Annex K

Report of the Sub-Committee on In-Depth Assessments

Participants: Palka (Convenor), Aguilar Arakaki, Allison, Baba, Babey, Baker, Bell, Botta, Bouzouma, Branch, Brownell, Butterworth, Calambokidis, Chauca Huánuco, Cheeseman, Choi, S-G., Cholewiak, Cipriano, Citta, Clapham, de Moor, Diallo, Doniol-Valcroze, Donovan, Double, Fernández-Maldonado, Fyfe, Galletti, Givens, Goetz, Hielscher, Hoelzel, Hughes, Iida, Iñíguez Bessega, Ivashchenko, Jaramillo Legorreta, Jimenez, Katara, Katsumata, Kelly, Kitakado, Lang, Leal, Lee, M-K., Lundquist, Mallette, Matsuoka, Mizroch, Nelson, New, O'Loughlin, Øien, Olson, Palacios, Pampoulie, Park, K-J., Pastene, Porter, Privitera-Johnson, Punt, Rand, Reeves, S., Robbins, Salvador, Schubert, Scordino, Sigurðsson, Stack, Staniland, Stimmelmayr, Sucunza, Tamura, Tiedemann, Tulloch, Urbán, Wade, Walløe, Weinrich, Weller, Wilberg, Witting, Yasokawa, Yoo, Yoshida, Zerbini.

1. OPENING REMARKS

Palka welcomed the participants.

2. ELECTION OF CHAIR

Palka was elected Chair.

3. APPOINTMENT OF RAPPORTEURS

Privitera-Johnson, Punt and Wade agreed to be rapporteurs.

4. ADOPTION OF AGENDA

The adopted Agenda is shown in Appendix 1.

5. DOCUMENTS AVAILABLE

The documents considered by the sub-committee were SC/69A/IA/01 and Martinez-Loustalot *et al*. (2020; 2023).

6. COMPREHENSIVE ASSESSMENT OF NORTH PACIFIC HUMPBACK WHALES

The Comprehensive Assessment of North Pacific humpback whales began in 2016 (IWC, 2017) with an intersessional workshop held in 2017 (IWC, 2018a). Since then, the type of assessment model to be applied has been refined (simplified given the nature of the available data; IWC, 2018a), additional analyses of abundance and genetic data have been undertaken, the structure of the areas included in the modelling and data analyses modified, and commercial catch series updated. In addition, the implementation of the stock structure assumptions (number of breeding stocks and the feeding areas to which they migrate) have been updated during discussions of the Scientific Committee. A summary was provided regarding the areas on which the Comprehensive Assessment will be based (Fig. 1), the current set of stock-structure hypotheses and the data available last year for inclusion in preliminary modelling runs (Cheeseman *et al*., 2022). Data included in the assessment model included commercial catches, non-whaling removals (bycatch and strandings), indices of absolute and relative abundance based on photo-ID methods and estimates of mixing rates based on photo-ID and genetic data.

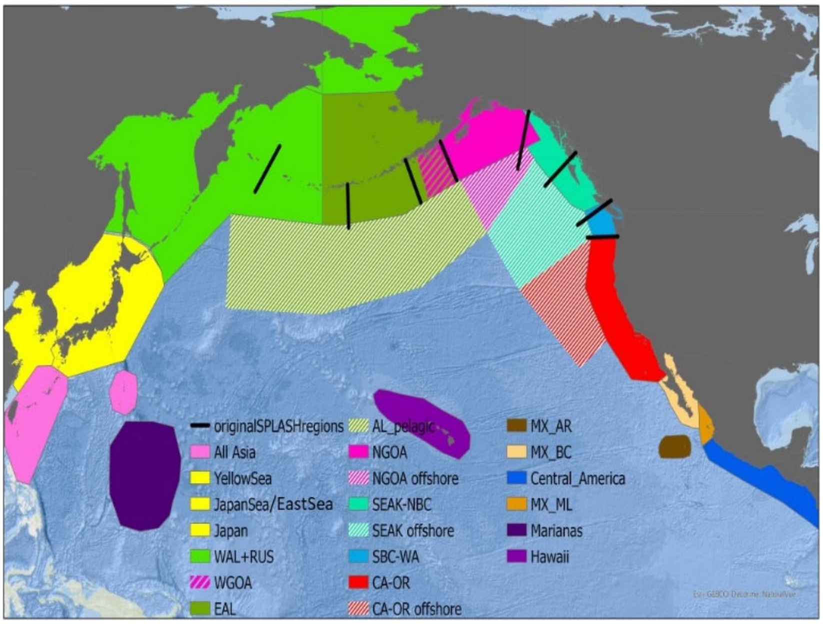

Fig. 1. Regions and region boundaries agreed by the Working Group on 20 April 2021; dark lines represent the boundaries from the original SPLASH project (as shown in Calambokidis *et al.,* 2008).

6.1 Stock Structure

The sub-committee discussed two papers on the stock structure of humpback whales along the southern Mexican Pacific coast (Martinez-Loustalot *et al*., 2023; Martinez-Loustalot *et al*., 2020). The SPLASH project (2004-06) revealed complex population structure and migratory connections in the North Pacific. However, it was unclear whether humpback whales documented in southern Mexican Pacific coast belong to the Mexican or Central American population units due to limited samples.

To fill this data gap, Martinez-Loustalot *et al*. (2023) reported on a dedicated photo-identification effort between 2013 and 2020 in eight locations along the Mexican and Central American Pacific coasts: two locations in northern and central Mexico, three in southern Mexico; and two in Nicaragua. The humpback whale photo-ID images were combined into one photo-ID catalogue and compared between the multiple locations. Whale movements among regions were estimated using the Interchange Index and the Movement Index. Results suggested that whales from southern Mexico belong to the Central American breeding population. The authors also documented humpback whales from the Central American breeding population migrating north to the feeding areas off the US West Coast during early spring and returning to Central America during late fall to breed and mate. During their transit along the mainland coast of Mexico, humpback whales may engage in mating behaviours or found in competitive groups. They move through Mexico quickly during the northern migration. They have also found a number of whales from offshore Mexico (Revillagigedo Archipelago) in central Mexico (Bahía de Banderas), revealing complex migration patterns.

Martinez-Loustalot *et al*. (2020) documented a genetics study that analysed the relationship of humpback whales from southern Mexico with whales from other regions in the Mexican Pacific and Central America based on 51 skin samples during the winter seasons of 2018 and 2019 from southern Mexico: Oaxaca (n=48) and Guerrero (n=3); and from northern Mexico: Baja California Peninsula (n=126). The authors found significantly different haplotype frequencies between northern and southern Mexico, but no difference over time in Baja between the SPLASH years 2004-06 (Baker *et al*., 2013) versus their 2018-19 samples. They also found the haplotypic frequency of samples from southern Mexico showed significant differences with the other three breeding sites studied in Mexico (Baja California Sur in northern Mexico, Bahía de Banderas in central Mexico, and offshore at the Revillagigedo Archipelago). In contrast, there were no significant differences between Southern Mexico and Central America based on 37 samples collected off Panama and Costa Rica during SPLASH 2004-2006.

SD-DNA reviewed these papers and agreed that the results in Martinez-Loustalot *et al*. (2023) and Martinez-Loustalot *et al*. (2020) were consistent (see Annex O).

The sub-committee **agreed** that the definition of the "Central American" breeding population should be expanded to include whales from the southern Mexican Pacific coast (Colima,[1] Guerrero, Oaxaca). The border between the Central American and Mexican population units appears to be in central Mexico (Bahía de Banderas), where individuals from

[1]For now we will assume Colima is part of Central America breeding stock, although there is some uncertainty due to limited data.

both population units are present, apparently with some temporary differences during the winter season. The sub-committee **agreed** to use this boundary definition in the assessment. It was noted that the multi-state mark-recapture analyses in Wade *et al*. (2022) and genetics analyses in Lizewski *et al*. (2022) presented last year used to estimate mixing proportions included southern Mexico within the Central American stratum.

Work is underway for the project 'Analysis of satellite tag data for incorporation into the stock assessment process: an application with North Pacific humpback whales'. This project uses an independent dataset consisting of 256 satellite tags deployed across several breeding and feeding grounds in the North Pacific spanning the period 1995-2019. The specific goals of the project include: (1) investigation of connectivity between breeding and feeding areas to confirm the current stock structure hypotheses; (2) derivation of movement patterns among the pre-defined subareas, including: a presence/absence matrix for input into the model; and (3) additional metrics including timing of occurrence, travel speed and residence time. The raw Argos locations have been run through a state-space model to obtain tracks with regularly spaced locations (at one location per day) and improved error characterisation. Initial computer code has been written to generate the matrix of presence/absence across all North Pacific regions identified by the Committee for the assessment. The boundaries for these regions were revised in 2021, but the underlying data are not available yet. Once the data for the revised regions are available, the code will be run to generate the final matrix and other metrics mentioned above. The project will be completed by the end of June 2023 and the results will be presented at the in-person workshop later this year. Also of note, arrangements are being made to incorporate additional tagging datasets into this project, including: (1) eight tags deployed in the eastern Aleutian Islands, Alaska, between 2007 and 2011, as reported in Kennedy *et al*. (2014); (2) 17 tags deployed by Urbán in Baja California, Mexico, in 2017; and (3) 18 tags deployed by Palacios in Bahía de Banderas, mainland Mexico, in 2023. This will increase the total number of tags available for this analysis to 299.

The sub-committee noted these results are an independent way to validate the assessment model's predicted distributions and migration patterns. The sub-committee **welcomed** this work and looked forward to seeing results next year.

6.2 Abundance

The sub-committee was presented with results by Cheeseman and colleagues on the abundance and population trends of humpback whales in the North Pacific Ocean from 2002 to 2020, using photo-ID data from a research collaboration of 43 organisations and 3,413 community science contributors. The photo-ID data were aggregated and reconciled in a single dataset through the research collaboration and community science web platform HappyWhale (https://happywhale.com/home). Identifications of whales were placed into geographic strata that followed the stratification used in Calambokidis *et al.* (2008), with a few adjustments to the Russia, Aleutian Islands and Bering Sea sampling areas. Additionally, samples from the Mariana Islands (which was not sampled in the SPLASH study) were pooled with the western Pacific stratum, and samples from southern Mexico were included with the Central America stratum. To be consistent with and comparable to the 2004-06 SPLASH abundance estimate (Barlow *et al*., 2011), the Chapman bias-corrected version of Petersen estimator was used with wintering area samples (pooled over three consecutive years) as one capture occasion and with summering area samples (pooled over two summers between the three winter samples) as the second capture occasion. They repeated this estimation process for all consecutive three-year periods from 2001 to 2021 to produce a time series of 19 abundance estimates, with labels based on the year of the first summer in each three-year period. Because the achieved geographic distribution of samples was uneven in many years, they applied a geographic bias correction based on a comparison to the sampling proportions that occurred during the SPLASH years (2004-06). They estimated a time series for total abundance in the North Pacific, only the Hawaii breeding area and only the Mexican breeding area. The latter two sets of estimates were considered indices of relative abundance because it was not possible to assume the winter area sample was a random sample of the migratory whales from all feeding areas. Overall, all three trend series generally showed an increase until about 2013 or 2016, and then a decline subsequent to that, with other variability seen in a few other years (e.g. a dip in 2010 in the Hawaii trend).

The sub-committee noted that the data set is now large enough that it contains the majority of living adult whales and even contains about 300 matches between the Hawaiian and Mexican breeding sites. It was also noted that there are now identified individuals from previously unavailable regions. For example, those from cruise ships in northern Russian waters and those from the IWC-POWER surveys in the pelagic areas in the western Bering Sea and south of the western Aleutians. Some known catalogues from Japan have not yet been incorporated. The sub-committee **commended** the IWC-POWER researchers who collected these rare photo-IDs, **encouraged** all photo-ID image owners to contribute to the HappyWhale dataset and **encouraged** the future IWC-POWER cruises to continue to collect humpback photo-IDs, particularly in the offshore regions.

It was noted that at several points in the time-series, there was a decline in relative abundance, then a subsequent increase that was faster than biologically possible. Possible reasons for this feature included simple sampling variation or perhaps perturbations due to environmental changes, such as the marine heatwave in the Gulf of Alaska, which might cause whales, particularly those that use Alaska and Hawaii, to move into other areas where they are not photographed. For example, they could move to the offshore regions, such as the regions surveyed by the offshore IWC-POWER cruises.

The sub-committee recognised that the assessment model could include abundance estimates from multiple studies. One such study was a time series developed from photo-ID data from California, Oregon and Washington (Calambokidis *et al*., 2020). It was noted that this smaller scale study resulted in an abundance trend that was not as smooth as that documented by Cheeseman and colleagues. The less smooth trend was probably due to the unaccounted for movements between the target feeding groups and other feeding areas. It was noted that if both time series were in the assessment model, the model would struggle with fitting the many sudden dips and increases in the Calambokidis *et al*. (2020) analysis.

Another set of abundance estimates the sub-committee considered should be included in the assessment was that resulting from the IWC-POWER cruises. The sub-committee **recommended** searching and evaluating other potential abundance estimates that could be used in the assessment model.

6.3 Removals

The sub-committee was presented with preliminary low, base case and high time series of non-commercial whaling human-caused mortalities and serious injuries from the eastern side of the Pacific from Alaska to the U.S.-Mexico border. The estimates were derived from counts of bycatch from observed commercial fisheries and from verified strandings records that were, if possible, assigned to a feeding group region and a cause of death (specific fishery, ship strike, debris, unidentified fishery, etc.). In the case of strandings data, if within a cause of death category, year and breeding area no observed strandings were recorded, then an average count of strandings was used, which was derived from an appropriate time period. Then counts of strandings were expanded by a factor that reflected the recovery rate of animals that died at sea then were eventually recorded as a stranding.

The sub-committee discussed the appropriate value of the expansion factors and **agreed** that a value of 4 was appropriate for the base case and 12.5 for the high case. The value 4 came from a study of stranding recovery rates of coastal bottlenose dolphins off California (Carretta *et al*., 2016) and was used in the assessment of eastern North Pacific gray whales conducted by the IWC (IWC, 2018b). The value of 12.5 reflected the ratio of the number of observed verified standings in 2015-2019 to the estimated average ship strike estimate of California humpback whales derived from a statistical model (Rockwood, 2017) for the same time and area. The sub-committee noted that when estimating the stranding count, it was important to take the general level of humpback whale abundance, fishery effort level, in addition to the general level of reliability of the strandings reports into account. The sub-committee **agreed** this type of data was needed for the assessment and **encouraged** following up to fill in mortality numbers for additional geographic areas, if possible. In particular, the sub-committee noted that the level of bycatch and ship strikes on the western side of the Pacific was largely unknown, but that the IWC progress reports should be investigated to get some indications.

6.4 Assessment model and sensitivity scenarios

The model for the assessment of North Pacific humpback whales is age-aggregated, due to a lack of age-based data. There are four primary sources of data: (1) direct catches going back to the 1650s (the commercial catches stopped in 1972) (compiled by Ivashchenko); (2) other human-caused mortalities, including bycatch, ship strikes and stranding data (compiled by Palka); (3) absolute or relative abundance and time-series (estimated by several authors); and 4) estimates of mixing proportions by area derived from photo-ID and genetic data (estimated by Wade and Baker, respectively).

In response to previous recommendations, this year the model was run using the three time series estimated from the Happywhale dataset (the entire North Pacific, Hawaiian breeding stock and Mexican breeding stock) in addition to estimates from SPLASH and other studies. The model was also modified to allow for whales to move between summer areas, and to allow for sudden jumps or declines in abundance in some areas (e.g., the drop in SEA-NBC in 2015 to allow model to fit jump in abundance in OR-CA). However, the model still fit poorly in several areas, such as Mexico. In an attempt to improve the fit, the model was adjusted so the starting year moved from 1656 to 1985, thus the assumption that the population was at carrying capacity was dropped (as is the case for the assessment of the eastern North Pacific gray whales). This improved the fit to the data, though it still does not fit Mexico data well. The sub-committee **agreed** that this adjustment should be included in the assessment model in future runs.

6.4.1 Abundance and environmental perturbations that may have impacted trends in abundance

The sub-committee noted that the assessment model failed to fit declines seen in some of the recent time-series of abundance (Hawaii, overall North Pacific), which coincided with a substantial environmental perturbation, the northeast Pacific marine heatwave. Therefore, the sub-committee briefly considered three papers that documented apparent effects on North Pacific humpback whales from the Pacific marine heatwave in 2014-16 in the Gulf of Alaska (and adjacent inland waters of Prince William Sound and Southeast Alaska). Suryan *et al*. (2021) provided an overview of the marine heatwave effects across all trophic levels and concluded that the 2014–2016 Pacific marine heatwave in the Gulf of Alaska was the longest lasting heatwave globally over the past decade (with continued warming in 2019). Their analysis of 187 time series from primary production to commercial fisheries to offshore oceanic domains demonstrated abrupt changes across trophic levels, with many responses persisting up to at least five years after the onset of the heatwave. Arimitsu *et al*. (2021) concluded that impacts on the forage fish community were an unprecedented disruption of the normal pelagic food web, resulting in higher trophic level disruptions during 2015–2016, when forage fish predators (seabirds, sea lions, humpback whales and groundfish) experienced shifts in distribution, mass mortalities and reproductive failure. Gabrielle *et al*. (2022), using a long-term study on humpback whales in Glacier Bay (inland waters of Southeast Alaska), showed that non-calf abundance decreased by 56% between 2013 and 2018, followed by increases in 2019-20, and that calf production 2015-19 was far lower than historic levels (0.041 calves per adult female, in contrast to 0.27 pre-PMH).

The sub-committee also considered Cartwright *et al*. (2019), which described fluctuations in encounter rates for Hawaiian humpback whales between 2008-18 during transect surveys of the Au'Au Channel, Maui, Hawaii. They showed that between 2013 and 2018, mother–calf encounter rates dropped by 76.5%, suggesting a rapid reduction in the reproductive rate of the population, which coincided with changes in the Pacific decadal oscillation, the development of the northeast Pacific marine heat wave and the evolution of the 2016 El Nino. The authors cautioned they had not exhaustively surveyed all areas where mother-calf pairs might be found, but provided supporting information to suggest this was a real effect. The sub-committee also noted that a workshop was held in Hawaii in 2018 to discuss apparent declines in sighting rates of humpback whales in several locations in Hawaii and Alaska (NOAA, 2019), including the studies noted above. Participants presented data from boat-based transect surveys, boat-based photo identification efforts, shore-based controlled scans using theodolite technology and shore-based citizen science counts. That workshop report concluded that information presented indicated an overall reduction in sighting rates of humpback whale calves and non-calves in Southeast Alaska, Prince William Sound, Hawaii Island and Maui over 2013-18. These findings were also consistent with data from passive acoustic monitoring recorders off Maui indicating a significant reduction in sound pressure levels of the chorusing of humpback whales over the same period (NOAA, 2019).

The sub-committee discussed whether the substantial decline of humpback whales from inland waters (such as Prince William Sound and Glacier Bay) shown in Arimitsu *et al*. (2021) and Gabrielle *et al*. (2022) represented mortality, or simply a movement of whales to, for example, offshore waters where they might have a lower probability of being photographed. To investigate this question it was suggested that data from winter areas showing sighting rates of whales known to have regularly occurred in those summer areas might provide some insight into whether this represented a mortality or a shift in distribution, or a combination of both (i.e. are whales from Prince William Sound and Glacier Bay seen in Hawaii often enough to examine whether their resight rate in Hawaii also dropped?). Given that the large majority of whales in Southeast Alaska and the Gulf of Alaska migrate to Hawaii, the evidence for declines in Hawaii, if true, suggests that either mortality truly increased, or that a substantial proportion of the population did not make the full migration to Hawaii. It was also noted that even if there was not a substantial impact on adult survival, there might still be an important impact on calf survival, which would be worth investigating.

In discussion, it was noted that figure A7 (showing a relationship between calf survival vs. temperature anomaly) in Gabrielle *et al*. (2022) might provide an example of a time-series that could be incorporated into the assessment model as a covariate of trend. The sub-committee did not discuss these papers in great detail, and so did not reach any final conclusion regarding the impacts of recent environmental events on North Pacific humpback whales, but **agreed** that the intersessional correspondence group should review this information in more detail to consider whether an environmental variable should be added to the assessment model to help explain the abundance trends.

6.4.2 Stock structure hypotheses

Two hypotheses for stock structure in the breeding areas are being considered, one with four breeding populations (Asia, Hawaii, Mexico, Central America), and one with five breeding populations (Asia, Hawaii, offshore Mexico, mainland Mexico, Central America). Implementing the four-stock assessment model, where Mexico is a single breeding stock, is relatively straightforward. However, preliminary runs indicate the more complex five-stock breeding hypothesis may be more appropriate. Thus, the sub-committee **agreed** that the most efficient way to move forward was to select the more complex five-stock breeding hypothesis, with two Mexico breeding stocks, and condition the model so that it fits all the sources of data. Then the other stock structure hypotheses could be investigated.

Two hypotheses for stock structure in the feeding areas are being considered: variants on which adjacent area the WGOA sampling subarea is combined. For the SPLASH data, the WGOA sampling area includes the western Gulf of Alaska, from west of Kodiak Island to approximately the eastern end (False Pass) of Unimak Island, with most of the samples coming from the Shumagin Islands, which are in the middle of that area. In the first variate, the WGOA area is combined with the area to the west, the eastern Aleutian Islands and Bering Sea, and in the second, the WGOA area is combined with the EGOA (eastern Gulf of Alaska, including Kodiak Island, Seward Peninsula and Prince William Sound). It was thought that one of those variants was favoured by the genetic data, so the decision about which feeding variation to use first was deferred until Baker could be consulted.

The sub-committee also discussed the apparent missing breeding area that was identified by the SPLASH study. That is, whales seen in the Aleutian Islands/Bering Sea have a lower re-sight rate in the winter areas than did whales from other summer areas. Whales are present in the Marianas Islands (Hill *et al*., 2020), although the numbers seen are not large enough to fully account for the total missing breeding area. It was noted that there are many island archipelagos in the western Pacific, so there may be whales in other areas not yet sampled. The possibility of trying to model a missing breeding area was raised, where the Marianas were considered just one small portion of that missing area. The sub-committee **agreed** that was certainly possible, but should represent a secondary priority analysis, to be considered at a later time.

6.4.3. Mixing proportions

There are two issues that make the Mexican part of the five-stock hypothesis more difficult to implement. First, whales from both units overlap in the waters of the Baja California Peninsula (Gonzalez-Peral, 2011, Urbán *et al*., 2017), with whales from the Revillagigedo Islands thought to move through on migration. And, as noted in Martinez-Loustalot *et al*. (2023), whales from Central America also migrate through the waters of the Baja California Peninsula. The second issue is that whales from three of the breeding populations (offshore Mexico, mainland Mexico, Central America) in the five-stock hypothesis are found in Bahia de Banderas, at least during the southward migration in November/December.

These issues affect the mixing proportion estimates derived from the SPLASH photo-IDs and genetic samples that are currently being used in the assessment model. As discussed last year the multi-strata photo-ID model was run with two variants for the two-stock Mexico hypothesis. In the first, offshore Mexico was one stratum, mainland Mexico was a second stratum and the data from the Baja sub-area were removed from the analysis (because of mixing of individuals from the other two sub-areas). However, this variant resulted in unreasonably low estimates of abundance for mainland Mexico (<1,000). In the second variant, offshore Mexico was one stratum and data from the sub-areas mainland Mexico and Baja were combined as the second stratum, representing the mainland Mexico breeding population. This provided more reasonable estimates of abundance for the mainland Mexico population, but interpretation of the migratory destination probabilities (mixing proportions) is now confounded by inclusion of whales sampled in Baja that are from the offshore Mexico breeding population. The sub-committee **agreed** to use the second version as the base hypothesis but consider the possibility of a sensitivity test removing the Baja sample in some way.

Due to these issues, the sub-committee noted that the genetic studies used to estimate the mixing proportions likely have some miss-assignment of individuals for genetic studies, meaning that they might have samples from the Central America breeding population migrating through or mixing in the central Mexico (Bahía de Banderas) breeding population. This will potentially lead to some bias or greater imprecision. The sub-committee suggested some possible approaches to create a purer genetic sample from the Bahía de Banderas animals: (1) use the fact that almost no F haplotypes are in the offshore Mexico population, and almost no A haplotypes are in the Central America breeding population (i.e. exclude some samples based on the haplotype of the samples from areas of mixing), (2) cross-reference the photo-identification data with the genetic samples, and try to subtract whales photo-IDed in offshore Mexico or Central America from their mainland Mexico sample and (3) use the fact that whales that go to California and Oregon are generally from the mainland Mexico breeding population, whereas the whales that go to the Alaska are generally from the offshore Mexico breeding population. Given the efficiency of matching through Happywhale.com, these data sets can be used to try to determine migratory destination of as many whales sampling in mainland Mexico and Baja as possible.

The sub-committee **agreed** that a sensitivity test could be run where one data set on mixing proportion (genetic vs photo-ID) could be down-weighted against the other. It was noted that the genetic results are more influential in the assessments in the current assessment runs since the genetic mixing proportions have a smaller CV than the photo-ID mixing proportions.

6.4.4. Removal levels

For levels of removals used in the assessment, the sub-committee **agreed** that the base case time series of the Pacific-wide catches, and eastern Pacific bycatch and ship strike mortality estimates would be appropriated for the base case assessment runs. A range of values would need to be developed for a time series of bycatch and ship strikes from the western Pacific, at least in the short term until more accurate data become available. The available high and low time series of catches and non-whaling interactions could be used in sensitivity trials.

6.5 Work plan

The sub-committee acknowledged the good progress undertaken during the intersessional period and at this meeting to assemble the input data and refine the assessment model. To future progress, the sub-committee re-established the intersessional correspondence group under Palka (Table 1). The ICG will need substantial help from the key individuals providing major datasets and/or modelling for the analyses, including Cheeseman, Wade, Baker and Punt. The workplan is below and summarised in Table 2.

(1) Intersessional period before 01 December 2023:

(a) Ivashchenko, Mizroch, Wade, Calambokidis to organise/update shape files to document the correct boundaries for the spatial strata of the feeding and breeding grounds. Share with everyone by 01 July 2023;

(b) Ivashchenko to finalise and document the catches low, base and high catch time series;

(c) Cheeseman *et al*. finalise and document the three abundance time series;

(d) Palka to finalise and document the low, base and high time series of bycatch and ship strike estimates for the eastern Pacific, Alaska to Mexico from at least 1985 to the present;

(e) Brownell to collate what information is available for bycatch and ship strike estimates for the western Pacific;

(f) Palka, Matsuoka, Urban to find existing papers on humpback whale abundance estimated derived from IWC-POWER, JARPN II, US, Mexico, Korea, Canada, Russia, if they exist;

(g) everyone to contact colleagues to determine if there are additional abundance estimates;

(h) Wade to finalise and document the mixing proportions using SPLASH photo-ID data for the various breeding-feeding stock hypotheses;

(i) Baker to finalise and document the mixing proportions using genetic data for the various breeding-feeding stock hypotheses;

(j) Wade and Palka to lead virtual discussions in November 2023 on what environmental indices to consider using by having a more detailed discussion of the published literature showing impacts of environmental events (such as the marine heatwave) on humpbacks. These discussions will need to occur early enough to assemble the covariate dataset by the same deadline;

(k) Punt and Privitera-Johnson to refine and document the code for the assessment model and output of diagnostics, if needed;

(l) Mizroch, Wade and Seattle analysts to find by June 15, 2023 a meeting room and nearby hotel for a four day in-person meeting; and

(m) Palka to talk to Secretariat to learn process of using the IWC funds for the travel to the Seattle meeting in February.

(2) Provide all input data to Punt and Privitera-Johnson by 01 December 2023.

(3) Share documentation with the group by 10 January 2024.

(4) Intersessional in-person workshop in February 2024:

(a) review all input data sources to determine what preliminary values should be inputted to the assessment model;

(b) suggest refinements to the input data time series, as appropriate;

(c) conduct initial assessment runs using the recommended initial breeding and feeding stock hypotheses;

(d) attempt to adjust model to fit data better;

(e) discuss environmental factors that may be related to abundance or demographic parameters and accessibility of that factor to be input into the assessment model; and

(f) make workplan for additional work to be conducted before the SC meeting.

Attention: SC

*The sub-committee **reiterated** the need to conduct the Comprehensive Assessment of North Pacific humpback whales. To accomplish this, the sub-committee:*

(1) ***established** a Steering Group under Palka to oversee the intersessional work, endorsed its work plan and*

(2) ***recommended** an intersessional in-person meeting to further the Assessment and present the results at SC69B.*

7. COMPREHENSIVE ASSESSMENT OF NORTH PACIFIC SEI WHALES

The Comprehensive Assessment of North Pacific sei whales had been structured around attempts to integrate information from the following sources of data: (1) historical commercial catches; (2) estimates of recent absolute abundance from IWC-POWER and other surveys; (3) indices of relative abundance derived from other surveys and scouting vessels extending back to 1965; and (4) data from Discovery marks and recoveries. A multi-area age-structured population model was developed that integrated the above sources of data into a common likelihood framework. The work was based on two working hypotheses regarding the population structure: (1) a single stock of sei whales distributed throughout the North Pacific; and (2) five stocks, centred on five designated sub-areas, but with some overlap in their summering grounds (Fig. 2). The sub-areas are Western Coastal, Aleutian, Pelagic, Eastern North Pacific and Eastern Coastal. A mixing sub-area was also defined in the Gulf of Alaska containing whales from Aleutian, Pelagic and Eastern North Pacific. There has not been consensus on the relative plausibility of the two hypotheses.

During 2021, the Committee agreed that it failed to find a population model that could consistently integrate all the available information on North Pacific sei whales due to fundamental conflicts in the data. That is, the absolute recent abundance for the Pelagic sub-area suggested a population that is much less depleted than indicated by the relative abundance and mark-recapture data. The point estimate of abundance for the Pelagic sub-area (approx. 30,000 whales) exceeded the inferred pre-exploitation size of the population in that sub-area. Therefore, the Committee recommended, as an alternative to a conventional-style assessment, a status document be developed that summarises the available information on North Pacific sei whales (focussing on what is most directly relevant to an assessment) and summarising the results of the attempts to fit a population model. An IA intersessional working group was set up to produce the summary document.

Following the Committee's protocol of reviewing all abundance estimates used in the in-depth assessment sub-committee, during 2022, the ASI sub-group started the review of Hakamada *et al*. (2009) and Hakamada *et al*. (2016), which are the source of some abundance data used in the assessment model (IWC, 2022, item 11.8 - ASI). An Intersessional Correspondence Group under ASI was established to conduct this review.

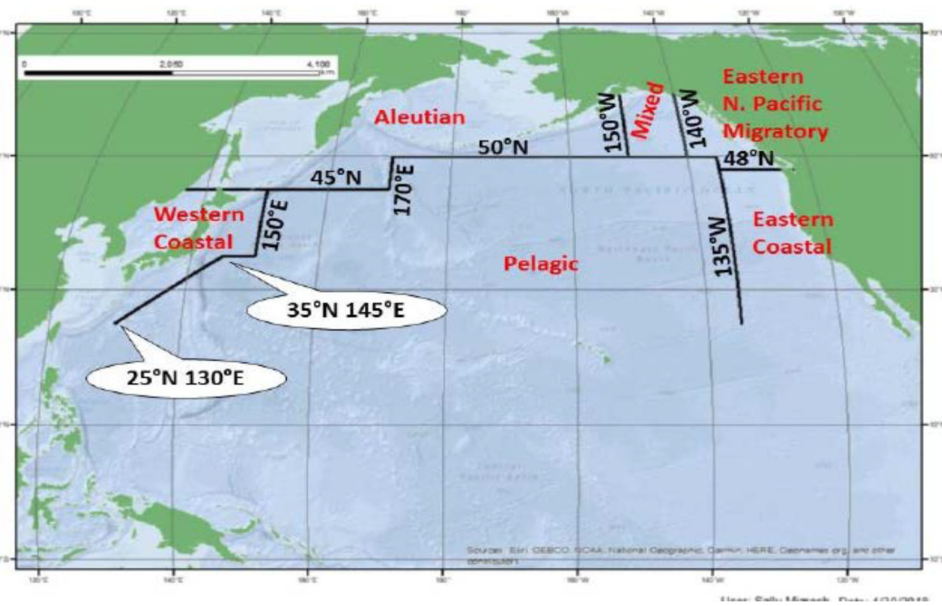

Fig. 2. The 6 sub-areas used in the Comprehensive Assessment for North Pacific sei whales.

7.1 Review progress from intersessional work

The IA Intersessional Steering Group reported that work on the summary document is not yet complete and work will have to be continued during the next intersessional period.

The ASI Intersessional Correspondence Group to review and categorise the abundance estimates in Hakamada *et al*. (2009) and Hakamada *et al.* (2016) completed their task and ASI **agreed** that these data were suitable for use in an assessment (see Annex D).

7.2 Workplan

The sub-committee **reiterated** that it is important that the input data and the model fits that were explored during the Comprehensive Assessment be documented in one place; and the available information on sei whales in each area of the North Pacific be summarised to provide a general picture of the status of the historical and current status of the species in each sub-area. Such a summary document should contain information on the following: abundance and trends; biological parameters; habitats and ecology; stock structure and movement; genetics; mark-recapture and tag-tracking; other indicators of movement; stock structure hypotheses; population modelling; and summary and conclusions. Such a summary document would normally not contain recommendations; however, recommendations arising (if any) would be an item for the IA agenda for SC69B.

> *Attention: SC*
>
> *The sub-committee **reiterated** the need to summarise the Comprehensive Assessment of North Pacific sei whales. To accomplish this, the sub-committee **recommended** developing a summary document that would be prepared in time for review by reviewers prior to SC69B and by the sub-committee at SC69B.*

8. PROGRESS ON IN-DEPTH ASSESSMENT OF WESTERN NORTH PACIFIC COMMON MINKE WHALES

8.1 Review progress from intersessional work

The in-depth assessment of Western North Pacific common minke whales is based on three stock hypotheses (see Fig. 3 for a map of the sub-areas and Fig. 4 for the genetics samples which led to the development of stock hypothesis E):

(1) there is a single J-stock that occurs to the west of Japan (Sea of Japan/East Sea and Yellow Sea) and the Pacific coast of Japan (sub-areas 2C, 7CS, 7CN, 11 and 12SW) and a single O-stock in sub-areas to the east and north of Japan (2C, 2R, 3, 4, 7CS, 7CN, 7WR, 7E, 8, 9, 9N, 10E, 11, 12SW, 12NE and 13) (referred to as hypothesis A);

(2) as for hypothesis (A), except there is a third stock (Y) that resides in the Yellow Sea (sub-areas 1W, 5 and 6W) and overlaps with J-stock in the southern part of sub-area 6W (referred to as hypothesis B); and

(3) there are four stocks, referred to as Y, J, P and O, two of which (Y and J) occur in the Sea of Japan/East Sea and three of which (J, P and O) are found to the east of Japan. Stock P is a coastal stock (referred to as hypothesis E).

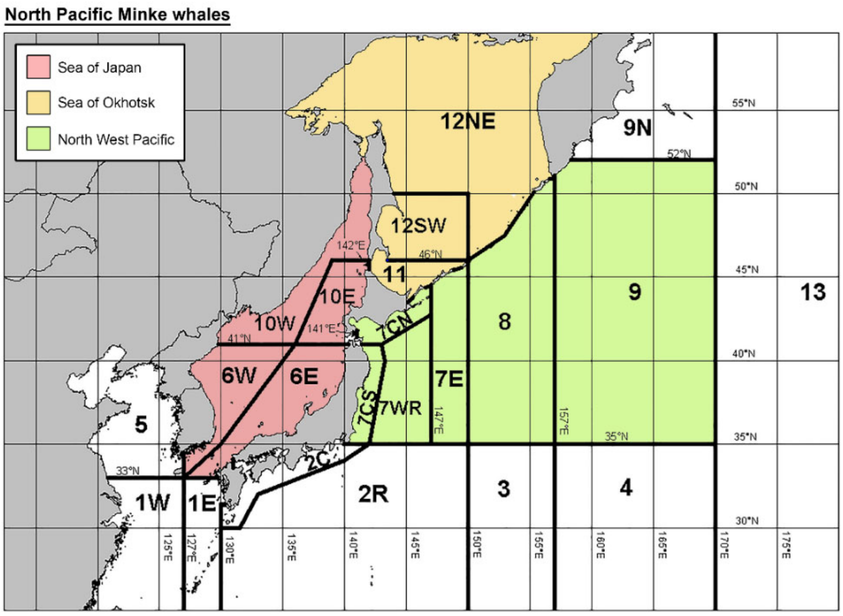

Fig. 3. The 22 sub-areas used in the in-depth assessment for western North Pacific common minke whales.

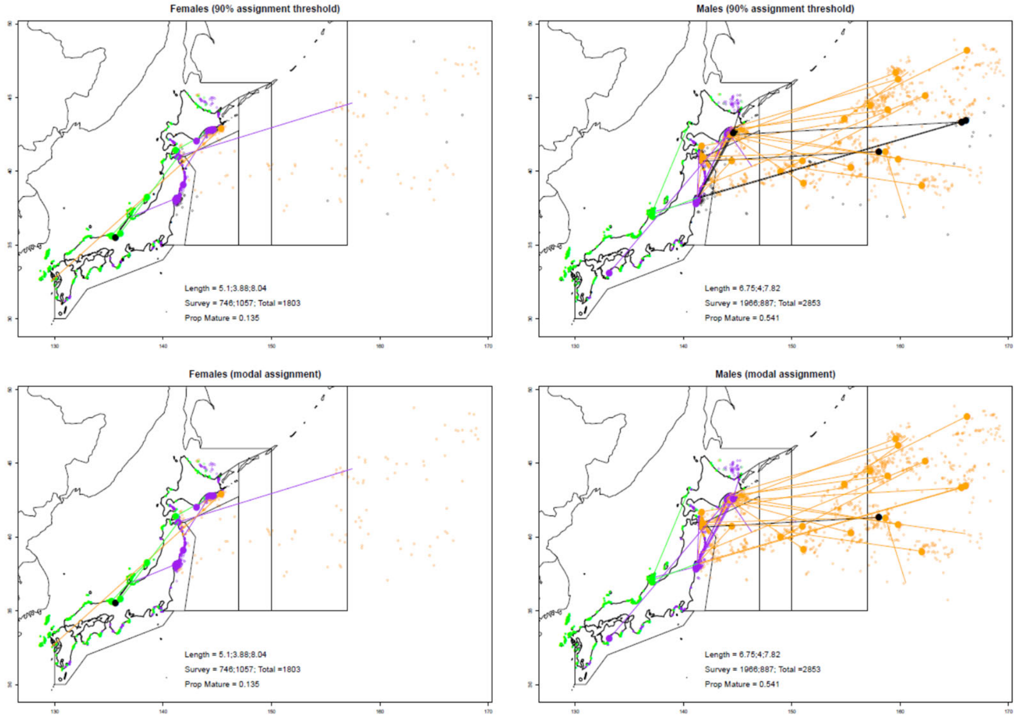

Fig. 4. Locations of the three putative clusters identified by Geneland ('green', 'orange', 'purple') and unassigned animals ('black'). Results are shown by sex and when a 90% threshold is applied as the basis for assignment (upper panels) and when the cluster is assigned based on the most likely assignment (lower panels). The lines connect parent-offspring pairs, with the colour assigned based on the parent (IWC, 2020).

The operating models for western North Pacific common minke whales were originally developed as part of an RMP *Implementation Review*, but following Japan leaving the IWC, the Committee had agreed that it was appropriate to continue the work in the form of an in-depth assessment (IWC, 2021, p.22) that will include a focus on the effects of bycatch, particularly on the J-stock, whilst recognising that Japan could continue whaling using domestically-set catch limits. During the intersessional period Allison, de Moor and Katara continued to work on the operating models on which the in-depth assessment will be based.

Last year, the Committee identified the next steps for the in-depth assessment as (item 8.1.2.2; IWC, 2022):

(1) finalise the conditioning and check that this has been achieved satisfactorily;

(2) assess if there are any data, not used for conditioning, that could be used to assess whether the results are realistic/plausible;

(3) project the population forward under scenarios for realistic levels of future bycatch and commercial removals; and

(4) determine the statistics and plots to be used to review the results of the projections and to develop advice on the status and the need, if any, for the provision of bycatch management advice.

The Committee agreed that guidance on the intersessional work would be led by a Steering Group under Donovan and that an intersessional workshop would be held to review diagnostic plots and tables related to conditioning, finalise plots and tables to summarise model outputs, and draw conclusions regarding the consequences of alternative removal scenarios. However, progress was insufficient to justify holding the workshop during the intersessional period since SC68D.

The Committee also agreed that the population model should be fitted to mixing proportions in sub-area 11 that are disaggregated between samples from bycatches and from Special Permit catches to assist the Committee to evaluate model fit and noted that this evaluation should account for sample sizes, which can be low. An additional reason for disaggregating these samples is because the modelled total (1+) stock sizes are fitted to the proportions obtained from bycatches whereas the recruited population is fitted to the proportions from Special Permit catches. The Committee agreed that the trial specifications for Hypothesis E should be updated to allow P-stock individuals to be found in sub-area 11 from October-December given data that suggest this is the case (three of 10 male and one of 11 female bycatch samples in October -November assigned as P-stock).

This year the genetic stock mixing proportions for sub-area 11 have been disaggregated and the trial specifications updated, as requested by the Committee last year. Other changes to the data inputs for the trials are: (a) the genetic stock mixing proportions in sub-area 7CN have been disaggregated between January-March and April-May to assist with model fitting (the proportions differ substantially between these two sets of months), and the genetic stock mixing proportions in sub-area 7CS have been disaggregated between January-March, April and May to assist with model fitting (the proportions differ substantially between January-March and April, May). Table 7a of Appendix 2 lists the revised set of mixing proportions used for conditioning the operating model.

8.1.1 Stock hypotheses A and B

In relation to stock hypotheses A and B, the mixing matrices have been updated so that no O-stock animals are found in sub-area 7CN during January-March, as suggested by the genetic mixing data. This change allows the operating model to fit the data exactly and reduces the number of free parameters estimated during the conditioning process. In addition, mixing matrices for the O-stock have been updated with a different γ in January-March in 7CS and with different multiples of γ_{22} in sub-area 11. These changes were proposed so that the operating model can better fit the data. The sub-committee **endorsed** the changes to the specifications (see Appendix 2 for the updated specifications).

Conditioning has been carried out for 100 replicates of the trials for hypotheses A and B (for the 1% and 4% cases). The diagnostic plots were developed to evaluate whether the conditioning had been achieved satisfactorily: (a) the fits to the abundance estimates by sub-area; (b) the fits to the mixing proportions by sub-area, sex and data type (bycatch vs Special Permit); and (c) the fits to the bycatch data. The diagnostic plots for the mixing proportions now include the annual proportions (in addition to the aggregated value used in the fitting process) to assess whether there are trends over time in mixing proportions, as requested by the Committee last year. However, no such trends are evident. The sub-committee was provided with plots of abundance by stock and of abundance by sub-area, sex and age-group (SC/69A/IA01). The distributions by stock, age and sex generally matched the qualitative patterns expected from existing data on changes in catches and length-frequency. Overall, although there are a few minor inconsistencies between data sources (e.g., the proportion of male J- and O-stock animals in sub-area 11), the sub-committee **agreed** that the conditioning has been achieved satisfactorily for the base-case trials for stock hypotheses A and B. The results provided little evidence to suggest that additional variance needs to be incorporated when conditioning the trials based on stock hypotheses A and B because the model fits the abundance estimates and mixing proportions adequately given their sampling-based confidence intervals.

The sub-committee noted that J-stock is estimated to be much more depleted than O-stock, especially when $MSYR_{1+}$=1%. It was noted that a large proportion of the historical commercial catch was taken from the areas west of Japan (Fig. 5), which are areas where most animals are J-stock.

8.1.2 Stock hypothesis E

Considerable intersessional work has been directed towards implementing the complex stock hypothesis E trials. This led to the following suggested changes to the specifications related to the mixing matrices for the trials based on stock hypothesis E given the data on mixing proportions: (1) no O-stock animals should occur in sub-area 7CN during January-March; and (2) no J-stock animals should occur in sub-area 7CS throughout the year, given data suggest this is the case.

The sub-committee reviewed the results of the conditioning based on the current set of specifications. It **agreed** that most of the fits to abundance and mixing proportion data were adequate. However, the modelled abundance in sub-area 7WR in August, that in sub-area 7CS+7CN+WR+7E in June, and particularly that in sub-area 11 in August and September was too high given the abundance estimates for these areas. Examination of the mixing matrices revealed that an unrealistic proportion of P-stock (often > 97%) was placed in sub-area 11 during June-October. The sub-committee was most concerned about the fits to the data for sub-area 11 and advised that one way to identify the conflict between the data and the current model specifications that is leading to the poor fits for sub-area 11 was to increase the weight on matching the abundance data for sub-area 11 and determining the data source that is then fitted poorly based on the resultant model fits.

8.1.3 Sensitivity tests

The sub-committee reviewed a set of sensitivity tests arising from a combination of those carried forward from the previous *Implementation Review* and new additions that have arisen as a result of changes to the input data and/or the modelling. Table 3 lists the possible sensitivity tests and indicates which sensitivity tests will form the basis for the in-depth assessment. The sub-committee **agreed** the following changes to the set of possible sensitivity trials:

- Items 1 and 2 should be dropped given there is no evidence for a 'C' stock in the genetic data;
- Items 4 and 5 should be dropped because the abundance estimates for these sub-areas have been updated to include all information in the baseline trials;
- Item 7 should be dropped as setting the model estimates of abundance to the mid-point of when the survey took place will have a minimal effect on the outcomes from the model, and exact dates are not known for all surveys;

- Item 14 should be dropped given there are no proposals for how time-varying mixing can be parameterised;
- Item 15 should only be conducted if the trend in the Japanese large-scale nets differs from that of the numbers of set nets;
- Item 16 should be dropped because the model predictions are very similar to the observations (see Figure 5);
- Item 22 should be dropped because it is a sub-item of item 21;
- Item 25 should be dropped because a constraint of 300 has been implemented in the baseline trials.

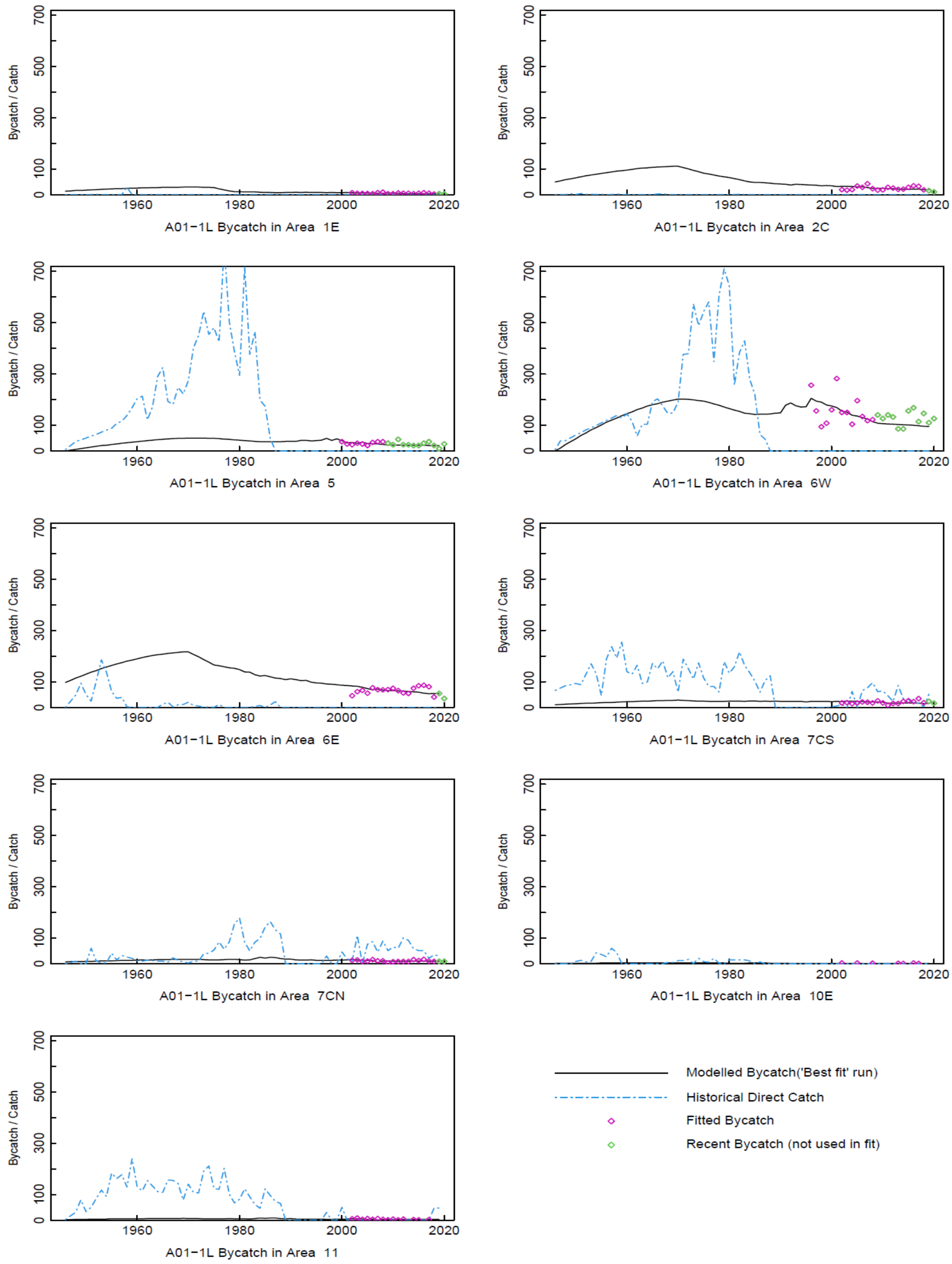

Fig. 5. Recorded historical directed catches (blue dashed lines), model-predicted bycatches (solid blacklines) and observed catches (open circles). The model predictions are based on the stock hypothesis A baseline trial ($MSYR_{1+}$=1%).

The sub-committee noted that the value of g(0) in the baseline trials (0.798) was based on Okamura *et al*. (2010). An approximate upper confidence interval for the estimate is 0.95. The value of 1 for item 3 is therefore based on a conservative, but not overly conservative, upper bound for the value for g(0). Item 11 should lead to more optimistic results but is retained given there is currently no information on the level of bycatch in the waters of the People's Republic of China, and this item represents an extreme situation. It is unclear how the changes to the threshold in item 17 will impact the mixing proportions used for conditioning. The sub-committee therefore **recommended** that the Steering Group should review the plots of samples by stock, the values of the mixing proportions and the changes to the mixing matrices before this sensitivity test is implemented. The sub-committee also **recommended** that the Steering Group should review the mixing matrices associated with items 23 and 24 before those sensitivity tests are undertaken.

The sub-committee noted that the results of the ICG on NP minke abundance[2] will need to become available before another in-depth assessment of the western North Pacific minke whales is undertaken. The sub-committee **agreed** that the sensitivity tests for stock hypothesis A would be limited to 8-13 while all of the agreed sensitivity tests would be conducted for stock hypotheses B and E because stock hypothesis B is likely more conservative than stock hypothesis A, and most of the sensitivity tests relate to the sub-areas in which J- and O-stock, and for the stock hypothesis E P-stock, are found.

8.2 Conclusions and work plan

The sub-committee acknowledged the considerable work undertaken during the intersessional period to implement these complex population models and hence progress in the in-depth assessment, and thanked Allison, de Moor and Katara. It noted that the work is computationally intensive and requires good computing support for the Secretariat and needs to be accorded high priority if the assessment is to be completed in a timely manner. It was supported by computations performed using facilities provided by the University of Cape Town's ICTS High Performance Computing team: http://hpc.uct.ac.za.

The sub-committee **agreed** that work presented to the sub-committee meant that the primary work to condition the trials for stock hypotheses A and B was complete – the sub-committee had previously agreed that projections for the sensitivity tests would only be based on 'best fits' and not multiple bootstrap replicates unless the Steering Group decides otherwise (IWC, 2023, p.x). However, while the results of the conditioning for stock hypothesis E were encouraging, they were still not adequate. The sub-committee noted that funds had been allocated last year to a workshop to progress this work. However, given the progress to date, the tasks at hand, and nature of the work it **recommended** that those funds be allocated to support travel so that Katara, de Moor, Allison (and perhaps Wilberg and Punt) can meet in person to deal with technical matters. This will complement regular virtual meetings to examine results and propose new changes to the trial specifications and should facilitate completion of the conditioning before next year's meeting (and hence completion of the in-depth assessment then).

The overall work plan is therefore:

(1) Intersessional period:

- (a) Katara, de Moor and Allison condition the sensitivity tests for stock hypotheses A and B (see Table 3).
- (b) Katara, de Moor and Allison condition stock hypothesis E with help from Wilberg and Punt, including conditioning the sensitivity tests.
- (c) The Steering Group (see below) reviews (during a virtual meeting or by correspondence) the conditioning for stock hypothesis E and advices whether the sensitivity analyses for stock E should be attempted.
- (d) The Steering Group identifies those sensitivity tests (if any) for which projections should be based on 100 parameter values and not just the best fits, during a virtual meeting or by correspondence.
- (e) The Steering Group examines (during a virtual meeting or by correspondence) identifies potential analyses that inform dispersal rates, which will require a DAA request to the data owners to investigate old existing data.
- (f) The Steering Group examines evidence regarding dispersal rates among stocks for stock hypothesis E, including information from parent-offspring pairs and the results of the BayesAss analyses.
- (g) Katara, de Moor and Allison develop code to summarise the results of the projections of the operating models using the relevant performance statistics for *Implementation Simulation Trials*, together with summaries of

[2] e.g., JCRM 22 (2021) Annex K; JCRM 21 (2020) p.305: Item 11.6 ASI ICG NP minke abundance: (1) Review the applicability of the accepted *g*(0) estimate to other cruises; and (2) try to develop robust estimates for use in the in-depth assessments and/or to provide management advice and/or to provide broader estimates for the public.

total removals and those due to bycatch, and the metrics proposed for inclusion in the SOSI summaries (SC/69A/ASI/06).

(2) 2024 Annual Meeting:

(a) The Committee conducts a final review of the conditioning.

(b) The Committee makes final decisions regarding plausibility of stock hypotheses.

(c) The Committee identifies a set of scenarios regarding future removals, which Katara, de Moor, and Allison would run. The Committee has previously agreed that projections should be conducted for: (a) no future removals; (b) future Korean bycatch only; (c) future Japanese bycatch only; (d) future Korean and Japanese bycatch; (e) as for (d) plus the current annual catch limit agreed by Japan of 167 minke whales; and (f) as for (e) except that the commercial catch limit by Japan doubles over the 100-year projection period, as well as additional scenarios that might be identified (IWC, 2023, p33).

(d) The in-depth assessment is completed.

Attention: SC

The sub-committee ***reiterated*** *the need to conduct an in-depth assessment of western North Pacific common minke whales with a focus on bycatch levels and the status of J-stock(s). It also:*

(1) ***recommended*** *that the final trials be based on the revised specifications in Appendix 2;*

(2) ***recommended*** *that the funds allocated two years ago for an intersessional workshop be used to support technical meetings between Katara, de Moor and Allison (Wilberg, Punt and others as needed);*

(3) ***established*** *a Steering Group under Donovan to oversee the intersessional work; and*

(4) ***recommended*** *that the computing work to run the trials is given high priority and the Secretariat given good computing support.*

Table 1

Work plan for Comprehensive and In-depth Assessments.

SC Agenda Item	Intersessional 2023/2024	2024 Annual Meeting (SC/69B)
Comprehensive Assessment of North Pacific humpback whales (Item 8.1.1)	Re-establish the ISG to further data preparation, and development of the assessment model using virtual meetings and an in-person workshop	Review progress of intersessional work and finalise/continue the assessment
Comprehensive Assessment of North Pacific sei whales (Item 8.1.2)	Summarise the assessment process and status in a single synthesis document	Review and finalise the assessment and synthesis document
In-depth Assessment of western North Pacific common minke whales (Item 8.1.3)	Re-establish the ISG to further develop the assessment, conduct small in-person technical meetings and broader participants virtual meetings	Finalise the assessment

For details of intersessional working groups, see Annex V.

Table 2

The possible sensitivity trials and a summary of the sub-committee's recommendations related to those that will form the basis for the in-depth assessment.

Item	Stock hypothesis	Description	Our Suggestion/Question
		Additional stock	
~~1~~	~~AE~~	~~With a C- ('Central' North Pacific) stock. The mixing matrices for J-,O-,P- and Y-stocks remain unchanged from the baseline.~~	~~Delete – no evidence for this~~
~~2~~	~~E~~	~~With a C- ('Central North' Pacific) stock, but no C animals in sub-area 12NE. The mixing matrices for J-,O-,P- and Y-stocks remain unchanged from the baseline.~~	~~Delete – no evidence for this~~
		Abundance	
3	~~ABE~~ BE	Assume g(0) = 1. Baseline trials assume g(0) = 0.798.	Keep
~~4~~	~~ABE~~	~~Alternative abundance estimates in sub-area 6E~~	~~Delete. This estimate is now included in the baseline~~
~~5~~	~~ABE~~	~~Additional abundance estimate in sub-area 10E in 2007~~	~~Delete. This estimate is now included in the baseline~~
6	~~ABE~~ BE	Use <60% coverage for minima estimates. Baseline uses <70% coverage to define minima estimates.	Keep
~~7~~	~~ABE~~	~~Set the model estimates of population size based on mid-point of when the survey took place; for surveys for which start and end dates of the survey have been provided~~	~~Lower priority?~~
		Catches and Bycatches	
8	ABE	High direct catches + alternative Korean & Japanese bycatch levels	Keep
9	ABE	More Korean catches in sub-area 5 (and fewer in sub-area 6W). Baselines use the best split.	Keep
10	ABE	More Korean catches in sub-area 6W (and fewer in 5)	Keep
11	ABE	Chinese incidental catch = 0. Baselines assume Chinese incidental catch = twice that of Korean incidental catch in sub-area 5.	Keep
12	ABE	The number of bycaught animals is proportional to √ abundance (in order to examine the impact of possible saturation effects). Baselines assume the number of bycaught animals is proportional to abundance.	~~Lower priority?~~ Keep
13	ABE	Use Korean net licence numbers from 1996-2017 as effort data to calculate model predicted bycatch. Baselines use net numbers from 1996-2009 (Equation D.6 of Specifications).	Keep
~~14~~	~~ABE~~	~~Time-varying mixing matrix for the bycatch. Baseline assumes time invariant mixing matrices which apply to all catches.~~	~~Requires specification if it is to be kept~~
15	~~ABE~~ BE	Use alternative time series of Japanese large scale set nets from Hakamada v the base case time series from Japanese Coast Guard (JCG).	~~Lower priority?~~ Check first if the trend in the effort data differ and keep if trends differ. Confirm with Steering Committee
~~16~~	~~ABE~~	~~Remove expected bycatches. Baseline trials remove observed bycatches.~~	~~Delete. Using observed bycatch is preferred~~
		Stock proportions	
17	~~ABE~~ BE	Alternative (70% probability) thresholds for assignment of stock proportions. This requires a change to the mixing matrix to allow P-stock in sub-areas 7WR, 7E, 8 and 9. Baselines use 90% probability thresholds.	~~Keep~~ The Steering Committee need to review the original maps, resultant stock mixing data and revised mixing matrices first to advise whether to keep or delete this
18	~~ABE~~ BE	No. of genetic samples assigned to stock in sub-areas 7CS and 7CN set using 2/60 weight for bycatch. Baselines use 5/60 weight.	Keep
19	~~ABE~~ BE	No. of genetic samples assigned to stock in sub-areas 7CS and 7CN set using 10/60 weight for bycatch. Baselines use 5/60 weight.	Keep
20	~~ABE~~ BE	Assume 10% J -stock in sub-area 12SW in June. Baselines assume 20%.	Keep
21	~~ABE~~ BE	Assume 30% J -stock in sub-area 12SW in June with 10% J-stock in 12NE in May-June. Baselines assume 20% J-stock in sub-area 12SW in June. Requires alternative J-stock mixing matrices to allow J-stock in 12NE.	Keep
~~22~~	~~ABE~~	~~Assume 10% J-stock in sub-area 12NE in May-July. Baselines have no J-stock in sub-area 12NE. Requires alternative J-stock mixing matrices~~	~~Lower priority?~~
		Stock distribution	
23	~~ABE~~ BE	A substantially larger fraction of whales ages 1-4 from O-stock are found in sub-areas 2R, 3 and 4 year-round (so the proportion of 1-4 whales in sub-area 9 is closer to expectations given the length-frequencies of catches from sub-area 9). The mixing matrices are adjusted such that the numbers of age 1-4 of O-stock animals in sub-areas 9 and 9N are no more than half the base case numbers; juveniles are allowed into sub-areas 2R, 3 and 4 in the corresponding months.	~~Lower priority?~~ Keep, but confirm the mixing matrix with the Steering Committee before running
24	~~ABE~~ BE	Set the proportion of O animals of ages 1-4 in sub-areas 9 and 9N to zero and allow the abundance in sub-areas 7CS and 7CN to exceed the abundance estimates in these sub-areas. Requires alternative mixing matrices. Projections for these sub-areas will need to account for the implied survey bias. [Requires code change to apply to historical abundance]	~~Lower priority?~~ Keep, but confirm the mixing matrix with the Steering Committee before running
~~25~~	~~ABE~~	~~The number of 1+ whales in 2009 in sub-area 2C in any month < 200 (if large numbers of whales were found in 2C, the historical catch would be expected to be much greater).~~	~~Delete. The baselines now include a penalty to ensure the number of 1+ animals in 2009 in 2C in any month < 300~~

9. OTHER

The Committee is considering ways in which to incorporate IWC Resolution 2022-1 (Resolution on Marine Plastic Pollution) into its work. The sub-committee noted its focus is assessing the status of whale populations. Current models used to assess the status includes time series of human removals due directed catches, fishery bycatch and ship strikes. In the future, removals due to marine plastics could be included in the assessments if the threat due to marine plastics is quantified. Thus, the sub-committee welcomes the input from the E and other sub-groups as they investigate this potential threat.

The sub-committee requested informal advice on additional methods and topics for providing advice to the Commission in light of SC/69A/O/05, the SC Communication Initiative. The sub-committee suggested possibilities included: (1) a factsheet on how to conduct an in-depth assessment and tie it to the communication about the Status of Stocks Initiative; and (2) if during SC69B the assessment of North Pacific humpback or western North Pacific minke whales is complete or nearly so, then a communication could highlight the results of the assessment.

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Appendix 1

AGENDA

1. Opening remarks
2. Election of chair
3. Appointment of rapporteurs
4. Adoption of agenda
5. Documents available
6. Comprehensive Assessment of North Pacific humpback whales
   - 6.1 Stock structure
   - 6.2 Abundance
   - 6.3 Removals
   - 6.4 Assessment model and sensitivity scenarios
     - 6.4.1 Abundance and environmental perturbations that may have impacted trends in abundance
     - 6.4.2 Stock structure hypotheses
     - 6.4.3 Mixing proportions
     - 6.4.4 Removal levels
   - 6.5 Workplan
7. Comprehensive Assessment of North Pacific sei whales
   - 7.1 Review progress from intersessional work
   - 7.2 Work plan
8. Progress on In-depth Assessment of western North Pacific common minke whales
   - 8.1 Review progress from intersessional work
     - 8.1.1 Stock hypotheses A and B
     - 8.1.2 Stock hypothesis E
     - 8.1.3 Sensitivity tests
   - 8.2 Workplan
9. Other

Annex K, Appendix 2 Rev 1

Specifications for the *In Depth Assessment* of Western North Pacific Minke Whales

C. Allison, C.L. de Moor and A.E. Punt

DRAFT – the details of some of these specifications remain to be finalised

A. Basic concepts and stock structure

The objective of this *In Depth Assessment* for western North Pacific minke whales is to review the current status of the stocks and to examine the effect of future catches, for example as set by the Revised Management Procedure (RMP). This assessment has been developed from the *Implementation Simulation Trials* previously used to test the performance of the RMP in scenarios that relate to the actual problem of managing a likely fishery for minke whales in the North Pacific (IWC, 2014a)[1]. The trials attempt to bound the range of plausible hypotheses regarding the number of minke whale stocks in the North Pacific, how they feed (by sex, age and month) and recruit and how surveys index them. The underlying dynamics model is age- and sex-structured and allows for multiple stocks.

The region to be managed (the western North Pacific) is divided into 22 sub-areas (see Fig. 1). Future surveys are unlikely to cover sub-areas 1, 2, 3, 4 and 13 (see Table 3) so these sub-areas are taken to be *Residual Areas* in the current trials (although allowance is made for future bycatches from some of these sub-areas – see section D). The term 'stock' refers to a group of whales from the same breeding ground.

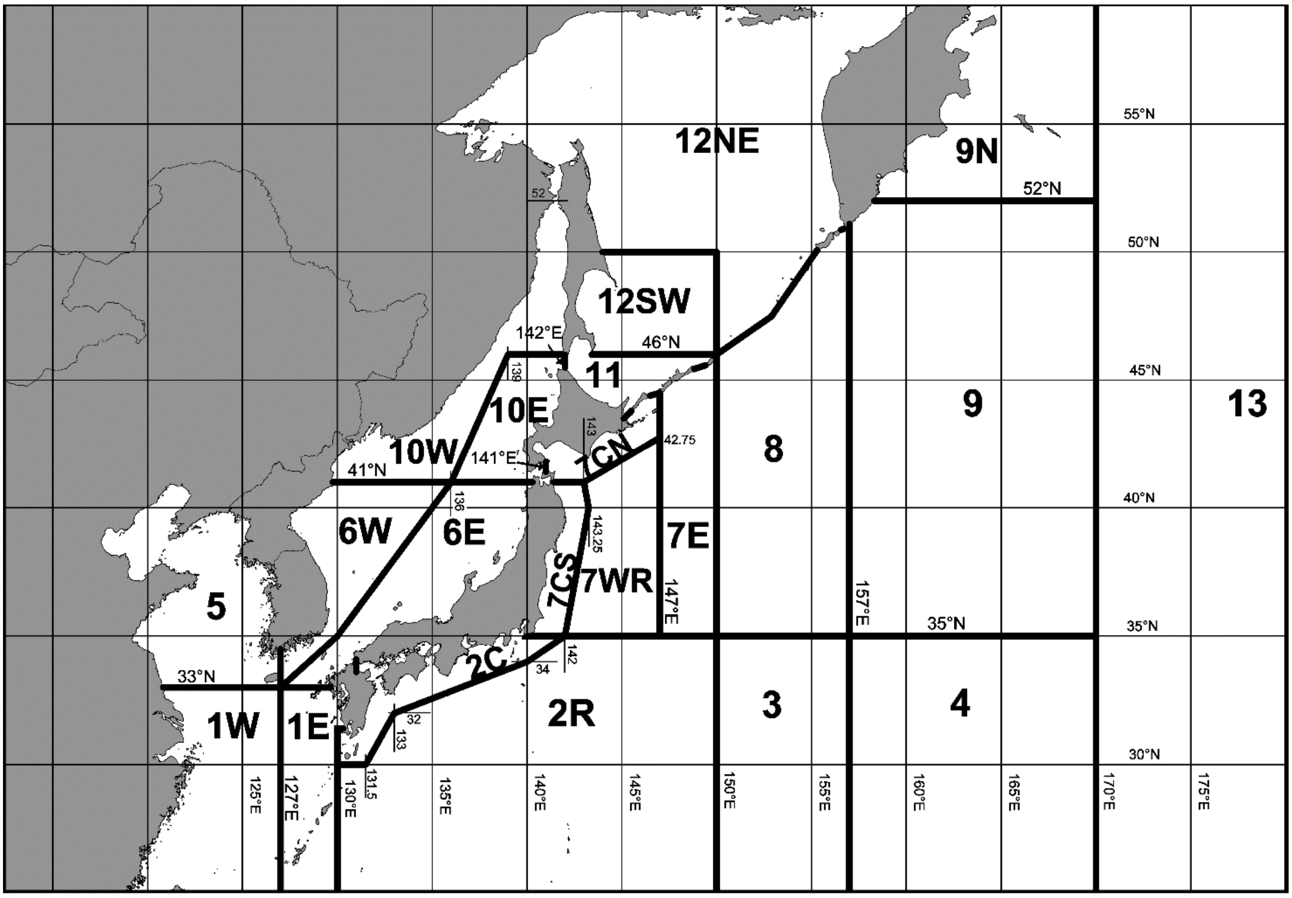

Fig. 1. The 22 sub-areas used in the *In Depth Assessment* for North Pacific minke whales

[1] Since this *Implementation Assessment* is developed from the *Implementation Simulation Trials* framework, we continue to use the testing nomenclature from the trials (e.g. conditioning rather than fitting).

Three fundamental hypotheses are considered to account for patterns observed in the results from the genetic analyses[2]:

(i) there is a single J-stock distributed to the west of Japan (sub-areas 1W, 1E, 5, 6W, 6E, 10W and 10E) and the Pacific coast of Japan (sub-areas 2C, 7CS, 7CN, 11 and 12SW) and a single O-stock in sub-areas to the east and north of Japan (2C, 2R, 3, 4, 7CS, 7CN, 7WR, 7E, 8, 9, 9N, 10E, 11, 12SW and 12NE) (referred to as hypothesis A);
(ii) as for hypothesis A, but there is a third stock (Y) that resides around the Korean peninsula (sub-areas 1W, 5 and 6W) and overlaps with J-stock in the southern part of sub-area 6W (referred to as hypothesis B); and
(iii) there are four stocks, referred to Y, J, P, and O, two of which (Y and J) occur to the west of Japan, and three of which (J, P, and O) are found to the east of Japan and in the Okhotsk Sea (referred to as hypothesis E). Stock P is a coastal stock.

B. Basic dynamics

Further details of the underlying age-structured model and its parameters can be found in IWC (1991, p112), except that the model has been extended to take sex-structure into account. The dynamics of the animals in stock j are governed by Equations B.1(a) except for hypothesis E, which allows for dispersal (permanent movement between stocks) as given by Equations B.1(b).

$$N_{t+1,a}^{g,j} = \begin{cases} 0.5\, b_{t+1}^{j} & \text{if } a=0 \\ (N_{t,a-1}^{g,j} - C_{t,a-1}^{g,j})\tilde{S}_{a-1} & \text{if } 1 \le a < x \\ (N_{t,x}^{g,j} - C_{t,x}^{g,j})\tilde{S}_{x} + (N_{t,x-1}^{g,j} - C_{t,x-1}^{g,j})\tilde{S}_{x-1} & \text{if } a = x \end{cases} \quad \text{(B.1a)}$$

$$N_{t+1,a}^{g,j} = \begin{cases} 0.5 b_{t+1}^{j} & \text{if } a=0 \\ \sum_{j\neq j'}[\left(1-D^{j,j'}\right)(N_{t,a-1}^{g,j} - C_{t,a-1}^{g,j})\tilde{S}_{a-1} + D^{j',j}(N_{t,a-1}^{g,j'} - C_{t,a-1}^{g,j'})\tilde{S}_{a-1}] & \text{if } 1 \le a < x \\ \sum_{j\neq j'}[\left(1-D^{j,j'}\right)\left((N_{t,x}^{g,j} - C_{t,x}^{g,j})\tilde{S}_{x} + (N_{t,x-1}^{g,j} - C_{t,x-1}^{g,j})\tilde{S}_{x-1}\right) & \\ \quad + D^{j',j}\left((N_{t,x}^{g,j'} - C_{t,x}^{g,j'})\tilde{S}_{x} + (N_{t,x-1}^{g,j'} - C_{t,x-1}^{g,j'})\tilde{S}_{x-1}\right)] & \text{if } a = x \end{cases} \quad \text{(B.1b)}$$

where $N_{t,a}^{g,j}$ is the number of animals of gender g and age a in stock j at the start of year t;

$C_{t,a}^{g,j}$ is the catch (in number) of animals of gender g and age a in stock j during year t (whaling is assumed to take place in a pulse at the start of each year);

b_t^j is the number of calves born to females from stock j at the start of year t;

$\tilde{S}_a$ is the survival rate = e^{-M_a} where M_a is the instantaneous rate of natural mortality (assumed to be independent of stock and sex);

x is the maximum age (treated as a plus-group); and

$D^{j,j'}$ is the dispersal rate (i.e. the probability of an animal moving permanently) from stock j to j'. It is assumed that the numbers dispersing from the j-stock to the j'-stock are the same as from the j'-stock to the j-stock at unexploited equilibrium and that the proportion of calves dispersing from the j-stock to the j'-stock at equilibrium is the same as that from the j'-stock to the j-stock.

Note that projections start in year t=2021.

For computational ease, natural mortality is applied at the end of each year when numbers-at-age by sex are updated, although catches are calculated and removed by month. This simplification is unlikely to affect the results substantially for two reasons: (1) catches would have very minor differences because they are at most only a few percent of the number of animals selected to the fisheries and the natural mortality rates are low; and (2) sightings survey estimates are subject to high variability so that the resultant slight positive bias in abundance estimates is almost certainly inconsequential.

C. Births

Density-dependence is assumed to act on the female component of the mature population. The convention of referring to the mature population is used here, although this actually refers to animals that have reached the age of first parturition.

[2] See (IWC, 2020, pp.376-381) for details of the data and analyses used in the development of these hypotheses.

$$b_t^j = B^j N_t^{\mathrm{f},j}\{1 + A^j(1-(N_t^{\mathrm{f},j}/K^{\mathrm{f},j})^{z^j})\}\tag{C.1}$$

where B^j is the average number of births (of both sexes) per year for a mature female in stock j in the pristine population;

A^j is the resilience parameter for stock j;

z^j is the degree of compensation for stock j;

$N_t^{\mathrm{f},j}$ is the number of 'mature' females in stock j at the start of year t:

$$N_t^{\mathrm{f},j} = \sum_{a=a_m}^{x} N_{t,a}^{\mathrm{f},j}\tag{C.2}$$

a_m is the age-at-first-parturition; and

$K^{\mathrm{f},j}$ is the number of mature females in stock j in the pristine (pre-exploitation, written as t=-∞) population:

$$K^{\mathrm{f},j} = \sum_{a=a_m}^{x} N_{-\infty,a}^{\mathrm{f},j}\tag{C.3}$$

The values of the parameters A^j and z^j for each stock are calculated from the values for $MSYL^j$ and $MSYR^j$ (Punt, 1999). Their calculation assumes harvesting equal proportions of males and females.

D. Catches

The operating model considers two sources for non-natural mortality: direct catches and bycatches (which are also referred to as incidental catches). In future (t > 2020), the former are set externally (e.g. by the RMP or specified as a time-series of fixed removals by sub-area), while the latter are a function of abundance and future fishery effort.

In cases in which the total catch limit (e.g. as set by the RMP) is less than the level of incidental catch, the total removals are taken to be the incidental catch only whereas if this total catch limit exceeds the incidental catch (if any), the level of the commercial removals is taken to be the difference between the total catch limit and the best estimate of the incidental catch (see 'Future incidental catches' below).

D.1 Direct catches

The direct historical (pre-2021) catch series used are listed in Appendix 1 and include both commercial and special permit catches. Details of the sources of the catch data are given in Allison (2011). The baseline trials use the 'best' direct catch series, and an alternative 'high' catch series is used in Trial 4. Trials 5 and 6 test the effect of the method used to allocate historical catches between sub-areas 5 and 6W. If catch limits are set by the RMP, it will use the 'best' series in all cases; i.e. it will use what are in effect incorrect catches for Trials 4, 5 and 6 to examine the implications of uncertainty about historical catches. Catch limits are set by *Small Area*. (Catches are always reported by *Small Area*).

Catches and bycatches are removed month by month from each sub-area. It is assumed that whales are homogeneously distributed across a sub-area (excepting in sub-areas 7CS and 7CN in the future), so historical catches and the future catch limits for a sub-area are allocated to stocks by sex and age relative to their true density within that sub-area, and a catch mixing matrix V that depends on sex, age and time of the year (and may also depend on year), i.e.

$$C_{t,a}^{g,j} = \sum_k \sum_q F_t^{g,k,q} V_{t,a}^{g,j,k,q} S_a^g \tilde{N}_{t,q,a}^{g,j}\tag{D.1}$$

$$F_t^{g,k,q} = \frac{C_t^{g,k,q}}{\sum_{j'} \sum_{a'} V_{t,a'}^{g,j',k,q} S_{a'}^g \tilde{N}_{t,q,a'}^{g,j'}}\tag{D.2}$$

where $F_t^{g,k,q}$ is the exploitation rate in sub-area k on fully recruited ($S_a^g \to 1$) animals of gender g during month q of year t;

S_a^g is the selectivity on animals of gender g and age a :

$$S_a^g = (1 + e^{-(a-a_{50}^g)/\delta^g})^{-1}\tag{D.3}$$

$\tilde{N}_{t,q,a}^{g,j}$ is the number of animals of gender g and age a in stock j at the start of month q in year t after removal of catches in earlier months and after removal of any bycatches in month q;

a_{50}^g, δ^g are the parameters of the (logistic) selectivity ogive for gender g; and

$C_t^{g,k,q}$ is the catch of animals of gender g in sub-area k during month q of year t (see Appendix 1 for the historical catches).

Each entry in the catch mixing matrix, $V_{t,a}^{g,j,k,q}$, is the fraction of males/females of age a from stock j that are found in sub-area k during month q of year t. The catch mixing matrix is different for each month to reflect the effects of migration between the breeding and the feeding grounds and back. Appendix 2 lists the catch mixing matrices considered. The matrices are based on the presence/absence matrices developed at the First Intersessional Workshop (IWC, 2020) and represent the relative fraction of an age-class in each of the sub-areas during the months March-October. Once the values of the parameters related to mixing rates (the γs – see section F) are specified (these are estimated separately for each trial and each replicate during the conditioning process), the catch mixing matrices can be converted to fractions of each age-class in each sub-area. The values for the γ parameters are selected to mimic available data (see Section F).

Catch mixing matrices are specified for ages 4 and 10 (these being three years below and above the assumed age-at-50%-maturity). Few animals of age 4 are mature while most of age 10 are. The catch mixing matrices for ages 0-3 are assumed to be the same as that for age 4, and those for ages 11+ the same as that for age 10. The catch mixing matrices for ages 5-9 are set by interpolating linearly between those for ages 4 and 10.

The trials model whale movements in the eight-months from March to October. In order to account for historical direct and incidental catches outside these months, all catches in January-March are modelled as being taken in March and the catches after October are assumed to have been taken in October. The historical direct catches by sex, sub-area, month and year are given in Appendix 1.

The trials are conducted assuming that the sub-areas for which future catch limits might be set are:

sub-area	7CS and 7CN	April to October (coastal/pelagic whaling outside a specified distance[3])
	7WR and 7E	April to October (pelagic whaling)
	8 and 9	April to October (pelagic whaling)
	11	April to October (coastal and pelagic whaling)
	12	April to October (coastal and pelagic whaling)

Future (t > 2020) commercial catches are allocated to sex, sub-area, month and year using the equation:

$$C_t^{g,k,q} = C_t^k \, Q^{g,k,q} \tag{D.4}$$

$Q^{g,k,q}$ is the fraction of the commercial catch in sub-area k of gender g that is taken during month q, the values of which are given in Table 1a; and

C_t^k is the commercial catch limit for sub-area k and year t (t > 2020). Note that C_t^k is equal to the total catch limit (eg as set by the RMP) less any reported incidental catch (constrained to be non-negative).

Entries in the Q matrix are determined by the options related to the sub-areas for which catch limits might be set; the non-zero entries (see Table 1a) reflect the historical breakdown of catches over the last 10 years of commercial whaling (1978-87) within each sub-area. In sub-areas for which there was no catch between 1978-87 (7E, 8 and 9), the entries in the *Q* matrix are set using the entire historical commercial and scientific catch in these sub-areas. In some instances where regulations limited the commercial whaling season, the matrix entries have been adjusted using the special permit data.

Future commercial catches are allocated to stock as described above (Equations D.1 and D.2) except in sub-areas 7CS and 7CN where the genetic data show differences between nearshore and offshore catches. It is assumed future catches will be taken offshore and are allocated to stock based on the mixing proportions set using genetic data from special permit samples only (Table 2a). The process of allocating removals to stock within sub-areas 7CS and 7CN involves first denoting the modelled mixing proportion used when conditioning, $R^{k,q}$, as:

$$R^{k,q} = \sum_{t=1996}^{2016} P_{1+,t}^{J/JE,k,q} \Big/ \sum_j \sum_{t=1996}^{2016} P_{1+,t}^{j,k,q}$$

where $P_{1+,t}^{j,k,q}$ is the average number of 1+ animals from stock j in sub-area k in month q of year t.

[3]Operations preliminarily being considered would be limited 'to outside a certain distance from the coast to minimise catch of J-stock whales' (IWC, 2020, p.387). The 2013 trials were conducted assuming whaling would be outside 10 n.miles.

The mixing proportions obtained from the offshore samples, $\tilde{R}^{k,q}$, are given in Table 2a. The proportion of J-stock animals in some future year would normally be $P_{1+,t}^{J,k,q} \big/ (P_{1+,t}^{J,k,q} + P_{1+,t}^{P,k,q} + P_{1+,t}^{O,k,q})$. For sub-areas 7CS and 7CN in future this equation is adjusted to:

$$\left(\tilde{R}^{k,q} \neq R^{k,q}\right) \; : \; \alpha^{k,q} P_{1+,t}^{J,k,q} \big/ (\alpha^{k,q} P_{1+,t}^{J,k,q} + P_{1+,t}^{P,k,q} + P_{1+,t}^{O,k,q}) \quad \text{where} \quad \alpha^{k,q} = \frac{(1-R^{k,q})\tilde{R}^{k,q}}{(1-\tilde{R}^{k,q})R^{k,q}} \qquad \text{(D.4a)}$$

The $\alpha^{k,q}$ factor is then applied to the recruited population from J-stock in sub-area k and month q when setting the commercial catch by stock using Equations D.1 and D.2.

Table 1a

The Q matrix used to allocate future commercial catches for a sub-area to sex and month. The entries give the percentage of the catch in sub-area *k* that is taken by sex and month for sub-areas other than *Residual Areas*. Dashes indicate sub-areas/months for which catch limits are defined to be zero. See text for description of how the entries are set. Values are set using catches taken up to and including 2018.

Sub-area	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
				Males								Females				
7CS	-	24.3	21.5	10.1	4.8	0.8	0.3	-	-	21.7	12.6	2.8	0.7	0.3	-	-
7CN	-	-	0.8	8.2	15.5	15.3	23.9	11.9	-	0.1	0.4	4.9	6.9	3.5	5.3	3.1
7WR	-	0.9	45.0	30.3	2.8	0.9	6.4	-	-	-	8.3	2.8	2.8	-	-	-
7E	-	-	32.9	19.3	1.9	7.2	12.6	1.0	-	-	3.9	1.9	5.3	5.3	8.7	-
8	-	-	12.8	33.6	31.9	4.4	3.0	2.0	-	-	2.7	2.0	3.4	2.0	0.7	1.7
9	-	-	5.4	13.6	30.4	36.3	2.9	-	-	-	1.5	1.8	2.7	4.9	0.5	-
11	-	1.3	5.5	9.6	9.6	4.0	3.0	0.6	0.1	10.6	19.3	18.5	10.7	4.5	2.3	0.4

Table 1b

QB matrix: the percentage of the incidental catch in sub-area *k* that is taken by sex and month. The values are set using all available bycatches known by sub-area, sex and month, up to and including 2016 (Japan) and 2017 (Korea). There are no known incidental catches in other sub-areas.

Sub-area	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Sample size
				Males								Females					
1E	17.1	9.21	1.32	9.21	1.32	0	0	3.95	18.4	6.58	10.5	7.89	6.58	2.63	0	5.26	76
2C	15.1	4.3	2.42	0.81	1.08	0.54	0	14.2	24.7	1.88	3.76	2.42	2.69	1.61	0.27	24.2	372
5	5.17	3.45	10.3	19.8	1.72	2.59	1.72	12.1	9.48	4.31	7.76	7.76	3.45	0	1.72	8.62	116
6W	13.3	5.91	6.6	4.75	2.67	3.01	4.17	14.6	13.2	4.98	4.63	6.14	1.16	1.51	1.74	11.6	863
6E	15.5	9.88	6.79	2	2.5	2.5	1.2	9.08	16.7	9.28	6.29	2.69	1.7	2.1	1.1	10.8	1002
7CS	7.89	5.02	10.4	7.17	2.51	1.08	0.36	11.5	10	8.96	9.32	8.6	2.15	1.43	1.08	12.5	279
7CN	4.19	4.79	3.59	8.38	7.19	1.8	1.2	9.58	2.99	8.98	12	9.58	6.59	2.99	1.8	14.4	167
10E	0	0	0	0	0	5.56	0	55.6	0	0	0	5.56	0	0	0	33.3	18
11	0	0	0	4.08	0	0	6.12	24.5	0	0	18.4	18.4	4.08	0	2.04	22.4	49

Table 2a

Time-invariant fixed proportions by stock to be used in removing **future commercial catches** from sub-areas 7CS and 7CN for each for stock hypothesis, based on the number of sampled whales that were assigned to each stock using the genetic data[4] limited to special permit samples only [in the 2013 trials this was limited to >10nm]. The values are set using data from 1996-2016.

			Sample size		Proportion	
Hypothesis	Sub-Area	Months	J-Stock	O-Stock	J-Stock	O-Stock
A & B	7CS	Apr	48	138	0.258	0.742
A & B	7CS	May	89	255	0.259	0.741
A & B	7CS	Jun-Sep	4	75	0.051	0.949
A & B	7CN	Apr-Jun	12	139	0.079	0.921
A & B	7CN	Jul-Dec	169	645	0.208	0.792

			Sample size			Proportion		
Hypothesis	Sub-Area	Months	J-Stock	P-Stock	O-Stock	J-Stock	P-Stock	O-Stock
E	7CS	Apr	0	188	0	0.000	1.000	0.000
E	7CS	May	0	303	24	0.000	0.927	0.073
E	7CS	Jun-Sep	0	5	73	0.000	0.064	0.936
E	7CN	Apr-Jun	2	28	109	0.014	0.201	0.784
E	7CN	Jul-Dec	10	574	225	0.012	0.710	0.278

[4] From the data file "Data_NPM_190226_v3.csv", based on "stock90" for Hypotheses A&B and "geneland.stock2" for Hypothesis E, using special permit data only. The months are based on the same month-split used in 2013 for commercial catches. There were no special permit catches in sub-areas 7CN & 7CS in Jan-Mar or in sub-area 7CS in Oct-Dec.

Table 2b

Time-invariant fixed proportions by stock to be used in removing **bycatch** from sub-areas 7CS and 7CN for each for stock hypothesis, based on the number of sampled whales that were assigned to each stock using genetic data[5] limited to bycatch only, using data from 2001-2016.

			Sample size		Proportion	
Hypothesis	Sub-Area	Months	J-Stock	O-Stock	J-Stock	O-Stock
A & B	7CS	Jan-Apr	43	34	0.558	0.442
A & B	7CS	May	16	31	0.340	0.660
A & B	7CS	Jun-Dec	86	34	0.717	0.283
A & B	7CN	Jan-Jun	38	44	0.463	0.537
A & B	7CN	Jul-Dec	51	15	0.773	0.227

			Sample size			Proportion		
Hypothesis	Sub-Area	Months	J-Stock	P-Stock	O-Stock	J-Stock	P-Stock	O-Stock
E	7CS	Jan-Apr	0	73	1	0.000	0.986	0.014
E	7CS	May	0	49	2	0.000	0.961	0.039
E	7CS	Jun-Dec	0	118	1	0.000	0.992	0.008
E	7CN	Jan-Jun	12	69	0	0.148	0.852	0.000
E	7CN	Jul-Dec	13	59	0	0.181	0.819	0.000

D.2 Incidental catches (also known as bycatches)

Incidental catches of minke whales are known to occur off Japan (in sub-areas 1E, 2C, 6E, 7CS, 7CN, 10E and 11 and small numbers in 6W) and the Republic of Korea (sub-areas 5 and 6W and small numbers in 1W).

Japan: It has been obligatory to report bycatches in Japan since 2001 since when the bycatch numbers are considered to be reliable. Earlier bycatches are believed to be under-reported based on the sudden increase in reported bycatches in 2001. In view of this, the relationship between bycatch and set-net effort is integrated into the conditioning process, with the advantage that the method is independent of the reporting rate prior to 2001. The reporting rate since 2001 is assumed to be constant at 100% (except in Trial 4 – see below).

Almost all of the reported bycatch off Japan occurred in set-net fisheries. Three types of set nets are used off Japan: large-scale (excluding salmon nets), salmon nets and small-scale. For fishing gears other than set-nets, incidental catch, retention and marketing of whales are prohibited by the 2001 regulation and a diagnostic DNA registry is used to deter illegal distribution of whales caught. Ideally, the catch by each gear type should be modelled separately to allow the historical (pre-2001) bycatch to be predicted. However, information on numbers of catches by net type is not available. Therefore, in the 2013 Implementation, the historical bycatches for each sub-area were set using the total number of incidental catches and the combined number of large-scale and salmon nets in each sub-area. The numbers of salmon nets since 2006 are not available and as the numbers caught in salmon nets are small in comparison to those from large-scale nets (see Appendix 1). In the current trials, the historical bycatches are extrapolated using the total number of incidental catches and the number of large-scale nets only in each sub-area over the period 2002-2018. For the best effort series, the number of nets from Japan is extrapolated from 1946 to 1969 assuming a linear relationship from 0 in 1935 to the known number in 1970 (Hakamada, 2010; Tobayama *et al.*, 1992). Incidental catches before 1946 are ignored because although some set-nets were in operation before 1946 (Brownell, pers. comm.) the numbers are highly uncertain and are sufficiently small that they are unlikely to affect the conditioning process.

The year 2001 is excluded from the fitting because the catch data are incomplete, as the new regulations date from June 2001. A sensitivity trial that uses a different series of nets provided by Hakamada (Trial 17) may be included. A high effort series is also generated, for use in Trial 4, in which the number of nets is double the best-case values from 1946-1969, up to a maximum equal to the number of nets in 1969. In Trial 4 all bycatches are assumed to be under-reported and are adjusted upward by a factor of 2.

Korea. The same method is used as for Japan above except the incidental catch numbers from 1996-2009 (sub-area 6W) and 2000-2009 (sub-area 5) are used to extrapolate backwards and the incidental catch numbers are adjusted to allow for underreporting. The bycatches in sub-area 6W (the East Sea) are adjusted upward by a factor of 2. The factor 2 is based on DNA profiling and a capture-recapture analysis of market products that estimated a total of 887 whales going through Korean markets from 1999-2003, in comparison to the reported catch of 458 whales (Baker *et al.*, 2007). The baseline trials assume that the bycatches in the Yellow Sea (sub-area 5) are fully reported as there is no evidence of under-reporting. The 'high' effort series for sub-area 5 used in Trial 4 will apply the same estimate of under-reporting as for sub-area 6W (i.e. a factor of 2) and the number of nets is set to twice the best-case values from 1946-1969, up to a maximum equal to the number of nets in 1969.

To account for bycatch prior to 1996, the average for the *adjusted* takes are used to extrapolate backwards to 1946 based on fisheries effort using the same approach as for Japan. Incidental catches before 1946 are ignored as for Japan.

[5] From the data file "Data_NPM_190226_v3.csv", based on "stock90" for Hypotheses A&B and "geneland.stock2" for stock hypothesis E, using bycatch data only. The months are based on the same month-split used in 2013 for bycatches.

China. There are no data on incidental catches off China, although they are known to occur. The trials therefore consider two (essentially arbitrary) scenarios: (i) the incidental catch by China is twice that reported by Korea in sub-area 5); and (ii) incidental catches off China are ignored. The first of the options forms part of the baseline specifications and the second is included in a sensitivity test (Trial 7) to determine the effects of the baseline assumptions.

Allocation to sex and month. Bycatches by sex, sub-area, month and year, $C_{B,t}^{g,k,q}$, are set using the equation:

$$C_{B,t}^{g,k,q} = C_{B,t}^{k} \, Q_{B}^{g,k,q} \tag{D.5}$$

$Q_B^{g,k,q}$ is the fraction of the bycatch of gender g in sub-area k which is taken during month q and, the values of which are given in Table 1b; and

$C_{B,t}^{k}$ is the bycatch in sub-area k and year t (as estimated by the model).

To avoid a proliferation of sub-areas and to avoid the need for finer time-steps than month, incidental catches in sub-areas other than 7CS and 7CN are apportioned to stock and age class in the same way as for the commercial catches in Equations D.1 and D.2, but assuming that the bycatch is taken uniformly from all age classes (i.e. selectivity=1). Thus

$$C_{B,t}^{g,j} = \sum_k \sum_q F_{B,t}^{g,k,q} \; V_{t,a}^{g,j,k,q} \ddot{N}_{t,q,a}^{g,j}$$

$F_{B,t}^{g,k,q}$ is the bycatch removal rate for gender g in sub-area k (all sub-areas except 7CS and 7CN) during month q of year t

$$F_{B,t}^{g,k,q} = \frac{C_{B,t}^{g,k,q}}{\sum_{j'} \sum_{a'} V_{t,a'}^{g,j',k,q} \ddot{N}_{t,q,a}^{g,j'}}$$

In sub-areas 7CS and 7CN, (where the genetic data show differences between nearshore and offshore catches) bycatches are taken nearshore and so are allocated to stock using mixing proportions calculated from the number of sampled whales that were assigned to each stock using genetic data from bycatches only (Table 2b).

$$\tilde{N}_{t,q,a}^{g,j} = \ddot{N}_{t,q,a}^{g,j} \left(1 - V_{t,a}^{g,j,k,q} F_{B,t}^{g,k,q}\right) \quad \text{for all sub-areas except 7CS and 7CN and}$$

$$\tilde{N}_{t,q,a}^{g,j} = \ddot{N}_{t,q,a}^{g,j} \left(1 - F_{B,t}^{g,k,q,j}\right) \quad \text{for sub-areas 7CS and 7CN,}$$

$F_{B,t}^{g,k,q,j}$ is the removal rate due to bycatch of gender g and stock j in sub-area k (sub-areas 7CS and 7CN) during month q of year t.

$$F_{B,t}^{g,k,q,j} = \frac{p_B^{k,q,j} C_{B,t}^{g,k,q}}{\sum_{a'} \ddot{N}_{t,q,a}^{g,j}} \quad \text{where } p_B^{k,q,j} \text{ is given by Table 2b; and}$$

$C_{B,t}^{g,k,q}$ is the bycatch of animals of gender g in sub-area k during month q of year t (given by Equation D.5).

The historical bycatch model: The historical bycatch $C_{B,t}^{k}$ in sub-area k in year t is given by:

$$C_{B,t}^{k} = A^k P_t^k E_t^k \tag{D.6}$$

where A^k is the bycatch constant, E_t^k is the number of nets in sub-area k during year t and P_t^k is the total population size (including calves) in sub-area k in year t averaged over all 8 time periods. In Trial 8, the abundance P_t^k in Equation D.6 is replaced by $\sqrt{\left(P_t^k\right)}$ to test an alternative assumption for the relationship between bycatch and abundance and the impact of possible saturation effects. The values of the bycatch constants are set by fitting during the conditioning process (see section F). In years where actual numbers of bycatches are known, these are the values removed from the population rather than the model estimated values.

The recent bycatches and the numbers of set-nets by type, year and area are listed in Appendix 1. Further details are given in Annex H of IWC (2012a).

Future bycatches: Future bycatches by sub-area (except in sub-areas 7CS and 7CN) are generated assuming that the exploitation rate due to bycatch in the future equals that estimated for the trial in question for the most recent five-years of data used in the conditioning process, i.e.:

$$C_{B,t}^{k} = \bar{F}^{k} P_{t}^{k} \tag{D.7}$$

where $C_{B,t}^{k}$ is the bycatch in sub-area k in year t, P_{t}^{k} is the total population (including calves) in sub-area k during year t averaged over all 8 time periods (March-October), and $\bar{F}^{k}$ is the average exploitation rate (sum over years of the known bycatch divided by the sum over years of P_{t}^{k}) over the last five years of the period used for conditioning (2016-20 for sub-areas off Japan and 2015-19 for those off Korea), i.e. F is reset for each of the 100 simulations within a trial. Thus, the future bycatch by sex, month and sub-area is given by:

$$C_{B,t}^{g,k,q} = Q_{B}^{g,k,q} \bar{F}^{k} P_{t}^{k} \tag{D.7a}$$

For Trial 8, the abundance P_{t}^{k} in Equation D.7a is replaced by $\sqrt{\left(P_{t}^{k}\right)}$.

To avoid possible dis-proportionate bycatches of J- to O-stock whales, Equation (D.7a) is replaced with (D.7b) in sub-areas 7CS and 7CN.

$$C_{B,t}^{g,k,q} = \tilde{P}_{t}^{k} \bar{F}^{k} Q_{B}^{g,k,q} \tag{D.7b}$$

where $\tilde{P}_{t}^{k,q}$ is the availability-weighted population size in sub-area k during month q:

$$\tilde{P}_{t}^{k,q} = (P_{t}^{k,q,J} + \lambda^{k,q} P_{t}^{k,q,O}) \frac{\bar{P}^{k,q,J} + \bar{P}^{k,q,O}}{\bar{P}^{k,q,J} + \lambda^{k,q} \bar{P}^{k,q,O}} \tag{D.8}$$

where $\bar{P}^{k,q,j}$ is the average number (including calves) of stock j animals in sub-area k during month q over the last five years of the period used for conditioning;

$P_{t}^{k,q,j}$ is the total population size (including calves) of stock j in sub-area k during month q of year t;

$\lambda^{k,q}$ is a relative availability factor for J whales relative to O whales:

$$\lambda^{k,q} = \frac{(1-\dddot{P}^{k,q})}{\dddot{P}^{k,q}} \frac{\bar{P}^{k,q,J}}{\bar{P}^{k,q,O}} \tag{D.9}$$

$\dddot{P}^{k,q}$ is the weighted mean proportion of J-stock in sub-area k during month q (as given in Table 2b).

This bycatch is allocated to stock as follows:

$$C_{B,t}^{g,k,q,J} = \frac{P_{t}^{g,k,q,J}}{\lambda^{k,q} P_{t}^{g,k,q,O} + P_{t}^{g,k,q,J}} C_{B,t}^{g,k,q} \tag{D.10a}$$

$$C_{B,t}^{g,k,q,O} = \frac{\lambda^{k,q} P_{t}^{g,k,q,O}}{\lambda^{k,q} P_{t}^{g,k,q,O} + P_{t}^{g,k,q,J}} C_{B,t}^{g,k,q} \tag{D.10b}$$

where $P_{t}^{g,k,q,j}$ is the total population size (including calves) of animals of gender g from stock j in sub-area k during month q of year t.

Reported bycatches

A single series of historical bycatches will be used for all of the trials when applying the RMP (i.e. for calculating catch limits), irrespective of the true values of the bycatches, which differ both among trials and simulations within trials. The estimate of the historical bycatches used by the CLA will be set to the averages of the predicted bycatches based on the fit to the actual data[6] of the operating model for the six baseline trials (i.e. using the 'best fit' simulation (0)). The series will be generated after conditioning is complete (see Appendix 1).

The future bycatches used when applying the RMP are the true bycatches in all sub-areas[7], except for Trial 4 (in which the estimated bycatches are in error to reflect the under-estimation of bycatch inherent in these trials) and Trial 7 (in which the bycatch by China is taken to be zero).

[6] In the case of sub-area 6W the actual data is the *adjusted* bycatch data.

[7] Including sub-area 6W since the best estimate of bycatches in this area is the adjusted figure.

E. Generation of data

In 2013, the *Implementation Simulation Trials* (IWC, 2014b) used to test the performance of the RMP required estimates of future abundance to be generated. This is retained in the control program although it is unnecessary for the current assessment. Tables 3 and 4 are omitted here, but the remaining tables are not renamed in order to maintain continuity with other documentation.

F. Parameter values and Conditioning

The biological parameters (natural mortality, age-at-maturity) and the technological parameters (selectivity) will be the same as for the previous *Implementations* (IWC, 1992a, p.160) (based on those for N Atlantic minke whales, IWC, 1992b, p.249)[8] i.e.:

Table 5

The values for the biological and technological parameters that are fixed.

Parameter	Value
Plus group age, *x*	20 yrs
Age-at-first-parturition, a_m	$m_{50} = 7$; $\sigma_m = 1.2$; first age at which a female can be mature is three,
Selectivity: Males and Females	$r_{50} = 4$; $\sigma_r = 1.2$
Maximum Sustainable Yield Level, *MSYL*	0.6 in terms of mature female component of the population

Natural mortality is age-dependent, and identical to that for the North Atlantic minke trials:

$$M_a = \begin{cases} 0.085 & \text{if } a \le 4 \\ 0.0775 + 0.001875a & \text{if } 4 < a < 20 \\ 0.115 & \text{if } a \ge 20 \end{cases}$$

The MSYR scenarios are specified in Section G.

The 'free' parameters of the above model are the initial (pre-exploitation) sizes of each of the stocks, the values that determine the mixing matrices (i.e. the γ parameters), the bycatch constants (A_k). The process used to select the 'free' parameters is known as conditioning. The conditioning process involves first generating 100 sets of 'target' data as 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 guessed values of the initial population sizes and projecting the operating model forward to 2020 to obtain values of abundance etc. for comparison with the generated data[9]. When performing the projections, the direct catches and known bycatches from each sub-area are set to their historical values – Appendix 1 and the bycatches are set as detailed below).

The information used in the conditioning process is as follows.

(C) *Abundance estimates*

The target values for the historical abundance by sub-area (except for the maximum and zero estimates – see below) are generated using the formula:

$$P_t^k = O_t^k \exp[\mu_t^k - (\sigma_t^k)^2 / 2] \qquad \mu_t^k \sim N[0;(\sigma_t^k)^2] \tag{F.1}$$

P_t^k is the abundance for sub-area k in year t

O_t^k is the actual survey estimate for sub-area k in year t (see Table 6); and

σ_t^k is the CV of O_t^k .

The trials are based on the use of two alternative values for *g*(0) in the conditioning process: *g*(0)=0.798 (the baseline value) and *g*(0)=1 (Trial 2) (IWC, 2012a, p.417; Okamura *et al.*, 2010). When *g*(0)=0.798 the values of the operating model abundances (P_t^k) are multiplied by this factor for comparison with the conditioning targets.

[8] The values are consistent with the results from JARPN. Japanese scientists advised that the above approach is appropriate given the well-known practical difficulties in using earplugs for age determination of North Pacific common minke whales. However, they also noted that technical advances mean that it may be possible to obtain age estimates in the future (IWC, 2014a, p.492).

[9] In order to check that the conditioning exercise has been successfully achieved, plots such as those shown in IWC (2003, pp.473-80) will be examined, together with time-trajectories of the fraction of each stock in each sub-area.

Minimum abundance estimates:
Table 6 includes several survey estimates that are assumed to be minima[10]. Target values for these are similarly generated using Equation (F.1).

Maximum abundance estimates.
Bounds need to be placed on the maximum size of populations in sub-areas 5 and 6W as there is insufficient information to estimate the abundance in sub-areas 5 and 6W, given that the only estimates available for these sub-areas have very low survey coverage. Target values were generated as $P_t^k = Z_t^k / \vartheta_t^k$, where Z_t^k is the minimum estimate for the survey in the same year and period and ϑ_t^k is the proportion of the sub-area that was covered by the survey.

Zero abundance estimates:
Table 6 includes several survey estimates of zero abundance. The target values for the historical abundance are generated using an over-dispersed Poisson distribution: the generated value is $\sqrt{\hat{\alpha}_n^k}$ multiplied by a Poisson random variable with a mean given by $n_n^k/\sqrt{\hat{\alpha}_n^k}$, where n_n^k is the number of animals seen during the *n*th survey in sub-area k and $\hat{\alpha}^k$ is defined below equation (F.4d).

(b) Proportion estimates
Estimates of the number of genetic samples assigned by stock in sub-areas 2C, 6W, 7CS, 7CN, 7WR, 10E and 11 are generated from a multinomial distribution that correspond to the observed data (see Table 7a). Some of the mixing proportions are based on data from several years so the model estimates to which these proportions are fitted during conditioning are sample size-weighted year-specific proportions.

Estimates of the proportion of recruited J-stock whales in sub-areas 6W (see Appendix 3 for how these proportions are estimated) are generated from appropriately truncated normal distributions that correspond to the observed data and are based on mtDNA and other genetic information (see Table 7b). Some of the mixing proportions are based on data from several years so year-specific proportions weighted by sample size are fitted during conditioning. A minimum standard error for the mixing proportions of 0.05 was imposed so as to prevent a few of the mixing proportions from dominating the conditioning processes – see IWC (2012b, p.106).

I Fixed stock proportion in sub-area 12SW
The data for sub-area 12SW are limited and so the proportion of J-stock in sub-area 12SW in June is fixed at 20% in the baseline trials. This value reflects a rough average of the J-stock mixing proportions for sub-area 11 (J-stock animals in sub-area 12SW need to pass through sub-area 11). Since the proportions for sub-area 11 are calculated from the 1984-1999 data, the 20% is taken as an average over these same years. Sensitivity trials test different levels of the sub-area 12SW proportion. In Trial 13 the proportion is 10 % (with 0% J-stock in sub-area 12NE as for the baseline trial) and in Trial 14 the proportion is 30% (with 10% J-stock in sub-area 12NE in the same months/years; the mixing matrix is adjusted accordingly).

(d) ***Limiting abundance in sub-areas 2C, 2R, 3 and 4Bycatch estimates***
Following a review of initial conditioning results, the population sizes in sub-areas 2C, 2R, 3 and 4 were seen to be unrealistically large. To allay this, two penalties have been added to the likelihood function: (i) to constrain the abundance in all months in 2009 in sub-area 2C to be less than 300 individuals; and (ii) to constrain the abundance in August and September in 2009 in sub-area 2R to be less than 500 individuals.

[10] Survey estimates based on less than 70% coverage are treated as 'minima' (except in sub-areas where there are no other estimates). Trial 3 investigates the sensitivity to this assumption by treating survey estimates based on less than 60% coverage as 'minima' (except in sub-areas where there are no other estimates).

Table 6

Abundance data used to condition the trials**. All estimates were calculated assuming *g*(0)=1 whereas the conditioning process assumes *g*(0)=0.798 (excepting Trial 2). See IWC (2014c, pp.126-9) for details of estimates used in the 2013 implementation.

Sub-area	Year	Season[a]	STD estimate[b]	CV[c]	Mode[d]	% Areal coverage	Use for Conditioning?[e]	Source
5	2001	Apr-May	1,534	0.523	NC	13	Min & Max[f]	An *et al.* (2010)
5	2004	Apr-May	799	0.321	NC	13	Min & Max[f]	An *et al.* (2010)
5	2008	Apr-May	680	0.372	NC	13	Min & Max[f]	An *et al.* (2010)
5	2011	Apr-May	587	0.405	NC	13	Min & Max[f]	Park *et al.* (2012)
6W	2000	May	549	0.419	NC	14.3	Min & Max[f]	An *et al.* (2010)
6W	2002	May-Jun	391	0.614	NC	14.3	Min & Max[f]	An *et al.* (2010)
6W	2003	Apr-May	485	0.343	NC	14.3	Min & Max[f]	An *et al.* (2010)
6W	2005	Apr-May	336	0.317	NC	14.3	Min & Max[f]	An *et al.* (2010)
6W	2006	Apr-May	459	0.516	NC	14.3	Min & Max[f]	An *et al.* (2010)
6W	2007	Apr-May	574	0.437	NC	14.3	Min & Max[f]	An *et al.* (2010)
6W	2009	Apr-May	884	0.286	NC	14.3	Min & Max[f]	An *et al.* (2010)
6W	2010	Apr-May	1,014	0.387	NC	23.6	Min & Max[f]	An *et al.* (2011)
6E	1992	Aug-Sep	893	0.67		56.8	Yes	Miyashita and Shimada (1994)
6E	2002	May-Jun	891	0.608	NC	79.1	Yes	Miyashita *et al.* (2009)
6E	2003	May-Jun	935	0.357	NC	79.1	Yes	Miyashita *et al.* (2009)
6E	2004	May-Jun	727	0.372	NC	79.1	Yes	Miyashita *et al.* (2009)
10W	2006	May-Jun	2,476	0.312	IO-PS	59.9	Yes	Miyashita and Okamura (2011)
10E	1992	Aug-Sep	707	0.57		30.0	Yes	Miyashita and Shimada (1994)
10E	2002	May-Jun	1,192	0.658	NC	100	Yes	Miyashita *et al.* (2009)
10E	2003	May-Jun	591	0.566	NC	100	Yes	Miyashita *et al.* (2009)
10E	2005	May-Jun	875	0.441	NC	64	Min	IWC (2014c, pp.126-9)
10E	2007	Jun	672	0.327	IO-PS	80.1	Yes	Miyashita *et al.* (2009)
10E	2014	Sep	872	0.585		100	Yes	Miyashita (2019)
10E	2018	May-Jun	620	0.478		100	Yes	Hakamada *et al.* (2019)
7CS	2004	May	504	0.291	NC	36.7	Min	IWC (2014c, pp.126-9, 181)
7CS	2006	Jul	3,690	1.199	NC	100	Yes	Hakamada and Kitakado (2011)
7CS	2012	May-Jun	537	0.346		100	Yes	Hakamada *et al.* (2016)
7CS	2016	Aug	0	-		100	Yes	Hakamada *et al.* (2019)
7CS	2017	May	284	0.497		100	Yes	Hakamada *et al.* (2019)
7CS	2018	May-Jun	245	0.828		100	Yes	Hakamada *et al.* (2019)
7CN	2012	May	542	0.601		66.7	Min	Hakamada *et al.* (2016)
7CN	2012	Sep	599	0.525		66.7	Min	Hakamada *et al.* (2016)
7CN	2014	Sep	244	0.454		75	Yes	Hakamada *et al.* (2016)
7CN	2016	Aug	185	0.423		66.7	Min	Miyashita (2019)
7CN	2017	May	179	0.377		75	Yes	Hakamada *et al.* (2019)
7CN	2018	May	212	0.784		75	Yes	Hakamada *et al.* (2019)
7WR	2003	May-Jun	267	0.7	NC	26.7	Min	IWC (2014c, pp.126-9)
7WR	2004	May-Jun	863	0.648	NC	88.8	Yes	Hakamada and Kitakado (2011)
7WR	2007	Jun-Jul	546	0.953		88.8	Yes	Hakamada and Kitakado (2011)
7WR	2012	Jun	378	0.79		88.8	Yes	Hakamada and Matsuoka (2016)
7WR	2013	May-Jun	65	1.007		89	Yes	Hakamada *et al.* (2019)
7WR	2016	Aug	75	1.062		89	Yes	Hakamada *et al.* (2019)
7W: 7CS+ 7CN+7WR	1991	Aug-Sep	1,164	0.183			Yes	Butterworth and Miyashita (2014)
7E	2004	Jun	440	0.779	NC	57.1	Yes	Hakamada and Kitakado (2011)
7E	2006	May-Jun	247	0.892	NC	57.1	Yes	Hakamada and Kitakado (2011)
7E	2007	Jun-Jul	0	-		57.1	Yes	Hakamada and Kitakado (2011)
7E	2012	Jun	0	-		57.1	Yes	Hakamada and Matsuoka (2016)
7E	2013	Jun	0	-		57.1	Yes	Hakamada *et al.* (2019)
7E	2016	Aug	0	-		57.1	Yes	Hakamada *et al.* (2019)
8	1990	Aug	1,057	0.706	NC	62.2	Yes	Buckland *et al.* (1992); Miyashita pers. com. 2021
8	2002	Jun-Jul	0	-	NC	65	Yes	Hakamada and Kitakado (2011)
8	2004	Jun	1,093	0.576	NC	40.5	Min	Hakamada and Kitakado (2011)
8	2005	May-Jul	132	1.047	NC	65	Yes	Hakamada and Kitakado (2011)
8	2006	May-Jul	309	0.677	NC	65	Yes	Hakamada and Kitakado (2011)
8	2007	Jun-Jul	391	1.013		65	Yes	Hakamada and Kitakado (2011)
8	2008	Jul-Aug	0	-		65	Yes	Hakamada and Matsuoka (2016)
8	2009	May-Jun	602	0.725		65	Yes	Hakamada and Matsuoka (2016)
8	2011	May	121	0.966		65	Yes	Hakamada and Matsuoka (2016)
8	2013	May-Jun	413	0.586		65	Yes	Hakamada *et al.* (2019)
9	1990	Aug	3,287	0.819	NC	61.4	Min	Buckland *et al.* (1992); Miyashita pers. com. 2021
9	2003	Jul-Sep	2,546	0.276	NC	33.2	Min	Hakamada and Kitakado (2011)
9	2008	Jul-Aug	2,458	0.664		87	Yes	Hakamada *et al.* (2016)
9	2009	May-Jun	2,079	0.688		63	Min	Hakamada *et al.* (2016)
9	2011	May	115	1.025		87	Yes	Hakamada *et al.* (2016)
9	2015	May	140	0.963		87	Yes	Hakamada *et al.* (2019)
9N	2005	Aug-Sep	420	0.969	IO-PS	67.8	Yes	Miyashita and Okamura (2011)
9N	2011	May-Jun			115	1.05	Yes	Hakamada *et al.* (2016)

Table 6 continued

Sub-area	Year	Season[a]	STD estimate[b]	CV[c]	Mode[d]	% Areal coverage	Use for Conditioning?[e]	Source
11	1990	Aug-Sep	2,120	0.449	NC	100	Yes	Buckland *et al.* (1992); IWC (2004, p.124)
11	1999	Aug-Sep	1,456	0.565	IO	100	Yes	IWC (2004, p.124)
11	2003	Aug-Sep	882	0.826	IO-AC	33.9	Min	Miyashita and Okamura (2011)
11	2007	Aug-Sep	377	0.389	IO-PS	20.2	Min	Miyashita and Okamura (2011)
11	2014	Aug	306	0.679		35	Min	Miyashita (2019)
11	2018	May	235	0.481		21.7	Min	Hakamada *et al.* (2019)
12SW	1990	Aug-Sep	4,774	0.508	NC	100	Yes	Buckland *et al.* (1992). Cv recalculated (Miyashita pers. comm 2021).
12SW	2003	Aug-Sep	3,401	0.409	IO-AC	100	Yes	Miyashita and Okamura (2011)
12NE	1990	Aug-Sep	11,805	0.377	NC	100	Yes	Buckland *et al.* (1992). Recalculated Miyashita pers. comm Nov 2021
12NE	1992	Aug-Sep	11,051	0.705	NC	[100]	Yes	Miyashita and Shimada (1994); Recalculated Miyashita pers. comm Nov 2021
12NE	1999	Aug-Sep	5,088	0.377	NC	63.8	Min	IWC (2014c, pp.126-9)
12NE	2003	Aug-Sep	13,067	0.287	IO-AC	41	Min	Miyashita and Okamura (2011)

** The above table lists estimates used in conditioning, including corrections received from Japan. The Secretariat maintains a full list of estimates including details of other estimates and the reason they were not included in the above table.

[a] Season: if a survey took place in less than 20% of a month, that month was not used as part of the survey-time-period in the likelihood calculation.

[b] Standard (STD) estimate based on 'Top and Upper bridge' assuming $g(0)=1$, but subsequently corrected by estimate of $g(0)$ for the combined platform 'Top and Upper bridge'.

[c] CV does not consider any process errors.

[d] Mode: NC=Normal-closing, IO-PS=Passing with IO mode, IO-AC=Abeam-closing with IO mode. (STD estimates by different modes, NC, IO-AC, IO-NC, are considered comparable.)

[e] Survey estimates based on less than 70% coverage are treated as 'minima' (except in sub-areas where there are no other estimates).

[f] Maximum values are calculated as the best estimate / coverage.

Table 7a

The number of sampled whales that were assigned to each stock using the genetic assignment data based on STRUCTURE (Hypothesis A & B) and Geneland (Hypothesis E) using a 90% probability of assignment, except for Trial 10 where a 70% probability of assignment is used. In sub-areas 7CS and 7CN the baseline and Trial 10 proportion of whales assigned to each stock is weighted by 5/60 of the bycatch proportion and 55/60 of the special permit proportion. The number assigned by stock is then taken as this proportion multiplied by the total number of assigned animals. In Trial 11 the proportion of whales assigned to each stock is weighted by 2/60 of the bycatch proportion and 58/60 of the special permit proportion, while in Trial 12 10/60 of the bycatch proportion and 50/60 of the special permit proportion are used. These data are used to condition the trials. To come – data for Sensitivity Trials 10, 11 and 12.

Hypothesis	Trial	Area	Years	Months	Sex	Total Sample	Bycatch Samples		Special Permit Samples		Weighted Total	
							J-Stock	O-Stock	J-Stock	O-Stock	J-Stock	O-Stock
A & B	Baseline	2C	2002-16	Jan-Apr	M+F	155	127	28			127	28
A & B	Baseline	2C	2001-16	May-Sep	M+F	56	46	10			46	10
A & B	Baseline	2C	2001-16	Oct-Dec	M+F	134	122	12			122	12
A & B	Baseline	7CS	2002-16	Jan-Mar	M+F	42	32	10			32	10
A & B	Baseline	7CS	2002-16	Apr	M+F	221	11	24	48	138	58	163
A & B	Baseline	7CS	2001-16	May	M+F	391	16	31	89	255	104	287
A & B	Baseline	7CS	1999-2016	Jun-Dec	M+F	199	86	34	4	75	21	178
A & B	Baseline	7CN	2002-14	Jan-Mar	M+F	11	11	0			11	0
A & B	Baseline	7CN	2002-16	Apr-May	M+F	89	16	29	6	38	14	75
A & B	Baseline	7CN	1999-2016	Jun	M+F	133	11	15	6	101	12	121
A & B	Baseline	7CN	1996-2016	Jul-Sep	M+F	610	16	13	103	478	127	483
A & B	Baseline	7CN	2001-16	Oct-Dec	M+F	270	35	2	66	167	91	179
A & B	Baseline	10E	2001-16	Jun-Dec	M+F	15	14	1			14	1
A & B	Baseline	11	2001-10	Jun-Sep*	M	5	4	1				
A & B	Baseline	11	1996-99	Jul-Aug	M	40			12	28		
A & B	Baseline	11	2002-15	May-Sep	F	18	8	10				
A & B	Baseline	11	1996-99	Jul-Aug	F	31			11	20		

Table 7a continued

Hypothesis	Trial	Area	Years	Months	Sex	Total Sample	J-Stk	P-Stk	O-Stk	J-Stk	P-Stk	O-Stk	J-Stk	P-Stk	O-Stk
E	Baseline	2C	2002-16	Jan-Apr	M+F	138	107	31	0				107	31	0
E	Baseline	2C	2001-16	May-Sep	M+F	49	32	17	0				32	17	0
E	Baseline	2C	2001-16	Oct-Dec	M+F	122	105	17	0				105	17	0
E	Baseline	7CS	2002-16	Jan-Mar	M+F	42	0	42	0				0	42	0
E	Baseline	7CS	2002-16	Apr	M+F	220	0	31	1	0	188	0	0	219	1
E	Baseline	7CS	2001-16	May	M+F	378	0	49	2	0	303	24	0	351	27
E	Baseline	7CS	1999-2016	Jun-Dec	M+F	197	0	118	1	0	5	73	0	28	169
E	Baseline	7CN	2002-14	Jan-Mar	M+F	11	5	6	0				5	6	-0
E	Baseline	7CN	2002-16	Apr-May	M+F	80	7	34	0	0	21	18	1	45	34
E	Baseline	7CN	1999-2016	Jun	M+F	129	0	29	0	2	7	91	2	19	108
E	Baseline	7CN	1996-2016	Jul-Sep	M+F	620	7	29	0	8	396	180	18	427	175
E	Baseline	7CN	2001-16	Oct-Dec	M+F	261	6	30	0	2	178	45	6	207	48
E	Baseline	11	2001-12	Jun-Nov	M	15	9	6	0						
E	Baseline	11	1996-99	Jul-Aug	M	44				4	39	1			
E	Baseline	11	2002-15	May-Nov	F	30	13	17	0						
E	Baseline	11	1996-99	Jul-Aug	F	33				5	24	4			

* Samples in October and November were assigned to the J-stock only. Hypotheses A and B assume only J-stock individuals in sub-area 11 in October-December.

Table 7b

Estimates of the proportion of recruited 'J'-whales used to condition the trials based on mtDNA and Allele samples.

Hypothesis	Area	Years	Months	Sex	Ratio	CV[11]	Data Type	Stock	
B and E	6W	1999-2007	Jan-Mar	M+F	0.584	0.131	mtDNA	J:Total	Bycatch samples
B and E	6W	1999-2007	Jan-Mar	M+F	0.672	0.05	Allelle	J:Total	Bycatch samples
B and E	6W	1999-2007	Apr-Jun	M+F	0.496	0.126	mtDNA	J:Total	Bycatch samples
B and E	6W	1999-2007	Apr-Jun	M+F	0.812	0.05	Allelle	J:Total	Bycatch samples
B and E	6W	1999-2007	Jul-Aug	M+F	1.000	0.05	mtDNA	J:Total	Bycatch samples
B and E	6W	1999-2007	Jul-Aug	M+F	0.749	0.077	Allelle	J:Total	Bycatch samples
B and E	6W	1999-2007	Sep-Dec	M+F	0.593	0.123	mtDNA	J:Total	Bycatch samples
B and E	6W	1999-2007	Sep-Dec	M+F	0.761	0.05	Allelle	J:Total	Bycatch samples

(f) Calculation of likelihood

The objective function consists of three components: Objective Function = -(L_1+L_2+L_3) Equations F.4-6 list the negative of the logarithm of the objective function for each of the three components:

Abundance estimates

$$L_{1a} = 0.5\sum_n \frac{1}{(\sigma_t^k)^2}\left(\ln\left(P_n^k / \hat{P}_n^k\right)\right)^2 \quad \text{(F.4a)}$$

where $\hat{P}_n^k$ is the model estimate of the abundance in the same year, period and sub-area as the *n*th estimate of abundance P_n^k.

Minimum abundance estimates

$$L_{1b} = \sum_n \left\{ln\sigma_t^k + \frac{1}{2(\sigma_t^k)^2} ln\left(P_n^k/\hat{P}_n^k\right)^2\right\}\left\{\frac{exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}{1+exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}\right\} + ln\sigma_t^k\left\{\frac{1}{1+exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}\right\} \quad \text{(F.4b)}$$

where Δ is a "large" number (here 30).

Maximum abundance estimates

$$L_{1c} = \sum_n \left\{ln\sigma_t^k + \frac{1}{2(\sigma_t^k)^2} ln\left(P_n^k/\hat{P}_n^k\right)^2\right\}\left\{\frac{1}{1+exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}\right\} + ln\sigma_t^k\left\{\frac{exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}{1+exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}\right\} \quad \text{(F.4c)}$$

Zero abundance estimates

$$L_{1d} = -\sum_n \left[n_n^k ln\left(\beta_n^k \hat{P}_n^k\right) - \beta_n^k \hat{P}_n^k\right]/\hat{\alpha}_n^k \quad \text{(F.4d)}$$

where n_n^k is the number of animals[12] seen during the *n*th survey in sub-area k , β_n^k is the realised track length for the *n*th survey in sub-area k multiplied by the average effective search half width, and divided by the sub-area size (Table 8), $\hat{P}_n^k$ is the model-estimate corresponding to the *n*th survey in sub-area k and $\hat{\alpha}^k$ is the adjusted coefficient of variation

[11] In cases when the sample size used to generate the proportion estimates is small and the se's are small (which will overweight such results), the standard error is set to 0.05.

[12] Alternatively, one could define n_n^k as the number of schools seen during the *n*th survey in sub-area k, with $\hat{P}_n^k$ being the model-estimate corresponding to the nth survey in sub-area k divided by the mean school size. In the calculation of $\hat{\alpha}^k$, m would then denote the number of (non-minima) survey estimates within sub-area k for which the number of schools seen and the CV of the survey estimate are available.

of the survey estimate P_n^k, $\hat{\alpha}^k = \frac{\sum_m (n_m^k)^2 CV^2(P_m^k)}{\sum_m n_m^k}$, constrained to $\hat{\alpha}^k \geq 1$, where m denotes the number of (non-minima) survey estimates within sub-area k for which the number of animals seen and the CV of the survey estimate are available. See Appendix 4 for the derivation of this equation.

Table 8

The realised track length, average effective search half width and sub-area size corresponding to the zero abundance estimates. The effective search half width is taken to be the average from other surveys (excluding those considered minimum estimates) in the same sub-area used in conditioning, for which effective search half width is available.

Year	Sub-Area	Realised track length (nm)	Average effective search half width (nm) [No. of surveys used]	Sub-area size (nm^2)	$\hat{\alpha}^k$
2016	7CS	754	0.3955 [4]	26,826	22.83
2007	7E	360	0.4225 [2]	84,427	1.73
2012	7E	302	0.4225 [2]	84,427	1.73
2013	7E	599	0.4225 [2]	84,427	1.73
2016	7E	472	0.4225 [2]	84,427	1.73
2008	7	887	0.374 [1]	217,678	1.00[13]
2002	8	1,184	0.5283 [7]	250,291	1.50
2008	8	1,194	0.5283 [7]	250,445	1.50

Stock proportions

For sub-areas 2C, 7CN, 7CS, 10E and 11:

$$L_2 = -\sum_j \sum_n N_{j,n}^k ln\left(\hat{p}_{j,n}^k / p_{j,n}^{obs,k}\right) \quad \text{(F.5a)}$$

where $\hat{p}_{j,n}^k$ is the model estimate of the proportion of *j*-stock whales in the same year, period, sub-area and gender as the *n*th set of data and $p_{j,n}^{obs,k}$ is the corresponding observed value, with $N_{j,n}^k$ denoting the observed number of samples of *j*-stock whales in the *n*th set of data. The model estimated proportion is calculated from the 1+ population when the data were generated from samples obtained from bycatches, and from the recruited population when the data were generated from samples obtained from special permit data. In sub-areas 7CN and 7CS the model estimated proportion is calculated from the recruited population due to the higher number of samples from special permit compared to bycatch data.

For sub-area 6W in Hypotheses B and E only:

$$L_2 = 0.5 \sum_n \frac{1}{(\sigma_n^k)^2} \left(p_n^k - \hat{p}_n^k\right)^2 \quad \text{(F.5b)}$$

where $\hat{p}_n^k$ is the model estimate of the proportion of whales in the same year, period and sub-area as the *n*th proportion estimate p_n^k.

Bycatch estimates

$$L_3 = 0.5 \sum_n \left(B_n^k - \hat{B}_n^k\right)^2 / 10 \quad \text{(F.6)}$$

where $\hat{B}_n^k$ is the model estimate of the total bycatch in sub-area k over the years being fitted and B_n^k is the observed bycatch in the same area and period.

G. Trials

The factors to be considered based on the previous trials are listed in Table 9 and the set of trials in Table 10. The sensitivity trials are variants of the base-case trials A01-1 etc. (see section A).

H. Management options

Future direct catch options will be specified later.

I. Output statistics

Population-size and continuing catch statistics are produced for each stock, and catch-related statistics for each sub-area. Catch-related statistics are produced both for the total catches (commercial and incidental) and for the commercial catches alone.

[13] Due to constraint of $\hat{\alpha}^k \geq 1$.

(1) Total catch (TC) distribution: (a) median; (b) 5th value; (c) 95th value.

(2) Initial mature female population size (P_{1930}) distribution: (a) median; (b) 5th value; (c) 95th value.

(3) Final mature female population size (P_{2120}) distribution: (a) median; (b) 5th value; (c) 95th value.

(4) Lowest mature female population size over 100 years (P_{low}) distribution: (a) median; (b) 5th value; (c) 95th value.

(5) Average catch over the last 10 years of the 100-year management period: (a) median; (b) 5th value; (c) 95th value.

(6) Catch by sub-area, stock and catch-type (incidental or commercial): (a) median; (b) 5th value; (c) 95th value.

(7) The median percentage of mature J-stock females being in sub-area 12 in June-August 1973-75.

(8) The median annual rate of decline in the number of whales assumed recruited to the Korean fishery over the period 1973-1986.

(9) The median 1+ population size for animals in sub-areas 6 and 10 in August-September in 1992 and in 2000 (corresponding to Sea of Japan/East Sea surveys).

(10) Proportion Mature: compare the numbers of mature animals by sub-area and time period with the (approximate) proportion mature in the available observation data.

(11) The mean proportion of J whales in the total (scientific, commercial and incidental) catch taken by Japan from 1993-98 is output in trials, for comparison with results obtained from market samples.

Table 9
Proposed factors to be considered in the Trials.

Factor
Stock structure hypothesis
Stock structure hypotheses A, B and E
MSYR
$1\%_{1+}$; $4\%_{mat}$
***g*(0)**
0.798; 1.00 (Trial 2)
Abundance estimates
<60% coverage for minima estimates (Trial 3)
Other stock structure issues
Alternative basis for mixing rates (Trial 10), which requires J-stock presence in sub-areas 7E,7WR,8,9 for Hyp A&B
10% J-stock in sub-area 12SW in June (Trial 13)
30% J-stock in sub-area 12SW in June and 10% J-stock in sub-area 12NE in June (Trial 14)
Catches and bycatches
High direct catch series (Baseline total = 39,299; high total = 40,879) + alternative Korea & Japan bycatch levels (Trial 4)
Different allocation of the catches off Korea between sub-areas 5 and 6W. (Trials 5 and 6) Rationale: the baseline uses the best split; these trials test alternatives in both directions
Chinese incidental catch = 0 (Trial 7) (Baseline value = 2* incidental catch off Korea in sub-area 5)
Number of bycaught animals is proportional to square root of abundance rather than proportional to abundance in order to examine the impact of possible saturation effects (Trial 8)
Use Korean net licence numbers from 1996-2017 as effort data instead of net numbers from 1996-2009 (Trial 9) (Equation D.6)
Alternative time series of large scale nets off Japan from Hakamada instead of Japanese Coast Guard (Trial 17)
Mixing and dispersion
Mixing proportion in sub-areas 7CS and 7CN calculated using alternative weighting for bycatch: 2/60 weight (Trial 11) and 10/60 weight (Trial 12)
A substantially larger fraction of whales aged 1-4 from O-stock are found in sub-areas 2R, 3 and 4 year round (so the proportion of 1-4 whales in sub-area 9 is closer to expectations given the length-frequencies of catches from sub-area 9) (Trial 15)
Set the proportion of O-stock animals of ages 1-4 in sub-areas 9 and 9N to zero (Trial 16)

Table 10
The list of trials (MSYR 1% is defined in terms of the total (1+) component and 4% on the mature female component of the population).

Stock hypothesis	Trial no.	MSYR	Mix matrix:	Description
A	A01-1 & A01-4	1%/ 4%	Baseline	Baseline A: 2 stocks (J- and O-); *g*(0) = 0.798; including Chinese bycatch
B	B01-1 & B01-4	1%/ 4%	Baseline	Baseline B: 3 stocks (J-, O,- and Y-); *g*(0) = 0.798; including Chinese bycatch
E	E01-1 & E01-4	1%/ 4%	Baseline	Baseline E: 4 stocks (J-, P-, O-, and Y-); *g*(0) = 0.798; including Chinese bycatch
BE	B02-1 etc	1%/ 4%	Baseline	Assume *g*(0) = 1
BE	B03-1 etc	1%/ 4%	Baseline	Use <60% coverage for minima estimates. (Baseline <70%)
ABE	A04-1 etc	1%/ 4%	Baseline	High direct catch series + alternative bycatch levels off Japan and Korea
ABE	A05-1 etc	1%/ 4%	Baseline	More catches off Korea in sub-area 5 (and fewer in sub-area 6W). (Baseline uses best split)
ABE	A06-1 etc	1%/ 4%	Baseline	More catches off Korea in sub-area 6W (and fewer in sub-area 5). (Baseline uses best split)
ABE	A07-1 etc	1%/ 4%	Baseline	Chinese incidental catch = 0 (Baseline value = twice that of Korea in sub-area 5)
ABE	A08-1 etc	1%/ 4%	Baseline	The number of bycaught animals is proportional to the square-root of abundance. (Baseline: number proportional to abundance)
ABE	A09-1 etc	1%/ 4%	Baseline	Bycatch effort is Korean net licence numbers from 1996-2017. (Baseline bycatch effort is net numbers from 1996-2009) (Equation D.6)
BE	B10-1 etc[16]	1%/ 4%	Trial 10	Alternative (70% probability) thresholds for assignment of stock proportions
BE	B11-1 etc	1%/ 4%	Baseline	No. of genetic samples assigned to stock in sub-areas 7CS and 7CN calculated using 2/60 weight for bycatch. (Baseline weight 5/60)
BE	B12-1 etc	1%/ 4%	Baseline	No. of genetic samples assigned to stock in sub-areas 7CS and 7CN calculated using 10/60 weight for bycatch. (Baseline weight 5/60)
BE	B13-1 etc	1%/ 4%	Baseline	10% J -stock in sub-area 12SW in June (Baseline value = 20%). See section FI.
BE	B14-1 etc	1%/ 4%	Trial 14	30% J -stock in sub-area 12SW in June (Baseline value = 20%) with 10% J-stock in 12NE in June. See section FI.
BE	B15-1 etc[14]	1%/ 4%	Trial 15	A substantially larger fraction of whales ages 1-4 from O-stock are found in sub-areas 2R, 3 and 4 year-round (so the proportion of 1-4 whales in sub-area 9 is closer to expectations given the length-frequencies of catches from sub-area 9). The mixing matrices are adjusted such that the numbers of age 1-4 of O-stock animals in sub-areas 9 and 9N are no more than half the baseline numbers; juveniles are allowed into sub-areas 2R, 3 and 4 in the corresponding months.
BE	B16-1 etc[16]	1%/ 4%	Trial 16	Set the proportion of O animals of ages 1-4 in sub-areas 9 and 9N to zero and allow the abundance in sub-areas 7CS and 7CN to exceed the abundance estimates for these sub-areas. Projections for these sub-areas will need to account for the implied survey bias
ABE	A17-1 etc[16]	1%/ 4%	Baseline	Use alternative time series of large scale set nets off Japan from Hakamada. (Baseline timeseries from Japanese Coast Guard (JCG))

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Appendix 1

The Historical Catch Series

C. Allison

Direct catches

The baseline trials use the 'best' estimates of the historical direct catch, which are summarised in Tables 1 and 2. Details of the sources and construction of the catch series are given in Allison (2011). The data are taken from the IWC individual catch database (Allison, 2020) where available; where these data are not available the catch series has been compiled to match all known sources of information.

An alternative 'high' catch series is used in Trial 4. Table 3 lists the 'high' catch numbers for the years and sub-areas where they differ from the 'best' catch series. The catches are identical to the 'best' series for all other areas and years.

The coastal catch off Japan from 1930-1 and 1936-45 (in sub-areas 7CS, 7CN and 11) is estimated (Ohsumi, 1982) and the values are doubled in the 'high' catch series. The catch series off Korea assumes a linear increase from 60 whales in 1946 to 249 in 1957 in the 'best' series whereas the 'high' series assumes an annual catch of 249 minke whales over this period.

The split between sub-areas 5 and 6W is unknown for most of the catches taken off Korea. The 'best' catch series includes 19,349 minke whales taken off Korea, of which 3,902 are recorded in the Yellow Sea and 4,199 in the Sea of Japan/East Sea and Southern waters. The remaining 11,248 of unknown area are allocated between sub-areas 5 and 6W in the ratio of the catches known by area from 1940-79[15] (2,028:2,517). Where catches are known by month from 1958-86, (Park, 1995) but not area, they are allocated to sub-area using the average known ratio in the given month. Trials 5 and 6 test the sensitivity to this assumption. In Trial 5 the number of whales allocated to sub-area 6W is reduced by 20% and reallocated to sub-area 5. In Trial 6, 20% fewer animals are allocated to sub-area 5 and are reallocated to sub-area 6W. The resulting catch series is given in Table 4.

Table 1

Summary of the final western North Pacific Minke Whale Direct Catch Series (1930-2020) by sub-area, sex and month. Catches that cannot be taken because no whales are modelled the area/month are highlighted.

	Males								Females										
Area	J-M	Apr	May	Jun	Jul	Aug	Sep	O-D	J-M	Apr	May	Jun	Jul	Aug	Sep	O-D	Total	M	F
1E	17	0	0	0	1	0	0	0	11	0	0	0	0	0	0	0	29	18	11
2C	`3	2	2	3	2	0	1	0	2	2	0	0	1	0	0	0	18	13	5
2R	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	4	2	2
5	981	1,280	906	671	568	322	102	174	1,128	1,457	1,244	757	570	300	121	185	10,766	5,004	5,762
6W	181	383	1,325	1,167	392	202	557	1,063	178	364	1,300	1,136	376	189	545	1,009	10,367	5,270	5,097
6E	181	223	135	13	21	0	8	2	95	144	95	16	3	0	6	1	943	583	360
7CS	210	1,011	1,826	768	129	8	1	0	164	1,134	1,371	464	27	1	0	0	7,114	3,953	3,161
7CN	0	0	77	241	387	426	940	199	0	20	89	101	163	122	312	113	3,190	2,270	920
7W	0	1	49	33	3	1	10	0	0	0	9	3	3	0	0	0	112	97	15
7E	0	0	37	21	3	0	13	1	0	0	7	2	0	0	9	0	93	75	18
8	0	0	39	101	99	21	11	6	0	0	8	10	17	4	5	6	327	277	50
9	0	0	32	82	183	218	17	0	0	0	9	11	16	29	3	0	600	532	68
9N	0	0	1	2	5	8	0	1	0	0	0	6	0	11	0	0	34	17	17
10W	0	0	6	12	1	0	2	0	0	2	0	9	0	0	0	0	32	21	11
10E	2	25	42	119	83	26	5	3	0	1	28	60	26	9	7	0	436	305	131
11	0	62	248	503	560	230	143	29	2	465	872	909	607	273	113	25	5,041	1,775	3,266
12SW	0	0	0	1	11	9	1	0	0	0	1	5	16	27	5	0	76	22	54
12NE	0	0	0	0	36	9	10	0	0	0	0	3	33	14	6	0	111	55	56
13	0	0	0	0	0	2	0	0	0	0	0	0	1	3	0	0	6	2	4
Total	1,576	2,988	4,725	3,737	2,484	1,482	1,821	1,478	1,581	3,589	5,033	3,492	1,859	982	1,133	1,339	39,299	20,291	19,008

[15]The period 1940-79 is used in view of a comment by Gong (1982) that, in 1980, Government policy led to a shift to the western sector in order to direct the minke whale fishery away from areas where the (protected) fin whale might also be caught.

Table 2
Summary of the ‘Best’ Direct Catch Series for western North Pacific Minke Whales by Year, sub-area and sex.

Males:

	1E	2C	2R	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE	13	Total
1930	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	1	0	0	0	8
1931	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	8
1932	0	0	0	0	9	0	13	1	0	0	0	0	0	0	0	0	0	0	0	23
1933	0	0	0	0	8	0	13	1	0	0	0	0	0	0	0	0	0	0	0	22
1934	0	0	0	1	21	0	20	1	0	0	0	0	0	0	0	0	0	0	0	43
1935	0	0	0	9	9	0	20	1	0	0	0	0	0	0	0	1	0	0	0	40
1936	0	0	0	12	14	0	15	0	0	0	0	0	0	0	0	0	0	0	0	41
1937	0	0	0	13	17	0	37	0	0	0	0	0	0	0	0	1	0	0	0	68
1938	0	0	0	15	20	0	44	0	0	0	0	0	0	0	0	1	0	0	0	80
1939	0	0	0	18	24	0	44	1	0	0	0	0	2	0	0	0	0	0	0	89
1940	0	0	0	15	33	0	52	0	0	0	0	0	0	0	0	1	0	0	0	101
1941	0	0	0	40	40	0	37	1	0	0	0	0	2	0	0	0	0	0	0	120
1942	0	0	0	53	67	0	44	0	0	0	0	0	1	0	0	1	0	0	0	166
1943	0	0	0	42	51	0	67	1	0	0	0	0	0	0	0	0	0	0	0	161
1944	0	0	0	38	47	0	52	0	0	0	0	0	0	0	0	1	0	0	0	138
1945	0	0	0	3	2	0	44	0	0	0	0	0	0	0	0	0	0	0	0	49
1946	0	0	0	11	21	14	51	4	0	0	0	0	1	0	0	4	0	0	0	106
1947	0	0	0	19	21	27	57	7	0	0	0	0	0	0	0	8	0	0	0	139
1948	0	3	0	22	26	56	57	1	0	0	1	0	0	0	0	26	0	0	0	192
1949	0	0	0	25	31	20	61	0	0	0	1	0	2	0	5	6	0	2	0	153
1950	0	3	0	29	37	15	63	41	0	0	2	0	1	0	13	18	0	0	0	222
1951	1	1	0	31	40	62	87	9	0	3	0	0	0	0	5	14	0	0	0	253
1952	0	1	0	36	45	142	92	1	0	0	0	0	1	0	9	20	0	0	0	347
1953	0	0	0	42	50	90	75	1	0	0	3	0	0	0	38	35	1	0	0	335
1954	0	0	1	43	54	35	24	26	0	0	0	0	0	0	32	59	1	0	0	275
1955	0	0	0	49	60	20	108	11	0	0	2	0	0	0	20	43	1	1	0	315
1956	0	0	0	54	62	16	140	25	0	1	3	0	0	0	47	69	0	0	0	417
1957	17	1	0	59	70	2	111	14	2	0	1	0	0	0	31	33	1	0	0	342
1958	0	0	0	67	65	0	126	13	0	0	1	0	0	0	0	86	0	0	0	358
1959	0	0	0	78	71	0	69	7	0	0	0	0	0	0	0	47	0	0	0	272
1960	0	0	0	72	59	0	64	6	0	1	1	0	0	0	0	41	0	0	0	244
1961	0	0	0	39	28	0	81	9	0	0	0	0	0	0	0	56	0	0	0	213
1962	0	0	0	55	52	0	46	7	0	0	0	0	0	0	0	48	0	0	0	208
1963	0	0	0	122	52	0	49	6	0	0	0	0	0	0	0	40	0	0	0	269
1964	0	0	0	139	95	6	85	6	0	0	0	0	0	0	0	39	0	0	0	370
1965	0	1	0	83	101	11	51	3	0	0	0	0	0	0	0	62	0	0	0	312
1966	0	2	0	76	87	0	81	8	1	0	0	0	0	0	0	71	0	0	0	326
1967	0	0	0	109	73	2	50	6	0	0	0	0	0	0	2	55	0	0	0	297
1968	0	0	0	98	75	8	58	4	1	0	0	0	0	2	0	22	0	0	0	268
1969	0	0	0	118	95	10	27	2	0	0	0	0	3	0	7	43	0	0	0	305
1970	0	0	0	186	188	5	101	5	1	0	0	2	4	0	8	38	0	0	2	540
1971	0	0	0	200	189	3	84	6	0	0	0	0	0	0	8	54	1	0	0	545
1972	0	0	0	252	286	0	35	17	0	0	0	0	0	0	0	78	0	0	0	668
1973	0	0	0	215	244	0	83	26	0	2	14	0	0	0	15	95	2	28	0	724
1974	0	0	0	213	271	0	63	34	0	9	0	0	0	1	5	44	4	22	0	666
1975	0	0	0	196	293	9	35	63	0	3	0	0	0	18	2	62	11	1	0	693
1976	0	0	0	353	174	0	35	27	0	0	0	0	0	0	10	89	0	0	0	688
1977	0	0	0	234	304	0	32	71	0	0	0	0	0	0	0	58	0	0	0	699
1978	0	0	0	181	354	0	93	133	0	0	0	0	0	0	0	19	0	0	0	780
1979	0	0	0	164	379	0	95	150	0	0	0	0	0	0	8	17	0	0	0	813
1980	0	0	0	447	147	0	88	72	0	0	0	0	0	0	10	40	0	0	0	804
1981	0	1	0	188	192	0	148	39	1	0	0	0	0	0	13	28	0	0	0	610
1982	0	0	0	229	210	2	105	56	1	0	0	0	0	0	9	5	0	0	0	617
1983	0	0	0	100	142	3	66	68	0	0	0	0	0	0	6	4	0	0	0	389
1984	0	0	0	87	105	0	64	88	0	0	0	0	0	0	0	46	0	0	0	390
1985	0	0	1	23	29	5	39	123	0	0	0	0	0	0	2	30	0	0	0	252
1986	0	0	0	1	31	20	69	89	0	0	0	0	0	0	0	19	0	0	0	229
1987	0	0	0	0	0	0	80	86	0	0	0	0	0	0	0	16	0	0	0	182
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	18
1995	0	0	0	0	0	0	0	0	0	0	0	91	0	0	0	0	0	0	0	91
1996	0	0	0	0	0	0	0	28	0	0	16	0	0	0	0	19	0	0	0	63
1997	0	0	0	0	0	0	0	0	1	1	30	55	0	0	0	0	0	0	0	87
1998	0	0	0	0	0	0	0	0	22	26	41	0	0	0	0	0	0	0	0	89
1999	0	0	0	0	0	0	2	39	2	0	0	0	0	0	0	28	0	0	0	71

Table 2. Males contd.

	1E	2C	2R	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE	13	Total
2000	0	0	0	0	0	0	4	15	0	0	0	16	0	0	0	0	0	0	0	35
2001	0	0	0	0	0	0	11	10	19	7	20	26	0	0	0	0	0	0	0	93
2002	0	0	0	0	0	0	0	79	1	0	8	31	0	0	0	0	0	0	0	119
2003	0	0	0	0	0	0	32	0	4	7	35	37	0	0	0	0	0	0	0	115
2004	0	0	0	0	0	0	0	62	0	0	0	75	0	0	0	0	0	1	0	138
2005	0	0	0	0	0	0	28	67	2	0	7	52	0	0	0	0	0	0	0	156
2006	0	0	0	0	0	0	41	33	11	1	36	23	0	0	0	0	0	0	0	145
2007	0	0	0	0	0	0	50	67	3	0	15	5	0	0	0	0	0	0	0	140
2008	0	0	0	0	0	0	23	33	0	0	5	48	0	0	0	0	0	0	0	109
2009	0	0	0	0	0	0	29	41	8	3	13	6	0	0	0	0	0	0	0	100
2010	0	0	0	0	0	0	17	40	0	0	0	12	0	0	0	0	0	0	0	69
2011	0	0	0	0	0	0	17	64	0	0	0	1	0	0	0	0	0	0	0	82
2012	0	0	0	0	0	0	47	61	4	0	3	0	0	0	0	0	0	0	0	115
2013	0	0	0	0	0	0	17	41	0	0	0	3	0	0	0	0	0	0	0	61
2014	0	0	0	0	0	0	16	35	0	0	0	0	0	0	0	0	0	0	0	51
2015	0	0	0	0	0	0	10	35	0	0	0	0	0	0	0	0	0	0	0	45
2016	0	0	0	0	0	0	7	8	0	0	0	0	0	0	0	0	0	0	0	15
2017	0	0	0	0	0	0	3	22	6	10	4	17	0	0	0	9	0	0	0	71
2018	0	0	0	0	0	0	28	22	4	1	15	14	0	0	0	16	0	0	0	100
2019	0	0	0	0	0	0	26	32	3	0	0	0	0	0	0	5	0	0	0	66
2020	0	0	0	0	0	0	1	58	0	0	0	0	0	0	0	4	0	0	0	63
Total	18	13	2	5,004	5,270	583	3,953	2,270	97	75	277	532	17	21	305	1,775	22	55	2	20,291

Females

	1E	2C	2R	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE	13	Total
1930	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	5
1931	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	2	0	0	0	6
1932	0	0	0	5	4	0	7	0	0	0	0	0	0	0	0	1	0	0	0	17
1933	0	0	0	5	4	0	7	1	0	0	0	0	0	1	0	1	0	0	0	19
1934	0	0	0	9	10	0	10	0	0	0	0	0	0	1	0	1	0	0	0	31
1935	0	0	0	8	14	0	10	0	0	0	0	0	0	0	0	1	0	0	0	33
1936	0	0	0	12	13	0	7	0	0	0	0	0	0	0	0	2	0	0	0	34
1937	0	0	0	14	18	0	18	1	0	0	0	0	0	0	0	1	0	0	0	52
1938	0	0	0	18	20	0	22	0	0	0	0	0	0	0	0	1	0	0	0	61
1939	0	0	0	19	23	0	22	0	0	0	0	0	1	0	0	2	0	0	1	68
1940	0	0	0	13	34	0	25	0	0	0	0	0	0	0	0	1	0	0	0	73
1941	0	0	0	64	38	0	18	0	0	0	0	0	0	0	0	2	0	0	0	122
1942	0	0	0	54	66	0	22	0	0	0	0	0	2	0	0	1	0	0	0	145
1943	0	0	0	39	51	0	32	0	0	0	0	0	0	0	0	2	0	0	0	124
1944	0	0	0	38	45	0	25	0	0	0	0	0	0	0	0	1	0	0	0	109
1945	0	0	0	2	3	0	22	1	0	0	0	0	0	0	0	2	0	0	0	30
1946	0	0	0	10	18	10	24	1	0	0	0	0	1	0	0	13	0	0	0	77
1947	0	0	0	18	19	21	27	3	0	0	0	0	0	0	0	23	0	0	0	111
1948	0	0	0	21	25	38	31	0	0	0	0	0	0	0	0	53	0	0	0	168
1949	0	0	0	25	31	30	32	0	0	0	2	0	0	0	4	27	0	1	0	152
1950	0	1	1	29	34	9	25	19	0	0	0	0	0	0	0	32	0	1	0	151
1951	0	0	0	33	42	39	42	2	0	2	1	0	2	0	2	70	0	1	0	236
1952	0	0	1	37	45	43	78	2	0	0	0	0	1	0	0	97	1	0	0	305
1953	0	0	0	39	49	47	56	2	0	0	3	0	0	0	5	57	1	0	0	259
1954	0	1	0	45	55	27	22	15	0	0	3	0	1	0	4	124	0	0	0	297
1955	0	0	0	58	59	15	80	4	0	0	3	0	0	0	7	119	0	2	0	347
1956	0	0	0	62	66	23	97	7	0	0	1	0	1	0	13	108	0	4	0	382
1957	11	1	0	79	68	0	81	12	2	0	3	0	0	0	13	96	1	0	0	367
1958	0	0	0	101	63	0	128	8	0	0	1	0	0	0	0	153	0	0	0	454
1959	0	0	0	126	73	0	70	4	0	0	0	0	0	0	0	83	0	1	0	357
1960	0	0	0	141	57	0	65	4	0	1	1	0	0	0	0	73	0	0	0	342
1961	0	0	0	82	30	0	83	5	0	0	1	0	0	0	0	98	0	0	0	299
1962	0	0	0	117	52	0	47	5	0	0	0	0	0	0	0	85	0	1	0	307
1963	0	0	0	168	52	0	50	4	0	0	0	0	0	0	0	71	0	0	0	345
1964	0	0	0	186	97	6	86	4	0	0	0	0	0	0	0	69	0	0	0	448
1965	0	1	0	110	102	9	99	3	0	0	0	0	0	0	0	94	0	0	0	418
1966	0	1	0	105	88	2	100	15	0	0	0	0	0	0	0	84	0	0	0	395
1967	0	0	0	139	73	8	65	7	0	0	0	0	0	0	3	87	0	0	0	382
1968	0	0	0	124	73	3	81	3	0	0	0	0	0	7	5	56	0	0	0	352
1969	0	0	0	156	96	10	32	1	0	0	0	0	8	0	5	97	0	0	0	405
1970	0	0	0	216	188	2	87	5	1	0	0	0	0	0	4	70	0	0	2	575
1971	0	0	0	250	190	2	67	4	0	0	0	0	0	0	9	52	0	0	0	574
1972	0	0	0	292	286	0	75	22	0	0	0	0	0	0	1	113	0	0	0	789
1973	0	0	0	239	244	2	90	15	0	2	7	0	0	0	6	116	11	27	0	759
1974	0	0	0	267	272	0	51	19	0	3	0	0	0	0	3	79	17	18	0	729
1975	0	0	0	229	288	2	46	22	0	4	0	0	0	2	4	58	23	0	0	678
1976	0	0	0	445	174	0	46	29	0	0	0	0	0	0	11	113	0	0	1	819

Table 2. Females contd.

	1E	2C	2R	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE	13	Total
1977	0	0	0	269	303	0	28	14	0	0	0	0	0	0	2	43	0	0	0	659
1978	0	0	0	207	356	0	85	22	0	0	0	0	0	0	0	48	0	0	0	718
1979	0	0	0	130	264	0	38	28	0	0	0	0	0	0	7	64	0	0	0	531
1980	0	0	0	272	109	0	70	12	0	0	0	0	0	0	5	82	0	0	0	550
1981	0	0	0	188	192	0	68	11	0	0	0	0	0	0	2	63	0	0	0	524
1982	0	0	0	236	219	2	58	28	0	0	0	0	0	0	6	56	0	0	0	605
1983	0	0	0	98	138	4	69	30	0	0	0	0	0	0	5	42	0	0	0	386
1984	0	0	0	87	114	0	38	55	0	0	0	0	0	0	0	76	0	0	0	370
1985	0	0	0	26	35	4	20	41	0	0	0	0	0	0	5	66	0	0	0	197
1986	0	0	0	0	15	2	35	43	2	0	0	0	0	0	0	54	0	0	0	151
1987	0	0	0	0	0	0	43	30	0	0	0	0	0	0	0	49	0	0	0	122
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
1995	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	9
1996	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	11	0	0	0	14
1997	0	0	0	0	0	0	0	0	0	0	1	12	0	0	0	0	0	0	0	13
1998	0	0	0	0	0	0	0	0	3	4	4	0	0	0	0	0	0	0	0	11
1999	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	22	0	0	0	29
2000	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	5
2001	0	0	0	0	0	0	0	0	3	0	1	3	0	0	0	0	0	0	0	7
2002	0	0	0	0	0	0	0	31	0	0	0	2	0	0	0	0	0	0	0	33
2003	0	0	0	0	0	0	30	0	1	0	3	2	0	0	0	0	0	0	0	36
2004	0	0	0	0	0	0	0	14	0	0	0	8	0	0	0	0	0	0	0	22
2005	0	0	0	0	0	0	37	19	0	0	7	3	0	0	0	0	0	0	0	66
2006	0	0	0	0	0	0	35	12	1	1	2	1	0	0	0	0	0	0	0	52
2007	0	0	0	0	0	0	46	21	0	0	0	1	0	0	0	0	0	0	0	68
2008	0	0	0	0	0	0	38	18	0	0	0	6	0	0	0	0	0	0	0	62
2009	0	0	0	0	0	0	35	24	0	0	5	1	0	0	0	0	0	0	0	65
2010	0	0	0	0	0	0	28	20	0	0	0	2	0	0	0	0	0	0	0	50
2011	0	0	0	0	0	0	6	37	0	0	0	1	0	0	0	0	0	0	0	44
2012	0	0	0	0	0	0	38	30	1	0	0	0	0	0	0	0	0	0	0	69
2013	0	0	0	0	0	0	17	17	0	0	0	0	0	0	0	0	0	0	0	34
2014	0	0	0	0	0	0	14	16	0	0	0	0	0	0	0	0	0	0	0	30
2015	0	0	0	0	0	0	9	16	0	0	0	0	0	0	0	0	0	0	0	25
2016	0	0	0	0	0	0	9	13	0	0	0	0	0	0	0	0	0	0	0	22
2017	0	0	0	0	0	0	0	13	0	1	0	6	0	0	0	38	0	0	0	58
2018	0	0	0	0	0	0	23	8	0	0	1	8	0	0	0	31	0	0	0	71
2019	0	0	0	0	0	0	20	10	0	0	0	0	0	0	0	27	0	0	0	57
2020	0	0	0	0	0	0	5	25	0	0	0	0	0	0	0	2	0	0	0	32
Total	11	5	2	5,762	5,097	360	3,161	920	15	18	50	68	17	11	131	3,266	54	56	4	19,008

Table 3

The High Catch Series.

Catches for the years and sub-areas where they differ from the 'best' catch series (1930-1, 1936-45 in sub-areas 7CS, 7CN and 11; 1947-56 in sub-areas 5 and 6W). Numbers from the 'best' catch series are shown for comparison. The 'high' catch series is identical to the 'best' series for all other areas and years.

Series:	Best	Best	High	High	Best	Best	High	High	Best	Best	High	High
Sub-area:	7CS	7CS	7CS	7CS	7CN	7CN	7CN	7CN	11	11	11	11
	Male	Fem	Male	Fem	Male	Fem	Male	Fem	Male	Fem	Male	Fem
1930	7	4	**14**	**8**	0	0	0	0	1	1	**2**	**2**
1931	7	4	**14**	**8**	1	0	**2**	0	0	2	0	**4**
1932	13	7	13	7	1	0	1	0	0	1	0	1
1933	13	7	13	7	1	1	1	1	0	1	0	1
1934	20	10	20	10	1	0	1	0	0	1	0	1
1935	20	10	20	10	1	0	1	0	1	1	1	1
1936	15	7	**30**	**14**	0	0	0	0	0	2	0	**4**
1937	37	18	**74**	**36**	0	1	0	**2**	1	1	**2**	**2**
1938	44	22	**88**	**44**	0	0	0	0	1	1	**2**	**2**
1939	44	22	**88**	**44**	1	0	**2**	0	0	2	0	**4**
1940	52	25	**104**	**50**	0	0	0	0	1	1	**2**	**2**
1941	37	18	**74**	**36**	1	0	**2**	0	0	2	0	**4**
1942	44	22	**88**	**44**	0	0	0	0	1	1	**2**	**2**
1943	67	32	**134**	**64**	1	0	**2**	0	0	2	0	**4**
1944	52	25	**104**	**50**	0	0	0	0	1	1	**2**	**2**
1945	44	22	**88**	**44**	0	1	0	**2**	0	2	0	**4**

Table 3 continued

Series:	Best	Best	High	High	Best	Best	High	High
Sub-area:	5	5	5	5	6W	6W	6W	6W
	Male	Fem	Male	Fem	Male	Fem	Male	Fem
1946	11	10	11	10	21	18	21	18
1947	19	18	**55**	**56**	21	19	**70**	**68**
1948	22	21	**55**	**56**	26	25	**70**	**68**
1949	25	25	**55**	**56**	31	31	**70**	**68**
1950	29	29	**55**	**56**	37	34	**70**	**68**
1951	31	33	**55**	**56**	40	42	**70**	**68**
1952	36	37	**55**	**56**	45	45	**70**	**68**
1953	42	39	**55**	**56**	50	49	**70**	**68**
1954	43	45	**55**	**56**	54	55	**70**	**68**
1955	49	58	**56**	**66**	60	59	**70**	**68**
1956	54	62	**57**	**66**	62	66	**70**	**68**
1957	59	79	59	79	70	68	70	68

Table 4

Catch series for Trials 5 and 6 used to test the sensitivity to the allocation of catches off Korea between sub-areas 5 and 6W. Catches in the other sub-areas are the same as for the 'Best' catch series.

	Trial 5				Trial 6			
Sub-area:	5	5	6W	6W	5	5	6W	6W
	Male	Fem	Male	Fem	Male	Fem	Male	Fem
1932	0	5	9	4	0	5	9	4
1933	0	5	8	4	0	5	8	4
1934	1	9	21	10	1	9	21	10
1935	9	12	9	10	7	7	12	14
1936	14	15	13	9	9	10	15	17
1937	17	16	14	15	12	9	21	20
1938	19	22	16	16	14	13	24	22
1939	23	23	20	18	15	15	27	27
1940	21	21	27	26	12	11	37	35
1941	48	72	31	31	38	62	41	41
1942	66	66	53	55	43	43	77	77
1943	51	51	40	41	31	33	59	60
1944	48	48	37	35	31	31	53	53
1945	3	2	2	3	3	2	2	3
1946	14	15	15	16	10	8	22	20
1947	24	21	16	16	15	15	23	24
1948	27	26	20	21	18	18	28	30
1949	30	32	25	25	18	22	36	36
1950	34	38	28	29	23	24	42	40
1951	40	40	33	33	26	26	47	47
1952	46	46	37	34	29	30	51	53
1953	50	51	40	39	31	33	58	58
1954	55	54	43	45	35	35	64	63
1955	62	69	46	49	39	48	70	69
1956	67	74	52	51	42	53	75	74
1957	73	92	56	55	49	66	79	82
1958	80	114	51	51	53	89	77	77
1959	93	141	57	57	63	110	86	89
1960	84	152	46	47	63	131	68	67
1961	44	87	24	24	35	77	33	34
1962	65	128	43	40	49	110	58	59
1963	131	179	43	41	104	149	71	70
1964	159	205	77	76	118	162	119	118
1965	102	131	82	81	68	97	116	115
1966	95	121	70	70	64	91	100	101
1967	125	153	59	57	91	120	93	90
1968	112	139	60	59	82	107	91	90
1969	137	176	75	77	98	138	114	115
1970	223	253	151	151	152	183	221	222
1971	239	286	152	152	165	214	225	225
1972	308	348	229	231	230	267	311	308
1973	251	275	208	208	197	220	262	263
1974	251	302	235	235	188	241	297	297
1975	253	287	235	231	159	196	327	324
1976	389	479	139	139	292	384	235	235
1977	294	331	242	243	192	226	346	346
1978	253	276	283	286	152	175	384	387
1979	164	130	379	264	164	130	379	264
1980	447	272	147	109	447	272	147	109
1981	188	188	192	192	188	188	192	192
1982	236	247	202	209	222	229	217	226
1983	100	98	142	138	100	98	142	138
1984	87	87	105	114	87	87	105	114
1985	23	26	29	35	23	26	29	35
1986	1	0	31	15	1	0	31	15

Bycatches

Tables 5 and 6 summarise recent bycatches (also referred to as incidental catches) off Japan and Korea by sub-area. Individual records, including position, date, length and sex, have been provided to the IWC by Japan for 1,964 by caught minke whales from 2001-16 received 28 May 2019) and by Korea for 1,883 by caught and stranded minke whales from 2001-17 (received 29 Mar 2019).

Table 5

Recent bycatches by Japan and Korea (some are updates to those listed in progress reports). It is known that the numbers off Japan in 2001 are incomplete. Bycatches from sub-area 6W by Japan are included with those in 6E (see text). No data for 2020 off Korea are available. Bycatches that are shown in grey are not used in the fitting process.

	Japan								Korea				
Year	1E	2C	6E	7CN	7CS	10E	11	Total	5	6W	1W	Posn.Unk	Total
1996										128	0	0	128
1997										78	0	0	78
1998										47	0	0	47
1999										54	0	0	54
2000									12	80	0	0	92
2001	1	10	25	3	8	4	3	54	9	141	0	0	150
2002	7	19	45	13	17	3	5	109	8	75	0	0	83
2003	5	17	61	15	18	0	8	124	10	75	2	0	87
2004	4	19	66	9	14	0	3	115	9	52	0	0	61
2005	4	33	55	10	17	3	6	128	7	98	0	0	105
2006	3	28	76	16	21	0	3	147	11	67	0	2	80
2007	7	42	69	11	20	0	6	155	12	59	0	1	72
2008	9	23	68	11	17	2	3	133	12	61	0	2	75
2009	3	17	69	3	25	0	1	118	10	70	0	2	82
2010	3	18	74	8	17	0	4	124	8	63	0	0	71
2011	6	28	65	9	8	0	1	117	15	70	0	1	86
2012	5	25	56	9	15	0	4	114	8	66	0	0	74
2013	5	20	54	9	15	2	0	105	8	43	0	0	51
2014	3	21	74	16	23	1	2	140	7	43	0	0	50
2015	5	28	84	12	26	0	1	156	7	78	1	1	87
2016	7	34	86	17	22	3	0	169	10	84	0	0	94
2017	5	32	80	10	34	1	2	164	12	57	0	0	69
2018	2	18	40	9	18	0	0	87	7	73	0	0	80
2019	3	15	54	9	23	0	0	104	3	55	0	0	58
2020	2	10	34	9	16	0	0	71					
Total	89	457	1235	374	208	19	52	2434					

In Japan it has been obligatory to report bycatches from 2001, since when the numbers are considered to be reliable. Almost all of the reported bycatch off Japan occurs in set-net fisheries. Three types of set nets are used: large-scale (excluding salmon nets), salmon nets and small-scale. For fishing gears other than set-nets, bycatch, retention and marketing of whales are prohibited by the 2001 regulation and a diagnostic DNA registry is used to deter illegal distribution of any whales caught.

Ideally, the catch by each gear type should be modelled separately to allow the historical (pre-2001) bycatch to be predicted. However, information on numbers of catches by net type is not available. Therefore, in the 2013 Implementation, the historical bycatches for each sub-area were set using the total number of bycatches and the combined number of large-scale and salmon nets in each sub-area (Allison, 2014). Japan has provided new information on the numbers of large-scale nets from 1979-2018, but numbers of salmon nets since 2016 are not available. The numbers of whales caught in salmon nets are small in comparison to those from large-scale nets (see Table 6 which lists the bycatches from 2001-9 by gear type), so in the current implementation, the historical bycatches are set using the total numbers of bycatches (Table 5) and the numbers of large-scale nets (Table 7) in each sub-area.

Table 6

Bycatches by Japan 2001-9 by gear type (Hakamada, pers. comm. 28/04/2011).

	Salmon	Large-scale	Small-scale	Other gear types
2001	3	68	9	0
2002	5	92	12	0
2003	8	99	18	0
2004	2	101	12	2
2005	7	105	17	0
2006	5	125	17	0
2007	8	131	16	0
2008	3	116	14	0
2009	4	101	13	0

Table 7

Numbers of nets. Sources: Japan 1935-70 – Set using linear interpolation, assuming 0 in 1935; Japan 1970-79 – Set using linear interpolation between the numbers for 1970 and 1975 from Tobayama *et al.* (1992); Japan 1979-2018 – Pastene, pers. comm. Apr 2021; Korea 1946-1996 – Set using linear interpolation, assuming 0 in 1946; Korea 1990-2009 – An, pers. comm. Missing data: where the numbers of nets are unknown (off Japan from 2019-20 and off Korea from 2010-20), the last known numbers are used.

	Japan large-scale trap nets								Korea nets		
	1E	2C	6E	7CS	7CN	10E	11	Total	5	6W	Total
1946	24	67	103	41	8	7	3	252	0	0	0
1947	26	73	112	44	9	7	3	275	2	5	7
1948	29	79	122	48	9	8	4	298	4	11	15
1949	31	85	131	52	10	8	4	321	6	16	22
1950	33	91	141	55	11	9	4	344	8	21	29
1951	35	97	150	59	11	10	5	367	10	27	37
1952	37	103	159	63	12	10	5	390	12	32	44
1953	40	109	169	66	13	11	5	412	14	38	52
1954	42	115	178	70	14	11	5	435	15	43	58
1955	44	121	187	74	14	12	6	458	17	48	65
1956	46	127	197	77	15	13	6	481	19	54	73
1957	48	133	206	81	16	13	6	504	21	59	80
1958	51	139	216	85	16	14	7	527	23	64	87
1959	53	145	225	88	17	14	7	550	25	70	95
1960	55	151	234	92	18	15	7	573	27	75	102
1961	57	157	244	96	19	16	7	596	29	80	109
1962	59	164	253	100	19	16	8	619	31	86	117
1963	62	170	262	103	20	17	8	642	33	91	124
1964	64	176	272	107	21	17	8	665	35	97	132
1965	66	182	281	111	21	18	9	687	37	102	139
1966	68	188	291	114	22	19	9	710	39	107	146
1967	70	194	300	118	23	19	9	733	41	113	154
1968	73	200	309	122	24	20	9	756	43	118	161
1969	75	206	319	125	24	20	10	779	44	123	167
1970	77	212	328	129	25	21	10	802	46	129	175
1971	80	209	324	127	25	21	10	795	48	134	182
1972	83	206	321	124	25	21	10	789	50	139	189
1973	86	203	317	122	24	20	9	782	52	145	197
1974	89	200	314	119	24	20	9	776	54	150	204
1975	92	197	310	117	24	20	9	769	56	156	212
1976	80	198	321	118	25	21	10	773	58	161	219
1977	69	199	332	119	27	22	10	777	60	166	226
1978	57	200	344	119	28	23	11	781	62	172	234
1979	46	205	361	122	30	25	11	800	64	177	241
1980	49	208	372	130	28	24	11	822	66	182	248
1981	51	205	375	134	26	21	10	823	68	188	256
1982	50	204	393	133	27	22	10	838	70	193	263
1983	54	199	392	132	37	31	14	859	71	198	269
1984	51	191	393	141	48	41	19	885	73	204	277
1985	47	192	419	141	42	36	16	894	75	209	284
1986	50	198	413	136	50	43	20	909	77	215	292
1987	47	196	409	138	48	41	19	900	79	220	299
1988	47	190	407	132	40	33	15	865	81	225	306
1989	56	185	398	142	35	29	13	857	83	231	314
1990	56	182	413	137	35	30	14	867	85	236	321
1991	61	178	410	135	29	24	11	847	85	286	371
1992	56	169	400	135	27	22	10	820	96	305	401
1993	62	183	406	135	28	22	10	845	96	291	387
1994	55	179	387	131	29	23	11	814	94	286	380
1995	57	179	380	119	26	20	9	790	97	292	389
1996	57	175	379	132	26	20	9	799	103	352	455
1997	54	172	376	132	25	19	9	787	123	340	463
1998	56	167	377	133	26	19	9	787	105	338	443
1999	55	170	370	131	28	22	10	786	120	321	441
2000	55	169	367	130	28	22	10	781	105	318	423
2001	58	154	367	132	29	23	11	775	82	311	393
2002	52	163	367	130	32	26	12	781	88	292	380
2003	49	164	363	137	31	25	12	781	81	286	367
2004	51	160	351	137	27	21	10	757	94	267	361
2005	52	159	329	132	26	21	9	729	81	263	344
2006	45	156	313	132	27	21	10	703	78	255	333
2007	43	146	329	123	8	4	2	654	77	247	324
2008	40	129	315	121	22	16	7	651	71	230	301
2009	42	130	311	121	22	16	7	648	68	219	287
2010	40	130	314	116	21	15	7	644	68	219	287
2011	40	130	311	94	21	15	7	617	68	219	287
2012	39	128	313	96	20	14	7	617	68	219	287
2013	38	120	307	92	20	14	7	598	68	219	287
2014	36	120	300	97	20	15	7	594	68	219	287
2015	35	115	300	101	20	15	7	592	68	219	287
2016	37	120	280	101	21	15	7	582	68	219	287
2017	36	122	275	93	21	15	7	569	68	219	287

Table 7. Numbers of nets contd.

	Japan large-scale trap nets								Korea nets		
	1E	2C	6E	7CS	7CN	10E	11	Total	5	6W	Total
2018	34	114	288	87	21	15	7	567	68	219	287
2019	34	114	288	87	21	15	7	567	68	219	287
2020	34	114	288	87	21	15	7	567	68	219	287

The bycatch in sub-area 6W by Japan is small (9 whales) (and there are no corresponding set net numbers) so the numbers are added to the bycatches for sub-area 6E. The bycatch by Korea in sub-area 1W is very small (3 whales in total) and there are no corresponding set net numbers so the numbers are added to the bycatches for sub-area 5.

Japan updated the numbers of large-scale nets up to and including 2018 and incorporated information from the Japanese Coast Guard for 2014 on the dates that the nets were in operation see (see IWC, 2020). The set nets are assigned to sub-area based on the position of the centre of the net, although some nets extend beyond a single sub-area. Korea provided revised data on the number of set nets in operation based on the number of licenses issued between 1994-2017 (Table 7, extrapolated from IWC, 2020), but the Committee (IWC, 2022, p.24, Item 8.1.3), decided that the number of nets provide a more reliable source of information than the number of licenses.

For the best effort series, the numbers of nets off Japan are extrapolated from 1946 to 1969 assuming a linear relationship from 0 in 1935 to the known numbers in 1970 (Hakamada, 2010; Tobayama *et al.*, 1992). Bycatches before 1946 are ignored because, although some set-nets were in operation before 1946 (Brownell, pers. comm.), the numbers are highly uncertain and are sufficiently small that they are unlikely to affect the implementation.

A sensitivity trial that uses a different series of nets provided by Hakamada (Trial 17) may be included.

The numbers of nets are listed in Table 7. The numbers of bycatches are only used in the likelihood in the trials where the number of nets is also known. Thus, for example for Japan, the catches from 2019-20 are not used and are shown greyed out in Table 5. The bycatches removed from the population in the trials are the model predicted numbers, except in years for which observed bycatches are available (Table 7, excluding 2001 for Japan).

A single series of historical bycatches is used for all of the trials when testing the effect of future catches (including those set by the RMP), irrespective of the true values of the bycatches, which differ both among trials and simulations within trials. The estimate of the future bycatch is set to the averages of the predicted bycatches based on the fit to the actual data of the operating model for the six baseline trials (i.e. using the 'best fit' simulation (0)). This series will be generated once conditioning is complete.

Korea: The same method as used for Japan is applied, except that bycatch numbers since 1945 are extrapolated from reported numbers in sub-areas 5 (Yellow Sea) and 6W (East Sea) since 2000 and 1996 respectively. Catches in sub-area 6W are assumed to be under-reported by 50% (based on DNA profiling and a capture-recapture analysis of market products, (Baker *et al.*, 2007).

A high effort sensitivity trial (Trial 4) will be undertaken that assumes bycatches by Japan since 2001 were under-reported by 50%, bycatches by Korea in sub-area 5 since 2000 were under-reported by 50%, and the numbers of nets were double the best-case values from 1946-1969 (up to a maximum equal to the number of nets in 1969).

China: There are no data on bycatches off China, although they are known to occur. There are not many set-nets in operation off China and the operations are likely to be similar to those off western Korea. In the absence of information the baseline trials assume that the bycatch off China is double that off western Korea. A sensitivity trial (Trial 7) ignores any possible bycatch off China.

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Appendix 2

Using the Genetic Stock Assignment by Sub-Area to Inform the Mixing Matrices of the North Pacific Minke Whale *Implementation Simulation Trials*

C.L. de Moor, C. Allison, A.E. Punt

This appendix details the stock assignment by sub-area and sex used to develop the data used to estimate mixing matrices for the North Pacific minke whale *Implementation Simulation Trials*. The baseline mixing matrices for Hypothesis E were newly developed for these *Implementation Simulation Trials*, largely informed by the genetic assignment tables below. The baseline mixing matrices for Hypotheses A and B were only changed from those used during the 2013 *Implementation Simulation Trials* where the genetic assignment tables below strongly supported such changes.

Baseline Trials, Hypotheses A and B

For the baseline trials, the stock assignment for Hypotheses A and B is based on the "stock90" assignment by STRUCTURE in *Data_NPM_190226_v3.csv*. The number of samples assigned to stock by sub-area is as follows. Table 7a of the Specifications (see main Annex K, Appendix 2 text) details the assigned numbers by stock, sub-area, period and sex used to condition the trials.

Males	**10E**	**11**	**1E**	**2C**	**6E**	**7CN**	**7CS**	**7E**	**7WR**	**8**	**9**
J-stock	8	28	29	107	453	158	135	0	0	0	1
O-stock	1	29	1	26	1	580	281	41	74	207	442
Unassigned	2	7	2	10	41	80	61	3	6	22	44
Females											
J-stock	6	28	42	188	471	112	151	0	1	0	0
O-stock	0	30	0	24	3	263	286	4	8	17	49
Unassigned	1	7	2	17	33	23	49	1	0	6	5

Grey highlight: stock **has** been assigned to a sub-area, but is not modelled in that sub-area in the mixing matrices

- The singleton assignment of a J-stock female to sub-area 7WR is ignored for the baseline trials, but in Trial 10 J-stock animals are assumed to be found in both sub-areas 7E and 7WR.
- The singleton assignment of an O-stock male to sub-area 1E is ignored for modelling purposes
- The singleton assignment of a J-stock male to sub-area 9 is small compared to the total sample size, and is therefore ignored for the baseline, but in Trial 10 J-stock animals are assumed to be found in sub-areas 8 and 9
- The assignment of O-stock animals to sub-area 6E are very small compared to the total sample size, and O-stock animals are therefore not modelled to be found in sub-area 6E.

Pink highlight: females of a stock **have not** been assigned to a sub-area, but are modelled in that sub-area in the mixing matrices

- The sample sizes in sub-area 10E are low and one cannot therefore discount the presence of O-stock females in sub-area 10E.

Female samples in sub-area 11:

	J-sk	O-sk	Blue	Green	Orange	Red
7 - SP	10	12	13	5	4	
8 - SP	1	8	11			
5	1	6				9
6	5	3		2		6
7	1	1				1
8						
9	1			1		
10	3			3		
11	6			7		

Red - Only Juvenile J-stock in 11 in Sep-Nov

Male samples in sub-area 11:

	J-sk	O-sk	Blue	Green	Orange	Red
7 - SP	5	20	22	3	1	
8 - SP	7	8	17	1		
5						
6	2					2
7						
8						
9	2	1		2		1
10	6			3		1
11	6			4		2

Red - Only Juvenile J-stock in 11 in Sep-Nov

J-Stock Baseline A (Matrix J-A)

Age/	Mon	Sub - Area																				
Sex		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	May	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_2$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	Jun	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_4$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Jul	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Aug	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Sep	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	O-D	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M	2	2	1				γ_{25}	$2\gamma_{25}$	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$4\gamma_1$	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	
	May	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$4\gamma_2$	$2\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	
	Jun	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	
	Jul	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Aug	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Sep	2	2	1				γ_{25}	$2\gamma_{25}$	$4\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7			
	O-D	4	4	1				γ_{25}	γ_{25}		$2\gamma_3$	$2\gamma_5$										
Ad.F	J-M	2	2	1				γ_{25}	$2\gamma_{25}$	$4\gamma_{29}$	γ_1	γ_4						γ_6	γ_7			
	Apr	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_1$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	
	May	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_2$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	
	Jun	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	γ_3	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	
	Jul	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Aug	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Sep	2	2	1				γ_{25}	$2\gamma_{25}$	$4\gamma_{29}$	γ_3	γ_5						γ_6	γ_7			
	O-D	4	4	1				γ_{25}	γ_{25}		γ_3	γ_5										

J-Stock Baseline B (Matrix J-B)

Age/	Mon	Sub - Area																				
Sex		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	May		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_2$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	Jun		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_4$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Jul		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Aug		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Sep		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	O-D		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	$4\gamma_1$	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	
	May		0	1					γ_{33}	$2\gamma_{29}$	$4\gamma_2$	$2\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	
	Jun		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	
	Jul		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Aug		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Sep		2	1					$2\gamma_{33}$	$4\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7			
	O-D		4	1					γ_{33}		$2\gamma_3$	$2\gamma_5$										
Ad.F	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	γ_1	γ_4						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_1$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	
	May		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_2$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	
	Jun		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	
	Jul		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Aug		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Sep		2	1					$2\gamma_{33}$	$4\gamma_{29}$	γ_3	γ_5						γ_6	γ_7			
	O-D		4	1					γ_{33}		γ_3	γ_5										

O-Stock Baseline A (Matrix O-AB)

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M			γ_{13}	4	4	4				$4\gamma_{34}$	0	0	0	0	0	0		γ_{30}	0	0	0
	Apr			γ_{14}	2	2	2				$8\gamma_{31}$	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	γ_{20}	0		$2\gamma_{30}$	$2\gamma_{22}$	γ_{23}	γ_{24}
	May			γ_{14}	2	2	2				$8\gamma_{31}$	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	γ_{20}	γ_{21}		$2\gamma_{30}$	$2\gamma_{22}$	γ_{23}	γ_{24}
	Jun			γ_{14}	2	2	2				$4\gamma_{31}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}		$4\gamma_{30}$	$2\gamma_{22}$	γ_{23}	γ_{24}
	Jul			γ_{15}	2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}		$4\gamma_{30}$	$2\gamma_{22}$	γ_{23}	γ_{24}
	Aug			γ_{15}	2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}		$4\gamma_{30}$	$2\gamma_{22}$	γ_{23}	γ_{24}
	Sep			γ_{15}	2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}		$4\gamma_{30}$	$2\gamma_{22}$	γ_{23}	γ_{24}
	O-D			γ_{15}	4	4	4				$4\gamma_{32}$	$2\gamma_{16}$	0	0	0	0	0		$2\gamma_{30}$	0	0	0
Ad.M	J-M			γ_{13}	4	4	4				γ_{34}	0	0	0	0	0	0		γ_{30}	0	0	0
	Apr			γ_{14}	2	2	2				$2\gamma_{31}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$2\gamma_{20}$	0		$2\gamma_{30}$	$2\gamma_{22}$	γ_{23}	$3\gamma_{24}$
	May			0	0	0	0				$2\gamma_{31}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$2\gamma_{20}$	$2\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	γ_{23}	$6\gamma_{24}$
	Jun			0	0	0	0				$2\gamma_{31}$	$4\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$		$4\gamma_{30}$	$2\gamma_{22}$	γ_{23}	$6\gamma_{24}$
	Jul			0	0	0	0				$2\gamma_{32}$	$4\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$		$4\gamma_{30}$	$2\gamma_{22}$	γ_{23}	$6\gamma_{24}$
	Aug			0	0	0	0				$2\gamma_{32}$	$4\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$		$4\gamma_{30}$	$2\gamma_{22}$	γ_{23}	$6\gamma_{24}$
	Sep			0	0	0	0				$2\gamma_{32}$	$4\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	γ_{21}		$4\gamma_{30}$	$2\gamma_{22}$	γ_{23}	$3\gamma_{24}$
	O-D			γ_{15}	4	4	4				γ_{32}	γ_{16}	0	0	0	0	0		γ_{30}	0	0	0
Ad.F	J-M			γ_{13}	4	4	4				γ_{34}	0	0	0	0	0	0		γ_{30}	0	0	0
	Apr			γ_{14}	2	2	2				γ_{31}	γ_{16}	$2\gamma_{17}$	$2\gamma_{18}$	$2\gamma_{19}$	γ_{20}	0		γ_{30}	$2\gamma_{22}$	γ_{23}	$3\gamma_{24}$
	May			0	0	0	0				γ_{31}	γ_{16}	γ_{17}	γ_{18}	γ_{19}	γ_{20}	$4\gamma_{21}$		γ_{30}	$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Jun			0	0	0	0				γ_{31}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Jul			0	0	0	0				γ_{32}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Aug			0	0	0	0				γ_{32}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Sep			0	0	0	0				γ_{32}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$2\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	$2\gamma_{23}$	$3\gamma_{24}$
	O-D			γ_{15}	4	4	4				γ_{32}	γ_{16}	0	0	0	0	0		γ_{30}	0	0	0

Y-Stock Baseline B (Matrix Y-B)

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													
AdM	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													
AdF	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													

Baseline Trials, Hypothesis E

For the baseline trials, stock assignment for Hypothesis E is based on the "geneland.stock2" assignment by GENELAND in *Data_NPM_190226_v3.csv*. The number of samples assigned to stock by sub-area is as follows. Table 7a of the Specifications (see main Annex K, Appendix 2 text) details the assigned numbers by stock, sub-area, period and sex used to condition the trials.

Males	**10E**	**11**	**1E**	**2C**	**6E**	**7CN**	**7CS**	**7E**	**7WR**	**8**	**9**
J-stock	8	13	31	88	492	20	0	0	0	0	0
P-stock	0	39	0	10	0	384	217	0	0	0	0
O-stock	0	1	0	0	0	280	83	41	70	207	464
Unassigned	0	6	0	19	0	55	105	0	0	0	0
Females											
J-stock	7	18	44	156	500	17	0	0	0	0	0
P-stock	0	24	0	10	0	216	296	0	0	0	0
O-stock	0	4	0	0	0	54	18	5	7	22	49
Unassigned	0	17	0	26	0	75	118	0	0	0	0

J-Stock Baseline E (Matrix J-E)

Age/	Mon	Sub - Area																				
Sex		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7			
	Apr		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	May		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	Jun		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Jul		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Aug		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Sep		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	O-D		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	0	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	
	May		0	4					γ_{33}	$2\gamma_{29}$	0	$2\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	
	Jun		0	4					γ_{33}	$2\gamma_{29}$	0	$4\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	
	Jul		0	4					γ_{33}	$2\gamma_{29}$	0	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Aug		0	4					γ_{33}	$2\gamma_{29}$	0	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Sep		2	4					$2\gamma_{33}$	$4\gamma_{29}$	0	$4\gamma_5$						γ_6	γ_7			
	O-D		4	1					γ_{33}		0	$2\gamma_5$										
Ad.F	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	0	γ_4						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	0	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	
	May		0	4					γ_{33}	$2\gamma_{29}$	0	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	
	Jun		0	4					γ_{33}	$2\gamma_{29}$	0	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	
	Jul		0	4					γ_{33}	$2\gamma_{29}$	0	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Aug		0	4					γ_{33}	$2\gamma_{29}$	0	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Sep		2	4					$2\gamma_{33}$	$4\gamma_{29}$	0	γ_5						γ_6	γ_7			
	O-D		4	1					γ_{33}		0	γ_5										

P-Stock Baseline E (Matrix P-E)

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M			γ_{13}							$2\gamma_{1}$	γ_{30}										
	Apr			γ_{14}							$2\gamma_{1}$	$2\gamma_{34}$								γ_{22}		
	May			γ_{14}							$2\gamma_{2}$	$2\gamma_{34}$								γ_{22}		
	Jun			γ_{14}							$2\gamma_{3}$	$4\gamma_{30}$								γ_{22}		
	Jul			γ_{15}							$2\gamma_{3}$	$4\gamma_{30}$								γ_{22}		
	Aug			γ_{15}							$2\gamma_{3}$	$4\gamma_{30}$								γ_{22}		
	Sep			γ_{15}							$2\gamma_{3}$	$4\gamma_{30}$								γ_{22}		
	O-D			γ_{15}							$2\gamma_{3}$	$2\gamma_{30}$										
Ad.M	J-M			γ_{13}							$2\gamma_{1}$	γ_{30}										
	Apr			γ_{14}							$4\gamma_{1}$	$2\gamma_{34}$								γ_{22}		
	May			0							$4\gamma_{2}$	$2\gamma_{34}$								γ_{22}		
	Jun			0							$2\gamma_{3}$	$4\gamma_{30}$								γ_{22}		
	Jul			0							$2\gamma_{3}$	$4\gamma_{30}$								γ_{22}		
	Aug			0							$2\gamma_{3}$	$4\gamma_{30}$								γ_{22}		
	Sep			0							$2\gamma_{3}$	$4\gamma_{30}$								γ_{22}		
	O-D			γ_{15}							$2\gamma_{3}$	γ_{30}								γ_{22}		
Ad.F	J-M			γ_{13}							γ_{1}	γ_{30}										
	Apr			γ_{14}							$2\gamma_{1}$	γ_{34}								γ_{22}		
	May			0							$2\gamma_{2}$	γ_{34}								$2\gamma_{22}$		
	Jun			0							γ_{3}	$2\gamma_{30}$								$2\gamma_{22}$		
	Jul			0							γ_{3}	$2\gamma_{30}$								$2\gamma_{22}$		
	Aug			0							γ_{3}	$2\gamma_{30}$								$2\gamma_{22}$		
	Sep			0							γ_{3}	$2\gamma_{30}$								$2\gamma_{22}$		
	O-D			γ_{15}							γ_{3}	γ_{30}								γ_{22}		

O-Stock Baseline E (Matrix O-E)

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M				4	4	4				0	0	0	0	0	0	0			0	0	0
	Apr				2	2	2				$8\gamma_{31}$	$1\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	γ_{20}	0			γ_{22}	γ_{23}	γ_{24}
	May				2	2	2				$8\gamma_{31}$	$1\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	γ_{20}	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	Jun				2	2	2				$4\gamma_{31}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	Jul				2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	Aug				2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	Sep				2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	O-D				4	4	4				$4\gamma_{32}$	$2\gamma_{16}$	0	0	0	0	0			0	0	0
Ad.M	J-M				4	4	4				0	0	0	0	0	0	0			0	0	0
	Apr				2	2	2				$2\gamma_{31}$	$1\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$2\gamma_{20}$	0			γ_{22}	γ_{23}	$3\gamma_{24}$
	May				0	0	0				$2\gamma_{31}$	$1\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$2\gamma_{20}$	$2\gamma_{21}$			γ_{22}	γ_{23}	$6\gamma_{24}$
	Jun				0	0	0				$2\gamma_{31}$	$1\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$			γ_{22}	γ_{23}	$6\gamma_{24}$
	Jul				0	0	0				$2\gamma_{32}$	$1\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$			γ_{22}	γ_{23}	$6\gamma_{24}$
	Aug				0	0	0				$2\gamma_{32}$	$1\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$			γ_{22}	γ_{23}	$6\gamma_{24}$
	Sep				0	0	0				$2\gamma_{32}$	$1\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	$3\gamma_{24}$
	O-D				4	4	4				γ_{32}	γ_{16}	0	0	0	0	0			0	0	0
Ad.F	J-M				4	4	4				0	0	0	0	0	0	0			0	0	0
	Apr				2	2	2				γ_{31}	γ_{16}	$2\gamma_{17}$	$2\gamma_{18}$	$2\gamma_{19}$	γ_{20}	0			γ_{22}	γ_{23}	$3\gamma_{24}$
	May				0	0	0				γ_{31}	γ_{16}	γ_{17}	γ_{18}	γ_{19}	γ_{20}	$4\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Jun				0	0	0				γ_{31}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Jul				0	0	0				γ_{32}	$1\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Aug				0	0	0				γ_{32}	$1\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Sep				0	0	0				γ_{32}	$1\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$2\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$3\gamma_{24}$
	O-D				4	4	4				γ_{32}	γ_{16}	0	0	0	0	0			0	0	0

Y-Stock Baseline E (Matrix Y-B)

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													
AdM	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													
AdF	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													

Trial 10 – Alternative (70% probability) thresholds for assignment of stock proportions

J-Stock Trial B10 (Matrix J-B10) Differences from the Baseline trial are highlighted in blue

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	May		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_2$	$2\gamma_4$	?	?	?	?		γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	Jun		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_4$	?	?	?	?		γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Jul		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$	?	?	?	?		γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Aug		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Sep		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	O-D		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	$4\gamma_1$	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	
	May		0	1					γ_{33}	$2\gamma_{29}$	$4\gamma_2$	$2\gamma_4$	?	?	?	?		$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	
	Jun		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_4$	?	?	?	?		$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	
	Jul		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$	?	?	?	?		γ_6	γ_7	γ_9	$2\gamma_9$	
	Aug		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Sep		2	1					$2\gamma_{33}$	$4\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7			
	O-D		4	1					γ_{33}		$2\gamma_3$	$2\gamma_5$										
Ad.F	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	γ_1	γ_4						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_1$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	
	May		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_2$	γ_4	?	?	?	?		$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	
	Jun		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_4	?	?	?	?		$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	
	Jul		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_5	?	?	?	?		γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Aug		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Sep		2	1					$2\gamma_{33}$	$4\gamma_{29}$	γ_3	γ_5						γ_6	γ_7			
	O-D		4	1					γ_{33}		γ_3	γ_5										

Trial 14 – 30% J-stock in sub-area 12SW in June with 10% J-stock in 12NE in June

J-Stock Trial B14 (Matrix J-B14) **Differences from the Baseline trial are highlighted in blue**

Age/	Mon										Sub -	Area										
Sex		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	$2\gamma_{35}$
	May		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_2$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	$2\gamma_{35}$
	Jun		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_4$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	$2\gamma_{35}$
	Jul		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	$2\gamma_{35}$
	Aug		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	$2\gamma_{35}$
	Sep		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	$2\gamma_{35}$
	O-D		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	$4\gamma_1$	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	γ_{35}
	May		0	1					γ_{33}	$2\gamma_{29}$	$4\gamma_2$	$2\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	$2\gamma_{35}$
	Jun		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	$2\gamma_{35}$
	Jul		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	$2\gamma_{35}$
	Aug		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	$2\gamma_{35}$
	Sep		2	1					$2\gamma_{33}$	$4\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7			
	O-D		4	1					γ_{33}		$2\gamma_3$	$2\gamma_5$										
Ad.F	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	γ_1	γ_4						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_1$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	γ_{35}
	May		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_2$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	$2\gamma_{35}$
	Jun		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	$2\gamma_{35}$
	Jul		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	$2\gamma_{35}$
	Aug		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	$2\gamma_{35}$
	Sep		2	1					$2\gamma_{33}$	$4\gamma_{29}$	γ_3	γ_5						γ_6	γ_7			
	O-D		4	1					γ_{33}		γ_3	γ_5										

J-Stock Trial E14 (Matrix J-E14) **Differences from the Baseline trial are highlighted in blue**

Age/	Mon										Sub -	Area										
Sex		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7			
	Apr		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	$2\gamma_{35}$
	May		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	$2\gamma_{35}$
	Jun		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	$2\gamma_{35}$
	Jul		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	$2\gamma_{35}$
	Aug		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	$2\gamma_{35}$
	Sep		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	$2\gamma_{35}$
	O-D		2	2					γ_{33}	$4\gamma_{29}$	0	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	0	$2\gamma_4$						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	0	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	γ_{35}
	May		0	4					γ_{33}	$2\gamma_{29}$	0	$2\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	$2\gamma_{35}$
	Jun		0	4					γ_{33}	$2\gamma_{29}$	0	$4\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	$2\gamma_{35}$
	Jul		0	4					γ_{33}	$2\gamma_{29}$	0	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	$2\gamma_{35}$
	Aug		0	4					γ_{33}	$2\gamma_{29}$	0	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	$2\gamma_{35}$
	Sep		2	4					$2\gamma_{33}$	$4\gamma_{29}$	0	$4\gamma_5$						γ_6	γ_7			
	O-D		4	1					γ_{33}		0	$2\gamma_5$										
Ad.F	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	0	γ_4						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	0	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	γ_{35}
	May		0	4					γ_{33}	$2\gamma_{29}$	0	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	$2\gamma_{35}$
	Jun		0	4					γ_{33}	$2\gamma_{29}$	0	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	$2\gamma_{35}$
	Jul		0	4					γ_{33}	$2\gamma_{29}$	0	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	$2\gamma_{35}$
	Aug		0	4					γ_{33}	$2\gamma_{29}$	0	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	$2\gamma_{35}$
	Sep		2	4					$2\gamma_{33}$	$4\gamma_{29}$	0	γ_5						γ_6	γ_7			
	O-D		4	1					γ_{33}		0	γ_5										

Appendix 3

Calculation of stock mixing proportions, including correction for "missing alleles":

Unpooled results for sub-area 6W

C.L. de Moor

This appendix is based on de Moor (2011, 2014) and details the calculation of the stock mixing proportions by month and sex used for conditioning the 2013 *Implementation Simulation Trials* of western North Pacific common minke whales (Allison *et al*, 2014).

In calculating the mixing proportions in sub-area 6W, samples representative of 'pure' Y-stock and J-stock animals were taken as follows:

Stock	Location / months to define pure sample	Haplotypes Sample Size	Loci Sample Size
Y-stock	5 (all months)	58	58 58 58 58 58 58 56 58 58 58 54
J-stock	6E (all months)	392	392 392 392 392 392 392 392 392 392 392 392 (392 391 392 392 392)

Mixing proportions in sub-area 6W were calculated from 415 samples from bycatch data only.

Hyp B and E: Proportion of J mixing with Y		Sample Size	Proportion Haplotypes	SE	Sample Size (x11)	Proportion Loci	SE
Jan-Mar	Males	83	0.555	0.142	83 with 81 in 11th	0.745	0.050
Apr		37	0.449	0.253	37 with 36 in 1st	0.963	0.083
May		41	0.749	0.243	41 with 40 in 8th	0.926	0.062
Jun		43	0.534	0.245	43	0.787	0.080
Jul		21	0.830	0.38	21	0.788	0.089
Aug		16	1.000	0.004	16 with 15 in 11th	0.726	0.137
Sep		20	0.533	0.335	20 with 18 in 11th	0.475	0.107
Oct-Dec		97	0.629	0.140	97 with 96 in 7th and 94 in 11th	0.859	0.049
Jan-Mar	Females	13	0.730	0.314	13 with 12 in 6th	0.284	0.128
Apr		3	0.002	0.139	3	0.751	0.301
May		7	0.000	0.006	7	0.529	0.148
Jun		10	0.364	0.309	10	0.583	0.167
Jul		1	1.000	0.009	1	0.999	0.000
Aug		4	1.000	0.024	4	0.457	0.323
Sep		6	0.415	0.636	6 with 5 in 9th	0.773	0.143
Oct-Dec		13	0.409	0.455	13 with 12 in 11th	0.806	0.130
Summary: all data		415	0.625	0.069	415 with 414 in 1st, 6-9th and 406 in 11th	0.776	0.109
Pooled Data							
Jan-Mar	M F	96	0.584	0.131	96 with 95 in 6th, 94 in 11th	0.672	0.047
Apr-Jun	M F	141	0.496	0.126	141 with 140 in 1st , 8th	0.812	0.04
Jul-Aug	M F	42	1.000	0.004	42 with 41 in 11th	0.749	0.077
Sep-Dec	M F	136	0.593	0.123	136 with 135 in 7th, 9th, 130 in 11th	0.761	0.04

Notation:

In most cases samples are obtained from 16 loci. In sub-area 6W samples from the first 11 loci only were available to be used in the calculation of the mixing proportions, denoted by (x11) in the above table. In some cases there was a missing value in a sample at a particular loci. Thus, for example if the total sample size were 50, for one of the loci (the 10th) the sample size is 49. This is noted by saying e.g. "50 with 49 in 10th".

References

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Appendix 4

Method to derive the adjusted coefficient of variation for zero survey estimates

A.E. Punt

Simple case - the data are the number of observed whales and the sampling process is Poisson (for the case of one area):

$$LnL = \sum_y (n_y^{obs} \ell n(\beta_y P_y) - \beta_y P_y) \quad (1)$$

where n_y^{obs} is the observed number of animals during the survey in year y, P_y is the true population size in year y, and β_y is the proportion of the area occupied that was sampled. For $\beta_y = 1$ this collapses to the standard Poisson likelihood.

Now consider the situation in which there is over-dispersion (e.g. clumping), one can account for this by defining an over-dispersed distribution for the data, i.e.

$$LnL -> \sum_y (n_y^{obs} \ell n(\beta_y P_y) - \beta_y P_y) / \alpha \quad (2)$$

where α is a measure of overdispersion (and would be greater than 1 for over-dispersed sampling). Cooke provided the following formula for α:

$$\alpha = \sum_{y'} CV(P_{y'}^{obs}) n_{y'}^{obs} / \sum_{y'} 1 \quad (3)$$

where the summation is over years for which there is a CV for the abundance estimate and a value for the number of sightings.

To derive 3, one estimator for α is:

$$\alpha = \sum_y \frac{\text{var}(\text{observed}_y)}{\text{var}(\text{expected}_y)} / \sum_y 1 \quad (4)$$

where $\text{var}(\text{observed}_y) = CV^2(P_y)(n_y^{obs})^2$ and $\text{var}(\text{expected}_y) = n_y^{obs}$ (under the Poisson assumption) so that

$$\frac{\text{var}(\text{observed}_y)}{\text{var}(\text{expected}_y)} \sim \frac{(n_y^{obs})^2 CV^2(n_y^{obs})}{E(n_y^{obs})} \cong \frac{(n_y^{obs})^2 CV^2(P_y)}{n_y^{obs}} = n_y^{obs} CV^2(P_y) \quad (5)$$

which is close to, but not identical to, 3. An alternative estimate for α would be:

$$\alpha = \frac{\sum_y \text{var}(\text{observed}_y)}{\sum_y \text{var}(\text{expected}_y)} \cong \frac{\sum_y (n_y^{obs})^2 CV^2(P_y)}{\sum_y n_y^{obs}} \quad (6)$$

Equation 6 would (I suspect) be more robust to odd outlying estimates of CV.