Annex D

Report of the Sub-Committee on the Revised Management Procedure (RMP)

Members: Bannister (Convenor), Acquarone, Allison, An, Baba, Baker, Bjørge, Borodin, Brandão, Brandon, Breiwick, Brownell, Butterworth, Campbell, Castellote, Childerhouse, Chilvers, Choi, Cipriano, Collins, Cooke, de Moor, Donoghue, Donovan, Edwards, Elvarsson, Ensor, Fujise, Funahashi, Gallego, Goodman, Gunnlaugsson, Hakamada, Hammond, Hatanaka, Holloway, Iñíguez, Jaramillo Legorreta, Kanda, Kelly, Kitakado, Koski, Leaper, Lens, Lockyer, Luna, Lusseau, Lyrholm, Matsuoka, Miyashita, Morishita, Muller, Murase, Øien, Okada, Okamura, Palka, Pampoulie, Panigada, Pastene, Punt, Robbins, Roel, Rojas-Bracho, Skaug, Uoya, Uozumi, Vazquez, Víkingsson, Wade, Walløe, Witting, Yamakage, Yasokawa, Yoshida, Zerbini.

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. Víkingsson proposed to add an agenda item on North Atlantic sei whales to discuss the proposal detailed in SC/62/RMP2. The Chair ruled that this item be deferred, given the length of the agenda and because North Atlantic sei whales were not referred to in IWC/62/7rev.

1.4 Available documents

The documents considered by the sub-committee were SC/62/RMP1, SC/62/RMP3-8, SC/62/RMP10, SC/62/Rep2, SC/62/O1 and relevant extracts from past reports of the Committee.

2. REVISED MANAGEMENT PROCEDURE (RMP) – GENERAL ISSUES

2.1 Review MSY rates

2.1.1 Report of the Intersessional Workshop

The Third Intersessional Workshop on the Review of MSYR for Baleen Whales was held at the School of Aquatic and Fishery Sciences, University of Washington, Seattle (20–24 April 2010). Donovan summarised its report which is given as SC/62/Rep2.

The Committee has been discussing the maximum sustainable yield rate (MSYR) issue for some time in the context of a general reconsideration of the plausible range to be used in population models used for testing the *Catch Limit Algorithm* (*CLA*) of the RMP. At present this range is 1% to 7% when expressed in terms of the mature component of the population. As part of the review process, information on observed population growth rates at low population sizes is being considered; Cooke (2007) noted that in circumstances where variability and/or temporal autocorrelation in the effects of environmental variability on population growth rates is high, simple use of such observed population growth rates could lead to incorrect inferences being drawn concerning the lower end of the range of plausible values for MSYR. The aim of the Third Workshop was to examine whether the observed levels of variation in baleen whale reproduction and annual survival rate parameters were sufficiently large that biases of the nature identified from population models incorporating environmentally-induced variability might be of concern.

The Chair expressed thanks to the scientists who had generously provided the data for consideration, many of whom attended the Workshop. A summary of the data received can be found in SC/62/Rep2, table 1. Detailed descriptions of the datasets can also be found in SC/62/Rep2. It is important to note that few data were available to inform on survival rate variation and this requires further consideration. After inspection of the datasets, a subset ('calving proportion indices' and 'calving interval estimates') was selected for further analysis (and see table 2 of SC/62/Rep2).

As a first step in the analytical work required to assist in addressing the objective of the Workshop, an approach was developed and followed to estimate the coefficient of variation (CV) and temporal autocorrelation for the time series of calving proportion index and calving interval data discussed above, recognising that this ignores observation error and thus results in positively biased estimates. This information (modified appropriately – see SC/62/Rep2) provides input for a method (see Annex D of SC/62/Rep2) developed to relate variability in calving proportion to variability in the annual growth rate of a population using a population dynamics model. The Annex D model is tuned by adjusting the input CV and temporal autocorrelation estimates in table 4 of SC/62/Rep2 upwards until the corresponding model outputs for these quantities match those in the table, i.e. until the variability simulated by the model matches that observed in the field. The model then outputs the CV and temporal autocorrelation to be expected in the growth of the population from year to year.

The Workshop identified two further steps needed before such results can be used to draw inferences about the plausible ranges for the CV and temporal autocorrelation parameters describing the effects of environmental variability on population dynamics in the model of Cooke (2007). These were incorporated into the work plan and are discussed under Item 2.1.2 of this report.

As noted above, although few data are available, environmentally-induced variability in population abundance can arise also from variation in the annual survival rate, and the Annex D model can also take this into account. The Workshop deferred decisions on the specific form of representations of this effect to the 2010 Annual Meeting (see Item 2.1.2 of this report).

The Workshop also addressed progress made on three other issues listed in the Work Plan for Completion of the MSYR Review (IWC, 2010d).

(1) Examination of information from other taxa via the GPDD (Global Population Dynamics Database – *http://www.cpb.bio.ic.ac.uk*), which is said to be one of the largest collections of animal and plant population data in the world, unfortunately revealed that this was very unlikely to contain information that would assist in the present Review. Although some other data series *might* provide useful information, these series were not generally readily available and the Workshop had agreed that further discussion on whether this issue should be followed up should be deferred to the 2010 Annual Meeting.

(2) For a variety of reasons, the expected genetic experts were unable to attend the Workshop and further consideration of this aspect was deferred to the 2010 Annual Meeting.

(3) Pressure of time to complete other computations meant that it had not been possible to complete the simulation study based on the environmental variability population model (Cooke, 2007) to determine the predicted relationship between the length of series and estimated level of variability for the standard scenarios (table 2 in IWC, 2010a). The Workshop had requested the Secretariat to complete this work for consideration at the 2010 Annual Meeting.

Turning to the issue of a meta-analysis of population growth rates previously discussed (IWC, 2010a); the Workshop was pleased to receive a revised approach (Punt, 2010) to that discussed at the 2009 Annual Meeting. The Workshop suggested some additional work to be completed before the 2010 Annual Meeting, recognising that this would represent an improvement on that used last year to construct a probability distribution for the rate of increase for an ‘unknown’ stock in the limit of zero population size, r_0.

The sub-committee expressed its appreciation to the Workshop participants and particularly to Donovan for his chairmanship.

2.1.2 Issues arising

SC/62/RMP3 responded to the recommendations of the Workshop to apply the age-structured Annex D model of SC/62/Rep2 to all of the data sets assembled during the Workshop to estimate the resultant CV and temporal auto-correlation in growth rate, and to conduct further tests of the Bayesian meta-analysis approach of Punt (2010) using scenarios which better reflect the data sets on which a posterior distribution for the rate of increase for an ‘unknown’ stock in the limit of zero population size, r_0, would be based. The inputs to age-structured model were selected so that the model-predictions of the variation and temporal autocorrelation in the calving rate matched those specified during the Workshop. The CV and temporal autocorrelation in the annual rate of increase was found to differ markedly among stocks, with the CV being largest for North Atlantic right and Gulf of California blue whales, and lowest for southeast Atlantic right whales. The estimates of lower percentiles for the posterior distribution for r_0 were shown to be somewhat positively biased, with estimation performance a function of the extent of measurement error, the number of stocks for which rates of increase were available, and the range of years over which the stock was monitored.

The sub-committee **agreed** that the Bayesian approach of Punt (2010) was acceptable as the basis to compute a posterior distribution for r_0, once the inputs needed to apply it (rates of increase and associated sampling CVs, and values for the extent and temporal-auto-correlation in environmentally-driven factors on the growth rate) become available. It also **agreed** that account would need to be taken, when making recommendations regarding appropriate values for MSYR for use in trials, that the estimates of lower posterior percentiles from this method are positively biased.

The sub-committee noted that the results in SC/62/RMP3 will need to be revised once the Committee agrees values for the extent of variation and temporal autocorrelation in demographic parameters.

SC/62/RMP2 and SC/62/RMP4 responded to the recommendations to use the environmental variability model of Cooke (2007) to provide CVs and temporal autocorrelation estimates for the growth of the population from one year to the next for the standard set of scenarios and to use this model to determine the predicted relationship between the length of series and the estimated level of variability in the population rate of increase. The CVs for the rate of population growth were negatively correlated with the MSY rate and positively correlated with the amount of process variation. This CV declined with increasing length of the series for all scenarios.

The Workshop thanked Allison and Punt, noting that it now had a basis to link variability in demographic processes with the inputs of the Cooke (2007) model.

Brandon, Kitakado and Cooke reported on efforts to fit models which account for both process and observation error to the data on calving rates and calving intervals. Numerical problems had been encountered during the intersessional period in implementing these models. A small group (Brandon, Cooke, Kitakado and Punt) was established to develop a work plan for completing this work. The sub-committee **endorsed** the work plan (Appendix 2), and looked forward to seeing the results of this work at the 2011 Annual Meeting. The approach in Appendix 2 ignores possible environmental covariates which determine annual changes in reproductive indices. Such covariates should be considered in future analyses.

The sub-committee noted that for many stocks, the available data are such that variation in reproductive rates can be estimated, but variation in survival rates cannot be estimated with useful precision. An important issue is how to relate variation in net recruitment rate, which depends on variation in both survival and reproduction, to variation in reproductive rates alone. The sub-committee considered Appendix 3 which showed that if variation in reproduction is due to variation in available energy (food), then for some parameter values, and under certain assumptions concerning the optimal allocation of energy between maintenance and reproduction, one would expect variation in survival to be positively correlated with variation in reproduction. In such cases, variation in net recruitment rate would be underestimated, if the survival rate is assumed to remain constant while reproductive rates vary.

Witting noted that empirical data sets for other species often show negative correlation between reproduction and survival rates. For example, experimental manipulation of reproductive rates in birds through removal of eggs has been shown to result in increased survival of adults. If baleen whale reproduction varies due to factors other than food availability (such as predation), a negative correlation between reproductive and survival rates might be expected, because reduced reproduction reduces the energy burden on mothers and could enhance their survival. Even if the variation in reproduction is due to variation in food availability, the specific timing of food limitation relative to reproduction could yield correlations of either sign. For example, if reproduction is suppressed one year due to low food availability at a point in the cycle critical for reproduction, but feeding conditions substantially improve thereafter, the reduced reproduction could enhance subsequent survival.

The sub-committee considered the question of correlations between survival and reproductive rates to be potentially important for the question of estimating typical levels of variation in net recruitment rate for baleen whales, but **agreed** that more analysis is required before any general inference can be drawn. The sub-committee **requested** in particular:

(1) a literature review with regard to the question of the circumstances under which correlations between survival and reproductive rates would be negative or positive;
(2) more extensive modelling to cover the full range of parameter values deemed to be plausible for baleen whales, in order to determine whether general inferences can be drawn, or at least to identify the circumstances where substantial correlations of a specific sign would be expected; and
(3) direct estimation of variability in survival rates to the extent this is possible.

The sub-committee **agreed** that if results from this work are available at its next meeting, then they should be taken into account in the sub-committee's deliberations with respect to the level of variability in baleen whale demography, but that lack of results will not preclude the sub-committee from completing its review of MSY rates.

The sub-committee considered the extent to which genetic data could place bounds on fluctuations in population size (see fig. 1 of IWC (2010c) for some examples of trajectories arising for the environmental variation model of Cooke (2007)). It was noted that, in principle, measures of genetic diversity and the ratio of effective to census population size could be used to impose such bounds. However, doing so is not straightforward and, for example, inferences regarding the size of a local population or stock based on measures of genetic diversity could be markedly in error if there is migration among local populations (Appendix 4). The sub-committee recognised the potential of genetic methods to inform its deliberations on the plausible range of MSYR values, but **agreed** that these methods could not be used during the current review. It **recommended** that the number of haplotypes in whale populations, along with other population and demographic measures, should be assembled. This might inform the current review. Brownell noted that he had started such a compilation and the sub-committee **encouraged** completion of this compilation. Members also noted that there are prospects for collating information on the ratio of effective to census population for whale species.

The sub-committee **agreed** that the use of time-series of abundance estimates for species other than whales to make inferences regarding the extent of variation and the temporal auto-correlation of the rate of growth remained a good idea. However, the lack of such time-series at present means that this source of information cannot be pursued during the current review of MSY rates.

2.1.3 Conclusions and recommendations

Although considerable progress was made during the current meeting, the sub-committee was once again not in position to complete the review. It established a work plan which addresses the final issues which need to be examined for the sub-committee to complete the review at next year's meeting.

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

The sub-committee was once again pleased to see the progress made at the MSYR Intersessional Workshop and during the current meeting, but again recognised that it could not complete discussions on amendments to the *CLA* until the range for MSYR values in the RMP was finalised.

2.2.1 Norwegian proposal

Walløe noted that all of the relevant trials results related to the Norwegian proposal were presented in Aldrin and Huseby (2007), but that evaluation of this proposal could not occur until the review of MSY rates was complete.

2.3 Version of *CLA* to be used in trials

SC/62/RMP10 examined the sensitivity of catch limits to the level of accuracy when computing posterior distributions using the *CLA*. SC/62/RMP10 found that the catch limits for some combinations of species, region and variant are very sensitive to the choice of the step sizes when applying the *CLA*. Furthermore, the choice of step sizes can have an impact on the selection among variants of the RMP. Four versions of programs used to implement the *CLA* were discussed.

The sub-committee **endorsed** the recommendations in SC/62/RMP10 that: (a) only the Norwegian version of the *CLA* should be used when conducting future trials; (b) any Second Intersessional Workshops (IWC, 2005a) will need to be carefully scheduled to ensure that all trials can be run before it takes place; (c) if special circumstances arise when it becomes necessary to run additional trials during a meeting (e.g. during a Second Intersessional Workshop), that the 'intermediate' version of the Cooke implementation that is more accurate than the 'trials' version (but less accurate than the 'accurate' or Norwegian version) be used for this purpose and the results confirmed using the Norwegian 'CatchLimit' program after the meeting; and (d) a full set of revised results for North Atlantic fin whales, Western North Pacific Bryde's whales, and North Atlantic minke whales should be run using the Norwegian 'CatchLimit' program and the results placed on the IWC website.

2.4 Updates to RMP specification and annotations

In the context of applying the RMP pursuant to Item 4 of this report, the sub-committee identified some issues where updating and clarification of the specifications of the RMP and the accompanying annotations and guidelines were warranted.

(1) The provision for the adjustment for sources of human-caused mortality other than commercial catches, as recommended by the Scientific Committee in 2000 (IWC, 2001b), should be included in the RMP with the qualification specified by the Commission (IWC, 2001a) that the provision be limited to mortality due to bycatches, ship strikes, non-IWC whaling, scientific permit catches and indigenous subsistence whaling. A new annotation should be added to provide the Committee with operational guidelines to implement this provision.
(2) The maximum period of validity of catch limit calculations should be extended from five to six years to be consistent with the six-year cycle of surveying specified in section 3.2.2 of the RMP, as

currently implemented for minke whales in the North Atlantic.

(3) The rule for rounding of catch limits to a whole number of whales should be clarified.

(4) The guidelines for conducting surveys under the RMP and those for *Implementing* the RMP (IWC, 2005a; 2005b) should be modified to clarify that changes to the guidelines are not retroactive. That is, results from surveys conducted in accordance with the earlier version of the guidelines would not become inadmissible for use in the RMP when the guidelines are changed.

Proposed amendments to the RMP and annotations to address the above issues are given in Appendix 5, along with some background information. The sub-committee **recommended** adoption of these amendments to the RMP specification and annotations. The sub-committee further **requested** the Editor to prepare a proposal to next year's meeting to update the guidelines to accommodate point (4) above.

The sub-committee noted that several amendments to the RMP specifications and annotations had been adopted since the most recent published version (IWC, 1999). These are listed in Appendix 5. The sub-committee **recommended** that a consolidated revised version be published in full in the next Supplement to *J. Cetacean Res. Manage*.

2.5 Work plan

The sub-committee **agreed** that its work plan for the 2011 Annual Meeting would be as follows.

(1) Brandon, Cooke, Kitakado and Punt to finalise the analyses of the calving rate and calving interval data (see Appendix 2 for details).
(2) Conduct analyses to examine variability in survival rates and the correlation between survival and reproductive rates.
(3) Complete the compilation of the number of haplotypes and other demographic parameters for whale populations.
(4) Complete the review of the range of MSYR values for use in the RMP.
(5) Finalise the approach for evaluating proposed amendments to the *CLA*.
(6) Evaluate the Norwegian proposal for amending the *CLA*.
(7) Consider the implications that the phase-out rule in the RMP is applied by *Small Area* when catch cascading is applied and the abundance estimates are based on multi-year surveys.
(8) The full set of revised results for North Atlantic fin whales, Western North Pacific Bryde's whales and North Atlantic minke whales run using the Norwegian 'CatchLimit' program should be conducted and placed on the IWC website.
(9) The Secretariat to modify the Norwegian 'CatchLimit' program to allow variance-covariance matrices to be specified for the abundance estimates. The results from the modified program should be compared with those from the 'accurate' version of the Cooke program for some cases.

3. RMP – SPECIFIC IMPLEMENTATIONS

3.1 Western North Pacific Bryde's whales

3.1.1 Survey data validation

Allison reported that Burt and Hughes had successfully completed an audit of the survey data.

3.1.2 Research proposal for the 'variant with research'

The Committee had agreed in 2007 (IWC, 2008) that three of the four RMP variants (1, 3 and 4) considered during the *Implementation* for the western North Pacific Bryde's whales, performed acceptably from a conservation perspective and recommended that those variants could be implemented without a research programme. It had also agreed that variant 2 (i.e. sub-area 2 is taken to be a *Small Area* and the complete sub-area 1 is treated as a *Small Area*) was not 'acceptable without research' because conservation performance was 'unacceptable' on three 'medium' plausibility trials in which there were two stocks of Bryde's whales in the western North Pacific, one of which consists of two sub-stocks (stock structure hypothesis 4).

The Committee reviewed a research proposal (Pastene *et al.*, 2008) at the 2008 Annual Meeting which aimed to determine whether or not sub-stocks occur in sub-area 1. Based on this review, the Committee recommended that the *Implementation Simulation Trials* for western North Pacific Bryde's whales be used to determine whether differences in age-compositions between sub-areas 1W and 1E could be used to resolve if there are sub-stocks in these sub-areas, and that results from previous (and any new) power analyses that assess the use of genetic methods to evaluate stock structure hypothesis 4 be included in the revised proposal.

Appendix 6 outlines a revised research plan. The sub-committee welcomed the work that has been done on the proposal and the fact that several of its earlier recommendations had been implemented. The results of the *Implementation Simulation Trials* showed that recent age structure data would not be able to distinguish between scenarios in which there is or is not age-structuring in sub-areas 1W and 1E. The sub-committee **recommended** that the proposal be revised further and, in particular, that the power analysis focus more clearly on the specific hypotheses for the Western North Pacific Bryde's whales. Pastene advised the sub-committee that a revised proposal will be presented next year which will focus to a greater extent on the use of genetic data.

3.1.3 Recommendations and work plan

The sub-committee **agreed** that its work plan for the 2011 Annual Meeting would be as follows.

(1) Review the research proposal for the 'variant with research' to be submitted to the 2011 meeting.

3.2 North Atlantic fin whales

Last year, the Committee completed the review of the *Implementation Simulation Trials* for North Atlantic fin whales. It agreed that if the RMP is implemented for these whales, variants 1, 3, 4, 5 and 6 (see table 4 of IWC, 2010c) can be implemented without an associated research programme. The Committee further agreed that variant 2 (sub-area WI+EG is a *Small Area*) cannot be implemented except in conjunction with a research programme that the Committee agrees could feasibly show that the trials on which variant 2 performs 'unacceptably' should have been assigned 'low' plausibility. The trials were based on stock structure hypothesis IV (four breeding stocks, but without dispersal between the C sub-stocks).

The comparison of results from different versions of the *CLA* (see Item 2.3) revealed that variant 3 (sub-areas WI+WG+EI/F are a *Small Area*) does not have 'acceptable' performance for some of the trials and can no longer be considered to be 'acceptable without research'.

3.2.1 Review estimates for use in the CLA

No abundance estimates were provided for adoption this year and the sub-committee was advised that no new abundance estimates were being prepared.

3.2.2 Research proposal for the 'variant with research'

Last year, Víkingsson, on behalf of Iceland, advised the Committee that a research proposal would be developed for this year's meeting. Last year, the Committee confirmed that use of variant 2 for ten years followed by variant 1 (sub-area WI is a *Small Area*) led to performance which was 'acceptable' for all trials and consequently that the requirements for stage 1 of the process for implementing a 'variant with research' had been met. The second stage of the process for implementing a 'variant with research' was for Iceland to demonstrate to the satisfaction of the Committee that a research programme has a good chance (within a 10-year period) of being able to clarify the situation with respect to stock structure, and in particular to confirm or deny that stock structure hypothesis IV is implausible.

SC/62/RMP1 presented the research proposal following the pro-forma agreed by the Committee in 2007. Hypothesis IV differs from the other hypotheses in that it assumes that there is no interchange among the three sub-stocks in the central North Atlantic in the breeding areas and that these whales have no memory next year of where they were this year and do not change their foraging behaviour in response to changes in density in any one feeding area but will go back to their native feeding area 95% of the time each year. Neither of these assumptions is based on any data. Genetic studies have found a lack of genetic structure in the North Atlantic. There has been no explanation of how such behaviour could have evolved and this behaviour would have grave consequences for the species in the event of anticipated environmental changes. Hypotheses where there is gradual dispersal over time do predict a trend with time in external recoveries. The existing Discovery mark data were tested and the availability of marks from *Small Area* EG was found to increase while it decreases in the *Small Area* WI and this is significant. These results are already sufficient to reject hypothesis IV. The proposed 100 biopsy samples from *Small Area* EG should double this dataset through direct matches and strengthen these results. A power analysis shows that comparison of relative relatedness of animals in *Small Areas* WI and EG also has a good chance of rejecting hypothesis IV. Comparison of relatedness with existing samples from the area and any samples from other areas could strengthen these. SC/62/RMP1 proposed satellite tagging early in the season to reveal animals moving across area boundaries within the season, which will add to the information from the genetic data. Satellite tags placed late during the season on the feeding grounds may survive long enough for detection of the breeding grounds. If the animals from the feeding areas breed in overlapping areas they would be expected to interbreed, which would show that the assumption of an isolated breeding stock is implausible. Models with biologically more plausible hypotheses are proposed to be developed that might provide a superior fit to the data, and methods to integrate different pieces of information, such as results from satellite tagging, that cannot be fitted in the *Implementation Simulations Trial* model will be identified.

The sub-committee welcomed the proposal, noting that it was not final and that Iceland was inviting suggestions for how it can be improved. In discussion, the sub-committee noted that the aim of the proposal should be to assess the probability of hypothesis IV relative to the probabilities for the other stock structure hypotheses. It noted that the *Implementation Simulation Trials* could be used to assess the effect sizes on which power analyses should be based. In particular, the sub-committee **recommended** that the lowest rate at which the C sub-stocks mix in sub-areas EC, WG, EG, WI, EI+F and N and where the performance of variant 2 is 'acceptable' for all trials, should be calculated and used when conducting power analyses.

The authors of SC/62/RMP1 argued that data on time-trends in recoveries of Discovery marks from the WI and EG *Small Areas* are already sufficient to reject stock structure hypothesis IV. The sub-committee noted that these mark-recapture data had been considered during the *Implementation Simulation Trials* and the fits to those data had been examined qualitatively at the 2008 and 2009 Annual Meetings. It **recommended** that quantitative analyses along the lines of appendix 3 of SC/62/RMP1 be conducted for each of the stock structure hypotheses.

Cooke noted that the proposed genetic mark-recapture studies could be partially confounded by male-mediated genetic exchange between breeding stocks, as is known to occur, for example, in humpback whales. Such male-mediated exchange would have no demographic consequences and, to the extent that it involves transference between breeding grounds rather than feeding grounds, would not affect the dynamics of feeding ground abundance as modelled in the trials. The presence or absence of such exchange therefore has no implications for any of the *Implementation Simulation Trials* conducted to date, and does not require development of any new hypotheses. It does, however, potentially reduce the power of genetic mark-recapture data to distinguish among the existing hypotheses. The proposed method should be modified so as not to be potentially confounded by male-mediated relatedness (such as paternal half-siblings), and its power re-calculated, for the purpose of evaluating the adequacy of the proposed research programme to distinguish between hypotheses within the 10-year time frame.

The authors of SC/62/RMP1 responded that the assumption under Hypothesis IV of a constant, but limited, mixing between the feeding grounds could not be explained if there were significant genetic interchange between the breeding stocks. However, these matters could be addressed in a revised proposal to be submitted to next year's meeting.

3.2.3 Work plan

The sub-committee **agreed** that its work plan for the 2011 Annual Meeting would be as follows.

(1) Review a revised research proposal for the 'variant with research' to be submitted to the 2011 meeting.
(2) Review any abundance estimates for use in the *CLA*.

3.3 North Atlantic minke whales

3.3.1 Stock boundaries

The sub-committee noted that some of the boundaries among the *Small Areas* for the North Atlantic minke whales had been changed during the 2003 *Implementation Review*. However, some of the boundaries among the *Small Areas* remain unspecified. The sub-committee **recommended** that a point at 63°N, 12°W be introduced to fill the 'hole' between the CM and CIP *Small Areas*, and that boundaries around the southern tip of Greenland be defined as shown in Fig. 1. The sub-committee **recommended** that the *Small Areas* in Fig. 1 be adopted for use when the applying the RMP for North Atlantic minke whales.

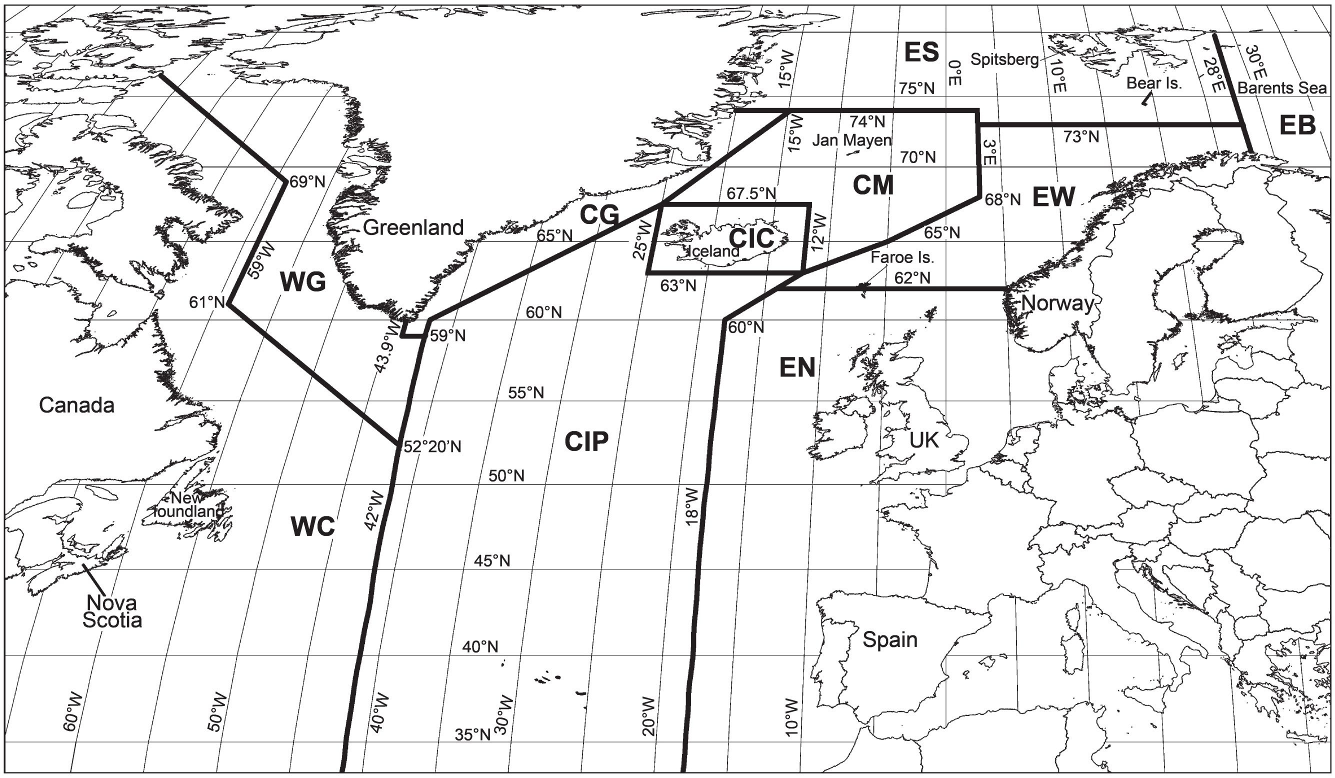

Fig. 1. The specifications for the *Small Areas* for the North Atlantic minke whales.

The boundary between the EB and EW *Small Areas* was based on genetic differences about the 28°E line of longitude for a small number of animals. Walløe informed the sub-committee that Norwegian scientists had checked the data for these animals and that no errors had been found.

3.3.2 Abundance estimates

SC/62/RMP6 presented a method for estimating $g(0)$ from single platform line transect data in which both the forward and perpendicular distances have been recorded. The method was applied to double platform northeastern Atlantic minke whale sightings surveys in which one of the platforms had been masked in different proportions of the time. It was found that the estimate of $g(0)$ did not break down in the limit where data only from a single platform were used. The context of this study was that Norway is conducting ecosystem surveys with (single platform) whale observers onboard. These data are currently not used for abundance estimation in the context of the RMP. There are several difficulties that must be overcome for this to be done: $g(0)$ estimation is one of them, but probably more important is the fact that the ecosystem surveys take place during another period of the year than the ordinary sighting surveys.

The sub-committee noted that attempts had been made in the past (Hiby and Thompson, 1985) to estimate $g(0)$ using data from a single platform. It is clearly desirable to be able to estimate $g(0)$ using the locations of the sightings from a single platform in two dimensions, and the sub-committee **encouraged** efforts to develop methods to achieve this. However, the sub-committee was concerned that the estimates of $g(0)$ would not be robust to model structure uncertainty, measurement error and diving pattern. The sub-committee **recommended** that the robustness of the method proposed in SC/62/RMP6 to these factors be examined.

SC/62/RMP7 summarised a sighting survey conducted in the North Sea area within *Small Area EN* during summer 2009. This was the second year in the six-year survey programme 2008–13 for minke whales in the northeast Atlantic. One vessel covered the area during the period 21 June to 31 July: in the periods 25 June to 12 July and 22 to 31 July as dedicated whale surveys and in the intervening period as a herring survey with whale counting as an opportunistic activity. The total survey area was divided into three ordinary blocks and one herring survey block which was contained within parts of two of the ordinary survey blocks. The survey procedures and sighting protocol as used in previous surveys were followed both in the dedicated and opportunistic parts of the survey and a double platform configuration was used exclusively. The vessel was able to survey about 1,500 n.miles with primary search effort during the dedicated parts and 700 n.miles during the herring survey. The most frequently observed species was the minke whale, of which 29 groups were observed from the primary platform during the dedicated parts and 11 groups during the herring survey. The North Sea area was last surveyed in the Norwegian survey programme in 2004. The most striking feature when comparing the 2009 survey with the 2004 survey is the nearly complete absence of harbour porpoise observations during 2009. Also, very few sightings of *Lagenorhynchus* species were made in 2009.

The sub-committee welcomed this information and noted that these data would be included in a future abundance estimate for the North Atlantic minke whales.

SC/62/RMP5 presented estimates of abundance for minke whales in the Central Atlantic from the North Atlantic Sightings Survey conducted by Icelandic and Faroese vessels during June/July 2007. Stratified line transect methods were used and the half-normal model provided the best fit to the data. No covariates improved the fit. Attempts to estimate $g(0)$ using these data based on only five duplicate sightings (Paxton *et al.*, 2009) were not accepted by the Committee in 2009 and estimation of $g(0)$ was not attempted in

SC/62/RMP5. The estimate using all sightings identified as minke whales and the original strata was 11,193 (CV 0.33; 95% CI 5,007 to 18,815) and is most comparable to earlier estimates from these surveys, but the poor coverage realised in the western part of the area near the East Greenland ice edge, that had high density in the earlier surveys, probably means that this estimate is substantially negatively biased compared with the earlier estimates for this area. All of these estimates should be considered to be substantially negatively biased due to uncorrected perception and availability biases.

The sub-committee **agreed** that the methods in SC/62/RMP5 followed the Guidelines for how survey results should be analysed if the estimates are to be used for the RMP. Table 1 lists the estimates of abundance for the CG and CIP *Small Area* obtained using the estimates by survey block in SC/62/RMP5. The sub-committee **agreed** to adopt the estimates of abundance for 2007 presented in Table 1 for use in the RMP.

Table 1

Abundance estimates for minke whales in the CG and CIP *Small Areas*. The survey block estimates were split on *Small Areas* in relation to the number of sightings and area overlap but inverse to effort. Similarly, the variance was split (SC/62/RMP1, Appendix 2).

Small Area	Estimate	CV
CG	1,048	0.60
CIP	1,350	0.38

The sub-committee noted that estimates for the component of the CG *Small Area* which was not covered during 2007, but was covered during previous surveys of the Central *Medium Area*, could be obtained using, for example, GLM models. The sub-committee noted that any estimates obtained using models would need further review before being adopted for use in the RMP.

Appendix 7 summarises how the Norwegian survey data for the northeast Atlantic were allocated to the *Small Areas* agreed during the 2003 *Implementation Review*. The proration method used resulted in differences from two estimates approved previously: that for 1989 E *Medium Area* and the 1989 CM *Small Area*. The argument for keeping the earlier approved estimates of respectively 64,730 and 2,650 animals (Schweder *et al.*, 1997) was that the intended coverage for the 1989 block causing the problem was within the area boundary of the northeastern stock of minke whales which corresponds exactly to the E *Medium Area* in the RMP *Implementation*. The sub-committee **endorsed** these abundance estimates for use in the RMP (see Table 2).

3.3.3 Recommendations and work plan

The sub-committee **recommended** that the boundaries in Fig. 1 be adopted for use when applying the RMP for the North Atlantic minke whales. It also **recommended** that abundance estimates in Tables 1 and 2 be adopted for use in the RMP.

The sub-committee **agreed** that its work plan for the 2011 Annual Meeting would be as follows:

(1) Review any new abundance estimates.

4. CONSIDERATION OF REQUESTS FOR ADVICE FROM THE COMMISSION

4.1 Review of Annex {SI} to IWC/62/7rev – scientific information requirements

The sub-committee **recommended** that the reference to bulla be removed from point 2(b) because the Committee has agreed that bullae do not provide a reliable means for estimating age (Olsen and Øien, 2002). The sub-committee also noted that earplugs do not provide reliable age estimates for North Atlantic minke whales. Walløe and Víkingsson noted that lengths could not always be recorded for minke whales in the North Atlantic in the manner specified, although estimates of length are reported to the Secretariat. The sub-committee **recommended** that the following footnote be added to point (a): '*Onboard small coastal whaling vessels such as those participating in Norwegian and Icelandic operations, it may be difficult to obtain accurate length measurements because whales are handled on a limited space. It is recognised that measurements in these cases may not be as accurate as those taken in ideal situations.*'

4.2 Review of Annex {OI} to IWC/62/7rev – operational information requirements

The sub-committee **endorsed** the operational information requirements in Annex {OI} of IWC/62/7rev.

4.3 Review of proposed timetable for future *Implementations and Implementation Reviews* (IWC/62/7rev, Appendix B)

At the outset, the sub-committee **agreed** with the Scientific Assessment Group (SAG) that the schedule in Section 5 of IWC/62/7rev is ambitious. It noted that *Implementations* and *Implementation Reviews* can (and do) involve considerable time and resources from national scientists and, especially in cases when *Implementation Simulation Trials* are required, the Secretariat. Moreover, delays can occur when conducting *Implementations* given that the same members of the Committee are involved in many of the *Implementations* and *Implementation Reviews*. The Committee has previously

Table 2

Estimates of abundance for CM *Small Area* and for the eastern *Medium Area* by *Small Areas*.

		EB			EN			ES			EW			E total			CM		
Survey period	Mid-year	Year	N	SD	Year	N	SD	Year	N	SD	Year	N	SD	Year	N	CV	Year	N	SD
1988–89	1989	1989	21,868	4,503	1989	8,318	2,113	1989	13,070	1,699	1989	20,991	3,552	1989	64,730[1]	0.192	1988	2,650[1]	1,283
1995	1995	1995	29,712	5,378	1995	22,536	5,263	1995	24,891	2,389	1995	34,986	4,033	1995	112,125	0.104	1995	6,174	2,203
1996–2001	1999	2000	25,885	6,219	1998	13,673	3,482	1999	17,406	2,454	1996	23,522	3,013	1999	80,487	0.15	1997	26,718	3,973
2002–07	2005	2007	28,625	6,709	2004	6,246	2,912	2003	19,377	5,335	2002, 2006	27,152	5,917	2005	81,401	0.23	2005	26,739	10,428

[1] These estimates are taken from Schweder *et al.* (1997) and are different from the results from direct application of area proration. The differences are caused by a very small part of the 1989 survey block (SN) falling within the CM *Small Area* in the area projection used here.

agreed that it can only conduct one *Implementation* at a time. The schedules for Western North Pacific Bryde's whales, and for North Atlantic common and fin whales, match the schedules expected from the *Implementations* for these species. The Committee has previously been able to complete an *Implementation Review* during a single meeting, provided that no *Implementation Simulation Trials* are required.

The sub-committee cannot conduct *Implementations* for the Western North Pacific sei and Antarctic minke whales at the same time. The SAG considered it more important to conduct an *Implementation* for the Western North Pacific sei whales first given the size of current catches and the estimates of abundance for this stock. However, the sub-committee noted that there are also reasons to conduct an *Implementation* for Antarctic minke whales starting in 2012. The issue of the relative merits of when to conduct these two *Implementations* will be discussed in Plenary, taking into account discussions in Annex G. The recommended order will thus be decided upon by the full Committee.

In relation to the Table, the sub-committee **recommended** that two years should be allowed for the *pre-Implementation assessment* for Antarctic minke whales irrespective of when the *Implementation* for these whales starts (under the current schedule, the first year of the *pre-Implementation assessment* would be 2014). It was also recognised that the current *Implementation* for these whales is sufficiently dated (1993) that it is unreasonable to expect that this 1993 *Implementation* can simply be reviewed after almost 20 years of developments in how to *Implement* the RMP. It therefore **recommended** that '/IR' be deleted from the box for 2015 for Antarctic minke whales.

4.4 Review of the Scientific Assessment Report

4.4.1 General issues

4.4.1.1 CATCH LIMIT CALCULATIONS (ACTIVATION, YEARS, INPUTS AND OUTPUTS)

As part of the SAG process, the RMP was applied to three species-Region combinations (western North Pacific Bryde's whales, North Atlantic minke whales, and North Atlantic fin whales). The calculations reported are therefore the results of applying the RMP, although results are also shown for tunings other than the Commission-agreed 0.72 tuning (the 0.6 tuning). When applying the *CLA*, the phase-out rule was applied for each *Small Area* after the catch limit was cascaded to the *Small Areas* from the *Medium Area* rather than applying the phase-out rule before cascading the *Medium Area* catch limit to the *Small Areas*.

4.4.1.2 TUNING LEVELS

The SAG report (and Appendix 8) provides results for the 0.72 and 0.6 tunings of the RMP because the whaling countries in the Commission's support group had requested the latter tunings. This issue is discussed more fully in the SAG report (IWC, 2010b). The sub-committee noted that although the 0.6, 0.66 and 0.72 tunings of the *CLA* were recommended to the Commission by the Committee, having been subjected to testing during the development of the RMP, the *Implementation Simulation Trials* have only been conducted by the Committee for the 0.72 tuning of the RMP. Norwegian scientists have run the *Implementation Simulation Trials* for minke whales in the northeast Atlantic for the 0.6 tuning of the RMP, but these calculations were not undertaken nor reviewed in detail by the Committee. It is also known that which RMP variants are 'acceptable' may change if the tuning level is changed.

The sub-committee **agreed** that the tuning level which was used when calculating catch limits using the *CLA* should be that which is tested in *Implementation Simulation Trials*; in this case only the 0.72 tuning. In principle, the *Implementation Simulation Trials* could be repeated for a new tuning if requested by the Commission. However, the criterion used to evaluate whether performance of an RMP variant is 'acceptable', 'borderline' or 'unacceptable' is linked to the 0.6 and 0.72 tunings of the RMP. The present criterion may need to be investigated if the Commission requested that a different tuning of the RMP should be considered.

4.4.2 Application of Stocks/Regions

The sub-committee requested that the Secretariat provide the specifications of how the RMP was applied during the SAG meeting to western North Pacific Bryde's whales, North Atlantic minke whales, and North Atlantic fin whales. The sub-committee reviewed the specifications. It **recommended** changes to the format (see Appendix 8 for the final format) to make the calculations clearer and to emphasise the results calculated using the Commission-agreed 0.72 tuning. The following sections summarise the modifications to the initial applications by the Secretariat by the sub-committee in reaching its **agreed** applications. Table 3 lists the resulting catch limits from the 0.72 and 0.6 tunings of the *CLA*.

4.4.2.1 WESTERN NORTH PACIFIC BRYDE'S WHALES

The application of the RMP to Western North Pacific Bryde's whales was based on a single abundance estimate

Table 3

Summary of the application of the RMP (full details of the inputs to the RMP as well as relevant intermediate calculations are given in Appendix 8). Phaseout has been applied where applicable.

Year	WNP Bryde's whales	N Atlantic fin whales		N Atlantic minke whales					
Sub-area	1W+1E	WI (variant 6)	WI (variant 2)	CIC	CM	ES	EB	EW	EN
(a) Catches limits based on the 72% tuning (Commission's agreed value)									
2010	5	46	87	224	135	58	92	152	70
2011	3	46	87	224	135	58	92	152	70
2012	1	46	87	224	135	46	92	152	70
2013	0	46	87	224	135	35	92	152	56
2014	0	46	87	224	108	14	92	152	42
(b) Catches limits based on the 60% tuning									
2010	33	90	155	345	208	122	195	322	148
2011	19	90	155	345	208	122	195	322	148
2012	4	90	155	345	208	97	195	322	148
2013	0	90	155	345	208	73	195	322	118
2014	0	90	155	345	166	29	195	322	89

for the *Region* (time-stamped at 2000). The sub-committee requested that the time-stamps for the *Small Areas* when applying catch cascading be set to the effort-weighted years. It was noted that survey data were available for 1988–96 and that these data were used when computing the additional variance for the 1998–2002 surveys (Shimada *et al.*, 2008). An abundance estimate can be computed for 1988–96, but the Committee has only accepted the estimate from the 1998–2002 surveys (IWC, 2009). The earlier surveys were not conducted under the new Guidelines for Conducting Surveys under the RMP (IWC, 2005b), although they did follow the protocols used during the IDCR surveys. Although abundance estimates could be computed for using the 1988–96 data, account would need to be taken of the correlation of these estimates with those for 1998–2002 if they were included in RMP calculations of catch limits. However, the presently-coded version of the RMP does not allow input of a variance-covariance matrix for the abundance estimates. The sub-committee therefore **recommended** that the program for the *CLA* be modified to allow variance-covariance matrices to be input (see Item 2.4). It also **recommended** that the data and resulting abundance estimates from the 1994–96 surveys should be reviewed for possible use in the RMP during the next *Implementation Review*. The final specifications for how the RMP was applied to these whales are listed in Appendix 8A.

4.4.2.2 NORTH ATLANTIC COMMON MINKE WHALES

The sub-committee **recommended** the following changes to the abundance estimates for minke whales in the Central North Atlantic.

(1) Use the estimates in Table 1 to construct an abundance estimate for *Small Areas* CG+CIP and include this abundance estimate in that for the C *Medium Area* for 2006.
(2) Use the estimate for the CM *Small Area* in 2005 of 12,043 (CV 0.28) in place of the estimate of 6,174 (CV 0.36) because the former estimate is based on surveys which covered more of the CM *Small Area*.
(3) Use the revised version of the estimate of abundance for 2005 of 26,739 (CV 0.39) in place of the estimate of 24,890 (CV 0.45).

Allison reported that she had recalculated the CVs for the abundance estimates for the C *Medium Area*.

The sub-committee **recommended** that the catch limits for the minke whales in the eastern North Atlantic be based on sex ratios for 2005–09 rather than 2004–08, reflecting the data for the most recent five years.

The final specifications for how the RMP was applied to these whales are listed in Appendix 8B.

4.4.2.3 NORTH ATLANTIC FIN WHALES

The sub-committee had no changes to the application of the RMP by the Secretariat. The specifications for how the RMP was applied to these whales are listed in Appendix 8C.

5. WORK PLAN

(1) RMP – general matters

(1) Brandon, Cooke, Kitakado and Punt to finalise the analyses of the calving rate and calving interval data (see Appendix 9).
(2) Conduct analyses to examine variability in survival rates and the correlation between survival and reproductive rates.
(3) Complete the compilation of the number of haplotypes and other demographic parameters for whale populations.
(4) Complete the review of the range of MSYR values for use in the RMP.
(5) Finalise the approach for evaluating proposed amendments to the *CLA*.
(6) Evaluate the Norwegian proposal for amending the *CLA*.
(7) Consider the implications that the phase-out rule in the RMP is applied by *Small Area* when catch cascading is applied and the abundance estimates are based on multi-year surveys.
(8) The full set of revised results for North Atlantic fin whales, Western North Pacific Bryde's whales, and North Atlantic minke whales run using the Norwegian 'CatchLimit' program should be conducted and placed on the IWC website.
(9) The Secretariat to modify the Norwegian 'CatchLimit' program to allow variance-covariance matrices to be specified for the abundance estimates. The results from the modified program should be compared with those from the 'accurate' version of the Cooke program for some cases.

Task (1) has funding implications. The sub-committee **endorsed** the funding request as in Appendix 9.

(2) *Implementation* for the western North Pacific Bryde's whales

(1) Review the research proposal for the 'variant with research' to be submitted to the 2011 meeting.

(3) *Implementation* for the North Atlantic fin whales

(1) Review a revised research proposal for the 'variant with research' to be submitted to the 2011 meeting.
(2) Review the abundance estimates for use in the *CLA*.

(4) *Implementation* for the North Atlantic minke whales

(1) Review any new abundance estimates.

6. ADOPTION OF REPORT

The report was adopted at 14:56 on 7 June 2010. The sub-committee thanked Bannister (and Hammond) for their excellent chairmanship, the rapporteur for his work, and Allison for conducting the applications of the RMP with her normal considerable care. The sub-committee wished Bannister a rapid recovery.

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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 Review MSY rates
        - 2.1.1 Report of intersessional workshop
        - 2.1.2 Issues arising
        - 2.1.3 Conclusions and recommendations
    - 2.2 Finalise the approach for evaluating proposed amendments to the *CLA*
        - 2.2.1 Norwegian proposal
    - 2.3 Version of *CLA* to be used in trials
    - 2.4 Modifications to RMP and its annotations
    - 2.5 Work plan

3. RMP – specific implementations
    - 3.1 Western North Pacific Bryde's whales
        - 3.1.1 Survey data validation
        - 3.1.2 Research proposal for the 'variant with research'
        - 3.1.3 Recommendations and work plan
    - 3.2 North Atlantic fin whales
        - 3.2.1 Review estimates for use in the *CLA*
        - 3.2.2 Research proposal for the 'variant with research'
        - 3.2.3 Work plan
    - 3.3 North Atlantic minke whales
        - 3.3.1 Stock boundaries
        - 3.3.2 Abundance estimates
        - 3.3.3 Recommendations and work plan

4. Consideration of requests for advice from the Commission
    - 4.1 Review of Annex {SI} to IWC/62/7rev – scientific information requirements
    - 4.2 Review of Annex {OI} to IWC/62/7rev – operational information requirements
    - 4.3 Review of proposed timetable for future *Implementations* and *Implementation Reviews* (IWC/62/7rev Appendix B)
    - 4.4 Review of the Scientific Assessment Report
        - 4.4.1 General issues
            - 4.4.1.1 Catch limit calculations (activation, years, inputs and outputs)
            - 4.4.1.2 Tuning levels
        - 4.4.2 Application of Stocks/Regions
            - 4.4.2.1 Western North Pacific Bryde's whales
            - 4.4.2.2 North Atlantic common minke whales
            - 4.4.2.3 North Atlantic fin whales

5. Work plan

6. Adoption of Report

Appendix 2

STEPS TO MOVE FORWARD REGARDING ESTIMATING VARIABILITY IN REPRODUCTION RATES

J. Brandon, J. Cooke, T. Kitakado and A. Punt

One potential structure:

(1) If known (annual) standard deviations are available, treat the data[1] as normally distributed, i.e.:

$$I_{i,y} \sim N(\mu_{i,y}, \sigma^2_{i,y})$$

where $I_{i,y}$ is the observed datum for stock i and year y, $\sigma_{i,y}$ is the (known) standard deviation for $I_{i,y}$.

(2) Model the process according to an AR1 formulation:

$$\mu_{i,y} \sim N(\rho_i \mu_{i,y-1}, \tilde{\sigma}^2_i)$$

where ρ_i is the extent of temporal auto-correlation in reproductive rate, and $\tilde{\sigma}^2_i$ is the variability in reproductive rate.

(3) Assume the following priors: $\mu_{i,1}$ (uninformative) normal for each i, arctan(ρ_i) normally distributed from a normal hyper-prior, and $\ell n\tilde{\sigma}_i$ normally distributed from a normal hyper-prior.

(4) Impose uninformative priors on the hyper-parameters of the hyper-priors.

The above model is a multivariable AR model (a simple example of a VAR model?). Example code exists to implement WinBUGS models for AR(1) models.

The aim of the analyses during the intersessional period should be to:

- Fit the above model to: (a) the real data; and (b) some simulated data sets.
- Represent the results from the model in the form of inputs to the age-structured model of Annex D of SC/62/Rep2 and use this model to compute the standard deviation and temporal auto-correlation in the annual rate of increase.
- Identify the values for the environmental model of Cooke (2007) which match the outputs from the age-structured model.
- Investigate improvements in modelling approaches for proportion data for which the sampling error variances are not known.

Appendix 3

A NOTE ON THE EXPECTED RELATIONSHIP BETWEEN VARIABILITY IN REPRODUCTIVE RATE AND VARIATION IN NET RECRUITMENT RATE BASED ON LIFE HISTORY TRADE-OFF MODELS

Justin G. Cooke

Introduction

The recent Workshop on the review of MSYR for baleen whales (SC/62/Rep2) examined a number of time series of different demographic parameters (mainly calving rates and/or calving intervals) from baleen whale populations (table 1 in SC/62/Rep2) with a view to estimating typical levels of variability in baleen whale net recruitment rates. An issue arising from the Workshop is the estimation of variance in net recruitment rate for the common case where an estimate of variance is known only for one or some of the life history parameters (typically calving rate) but not for others (typically survival). The assumption that all parameters remain constant, except those for which the variance has been estimated, may result in underestimation of the variability in net recruitment rate, unless the variation in the different life history parameters is mutually compensatory.

There is a substantial body of literature on both empirical and theoretical results relating to trade-offs in life history parameters and especially trade-offs in energy investment between reproduction and survival (see, e.g. the review by Perrin and Sibly, 1993). These approaches might provide some insight into how reproductive and survival rates may be expected to co-vary. In this appendix a simple example of such a model is used to generate predictions of what co-variation might be expected between reproductive and survival rates in baleen whale populations. This could be used as a first-order approach for estimation of inferred variation in net recruitment rate from the observed variation in one or more demographic parameters.

Methods

For simplicity we consider species with a 1-year reproductive cycle such as minke whales. For species with multi-year breeding cycles, issues of energy storage over the cycle may need to be taken into account explicitly.

Suppose that in each year there is a ration y of energy available to the individual of which an amount x (where $0 \le x < y$) can be invested in reproduction. For female adults, the survival rate of the calf depends on the invested energy x, and the survival rate of the mother depends on the remaining energy y–x. The total energy ration y is assumed given by environmental factors, but the part of this invested in reproduction can be optimised by the individual.

The factors of interest are S, the adult survival probability, and R, the effective reproductive rate. R is expressed in terms of the probability of raising a female calf that survives to maturity, so that the expected net recruitment rate is $S + R - 1$.

One would expect the relationship between available energy and survival to be roughly of the shape of the curves

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[1] Some of the proportion data are zeros and will need to be transformed (e.g. using the arctan function) prior to modelling.

shown in Fig. 1, with diminishing returns at higher energy levels, but with survival rates of adults and calves possibly declining rapidly when the available energy drops below critical levels.

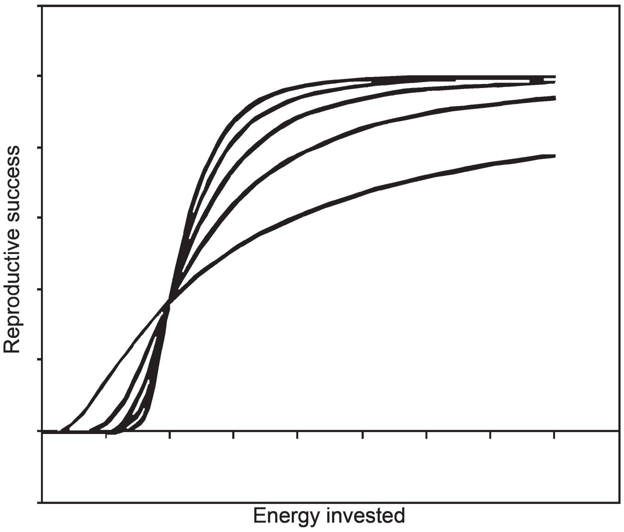

Fig. 1. Curves of potential relationships between effective reproductive success and energy invested in reproduction (analogous curves for the energy/survival relationship).

Curves of this shape can be modelled by:

$$S(x) = S_{\max} \exp\left(-\left(\frac{\alpha_S}{y-x}\right)^z\right) \quad (1)$$

$$R(x) = R_{\max} \exp\left(-\left(\frac{\alpha_R}{x}\right)^z\right) \quad (2)$$

where α_S and α_R are population-specific parameters and z is an exponent parameter introduced to allow flexibility in the shape of the relationships. The values $S_{\max}$ and $R_{\max}$ denote the maximum survival rates of adults and offspring in times of plenty.

If the individual 'chooses' x optimally then two outcomes are possible, depending on the total available energy y. For low values of y, the optimal choice is to set $x = 0$ and not to attempt reproduction ($R = 0$). For higher values of y, the optimal choice is at a local maximum that satisfies:

$$dR/dx + dS/dx = 0 \quad (3)$$

The globally optimum value of x can be determined for given values of y and the parameters as follows:

(i) solve equation (3) for x in $0 < x < y$, if possible, to obtain a local maximum of $S + R$;
(ii) calculate S for $x = 0$ (implying $R = 0$); and
(iii) choose either the local maximum or $x = 0$ depending which yields the higher value of $S + R$.

Example results and discussion

Figs 2–4 show some example results for the parameter values: $S_{max} = 0.99$, $R_{max} = 0.1$, $\alpha_S = \alpha_R = 1$, $z = 2$. Fig. 2 shows the net recruitment rate as a function of available energy for (a) choice of x yielding a local maximum and (b) $x = 0$ (no reproduction). The optimum lies on curve (a) to the right of the crossover and on curve (b) to the left of the crossover. The crossover point is the critical energy level below which reproduction is not worthwhile.

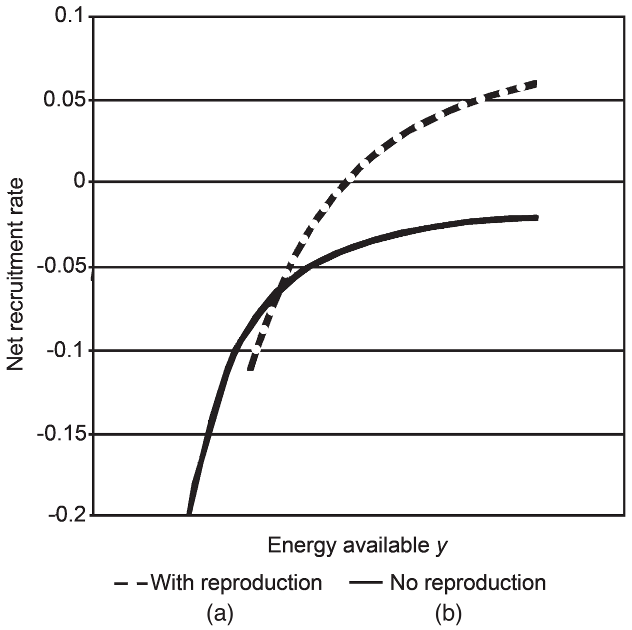

Fig. 2. Net recruitment as a function of available energy for: (a) choice of x yielding a local maximum; and (b) $x = 0$ (no reproduction). The optimum lies on curve (a) to the right of the crossover and on curve (b) to the left of the crossover.

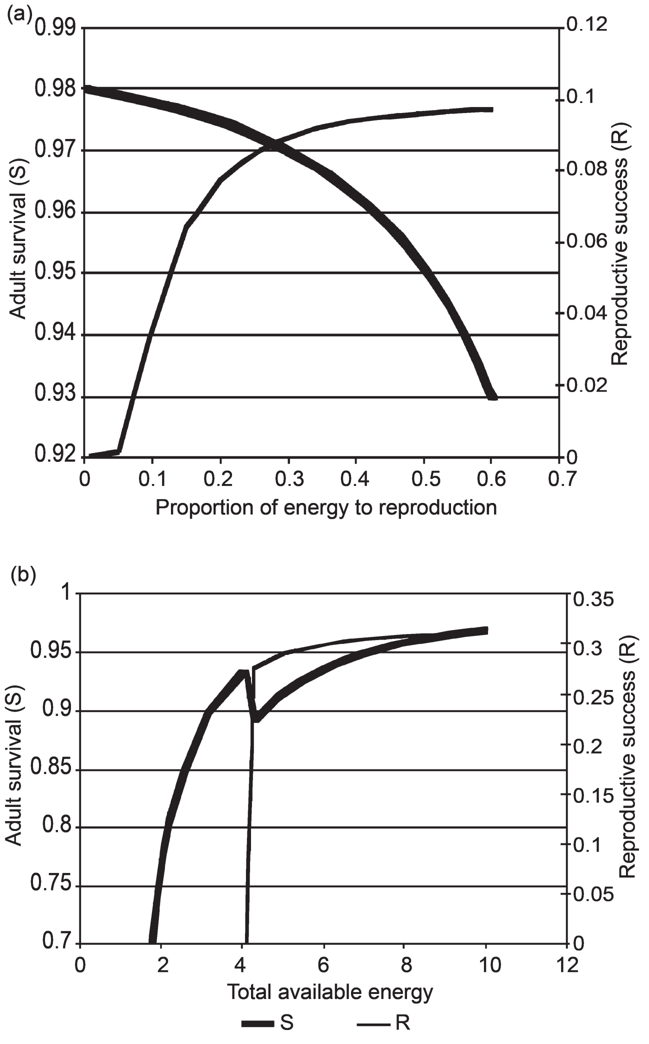

Fig. 3 (a) Survival and reproductive success as a function of proportion of available energy invested in reproduction for fixed total available energy. (b) Survival and reproductive success as a function of total available energy, assuming optimal allocation to reproduction.

Fig. 3a shows the relationship between S and R as a function of x for fixed y. The relationship between survival and reproduction is negative, because of the trade-off involved in investing energy into reproduction. Fig. 3b shows the relationship between S and R as a function of y, the total energy available, when x is chosen optimally. The correlation is positive, except for energy levels near the critical level where reproduction is abandoned. Environmentally driven variation in the available energy is thus predicted to generate positive covariance between survival and reproduction except over a limited range of energies.

Fig. 4 shows the fraction x/y of available energy invested in reproduction for the globally optimal choice of x as a function of y, along with the values of S and R (where S has been expressed in terms of $M = 1 - S$ to make it more comparable with R). Fig. 4 shows that the optimal proportion of energy invested in reproduction remains fairly constant above the critical energy level at which reproduction is abandoned, except when very close to the critical level.

Fig. 4 also shows that the adult survival rate S declines (M increases) substantially with decreasing energy levels even well above the critical level. The absolute variation in S (or M) over energy levels above the critical level is similar in magnitude to the absolute variation in R. For the net recruitment rate, $R - M$, the absolute (not relative) variation in S and R is decisive. If only the variation in R were measured, then the assumption that S is constant would in this model lead to substantial underestimation of the variability in the net recruitment rate.

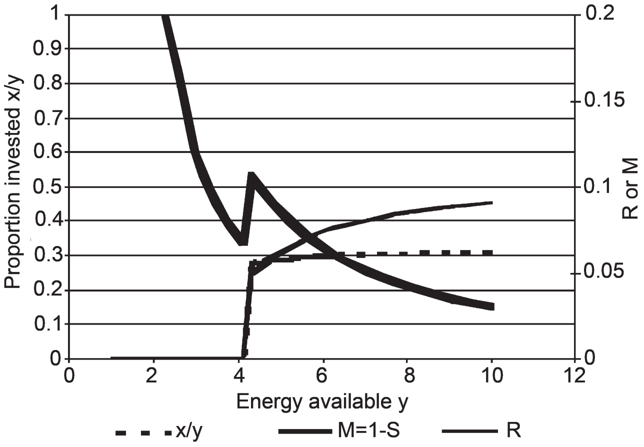

Fig. 4. Reproductive success (R), mortality (M = 1 – S) and proportion (x/y) of energy invested in reproduction as a function of total energy available (y).

If exploration of a wider range of models and parameter values confirms this finding, then it will be necessary to take account of potential variation in survival, even in cases where it is hard to measure empirically. Where data are lacking, the assumption that variation in adult survival rates and reproduction are equally important may be a preferable null hypothesis to the assumption that adult survival rates do not vary.

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Appendix 4

GENETIC DIVERSITY, MIGRATION, AND POPULATION SIZE

Robin Waples

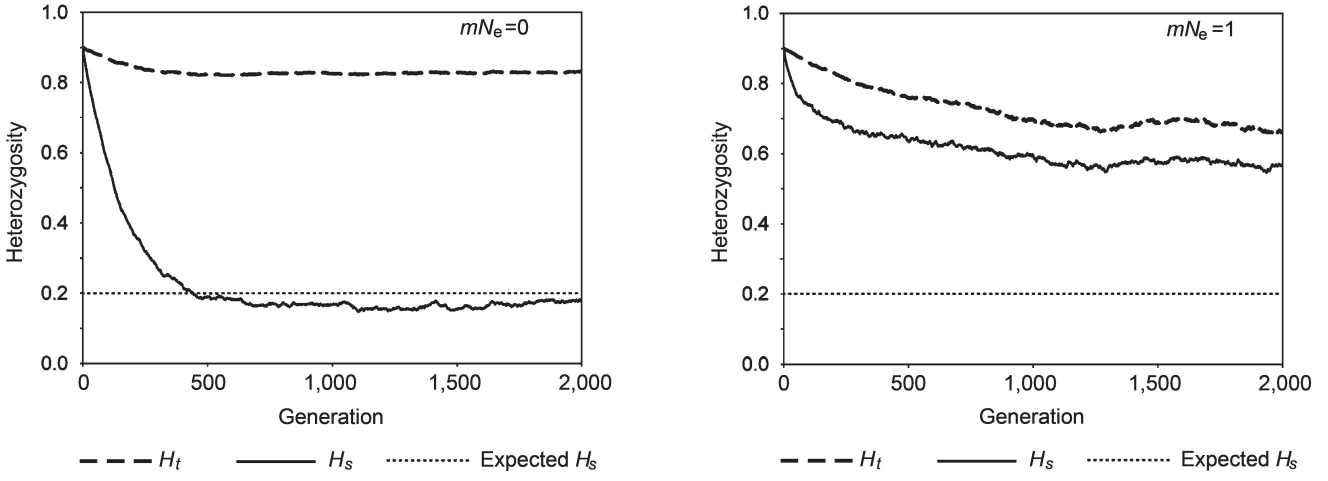

Fig. 1. Relationship between mean within-population expected heterozygosity (H_s) and expected heterozygosity for a metapopulation as a whole (H_t) as a function of level of gene flow (mN_e) and time since initialisation (Waples, 2010). Black dotted lines show expected value of H_s for a local subpopulation; solid and dashed lines show data for simulated Wright-Fisher populations (EasyPop; Balloux, 2001). Simulations used 4 subpopulations of 100 ideal individuals each in an island model; each of 20 neutral gene loci had a maximum of 10 allelic states and a mutation rate of 5×10^{-4}, and the first generation was initiated with the maximal diversity option.

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Waples, R.S. 2010. Spatial-temporal stratifications in natural populations and how they affect understanding and estimation of effective population size. *Molecular Ecology Resources* (doi: 10.1111/j.1755–0998.2010.02876.x; published online early May 2010).

Appendix 5

UPDATES TO THE RMP SPECIFICATIONS AND ANNOTATIONS

Background

The last full published version of the RMP was included in IWC (1999). Subsequently there have been a number of revisions to the annotations:

(1) IWC (2002, p.5): inserting of the correct percentile in paragraph 4.4 and annotation 31;
(2) Allison *et al.* (2002): addition of footnotes on additional variance when combining estimates from different years (21); time stamp (20a); phase-out (23a); unsurveyed areas (21a) and order of adjustments (26a); and
(3) IWC (2006); revision to RMP annotation 2 regarding *Small Areas*.

Additional text related to catches over time had been developed in an RMS context in IWC (2001, p.5), as follows:

Catch limits calculated under the Revised Management Procedure shall be adjusted downwards to account for human-induced mortalities due to sources other than commercial catches. Each such adjustment shall be based on an estimate provided by the Scientific Committee of the size of adjustment required to ensure that total removals over time from each population and area do not exceed the limits set by the Revised Management Procedure. Total removals include commercial catches and other human-induced mortalities, to the extent that these are known or can reasonably be estimated.

An amendment to limit the provision to specific types of human-induced mortality was proposed by the RMS working group and accepted by the Commission (IWC, 2000, pp.32–33):

Catch limits calculated under the Revised Management Procedure shall be adjusted downwards to account for human-induced mortalities due to sources other than commercial catches. Each such adjustment shall be based on an estimate provided by the Scientific Committee of the size of adjustment required to ensure that total removals over time from each population and area do not exceed the limits set by the Revised Management Procedure. Total removals include commercial catches and other human-induced mortalities **caused by indigenous subsistence whaling, whaling under Special Permit for scientific research, whaling outside the IWC, bycatches and ship strikes** to the extent that these are known or can be reasonably estimated.

Proposed new amendments

1. Human-induced mortalities

The sub-committee agreed that the Commission's amendment was best included in the RMP specification as a new paragraph 3.6 and that the following new annotation should be added to provide the Committee with operational guidelines for implementing this provision:

3.6. Adjustment for other sources of human-caused mortality

(26aa). For the purpose of this provision, 'known or can be reasonably estimated' shall be interpreted as follows:

(a) if the recorded mortalities of the specified types are considered by the Scientific Committee to be reasonably complete, the adjustment shall be based on these;
(b) if the recorded mortalities of a given type are considered to be incomplete, but an estimate is available that is acceptable to the Scientific Committee, the estimate shall be used; and
(c) if the recorded mortalities of a given type are considered to be incomplete, but there is insufficient information to make an acceptable estimate, the recorded mortalities shall be used as a fall-back, but the Committee shall note the problem in its report.

In the case of bycatch, ship strikes, and non-IWC whaling, the 'size of adjustment required to ensure that total removals over time from each population and area do not exceed the limits set by the Revised Management Procedure' should normally be calculated as follows, unless specific circumstances indicate otherwise: the catch limit for each *Year* of the *Catch Limit Calculation* shall be reduced by 20% of the total (over the most recent five-year period for which data or estimates are available) of the recorded or reasonably estimated mortalities for the *Management Area* to which the catch limit applies. The adjustment shall be calculated at the time of the *Catch Limit Calculation*.

In the case of Scientific Permit catches, the adjustment to the catch limit for each *Year* shall be based on the maximum proposed scientific take for the given *Management Area* in the given *Year* as specified in a research whaling proposal submitted to the Scientific Committee. The adjustment can be made whenever a research proposal is submitted, without performing a new *Catch Limit Calculation*. In the case of indigenous subsistence whaling regulated by the IWC, the adjustment to the catch limit for each *Year* shall be based on the maximum allowed strike permitted for that *Year*, or, in the case of a multi-year strike limit, on the average annual strike limit.

If the unadjusted catch limit for a *Management Area* is less than the adjustment, the resulting catch limit is zero. In the cases of uncertainty with respect to location, mortalities shall be allocated to *Management Areas* as specified in section 3.2.1. In cases where a carry-over provision under section 3.1 is operative, the carry-over is applied to the catch limits after the adjustment under section 3.6. For example, suppose that there is a catch limit of 850 in a given year, but a scientific catch of 350 whales is proposed: the commercial catch limit for the year is reduced to 500. If the commercial limit is fully taken, but only 200 whales are taken under the scientific permit, the shortfall of 150 whales will be carried over and added to the catch limit for the following year.

To the extent known, the sex ratio of the human-caused mortalities that are taken into account in section 3.6 should be taken into account in the calculation of the sex ratio of the recent total catch as specified in section 3.5.

Annotation 26b is amended to clarify that the adjustment under the new paragraph 3.6 is made after all other calculations and adjustments have been effected except for catch-capping (amendment in ***bold***).

(26b) The order in which catch limits are calculated is as follows:

(i) the *Catch Limit Algorithm* is applied to compute catch limits for *Small Areas* and/or *Medium/Large Areas* and *Combination Areas* as required, with the associated abundance estimates utilised having the time stamps specified in annotation 20a;
(ii) when *Catch-cascading* is involved the associated catch limit for a *Combination Area* is distributed amongst the constituent *Small Areas* (see annotation 9);
(iii) the *Phaseout Rule* (Section 3.4) is applied to catch limits for *Small Areas*;
(iv) the adjustment for recent sex ratios in the catch (see Section 3.5) is applied to catch limits for *Small Areas*;
(v) ***the adjustment for other sources of human-caused mortality (Section 3.6) is applied to the catch limits for each Management Area (Small, Medium, Large);***

(vi) *Catch-capping* limitations, if relevant, relate to *Small Area* limits as evaluated at stage (v).

Note:

~~(1) 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.~~

(2) *Catch-capping* has effect only when the catch limit for a *Medium/Large Area* is less than the sum of the limits for the constituent *Areas*. The RMP does not specify how limits are then reduced in these *Areas* – that is left to the operators – though RMP trials assume pro rata reductions. Sections 3.4 and 3.5 of the RMP indicate that phaseout and sex ratio adjustments apply only to *Small Areas*, so that steps (iii) and (iv) above do not affect *Medium/Large Area* limits computed in step (i) if *Catch-capping* applies.

2. Period of catch limit calculations

This should be extended from five to six years for the reasons given in the sub-committee report. The recommended interval between *Implementation Reviews* should also be changed from five to six years. The references to the five-year period that are to be changed occur in section 3.1 of the specifications and in annotations 9, 11, 11A, 25 and 26. There is no need to change the period specified for calculating adjustments for sex ratios and other sources of mortality (the past five years for which data are available), but the adjustments will apply to the full set of six catch limits. Simulation trials conducted during the development of the *CLA* confirmed that the performance of the *CLA* is robust even if the catch limit is set for 10-year periods.

3. Rounding of catch limits

Section 4.5 (computation) is augmented to clarify that the rounding of each catch limit to the nearest integer should be performed after all other apportionments and adjustments have been effected (amendment in ***bold***).

4.5 Computation

All steps in the above algorithm for the calculation of the nominal catch limit shall be performed using a computer program validated by the IWC Secretariat and with sufficient numerical accuracy that the calculated nominal catch limit is numerically accurate to within one whale. ***Catch limits shall be rounded to the nearest integer number of whales after the apportionment of limits to Small Areas (when catch-cascading is applied) and after performing each of the adjustments specified in sections 3.4, 3.5 and 3.6.***

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Appendix 6

ON THE PENDING ISSUES RELATED TO RESEARCH PROPOSAL ACCOMPANYING MANAGEMENT VARIANT 2 FOR WESTERN NORTH PACIFIC BRYDE'S WHALE

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Introduction

Management variant 2 of the RMP *Implementation* for western North Pacific Bryde's whale had acceptable performance for all 'high' weight trials. However, the conservation performance was 'unacceptable' for the 'medium' weight trials BR13, BR15 and BR17. All these trials are related to the hypothesis of two sub-stocks in sub-area 1, which mix across to each other across the boundary of the 1W and 1E sub-areas (stock structure hypothesis 4, Fig. 1). This means that variant 2 could be implemented with a research program accepted by the IWC Scientific Committee ('variant with research option').

A research proposal written following the pro-forma agreed by the Scientific Committee in 2007 was presented to the Scientific Committee in 2008 (Pastene *et al.*, 2008). The ultimate objective of the research programme was to be able to provide information to the Committee so that it could modify (or confirm) its decisions regarding the appropriate plausibility level for the trials on which variant 2 performed 'unacceptably'.

The research proposal was discussed at the Scientific Committee meeting in 2008 and some comments and suggestions were provided. At the 2009 Scientific Committee meeting no discussion on this matter was conducted but the proponents informed that a revised research proposal would be presented once the analyses/pending issues are completed/elucidated.

The objective of this Appendix is to summarise the results of some analyses and the view of the proponents regarding the following pending issues: age composition data, power analyses of the genetic work and utility of the satellite tags for elucidating problems of stock structure.

Age composition data

Analyses of age distribution data indicated some differences in age distribution between whales in sub-areas 1W and 1E+2 (IWC, 2007). Explanations given for such differences were: (a) differences are real and reflect stock structure; (b) differences are real and reflect age-segregated distribution within a population; and (c) differences are related to age reading and/or sampling issues in the commercial data.

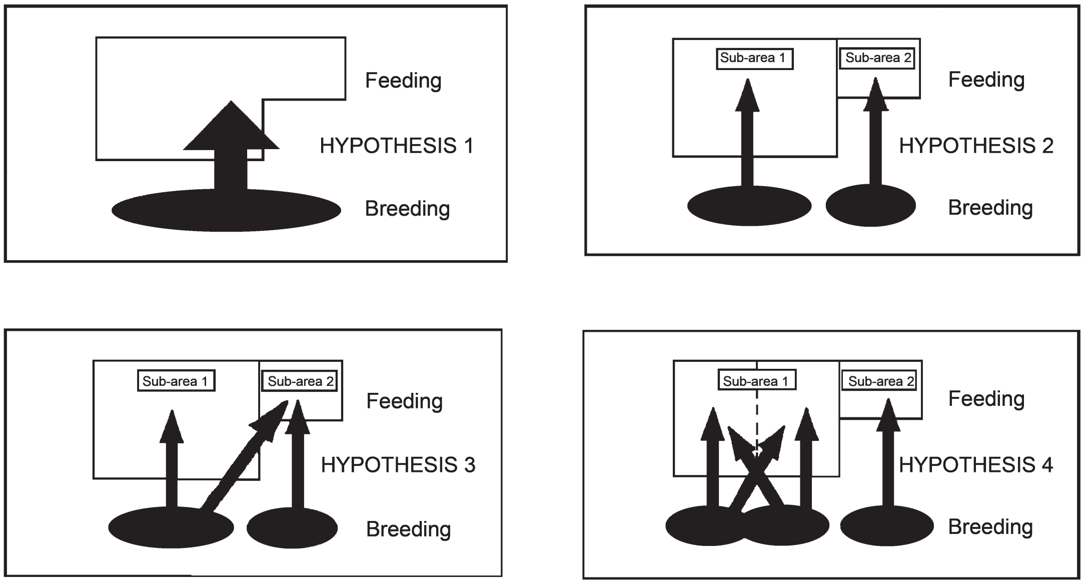

Fig. 1. Hypotheses on stock structure in the western North Pacific Bryde's whale.

Arguing that the old commercial data included some bias, and therefore re-reading of old earplugs might not resolve whether the differences in age composition between sub-areas 1W and 1E reflect sub-stocks or not, the research proposal was aimed to examine earplug data for future whaling operations in sub-areas 1W and 1E. In 2008 the Scientific Committee noted however, that it was not clear whether the effect would be as large today as during the period of commercial whaling. The Scientific Committee noted that this could be examined using the *IST*s based on the stock structure hypothesis 4 and it recommended that this work be done (IWC, 2009).

Analysis conducted

Just after completion of the 2009 Scientific Committee meeting Allison conducted some analyses related to this work. The rational for this analysis under stock structure hypothesis 4 is as follows. As most of the past catches were in sub-area 1W, differences in historical age data between sub-areas 1W and 1E could be ascribed to low mixing between these sub-areas. So if we look at two different trials (one that does have age sub-structure and the other which does not) and age composition data at two different times (one just after commercial whaling ended and the other in recent years), the extent of the effect in recent samples can be evaluated.

Table 1 looks at trials 9 which does have age sub-structure and 3 which does not, and age composition data for two years 1987 and 2006. Differences can be observed in the age composition of the population in 1987 depending on whether or not there is this substructure. For 2006 differences between trials 3 and 9 are virtually zero.

An explanation for this result is that the original difference evident in 1987 came from the different levels of exploitation on the two assumed sub-stocks at that time (if one accepts hypothesis 4). However by 2006, following a period of minimal catches, the total mortality has been the same (just the natural mortality) for a long time.

Results of this analysis suggest that the effect of age composition differences might not be detected using recent or future age samples.

However these results are not inconsistent with explanation (c) above that attributed the differences in age composition to age reading and/or sampling issues in the commercial data. Recent samples have been collected under a scientific research programme, which is less biased than samples obtained by commercial whaling operations in the past. Furthermore in recent years earplugs have been read by a single researcher. In other words the fact that no differences in age composition are found in recent years could just reflect the fact that reading and sampling bias have been resolved under scientific surveys.

We still consider that re-reading of old earplugs might not resolve whether the differences in age composition between sub-areas 1W and 1E reflect sub-stocks or not. Even if we re-read ages of old samples a considerable difference might be found because the body size limit regulation was different between coastal (10.7m) and pelagic (12.2m) whaling. Thus, re-reading might not help at all to resolve the matter. Therefore sub-structure in sub-area 1 should be better elucidated by using genetic analysis as the main analytical tool.

Power analysis of the genetic work

Some members of the Scientific Committee have argued that in absence of power analyses results it would be difficult to assess whether the genetic data, in themselves, would be sufficient to be able to show that stock structure hypothesis 4 was implausible. The Scientific Committee recommended that the results from previous (and any new) power analyses be presented and discussed at the SC meeting (IWC, 2009).

Review of previous work

Earlier work to estimate the power of the genetic analyses for the western North Pacific Bryde's whale was conducted by Kitakado *et al*. (2005) who evaluated power under an island model. Results of this work were presented to the Workshop on the *pre-Implementation assessment* of western North Pacific Bryde's whales (IWC, 2006). The Workshop agreed that the analyses presented had shown that for the sample sizes available, the power to detect genetic differences is high unless the value of F_{st} is very small. The Workshop offered several recommendations to improve this work.

More recently Kanda *et al*. (2009a) presented a power analysis for their hypothesis testing study on stock structure of the O stock common minke whale (based on microsatellite

Table 1

Results of the simulation study to investigate the effect of age composition difference through *IST*s. The columns show the estimated proportion by age and sex of the population under various trials for 1987 and 2006.

	Br09	Br09	Br09	Br09	Br03	Br03	Br03	Br03				
	m87	F87	M06	F06	m87	F87	M06	F06	m87	F87	M06	F06
Difference between Br09 and Br03												
1	0.0884	0.0827	0.0835	0.0824	0.0887	0.0828	0.0836	0.0825	-0.0003	-0.0001	-0.0001	-0.0001
2	0.0817	0.0764	0.0769	0.0759	0.0819	0.0765	0.0770	0.0760	-0.0003	-0.0001	-0.0001	-0.0001
3	0.0761	0.0712	0.0708	0.0699	0.0763	0.0713	0.0710	0.0700	-0.0003	-0.0001	-0.0001	-0.0001
4	0.0703	0.0658	0.0652	0.0644	0.0706	0.0659	0.0653	0.0645	-0.0003	-0.0001	-0.0001	-0.0001
5	0.0654	0.0612	0.0601	0.0594	0.0656	0.0613	0.0602	0.0594	-0.0003	-0.0001	-0.0001	-0.0001
6	0.0582	0.0559	0.0551	0.0544	0.0587	0.0561	0.0553	0.0545	-0.0005	-0.0002	-0.0001	-0.0001
7	0.0524	0.0519	0.0505	0.0497	0.0532	0.0522	0.0506	0.0498	-0.0008	-0.0003	-0.0001	-0.0001
8	0.0475	0.0487	0.0462	0.0454	0.0486	0.0493	0.0463	0.0455	-0.0011	-0.0006	-0.0001	-0.0001
9	0.0417	0.0449	0.0422	0.0414	0.0429	0.0455	0.0423	0.0416	-0.0013	-0.0006	-0.0001	-0.0001
10	0.0380	0.0413	0.0386	0.0378	0.0392	0.0420	0.0387	0.0379	-0.0013	-0.0007	-0.0001	-0.0001
11	0.0358	0.0389	0.0353	0.0346	0.0371	0.0398	0.0354	0.0347	-0.0013	-0.0009	-0.0001	-0.0001
12	0.0323	0.0353	0.0324	0.0318	0.0336	0.0363	0.0325	0.0318	-0.0013	-0.0010	-0.0001	-0.0001
13	0.0283	0.0314	0.0298	0.0292	0.0298	0.0325	0.0298	0.0292	-0.0014	-0.0012	-0.0001	-0.0001
14	0.0261	0.0290	0.0273	0.0268	0.0274	0.0301	0.0274	0.0268	-0.0013	-0.0011	0.0000	0.0000
15	0.0229	0.0254	0.0251	0.0245	0.0240	0.0264	0.0251	0.0246	-0.0011	-0.0010	0.0000	0.0000
16	0.0208	0.0228	0.0229	0.0225	0.0218	0.0238	0.0230	0.0225	-0.0010	-0.0010	0.0000	0.0000
17	0.0184	0.0201	0.0210	0.0206	0.0193	0.0210	0.0210	0.0205	-0.0008	-0.0008	0.0000	0.0000
18	0.0161	0.0173	0.0192	0.0188	0.0167	0.0180	0.0192	0.0188	-0.0006	-0.0007	0.0000	0.0000
19	0.0145	0.0152	0.0177	0.0173	0.0149	0.0157	0.0177	0.0173	-0.0004	-0.0005	0.0000	0.0000
20	0.0127	0.0135	0.0164	0.0160	0.0128	0.0138	0.0164	0.0160	-0.0001	-0.0003	0.0000	0.0000
21	0.0115	0.0120	0.0151	0.0148	0.0114	0.0121	0.0151	0.0148	0.0000	-0.0001	0.0000	0.0000
22	0.0104	0.0108	0.0141	0.0138	0.0102	0.0108	0.0141	0.0138	0.0001	0.0000	0.0000	0.0000
23	0.0096	0.0099	0.0130	0.0128	0.0094	0.0098	0.0130	0.0128	0.0002	0.0001	0.0000	0.0000
24	0.0089	0.0091	0.0115	0.0117	0.0086	0.0089	0.0115	0.0117	0.0003	0.0001	-0.0001	0.0000
25	0.0082	0.0083	0.0102	0.0107	0.0079	0.0080	0.0103	0.0108	0.0003	0.0002	-0.0001	0.0000
26	0.0076	0.0076	0.0092	0.0100	0.0072	0.0074	0.0094	0.0100	0.0004	0.0003	-0.0001	0.0000
27	0.0072	0.0072	0.0084	0.0094	0.0068	0.0069	0.0086	0.0094	0.0004	0.0003	-0.0002	-0.0001
28	0.0067	0.0067	0.0074	0.0086	0.0063	0.0064	0.0076	0.0087	0.0004	0.0003	-0.0002	-0.0001
29	0.0062	0.0062	0.0067	0.0079	0.0058	0.0059	0.0069	0.0080	0.0005	0.0003	-0.0002	-0.0001
30	0.0057	0.0055	0.0063	0.0075	0.0052	0.0053	0.0065	0.0076	0.0004	0.0003	-0.0002	-0.0001
31	0.0052	0.0051	0.0057	0.0068	0.0048	0.0048	0.0059	0.0070	0.0004	0.0003	-0.0002	-0.0002
32	0.0047	0.0046	0.0050	0.0060	0.0043	0.0043	0.0052	0.0062	0.0004	0.0003	-0.0002	-0.0002
33	0.0043	0.0042	0.0046	0.0056	0.0039	0.0039	0.0048	0.0058	0.0004	0.0003	-0.0002	-0.0002
34	0.0040	0.0039	0.0041	0.0049	0.0036	0.0036	0.0042	0.0051	0.0004	0.0003	-0.0002	-0.0002
35	0.0038	0.0036	0.0037	0.0044	0.0033	0.0033	0.0038	0.0046	0.0004	0.0003	-0.0001	-0.0002
36	0.0035	0.0034	0.0033	0.0039	0.0031	0.0031	0.0034	0.0040	0.0004	0.0003	-0.0001	-0.0001
37	0.0033	0.0032	0.0029	0.0034	0.0029	0.0029	0.0029	0.0034	0.0004	0.0003	-0.0001	-0.0001
38	0.0031	0.0030	0.0026	0.0029	0.0026	0.0026	0.0026	0.0030	0.0004	0.0003	0.0000	-0.0001
39	0.0029	0.0028	0.0023	0.0026	0.0024	0.0024	0.0023	0.0026	0.0004	0.0003	0.0000	0.0000
40	0.0026	0.0025	0.0020	0.0023	0.0022	0.0022	0.0020	0.0023	0.0004	0.0003	0.0000	0.0000
41	0.0024	0.0023	0.0019	0.0021	0.0020	0.0020	0.0018	0.0021	0.0004	0.0003	0.0001	0.0000
42	0.0022	0.0021	0.0017	0.0019	0.0018	0.0018	0.0017	0.0019	0.0004	0.0003	0.0001	0.0000
43	0.0020	0.0020	0.0016	0.0018	0.0017	0.0017	0.0015	0.0017	0.0004	0.0003	0.0001	0.0000
44	0.0019	0.0018	0.0015	0.0016	0.0015	0.0015	0.0014	0.0015	0.0004	0.0003	0.0001	0.0001
45	0.0017	0.0017	0.0014	0.0015	0.0014	0.0014	0.0013	0.0014	0.0003	0.0003	0.0001	0.0001
46	0.0016	0.0016	0.0013	0.0014	0.0013	0.0013	0.0012	0.0013	0.0003	0.0003	0.0001	0.0001
47	0.0015	0.0014	0.0012	0.0013	0.0012	0.0012	0.0011	0.0012	0.0003	0.0003	0.0001	0.0001
48	0.0014	0.0014	0.0011	0.0012	0.0011	0.0011	0.0010	0.0011	0.0003	0.0002	0.0001	0.0001
49	0.0013	0.0013	0.0010	0.0011	0.0010	0.0010	0.0009	0.0010	0.0003	0.0002	0.0001	0.0001
50	0.0169	0.0159	0.0128	0.0132	0.0118	0.0118	0.0102	0.0111	0.0051	0.0041	0.0026	0.0021

data). Genotypic data were generated using the computer software EASYPOP and heterogeneity tests were conducted with the generated data. The number of populations was determined depending on the stock structure scenario tested. The same method was employed to evaluate the power of the genetic analysis on Bryde's whale stock structure conducted by Kanda *et al*. (2009b).

Results suggested that from a genetics perspective, it was reasonable to conclude that the data set had adequate statistical power to study genetic differentiation in the Bryde's whale samples. This simulation analysis supported the conclusion of a single stock of Bryde's whales in sub-area 1 (see Adjunct 1 for details of this analysis).

Utility of the satellite tags for elucidating problems of stock structure

The research proposal presented in 2008 included experiments on satellite tagging. Some Scientific Committee members highlighted the value of tag-based techniques to evaluate stock structure hypothesis. The Scientific Committee noted the necessity to evaluate the trade-off between the cost of finding Bryde's whales and successfully attaching satellite tags and the value of this information to address questions of stock structure.

Experiments on satellite tags under JARPN II
Evaluation of satellite tagging for stock structure studies can be done by examining the experiments on satellite tagging in Bryde's whales conducted under JARPN II. Experiments were conducted in 2004, 2006 and 2008. The number of trials in each of these years was 3, 3 and 13 involving 59, 85 and 488 minutes of experimental effort, respectively.

Two satellite tags were successfully attached to Bryde's whales, one in 2006 and the other in 2008, providing information on movement of the animals for periods of 15 and 21 days, respectively (Nishiwaki *et al.*, 2009).

A large number of marks will be required if the aim is to investigate mixing across the boundary line separating sub-areas 1W and 1E. If the same experimental effort is maintained during future commercial operations (during which the research plan will be implemented) we cannot expect a large number of marks successfully attached. However as the original research plan noted, the aim of the satellite tagging experiment is to obtain information on the pattern of migration and location of breeding grounds. For this aim experiments should be conducted at the end of the feeding season and large sample numbers might not be required. Biopsy sampling would be conducted on the same animals.

Conclusions
As noted in the original plan, the research will start once the RMP is implemented for the western North Pacific Bryde's whale. Based on the results of the power analyses conducted we consider that genetics should be the main analytical tool to investigate sub-stock structure in sub-area 1. Age data are not required as a tool to investigate stock structure. Experiments on satellite tagging could be valuable to investigate patterns of migration and location of breeding grounds, and a large number of samples might not be required. This information will facilitate the interpretation of the results of the genetic analyses. It is unlikely that the collection of age data from new samples will provide information on age composition differences between sub-areas. However these data will be collected as they are essential for the estimation of biological parameters, which can be examined to further interpret results of the main analytical tool: genetics.

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Adjunct 1

Assessment of statistical power for the tests of homogeneity on Bryde's whales in Kanda *et al.* (2009)

In order to assess statistical power for tests of homogeneity (e.g. Waples and Gaggiotti, 2006), we generated genotypic data using computer software EASYPOP (Balloux, 2001) and conducted heterogeneity tests with these generated data Table 1). We conducted the simulation analysis for assessing the statistical power for the tests between the samples from sub-areas 1W and 1E for Bryde's whales (Kanda *et al.*, 2009).

We assumed two populations, each of which consists of diploid individuals with a constant size and equal sex ratio with random mating. We assumed the ratio of effective population size to census population size to be 1/3 to 1/4 (Roman and Palumbi, 2003). We used a census population size of 15,000. These numbers were set on the basis of the IWC's accepted population abundance estimates for this species in the North Pacific.

Each generation, simulation produces a genotypic data set for 17 independent nuclear gene loci (microsatellites) for each individual. The number of the loci simulated and maximum number of the allelic states (18) was set based on the observed data in this study. Bidirectional migration was assumed with equal migration rates (m). Different levels of the migration rates were selected, some of which were quite high for the genetic method to detect. We specified a range of genetic divergence using F_{ST} values estimated assuming an island model between the two populations by changing migration rate. A mutation rate of 5×10^{-4} was chosen to represent microsatellite loci. For each simulation parameter set, we made 100 replicates. We ran 5,000 generations for each replicate before collecting data. In the final generation of each replicate, a sample of 140 individuals was taken from each population for genetic analysis. This sample size was set to reflect the observed data, although the program was only able to have equal sample size over the populations. The sample size for Bryde's whales equalled the sum of the sample size from the sub-area 1E.We conducted homogeneity tests for the generated data set using pairwise tests of differentiation option in the FSTAT 2.9.3 (Goudet, 1995). In this option, for each pair of samples, multi-loci genotypes are randomised between the two samples. The overall loci G-statistic is given and statistical significance was decided with a table wide level of significance at 5%.

The simulation analysis was carried out to see if our genetic data set was adequate to test genetic heterogeneity between the samples from sub-areas 1W and 1E. Percent of rejecting panmixia with our data set (sample size of 140 and genetic variation at 17 microsatellite loci) was close to 100% at the mutation rate of 0.02 (estimated F_{ST} less than 0.0050). From a genetics perspectives, it is therefore reasonable to say that our data set has adequate statistical power to study genetic differentiation in our Bryde's whale samples. This simulation analysis supported our conclusion of a single stock of Bryde's whales in the sub-area 1.

Table 1

Input parameter sets used for generating simulated data set using EASYPOP to assess statistical power in our samples and results of the homogeneity tests with the simulated data. The following were fixed in all sets other than shown in the table: diploid, random mating, equal sex ratio, subpopulations of constant Ne, mutation rate of 0.0005, and 100 replicates each with 5,000 generations.

n	N	Ne	m	Nem	F_{ST}	S	L	A	% rejecting panmixia
N=3Ne									
2	15,000	5,000	0.01	50	0.0050	140	17	18	100
2	15,000	5,000	0.02	100	0.0025	140	17	18	85
2	15,000	5,000	0.05	250	0.0010	140	17	18	27
2	15,000	5,000	0.1	500	0.0005	140	17	18	5
2	15,000	5,000	0.2	1,000	0.0002	140	17	18	9
N=4Ne									
2	15,000	3,750	0.01	38	0.0066	140	17	18	100
2	15,000	3,750	0.02	75	0.0033	140	17	18	95
2	15,000	3,750	0.05	188	0.0013	140	17	18	46
2	15,000	3,750	0.1	375	0.0007	140	17	18	14
2	15,000	3,750	0.2	750	0.0003	140	17	18	15

N=census population size; Ne=effective population size; m=mutation rate; Nem=number of migrants per generation; S=number of sample size; L=number of loci analysed; A=possible number of alleli.

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Appendix 7

ESTIMATES USED FOR CATCH LIMIT CALCULATIONS IN NORTHEAST ATLANTIC MINKE WHALES

Gjermund Bøthun and Nils Øien

A series of four surveys were conducted by Norway to estimate the abundance of minke whales in the northeastern Atlantic: 1988/89 and 1995 (Schweder *et al.*, 1997), 1996–2001 (Skaug *et al.*, 2004) and 2002–07 (Bøthun *et al.*, 2009).

The surveys in 1988 and 1989 were conducted before the RMP *Implementation* of North Atlantic minke whales and thus the block structure of those surveys was not fitted to the *Small Management Areas* (SMA) later implemented (IWC, 1993, p.115). For the surveys following in 1995 and onwards the SMAs were taken into consideration when establishing the block structure. However, during the *Implementation Review* in Berlin in 2003, some changes were made to the original SMA definitions. In the last survey period from 2002–07 the necessary adjustments of the underlying survey block structure to the new SMA definitions were made, so estimates for that survey period were directly calculated with respect to the 2003 SMA structure based on the survey block structure. However, for the earlier surveys, the new SMA boundaries divide some of the survey blocks used, and estimates have to be recalculated to fit the present SMAs. The method chosen here is to assign estimates from divided blocks proportionally to SMAs by area as follows:

A_{ij} = area of survey block i within SMA_j

A_i = total area of survey block i

Let **F** be a matrix with element $\{F\}_{ij} = A_{ij} / A_i$

Let **N** be a vector with element $\{N\}_i$ = abundance in survey block i

The elements of matrix **F** are given in Tables 2, 5, 8 and 11.

The elements of vector **N** are given in Tables 3, 6, 9 and 12.

Abundances by new small areas ($\mathbf{N}_{SMA}$) are given in Table 13 and are found by:

$\mathbf{N}_{SMA} = \mathbf{N*F}$ (assuming the same order of survey blocks in N and F).

Let $\sum$ be the covariance matrix corresponding to N with element $\sum_{ii}$ corresponding to the standard deviation given in Tables 3, 6, 9, and 12 and assume $\sum_{i \neq j} = 0$. Then the standard deviations in Table 13 are given by diagonals in $(\mathbf{F'\sum F})^{½}$.

The areas listed in Tables 1, 4, 7 and 10 have been calculated using GIS with an Albers equal area projection. Maps are shown in Figs 1–4.

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Table 1

Areas in km² for 1988/89 survey blocks divided by 2004 small areas.

Small Area	Survey block	Area km²
CM	SN	8,004.0
EB	BA	292,633.0
EB	FI	14,633.6
EB	GA	158,937.0
EB	KO	85,021.0
EN	NS	247,229.0
EN	SN	113,775.0
ES	BA	67,136.4
ES	BJ	75,370.0
ES	NO	90,192.5
ES	SV	79,351.7
ES	VSN	13,104.5
ES	VSS	26,838.8
EW	FI	75,040.3
EW	LO	121,875.0
EW	NO	255,970.0
EW	SN	346,852.0

Table 2

Fraction of 1988/1989 survey blocks belonging to given SMAs.

Survey block	CM	EB	EN	ES	EW
BA	0	0.81	0	0.19	0
BJ	0	0	0	1	0
FI	0	0.16	0	0	0.84
GA	0	1	0	0	0
JM	1	0	0	0	0
KO	0	1	0	0	0
LO	0	0	0	0	1
NO	0	0	0	0.26	0.74
NS	0	0	1	0	0
NV	1	0	0	0	0
SN	0.04	0	0.24	0	0.72
SV	0	0	0	1	0
VSN	0	0	0	1	0
VSS	0	0	0	1	0

Table 3

Combined 1988/89 abundance estimates with standard errors by block.

Survey block	Abundance	SD
BA	5,364	2,241
BJ	2,549	541
FI	2,626	926
GA	2,522	1,108
JM	847	298
KO	14,554	3,963
LO	3,192	901
NO	9,519	2,266
NS	5,429	1,873
NV	1,803	1,214
SN	11,935	4,039
SV	4,052	1,260
VS	2,988	694

Table 4

Areas in km² for 1995 survey blocks divided by 2004 small areas.

Small Area	Survey block	Area km²
ES	VSI	–
ES	VSN	17,133.0
ES	VSS	27,228.0
ES	SV	88,250.0
ES	SVI	142,424.0
ES	NON	88,970.0
ES	BJ	74,607.0
ES	BAW	79,602.0
EB	BAW	28,745.0
EB	FI	14,343.0
EB	BAE	457,068.0
EB	KO	85,586.0
EB	GA	160,666.0
EW	NOS	396,650.0
EW	LOC	95,109.0
EW	FI	75,280.0
EW	NSC	208,335.0
EN	NSC	96,725.0
EN	NS	248,689.0
CM	JMC	67,858.0
CM	NVN	356,290.0
CM	NVS	238,237.0

Table 5

Fraction of 1995 survey blocks belonging to given SMAs.

Survey block	CM	EB	EN	ES	EW
BAE	0	1	0	0	0
BAW	0	0.27	0	0.73	0
BJ	0	0	0	1	0
FI	0	0.16	0	0	0.84
GA	0	1	0	0	0
JMC	1	0	0	0	0
KO	0	1	0	0	0
LOC	0	0	0	0	1
NON	0	0	0	1	0
NOS	0	0	0	0	1
NS	0	0	1	0	0
NSC	0	0	0.32	0	0.68
NVN	1	0	0	0	0
NVS	1	0	0	0	0
SV	0	0	0	1	0
SVI	0	0	0	1	0
VSI	0	0	0	1	0
VSN	0	0	0	1	0
VSS	0	0	0	1	0

Table 6

Combined 1995 abundance estimates with standard errors by block.

Survey block	Abundance	SD
BAE	16,101	4,819
BAW	4,062	1,075
BJ	7,164	1,677
FI	5,974	1,771
GA	10,615	2,291
JMC	1,339	750
KO	962	544
LOC	2,462	562
NON	3,357	873
NOS	22,678	3,527
NS	20,294	5,237
NSC	7,070	1,670
NVN	4,835	2,072
SV	4,719	767
SVI	2,691	768
VSI	345	140
VSN	1,672	326
VSS	1,959	456
NVS	0	0

Table 7

Areas in km² for 1996–2001 survey blocks divided by 2004 SMAs.

Small Area	Survey block	Area km²
ES	VSI	22,130.0
ES	VSN	17,133.0
ES	VSS	27,228.0
ES	SV	88,609.0
ES	SVI	177,972.0
ES	NON	88,970.0
ES	BJ	74,607.0
ES	BAW	101,946.0
EB	BAW	33,045.0
EB	FI	14,343.0
EB	BAE	525,391.0
EB	KO	85,586.0
EB	GA	160,666.0
EW	NOS	396,650.0
EW	LOC	95,109.0
EW	FI	75,280.0
EW	NSC	208,335.0
EN	NSC	96,725.0
EN	NS	248,689.0
CM	JMC	67,858.0
CM	NVN	329,467.0
CM	NVS	298,076.0

Table 8

Fraction of 1996–2001 survey blocks belonging to given SMAs.

Survey block	CM	EB	EN	ES	EW
BAE	0	1	0	0	0
BAW	0	0.24	0	0.76	0
BJ	0	0	0	1	0
FI	0	0.16	0	0	0.84
GA	0	1	0	0	0
JMC	1	0	0	0	0
KO	0	1	0	0	0
LOC	0	0	0	0	1
NON	0	0	0	1	0
NOS	0	0	0	0	1
NS	0	0	1	0	0
NSC	0	0	0.32	0	0.68
NVN	1	0	0	0	0
NVS	1	0	0	0	0
SV	0	0	0	1	0
SVI	0	0	0	1	0
VSI	0	0	0	1	0
VSN	0	0	0	1	0
VSS	0	0	0	1	0

Table 9

Combined 1996–2001 abundance estimates with standard errors by block.

Survey block	Abundance	SD
JMC	4,432	921
NVN	9,554	1,789
NVS	12,732	3,426
BAE	11,605	4,888
FI	6,762	1,563
GA	9,971	3,730
KO	2,461	819
NOS	13,037	2,478
LOC	584	818
NS	11,713	3,455
NSC	6,182	1,368
BAW	3,128	1,516
BJ	1,909	403
NON	2,579	704
SV	4,699	1,214
SVI	1,932	1,315
VSI	226	140
VSN	1,540	304
VSS	2,159	860

Table 10

Areas in km² for 2002–2007 survey blocks divided by 2004 SMAs.

Small Area	Survey block	Area km²
ES	VSI	0.0
ES	VSN	17,133.0
ES	VSS	27,228.0
ES	SV	85,278.0
ES	SVI	138,000.0
ES	NON	88,970.0
ES	BJ	74,607.0
ES	BAW1	100,726.0
EB	BAW2	24,536.0
EB	FI2	14,343.0
EB	BAE	392,666.0
EB	KO	85,586.0
EB	GA	160,666.0
EW	NOS	396,650.0
EW	LOC	95,109.0
EW	FI1	75,280.0
EW	NSC1	208,335.0
EN	NSC2	96,725.0
EN	NS	248,689.0
CM	JMC	67,858.0
CM	NVN	355,563.0
CM	NVS	319,571.0

Table 11

Fraction of 2002–07 survey blocks belonging to given SMAs.

Survey block	CM	EB	EN	ES	EW
BAE	**0**	**1**	**0**	**0**	**0**
BAW1	**0**	**0**	**0**	**1**	**0**
BAW2	0	1	0	0	0
BJ	0	0	0	1	0
FI1	0	0	0	0	1
FI2	0	1	0	0	0
GA	0	1	0	0	0
JMC	1	0	0	0	0
KO	0	1	0	0	0
LOC	0	0	0	0	1
NON	0	0	0	1	0
NOS	0	0	0	0	1
NS	0	0	1	0	0
NSC1	0	0	0	0	1
NSC2	0	0	1	0	0
NVN	1	0	0	0	0
NVS	1	0	0	0	0
SV	0	0	0	1	0
SVI	0	0	0	1	0
VSI	0	0	0	1	0
VSN	0	0	0	1	0
VSS	0	0	0	1	0

Table 12

Combined 2002–07 abundance estimates with standard errors by block.

Survey block	Abundance	SD
JMC	9,904.9	3,680
NVN	13,445.5	9,316
NVS	3,388.3	1,979
BAE	13,264.7	5,077
BAW2	31.5	61
FI2	204.6	243
GA	8,114.6	3,388
KO	7,009.8	2,778
NSC2	3,382.0	2,550
NS	2,864.4	1,406
BAW1	3,401.9	1,819
BJ	4,630.8	1,564
NON	3,123.2	1,230
SV	7,060.4	4,570
VSN	314.4	226
VSS	846.6	505
VSI	–	0
SVI	–	0
FI1	2,201.0	1,208
LOC	3,456.6	1,718
NSC1	4,321.2	1,760
NOS	17,173.0	4,953

Table 13

Summary of estimates by 2004 SMAs.

Survey period	Mid-year	EB			EN			ES			EW			E total			CM		
		Year	N	SD	*Year*	N	SD	*Year*	N	SD	*Year*	N	SD	*Year*	N	CV	*Year*	N	SD
1988–89	1989	*1989*	21,868	4,503	*1989*	8,318	2,113	*1989*	13,070	1,699	*1989*	20,991	3,552	*1989*	64,730[1]	0.192	*1988*	2,650[1]	1,283
1995	1995	*1995*	29,712	5,378	*1995*	22,536	5,263	*1995*	24,891	2,389	*1995*	34,986	4,033	*1995*	112,125	0.104	*1995*	6,174	2,203
1996–2001	1999	*2000*	25,885	6,219	*1998*	13,673	3,482	*1999*	17,406	2,454	*1996*	23,522	3,013	*1999*	80,487	0.15	*1997*	26,718	3,973
2002–07	2005	*2007*	28,625	6,709	*2004*	6,246	2,912	*2003*	19,377	5,335	*2002, 2006*	27,152	5,917	*2005*	81,401	0.23	*2005*	26,739	10,428

[1] These estimates are taken from Schweder *et al.* (1997) and are different from the results from direct application of area proration. The differences are caused by a very small part of the 1989 survey block (SN) falling within the CM *Small Area* in the area projection used here.

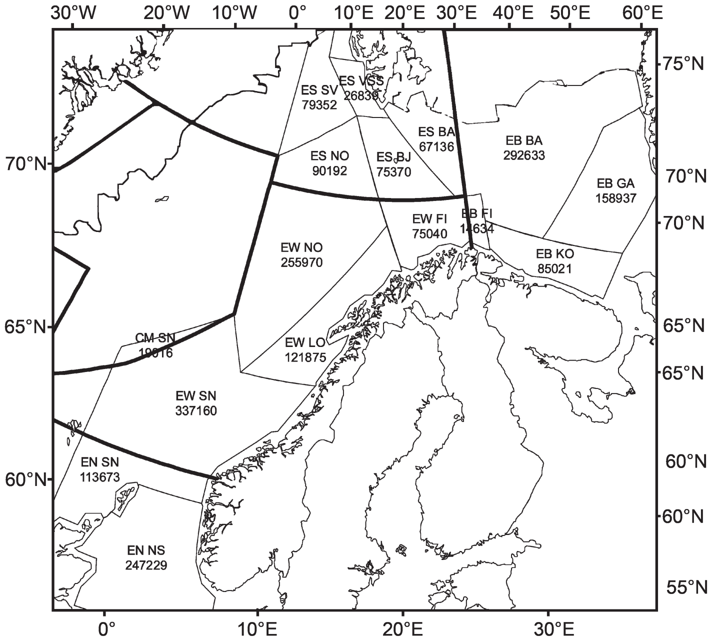

Fig. 1. 1989 survey blocks divided by 2004 SMAs.

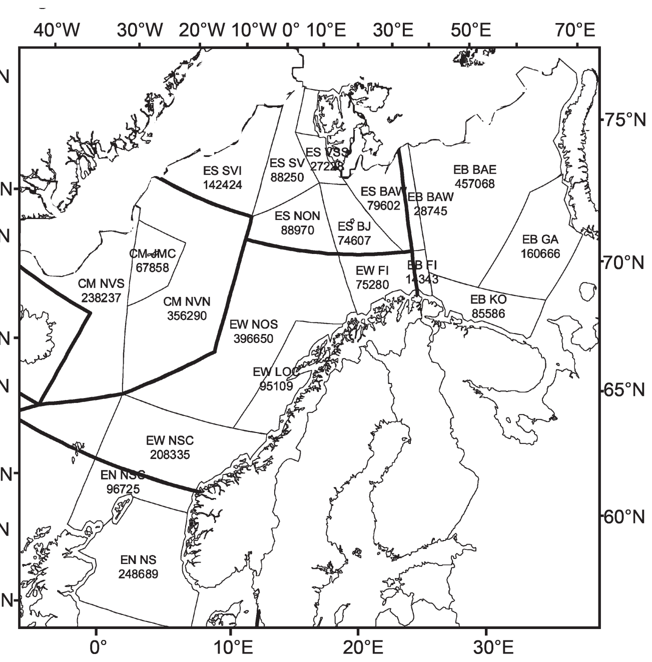

Fig. 2. 1995 survey blocks divided by 2004 SMAs.

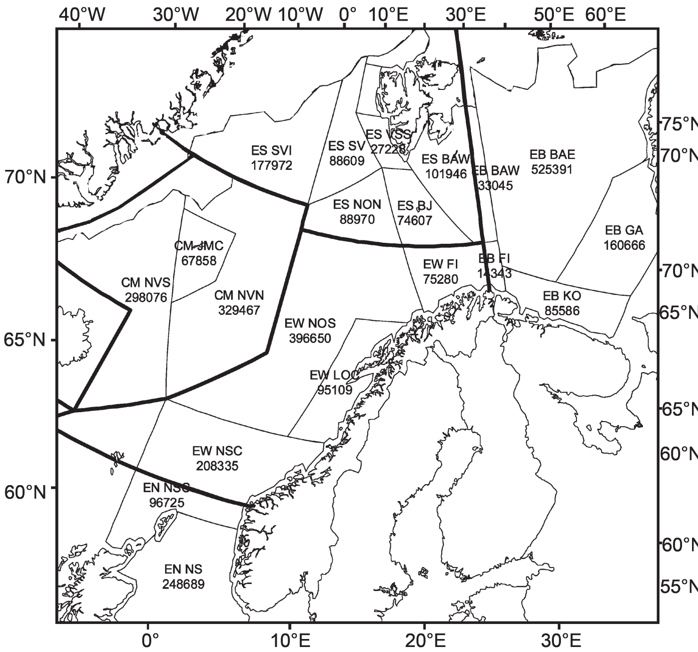

Fig. 3. 1996–2001 survey blocks divided by 2004 SMAs.

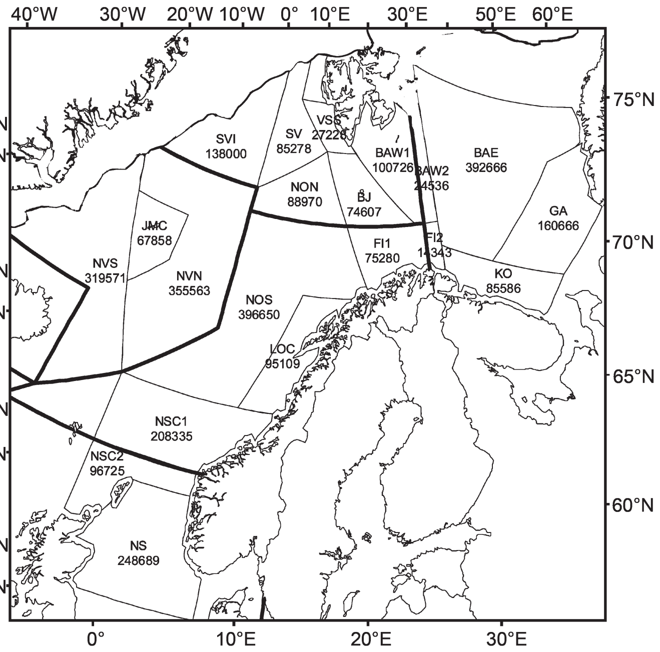

Fig. 4. 2002–07 survey blocks divided by 2004 SMAs.

Appendix 8

DATA USED IN CALCULATION OF CATCH LIMITS

C. Allison

A. Western North Pacific Bryde's whales

Catch data (sub-areas 1W+1E+2 combined)

Year	Catch	Year	Catch	Year	Catch	Year	Catch	Year	Catch
1906	13	1927	118	1948	134	1969	89	1990	0
1907	34	1928	80	1949	199	1970	139	1991	0
1908	82	1929	63	1950	288	1971	919	1992	0
1909	47	1930	62	1951	307	1972	160	1993	0
1910	51	1931	135	1952	491	1973	699	1994	0
1911	156	1932	104	1953	61	1974	1,323	1995	0
1912	81	1933	84	1954	75	1975	1,432	1996	0
1913	125	1934	93	1955	94	1976	1,459	1997	0
1914	56	1935	92	1956	24	1977	946	1998	1
1915	169	1936	87	1957	39	1978	796	1999	0
1916	105	1937	122	1958	254	1979	1,281	2000	43
1917	181	1938	160	1959	263	1980	755	2001	50
1918	148	1939	193	1960	404	1981	485	2002	50
1919	161	1940	110	1961	167	1982	482	2003	50
1920	92	1941	144	1962	504	1983	545	2004	51
1921	89	1942	21	1963	210	1984	528	2005	50
1922	81	1943	29	1964	68	1985	357	2006	51
1923	75	1944	74	1965	8	1986	317	2007	50
1924	111	1945	12	1966	55	1987	317	2008	50
1925	118	1946	126	1967	45	1988	0	2009	50
1926	134	1947	106	1968	171	1989	0		

Incidental catches. Extract from the *Implementation* trial specifications (IWC, 2008b, p.463):

> Only four incidental catches have been recorded since 1975 (of which one (in October 2003) from a trap net in Shizuoka) was identified as an offshore type Bryde's whale. The remaining three (in August 1978 from Oita, April 1988 from Hyogo and March 1995 from Kochi (released) are all thought to have been inshore forms although no DNA data is available to confirm this. In addition three Bryde's whales have been stranded.

Recent progress reports (covering the period 2004–09) list two incidental catches of Bryde's whales by Japan in 2004 (one from Chiba and one from Nagasaki in trap nets) and one by Korea in 2007 (a female in the Korea Strait).

Abundance estimate:

Year	Estimate	CV	Reference
2000	20,501	0.3366	IWC (2009a, pp.6–7)

The Catch Limit is calculated using Management Variant 4. Sub-areas 1 and 2 (combined) are taken to be a *Combination area*, and sub-areas 1W, 1E and 2 are *Small Areas*, with *catch-cascading* applied – see IWC (2008a, p.95).

The 'raw'[1] Catch Limits set for *Combination area* 1+2 are 15.5 and 91.9 whales for the 72% and 60% tunings respectively.

The 'raw' Catch Limits are split between *Small Areas* 1E, 1W and 2 using abundance estimates of 4,957, 11,213 and 4,331 respectively (IWC, 2009a, pp.6–7) and the phaseout reduction applied (the Area 2 limit is not used).

						Catch limits (after applying phaseout)				
Area	Abundance	CV	Abundance date stamp	Tuning level	Catch limit split to area	2010	2011	2012	2013	2014
1W	4,957	0.398	2000	72%	3.7	2	1	1	0	0
1E	11,213	0.498	1999	72%	8.5	3	2	0	0	0
2	4,331	0.553	2002	72%	(3.3)					
1W	4,957	0.398	2000	60%	22.2	13	9	4	0	0
1E	11,213	0.498	1999	60%	50.3	20	10	0	0	0
2	4,331	0.553	2002	60%	(19.4)					

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[1] The 'raw' catch limit is the catch limit set by the 'CatchLimit program', before catch cascading, sex ratio correction and phaseout is applied.

The Final catch limits for Western North Pacific Bryde's whales in Areas 1W+1E. No adjustment for sex imbalance is necessary.

Area	Year	Catch limit 72% tuning	Catch limit 60% tuning
1W+1E	**2010**	**5**	33
1W+1E	**2011**	**3**	19
1W+1E	**2012**	**1**	4
1W+1E	**2013**	**0**	0
1W+1E	**2014**	**0**	0

B. North Atlantic minke whales

Historic catches:

Year	C	E	Year	C	E	Year	C	E	Year	C	E	Year	C	E
1914	1		1934	6	700	1954	38	3,499	1974	252	1,420	1994	46	239
1915	10		1935	6	878	1955	58	4,309	1975	422	1,430	1995	51	176
1916	6		1936	1	1,053	1956	47	3,656	1976	286	1,889	1996	52	348
1917	6		1937	1	1,231	1957	46	3,634	1977	195	1,699	1997	34	483
1918	6		1938	1	1,353	1958	44	4,341	1978	332	1,383	1998	67	568
1919	6		1939	1	918	1959	61	3,076	1979	319	1,786	1999	73	533
1920	6		1940	1	552	1960	69	3,273	1980	320	1,807	2000	67	430
1921	20		1941	14	2,110	1961	181	3,107	1981	246	1,771	2001	48	521
1922	20		1942	14	2,134	1962	289	3,062	1982	321	1,782	2002	45	599
1923	20		1943	14	1,613	1963	218	3,067	1983	317	1,688	2003	72	626
1924	20		1944	14	1,349	1964	322	2,469	1984	293	630	2004	53	527
1925	20		1945	14	1,786	1965	400	2,122	1985	244	634	2005	48	634
1926	9	4	1946	33	1,883	1966	354	1,923	1986	52	329	2006	64	545
1927	9	4	1947	45	2,556	1967	475	1,827	1987	54	323	2007	47	597
1928	9	0	1948	99	3,487	1968	743	2,108	1988	10	29	2008	69	506
1929	9	6	1949	111	3,841	1969	296	2,032	1989	10	17	2009	85	485
1930	9	38	1950	33	1,990	1970	373	1,912	1990	6	5			
1931	6	175	1951	38	2,752	1971	303	1,802	1991	7	1			
1932	6	350	1952	40	3,325	1972	373	2,175	1992	11	95			
1933	6	525	1953	38	2,435	1973	388	1,562	1993	22	213			

Recent catches by sex (excludes lost whales and others of unknown sex). The catch limit calculation for the SAG used the catches by sex for 2004–08 period when applying the sex correction to the catch limit. The figures for 2005–09 are now available and are also shown below.

Subarea		CIC	CIC	CM	CM	EN	EN	EW	EW	ES	ES	EB	EB
Year	Sex:	M	F	M	F	M	F	M	F	M	F	M	F
2005		20	14	4	1	6	1	108	133	5	92	31	249
2006		31	28	0	0	10	20	200	166	9	108	0	22
2007		14	28	0	0	52	44	86	88	12	271	20	8
2008		28	7	5	25	43	48	99	55	9	220	12	10
2009		64	14	0	0	28	21	83	97	13	234	1	3
Female Ratio 2005–09			0.37		0.74		0.49		0.48		0.95		0.82

Incidental catches. Recent progress reports (covering the period 2004–09) list the following minke whales:

Year		Nation	Number
2009	Ship strike	UK	1
2009	Incidental catch	Denmark	1
2009	Incidental catch	Norway	1
2008	Incidental catch	Denmark	1
2008	Incidental catch	Iceland	1
2008	Incidental catch	Spain	2
2008	Incidental catch	UK	2
2007	Incidental catch	UK	1
2006	Incidental catch	Iceland	1
2006	Incidental catch	Portugal	1
2006	Incidental catch	UK	2
2005	Incidental catch	Iceland	1
2005	Incidental catch	Portugal	1
2005	Incidental catch	UK	1
2004	Incidental catch	Belgium	1
2004	Incidental catch	Portugal	1

Central Area Abundance estimates (taken from IWC, 2009b, p.135 unless otherwise noted).

Area	Year	Estimate	CV	Notes
C	1988	39,250	0.210	Combination of estimates (a), (d) and (g) below
C	2000	93,943	0.117	Combination of estimates (b), (e) and (h) below
C	2006	39,817	0.274	Combination of estimates (c), (f), (i) and (j) below
CM	1988	4,732	0.229	(a) Estimate is a combination of 5,609 (CV 0.26) in 1987 and 2,650 (CV 0.48) in 1988–89
CM	1995	(6,174)	(0.36)	Not used: the 12,043 estimate is used instead as it has better coverage of the area
CM	1995	12,043	0.28	
CM	1997	26,718	0.14	(b)
CM	2005	26,739	0.45	(c) See IWC (2010b, p.140) (update to 26,739 estimate in IWC (2009b, p.135))
CIC	1987	24,532	0.324	(d)
CIC	2001	43,633	0.19	(e)
CIC	2007	10,680	0.29	(f)
CG+CIP	1989	9,986	0.22	(g) Minimum estimate
CG+CIP	1995	4,854	0.27	Minimum estimate
CG+CIP	2001	23,592	0.26	(h) Minimum estimate
CG	2007	1,048	0.60	(i)
CIP	2007	1,350	0.38	(j)

The Central Area Catch Limits are calculated taking the C *Medium Area* to be a *Combination area*, and sub-areas CM, CIC and CG+CIP are *Small Areas*, with *catch-cascading* applied. The catch allocated to the CG+CIP area is not used.

The 'raw' Catch Limits set for the C *Combination area* are 491.8 and 756.5 whales for the 72% and 60% tunings respectively. The Catch Limits are split between *Small Areas* (the CG+CIP limit is not used) and the sex ratio correction applied to give the following catch limits.

	Year of most recent abundance estimate	Split to *Small Area* 72% tuning	Sex-ratio	**Catch limit 72% tuning**	Split to *Small Area* 60% tuning	Sex-ratio	**Catch limit 60% tuning**
CIC	2007	224.1	0.37	**224**	344.7	0.37	**345**
CM	2005	200.7	0.74	**135**	308.8	0.74	**208**
CG+CIP	2007	(66.9)			(103.0)		

The Final Catch Limits for North Atlantic minke whales from the Central area (including phaseout):

	Catch limits with 72% tuning		Catch limits with 60% tuning	
Year	CIC	CM	CIC	CM
2010	**224**	**135**	345	208
2011	**224**	**135**	345	208
2012	**224**	**135**	345	208
2013	**224**	**135**	345	208
2014	**224**	**108**	345	166

The Abundance estimates for the E Combination Area – see IWC (2009b, p.135; 2010b) and SC/62/RMP2:

Year	Date stamp	Estimate	CV	Notes
1988–89	1989	64,730	0.192	63,730 CV 0.19 in IWC (2009b, p.135) but 64,730 in original (Schweder, 1997, p.470).
1995	1995	112,125	0.104	
1996–2001	1998	80,487	0.15	
2002–07	2004	81,401	0.23	Approved estimate rounded to 81,000 in IWC (2010b).

Abundance estimates for the individual Eastern Small Areas (see Appendix 7):

ES			EB			EW			EN		
Year	Abundance	CV	Year	Abundance	CV	Year	Abundance	CV	Year	Abundance	CV
1989	13,070	0.1300	1989	21,868	0.2059	1989	20,991	0.1692	1989	8,318	0.2540
1995	24,891	0.0960	1995	29,712	0.1810	1995	34,986	0.1153	1995	22,536	0.2336
1999	17,406	0.1410	2000	25,885	0.2403	1996	23,522	0.1281	1998	13,673	0.2547
2003	19,377	0.2753	2007	28,625	0.2344	2006	27,152	0.2179	2004	6,246	0.4662

The Eastern Area Catch Limits are calculated taking the E *Medium Area* to be a *Combination area*, and sub-areas ES, EB, EW and EN to be *Small Areas*, with *catch-cascading* applied.

The 'raw' Catch Limits set for the E *Combination area* are 483.2 and 1021.5 whales for the 72% and 60% tunings respectively.

The 'raw' Catch Limits are split between *Small Areas* and the sex ratio correction applied where necessary to give the following catch limits:

	Year of most recent abundance	Split to *Small Area* 72% tuning	Sex-ratio	Catch limit 72% tuning	Split to *Small Area* 60% tuning	Sex-ratio	Catch limit 60% tuning
ES	2003	109.4	0.95	58	231.3	0.95	122
EB	2007	151.5	0.82	92	320.3	0.82	195
EW	2006	152.3	0.49	152	321.9	0.49	322
EN	2004	70.0	0.48	70	148.0	0.48	148

The Final Catch Limits for North Atlantic minke whales from the Eastern area (including phaseout):

	Catch limits with 72% tuning				Catch limits with 60% tuning			
Year	ES	EB	EW	EN	ES	EB	EW	EN
2010	**58**	**92**	**152**	**70**	122	195	322	148
2011	**58**	**92**	**152**	**70**	122	195	322	148
2012	**46**	**92**	**152**	**70**	97	195	322	148
2013	**35**	**92**	**152**	**56**	73	195	322	118
2014	**14**	**92**	**152**	**42**	29	195	322	89

C. North Atlantic fin whales

Historic catches for the 2 management variants considered: WI+EG (Variant 2) and WI+EG+EI/F (Variant 6)

Year	WI+EG	WI+EG+EI/F	Year	WI+EG	WI+EG+EI/F	Year	WI+EG	WI+EG+EI/F	Year	WI+EG	WI+EG+EI/F
1865		8	1901	532	736	1938	113	296	1975	245	245
1866		24	1902	485	780	1939	109	262	1976	275	275
1867		19	1903	322	1,157	1940	0	0	1977	144	144
1868		2	1904	255	1,473	1941	0	0	1978	236	243
1869		0	1905	202	1,685	1942	0	0	1979	260	271
1870		0	1906	151	1,116	1943	0	0	1980	237	237
1871		5	1907	131	1,719	1944	0	0	1981	254	257
1872		0	1908	138	1,534	1945	0	30	1982	194	197
1873		0	1909	261	1,928	1946	0	94	1983	144	149
1874		0	1910	198	1,556	1947	0	196	1984	167	169
1875		0	1911	153	1,444	1948	195	418	1985	161	161
1876		0	1912	97	772	1949	249	471	1986	76	76
1877		0	1913	49	701	1950	226	635	1987	80	80
1878		0	1914	26	694	1951	312	481	1988	68	68
1879		0	1915	59	405	1952	224	244	1989	68	68
1880		0	1916	0	208	1953	207	294	1990	0	0
1881		0	1917	0	0	1954	177	194	1991	0	0
1882		0	1918	0	0	1955	236	316	1992	0	0
1883		0	1919	22	22	1956	265	308	1993	0	0
1884	3	3	1920	36	717	1957	348	489	1994	0	0
1885	18	18	1921	0	174	1958	289	305	1995	0	0
1886	14	14	1922	0	437	1959	178	178	1996	0	0
1887	28	28	1923	0	505	1960	160	160	1997	0	0
1888	47	47	1924	0	746	1961	142	142	1998	0	0
1889	86	86	1925	0	540	1962	303	309	1999	0	0
1890	105	105	1926	0	556	1963	283	286	2000	0	0
1891	119	119	1927	0	434	1964	217	230	2001	0	0
1892	164	169	1928	0	419	1965	288	298	2002	0	0
1893	403	407	1929	0	233	1966	310	314	2003	0	0
1894	273	291	1930	167	405	1967	239	239	2004	0	0
1895	372	382	1931	8	8	1968	202	208	2005	0	0
1896	235	261	1932	194	194	1969	251	251	2006	8	0
1897	329	362	1933	347	442	1970	291	291	2007	0	0
1898	249	298	1934	98	172	1971	208	208	2008	0	0
1899	389	450	1935	25	100	1972	238	238	2009	125	125
1900	425	511	1936	72	154	1973	267	267			
			1937	353	527	1974	285	285			

Incidental catches. Recent progress reports (covering the period 2004–09) list a fin whale ship strike by the UK in 2004 in the NE Atlantic and an incidental catch (probable entanglement) of a female by the UK on 30 October 2007 from Raffin, Highlands, Scotland.

The Abundance estimates are documented in Wade (2009) and IWC (2010a, p.602).

	Variant 6								Variant 2	
Year	EG+WI+EI/F		WI		EG		EI/F		EG+WI	
1988	14,773	0.1424	4,243	0.229	5,269	0.221	5,261	0.277	9,512	0.1594
1995	21,859	0.1567	6,800	0.218	8,412	0.288	6,647	0.288	15,212	0.1867
2001	25,761	0.1253	6,565	0.194	11,706	0.194	7,490	0.255	18,271	0.1425
2007	21,946	0.1483	8,118	0.260	12,215	0.20	1,613	0.260	20,333	0.1588

(1) The Catch Limit is calculated for Management Variant 6: WI, EG and EI/F are *Small Areas*; WI+EG+EI/F is a *Combination Area*. The 'raw' Catch Limit is split between *Small Areas* WI, EG and EI/F using the above abundance estimates. Only the catch limit set for the WI area is used.

(2) In addition the Catch Limit was calculated for Management Variant 2: WI+EG is a *Small Area*. All of the catch is taken in the WI sub-area.

The 'raw' Catch Limits and the split to *Small Area* are given below (only the catch limit for WI is used):

Area	Year	Catch limit 72% tuning	WI 72% tuning	WG	EI/F	Catch limit 60% tuning	WI 60% tuning	WG	EI/F
V6:WI+EG+EI/F	2010	142.1	46	(74)	(21)	276.8	90	(145)	(42)
V2: WI+EG	2010	87.5	87	–	–	155.0	155	–	–

The Final Catch Limits. No adjustment for sex imbalance or phaseout is necessary.

Area	Year	Variant V6 catch limit 72% tuning	Variant V2 catch limit 72% tuning	Variant V6 catch limit 60% tuning	Variant V2 catch limit 60% tuning
WI	**2010**	**46**	**87**	90	155
WI	**2011**	**46**	**87**	90	155
WI	**2012**	**46**	**87**	90	155
WI	**2013**	**46**	**87**	90	155
WI	**2014**	**46**	**87**	90	155

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Appendix 9

PROPOSAL: TO CONTRIBUTE TO THE ANALYSIS AND USE OF TIME-SERIES OF DATA ON CALVING RATES AND CALVING INTERVALS FOR USE IN THE REVIEW OF MSY RATES

(Revised and consolidated)

Relevant agenda item (no. and title)

Annex D, item 2.4.

Brief description of project and why it is necessary to the sub-committee

The Scientific Committee of the International Whaling Commission is conducting a review of the range of MSYR values to include in simulation trials when selecting among variants of the Revised Management Procedure (RMP). As part of the review process, information on observed population growth rates at low population sizes, r_0, is being considered; Cooke (2007) noted that in circumstances where variability and/or temporal autocorrelation in the effects of environmental variability on population growth rates is high, simple use of such observed population growth rates could lead to incorrect inferences being drawn concerning the lower end of the range of plausible values for MSYR. The Third Intersessional Workshop on the Review of MSYR assembled a number of data sets on calving rates and calving intervals for baleen whales. Efforts were made following the Workshop to fit models which account for both process and observation error to the data on calving rates and calving intervals. However, numerical problems had been encountered during the intersessional period implementing these models. The sub-committee therefore developed a work plan (see Appendix 2) based on a method which should overcome these numerical problems and which provides the inputs needed to apply the Bayesian hierarchical method adopted by the sub-committee for computing a posterior distribution for r_0. The work plan (and its relationship to this proposal) is as follows.

(1) Investigate improvements to the model of Appendix 2 to handle proportion data for which the sampling error variances are not known.
(2) Brandon and Kitakado to fit the model of Appendix 2 to (a) the real data, and (b) some simulated data sets.
(3) Represent the results from the model in the form of inputs to the age-structured model of Annex D of SC/62/Rep2 and use this model to compute the standard deviation and temporal auto-correlation in the annual rate of increase
(4) Identify the values for the environmental model of Cooke (2007) which match the outputs from the age-structured model.

Timetable

- Kitakado, Brandon, and Punt to refine the specifications for the analyses of calving rate and calving interval data (July–September 2010).
- Kitakado and Brandon (with assistance from Punt) to implement the refined specifications for the analyses (October 2010–February 2011).
- Progress report to the Secretariat (January 2011).
- Punt to use the results of the analyses to develop the basis for applying the Bayesian hierarchical method adopted by the sub-committee (March–May 2011).
- Final report presented to the 2011 Annual Meeting.

Researchers' names

John Brandon (LGL); Toshihide Kitakado (Tokyo University of Marine Science and Technology); André Punt (University of Washington).

Estimated total cost with breakdown as needed

Total budget: £7,000 (Brandon £2,500; Kitakado: £2,000; Punt: £2,500).

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