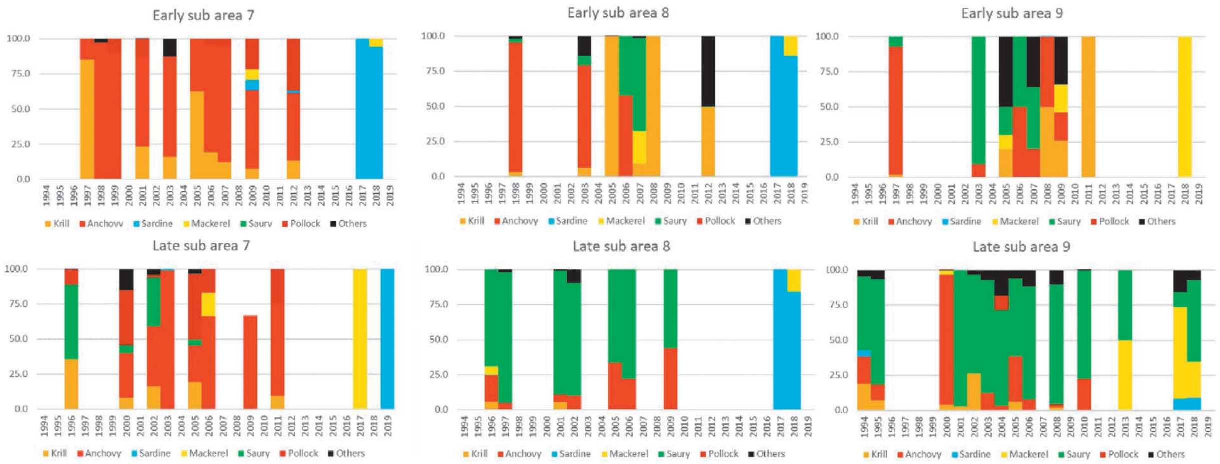


Figure 9. Prey composition in the stomach of common minke whales by season, sub-area and year, in the period 1994–2019 (partially from Konishi *et al.*, 2017).

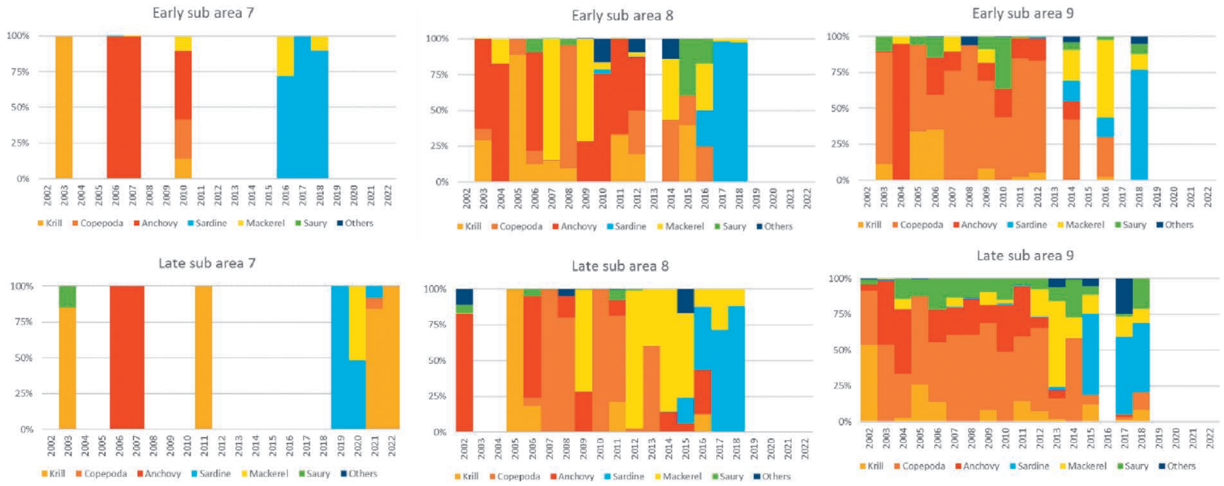


Figure 10. Prey composition in the stomach of sei whales by season, sub-area and year, in the period 2002–2022 (partially from Konishi *et al.*, 2017).

1994. After 2017, Japanese sardine has become an important prey.

In sub-area 9, Japanese anchovy and krill have been important preys since 1994. After 2017, mackerels have become important preys in the early season. In late season, Pacific saury has been an important prey since 1994. After 2017, Pacific saury and mackerels have become important preys.

Sei whales (2002–2022)

Prey composition in the stomach of sei whales is shown for each season, sub-area and year in Figure 10. The composition of main prey species is highly variable among years.

In sub-area 7, krill and Japanese anchovy have been important preys since 2003. After 2016, Japanese sardine has become an important prey in the early season. In the late season, krill and Japanese anchovy have been important preys since 2003. After 2019, Japanese sardine and krill have become important preys.

In sub-area 8, krill, copepod, Japanese anchovy and mackerels have been important preys since 2002 in both seasons. After 2017, Japanese sardine has become an important prey.

In sub-area 9, copepod has been an important prey since 2002 in both seasons. After 2015, Japanese sardine and mackerels have become important preys.

Bryde′s whales (2000–2022)

Prey composition in the stomach of Bryde′s whales is shown for each season, sub-area and year in Figure 11.

In sub-area 7, krill and Japanese anchovy have been important preys since 2000. After 2020, Japanese sardine has become an important prey in the early season. In the late season, krill and Japanese anchovy have been important preys since 2000.

In sub-areas 8 and 9, krill and Japanese anchovy have been important preys since 2002 in both seasons. Occasionally, high proportions of lantern fishes were observed. After 2016, Japanese sardine has also been observed as the main prey.

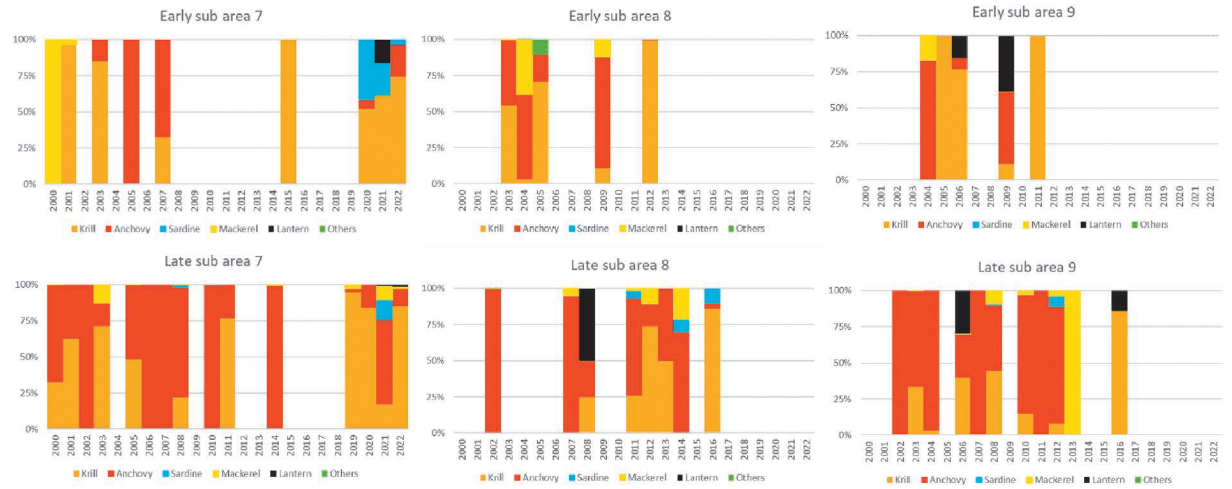


Figure 11. Prey composition in the stomach of Bryde′s whales, by season, sub-area and year, in the period 2000–2022 (partially from Konishi *et al.*, 2017).

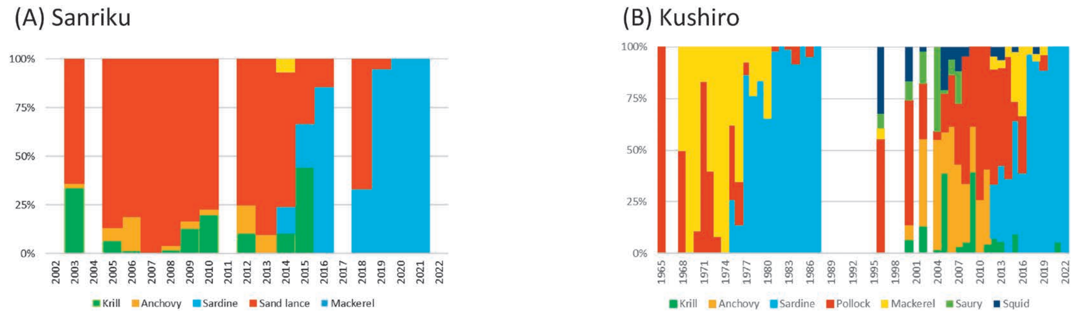


Figure 12. Yearly change of dominant prey species of common minke whales in Sanriku (A) and Kushiro (B), in the period 2002–2022 (partially from Tamura *et al.*, 2016).

Geographical and yearly changes of main prey species of common minke whales in the coastal areas (2002–2022)

Sanriku

Figure 12 shows the yearly changes in prey composition based on data from commercial whaling and some scientific surveys in Sanriku. After 2003, sand lance has been the dominant prey species. Since 2016, the dominant prey species switched from sand lance to Japanese sardine.

Kushiro

Long term information of prey composition is available from past commercial whaling (Kasamatsu and Tanaka, 1992). Figure 12 shows the yearly changes in prey composition based on data from commercial whaling and some scientific surveys in Kushiro. Until 1976, the dominant prey species of common minke whales was the chub mackerel. The dominant prey species switched from chub mackerel to Japanese sardine in 1977, from Japanese sardine to Pacific saury or Japanese anchovy in 1996, and from Pacific saury or Japanese anchovy to Japanese sardine and mackerels in 2012.

Daily and seasonal prey consumption by whales

Offshore area

The estimated daily prey consumption by sex and reproductive status is shown in Table 5 for the three species of baleen whales.

Estimated prey consumption (thousand tons) *per year* over 150 days, from May to September, in two periods (2000–2007 and 2008–2016) by three baleen whale species is shown in Table 6. See details of this calculation in Tamura *et al.* (2019). The consumption per year of Japanese anchovy by three baleen whale species in the two periods (2000–2007 and 2008–2016) were 754 thousand tons and 565 thousand ton, respectively. The consumption per year of mackerels by three baleen whale species in the same two periods was 25 thousand tons and 74 thousand tons, respectively. The consumption per year of Pacific saury by common minke and sei whales in the same two periods was 38 thousand tons and 35 thousand tons, respectively. Recently, Japanese sardine has been the dominant prey species for three baleen whale species. The consumption *per year* of Japanese sardine by three baleen whale species in the 2008–2016 period was 54 thousand tons.

Coastal areas

For Sanriku, prey consumption *per year* during mid-March to mid-June (90 days) by common minke whales is shown in Table 7. For Kushiro, seasonal prey consumption *per year* during September-October (60 days) by common

Table 5

Estimates of daily prey consumption (kg) by three baleen whale species in the offshore area, by sex and reproductive status (from Tamura *et al.*, 2019).

Species	Male		Female	
	Immature	Mature	Immature	Mature
Common minke whale	73–187	118–304	69–179	140–359
Bryde's whale	380–578	51–839	369–563	619–943
Sei whale	265–665	341–878	294–727	405–1,021

Table 6

Estimates of prey consumption (thousand tons) per year by common minke, Bryde′s and sei whales in the offshore area in two different periods (from Tamura *et al.*, 2019).

Period	Prey species	Consumption (thousand tons)	Period	Prey species	Consumption (thousand tons)
2000–2007	Japanese anchovy	754	2008–2016	Japanese anchovy	565
	Pacific saury	38		Pacific saury	35
	Mackerels	25		Mackerels	74
	Japanese sardine	0		Japanese sardine	54
	Other	349		Other	593
	Total	1,166		Total	1,321

Table 7
Estimates of prey consumption (tons) by common minke whales in coastal areas of the western North Pacific based on data collected between 2002 and 2012 (from Tamura *et al.*, 2019).

Year	Sanriku				Kushiro							
	Krill	Sandlance	Anchovy	Total	Krill	Anchovy	Sardine	Saury	Mackerels	Pollock	Squid	Total
2002	—	—	—	—	453	733	0	635	0	815	1394	4,030
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	—	—	—	—	41	1,171	0	878	0	76	0	2,166
2005	1,533	2,338	606	4,477	241	170	0	20	0	1,562	101	2,094
2006	758	1,033	363	2,154	8	907	0	118	0	378	92	1,503
2007	—	—	—	—	27	292	0	125	0	227	111	782
2012	356	472	269	1,097	217	2	669	0	178	902	92	2,060
Average	882	1,281	413	2,576	165	546	112	296	30	660	298	2,106

Table 8
Prey consumption (tons) by common minke whales and fisheries catch of sand lance in Sanriku in the period 2002 and 2012. Fisheries catch data were obtained from Statistical Survey on Marine Fishery Production (https://www.maff.go.jp/j/tokei/kouhyou/kaimen_gyosei/).

Year	Prey consumption (tons)	Fisheries catch (tons)	Ratio (%)
2002	—	—	—
2003	—	—	—
2004	—	—	—
2005	2,338	8,679	26.9
2006	1,033	5,250	19.7
2007	—	—	—
2012	472	479	98.5
Average	1,281	4,803	26.7

minke whales is shown in the same table.

Amount of prey consumed by common minke whales in comparison with catch by fisheries

The estimated consumption of sand lance by common minke whales and fisheries catch of sand lance in Sanriku is shown in Table 8.

The estimated consumption of Pacific saury and walleye pollock by common minke whales and fisheries catch of those species in Kushiro is shown in Table 9. The prey consumption of Pacific saury and walleye pollock by common minke whales in Kushiro were calculated as 0–878 tons and 76–1,562 tons. Consumption of them by common minke whales in Kushiro waters corresponded to approximately 0–3% of the fisheries catch of these resources (Table 9).

To further evaluate the interaction between whale and fisheries, long-term information of prey composition of whales, accurate abundance of prey species and each whale, and accurate resident period of each whale are needed.

PROGRESS IN MODELLING WORK

This section presents an overview of the objectives and progress made in the research on ecosystem modelling in the western North Pacific. Whale abundance, prey composition and prey consumption of whales have been used as input data to the models. Those values were obtained as described above.

Offshore area

Mori *et al.* (2009) developed the EwE in the western North Pacific (north of 35°N and west of 170°E), where JARPNII surveys were conducted. The model consists of 31 species/groups ranging from detritus to whales (Table 10). Input data required for the model were biomass, production, prey consumption, diet composition and total fishery catch of each predator in the target area. When production is not available, total mortality was used in the Ecopath instead of production per biomass. Once the mass-balance model was constructed, possible effect by fisheries of the species in the model were simulated by using Ecosim under the harvesting scenarios examined.

The work by Mori *et al.* (2009) was updated in the studies by Murase *et al.* (2016b) and Watari *et al.* (2019). They have focused on the interactions between forage fish and their predators including target species of JARPNII (common minke, sei, Bryde's and sperm whales). They have updated the input data to the models by considering the data available in the period 1994–2013 and made several technical adjustments following recommendations from

Table 9

Prey consumption (tons) by common minke whales and fisheries catch of Pacific saury and walleye pollock in Kushiro in the period 2002 and 2012. Fisheries catch data were obtained from Statistical Survey on Marine Fishery Production (https://www.maff.go.jp/j/tokei/kouhyou/kaimen_gyosei/).

Prey species: Pacific saury

Year	Prey consumption (tons)	Fisheries catch (tons)	Ratio (%)
2002	635	55,594	1.1
2004	878	48,403	1.8
2005	20	58,528	0.0
2006	118	61,895	0.2
2007	125	69,629	0.2
2012	0	49,550	0.0
Average	296	57,267	0.6

Prey species: Walleys pollock

Year	Prey consumption (tons)	Fisheries catch (tons)	Ratio (%)
2002	815	52,524	1.6
2004	76	65,186	0.1
2005	1,562	54,628	2.9
2006	378	56,582	0.7
2007	227	51,088	0.4
2012	902	59,061	1.5
Average	660	56,512	1.2

Table 10

List of the species/groups used in the EwE model and Trophic Level (TL) estimated by Ecopath (from Mori *et al.*, 2009).

Species/Group	TL	Species/Group	TL	Species/Group	TL
Minke whale	3.99	Albacore	4.08	Pacific ponfret	4.20
Bryde's whale	3.83	Sword fish	4.81	Sardine	2.30
Sei whale	3.73	Skipjack tuna	3.97	Anchovy (<8 cm)	3.04
Other baleen whales	3.23	Blue shark	4.27	Anchovy (>8 cm)	3.04
Sperm whale	4.17	Samon shark	4.35	Pacific saury	3.12
Baird's beaked whale	4.15	Lantern fish	3.06	Phytoplankton	1.00
Short-finned pilot whale	4.40	Neon flying squid	4.12	Euphausiids	2.18
Ziphidae	4.24	Large surface squid	3.41	Copepods eaten by whales	2.00
Other toothed whales	4.46	Small surface squid	3.01	Other Copopods	2.00
Northern fur seal	4.08	Mid-deep water sea squid	3.11	Detritus	1.00
Marine birds	4.24	Mackerels	3.30		

the IWC Scientific Committee. They have identified several potential future data and tasks required to progress the development of ecosystem modelling in the western North Pacific.

Coastal areas

Okamura *et al.* (2009) examined the effects of predation of common minke whales on sand lance stock off Sanriku in order to investigate the effect of predation by the common minke whales in terms of MSY of sand lance population. Bayesian delay-difference model was used to develop an ecosystem model. By using new data, Kitakado *et al.* (2016) updated the model work by Okamura *et al.* (2009). The predation by the common minke whales accounts for a certain proportion of the current adult biomass of the sand lance population, although the level of proportion is sensitive to the model assumption.

The results are still preliminary because further validation of consumption of sand lance by predator species and further modelling process for linking sand lance and several predators through simultaneous estimation of populations dynamics are needed. Progress in the work on the MRM is presented in a different paper to this meeting (Kawano *et al.*, 2019).

CONCLUSIONS

The Japanese whale research programs under special permit provided important information on the ecology of several baleen whale species in the western North Pacific. Such information is key for the elucidation of the role of whales in the ecosystem. There is a need to further evaluate the interaction between prey consumption by whales and commercial fisheries, either directly or indirectly, using simulation models for specific geographical regions. The commercial whaling within Japan's Exclusive Economic Zone commenced in 2019. It is important to collect additional information on the feeding ecology of baleen whales from this source.

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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 a part of Area VI in the 2022/2023 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 2022/2023 austral summer season are reported. Two dedicated sighting vessels were engaged in the line transect method survey in a part of Antarctic Area VI (145°W–130°W) for 28 days, from 10 January to 6 February 2023. For the survey, the research area was divided into northern and southern strata. In addition, surveys were conducted successfully in coastal ice-free waters, south of 71°30’S, an area that is normally covered by pack-ice and difficult for vessels to access. The total searching distance in the research area was 2,168.6 n.miles (4,016.2 km). Four baleen whale species and at least two 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 data and samples collected are required for the main and secondary research objectives of JASS-A.

INTRODUCTION

Long-term systematic surveys on whales and the ecosystem in the Antarctic, such as the JARPA/JARPAII[1], NEWREP-A[2] and IWC IDCR/SOWER[3], obtained important data pertaining to the study of abundance and abundance trends of large whales and their biology as well as the role of whales in the Antarctic ecosystem. All these research programs have been terminated. The last NEWREP-A survey was carried out in the 2018/2019 austral summer season.

The Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A) commenced in the 2019/2020 austral summer season because it was considered important to continue with the whale and ecosystem surveys in the Indo-Pacific region of the Antarctic Ocean 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, genetic data to estimate abundance, 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 line transect method. Surveys are designed and conducted following the protocols included in the ‘Requirements and Guidelines for Conducting Surveys and Analysing Data within the Revised Management Scheme’ (IWC, 2012). Sighting protocols are the same as those used in the former IDCR/SOWER surveys (Matsuoka *et al.*, 2003; IWC, 2008). The JASS-A surveys are conducted alternatively in IWC Management Areas III, IV, V and VI by one or two specialized vessels, over a tentative period of eight austral summer seasons.

The first to third JASS-A surveys were carried out in the

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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

2019/2020, 2020/2021 and 2021/2022 austral summer seasons, respectively, and covered the sector 000°–035°E of Antarctic Area III West and 130°W–120°W of Antarctic Area VI East.

The fourth JASS-A survey was carried out in the 2022/2023 season and covered the sector 145°W–130°W of Antarctic Area VI. This paper presents a summary of the 2022/2023 JASS-A survey results.

SURVEY DESIGN

Research area

The research area of JASS-A is comprised of IWC Management Areas III, IV, V and VI, south of 60°S (Figure 1). The research area in the 2022/2023 season was a part of Antarctic Area VI (145°W–130°W), south of 60°S (Figure 1). The area was divided into northern and southern strata. The boundary between these strata was defined by a line 45 n.miles from the northern edge of the pack-ice (Figure 2). In addition, the sea ice on the coastal area opened and formed ice-free waters in early January. The ice-free waters (in the range of 145°W to 130°W) became accessible to the vessel in early February. Details of the ice configuration are shown in Figure 3.

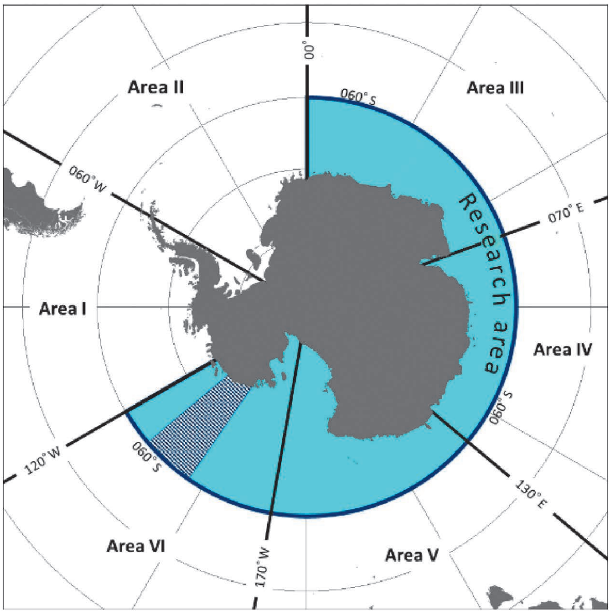

Figure 1. Research area of JASS-A. The shaded area (145°W–130°W) indicates the surveyed area in the 2022/2023 austral summer season.

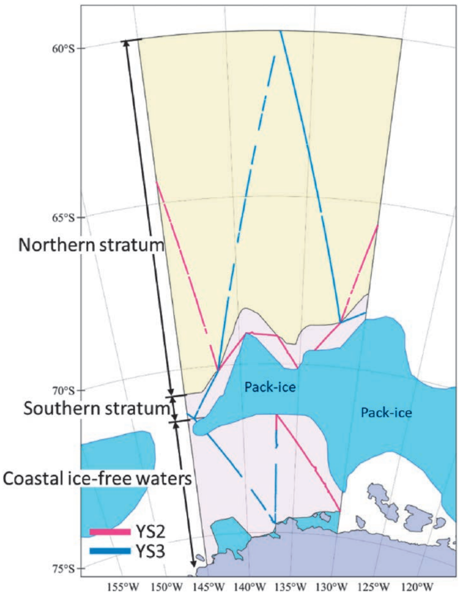

Figure 2. Research area (145°W–130°W) indicating northern, southern strata, and coastal ice-free waters searching efforts (red and blue lines for *Yushin-Maru* No. 2 (*YS2*) and *Yushin-Maru* No. 3 (*YS3*), respectively) of the JASS-A survey in the 2022/2023 austral summer season. The research commenced with *YS2* at 65°41′S; 130°00′W and *YS3* at 68°17′S; 130°00′W, and ended with *YS2* at 74°14′S; 130°00′W and with *YS3* at 72°59′S; 143°21′W. Note the ice-free waters south of 71°30′S.

Research vessels

The dedicated sighting vessels *Yushin-Maru* No. 2 (*YS2*) and *Yushin-Maru* No. 3 (*YS3*) were engaged in the survey. The specifications for both vessels are the same and are shown in Figure 4. Eight researchers participated in the survey, four in *YS2* and four in *YS3*. They had experience in conducting line transect surveys, biopsy sampling, photo-identification (photo-ID), satellite tagging and oceanographic survey through the previous JARPA/JARPAII, NEWREP-A and previous JASS-A surveys.

Sighting procedures and experiments

The procedures for sighting and experiments were the same as in previous JASS-A surveys. See Isoda *et al.* (2023) 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.

RESULTS OF THE SURVEY

Narrative of the survey

Table 1 shows the itinerary of the survey. The duration of this cruise was 99 days (*YS2*) and 97 days (*YS3*). The *YS2* and *YS3* departed Japan on 5 and 7 December 2022, respectively. They arrived at the home port on 22 December. The *YS2 and YS3* started the sighting survey in Antarctic Area VI at 65°41′S; 130°00′W on 11 January, and at

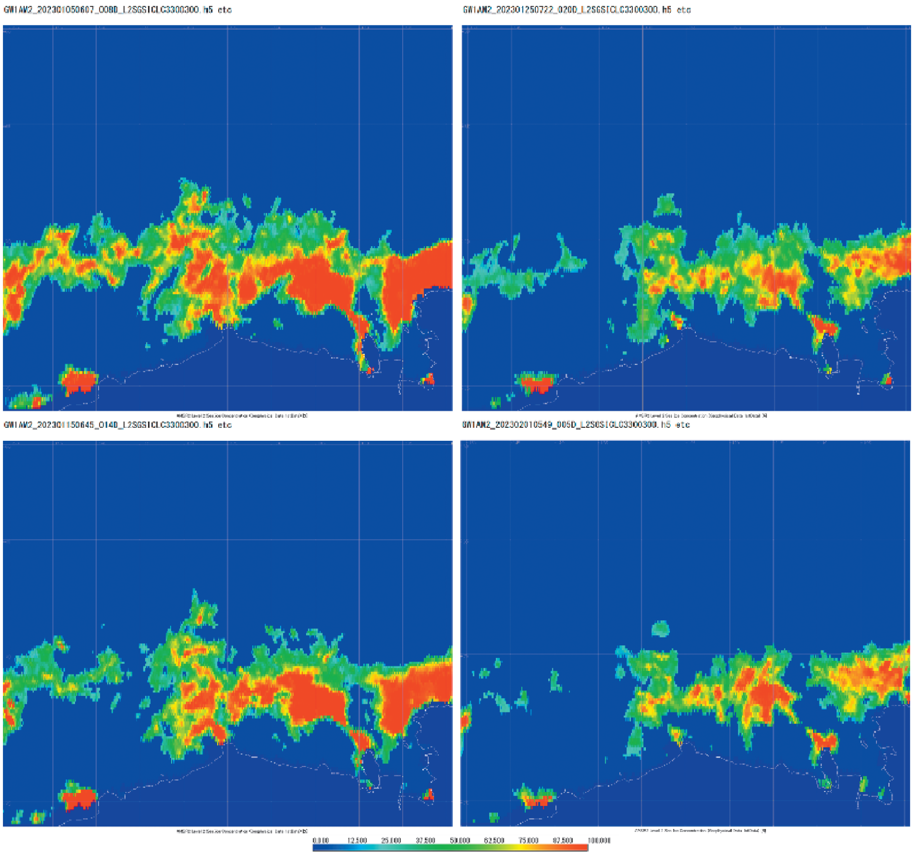

Figure 3. Maps of the pack-ice distributions in the research area for dates 5 January (upper left), 15 January (lower left), 25 January (upper right) and 1 February (lower right) 2023, constructed by Japan Aerospace Exploration Agency (JAXA), based on observational data acquired by the Advanced Microwave Scanning Radiometer 2 (AMSR2). Note that the ice-free waters became accessible to the vessel in early February.

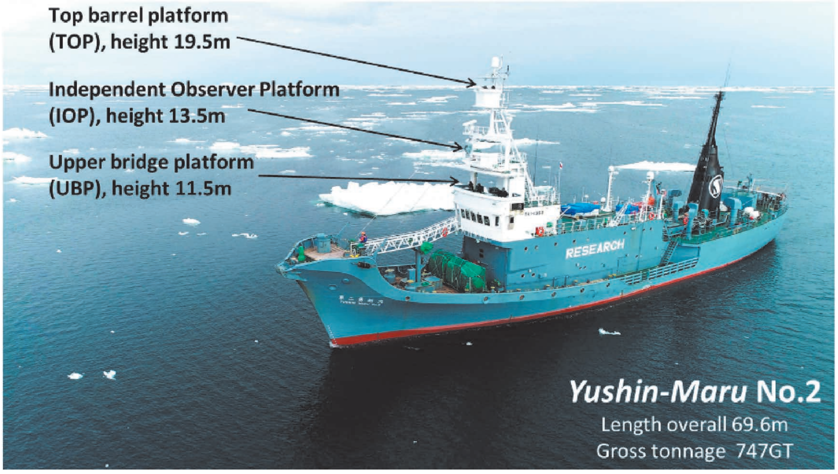

Figure 4. Specifications of the dedicated sighting vessel *Yushin-Maru* No. 2, which is similar to *Yushin-Maru* No. 3.

68°17′S; 130°00′W on 10 January 2023, respectively. The *YS2* and *YS3* completed the surveys at position 74°14′S; 130°00′W and 72°59′S; 143°21′W respectively, on 6 February. The *YS2* and *YS3* arrived at the home port on 22 February, and finally in Japan on 13 March.

Research effort in the research area

Table 2 shows a summary of the searching effort spent during the survey. The *YS2* and *YS3* were engaged in the research for 27 days and 28 days, respectively. The total searching effort of both vessels was 2,168.6 n. miles (4,016.2 km); 1,051.1 n.miles in NSP mode during

Table 1
Itinerary of the 2022/2023 JASS-A dedicated sighting survey.

Date (y/m/d)	Event
2022/11/16	Planning meeting at Tokyo, Japan
2022/12/2	Pre-cruise meeting at Shiogama, Japan
2022/12/5	*YS2* departed Shiogama, Japan
2022/12/7	*YS3* departed Shiogama, Japan
2022/12/7	*YS2* started transit survey at 31°20′N; 145°35′E (high sea)
2022/12/8	*YS3* started transit survey at 35°20′N; 143°20′E (high sea)
2022/12/22	*YS2* and *YS3* arrived in the home port (Suva, Fiji)
2023/1/10	*YS3* finished transit survey and started survey in the research area at 68°17′S; 130°00′W
2023/1/11	*YS2* finished transit survey and started survey in the research area at 65°41′S; 130°00′W
2023/2/6	*YS2* and *YS3* completed surveys in the research area (27 days and 28 days, respectively) and started transit survey at 74°14′S; 130°00′W and at 72°59′S; 143°21′W, respectively
2023/2/22	*YS2* and *YS3* arrived in the home port (Suva, Fiji)
2023/3/10	*YS2* and *YS3* finished transit survey at 31°05′N; 145°44′E and at 27°59′N; 138°11′E, respectively
2023/3/13	*YS2* and *YS3* arrived in Japan and post cruise meetings at Shiogama and Shimonoseki, Japan, were carried out respectively

98 hours 2 minutes of research and 1,117.4 n.miles in IO mode during 104 hours 33 minutes of research.

In the northern stratum, the total searching effort was 1,295.8 n.miles (NSP: 637.8 n.miles; IO: 658.0 n.miles), and the searching effort coverage was 76%. In the southern stratum, the total searching effort was 393.3 n.miles (NSP: 209.3 n.miles; IO: 184.0 n.miles), and the searching effort coverage was 91%. In the coastal ice-free waters, the total searching effort was 479.4 n.miles (NSP: 203.8 n.miles; IO: 275.6 n.miles), and the searching effort coverage was 75%.

Therefore, a good distribution of effort within all strata and survey mode was achieved. The total experimental time for photo-ID, biopsy sampling, tagging and distance and angle experiment was 45 hours 26 minutes.

Whale sightings in the research area

Four baleen whale species and at least two toothed whale species were sighted in the research area. The dominant whale species in the research area was the Antarctic minke whale (242 schools/521 individuals) followed by the fin whale (59/137). Sightings of other species were as follows; humpback (21/46), Antarctic blue (20/31), sperm (7/7), killer (11/117, including Type A, Type B, Type C and undetermined type) and Ziphiidae (1/2) whales (Table 3).

Antarctic minke whales

Antarctic minke whales were widely distributed in the research area including in the coastal ice-free waters (Figure 4). This result is consistent with the interpretation of Fujise and Pastene (2021) that larger number of this species are being distributed in polynyas within the pack-ice in recent years, possibly in searching of alternative feeding areas in response to the increase in abundance and geographical expansion of other large whale species (e.g. humpback and fin whales). On the other hand, a sighting survey using an icebreaker vessel found no Antarctic minke whales within coastal polynyas in a similar location to that surveyed in the present survey (Ainley *et al.*, 2007). However, this survey was conducted in 1994 and it was suggested that the distribution of this species has changed in recent years.

The Amundsen Sea Coastal Polynya overlaps partially with the eastern side of Antarctic Area VI East. Here high densities of the ice krill (*Euphausia crystallorophias*) were observed along the ice shelf and near the boundary between pack-ice and coastal polynya. These high densities are an order of magnitude higher than recorded previously in the Ross Sea Polynya (La *et al.*, 2015). The ice krill is the predominant prey species on coastal (shallow) area on continental shelf (Tamura and Konishi, 2009). The high density of Antarctic mink whale in coastal ice-free waters in the 2021/2022 and 2022/2023 seasons might be related to high densities of this prey species.

Fin whales

Fin whales were widely distributed only in the northern stratum (Figure 4). The density was higher than that in the previous 2000/2001 IWC-SOWER survey in the sector 140°W–120°W (Ensor *et al.*, 2001). An increasing trend in abundance of this species was already suggested for in the area adjacent to the west side: Areas V+VI West (Matsuoka and Hakamada, 2014).

Table 2
Summary of searching effort and time spent by *YS2* and *YS3* during the 2022/2023 JASS-A survey.

Vessel: ***YS2***	Date and time		Searching effort (distance [n.miles] and time [hours: minutes: seconds])				Experiments time (hours: minutes: seconds)	
Survey Sections	Start	End	NSP		IO		Photo-ID, Biopsy, Satellite tagexperiment	Estimated angle and distance training/ experiment
Transit survey (Shiogama-Equator)	2022/12/07 07 : 05	2022/12/15 12 : 46	473.1	40 : 57 : 38	—	—	02 : 54 : 49	—
Transit survey (Equator-Research area)	2022/12/15 12 : 47	2023/1/10 18:00	519.7	45 : 42 : 44	—	—	04 : 13 : 33	—
Research area (Area VIE 145°W-130°W)	2023/1/11 06 : 00	2023/2/1 12 : 15	347.5	31 : 48 : 56	342.7	31 : 36 : 47	16 : 27 : 28	05 : 27 : 16
Coastal ice-free waters, south of 71°30'S (145°W-130°W)	2023/2/1 12 : 16	2023/2/6 16 : 19	99.1	09 : 31 : 03	122.9	12 : 00 : 45	01 : 38 : 25	—
Transit survey (Research area-Equator)	2023/2/6 16 : 20	2023/3/2 09 : 20	709.7	60 : 53 : 25	—	—	01 : 35 : 15	—
Transit survey (Equator-Shiogama)	2023/3/3 06 : 00	2023/3/10 16 : 20	305.9	25 : 33 : 15	—	—	00 : 42 : 28	—
Total			2455.0	214 : 27 : 01	465.6	43 : 37 : 32	27 : 31 : 58	05 : 27 : 16

Vessel: ***YS3***	Date and time		Searching effort (distance [n.miles] and time [hours: minutes: seconds])				Experiments time (hours: minutes: seconds)	
Survey Sections	Start	End	NSP		IO		Photo-ID, Biopsy, Satellite tag experiment	Estimated angle and distance training/ experiment
Transit survey (Shiogama-Equator)	2022/12/8 07 : 25	2022/12/16 14:00	436.3	36 : 25 : 34	—	—	00 : 46 : 01	—
Transit survey (Equator-Research area)	2022/12/16 14:01	2023/1/9 18:00	472.5	40 : 20 : 53	—	—	01 : 20 : 18	—
Research area (Area VIE 145°W-130°W)	2023/1/10 06 : 00	2023/1/31 16 : 42	499.7	46 : 11 : 38	499.2	46 : 23 : 09	14 : 10 : 21	01 : 29 : 12
Coastal ice-free waters, south of 71°30'S (145°W-130°W)	2023/1/31 16 : 42	2023/2/6 17 : 10	104.8	10 : 30 : 23	152.7	14 : 32 : 19	02 : 00 : 09	04 : 12 : 48
Transit survey (Research area-Equator)	2023/2/7 06 : 00	2023/3/2 15 : 20	794.8	67 : 29 : 11	—	—	03 : 01 : 48	—
Transit survey (Equator-Shimonoseki)	2023/3/3 06 : 00	2023/3/10 16 : 50	295.5	24 : 46 : 55	—	—	00 : 00 : 00	—
Total			2,603.6	225 : 44 : 34	651.9	60 : 55 : 28	21 : 18 : 37	05 : 42 : 00

Humpback whales

Humpback whales were widely distributed in the northern stratum with higher concentrations observed in the northern part of this stratum (Figure 4). The density was slightly higher than that in the 2000/2001 IWC-SOWER cruise in the same sector (Ensor *et al.*, 2001). This result suggests that abundance of this species is relatively stable in this area.

Antarctic blue whales

Antarctic blue whales were sighted in the northern and southern strata with higher densities in the former stratum (Figure 4). Four mother and calf pairs were observed. There were only two schools (four individuals) in the 2000/2001 IWC-SOWER cruise in the same sector (Ensor *et al.*, 2001). This information is crucial for monitoring the Antarctic blue whale population recovery.

Table 3

Number of sightings made during the 2022/2023 JASS-A survey in the research area, by stratum and species.

Species	Western part of Area VIE (145°W–130°W)												Sub-total				Total	
	Southern stratum				Northern stratum				Coastal ice-free waters, south of 71°30'S									
	Prim.		Second.		Prim.		Second.		Prim.		Second.		Prim.		Second.			
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Antarctic blue whale	2	2	0	0	17	27	1	2	0	0	0	0	19	29	1	2	20	31
Fin whale	0	0	0	0	50	117	9	20	0	0	0	0	50	117	9	20	59	137
Antarctic minke whale	48	85	17	31	48	101	6	9	102	238	21	57	198	424	44	97	242	521
Like minke whale	3	3	1	10	2	3	1	1	8	8	2	3	13	14	4	14	17	28
Like Antarctic minke whale	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	1	1
Humpback whale	0	0	0	0	20	36	1	10	0	0	0	0	20	36	1	10	21	46
Baleen whales	2	2	0	0	9	9	1	1	2	2	0	0	13	13	1	1	14	14
Sperm whale	1	1	0	0	6	6	0	0	0	0	0	0	7	7	0	0	7	7
Killer whale (Undetermined)	1	3	0	0	1	9	0	0	2	7	0	0	4	19	0	0	4	19
Killer whale (Type A)	0	0	0	0	1	8	0	0	0	0	0	0	1	8	0	0	1	8
Killer whale (Type B)	0	0	0	0	1	13	0	0	2	21	1	9	3	34	1	9	4	43
Killer whale (Type C)	0	0	0	0	0	0	0	0	2	47	0	0	2	47	0	0	2	47
Ziphiidae	0	0	0	0	1	2	0	0	0	0	0	0	1	2	0	0	1	2
Unidentified whales	1	1	0	0	4	4	0	0	3	3	0	0	8	8	0	0	8	8

Prim.: Primary sighting, Second.: secondary sighting, Sch.: Schools, Ind.: individuals

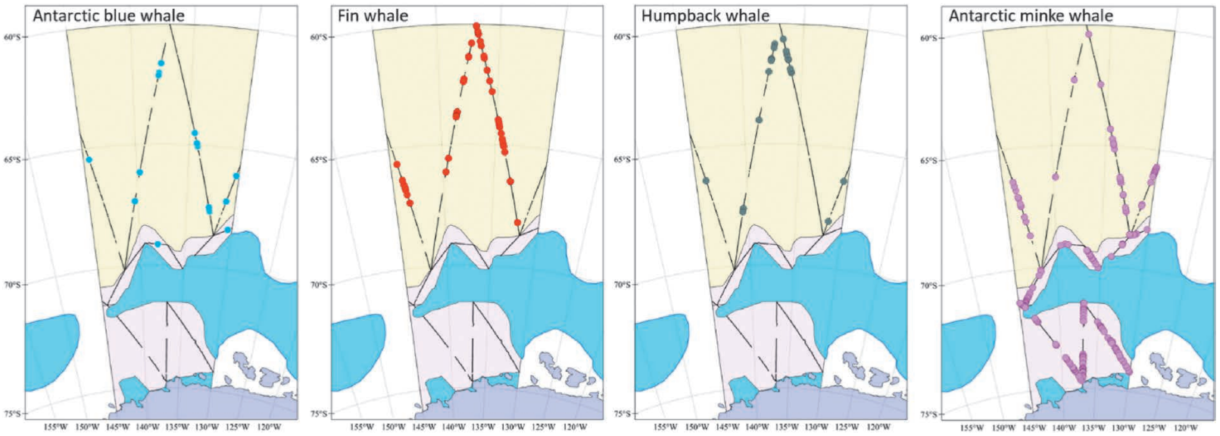

Figure 4. Geographical distribution of primary sightings of Antarctic blue, fin, humpback, and Antarctic minke whales during the 2022/2023 JASS-A survey.

Duplicate sightings

Duplicates sightings were those sightings made concurrently 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 will be used to adjust estimates of abundance. There was a total of 63 duplicates involving several whale species.

Other research activities

Table 4 shows a summary of results of different experiments.

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. The actual experiments were successfully completed on 1 February for 120 trials in *YS2*, and on 4 February for 128 trials in *YS3*.

Photo-ID

Photo-ID data is used for individual matching exercise to investigate distribution and movement of large whales. A total of 26 Antarctic blue, 11 humpback and 37 killer

Table 4

Summary of the results of experiments conducted during the 2022/2023 JASS-A survey.

Experiments	Results and descriptions
Sighting distance and angle experiment	248 trials completed
Photo-ID	Obtained from 26 Antarctic blue, 11 humpback and 37 killer whales
Biopsy sampling	Collected from 8 Antarctic blue, 20 fin, 28 Antarctic minke, 6 sei, 16 humpback, 2 pygmy right and 9 killer whales
Satellite tagging	Deployed on 8 fin, 25 Antarctic minke, 2 sei, 2 humpback and 1 pygmy right whales
Oceanographic survey	137 XCTD casts
Marine debris observation	8 fishing buoy and 1 plastic tank were observed in the research area
UAV	Aerial images collected from 6 Antarctic blue, 7 Antarctic minke and 1 pygmy right whales

whales were successfully photo-identified during the entire survey. These data will be registered into the Institute of Cetacean Research (ICR) database (see Matsuoka and Pastene, 2014).

Biopsy sampling

Biopsy samples are used for genetic studies on stock structure of large whales and for other feasibility studies related to the specific objectives of the JASS-A. For the entire survey, a total of 89 biopsy samples were collected from 8 Antarctic blue, 20 fin, 28 Antarctic minke, 6 sei, 16 humpback, 2 pygmy right and 9 killer whales, using the Larsen system (Larsen, 1998). 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 (SPOT and SPLASH-types, Wildlife Computers, Redmond, Washington, USA) were deployed with the Air Rocket Transmitter System (ARTS) (LK-ARTS, Skutvik, Norway). The detail of deployment system, protocols and research results to date were described in Konishi *et al.* (2020). During the whole survey, 8 fin, 25 Antarctic minke, 2 sei, 2 humpback and 1 pygmy right whales were tagged.

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 profiler, Tsurumi-Seiki Co., Ltd., Yokohama, Japan; probe type: XCTD-4N) with Digital Converter MK-150P (*YS2*) and MK-150N (*YS3*) at 137 stations (Figure 5a).

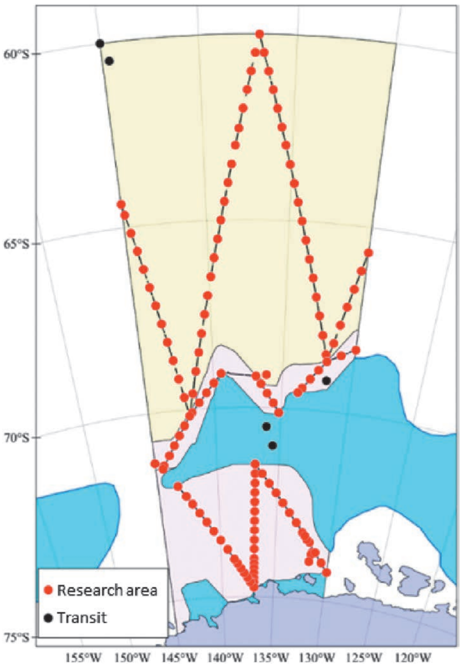

Figure 5a. Oceanographic stations (XCTD casting points) at the 2022/2023 JASS-A survey. Red circle: stations at the research area; black circle: stations at the transit area.

The vertical structure of temperature and salinity between 5 m and 800 m were illustrated in Figure 5b. In the offshore area, cold water was distributed at 50 to 150 m, while in the coastal area cold water was distributed at 100 to 300 m. 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. It is therefore important to continue with this kind of survey in order to monitor future trends in the occurrence of marine debris. Eight fishing buoys and one plastic tank were observed in the research area. These data will be registered into the ICR database and reported in the fu-

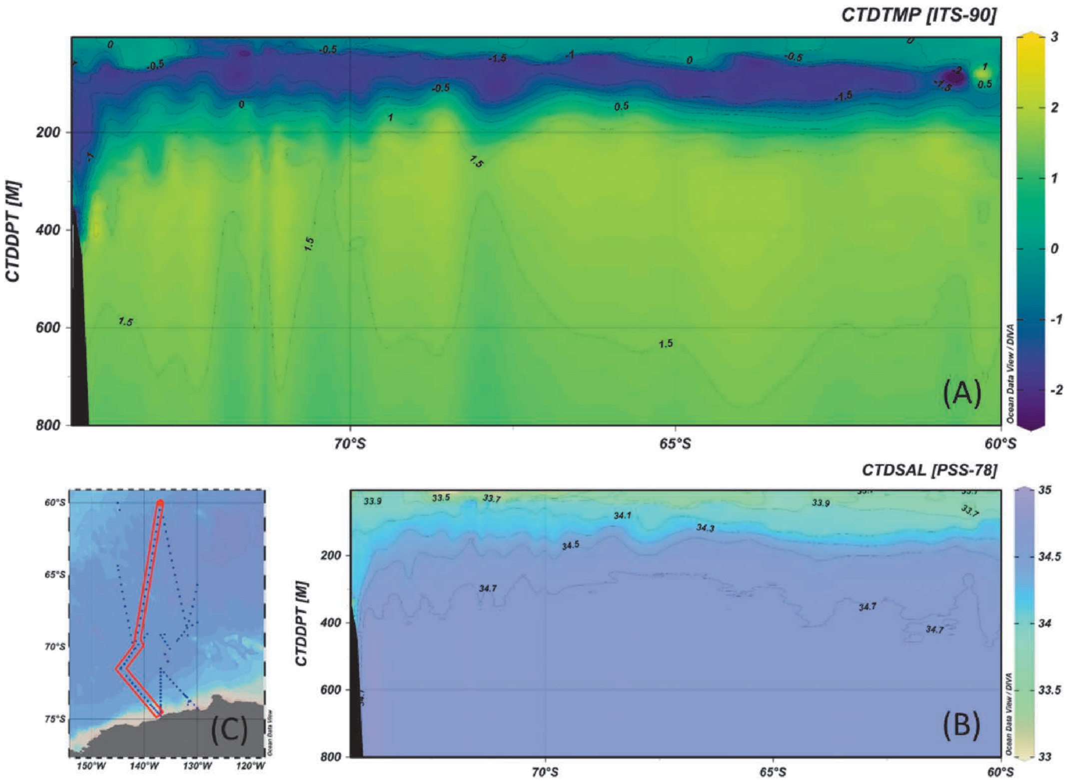

Figure 5b. Preliminary analysis of the latitude-depth sections of temperature (°C) (A) and salinity (PSU) (B), along a track line between 60°00' and 74°45'S (C) using data obtained during the 2022/2023 JASS-A survey. Figures were generated using Ocean Data View (Schlitzer, 2020).

ture (e.g. Isoda *et al.*, 2021).

Feasibility study on the utility of UAV

UAV will be used to refine observations related with whale abundance and distribution, e.g. determine the number of individuals in the schools. The technique can be used also for photogrammetry studies. Aerial images were collected for a total of 6 Antarctic blue, 7 Antarctic minke and 1 pygmy right whales, using a small UAV, Inspire 2 Pro and DJI phantom 4 Pro (video clips can be accessed at https://www.youtube.com/channel/UCz3c9I-IMiQPVeryAogmJIig). These data will be registered into the photo-ID catalogue of ICR.

This UAV ASUKA is being developed to collect information on whales in areas of difficult access to the vessels e.g. ice-bound seas in the Antarctic (Matsuoka and Yoshida, 2021; Katsumata and Yoshida, 2023). In this survey, the UAV ASUKA departed and arrived using the platform of the research vessel. UAV ASUKA operated for an approximate time of 32 h during the daytime. Basic data for improving UAV ASUKA flight performance in the polar regions were obtained.

Sighting survey in low-middle latitude area

Sighting surveys in low-mid latitude areas have the potential to collect data on seasonal movement and possible breeding grounds of whale species. JASS-A has been collecting information on cetaceans by conducting sighting surveys in the low-middle latitude area using the opportunity of a round-trip cruise to the Antarctic, excluding waters of foreign countries EEZs. In transit from Japan to the equator, the total searching effort was 909.3 n.miles (Table 2). Bryde's (3/3), sei (4/6), fin (2/2), sperm (10/17), Ziphiidae (6/16) and *Mesoplodon* (2/4) whales were sighted. Biopsy samples were collected from four sei whales and satellite tags were attached on two sei whales.

In transit from the equator to the starting position in the Antarctic research area, the total searching effort was 992.2 n.miles (Table 2). Fin (30/61), sei (5/6), Bryde's (1/1), Antarctic minke (7/9), humpback (4/7), sperm (3/3), Ziphiidae (1/1) and *Mesoplodon* (5/10) whales were sighted. Biopsy samples were collected from 4 fin, 1 sei, 3 Antarctic minke and 1 humpback whale, and satellite tags were attached on 3 Antarctic minke whales.

In transit from the ending position in the Antarctic research area to the equator, the total searching effort was 1,504.4 n.miles (Table 2). Fin (2/3), Antarctic minke (30/45), humpback (1/2), sei (1/1), pygmy right (2/2), sperm (1/3), southern bottlenose (1/2), killer (Type A)

(1/13), Ziphiidae (10/22) and *Mesoplodon* (5/13) whales were sighted. Biopsy samples were collected from 1 fin, 3 Antarctic minke, 1 sei, 2 humpback and 2 pygmy right and 2 killer whales. Satellite tags were attached to 3 Antarctic minke whales and 1 pygmy right whale.

In transit from the equator to Japan, the total searching effort was 601.4 n.miles (Table 2). Fin (1/1) and Ziphiidae (1/1) whales were sighted.

HIGHLIGHTS OF THE SURVEY

The 2022/2023 JASS-A survey covered a part of Area VI (145°W–130°W) and succeeded in collecting sighting data necessary for the abundance estimation of cetaceans in this area. Of particular importance was the survey conducted in ice-free waters south of 71°30'S, same as in the 2021/2022 season. 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/JARPAII, NEWREP-A and IDCR/SOWER surveys in the same region so that the analyses can be based on a long and consistent data set.

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Appendix 1.

Photographs from the 2022/2023 JASS-A survey in Antarctic Area VI

Photo 1. Antarctic blue whale.

Photo 2. Antarctic blue whale mother and calf.

Photo 3. Fin whale.

Photo 4. A large school of Antarctic minke whales observed in the coastal ice-free waters.

Photo 5. Humpback whale.

Photo 6. Killer whales (type A).

Photo 7. Pigmy right whale sighted during the low-middle latitude area survey.

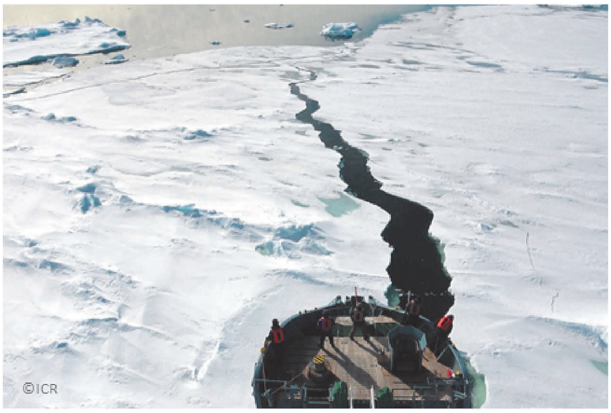

Photo 8. Navigating within the pack-ice.

Photo 9. Sighting activity at top barrel platform.

Photo 10. Buoy used in the angle and distance experiment.

Photo 11. Biopsy and satellite tagging experiments.

Photo 12. VTOL-UAV ASUKA takes off from the vessel.

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Technical report (not peer reviewed)

Report and highlights of the Japanese dedicated sighting surveys in the North Pacific in 2022

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ABSTRACT

This paper presents the results of vessel-based sighting surveys conducted in 2022 by the Institute of Cetacean Research in the North Pacific. The research area was set between 35°N–46°N and 140°E–175°W. The surveys were conducted between 7 April and 10 November involving three seasons: spring, late summer and autumn. The spring and late summer surveys were conducted to examine the distribution and abundance of whales, and the autumn survey was conducted to investigate the migration of sei whales using satellite tags. The research vessels *Yushin-Maru, Yushin-Maru* No. 2 and *Kaiyo-Maru* No. 7 were engaged in the surveys. A total of 8,340.9 n.miles was searched in the research area. Coverage of the searching efforts on the planned cruise track line was 81.1%. In total, eight large whale species, including blue (3 schools/3 individuals), fin (105/165), sei (32/44), Bryde′s (248/274), common minke (151/172), humpback (52/62), North Pacific right (1/1) and sperm (198/375) whales were sighted during the whole research. Photo-ID images were collected from blue (n=2), humpback (n=7), North Pacific right (n=1) and killer (n=2) whales. Biopsy skin samples using a Larsen system were collected from fin (n=1), sei (n=16), Bryde′s (n=6), common minke (n=6) and North Pacific right (n=1) whales. Satellite tags were attached on fin (n=1), sei (n=16), Bryde′s (n=5) and common minke (n=1) whales. Data collected during these surveys will be used in studies on abundance, distribution, movement and stock structure of several whale species.

INTRODUCTION

Dedicated cetacean sighting surveys in the western North Pacific were conducted in the late summer season since 1995 as a part of the 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) based on the survey procedures of the International Whaling Commission/Southern Ocean Whale and Ecosystem Research (IWC/SOWER) (IWC, 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 Scientific Committee (SC) (IWC, 2001; 2010; 2016).

The Fisheries Resources Institute (FRI) has also conducted dedicated sighting surveys for cetaceans in the North Pacific since the 1980s (Buckland *et al.*, 1992; Miyashita *et al.*, 1995; Miyashita and Kato, 2004; 2005; Shimada, 2004; Kanaji *et al.*, 2012). In 2019 the Government of Japan decided to continue the sighting surveys in the North Pacific (IWC, 2019) under the rational 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 7 April and 10 November 2022 involving three seasons: spring, late summer and autumn.

SURVEY DESIGN

Research period and area

In 2022, the surveys were conducted in three seasons: spring, late summer and autumn. The objective of spring and late summer surveys was the study of distribution and abundance of large whales from poorly documented seasons. Autumn survey aimed to study the movement and southern migration of sei whales using satellite tags. Figure 1 illustrates the research areas covered in each season.

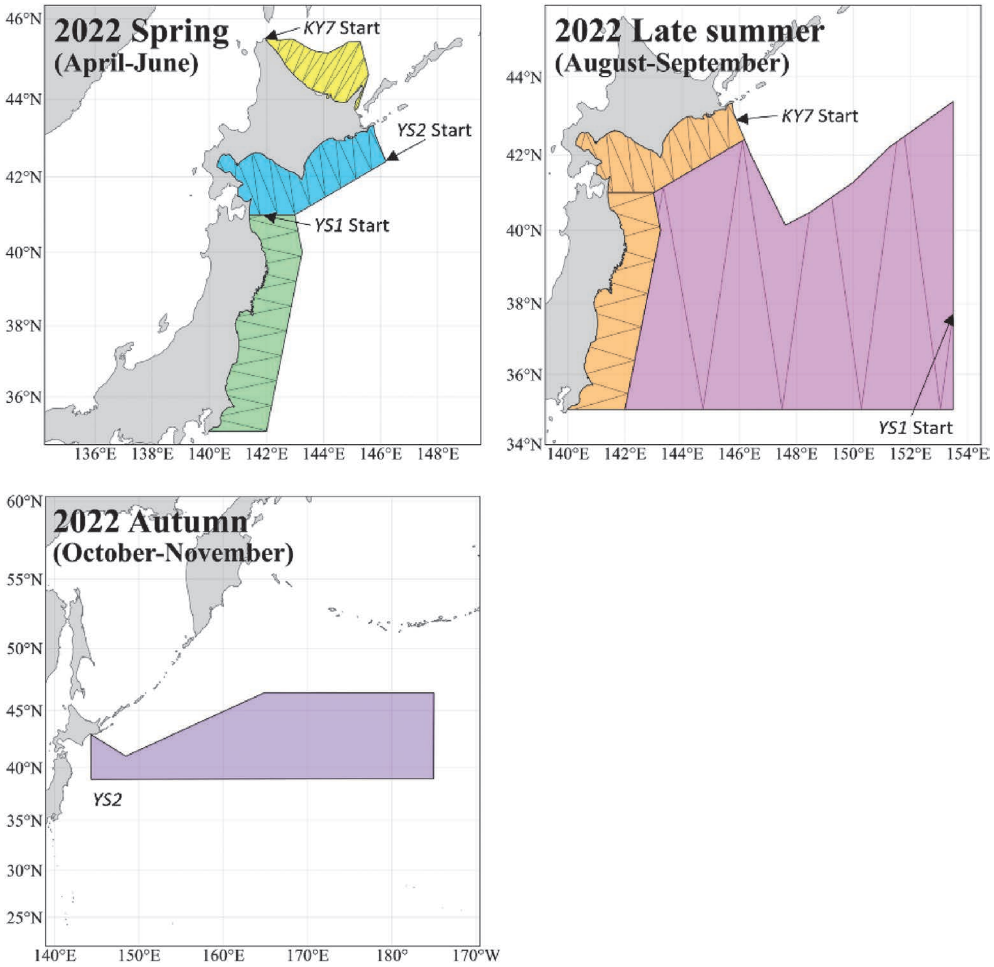

Figure 1. Research areas covered by the 2022 dedicated sighting surveys in each season. Upper left: spring survey. *Kaiyo-Maru* No. 7 (*KY7*) covered the yellow area, *Yushin-Maru* (*YS1*) covered the green area, and *Yushin-Maru* No. 2 (*YS2*) covered the blue area. Upper right: late summer survey. *KY7* covered the orange area, and *YS1* covered the pink area. Lower left: autumn survey. *YS2* covered the purple area. The autumn survey did not have a pre-determined track line.

In spring (April to June), the research area was set up between 35°N–46°N and 140°E–146°E. In late summer (August to September), the research area was set up between 35°N–44°N and 140°E–154°E. Finally, in autumn season (October to November), the research area was set up between 38°N–46°N and 141°E–175°W.

Research vessels

The sighting surveys in 2022 were conducted by the research vessels *Yushin-Maru* (*YS1*), *Yushin-Maru* No. 2 (*YS2*) and *Kaiyo-Maru* No. 7 (*KY7*) (Figure 2). The vessels were equipped with a top barrel platform (TOP), IO barrel platform (IOP) and upper bridge.

Track line design

The pre-determined track lines in spring and late summer surveys are shown in Figure 1. The start points of the track lines were decided randomly using the ʻDistance program ver. 7.3ʹ (Thomas *et al.*, 2010) and the number of the line (width in the longitude) was decided by the research schedule based on the IWC survey guidelines (IWC, 2012). The autumn survey did not set track lines because the objective in this season was not abundance estimates but satellite tagging of sei whales.

Sighting procedure

The sighting surveys were conducted using (1) Normal Passing mode (NSP), (2) Normal Closing mode (ASP) and (3) Passing with Independent Observer mode (IO) in order to estimate whale abundance considering estimated *g*(0). The survey modes adopted for each survey are shown in Table 1. Three survey modes followed the protocol endorsed for the SOWER surveys (e.g. Matsuoka *et al.*, 2003; IWC, 2008; 2012). As data from late summer survey are used to estimate the abundance of large whales, the IO mode was also adopted for this survey, as

Figure 2. Research vessels participating in the 2022 dedicated sighting surveys: *Yushin-Maru* (*YS1*) (upper left), *Yushin-Maru* No. 2 (*YS2*) (upper right) and *Kaiyo-Maru* No. 7 (*KY7*) (lower left).

Table 1
Summary of the survey modes and searching conditions by each seasonal survey during the 2022 dedicated sighting surveys.

Season	Vessel	Survey mode	Searching conditions		
			Visibility (n.miles)	Wind speed (kt)	Searching speed (kt)
Spring	*KY7*, *YS1*, *YS2*	Normal Passing mode	≥2.0	17.0>	10.0≥
Late summer	*KY7*, *YS1*	Normal Passing mode Passing with Independent Observer mode	≥2.0	17.0>	10.0≥
Autumn	*YS2*	Normal Closing mode	≥2.0	21.0>	11.5≥

this survey can provide important data to calculate *g*(0).

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

For IO mode, there were two primary observers on the TOP and two in the independent observer platform (IOP). These observers conducted searching for cetaceans by using angle board and scaled binoculars (7x). 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, only to clarify information and did not distract the top-men from their normal searching procedure. These primary observers report sighting-information to researchers and other observers on the upper bridge for data recording.

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 mealtime for lunch and supper, when surveying in IO mode) when the weather conditions were acceptable for observations. Detailed search conditions for each survey are shown in Table 1.

Experiments

Table 2 describes the details of the planned experiments for each survey. Distance and angle experiments were conducted in the middle of the survey period. The experiment was conducted to evaluate measurement error and followed the protocol of the IWC/SOWER and IWC-POWER surveys (IWC, 2012).

When large cetaceans such as blue and humpback whales were found, 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 system (Larsen, 1998) was conducted when blue, fin, sei and humpback whales were sighted. The satellite tagging experiment using the Air Rocket Transmitter System (LK-ARTS) was also conducted for fin, sei, Bryde′s and common minke whales.

RESULTS

Brief narrative of the surveys

Spring (April–June)

KY7 departed Hakodate, Hokkaido, Japan on 7 April, and started the survey in the research area on 8 April. *KY7* paused the survey on 4 May for a scheduled port call, and entered Hakodate, on 6 May for refueling and disembarkation of researchers. On 11 May, *KY7* departed Hakodate, and resumed the survey on 12 May. The survey was completed on 7 June. *KY7* arrived in Hakodate on 9 June.

YS1 and *YS2* departed Shiogama, Miyagi, Japan on 14 April. *YS1* and *YS2* started the survey in the research area on 15 April and completed it on 21 May. *YS1* and *YS2* arrived in Shiogama on 23 May.

Late summer (August–September)

YS1 and *KY7* departed Shiogama on 2 August and 3 August, and started the surveys on 3 and 4 August, respectively. On 24 August, *KY7* suspended the survey and entered Hakodate for refueling. *KY7* departed Hakodate and recommenced the survey on 25 August. *KY7* completed the survey on 16 September and arrived in Shiogama on 17 September. *YS1* completed the survey on 22 September and arrived in Shiogama on 30 September.

Autumn (October–November)

The *YS2* departed Shiogama on 17 October and began the survey on 18 October. The vessel completed the survey on 9 November and arrived in Shiogama on 10 November.

Searching effort

A summary of searching effort and coverage in each seasonal survey is shown in Table 3. A total of 8,340.9 n.miles (15,447.3 km) were searched in all seasonal surveys.

Table 2
Experiments planned in each seasonal survey during the 2022 dedicated sighting surveys.

Season	Vessel	Planned experiments
Spring	*KY7*, *YS1*, *YS2*	Photo-ID, biopsy, satellite tagging, distance and angle experiments
Late summer	*KY7*, *YS1*	Photo-ID, biopsy, satellite tagging, distance and angle experiments
Autumn	*YS2*	Photo-ID, biopsy, satellite tagging

Table 3
Summary of the survey periods and searching effort by each seasonal survey in the 2022 dedicated sighting surveys.

Season	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 (%)
Spring	*KY7*	2022/04/08–05/04	1,019.2	781.9	–	781.9	76.7
		2022/05/12–06/07	1,019.2	607.9	–	607.9	59.6
	YS1	2022/04/15–05/21	1,298.1	1,139.7	–	1,139.7	87.8
	YS2	2022/04/15–05/21	1,317.4	936.1	–	936.1	71.1
	Sub total	—	4,653.9	3,465.6	–	3,465.6	74.5
Late summer	*KY7*	2022/08/04–08/24	1,122.3	484.9	463.1	948.0	84.5
		2022/08/25–09/16	965.7	439.4	407.9	847.3	87.7
	YS1	2022/08/03–09/22	3,060.8	1,351.2	1,339.2	2,690.4	87.9
	Sub total	—	5,148.8	2,275.5	2,210.2	4,485.7	87.1
Autumn	*YS2*	2022/10/18–11/09	—	389.6*	—	389.6	—
Total		—	9,802.7	6,130.7	2,210.2	8,340.9	81.1

* Searching effort ASP (n.miles).

Sightings

Spring

Tables 4a and 4b show the total sightings for large and small cetacean species, respectively, made in spring season 2022. The sighting locations of each species are shown in Figure 3 together with sea surface temperature (SST).

Blue whale

This species was not sighted in the spring season.

Fin whale

A total of 96 schools (153 individuals including three mother and calf pairs) were sighted north of 40°N (Figure 3). The range of SST in the sighting positions was 1.8°C–9.2°C (mean SST: 5.2°C), and the mean school size was 1.59. One biopsy sample was collected from one individual. The Density Index (DI: schools of primary sighted/100 n. miles searching distance) of *KY7* in April and May were 4.48 and 8.39, respectively while the DIs of *YS1* and *YS2* were 0.09 and 0.11, respectively.

Sei whale

This species was not sighted in the spring season.

Bryde's whale

A total of 14 schools (19 individuals including one mother and calf pair) were sighted south of 38°N (Figure 3). The range of SST at the sighting positions was 8.8°C–21.0°C (mean SST: 18.6°C). Observed mean school size was 1.36. The DI of *YS1* was 0.44.

Common minke whale

This species was the most frequently sighted species in the spring season (149 schools and 170 individuals) (Figure 3). One mother and calf pair was sighted at position 42°40′N, 145°03′E. The mean school size was 1.14 and the range of SST at the sighting positions was 1.3°C–

Table 4a

Total number of sightings of large whales made in spring 2022, by research vessel and species.

Species	*KY7* (Apr.)		*KY7* (May)		*YS1*		*YS2*		Total	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Fin whale	39	46	55	105	1	1	1	1	96	153
Bryde's whale	0	0	0	0	14	19	0	0	14	19
Common minke whale	59	67	84	96	2	2	4	5	149	170
Humpback whale	1	1	1	1	32	38	12	15	46	55
North Pacific right whale	0	0	0	0	0	0	1	1	1	1
Sperm whale	0	0	2	4	30	59	3	3	35	66

Sch.: Schools, Ind.: Individuals.

Table 4b

Total number of sightings of small cetaceans made in spring 2022, by research vessel and species.

Species	*KY7* (Apr.)		*KY7* (May)		*YS1*		*YS2*		Total	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Baird's beaked whale	10	36	9	46	2	11	0	0	21	93
Common dolphin	0	0	0	0	1	25	0	0	1	25
Northern form short-finned pilot whale	0	0	0	0	6	66	0	0	6	66
Southern form short-finned pilot whale	0	0	0	0	0	0	1	30	1	30
Risso's dolphin	0	0	0	0	2	18	0	0	2	18
Killer whale	11	89	7	73	7	19	1	3	26	184
True type Dall's porpoise	0	0	0	0	17	114	16	90	33	204
Dalli type Dall's porpoise	0	0	1	7	1	8	0	0	2	15
Unidentified type Dall's porpoise	0	0	11	30	18	150	8	32	37	212
Ziphiidae	0	0	0	0	5	9	3	5	8	14
Mesoplodon spp.	0	0	0	0	4	5	0	0	4	5

Sch.: Schools, Ind.: Individuals.

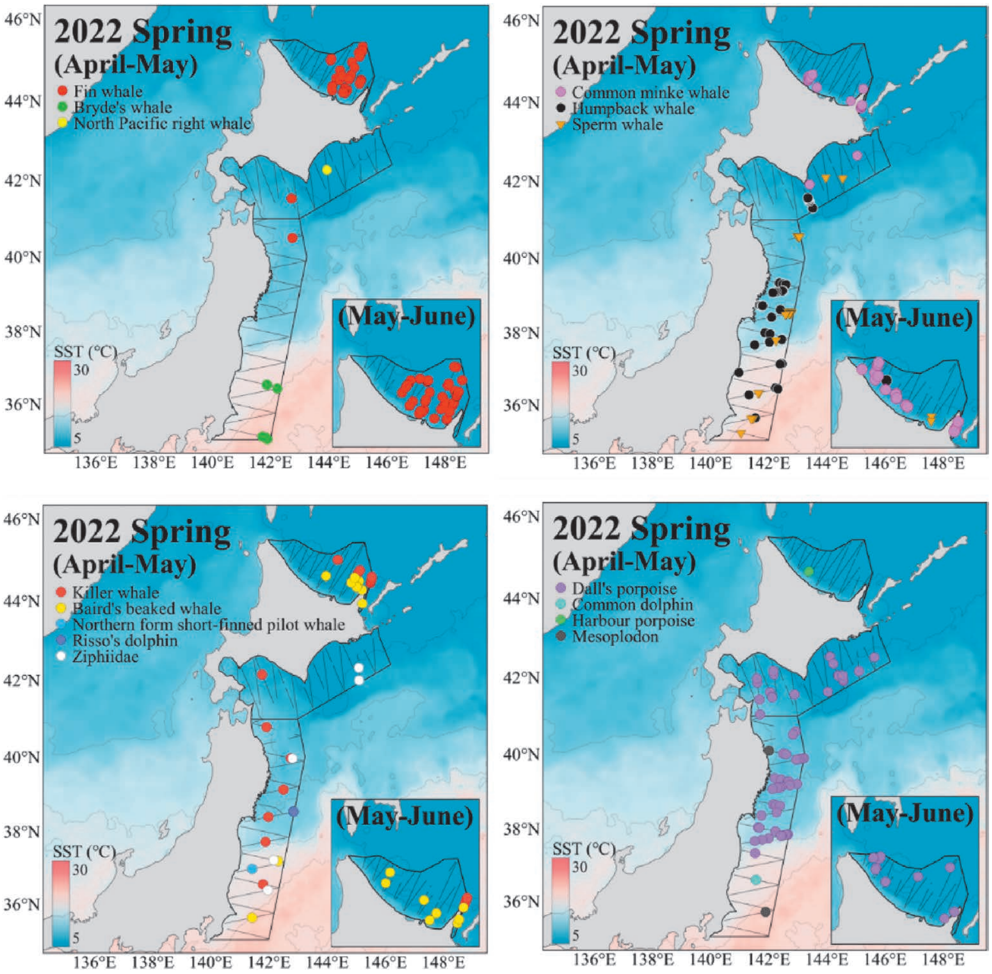

Figure 3. The locations of large and small cetaceans sighted during the spring season 2022. Rolling 32 days average sea surface temperature data from 23 April to 23 May 2022 and 9 May to 9 June obtained by MODIS-Aqua (Original data: Ocean color web, from https://oceancolor.gsfc.nasa.gov/ (Accessed 2023-4-20)), are also shown.

15.9°C (mean SST: 5.2°C). The DIs of *KY7* in April and May were 2.05 and 3.62, respectively. The DI of *YS2* was 0.21. Six biopsy samples were collected, and one satellite tag was attached to one individual.

Humpback whale

A total of 46 schools (55 individuals including one mother and calf pair) were sighted (Figure 3). The mother and calf pair was sighted at 36°48′N, 142°02′E. Observed mean school size was 1.20. The range of SST in the sighting positions was 2.9°C–21.0°C (mean SST: 9.1°C). The DI of *KY7* in May was 0.33. The DIs of *YS1* and *YS2* were 2.19 and 0.21, respectively. Seven individuals were photographed.

North Pacific right whale

One school (one individual) of estimated body length of 12.1 m was sighted at 42°16′N, 143°57′E (Figures 3 and 4). The SST in the sighting position was 5.3°C. This individual was photographed and a biopsy sample was obtained. The DI of *YS2* was 0.11.

Figure 4. A North Pacific right whale sighted in spring 2022 (17 May) during the 2022 dedicated sighting surveys.

Sperm whale

A total of 35 schools (66 individuals) were sighted (Figure 3). The range of SST in the sighting positions was 1.5°C–

21.1°C (mean SST: 9.6°C). Because the opportunity to approach the schools was limited, there was little information on school size, body length and calves. The mean school size was 1.89 when the school size was confirmed. The DIs differed markedly between seasonal surveys, 0.33 for *KY7*, 2.19 for *YS1* and 0.21 for *YS2*.

Small cetaceans

Five species of the the family Delphinidae, three species of the family Phocoenidae and three species of the family Ziphiidae were sighted (Table 4b). The most common species sighted was the Dall's porpoise (72/431), followed by killer whale (26/184). Dall's porpoises were sighted primarily at the 37°N–41°N latitudinal band in April–May, and north of 44°N in May–June. Killer whales and Baird's beaked whales were mainly sighted north of 44°N.

Late summer

Tables 5a and 5b show the total sightings for large and small cetacean species, respectively, made in late summer season 2022. The sighting locations of each species are shown in Figure 4 together with SSTs.

Blue whale

This species was not sighted in the late summer season.

Fin whale

Four schools (four individuals) were sighted north of 39°N (Figure 5). Mean school size was 1.00. The SST in the sighting position was 18.9°C–22.2°C (mean SST: 21.2°C). The DIs were 0.11 and 0.11 by *KY7* (August) and *YS1*, respectively.

Table 5a

Total number of sightings of large whales made in late summer 2022, by research vessel and species.

Species	*KY7* (Aug.)		*KY7* (Sep.)		*YS1*		Total	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Fin whale	1	1	0	0	3	3	4	4
Bryde's whale	18	18	23	24	190	210	231	252
Common minke whale	2	2	0	0	0	0	2	2
Humpback whale	2	3	0	0	0	0	2	3
Sperm whale	16	73	10	24	130	203	156	300

Sch.: Schools, Ind.: Individuals.

Table 5b

Total number of sightings of small cetaceans made in late summer 2022, by research vessel and species.

Species	*KY7* (Aug.)		*KY7* (Sep.)		*YS1*		Total	
	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.	Sch.	Ind.
Baird's beaked whale	7	35	17	103	3	28	27	166
Common dolphin	0	0	0	0	13	787	13	787
Northern form short-finned pilot whale	1	18	1	95	0	0	2	113
Southern form short-finned pilot whale	0	0	0	0	2	89	2	89
Risso's dolphin	1	45	3	70	7	59	11	174
Pacific white-sided dolphin	5	293	0	0	0	0	5	293
Killer whale	0	0	0	0	1	8	1	8
Melon-headed whale	0	0	1	15	0	0	1	15
Spotted dolphin	0	0	0	0	1	45	1	45
Striped dolphin	0	0	0	0	22	1,273	22	1,273
Bottlenose dolphin	1	10	2	20	0	0	3	30
True type Dall's porpoise	3	29	0	0	0	0	3	29
Dalli type Dall's porpoise	0	0	0	0	0	0	0	0
Unidentified type Dall's porpoise	4	38	1	3	2	22	7	63
Ziphiidae	0	0	7	23	57	117	64	140
Mesoplodon spp.	0	0	3	9	2	5	5	14

Sch.: Schools, Ind.: Individuals.

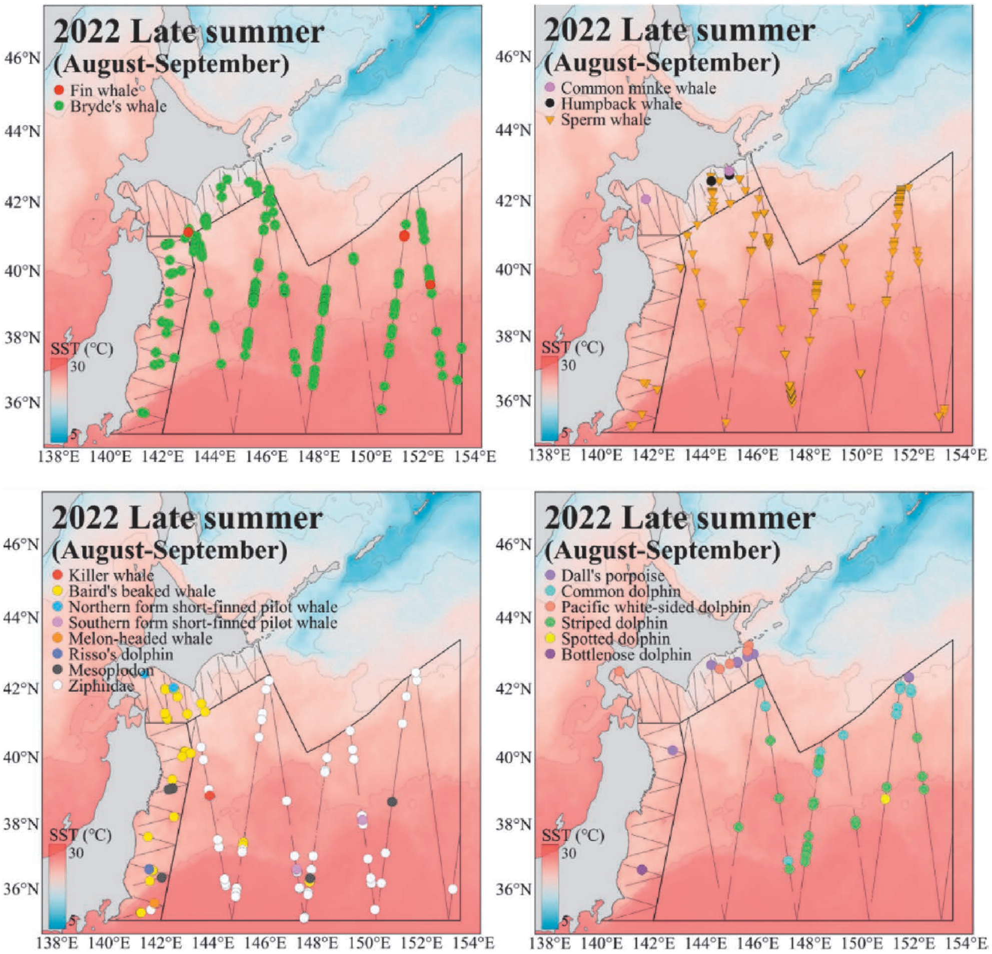

Figure 5. The locations of large and small cetaceans sighted during the late summer. Rolling 32 days average sea surface temperature data from 21 August to 21 September 2022 obtained by MODIS-Aqua (Original data: Ocean color web, from https://oceancolor.gsfc.nasa.gov/ (Accessed 2023-4-20)), are also shown.

Sei whale

This species was not sighted in the late summer season.

Bryde's whale

Bryde's whales were the most frequently sighted species in this season (Figure 5). A total of 231 schools (252 individuals) were sighted. Mean school size was 1.09. The range of SST at the sighting positions was 16.2°C–27.4°C (mean SST: 23.0°C). The DIs were 1.90, 2.71 and 6.91 by *KY7* (August), *KY7* (September) and *YS1*, respectively.

Common minke whale

Two schools (two individuals) were sighted north of 42°N (Figure 5). The SSTs in the sighting position were 14.4°C and 21.7°C. The DI of *KY7* (August) was 0.21.

Humpback whale

Two schools (three individuals) were sighted (Figure 5). Mean school size was 1.50. The SST at the sighting position were 16.4°C and 21.4°C. The DI of *KY7* (August) was 0.21.

Sperm whale

A total of 156 schools (300 individuals including one mother and calf pair) were sighted in this season (Figure 5). A school consisting of 22 sperm whales was sighted at 42°15′N, 144°16′E. Mean school size was 1.92. The range of the SST in the sighting position was 16.0°C–29.6°C (mean SST: 22.2°C). The DIs were 1.69, 1.18 and 4.68 for *KY7* (August), *KY7* (September) and *YS1*, respectively.

Small cetaceans

In this season, ten species of the family Delphinidae, three species of the family Phocoenidae and three species of the family Ziphiidae, were sighted (Table 5b). The most common sighted species was the striped dolphins (22/1,273), followed by the common dolphins (13/787). Pacific white-sided dolphins and Dall's porpoises were mainly sighted north of 40°N. Common dolphins and striped dolphins were sighted primarily east of 145°E.

Baird's beaked whales were sighted mainly west of 143°E. The species of the family Ziphiidae were sighted east of 143°E.

Duplicate sightings

A total of 26 and 104 re-sightings of large cetaceans were recorded during IO mode throughout this season involving several species.

Autumn

Tables 6 shows the total sightings for large and small cetacean species, made in autumn 2022. The sighting location of each species is shown in Figure 6 together with SSTs.

Blue whale

Three schools (three individuals) with body lengths of 17.8 m, 23.8 m and 24.1 m were sighted west of 150°E (Figure 6). The range of SST was 9.7°C–17.2°C (mean SST: 12.5°C). Two individuals were photographed.

Fin whale

Five schools (eight individuals) were sighted (Figure 6). Mean school size was 1.60, and the range of SST at the sighting positions was 11.7°C–14.8°C (mean SST: 13.6°C).

Table 6

Total number of sightings of large whales and small cetaceans made in autumn 2022, by research vessel and species.

Species	*YS2*	
	Sch.	Ind.
Blue whale	3	3
Fin whale	5	8
Sei whale	32	44
Bryde's whale	3	3
Humpback whale	4	4
Sperm whale	7	9
Northern right whale dolphin	1	6
Risso's dolphin	1	8

Sch.: Schools, Ind.: Individuals.

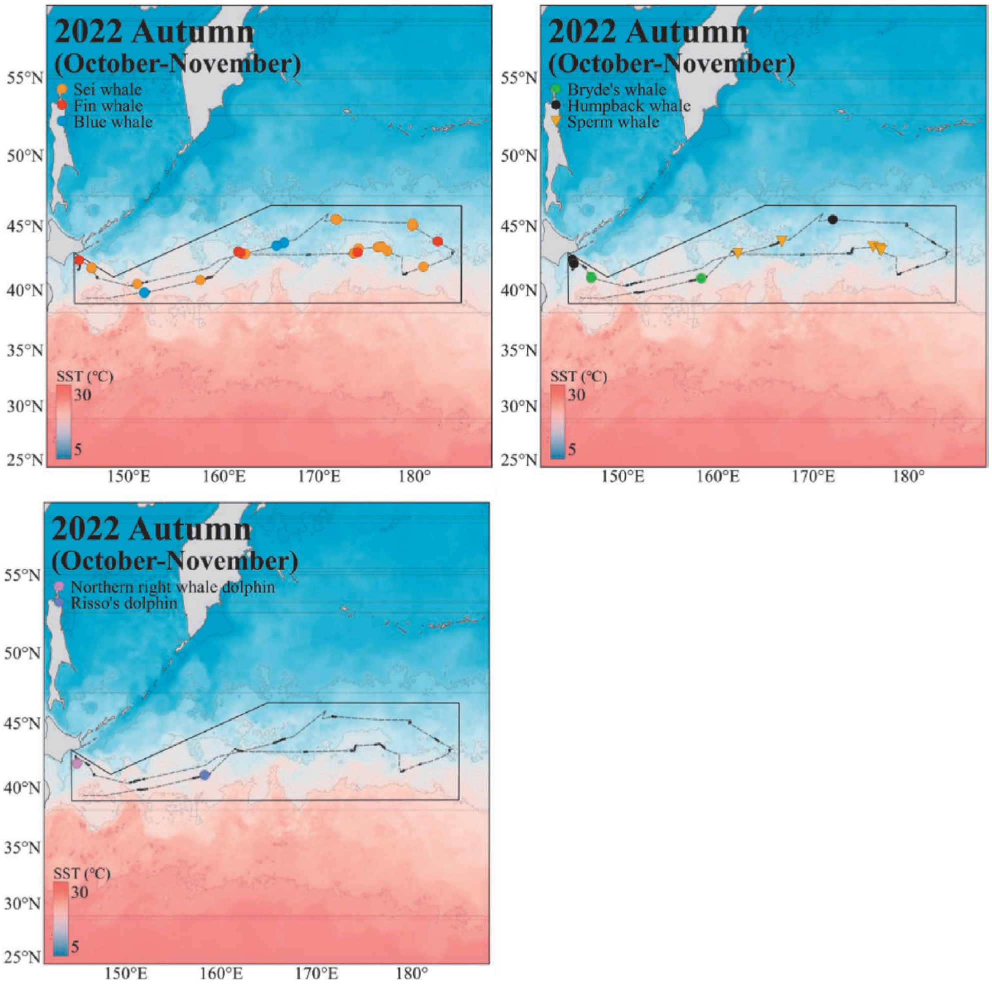

Figure 6. The locations of large and small cetaceans sighted during autumn 2022. Rolling 32-days average sea surface temperature data from 16 October to 16 November 2022 obtained by MODIS-Aqua (Original data: Ocean color web, from https://oceancolor.gsfc.nasa.gov/ (Accessed 2023-4-20)), are also shown.

Sei whale

A total of 32 schools (44 individuals) were sighted (Figure 6). The range of SST at the sighting positions was 10.1°C–17.8°C (mean SST: 13.4°C). Mean school size 1.38. Biopsy samples were collected from 16 individuals, and satellite tags were attached on 16 individuals.

Bryde′s whale

Three schools (three individuals) were sighted (Figure 6) with estimated body lengths of 11.3 m, 11.8 m, and 12.8 m. SST at the sighting position were 14.6°C, 14.9°C and 18.5°C.

Common minke whale

This species was not sighted in the autumn season.

Humpback whale

Four schools (four individuals) were sighted (Figure 6). The range of SST in the sighting position was 10.4°C–12.9°C (mean SST: 11.6°C).

Sperm whale

In total, seven schools (nine individuals) were sighted (Figure 6). Mean school size was 1.29. The range of SST was 10.7°C–15.0°C (mean SST: 13.7°C).

Small cetaceans

In this season, two species of the family Delphinidae were sighted (Table 6): Risso′s dolphin (1/8) and northern right whale dolphin (1/6).

Experiments

Sighting distance and angle experiment

In spring, the Estimated Angle and Distance Experiment was conducted by *KY7* on 26 April and 28 May. It was conducted on 5 May by *YS1* and on 11 May by *YS2*. In late summer, the experiment was conducted on 15 September by *KY7* and on 3 September by *YS1*. The results of this experiment will be used for calibrating the sighting distances and angle data used for the calculation of abundance estimates.

Photo-ID

The number of individual photographed is shown in Table 7, by species. All photographs were stored in the ICR catalogs and will be used for investigating the stock structure and movement of those cetacean species in the future.

Biopsy sampling

A total of 30 biopsy samples were collected during the 2022 dedicated sighting surveys. Table 8 shows the number of biopsies, by seasonal survey, research vessels and

Table 7

Numbers of individuals photographed during the 2022 dedicated sighting surveys, by seasonal survey, research vessel and species.

Species	Spring				Late summer			Autumn	Total
	KY7 (Apr.)	*KY7* (May)	*YS1*	*YS2*	*KY7* (Aug.)	*KY7* (Sep.)	*YS1*	*YS2*	
Blue whale	0	0	0	0	0	0	0	2	2
Humpback whale	1	1	4	1	0	0	0	0	7
North Pacific right whale	0	0	0	1	0	0	0	0	1
Killer whale	0	2	0	0	0	0	0	0	2
Total	1	3	4	2	0	0	0	2	12

Table 8

Numbers of biopsy samples collected during the 2022 dedicated sighting surveys, by seasonal survey, research vessel and species.

Species	Spring				Late summer			Autumn	Total
	KY7 (Apr.)	*KY7* (May)	*YS1*	*YS2*	*KY7* (Aug.)	*KY7* (Sep.)	*YS1*	*YS2*	
Fin whale	0	0	0	1	0	0	0	0	1
Sei whale	0	0	0	0	0	0	0	16	16
Bryde′s whale	0	0	6	0	0	0	0	0	6
Common minke whale	0	3	2	1	0	0	0	0	6
North Pacific right whale	0	0	0	1	0	0	0	0	1
Total	0	3	8	3	0	0	0	16	30

species. All samples were stored at the ICR laboratory and will be used in genetic analyses for investigating the stock structure of those species in the future.

Satellite tagging

Satellite tag attachments were attempted during each seasonal survey, but attachments only occurred during spring and autumn. The number of individuals tagged is shown in Table 9, by seasonal survey, research vessel and species. A total of 16 sei whales were tagged, all in autumn. These were evenly attached among the sightings (Figure 7). 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 high latitude feeding areas and low latitude breeding areas.

HIGHLIGHTS OF THE SURVEY

The sighting surveys conducted in 2022 were completed successfully. They provided unique data obtained not only in the late summer, but also in the spring and autumn 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 fin and common minke whales were sighted in April–June in the Japanese side of the Sea of Okhotsk. Common minke whales were mainly sighted east coast of the Shiretoko Peninsula and west coast of 144°E. On the other hand, fin whales were sighted east of 144°E which suggests that these species were separated in distribution at the western coast of the Sea of Okhotsk. Direct feeding behavior was not observed, but seabirds were concentrated close to the sighting positions of fin and common minke whales. From this, it is possible that these two species were distributed in this area for feeding during this season.

A large number of humpback whales were sighted in April–June in the southern part of the Pacific side of Japan. Most of humpback whales were sighted south of 40°N probably during their northward migratory path. At the same time, it was confirmed that Bryde′s whales were also distributed south of 37°N, although in small numbers.

The August-September survey covered the North Pacific from the coast of Japan to 154°E, providing important late summer sighting data for Bryde′s and sperm whales. At the same time, several sighting data for fin, common minke and humpback whales were obtained in

Table 9

Numbers of individuals attached with satellite tags, by each season and research vessel in 2022.

Species	Spring				Late summer			Autumn	Total
	KY7 (Apr.)	*KY7* (May)	*YS1*	*YS2*	*KY7* (Aug.)	*KY7* (Sep.)	*YS1*	*YS2*	
Fin whale	0	0	0	1	0	0	0	0	1
Sei whale	0	0	0	0	0	0	0	16	16
Bryde′s whale	0	0	5	0	0	0	0	0	5
Common minke whale	0	0	0	1	0	0	0	0	1
Total	0	0	5	2	0	0	0	16	23

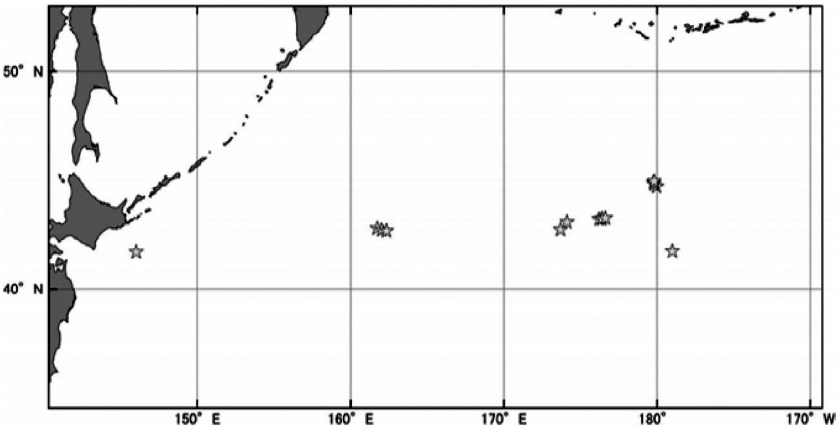

Figure 7. The locations of tagged sei whales during autumn 2022. Locations were obtained from photographs taken at the time of the tagging.

this season. These three species were sighted north of 40°N. Compared to previous surveys conducted during the same seasons and same research area (Katsumata *et al.*, 2021), Bryde's whales in 2022 were more northernly distributed. The northward extention of this species could have been influenced by higher monthly mean SSTs between 41°N–43°N than in 2020 (Figure 8). The monthly mean SST between 41°N–43°N was higher than in 2020, which could explain the northward migration of this species.

Consistent with previous surveys in 2020 (Katsumata *et al.*, 2021), no common minke whales were sighted in the pelagic part. Murase *et al.* (2023) reported the mean SST for sighting position of this species over the past four years (2002, 2004, 2005, 2006) was 15.5°C. In this season, the monthly mean SST at the research area was higher than 16°C, and cold water below 16°C formed north of 43°N. From this, it is considered that common minke whales distribution was shifted to the north in 2022.

In October–November, a large number of sei whales were sighted in the northwest side of the Pacific. Sei whales were distributed in high density near 180°, and the SST in this area was in the 10°C range. Although just a single feeding behavior was observed, this area could be a feeding area for this species because seabirds were concentrated around the sighting positions. Satellite tags were successfully attached on 16 individuals to study the movement and southern migration of sei whales. The study of the migration will contribute to resource management by assisting the interpretation of the genetic analyses on stock structure. Several blue, fin, humpback and sperm whales were also sighted in this area.

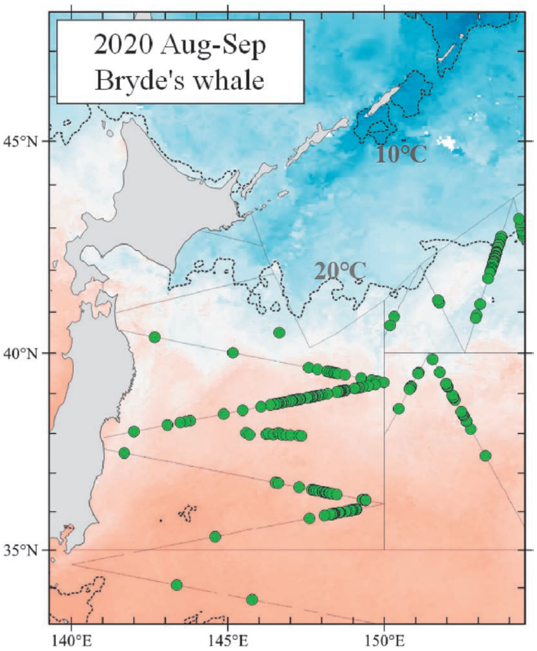

Figure 8. Sighting position of Bryde's whales and monthly SSTs in the 2020 sighting survey (modified from Katsumata *et al.*, 2021).

As in the previous surveys, the 2022 surveys collected data on small cetaceans in the same way as large cetaceans. The analyses of these data will provide valuable information on the distribution and abundance of small cetaceans in different seasons.

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We acknowledge the Government of Japan's assistance in providing the research permits and funding for these cruises. We also thank the Captains Koji Maki, Chikamasa Okoshi, Hidenori Kasai, Yasuaki Sasaki, and their officers and crew of the *Yushin-Maru*, *Yushin-Maru* No. 2 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 of the Institute of Cetacean Research (Tokyo) for expert support in planning survey design. We thank Yoshihiro Fujise and Tsutomu Tamura and the staff of the Institute of Cetacean Research (ICR) and Kyodo Senpaku Co., Ltd. for their assistance in arrangements and support for the cruise. We also thank Kenji Konishi of ICR for satellite tagging and Mioko Taguchi of ICR for biopsy sample management. Finally, we thank Luis A. Pastene for his assistance in preparing this report and to the Editorial Team of TEREP-ICR for editorial work.

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Technical Reports of the Institute of Cetacean Research (2023) pp. 47–54

Technical Report (not peer reviewed)

Results of the IWC-Pacific Ocean Whale and Ecosystem Research (IWC-POWER) dedicated sighting survey in 2022—An overview—

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ABSTRACT

This paper outlines the main results of the 2022 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, in special partnership with the Government of Japan. The surveys have been conducted since 2010 as the first phase with the long-term objective: ʻ(to) provide 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 actionsʼ. The 2022 survey was conducted between 2 August and 30 September, south of the western Aleutian Islands, within the U.S. Exclusive Economic Zone. This area was also surveyed in 2010 on the first IWC-POWER cruise. The current survey was conducted aboard the Japanese R/V *Yushin-Maru* No. 2. The acoustic survey was conducted for monitoring the presence of marine mammals, with particular emphasis on North Pacific right whales. Sixty-two percent of the planned survey track line was covered (917.3 n.miles of a planned distance of 1,486.4 n.miles). During the survey, blue (20 schools/21 individuals), fin (36/54), sei (21/23), common minke (3/3), humpback (12/12), sperm (38/38) and killer (14/63) whales were observed in the research area. No North Pacific right whales were seen or acoustically detected during the entire cruise. Photo-identification data were collected for 16 blue, 7 fin, 8 sei, 6 humpback and 8 killer whales. A total of 16 biopsy samples were collected from 4 blue, 4 fin, 6 sei and 2 humpback whales. A total of 34 sonobuoys were deployed, of which 33 were successful, for a total of over 210 monitoring hours. Data collected during this survey will be used mainly for abundance estimation and stock structure research 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) and cooperating institutes such as Tokyo University of Marine Science and Technology 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 were conducted in the Antarctic between 1978/79 and 2009/10. 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 actionsʼ.

The past IWC-POWER surveys provided critical information on rare whale species such as North Pacific right whale (Matsuoka *et al.*, 2022). The first survey of this program was conducted in 2010 and the most recent one in 2022 (IWC, in press). The IWC SC is close to completing the first phase of the IWC-POWER, which focuses on its short-term priorities. The IWC SC is preparing for the second phase which relates 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 2022 IWC-POWER survey based on Morse *et al.* (2023). For a general background of the IWC-

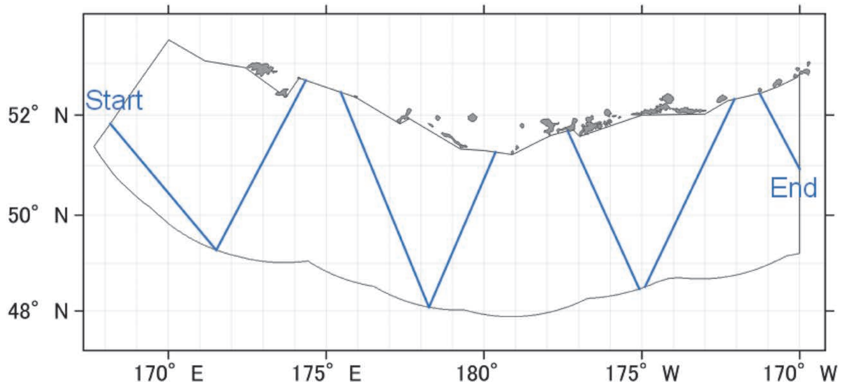

Figure 1. Research area and survey track lines with start and end points for the 2022 IWC-POWER survey.

Table 1
The 2022 IWC-POWER survey itinerary.

Date	Event
2022/08/01	Pre-cruise meeting at Shiogama
2022/08/02	Vessel departed Shiogama
2022/08/10	Vessel arrived at Dutch Harbor
2022/08/15	Cruise leader and US researcher came on board and vessel departed Dutch Harbor
2022/08/20	Survey commenced in the research area
2022/09/13	Survey finished in the research area
2022/09/15	Vessel arrived at Dutch Harbor
2022/09/18	Vessel departed Dutch Harbor
2022/09/30	Vessel arrived at Shiogama

POWER including objectives, research area, and general methodology, see Matsuoka (2020).

RESULTS OF THE 2022 IWC-POWER SURVEY

The main results of the 2022 IWC-POWER survey in this document were based on Morse *et al.* (2023). All research activities (i.e. approaching cetaceans for species identification, school size estimates, digital photography, and biopsy sample collection) that were carried out within the U.S. EEZ were permitted under U.S. National Marine Fisheries Service (NMFS) Permit no. 25563 (issued to AFSC, Marine Mammal Laboratory). Cetacean research activities conducted on the high seas in international waters by Japanese researchers aboard the R/V *Yushin-Maru* No. 2 were authorized under permit SUIKAN 4-1112 (dated 12 July 2022) issued by the Fisheries Agency, Government of Japan.

Itinerary

The 2022 survey was conducted between 2 August and 30 September by the Japanese R/V *Yushin-Maru* No. 2. The itinerary is shown in Table 1.

Figure 2. The R/V *Yushin-Maru* No. 2 in Dutch Harbor (date: 15 August 2022).

Research area

The research area was off the southern Aleutian Islands bounded by the US Exclusive Economic Zone (EEZ), between 167°38’E and 170°00’W (Figure 1).

Research vessel and scientific personnel

The R/V *Yushin-Maru* No. 2 (747GT) was contracted for this cruise (Figure 2 and Table 2). The vessel is a sister ship of the *Yushin-Maru* No. 3 which was contracted in previous years. Four international researchers were nominated by the IWC SC for this survey.

Laura Morse (USA) – Cruise Leader/Chief Scientist; sighting and photo-ID
Jessica Crance (USA) – acoustics and photo-ID
Taiki Katsumata (Japan) – sighting, photo-ID data management and marine debris
Isamu Yoshimura (Japan) – sighting data, marine debris and biopsy sample management

Searching effort

Survey track line coverage in the research area was 62% (917.3 n.miles of a planned distance of 1,486.4 n.miles), with a total of 491.2 n.miles in Passing with abeam closing mode (NSP) and 426.1 n.miles in Independent Observer passing mode (IO). The effort spent on the sighting survey is shown in Table 3.

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

Summary of the sightings

During the survey in the research area, the following sightings were made: blue (20 schools/21 individuals), fin (36/54), sei (21/23), common minke (3/3), humpback (12/12), sperm (38/38) and killer (14/63) whales (Table 4). The sea surface temperature (SST) of each species on the sighting position is summarized in Table 5.

Geographical distribution by species

Blue whale (Balaenoptera musculus)

Blue whales were widely distributed and mainly sighted in the western part of the research area (Figure 3a). They appeared to be spatially separated from sei whales with

Table 3

Summary of the searching effort in the research area conducted during the 2022 IWC-POWER survey. NSP: Normal Passing with abeam Closing Mode, IO: Independent Observer Mode.

Area	Area Code	Leg No.	Start	End	NSP		IO		NSP+IO	
		Start	Date	Date	Time	Dist. (n.m.)	Time	Dist. (n.m.)	Time	Dist. (n.m.)
		End	Time	Time						
Western Stratum (167°38′E–180°)	87	134	20-Aug.	5-Sep.	25:09:19	287.4	23:05:16	265.2	48:14:35	552.6
	US EEZ	114	6:40	11:49						
Eastern Stratum (180°–170°00′W)	86	112	5-Sep.	13-Sep.	17:32:14	203.8	13:46:41	160.9	31:18:55	364.7
	US EEZ	101	11:49	17:35						
Total			20-Aug.	13-Sep.	42:41:33	491.2	36:51:57	426.1	79:33:30	917.3
			6:40	17:35						

Table 4

Number of sightings (schools and individuals) for all species observed in the research area (original and transit track lines in the research area) by effort mode. NSP: Normal Passing with abeam Closing Mode, IO: Independent Observer Mode, OE: Top Down (TD) and Drifting (DR), Sch.: schools, Ind.: individuals.

Species	NSP			IO			OE			Total		
	Sch.	Ind.	Calf	Sch.	Ind.	Calf	Sch.	Ind.	Calf	Sch.	Ind.	Calf
Blue whale	12	13	0	7	7	0	1	1	0	20	21	0
Fin whale	18	28	2	17	25	1	1	1	0	36	54	3
Sei whale	10	11	0	10	11	0	1	1	0	21	23	0
Common minke whale	2	2	0	1	1	0	0	0	0	3	3	0
Humpback whale	6	6	0	5	5	0	1	1	0	12	12	0
Sperm whale	22	22	0	14	14	0	2	2	0	38	38	0
Killer whale	3	15	0	10	47	1	1	1	0	14	63	1

Table 5
Minimum, maximum, range and 25th to 75th quartiles of sea surface temperatures (SSTs) in degrees Celsius for each species sighted in the research area (original track line). Also noted are the number of sightings for each species.

Species	Number of sightings	Minimum SST	Maximum SST	Temperature range	25th to 75th Quartile
Blue whale	20	6.8	10.8	4.0	7.9–10.1
Fin whale	36	5.4	11.2	5.8	8.7–9.6
Sei whale	21	9.3	12.0	2.7	10.0–11.6
Common minke whale	3	8.0	9.9	1.9	8.7–9.6
Humpback whale	12	6.5	12.0	5.5	7.2–9.3
Sperm whale	38	5.7	11.2	5.5	8.9–10.2
Killer whale	14	3.4	11.9	8.5	6.8–10.1

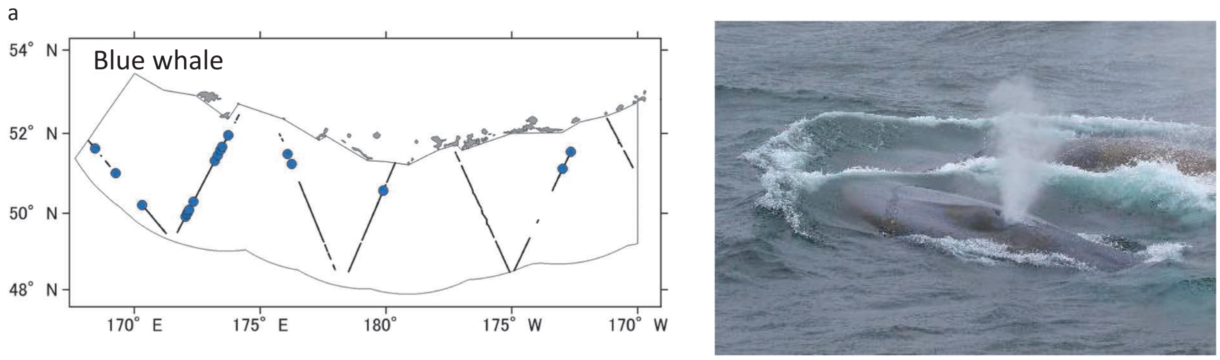

Figure 3a. The searching effort (thin line) and sighting positions (blue circles) of blue whales during the 2022 IWC-POWER survey (left) and surfacing blue whales photographed in the research area (right).

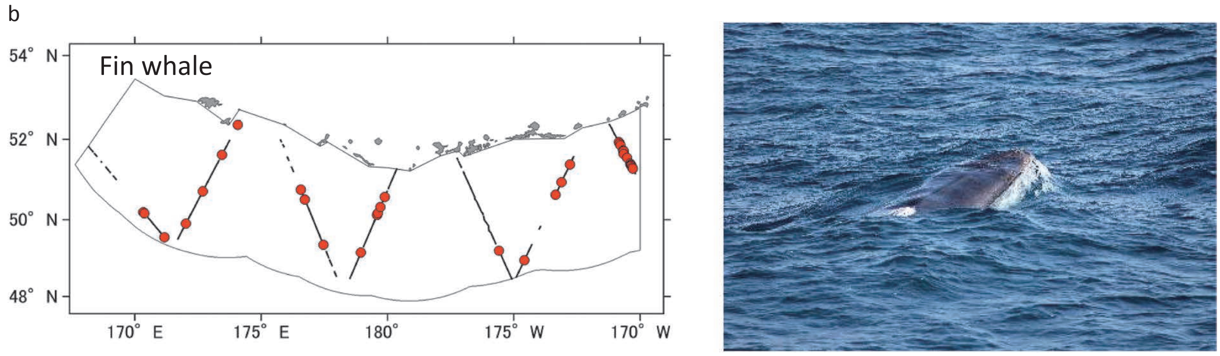

Figure 3b. The searching effort (thin line) and sighting positions (red circles) of fin whales during the 2022 IWC-POWER survey (left) and a surfacing fin whale photographed in the research area (right).

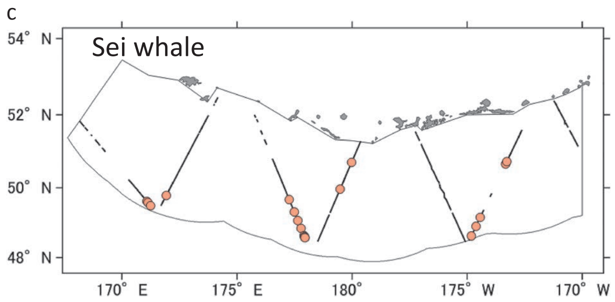

Figure 3c. The searching effort (thin line) and sighting positions (orange circles) of sei whales during the 2022 IWC-POWER survey.

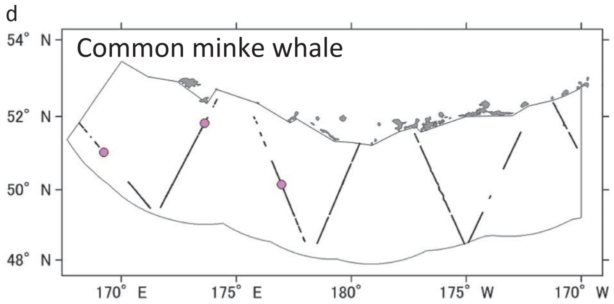

Figure 3d. The searching effort (thin line) and sighting positions (pink circles) of common minke whales during the 2022 IWC-POWER survey.

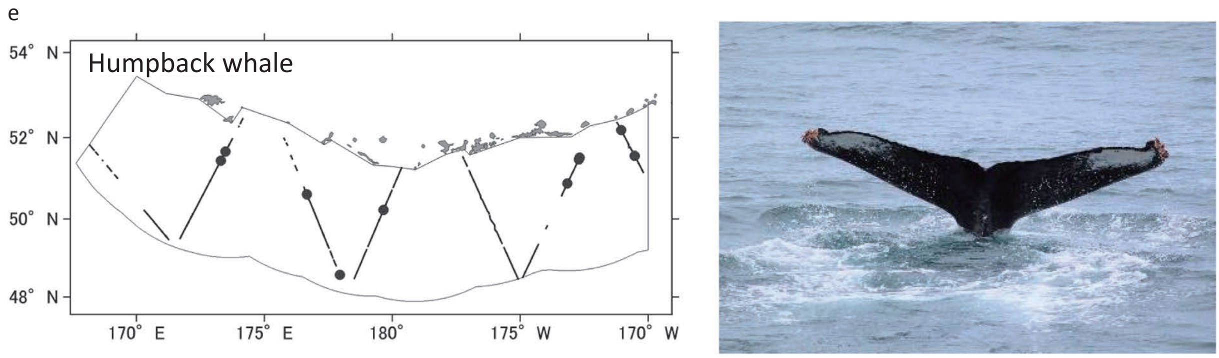

Figure 3e. The searching effort (thin line) and sighting positions (black circles) of humpback whales during the 2022 IWC-POWER survey (left) and fluke of a humpback whale photographed in the research area (right).

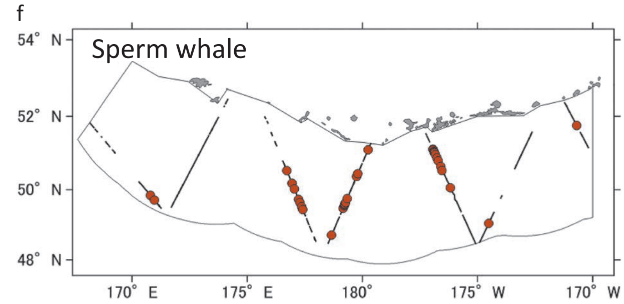

Figure 3f. The searching effort (thin line) and sighting positions (brown circles) of sperm whales during the 2022 IWC-POWER survey.

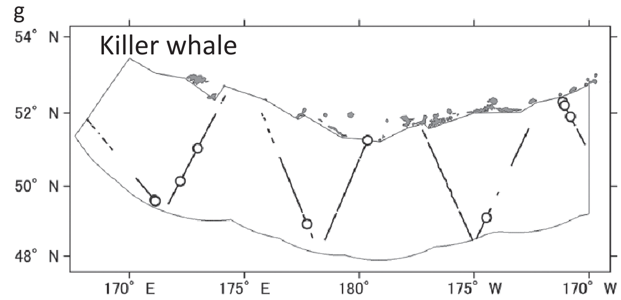

Figure 3g. The searching effort (thin line) and sighting positions (white circles) of killer whales during the 2022 IWC-POWER survey.

associated SSTs at the sighting positions ranging between 6.8°C and 10.8°C (25th to 75th quartiles: 7.9–10.1°C) which was lower than the range for sei whales (Table 5).

Fin whale (Balaenoptera physalus)
Fin whales were widely distributed throughout the survey area. Several high-density areas were observed along the most east transect and through Samalga Pass during the transit to Dutch Harbor from the survey area (Figure 3b). Sea temperatures ranged from 5.4°C to 11.2°C (25th to 75th quartiles: 8.7–9.6°C) (Table 5).

Sei whale (Balaenoptera borealis)
Sei whales were the second most frequently encountered baleen whale species through this survey. Sei whales were widely distributed but appeared to be spatially separated from blue whales with associated SST differences (Figure 3c). SSTs ranged from 9.3°C to 12.0°C (25th to 75th quartiles: 10.0–11.6°C), which was higher than the range for blue whales (Table 5).

Common minke whale (Balaenoptera acutorostrata)
Common minke whales were the rarest baleen whale species in the research area and were only sighted west of 180° (Figure 3d). A total of 3 schools (3 individuals) were observed. SSTs at the sighting locations ranged from 8.0°C to 9.9°C (25th to 75th quartiles: 8.7–9.6°C) (Table 5). During this survey, sea states averaged 4–5 on the Beaufort scale, which is assumed to be too rough for sighting common minke whales.

Humpback whale (Megaptera novaeangliae)
Humpback whales were sporadically distributed in the research area (Figure 3e). SSTs at the sighting positions ranged from 6.5°C to 12.0°C (25th to 75th quartiles: 7.2–9.3°C) (Table 5).

Sperm whale (Physeter macrocephalus)
Sperm whales were widely distributed throughout the research area, with the highest densities observed between 175°E and 175°W (Figure 3f). All schools were observed as solitary individuals (probably large males). Sperm whales were recorded in waters with SSTs ranging from 5.7°C to 11.2°C (25th to 75th quartiles: 8.9–10.2°C) (Table 5).

Killer whale (Orcinus Orca)
Killer whales were widely distributed in the research area

Table 6
Identification of duplicate sightings (main species) observed during the Independent Observer (IO) mode survey (original track line). Duplicate status was based on the number of sightings made by the Independent Observer Platform (IOP) that were observed also by the Topmen in the Standard TOP Barrel. Status codes D: Definite duplicate, P: Possible duplicate, R: Remote duplicate, N: Not duplicate.

Species	Number of all schools sighted by TOP and IOP	Number of all schools sighted by IOP	Duplicate Status			
			D	P	R	N
Blue whale	12	5	5	0	0	0
Fin whale	21	10	6	0	0	4
Sei whale	10	5	2	0	0	3
Common minke whale	1	0	0	0	0	0
Humpback whale	3	3	0	0	0	3
Sperm whale	21	11	7	0	0	4
Killer whale	13	4	4	0	0	0

Table 7a
Summary of the information on photo-ID experiments during the 2022 IWC-POWER survey, by species.

Photo-ID	Blue whale	Fin whale	Sei whale	Humpback whale	Killer whale	Total
Research area	14	7	7	2	8	38
Transit	2	0	1	4	0	7
Total	16	7	8	6	8	45

Table 7b
Summary of the number of biopsy samples collected during the 2022 IWC-POWER survey, by species.

Biopsy samples	Blue whale	Fin whale	Sei whale	Humpback whale	Total
Research area	4	4	5	2	15
Transit	0	0	1	0	1
Total	4	4	6	2	16

(Figure 3g). They were sighted in waters with SSTs ranging from 3.4°C to 11.9°C (25th to 75th quartiles: 6.8–10.1°C) (Table 5).

Summary of Acoustic monitoring

A total of 34 sonobuoys were deployed during the cruise. Of these, 33 were deployed and transmitted successfully for an overall success rate of 97.05%. A total of 211.46 hours of acoustic monitoring occurred during the survey. The most common species detected were sperm and fin whales, both detected on 31 of 33 buoys (93.9%), followed by killer whales (23, 69.6%), blue whales (18, 54.5%) and humpback whales (7, 21.2%). More detailed results are described in Morse *et al.* (2023).

Identification of duplicated sightings

Resight data were recorded for a total of 68 sightings during IO Mode involving several baleen whale species (Table 6). These data will be used to estimate *g*(0), which in turn will be used to adjust abundance estimates.

Photo-ID experiments

Photo-ID experiments were conducted on blue (16 individuals), fin (7), sei (8), humpback (6) and killer (8) whales (Table 7a).

Biopsy sampling

Biopsy samples were collected from 4 blue, 4 fin, 6 sei and 2 humpback whales (Table 7b). Every biopsy encounter was documented photographically. All biopsy samples were catalogued and stored on the vessel in cryo-vials frozen at a temperature of −30°C.

Estimated Angle and Distance Experiment

The Estimated Angle and Distance Experiment was conducted on 1 September for 7 hours 51 minutes whilst in the research area. A total of 84 trials were conducted for each platform (TOP and IO barrels and upper bridge).

Table 8
The diving and surfacing durations of a sei whale tagged during the 2022 IWC-POWER survey.

PTT ID	Number of days with data obtained	type	*n*	duration mean (sec.)	SD	Duration minimum (sec.)	Duration maximum (sec.)	Duration range (sec.)
207833	4.6	Dive	573	83.48	144.57	4	772	768
		Surfacing	570	60.60	185.28	2	2728	2726

Figure 4. International researchers and crew of the 2022 IWC-POWER survey with *Yushin-Maru* No. 2. The picture was taken at the end of the survey in Dutch Harbor (date: 18 September 2022).

Both the Estimated Angle and Distance Training Exercises and Experiments were performed using the improved protocol (IWC, 2017).

Marine debris observations

A total of eight marine debris were observed. A total of seven items were recorded ʻon effortʼ (i.e. during the first 15 minutes of each hour) and one item was recorded during ʻoff effortʼ. Marine debris were scarce and sparsely distributed in the survey area, compared to previous years (Matsuoka *et al.*, 2013; 2014).

Satellite tagging studies

During the transit survey on the high sea, satellite-linked dive behavior tags were experimentally deployed as a feasibility study at the discretion of Japan. The tag was attached to one sei whale on 24 September. The diving and surfacing duration obtained by 1 October are summarised in Table 8. The obtained data could be used to correct availability bias in future abundance estimation work.

HIGHLIGHT OF THE SURVEY

The 2022 annual IWC-POWER survey was successfully conducted by a group of international scientists using the Japanese R/V *Yushin-Maru* No. 2 (Figure 4), and valuable data were collected for several cetacean species. Such data will allow for further studies on the distribution, abundance and stock structure of large cetaceans in this particular area of the North Pacific.

This survey provided critical information on seasonal distribution and abundance of baleen whales. The research area of the 2022 survey was also surveyed in 2010 (Matsuoka *et al.*, 2011). Some differences were noted between the two surveys. Sei whales are moving northward, indicating they are distributed at higher latitudes in August–September. In addition, the 2010 survey had poor coverage of 34% due to bad weather. On the other hand, the coverage was 62% in 2022, which provides sufficient data for abundance estimation. Furthermore, it should be noted that biopsy samples were collected for the first time in this area. These samples will be used for molecular genetics analyses on stock identification.

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Technical Report (not peer reviewed)

An update of the study on age at sexual maturity trends in the Antarctic minke whale

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ABSTRACT

An update of the analysis of age at sexual maturity in the Antarctic minke whale based on the transition phase was carried out by using all samples available from former Japanese whale research programs under special permit in the Antarctic (JARPA, JARPAII, NEWREP-A) from the 1987/88 to the 2018/19 austral summer seasons. These research programs and surveys, designed and implemented by the Institute of Cetacean Research, were conducted in the Indo-Pacific sector of the Antarctic (0°–120°W, south of 60°S). The updated analyses confirmed that the age at sexual maturity of this species declined from 10–12 years old in the mid-1940s year classes to 7–8 years old in the early 1970s year classes. The age at sexual maturity remained stable at that level until the 2000s year classes. Although some significant statistical trends were found for the recent year classes (from the 1970s), the extent of such changes, when confirmed, is very small in comparison with the extent of the changes observed in the middle of the past century. These results for the age at sexual maturity are interpreted and discussed in conjunction with changes observed in other ecological and biological parameters of the Antarctic minke whale, in the context of some established hypotheses on changes of the Antarctic ecosystem.

INTRODUCTION

Since the moratorium on commercial whaling was implemented in 1988, the Institute of Cetacean Research (ICR) undertook different whale research programs in the Antarctic Ocean under Article VIII of the International Convention for the Regulation of Whaling (ICRW). The Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) was conducted in the austral summers from 1987/88 to 2004/05 and in a second phase (JARPAII) from 2005/06 to 2013/14. The New Scientific Whale Research Program in the Antarctic Ocean (NEWREP-A) was conducted from 2015/16 to 2018/19. These programs carried out systematic surveys in the Indo-Pacific sector (0°–120°W, south of 60°S) of the Antarctic using both lethal (biological sampling of a limited number of Antarctic minke whales [*Balaenoptera bonaerensis*]) and non-lethal (biopsy sampling and photo-identification of several whale species, oceanographic and marine debris surveys, dedicated sighting surveys) approaches.

Data and samples obtained from the Antarctic minke whales were analyzed in regard to several objectives of the research programs related to both assessment (e.g. stock structure, biological parameters, abundance estimates) and ecological (e.g. feeding ecology, environmental pollutants) aspects of this species (see Tamura *et al.*, 2017). The long time series of data allowed scientists to investigate and interpret the temporal trend in several biological and demographic parameters of the Antarctic minke whale in the context of some established hypotheses on changes in the Antarctic ecosystem. Fujise and Pastene (2021) discussed the historical and current ecosystem changes in the Indo-Pacific sector of the Antarctic through the examination of the information on biological and demographical parameters of mainly Antarctic minke whales and other whales, which are sea-based predators.

Regarding historical changes, Fujise and Pastene (2021) concluded that the increased krill availability in the middle of the past century as a result of the heavy harvesting of the larger baleen whale species could have translated into better nutritional conditions for the Antarctic minke whale, resulting in a decreasing trend in the age at sexual maturity and an increasing trend in recruitment rate and hence total population size between approximately 1940 and 1970. Regarding current changes, Fujise and Pastene (2021) concluded that the nutritional conditions of the Antarctic minke whale have deteriorated more recently, as confirmed by a decrease in energy storage and stomach content weight observed since the 1980′s. These changes coincide with appreciable increases in the abundance of humpback (*Megaptera novaeangliae*) and fin (*B. physalus*) whales, which are also krill-eaters and were heavily harvested in the first half of the past century.

Fujise and Pastene (2021) suggested that the historical changes were consistent with the pattern to be expected under the krill surplus hypothesis and that the most recent scenario shows the Antarctic minke whale again competing with other (recovering) baleen whale species for krill. Furthermore, these authors suggested that Antarctic minke whales could be using alternative feeding areas (e.g. polynyas within the pack-ice) in response to the increase in abundance and geographical expansion of other large whale species.

One of the biological parameters discussed in the review by Fujise and Pastene (2021) was the age at sexual maturity, which is considered a good indicator of changes in the environment of whales. Previous studies used data

Table 1

Number of Antarctic minke whales sampled by Japanese surveys in the Antarctic during 1987/88 to 2018/19, and number of whales examined for age at transition phase (TP).

Survey year	Female		Male		Total	
	n	Number of TP* determined	*n*	Number of TP* determined	*n*	Number of TP* determined
1987/88	119	41	153	81	272	122
1988/89	151	48	85	18	236	66
1989/90	142	34	184	76	326	110
1990/91	159	56	164	51	323	107
1991/92	123	31	165	52	288	83
1992/93	160	69	167	87	327	156
1993/94	130	32	200	81	330	113
1994/95	130	51	200	106	330	157
1995/96	167	59	273	137	440	196
1996/97	234	137	206	124	440	261
1997/98	159	27	279	119	438	146
1998/99	142	46	247	114	389	160
1999/00	206	77	233	112	439	189
2000/01	182	64	258	136	440	200
2001/02	239	76	201	88	440	164
2002/03	205	80	235	104	440	184
2003/04	240	96	200	68	440	164
2004/05	263	131	177	89	440	220
2005/06	391	156	462	225	853	381
2006/07	351	152	154	75	505	227
2007/08	278	114	273	100	551	214
2008/09	304	129	375	148	679	277
2009/10	269	104	237	87	506	191
2010/11	108	52	62	32	170	84
2011/12	167	82	99	50	266	132
2012/13	53	13	50	16	103	29
2013/14	125	26	125	35	250	61
2015/16	230	103	103	45	333	148
2016/17	178	79	155	69	333	148
2017/18	181	54	152	40	333	94
2018/19	147	44	186	93	333	137
total	5,933	2,263	6,060	2,658	11,993	4,921

*TP: age at which transition phase layer was formed in the earplug.

and samples collected from 1987/88 to 2010/11 surveys (Bando *et al.*, 2014). Additional samples and data are available up to the 2018/19 season.

The objective of this study was to update the analyses of the age at sexual maturity of Antarctic minke whale by using all the available samples and data. The results of these analyses will contribute further to the interpretation of current changes in the ecosystem of the Indo-Pacific sector of the Antarctic.

SAMPLES

Biological samples were collected under the surveys of JARPA (1987/88–2004/05), JARPAII (2005/06–2013/14) and the New Scientific Whale Research Program in the Antarctic Ocean (NEWREP-A) (2015/16–2018/19). A total of 11,993 Antarctic minke whales were sampled in the whole period. Previous analyses included samples from 1987/88 to 2010/11. The present study included samples collected from 1987/88 to 2018/19, which incorporates new samples collected by NEWREP-A surveys. Table 1 shows the number of Antarctic minke whales sampled and the number of whales examined for age at transition phase, which is considered as the age at sexual maturity (see Bando, 2017 and the next section).

ANALYTICAL PROCEDURES

Age at sexual maturity by transition phase

The age of baleen whales was estimated by counting growth layers accumulated in the earplug (Lockyer, 1984). The layer at which the spacing changed abruptly from irregular early younger layers in the earplug is called the transition phase (Lockyer, 1972). It is generally known that the transition phase in earplugs of baleen whales indicates the age at sexual maturity (Lockyer, 1972). Therefore, the age at the transition layer was recorded, if it was present, when observing the earplug.

Year of birth

The year of birth (=year class) in each individual was defined as: (starting year of an austral survey season, e.g. 1987 in the case of 1987/88 season)−(age at capture).

Evaluation of age data reading

Age and transition phase in earplugs were read by three different readers during the period of study. A test to evaluate the consistency and comparability of reading among readers was required. Results of the test indicated that the data from different readers were consistent and comparable (see details of the test in Bando *et al.*, 2014). Therefore, the whole data set for the whole period was used in the present analysis.

Truncation bias

It is known that the age at sexual maturity in recent age classes will be underestimated when using the transition phase analysis, due to the under-representation of late maturing individuals (Figure 1). This is known as the truncation effect. This can be addressed by combining samples from different year classes (Kato, 1985; Zenitani, 2011). Furthermore, in consideration of the information in Figure 2, only transition phase data for individuals older than certain ages were used as shown below:

Year classes 1971–1975: 15 years
Year classes 1976–1980: 12 years
Year classes 1981–1985: 12 years
Year classes 1986–1990: 12 years
Year classes 1991–1995: 12 years
Year classes 1996–2000: 12 years
Year classes 2001–2010: 12 years

Data for these age values and older should therefore be free of truncation bias, however the sample size will be reduced.

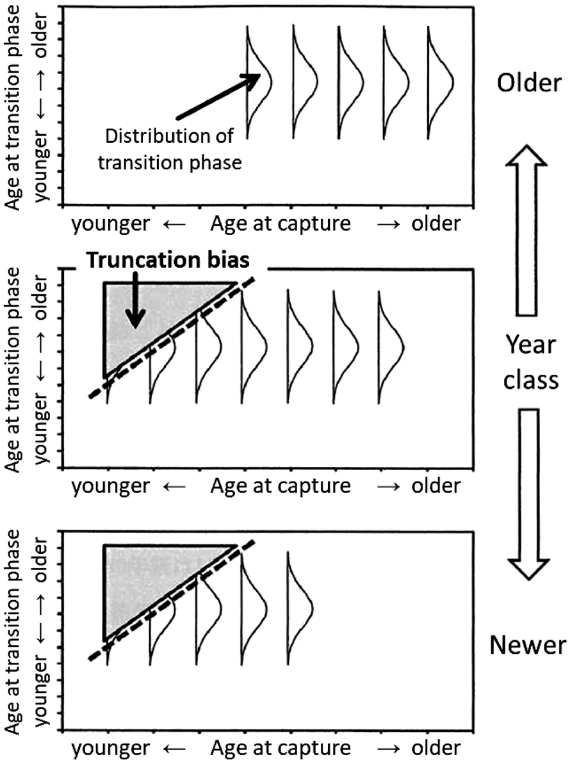
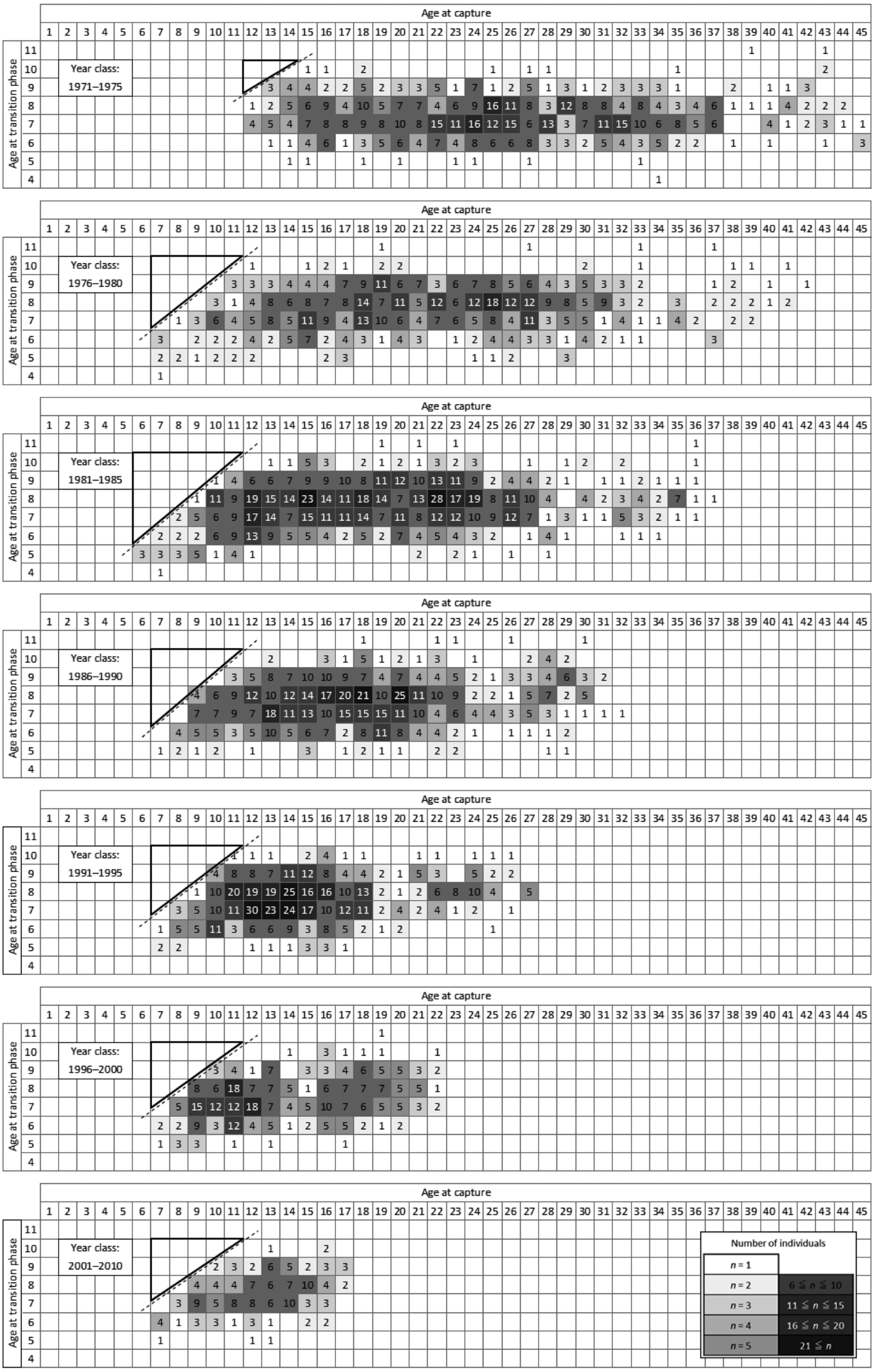


Figure 1. Schematic illustration of the relationship between distribution of age at transition phase and age at capture in certain year classes with truncation bias (after Zenitani, 2011).



Year class: 1971–1975

	Age at capture																																												
Age at transition phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
11																																							1				1		
10															1	1		2							1		1	1							1								2		
9													3	4	4	2	2	5	2	3	3	5	1	7	1	2	5	1	3	1	2	3	3	3	1			2		1	1	3			
8												1	2	5	6	9	4	10	5	7	7	4	6	9	16	11	8	3	12	8	8	4	8	4	3	4	6	1	1	1	4	2	2	2	
7												4	5	4	7	8	8	9	8	10	8	15	11	16	12	15	6	13	3	7	11	15	10	6	8	5	6			4	1	2	3	1	1
6													1	1	4	6	1	3	5	6	4	7	4	8	6	6	8	3	3	2	5	4	3	5	2	2		1		1			1		3
5														1	1			1		1			1	1			1						1												
4																																		1											

Year class: 1976–1980

	Age at capture																																												
Age at transition phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
11																			1								1						1				1								
10												1			1	2	1		2	2										2			1					1	1		1				
9											3	3	3	4	4	4	7	9	11	6	7	3	6	7	8	5	6	4	3	5	3	3	2				1	2		1		1			
8										3	1	4	8	6	8	7	8	14	7	11	5	12	6	12	18	12	12	9	8	5	9	3	2		3		2	2	2	1	2				
7								1	3	6	4	5	8	5	11	9	4	13	10	6	4	7	6	5	8	4	11	3	5	5	1	4	1	1	4	2		2	2						
6							3		2	2	2	4	2	5	7	2	4	3	1	4	3		1	2	4	4	3	3	1	4	2	1	1				3								
5							2	2	1	2	2	2				2	3							1	1	2			3																
4							1																																						

Year class: 1981–1985

	Age at capture																																												
Age at transition phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
11																			1		1		1													1									
10													1	1	5	3		2	1	2	1	3	2	3			1		1	2		2				1									
9										1	4	6	6	7	9	9	10	8	11	12	10	13	11	9	2	4	4	2	1		1	1	2	1	1	1									
8									1	11	9	19	15	14	23	14	11	18	14	7	13	28	17	19	8	11	10	4		4	2	3	4	2	7	1	1								
7								2	5	6	9	17	14	7	15	11	11	14	7	11	8	12	12	10	9	12	7	1	3	1	1	5	3	2	1	1									
6							2	2	2	6	9	13	9	5	5	4	2	5	2	7	4	5	4	3	2		1	4	1			1	1	1											
5						3	3	3	5	1	4	1									2		2	1		1		1																	
4							1																																						

Year class: 1986–1990

	Age at capture																																												
Age at transition phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
11																		1				1	1			1				1															
10													2			3	1	5	1	2	1	3		1			2	4	2																
9											3	5	8	7	10	10	9	7	4	7	4	4	5	2	1	3	3	4	6	3	2														
8									4	6	9	12	10	12	14	17	20	21	10	25	11	10	9	2	2	1	5	7	2	5															
7									7	7	9	7	18	11	13	10	15	15	15	11	10	4	6	4	4	3	5	3	1	1	1	1													
6								4	5	5	3	5	10	5	6	7	2	8	11	8	4	4	2	1		1	1	1	2																
5							1	2	1	2		1			3		1	2	1	1		2	2					1	1																
4																																													

Year class: 1991–1995

	Age at capture																																												
Age at transition phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
11																																													
10											1	1	1		2	4	1	1			1	1		1	1	1																			
9										4	8	8	7	11	12	8	4	4	2	1	5	3		5	2	2																			
8									1	10	20	19	19	25	16	16	10	13	2	1	2	6	8	10	4		5																		
7								3	5	10	11	30	23	24	17	10	12	11	2	4	2	4	1	2		1																			
6							1	5	5	11	3	6	6	9	3	8	5	2	1	2					1																				
5							2	2				1	1	1	3	3	1																												
4																																													

Year class: 1996–2000

	Age at capture																																												
Age at transition phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
11																			1																										
10														1		3	1	1	1			1																							
9										3	4	1	7		3	3	4	6	5	5	3	2																							
8									8	6	18	7	7	5	1	6	7	7	7	5	5	1																							
7								5	15	12	12	18	7	4	5	10	7	6	5	5	3	2																							
6							2	2	9	3	12	4	5	1	2	5	5	2	1	2																									
5							1	3	3		1		1				1																												
4																																													

Year class: 2001–2010

	Age at capture																																												
Age at transition phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
11																																													
10													1			2																													
9										2	3	2	6	5	2	3	3																												
8									4	4	4	7	6	7	10	4	2																												
7								3	9	5	8	8	6	10	3	3																													
6							4	1	3	3	1	3	1		2	2																													
5							1					1	1																																
4																																													

Number of individuals

$n = 1$	
$n = 2$	$6 \leqq n \leqq 10$
$n = 3$	$11 \leqq n \leqq 15$
$n = 4$	$16 \leqq n \leqq 20$
$n = 5$	$21 \leqq n$

Figure 2. Distribution of age at transition phase against age at capture in each year class group. The triangle corresponds to truncation bias. Maximum age for truncation bias is indicated by the corner of the triangle.

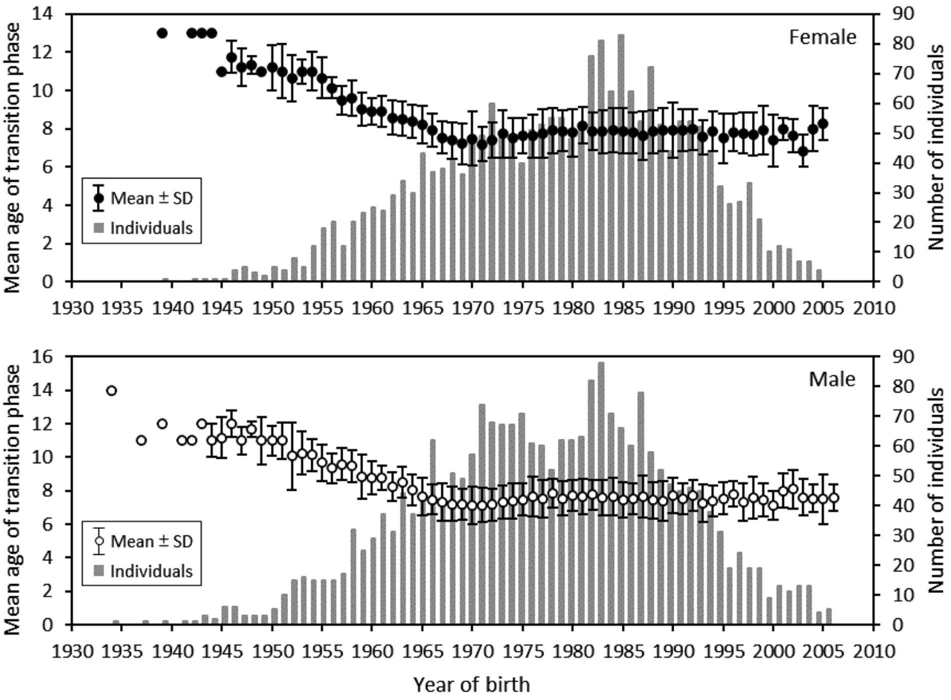


Figure 3. Temporal trend of mean age at sexual maturity by a transition phase of Antarctic minke whales by year class and sex, for the whole area.

After considering truncation bias, this study used a total of 4,417 (2,078 females and 2,339 males) age and transition phase data for temporal trend analysis.

Statistical analysis

Linear regression analysis was applied to examine long-term trends in the age at sexual maturity from the year in which the trend had stabilized, e.g. 1970′s (Bando *et al.*, 2014). For the statistical test on trend, p values < 0.05 were considered to be statistically significant.

RESULTS

Temporal trend of age at sexual maturity for the whole area

The analysis involved samples from 4,417 Antarctic minke whales (2,078 females and 2,339 males) taken from 0°–120°W of the Indo-Pacific region, south of 60°S. The mean age at sexual maturity by year class and sex is shown in Figure 3, and detailed values are available in Table 2. Age at sexual maturity in the most recent year class was estimated to be about 7–9 years old in 2005 for females and about 7–9 years old in 2006 for males.

The statistical examination of the trend of age at sexual maturity from 1970 to 2005 in females and from 1970 to 2006 in males (e.g. recent changes) revealed results of interest. The age at sexual maturity increased slightly for year class after the 1970s in both sexes. The regression equations were $y=0.0084x-8.8299$ for females, and $y=0.0085x-9.3362$ in males (y is mean age at sexual maturity and x is year of birth). In both cases the trend was statistically significant ($p<0.05$).

Temporal trend of sexual maturity by stocks

At least two stocks of Antarctic minke whales occur in the Indo-Pacific sector of the Antarctic (I- and P-stocks) (Pastene and Goto, 2016; Murase *et al.*, 2020). The boundary between these two stocks is variable and changes by year and sex (Kitakado *et al.*, 2014). Figure 4 shows the temporal trend of age at sexual maturity for the main areas occupied by the two stocks, 0°–130°E for the I-stock and 165°E–120°W for the P-stock. Table 2 shows the data on age at sexual maturity by year class, sex and stock.

The regression equations for the recent trend for each case in Figure 4 were:

I-stock, female: $y=0.0051x-2.3859$

I-stock, male: $y=0.0113x-14.8503$

P-stock, female: $y=0.0082x-8.5696$

P-stock, Male: $y=0.0019x+3.7597$

The statistical test for temporal trend indicated that only the age at sexual maturity for males of the I-stock was significant ($p<0.05$).

Table 2

Age at sexual maturity of Antarctic minke whales derived from a transition phase in earplugs by year class, sex and stock.

Year of class	0°–120°W as “All area”								0°–130°E as “Indian sector”								165°E–120°W as “Pacific sector”							
	Female				Male				Female				Male				Female				Male			
	Mean	SD	Range	*n*	Mean	SD	Range	*n*	Mean	SD	Range	*n*	Mean	SD	Range	*n*	Mean	SD	Range	*n*	Mean	SD	Range	*n*
1934	—	—	—	—	14.00	—	—	1	—	—	—	—	14.00	—	—	1	—	—	—	—	—	—	—	—
1935	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1936	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1937	—	—	—	—	11.00	—	—	1	—	—	—	—	11.00	—	—	1	—	—	—	—	—	—	—	—
1938	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1939	13.00	—	—	1	12.00	—	—	1	13.00	—	—	1	12.00	—	—	1	—	—	—	—	—	—	—	—
1940	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1941	—	—	—	—	11.00	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1942	13.00	—	—	1	11.00	—	—	1	—	—	—	—	11.00	—	—	1	—	—	—	—	—	—	—	—
1943	13.00	—	—	1	12.00	0.00	12–12	3	13.00	—	—	1	12.00	—	—	1	—	—	—	—	—	—	—	—
1944	13.00	—	—	1	11.00	1.00	10–12	2	—	—	—	—	11.00	1.00	10–12	2	13.00	—	—	1	—	—	—	—
1945	11.00	—	—	1	11.17	1.21	9–13	6	—	—	—	—	10.67	1.25	9–12	3	11.00	—	—	1	11.00	—	—	1
1946	11.75	0.83	11–13	4	12.00	0.82	11–13	6	—	—	—	—	12.00	0.89	11–13	5	13.00	—	—	1	12.00	—	—	1
1947	11.20	0.98	10–12	5	11.00	0.82	10–12	3	12.00	—	—	1	10.00	—	—	1	12.00	—	—	1	11.00	—	—	1
1948	11.33	0.47	11–12	3	11.67	0.47	11–12	3	11.33	0.47	11–12	3	12.00	—	—	1	—	—	—	—	—	—	—	—
1949	11.00	0.00	11–11	2	11.00	1.41	9–12	3	11.00	—	—	1	11.00	1.41	9–12	3	11.00	—	—	1	—	—	—	—
1950	11.20	1.17	10–13	5	11.00	0.89	10–12	5	10.50	0.50	10–11	2	11.00	1.00	10–12	2	11.67	1.25	10–13	3	10.00	—	—	1
1951	11.00	1.41	9–13	4	11.00	1.10	10–13	10	12.00	1.00	11–13	2	10.80	1.17	10–13	5	10.00	1.00	9–11	2	10.67	0.94	10–12	3
1952	10.63	1.22	8–12	8	10.07	2.02	7–15	15	10.25	1.48	8–12	4	9.89	2.18	7–15	9	10.50	0.50	10–11	2	9.75	1.48	8–12	4
1953	11.00	0.63	10–12	5	10.25	1.30	8–12	16	11.33	0.47	11–12	3	10.00	1.13	8–12	11	11.00	—	—	1	12.00	—	—	1
1954	11.00	1.00	9–13	12	10.13	0.96	9–12	15	10.75	0.43	10–11	4	10.40	0.92	9–12	10	11.00	0.71	10–12	4	10.00	0.82	9–11	3
1955	10.67	1.05	8–12	18	9.67	1.07	7–11	15	9.80	1.17	8–11	5	9.60	1.02	8–11	5	11.13	0.78	10–12	8	9.88	0.60	9–11	8
1956	10.15	0.57	9–11	20	9.33	0.87	8–11	15	10.29	0.45	10–11	7	9.33	0.94	8–11	9	10.50	0.50	10–11	4	9.00	0.82	8–10	3
1957	9.50	0.76	8–11	12	9.59	0.97	8–12	17	10.00	0.82	9–11	3	9.40	0.66	8–10	10	9.50	0.50	9–10	6	9.67	1.70	8–12	3
1958	9.60	0.92	8–12	20	9.47	0.93	7–12	32	9.60	0.49	9–10	5	9.37	1.04	7–12	19	9.11	0.74	8–10	9	9.20	0.75	8–10	5
1959	9.04	0.86	7–11	23	8.84	1.32	6–11	25	8.57	0.90	7–10	7	8.92	1.33	6–11	13	9.18	0.72	8–10	11	8.43	1.50	6–11	7
1960	8.92	0.69	8–10	25	8.76	0.97	6–10	29	9.09	0.79	8–10	11	8.59	1.14	6–10	17	9.00	0.47	8–10	9	8.83	0.69	8–10	6
1961	8.92	0.81	7–10	24	8.76	0.71	8–10	37	8.92	0.86	7–10	12	8.72	0.72	8–10	25	8.86	0.83	8–10	7	8.67	0.75	8–10	6
1962	8.59	0.89	7–10	29	8.26	0.84	6–10	31	8.73	0.93	7–10	15	8.06	0.85	6–9	18	8.33	0.75	7–9	6	8.67	0.47	8–9	6
1963	8.53	0.92	6–10	34	8.50	0.92	7–10	44	8.56	1.00	6–10	16	8.65	0.96	7–10	23	8.36	0.77	7–9	11	8.08	0.86	7–9	12
1964	8.40	0.88	6–10	30	8.03	0.91	6–10	37	8.42	0.86	7–10	12	7.94	0.97	6–9	16	8.36	1.07	6–10	11	8.25	0.66	7–9	8
1965	8.23	0.98	5–10	43	7.67	1.11	5–10	42	8.48	1.14	5–10	21	7.96	0.89	6–10	24	8.00	0.69	7–9	17	7.33	1.25	5–9	9
1966	7.95	0.87	6–10	37	7.48	0.91	6–10	62	8.06	0.87	7–10	17	7.55	0.94	6–10	31	7.81	0.73	6–9	16	7.53	0.88	6–9	15
1967	7.55	0.85	6–10	38	7.32	1.11	5–10	41	7.53	1.09	6–10	17	7.30	1.19	5–10	20	7.63	0.60	7–9	16	7.50	1.12	6–9	14
1968	7.39	0.93	6–9	41	7.22	1.00	5–10	51	7.21	1.01	6–9	14	7.21	1.05	5–10	28	7.55	0.89	6–9	22	7.33	1.11	6–10	12
1969	7.22	1.06	5–10	36	7.18	0.92	5–9	49	7.11	0.94	5–9	18	6.86	0.74	6–8	14	7.21	1.26	5–10	14	7.17	0.90	5–9	18
1970	7.49	1.40	4–11	49	7.14	1.12	5–10	57	7.53	1.61	4–10	17	7.00	1.15	5–9	27	7.56	1.26	6–11	27	7.65	1.13	6–10	17
1971	7.20	0.90	5–9	49	7.15	1.02	5–10	74	7.22	0.97	5–9	18	7.12	1.02	6–10	43	7.26	0.85	6–9	23	7.05	0.97	5–9	20
1972	7.42	0.94	6–11	60	7.16	0.95	5–9	68	7.45	0.80	6–9	20	7.27	0.93	5–9	33	7.52	1.01	6–11	31	7.26	0.96	6–9	19
1973	7.73	1.24	6–10	49	7.33	0.98	4–10	67	7.59	1.24	6–10	17	7.20	1.23	4–10	25	7.79	1.21	6–10	28	7.53	0.72	6–9	30
1974	7.52	1.02	6–10	48	7.39	1.08	5–11	67	7.53	1.20	6–10	15	7.29	0.98	5–9	21	7.46	0.89	6–9	26	7.36	1.11	6–11	28
1975	7.63	0.91	6–9	40	7.48	0.95	5–9	71	7.67	0.79	6–9	15	7.38	1.03	5–9	34	7.64	1.02	6–9	22	7.67	0.77	6–9	27
1976	7.63	1.14	6–10	51	7.62	1.19	5–10	61	7.80	1.11	6–9	15	7.81	1.33	5–10	26	7.55	1.19	6–10	31	7.42	0.95	6–9	24
1977	7.77	1.27	5–10	53	7.53	1.13	5–10	60	8.25	1.30	6–10	16	7.69	1.05	5–10	29	7.52	1.16	5–10	31	7.56	1.12	5–10	18
1978	7.91	1.18	5–11	55	7.85	0.84	6–9	52	7.86	0.91	6–9	14	8.10	0.77	7–9	20	7.94	1.32	5–11	33	7.59	0.84	6–9	17
1979	7.89	1.07	5–11	55	7.55	1.04	5–9	62	7.84	1.23	5–11	19	7.48	1.06	5–9	23	7.80	1.02	6–10	25	7.57	0.94	6–9	28
1980	7.79	1.26	5–11	48	7.73	0.94	5–9	62	7.95	1.43	5–11	20	7.65	0.90	6–9	31	7.74	1.25	5–10	19	8.00	0.62	7–9	21
1981	8.19	0.95	6–11	53	7.63	1.06	6–11	63	8.05	0.64	7–9	22	7.48	0.93	6–9	29	8.35	1.13	6–11	23	7.81	1.26	6–11	21
1982	7.88	1.00	5–10	76	7.77	0.90	6–10	82	8.03	1.02	5–10	30	7.88	0.90	6–10	34	7.91	0.95	6–10	34	7.84	0.83	6–10	32
1983	7.86	1.12	5–11	81	7.60	1.06	5–10	88	7.85	1.00	6–10	39	7.70	1.00	5–10	40	7.91	1.11	6–10	33	7.68	1.07	6–10	28
1984	7.92	1.14	5–10	64	7.65	1.14	5–11	71	8.00	1.02	5–10	21	7.96	0.98	7–11	24	7.82	1.17	6–10	34	7.34	1.21	5–9	29
1985	7.89	1.18	5–10	83	7.45	1.03	6–10	66	8.00	1.05	6–10	36	7.46	1.18	6–10	28	7.84	1.18	5–10	38	7.48	0.94	6–9	25
1986	7.80	1.08	5–10	64	7.52	0.92	5–9	60	7.81	0.96	6–10	21	7.38	0.90	5–9	24	7.63	1.07	5–10	35	7.85	0.79	6–9	20
1987	7.63	1.27	5–10	54	7.64	1.26	5–11	78	7.74	1.29	5–10	27	7.61	1.28	5–11	33	7.40	1.32	5–10	20	7.57	1.12	5–11	30
1988	7.86	1.13	6–11	72	7.43	1.10	5–10	58	7.75	0.97	6–10	40	7.57	1.28	5–10	23	7.96	1.34	6–11	26	7.38	0.90	6–9	21
1989	7.94	1.12	6–10	53	7.38	1.20	5–10	52	8.21	0.89	7–10	19	7.48	1.13	5–10	27	7.83	1.34	6–10	23	7.11	1.15	5–9	18
1990	7.91	1.44	5–11	44	7.70	1.05	6–11	47	7.53	1.53	5–11	19	7.53	0.92	6–9	30	8.14	1.36	6–10	21	8.07	1.24	6–11	15
1991	7.93	1.09	6–10	54	7.53	0.93	6–10	45	8.08	1.15	6–10	24	7.33	0.90	6–9	24	7.84	1.05	6–10	25	8.07	0.85	7–10	15
1992	7.96	1.07	5–10	54	7.72	0.90	5–10	46	7.83	0.90	7–9	12	7.83	1.07	5–10	24	8.06	1.20	5–10	32	7.63	0.70	6–9	16
1993	7.56	0.89	5–9	52	7.27	1.12	5–9	45	7.27	1.01	5–9	22	7.38	1.11	5–9	24	7.88	0.65	6–9	25	7.08	1.14	5–9	13
1994	7.89	1.05	5–10	44	7.37	0.93	6–9	38	7.68	1.13	5–10	19	7.31	0.85	6–9	16	8.18	0.92	7–10	17	7.25	0.90	6–9	16
1995	7.50	1.27	5–10	32	7.55	0.94	6–10	31	7.36	0.81	6–9	14	7.57	0.73	6–9	14	7.56	1.46	5–10	16	7.78	1.23	6–10	9
1996	7.81	0.96	6–10	26	7.79	0.77	7–9	19	7.85	1.10	6–10	13	7.83	0.90	7–9	6	7.73	0.86	7–9	11	7.75	0.72	7–9	12
1997	7.78	1.07	6–11	27	7.33	1.11	6–10	24	8.50	1.20	7–11	10	7.64	0.88	6–9	11	7.38	0.70	6–8	16	7.17	1.21	6–10	12
1998	7.73	1.11	6–10	33	7.58	1.23	5–10	19	8.11	0.87	7–9	9	8.50	1.12	7–10	4	7.58	1.15	6–10	24	7.36	0.98	6–9	11
1999	7.90	1.27	6–10	21	7.47	0.99	5–9	19	7.22	1.13	6–9	9	7.22	1.13	5–9	9	8.42	1.11	6–10	12	7.78	0.79	7–9	9
2000	7.40	1.36	6–10	10	7.11	0.87	6–9	9	7.20	1.47	6–10	5	7.25	0.83	6–9	8	7.60	1.20	6–9	5	6.00	—	—	1
2001	8.00	0.58	7–9	12	8.00	1.04	6–9	13	8.00	0.00	8–8	5	8.17	1.07	6–9	6	8.00	0.76	7–9	7	7.86	0.99	6–9	7
2002	7.64	0.88	6–9	11	8.09	1.16	6–10	11	8.00	—	—	1	8.11	1.29	6–10	9	7.56	0.96	6–9	9	8.00	0.00	8–8	2
2003	6.86	0.83	5–8	7	7.62	1.08	6–10	13	7.50	0.50	7–8	2	8.00	1.00	7–10	8	6.60	0.80	5–7	5	7.00	0.89	6–8	5
2004	8.00	1.20	6–9	7	7.54	0.84	6–9	13	8.00	1.00	7–9	4	7.54	0.84	6–9	13	8.00	1.41	6–9	3	—	—	—	—
2005	8.25	0.83	7–9	4	7.50	1.50	5–9	4	8.33	0.94	7–9	3	7.50	1.50	5–9	4	8.00	—	—	1	—	—	—	—
2006	—	—	—	—	7.6	0.80	7–9	5	—	—	—	—	7.60	0.80	7–9	5	—	—	—	—	—	—	—	—
total	8.00	1.31	4–13	2,078	7.78	1.30	4–15	2,339	8.01	1.29	4–13	814	7.85	1.35	4–15	1,118	7.93	1.27	5–13	975	7.69	1.15	5–12	763

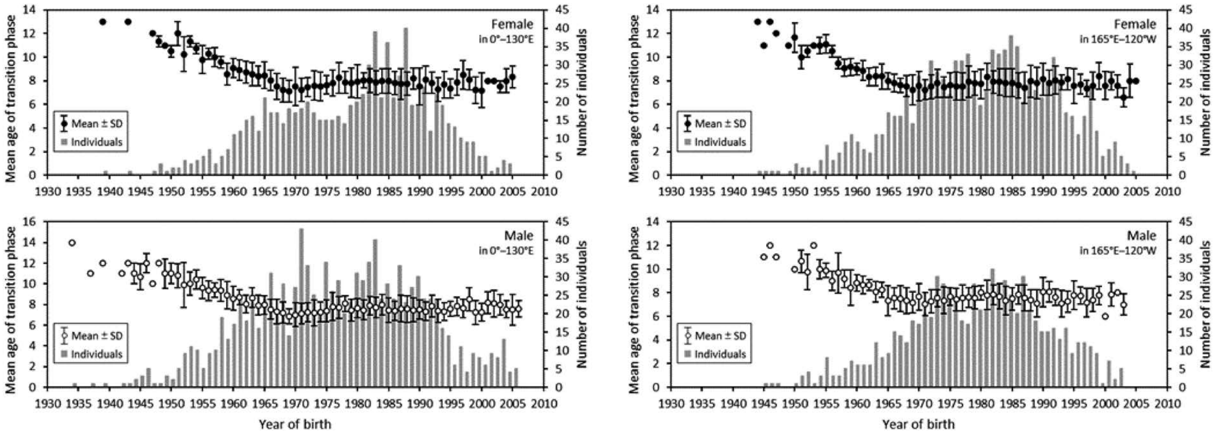


Figure 4. Temporal trend of sexual maturity by transition phase of Antarctic minke whales by year class, sex and stock (left: I-stock; right: P-stock).

SUMMAY AND INTERPRETATION OF RESULTS

The previous study by Bando *et al.* (2014) examined the age at sexual maturity (based on a transition phase) until the 1998′s year class. This study updated the analyses by examining seven additional year classes (1999–2006). The updated analyses confirmed that the age at sexual maturity of this species declined from 10–12 years old in the mid-1940s year classes to 7–8 years old in the early 1970s year classes, and that has remained stable at that level till the 2000s year classes. There were no substantial differences when the analyses were conducted by stock.

Although some significant statistical trends were found for the recent year classes (from the 1970′s), the extent of such changes, when confirmed, is very small in comparison with the extent of the changes observed in the middle of the past century. In general, the age at sexual maturity in recent year classes (from the 1970′s) has remained stable at around 7–9 years old.

The results of stable age at sexual maturity in this study should be examined in conjunction with the information on recent trends in other biological and ecological aspects. In recent years the Antarctic minke whale has maintained a high apparent pregnancy rate of over 90% (Bando *et al.*, 2006); the recruitment estimated by Statistical Catch-At-Age (SCAA) analysis has not increased and has remained somewhat constant at a level that is not as high as that observed between 1940 and 1970 (Punt *et al.*, 2014); and a decrease in blubber thickness and average stomach contents weight has been reported (blubber thickness: Konishi *et al.*, 2008; stomach contents: Konishi *et al.*, 2014). In addition, Antarctic minke whales have been observed in polynyas in recent years while an increase in the abundance of other large whale species has been reported (e.g. humpback whale: Hakamada and Matsuoka, 2014; fin whale: Matsuoka and Hakamada, 2014). These results are consistent with the following two hypotheses:

Hypothesis 1: interspecific competition for krill resources

Under this hypothesis, the deteriorating nutritional conditions of the Antarctic minke whale are a consequence of limited krill availability, which in turn is due to the increase in the abundance of other krill-eater whale species. The distribution of Antarctic minke whales in polynyas is part of this hypothesis as the increasing abundance (and expanded distribution) of other large whale species has pushed the Antarctic minke whale to find other areas for feeding. The observations that the recruitment has not increased in recent years and remaining somewhat constant at a level but not as high as that observed between 1940 and 1970, and that the abundance of Antarctic minke whale has remained constant/slightly decreased are consistent with this hypothesis. The apparent contradiction between low age at sexual maturity/high pregnancy rates and current recruitment rates are due to a temporal phenomenon in which the response of biological parameters to environmental changes (food limitation) may be subjected to time lags (Bjerke and Walløe, in press).

Hypothesis 2: the environmental conditions for Antarctic minke whale remain optimal

Low age at sexual maturity and high pregnancy rates are consistent with this hypothesis. Although the nutritional conditions have deteriorated slightly, such conditions are not critical for the population. The observations that the recruitment has not increased and has remained somewhat constant at a level but not as high as that observed between 1940 and 1970, and that the abundance trends have remained constant are a reflection of the constraints of the surveys, which cannot cover new areas of distribution of the Antarctic minke whale such as the polynyas. Colonizing of new areas by the Antarctic minke whale has been facilitated by environmental changes such as the increase of surface temperature, which are opening new routes into the pack ice.

Further monitoring of biological and ecological parameters of the Antarctic minke whale is required to discern between the two proposed hypotheses. Also, additional analytical procedures are required. For example, in the case of the age at sexual maturity based on transition phase, model-based analysis (e.g. Thomson *et al.*, 1999), should be used in the future to further address the truncation bias and the fringe effect of age data at the transition phase in earplugs.

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Technical Reports of the Institute of Cetacean Research (2023) pp. 64–68

Technical Report (not peer reviewed)

Utility of data logging for the estimation of availability bias in sighting surveys

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ABSTRACT

This paper describes the progress of the work by the Institute of Cetacean Research on satellite-based data logging experiments conducted with the aim of obtaining diving and surfacing duration data of the Antarctic minke whale for estimating availability bias. The paper is organized to provide information on field equipment for tagging, the data obtained on Antarctic minke whale and results of preliminary estimation of availability bias. Tags were successfully attached to Antarctic minke whales, and some diving and surfacing duration data were obtained. Based on these data, estimates of availability bias are presented. However, such estimates should be considered as preliminary and further experiments to obtain additional behavioral data are recommended.

INTRODUCTION

Abundance estimates of whales based on sighting data and the distance sampling method are affected by a negative bias called ʻavailability biasʼ (McLaren, 1961; Marsh and Sinclair, 1989). To address this point, Laake *et al.* (1997), Okamura *et al.* (2012) and Borchers *et al.* (2013) presented analytical methods that used whale diving and surfacing duration data to correct for availability bias. These studies were based on diving and surfacing duration data from visual observations or from archival tags. However, visual observation is not ideal for obtaining data on diving and surfacing behavior particularly in elusive species such as the Antarctic minke whale. Also, retrieving archival tags over several days while conducting the sighting survey is not a practical approach.

Satellite tagging provides a new and useful alternative to in obtaining data on diving and surfacing behavior. Satellite tags were deployed on Antarctic minke whales during the 2021/22 and 2022/23 Japanese Antarctic Sighting and Stock structure Survey (JASS-A) surveys with a particular aim to obtain diving and surfacing duration data. Such data could be used to estimate availability bias following some of the methods indicated above.

This paper briefly reports the details of field equipment for tagging, the data obtained on the Antarctic minke whale and the results of preliminary estimation of availability bias.

FIELD EQUIPMENT FOR TAGGING EXPERIMENTS

The following equipment was used in the tagging experiment:

- Satellite tags (SPLASH10-f-333, Wildlife Computers, US) in the Low-Impact Minimally Percutaneous External electronics Tag (LIMPET) with two 6.8 cm darts and six petals;
- Aerial Rocket Transmitter System (LK-ARTS, Skutvik, Norway); and
- Deployment arrows (originally developed by Wildlife Computers and modified by the Institute of Cetacean Research [ICR]) (Figure 1).

The deployment arrows and tag were attached using adhesive (Aron Alpha Jelly, TOAGOSEI Co., LTD., Japan). The tags were shot from the bow deck (8 m above the sea) using an LK-ARTS, with air pressure set at 14 bar. The video of the experiment in the Antarctic Ocean can be seen at the following URL: https://www.youtube.com/watch?v=_wlSpleQEM8.

The SPLASH 10-f-333 can be configured to define specific ranges of diving and the types of data sought using the software Mk10 Host (Wildlife Computers, 2023). Data such as the maximum depth of each dive and the duration of diving and surfacing are received, rather than a full-resolution diving behavior.

In this study, the tags were configured to provide data for each diving and surfacing event as behavior message. A whale was considered diving when it penetrated deeper

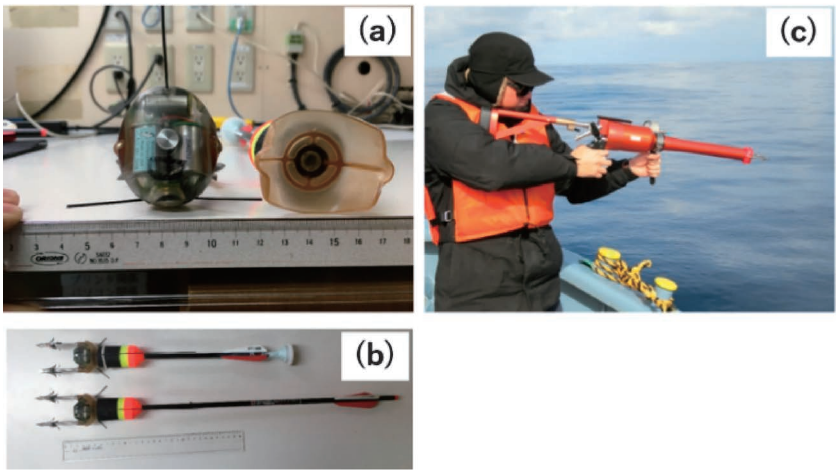


Figure 1. Equipment for satellite tagging: the satellite tags (SPLASH10-f-333) and the cup of the deployment arrow (a); original arrows developed by Wildlife Computers for a crossbow (b); and aerial rocket transmitter system (LK-ARTS) (c).

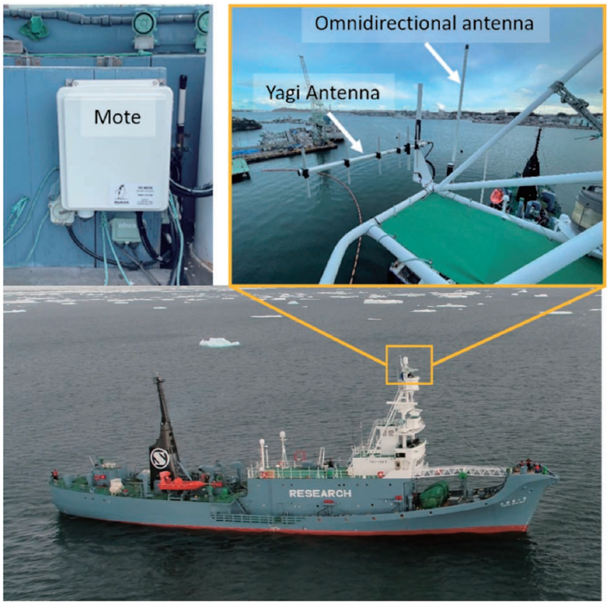


Figure 2. Mote Enclosure mounted on the upper bridge (upper left), and Yagi and omnidirectional antenna mounted on the top barrel of the research vessel (upper right). By connecting an USB memory stick to the Mote Enclosure, the data received by the antenna can be retrieved (the retrieved data must be decoded by Wildlife Computers portal).

than 4 m. The start and end of the recording were based on a depth of 1 m, and the sampling interval was one second. The percentages of time spent in arbitrary depth bins (0; 1; 3; 5; 10; 30; 50; 100; 150; 200; 250; 300; 400; >400 m) were obtained, and the diving duration bins (10; 20; 30; 40; 50 sec; 1; 2; 3; 4; 5; 10; 15; 20; >20 min) were recorded 12 times a day at two-hour intervals starting at 00:00 UTC. Tags were programmed to transmit 24 hours a day and were limited to 3,000 transmissions per day.

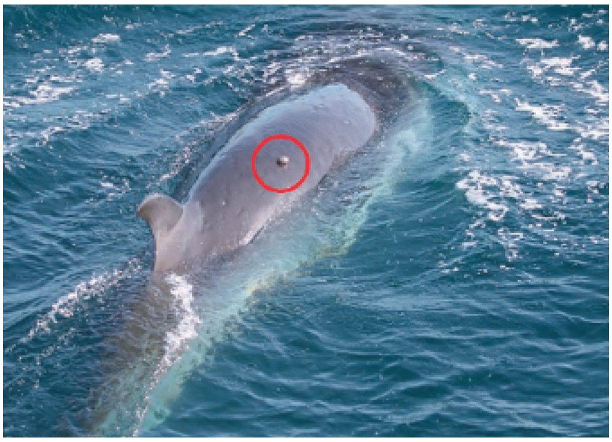


Figure 3. Antarctic minke whale with a SPLASH10-f-333 tag attached on 2 February 2022, at 71°16′S, 132°10′W. The red circle indicates the attached position of the tag.

Mote (Wildlife Computers, US) is a stationary listening station and can continuously log telemetry data from satellite tags on animals within the reception range (Jeanniard-du-Dot *et al.*, 2017). Mote was installed on the research vessel (*Yushin-Maru* No. 2, *YS2*), and Yagi and omnidirectional antenna were equipped on the top barrel (approximately 20 m above the sea level) (Figure 2). The Yagi antenna has directivity and about a 60° beamwidth within which distant signals (about 8.5 nautical miles when placed at 20 meters) were received. The omnidirectional antenna can receive signals from all directions, but the distance will be shorter.

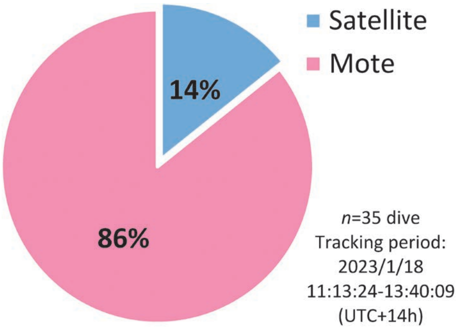
DATA OBTAINED

In the 2021/22 JASS-A survey, two Antarctic minke whales were tagged. Figure 3 shows the tag attached to the whale′s body (PTT 207827). The vessel tracked this

Table 1

Details of diving and surfacing duration data of an Antarctic minke whale tagged in the 2021/22 JASS-A survey. Data obtained from 6 February 00:01:00 (UTC) to 17 February 13:33:24 (UTC) 2022.

PTT ID	Number of days with data obtained	Type	*n*	duration mean (sec)	SD	Duration min (sec)	Duration max (sec)	Duration range (sec)
207827	11.6	Dive	50	196.52	145.91	6	680	674
		Surfacing	50	39.12	65.55	2	348	346



n=35 dive
Tracking period:
2023/1/18
11:13:24-13:40:09
(UTC+14h)

Figure 4. Percentage of behavioral data recorded by satellite and Mote from an Antarctic minke whale tagged in the 2022/23 JASS-A survey.

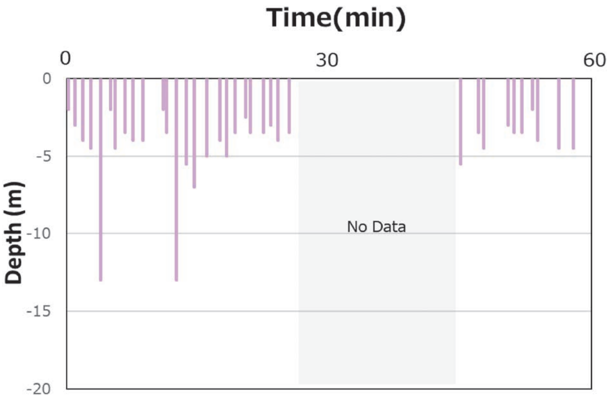


Figure 5. The diving behavior of an Antarctic minke whale (PTT 224705) tagged during the 2022/23, and recorded for 60 min after tag attachment. This whale repeatedly dived at depths shallower than 15 m. There were periods when data was not received even while the Mote was tracking the individual.

individual and stayed more than 0.5 n.miles away from the whale during the tracking. During the tracking diving and surfacing duration data were received via Mote consecutively for 26 min, but no data were received via satellite. The diving and surfacing duration of this whale are summarized in Table 1. Although the tag was attached to the whale for more than 10 days, only 50 dives were recorded in total. This is possibly because the tag was not sufficiently out of the water and the signal was weak.

In the 2022/23 survey, two Antarctic minke whales were successfully tagged. Antarctic minke whale (PTT 224705) was tracked on 18 January 2023, from 11:13 to 13:40 (UTC+14 hours) and data were received via Mote. There were 35 dives recorded during the tracking. Of these, 30 dives were recorded by the Mote, indicating its usefulness (Figure 4). The time duration of the attached tag on the water surface may be too short to transmit behavior messages to a satellite.

The Mote is suited for acquiring a large amount of data and can obtain each diving and surfacing duration of a whale, which is challenging to collect by satellite alone.

Figure 5 shows the diving behavior of the same whale recorded for 60 minutes after the tag was attached. The time period during which data could not be received, even when the Mote was running, suggests that it is particularly difficult to receive data from this species.

ESTIMATION OF AVAILABILITY BIAS

Table 2 summarizes the Antarctic minke whale's diving and surfacing duration data (PTT 224705) obtained during the 2022/23 JASS-A survey. Using the values of surfacing duration of 4.54 s and diving duration of 60.03 s, a preliminary estimation of availability bias was conducted based on the relatively simple method of Laake *et al.* (1997) under the following two survey cases: the first case is the ICR's vessel-based visual survey (see Isoda *et al.*, 2020), and the second is the ICR's planned UAV-based aerial survey (see Matsuoka and Yoshida, 2021; Katsumata and Yoshida, 2023).

Laake *et al.* (1997)'s formula to estimate availability bias is:

$$a = \frac{E(s)}{E(s)+E(d)} + \frac{E(d)\left[1-\exp\left\{-\dfrac{t(y_{max})}{E(d)}\right\}\right]}{E(s)+E(d)}$$

where a is the probability of a single whale being available on the transect line, $E(s)$ is the mean duration of surfacing, $E(d)$ is the mean duration of diving, and $t(y_{max})$ is the amount of time the ocean is in the observer's view on the transect line.

Table 2

Details of diving and surfacing duration from behavior messages on an Antarctic minke whale in the 2022/23 JASS-A cruise. Data were obtained from January 18, 2023, 11:13:24 (UTC+14h) to 13:40:09 (UTC+14h).

PTT ID	Type	*n*	Duration mean (sec)	SD	Duration min (sec)	Duration max (sec)	Duration range (sec)
224705	Dive	35	60.03	37.54	1	162	161
	Surfacing	35	4.54	1.79	2	12	10

Case 1: Vessel-based visual survey

Here it is assumed that the survey speed is 11.5 knots (approx. 21 km/h) and that an Antarctic minke whale can be sighted up to 2 n.miles ahead. Under these assumptions, the value of $t\ (y_{max})$ is 626.1 seconds; that of a is 1.00. This suggests that there are no missing Antarctic minke whale in the vessel-based survey due to diving.

Case2: UAV-based aerial survey

Here it is assumed that the survey speed is 43 knots (approx. 80 km/h), and that the UAV flies at an altitude at 100 m above the sea and that the camera captures a range 0.1 n.miles directly below the aircraft. Under these assumptions the value of $t(y_{max})$ is 8.4 seconds; that of a is 0.19. This suggests that more than 80% of Antarctic minke whales are not sighted due to diving.

DISCUSSION

This study presented the results of the first tagging experiment using SPLASH10-f-333 on Antarctic minke whales during Japanese whale surveys in the Antarctic. Tags were attached and data were obtained. Thus, this first attempt can be considered successful. This approach proved to be useful to obtain diving and surfacing duration data from an elusive species as is the case with the Antarctic minke whale. However, a data gap was observed in the behavior message even while Mote was active (Figure 5). In the case of animals that repeatedly make short diving, it is possible that too many behavior messages were created and transmitted. Since SPLASH10-f-333 can set the diving definition and types of data produced in a flexible way, it is important to set it to a configuration that maximizes the data collection relevant to the estimation of availability bias.

Laake's method has been applied to vessel-based visual surveys previously (e.g. Weir *et al.*, 2021). However, this method assumes that whales above the sea surface will always be sighted regardless of forward distance. However, the Antarctic minke whale has small blows and sometimes only the body is visible. Therefore, the assumption that these whales are always sighted up to 2 n.miles ahead is unlikely to be met. As a consequence, availability bias could be overestimated with this method, leading to an underestimation of abundance estimation. As for the vessel-based visual survey, the detection probability should be considered for the forward distance, as was described in Borchers *et al.* (2013).

For the aerial survey, the value a 0.19 is considered reasonable, because it is similar to Hansen *et al.* (2018), which estimates availability bias on aerial surveys using Laake′s method for common minke whales in the North Atlantic Ocean. However, in the case of the aerial survey, the availability bias changes depending on the depth to which whales can be detected. The data in this study assumed that it can be detected when shallower than one meter, but this assumption also needs to be examined in the future. In both cases, the sample size of the diving and surfacing duration is still small, so it is necessary to accumulate more data to accurately correct the availability bias of abundance estimates using the distance sampling method.

In the 2022/23 JASS-A surveys, one fin whale and two humpback whales were successfully tagged and data on diving and surfacing duration were obtained. These data will be used to estimate the availability bias for these species in the near future.

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We acknowledge Yong Huang (Enfotran Corporation) and Kevin Lay (Wildlife Computers) for their technical advice regarding the tagging of the SPLASH10-f-333, Mote, and related data processing. We also acknowledge Hiroto Murase (Tokyo University of Marine Science and Technology) for his advice on operating SPLASH10-f-333 and installing Mote on the JASS-A cruise. We appreciate Yoshihiro Fujise and Takashi Hakamada (ICR) for supporting the experiments and the preliminary analysis. We thank Captains Hidenori Kasai and Nobuo Abe, and their crew members, and the researchers who participated in the 2021/22 and 2022/23 JASS-A surveys for their effort in the tagging experiment. We are grateful to Luis A. Pastene (ICR) for his assistance in preparing this report and to the Editorial

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Technical Reports of the Institute of Cetacean Research (2023) pp. 69–73

Technical Report (not peer reviewed)

Using satellite-linked tags for studying the feeding ecology of fin whales in the southern Okhotsk Sea

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ABSTRACT

This paper reports the tagging of satellite transmitters on fin whales in the southern Okhotsk Sea to simultaneously collect data on their diving and movement behaviors during the spring season. This information is essential for understanding the feeding ecology of the species. Transdermal and LIMPET-type tags (attached to the fin with anchors) were deployed using a whale-watching boat in spring 2021 and 2022, and two fin whales (one tagged with transdermal and the other with LIMPET) were tracked for 40 and 50 days, respectively. The transdermal tag was deployed with a newly developed tether-type carrier using a pneumatic air launcher, while the LIMPET tag was deployed with a crossbow. The tracking data revealed that fin whales repeat foraging in waters shallower than 150 m. This marks the first instance of tagging a TDR-installed satellite transmitter by the Institute of Cetacean Research.

INTRODUCTION

Understanding the ecology of large whales has been challenging owing to their massive size and offshore distribution. In particular, information about their long-range movement and diving profiles, important for understanding their feeding habits, has been difficult to obtain through traditional techniques such as vessel observations.

The development of satellite-linked tags has made remarkable progress in studying the spatio-temporal distribution and diving behavior of baleen whales without recovering the tags (Ainley *et al.*, 2020; Andrews *et al.*, 2019; Heide-Jørgensen *et al.*, 2001; Mate *et al.*, 2007; Palacios *et al.*, 2022). These electronic tags can monitor whale behavior over time and transmit data via satellite systems. Tracking records are also valuable for deciphering the mechanisms behind whale distribution in specific ecosystems, helping us to understand their movement and feeding behaviors.

The Institute of Cetacean Research (ICR) has been planning satellite-linked biologging experiments since 2015 as part of the surveys conducted under NEWREP-A (the New Scientific Whale Research Program in the Antarctic Ocean; https://www.jfa.maff.go.jp/j/whale/pdf/151127newrep-a.pdf). These experiments aim to gain insights into the feeding behavior and movements of Antarctic baleen whales. This non-lethal technique was developed in collaboration with a Norwegian tagging specialist and has been utilized in ICR surveys in both the Antarctic and western North Pacific.

For successful tracking of whales, the development of tags and suitable tagging equipment is crucial. This paper provides technical insights into tagging experiments designed to monitor the concurrent movement and diving behavior of fin whales (*Balaenoptera physalus*) in the southern Okhotsk Sea during the spring season, with the objective of enhancing our understanding of their feeding behavior in this region.

MATERIALS AND METHODS

Tags

Streamlining the deployment procedure and tag arrangement for each whale species and survey platforms is a critical aspect for ensuring successful deployments and tracking. In our efforts, we tested a transdermal tag, designed for large whales, with a tether-type carrier using the pneumatic air launcher ARTS (Kleivane *et al.*, 2022). Additionally, we introduced the LIMPET-type tag from Wildlife Computers Inc., a compact tag that can be deployed on the dorsal fin with two anchors inserted into the whale′s body to stabilize the transmitter. These tags enable tracking of whales over an extended period compared to recovery-type tags, which usually capture a large volume of data but over relatively short period (Cade

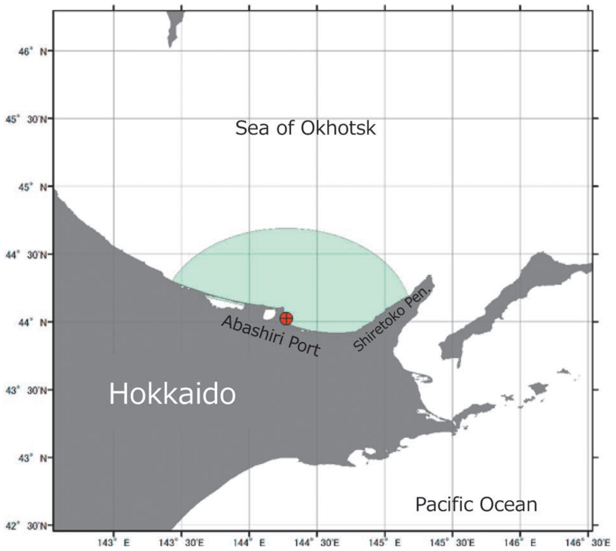

Figure 1. Research area for the satellite tagging experiments. Tagging was conducted in the area within 40 nautical miles of Abashiri port in the southern Sea of Okhotsk.

Figure 2. Whale-watching boat "*Chipashiri*" (4.9 t; 10.45 m). A safety fence was installed at the bow during the survey. The height of bow deck is 130 cm from the water.

et al., 2023; Friedlaender *et al.*, 2013; Savoca *et al.*, 2021).

Survey area and boat

The tagging experiments took place off the coast of Abashiri, Hokkaido, in the southern Okhotsk Sea (Figure 1). Recently, fin whales have been observed in the vicinity of the Abashiri area, enabling us to conduct experiments using a small boat that can closely approach the whales. We utilized the vessel "*Chipashiri*" (10.45 m) for these tagging experiments and made preparations for safety, including the installation of a safety fence and a small deck at the bow of the boat during the survey (Figure 2). Two highly skilled crew members with expertise in spotting and approaching marine mammals were present. In most instances, two shooters were responsible for tagging and conducting biopsy sampling within the confines of the safety fence (Figure 3).

Figure 3. Simultaneous shootings of a tag with ARTSTBC using LK-ARTS (left) and a biopsy dart with a crossbow on the bow of a boat, *Chipashiri*.

Tags and equipment

We deployed two types of tags—a transdermal tag SPLASH10-302B (300 ∗ 24 mm; 390 g) and a fin mount LIMPET (Low Impact Minimally Percutaneous Electronic Transmitter) tag SPLASH10-F-333 (56 ∗ 50 ∗ 27 mm; 69 g) (Wildlife Computers; Redmond, WA, USA)—on adult-sized fin whales during the spring feeding season. The former tag has a long battery life and is larger, while the latter is a compact GPS positioning LIMPET tag with anchors designed to be attached to the dorsal fin (www.wildlifecomputers.com). All experiments off Abashiri were approved by Fisheries Agency of Japan under the permit SUIKAN3-367.

Tagging results

Case1 (transdermal tag SPLASH10-302B)

To launch the transdermal tags, we utilized a carrier known as ARTSTBC (the tethered ARTS carrier for Wildlife Computer tags in the 300 series, with simultaneous biopsy sampling), which was developed during the project (LKARTS-Norway; Figure 4). During the carrier's development, numerous tests were conducted in both Norway and Japan to enhance deployment procedures and address safety concerns (Figure 5 and 6). A tag was

Figure 4. Wildlife Computers SPOT303 SPLASH302B-type tag connected to ARTSTBC.

Figure 5. Test of releasing tag from ARTSTBC in the manufacturer's laboratory in Japan.

Figure 6. Test shooting of a dummy tag with ARTSTBC in Norway.

Figure 7. Transdermal SPLASH10-302B (Wildlife Computers Inc.) tag was deployed at the base of the dorsal fin off the coast of Abashiri on May 20, 2021. This picture was taken by a drone.

deployed on a fin whale on 20 May 2021, and tracked until 30 June, covering a period of 40 days (Figure 7). The shooting angle was set at 20 degree with a distance of 20 m. The ARTS pressure used was 16 bar, and the tag penetrated to a depth of 4–5 cm anterior to the triangle stopper. The ARTSTBC was released upon impact during deployment and subsequently recovered. This 2021 deployment marks the first use of TDR-installed satellite-linked tags for monitoring location and diving behavior at the ICR.

Case2 (LIMPET-type SPLASH10-F-333)

To deploy the LIMPET tag, we employed a combination of a 150lb compound crossbow and an arrow-type carrier (Figure 8). These anchors are designed to attach securely to hard fibrous tissues, such as the dorsal fin. The LIMPET tag was placed beneath the dorsal fin of the fin whale on May 10, 2022, and tracking was conducted until July 29, covering a period of 50 days (Figure 9).

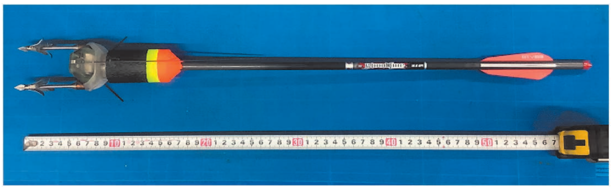

Figure 8. A set of SPLASH10-F-333 and its carrier are designed for a crossbow manufactured by Wildlife Computers.

Diving profiles

Fin whales in the southern Okhotsk Sea predominantly

Figure 9. LIMPET-type SPLASH-F-333 (Wildlife Computers Inc.) was attached to the dorsal fin of a fin whale off the coast of Abashiri on 10 May 2022. The arrow-type carrier is also visible in the image.

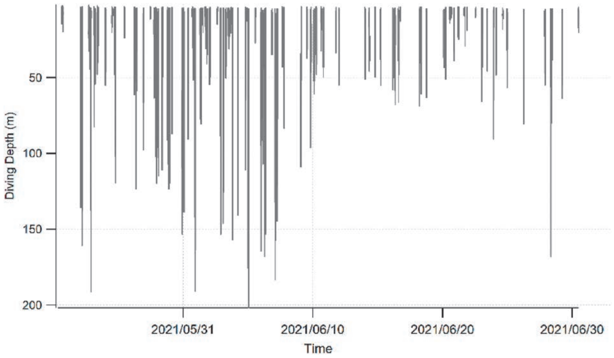

Figure 10. Diving profile of the fin whale (PTT ID 54121) tracked in May–June 2021. The record is depicted at ten-minute intervals using the *Ethographer* program (Sakamoto *et al.*, 2009) within the IGOR Pro 6.3.6 software.

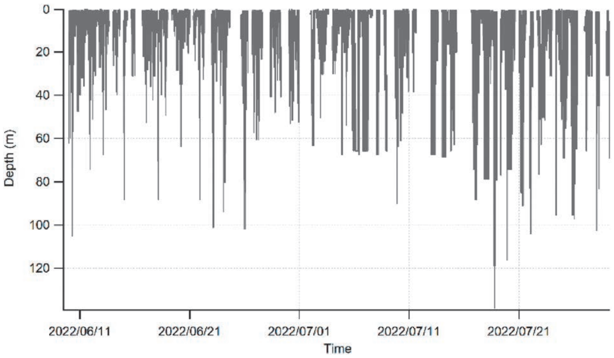

Figure 11. Diving profile of the fin whale (PTT ID 212345) tracked in June and July 2022. The record is plotted at ten-minute intervals.

feed at water depths shallower than 150 m (Figure 10 and 11). However, it's worth noting that their diving behaviors exhibit temporal variations on a daily and weekly basis. These tags also recorded positional data during their transmissions. The data collected from these two data loggers provides a substantial dataset that will enable us to gain a comprehensive understanding of their feeding behaviors. We plan to analyze this data in conjunction with environmental information, biopsy samples, and tracking records from other location-only tags to elucidate the feeding ecology of fin whales in the study area.

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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

The current utility of data and samples collected by former Japanese whale research programs under special scientific permit

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Japan, through the Institute of Cetacean Research (ICR), designed and implemented several whale research programs under special permits based on Article VIII of the International Convention for the Regulation of Whaling (ICRW). Those programs were implemented in both the Indo-Pacific sector of the Antarctic and in the western North Pacific as follow:

Antarctic

1. Japanese Whale Research Program under Special Permit in the Antarctic (JARPA): 1987/88–2004/05
2. Japanese Whale Research Program under Special Permit in the Antarctic-Phase II (JARPAII): 2005/06–2013/14
3. New Scientific Whale Research Program in the Antarctic Ocean (NEWREP-A): 2015/16–2018/19

Western North Pacific

4. Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN): 1994–1999
5. Japanese Whale Research Program under Special Permit in the western North Pacific-Phase II (JARPNII): 2000–2016
6. New Scientific Whale Research Program in the western North Pacific (NEWREP-NP): 2017–2019

Japan also conducted dedicated sighting surveys, which were independent from those research programs under special scientific permit. For example, a dedicated sighting survey was conducted in the Antarctic in the austral summer 2014/15.

Those six former whale research programs under special permits (FWRPs) above had research objectives related with the assessment and management of whale resources as well as to the role of whales in the ecosystem. The target species of the lethal sampling in the Antarctic FWRPs were the Antarctic minke whale (JARPA), Antarctic minke and fin whales (JARPAII) and Antarctic minke whale (NEWREP-A). In the western North Pacific, the target species of the lethal sampling were the common minke whale (JARPN), common minke, Bryde′s, sei and sperm whales (JARPNII) and common minke and sei whales (NEWREP-NP).

An important characteristic of the Japanese FWRPs was the combination of lethal and non-lethal sampling. Among the former, a limited number of whales were taken as indicated above for the objective of collecting information on age, reproductive status, and stomach contents mainly. Among the latter, techniques such as systematic sighting surveys, photo-identification, and biopsy sampling were conducted for all large whale species distributed in the research area. Oceanographic and marine debris surveys were also conducted to understand the whale′s physical environment.

The Japanese FWRP programs were duly reviewed by international specialists in workshops organized by the International Whaling Commission′s Scientific Committee (IWC SC). Reports of the review workshops are available in IWC (2008) for JARPA; IWC (2015) for JARPAII; IWC (2001) for JARPN and IWC (2017) for JARPNII. These programs left behind unique data and sample sets that represent around 30 years of systematic research in both the Antarctic and western North Pacific. See IWC (2015) and IWC (2017) for examples of lists of samples and data obtained in the Antarctic and western North Pacific, respectively. All those samples and data were collected in a consistent and systematic way for the objectives of each research program.

Scientific outputs from the Japanese FWRPs are available in a substantial number of peer-reviewed publications (see the last section of this TEREP-ICR issue) and in scientific documents presented to national and international meetings, mainly to meetings of scientific committee of international organizations in charge of the conservation and management of marine resources including large whales.

In 2018, Japan announced its withdrawal from the

ICRW, which came into effect on 30 June 2019 (see Pastene, 2019). Because the Japanese FWRPs were conducted under Article VIII of the ICRW, Japan had to cease the NEWREP-A and NEWREP-NP from that same date. Instead, Japan, through the ICR started dedicated sighting surveys in the Antarctic and western North Pacific. These new surveys collect information like that obtained by the non-lethal component of the FWRP informed above. The most important data collected by recent non-lethal surveys are the sighting data for abundance estimate purposes.

Given the new whaling policy by Japan, a question emerges about the current utility of the existing samples[1] and data collected by the completed FWRPs (JARPA, JARPAII, JARPN, JARPANII) and by the FWRPs that ceased in 2019 (NEWREP-A and NEWREP-NP). To my view the samples and data collected by the Japanese FWRP have important future utilities on the following research topics:

i) Assessment and management of whale resources in Japanese waters
ii) Assessment of whale resources in the Antarctic
iii) Role of whales in the marine ecosystem
iv) Calibration of non-lethal techniques

i) Assessment and management of whale resources in Japanese waters

From 1 July 2019, Japan started commercial whaling on common minke, Bryde′s and sei whales within its territorial sea and Exclusive Economic Zone (EEZ). Catch limits were calculated in line with the IWC-endorsed Revised Management Procedure (RMP) and the uncertainties evaluated through the process known as *Implementation Simulation Trials* (*ISTs*). The application of the RMP and *ISTs* are based on the best available scientific information for the target whale species. Relevant information is revised from time to time so that future catch limits can be adjusted by taking into consideration the most recent scientific information.

The most relevant information for the application of the RMP and *ISTs* are stock structure (important for defining management areas), catch history (available from the IWC database), abundance series, and reproductive information of the relevant whale species.

The analysis of genetic samples obtained during the Japanese FWRPs is essential for the application of the RMP and *ISTs* for two main reasons. The first is that, though valuable, genetic analysis of genetic samples collected by biopsy sampling during recent dedicated sighting surveys is not sufficient to elucidate stock structure. This is because the sample size is small, and the sampling is limited in geographical distribution. These new genetic samples should be analyzed in conjunction with genetic samples from the FWRPs to provide sound stock structure hypothesis for management purposes. Second, the genetic analysis on stock structure should be conducted considering the temporal factor as distribution and stock structure of a species can change with time due to environmental factors. In this context, genetic samples from FWRPs can be used as a reference in future studies on stock structure of the relevant whale species.

In the same way, sighting data obtained through the Japanese FWRPs should be analyzed in conjunction with sighting data from more recent dedicated sighting surveys to get time series abundance estimates for use in RMP and *ISTs*. Under the RMP a larger time series of abundance is preferred as it will increase the precision of the estimates and therefore will optimize the use of the RMP for calculating catch limits. In this context, the abundance estimates from the Japanese FWRPs have been and will be important for the Japanese RMP domestic process.

Information on natural mortality and age at sexual maturity is particularly important for the *ISTs*. Because such information cannot be obtained by the current dedicated sighting surveys, the use of parameters estimated from the Japanese FWRPs will continue in the future.

It should be noted here that the domestic application of the RMP and *ISTs* in Japan is responsibility of an *ad-hoc* group from different research organization. The Terms of Reference (TORs) and main works of this group were explained in Pastene (2019). One of the TORs of this group is ʻthe identification of biological data (e.g. age, reproductive data) and the process required to improve/optimize the use of the current RMPʼ. The research objectives of the NEWREP-NP were directly related to this TOR and therefore the samples and data from that program related to common and sei whales are relevant to fulfill this TOR in the near future.

ii) Assessment of whale resources in the Antarctic

The monitoring of the abundance and abundance

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[1] Not all samples are still available. A substantial number of samples collected by the FWRPs were lost because of the earthquake and tsunami that occurred in Japan in February 2011. The tsunami destroyed the marine research station of Ayukawa where most of the samples collected until that year were stored.

trends of large whales in the Antarctic is very important. For the cases of species that were heavily exploited by the middle of the 20th century, it is important to monitor their recovery and how this recovery is affecting other components of the marine ecosystem including those whale species that were not exploited substantially in the past.

Long-term abundance series can be obtained when sighting data collected by past surveys associated and not associated with FWRPs are analyzed in conjunction with more recent sighting data collected by current dedicated sighting surveys in the Antarctic, e.g. by the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A) program.

Also, genetic samples from different baleen whale species collected by biopsy sampling under the FWRPs can be analyzed with those obtained by the JASS-A and contribute in this way to understand the stock structure of those species, which is essential to interpret abundance estimates.

iii) Role of whales in the marine ecosystem

Apart from the samples and data directly relevant for management under the RMP, the Japanese FWRPs collected important data to study the role and health of whales in the marine ecosystem in both the Antarctic and western North Pacific. For example, qualitative and quantitative data on stomach content, surveys of the prey species of whales, oceanographic surveys to understand the environment of whales, samples to examine the concentration of different chemical pollutants in both whales and prey species, and surveys on marine debris on both seas surface and whales, were collected systematically.

Only the information collected by the non-lethal component of the FWRPs can be obtained by recent dedicated sighting surveys, e.g. sighting, oceanographic and marine debris surveys. The time series of such data, constructed by combining FWRPs and recent sighting surveys, are very important to investigate changes in the environment surrounding the whales. This is very important in times of climate change. Changes in the oceanographic conditions will imply changes in whale's prey distribution and by implication, changes in the distribution of whales.

Information already obtained on feeding ecology and chemical pollution from the Japanese FWRPs will be important for comparative purposes when new data on those topics emerge in the future.

iv) Calibration of non-lethal techniques

Several non-lethal research techniques are being developed by the ICR. For example, the potential use of biopsy samples for epigenetic estimation of age, analysis of progesterone in biopsy samples to obtain information of reproductive status of female whales and stable isotope to obtain information on the feeding ecology of whales. The samples and data from Japanese FWRPs can be used to calibrate non-lethal methodologies, e.g. Goto *et al.* (2020) for epigenetic analyses, Takahashi *et al.* (2022) for stable isotope analyses and Inoue *et al.* (2019) for progesterone analyses.

Also, results on non-lethal techniques such as photo-identification and satellite tracking of whales used for studying the movement and distribution of whales, can be better interpreted in the context of the stock structure analyses conducted using genetic samples obtained during the Japanese FWRPs.

CONCLUSION

The samples and data collected under the Japanese FWRPs have been and will be important for studies on assessment and management of whales targeted by Japanese commercial whaling, assessment of large whales in the Antarctic, role of whales in the marine ecosystem and in studies of calibration of new non-lethal techniques. In addition, samples and data from the FWRPs can be used in worldwide comparative studies of a more academic nature, for example on taxonomy e.g. Milmann *et al.* (2021).

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National meetings

Participation of scientists from the Institute of Cetacean Research in National Meetings in 2023

The 2023 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 2023 spring meeting of the JSFS was held in-person and online from 28 to 31 March at Tokyo University of Marine Science and Technology. Katsumata from the Institute of Cetacean Research (ICR) participated in the meeting as co-author of the studies 'Site fidelity of humpback whales around Hachijo-Jima water and interchange with Ogasawara water' and 'Age estimation of humpback whales migrating to Hachijo-Jima water in 2018–21 using DNA methylation analysis'. Matsuoka from the ICR participated in the meeting as co-author of the study 'Trial of cetacean vocalization monitoring survey by the Sea Explorer Glider'.

The 2023 meeting of the Marine Acoustic Society of Japan (MASJ)

The Marine Acoustic Society of Japan (MASJ) was established in 1973. This society implements projects related to academic survey research, dissemination and enlightenment, and encouragement of research and development related to ocean acoustics for people who are widely interested in this field. MASJ aims to spread ocean acoustics and ocean acoustic technology through Japan.

The 2023 meeting of the MASJ was held in-person and online from 25 to 26 May at Kanagawa University. Matsuoka from the ICR participated in the meeting as co-author of the study 'Development of ultra-low frequency underwater recording device'.

International meetings

Participation of scientists from the Institute of Cetacean Research in International Meetings in 2023

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 industryʼ. One of the important subsidiary bodies of the IWC is its Scientific Committee (SC), which meets annually.

The 2023 meeting of the IWC SC (SC69A) was held from 24 April to 6 May in Bled, Slovenia. This was the first in-person Committee meeting since 2019 (SC68A). Four scientists from the Institute of Cetacean Research (ICR) participated in the meetings (Pastene, Tamura, Matsuoka 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).

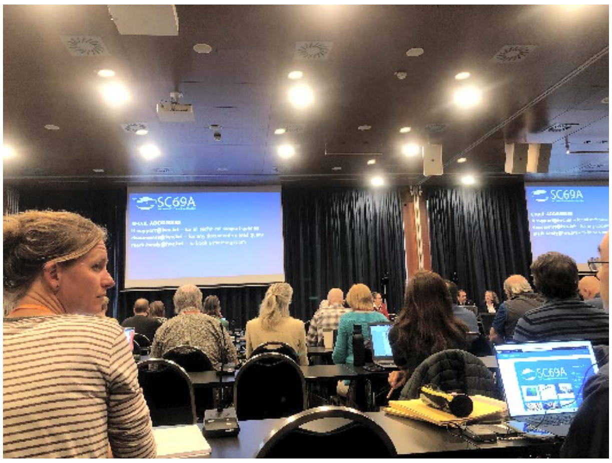
The 2024 IWC SC meeting (SC69B) will be held in Bled, Slovenia from 22 April to 4 May.

The report of the IWC SC meeting can be found on the website of the IWC (https://archive.iwc.int/pages/view.php?ref=20108&k=).

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 2023 meeting of the EMM Working Group was held from 3 to 14 July in Kochi, India. The main items on the meeting agenda were krill fishery management, spatial management and ecosystem monitoring. Under the spatial overlap analysis approach, several papers on monitoring of krill-dependent predators including whales



Meeting of the International Whaling Commission (IWC) Scientific Committee (SC69A) held at the Rikli Hotel, Bled, Slovenia.

The meeting of the Conservation of Antarctic Marine Living Resources (CCAMLR)- Ecosystem Monitoring and Management (EMM) Working Group in Kochi, India.

in western Antarctic were presented. Isoda from the ICR participated in the meeting, presenting the document entitled ‘Summary of the dedicated sighting survey under the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A) in four austral summer seasons (2019/2020–2022/2023)’.

The report of the meeting can be found on the website of the CCAMLR (https://meetings.ccamlr.org/en/wg-emm-2023).

Scientific Committee on Antarctic Research (SCAR) Biology Symposium 2023

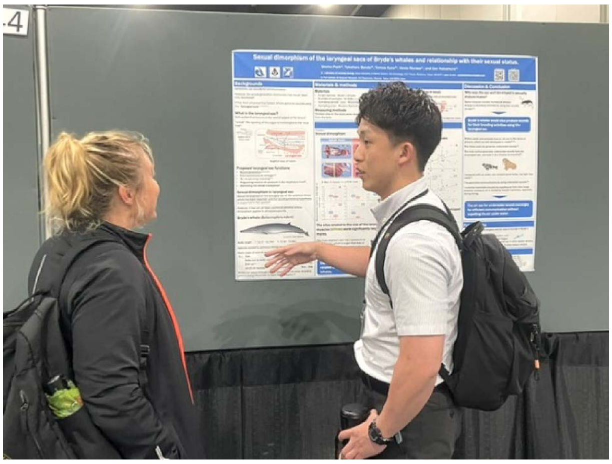
The Scientific Committee on Antarctic Research (SCAR) is a thematic organization of the International Science Council (ISC), and it was created in 1958. SCAR is charged with initiating, developing and coordinating high quality international scientific research in the Antarctic region (including the Southern Ocean), and on the role of the Antarctic region in the Earth system. SCAR provides objective and independent scientific advice to the Antarctic Treaty Consultative Meetings and other organizations such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) on issues of science and conservation affecting the management of Antarctica and the Southern Ocean and on the role of the Antarctic region in the Earth system.

The XIII SCAR Biology Symposium was held from 31 July to 4 August 2023 in Christchurch, New Zealand. Katsumata from ICR participated in the meeting. He made an oral presentation of the study ‘Wide range distribution of baleen whales in the Antarctic based on the data from the Japanese long-term ship-based monitoring’.

Presentation at the Scientific Committee on Antarctic Research (SCAR) Biology Symposium in Christchurch, New Zealand.

The 13th International Mammalogical Congress (IMC-13)

The IMC-13 meeting was co-hosted by the American Society of Mammologists and the International Federation of Mammologists. This meeting was held from 14 July to 20 July 2023 in Anchorage, Alaska, USA. Bando and Kuno from the ICR were co-authors of a poster presentation to the meeting entitled ‘Sexual dimorphism of the laryngeal sacs of Bryde's whales and its relationship with their sexual status’.



Poster presentation at the International Federation of Mammologists (IMC-13) meeting in Alaska, USA.

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 ecosystem 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 2023 NAMMCO SC (SC29) meeting was held from 23 to 26 January in Copenhagen, Denmark. Four scientists from ICR participated in the meeting (Pastene, Tamura, Konishi and Inoue) as observers from Japan. They presented the following documents: the 2021–2022 Japan progress report on large cetacean research, the 2019–2020 Japan progress report on small cetacean research, proposal for starting a collaborative study to further understand the role of baleen whales in the western North Pacific ecosystem and the 2021–2022 report on satellite tagging experiments at the Institute of Cetacean Research. The report of the meeting can be found on the website of NAMMCO (https://nammco.no/wp-content/uploads/2023/02/report-sc29_16022023_rev.pdf).

Scientists participating in the 2023 North Atlantic Marine Mammal Commission (NAMMCO) Scientific Committee meeting (SC29) in the Greenlandic Representation, Copenhagen, Denmark.

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 (MINTAG). The project started in 2022 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 meeting of the MINTAG Steering Group was held on 24 January 2023 during the NAMMCO SC meeting in Copenhagen. The main topics of the meeting were the tender material for tags, the web blog and the schedule for the test tagging experiments. Two scientists from the ICR (Pastene and Konishi) participated in the meeting as members of the Steering Group. The 6th MINTAG meeting was held on 10 October 2023 online and two scientists from ICR (Pastene and Konishi) participated the meeting. Konishi presented an update of the Japanese efforts for tagging five fin whales in June 2023. The activities of the MINTAG project can be found on the website (https://mintag-project.com/).

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 2023 meeting of the PICES was held in Seattle, USA from 23 to 27 October. The business meeting of the Marine Bird and Mammals (S-MBM) section was held on 24 September 2023. 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 on the website of PICES (https://meetings.pices.int/).

The meeting of the 2023 North Pacific Marine Science Organization (PICES) in Seattle, USA.

Peer-reviewed publications

List of peer-reviewed publications based on the Institute of Cetacean Research (ICR)'s surveys up to 2023

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).

Kasamatsu, F., Kishino, H. and Hiroyama, H. 1990. Estimation of the number of minke whale (*Balaenoptera acutorostrata*) schools and individuals based on the 1987/88 Japanese feasibility study data. *Rep. int. Whal. Commn* 40: 239–247.

Kato, H., Fujise, Y., Yoshida, H., Nakagawa, S., Ishida, M. and Tanifuji, S. 1990. Cruise report and preliminary analysis of the 1988/89 Japanese feasibility study of the special permit proposal for southern hemisphere minke whales. *Rep. int. Whal. Commn* 40: 289–300.

Kato, H., Kishino, H. and Fujise, Y. 1990. Some analyses on age composition and segregation of southern minke whales using samples obtained by the Japanese feasibility study in 1987/88. *Rep. int. Whal. Commn* 40: 249–256.

Nagasaki, F. 1990. The Case for Scientific Whaling. *Nature* 334: 189–190.

Tanaka, S. 1990. Estimation of natural mortality coefficient of whales from the estimates of abundance and age composition data obtained from research catches. *Rep. int. Whal. Commn* 40: 531–536.

1991 (9)

Bergh, M.O., Butterworth, D.S. and Punt, A.E. 1991. Further examination of the potential information content of age-structure data from Antarctic minke whale research catches. *Rep. int. Whal. Commn* 41: 349–361.

Ichii, T. and Kato, H. 1991. Food and daily food consumption of southern minke whales in the Antarctic. *Polar Biol* 11 (7): 479–487.

Kasamatsu, F., Kishino, H. and Taga, Y. 1991. Estimation of southern minke whale abundance and school size composition based on the 1988/89 Japanese feasibility study data. *Rep. int. Whal. Commn* 41: 293–301.

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