Annex D

Report of the Sub-Committee on the Revised Management Procedure

Members: Bannister (Convenor), Allison, An, Baba, Bando, Baulch, Bell, Bjørge, Brandão, Bravington, Brockington, Butterworth, Chilvers, Cipriano, Cooke, de la Mare, de Moor, Diallo, Donovan, Double, Elvarsson, Gaggiotti, Goodman, Gunnlaugsson, Hakamada, Haug, Hoelzel, Iñíguez, Kato, Kelly, Kishiro, Kitakado, Leaper, Lundquist, Miller, Miyashita, Morishita, Moronuki, Murase, Naoko, Nawaz, Øien, Okazoe, Palka, Palsbøll, Panigada, Park, Pastene, Prewitt, Punt, Rendell, Reyes, Roel, Skaug, Solvang, Stenseth, Tiedemann, Víkingsson, Wade, Waples, Walløe, Williams, Witting, Yoshida.

1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks
As Convenor, Bannister welcomed the participants.

1.2 Election of Chair and appointment of rapporteurs
Bannister was elected Chair. Punt acted as rapporteur.

1.3 Adoption of Agenda
The adopted Agenda is shown in Appendix 1.

1.4 Available documents
The documents considered by the sub-committee were SC/65b/RMP01-11, SC/65b/Rep04, SC/65b/Rep07, Gunnlaugsson *et al.* (2003), Pike *et al.* (2010a; 2010b), and relevant extracts from past reports of the Committee.

2. REVISED MANAGEMENT PROCEDURE (RMP) – GENERAL ISSUES

2.1 Use of individual based energetics model
Last year, the Committee recommended that $MSYR_{1+}$=1% be adopted as a pragmatic and precautionary lower bound for use in trials, and that $MSYR_{mat}$=7% be changed to the roughly equivalent $MSYR_{1+}$=4%. However, it recognised that much remains to be learnt regarding MSYR for baleen whales and that the issue of the appropriate range for MSYR should continue to be reviewed as new information becomes available. Last year, the Committee identified a work plan for a modelling framework that uses spatially-resolved individual animal behaviour and detailed energy budgets to determine reproductive success and mortality in an environment where food has a patchy spatial distribution. This work plan included the establishment of a correspondence group to consider the incorporation of the individual based energetics model (IBEM) into the RMP software framework.

SC/65b/RMP03 reported on progress linking the IBEM into the RMP testing software. There were no technical difficulties in calling the individual-based model software from the existing FORTRAN master program. A set of appropriate functions for incorporating the energetics model into the RMP framework has been written and tested successfully using a mixed language framework. Results from one set of 100 trials for the MSYR ~4% development case showed that the software produced results in that trial that were broadly consistent with those using the standard population models.

The sub-committee **welcomed** this work which allows the Committee to conduct trials of the RMP in which the operating model is spatially- and individually-based. It was noted that prior to the use of this model by the Committee, the code would need to be validated by the Secretariat.

2.2 Relationship between $MSYR_{mat}$ and $MSYR_{1+}$
SC/65b/RMP04 included results requested by the Ecosystem Modelling (EM) Working Group at last year's meeting which used the IBEM to examine the relationship between the $MSYR_{1+}$ and $MSYR_{mat}$. The results were compared with those from the standard Baleen II model. The energetics-based model indicates that MSY rates of 1% to 7% for the mature population translate into a range for MSY rates for the population aged one and above of 1% to 6%. The relationships between the 1+ and mature MSY rates are quite different from those derived from the standard Baleen II model. SC/65b/RMP04 attributed the differences to the difference in the action of density dependence. Density dependence in the standard Baleen II model is assumed to affect recruitment only, whereas the IBEM results in density dependence in a wide range of demographic parameters. The author of SC/65b/RMP04 concluded that the standard Baleen II model should not be used for inferring the relationship between $MSYR_{1+}$ and $MSYR_{mat}$.

The energetics-based model is rather complex with several functional relationships leading to different density-dependent processes. Its behaviour also depends on the values selected for its parameters. The sub-committee noted that several of the qualitative outcomes from the model runs were consistent with the results from the stochastic model of Cooke (2007), and that the qualitative emergent properties were *a priori* plausible; at this stage it is not possible to reach conclusions on the quantitative nature of the results. The sub-committee considered it important to obtain a better understanding of the reasons underlying these emergent properties, including whether the conclusions regarding the relationship between $MSYR_{mat}$ and $MSYR_{1+}$ were robust to, *inter alia*, species life history.

The sub-committee **agreed** that the plausibility of the choices for functional forms and values for parameters could be explored through analyses of existing data. It noted that there were relatively few suitable datasets for this purpose and identified western North Pacific gray whales, and southwest and southeast Atlantic right whales as candidates. However, it was noted that while the power to detect relationships in the data between calf and juvenile survival rates and reproductive rates seems to be quite high, the power to detect effects on adult survival rate may be lower. For populations where a substantial fraction of the population has been marked, and resight effort is sufficiently high, changes over time in calf production can be detected using data on calving intervals, while such changes in calf survival can be detected using the resight history for animals first noted as calves. In contrast, annual fluctuations in adult survival cannot be detected because year effects on survival leave no signal of their own.

Recognising the importance of this issue in an RMP context, the sub-committee **agreed** that it was desirable to explore the relationship between $MSYR_{mat}$ and $MSYR_{1+}$ arising out of the energetics-based model results further, and developed a two-year work plan to achieve this. This work is necessary before any conclusions or the need for additional RMP/*CLA*-related trials are considered. This work does not imply the need to change or delay the current *Implementations* of the RMP for the North Atlantic minke and fin whales pending completion of such exploration.

The work plan addresses two aspects related to evaluating the energetics-based model: (a) exploration as to whether a simpler model can exhibit the same dynamical behaviour as the energetics-based model and determining what can be learnt about that model based on a simpler model; and (b) examination of the data for gray and right whales to determine whether the emergent relationships from the energetics model are consistent with the data for these species. At this stage, the work plan does not address assumptions related to the components of the model which have been the focus for discussion in the EM Working Group. The sub-committee established a Steering Group (de la Mare [Convenor], Allison, Butterworth, Cooke, Kitakado and Punt) to coordinate the intersessional work.

The steps to explore a simpler model which can mimic (emulate) the energetics-based model are as follows.

(1) Develop a table which lists for each energetics-based model run: $MSYR_{1+}$, and $MSYR_{mat}$, further over a range of exploitation rates, the expected number of 1+ animals relative to the corresponding unfished number, the expected number of mature animals relative to the corresponding unfished number, calving interval, the reproductive rate, the calf survival rate, the juvenile survival rate, and the adult survival rate. This information can be used to develop relationships between changes in density and changes in biological parameters.
(2) Develop age-structured emulator models which are able to mimic the key properties of the energetics model such as $MSYR_{1+}$, the ratio $MSYR_{1+}/MSYR_{mat}$, and the extent of stochasticity. The information collated under step (1) should be used to parameterise the emulator models. Appendix 2 shows that simply changing the density-dependent component from fecundity to age-independent natural mortality is insufficient to mimic the $MSYR_{1+}/MSYR_{mat}$ ratio from the energetics-based model.
(3) Use the energetics-based model to implement the base case development and rehabilitation scenarios for $MSYR_{mat}$=1% and 4% (i.e. trials T1-D1, T1-R1, T4-D1 and T4-R1).
(4) Use the emulator models to repeat the T1-D1, T1-R1, T4-D1 and T4-R1 trials.
(5) Evaluate the properties of the emulator models in terms of the plausibility of the density-dependence relationships which underlie them.

The sub-committee noted that emulator models which mimic $MSYR_{1+}$ and $MSYR_{mat}$, and the relationships between density and reproductive rate and natural mortality at various life stages, may nevertheless not be able to mimic the predictions of the energetics-based model in terms of its dynamical properties, as a result perhaps of time-lags in the processes within that latter model.

The current version of the energetics-based model is based on humpback whales (a two-year reproductive cycle). However, there are insufficient data on reproductive rates and survival rates for humpback whales to allow the current version of the energetics model to be tested by comparing its outputs with data. In relation to using data to evaluate the plausibility of the predictions of the energetics-based model, the sub-committee identified the following steps:

(1) develop versions of the energetics-based model for minke and right whales (species with one- and three-year reproductive cycles) to evaluate the robustness of predictions of $MSYR_{1+}/MSYR_{mat}$ ratios to life history parameters and construction of tables along the lines outlined above;
(2) use of the results of these versions of the model to identify how data for western North Pacific gray and southwest and southeast Atlantic right whales can be used to test the energetics model; and
(3) analyse existing data based on the results of step (2).

Recognising that the energetics-based model is just one approach to this issue, the sub-committee also **encouraged** the development/presentation at SC/66a of alternative models which represent alternative plausible density-dependent processes.

2.3 Finalise the approach for evaluating proposed amendments to the *CLA*

The Committee agreed in 2006 that two steps needed to be completed before the evaluation of the Norwegian proposal to amend the *CLA* could be completed. The first of these was the review of MSY rates, which was completed in 2013, and the second was specification of additional trials for testing the *CLA* and amendments thereto and to the RMP. The second step related to modelling the effects of possible environmental degradation in addition to, or possibly replacing, the trials in which *K*, perhaps with MSYR, varies over time. This is because the current changing *K* trials have questionable behaviour when modelling population sizes above *K*. Last year, the sub-committee re-established a working group under Allison (members: Allison, Butterworth, Cooke, de la Mare, Donovan, Punt, Walløe) to formulate and run trials related to environmental degradation.

Appendix 3 reports the results of trials in which the density-dependence function is modified so that the change in fecundity with density for stocks sizes above *K* is not as extreme as implied by the conventional Pella-Tomlinson model. These results suggest that the proposed solution does not lead to results which differ much from those when density-dependence is modelled using the standard Pella-Tomlinson approach.

The sub-committee thanked Punt and Allison for conducting this work. However, it was noted that assuming that density-dependence acts on fecundity, along with the constraint that the number of calves cannot be less than zero, limits the extent to which changes in MSYR and *K* can impact the population dynamics. It noted that allowing natural mortality to be density-dependent would provide a more stringent test for the impacts of environmental change. It **recommended** that Allison and Punt include the model of density-dependence in natural mortality in Appendix 3 into the common control rule program and provide results of such tests of the *CLA* to SC/66a.

2.4 Evaluate the Norwegian proposal for amending the *CLA*

Walløe reminded the sub-committee that Norway had formally notified the Committee that it intended to develop and propose a change to the *CLA* of the RMP at the SC/56 meeting in 2004. A working group established by Norway had proposed a new tuning mechanism for the *CLA*; it had also proposed that the MSYR should refer to the 1+ component of the population (with $MSYR_{1+}$=1% as the minimum) instead of the mature component. The revised tuning mechanism and some simulation results were presented to the Committee in 2006 and discussed extensively. Two working groups were established at the 2006 meeting, one of which led to the MSYR review which was completed in 2013 and the other was to specify trials and diagnostic plots for testing amendments to the *CLA*. Revised results (Aldrin and Huseby, 2007) were presented to the Committee in 2007. However, the MSYR review had not been completed so no decision had been made at that time.

The MSYR review was completed last year and had concluded that the lower bound for MSYR in trials would be $MSYR_{1+}$=1%. However, as noted in Item 2.3, some work remains to be completed in regards to trials in which MSYR and *K* change over time.

The sub-committee **recommended** that Punt and Allison include the variants of the *CLA* considered by Aldrin and Huseby (2007) in their further analyses. The Chair noted that this item had been outstanding for many years and the sub-committee **confirmed** its intention that the evaluation of the Norwegian proposal would be completed at SC/66a.

2.5 Other computing matters related to the *CLA*

Allison noted that a few minor issues related to how the code for the *CLA* was integrated into the control program remained outstanding. There had been insufficient time during the intersessional period to address these issues. She stated that they would be addressed during the current intersessional period and a report provided to SC/66a.

2.6 Update ‘Requirements and Guidelines for conducting surveys and *Implementations*’

SC/65b/RMP11 was written in response to a request (and contract) from the Committee to update the Requirements and Guidelines for Conducting Surveys and Analysing Data within the Revised Management Scheme (IWC, 2012, hereafter ‘the Guidelines’). The specific tasks were to summarise developments in design- and (spatial) model-based abundance estimation since 2004 when the Guidelines were last revised, and to provide suggested text for updates to the Guidelines. This is in recognition that spatial modelling is a potentially powerful way to reduce bias and stabilise the CVs of abundance estimates, and that spatial modelling tools have improved considerably over the last decade in reliability and usability. Nevertheless, spatial modelling remains (and probably always will be) an exercise that can go wrong, and which requires skill and judgement to implement and check. SC/65b/RMP11 therefore: (1) reviewed the fundamentals of design-based abundance estimation (which will never change, as they rely on notions of randomised trackline placement with estimable coverage probability across the region); (2) described new approaches to variance estimation for design-based analysis; considered how the Committee might decide whether the criteria for design-based assessment had been met; (3) suggested some ways to evaluate the adequacy of design-based estimates when the strict criteria are not met; (4) presented a paradigm for (spatial-)model-based abundance estimation, and a checklist of decisions that need to be made when making a spatial abundance estimate; and (5) proposed some updated text for the Guidelines. An important overall conclusion concerned the necessity, when the Committee (or other scientific body) reviews an abundance estimate for ‘acceptability’, for thorough descriptions of the design and analysis process, including the rationale for making particular choices.

In discussion, some issues were raised about the presentation and interpretation of the POWER cruise track designs used as an example. There was no time to resolve the issues at SC/65b, but the authors of SC/65b/RMP11 offered to follow up with POWER cruise track designers intersessionally to ensure that any revised version of SC/65b/RMP11 for SC/66a is accurate.

The sub-committee noted that having up-to-date criteria for evaluating abundance estimates (both design- and model-based) would be of great value to the entire Committee, since abundance estimates are central to much of its work (see Appendix 4 for additional details). In order to progress the update of Guidelines (both in an RMP sense and in a wider context) to assist evaluation of design-based estimates of abundance and accommodate recent (and future) developments in abundance estimation, the sub-committee **recommended** the following.

(1) Develop a simple-to-use diagnostic software that uses model-based analysis to assist in evaluating design-based estimates which have been applied when design-based criteria are not strictly met. The software, which might for example consist of an R package that uses the data format of the widely-used ‘mrds’ and ‘dsm’ packages for Distance-sampling abundance estimation, would entail automated parameter selection and fitting of one or more spatial abundance-estimation models, and the calculation and reporting of appropriate diagnostics (including but not limited to the comparison of point estimates). It would be for use as a robustness/sensitivity check only, and not as an all-purpose abundance estimator in its own right. The general idea is that surveys with dense and evenly-distributed coverage should readily pass the diagnostic tests, whereas surveys with low or badly imbalanced coverage should raise a flag. Naturally, the software would need to be tested in this regard.

(2) Refine the material in SC/65b/RMP11, both in the explanatory background text and in the proposed Guidelines, on specific issues such as (but not necessarily limited to):
   (a) time series of repeated surveys;
   (b) multi-year surveys with partial coverage annually;
   (c) different levels of ‘acceptability’ within the RMP process;
   (d) design-based variance estimation for stratified surveys; and
   (e) an update on pitfalls to avoid when designing surveys.

(3) Hold a workshop with two objectives:
   (a) to test the proposed new Guidelines against several test cases of model-based abundance estimates made specifically for and during the workshop; and
   (b) to demonstrate and discuss the proposed diagnostic software with a wider Committee audience involved in basic line-transect abundance estimation.

Part 3(a) would involve only a small number of statistical analysts familiar with spatial modelling and could be held as a pre-meeting for SC/66a, with part 3(b) to follow on during the SC/66a meeting. Updates to the Guidelines could then be considered during the full SC/66a meeting next year.

An appreciable amount of intersessional work would be required, particularly for item (1) and preparation for item (3). The sub-committee appointed a Steering Group (Bravington [Chair], Butterworth, Cooke, Hedley, Kitakado and Leaper) to develop an agenda for the Workshop and facilitate preparations.

2.7 Imbalanced sex ratio in incidental catches

Last year, the Committee requested that the current meeting address the generic issue of how to deal with imbalanced sex ratios in incidental catches under the RMP. The sub-committee noted that the current specifications for the RMP covered this issue. However, it **recommends** that annotation 26(a) to the RMP be adjusted to improved clarity. The revised annotation would be:

> 'Any subtraction of incidental catches from the catch limits output from the RMP as above would take place at the end of this process at the *Small Area* level, and separately at the *Medium/Large Area* level if Catch-capping was applied. However, as this is an RMS rather than an RMP feature, no wording to cover this is proposed here. Since imbalanced sex ratios in incidental catches have been taken into account in (iv) above, as this computation is with respect to the total catch, there is no need for further adjustment for this factor in this subtraction.

2.8 Work plan

The sub-committee noted that the iterative nature of its work means that is challenging to determine the exact nature of its work plan beyond a single year.

The sub-committee agreed that its work plan before the 2015 Annual Meeting would be as follows:

(1) conduct work to evaluate the energetics-based model (Item 2.2):
    (a) produce of a table of model outputs (de la Mare);
    (b) develop emulator models (Butterworth, Punt, Cooke);
    (c) conduct simulations of the *CLA* for the energetics model (de la Mare);
    (d) conduct simulations of the *CLA* for the emulator models (Butterworth, Punt, Cooke);
(2) evaluate the performance of the *CLA* for trials when natural mortality rather than fecundity is density-dependent (Allison and Punt, Items 2.3 and 2.4);
(3) address the remaining tasks related to testing the *CLA* (Allison, Item 2.5);
(4) develop a simple-to-use diagnostic software that uses model-based analysis to assist in evaluating design-based estimates (Hedley and Bravington, Item 2.6).

The sub-committee agreed that its work plan during the 2015 Annual Meeting would be as follows:

(1) review intersessional progress on evaluating the energetics-based model (Item 2.2);
(2) review the results of the trials (Items 2.3 and 2.4);
(3) evaluate the Norwegian proposal for amending the RMP (Item 2.4);
(4) hold a pre-meeting Workshop with Terms of Reference: (i) to test proposed new Guidelines against several test cases of model-based abundance estimates made specifically for and during the Workshop; and (ii) to demonstrate and discuss the proposed diagnostic software with a wider Committee audience. There will be costs involved for travel and subsistence (Item 2.6); and
(5) refine the draft 2015 work plan (Item 2.8).

The sub-committee agreed that its work plan before the 2016 Annual Meeting would be as follows:

(1) continue work to evaluate the energetics-based model (Item 2.2).

The sub-committee agreed that its work plan during the 2016 Annual Meeting would be as follows:

(1) review intersessional progress on evaluating the energetics-based model (Item 2.2); and
(2) progress work identified during the 2015 meeting.

3. RMP – *IMPLEMENTATION*-RELATED MATTERS

3.1 North Pacific common minke whales

3.1.1 Review of intersessional work

Last year, the *Implementation* for the North Pacific common minke whales identified six RMP variants which were 'acceptable without research' and four RMP variants which were candidates for being 'acceptable with research'. RMP variants which are 'acceptable with research' need to have a research program which can show within ten years that the trials on which performance was not 'acceptable' should have been assigned low plausibility. The Committee established an Advisory Group (Butterworth [Convenor], Allison, An, Baker, de Moor, Donovan, Double, Gaggiotti, Hoelzel, Kanda, Kelly, Kitakado, Miyashita, Park, Pastene, Punt, Wade and Waples) to provide feedback to those developing research programmes during the intersessional period. Pastene reported that Japan had not developed a research program to date.

The sub-committee re-established the Advisory Group to provide advice to those developing research programmes if such activities take place intersessionally.

3.1.2 Future surveys

SC/65a/RMP02 presented a revised research plan for a sighting survey for common minke whales in the Sea of Okhotsk, including the Russian EEZ, in summer 2014. The research plan was revised from that presented last year owing to logistical issues and issues related to obtaining permits. The primary aim of the survey is now to obtain biopsy samples in sub-area 12NE rather than obtaining abundance estimates for the whole of the Okhotsk Sea. Abundance estimates for the Okhotsk Sea are, however, important given the need to obtain information on the mixing rate of J- and O-stocks, and the distribution of J-stock in the Sea of Okhotsk Sea. The survey will be conducted using two dedicated sighting survey vessels during July to September 2014. SC/65b/RMP02 also reported plans for a joint Russian-Japanese sighting survey in the Okhotsk Sea in summer 2015.

The sub-committee noted the revised research plan and **welcomed** the plan for a joint Russian-Japanese survey for common minke whales in Okhotsk Sea. It looks forward to seeing a detailed research plan for this latter survey at SC66a. It again **strongly recommends** that the Government of the Russian Federation give permission for the survey to take place in its EEZ throughout sub-area 12, noting that there are often major difficulties making use of abundance estimates for only part of a sub-area. The sub-committee appointed Miyashita to provide oversight on behalf of the Committee.

3.1.3 Recommendations

The sub-committee **recommends** that future surveys be as synoptic as possible as this will better facilitate their use in the RMP.

3.2 North Atlantic fin whales

3.2.1 Report of intersessional Workshop

Donovan introduced SC/65b/Rep07, the report of the Intersessional Workshop on the *Implementation Review* for North Atlantic fin whales, which was held at the Greenland Representation in Copenhagen, 6-8 January 2014. The Workshop was primarily a technical workshop to finalise trial specifications and make progress towards conditioning the trials.

The Workshop noted the progress made since SC/65a which included inclusion in the code for the control program of a new likelihood function for the catch-at-age data, density-dependent dispersal, allowance for sex-specific selectivity, and initialisation of the population trajectory in a harvested state. It made several additional changes to the code for the operating model, including the optimisation algorithm and the way the data are weighted. However, conditioning had not been successfully achieved by the end of the Workshop.

The Workshop developed a work plan so that the Committee would be in a position to finish the *Implementation Review* at the 2015 Annual Meeting, and established a Steering Group (Elvarsson [Chair], with members Allison, Butterworth, de Moor, Donovan, Elvarsson, Gunnlaugsson, Punt, and Witting) to assist with implementing the work plan.

The sub-committee thanked Donovan for chairing the intersessional Workshop and the participants for their work during the Workshop and subsequently, in particularly Elvarsson. It then reviewed the progress made since the Workshop. It noted that further changes to the optimisation method had been implemented and the density-dependent dispersal model had been developed and included in the control program. Progress has been made assembling data so that sub-areas EG and WI can be combined and in updating the catch series to include incidental catches off eastern Canada. In addition, Elvarsson had conditioned base-case trials for eight stock-structure hypotheses for three hypotheses regarding dispersal and for three starting years for the projections.

3.2.2 Consideration of available results

Elvarsson provided an overview of progress on conditioning the set of trials identified during the January 2014 Workshop. He noted that many of the trials can now be conditioned successfully. However, there are still some trials for which there appear to be problems achieving convergence of the minimisation algorithm. It was also noted that some of the fits to the age data were poor, probably because the selectivity patterns are being estimated to be knife-edged.

The sub-committee **recommends** that a Workshop takes place in early 2015 to ensure that the Committee is in a position to complete the *Implementation Review* at the 2016 Annual Meeting, if not earlier. A Steering Group (Donovan, [Convenor], Allison, Butterworth, Punt, Víkingsson, Walløe and Witting) was established to progress the work.

SC/65b/RMP06 presented cetacean sightings and effort during winter fishery (mainly capelin) surveys conducted during 1991-95, 2003 and 2009 around Iceland. Humpback whales are observed most commonly in these surveys and in association with capelin. As in other data sets, an increase in abundance is observed in this species. Only a single fin whale had been observed in two surveys up to 2003, but in 2009 there were 13 sightings. An increase in fin whales is also observed from autumn surveys conducted during 1983-86 and during 1990-95. Abundance of fin whales in the NASS surveys increased from 1987 to 2001, but the increase was not significant. There was no increase in fin whale abundance in the NASS surveys between 2001 and 2007. The feeding on capelin by fin whales during winter may be related to the low fertility observed in the recent catch, reflecting poor energetic condition in these whales.

SC/65b/RMP08 investigated the differences in the first and second or later fin whales taken per trip in light of the differences in the recent catch compared to that during the earlier period. The recent catches are considerably larger by sex while the larger females are rather fewer. Once a whale has been caught, for meat quality, it has to be brought in to the station quickly so there is little time to select later animals. The whalers may spend some time on choosing the first animal given that the more valuable fin whales are taken more frequently as the first whale when there was a multi-species fishery. The proportion of females is also higher as the first than later whale caught and the first whale is larger by sex. Recent catches show the same pattern, except that the proportion of females is lower and the size of the whales is larger. The differences between the first and second whale have remained the same so it is concluded that there has not been a change in selection, but rather the catches, both of the first and second whale, reflect a change in the population, where there are now very few small (immature) whales.

The sub-committee welcomed these papers and noted they may be useful when assigning plausibility ranks to the *Implementation Simulation Trials* during the 2015 Annual Meeting.

3.3 North Atlantic common minke whales

The *Implementation Review* for the North Atlantic minke whales started with an AWMP/RMP joint Workshop on stock structure in April 2014. The *Implementation Review* continued with a meeting of the Working Group immediately prior to SC/65b, whose report is given as Appendix 5.

The sub-committee endorsed the report of the Working Group and adopted the work plan established by the pre-meeting. The sub-committee thanked Donovan for chairing the Working Group and the participants for their work. It established a Steering Group (Walløe [Convenor], Allison, Butterworth, de Moor, Donovan, Palsbøll, Punt, Prieto, Víkingsson and Witting) to guide the intersessional work, including the holding of an intersessional Workshop to review progress on conditioning.

3.4 North Atlantic sei whales

3.4.1 Pre-Implementation assessment

The North Atlantic sei whale Steering Group reported that it was premature to conclude whether a *pre-Implementation Review* was feasible given the available information. Accordingly, it proposed that the feasibility of a *pre-Implementation Review* be investigated further during the intersessional period by a Correspondence Group chaired by Víkingsson (members: Allison, Donovan, Øien, Palka, Palsbøll, Pampoulie, Prieto, Tiedemann, Waples and Witting). The Terms of Reference of this new group are to finalise the compilation of the available data and develop a draft set of possible stock structure hypotheses for consideration during SC/66a. Donovan noted that while the Committee can conduct a *pre-Implementation*, initiation of an *Implementation* follows only from a decision by the Commission.

As for some other North Atlantic balaenopterids, genetic analyses conducted so far for sei whales indicate low levels of population genetic structure. However, the sample sizes are low and the geographic coverage is limited. The Steering Group saw value in conducting further genetic analyses to aid in the formulation of plausible stock hypotheses for North Atlantic sei whales.

3.4.2 Recommendations

To maximise the amount of genetic data from the existing set of samples, the subcommittee **recommends** the generation and analysis of ddRAD-based SNP genotypes (Peterson *et al.*, 2012) from the available tissue samples. In addition, the sub-committee **recommends** that information on the distribution of sei whales from catch records be summarised.

Table 1

Overview of the work plan as it relates to *Implementations*.

Species/area	Intersessional 2014-15	SC/66a 2015	Intersessional 2015-16	SC/66b 2016
Minke whales (western North Pacific)	-	Review hybrid RMP variants and research proposals	-	Review hybrid RMP variants and research proposals
Minke whales (North Atlantic)	Assemble data Finalise trial specifications Validate code and condition Hold intersessional Workshop	Review trial results Assign plausibility to trials Finish *Implementation Review?*	Hold intersessional Workshop (if needed)	Finish *Implementation Review* (if needed)
Fin whales (North Atlantic)	Assemble data Validate code Hold intersessional Workshop	Review trial results Assign plausibility to trials Finish *Implementation Review?*	Hold intersessional Workshop (if needed)	Finish *Implementation Review* (if needed)
Sei whales (North Atlantic)	Summarise data on stock structure	Decide whether to initiate *pre-Implementation assessment*	-	*Pre-Implementation assessment* (if agreed at SC/66a)
Bryde's whale (western North Pacific)	-	Review new information	-	Review new information

3.5 Western North Pacific Bryde's whales

3.5.1 Prepare for 2016 Implementation Review

The *Implementation Review* for western North Pacific Bryde's whales was originally scheduled for 2013. However, in 2012, the Committee postponed the *Implementation Review* until 2016 to allow additional sightings and genetics data to be available and analysed (IWC, 2013). Miyashita, on behalf of Japan, requested that the *Implementation Review* be deferred to 2017 because:

(1) the JARPN II review is planned for 2016 - a large amount of data, including genetics and sighting data will be analysed for that review; and it is expected that these analyses will yield new information on Bryde's whales in the North Pacific;
(2) additional sightings data and genetic samples will be collected during the IWC/POWER cruises;
(3) satellite tracking of Bryde's whales is expected to be conducted in the near future during dedicated sighting surveys; this may lead to new information on migration between wintering and summering grounds; and
(4) observations of diving and feeding behaviour have been carried out in 2013 using pingers and is also planned for the future dedicated surveys - the analysis of these data is ongoing and will be presented in the near future.

In discussion, it was noted that considerable new data were likely to be available by 2017. Given this, the sub-committee **recommends** that the next *Implementation Review* be a 'full review' like those currently being undertaken for the North Atlantic minke and fin whales in which all aspects of the *Implementation* are reviewed instead of only updating the abundance estimates and catches and determining whether new research suggests that the trial scenarios considered during the *Implementation* remain plausible. The *Implementation Reviews* for North Atlantic minke and fin whales will not both be completed before the 2016 Annual Meeting; it would be infeasible in any case for the Committee to initiate another 'full' *Implementation Review* until these two reviews are completed.

It was noted that since no new abundance estimates have been adopted by the Committee, application of the RMP would lead to use of the 'phase out rule'.

3.5.2 Recommendations

The sub-committee **recommends** that the *Implementation Review* for the western North Pacific Bryde's whales be conducted in 2017 and that it be a 'full' *Implementation Review*.

3.6 Other

3.6.1 Updated table of abundance

Allison advised that the 2001 estimate of abundance for sub-areas CG+CIP for the North Atlantic minke whales of 23,592 was an error and the correct estimate is 10,740. This estimate had been used in the applications of the RMP, which took place in 2010 (IWC, 2011).

Appendix 6 lists the updated abundance estimates for the North Atlantic minke and fin whales and North Pacific minke and Bryde's whales. The sub-committee was advised by Allison that these estimates may be further revised after the end of its meeting. Allison will report any updated values to Plenary. If any estimates are updated, Appendix 6 should be updated with the new information.

3.7 Work plan

The sub-committee noted that the iterative nature of its work means that it is challenging to determine the exact nature of its work plan beyond a single year. Table 1 provides a broad overview of the work plan as it pertains to *Implementations*.

The sub-committee **agreed** that its work plan before the 2015 Annual Meeting would be as follows:

(1) North Atlantic fin whales:
    (a) assemble data when sub-areas EG and WI are combined (stock structure hypothesis VII) (Allison, Item 3.2.1);
    (b) update the catch series to include incidental catches off Eastern Canada (Allison, Item 3.2.1);
    (c) finalise the initial validate of the code (de Moor and Allison, Item 3.2.1);
    (d) continue to work towards conditioned *Implementation Simulation Trials* (Elvarsson, Item 3.2.2); and
    (e) hold an interessional Workshop to review progress in terms of conditioning the *Implementation Simulation Trials* and finalising the trial specifications. There will be costs involved for travel and subsistence (Item 3.2).

(2) North Atlantic minke whales:
    (a) finalise survey estimates for conditioning (Øien, Gunnlaugsson, Witting, Item 3.3);
    (b) finalise (commercial and aboriginal) catch series (Allison, Item 3.3);
    (c) steering-Group-suggested final trial specifications distributed (Allison, Punt, de Moor, Item 3.3);
    (d) code finalisation and conditioning (Allison, de Moor, Punt, Item 3.3);
    (e) hold a Workshop to evaluate conditioning, confirm/amend/finalise trial specifications. There will be costs involved for travel and subsistence (Item 3.3); and
    (f) conduct projections and circulate results (Allison, Punt, de Moor, Item 3.3).

(3) North Atlantic sei whales:
    (a) summarise information on the distribution of sei whales from catch records (Allison, Item 3.4.2); and
    (b) determine stock structure hypotheses using genetics and non-genetics data to form the basis for discussions regarding whether a *pre-Implementation assessment* can be initiated (Correspondence Group, Item 3.4.2).

The sub-committee **agreed** that its work plan during the 2015 Annual Meeting would be as follows:

(1) Western North Pacific minke whales:
    (a) review the results of possible proposed 'hybrid' versions of RMP variants to allow an evaluation of any candidate 'variant with research' (Allison, based on advice from Japan; Item 3.1);
    (b) review any research proposals related to a candidate 'variant with research' (Item 3.1); and
    (c) agree the estimates of abundance for use in actual applications of the RMP (Item 3.1).
(2) North Atlantic fin whales:
    (a) review the results of the conditioning and complete the tasks normally conducted at the First Annual Meeting (Item 3.2).
(3) North Atlantic minke whales:
    (a) review the results of the conditioning and complete the tasks normally conducted at the First Annual Meeting (Item 3.3).
(4) North Atlantic sei whales:
    (a) make a decision whether to proceed with a *pre-Implementation assessment* based on the information assembled by the Correspondence Group (Item 3.42).

The sub-committee **agreed** that its work plan before the 2016 Annual Meeting would be as follows:

(1) North Atlantic fin whales:
    (a) hold an intersessional Workshop to prepare if necessary (Item 3.2).
(2) North Atlantic minke whales:
    (a) hold an intersessional Workshop to prepare if necessary (Item 3.3).

The sub-committee **agreed** that its work plan during the 2016 Annual Meeting would be as follows:

(1) Western North Pacific minke whales:
    (a) review the results of possible proposed 'hybrid' versions of RMP variants to allow an evaluation of any candidate 'variant with research' (Allison, based on advice from Japan; Item 3.1);
    (b) review any research proposals related to a candidate 'variant with research' (Item 3.1); and
    (c) agree the estimates of abundance for use in actual applications of the RMP (Item 3.1).
(2) North Atlantic fin whales:
    (a) finalise the *Implementation Review* if not completed during the 2015 Annual Meeting (Item 3.2).
(3) North Atlantic minke whales:
    (a) finalise the *Implementation Review* if not completed during the 2015 Annual Meeting (Item 3.3).
(4) North Atlantic sei whales:
    (a) initiate a *pre-Implementation assessment* (if the Committee agreed to initiate a *pre-Implementation assessment* during the 2015 Annual Meeting) (Item 3.4).

4. OTHER

The sub-committee **draws attention** to the fact that the RMP (and AWMP) approach, which was pioneered at the IWC and is now increasingly being used in fisheries management, is of broad relevance to the work of the Committee when examining status and the effects of human-related mortality. Irrespective of whether the *CLA* (or *SLA*) itself is used, the modelling framework and approach to dealing with uncertainty is of wide application. Lessons learned during the RMP *Implementation*s and *Implementation Reviews* are of value in assessments generally. It was noted that this approach is now being used for North Pacific gray whales (SC/65b/Rep08).

5. STEERING, CORRESPONDENCE AND ADVISORY GROUPS

The sub-committee established the following groups to facilitate progress on the work plan during the intersessional period.

(1) Steering Group: de la Mare (Convenor) with members Allison, Butterworth, Cooke, Kitakado and Punt, to coordinate the intersessional work exploring the relationship between $MSYR_{mat}$ and $MSYR_{1+}$ (Item 2.2).
(2) Steering Group: Bravington (Chair) with members Butterworth, Cooke, Hedley, Kitakado and Leaper, to develop an agenda for the Workshop on abundance estimation and facilitate preparations (Item 2.6).
(3) Advisory Group: Butterworth (Convenor) with members Allison, An, Baker, de Moor, Donovan, Double, Gaggiotti, Hoelzel, Kanda, Kelly, Kitakado, Miyashita, Park, Pastene, Punt, Wade and Waples, to provide feedback to those developing research programmes for the North Pacific minke whales during the intersessional period (Item 3.1).
(4) Steering Group: Elvarsson (Chair) with members Allison, Butterworth, de Moor, Donovan, Gunnlaugsson, Punt and Witting, to assist with implementing the work plan for the North Atlantic fin whales *Implementation Review* (Item 3.2.1).
(5) Steering Group: Donovan (Convenor) with members Allison, Butterworth, Punt, Víkingsson, Walløe and Witting, for a Workshop to ensure further progress on the *Implementation Review* for North Atlantic fin whales (Item 3.2.2).
(6) Steering Group: Walløe (Convenor) with members Allison, Butterworth, de Moor, Donovan, Palsbøll, Punt, Víkingsson and Witting, to guide the intersessional work on the *Implementation Review* for the North Atlantic minke whales (Item 3.3).
(7) Correspondence Group: Víkingsson (Chair) with members Allison, Donovan, Øien, Palka, Palsbøll, Pampoulie, Prieto, Tiedemann, Waples and Witting, to review the available data for North Atlantic sei whales in the context of a *pre-Implementation assessment* and provide a report to the 2015 Annual Meeting (Item 3.4).

6. PRIORITISED BUDGET REQUESTS

The sub-committee received budget requests for four research projects and two intersessional Workshops (RMP-WP01-06).

The research projects are:

(1) evaluation of density dependence parameters for inclusion in RMP testing based on energetics modelling (Investigators: de la Mare and Andrews-Goff) (£12,000; Item 2.2);
(2) guidelines for evaluating abundance estimates: diagnostics and testing (Investigators: Hedley and Bravington) (£14,300; Item 2.6);
(3) genetic analysis to aid the formulation of plausible stock hypotheses for *pre-Implementation assessment* North

Atlantic sei whales (Investigators: Palsbøll, Pampoulie, Palka, Robbins and Víkingsson) (£4,100; Item 3.4); and

(4) essential computing support to the Secretariat for RMP (Investigator: de Moor) (£10,000 per year; Items 3.2 and 3.3)

The intersessional Workshops are:

(1) a pre-meeting to test the proposed new Guidelines against several test cases of model-based abundance estimates made specifically for and during the Workshop and to demonstrate and discuss the proposed diagnostic software with a wider Committee audience involved in basic line-transect abundance estimation (Convenors: Hedley and Bravington) (£2,200; Item 2.6); and

(2) an intersessional Workshop to continue the *Implementation Reviews* for the North Atlantic fin and minke whales, with a focus on evaluating conditioning and finalising trial specifications (Convenors: Walløe and Donovan) (£7,000 per year; Items 3.2 and 3.3).

The sub-committee recognised that all of the research projects, if completed, should substantially contribute to the Committee's work to implement the RMP. The sub-committee **recommended** that all of these proposals and Workshops should be funded. However, in the event that this is not possible, it provides the proposals in rank order. In ranking the research projects and Workshops, the sub-committee recognised that some of the projects and Workshops are linked. Specifically project (2) and Workshop (1) are essentially a joint item as are project (4) and Workshop (2). The primary basis for the rankings by the sub-committee related to the needs of the ongoing work plan. The projects in rank order are as follows:

(A) Research project (4) and Workshop (2). These are required for the sub-committee to complete two current *Implementation Reviews*.

(B) Research project (2) and Workshop (1). These will follow up on ongoing work (Item 2.6); this work to provide guidelines for evaluating abundance estimates will have benefits for the Committee as a whole because the proposed guidelines would be applicable to surveys reported to, for example, the AWMP SWG and the IA, BRG and SH sub-committees.

(C) Research Project (1). This project will substantially enhance the ability of the sub-committee to resolve the outstanding question of the relationship between $MSYR_{mat}$ and $MSYR_{1+}$ but is not essential for completion of any ongoing work.

(D) Research Project (3). This project will help the Committee decide whether to initiate a *pre-Implementation assessment* for North Atlantic sei whales but there is no immediate need to initiate such a *pre-Implementation assessment*.

7. ADOPTION OF REPORT

The Report was adopted at 14:10 on 21 May 2013. The sub-committee thanked Punt for his customary expertly efficient rapporteuring and Bannister for his excellent Chairmanship.

REFERENCES

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Peterson, B.K., Weber, J.N., Kay, E.H., Fisher, H.S. and Hoekstra, H.E. 2012. Double Digest RADseq: an inexpensive method for De Novo SNP Discovery and Genotype in Model and Non-Model Species. *PLoS ONE* 7(5): e37135. doi: 10.1371/journal.pone.0037135.

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Appendix 1

AGENDA

1. Introductory items
    - 1.1 Convenor's opening remarks
    - 1.2 Election of Chair, appointment of rapporteurs
    - 1.3 Adoption of Agenda
    - 1.4 Available documents
2. Revised Management Procedure (RMP) – general issues
    - 2.1 Use of individual based energetics model
    - 2.2 Relationship between $\mathrm{MSYR}_{\mathrm{mat}}$ and MSYR_1
    - 2.3 Finalise the approach for evaluating proposed amendments to the *CLA*
    - 2.4 Evaluate the Norwegian proposal for amending the *CLA*
    - 2.5 Other computing matters related to the *CLA*
    - 2.6 Update 'Requirements and Guidelines for conducting surveys and *Implementations*'
        - 2.6.1 Model-based estimates
        - 2.6.2 Changing survey coverage in time series of estimates
        - 2.6.3 Use of surveys in different months
        - 2.6.4 Other
    - 2.7 Imbalanced sex ratio in incidental catches
    - 2.8 Work plan
3. RMP – *Implementation*-related matters
    - 3.1 North Pacific common minke whales
        - 3.1.1 Review of intersessional work
        - 3.1.2 Future surveys
        - 3.1.3 Recommendations
    - 3.2 North Atlantic fin whales
        - 3.2.1 Report of intersessional Workshop
        - 3.2.2 Consideration of available results
    - 3.3 North Atlantic common minke whales
    - 3.4 North Atlantic sei whales
        - 3.4.1 *Pre-Implementation assessment*
        - 3.4.2 Recommendations
    - 3.5 Western North Pacific Bryde's whales
        - 3.5.1 Prepare for 2016 *Implementation Review*
        - 3.5.2 Recommendations
    - 3.6 Other
        - 3.6.1 Updated table of abundance
    - 3.7 Work plan
4. Other
5. Steering, correspondence and advisory groups
6. Prioritised budget requests
7. Adoption of Report

Appendix 2

RESULTS OF THE RMP TIME-VARYING TRIALS

Cherry Allison and Andre E. Punt

Introduction and methods

IWC (2007) noted that 'the current varying K trials have questionable behaviour when modelling population sizes above *K* and might better be modelled using an exponential model.' For the trials in Table 1, variation in *K* and MSYR could result in the population at certain times exceeding the effective value of *K* at that time (and hence, even without harvesting, be subject to losing more whales to natural mortality than gaining from new births for that year), and can lead to oscillatory behaviour.

Table 1

The trials in which *K* and/or MSYR vary over time considered in this document (IWC, 2007).

	Description
T12A	*K* doubles over management period.
T12B	*K* halves over management period.
T13A	33 year cycle in MSYR (141).
T13B	33 year cycle in MSYR (414).
T17	*K* and MSYR decline linearly to half initial values.

The conventional equation used to determine births in the population model used for trials is:

$$b^{*}_{y} = f_0(1+^{A}(1-(N^{m}_{y} / K^{m}_{y})^{z})) \tag{1}$$

However, the number of births is negative if:

$$N^{m}_{y} > K^{m}_{y}((\mathrm{A}+1) / \mathrm{A})^{1/z} \tag{2}$$

The solution suggested to (and agreed by) the intersessional group was to substitute the functional form of equation (1) for $N_y^m > K^m$ by a negative exponential form for which the parameter λ governing the rate of decline is chosen to ensure derivative continuity at $N_y^m = K_y^m$, i.e.:

$$b_y^* = f_{0^{e-\lambda(N_y^m/K_y^m-1)}} \text{ for } N_y^m > K^m \qquad (3)$$

where $\lambda = A_z$.

Table 2

Final and lowest depletion statistics for the base trials and the trials used to explore the impact of time-varying *K* and MSYR.

	Final depletion			Lowest depletion		
Trial	Median	5%	95%	Median	5%	95%
T1-D1	0.723	0.608	0.806	0.598	0.619	0.653
T1-R1	0.899	0.791	0.963	0.787	0.808	0.857
T12A-D1	0.576	0.468	0.678	0.468	0.502	0.543
T12A-R1	0.874	0.732	0.957	0.732	0.769	0.827
T12B-D1	0.821	0.709	0.889	0.662	0.682	0.698
T12B-R1	0.933	0.837	0.982	0.810	0.829	0.876
T13A-D1	0.921	0.832	0.983	0.686	0.713	0.743
T13A-R1	0.927	0.870	0.979	0.736	0.758	0.790
T13B-D1	0.798	0.690	0.913	0.666	0.682	0.713
T13B-R1	0.894	0.785	0.963	0.785	0.813	0.861
T17-D1	0.752	0.642	0.829	0.614	0.642	0.675
T17-R1	0.923	0.820	0.982	0.804	0.825	0.879

The trials in Table 1, as well as the base-case trials, were conducted with MSYR_{mat}[1] set to 1% for the development (D) and rehabilitation (R) cases. The results are reported as final and lowest depletion statistics in terms of the mature female component of population. The number of mature females each year is scaled by the number of mature females had there been no catches after the *CLA* is first implemented, as is common for trials in which *K* and MSYR are varying[2]. Results are also available for the 1+ component of the population, as well as for catches and catch variation. However, values for these statistics are not reported here given the focus on the conservation performance of the RMP given variation in *K* and MSYR.

Results

Table 2 lists the 5%, 95% and median values for the final depletion and the lowest depletion statistics for each trial. Results for these trials when the population dynamics are governed by Equation 1 (Table 3) suggest that the performance statistics are not substantially different from those when the population dynamics are based on Equation 1.

Table 3

Final and lowest depletion statistics for the base trials and the trials used to explore the impact of time-varying *K* and MSYR when the operating model is based on Equation 1.

	Final depletion			Lowest depletion		
Trial	Median	5%	95%	Median	5%	95%
T1-D1	0.723	0.608	0.806	0.598	0.619	0.653
T1-R1	0.899	0.791	0.963	0.787	0.808	0.857
T12A-D1	0.576	0.468	0.678	0.468	0.502	0.543
T12A-R1	0.874	0.732	0.957	0.732	0.769	0.827
T12B-D1	0.858	0.742	0.926	0.668	0.688	0.707
T12B-R1	0.934	0.837	0.982	0.810	0.829	0.876
T13A-D1	0.921	0.832	0.983	0.686	0.713	0.743
T13A-R1	0.927	0.870	0.979	0.736	0.758	0.790
T13B-D1	0.798	0.690	0.913	0.666	0.682	0.713
T13B-R1	0.894	0.785	0.963	0.785	0.813	0.861
T17-D1	0.786	0.671	0.864	0.634	0.659	0.684
T17-R1	0.923	0.820	0.982	0.804	0.825	0.879

REFERENCE

International Whaling Commission. 2007. Report of the Sub-Committee on the Revised Management Procedure (RMP). *J. Cetacean Res. Manage. (Suppl.)* 9: 88-128.

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[1] For consistency with the earlier trials.

[2] This has also been done for the base-case trials to ensure comparability of results.

Appendix 3

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN MSYR_{MAT} AND MSYR_{1+} BASED ON A NON-INDIVIDUAL-BASED MODEL

André E. Punt

School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98195, USA

There is an implicit relationship between MSYR_{mat} and MSYR_{1+} in any population dynamics model, with the ratio of MSYR_{mat} to MSYR_{1+} depending on the values for biological parameters and MSYR_{mat}. SC/65b/RMP04 suggests that this relationship may depend on how density-dependence is modelled. Rather than constructing an individual-based model, two versions of an age-structured non-individual-based model are used here to explore this relationship.

The population model assumes that natural mortality at carrying capacity is 0.08yr^{-1}, and the age-at-first-parturition is 8 years. Two versions of density-dependence are modelled (see Punt, 1996).

(1) Density-dependent fecundity:

$$b_t = BN_t\{1+A(1-(N_t K)^z)\} \tag{1}$$

where b_t is the birth rate in year t, B is the fecundity at carrying capacity, N_t is the number of mature females at the start of year t, A is the resilience parameter, z is the degree of compensation, and K is carrying capacity.

(2) Density-dependent natural mortality:

$$M_t = M_\infty \frac{1+A(N_t/K)^z}{1+A} \tag{2}$$

where M_∞ is the rate of natural mortality at carrying capacity (0.08yr^{-1}).

For each type of density-dependence, the values for A and z were selected given a value for MSYR_{mat} so that MSY occurs when the exploitation rate equals MSYR_{mat} and

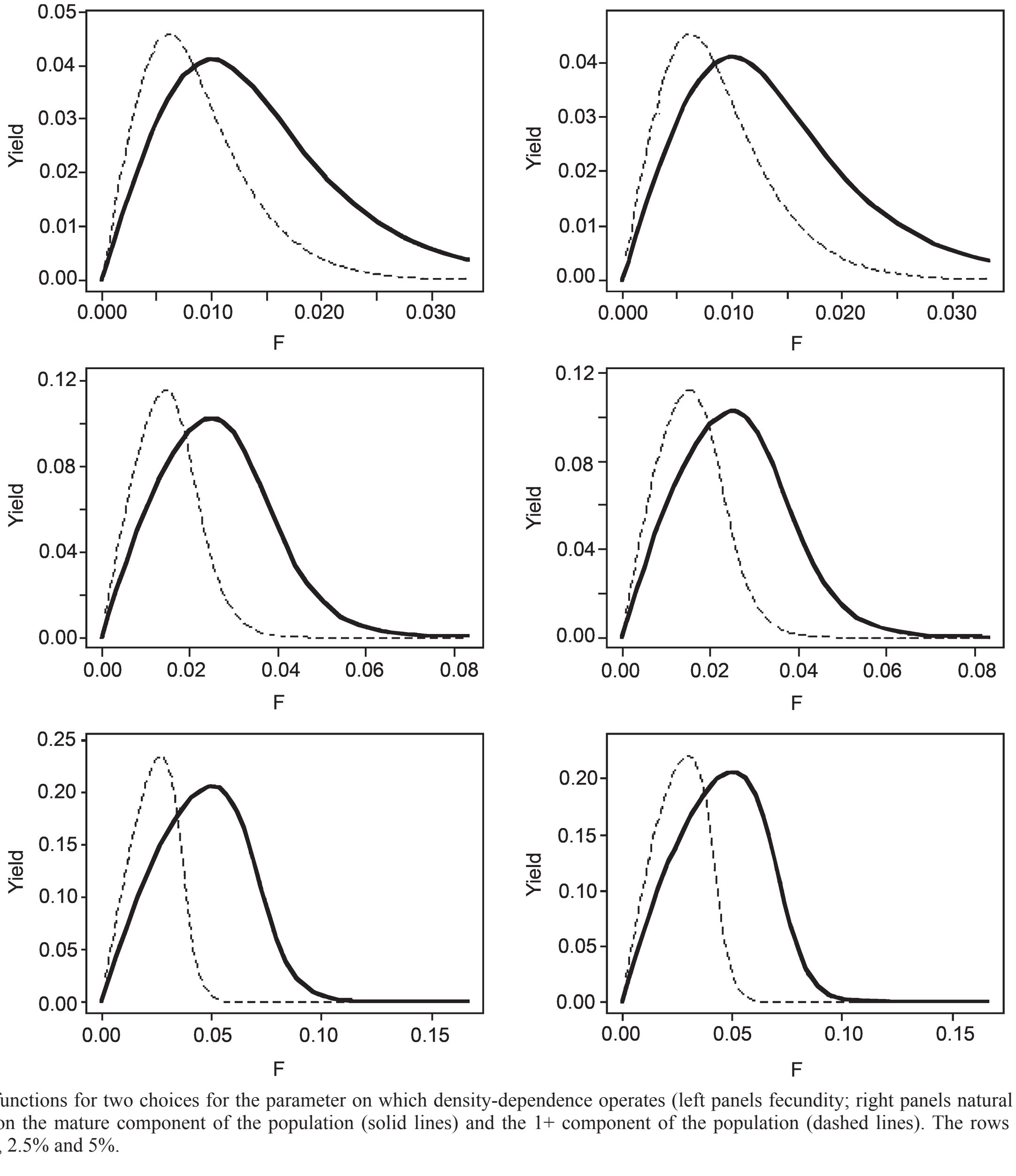

Fig. 1. Yield functions for two choices for the parameter on which density-dependence operates (left panels fecundity; right panels natural mortality) when selectivity is on the mature component of the population (solid lines) and the 1+ component of the population (dashed lines). The rows show results for MSYR_{mat}=1%, 2.5% and 5%.

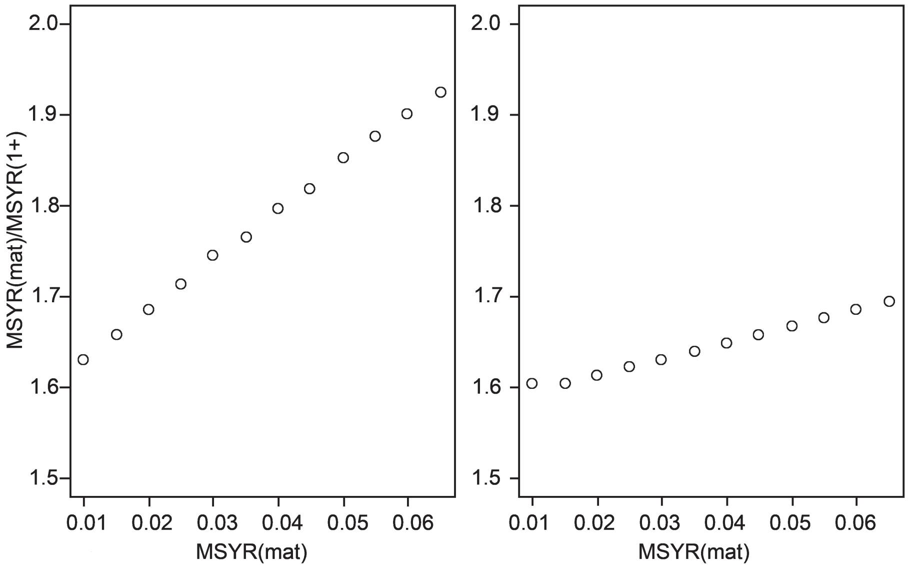

Fig. 2. $MSYR_{mat}/MSYR_{1+}$ *vs* $MSYR_{mat}$ when density-dependence is on fecundity (left panel) and natural mortality (right panel).

MSYL is 0.6*K* and selection is knife-edged at age 8. Given the calculated values for *A* and *z*, the value for $MSYR_{1+}$ is computed by assuming that selectivity is 1 on animals on age 1 and older and finding the exploitation rate at which MSY is achieved.

Fig. 1 shows yield curves (yield vs exploitation rate) for density-dependence on fecundity and natural mortality – solid and dashed lines for three choices for $MSYR_{mat}$ (1%, 2.5% and 5%). Fig. 2 shows the ratio of $MSYR_{mat}$ to $MSYR_{1+}$ as a function of $MSYR_{mat}$ and the two choices for density-dependence. The relationship between $MSYR_{mat}/MSYR_{1+}$ and $MSYR_{mat}$ clearly depends on the choice of how density-dependence operates but the ratio is an increasing function of $MSYR_{mat}$ for both choices for how density-dependence operates.

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Appendix 4

REPORT OF THE SMALL GROUP ON SURVEY GUIDELINES

Members: Bravington, Butterworth, Cooke, Kitakado and Leaper.

There have been substantial developments in design-based abundance estimation, and especially in spatial-model-based abundance estimation, since the last revision of the 'Guidelines' document (IWC, 2012). The review material and proposed evaluation criteria in SC/65b/RMP11 should (after some refinement) provide a valuable basis for evaluating abundance estimates in many applications considered by the Committee. In particular, spatial model-based estimates have the potential to reduce bias in abundance estimates arising from unbalanced coverage (for whatever reason that arises), and to provide more stable variance estimates especially in repeat surveys. However, like most powerful tools, spatial models can easily go wrong if misapplied, so it is important to have clear criteria for assessment; these apply to many sub-committees besides RMP. Apart from numerical or graphical diagnostics, it is essential when reviewing both design-based and model-based estimates to have thorough descriptions of processes followed and decisions made during design and analysis (as already specified in the Committee's 'guidelines' for the conduct and protocols of the survey operation itself).

The Committee is often faced with interpreting 'design-based estimates' applied to surveys which do not meet the strict criteria for design-based analysis (randomisation, estimable coverage probability, etc.; as per Buckland *et al.* (2001), and summarised in SC/65b/RMP11). However, this description applies to a wide range of cases, of which some will be problematic and others will not be. There is a continuum from: (i) cases where the coverage is clearly uneven and there is clear potential for bias if a 'design-based estimate' is applied; to (ii) cases where the coverage is dense and uniform but no randomisation has been used, so that a 'design-based estimate' should in practice give similar results to any reasonable spatial model even though the formal justification for design-based analysis is lacking. There is no implication that a non-randomised survey design is necessarily 'inferior' to a randomised design; the point is simply that the statistical rationale for design-based analysis is entirely built around randomisation. A 'design-based estimate' can also be viewed as a very simple type of (spatial) model-based abundance estimate, so in principle such estimates could be assessed by the same guidelines proposed for fully-developed spatial model-based estimates. However, proper spatial modelling requires substantial analytical skills beyond those required for classical Distance-sampling-based abundance estimation, even to report against all of the guidelines. Therefore it would be very useful to have a largely automated default set of 'simple' spatial-model-based diagnostics, to be applied to any simple design-based estimate where the strict design criteria are not clearly met. The diagnostics should be set up so that they are not onerous for the person doing the abundance estimation, but that would enlighten the Committee about the sensitivity and robustness and potential biases of point estimates and CVs from the proposed design-based estimate. The general idea is that surveys with dense and evenly-distributed coverage should readily pass the diagnostic tests, whereas surveys with low or badly imbalanced coverage should raise a flag. Importantly, any automated default spatial analysis would only be a tool for assessing a simpler estimate, and would not in itself yield a suitable abundance estimate (unless accompanied by a satisfactory report against all the proposed guidelines for full model-based analysis).

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International Whaling Commission. 2012. Requirements and Guidelines for Conducting Surveys and Analysing Data with the Revised Management Scheme. *J. Ceatean Res. Manage. (Suppl.)* 13: 509-17.

Appendix 5

IMPLEMENTATION REVIEW FOR NORTH ATLANTIC COMMON MINKE WHALES

Members: Allison, Bando, Bannister, Bell, Bjørge, Brockington, Butterworth, Cipriano, Cooke, de Moor, Donovan, Gunnlaugsson, Haug, Hoelzel, Kim, Kitakado, Moronuki, Øien, Palsbøll, Pastene, Prewitt, Punt, Skaug, Solvang, Stenseth, Tiedemann, Víkingsson, Walløe, Waples, Witting.

1. INTRODUCTORY ITEMS

The *Implementation Review* discussions were begun at a pre-meeting to the annual Scientific Committee meeting from 9-11 May in Bled, Slovenia. The Working Group continued its deliberations during the first week of the Scientific Committee and reported its conclusions to the sub-committee on the RMP.

1.1 Convenor's opening remarks

In 1992, the Committee completed its work on the RMP *Implementation* of common minke whales (IWC, 1993). Since then two *Implementation Reviews* had been undertaken (IWC, 2004; 2008). Since the original *Implementation* had been developed prior to the development of the Committee's 'Requirements and Guidelines for *Implementations*' (IWC, 2012), the Committee had agreed that it was timely for a full re-examination of the information following the new Guidelines. The Committee had agreed that the starting point for consideration was the trial structure for the 1992 RMP *Implementation* (and any amendments made at the two subsequent *Implementation Reviews*).

1.2 Election of Chair

Donovan was elected Chair.

1.3 Appointment of rapporteurs

Allison, Haug, Punt and Waples acted as rapporteurs, assisted by the Chair.

1.4 Adoption of Agenda

The adopted Agenda is shown as Adjunct 1.

1.5 Documents available

The Working Group had available the following new documents: SC/65b/RMP01, SC/65b/RMP05-RMP10 and SC/65b/Rep04.

2. STOCK STRUCTURE

2.1 Review of the intersessional joint Workshop

The Working Group received the report of the AWMP/RMP Joint Workshop on the stock structure of North Atlantic common minke whales held in Copenhagen from 14-17 April 2014 (SC/65b/Rep04). A short Chair's summary (Donovan) of the results of the Workshop relevant to the Working Group is given below.

2.1.1 Summary of existing hypotheses

The Workshop had reviewed the hypotheses from the 1992 RMP *Implementation* as modified subsequently by the Committee as a starting point for its discussions. This had involved three stocks of minke whales in the North Atlantic: W(est), C(entral) and E(ast). These in turn were comprised of two (WC and WG), four (CG, CIP, CIC and CM) and four (EN, EC, ES and EB) sub-stocks respectively. Each sub-stock was modelled as a separate stock but with the possibility of diffusive exchange. The proportions of sub-stocks found in each sub-area was defined by catch mixing and sighting mixing matrices specified on the basis of expert judgement at that time.

2.1.2 Use of RMP/AWMP-lite

SC/A14/AWMP-RMP01 applied an RMP/AWMP-lite framework to the North Atlantic minke whales to explore 'tipping points' i.e. the level of dispersal that is sufficient to overcome poor management performance caused by uncertainty regarding stock structure. This work was funded by the Committee last year. Illustrative examples found that for the cases considered, only a high rate of dispersal (~5% each year) was able to overcome uncertainty when all catches were taken from one *Small Area* and with mixing on feeding grounds when surveys are undertaken.

The Workshop agreed that the framework provided a useful and rapidly implementable tool which could be used, if required, to determine the extent of dispersal which would be required to effect a qualitative change in the conservation performance of a particular RMP (or AWMP) variant. However, final evaluation using the 'full' approach would still be required before any final recommended implementation advice could be provided.

2.1.3 Progress and results of genetic simulations at 'management tipping points'

SC/A14/AWMP-RMP05 evaluated by simulation, clustering methods' ability to detect population genetic structure in a management context, with a focus on the Discriminant Analysis of Principal Components (DAPC) suggested last year (IWC, 2014). The Workshop concurred with the authors that the DAPC method was ill-suited for testing the null hypothesis of panmixia (it would always indicate more than one cluster) and would probably be unable to discriminate dispersal rates at which management performance would be impacted. Broadly speaking, the type of approach considered was useful, but the DAPC method was not appropriate for the needs of the *Implementation.*

2.1.4 New information

2.1.4.1 GENETIC DATA

The Workshop received six valuable new papers examining genetic data (SC/A14/AWMP-RMP02-SC/A14/AWMP-RMP06 and Quintela *et al.* (In review)). These involved samples from all *Medium Areas* and a number of genetic markers and analytical approaches. Details of the papers are not given in this summary but are provided in SC/65b/Rep04 under Item 3.1. The Workshop commended the tremendous effort undertaken to create the substantial sample and data sets on the genetics of North Atlantic minke whales.

In short, the analyses presented comparing adjacent *Small Areas*, provided no evidence for small scale genetic structuring, in contrast to previous reports (Andersen *et al.*, 2003). There was some evidence for a subtle differentiation between the western (W) and the eastern (E) stock, but the level of differentiation is low (pairwise F_{ST} ranging from 0.001 to 0.005). There was also valuable further discussion of the utility of DAPC based on real data (again it was found that it is not suitable for evaluating k=1). Although not consistent among studies, one study found well-supported clusters based on DAPC using microsatellite DNA loci that were supported by significant differentiation at an mtDNA marker. These clusters did not correspond to geographic populations, suggesting possible cryptic breeding stocks mixing on feeding grounds.

The Workshop also discussed the earlier genetic work that had been considered in the original *Implementation.* The main focus was on the results of some older studies such as (Andersen, 2004; Daníelsdóttir *et al.*, 1992) that found substantial genetic differentiation with more recent studies that found little or no evidence for differentiation. A systematic approach to address this issue in the future was developed and details are given in SC/65b/Rep04.

2.1.4.2 DISCOVERY MARK-RECAPTURE DATA[1]

The Workshop reviewed these data, noting that no new recaptures had occurred since the original *Implementation.* In summary, the information was limited in that almost 80% of the marks were placed around Bear Island. However, broadly the recaptures were all within same *Medium Areas* (apart from one moving from just inside C to E) but there were several movements across the *Small Areas* within the E *Medium Area* (ES to EB and ES to EW).

2.1.4.3 PHOTO-IDENTIFICATION DATA

The Workshop reviewed information from a photo-identification study in Icelandic waters (Bertulli *et al.*, 2013). The results, while limited in scope, do not suggest a strong level of long-term site fidelity to certain feeding grounds such as that observed in minke whales in parts of the eastern North Pacific - e.g. San Juan Islands (Dorsey *et al.*, 1990).

Recognising that photographic identification of common minke whales is relatively difficult, the Workshop **recommends** that where possible, biopsy samples are taken of photographed whales so that genetic individual identification studies can be carried out on the same animals to review the photo-identification approach and evaluate *inter alia* the occurrence of false positives and negatives.

2.1.4.4 TELEMETRY DATA

Satellite telemetry has proved to be difficult for common minke whales. A small number of tags have been placed off West Greenland (n=3), Iceland (n=8), Norway (n=2) and Denmark (n=1). Several showed only local movements as they transmitted for only a short time. However, three showed at least the start of southerly migrations. The authors of SC/A14/WMP-RMP07 suggested that the direction of the combined movements of minke whales from Greenland and Iceland suggest offshore wintering areas in southern part (<30°N) of the North Atlantic. There could be both an eastern and a western migratory route, but it is too early to say if there are separate wintering grounds. There was no strong evidence for east-west movement but this is not unexpected given the duration of the tag deployments.

2.1.4.5 MORPHOMETRICS

The Workshop examined the available morphometric analyses (Hauksson *et al.*, 2013a) but agreed that while differences were observed they were difficult to interpret in terms of stock structure.

2.1.4.6 ACOUSTICS

The Workshop reviewed some limited acoustic data that showed that the timing of the southerly migration through Stellwagen Bank was in accord with the timing of the southerly migration from the telemetry data.

2.1.4.7 CHEMICAL STUDIES

The Workshop reviewed a number of chemical studies (pollutants and fatty acids) that can provide some insights (of course not definitive) into stock structure via diet. One study and review (see SC/A14/AWMP-RMP08 and Gouteux *et al.*, 2008) suggested the following inferences whilst recognising the limitations:

(1) toxaphenes and POPs: perhaps group west and southeast Greenland (low), Iceland (high), little differences amongst the rest of the sampled areas although Lofoten/Vestfjord is lower;
(2) Hg, Cd, Se: perhaps group West Greenland, the central area including Jan Mayen, North Sea, the northeastern area;
(3) fatty acid profiles: perhaps group West and East Greenland, Central and northeastern, North Sea; and
(4) combination of above : perhaps group West Greenland, Central Atlantic including Jan Mayen, northeastern group, and North Sea group.

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[1] 'Discovery' marks were numbered small stainless steel tubes that were fired into the body of whales and could be recovered from the carcase if the animal was captured in a whaling operation (Brown, 1983).

2.1.4.8 BIOLOGICAL PARAMETERS

The Workshop agreed that there were insufficient data to inform stock structure discussions greatly, although there was some suggestion of differences in the timing of reproduction between the Central and Eastern *Medium Areas* (SC/A14/AWMP-RMP08).

2.1.4.9 DISTRIBUTION AND CATCH DATA

The Workshop noted the large changes in the Icelandic continental shelf ecosystem in recent years and the reported effect this has had on common minke whale diet around Iceland (Víkingsson *et al.*, 2013). There have also been considerable changes in distribution and fluctuations in abundance by *Small Areas* within C revealed by sightings surveys. The original CIC area was largely based on logistical information (it was the area where catches took place and was based on the boundaries for the aerial surveys). Plausible stock structure hypotheses (or RMP variants) should be able to account for these observed changes within the several C *Small Areas*. This could be done by re-defining *Small Areas* or allowing for the observed level of movements.

The Workshop noted that the distribution of common minke whales from the recent Norwegian sightings surveys have broadly been similar since the synoptic survey in 1995. Catch distributions were also broadly similar except for changes clearly attributable to logistic and operational reasons. The Workshop agreed that it would be valuable to examine density plots from Norwegian sightings surveys and Walløe agreed to see if this could be developed before SC/65b.

For Greenland, it was noted that while there are no studies that show a change in the distribution of common minke whales off Greenland; in recent years they have been reported from northern areas in West Greenland where they apparently were absent in the past.

Given that Norwegian whaling has at some time covered large areas of the North Atlantic, the Workshop examined preliminary plots which provided indicative although not definitive evidence of separate C and E stocks and the appropriate position of a boundary between them. The Workshop agreed that it would be valuable to further investigate catch data plots by sex and time.

2.1.4.10 CATCH PER UNIT EFFORT DATA (CPUE)

The Workshop examined the available CPUE analyses. Given the disparate analyses of the Norwegian data, the lack of trend in the Icelandic data and the known difficulties in interpreting CPUE data, it agreed that such data provided no information on stock structure to inform the *Implementation Review*.

2.1.5 Consideration of revised/new hypotheses

After reviewing the available information from a suite of techniques the Workshop agreed that the new information presented (and genetic data in particular) did not rule out panmixia across the whole North Atlantic. However, given some information that suggested possible further structuring, the Workshop agreed that all of one (O), two (W+C = W* and E) and three (W, C and E) stock hypotheses should be taken forward. Further, given the lack of precise information on any sub-area boundaries (which in any event might be expected to change somewhat from year to year in dynamic biological systems), for pragmatic reasons (e.g. the regions to which existing estimates of abundance had been calculated to correspond), the Workshop agreed that changes to sub-areas should only be made where there was good evidence to support it (see below) and where management consequences were likely to result.

The Workshop also agreed that to evaluate conservation performance, statistics would be reported by stock, as for the original *Implementation Simulation Trials* for the North Atlantic common minke whales. In order to evaluate catch performance, statistics should also be reported by feeding ground areas.

The three main hypotheses are summarised below; the rationale is given in SC/65b/Rep04 and in Adjunct 2.

2.1.5.1 THREE STOCK HYPOTHESIS (W, C AND E; FIG. 1 IN ADJUNCT 2)

E STOCK

The Workshop agreed that the new evidence available since the original *Implementation* supported two sub-stocks rather than four, an EN sub-stock and an EA sub-stock (ES+EW+EB).

C STOCK

The Workshop agreed that no sub-stock structure was required. However, as with the EA sub-stock, the sub-areas within the C stock would be retained so that trial hypotheses are able to reflect different size and sex compositions of whales caught in each of these sub-areas.

W STOCK

The Workshop agreed to retain the existing structure within the W stock of WC and WG sub-stocks. The trials will take into account that many males are present within the W *Medium Area* that are neither counted in surveys off West Greenland and the Gulf of St Lawrence nor taken in the associated catches. It noted that sensitivity trials merging the two W sub-stocks should also be undertaken.

In conclusion, the Workshop agreed that the revised three stock hypothesis thus includes five sub-stocks, each of which is modelled as an isolated stock (the 1993 *Implementation* had involved 10 sub-stocks).

2.1.5.2 TWO STOCK HYPOTHESIS (W* AND E; FIG. 2 IN ADJUNCT 2)

For this hypothesis, the W and C regions are combined to contain a single W* stock, which is comprised of two sub-stocks: WC and [WG+C]. The existing sub-areas are retained to admit size and sex differences in different regions within the range of the W* stock. The two stock hypothesis thus involves four sub-stocks. The cryptic population structure scenario will be considered under this hypothesis by adjusting mixing matrices.

2.1.5.3 ONE STOCK HYPOTHESIS (O)

The single O stock is comprised of all sub-areas and involves no sub-stocks.

2.2 Some preliminary ideas for sensitivities related to stock structure hypotheses to be examined in the trials

The Workshop developed some initial ideas of stock structure sensitivities to be examined in the trials. These were:

(1) three stocks with WG part of C (consistent with catch/distribution patterns and catch sex ratios but not past allozyme data) i.e. only four sub-stocks; and
(2) three stocks with a changed CM/ES boundary (the ES sub-area is to the north of the CM sub-area with a boundary based on primarily catch data - uncertainty in this boundary will be tested) such that ES is split into ESW and ESE with the large catches in ESE and the ESW sub-area included as part of the C stock.

2.2.1 Initial consideration of mixing matrices

The Workshop developed an initial set of mixing matrices, with an emphasis on the three stock (five sub-stock) case. These can be found in SC/65b/Rep04, Item 4.

Unlike the trials developed by IWC (1993), the Workshop agreed that an initial examination of the data suggests no need for separate catch and sighting matrices but that this will be subject to confirmation by overlaying catch distributions on survey densities by year and sub-area.

2.2.2 Work plan

The Workshop agreed the following work plan.

1. Test the assumption the catch and sightings mixing matrices are roughly the same by plotting catch positions on the distributions of sightings densities.
2. Implement this specification for AWMP-RMP-lite with a view to checking if it is at least self-consistent.
3. Submit the full set of genetic data to the Secretariat
4. Propose trial specifications for discussion at the Scientific Committee.

2.3 New information

SC/65b/RMP05 utilises a data set of 244 samples of Icelandic minke whales completely typed (=no missing data) for 16 microsatellites to look for related individuals with a likelihood-based approach based on probabilities to share a certain number of alleles identical-by-descent at a given locus. Simulated data sets are used both to establish statistical significance (controlling for the false-discovery rate, FDR) and to estimate the power of detection. The impact of typing error on relatedness inference is also investigated. For duplicate samples and without typing error, the power of detection is 100% under all applied FDRs. For detection of parent-offspring pairs and full siblings, the power is still acceptable, while it is poor for pairs with lower level of relatedness (half siblings, first cousins). Having 15 mother-foetus pairs in the data set allowed us to compare the estimated detection power to the observed probability of detection. These measures are closely correlated, pointing towards the validity of the applied power estimation. Two duplicate samples were identified. Except for mother-foetus pairs, one additional parent-offspring pair was inferred. For three further pairs it is reasonable to assume that they might constitute also parent-offspring pairs, which were not unambiguously identified as such due to a single mistyped locus. Having up to four mother-offspring pairs identified from a rather small data set (229 specimens, if foetuses are not counted) of a restricted area may indicate some non-random spatial aggregation of kin. It would translate into a conservative abundance estimate of 7,849 individuals for West Iceland, a number in line with sighting surveys.

In discussion, it was pointed out that observed sex ratios in western Iceland are very skewed toward males, which suggests that this area cannot plausibly be considered a closed population. Some scepticism was therefore expressed as to the usefulness of estimating abundance from this area from the close-kin data described in this paper. The author noted that this was included merely to demonstrate how the method can be used to generate abundance estimates and should be considered in that context. It seems clear from this study that with the current array of 16 microsatellite loci, power is sufficient to infer parent-offspring relationships, but not half-siblings or other more distant relationships. The Workgroup **agreed** that it would be useful to apply this methodology to the larger dataset in SC/65b/RMP09, which includes broader geographic range and 1,100 minke whales.

With the addition of 348 specimens typed at the conventional 16 microsatellites previously used on minke whales and 682 specimens sequenced at 369bp of the mitochondrial control region, a data set of around 1,200 specimens of North Atlantic minke whales was compiled and analysed in SC/65b/RMP09. According to the IWC, these samples represent the Western (West Greenland), the Central (East Greenland, Iceland), and the Eastern stock (Norway, Spitsbergen, Barent Sea, North Sea). Most (over 99%) of the genetic variation is assigned to the lowest level of geographic stratification in both microsatellites (i.e. the individual level) and mtDNA (i.e. the locality level). Nonetheless, there is a consistent tendency towards a subtle differentiation among the putative stocks. In all analyses, West Greenland and the Eastern stock are slightly more differentiated. The Central stock is intermediate, with a closer affinity towards West Greenland. Locus-specific analysis reveals that: (1) significance in the microsatellite data is due to divergence at a single locus; (2) levels of differentiation at mitochondrial DNA are similar to those revealed in a previous study (Andersen *et al.*, 2003); and (3) microsatellite F_{ST} values – even if corrected for within population variability – are considerably lower than values derived from an earlier allozyme study. Possible reasons for these differences are discussed. In an addendum to the paper, a network of mitochondrial haplotypes is presented which shows the existence of two maternal lineages. There is no evident spatial pattern, neither in the occurrence of these two lineages nor in the prevalence of any of the more abundant haplotypes in any area. However, some less abundant haplotypes preferentially or entirely occurred in certain areas. This would be compatible with some matrilinearity in North Atlantic minke whales. This study is generally compatible with the IWC-three stock hypothesis (W, C, E), but would not contradict a two stock hypothesis (W+C, E) either, as none of the analyses revealed any difference between W and C stock.

The Workgroup **thanked** the authors for preparing this paper, which updated paper SC/A14/AWMP-RMP03 from the April workshop to allow a comparison of standardised measures of genetic differentiation (F_{ST}') for both the recent microsatellite data and the allozyme data from Daníelsdóttir *et al.* (1992). This type of comparison was identified in the SC/65b/Rep04 as one of the important analyses to conduct. Tiedemann agreed to work with Waples to produce a larger analysis of this type that will include results from other key genetics papers relating to stock structure of North Atlantic minke whales. It was noted that the weak signal of differentiation in the microsatellite data is due entirely to a single locus, sam25 (F_{ST}'=0.157 compared to a maximum of 0.011 for the other 15 loci). In response to a question as to whether this locus exhibited any other unusual behaviour, Tiedemann acknowledged that alleles are regularly scored and confirmed by re-typing that are only 1bp apart, in contrast to differences of 2bp for typical dinucleotide loci. A single base pair is likely to be at or close to the maximal level of resolution of the automatic sequencers used in this study, which means that the locus is potentially more prone to scoring errors. However, blind tests involving duplicate samples analysed in different laboratories indicated that repeatability in scoring for this locus was equivalent to that for other loci.

2.4 Conclusions and recommendations for use in trials

The Working Group **endorsed** the report of the Workshop and **endorsed** its conclusions.

The Working Group **agreed** that it would be useful to apply the methodology in SC/65b/RMP05 to the larger dataset in SC/65b/RMP09, which includes a broader geographic range and ~1,000 minke whales. Adjunct 2 shows that of 14 inferred parent-offspring pairs, four were found within sub-areas and 10 were found between sub-areas. The number of pairwise comparisons differed among

Table 1

Approximate coverage by Norwegian surveys within the E and CM areas.

		Areal coverage		
Survey year(s)	Realised primary effort	E *Medium Area*	CM	Comments
1988	1988-89 combined: 103%[1]	23 %	28 %	Survey area related to known whaling grounds.
1989	1988-89 combined: 103%[1]	91 %	0	Faroe Islands corner and parts of the Greenland Sea not covered. In later analyses, the 1988 and 1989 data have been combined.
1995	101%[1]	97 %	60 %	Faroe Islands corner and southern part of the Jan Mayen area not surveyed.
1996-2001	83%[1]	97 %	100 %	Faroe Islands corner not surveyed.
2002-07	79%[1]	97 %	100 %	Faroe Islands corner not surveyed.
2008-13	63%[2]	97 %	100 %	EW4 block not surveyed.

Notes: many the *Small Areas* do not have an explicit defined southern boundary. The North Sea EN block is considered here to be bounded to the west through 2°W. The North Sea has never been fully covered as large parts of it are considered unsuitable minke whale habitat; nevertheless the coverage here is set to 100%. In addition, northern boundaries have been limited by ice which varies from year to year, but the surveys are considered complete as established procedures have been followed in ice areas. No survey activities have been conducted within the ice boundaries.

[1] The surveys were planned with estimated survey effort shared between two transects; one primary transect which should be covered as completely as possible and a secondary transect where certain rules were applied to ensure that realised effort was not clumped within the survey block.

[2] Longer transects were planned such that the vessels progressed along transects every day and set watches according to sighting conditions. In all cases, the realised primary search effort was approximately 20% of available ship time.

sub-areas because sample sizes differed among sub-areas. The fraction of inferred pairs did not differ appreciably from the expectation under the null hypothesis of random distribution after standardising the results to account for the expected number of parent-offspring pairs for each sub-area x sub-area comparison. However, a formal statistical test was not conducted given the small total number of matches.

Previously-published papers (Andersen *et al.*, 2003; Anderwald *et al.*, 2011; Daníelsdóttir *et al.*, 1992) and new ones presented at the Copenhagen Workshop and this meeting (SC/A14/AWMP-RMP04, SC/65b/RMP09, Quintela *et al.*, 2014) have drawn different conclusions regarding stock structure of North Atlantic common minke whales. SC/65b/Rep04 identified several key questions designed to identify the causes of these difference. Adjunct 3 accounts for different levels of genetic variation associated with the various types of markers and how that affects results. This involved standardising the common measure of genetic differentiation among populations (F_{ST}) to account for different levels of variation within populations, producing an adjusted value F_{ST}’. Fig. 1 in Adjunct 3 shows that loci with high adjusted F_{ST}’ were primarily found in two of the five studies. Furthermore, elevated F_{ST}’ values (>0.06) occurred at a dozen gene loci, which ruled out the possibility that the discrepant results could be explained by one or two outlier loci. The Working Group **recommended** that the follow steps be taken to try to narrow down the range of possible explanations for this result:

(1) compare agreement among the genotypes for the same loci and tissue samples originally scored in different laboratories;
(2) expand analyses of F_{ST}’ to include comparisons between specific sets of populations, rather than across the entire dataset;
(3) use resampling techniques to evaluate the effect of small samples and uneven sample sizes; and
(4) use methods for detecting outlier loci to identify loci that have implausibly high F_{ST}’ values and hence might be affected by natural selection.

3. ABUNDANCE ESTIMATES

3.1 New information

Norwegian surveys

SC/65b/RMP07 presented a preliminary estimate of abundance of common minke whales in the northeast Atlantic based on data collected over the period 2008-13. The preliminary results indicate that the estimate for the total area has decreased compared to the two preceding survey periods, i.e. from about 108,000 to about 94,000 minke whales. The decrease seems to have occurred within the CM *Small Area*, with the estimate now being ~40% of those from the 1996-2001 and 2002-07 cycles. Within the E region, the estimate is of the same magnitude as in the previous two cycles, i.e. about 83,000 animals. However, there are signs of a distributional shift northward within this region from the Norwegian Sea to the Svalbard area. The estimate has not been bias corrected using the same procedure that was applied estimates for previous survey periods, and a measure of uncertainty is not yet available.

In discussion the uneven coverage of the survey blocks CM2 and EB2 was noted. A partial explanation for this was a change in the survey protocol to allow the vessel to continue to move along the trackline even if sighting conditions for minke whales were not met.

A plan for finalising the abundance estimate during the next intersessional period was outlined. This plan involved simplification of the bias correction procedure and the variance estimation method used in the past as detailed in Adjunct 4. It was noted that there is nothing wrong with the previous procedure, except that it is hard to operate. This is particularly so for the simulation module, which has been used for both bias correction and variance calculation. The net magnitude of the bias correction has been very small for the two last survey periods. There are three main sources of bias: errors in the duplicate identification rule; errors in distance and angle estimates; and non-Poisson dive time patterns. In the new procedure, the latter two will be incorporated directly into the likelihood, following standard principles. With regards to duplicate identification errors, these will be inspected and corrected for manually using graphical tools. For the variance calculations, the previous parametric bootstrap approach will be replaced by a classical delta-method approach, and a process that corresponds to the ‘replicate transect leg’ approach to quantifying the effect of animal clustering.

The Working Group **agreed** that these suggestions followed sound principles, but that the new approach should be verified by applying it to a previous survey period to allow comparison with the previous method. It is important to validate both the new bias correction and variance estimation procedure. The survey period 1996-2001 was identified as suitable for this purpose, and it was **agreed** that the new method will be applied intersessionally to both the 1996-2001 and the 2008-13 data.

Icelandic surveys
Reports on the 2007 and 2009 aerial surveys around Iceland were presented (Pike *et al.*, 2010a; 2010b). Bias-corrected estimates were presented for each survey using an independent observer configuration as done in the 2001 survey. These papers were initially presented in 2011, but were then referred to the 2014 *Implementation Review.* The cue-counting methodology was used and Mark-Recapture Distance Sampling (MRDS) techniques were applied in the analysis assuming full independence.

Sightings were very few in 2007 and due to technical failures, very limited duplicate data were available for one observer, so the estimate was based solely on the other primary observer. This resulted in a corrected total estimate of 20,834 (95% CI 9,808, 37,042). More minke whales were seen during the 2009 survey, although not as many as in 2001, but distances to minke whales were about double those recorded in earlier surveys resulting in the lowest total estimate in this series of 9,588 (95% CI 5,274, 14,420). No significant distance estimation bias was detected through the duplicate data and a comparison of perpendicular sighting distances for dolphins and humpback whales in 2009 to earlier surveys showed that they were quite similar, suggesting that the anomalous results for minke whales were not characteristic of other species.

The abundance estimates were accepted for use both in conditioning and in the trials. A decision regarding use in an actual *Implementation* was postponed until the end of the *Implementation*.

Sightings distribution
Fig. 1 depicts the distribution of minke whale sighting rates (as a proxy for sighting densities) from the 2008-13 cycle of Norwegian surveys. This shows a relatively uniform density of minke whales across the surveyed areas. The density expressed as sighting rate is <0.03 whales/km for most of the area. However, densities above this are seen in the southern Norwegian Sea and in the northern Norwegian Sea as well as in the waters south and southwest off Spitsbergen (Bear Island). The most prominent peaks of density (hot spots) are seen in the southeastern and eastern Barents Sea, perhaps indicating an 'eastern' distribution at present (e.g. Øien *et al.*, 1987).

The catch distributions off Spitsbergen seem to be associated with higher than average density, while the catches off coastal northern Norway are not. The reason is that this is probably a migration corridor and the catch operation is adapted to this (Christensen and Øien, 1990).

It was noted that the northward movement of minke whales in recent years is similar to that of fin whales from the Norwegian Sea to Spitzbergen. It was suggested that the change in distribution patterns may be related to the movement of prey species such as capelin. Surveys in the Iceland area have sighted fewer minke whales but the reason is unclear – the whales may have moved north to the ES sub-area or followed a shift in capelin distribution from Iceland towards the CG sub-area (Pálsson *et al.*, 2012). Iceland intends to put effort into investigating this further in a 2015 survey with Greenland.

The high variability in the abundance estimates in the CM sub-area over time (2,600 to 26,700) was noted. This may reflect changes in the minke whale population but the difficulties inherent in surveying the CM sub-area (frequent bad weather and strong currents) may also contribute.

Table 1 gives approximate percentages of the coverage by Norwegian surveys within the E area and separately within the CM *Small Area* of the C region.

3.2 Estimates for use in trials

The new 2008-13 abundance estimates from Norwegian surveys were accepted for use in conditioning. It was agreed that, in the absence of an associated CV for these estimates, the maximum of the previous CVs observed in the relevant sub-area will be used.

The abundance estimates from the Icelandic aerial surveys in 2007 and 2009 were accepted for use both in conditioning and in the trials.

A list of all the available minke whale abundance estimates and their agreed status is given in Table 2. Øien will provide abundance estimates for the ESW and ESE subareas.

During the compilation of Table 2, an error was found in published estimates of abundance for the CG/CIP area in 2001 (IWC, 2009, p.135). The combined estimate should be 10,740 (=3,391+7,349) and not 23,592.

Although covariance exists between abundance estimates, it was agreed that it does not need to be considered in the trials as it is a second order effect in comparison with sightings rate considerations.

4. BIOLOGICAL AND OPERATIONAL PARAMETERS

4.1 Past and new information

IWC (1991) gave a comprehensive compilation of information on biological and operational parameters in North Atlantic minke whales, as shown in Table 3a. The Table also gives references to papers from which the data used had been drawn. IWC (1991) also gave parameter values used in assessments at that time (Table 3b).

No new quantitative information has become available since 1991 on biological parameters in common minke whales from the West Greenland and the Northeast Atlantic stock. The same is broadly true for the Central stock, but some preliminary new results are available from the Icelandic research programme. Hauksson *et al.* (2013b) reported apparent pregnancy rates of 0.91 (n=82), slightly but not significantly lower than that given by IWC (1991). A new age determination method for common minke whales in Icelandic waters based on amino acid racemisation is at a final stage of validation (Auðunsson *et al.*, 2013). The results will be used to estimate biological parameters in this population.

Considerable effort was spent to assess whether the ear bones (*tympanic bullae*) could be used to age common minke whales as suggested by Christensen (1981) during the Norwegian research programme on marine mammals in the late 1980s and early 1990s. Unfortunately, the method proved useless. In addition, the method based on amino acid racemisation in the eye lens has been tested in the past (Olsen and Sunde, 2002), but has not been implemented as part of the routine monitoring of the whales.

The 1993 *Implementation* used the following values for the biological and operational parameters.

Parameter	Value	
Plus group age, x	20 years	
Natural mortality, M	0.085	if $a \leq 4$
	$M_a =$ 0.0775+0.001875a	if $4<a<40$
	0.115	if $a \geq 20$
Selectivity, S_g^a	$a^E_{50} = 4$; $\delta^E = 1.2$	
Maturity (first parturition), β_a	$a_{50} = 7$; $\delta = 1.2$	
Maximum Sustainable Yield Level, *MSYL*	0.6 in terms of mature female component of the population	

Table 2

A list of the available North Atlantic minke whale abundance estimates by sub-area and their agreed status (see also Appendix 6).

Sub-area	Year	Estimate	Sampling CV	Source and notes	Status
EB	1989	21,868	0.21	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EB	1995	29,712	0.18	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EB	2000	25,885	0.24	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EB	2007	28,625	0.23	Bøthun and Øien (2011); IWC (2011, p.95); CV=0.26 in Bøthun *et al.* (2009): see*.	IC
EB	2013	27,336	0.24	Solvang *et al.* (2014). Preliminary estimate; CV=highest historical value in EB.	CP
EN	1989	8,318	0.25	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EN	1995	22,536	0.23	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EN	1998	13,673	0.25	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EN	2004	6,246	0.47	Bøthun and Øien (2011); IWC (2011, p.95); CV=0.48 in Bøthum *et al*. (2009): see*.	IC
EN	2009	8,867	0.47	Solvang *et al*. (2014). Preliminary estimate; CV=highest historical value in EN.	CP
ES	1989	13,070	0.13	Bøthun and Øien (2011); IWC (2011, p.95).	IC
ES	1995	24,891	0.10	Bøthun and Øien (2011); IWC (2011, p.95).	IC
ES	1999	17,406	0.14	Bøthun and Øien (2011); IWC (2011, p.95).	IC
ES	2003	19,377	0.28	Bøthun and Øien (2011); IWC (2011, p.95); CV=0.33 in Bøthum *et al*. (2009): see*.	IC
ES	2008	26,211	0.28	Solvang *et al*. (2014). Preliminary estimate; CV=highest historical value in ES.	CP
EW	1989	20,991	0.17	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EW	1995	34,986	0.12	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EW	1996	23,522	0.13	Bøthun and Øien (2011); IWC (2011, p.95).	IC
EW	2006	27,152	0.218	Bøthum *et al*. (2009); Bøthun and Øien (2011); IWC (2011, p.95).	IC
EW	2011	20,158	0.22	Solvang *et al*. (2014). Preliminary estimate; CV=highest historical value in EW.	CP
CM	1988	4,732	0.23	IWC (2009, p.135). Combination of estimates for 1987: 5,609, CV=0.26 (Øien, 2000) and 1988-89: 2,650, CV=0.48 (Schweder *et al.*, 1997, no NVS).	IC
CM	1995	[6,174]	0.36	Bøthun and Øien (2011) and IWC (2009, p.135) from Schweder *et al.* (1997). No NVS. The 12,043 estimate had better areal coverage.	**No**
CM	1995	12,043	0.28	IWC (2009, p.135) from Borchers *et al.* (1998). Combined Norway and Iceland.	IC
CM	1997	26,718	0.14	Bøthun and Øien (2011). IWC (2009, p.135) from Skaug *et al.* (2004).	IC
CM	2005	26,739	0.39	Bøthun and Øien (2011); Bøthum *et al*. (2009). Update to 24,890, CV=0.45, in IWC (2009, p.135).	IC
CM	2010	11,249	0.39	Solvang *et al*. (2014). Preliminary estimate; CV=highest historical value in CM.	CP
CIC	1987	24,532	0.32	IWC (2009, p.135); Borchers *et al.* (2008).	IC
CIC	1995	-	-	Not estimated; Borchers *et al.* (1997).	**No**
CIC	2001	43,633	0.19	IWC (2009, p.135); Borchers *et al* (2008).	IC
CIC	2007	20,834	0.35	IWC (2014), Appendix 5; Pike *et al.* (2011). Replaces 10,680 (0.29) agreed in IWC (2009, pp.135-37).	IC
CIC	2009	9,588	0.24	IWC (2014), Appendix 5; Pike *et al.* (2011).	IC
CIP	1987-89	8,431	0.245	IWC (1993, p.66, pp.128-29). Used in CG+CIP estimate of 9,986 (IWC, 2009, p.135). Used as a minimum estimate: no *g*(0) correction.	IC
CIP	2001	3,391	0.82	Gunnlaugsson *et al.* (2003) (blocks A+B). Used in CG+CIP estimate of 23,592, see ‡. Used as a minimum estimate: no *g*(0) correction.	IC
CIP	2007	1,350	0.38	SC/2009 (TNASS), IWC (2011, p.95).	IC
CG	1987	1,555	0.26	IWC (1993, p.66, pp.128-29). Used in CG+CIP estimate of 9,986 (IWC, 2009, p.135). Used as a minimum estimate: no *g*(0) correction.	IC
CG+CIP	1995	4,854	0.27	Pike *et al* (2002), IWC (2009, p.135). Used as a minimum estimate: no *g*(0) correction.	IC
CG	2001	7,349	0.31	Gunnlaugsson *et al.* (2003) (blocks Bx+Wx). Used in CG+CIP estimate of 23,592 - see ‡. Used as a minimum estimate: no *g*(0) correction.	IC
CG	2007	1,048	0.60	SC/2009 (TNASS), IWC (2011, p.95).	IC
WG	1987-88	3,266	0.31	IWC (2009, p.135); IWC (1990, p.43). Partial coverage of area.	C_{min}
WG	1993	8,371	0.43	IWC (2009, p.135); Larsen (1995). Known not to cover all of population. Reanalysed by Hedley *et al.* (1997): 6,385, CV=0.411 [or 6,342, CV=0.35 in IWC (2009, p.135)].	C_{min}
WG	2005	10,792	0.59	IWC (2008, p.126); Heide-Jørgensen *et al.* (2008). Known not to cover all of population.	C_{min}
WG	2007	16,609	0.428	IWC (2012, p.130); Heide-Jørgensen *et al.* (2010). Known not to cover all of population.	C_{min}
WC	2007	20,741	0.30	NOAA, 2012 (Lawson, DFO, pers. comm.) from NASS 2007.	C

*Bøthum and Øien (2011), recalculated the 1989 and 1995 estimates and associated CVs for the revised sub-areas; the CVs for the 2003-07 period were also recalculated using the same method: they differ from those in Bøthum *et al.* (2009) that were calculated using a simulation approach. The Bøthum and Øien (2011) CVs are used here as they are comparable with those from earlier years.

‡ IWC (2009, p.135) shows a combined estimate for CG+CIP in 2001 as 23,592. This should be 10,740 (=3,391+7,349).

See also IWC (2009, p.135) for 3 other WC estimates for parts of the area.

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Table 3a

Biological parameters of North Atlantic minke whales.

	Canadian east coast stock	West Greenland stock	Central North Atlantic stock	Northeastern Atlantic stock
Age at full recruitment	-	-	-	7-8[15]
Age at sexual maturity (females)	5.8 (regression)[2] 6-8 (50% mature)[2] 7.3 (1 ovulation)[2]	-	6 (regression)[4] 6-7 (50% mature)[4] 5-6 (regression)[11]	7 (50% mature)[6]
Sex rations (in catch)	74.3% females[9]	68% female[8]	43% female (East Greenland)[7] 43.4% female (Iceland)[11]	56-67% female[10, 12]
Sex ratios at birth	47.5% females[9]	41% females[8]	-	48.5 females[5]
Pregnancy rates	0.86-0.93 (1954-57)[1] 0.86 (1965-72)[2]	0.89-0.91 (1976-81)[3]	0.94 (1977-78)[4]	0.96 (1943-50)[5] 0.94-0.99 (1972-77)[6]
Natural mortality rates	-	-	0.10[16]	0.09[14]
Catch at age/length data	-	[7]	[7](East Greenland) [11](Iceland)	[13]

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Table 3b

The parameter values used in assessments taken from IWC (1991).

	West Greenland stock	Central stock	Northeastern stock
Age at full recruitment	5[1]	4[2]	5[3]
Age at first parturition	8[1]	-	8[3]
Natural mortality rate	0.10[1]	0.10[2]	0.10[3]

[1] IWC (1989, p.90, Table 2).

[2] IWC (1989, p.89, Table 1).

[3] IWC (1987, p.91, Table1).

The natural mortality value is close to the value given in IWC (1991), although for trial purposes, it varies with age (note the age-specific values are not based on data for those ages).

The parameter 'Selectivity' corresponds to the parameter 'Age at full recruitment' in IWC (1991). The value of 4 corresponds with the previous value used for the Central stock, but it is lower than the previous values estimated for the West Greenland and northeast Atlantic stocks (5). It was noted that the data for West Greenland used in IWC (1991) came from the Norwegian commercial whaling that then took place. Only subsistence whaling now occurs off West Greenland and for AWMP purposes all 1+ animals are assumed available to the hunters.

The maturity age used previously in the trials (7 years) is the same as the age used previously (8 years at first parturition which would imply 7 years at maturity) for the West Greenland and northeast Atlantic stocks.

4.2 Values for use in trials

The Working Group noted that, when using the current models, the *CLA* is not particularly sensitive to biological parameter values. Values agreed for use in the trials are given in Table 4 below and in Adjunct 2.

5. REMOVALS DATA (CATCHES, BYCATCH, SHIP STRIKES)

5.1 New information

Table 5, which lists minke whale catches known by sex, year block and month, was reviewed in order to investigate

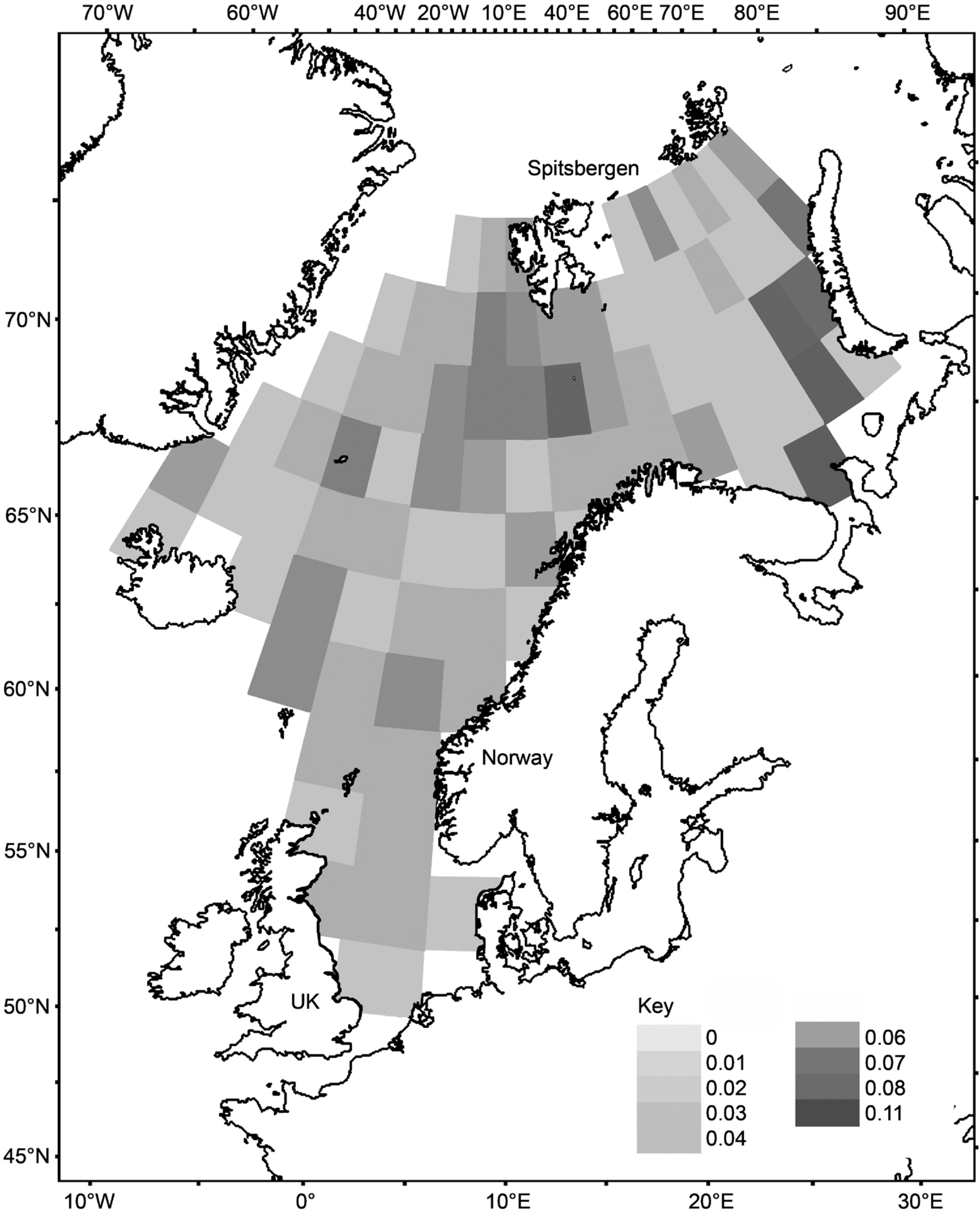

Fig. 1. Distribution of minke whale sighting rates (as a proxy for sighting densities) from the 2008-2013 cycle of Norwegian surveys.

Table 4a
The values for the biological parameters that are fixed.

Parameter	Value	
Plus group age, x	20 years	
Natural mortality, M	0.085	if $a \leq 4$
	M_a= 0.0775+0.001875a	if 4<a<20
	0.115	if $a \geq 20$
Maturity (first parturition), β_a	$a_{50} = 8$; $\delta = 1.2$	
Maximum Sustainable Yield Level, $MSYL$	0.6 in terms of mature female component of the population	

Table 4b
The values for the selectivity parameters by area.

Parameter	Value
West Medium Area (commercial)	$a_{50}^{g,k} = 5; \delta^{g,k} = 1.2$
West Greenland (aboriginal)	$a_{50}^{g,k} = 1; \delta^{g,k} = 1.2$
Central Medium Area	$a_{50}^{g,k} = 4; \delta^{g,k} = 1.2$
Eastern Medium Area	$a_{50}^{g,k} = 5; \delta^{g,k} = 1.2$

changes in minke whale catches over time (both within year and between years). In particular, the question of whether the sex ratio of catches in July (when the surveys take place) differs from those in other months, was examined.

There have been several changes in regulation and operational practice over time which causes difficulties interpreting the data. Changes before 1986, when the moratorium on commercial whaling came into effect, are described in Øien *et al.* (1987), and include the following: (1) during the 1960s catches in the Barents Sea decreased as Norwegian whaling expanded into East Greenland and Icelandic regions; (2) Barents Sea catches increased again in the 1970s when extensions to the Icelandic fisheries zone excluded Norwegian vessels; and (3) the introduction of quotas in 1976 led to a transfer of vessels to the Barents Sea where chances for a share of the total quota were better than in coastal waters further south. More recent changes include: (1) Russian regulations that have excluded Norwegian boats from Russian waters in the Barents Sea since 1993; (2) since 2010 it has not been profitable for Norwegian whalers to go to the Jan Mayen area (CM) because of the high cost of bunker oil and the uncertain weather conditions there (much fog); and (3) Norwegian whaling has lately been focussed on a lower number of larger and more modern boats, which have certificates to go to Spitsbergen (ES). They prefer to go there because of generally better weather conditions than on the Norwegian coast and because the whales appear to be more concentrated in local areas there.

The sex ratios in the catches were shown to be both spatially and seasonally variable. The more northern sub-areas exhibit an increase in the proportion of males as the season progresses, particularly in the ES sub-area.

Prior to the onset of the moratorium in 1986, minke whaling in Iceland was mostly confined to coastal areas in northern and northwestern Iceland (Sigurjónsson, 1982). A total of 200 minke whales were taken all around Iceland as a part of a research program during 2003-07. Since the resumption of commercial whaling in 2006, most of the catch has been taken in southwestern Icelandic waters for operational reasons.

In discussion, it was noted that the sex ratios in the catch may not be uniform across a sub-area, for example: (i) the proportion of females caught to the North of Iceland in the CIP sub-area is higher than for catches off South Iceland; (ii) the sex ratio shown in the recent aboriginal hunt off West Greenland differs from that in the earlier commercial catches; and (iii) catches taken under special permit are often more widely distributed across the area than commercial catches and hence their sex ratios may differ.

Table 6a and Table 6b list the known bycatches and ship strikes of North Atlantic minke whales, although it is recognised that this list is not comprehensive. These will be included in the total historical catch series. The trials Steering Group will confirm any assumption regarding future bycatches to be tested in the trial structure.

6. *IMPLEMENTATION* TRIALS STRUCTURE

SC/65b/RMP01 provided a draft set of specifications for a trials structure for evaluating *SLA*s for the West Greenland aboriginal subsistence hunt and for evaluating variants of the RMP for commercial whaling operations off Iceland and by Norway. The specifications are based on the trials conducted during 1993 (IWC, 1993) as well as the discussions held during the joint Workshop on stock structure of North Atlantic common minke whales (SC/65b/Rep05). The primary aim of SC/65b/RMP01 was to identify issues which needed to be discussed to complete the trials specifications.

The Working Group thanked Punt for developing these draft specifications. The Group **agreed** to modify the biological and operational parameters used for the trials conducted in 1993 to the revised values in Item 4.2.

6.1 Mixing matrices

The trials are based on sighting and catch mixing matrices. The sighting mixing matrix is used to calculate the number of animals in each sub-area by stock, sex and age in order to generate the sightings abundance estimates on which *SLA*s and the RMP are based (see Adjunct 5, Section F). The catch mixing matrix is used to calculate the numbers of animals in each sub-area by stock, sex and age when whaling occurs. The trials structure in SC/65b/RMP01 assumed that the catch and sighting mixing matrices are identical. However, that assumption is not supported by the data on catch sex-ratios by month (Item 5; Table 5), which suggest that the relative proportion of males differs between the primary catching season (i.e. before July) and the time when surveys are conducted and thereafter (July onwards) for at least sub-areas ES and EB.

In principle, the entries of the catch and sightings mixing matrices can be estimated given information on the numbers of animals by sub-area and their age-/sex-structure when catching/sighting surveys take place. However, this information is not available for minke whales in the North Atlantic Ocean. Consequently, the Working Group **agreed** that the values for the parameters of the sightings mixing matrix be estimated for each replicate by conditioning the operating model to the abundance estimates by sub-area and the average sex-ratio by sub-area during July (when surveys are conducted). The average sex-ratio is defined as the average of the sex-ratio for July by period in Table 5 (excluding the 1986-92 period when catches were primarily during a scientific whaling programme).

No catch mixing matrix is defined for these trials. Rather the proportion of the population in each area by stock, sex and age is based on the sightings mixing matrix, with the selectivity pattern by sex adjusted for each sub-area so that the split of the catch to sex matches that actually observed for the most recent period (2008-12) if the whalers selected whales from those available to them at random. The most recent period is used to estimate the parameters by sub-area

Table 5

Table of North Atlantic minke whales known by sex and season (January to June=S1; July=S2; August to December=S3).

		S1			S2			S3			S1	S2	S3	S1	S2	S3	S1	S2	S3
Sub-area	Year	M	F	Total	M	F	Total	M	F	Total	**% M**	**% M**	**% M**	# mat F	# mat F	# mat F	% F mat	% F mat	% F mat
EB	pre 1960	4,550	6,896	11,446	1,087	939	2026	482	586	1,068	**40**	**54**	**45**	1,818	249	238	26	27	41
EB	1960-72	3,084	6,228	9,312	47	36	83	100	57	157	**33**	**57**	**64**	1,363	12	15	22	33	26
EB	1973-85	3,032	5,767	8,799	453	522	975	3	1	4	**34**	**46**	**75**	1,142	95	0	20	18	0
EB	1986-92	41	19	60	22	11	33	5	3	8	**68**	**67**	**63**	4	6	2	21	55	67
EB	1993-2001	205	714	919	74	57	131	3	7	10	**22**	**56**	**30**	366	38	0	51	67	0
EB	2002-7	161	591	752	2	11	13	22	6	28	**21**	**15**	**79**	215	6	0	36	55	0
EB	2008-12	24	99	123	9	4	13	5	7	12	**20**	**69**	**42**	35	1	2	35	25	29
EB	Total	11,097	20,314	31,411	1,694	1,580	3274	620	667	1,287	**35**	**52**	**48**	4,943	407	257	24	26	39
EN	pre 1960	1,736	1,036	2,772	726	481	1207	1,134	733	1,867	**63**	**60**	**61**	147	78	165	14	16	23
EN	1960-72	1,980	1,144	3,124	492	179	671	671	324	995	**63**	**73**	**67**	230	25	128	20	14	40
EN	1973-85	419	314	733	162	81	243	221	81	302	**57**	**67**	**73**	83	28	30	26	35	37
EN	1986-92	17	18	35	27	5	32	0	0	0	**49**	**84**		9	1	0	50	20	
EN	1993-2001	79	210	289	87	108	195	8	2	10	**27**	**45**	**80**	133	61	2	63	56	100
EN	2002-7	139	162	301	21	23	44	25	14	39	**46**	**48**	**64**	100	13	11	62	57	79
EN	2008-12	70	115	185	2	5	7	5	4	9	**38**	**29**	**56**	46	1	1	40	20	25
EN	Total	4,440	2,999	7,439	1,517	882	2,399	2,064	1,158	3,222	**60**	**63**	**64**	748	207	337	25	23	29
ES	pre 1960	1,081	2,632	3,713	211	196	407	245	128	373	**29**	**52**	**66**	865	71	35	33	36	27
ES	1960-72	1,689	3,347	5,036	16	22	38	100	74	174	**34**	**42**	**57**	945	10	25	28	45	34
ES	1973-85	1,134	3,057	4,191	212	359	571	19	14	33	**27**	**37**	**58**	578	113	7	19	31	50
ES	1986-92	82	120	202	59	71	130	2	2	4	**41**	**45**	**50**	82	28	1	68	39	50
ES	1993-2001	10	740	750	8	46	54	1	4	5	**1**	**15**	**20**	466	18	0	63	39	0
ES	2002-7	35	744	779	5	59	64	14	26	40	**4**	**8**	**35**	376	35	12	51	59	46
ES	2008-12	69	1,018	1,087	16	82	98	0	0	0	**6**	**16**		455	51	0	45	62	
ES	Total	4,100	11,658	15,758	527	835	1,362	381	248	629	**26**	**39**	**61**	3,767	326	80	32	39	32
EW	pre 1960	8,256	7,226	15,482	4,058	3,264	7,322	4,971	3,330	8,301	**53**	**55**	**60**	623	221	179	9	7	5
EW	1960-72	3,330	2,580	5,910	929	734	1,663	2,077	1,367	3,444	**56**	**56**	**60**	207	47	86	8	6	6
EW	1973-85	1,523	1,199	2,722	375	115	490	202	83	285	**56**	**77**	**71**	116	20	5	10	17	6
EW	1986-92	86	48	134	83	24	107	34	15	49	**64**	**78**	**69**	16	7	1	33	29	7
EW	1993-2001	332	379	711	160	94	254	62	23	85	**47**	**63**	**73**	159	39	11	42	41	48
EW	2002-7	505	550	1,055	143	103	246	54	29	83	**48**	**58**	**65**	186	25	5	34	24	17
EW	2008-12	295	290	585	146	80	226	55	27	82	**50**	**65**	**67**	43	8	2	15	10	7
EW	Total	14,327	12,272	26,599	5,894	4,414	10,308	7,455	4,874	12,329	**54**	**57**	**60**	1,350	367	289	11	8	6
CG	pre 1960	0	0	0	0	0	0	10	10	20			**50**	0	0	3			30
CG	1960-72	46	59	105	105	58	163	408	221	629	**44**	**64**	**65**	20	18	110	34	31	50
CG	1973-85	19	21	40	203	169	372	541	315	856	**48**	**55**	**63**	9	90	130	43	53	41
CG	1986-92	0	0	0	0	0	0	1	9	10			**10**	0	0	4			44
CG	Total	65	80	145	308	227	535	960	555	1,515	**45**	**58**	**63**	29	108	247	36	48	45
CIC	pre 1960	8	7	15	41	36	77	43	31	74	**53**	**53**	**58**	1	5	4	14	14	13
CIC	1960-72	212	201	413	205	137	342	310	111	421	**51**	**60**	**74**	38	60	42	19	44	38
CIC	1973-85	310	444	754	412	290	702	513	239	752	**41**	**59**	**68**	1	1	6	0	0	3
CIC	2002-7	25	36	61	25	32	57	48	30	78	**41**	**44**	**62**	0	2	5	0	6	17
CIC	2008-12	105	28	133	66	15	81	51	14	65	**79**	**81**	**78**	5	0	1	18	0	7
CIC	Total	660	716	1,376	749	510	1,259	965	425	1,390	**48**	**59**	**69**	45	68	58	6	13	14
CIP	pre 1960	0	0	0	0	0	0	1	0	1			**100**	0	0	0			
CIP	1960-72	61	56	117	17	8	25	42	19	61	**52**	**68**	**69**	9	2	11	16	25	58
CIP	1973-85	6	6	12	12	5	17	16	7	23	**50**	**71**	**70**	0	0	2	0	0	29
CIP	Total	67	62	129	29	13	42	59	26	85	**52**	**69**	**69**	9	2	13	15	15	50
CM	Pre 1960	0	1	1	6	5	11	0	1	1	**0**	**55**	**0**	0	1	0	0	20	0
CM	1960-72	69	211	280	199	153	352	196	137	333	**25**	**57**	**59**	79	50	51	37	33	37
CM	1973-85	10	66	76	27	67	94	0	9	9	**13**	**29**	**0**	27	28	7	41	42	78
CM	1986-92	4	38	42	13	41	54	1	3	4	**10**	**24**	**25**	25	30	3	66	73	100
CM	1993-2001	48	252	300	7	45	52	2	0	2	**16**	**13**	**100**	166	24	0	66	53	
CM	2002-7	6	44	50	1	7	8	4	15	19	**12**	**13**	**21**	28	3	12	64	43	80
CM	2008-12	0	1	1	5	25	30	0	0	0	**0**	**17**		0	18	0	0	72	
CM	Total	137	613	750	258	343	601	203	165	368	**18**	**43**	**55**	325	154	73	53	45	44
WC	pre 1960	79	83	162	66	57	123	11	10	21	**49**	**54**	**52**	22	17	4	27	30	40
WC	1960-72	140	262	402	55	78	133	14	16	30	**35**	**41**	**47**	32	6	3	12	8	19
WC	Total	219	345	564	121	135	256	25	26	51	**39**	**47**	**49**	54	23	7	16	17	27
WG	1960-72	42	143	185	15	11	26	286	285	571	**23**	**58**	**50**	50	5	131	35	45	46
WG	1973-85	47	196	243	71	308	379	231	541	772	**19**	**19**	**30**	134	190	356	68	62	66
WG	1986-92	9	16	25	6	24	30	17	51	68	**36**	**20**	**25**	6	5	18	38	21	35
WG	1993-2001	34	192	226	64	188	252	208	519	727	**15**	**25**	**29**	-	-	-	-	-	-
WG	2002-07	35	174	209	53	142	195	161	406	567	**17**	**27**	**28**	-	-	-	-	-	-
WG	2008-12	34	153	187	52	96	148	133	295	428	**18**	**35**	**31**	-	-	-	-	-	-
WG	Total	206	926	1,132	276	806	1,082	1,069	2,215	3,284	**18**	**26**	**33**	190	200	505	54	58	58
		35,210	49,414	84,624	11,189	9,282	20,471	13,266	9,021	22,287				11,460	1,862	1,866			

Table 6a

List of known incidental catches, entanglements and ship strikes of North Atlantic minke whales from progress reports and other submitted data.

Year	Type	Number	Sub-area	Source	Sex	Notes
Belgium						
2004	Entangled	1	EN	PR	1F	
Denmark						
1990	Incidental catch	3	WG	LW	1M; 2F	
1991	Incidental catch	10	WG	LW; Inf.Rep	2M; 6F; 2U	
1992	Incidental catch	3	WG	LW; PR	3F	
1993	Incidental catch	6	WG	PR; LW	2M; 1F; 3U	
1995	Incidental catch	2	WG	LW	2F	
1996	Incidental catch	3	WG	LW	2M; 1F	
1998	Incidental catch	3	WG	LW	1M; 2F	
2000	Incidental catch	2	WG	PR	1M; 1F	
2002	Incidental catch	1	WG	PR	1F	
2008	Incidental catch	1	WG	PR	1F	
2009	Incidental catch	1	WG	PR	1F	
Iceland						
2002	Entangled	2	CIC	PR	1M; 1F	
2005	Entangled	2	CIC	PR	1F; 1U	
2006	Entangled	1	CIC	PR	1U	
2008	Bycatch	1	CM	PR	1F	
Norway						
2009	Bycatch	1	EW	CI; PR	1U	
Portugal						
2004	Bycatch	1	EN	PR	1F	
2005	Bycatch	1	EN	PR	1F	
2006	Bycatch	1	EN	PR	1M	
Spain						
2008	Bycatch	2	EN	PR	1M; 1F	
UK						
2004	Bycatch	1	EN?	PR	1U	‘Possible bycatch’ in NE Atlantic
2005	Bycatch	1	EN?	PR	1F	No position given
2006	Bycatch	2	EN	PR	1F; 1U	
2007	Entangled	1	EN	PR	1U	
2008	Entangled	2	EN	PR	1F; 1U	
2009	Ship strike	1	EN	PR	1M	
2010	Bycatch	1	EN	PR	1M	
USA (excluding 3 in 2001 and 2 in 2008 caught off Canada and assumed to be included in Table 6b below)						
1975	Ship strike	1	WC	SS report	1U	USA (dead)
1988	Ship strike	1	WC	SS report	1U	USA (dead)
1992	Ship strike	1	WC	SS report	1F	USA (dead)
1993	Ship strike	3	WC	SS report	1M; 2U	USA (dead)
1994	Ship strike	1	WC	SS report	1U	USA (dead)
1995	Ship strike	2	WC	SS report	1F; 1U	USA (1 dead, 1 fate unknown)
1997	Ship strike	1	WC	SS report	1U	USA (dead)
1998	Entangled	1	WC	PR	1M	Long Beach, NY
1998	Ship strike	1	WC	PR	1U	Cape Cod Bay, MA
1998	Ship strike	3	WC	SS report	3U	USA (1 dead, 2 injured)
1999	Ship strike	1	WC	SS report	1U	USA (dead)
1999	Entangled	1	WC	PR	1F	Cape Lookout, NC
1999	Entangled	1	WC	PR	1F	Orleans, MA
1999	Entangled	1	WC	PR	1U	Sakonnet River, RI
1999	Entangled	1	WC	PR	1U	Pt. Judith Light, RI
1999	Entangled	1	WC	PR	1F	Provincetown, MA
2000	Entangled	1	WC	PR	1U	Rockland, ME
2001	Ship strike	1 Mi/Sei	WC	SS report	1U	USA (dead) 7.6m minke or small sei
2002	Entangled	1	WC	PR	1F	Bar Harbor, ME
2002	Entangled	1	WC	PR	1F	Gloucester, MA
2003	Bycatch	1	WC	PR	1F	Martha’s Vineyard, MA
2003	Bycatch	1	WC	PR	1U	Harwich, MA
2003	Bycatch	1	WC	PR	1M	Glouster, MA
2003	Bycatch	1	WC	PR	1M	Chatham, MA
2003	Bycatch	1	WC	PR	1F	Maine
2004	Ship strike	1	WC	PR	1F	Chatham, MA
2004	Bycatch	1	WC	PR	1F	Martha’s Vinyard
2004	Bycatch	1	WC	PR	1F	Eastham, MA
2005	Ship strike	1	WC	PR	1M	Port Elizabeth, NJ
2005	Bycatch	1	WC	PR	1U	Gulf of Mexico
2007	Bycatch	1	WC	PR	1U	Trescott, ME
2007	Bycatch	1	WC	PR	1F	Cape Cod Bay, MA
2008	Bycatch	1	WC	PR	1F	Orleans, MA
2008	Bycatch	1	WC	PR	1U	Off Richibucto Cape, New Brunswick
2010	Bycatch	5	WC	PR	1M; 4U	North Atlantic. 1 seriously injured; 3 injured; 1 dead (M)
2011	Bycatch	4	WC	PR	4U	North Atlantic

Sources: PR=Progress report; Inf Rep=Infractions report; LW=Individual data received from L. Witting; CI=Individual catch data.

Table 6b

Information on entanglements and ship strikes off E Canada.

Year	Type	Number	Sub-area	Source	Sex	Notes
1973	Entangled	3	WC	Perkins and Beamish (1979)	3U	
1974	Entangled	3	WC	Perkins and Beamish (1979)	1M;2U	
1975	Entangled	3	WC	Perkins and Beamish (1979)	3U	
1976	Entangled	3	WC	Perkins and Beamish (1979)	1F;2U	
1977	Entangled	1	WC	Perkins and Beamish (1979)	1U	
1978	Entangled	2	WC	Lein (1981)	2U	
1979	Entangled	9	WC	Lein (1981)	1F; 8U	Also 1 released alive
1980	Entangled	9	WC	Lein (1981)	1F; 2M; 6U	Also 3 released alive
1981	Entangled	8	WC	Lein (1994)	-	Also 3 released alive
1982	Entangled	4	WC	Lein (1994)	-	Also 5 released alive
1983	Entangled	4	WC	Lein (1994)	-	Also 7 released alive
1984	Entangled	6	WC	Lein (1994)	-	Also 2 released alive
1985	Entangled	7	WC	Lein (1994)	-	Also 2 released alive
1986	Entangled	4	WC	Lein (1994)	-	Also 3 released alive
1987	Entangled	8	WC	Lein (1994)	-	Also 4 released alive
1988	Entangled	8	WC	Lein (1994)	-	Also 2 released alive
1989	Entangled	10	WC	Lein (1994)	-	Also 2 released alive
1990	Entangled	11	WC	Lein (1994)	-	Also 3 released alive
1991	Entangled	5	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1979-92=0.68
1992	Entangled	7	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1979-92=0.68
1993	Entangled	2	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
1994	Entangled	4	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
1995	Entangled	4	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
1995	Ship strike	1	WC	SS report*	1U	Canada (Fate unknown)
1996	Entangled		WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
1997	Entangled	1	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
1998	Entangled		WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
1999	Entangled	3	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2000	Entangled		WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2001	Entangled	9	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2002	Entangled	7	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2003	Entangled	1	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2004	Entangled	5	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2005	Entangled	4	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2006	Entangled	2	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2007	Entangled	5	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51
2008	Entangled	4	WC	Benjamins *et al*. (2012)	-	No. released not given; average mortality 1993-2008=0.51

*SS report=Jensen and Silber (2004). Large whale ship strike database.

Table 7

Plans for future sightings surveys.

	WC	WG	CIP	CG	CIC	CM	EN	EW	ES	EB
2014									X	
2015	?	X	X	X	X	X		X		
2016										X
2017							X			
2018						X				
2019										
2020										
2021										
2022	?		X	X	X	X				
2023										
2024										
2025		X								

to adjust the selectivity pattern given that this period is likely to be best reflective of how future whaling operations will occur, and will be trial-dependent.

6.2 Management variants

Management variants are selected by the representatives of the governments who wish to conduct whaling. For these trials, the strike limit for West Greenland is based on the interim *SLA* while catch limits for areas subject to commercial whaling are based on the permissible variants of the RMP. The need envelope for West Greenland will be confirmed later but will include a constant level of need at the current value. The baseline management variant (V1) attempts to mimic the *Implementation* selected by IWC (1994):

> 'Sub-areas CIC, CM, EN, EB, ES and EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Medium Areas*. The catch limits set for the CG and CIP *Small Areas* are not taken; sub-area WC is a *Residual Area*.'

The alternative management variants (V2-V5) are as follows:

> V2: Sub-areas CIC, CM, EN and EB+ES+EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Medium Areas*. The catch from the EB+ES+EW Small Area is all taken from the EW sub-area. The catch limits set for the CG and CIP *Small Areas* are not taken; sub-area WC is a Residual Area.
>
> V3: Sub-areas CIC, CM, EN, ES, and EB+EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Medium Areas*. The catch from the EB+ EW Small Area is all taken from the EW sub-area. The catch limits set for the CG and CIP *Small Areas* are not taken; sub-area WC is a Residual Area.
>
> V4: As for V1, except that sub-areas CIC, CIP and CM as one *Small Area* and all of the catches are taken in the CIC sub-area.
>
> V5: As for V1, except that sub-areas CIP, CIC, CG and CM are on *Small Are*a and all of the catches are taken in the CIC sub-area.

6.3 Future sightings plans

Norwegian, Icelandic and West Greenland scientists provided plans for future sightings surveys for minke whales in the North Atlantic (Table 7). Norway intends to continue the six-year cycle of surveys (a new cycle starts in 2014), covering one *Small Area* each year. Iceland intends to survey on a seven-year schedule while Greenland has not decided on long-term survey plans. Adjunct 5 lists the survey plans and also how the results from surveys are to be used to compute the survey estimates of abundance for the *Medium Areas*.

Table 8

Draft work plan for completion of the North Atlantic minke whale *Implementation*.

What	Who	When
Finalise survey estimates for conditioning	Øien, Gunnlaugsson, Witting	30 June 2014
Finalise (commercial and aboriginal) catch series	Allison, Witting	30 June 2014
Steering-Group-suggested final trial specifications distributed	Allison, Punt, de Moor	15 July 2014
Code finalisation	Allison, de Moor, Punt	15 September 2014
Conditioning	Allison	1 January
Workshop to evaluate conditioning, confirm/amend finalise trial specifications (if needed)	Steering Group	January 2015
Amendments to code completed and any revised conditioning	Allison, de Moor	1 March 2015
Projections completed	Allison, de Moor	1 month before SC/66a
Equivalent single stock trials specified	Punt, Allison	1 month before SC/66a
Trial results circulated to Steering Group	Allison	3 weeks prior to SC/66a
Steering Group identifies 'key' results to go as WP to SC	Steering Group	1 week prior to SC/66a
Assigning plausibility, evaluation of trials results	All	SC/66a

6.4 Final trials structure

Adjunct 5 lists the final trials specifications. This adjunct reflects the discussions of the group. The trials capture uncertainty regarding stock structure and MSYR, as well as uncertainty regarding selectivity and the parameterisation of the selectivity patterns by sex and age and the catch mixing matrix and the sightings mixing matrix. The bulk of the sensitivity tests are based on stock structure hypothesis I because this hypothesis is likely to be the most challenging from a conservation standpoint.

7. WORK PLAN AND RECOMMENDATIONS

The draft work plan for completion of the North Atlantic minke *Implementation* is given as Table 8.

In addition genetics work will continue (see Item 2.4); updates on progress will be provided at SC/66a and SC/66b.

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Adjunct 1

Pre-meeting Agenda

1. Introductory items
   1.1 Convenor’s opening remarks
   1.2 Election of Chair
   1.3 Appointment of rapporteurs
   1.4 Adoption of Agenda
   1.5 Documents available
2. Stock structure
   2.1 Review of the intersessional joint Workshop
   2.2 Preliminary ideas for sensitivities related to stock structure hypotheses to be examined in the trials
   2.3 New information
   2.4 Conclusions and recommendations for use in trials
3. Abundance estimates
   3.1 New information
   3.2 Estimates for use in trials
4. Biological parameters
   4.1 Past and new information
   4.2 Values for use in trials
5. Removals data (catches, bycatch, ship strikes)
   5.1 New information
   5.2 Series for use in trials
6. *Implementation Simulation Trial* structure (SC/65b/RMP01)
   6.1 Mixing matrices
   6.2 Management variants
   6.3 Future sighting survey plans
   6.4 Final trial structure
7. Work plan and recommendations

Adjunct 2

Finding relatives among North Atlantic common minke whales (*Balaenoptera acutorostrata*) based on microsatellite data from the entire North Atlantic

Ralph Tiedemann[1], Magnús R. Tiedemann[2], Thorvaldur Gunnlaugsson[3], Christophe Pampoulie[2] and Gísli A. Víkingsson[2]

As recommended, we applied the likelihood-based relatedness inference method described in SC/65b/RMP05 to the entire microsatellite data set of SC/65b/RMP09 (n=996). The estimated detection power is given in Table 1. Table 2 summarises the inferred parent-offspring pairs (mother-foetus data not included). In total, 14 parent-offspring pairs were inferred, of which only four occurred in the same area. Parent-offspring pairs among specimens from different areas were detected between CIC and WG (1), CIC and CG (1), CIC and EW (7), as well as CIC and ES (1). For one foetus from an Icelandic mother-foetus catch from 2005, a parent-offspring relationship was established to a Norwegian specimen from 2004. If this specimen is a male and the difference in time of catch is shorter than the length of gravidity, this could be a confirmed pair between an Icelandic female and a Norwegian male minke whale.

Table 1

Detection power in relation to typing error and false discovery rate (FDR).

		Power (FDR)			
Relatedness	Typing error	0.1	0.05	0.01	0.001
Identity	0.00	1.00	1.00	1.00	1.00
	0.01	1.00	1.00	1.00	1.00
	0.02	1.00	1.00	1.00	1.00
Parent-offspring	0.00	0.62	0.52	0.40	0.40
	0.01	0.61	0.51	0.41	0.41
	0.02	0.54	0.56	0.34	0.34

Table 2

Number of inferred parent-offspring pairs in NA-minke whales based on 16 microsatellites, FDR=0.05, typing error 0.00-0.02.

	WG (n=66)	CG (n=16)	CIC (n=571)	EW (n=318)	ES (n=63)	EB (n=50)	EN (n=7)
WG (n=66)	-	-	-	-	-	-	-
CG (n=16)	-	1	-	-	-	-	-
CIC (n=571)	1	1	2	-	-	-	-
EW (n=318)	-	-	7	-	-	-	-
ES (n=63)	-	-	1	-	1	-	-
EB (n=50)	-	-	-	-	-	-	-
EN (n=7)	-	-	-	-	-	-	-

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Adjunct 3

Standardised (across different marker types and studies) measures of genetic differentiation in North Atlantic minke whales

R. Waples, R. Tiedemann, P. Palsbøll, R. Hoelzel, L. Andersen

At least a half-dozen studies of genetic differentiation of North Atlantic minke whales have been published, and these studies have come to (sometimes dramatically) different conclusions regarding the evidence for population genetic structure. Interpreting these differences is difficult because several potentially confounding variables also differ among studies: types of genetic markers used (allozymes, mtDNA, microsatellites), geographic areas sampled, years sampled, sample sizes, and laboratories that conducted the analyses. The ‘Report of the AWMP/RMP Joint Workshop on the stock structure of North Atlantic common minke whales’ (SC/65b/Rep04) identified several steps that could be taken to try to pinpoint the causes of the observed differences. This Adjunct addresses the first suggestion in that report, which was to try to account for different levels of genetic variation associated with different types of markers and how that affects results. F_{ST} is a common measure of genetic differentiation; it can be interpreted as the fraction of overall genetic variation that is found among populations (the remainder being differences among individuals within populations). This latter quantity is represented by the average heterozygosity, H, in each population. In theory, F_{ST} can range between 0 and 1, with larger values indicating stronger genetic differences. However, the maximum $F_{ST}=1$ can only be achieved when H=0 within each population (that is, when different populations are fixed for different alleles). Higher levels of heterozygosity reduce the maximum value F_{ST} can attain. This means that, all else being equal, studies using microsatellites (which typically have high H) will produce lower F_{ST} values than studies that use allozymes (which typically have low H).

We accounted for the effects of levels of genetic variation and marker type on five different studies of North Atlantic minke whales: allozymes: Daníelsdóttir *et al.* (1992); microsatellites: Andersen *et al.* (2003), Anderwald *et al.* (2011), SC/A14/AWMP-RMP04, and SC/65b/RMP09, as follows.

1. For each locus, we calculated an unbiased F_{ST} across all samples taken from the North Atlantic. An unbiased F_{ST} is one that explicitly accounts for effects of sampling a finite number (S) of individuals from each population, which on average adds approximately $1/(2S)$ to the estimate of F_{ST}. Weir and Cockerham (1984) and Nei and Chesser (1983) are examples of unbiased estimators of F_{ST}.
2. For each locus in each population, we calculated an unbiased measure of average expected H, using the method of Nei (1978) or a comparable approach. These unbiased measures also account for sampling error. We then took an unweighted arithmetic average of the H values for each population to arrive at an overall mean H for that locus.
3. Finally, we calculated an adjusted F_{ST} for each locus as $F_{ST}'=F_{ST}/(1\text{-}H)$. This F_{ST}’ provides an approximate adjustment for the level of genetic variability at each locus (modified from the method proposed by (modified from the method proposed by Hedrick, 2005).

Authors of the microsatellite papers provided these indices or provided the data so we could calculate them. Original genotypes are not available for Daníelsdóttir *et al.* (1992), so we calculated F_{ST} and H from the published allele frequencies.

Results of these analyses are shown in Fig. 1, which updates a similar figure shown in SC/65b/RMP09. Several things can be noted.

1. 7 of the 10 allozyme loci have adjusted F_{ST}’ values > 0.08.
2. 34 of the 35 microsatellite loci in the Palsbøll and Tiedemann *et al.* studies have F_{ST}’ values <0.02.
3. In the Tiedemann study, the F_{ST}’ for the locus sam25 is an order of magnitude larger than for any other locus.
4. 4 of 16 microsatellite loci in the Andersen *et al.* study have F_{ST}’ values >0.06.

We have not conducted any formal tests of the combined data, but it seems unlikely that they can all be explained as arising from a random sampling process from a single distribution of parametric F_{ST}’ values. Geographic coverage differed somewhat among the studies (Table 1), but the overlap was substantial enough that, by itself, this factor also seems unlikely to be able to explain the different results. Adjusted F_{ST}’ values for each locus in each study are in Table 2.

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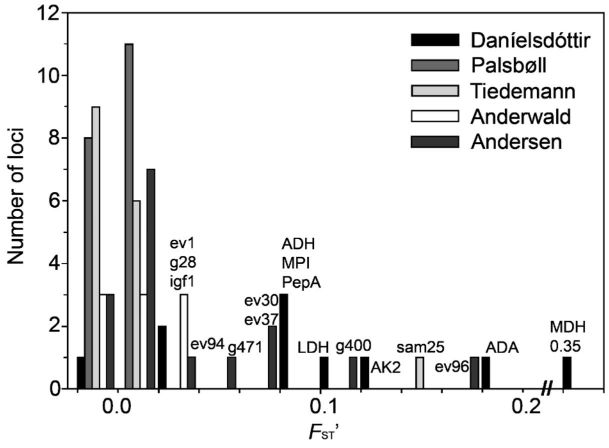

Fig. 1. Distribution of locus-specific values of F_{ST}’ across 5 genetic studies of North Atlantic minke whales. F_{ST}’ is an unbiased measure of F_{ST}’ that is adjusted to account for mean expected heterozygosity within populations. F_{ST}’ was computed across all samples from the North Atlantic, as shown in Table 1. Outlier loci are identified.

Table 1

Number of individuals from each IWC *Small Area* sampled and analysed by five population genetic studies of North Atlantic minke whales.

	Tiedemann 16 STR	Anderwald 9 STR	Palsbøll 19 STR	Andersen 16 STR	Danielsdottir 10 allozymes
W Canada	-	15	157	-	-
W Greenland	66	36	283	166	50
Central E Greenland	16	-	2	30	-
Central Iceland pelagic	-	-	-	-	-
Central Iceland coastal	571	60	51	-	114
Central Jan Mayen	-	17	-	24	-
E North Sea	7	83	-	23	12
E coastal Norway	318*	-	343*	14	-
E Svalbard	63	48	-	16	-
E Barents Sea	50	-	-	33	-
Total	1,091	259	836	306	176

*These samples are from Norway but exact location is not known.

Table 2

Locus specific values of adjusted F_{ST}' for four microsatellite studies of North Atlantic minke whales.

Locus	Palsbøll	Tiedemann	Anderwald	Andersen
AC045	0.011			
AC087	0.000			
AC137	0.002			
ACCC392			0.010	
CA128	0.001			
EV001	0.002		0.026	0.002
EV021				0.008
EV030				0.068
EV037	-0.001		0.007	0.068
EV094	0.003	-0.002		0.035
EV096	-0.001	-0.002		0.162
EV1Pm		0.000		
EV37Mn		-0.003		
GAAT400				0.104
GATA028	-0.001	0.011	0.033	-0.002
GATA053		-0.002		
GATA098	-0.002	0.002		-0.008
GATA417	0.003	-0.002	-0.003	0.051
GO98			0.002	
GT011		0.000		0.001
GT023	0.002	0.010		
GT129	-0.001			
GT195	-0.001	0.003		
GT211	0.006	-0.002		
GT310	0.007	-0.005		
GT509	-0.002	-0.001	-0.011	
GT541	-0.001			
GT575	0.004	0.002		
IGF1			0.025	0.004
K2a			-0.016	
rw26				0.019
rw31				-0.002
rw48				0.002
sam25		0.157		0.000
Mean	**0.002**	**0.010**	**0.008**	**0.032**

Adjunct 4

Simplification of the estimation procedure for Norwegian minke whale surveys

Hans J. Skaug

The abundance estimation procedure that has been applied to the Norwegian minke whale surveys in the northeastern Atlantic in the past (Bøthun *et al.*, 2009; Schweder *et al.*, 1997; Skaug *et al.*, 2004) has included a simulation module which has served two purposes: bias reduction and variance calculation. The plan for the analysis of the 2008-13 survey period is to replace the simulation module by an analytical formula in order to simplify the production pipeline for the abundance estimate.

Bias correction

The simulation-based bias correction adjusts for the following sources of bias: (1) errors in the duplicate identification rule; (2) errors in distance and angle estimates; and (3) non-Poisson dive time patterns.

However, the magnitude of the bias correction has been small for the survey cycles of 1996-2001 and 2002-07: -2.5 % and -3.7 % respectively (SC/65b/RMP07). One reason for this is that the duplicate identification routine has been tuned to keep the number of false positives and false negatives (missed duplicates) low (Bøthun and Skaug, 2009).

New procedure

The idea is to build the effect of measurement error and non-Poisson dive time patterns directly into the likelihood, similar to what has been done for measurement error in distance in the literature (Borchers *et al.*, 2010). This will account for (2) and (3) above. Regarding (1), one can either take the output from the duplicate identification routine, without any correction, or alternatively undertake a manual inspection of the duplicate judgments.

In addition to the improved tuning of the duplicate identification rule (Bøthun and Skaug, 2009), visual inspections of the 2008-13 data indicate that there are few cases of any doubt about the duplicate identification. The cases for which there is uncertainty will be documented graphically, which will allow Scientific Committee members to assess whether the duplicate identification decisions made are considered to have been satisfactory.

Variance calculations

In the past the variance estimate was obtained by a 'parametric bootstrapping' process in which the simulation program was used to obtain simulated replicates. Instead the variance estimates will be based on the delta-method, and a process that corresponds to the 'replicate transect leg' approach to quantifying the effect of animal clustering. The resultant procedure will then be close to the classical line transect approach.

Discussion

There is nothing wrong with the previous estimation procedure, except that it is very demanding to carry out. Hence, there is no need to make any changes to previous abundance estimates. The new approach will be applied only to the 2008-13 and future data.

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Adjunct 5

The AWMP/RMP *Implementation Simulation Trials* for the North Atlantic minke whales

A. Basic concepts and stock-structure

The objective of these trials is to examine the performance of the RMP when managing a fishery for North Atlantic minke whales. Allowance is made for both commercial and aboriginal subsistence catches. The underlying dynamics model allows for multiple stocks and sub-stocks, and is age- and sex-structured.

The region to be managed (the northern North Atlantic) is divided into 11 sub-areas (see Fig. 1). The term 'stock' refers to a group of whales from the same (putative) breeding ground. The 3-stock models assume there is western 'W' stock (which feeds at least in the 'WG' and 'WC' sub-areas), a central 'C' stock (which feeds at least in the 'CG', 'CIC', 'CIP', and 'CM' sub-areas), and an eastern 'E' stock (which feeds at least in the 'EN', 'EB', 'ESW', 'ESE', and 'EW' sub-areas). The 'E' and 'W' stocks are divided into sub-stocks for some of trials (sub-stocks 'E-1' and 'E-2' for the 'E' stock; sub-stocks 'W-1' and 'W-2' for the 'W' stock). There is no interchange between stocks, or sub-stocks, at least in the base-case trials. The rationale for the position of the sub-area boundaries is given in IWC (2004a) and IWC (2009, p138).

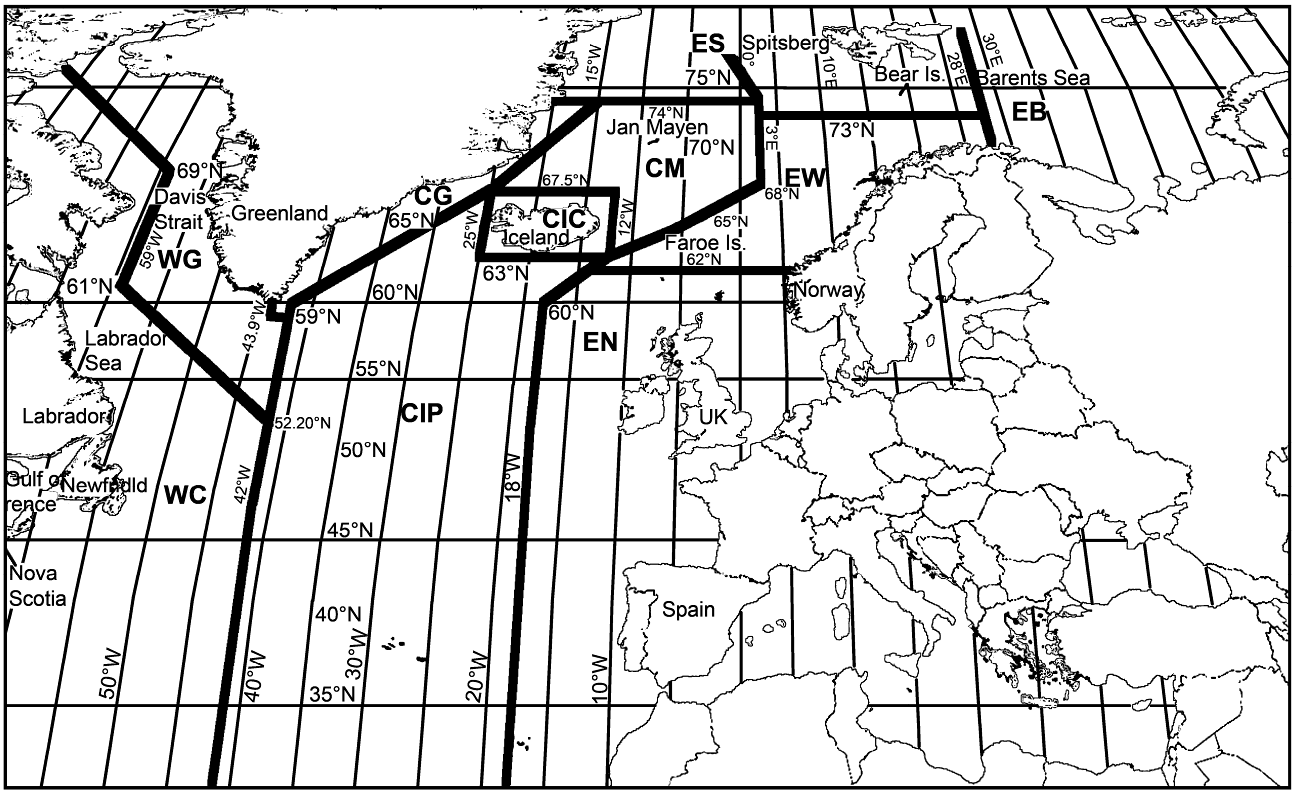

Fig. 1. Map of the North Atlantic showing the sub-areas defined for the North Atlantic minke whales.

There are three general hypotheses regarding stock structure - see SC/65b/Rep04 for the rationale for these hypotheses:

(I) Three stocks. There are three stocks 'W', 'C', and 'E'. The 'W' stock consists of two sub-stocks ('W-1' and 'W-2') and the 'E' stock consists of two sub-stocks ('E-1' and 'E-2').

(II) Two stocks. There are two stocks 'W*', and 'E'. The 'W*' stock consists of two sub-stocks ('W' and 'C*') where the C* stock is the same as the 'C' stock for stock hypothesis I, except that the whales that occur primarily in the 'WG' sub-area are also part of this stock. The 'E' stock is defined as for stock hypothesis I.

(III) One stock. There is only a single ('O') stock of minke whales in the North Atlantic.

(IV) Two cryptic stocks. There are two stocks ('O-1' and 'O-2') of minke whales in the North Atlantic. The two stocks are found in all 11 sub-areas[1].

The trials (see Section H) include variants of these general hypotheses to capture further aspects of uncertainty regarding stock structure.

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[1] This stock structure hypothesis was discussed by the April 2014 Joint AWMP/RMP North Atlantic minke whale stock structure Workshop, though it was not included in the final report of that meeting (SC/65b/Rep04).

B. Basic dynamics

The dynamics of the animals in stock/sub-stock *j* are governed by equation B.1:

$$N^{g,j}_{t+1,a} = \begin{cases} 0.5b^{j}_{t+1} & \text{if } a = 0 \\ (N^{g,j}_{t,a-1} - C^{g,j}_{t,a-1})\tilde{S}_{a-1} & \text{if } 1 \leq a < x \\ (N^{g,j}_{t,x} - C^{g,j}_{t,x})\tilde{S}_{x} + (N^{g,j}_{t,x-1} - C^{g,j}_{t,x-1})\tilde{S}_{x-1} & \text{if } a = x \end{cases} \qquad \text{(B.1)}$$

where:

$N^{g,j}_{t,a}$	is the number of animals of gender *g* and age *a* in stock/sub-stock *j* at the start of year *t*;
$C^{g,j}_{t,a}$	is the catch (in number) of animals of gender *g* and age *a* in stock/sub-stock *j* during year *t* (whaling is assumed to take place in a pulse at the start of each year);
b^{j}_{t}	is the number of calves born to females from stock/sub-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 gender); and
x	is the maximum age (treated as a plus-group).

Note that t=0, the year for which catch limits might first be set, corresponds to 2014.

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.

$$b^{j}_{t} = B^{j} N^{\mathrm{f},j}_{t} \{1 + A^{j}(1 - (N^{\mathrm{f},j}_{t} / K^{\mathrm{f},j})^{z^{j}})\} \qquad \text{(C.1)}$$

where:

B^{j}	is the average number of births (of both sexes) per year for a mature female in stock/sub-stock *j* in the pristine population;
A^{j}	is the resilience parameter for stock/sub-stock *j*;
z^{j}	is the degree of compensation for stock/sub-stock *j*;
$N^{\mathrm{f},j}_{t}$	is the number of 'mature' females in stock/sub-stock *j* at the start of year *t*:

$$N^{\mathrm{f},j}_{t} = \sum_{a=3}^{x} \beta_a N^{\mathrm{f},j}_{t,a} \qquad \text{(C.2)}$$

β_a	is the proportion of females of age *a* which have reached the age-at-first partition; and
$K^{\mathrm{f},j}$	is the number of mature females in stock/sub-stock *j* in the pristine (pre-exploitation, written as t=-∞) population:

$$K^{\mathrm{f},j} = \sum_{a=3}^{x} \beta_a N^{\mathrm{f},j}_{-\infty,a} \qquad \text{(C.3)}$$

The values of the parameters A^{j} and z^{j} for each stock/sub-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

It is assumed that whales are homogeneously distributed across a sub-area. The catch/strike limit for a sub-area is therefore allocated to stocks/sub-stocks by sex and age relative to their true density within that sub-area and a mixing matrix *V*, i.e.:

$$C^{g,j}_{t,a} = \sum_{k} F^{g,k}_{t} V^{g,j,k}_{t,a} S^{g}_{a} N^{g,j}_{t,a} \qquad \text{(D.1)}$$

$$F^{g,k}_{t} = \frac{C^{g,k}_{t}}{\sum_{j'}\sum_{a'} V^{g,j',k}_{t,a} S^{g}_{a'} N^{g,j'}_{t,a'}} \qquad \text{(D.2)}$$

where:

$F^{g,k}_{t}$	is the exploitation rate in sub-area *k* on fully recruited ($S^{g}_{a} \to 1$) animals of gender *g* during year *t*;
S^{g}_{a}	is the selectivity on animals of gender *g* and age *a*:

$$S^{g}_{a} = (1 + e^{-(a - a^{g}_{50})/\delta^{g}})^{-1} \qquad \text{(D.3)}$$

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

$C_{t}^{g,k}$ is the catch of animals of gender g in sub-area k during year t (see sub-adjunct 1); and

$V_{t,a}^{g,j,k}$ is the fraction of animals in stock/sub-stock j of gender g and age a that is in sub-area k during year t.

E. Mixing

The entries in the mixing matrix V are selected to model the distribution of each stock/sub-stock at the time when the catch is removed/when the surveys are conducted. Mixing is stochastic. For the two and three stock hypotheses, the mixing matrix for each year is selected at random from a matrix in which mixing is 'high' and in which it is 'low' (matrices A and B in Table 1). For the one stock and two cryptic stocks hypotheses, the values for the mixing matrix in Table 1 are each multiplied by a log-normal normal random variable, with mean 1 and CV to be calculated from the additional variance and renormalised. The entries in the mixing matrices for sub-stocks W-1 and W-2 (hypothesis I) and W (hypothesis II) sum to less than 1 for males and juveniles because the survey/catch data indicate that insufficient males are available in the areas for which data are available given the greater than 50% proportions of females in the catches (SC/65b/Rep04).

Table 1

The mixing matrices. The γs and Ωs indicate that the entry concerned is to be estimated during the conditioning process. An asterisk indicates that the row concerned sums to 1. Note that the values for the γs and Ωs are the same for the high and low mixing matrices for each stock structure hypothesis.

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Stock structure hypothesis I (matrix A) [high mixing]											
Adult females (ages 10+)											
W-1*	0.50	0.50	-	-	-	-	-	-	-	-	-
W-2*	0.20	0.45	0.15	0.20	-	-	-	-	-	-	-
C*	-	0.1	γ_2	γ_3	0.5 γ_4	γ_5	0.05	-	γ_6	-	-
E-1*	-	-	-	-	-	-	0.1	γ_7	$0.1\gamma_8$	γ_8	γ_9
E-2*	-	-	-	-	-	0.1	0.8	0.1	-	-	-
Adult males (ages 10+) and juveniles											
W-1	0.5 Ω_1	0.5 Ω_2	-	-	-	-	-	-	-	-	-
W-2	0.2 Ω_1	0.45 Ω_2	0.10 Ω_3	$0.20\Omega_4$	-	-	-	-	-	-	-
C*	-	0.1 Ω_2	$\gamma_2 \Omega_3$	$\gamma_3 \Omega_4$	$\gamma_4 \Omega_5$	$\gamma_5 \Omega_6$	0.05 Ω_7	-	-	-	-
E-1*	-	-	-	-	-	-	0.1 Ω_7	$\gamma_7 \Omega_8$	$0.1\gamma_8 \Omega_9$	$\gamma_8 \Omega_{10}$	$\gamma_9 \Omega_{11}$
E-2*	-	-	-	-	-	$0.1\Omega_6$	0.8 Ω_7	0.1 Ω_8	-	-	-
Stock structure hypothesis I (matrix B) [low mixing]											
Adult females (ages 10+)											
W-1*	1	-	-	-	-	-	-	-	-	-	-
W-2*	-	1	-	-	-	-	-	-	-	-	-
C*	-	-	γ_2	γ_3	γ_4	γ_5	-	-	-	-	-
E-1*	-	-	-	-	-	-	-	γ_7	$5\gamma_8$	$5\gamma_8$	γ_9
E-2*	-	-	-	-	-	-	1	-	-	-	-
Adult males (ages 10+) and juveniles											
W-1	Ω_1	-	-	-	-	-	-	-	-	-	-
W-2	-	Ω_2	-	-	-	-	-	-	-	-	-
C*	-	-	$\gamma_2 \Omega_3$	$\gamma_3 \backslash \Omega_4$	2 $\gamma_4 \Omega_5$	$\gamma_5 \Omega_6$	-	-	-	-	-
E-1*	-	-	-	-	-	-	-	$\gamma_7 \Omega_8$	$5\gamma_8 \Omega_9$	5 $\gamma_8 \Omega_{10}$	$\gamma_9 \Omega_{11}$
E-2*	-	-	-	-	-	-	Ω_7	-	-	-	-
Stock structure hypothesis II (matrix A) [high mixing]											
Adult females (ages 10+)											
W*	0.6	0.2	0.15	0.2	-	-	-	-	-	-	-
C*	-	γ_1	γ_2	γ_3	0.5 γ_4	γ_5	0.05	-	γ_8	-	-
E-1*	-	-	-	-	-	-	0.1	γ_7	$0.1\gamma_8$	γ_8	γ_9
E-2*	-	-	-	-	-	0.1	0.8	0.1	-	-	-
Adult males (ages 10+) and juveniles											
W	0.2 Ω_1	Ω_2	0.10 Ω_3	$0.20\Omega_4$	-	-	-	-	-	-	-
C*	-	0.1 $\gamma_1\Omega_2$	$\gamma_2 \Omega_3$	$\gamma_3 \Omega_4$	$\gamma_4 \Omega_5$	$\gamma_5 \Omega_6$	0.05 Ω_7	-	-	-	-
E-1*	-	-	-	-	-	-	0.1 Ω_7	$\gamma_7 \Omega_8$	$0.1\gamma_8\Omega_9$	$\gamma_8 \Omega_{10}$	$\gamma_9 \Omega_{11}$
E-2*	-	-	-	-	-	$0.1\Omega_6$	0.8 Ω_7	0.1 Ω_8	-	-	-
Stock structure hypothesis II (matrix B) [low mixing]											
Adult females (ages 10+)											
W*	1	-	-	-	-	-	-	-	-	-	-
C*	-	γ_1	γ_2	γ_3	γ_4	γ_5	-	-	-	-	-
E-1*	-	-	-	-	-	-	-	γ_7	$5\gamma_8$	$5\gamma_8$	γ_9
E-2*	-	-	-	-	-	-	1	-	-	-	-
Adult males (ages 10+) and juveniles											
W	Ω_1	-	-	-	-	-	-	-	-	-	-
C*	-	$\gamma_1 \Omega_2$	$\gamma_2 \Omega_3$	$\gamma_3 \backslash \Omega_4$	2 $\gamma_4 \Omega_5$	$\gamma_5 \Omega_6$	-	-	-	-	-
E-1*	-	-	-	-	-	-	-	$\gamma_7 \Omega_8$	$5\gamma_8 \Omega_9$	5 $\gamma_8 \Omega_{10}$	$\gamma_9 \Omega_{11}$
E-2*	-	-	-	-	-	-	Ω_7	-	-	-	-
Stock structure hypotheses III and IV [high mixing]											
Adult females (ages 10+)											
O*	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
Adult males (ages 10+) and juveniles											
O*	$\gamma_1 \Omega_1$	$\gamma_2 \Omega_2$	$\gamma_3 \Omega_3$	$\gamma_4 \Omega_4$	$\gamma_5 \Omega_5$	$\gamma_6 \Omega_6$	$\gamma_7 \Omega_7$	$\gamma_8 \Omega_8$	$\gamma_9 \Omega_9$	$\gamma_{10} \Omega_{10}$	$\gamma_{11} \Omega_{11}$

F. Generation of data

The actual historical estimates of absolute abundance (and their associated CVs) provided to the RMP are listed in Table 2. The proposed plan for future surveys is given in Table 3. The trials assume that it takes two years for the results of a sighting survey to become available for use by the RMP and *SLA*, i.e. a survey conducted in 2009 could first be used for setting the catch limit in 2011.

Table 2
The estimates of abundance and their sampling standard errors
[See Table 2 on p.118]

Table 3
Sighting survey plan.

	Country		
Season	Norway	Iceland	Greenland
2014	ES	-	-
2015	EW, CM*	CIC, CIP, CG	WG
2016	EB	-	-
2017	EN	-	-
2018	-	-	-
2019	-	-	-
2020	EW	-	-
2021	ES	-	-
2022	EB	CIC, CIP, CG, CM	-
2023	EN	-	-
2024	-	-	-
2025	-	-	WG

*CM to be covered as a NAMMCO joint effort in TNASS-2015.

The future estimates of abundance for a survey area (a sub-area for these trials) (say survey area E) are generated using the formula:

$$\hat{P} = P\,Y\,w/\mu = P^*\,\beta^2\,Y\,w \tag{F.1}$$

where:

Y is a lognormal random variable $Y=e^{\delta}$ where $\varepsilon \sim N(0;\sigma_\varepsilon^2)$ and $\sigma_\varepsilon^2 = \ell n(1+\alpha^2)$;

w is a Poisson random variable with $E(w)=\text{var}(w)=\mu=(P/P^*)/\beta^2$, Y and w are independent;

P is the current total (1+) population size in survey area E:

$$P = P_t^E = \sum_{k\in E}\sum_j V_t^{j,k} \sum_g \sum_{a\geq 1} N_{t,a}^{g,j} \tag{F.2}$$

P^* is the reference population level, and is equal to the total (1+) population size in the survey area prior to the commencement of exploitation in the area being surveyed; and

F is the set of sub-areas making up survey area E.

Note that under the approximation $CV^2(ab)=CV^2(a)+CV^2(b)$, $E(\hat{P})=P$ and $CV^2(\hat{P})= \alpha^2 + \beta^2P^*/P$. For consistency with the first stage screening trials for a single stock (IWC, 1991, p.109; 1994, p.85), the ratio $\alpha^2 : \beta^2 = 0.12 : 0.025$, so that:

$$CV^2(\hat{P}) = \tau(0.12 + 0.025P^*/P) \tag{F.3}$$

The value of τ is calculated from the survey sampling CV's of earlier surveys in area E. If $\overline{CV^2}$ is the average value of CV^2 estimated for each of these surveys, and $\overline{P}$ is the average value of the total (1+) population sizes in area E in the years of these surveys, then:

$$\tau = \overline{CV^2} / \left(0.12 + 0.025P/\overline{P}\right) \tag{F.4}$$

Note therefore that:

$$\alpha^2 = 0.12\tau \qquad \beta^2 = 0.025\tau \tag{F.5}$$

The above equations apply in the absence of additional variance. If this is present with a CV of CV_{add}, then the following adjustment is made:

$$\sigma_\varepsilon^2 = \ell n\left(1+\alpha^2+CV_{add}^2\right) \tag{F.6}$$

An estimate of the CV is generated for each sighting survey estimate of abundance $\hat{P}$:

$$CV\left(\hat{P}\right)_{est}^2 = \sigma^2\chi^2 / n \tag{F.7}$$

where $\sigma^2 = \ell n\left(1+\alpha^2+\beta^2 P^*/\hat{P}\right)$, and

χ^2 is a random number from a Chi-square distribution with n degrees of freedom, where n=10 as used for NP minke trials (IWC, 2004b).

G. Parameters and conditioning

The values for the biological and technological parameters are listed in Table 4.

Table 4a

The values for the biological parameters that are fixed.

Parameter	Value
Plus group age, *x*	20 years
Natural mortality, *M*	$M_a = \begin{cases} 0.085 & \text{if } a \le 4 \\ 0.0775 + 0.001875a & \text{if } 4 < a < 20 \\ 0.115 & \text{if } a \ge 20 \end{cases}$
Maturity (first parturition), β_a	a_{50}=8; δ=1.2
Maximum Sustainable Yield Level, *MSYL*	0.6 in terms of mature female component of the population

Table 4b

The values for the selectivity parameters by area.

Parameter	Value
West Medium Area (commercial)	$a_{50}^{g,k} = 5;\ \delta^{g,k} = 1.2$
West Greenland (aboriginal)	$a_{50}^{g,k} = 1;\ \delta^{g,k} = 1.2$
Central Medium Area	$a_{50}^{g,k} = 4;\ \delta^{g,k} = 1.2$
Eastern Medium Area	$a_{50}^{g,k} = 5;\ \delta^{g,k} = 1.2$

The ‘free’ parameters of the model above are the initial (pre-exploitation) sizes of each of the sub-stocks/stocks, and the values that determine the mixing matrices (i.e. the γ and Ω parameters). The process used to select the values for these ‘free’ parameters is known as conditioning. The conditioning process involves first generating 100 sets of ‘target’ data as detailed in steps (a), (b) and (c) 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 2013 to obtain values of abundance etc. for comparison with the generated data.

The information used in the conditioning process is as follows.

(a) The ‘target’ values for the historical abundance by sub-area are generated using the formula:

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

where:

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 (Table 2); and

σ_t^k is the CV of O_t^k .

(b) The ‘target’ values for the sex-ratios by sub-area during July are obtained by assigning sex ratios to each sub-area and year for which the actual sex-ratio is non-zero by sampling sex-ratios for July with replacement for that sub-area.

(c) The 'target' values for the sex-ratios by sub-area when catches take place are obtained by assigning sex ratios to each sub-area and year by sampling with replacement from those for 2008-12, and computing an overall sex ratio by weighting each resampled sex-ratio by the annual catch.

The likelihood function consists of two components.

(a) Abundance estimates

$$L_1 = 0.5\sum_k \sum_t \frac{1}{(\sigma_t^k)^2}\left(P_t^k / \hat{P}_t^k\right)^2 \tag{G.2}$$

where:

$\hat{P}_t^k$ is the model estimate of the number of animals aged 1 and older at the start of year *t*.

(b) Catch sex ratio

$$L_2 = \frac{1}{2(\sigma^{1,k})^2}\sum_k (\hat{\lambda}^k - \lambda^k)^2 \tag{G.3}$$

where:

λ^k is the observed catch sex-ratio (proportion of females) for sub-area *k*;

$\hat{\lambda}^k$ is the model-estimate of the sex-ratio:

$$\hat{\lambda}^k = \sum_t (C_t^{\mathrm{m},k} + C_t^{\mathrm{f},k}) \frac{\sum_a \sum_j V_{t,a}^{\mathrm{f},j,k} S_a^{\mathrm{f}} N_{t,a}^{\mathrm{f},j}}{\sum_g \sum_a \sum_j V_{t,a}^{g,j',k} S_{a'}^{g} N_{t,a'}^{g,j'}} \Big/ \sum_{t'} (C_{t'}^{\mathrm{m},k} + C_{t'}^{\mathrm{f},k}) \tag{G.4}$$

$\sigma^{1,k}$ is the between-year variation in catch sex-ratios for sub-area *k*.

(c) Sex ratio during sighting surveys

$$L_3 = \frac{1}{2(\sigma^{2,k})^2}\sum_k (\hat{\lambda}^k - \lambda^k)^2 \tag{G.5}$$

where:

λ^k is the observed catch sex-ratio (proportion of females) for sub-area *k* during July:

$\hat{\lambda}^k$ is the model-estimate of the sex-ratio:

$$\hat{\lambda}^k = \frac{\sum_a \sum_j V_{-\infty,a}^{\mathrm{f},j,k} N_{-\infty,a}^{\mathrm{f},j}}{\sum_g \sum_a \sum_j V_{-\infty,a}^{g,j',k} N_{-\infty,a'}^{g,j'}} \tag{G.6}$$

$\sigma^{2,k}$ is the between-period variation in the July catch sex-ratios for sub-area *k*.

H. Trials

The *Implementation Simulation Trials* for the North Atlantic minke whales are listed in Table 5.

Table 5

The *Implementation Simulation Trials* for North Atlantic minke whales.

Trial no.	Stock hyp-othesis	*MSYR*	No. of Stocks	Boundaries	Catch sex-ratio for selectivity	Sex ratio in sub-areas ES, EB and WG, CM	Trial weight	Notes
NM01-1	I	1%[1]	3	Baseline	2008-12	Baseline		3 stocks, E and W with sub-stocks
NM01-4	I	4%[2]	3	Baseline	2008-12	Baseline		3 stocks, E and W with sub-stocks
NM02-1	II	1%[1]	2	Baseline	2008-12	Baseline		2 stocks, E with sub-stocks
NM02-4	II	4%[2]	2	Baseline	2008-12	Baseline		2 stocks, E with sub-stocks
NM03-1	III	1%[1]	1	Baseline	2008-12	Baseline		1 stock
NM03-4	III	4%[2]	1	Baseline	2008-12	Baseline		1 stock
NM04-1	IV	1%[1]	2	Baseline	2008-12	Baseline		2 cryptic stocks
NM04-4	IV	4%[2]	2	Baseline	2008-12	Baseline		2 cryptic stocks
NM05-1	I	1%[1]	3	Stock C not in ESW	2008-12	Baseline		3 stocks, E and W with sub-stocks
NM05-4	I	4%[2]	3	Stock C not in ESW	2008-12	Baseline		3 stocks, E and W with sub-stocks
NM06-1	II	1%[1]	2	Stock C not in ESW	2008-12	Baseline		2 stocks, E with sub-stocks
NM06-4	II	4%[2]	2	Stock C not in ESW	2008-12	Baseline		2 stocks, E with sub-stocks
NM07-1	I	1%[1]	3	Baseline	**2002-07**	Baseline		Alternative years to adjust selectivity-at-age
NM07-2	I	4%[2]	3	Baseline	**2002-07**	Baseline		Alternative years to adjust selectivity-at-age
NM08-1	I	1%[1]	3	Baseline	2008-12	Half baseline		Lower proportion of males in the northern areas
NM08-2	I	4%[2]	3	Baseline	2008-12	Half baseline		Lower proportion of males in the northern areas

1-1+; 2-mature.

I. Management options

The following management variants will be considered:

V1 [Status-quo-like] Catch limits for sub-area WG are based on an *SLA*; sub-areas CIC, CM, EN, EB, ES and EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Medium Areas*. The catch limits set for the CG and CIP *Small Area* are not taken; sub-area WC is a *Residual Area*.

V2 Sub-areas CIC, CM, EN and EB+ES+EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Medium Areas*. The catch from the EB+ES+EW *Small Area* is all taken from the EW sub-area. The catch limits set for the CG and CIP *Small Areas* are not taken; sub-area WC is a *Residual Area*.

V3 Sub-areas CIC, CM, EN, ES, and EB+EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Medium Areas*. The catch from the EB+ EW *Small Area* is all taken from the EW sub-area. The catch limits set for the CG and CIP *Small Areas* are not taken; sub-area WC is a *Residual Area*.

V4 As for V1, except that sub-areas CIC, CIP and CM as one *Small Area* and all of the catches are taken in the CIC sub-area.

V5 As for V1, except that sub-areas CIP, CIC, CG and CM are one *Small Area* and all of the catches are taken in the CIC sub-area.

J. Output statistics

The population-size statistics are produced for each feeding ground and stock, while the catch-related statistics are for each sub-area.

(1) Total catch (TC) distribution: (a) median; (b) 5th value; (c) 95th value.
(2) Initial mature female population size (P_{initial}) distribution: (a) median; (b) 5th value; (c) 95th value.
(3) Final mature female population size (P_{final} distribution: (a) median; (b) 5th value; (c) 95th value.
(4) Lowest mature female population size (P_{lowest}) distribution: (a) median; (b) 5th value; (c) 95th value.
(5) Average catch by sub-area over the first ten years of the 100 year management period: (a) median; (b) 5th value; (c) 95th value.
(6) Average catch by sub-area over the last ten years of the 100 year management period: (a) median; (b) 5th value; (c) 95th value.

K. References

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Appendix 6

ABUNDANCE ESTIMATES AGREED BY THE SCIENTIFIC COMMITTEE FOR USE IN THE *CLA*[2]

The following tables list the accepted abundance estimates used in the RMP context for: (i) North Atlantic fin whales; (ii) North Atlantic minke whales; (iii) western North Pacific minke whales; and (iv) North Pacific Bryde's whales. The abundance estimates are provided not for populations but for subareas, given consideration of existing multiple stock structure hypotheses.[2] Abbreviations used as follows:

Category

(1) acceptable for use in in-depth assessments or for providing management advice;
(2) underestimate - suitable for 'conservative' management but not reflective of general abundance; or
(3) while not acceptable for use as in (1), adequate to provide a general indication of abundance. Provisional estimates are included as Category (3).

Evaluation extent

(1) estimate was examined in detail by the sub-group;
(2) estimate was partially examined by the sub-group but method standard;
(3) degree to which the estimate was considered by the sub-group is unclear but method standard;
(4) estimate was partially considered by the sub-group and a new method was used; and
(5) degree to which the estimate was considered by the sub-group is unclear and a new method was used.

Status

Status in RMP trials. 'I' agreed to be suitable for use in a real *Implementation*; 'C' or 'C_{min}': used in the trial conditioning as an absolute or minimum estimate of abundance, respectively; 'C_P': provisional estimate suitable for use in conditioning but further analysis needs to be considered before use in an actual *CLA* calculation; 'T' used in RMP trials but further analysis needs to be considered before use in an actual *CLA* calculation; 'No' no acceptable estimate available/possible.

Method

'DS' distance-sampling; 'LT' line transect; 'CC' Cue counting; 'MR' mark-recapture; 'SM' spatial modelling; 'PA' population assessment, 1+

Corrected

Indicates if corrected for availability and/ or perception bias (A, P or A+P); '-' not corrected.

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[2] While, as stated in Item 3.6.1, Allison did update this Appendix during the remainder of the meeting, it proved impossible to complete this task during that period. This Appendix should therefore be considered as a work in progress for further review during the 2015 Annual Meeting of the Scientific Committee.

Table 1a

North Atlantic fin whales.

North Atlantic fin whale abundance estimates came from shipboard surveys in 1988 (Buckland *et al.*, 1992a), 1995 (Borchers and Burt, 1997), 2001 (Gunnlaugsson *et al.*, 2002) and 2007 (Pike *et al.*, 2008) were discussed and summarised in Wade (2009) and IWC (2010a).

Sub-area	Cat.	Eval. ext.	Status	Year	Meth.	Corr.	Estimate	CV	Approx. 95% CI	Reference	Notes
EC	-	-	-	1965-72	MR	-	10,818	0.36	5,340-21,900	IWC (1992a, p.600); Cooke (1992)	-
(EC)	-	-	-	1999	-	-	2,814	0.21	1,860-4,240	Wade (2009)	Georges Bank to mouth of Gulf of St. Lawrence.
(EC)	-	-	-	2002	-	-	2,933	0.49	1,120-7,660	Wade (2009)	S Gulf of Maine to Maine.
(EC)	-	-	-	2004	-	-	1,925	0.55	650-5,650	Wade (2009)	Gulf of Maine to lower Bay of Fundy.
(EC)	-	-	-	2006	-	-	2,269	0.37	1,090-4,680	Palka, pers. comm.; Wade (2009)	S Gulf of Maine - upper Bay of Fundy - Gulf of St. Lawrence.
(EC)	-	-	-	2007	-	-	-	-	-	-	US waters.
EC	3	-	C	2007	-	-	10,105	0.4	4,610-22,130	Lawson (2006)	Lawson's estimate for Newfoundland waters is used rather than an uncorrected estimate of 2,808, CV=0.302.
WG		1	C	1987/88	CC	-	1,096	0.35	560-2,130	IWC (1992a, p.606); IWC (1993, p.75)	Revised from IWC (1992b, p.70, p.200) and Hiby *et al.* (1989) to use revised blow rate estimate.
WG	1	1	C	2005	LT	P	3,234	0.44	1,400-7,400	Heide-Jørgensen *et al.* (2008); IWC (2008, p.126)	Revised from Heide-Jørgensen *et al.* (2007) and IWC (2008 pp.125-26). Potential negative bias as no adjustment for availability bias.
WG	1	1	I,C	2007	LT	-	4,359	0.45	1,900-10,100	Heide-Jørgensen *et al.* (2010); IWC (2010b; p.23)	Negatively biased (no correction for whales submerged during passage of the survey plane). See IWC (2009, p.12) for status.
EG	1	1	I,C	1987-89	LT	-	5,269	0.221	3,410-8,120	Pike and Gunnlaugsson (2006); Wade (2009)	Averaged value using 1987 and 1989 estimates.
EG	1	1	I,C	1995	LT	-	8,412	0.288	4,780-14,790	Pike and Gunnlaugsson (2006)	Sum of A-East and B-East.
EG	1	1	I,C	2001	LT	-	11,706	0.194	8,000-17,120	Pike and Gunnlaugsson (2006)	Sum of A-East and B-East.
EG	1	1	I,C	2007	LT	-	12,215	0.2	8,250-18,070	Pike *et al.* (2008)	-
WI	1	1	I,C	1988	LT	-	4,243	0.229	2,700-6,640	Pike and Gunnlaugsson (2006); Wade (2009)	Averaged value using 1987 and 1989 estimates.
WI	1	1	I,C	1995	LT	-	6,800	0.218	4,430-10,420	Pike and Gunnlaugsson (2006)	Sum of A-East (very low coverage) and B-East.
WI	1	1	I,C	2001	LT	-	6,565	0.194	4,480-9,600	Pike and Gunnlaugsson (2006)	Sum of A-East and B-East.
WI	1	1	I,C	2007	LT	-	8,118	0.26	4,870-13,510	Pike *et al.* (2008)	-
EI/F	1	1	I,C	1987/8	LT	-	5,261	0.277	3,050-9,050	Christensen *et al.* (1992), Wade (2009); Pike and Gunnlaugsson (2006); Øien (1990)	Averaged value using 1987 and 1988 estimates.
EI/F	-	-	-	1989	-	-	-	-	-	Christensen *et al.* (1992)	Not used: survey did not go N of Iceland.
EI/F	1	1	I,C	1995	LT	-	6,647	0.288	3,770-11,680	Øien (2003); Pike and Gunnlaugsson (2006)	Sum of EGI+WN-SPB (NASS) and NVN+JMC (Øien) blocks.
EI/F	1	1	I,C	2001	LT	-	7,490	0.255	4,540-12,340	Wade (2009); Pike and Gunnlaugsson (2006)	Coverage of WN-SPB block did not go as far South as in previous years.
EI/F	1	1	I,C	2007	LT	-	1,613	0.26	960-2,680	Pike *et al.* (2008)	-
N	-	-	No	1988	-	-	-	-	-	-	Estimates not available without further analysis.
N	-	-	C	1995	LT	-	3,964	0.21	2,620-5,980	Wade (2009)	Skaug based on Øien (2003).
N	-	-	C	1999	LT	-	3,749	0.24	2,340-6,000	Wade (2009)	Skaug based on Øien (2003).
Sp	-	-	-	1982	-	-	1,696	0.27	990-2,870	Mizroch and Sanpera (1984)	Covered a smaller area than in 1989 so not used in RMP trials.
Sp	-	-	-	1987	-	-	4,617	0.098	3,800-5,600	IWC (1992a, p.600)	Revised from Sanpera and Jover (1989). Covered a smaller area than in 1989 (~½) so not used in RMP trials.
Sp	-	-	C	1989	LT	-	17,355	0.265	10,400-28,900	IWC (1992a, p.606); IWC (1993, p.67); Buckland *et al.* (1992b)	42-52°S, extending out to 25°W.
Sp	-	-	-	1993	-	-	7,507	0.15	5,600-10,100	Goujon *et al.* (1995)	Survey designed primarily for small cetaceans, thought to cover a small area so not used in RMP trials.
Med	-	-	-	1991	LT	-	3,583	0.27	2,100-6,000	Forcada *et al.* (1996); Notarbartolo di Sciara *et al.* (2003)	Estimate for the western basin portion of the Mediterranean, where most of the population is found.

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Table 1b

North Atlantic minke whales. The table includes the sub-area, category, evaluation extent, status, year, method and correction.

Sub-area	Cat.	Eval. ext.	Status	Year	Meth.	Corr.	Estimate	CV	Approx. 95% CI	Reference	Notes
EB	1	1	I,C	1989	LT	A+P	21,868	0.21	14,600-32,730	Bøthun and Øien (2011); IWC (2011, p.95)	-
EB	1	1	I,C	1995	LT	A+P	29,712	0.18	20,830-42,360	Bøthun and Øien (2011); IWC (2011, p.95)	-
EB	1	1	I,C	2000	LT	A+P	25,885	0.24	16,160-41,450	Bøthun and Øien (2011); IWC (2011, p.95)	-
EB	1	1	I,C	2007	LT	A+P	28,625	0.23	18,080-45,310	Bøthun and Øien (2011); IWC (2011, p.95)	CV=0.26 in Bøthun *et al.* (2009): see*.
EB	3	-	C_P	2013	LT	-	27,336	0.24	17,070-43,750	Solvang *et al.* (2014)	Preliminary estimate; CV=highest hist. value in EB.
EN	1	1	I,C	1989	LT	A+P	8,318	0.25	5,050-13,680	Bøthun and Øien (2011); IWC (2011, p.95)	-
EN	1	1	I,C	1995	LT	A+P	22,536	0.23	14,250-35,620	Bøthun and Øien (2011); IWC (2011, p.95)	-
EN	1	1	I,C	1998	LT	A+P	13,673	0.25	82,90-22,520	Bøthun and Øien (2011); IWC (2011, p.95)	-
EN	1	1	I,C	2004	LT	A+P	6,246	0.47	2,500-15,570	Bøthun and Øien (2011); IWC (2011, p.95)	CV=0.48 in Bøthun *et al.* (2009): see*.
EN	3	-	C_P	2009	LT	-	8,867	0.47	3,520-22,270	Solvang *et al.* (2014)	Preliminary estimate; CV= highest historical value in EN.
ES	1	1	I,C	1989	LT	A+P	13,070	0.13	10,130-16,860	Bøthun and Øien (2011); IWC (2011, p.95)	-
ES	1	1	I,C	1995	LT	A+P	24,891	0.10	20,620-30,040	Bøthun and Øien (2011); IWC (2011, p.95)	-
ES	1	1	I,C	1999	LT	A+P	17,406	0.14	13,200-22,940	Bøthun and Øien (2011); IWC (2011, p.95)	-
ES	1	1	I,C	2003	LT	A+P	19,377	0.28	11,290-33,230	Bøthun and Øien (2011); IWC (2011, p.95)	CV=0.33 in Bøthun *et al.* (2009): see*.
ES	3	-	C_P	2008	LT	-	26,211	0.28	15,140-45,370	Solvang *et al.* (2014)	Preliminary estimate; CV=highest hist. value in ES.
EW	1	1	I,C	1989	LT	A+P	20,991	0.17	15,060-29,240	Bøthun and Øien (2011); IWC (2011, p.95)	-
EW	1	1	I,C	1995	LT	A+P	34,986	0.12	27,900-43,850	Bøthun and Øien (2011); IWC (2011, p.95)	-
EW	1	1	I,C	1996	LT	A+P	23,522	0.13	18,290-30,230	Bøthun and Øien (2011); IWC (2011, p.95)	-
EW	1	1	I,C	2006	LT	A+P	27,152	0.218	17,710-41,610	Bøthum *et al.* (2009); Bøthun and Øien (2011); IWC (2011, p.95)	-
EW	3	-	C_P	2011	LT	-	20,158	0.22	13,090-31,020	Solvang *et al.* (2014)	Preliminary estimate; CV=highest hist. value in EW.
CM	1	1	I,C	1988	LT	-	4,732	0.23	3,020-7,410	IWC (2009, p.135)	Combination of estimates: 5,609, CV=0.26 (Øien, 2000) and 1988-89: 2,650, CV=0.48 (Schweder *et al.*, 1997, no NVS).
CM	-	1	**No**	1995	LT	-	[6,174]	0.36	-	Bøthun and Øien (2011) and IWC (2009, p.135) from Schweder *et al.* (1997)	No NVS. 12,043 estimate had better areal coverage.
CM	1	1	I,C	1995	LT	-	12,043	0.28	6,950-20,840	IWC (2009, p.135) from Borchers *et al.* (1998)	Combined Norway and Iceland.
CM	1	1	I,C	1997	LT	A+P	26,718	0.14	20,300-35,150	Bøthun and Øien (2011), IWC (2009, p.135) from Skaug *et al.* (2004)	-
CM	1	1	I,C	2005	LT	A+P	26,739	0.39	12,450-57,420	Bøthun and Øien (2011); Bøthum *et al.* (2009)	Update to 24,890, CV=0.45, in IWC (2009, p.135).
CM	3	-	C_P	2010	LT	-	11,249	0.39	5,230-24,150	Solvang *et al.* (2014)	Preliminary estimate; CV=highest hist. value in CM.
CIC	1	1	I,C	1987	CC	A+P	24,532	0.32	12,990-46,290	IWC (2009, p.135); Borchers *et al.* (2008)	-
CIC	-	-	**No**	1995	CC	-	-	-	-	Not estimated; Borchers *et al.* (1997)	-
CIC	1	1	I,C	2001	CC	A+P	43,633	0.19	3,0060-63,320	IWC (2009, p.135); Borchers *et al* (2008)	-
CIC	1	1	I,C	2007	CC	A+P	20,834	0.35	10,490-41,370	IWC (2014), Appendix 5; Pike *et al.* (2011)	Replaces 10,680 (0.29) agreed IWC (2009, pp.135-37).
CIC	1	1	I,C	2009	CC	A+P	9,588	0.24	5,990-15,340	IWC (2014), Appendix 5; Pike *et al.* (2011)	-
CIP	1	1	I,C	1987-89	LT	-	8,431	0.245	5,210-13,620	IWC (1993, p.66, pp.128-29)	Used as a minimum estimate: no *g*(0) correction.
CIP	1	1	I,C	2001	LT	-	3,391	0.82	670-16,910	Gunnlaugsson *et al.* (2003)	Used as a minimum estimate: no *g*(0) correction.
CIP	1	1	I,C	2007	LT	-	1,350	0.38	640-2,840	SC/2009 (TNASS), IWC (2011, p.95)	-
CG	1	1	I,C	1987	LT	-	1,555	0.26	930-2,580	IWC (1993, p.66, pp.128-29)	Used as a minimum estimate: no *g*(0) correction.
CG+CIP	1	1	I,C	1995	LT	-	4,854	0.27	2,850-8,240	Pike *et al.* (2002), IWC (2009, p.135)	Used as a minimum estimate: no *g*(0) correction.
CG	1	1	I,C	2001	LT	-	7,349	0.31	4,000-13,490	Gunnlaugsson *et al.* (2003)	Blocks Bx and Wx. Used as a minimum estimate: no *g*(0) correction.
CG	1	1	I,C	2007	LT	-	1,048	0.60	320-3,390	SC/2009 (TNASS), IWC (2011), p.95.	-

Cont.

Sub-area	Cat.	Eval. ext.	Status	Year	Meth.	Corr.	Estimate	CV	Approx. 95% CI	Reference	Notes
WG	2	1	C_{min}	1987-8	DS	-	3,266	0.31	1,770-5,990	IWC (2009, p.135); IWC (1990, p.43)	Partial coverage of area.
WG	2	-	C_{min}	1993	DS	A	8,371	0.43	3,600-19,440	IWC (2009, p.135); Larsen (1995)	Known not to cover all of population. Reanalysed by Hedley *et al.* (1997): 6,385, CV=0.411.
WG	2	-	C_{min}	2005	DS	A+P	10,792	0.59	3,600-32,400	IWC (2008, p.126); Heide-Jørgensen *et al.* (2008)	Known not to cover all of population.
WG	2	-	C_{min}	2007	DS	A+P	16,609	0.428	7,200-38,500	IWC (2012, p.130); Heide-Jørgensen *et al.* (2010)	Known not to cover all of population. See IWC (2010, pp.138-39) for discussion of method.
WC	-	-	C	2007	DS	-	20,741	0.30	11,520-37,340	NOAA, 2012 (Lawson, DFO, pers. comm.)	From NASS2007

*Bøthum and Øien (2011) recalculated the 1989 and 1995 estimates and associated CVs for the revised sub-areas; the CVs for the 2003-07 period were also recalculated using the same method: they differ from those in Bøthun *et al.* (2009) that were calculated using a simulation approach. The CVs from Bøthum and Øien (2011) are used here as they are comparable with those from earlier years. See also IWC (2009, p.135) for three other estimates for parts of the WC sub-area.

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Table 1c

Western North Pacific minke whales.
If not otherwise stated, the abundance estimates are given under the assumption of $g(0)=1$. Additional estimates are available but it was agreed they would not be used in the 2013 trials so they are not included here (for details see IWC (2012), pp.422-23; pp.451-53).
See IWC (2014b) pp.126-27 and pp.181-88 for further details.

Sub-area	Cat.	Evaln. extent	Status	Year	Method	Corrected	Estimate and approx. 95% CI or equivalent	IWC reference	Original reference	Comments
6E	1	1	I,C	2003	LT	P	940 (470-1,840)	IWC (2014c)	Miyashita *et al.* (2009)	-
6E	1	1	I,C	2004	LT	P	730 (360-1,470)	IWC (2014c)	Miyashita *et al.* (2009)	-
10W	1	1	I,C	2006	LT	P	2,480 (1,360-4,500)	IWC (2014c)	Miyashita and Okamura (2011)	*g*(0)-corrected estimate 3,400 (2,600-4,400) Okamura *et al.* (2010)
10E	1	1	I,C	2002	LT	P	820 (250-2,640)	IWC (2014c)	Miyashita *et al.* (2009)	-
10E	1	1	I,C	2003	LT	P	410 (140-1,140)	IWC (2014c)	Miyashita *et al.* (2009)	-
10E	1	1	I,C	2005	LT	P	600 (260-1,370)	IWC (2014c)	IWC (2014a, pp504-6)	-
7WR	1	1	I,C	2004	LT	P	860 (270-2,750)	IWC (2014c)	Hakamada and Kitakado (2010)	-
7E	1	1	I,C	2004	LT	P	440 (110-1,700)	IWC (2014c)	Hakamada and Kitakado (2010)	-
7E	1	1	I,C	2006	LT	P	250 (60-1,110)	IWC (2014c)	Hakamada and Kitakado (2010)	-
8	1	1	I,C	1990	LT	P	1,060 (300-3,680)	IWC (2014c)	IWC (2004, p.124); IWC (1997, p.20)	-
8	1	1	I,C	2002	LT	P	0	IWC (2014c)	Hakamada and Kitakado (2010)	-
8	1	1	I,C	2004	LT	P	1,090 (380-3,120)	IWC (2014c)	Hakamada and Kitakado (2010)	-
8	1	1	I,C	2006	LT	P	310 (90-1,030)	IWC (2014c)	Hakamada and Kitakado (2010)	-
9	1	1	I,C	1990	LT	P	8,300 (3,900-17,500)	IWC (2014c)	IWC (2004, p.124); IWC (1997, p.203, 211)	-
9	1	1	I,C	2003	LT	P	2,550 (1,500-4,330)	IWC (2014c)	Hakamada and Kitakado (2010)	-
9N	1	1	I,C	2005	LT	P	420 (90-2,070)	IWC (2014c)	Miyashita and Okamura (2011)	*g*(0)-corrected estimate 2,080 (1,600-2,600) for SA 8+9+12, Okamura *et al.* (2010)
11	1	1	I,C	1990	LT	P	2,120 (920-4,910)	IWC (2014c)	IWC (2004, p.124); IWC (1997, p.203, 211).	-
11	1	1	I,C	1999	LT	P	1,460 (520-4,090)	IWC (2014c)	IWC (2004, p.124); IWC (2003, p.470-72)	-
5	2	1	C_{min},T	2001	LT	P	1,530 (590-4,020)	IWC (2014c)	An *et al.* (2010)	13% area coverage
5	2	1	C_{min},T	2004	LT	P	800 (430-1,480)	IWC (2014c)	An *et al.* (2010)	13% area coverage
5	2	1	C_{min},T	2008	LT	P	680 (340-1,380)	IWC (2014c)	An *et al.* (2010)	13% area coverage
5	2	1	T	2011	LT	P	590 (270-1,260)	IWC (2014c)	Park *et al.* (2012)	13% area coverage
6W	2	1	C_{min},T	2000	LT	P	550 (250-1,210)	IWC (2014c)	An *et al.* (2010)	14% area coverage
6W	2	1	C_{min},T	2002	LT	P	390 (130-1,180)	IWC (2014c)	An *et al.* (2010)	14% area coverage
6W	2	1	C_{min},T	2003	LT	P	490 (250-930)	IWC (2014c)	An *et al.* (2010)	14% area coverage
6W	2	1	C_{min},T	2005	LT	P	340 (180-620)	IWC (2014c)	An *et al.* (2010)	14% area coverage
6W	2	1	C_{min},T	2006	LT	P	460 (180-1,190)	IWC (2014c)	An *et al.* (2010)	14% area coverage
6W	2	1	C_{min},T	2007	LT	P	570 (250-1,300)	IWC (2014c)	An *et al.* (2010)	14% area coverage
6W	2	1	C_{min},T	2009	LT	P	880 (510-1,530)	IWC (2014c)	An *et al.* (2010)	14% area coverage
6W	2	1	T	2010	LT	P	1,010 (480-2,150)	IWC (2014c)	An *et al.* (2011)	14% area coverage
6E	2	1	C,T	2002	LT	P	890 (300-2,670)	IWC (2014c)	Miyashita *et al.* (2009)	Poor coverage and analysis difficulties
7CS	2	1	T	1991	LT	P	0	IWC (2014c)	Butterworth and Miyashita (2014)	-
7CS	2	1	C,T	2004	LT	P	500 (290-880)	IWC (2014c)	IWC (2014a, p492-6, 504-6)	-
7CS	2	1	C,T	2006	LT	P	3,700 (600-23,500)	IWC (2014c)	Hakamada and Kitakado (2010)	Non-random start
7CS	2	1	T	2012	LT	P	890 (420-1,870)	IWC (2014c)	Hakamada *et al.* (2013)	-
7CN	2	1	T	1991	LT	P	850 (550-1,330)	IWC (2014c)	Butterworth and Miyashita (2014)	-
7CN	2	1	T	2012	LT	P	300 (130-710)	IWC (2014c)	Hakamada *et al.* (2013)	-
7CN	2	1	T	2012	LT	P	400 (160-1,020)	IWC (2014c)	Hakamada *et al.* (2013)	-
7WR	2	1	T	1991	LT	P	310 (200-490)	IWC (2014c)	Butterworth and Miyashita (2014)	-
7WR	2	1	C_{min},T	2003	LT	P	270 (80-920)	IWC (2014c)	IWC (2014a, p492-6, 504-6)	27% coverage

Cont.

Sub-area	Cat.	Evaln. extent	Status	Year	Method	Corrected	Estimate and approx. 95% CI or equivalent	IWC reference	Original reference	Comments
7WR	2	1	C,T	2007	LT	P	550 (110-2,640)	IWC (2014c)	Hakamada and Kitakado (2010)	Non-random start
7E	2	1	C,T	2007	LT	P	0	IWC (2014c)	Hakamada and Kitakado (2010)	Non-random start etc.
8	2	1	C,T	2005	LT	P	130 (24-710)	IWC (2014c)	Hakamada and Kitakado (2010)	Non-random start etc.
8	2	1	C,T	2007	LT	P	390 (80-2,030)	IWC (2014c)	Hakamada and Kitakado (2010)	Non-random start etc.
11	2	1	C,T	2003	LT	P	880 (220-3,600)	IWC (2014c)	Miyashita and Okamura (2011)	*g*(0)-corrected estimate 42,100 (32,700-54,200) in SA 11+12SW+12NE Okamura *et al.* (2010)
11	2	1	C_{min},T	2007	LT	P	380 (180-790)	IWC (2014c)	Miyashita and Okamura (2011)	20% coverage. *g*(0)-corrected estimate 500 (250-1,000) in SA11. Okamura *et al.* (2010)
12SW	2	1	C,T	1990	LT	P	5,240 (1,300-21,000)	IWC (2014c)	IWC (2004, p.124)	-
12SW	2	1	C,T	2003	LT	P	3,400 (1,570-7,350)	IWC (2014c)	Miyashita and Okamura (2011)	*g*(0)-corrected estimate 42,100 (32,700-54,200) in SA 11+12SW+12NE Okamura *et al.* (2010)
12NE	2	1	C,T	1990	LT	P	10,400 (5,200-20,800)	IWC (2014c)	IWC (2004, p.124)	-
12NE	2	1	C,T	1992	LT	P	11,500 (5,620-23,700)	IWC (2014c)	IWC (2004, p.124)	-
12NE	2	1	T	1999	LT	P	5,100 (2,500-10,400)	IWC (2014c)	IWC (2014a, pp.492-6, 504-6)	-
12NE	2	1	C,T	2003	LT	P	13,100 (7,500-22,700)	IWC (2014c)	Miyashita and Okamura (2011)	*g*(0)-corrected estimate 42,100 (32,700-54,200) in SA 11+12SW+12NE Okamura *et al.* (2010)
10E	3	1	C	2004	LT	P	470 (180-1,270)	IWC (2014c)	Miyashita *et al.* (2009)	Design questioned
10E	3	1	C	2007	LT	P	580 (310-1,070)	IWC (2014c)	Miyashita *et al.* (2009)	-
7CN	3	1	C	2003	LT	P	180 (50-740)	IWC (2014c)	Hakamada and Kitakado (2010)	Problem in coverage
7E	3	1		1990	LT	P	790 (70-8,620)	IWC (2014c)	IWC (2004, p.124)	CV too high to be meaningful

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Table 1d

Western North Pacific Bryde's whales.

Area	Cat.	Evaln. extent	Status	Year	Meth.	Corr.	Estimate	CV	95% CI	Reference	Abundance date stamp
1W	1	1	I, C	1998-2002	LT		4,957	0.398	2,270-10,810	IWC (2009, pp.6-7); Kitakado *et al.* (2009); Shimada *et al.* (2009)	2000
1E	1	1	I, C	1998-2002	LT		11,213	0.498	4,220-29,750	As for 1W	1999
2	1	1	I, C	1998-2002	LT		4,331	0.553	1,460-12,800	As for 1W	2002

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