Catch limits for western North Pacific fin whales calculated in line with the IWC's Revised Management Procedure (RMP)

Japan's RMP Team

EXECUTIVE SUMMARY

Background

After withdrawal from the International Convention for the Regulation of Whaling (ICRW), Japan resumed commercial whaling from July 2019 within Japan's territorial waters and Exclusive Economic Zone (EEZ).

Under the Act for Ensuring Sustainable Use of Whales, enacted in 2017, the Government of Japan (GOJ) is required to support the sustainable development of whaling. For this purpose, based on the best scientific information available, GOJ specified that the western North Pacific fin whale (*Balaenoptera physalus*) is appropriate as a further baleen whale species to be targeted by commercial whaling. The sea area of operations for fin whales will remain within Japan's territorial waters and its EEZ.

Catch limits for western North Pacific fin whales have been calculated in line with the IWC's Revised Management Procedure (RMP), based on the Norwegian Catch Limit Algorithm (CLA) computer code and for a tuning level of 0.6.

The application of the CLA was based on the best and latest scientific information on stock structure, which is essential to define management areas (*Small Areas*) and estimate abundance.

Small Areas and abundance

Two *Small Areas* were developed based on the best information on stock structure. The latest (2020) estimate of abundance for the *Small Area* chosen was 19,734.

Catch limits

Based on the CLA, catch limit for fin whales was calculated as 205. The robustness of this catch limit was examined for some uncertainties through the *Implementation Simulation Trials* (*ISTs*). This catch limit was robust to alternative catch series, alternative additional variance, alternative productivity, alternative natural mortality and alternative g(0) values.

Japan's implementation of the RMP will continue to be based on the best available science; hence, the catch limit will be revised from time to time to take account of the latest scientific information.

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1. INTRODUCTION

After withdrawal from the International Convention for the Regulation of Whaling (ICRW), Japan resumed commercial whaling from July 2019 within Japan's territorial waters and Exclusive Economic Zone (EEZ).

Under the Act for Ensuring Sustainable Use of Whales, enacted in 2017, the Government of Japan (GOJ) is required to support the sustainable development of whaling. For this purpose, based on the best scientific information available, GOJ specified that the western North Pacific fin whale (*Balaenoptera physalus*) is appropriate as a further baleen whale species to be targeted by commercial whaling. The sea area of operations for fin whales will remain within Japan's territorial waters and its EEZ.

The objective of this document is to describe the process for the catch limit calculation in line with the International Whaling Commission's (IWC's) Revised Management Procedure (RMP), by a domestic specialist's group (Japan's RMP team), together with an explanation of the data and analytical procedures used in the process. The process, data and analytical procedures summarized in this document will be reviewed by an independent group of international scientists (Review Panel).

First, the genetic and non-genetic data are analyzed in detail to establish stock structure hypotheses. Then sub-areas and management areas (*Small Areas*) are defined based on the information regarding the most plausible stock structure hypothesis. Secondly, the abundance estimates and data on removals in sub-areas and *Small Areas* are explained in detail. Finally, the calculation of catch limit in line with the RMP is explained together with analyses related to uncertainty based on *Implementation Simulation Trials* (*ISTs*).

2. JAPANESE CONCEPT FOR THE IMPLEMENTATION OF THE RMP FOR WESTERN NORTH PACIFIC FIN WHALES

Japan's implementation of the RMP has been and will be based on the best available science; hence the catch limits will be revised from time to time to reflect the latest scientific information. Therefore, Japan will continue to update abundance estimates and refine the stock structure hypothesis based on data and samples obtained from new surveys. It will also investigate other aspects of uncertainties such as the value of Maximum Sustainable Yield Rate (MSYR) based on the analyses of new data and samples to be obtained from commercial whaling operations. All these aspects will be duly examined at the assessment review planned tentatively after six years-period.

Also, in the same way as the catch limit calculations of western North Pacific sei, Bryde's and common minke whales (JRT, 2019; JRT, 2021), catch limits of western North Pacific fin whale have been calculated based on the Norwegian Catch Limit Algorithm (CLA) (Aldrin and Huseby, 2007; Aldrin et al., 2008), fixing a tuning level of 0.6. Acceptability of management variants was evaluated through the *ISTs* using a modified version of the IWC program for western North Pacific Bryde's whales (Allison and de Moor, 2020). This was considered appropriate because the structure of the population dynamics model used in the Bryde's whale *IST* program, such as the number of the sub-areas and time interval, was similar to the North Pacific fin whale case.

Modifications to the Bryde's whale program were made to match the input data (e.g., historical catches, abundance estimates, mixing proportions) for North Pacific fin whales, and to allow for a g(0) estimate to be incorporated into the robustness trials.

3. STOCK STRUCTURE AND DEFINITION OF *SMALL AREAS*

3.1 Summary of genetic studies

Genetic analyses on the stock structure of North Pacific fin whales were based on all available genetic samples in this oceanic basin (Taguchi and Goto, 2023; this meeting). Those authors also provided a brief review of previous genetic studies of this species in the North Pacific. The section below is a summary of the information provided and analyses conducted by those authors.

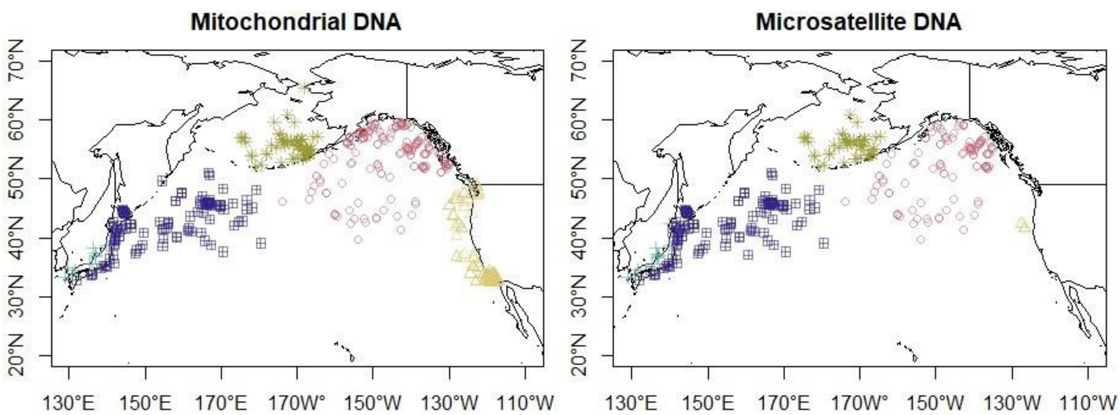
Previous genetic studies
Fujino (1960) investigated the stock structure of North Pacific fin whales using blood group antigens in whales from the East China Sea, off Kamchatka, and south and north of the eastern Aleutians. The study suggested the following possibilities: (1) there are different stocks in the western and eastern Aleutians, (2) whales from the East China Sea belong to a local stock which is nearly isolated from stocks in other areas studied; and (3) some degree of mingling occurs between west and east areas around the Aleutians.

Wada and Numachi (1991) conducted allozyme analyses to estimate the level of genetic variability and genetic differentiation of the Balaenoptera at inter and intra species levels using North Pacific fin whale specimens collected in the east of 160°E. These found no evidence of genetic heterogeneity within the sample set.

Bérubé *et al*. (2002) analyzed the geographic distribution of genetic variation for mitochondrial (mtDNA) control region sequences and microsatellite (msDNA) genotypes in specimens collected from year-round resident fin whales in the Sea of Cortez as well as from the eastern North Pacific. Their results showed that fin whales in the Sea of Cortez constitute a highly isolated and thus evolutionary unique population.

Genetic samples and dataset
A total of 343 genetic samples from the seven sources was used: (1) biopsy sampling under the Japanese Whale Research Program under Special Permit in the western North Pacific (JARPN) and from the second phase of JARPN (JARPNII); (2) bycatches; (3) biopsy sampling under the International Whaling Commission–Pacific Ocean Whale and Ecosystem Research (IWC-POWER) program; (4) biopsy sampling under the Japanese dedicated sighting surveys, (5) biopsy sampling conducted in the tagging and biopsy experiment off Abashiri; (6) strandings and (7) historical commercial whaling.

The dataset generated from these samples yielded a total of 331 msDNA genotypes at 16 loci after data validation (Figure 1). For mtDNA, a total of 309 control region sequences generated from those samples was combined with the data generated by Archer *et al*. (2019) and Kim *et al*. (2018), which resulted in a total of 613 sequences for the data analysis (Figure 1).



SOJ ✚	WNP ⊞	BRS ✳	ENP ○	C-ENP △	Total
13/11	85/87	70/48	276/161	169/4	613/311

Figure 1. Sampling position and number (mtDNA / msDNA) of North Pacific fin whales used in the data analysis. Symbol shape and color indicate the sample group that was defined, based on the grouping derived from the exploratory analyses.

Analytical approaches
First, exploratory analyses were performed using both mtDNA and msDNA markers and arbitrary sample groups, which resulted in specifying the five sample groups as shown in Figure 1: the Sea of Japan (SOJ), the western North Pacific plus the Okhotsk Sea (WNP), the Bering Sea (BRS), the offshore eastern North Pacific plus Gulf of Alaska (ENP), and the coastal eastern North Pacific (C-ENP).

mtDNA variation was estimated by nucleotide (π) and haplotype (h) diversities (Nei 1987). The differences in haplotype frequencies between the sample groups were examined, and the degrees of the differentiation were assessed by pairwise F_{ST} estimates (Weir and Cockerham 1984).

msDNA variations (*i.e.*, the number of alleles, inbreeding coefficient, and the expected and observed heterozygosities) were estimated, and departure from Hardy–Weinberg equilibrium was also tested. The genetic differentiation between the sample groups was examined in the same manner as for the mtDNA.

A spatial Principal Component Analysis (sPCA, Jombart et al. 2008) was performed to investigate the spatial patterns in genetic variability. Possible change in genetic variation was also examined along a longitudinal cline in the North Pacific using genetic statistics (*i.e.*, global scores of sPCA and h).

Results and conclusions of the genetic analyses
The heterogeneity test showed genetic divergence of SOJ and C-ENP for both markers, and further differentiation among WNP, ENP and BRS at least for mtDNA. The F_{ST} estimates also suggested that the degrees of differentiation are different among the pairwise comparisons.

The sPCA analysis showed a genetic structuring with two clusters (Figure 2): one cluster occurring mostly in the North Pacific, west of 175°E and the Okhotsk Sea, and the other distributed mainly in the North Pacific, east of 175°E as well as in the Bering Sea. This finding was also favored by a high-resolution analysis of the genetic statistics, which showed a switch between the western and eastern North Pacific.

Overall then, the present genetic analyses demonstrate the existence of the three stocks in the research area. Two of them, which have management relevance, were found in the North Pacific: (1) 'WNP' stock distributed mainly in the North Pacific, west of 175°E and in the Okhotsk Sea; and (2) 'ENP' stock distributed mainly in the North Pacific, east of 175°E and in the Bering Sea. The third stock (SOJ) is distributed in the Sea of Japan. As reported above, another local stock is to be found in the Sea of Cortez (SOC, Bérubé et al. 2002); neither of these have immediate management relevance. Quotation marks are used to refer name of stocks.

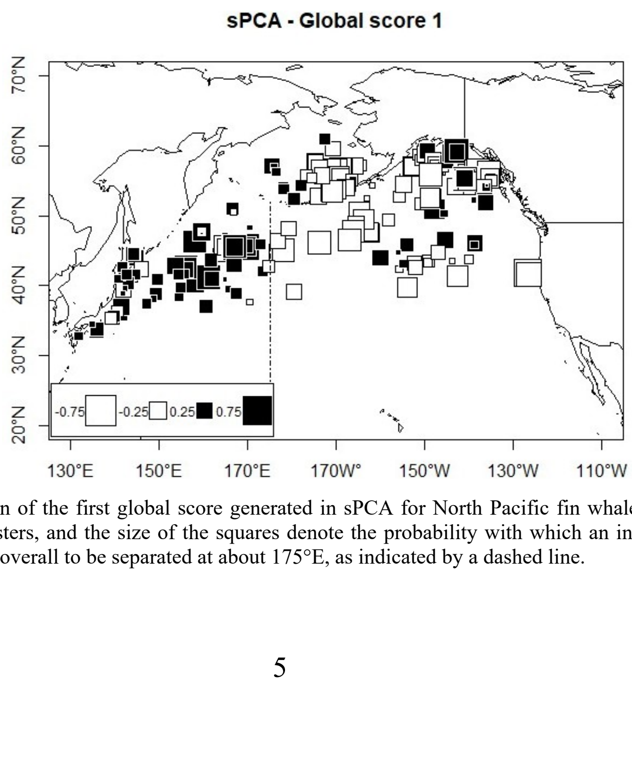


Figure 2. Geographical distribution of the first global score generated in sPCA for North Pacific fin whales. The black and white squares represent two distinct clusters, and the size of the squares denote the probability with which an individual belongs to that cluster. The two clusters appeared overall to be separated at about 175°E, as indicated by a dashed line.

The sPCA analysis also suggested mixing between ‘WNP’ and ‘ENP’ stocks in different localities and at different proportions, which was consistent with the results of F_{ST} estimates showing different degrees of differentiation. The proportions present of ‘WNP’ and ‘ENP’ stocks were, thus, tentatively calculated by sub-area (Figure 3) (see sub-area definition in Item 3.4), based on the sPCA assignment: whales with smaller than -0.2 and larger than 0.2 for the first global score were assigned to ‘ENP’ and ‘WNP’ stocks, respectively. This calculation suggested that the proportions of ‘WNP’ stock were 94%, 5%, and 33% for sub-areas 1, 2 and 3, respectively (Figure 3).

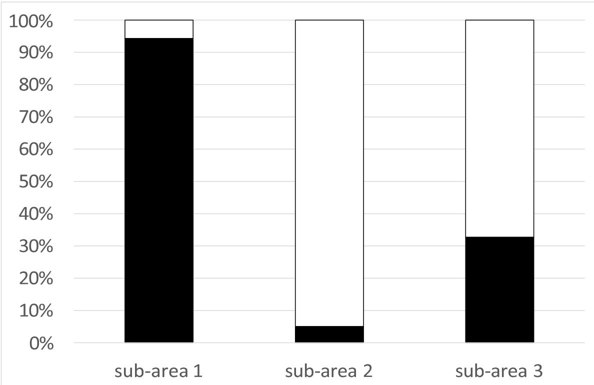


Figure 3. Mixing proportions of ‘WNP (black)’ and ‘ENP (white)’ fin whales based on the assignment by the sPCA first global score by sub-area.

3.2 Summary of non-genetic studies

A brief review of the historical and current non-genetic information on stock structure in the North Pacific has been conducted by Konishi *et al*. (2023) (this meeting). The non-genetic information summarized involved distribution of historical catches, sighting distribution, biological data, Discovery-type mark-recapture data and satellite-monitored tagging.

Commercial catches and sighting survey data show no gaps in the North Pacific while a clear separation between the Sea of Japan/East China Sea and the Pacific Ocean is evident in the commercial catches. Movements of fin whales from the Discovery-type mark-recapture records and recent satellite-monitored tagging show movements of fin whales among regions in the eastern and western North Pacific, Bering Sea and the California coast, but no movements from and into the Sea of Japan from other regions. Frequent movements of fin whales have been observed between the Okhotsk Sea and the western North Pacific. In addition, some biological features differ between fin whales in the East China Sea and other areas.

In summary, overall most of the non-genetic information reviewed suggests continuity in the distribution of fin whales throughout the North Pacific and adjacent seas. There is some evidence from the non-genetic information indicating separation of fin whales between the East China Sea/Sea of Japan and other regions in the North Pacific.

3.3 Hypothesis on stock structure

Goto and Taguchi (2023) (this meeting) have identified the most plausible stock structure hypothesis based on the newest genetic analyses and the review of non-genetic information. This hypothesis is presented in this section. They propose a four-stock structure hypothesis. The four stocks are the following:

Sea of Japan/East China Sea stock (‘SOJ’): distributed mainly in the Sea of Japan and East China Sea. There are genetic and non-genetic data supporting the separation of this stock from the others.

Western North Pacific stock (‘WNP’): distributed mainly in coastal and offshore areas of the western North Pacific, west of 175°E and the Okhotsk Sea. There are genetic data supporting the differentiation of this stock from that found mainly in the eastern North Pacific.

Eastern North Pacific stock ('ENP'): distributed mainly in coastal and offshore areas of the eastern North Pacific, east of 175°E and the Bering Sea. There are genetic data supporting the differentiation of this stock from that found mainly in the western North Pacific.

Sea of Cortez stock ('SOC)': distributed in the Sea of Cortez (Gulf of California). Such a separate stock was proposed previously based on genetic analyses (Bérubé *et al*., 2002).

The stocks relevant for current management are the 'WNP' and 'ENP' stocks. These two stocks mix geographically in different proportions in different regions of the North Pacific, as shown graphically in Figure 4. Details of the mixing proportions are provided in section 3.1.

This stock structure hypothesis is the basis for the definition of sub-areas and *Small Areas*.

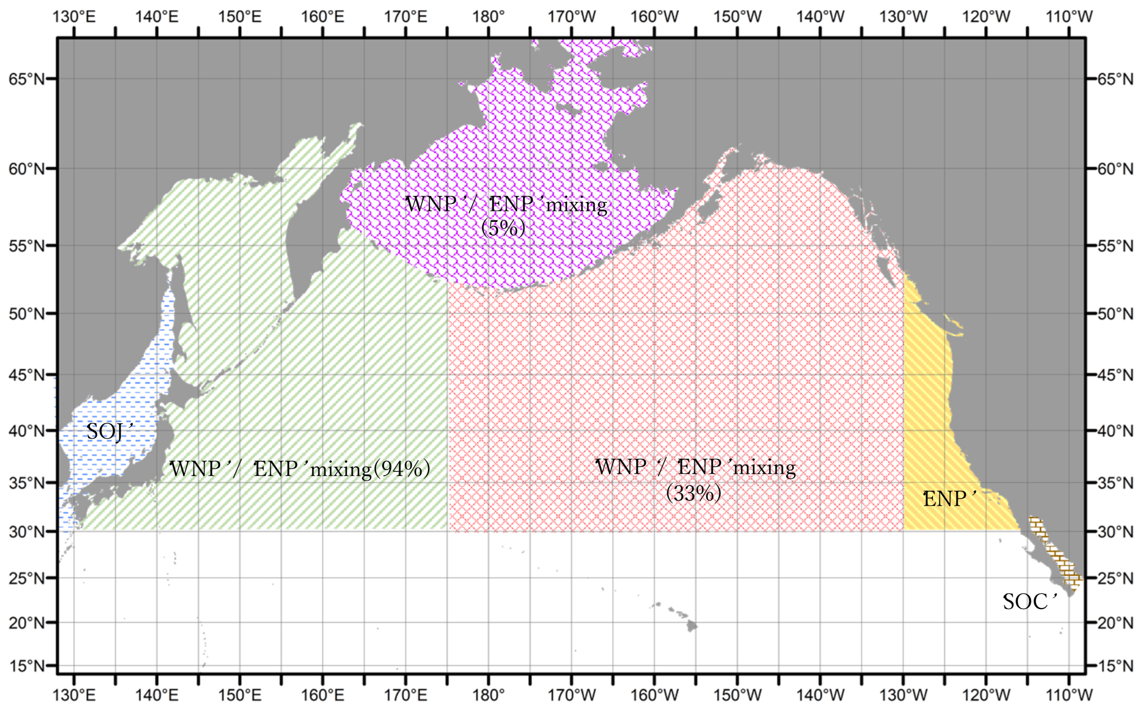


Figure 4. Approximate distribution of stocks under the four-stock structure hypothesis for fin whales in the North Pacific, suggested by a combination of genetic and non-genetic data. Hatching indicates core distribution area for each stock. Figures in parenthesis show proportions of the 'WNP' stock.

3.4 Definition of sub-areas

The regions to be managed (Okhotsk Sea, North Pacific and Bering Sea) were divided into four sub-areas (Figure 5), which were used to develop the *Implementation Simulation Trials* for this species (see section 8 for more details). Sub-area 1 is defined as Okhotsk Sea and western North Pacific (WNP), north of 35°N and between the eastern coast of Japan and the 175°E longitudinal line. Sub-area 2 is defined as Bering Sea. Sub-area 3 is defined as eastern North Pacific (ENP) north of 35°N in the longitudinal sector between 175°E and 180°, and north of 40°N in the longitudinal sector between 180° and 135°W.

In order to define *Small Areas* (see section 3.5), sub-area 3 was divided into western and eastern parts by the longitudinal line of 160°W. We refer the western part as sub-area 3W and the eastern part as sub-area 3E.

The longitudinal boundary between sub-areas 1 and 3 has been determined based on the results for longitudinal genetic variations in Taguchi and Goto (2023) (this meeting). The southern boundary of sub-areas 1 and 3 and eastern boundary of sub-area 3 are defined according to areas where dedicated sighting surveys were conducted in 2017-2022 summer (July – September). It should be noted that a few genetic samples are available from south of those boundaries.

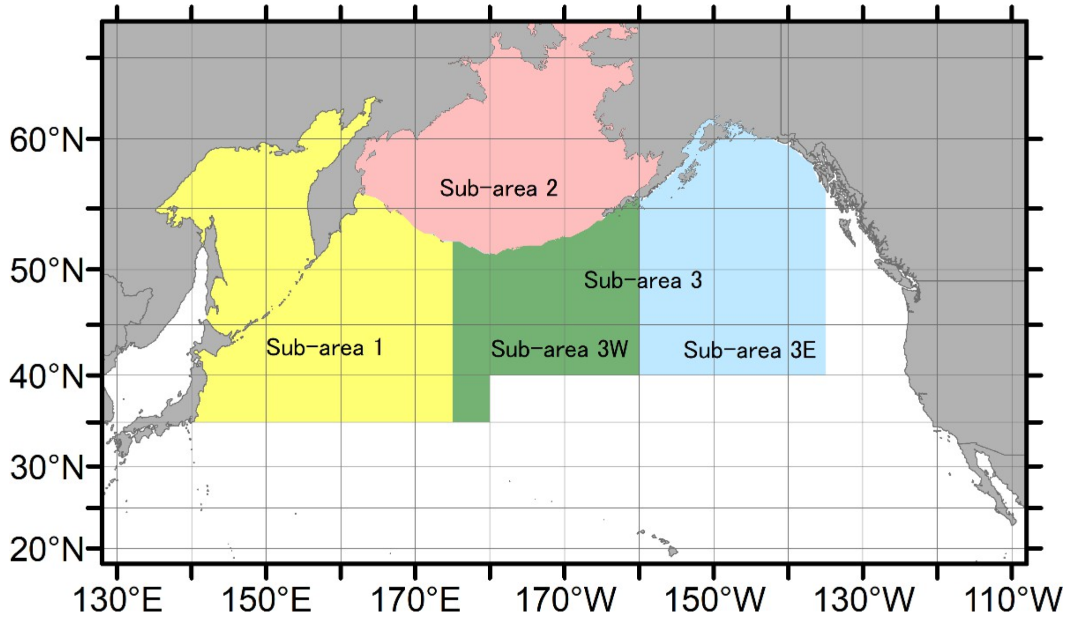


Figure 5. The four sub-areas used for the *Implementation Simulation Trials* (*IST*) for North Pacific fin whales.

3.5 Definition of *Small Areas*

Two *Small Areas* were defined:

i) Sub-area 1 is a *Small Area*
ii) Sub-area 1 and sub-area 3W is a *Small Area*

It is noted that whaling operations will be conducted in sub-area 1 within Japan's territorial waters and EEZ, where most of the fin whales are expected to be from the 'WNP' stock though a small portion of 'ENP' stock animals could be taken given the stocks proportions shown in Figure 4.

4. ABUNDANCE ESTIMATES

4.1 Abundance estimates from previous studies

Japanese dedicated sighting surveys were conducted during the decade 2003-2014 in different regions including the Sea of Okhotsk, the western North Pacific, and the eastern North Pacific, using the line transect method. Abundance estimates from those surveys assuming g(0) = 1 are shown below.

In the Sea of Okhotsk the abundance was estimated to be 3,730 (CV = 0.310) in 2003 (Kato, 2009); in the western North Pacific Ocean it was estimated as 3,958 (CV = 0.425) in 2008 (Hakamada and Matsuoka, 2016); in the area to the east of the Okhotsk Sea (EO) it was estimated as 2,004 (CV = 0.385) in 2005 (Kato, 2009); and in the eastern North Pacific it was estimated as 30,982 (CV = 0.199) in 2010-2012 (Takahashi *et al.*, *in prep.*).

4.2 Recent abundance estimate in the North Pacific assuming g(0)=1

Takahashi *et al*. (2023a) (this meeting) have estimated the abundance of fin whales in the North Pacific based on surveys that covered the whole oceanic basin. A summary of their results is presented in this section.

Data used
Japanese dedicated sighting surveys were conducted during the summer season (July-September) in 2020 and 2021 (Katsumata *et al*., 2021; 2022). The IWC-POWER sighting surveys were conducted in 2017-2022 (Matsuoka *et al*., 2018; 2019; 2020; Murase *et al*., 2021; 2022; Morse *et al*., 2023). All these surveys were conducted in July-August.

These surveys were all conducted in a systematic manner during these years, and they followed the survey design guidelines of the IWC SC (IWC, 2012a). Figure 6 shows the tracklines and sighting positions from those surveys.

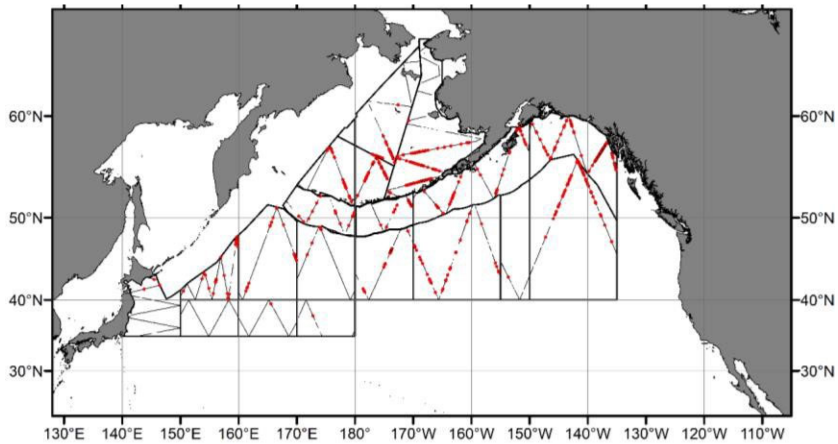


Figure 6. Surveyed track-lines and the positions of primary sightings of fin whales (red circles) for the Japanese dedicated sighting surveys conducted in 2020-2021, and IWC-POWER surveys conducted over 2017-2022. All these surveys were conducted in July-September.

Analytical procedures
Analytical procedures followed the IWC SC guidelines (IWC, 2012a). Basically, the distance sampling method is applied to estimate abundance. Abundance estimates and their CVs were estimated based on a Horviz-Thompson-like estimator. The computations were conducted truncating the detections at 3.0 n. miles perpendicular distance for this species as is conventional, and the probability of detection on the trackline was assumed to be 1 ($g(0) = 1$). Hazard-rate and Half-normal models were considered as candidate models for the detection function.

In order to consider the effect of factors which affected detectability such as school size, Beaufort Sea state and visibility, those were treated as covariates in the Multiple Covariates Distance Sampling within the DISTANCE program. The best model was selected as the one for which the Akaike's Information Criterion (AIC) value was the smallest.

Results
Abundance estimates were computed for the Bering Sea, and the western and eastern North Pacific (divided at 180°). Table 1 shows the abundance estimate by geographical area.

Table 1. Abundance estimates for North Pacific fin whales, by geographical area, based on sightings from Japanese dedicated sighting surveys (western and central North Pacific) and IWC-POWER sighting surveys (western, central and eastern North Pacific and the Bering Sea) assuming g(0)=1.

Geographical area	Year	Abundance	CV
Bering Sea	2018	9,885	0.201
Western North Pacific	2020	4,405	0.241
Eastern North Pacific	2020	37,297	0.181

4.3 Recent abundance estimates in the Okhotsk Sea assuming g(0)=1

Miyashita (2023) (this meeting) has estimated the abundance of fin whales in the Okhotsk Sea based on collaborative Russia-Japan sighting surveys. A summary of his results is presented in this section.

Data used

To cover the restricted area in the north-eastern waters of the Sea of Okhotsk which had been in place for a long time, the first survey under the Russia-Japan cooperative project was launched in 2015. Since then, these surveys have been conducted every year in August-September, following the IWC/SC sighting survey guidelines and using the same Russian research vessel.

The vessel is equipped with a barrel 15m in height from the sea surface, and two observers have conducted sighting regularly from this platform. The survey mode was closing mode for large whales under the suitable weather conditions. Observers used naked eyes for primary observation, and binoculars were used as a supplement for confirmation of sightings including species identification and school size estimation.

The track line traversed with sighting effort and positions of primary sightings of fin whales are shown in Figure 7.

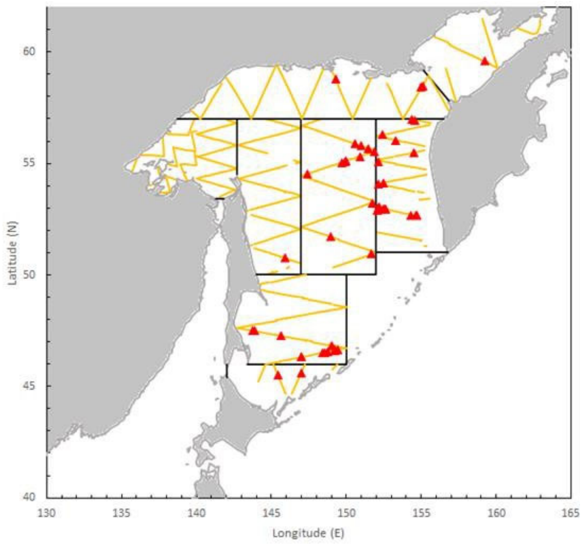


Figure 7. Track line traversed with sighting effort (yellow line) and positions of primary sightings of fin whales (red triangle) in Okhotsk Sea surveys.

Analytical procedures

Analyses were carried out using the Multiple Covariate Distance Sampling (MCDS) Engine in Distance 7.3 Release 1 (Thomas et al., 2010) and the abundance was estimated based on detection probability in a Horvitz-Thompson-like estimator. The basic models for fitting the perpendicular distance distribution were the Half-normal and Hazard-rate, while weather conditions (wind force and visibility) and school size were considered as covariates. AIC was used to select the best model.

Results
The best fitted model was the Half-normal model with no covariates. The total abundance estimate was 2,715 (CV 0.269, 95% CI 1,616 – 4,560).

4.4 Estimate of g (0)
Data used
To obtain this estimate, mark-recapture-like data, *i.e.*., Independent Observer (IO) data, were collected during IO mode surveys which have been conducted for the Japanese dedicated and IWC-POWER sighting surveys.

Analytical procedures
Mark-recapture distance sampling (MRDS) method were used to estimate the probability of detection on the trackline, i.e., $g(0)$, for correcting abundance estimates assuming $g(0) = 1$ which include perception bias due to sightings that are missed. The details of the MRDS method are described in Laake and Borchers (2004) and Burt *et al*. (2014). The analyses were conducted using the package "mrds" in R-DISTANCE (Thomas *et al*., 2010). Details of the application of this method to the present data are given in Takahashi *et al.*(2023b) (this meeting).

The probability of detection by an observer, given detection by the other observer, was provided by the MR model which was modelled by a logistic regression with the following covariates: platform (TOP or IO barrel), school size, Beaufort Sea state, sightability and visibility. The candidate models were fitted to the four IO data sets, with and without geographical stratification as for that in the recent abundance estimation in the North Pacific. The best-fitted model was selected by using AIC. Furthermore, the conditional detection probabilities can be used to estimate the probability of detection on the trackline by at least one observer.

Results
The best models selected by AIC include the MR model with the covariates platform, school size and visibility, and a DS model with the covariate school size. From the best fitted MR model, the probabilities of detection on the trackline by observers from one platform, given that it was detected by observers from another platform, were 0.864 (CV = 0.031) for the top barrel and 0.773 (CV = 0.047) for the IO platform. The probability of detection on the trackline by at least one observer was 0.967 (CV = 0.012). Abundance estimates by geographical areas adjusting by the g(0) estimates using the method mentioned in sections 7 and 8 were shown in Table 2. Using the mixing proportion described in Figure 3, sum of the abundance estimates in Table 2 corresponding to 'WNP' and 'ENP' stocks are 19,299 (CV=0.145) and 35,430 (CV=0.143) respectively

Note: The computation of abundance estimates and the use of *g* (0) for management purposes, i.e., by *Small Area*, is explained in sections 7 and 8.

Table 2. Abundance estimates for North Pacific fin whales, by geographical area, adjusted by the g(0) estimate.

Geographical area	Year	Abundance	CV
Okhotsk Sea	2019	3,142	0.271
Bering Sea	2018	9,885	0.201
Western North Pacific	2020	4,405	0.241
Eastern North Pacific	2020	37,297	0.181

5. CATCH HISTORY

Yoshida and Maeda (2023) (this meeting) have summarized the catch history of fin whales in the North Pacific. The catch series for fin whales in the North Pacific were constructed from the latest IWC individual and summary catch database Version 7.1 (Allison, 2020), following the same procedure as used for compiling the catch series for western North Pacific Bryde's whales (IWC, 2008).

In some years, catch data for North Pacific whales were insufficient to allocate catches to species and/or to operational area with sufficient reliability. Unspecified catches of whales were allocated to species using the best available information on the species composition of the catch. Animals with no information on the operational area were allocated to area using proportion by area of animals for which the species was known. Where the sex ratio of catches was not known accurately, a 50:50 sex ratio (derived from sex of known animals) was used to allocate catches of sex. The catch series also includes anthropogenic mortality of animals recorded in the North Pacific during 2004-2021. Lastly, catches were allocated to each of the sub-areas, using information on catch positions. Best and high catch series were constructed. High catch series were obtained assuming that all the unspecified whales taken were fin whales (Yoshida and Maeda, 2023) (this meeting).

Note: Catch series for use for management purposes are given in sections 7 and 8.

6. BIOLOGICAL PARAMETERS

A brief review of the information on biological parameters has been conducted by Maeda and Hakamada (2023) (this meeting). Those authors concluded that the information on biological parameters for fin whales in the North Pacific relevant for management is dated, as the values were estimated some 50 years ago. If the abundance has increased since the end of commercial whaling in 1975, the values of biological parameter estimated at that time have probably changed.

On the other hand, the biological parameter values for North Atlantic fin whales have been obtained in more recent years. For this reason, the relevant biological parameters used for the *ISTs* of North Atlantic fin whales conducted in 2016 (IWC, 2017) have been used in the case of North Pacific fin whales.

For assumptions on selectivity, the values used during the 1991's comprehensive assessment of North Atlantic fin whales for age at recruitment were used because the method used for the 2016 *ISTs* for the North Atlantic fin whales cannot be applied to estimate the selectivity parameter of the North Pacific fin whales due to the lack of catch-at-age data. The natural mortality rate of 0.08 used in the 2016 *ISTs* is unrealistically high. Given the natural mortality estimates for other large baleen whales, 0.05 will be used for the base case scenario and 0.07 for the sensitivity test.

7. CATCH LIMIT

The CLA was applied to Small Areas i) and ii) defined in section 3.5. The CLA requires historical catch and abundance data for the corresponding *Small Areas*.

7.1 Catch data used in the CLA

Historical catch data in the two *Small Areas* during 1906-2021 are shown in Tables 3 and 4 based on Yoshida and Maeda (2023) (this meeting). The numbers of catches in 2022 and 2023 are assumed to be same as those in 2021.

Table 3. The numbers of historical catches of North Pacific fin whales consisting of commercial catches during 1906-1975 based on IWC DB ver 7.1 and anthropogenic mortalities during 2004-2021 based on national progress reports in *Small Area* i) (Yoshida and Maeda, 2023) (this meeting).

Year	Small area		Total	Year	Small area		Total
	M	F			M	F	
1906	12	12	24	1950	164	130	294
1907	31	30	61	1951	236	176	412
1908	72	72	144	1952	422	360	782
1909	41	42	83	1953	512	445	957
1910	105	104	209	1954	620	527	1147
1911	230	230	460	1955	264	271	535
1912	173	174	347	1956	355	319	674
1913	229	227	456	1957	258	262	520
1914	325	325	650	1958	277	272	549
1915	196	197	393	1959	214	198	412
1916	225	225	450	1960	239	243	482
1917	170	169	339	1961	236	185	421
1918	204	204	408	1962	198	175	373
1919	119	120	239	1963	529	587	1116
1920	115	115	230	1964	825	813	1638
1921	129	129	258	1965	312	302	614
1922	48	48	96	1966	288	307	595
1923	124	124	248	1967	384	473	857
1924	90	92	182	1968	398	403	801
1925	107	107	214	1969	315	305	620
1926	112	111	223	1970	170	168	338
1927	80	79	159	1971	157	147	304
1928	85	85	170	1972	287	240	527
1929	105	111	216	1973	77	73	150
1930	68	69	137	1974	48	50	98
1931	75	74	149	1975	27	22	49
1932	52	50	102	2004	0	0	0
1933	82	83	165	2005	0	0	0
1934	113	114	227	2006	0	0	0
1935	126	117	243	2007	1	0	1
1936	105	102	207	2008	0	1	1
1937	75	80	155	2010	0	0	0
1938	85	80	165	2011	0	0	0
1939	109	111	220	2012	0	0	0
1940	211	192	403	2013	3	3	6
1941	290	296	586	2014	1	0	1
1942	193	168	361	2015	0	0	0
1943	126	137	263	2016	0	1	1
1944	129	144	273	2017	0	0	0
1945	81	82	163	2018	0	0	0
1946	141	158	299	2019	0	0	0
1947	163	159	322	2020	0	1	1
1948	171	155	326	2021	2	1	3
1949	160	138	298	Total	13470	13072	26542

Table 4. The numbers of historical catches of North Pacific fin whales consisting of commercial catches during 1906-1975 based on IWC DB ver 7.1 and anthropogenic mortalities during 2004-2021 based on national progress reports in *Small Area* ii) (Yoshida and Maeda, 2023) (this meeting).

Year	Small area		Total	Year	Small area		Total
	M	F			M	F	
1906	12	12	24	1950	171	134	305
1907	31	30	61	1951	241	180	421
1908	72	72	144	1952	435	373	808
1909	41	42	83	1953	520	453	973
1910	105	104	209	1954	737	650	1387
1911	230	230	460	1955	304	319	623
1912	223	223	446	1956	437	411	848
1913	229	227	456	1957	533	516	1049
1914	386	385	771	1958	550	478	1028
1915	253	254	507	1959	252	246	498
1916	256	256	512	1960	285	289	574
1917	205	204	409	1961	400	316	716
1918	250	250	500	1962	390	326	716
1919	183	185	368	1963	633	693	1326
1920	157	157	314	1964	1098	1070	2168
1921	129	129	258	1965	472	446	918
1922	102	102	204	1966	417	447	864
1923	170	170	340	1967	496	620	1116
1924	136	146	282	1968	437	452	889
1925	167	168	335	1969	452	443	895
1926	163	190	353	1970	195	194	389
1927	95	105	200	1971	197	178	375
1928	102	109	211	1972	327	273	600
1929	125	139	264	1973	84	81	165
1930	78	78	156	1974	50	55	105
1931	75	74	149	1975	29	27	56
1932	52	51	103	2004	0	0	0
1933	88	88	176	2005	0	0	0
1934	157	152	309	2006	1	0	1
1935	148	144	292	2007	1	0	1
1936	146	144	290	2008	0	1	1
1937	119	115	234	2010	0	0	0
1938	111	103	214	2011	0	0	0
1939	142	155	297	2012	0	0	0
1940	220	200	420	2013	3	3	6
1941	303	309	612	2014	1	0	1
1942	204	179	383	2015	0	0	0
1943	133	144	277	2016	0	1	1
1944	136	152	288	2017	0	0	0
1945	88	89	177	2018	0	0	0
1946	141	158	299	2019	0	0	0
1947	163	159	322	2020	0	1	1
1948	171	155	326	2021	2	1	3
1949	160	138	298	Total	16807	16353	33160

7.2 Abundance estimates used in the CLA

Abundance estimates based on the sighting surveys were obtained as described in the section 4. Abundance estimates by survey region that are necessary to calculate abundance estimates for use in the CLA are listed in Table 5. A map showing the regions is provided in Figure 8.

Table 5. Abundance estimates by survey region used for derivation of the abundance estimates needed to apply the CLA. Region refers to the survey regions shown in Figure 8. EO is the area to the east of the Okhotsk Sea. POWER indicates if the survey was part of the IWC-POWER programme. Period is 1st period (2003-2014) or 2nd period (2017-2022). SA is the sub-area in which the region is included. Year is the average of the years when survey was conducted. AC (%) is proportional areal coverage. IO indicates if IO mode survey was conducted. g(0) indicates point estimate of g(0) to be applied. References are 1: Kato (2009), 2: Miyashita (2023), 3: Hakamada and Matsuoka (2016), 4: Takahashi et al. (2023a), 5: Takahashi (in prep.).

Region	POWER	Period	SA	Year	Abundance	CV	AC(%)	IO	g(0)	Ref
Okhotsk Sea	N	1st	1	2003	3,730	0.310	81.6	N	0.864	1
	N	2nd		2019	2,715	0.269	90.9	N	0.864	2
JARPNII (ex. Foreign EEZ) EO	N	1st	1	2008	3,958	0.425	100.0	N	0.864	3
	N	2nd		2020	2,696	0.324	100.0	Y	1.000	4
WNP_E (170E-175E)	N	1st	1	2005	2,004	0.385	100.0	N	0.864	1
	Y	1st	1	2011	176	0.872	100.0	N	0.864	5
	Y	2nd		2021	884	0.465	100.0	Y	1.000	4
WNP (Total of JARPNII, EO and WNP_E)	-	1st	1	2008	6,138	0.303	100.0	N	0.864	-
	-	2nd		2020	3,580	0.270	78.7	Y	1.000	-
ENP_W (175E-160W)	Y	1st	3W	2011	7,143	0.346	100.0	N	0.864	5
	Y	2nd		2021	13,012	0.227	100.0	Y	1.000	4

Derivation of abundance estimates in the management areas was conducted as follows. Abundance estimates in sub-area 1 (i.e., management area i)) are the sum of the abundance estimates for the Okhotsk Sea, JARPNII, EO and WNP_E. Abundance estimates in management area ii) are the sum of abundance estimates for sub-area 1 and the western part of ENP (175ºE-160ºW). For abundance estimates based on the surveys for which IO mode was not conducted, abundance estimates by region were divided by $g_{TOP}(0)$ of 0.864 (CV=0.031) for the TOP barrel (Takahashi *et al.*, 2023b) before summation of the estimates by region. Note that extrapolation to unsurveyed area was not conducted because a zero abundance is assigned to an unsurveyed area in the RMP. Thus, abundance estimates for use in CLA were obtained for each management area (Table 6).

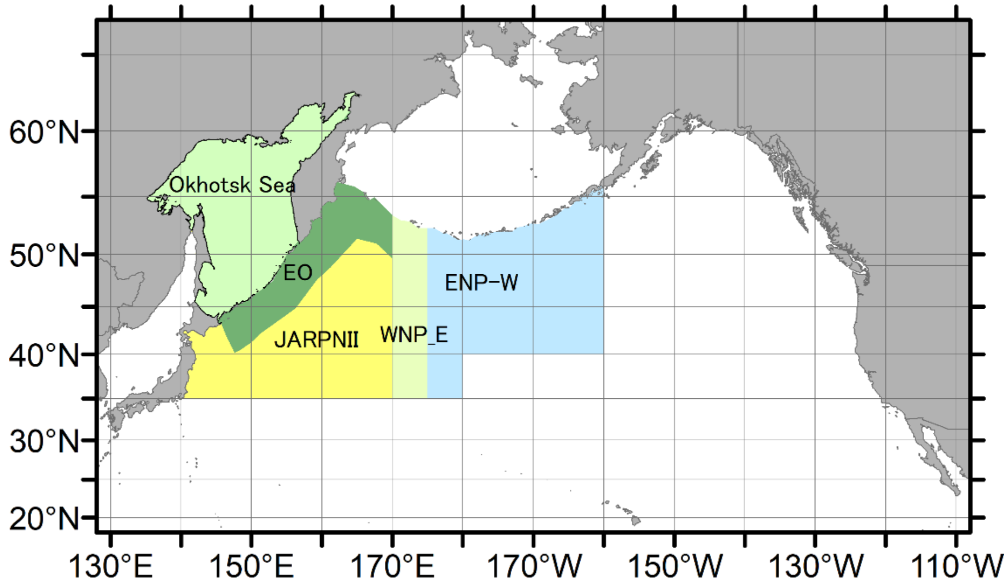


Figure 8. Map for regions shown in Table 5. Sub-area 1 consists of four regions (Okhotsk Sea, EO, JARPNII and WNP-E). ENP-W is part of sub-area 3. *Small Area* i) consists of sub-area 1 and *Small Area* ii) consists of sub-areas 1 and 3W (ENP-W).

Table 6. Abundance estimates and their precision to apply the CLA for the *Small Areas* based on abundance and g(0) estimates.

Small Area i)			*Small Area* ii)		
Year	Estimate	CV	Year	Estimate	CV
2007	11,421	0.224	2007	19,689	0.197
2020	6,722	0.191	2020	19,734	0.164

7.3 Results of the CLA
Table 7 shows catch limit for two management options. An adjustment for sex ratio was not required because the actual sex ratio of female is below 50%, as shown in Tables 3 and 4.

Table 7. Catch limits for the western North Pacific fin whale based on the CLA with a tuning level of 0.6, for two *Small Areas*.

Tuning level	*Small Area* i)	*Small Area* ii)
	Sub-area 1	Sub-areas 1 and 3W
0.6	60	205

8. TESTING FOR UNCERTAINTIES (*ISTs*)

For testing the consequences of the uncertainty associated with some basic information, *IST*s for North Pacific fin whales have been conducted which model two stocks: the 'WNP' and 'ENP' stocks, and simulating 100 years-of whaling in the western part of the North Pacific. The three sub-areas shown in Figure 5 were considered in the *ISTs*.

8.1 Conditioning
The following explanation is repeated from Allison and de Moor (2020). The 'free' parameters for the model above are the initial (pre-exploitation) sizes of each of the stocks and the values that determine the mixing matrices. The process used to select the values for these 'free' parameters is known as conditioning. The

conditioning process involves first generating 100 sets of 'target' data, detailed in steps (a) and (b) below, and then fitting the population model to each (in the spirit of a bootstrap). The number of animals in sub-area k at the start of year t is calculated starting with some initial values for the initial population sizes and then projecting the operating model forward to 2023 to obtain values of abundance by stock and mixing proportions for comparison with the generated data.

(a) The 'target' values for the historical abundance by survey-area are generated using the formula:

$$P_t^E = O_t^E \exp[\mu_t^E - (\sigma_t^E)^2/2]; \quad \mu_t^E \sim N[0; (\sigma_t^E)^2]$$

where P_t^E is the abundance for survey-area E in year t;
O_t^E is the actual survey estimate for survey-area E in year t; and
σ_t^E is the CV of O_t^E (Table 9).

(b) The 'targets' for the mixing proportion in the mixing area trials are generated from normal distributions (mean and SD given in Table 10), truncated at 0 and 1.

Historical abundance estimates for conditioning
The actual historical abundance estimates assuming g(0)=1 and their associated CVs are shown in Table 8, together with survey information such as areal coverage and whether IO mode survey was conducted. These estimates are based on sighting surveys conducted during July – September. From these estimates, abundance estimates by sub-area can be obtained for two different time periods, except for sub-area 2 (the Bering Sea). These abundance estimates were used to derive the abundance estimate used in the conditioning.

Table 8. Abundance estimates by survey regions assuming g(0)=1 to calculate abundance estimates used for conditioning. Region refers to the survey regions shown in Figure 9. EO is the area to the east of the Okhotsk Sea. POWER indicates if the survey was part of the IWC-POWER programme. Period is 1st period (2003-2014) or 2nd period (2017-2022). SA is the sub-area where the region is included. Year is (the average of) the years when survey was conducted. AC(%) is the proportion of the areal coverage. IO indicates vessels with two platforms and that IO mode survey was conducted. g(0) indicates point estimate of g(0) to be applied. References are 1: Kato (2009), 2: Miyashita (2023), 3: Hakamada and Matsuoka (2016), 4: Takahashi et al. (2023a), 5: Takahashi (in prep.).

Region	POWER	Period	SA	Year	Abundance	CV	AC(%)	IO	g(0)	Ref
Okhotsk Sea	N	1st	1	2003	3,730	0.310	81.6	N	0.864	1
	N	2nd		2019	2,715	0.269	90.9	N	0.864	2
JARPNII (ex. Foreign EEZ) EO	N	1st	1	2008	3,958	0.425	100.0	N	0.864	3
	N	2nd		2020	2,696	0.324	100.0	Y	1.000	4
WNP_E (170E-175E)	N	1st	1	2005	2,004	0.385	100.0	N	0.864	1
	Y	1st	1	2011	176	0.872	100.0	N	0.864	5
WNP (Total of JARPNII, EO and WNP_E)	Y	2nd		2021	884	0.465	100.0	Y	1.000	4
	-	1st	1	2008	6,138	0.303	100.0	N	0.864	-
ENP (175E-135W)	-	2nd		2020	3,580	0.270	78.7	Y	1.000	-
	Y	1st	3	2011	31,480	0.218	100.0	N	0.864	5
Bering Sea	Y	2nd		2018	38,122	0.178	100.0	Y	1.000	4
	Y	2nd	2	2018	9,885	0.201	71.4	Y	1.000	4

Takahashi *et al*. (2023b) (this meeting) has calculated g(0) estimates for the top barrel, IO and for both platform for North Pacific surveys. For surveys using vessels with two platforms (TOP and IO) (Y in Table 8), as for the recent surveys conducted in the North Pacific and the Bering Sea, g(0)=1 was used. For surveys with vessel using a single platform, as for previous surveys in the North Pacific and Okhotsk Sea and the recent survey conducted in the Okhotsk Sea (N in Table 8), g(0)= 0.864 (CV=0.031) was used.

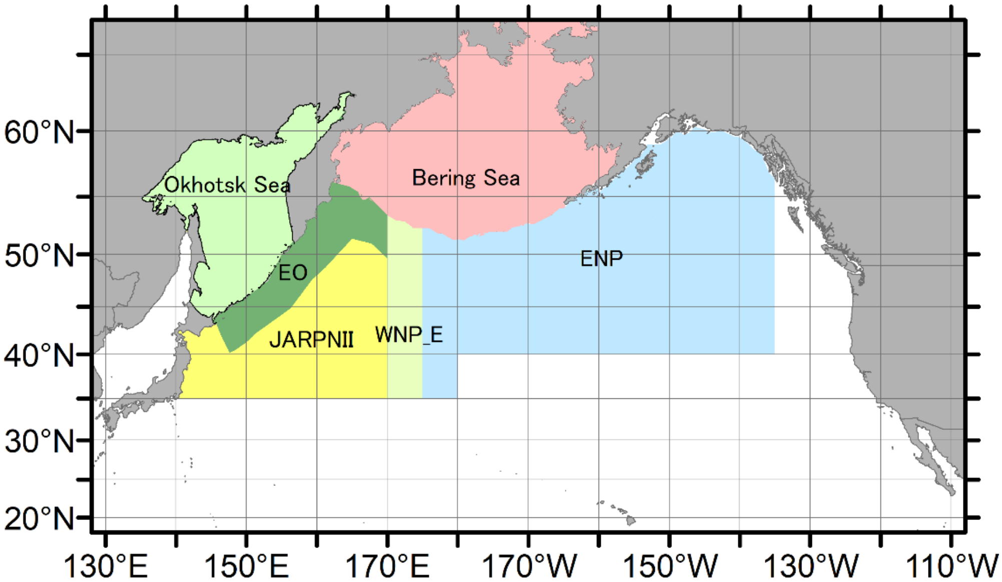


Figure 9. Map for regions shown in Table 8. Sub-area 1 consists of four regions: the Okhotsk, EO, JARPNII and WNP_E, Sub-areas 2 and 3 are the Bering Sea and ENP, respectively.

In the conditioning process, abundance estimate for Okhotsk Sea, WNP and Bering Sea to be fit to the population dynamics model are divided by the areal coverage in Table 8 (i.e. there is extrapolation to unsurveyed areas). Table 9 shows abundance estimates by sub-area for use in the conditioning process.

Table 9. Historical abundance estimates with their sampling CV by sub-area for use in conditioning. Abundance estimates based on the surveys without IO mode were adjusted using the g(0) estimate for the top barrel of 0.864 with CV=0.031 (Takahashi *et al.*, 2023b). The extent of areal coverage is also taken into account.

Sub-area 1			Sub-area 2			Sub-area 3		
Year	Estimate	CV	Year	Estimate	CV	Year	Estimate	CV
2007	12,397	0.220	-	-	-	2011	35,859	0.201
2020	8,008	0.193	2018	13,842	0.201	2018	38,122	0.178

Mixing proportions for conditioning

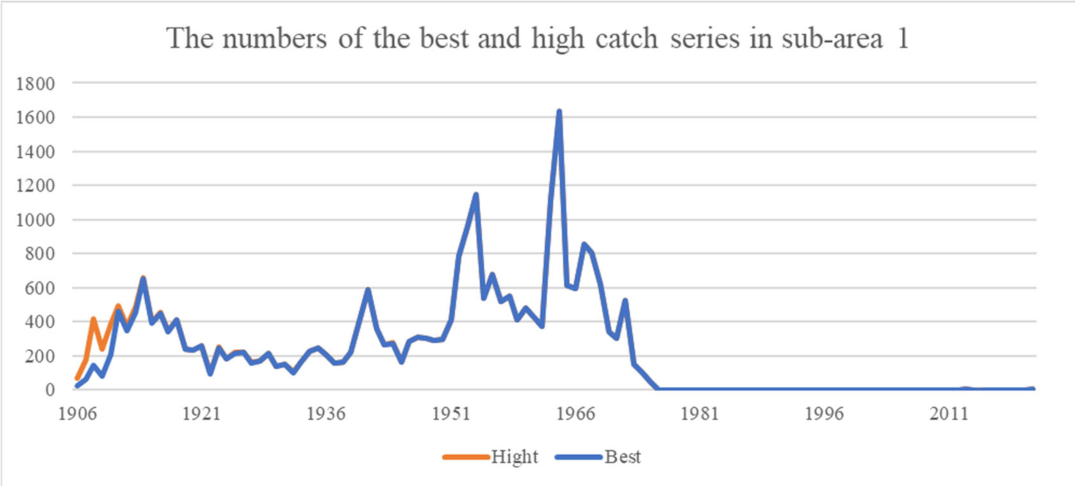
In the *ISTs* it is assumed that mixing is deterministic. Table 10 lists the mixing proportion for the 'WNP' stock for each sub-area. Year is average of the years when the samples were collected for use in the calculation of the mixing proportions.

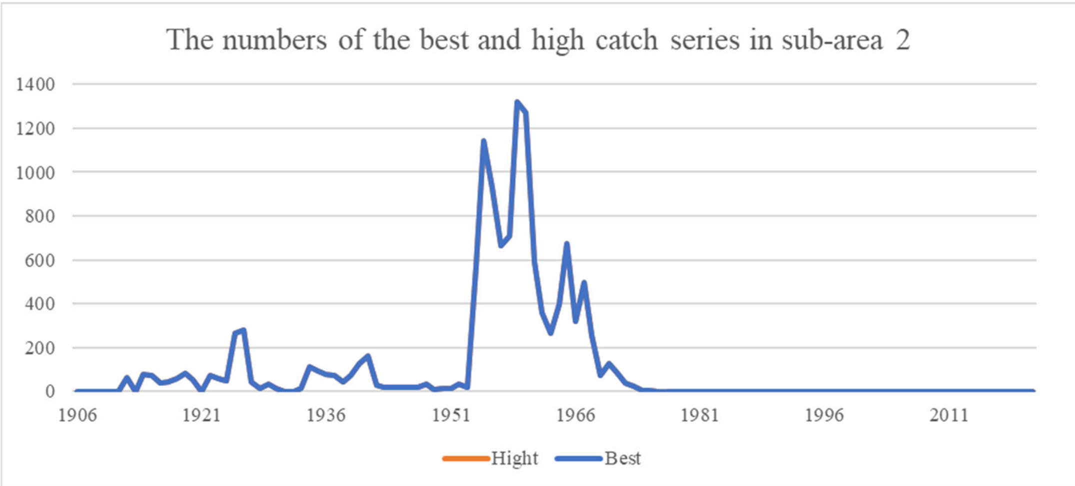
Table 10. Mixing proportions of the 'WNP' stock in sub-areas based on Taguchi and Goto (2023). The standard errors (SEs) were calculated assuming that the mixing proportions are binomially distributed.

Sub-area 1			Sub-area 2			Sub-area 3		
Year	Proportion	SE	Year	Proportion	SE	Year	Proportion	SE
2007	0.943	0.009	2017	0.050	0.011	2007	0.327	0.031

Historical catches by sub-areas for conditioning

Yoshida and Maeda (2023) produced 'Best' and 'High' catch series by sex and by sub-areas based on IWC catch data base ver 7.1 (Annex 1). Plots of the historical catches of the fin whales by sub-areas for the best and high series are shown in Figure 10. Similar to section 7, the numbers of catches in 2022 and 2023 are assumed to be the same as those in 2021.





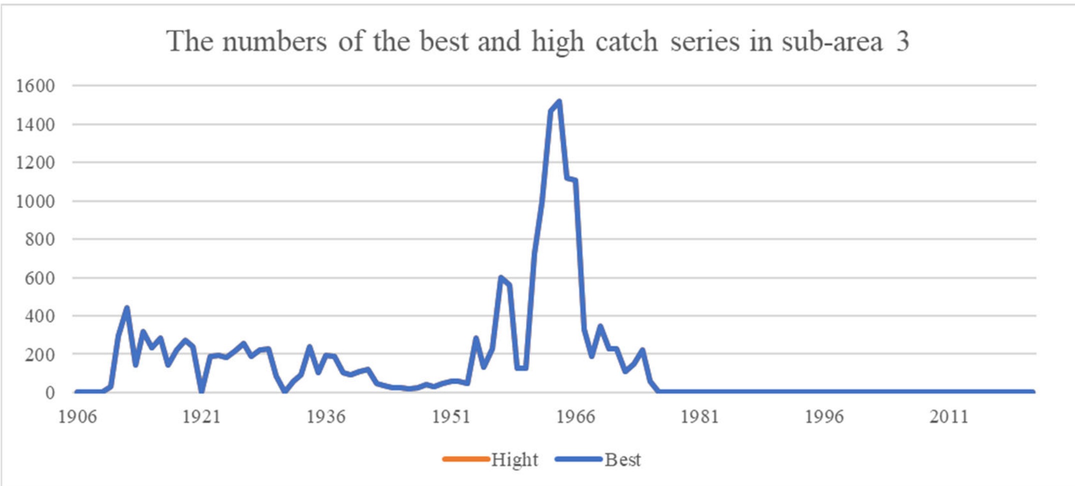


Figure 10. Plot of the best and the high series of annual catches over 1906-2021 by sub-area for North Pacific fin whales, based on IWCDB ver 7.1. The upper, the middle and the lower panel are for sub-areas 1, 2 and 3, respectively (see section 5 for further

explanation).

8.2 Trials

In the *ISTs,* uncertainty is taken into account by considering different trial scenarios with their corresponding operating models.

Trial scenarios

Table 11 lists the factors considered in the trials while Table 12 shows the list of trials in the *ISTs* considered for the North Pacific fin whales. Because there is no estimate of additional variance for the North Pacific fin whale surveys, the additional CV and its upper limit estimated for the western North Pacific Bryde's whales were used (Best: 0.335; High: 0.737) (Allison and de Moor, 2020). High plausibility was allocated for the F01-1 and F01-4 trials in Table 12 because only best values/series were input for all the factors (see Table 11). These two trials are referred to as "base case trials" hereafter.

Table 11. Factors considered in the trials. The values in bold are the baseline values.

Factor	Values considered
MSYR	**1% (1+), 4%(mature)**
Catch	**Best**, High
Natural mortality coefficient	**0.05 yr^{-1} (Best),** 0.07 yr^{-1} (High)
Estimated $g_{TOP}(0)$	**0.864 (Best),** 1.0 (High)
Additional CV	**0.335 (Best),** 0.737 (High)

Table 12. List of trials for the *IST* for North Pacific fin whales together with their plausibility.The first two trials are the base case trials.

Trial	Plausibility	MSYR*	Natural mortality	Catch	g(0)	Additional Variance
F01-1	H	1	Best	Best	Best	Best
F01-4	H	4	Best	Best	Best	Best
F02-1	M	1	Best	High	Best	Best
F02-4	M	4	Best	High	Best	Best
F03-1	M	1	High	Best	Best	Best
F03-4	M	4	High	Best	Best	Best
F04-1	M	1	Best	Best	High	Best
F04-4	M	4	Best	Best	High	Best
F05-1	M	1	Best	Best	Best	High
F05-4	M	4	Best	Best	Best	High

*:MSYR=1% is related to 1+ component, and MSYR=4% is related to mature component.

8.3 Management variants

All future catches are simulated to be taken in sub-area 1 only. Three variants, named Variants 0, 1 and 2 (hereafter V0, V1 and V2) are considered;

V0: No future catches (for comparison purposes)
V1: Sub-area 1 is a *Small Area*.
V2: Sub-areas 1 and the western part of sub-area 3 (175°E-160°W) combined is a *Small Area*.

Abundance estimates and historical catches used for application of CLA (section 7) are used for *ISTs*.

8.4 Future survey plans

Future surveys will be conducted in the Okhotsk Sea, western North Pacific, Bering Sea and eastern North Pacific. Sub-areas 1, 2 and 3 will be surveyed once in every six years. Within these three sub-areas, there are EEZs of other coastal states, and the conduct of surveys in these EEZs will be subject to permission being granted by these coastal states. Table 13 shows the tentative future survey plan over 2023-2028. In the trials, this pattern will be repeated every six years. Blank cells in Table 13 indicate that no survey is planned, at least for fin whales. For example, western North Pacific in 2023 is blank because a survey is planned south of 30°N for Bryde's whales. Double platform surveys (i.e., using an IO platform) are planned for all the sighting surveys listed in Table 13 except for the Russia-Japan cooperative surveys.

Future abundance estimates in sub-areas are generated in terms of the assumptions mentioned below for use in the CLA. In the Okhotsk Sea, it is assumed that one abundance estimate is obtained in the fourth year (the average of the years over which these surveys will be conducted) of every six years in the trials. Similarly, it is assumed that one abundance estimate is obtained in the fourth year every six years in the WNP, and that one abundance estimate in sub-area 3 is obtained in the fourth year during every six years. The ratio of abundance in Okhotsk Sea to that in western North Pacific is assumed to be 3:5 which is average ratio for past surveys (see Table 8 in section 7).

Table 13. Tentative future survey plan for North Pacific fin whales assumed for the *ISTs*. It is assumed that the same pattern will be repeated every six years.

Year	Sub-area 1		Sub-area 2	Sub-area 3
	Okhotsk Sea	Western North Pacific	Bering Sea	Eastern North Pacific
2023	Yes*1			Yes
2024	Yes*1	Yes*2		
2025	Yes*1	Yes*2	Yes	
2026	Yes*1		Yes	
2027	Yes*1	Yes*2		Yes
2028	Yes*1	Yes*2		Yes

*1: The survey area in Okhotsk Sea is divided by nine blocks, with one or two blocks being covered annually.
*2: The survey area in WNP is divided by four blocks with one block being covered annually.
NOTE: Future surveys are subject to budget availability and permissions being granted by coastal states.

8.5 Result of conditioning.

The following results are plotted for the base case trials F01-1 and F01-4 only because the plots are not substantially different amongst the trials (Figures 11 and 12).

(1) Plot of the 1+population by sub-area

Deterministic (red line), median and 90% confidence intervals for the 1+ population. The abundance estimates are shown (x) together with 90% confidence intervals by sub-area. The extended blue dashed line indicates the additional variance about the abundance estimates; these are not used during conditioning but are taken into account when generating future abundance estimates for each sub-area.

(2) Plot of the mixing proportion of the 'WNP' stock by sub-areas

Deterministic (red line), median and 90% confidence intervals for the proportion of stock 1 ('WNP' stock) by sub-areas. The proportions estimated from commercial and survey samples are shown (x) together with 90% confidence intervals based on the sampling standard error.

(3) Plot of the mature female component of the populations by stock

Deterministic (red line), median and 90% confidence intervals for the mature female abundance by stock and on the same scale.

(4) Plot of the 1+ population by sub-area with the first 10 individual population trajectories

As per (1), but with the first 10 individual trajectories rather than the median and 90% confidence intervals.

Plots of the population trajectories and the proportion of the stock 1 (i.e., the 'WNP' stock) by sub-area indicate that model estimates are quite compatible with the historical abundance and the proportion data.

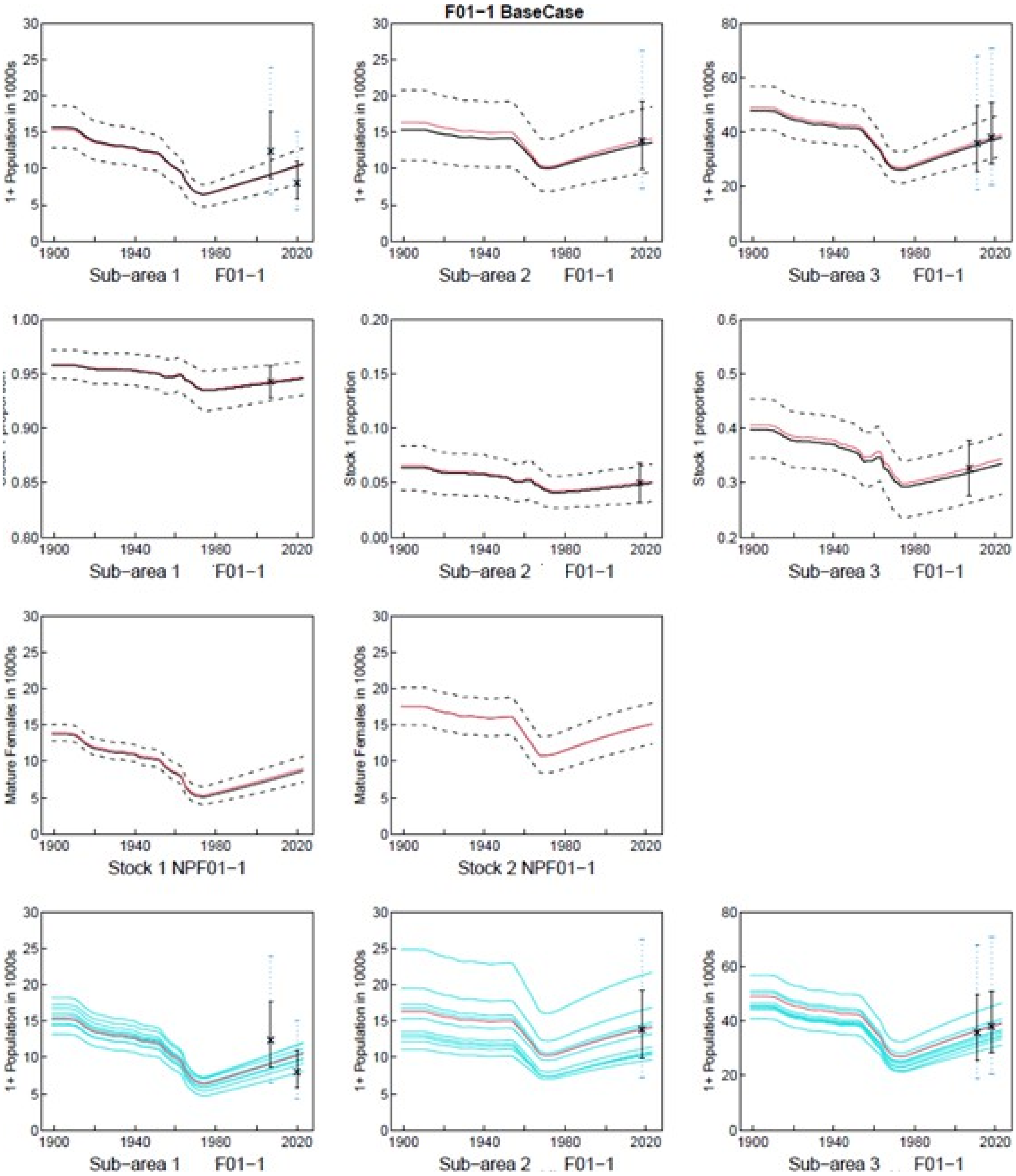


Figure 11. Plots showing results of the conditioning. (1) Plots for the 1+ population by sub-area, (2) Plots for the mixing proportion of 'WNP' stocks by sub-area, (3) Plots of mature female population by stock and (4) Plot of the 1+ population by sub-area with the first 10 trajectories for trial F01-1.

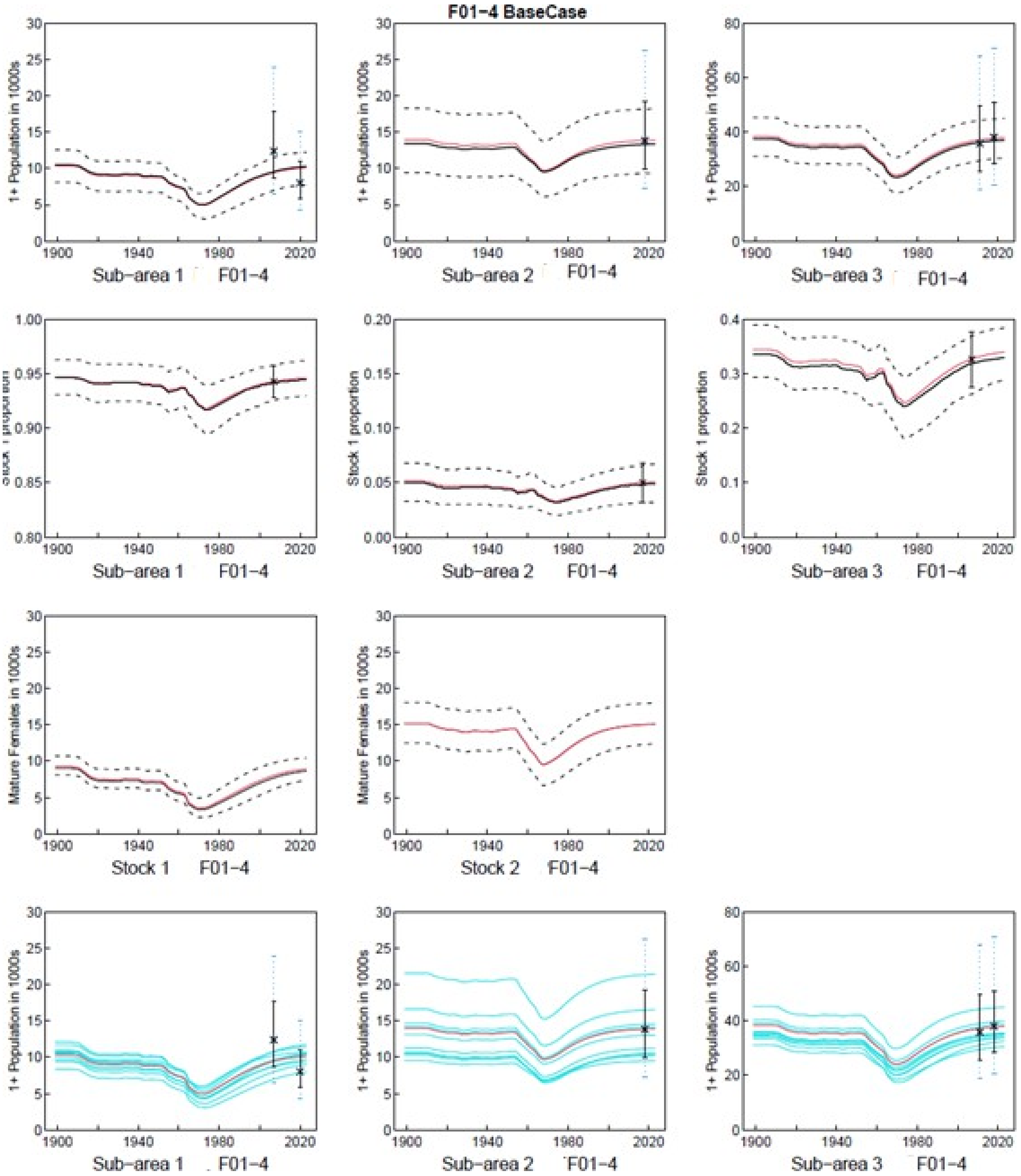


Figure 12. Same as Figure 11 for trial F01-4.

8.6 Results of trials

There are two performance measures which pertain to acceptable performance in terms of this IWC RMP-like approach: the final depletion at the end of the 100-year projection period under the MP (P-fin), and the minimum depletion ratio (P-min, which is defined as the minimum over each of these 100-year projections in a trial of the ratio of the population size to that when there are only incidental catches – though such catches are very small in this case). Attainment of 'acceptable performance' is required for the more difficult MSYR=1% trials only, as if attained for those, these requirements will also be met for trials with higher

MSYR values. The lower 5%-ile of P-fin and P-min were calculated for the two stocks in all the combinations of the trials with MSYR=1% and three management variants (Figure 13).

IWC (2012b) formally defines "acceptability" of a management variant as follows. The lower 5%-ile of P-fin or P-min must be above the dashed lines shown in the Figure 13, where these dashed lines reflect the corresponding results for an "equivalent" single stock trial for an MP with a tuning level of 0.60 (as applies to this MP).

As shown in Figure 13, both of the two performance measures are above the dashed line for stocks S1 ('WNP' stock) and S2 ('ENP' stock) for all the trials with MSYR(1+)=1%. From this it follows that each of the two management variants examined which involve catches (V1 and V2) is acceptable.

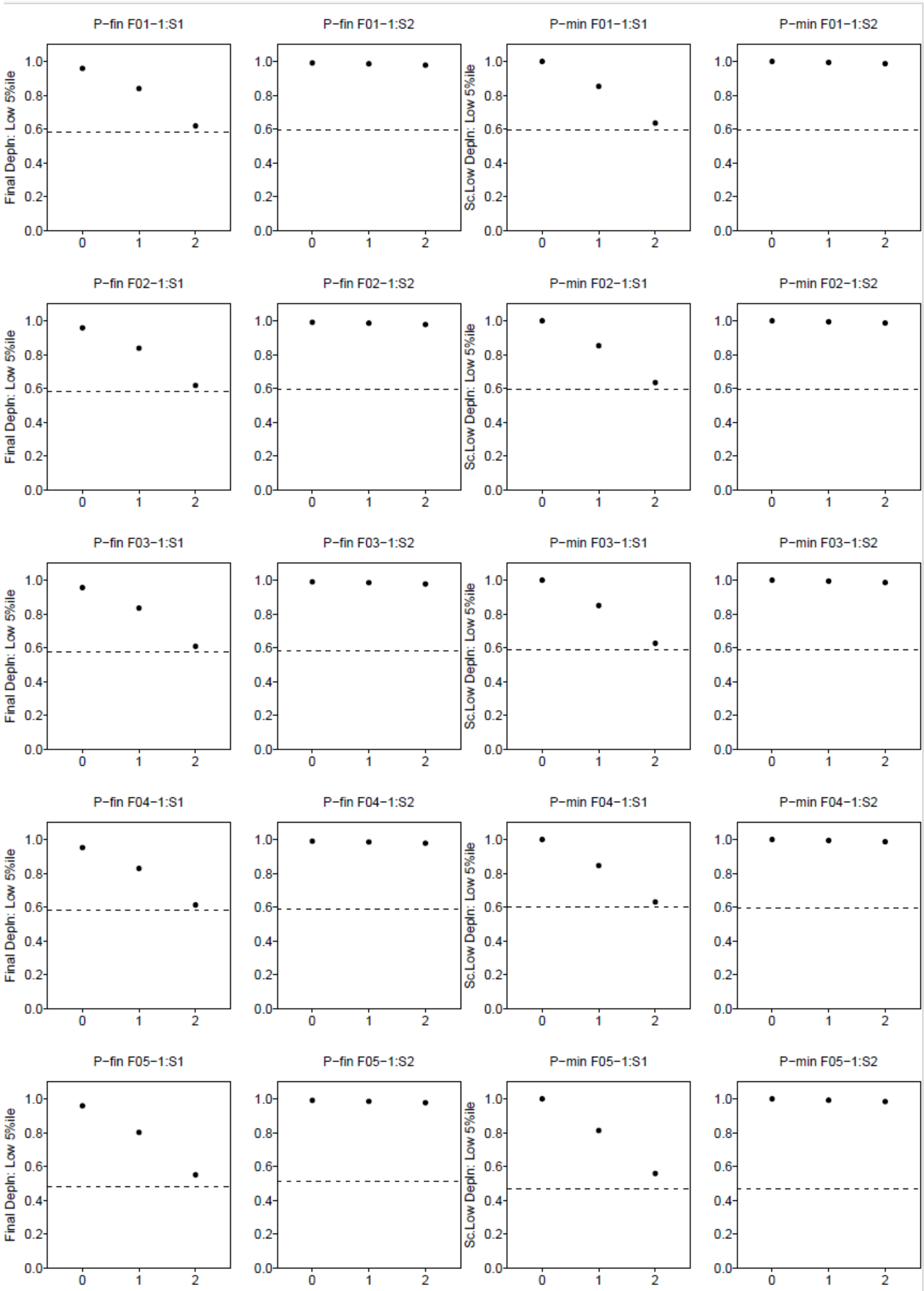


Figure 13. Summary plot of the performance of the three RMP variants, V0, V1 and V2 for MSYR(1+)=1%. Variants V0, V1 and V2 are denoted 0, 1, and 2 on the horizontal-axis, respectively, with results shown by black dots in the plots. 'Acceptable' performance is indicated by a point above the dashed line, The minimum depletion ratio, S1 for the 'WNP' stock, and S2 for the 'ENP' stock.

9. WHALING OPERATIONS AND FUTURE BIOLOGICAL SURVEYS

As mentioned in the section 8.6, both management variants are acceptable. The GOJ is to adopt management variant V2 because of the better catch performance of this variant.

Future sighting surveys for providing further abundance estimates for use in the CLA will be conducted in line with the options shown in section 8.4. Collection of biological data and samples from harvested whales will be conducted for monitoring the exploited stock, and improving specification of the scenarios to be considered in future trials.

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