Annex D
Report of the Sub-Committee on the Revised Management Procedure

Members: Bannister (Convenor), Acquarone, Allison, Alter, An, Andreu, Apostolaki, Baba, Baker, Bjørge, Borodin, Bøthun, Brandao, Breiwick, Butterworth, Chilvers, Choi, Cipriano, Cooke, De Decker, de Moor, Donoghue, Donovan, Fortuna, Fujise, Gallego, Goto, Grønvik, Gunnlaugsson, Hakamada, Hammond, Hatanaka, Hedley, Holloway, Ilyashenko, Iñíguez, Johnston, Kanda, Kelly, Kishiro, Kitakado, Kock, Koski, Leaper, Lens, Lockyer, Lusseau, Lyrholm, Melton, Miller, Miyashita, Morishita, Muller, Øien, Okada, Okamura, Palka, Palsboll, Panigada, Parsons, Pastene, Perrin, Polacheck, Punt, Robbins, Santos, N., Schweder, Simmonds, Skaug, Tamura, Uoya, Uozumi, Vazquez, Víkingsson, Wade, Walløe, Yamakage, Yasokawa, Young, 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. Butterworth, Hammond, and Punt acted as rapporteurs.

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

1.4 Available documents
The documents considered by the sub-committee were SC/61/RMP1-13, SC/61/O2, SC/61/O7, SC/61/O10, SC/61/Rep3, SC/61/Rep6, SC/61/FI43 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 Intersessional Workshop
Donovan introduced the report of the second intersessional workshop on MSYR for baleen whales which was held in Seattle from 6-9 February 2009 (SC/61/Rep6). The first task of the Workshop was to update the table summarising the available information relative to MSYR initially developed at the first workshop (IWC 2009a). The updated table (Table 1 of SC/61/Rep6), included: (1) an assessment of reliability (high, medium or low); and (2) a coarse assessment as to whether the population (at the time of the trend estimate) was considered to be low (<1/3), medium (1/3-2/3) or high (>2/3) relative to pre-exploitation abundance. Any meta-analysis (see below) would only be undertaken using reliable estimates and for populations at low levels related to pre-exploitation abundance (i.e. it can be used to make inferences regarding r_0, the population growth rate in the limit of population size approaching zero).

With respect to undertaking a meta-analysis, the Workshop considered a Bayesian approach (SC/F09/MSYR1 and Annex D of SC/61/Rep6) and a linear mixed effects model (Annex C of SC/61/Rep6). These two methods gave essentially the same results. A key assumption of both approaches was the assumption that stocks were interchangeable (i.e. a random subset of stocks). There are many ways in which this assumption might be violated and so it was agreed that one way to investigate the effects of this would be to ignore the data for each species in turn and compare the results. The Workshop also agreed that meta-analyses should be based on a model in which there is between-stock variation in the rate of increase but not between-species variation.

Following discussions at previous meetings (e.g. IWC, 2009a), the Workshop received a revised version of Cooke (2007) that described a framework for incorporating environmental variability into models of net recruitment rate and yield curves. Three major changes from the original paper were made related to fixing not estimating MSYL: fitting in two ways with respect to initial population size and *K*, and changing the fitting process to account for multiple maxima. The paper found that estimates of MSYR tend to be positively biased, especially for low true MSY rates for scenarios with high environmental variability. Possible causes of the bias were discussed including mismatch between true and assumed MSYL, a cause which was examined using a model developed by Kitakado. The Workshop spent some time discussing the appropriate levels of environmental variability and correlation and recommended that all available data sets with information on recruitment variability in whales be examined, recognising that information on survival parameters would be more difficult to detect. The true extent of variance in net recruitment may be underestimated if it is assumed that only those parameters whose variation can be detected vary.

After considerable discussion the Workshop agreed *inter alia* that:

(1) the scenarios listed in Table 1 of Annex D of SC/61/Rep6 should be used to test MSYR estimation with environmental stochasticity;
(2) trajectory plots should be examined when considering the model results;
(3) MSYR is defined as the constant fishing mortality rate that has the highest long-term average yield and should be computed as part of the results;
(4) the realism of scenarios be examined by recording the frequency of cases where the population declines by more than 50% in 5 years for different ranges of population size relative to *K*;
(5) the values of 0.0, 0.5 and 1.0 for the environmental variability (σ) and 0.0, 0.5, and 0.9 for the serial correlation (ρ) be retained until more information on typical levels is available;
(6) the serial correlation in the abundance of prey species such as krill and capelin might useful to examine;
(7) it would be useful to examine a case with an explicit multi-year calving cycle, such as 3+ years as for bowhead and right whales, to examine how the assumed levels of environmental variability would relate to variability in calf production (the calving probability could be assumed, for example, to depend on the stored energy accumulated since the previous calving);
(8) some alternative formulations to those used in Cooke (2007, revised) for modelling the relationship between environmental variability and net recruitment should be tried (although no specific proposals were made).

The Workshop considered SC/F09/MSYR3 which examined the question of under what circumstances could the standard deterministic density-dependent model be tested using observations of recovering stocks. A test is possible only for stocks which have (i) been substantially reduced by past catches; (ii) recovered to a high fraction of *K*; and (iii) are subject to regular monitoring, but few stocks or stock complexes meet these criteria.

The simulation framework developed in Cooke (2007) was used to examine how likely it is that the standard density-dependent model would be rejected by the data. The author of SC/F09/MSYR3 drew two conclusions: (i) the results suggest that cases such as gray and humpback whales where the standard model cannot be fitted should perhaps not be regarded as anomalies, but as in accordance with expectation; (ii) fitting a trend in *K* to "repair" a lack of fit by the standard model can make estimates of MSYR poorer, not better.

In discussion the Workshop agreed that, even when the simulations suggested that the assumption of constant *K* reduced the bias in MSYR estimates, it would be unrealistic to expect the Scientific Committee to accept assessments that were so clearly rejected by the data as in the case of eastern gray whales and North Atlantic humpbacks.

The Workshop agreed that the following analyses should be undertaken to explore this question for the eastern North Pacific gray whales and North Atlantic humpback whales:

(1) determine the size of effects needed to explain the observed trend using the breeding disruption hypothesis of Reeves *et al* (in prep);
(2) determine the level of environmental variability that is required to fit the trends in gray and humpback whales using the aggregated stochastic model of Cooke (2007)[1]; and
(3) repeat task 2 for an age-structured stochastic model, such as that used in Punt (In press).

The Workshop then went on to consider the approaches to estimating MSYR and their limitations. With respect to the use of trends in abundance, it was noted that the Scientific Committee has discussed the relationship between the rate of increase in the limit of zero population size and MSYR extensively in the past. Two main views have emerged. One view, based on Butterworth and Best (1990), argues that estimates for $MSYR_{1+}$ can be inferred from estimates of r_0 given the bound $MSYR_{1+} \geq r_0/2$. The other is based on the 'basin model' and 'supercompensation' arguments (e.g. de la Mare, 1994) and that the impact of stochasticity in the population dynamics will reduce (or eliminate) the difference between $MSYR_{1+}$ and r_0 for some stocks.

The Workshop agreed that while both views remained, the fact that there is no evidence for a reduction in the growth rates for the right (and particularly) humpback whales that have been monitored regularly over the past two decades (some humpback stocks are now in the region of 0.3*K*) implies that the 'supercompensation' and 'basin model' arguments are not as plausible as was the case in the past.

With respect to other approaches (population dynamics models and catch-at-age data, changes in biological parameters, maxima inferred from demographics), the Workshop agreed that these would not provide useful information for the present task.

The Workshop then considered how its deliberations affected progress with respect to proposals to amend the RMP. IWC (1994, p.47) specified the protocol for evaluating proposed amendments to the RMP. In reviewing the protocol in 2006, the Committee agreed (IWC, 2007) that three factors needed to be considered further:

(1) the appropriate range of MSYRs to be used in trials;
(2) development of an appropriate set of simulation trials;
(3) definition of an appropriate set of performance statistics.

The Workshop had focussed on (1). Aside from the issue of MSYR, the Scientific Committee agreed on a number of trials and performance statistics (IWC, 2006) pending completion of the work on MSYR, noting that once that work had been completed, it would be in a better position to consider whether further trials incorporating environmental variation were required. Last year (IWC, 2009b) the Scientific Committee noted that Norway had completed the required work for the trials developed thus far evaluating proposed amendments.

The Workshop agreed that in finalising the trial specifications for proposals to amend the RMP, the Scientific Committee should take into account: (1) the results of the additional work regarding the appropriate range of MSYRs it had recommended; and (2) the approach used in Cooke (2007, revised) as a possible basis for further robustness trials with respect to environmental variability. It noted that any new trials should also be applied to the existing *CLA*. It also agreed that as the ultimate use of the analyses was to determine the appropriate range of MSYR values to be used in the RMP, then it was essential that any computer programs used in the process must be validated by the Secretariat. The Workshop developed a work plan and progress on that is reported in the report of the sub-committee below. In concluding his Chair's summary, Donovan thanked the participants for the hard work they had put in before, during and indeed after the Workshop.

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

2.1.2 Matters arising

Population models incorporating environmental variation

SC/61/RMP1 responded to one of the recommendations from the report of the Intersessional Workshop. It outlined four alternative definitions for statistics to quantify 'abrupt changes' in population size for use when evaluating simulation trials which explore the impact of environmental variation on the ability to estimate MSYR. These definitions are based on the frequency of years in which abundance drops by a pre-specified percentage over a given number of years.

In discussion, it was noted that the frequency of 'abrupt changes' in abundance could also be examined using plots, even though this can lead to a large amount of information to consider.

SC/61/RMP13 provided results of simulation trials of the estimation of *MSYR* in scenarios based on the environmental variability model that was introduced in Cooke (2006) and further developed in Cooke (2007). The scenarios were those selected by the February 2009 workshop on MSYR (SC/61/Rep6, Table 2). *MSYR* estimates from 400 replicates of each scenario were obtained in each of three ways: (i) assuming the population is at *K* prior to exploitation; (ii) treating the initial stock size relative to *K* as a free parameter to be estimated; (iii) assuming the population is at *K* prior to exploitation, except when the data reject this assumption at the 5% level of significance. The results confirmed earlier findings that *MSYR* can be substantially overestimated when the true *MSYR* is low. When the true *MSYR* is 1%, the median *MSYR* estimate can be up to 5% in scenarios with

[1] For this purpose the serial correlation coefficient ρ should be fixed at different values (e.g. 0.0, 0.5 and 0.9) and σ estimated because it would clearly be impossible to estimate both.

high environmental variability. Furthermore, there is a high probability (which exceeds 50% in some scenarios) that a model with the conventional assumption that the population is at its carrying capacity *K* at the start of exploitation will fail to fit the observed time series. The overestimation of *MSYR* rates is less severe if the assumption that the population is at *K* at the start of exploitation is retained, even when the data are incompatible with this assumption. The median realised stochastic *MSYR* in the presence of environmental variability is found to be close to the nominal *MSYR* of the model if the true *MSYR* rate is defined as the long-term constant exploitation rate that results in the highest average yield.

As recommended by the Workshop, the Secretariat had coded the process of generating simulated data sets based on the specifications on which SC/61/RMP13 was based. The sub-committee thanked Allison for implementing the specifications of the simulations for MSYR estimation. Butterworth reported that DeDecker had repeated several of the calculations in SC/61/RMP13 using data sets for the low MSYR scenarios generated based on software produced by the Secretariat. Although these calculations were based on a different estimation method than that on which SC/61/RMP13 was based, the median estimates of MSYR were similar to those in SC/61/RMP13. The upper 95% intervals for MSYR were generally smaller than those in SC/61/RMP13, but this may have been because of stochastic effects owing to the relatively small number of simulations (100).

The sub-committee noted that the extent of positive bias in MSYR was a function of both the extent of environmental variation, σ, and the auto-correlation in the impact of the environment on productivity, ρ. It **agreed** that that it was necessary to confirm that the values for the parameters considered in the simulations were plausible for baleen whales. Cooke advised that the relationship between the net recruitment rate and density was derived from a relationship between net recruitment rate and environmental resources, such that when food resources are plentiful, the net recruitment rate is close to the biological maximum, whereas lack of resources leads to lower reproduction and higher mortality, and hence a lower net recruitment rate. One of the implications of the way in which environmental impacts are modelled is that both the net recruitment rate and carrying capacity vary with environmental conditions.

The sub-committee noted that the average size of the population in the absence of exploitation (stochastic carrying capacity) was not the same as the nominal carrying capacity (*K*), and requested Cooke to document the extent to which stochastic and nominal carrying capacity differ for the scenarios considered in SC/61/RMP13. Cooke subsequently reported results that showed that median realised stochastic carrying capacity levels increase above deterministic levels by 1 – 13% for most of the scenarios considered (σ=0.5, ρ=0.5), though stochastic carrying capacity exceeded K by 50% for the scenario with the largest variability (σ=1) and serial correlation (ρ=0.9) values considered.

The sub-committee noted that the population dynamics model on which SC/61/RMP13 was based was designed so that the expected net recruitment rate at any population size equals the value for the net recruitment rate based on the deterministic form of the relationship between net recruitment rate and density. However, most simulated net recruitment rates are higher than the mean net recruitment rate when there is environmental stochasticity because there is an upper bound of r_{max} on the extent to which the population can increase when resources are plentiful, but there is no limit on the extent to which it can decline when resources are scarce (so that the distribution of net recruitment rates is necessarily skewed left). This means that population trajectories tend to increase faster than the average rate of increase for fairly long periods after which there is a (stochastically) abrupt reduction in population size (see, for example, Fig. 1). One consequence of this is that the median rate of increase at low population size is positively biased relative to the true rate of increase although the mean rate of increase is closer to the true rate of increase (Table 1; Fig. 2).

Table 1
Deterministic rate of increase for a population initially at 0.01*K* with q=0.1 and r_{max}=0.1 (estimated from a regression of log(abundance) on year), the mean rate of increase, and the median rate of increase for four combinations of σ and ρ.

Scenario	Deterministic ROI	Mean ROI	Median ROI
σ=0.5; ρ=0.5	0.0219	0.0219	0.0228
σ=0.5; ρ=0.9	0.0219	0.0219	0.0265
σ=1.0; ρ=0.5	0.0219	0.0236	0.0279
σ=1.0; ρ=0.9	0.0219	0.0228	0.0356

Information available related to MSYR for stocks of baleen whales

Table 1 of SC/61/Rep6 provides this information as assembled by the Workshop. The following amendments were **agreed** to this Table in respect of whale population increase rates:

(a) the entry for Eastern North Pacific gray whales was temporarily removed as the data upon which this is based are under revision;
(b) the entry for Southern Hemisphere humpback Breeding Stock A off Brazil was temporarily removed as the variance computation needs correction; and
(c) an entry was added for Gulf of Maine humpback whales, reflecting a growth rate of 6.3% (SE 1.2%) over the period 1979-91 based upon Barlow and Clapham (1997).

It was **agreed** that the populations to be included in a meta-analysis of growth rate at low levels of abundance should include all stocks considered to have been less than some 0.33*K* at the time monitoring of their abundance commenced. The list in Table 1 of Annex D of SC/61/Rep6 of stocks to be included in this meta-analysis was amended to exclude Eastern North Pacific gray whales and include Gulf of Maine humpbacks. Because the entry for Southern Hemisphere blue whales applies to a group of stocks rather than to a single stock, it was decided to run the meta-analysis both including and excluding this entry.

Table 2 lists the stocks on which the Bayesian meta-analysis is based, along with their rates of increase at low population size, r_0. The sub-committee **agreed** that the values in Table 2 are the best currently available for the purpose in question. It discussed the extent to which inferences based on the values in Table 2 can be extrapolated beyond the species (and stocks) represented in Table 2, and noted certain potential sources of bias in terms of the representativeness of the species/ stocks in Table 2:

(1) Stocks with low values of habitat quality (the parameter q in the model of SC/61/RMP13), such as sei and Bryde's whales, which tend to have low average densities across their range, may be under-represented in Table 2; for these populations, the difference in health and productivity between populations at a low level and populations near *K* might not be as great as for species such as Antarctic blue and humpback whales which tend be quite abundant on their feeding grounds when near *K*.
(2) The Table lacks data for the smaller baleen whale species (sei, minke and Bryde's whales).
(3) Productive stocks which at the time monitoring started had recovered to the cut-off for inclusion in Table 1 (0.33*K*) are excluded from consideration.

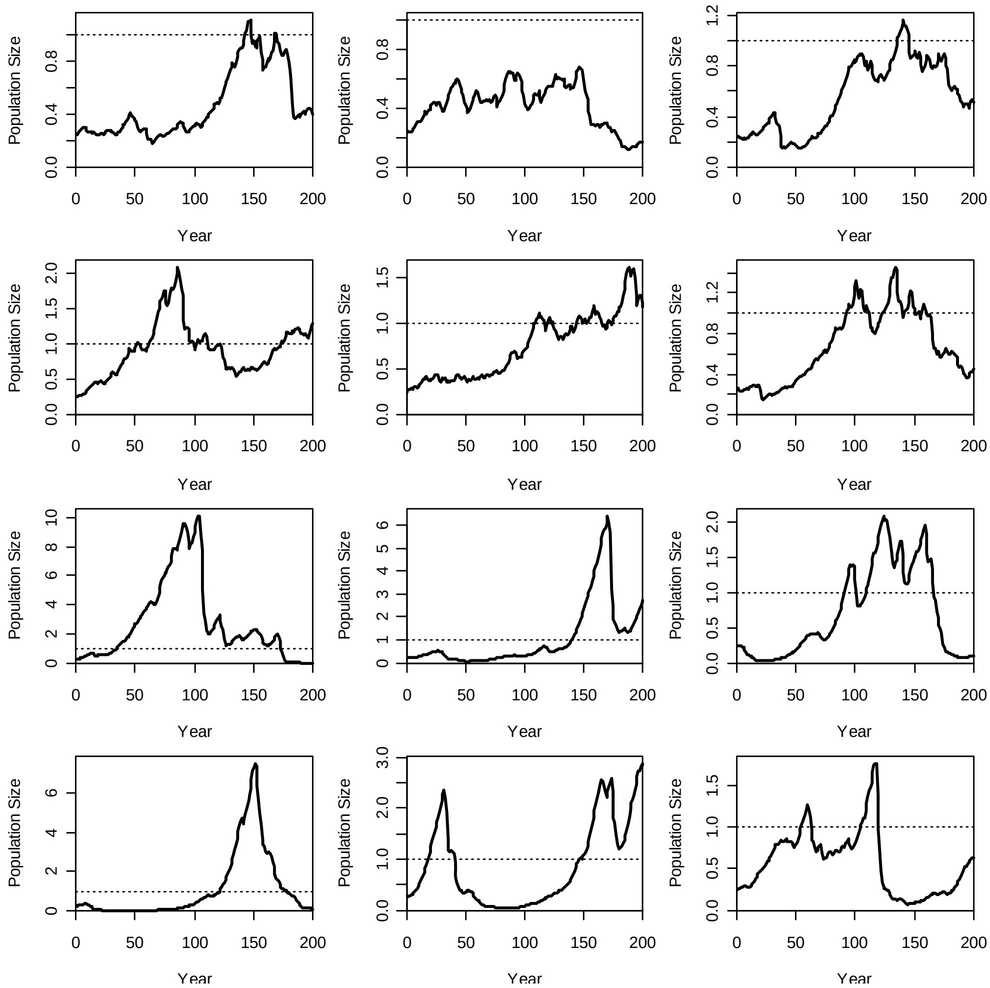

Fig. 1. Six randomly-selected time-trajectories of population size (initial population size 0.25*K*) for two choices for the parameters which determine the extent of environmental variation on the net recruitment rate. The upper six panels show results for (σ=0.5, ρ=0.5) and the lower six panels those for (σ=1, ρ=0.9)

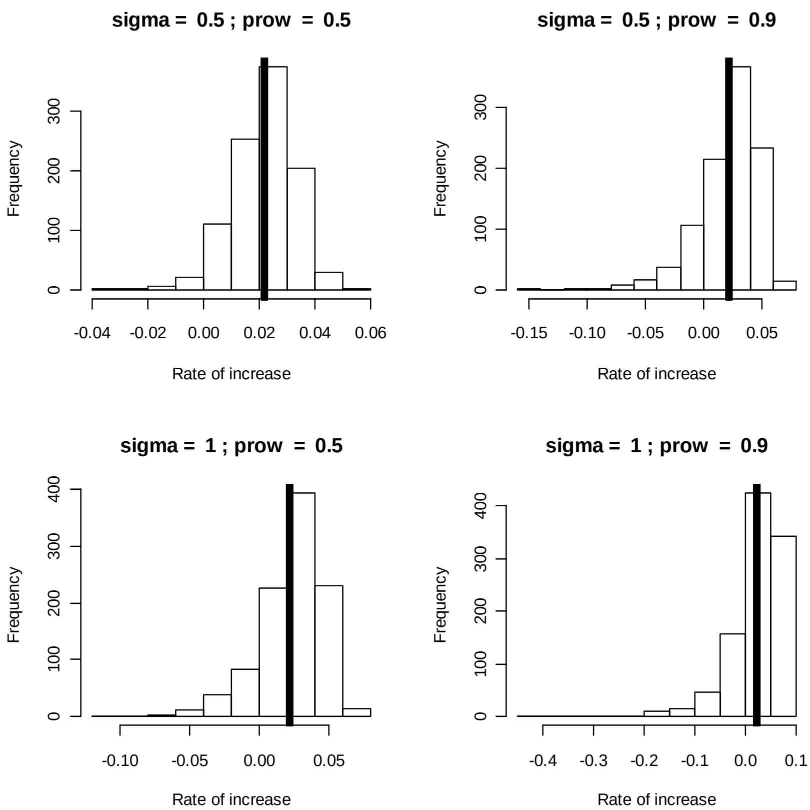

Fig. 2. Histograms of the rate of increase (estimated from a regression of log(abundance) on year) for 1000 simulations based on four combinations of σ and ρ. The vertical lines denote the deterministic rate of increase.

The sub-committee noted that Best (1993) had examined whether an earlier review of rates of increase was biased because only those stocks which are growing rapidly would be sufficiently large to be monitored. Best (1993) had concluded that this was not the case.

Table 3 summarizes the lower percentiles for the rate of increase for an 'unknown stock' (i.e. a lower 5th percentile in Table 3 implies that 5% of all possible stocks to which Table 3 applies will have MSYRs less than the value reported). Additional information on the Bayesian analysis on which Table 3 is based is given in Appendix 2.

Table 2
Estimates of r_0 used in the meta-analyses.

Stock	r_0 (%) (95% CI)	SE
Blue		
Central North Atlantic	9.0 (2.0, 17.0)	3.83[a]
Southern Hemisphere[c]	8.2 (1.6, 14.8)	3.37[a]
Eastern North Pacific	3.2	1.4
Fin		
North Norway	5 (-13, 26)	9.95[a]
Eastern North Pacific	4.8 (-1.6, 11.1)	3.24[a]
Humpback		
Western Australia	10.1 (0.9, 19.3)	4.69[a]
Eastern Australia	10.9 (10.5, 11.4)	0.23[a]
Eastern North Pacific	6.4	0.9
Hawaii	10 (3-16)	3.32[a]
Gulf of Maine	6.3	1.2
Gray		
Western	2.9 (1.9, 4.0)	0.54[b]
Bowhead		
Bering-Chukchi-Beaufort	3.9 (2.2, 5.5)	0.84[b]
North Atlantic Right		
Western	2.23 (1.23, 3.23)	0.51[a]
Southern Right		
SE Atlantic	7.3 (6.6 ,7.9)	0.33[a]
SW Atlantic	6.8 (5.8 ,7.8)	0.51[a]
SE Indian	8.10 (4.48-11.83)	1.88[a]

a – computed from the 95% confidence interval by dividing by 3.92
b – computed from the 90% confidence interval by dividing by 3.28
c – not a single stock, excluded in a sensitivity test

Table 3
Lower percentiles of the posterior distribution for the rate of increase for an unknown stock

Percentage	r_0 (%) Inc. SH blue	r_0 (%) Exc. SH blue
1	-0.87	-1.1
2	0.13	-0.08
5	1.50	1.32
10	2.62	2.46
20	3.89	3.76

SC/61/Rep6 summarized how the results in Table 1 might be used to refine the range for MSYR used in simulation trials. In summary, there have been two views. One view, based on Butterworth and Best (1990), argues that estimates of $MSYR_{1+}$ can be inferred from estimates of r_0 given the bound $MSYR_{1+} \geq r_0/2$. This view arises from the assumption that the relationship between per capita growth rate and population size is smooth and convex so $MSYL_{1+} \geq 0.5$, as suggested by Fowler and Baker (1991). The counter view is based on the arguments that: a) the per-capita growth rate may be high at low stock population size, but drop quickly thereafter (the 'basin model' and 'hypercompensation' arguments), b) the data analysed by Fowler and Baker (1991) do not enable any conclusions to be drawn that recruitment surveys have negative second derivative (de la Mare, 1994), and on c) the impact of stochasticity in the population dynamics which leads to positively biased estimates of r_0.

SC/59/RMP10 examined the relationship between the net recruitment rate and density when there is a convex relationship between the net recruitment rate and the environment. SC/59/RMP10 found that the relationship between the net recruitment rate and density was convex, but not as convex as that between the net recruitment rate and the environment. Taylor and DeMaster (1993) found that the extent of convexity in the relationship between the net recruitment rate and density was less convex than that between the change in a single life-history parameter and density, but that the relationship between net recruitment rate and density remained convex. In relation to 'basin model'/'supercomposition' arguments, the Intersessional workshop had agreed that the lack of decline in the rates of increase for depleted right and humpback stocks implied that these arguments are less plausible than was the case in the past. In summary, the sub-committee agreed that there was no direct evidence that the relationship between net recruitment and density was not convex, and accordingly that estimates of $r_0/2$ provided negatively biased estimates of $MSYR_{1+}$.

In relation to the biases evident in SC/61/RMP13, Butterworth noted that this effect was largest at low MSYR and that the mean bias is lower than the median bias. The sub-committee agreed that the impact on the posterior distribution for r_0 of the bias due to environmental variation on r_0 should be explored further. This should include consideration of the robustness of the magnitude of this bias to alternative models of the distribution of environmental variability. Further, given the importance of confirming the plausibility of the values of distributional parameters (σ and ρ) considered in the simulations of environmental variability, the sub-committee identified a number of studies that could shed light on this issue (Appendix 3), noting that estimates of environmental variance from time-series data increase with the length of the data series. Therefore, estimates of environmental variance from shorter time-series will tend to under-estimate environmental variance. The sub-committee therefore recommended that a group (Butterworth convenor) should be established to coordinate this work. The sub-committee identified the following potential case studies: SW Atlantic right (Cooke), Eastern North Pacific gray whales (Brandon), BCB Bowhead (Koski), North Atlantic right (Krauss), SE Atlantic right (Best), California humpbacks and blues (Calambokidis), Gulf of Maine humpbacks (Robbins), and SE Alaska humpbacks (Straley and Gabriele)

Inferences related to the range of values for MSYR for stocks of baleen whales

Appendix 4 outlines a proposal for changing the metric in which MSYR is expressed and the range of values for MSYR for use in RMP trials. Appendix 5 noted that the approach on which Appendix 2 is based leads to values for r_0 for the unknown stock which are biologically implausible and fails to account for the impact of environmental variation. The sub-committee agreed that the issues raised in Appendix 5 required resolution before it was possible to evaluate proposals such as that in Appendix 4. The sub-committee agreed that the most appropriate way to finalize its discussions regarding the range for MSYR would be to hold an intersessional workshop which would have the following terms of reference:

(1) Use the information for the stocks identified above to estimate the parameters which determine the extent of environmental variation.

(2) Use information from genetic considerations to refine these parameters.

(3) Revise and finalize the Bayesian meta-analysis which will be used to calculate the distribution for the rate of increase at low stock size.

A Steering Group comprised of Butterworth (Convenor), Allison, Cooke, Donovan, Gunnlaugsson, Kitakado, Punt, Wade and Walløe was appointed to guide the work and organize the meeting.

The sub-committee had insufficient time to revise the approach in Appendix 5 prior to the end of its meeting and therefore established a small group (Butterworth (chair), Allison, Cooke, Gunnlaugsson, Kitakado, Wade, and Walløe) to report to Plenary. The terms of reference for this group were to (1) initiate contact with the data holders identified above to determine that they would be willing to provide the necessary analyses, participate in the intersessional workshop, and provide data under the data availability provisions which apply to the work of the sub-committee, and (2) further refine the approach for constructing a posterior distribution for an unknown stock in Appendix 5.

2.2 Finalise the process for evaluating 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, in particular the agreement on a list of values for r_0 (Table 2), but recognized that it could not complete discussions on amendments to the CLA until the range for MSYR in the RMP was finalized.

2.3 Work plan

The sub-committee agreed that its work plan for the 2010 Annual meeting would be as follows.

(1) A four-day intersessional workshop needs to be conducted to estimate the parameters of the environmental model and finalize the Bayesian meta-analysis so that a final decision can be made on the range for MSYR in the RMP at the 2010 Annual Meeting. Costs associated with travel and subsistence for this meeting (8 paid-for participants for 4 days) are estimated to be £17,500. An intersessional Steering Group comprised of Butterworth (Convenor), Allison, Cooke, Donovan, Gunnlaugsson, Kitakado, Punt, Wade and Walløe was appointed to guide the work and organize the meeting.

(2) Complete the review of the range of MSYR values for use in the RMP.

(3) Finalize the approach for evaluating proposal amendments to the CLA.

3. RMP – PREPARATIONS FOR IMPLEMENTATION

3.1 Western North Pacific Bryde's whales

3.1.1 Research proposal for the 'variant with research'

The Committee 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 program. It 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).

Last year, the Committee reviewed a research proposal (Pastene *et al*. 2008) 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 the 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 whether 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.

The sub-committee noted that no new research proposal had been provided by Japan this year. Pastene advised that a revised research proposal will be submitted once the required analyses are completed. The sub-committee recommended that the tasks identified last year be completed for next year's meeting.

3.1.2 Other

SC/61/O7 reported that a satellite tag had been successfully attached on one Bryde's whale in the western North Pacific during the research conducted by JARPN II in each of 2006 and 2008 using an air gun system (ICR air gun). The movements of these two whales were tracked for a period of 15 and 21 days, respectively. In general, movement in both cases was from temperate to subtropical waters. An Argos transmitter was attached at 37º 36N 156º10E on 13 July 2006. The whale had an estimated body length of 12.5m and was accompanied by a calf (estimated body length of 8.7m). The distance of movement during the transmission was approximately 1,024.53km and the daily average movement distance was 77.13km. The whale showed movement from north to south. An Argos transmitter was attached at 37º56N 147º51E on 24 July 2008. The whale had an estimated body length of 12.6m. The distance of movement during the transmission was approximately 2,629.70km and the daily average movement distance was 127.14km. This whale moved in an easterly direction for the first nine days reaching 160ºE after which it moved in a southerly direction for the last 12 days of transmission. These results demonstrated that the ICR system for delivering satellite tags is useful for fast swimming whales in pelagic waters. Information on movement and residence time in the feeding grounds will be useful to assist the stock structure studies of Bryde's whales in this ocean basin, which is an important piece of information for the RMP's *Implementation Simulation Trials*.

The sub-committee welcomed the information in SC/61/O7, noting that the use of satellite tags was one way to evaluate the plausibility of stock structure hypothesis 4. It recommended that 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 be evaluated. The sub-committee encouraged further satellite tagging of western North Pacific Bryde's whales.

3.1.3 Work plan

The sub-committee agreed that its work plan for the 2010 Annual meeting would be as follows.

(1) Finalize the audit of the Bryde's whale survey data.
(2) Allison and Pastene should use the Bryde's whale *Implementation Simulation Trials* to evaluate the effect size (and power) for current and historical age-composition data
(3) Previous (and any new) genetic power analyses for the western North Pacific Bryde's whales should be reviewed.
(4) 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 should be evaluated.
(5) Review the research proposal for the 'variant with research' to be submitted to the 2010 meeting.

3.2 North Atlantic fin whales

3.2.1 Complete Implementation

3.2.1.1 REPORT OF INTERSESSIONAL WORKSHOP

Donovan introduced SC/61/Rep3. The Workshop was held at the Greenland Representation, Copenhagen, from 19-22 March 2009. In the *Implementation* process, the 2nd intersessional workshop is essentially a technical workshop to review the results of final trials agreed by the Scientific Committee at the previous Annual Meeting following agreed quantitative guidelines and to make recommendations for consideration by the full Committee on:

(1) *management areas*;
(2) RMP variants (e.g. catch-cascading, catch-capping);
(3) suggestions for future research (either within or outside whaling operations) to narrow the range of plausible hypotheses/ eliminate some hypotheses; and
(4) 'less conservative' variants(s) with their associated required research programmes and associated duration.

At the 2008 Annual Meeting, the Committee had agreed that the conditioning[2] had been completed satisfactorily (IWC, 2009b). However, during the intervening period, Allison had noted that there were some issues that required further discussion (e.g. incorporation of 2007 T-NASS data, assumption of fixed future annual catches off West Greenland) as well as some minor adjustments to some of the datasets (e.g. *Discovery* mark data, correction of catch series when sex data absent). These issues are discussed under item 2 of SC/61/Rep3 where, in summary, the Workshop agreed: (1) to account for additional variance where this could be estimated (see Annex C of SC/61/Rep3) and apply this to all trials; and (2) clarification of the specification of Trial N15. The full set of trials is given in Table 2 of SC/61/Rep3. In view of this discussion, the Workshop agreed that it was appropriate to rerun all of the conditioning trials.

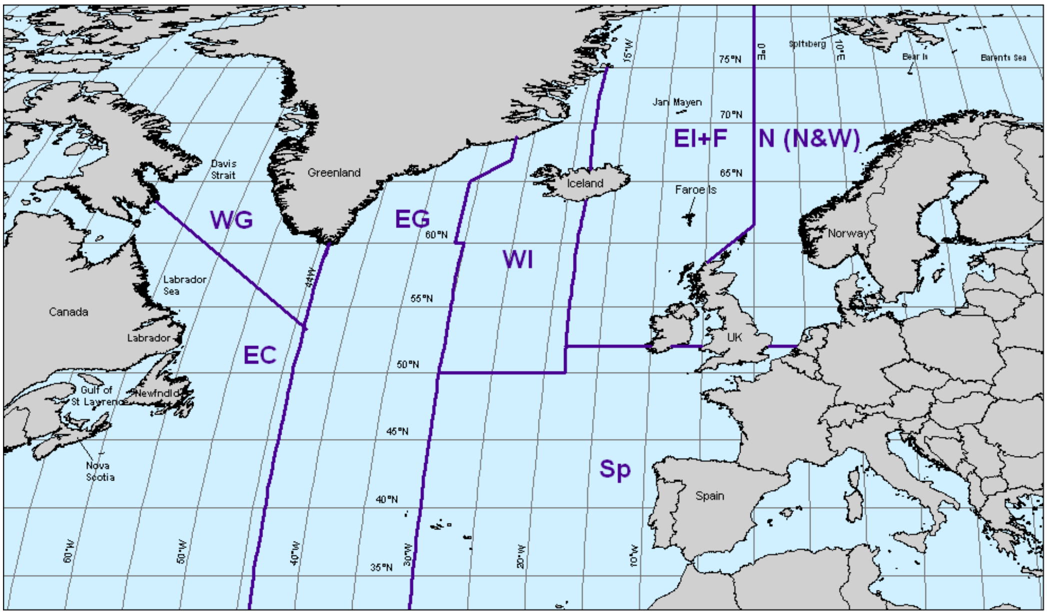

Fig. 3. Map of the North Atlantic showing the sub-areas defined for North Atlantic fin whales.

The Workshop then discussed the results of the revised conditioning. The time-trajectories of abundance in the revised plots were not always identical to those considered at the 2008 Annual Meeting (IWC, 2009b) given the new abundance estimates and the fact that additional variance places relatively more weight on fitting the mark-recapture data. Attention focussed on a number of issues related to the ability to mimic: (1) the abundance estimate for Spain for trials based on Hypothesis IV; (2) numbers of recaptures in sub-area WI of animals tagged in sub-area EG; (3) abundance in sub-area EI/F. After some discussion (SC/61/Rep3 item 3) the Workshop agreed that conditioning was satisfactory. The full conditioning plots are available on the IWC website.

The Workshop then went on to review the results of the agreed *Implementation Simulation Trials.* The Committee has agreed a quantitative approach to reviewing such trials and a standard graphical and tabular presentation of the results; this is given under items 4.1 and 4.2 of SC/61/Rep3. A schematic summary of the procedure is given in Fig. 4.

[2] 'Conditioning' a set of simulation trials involves fitting the operating models to the available data. The conditioned trials should be able to mimic the available data adequately. The *Implementation Simulation Trials* for North Atlantic fin whales are based on abundance and tagging data (all trials) and CPUE data (a subset of the trials).

In summary, the performance of variants in the trials can be classified as 'acceptable', 'borderline' or 'unacceptable' based on their conservation performance with respect to final depletion and the minimum depletion ratio. If the performance for a small number of medium weight trials is 'borderline', but closer to 'acceptable', then performance of the variant can be considered 'acceptable' without research. A variant can be recommended 'with research' if (a) it can be shown that this variant followed by another variant after 10 years performs 'acceptably' and (b) a research proposal can be developed which has a reasonable chance of showing within 10 years that the hypotheses on which the trials for which the variant performed 'unacceptably' were implausible.

As commercial catches are taken only from the WI sub-area, they primarily affect the C2 sub-stock, with some impact on the adjacent C1 and C3 sub-stocks, but hardly any on stocks further to the west and east. Accordingly, stock status related results are provided only for the three C sub-stocks and the primary focus of the evaluation was on those.

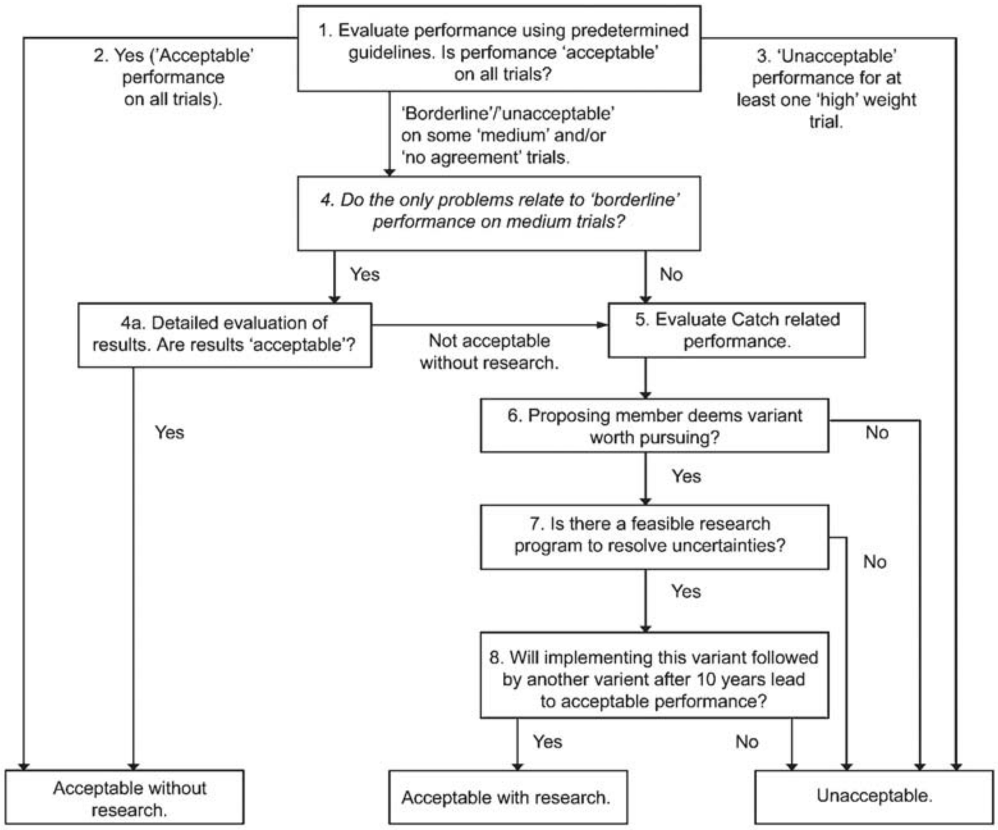

Fig. 4. Procedure for reviewing *Implementation Simulation Trials*

The six management variants were:

- V1 Sub-area WI is a *Small Area*;
- V2 Sub-area (WI+EG) is a *Small Area*. All of the catch is taken in the WI sub-area;
- V3 Sub-area (WI+EG+EI/F) is a *Small Area*. All of the catch is taken in the WI sub-area;
- V4 Sub-area WI is a *Small Area*. Catch limits will be set based on survey estimates for the WI sub-area north of 60°N (both historic and future surveys). Note: trial NF15 is not applicable for this variant. The same proportions are used in setting future abundance estimates as for trial NF15 (see item F of Annex B). The catch series is unchanged as all historic catches in the WI sub-area were taken north of 60°N;
- V5 Sub-areas WI and EG are taken to be *Small Areas* and sub-area WI+EG is taken to be a *Combination Area*. The catch limits set for the EG *Small Area* are not taken;
- V6 Sub-areas WI, EI/F and EG are taken to be *Small Areas* and sub-area WI+EI/F+EG is taken to be a *Combination Area*. The catch limits set for the EG & EI/F *Small Areas* are not taken.

The Workshop's consideration of the results by variant are summarised in Table 4.

In terms of catch-related performance, the Workshop noted that variant 2 gave, by an appreciable margin, the best catch-related performance over the trials as a whole. It was followed in this respect by variant 3.

Iceland indicated that they wished to pursue the option of presenting a research program to the Committee that would allow variant 2 to be classified as 'acceptable with research'.

This is a two-stage process. The first stage is to determine whether performance is 'acceptable' if variant 2 is replaced by variant 3 (preferred) or if not variant 1 after a 10-year initial period. If so, the second stage is for Iceland to demonstrate to the satisfaction of the Scientific Committee that a research programme has a good chance (within the 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, i.e. whether there is appreciable dispersal of whales between, in particular, sub-stocks C1 and C2. There was insufficient time to discuss this in any detail at the Workshop. A template for proposed research programmes is given in IWC (2008). In a short initial discussion it was suggested that further work involving biopsy sampling, telemetry and photo-id studies may be able to provide a basis to discriminate dispersal from feeding ground mixing of C1 and C2 whales.

The Workshop agreed that the Secretariat should undertake such calculations as soon as possible and the results are given as Annex E (variant 7) for completeness but these results were not reviewed at the Workshop; that was to be done at this meeting.

Table 4
Summary of variants and their performances

	Description of variant	Comments	Conclusion
1	sub-area WI is a *Small Area*	'acceptable' performance on all 'high' and 'medium' weight trials.	'acceptable without research'.
2	sub-area (WI+EG) is a *Small Area*. All of the catch is taken in the WI sub-area.	'acceptable' performance on all but one of the 27 'high' trials; 'borderline' performance on 11 of the 28 'medium' weight trials; 'unacceptable' performance resulted for trials NF-04-1, NF-20-1 and NF-28-1, all of which are based hypothesis IV	not 'acceptable without research'
3	sub-area (WI+EG+EI/F) is a *Small Area*. All of the catch is taken in the WI sub-area	'acceptable' performance on all of the 27 'high' trials and all except three of the 28 medium weight trials (NF04-1, NF20-1 and NF28-1), for which performance was 'borderline' but closer to acceptable.	'acceptable without research'.
4	sub-area WI is a *Small Area*. Catch limits are set based on survey estimates for the WI sub-area north of 60°N (both historic and future surveys)	See variant 1 comments	'acceptable without research'.
5	sub-areas WI and EG are taken to be *Small Areas* and sub-areas WI and EG are taken to be a *Combination Area*. The catch limits set for the EG *Small Area* are not taken	See variant 1 comments	'acceptable without research'.
6	sub-areas WI, EI/F and EG are taken to be *Small Areas* and sub-areas WI, EI/F and EG are together taken to be a *Combination Area*. The catch limits set for the EG and EI/F *Small Areas* are not taken.	See variant 1 comments	'acceptable without research'.

The Workshop made the following recommendations to the Scientific Committee:

<u>Management Areas</u>
The recommended *Management Areas* are shown in Fig. 3. Under the management options recommended, the designations are as follows:

(1) Variant 1: sub-area WI is a *Small Area*;
(2) Variant 3: sub-area (WI+EG+EI/F) is a *Small Area* (all of the catch is taken in the WI sub-area);
(3) Variant 4: sub-area WI is a *Small Area* (catch limits are set based on survey estimates for the WI sub-area north of 60°N);
(4) Variant 5: sub-areas WI and EG are taken to be *Small Areas* and sub-areas WI and EG are taken to be a *Combination area* (catch limits set for the EG *Small Area* are not taken);
(5) Variant 6: sub-areas WI, EI/F and EG are taken to be *Small Areas* and sub-areas WI, EI/F and EG are together taken to be a *Combination area* (catch limits set for the EG and EI/F *Small Areas* are not taken).
(6) If Variant 2 proves to be acceptable with research, then sub-area (WI+EG) is a *Small Area* (all of the catch is taken in the WI sub-area), at least for the first 10 years.

<u>Variant(s)</u>
The Workshop agreed that all of the variants apart from variant 2 are 'acceptable'. As noted above, variant 2 will be investigated to see if it qualifies as 'acceptable with research' in conjunction with another variant (the results of this work, undertaken after the Workshop was completed, are included in Annex E to SC/61/Rep3; the results are given for an additional variant denoted as 'V7' under which the V2 management regime is used for the first 10 years, followed by a phase in to regime V1 from year 15).

<u>Inputs for *CLA*</u>
Estimates of abundance
The Workshop agreed that the data from the 2007 NASS and CODA surveys should be analysed and used as the basis for developing a final abundance estimate for the EI/F sub-area. It agreed that Gunnlaugsson should liaise with Hammond to facilitate this work. The Scientific Committee will need to formally agree all of the estimates necessary for use in the *CLA.* The basis for most of these abundance estimates has been reviewed in IWC (2008).

Past removals
The Workshop agreed that the 'best' series should be used (see Annex B of SC/61/Rep3).

Future removals
The Workshop agreed that the issues of ship strikes and bycatches were not relevant for this *Implementation.*

The Workshop agreed to the following work plan:

(1) Secretariat to undertake the calculations necessary to determine whether (and with which variant) variant 2 may be classified as 'acceptable with research'.
(2) Gunnlaugsson to liaise with Hammond with respect to use of the 2007 CODA data.
(3) If variant 2 proves to be acceptable with research, Icelandic scientists to prepare a research programme for consideration by the Scientific Committee.

In conclusion, Donovan paid tribute to the hard work of Allison and Rademeyer who undertook a considerable amount of computing work during the Workshop itself.
The sub-committee thanked Donovan for his leadership in running a successful Workshop and ensuring that the *Implementation* process for North Atlantic fin whales can be completed as scheduled.

3.2.1.2 MATTERS AND RECOMMENDATIONS ARISING

In response to a question, it was noted that the new abundance estimate for 2007 for sub-area EI/F fell outside of the simulation intervals for the variants of the trials examined by the Committee last year. However, allowing for additional variance led to wider simulation intervals and a lower median population size, factors which should pose more of a challenge to the RMP variants.

SC/61/RMP10 presented estimates of the abundance of fin whales and other baleen whales in the European Atlantic. The survey area covered offshore waters beyond the continental shelf of the UK, Ireland, France and Spain. The area was stratified into four blocks and was surveyed by five ships during July 2007. Double platform methods employing the trial-configuration method (BT-method) were used to take account of animals missed on the transect line and any responsive movement. Abundance was estimated for fin, sei and minke whales, for 'large baleen whales' which included fin, sei, fin/sei and blue whales, and for 'unidentified large whales', which included mostly baleen whales but could also have included some sperm whales. Abundance of the larger species (i.e. all except minke whales) was estimated using mark-recapture line transect design-based methods and also model-based methods using density surface modelling. The density of large baleen whale species was greatest in the southern end of the survey area; water depth, temperature, and distance to the 2000m contour were important predictors of their distribution. Estimates from the design- and model-based methods were comparable but model-based methods improved the precision of the estimates and were considered the best estimates. Total abundance estimated for the entire survey area was 9,019 (CV=0.11) fin whales and 9,619 (CV= 0.11) large baleen whales. The effect on estimates of uncertainty in duplicate classification and species identification was explored; the former had little effect, the latter a greater effect. The fin whale estimate is likely an underestimate because it excludes unidentified large whales, of which a large proportion was likely to have been fin whales. The design-based estimate of abundance of fin whales in the northern survey block that contributes to the EI/F area was 248 (CV=0.45).

In discussion, it was noted that collection of biopsies would assist in reviewing the basis for the southern boundary for the EI/F sub-area and hence the basis for abundance estimates for this sub-area. Hammond noted that densities were low south of the (current) southern boundary of sub-area EI/F so small changes in this boundary would not impact the estimated abundance for this sub-area.

The sub-committee reviewed the recommendations arising from the Workshop and endorsed these regarding *management areas*, the variants which were 'acceptable' for implementation without research, and the best series of catches that should be used when applying the RMP.

3.2.1.3 CONSIDERATION OF ADDITIONAL TRIAL RESULTS RELEVANT TO THE 'VARIANT WITH RESEARCH' OPTION

Variant 2 (sub-area (WI+EG) is a *Small Area*. All of the catch is taken in the WI sub-area) was not 'acceptable'. The sub-committee was advised that the conservation performance of an RMP variant is evaluated for a particular trial by comparing its performance to that when the RMP is applied to a single stock trial which is as similar as possible to the trial under consideration. Performance is evaluated relative to both final depletion and the minimum depletion ratio (the ratio of the population size under RMP catches to the population size if there were no future catches). The Scientific Committee has agreed that 'acceptable' conservation performance for each stock within a trial involves achieving performance statistics that are at least as conservative as the 0.72 tuning of the RMP (JCRM (Suppl) 9:109).

The combination of variant 2 for ten years following by variant 1 (sub-area WI is a *Small Area*) led to performance which was 'acceptable' for all trials (Annex E of SC/61/Rep3). The sub-committee therefore agreed that the requirements for stage 1 of the process for implementing a 'variant with research' had been met.

3.2.1.4 CONSIDERATION OF POTENTIAL RESEARCH PROGRAMME TO ACCOMPANY 'VARIANT WITH RESEARCH'

The second stage of the process for implementing a 'variant with research' is for Iceland to demonstrate to the satisfaction of the Scientific Committee that a research program has a good chance (within the 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/61/RMP9 was written in response to the outcomes of the Workshop where variant 2 performed unacceptably for three trials (two of which were essentially identical) that had been assigned medium plausibility (despite objections to the assignment of plausibility). These trials had MSYR(mat)=1% and were based on stock hypothesis IV. This hypothesis assumes no interchange between three breeding sub-stocks in the Central North Atlantic. In particular trials based on hypothesis IV are difficult to reconcile with the known catch history off West Iceland. Appendix 6 outlines the concerns of the authors of SC/61/RMP9 with this hypothesis in more detail. The authors of SC/61/RMP9 requested an explanation, or any example, of what could be the biological realism of this hypothesis from those who supported it. SC/61/RMP9 also identified several aspects of a research programme which could be used to refute hypothesis IV: (a) a satellite tagging programme that could reveal within-season mixing on the feeding grounds and late summer tagging that could locate the breeding grounds, and (b) collection of DNA from biopsies for comparison with existing collections. SC/61/RMP9 noted that the research programme did not aim to address the issue of MSYR, but that is currently being addressed by the Committee.

The sub-committee noted that some of the issues raised in Appendix 6 (e.g. the trajectories of population size) had been considered in detail by the Committee last year, while the behaviour of a single tag was not sufficient to refute a hypothesis. However, the sub-committee noted that the concerns regarding the fits of trials based on hypothesis IV could be examined further as part of a research programme because a research programme need not involve only field work-based research.

Víkingsson, on behalf of Iceland, stated that a research proposal would be developed for next year's meeting and requested that an Advisory Group (IWC 2008, pg 96) be established to advise the Icelandic scientists as needed. Allison, Butterworth, Donovan, Punt and Skaug agreed to participate on the Advisory Group. In relation to the research proposal, the sub-committee noted the need follow the proforma agreed in 2007 (IWC, 2008, pg. 96-97, 115) and suggested that power analyses (perhaps based on *Implementation Simulations Trials*) be conducted as needed.

3.2.1.5 ABSOLUTE ABUNDANCE ESTIMATES FOR USE IN THE CLA

No abundance estimates were provided for adoption. The sub-committee agreed that the estimates need to be assembled and provided for consideration at next year's meeting.

3.2.1.6 RECOMMENDATIONS FOR THE COMMISSION

The sub-committee agreed that if the RMP is implemented, variants 1, 3, 4, 5 and 6 can be implemented without an associated research programme. The recommended *management areas* for each variant are given in Table 4. The sub-committee further agreed that variant 2 cannot be implemented except in conjunction with a research program that the Committee agrees could feasibly show that the trials on which variant 2 performs 'unacceptably' should have been assigned 'low' plausibility. The sub-committee anticipates being provided with such a research program and reviewing it at the 2010 Annual Meeting.

3.2.2 Work plan
The sub-committee **agreed** that its work plan for the 2010 Annual Meeting would be as follows.

(1) Review the research proposal for the 'variant with research' to be submitted to the 2010 meeting.
(2) Review the abundance estimates for use in the CLA.

3.3 North Atlantic Common minke whales

3.3.1 Complete the Implementation Review

3.3.1.1 CONSIDERATION OF REVISION OF BOUNDARIES

The sub-committee recalled that last year an issue regarding stock structure had remained unresolved. This related to differences in results of analyses of genetic data from 1997-2002 and from 2003-2006. It had been suggested that the heterogeneity apparent in the 1997-2002 data (considered in the 2003 *Implementation Review*) that was absent in the 2003-2006 data could have been a laboratory artefact. The sub-committee had recommended that the 1997-2002 data be analysed in more detail to clarify this. No new analyses were presented this year to address this issue. In the absence of any new information the sub-committee **agreed** that it should accept the current boundary. The boundaries agreed at the 2003 *Implementation Review* would therefore remain the same for this *Implementation Review*.

3.3.1.2 ABUNDANCE ESTIMATES AND ADDITIONAL VARIANCE

Skaug presented a working paper that raised the issue of using methods other than conventional line transect sampling to calculate estimates of abundance that would be acceptable for use in the RMP. The two methods were mark-recapture analysis of genetic data and spatial modelling of data from multipurpose surveys.

The sub-committee referred to its Requirements and Guidelines for conducting surveys and analysing data within the Revised Management Scheme (IWC 2005). It noted that although the RMP does not preclude the use of direct methods of estimating absolute abundance other than shipboard or aerial sightings surveys, such as capture-recapture analyses, until the properties of such estimates and the implications for their use in the RMP have been further examined, sightings surveys remain the primary methods. However, the sub-committee believed that it was important to consider this issue and **agreed** that it should be placed on its agenda for its 2010 meeting. It encouraged members to submit papers for consideration next year.

SC/61/RMP3 described the duplicate identification routine used when analysing the data from Norwegian minke whale sighting surveys. The routine has two major elements: a matching part and a legality part. The matching part uses a score function to evaluate possible candidate duplicates based on temporal and spatial differences; the objective is to match the initial surfacing correctly. The legality part of the routine defines the maximum allowable differences in time and space for two observations to be considered as a duplicate. SC/61/RMP3 tested the performance of the routine with simulations for different setting of the legality criterion. The routine was tested under a broad range of settings of the operating model based on the model used in SC/61/RMP2. Several different performance metrics were defined: the two main ones were the number of true duplicates that the routine failed to detect and the number of falsely detected duplicates. Based on the simulation results, a criterion called 'strict', which allowed a maximum of 12 seconds difference in time was used. Given this setting of the legality criterion the routine was able to detect around 90% of the duplicate observations correctly. Furthermore, the two types of error were of same magnitude.

In discussion, it was confirmed that a range of densities used in the simulations. It was also noted that when investigating this problem previously, the Committee had identified a number of other issues that might usefully be considered.

SC/61/RMP4 was an addendum to Bøthun et al. (2008) presented last year and addressed questions raised during that meeting, mainly relating to observer-specific effects. The baseline for these analyses was a log-linear model; residuals for each observer were shown as boxplots. These varied both on average and in spread among observers. There was a substantial amount of serial correlation between experiments close in time for model 1. Residuals from model 1 plotted against observation number for some selected observers for the port and starboard buoy indicated that the serial correlation was independent of buoy. In fact, models that included buoy performed worse according to AIC. Motivated by this and the suggestions during last year's meeting, the data were modelled as a mixed-effect model. Further, the serial correlation was modelled with an AR(2) process. Models that allowed residuals to vary between observers were also fitted; Beaufort sea-state, platform, vessel, etc were included as covariates. After accounting for serial correlation random effects the analysis showed that distance estimates made by naked eye at sea are unbiased on a log scale. It was noted that the AICs were very different for these models and it was surprising to see that these effects were important.

SC/61/RMP5 presented a new method for estimating the Neyman-Scott parameters that are part of the input to the simulation model used to estimate variance in SC/61/RMP2. The new estimation method involved fitting a Markov modulated Poisson process to the encounter rate data. The reason for introducing a new estimation method was that the approach used previously was computationally demanding. It was noted that the model underlying the new estimation method was rather different from the Neyman-Scott process, but the author believed that it nevertheless produces reliable estimates.

SC/61/RMP7 provided information on a new VHF series of dive times collected from a minke whale in the southeastern Barents Sea in 2008, and summarized all the VHF dive time series which have been collected to date as part of the Norwegian minke whale survey programme. In September 2008, a VHF radio tag was applied on a minke whale in Varangerfjord, southeastern Barents Sea. The whale was followed for 60 hours over a period of five days, and the mean blow rate was 38 blows/hour. In total, 20 dive time series of varying lengths, from 2 to 120 hours, have now been collected from the North Sea, Norwegian Sea, Svalbard and the southeastern Barents Sea. Of these, 12 series have been collected over the period 2001-2008. Large variations in blow rates have been observed, both within and between individuals. On an individual basis, the blow rate varies from 29 to 72 blows/whale/hour. The mean blow rate for all data is 49 blows/whale/hour. This estimate is in accordance with what has been found in similar VHF experiments as well as from visual dive time experiments, but the longer series, in particular, demonstrates that the variation in blow rates seen on an individual basis is at least as large as that recorded as means between individuals.

The sub-committee welcomed this work in response to previous requests for more information on surfacing rate data. It briefly discussed to what extent there were area-specific differences in inter-surfacing intervals and blow rates. There does seem to be some structure in the data but this did not appear to be systematic, which made it difficult to identify any area-specific effects. It could be informative to obtain data on the prey of minke whales in different areas to explain inter-area variability.

SC/61RMP6 compared surfacing rates from VHF tagged animals with the surfacing rate observed in the sighting surveys. According to the survey protocol the time point of each detected cue shall be recorded, which allowed a mean surfacing rate to be estimated for each observed whale track. To account for the selection bias in the surveys, i.e. that individuals with a high surfacing rate are more likely to be detected; the simulation program used in SC/61/RMP2 was used. It was found that the surfacing rate is higher in the surveys than in the VHF data. No explanation for this result was given, but it was concluded it will not lead to a positive bias in the abundance estimate presented in SC/61/RMP2.

The sub-committee was pleased to see this work because of its previous concerns about the surfacing rate data used in the estimation of abundance. The results indicate that there do not appear to be any problems of bias with the use of these data.

SC/61/O2 presented an analysis of the effect of unmodelled heterogeneity in detectability in the context of line transect surveys. The work was motivated by the lack-of-fit for the proportion of duplicate sightings at long distance seen in SC/61/RMP2, and in the previous Northeast Atlantic minke whales surveys. The paper addressed both heterogeneity between cues within a track, and heterogeneity between tracks, and found that both types of heterogeneity can yield a negative bias in the abundance estimate when ignored.

The sub-committee noted the main result that ignoring heterogeneity in cue rate or cue strength can lead to negative bias in abundance, is as expected. It further noted that the intention of presenting the work here was to show the lack of any positive bias. On the question of whether or not this should be taken through into estimation of abundance for use in the RMP, the sub-committee noted that this did not require additional data and was informed that the method could readily be incorporated into the abundance estimation models. The sub-committee encouraged further work but noted that care should be taken not to generate estimates that could contain elements of positive bias. It referred the authors to its Requirements and Guidelines for conducting surveys and analysing data within the Revised Management Scheme (IWC 2005).

SC/61/RMP2 contained an abundance estimate for Northeast Atlantic minke whales based on the partial sighting surveys conducted over the period 2002-2007. The survey methodology was the same as that used for earlier survey periods in this region, but some modifications had been made to the analysis method, as outlined in the papers SC/61/RMP3-5. The total abundance for the areas covered by the survey was 108,000 (CV 0.23), and the estimate for the Eastern Medium Area only was 81,000 (CV 0.23). These estimates are in accordance with the corresponding estimates from the previous survey period 1996-2001, although the uncertainty is larger. The uncertainty estimates had been corrected for inter-annual variation in the spatial distribution of whales (additional variance).

The sub-committee discussed the possible reasons why the CVs of the new estimates for 2002-2007 were higher than for the previous period of 1996-2001. Fewer sightings were made in 2002-2007, but the abundance estimate is very similar. The authors suggested that the difference might be partly related to the bias correction procedure. Notwithstanding this, the sub-committee agreed to adopt the estimates of abundance for 2002-2007 presented in SC/61/RMP2.

The new methods used to analyse the 2002-2007 data have not been applied to data from previous surveys. The sub-committee agreed that this was desirable so that the time series of abundance estimates used in the RMP were as consistent as possible. However, from the perspective of the CLA the priority is to reduce bias. The Requirements and Guidelines for conducting surveys (IWC 2005) consider this issue in the context of data collection but not with respect to data analysis. The sub-committee agreed that the new methods should be used to update previous estimates, as far as possible, and requested that the results of this work be presented to the Committee. Notwithstanding this, the sub-committee agreed that any issues regarding consistency should be minor and that this should not delay the completion of the *Implementation Review*.

SC/61/RMP12 presented analyses of the T-NASS 2007 data from the six vessels operating in the central North Atlantic. Three vessels surveyed using double platform BT methods with two observers on a lower Primary platform searching with naked eye and two trackers, a data recorder and a duplicate identifier on an upper Tracker platform. Two dedicated cetacean observers searched on each of three other research vessels engaged primarily in other research activities. These vessels are referred to as extension vessels and the intention was for them to extend survey coverage to areas not surveyed by the main sightings survey vessels. One of these vessels made no minke whale sightings on full effort and so the area covered only by this vessel receives zero abundance. Abundance in the coastal Icelandic block was covered by aircraft and was not considered here. The highest density region in the survey area along the coast of East Greenland and the ice edge received little coverage due to poor conditions there. In total, 30 sightings were made in BT mode and 7 sightings in combined platform mode, that is, during periods when BT mode could not be maintained for logistic reasons. In addition 20 sightings were made in single platform mode, mainly on the extension vessels. There were 24 trials (tracker sightings) of which 4 to 5 were likely duplicates all at short distances.

SC/61/RMP12 presented an analysis from all the vessels combined. Results from both Point Independence and Full Independence were considered and in both cases g(0) was estimated at 0.95; i.e. close to 1. Including the combined mode effort as primary effort had, contrary to expectation, reduced the estimate of abundance. The results were tested for bias in distance estimates by primary platform (naked eye estimates). Multiplying up the primary distances by 1.34 (based on comparison of primary and tracker distance estimates to immediate duplicates of fin whales) led to estimates that were 11% lower. The estimates were not more affected because most of the sightings distances came from the tracker platform and when the primary distances are multiplied up there is more overlap with the tracker sightings that were missed by the primary platform which then leads to a lower g(0) and compensates for the wider effective strip width. Assuming no responsive movement (Point Independence model) and using the extension vessel data only when no dedicated sighting vessel data were available (in block CL) gave an estimate for the NASS-07 survey area of 10,900. Full bootstrap confidence intervals are 6,600-30,000. The estimate for the surveyed part of the Central Area is 11,100 (6,400-30,600). The Full Independence model estimates were almost three times higher, which implies extreme avoidance of the animals to the sighting vessels. This level of avoidance has not been documented and so the Point Independence model estimates are preferred. A number of problems were identified in the implementation of the BT method in this survey which most likely introduced negative biases due to incomplete recording or not fully independent recording of the uncertainty/incompatibility in species identification from the platforms. These estimates are not corrected for availability bias and where such estimates exist (e.g. from the Norwegian line transect surveys, which have minke whales as the target species) they should be preferred.

In discussion, some concerns about the analysis were expressed. In particular, a question was raised about whether the method was appropriate given the very small number of duplicates observed on the survey. The sub-committee concluded that the information in the paper was insufficient to assess fully the methodology and diagnostics and noted that the senior author was unable to attend the meeting. The sub-committee agreed that it was premature to adopt the estimates in SC/61/RMP12 for use in the RMP. A revised version of the analyses that addresses the concerns expressed should be considered by the Committee in the future.

SC/61/RMP11 presented a partial aerial survey of coastal Icelandic waters conducted in the Faxaflói area of southwest Iceland in late June - July 2008. The relative cue distribution, duplicates and measurement errors in the 2008 survey were detailed and sighting rates were compared to earlier surveys in this block. This is the twelfth time that this block has been surveyed in a similar manner. The sighting frequency of common minke whales, the target species in these surveys, was similar to most of the earlier midsummer surveys and higher than in 2007, when densities were extremely low. The distribution of minke whales within the area was apparently more concentrated in shallow waters inside Faxaflói bay in 2008 than in any earlier survey. SC/61/RMP8 presented separate counts by primary observers; counts for the two track line sets in the block are presented separately as well as when there were repeats of the track lines within a survey. It was found that although the detection functions of observers in a survey varied, which resulted in quite different abundance estimates for each observer, the sighting rates for the observers in each survey were very similar, even though conditions such as glare affected them differently. Repeats within a survey differed more but much less so than between surveys. The differences between repeats may generally be explained by differences in sighting conditions but the conditions during, for instance, the extremely low 2007 survey were not exceptional. This indicates that the survey differences are real and that the whales leave the area when food there is scarce, but does not support the view that there was any collapse in the stock in 2007. A full scale survey is planned for June - July 2009.

The sub-committee welcomed this paper. Donovan was appointed to provide oversight for the surveys on behalf of the Committee.

SC/61/RMP8 summarized a sighting survey conducted in the Svalbard area, the *Small Management Area* ES, in the summer 2008 as the first year in a new six-year survey programme for minke whales in the Northeast Atlantic over the period 2008-2013. The area was last covered in 2003. There were two vessels participating in the 2008 survey, which was conducted between 30 June to 3 August and 30 June to 25 July 2008 for the two vessels respectively. The two vessels were able to survey about 2,800 nautical miles, which was somewhat higher than had been anticipated at the planning stage based on earlier experience of weather and conditions. All the four designed blocks were surveyed with a reasonable coverage, with the exception of an area south-west in the Greenland Sea. This was due to bad weather conditions and time constraints when the vessel was in that area. The most frequently sighted species was the minke whale, for which 128 groups were recorded on effort from the primary search platform. Other species recorded during primary search included fin whales, humpback whales, Northern bottlenose whales, blue whales, sperm whales and dolphin spp. The survey procedures followed and equipment used were basically the same as used in previous surveys. Double platform effort is used exclusively, and the observers are organised into teams of two persons. This has been consistent in all the previous Norwegian surveys since 1997. Biopsy sampling and photo identification were conducted on an opportunistic basis during the sighting surveys. Biopsies were collected from 11 humpback whales and 12 fin whales. In addition, fluke photos from about 54 humpback whales were collected, mostly from the area around Bear Island, and photo ID from 8 fin whales, 10 minke whales and 3 blue whales.

The authors of SC/61/FI43 commented that the three years of visual surveys, with 1367 dive sequences, illustrate significant diel and seasonal differences in the dive times for mean surfacing intervals of North Atlantic minke whales. They believed these data might be useful in survey analysis.

The sub-committee did not discuss this paper. Walløe commented that studies by Norwegian scientists (e.g. SC/61/RMP7) do not support the conclusions of SC/61/FI43.

3.3.2 Recommendations

The sub-committee recommended that the estimate of abundance for the Eastern Medium Area of 81,000 (CV 0.23) for 2002-2007 be adopted for use in the *CLA*.

The sub-committee agreed that the *Implementation Review* for the North Atlantic minke whales was now complete.

4. WORK PLAN

(1) RMP – general matters

(1) Conduct a four-day intersessional workshop (Steering Group Butterworth (Convenor), Allison, Cooke, Donovan, Gunnlaugsson, Kitakado, Punt, Wade, and Walløe)) to estimate the parameters of the environmental model and finalize the Bayesian meta-analysis so that a final decision can be made on the range for MSYR in the RMP at the 2010 Annual Meeting.
(2) Complete the review of the range of MSYR values for use in the RMP.
(3) Finalize the approach for evaluating proposal amendments to the CLA.

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

(1) Secretariat to finalize the audit of the Bryde's whale survey data.
(2) Allison and Pastene to use the Bryde's whales *Implementation Simulation Trials* to evaluate the effect size (and power) for current and historical age-composition data
(3) Japanese scientists to review previous (and any new) genetic power analyses for the western North Pacific Bryde's whales
(4) Japanese scientists 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.
(5) Committee to review the research proposal for the 'variant with research' to be submitted to the 2010 meeting.

(3) Implementation for the North Atlantic fin whales

Committee to

(1) Review the research proposal for the 'variant with research' to be submitted to the 2010 meeting
(2) Review the abundance estimates for use in the CLA.

5. ADOPTION OF REPORT

The report was adopted at 17:29 on 8 June 2009. The sub-committee thanked the Chair for guiding them though a long agenda. The Chair expressed his appreciation to the rapporteurs for their hard work and to sub-committee members for their forbearance.

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Appendix 1

AGENDA

1. INTRODUCTORY ITEMS
1.1 Convenor's opening remarks
1.2 Election of Chair and 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 Matters Arising
2.2 Finalise the process for evaluating amendments to the RMP
2.3 Work plan

3. RMP – PREPARATIONS FOR IMPLEMENTATION
3.1 Western North Pacific Bryde's whales
3.1.1 Research proposal for the 'variant with research'
3.1.2 Other
3.1.3 Work plan
3.2 North Atlantic fin whales
3.2.1 Complete *Implementation*
3.2.1.1 Report of Intersessional Workshop
3.2.1.2 Matters and recommendations arising
3.2.1.3 Consideration of additional trial results relevant to the 'variant with research' option
3.2.1.4 Consideration of potential research programme to accompany 'variant with research'
3.2.1.5 Absolute abundance estimates for use in the CLA
3.2.1.6 Recommendations for the Commission
3.2.2 Work plan
3.3 North Atlantic common minke whales
3.3.1 Complete the *Implementation Review*
3.3.1.1 Consideration on revision of boundaries
3.3.1.2 Abundance estimates and additional variance
3.3.2 Recommendations

4. WORK PLAN

5. ADOPTION OF REPORT

Appendix 2

REVISED OUTCOMES FROM THE BAYESIAN META-ANALYSIS

Andre E. Punt and Cherry Allison

The Bayesian meta-analysis of SC/F07/MSYR1 was applied to the data in Table 1 based on 5,000,000 cycles, excluding the first 2,000,000 as a burn-in and selecting a thinning rate such that the final sample from the posterior was based on 10,000 draws. This number of cycles is sufficient that the extent of auto-correlation between subsequent samples is negligible ($|\rho|<0.02$). The analysis was run including and excluding the data for the Southern Hemisphere blue whales (because it does not come from a single stock).

Figs. 1 and 3 shows the posterior distributions for μ and σ (the population mean value of r_0 and the between-population standard deviation for r_0), and Figs. 2 and 4 that for the rate of increase for an 'unknown' stock.

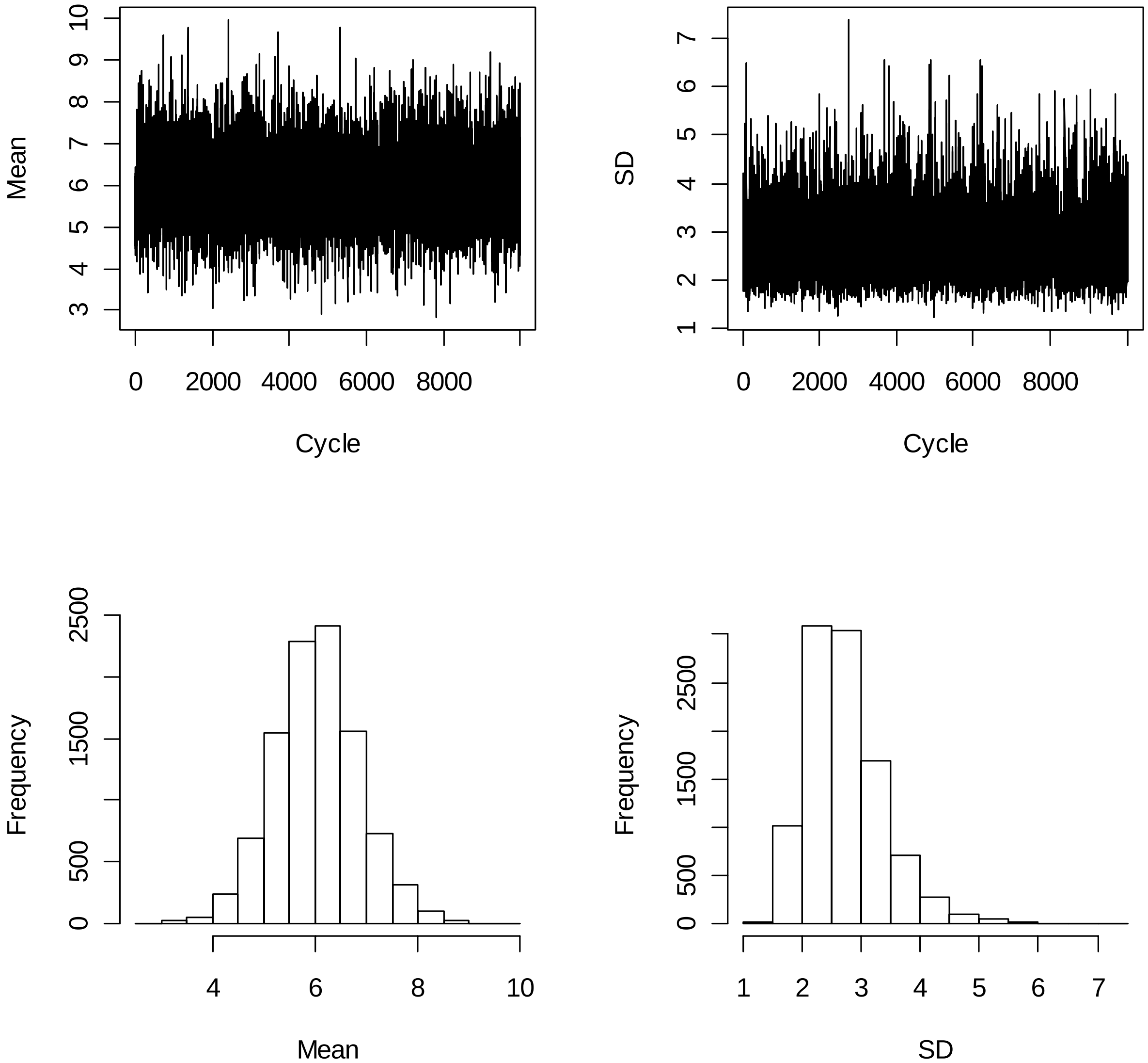

Fig. 1. Posterior distribution for the population mean values for the rate of increase (expressed as percentage) in the limit of zero population size, r_0, and the between-population standard deviation for the rate of increase, when including SH blue data. The upper plots are traces. The means and standard deviations of the hyper-distributions for the population mean and standard deviation are respectively 6.20/0.84 and 2.70/0.66.

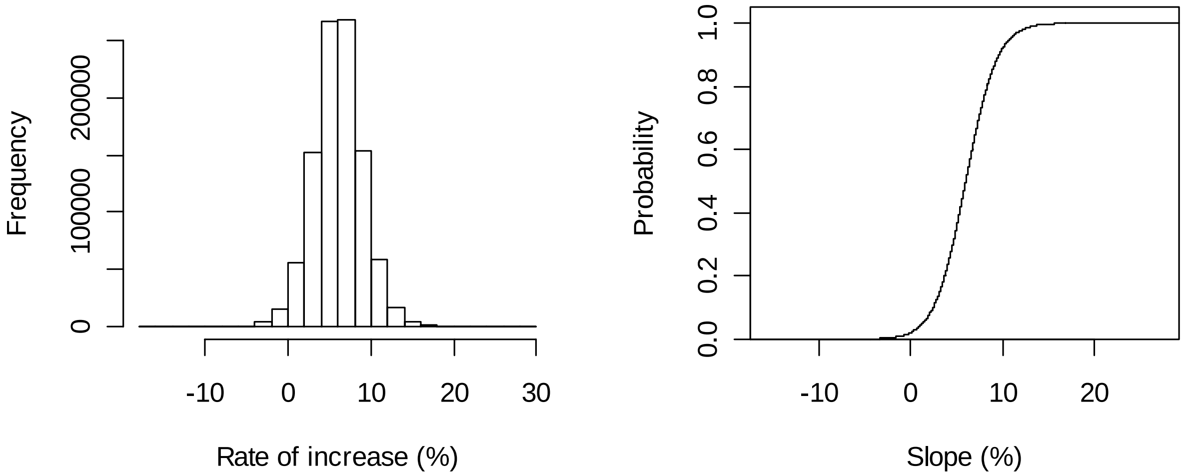

Fig. 2. Posterior distribution for r_0 for an “unknown” stock, when including SH blue data. The mean and standard deviation of this distribution are respectively 6.20 and 2.90.

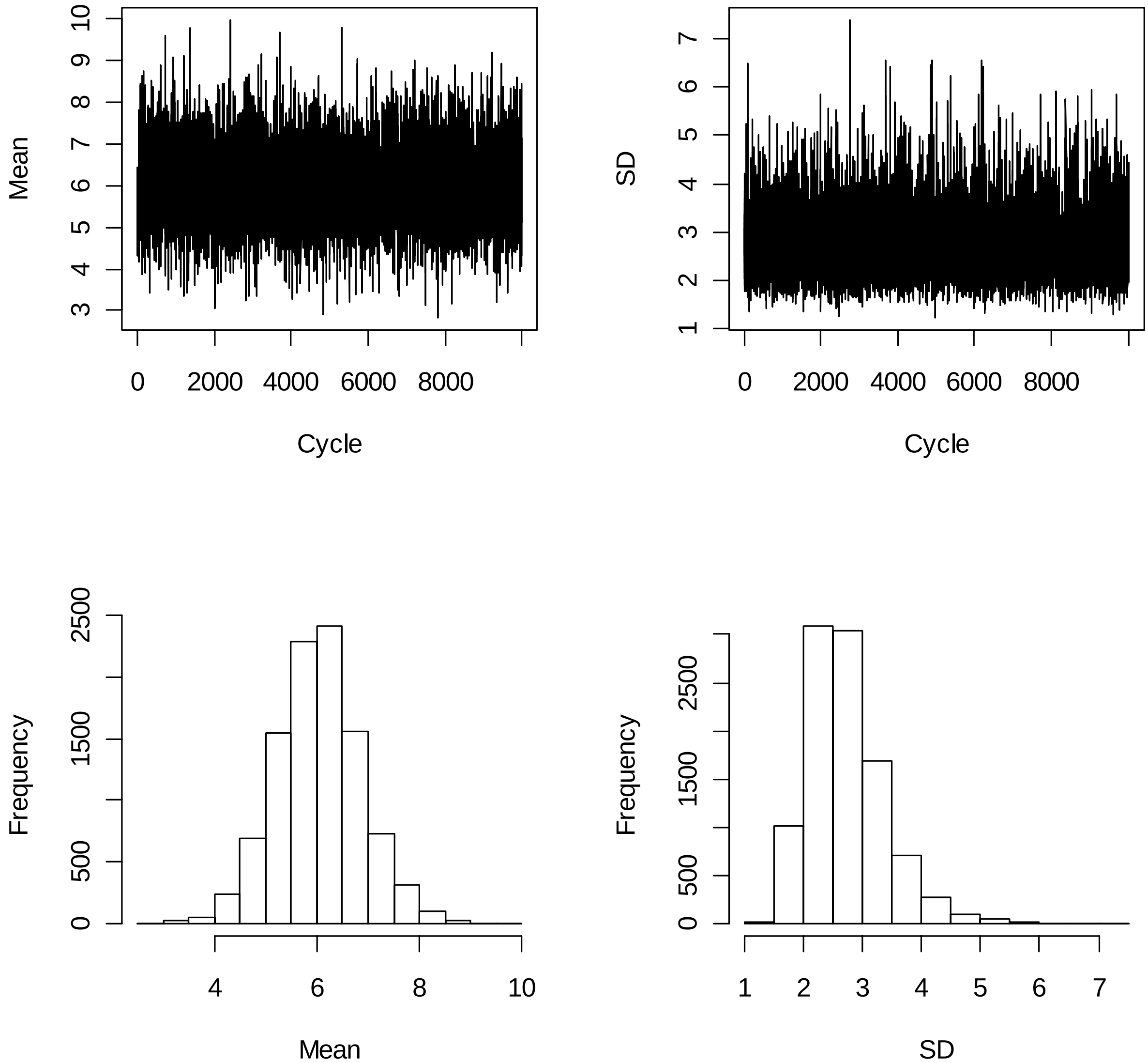

Fig. 3. Posterior distribution for the population mean values for the rate of increase (expressed as percentage) in the limit of zero population size, r_0, and the between-population standard deviation for the rate of increase, when excluding SH blue data. The upper plots are traces. The means and standard deviations of the hyper-distributions for the population mean and standard deviation are respectively 6.11/0.88 and 2.74/0.67.

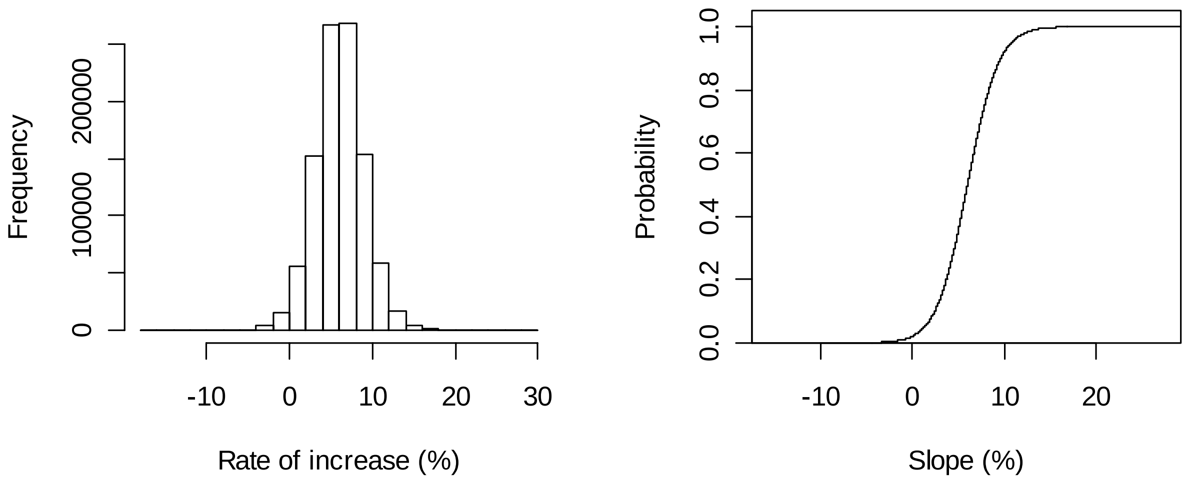

Fig. 4. Posterior distribution for r_0 for an "unknown" stock, when excluding SH blue data. The mean and standard deviation of this distribution are respectively 6.10 and 2.96.

Appendix 3

A NOTE ON THE POTENTIAL OF DIFFERENT TYPES OF DATA TO PROVIDE INFORMATION INTO THE NATURE AND EXTENT OF POPULATION LEVEL VARIABILITY IN LIFE HISTORY PARAMETERS

John R. Brandon and A.E. Punt

There exist several potential categories of data which may provide information on the extent of population level variability in life history parameters of large whales. These include: (i) biological sampling from catches; (ii) photo-ID data, and; (iii) annual surveys of the number of animals which are born or die (i.e. calf and stranding counts).

In theory, biological data from catches could provide information on the degree of variability in certain life history parameters. In practice however, there are several aspects of sampling from catches which limit the usefulness of this data type. These uncertainties include (but are not limited to): the selectivity of the hunt (i.e., whether the biological samples represent a random sample from the population) and issues of sample size. The latter is perhaps most limiting in the ability of catch data to discern the extent of variability in vital rates, but other complications (e.g., uncertainties in pre- and neonate mortality) also make catch data generally un-informative with respect to this issue.

Photo-ID data are well suited to providing estimates of life history parameters and could therefore potentially provide some measure of the extent of variation therein. In general though, missing observations of individuals will confound efforts to estimate the extent of variability in vital rates. For example, in large populations (e.g., southern hemisphere populations of humpbacks) difficulties in obtaining sufficient recaptures limit the power to detect changes in life history parameters. On the other hand, the variability in these rates as observed from very small and well monitored populations (e.g. western gray whales) will be dominated by individual stochasticity. Therefore, in this category the best candidates for providing relevant estimates are medium sized populations which have been studied for long enough to enable population level changes in demographic parameters to be detected (e.g. southern hemisphere populations of right whales).

Annual surveys which provide estimates of the number of animals which are born or die each year (i.e. calf and strandings counts) can also be used to infer the extent of variation in vital rates. However, these estimates alone are not sufficient; it is also necessary to have estimates of abundance (in order to scale the calf counts and number of stranded animals) during those years for which estimates of the number of births and/or deaths exist. Although strandings counts represent only an unknown proportion of deaths occurring in the population, they might still provide a useful index of mortality (especially for coastal populations) and therefore information on the variability in this rate. Therefore, annual surveys of calf production and strandings counts for coastal populations of large whales (e.g., eastern North Pacific gray whales) are likely to provide promising candidate studies on which to base inference.

All else being equal, the power of alternative sources of information to provide estimates of the extent of population level variability in vital rates will be a function of several factors, including the length of time series of observations, the extent of observation error in relevant estimates, and the extent of variability in the vital rate of interest. Longer time series with lower measurement error CVs, which are used to measure vital rates that are more variable, will have a higher power to detect the extent of variability in these rates. Therefore, before embarking on future studies to understand the extent of this variability, it would be prudent to conduct a power analysis to determine the necessary design parameters of those studies that would enable them to detect changes in vital rates and hence the extent of variability in those rates.

Appendix 4

PROPOSAL RE RANGE OF MSYR VALUES TO BE CONSIDERED IN TRIALS OF THE RMP FOR BALEEN WHALES

D.S. Butterworth

Background

When the RMP development process commenced with a Workshop in 1987, trials were developed for MSYR values of 1% and 4%, with 7% added to this set at the 1990 SC meeting.

At a further Workshop in December 1990, the decision was made to move from age-aggregated to age-structured population models for trials, and that the 1%/4%/7% values of MSYR and MSYL for trials pertain to the mature component of the population, where the recruited and mature components of the population would be treated as identical in the model utilized. This decision was in part based on conventional wisdom in the SC at that time that a 1%-4% range applied to Southern Hemisphere minke whales (for which ages at recruitment and maturity were comparable), and referred to the recruited component of the population. [Recall that prior to that time much population modelling in the SC had been based on CPUE data, which referred to the recruited component of the population.]

A more thorough review of information available relating to MSYR conducted during the 1993 meeting of the SC concluded with consensus that 1%-7% of the mature component of the population was an appropriate range to use in trials for MSYR.

The 2006 meeting of the SC decided to review this decision in the light of further information on baleen whale population productivity that had since become available.

It should be noted that the *modus operandi* that has developed over recent years in reviewing results of RMP *Implementation Simulation Trials* is that trials with MSYR = 4% are accorded high weight and those with MSYR = 1% medium weight (hypotheses accorded low weight are disregarded). In practice, trials with MSYR = 7% tend not to be run, as their results provide little more information pertinent to RMP variant selection than is already available from trials with MSYR = 4%. Different rules apply as regards acceptable conservation performance for trials accorded high and accorded medium weight (i.e. plausibility).

Proposal

Revise the MSYR values for use in trials to MSYR = 3% accorded high weight, and MSYR = 1% accorded medium weight, where both these rates (and also MSYL) refer to the 1+ component of the population.

Formally the accepted range for MSYR for use in RMP trials would change from the current 1% - 7% in terms of the mature component of the population to 1% - 5% in terms of the 1+ component of the population.

Motivation

Change of metric

As the review of information relating to MSYR has indicated, the primary information bearing on this topic is that on population increase rates (at relatively low abundance levels). These measurements relate directly to MSYR in terms of the 1+ population component (strictly 0+, but the difference is minimal). Relating further to other population components such as the mature animals requires additional assumptions about parameters, such as natural mortality, whose values are usually not well known.

Choice of high weight value

The means of the distributions for population growth rates for an unknown population resulting from the meta-analysis in RMP WP 8 are close to 6%. The central value of these distributions would seem a sensible basis for the MSYR value to be given high weight in RMP trials. In terms of the relationship used to infer MSYR(1+) from this growth rate information, this corresponds to an MSYR value of 3%.

Choice of the medium weight value

This choice is not as straightforward as that for the high weight value. The value of MSYR(1+) = 1% corresponds to a percentile between 5% and 10% for the distributions for an unknown stock in the meta-analyses of RMP WP 8. Motivations are:

(a) a value lower than this would be somewhat difficult to defend as one of “medium plausibility”, given the low percentile of the growth rate distribution to which it would correspond (it should be noted that the conservation-related statistics examined in such trials already incorporate caution as they pertain to lower 5%-iles of population size distributions);

(b) since the last SC decision on this matter 16 years ago, considerable further information on baleen whale population growth rates has become available, nearly all of which has led to higher and more precise estimates of growth rates than were available in 1993; this should be recognized through adjusting the medium plausibility value for MSYR upwards somewhat – note that for minke whales, for example MSYR(mat) = 1% corresponds approximately to MSYR(1+) of 0.7%.

Choice of range

This is somewhat academic in practice, since only the 1% and 4% values of the original 1%/4%/7% agreed range have come to be used in trials. However, for completeness, given that the growth rate distribution in RMP WP8 are reasonably symmetric, the selections of 1% and 3% above would imply a formal range for use in RMP trials of 1% - 5% in terms of the 1+ component of the population.

Caveats

Two caveats apply to this proposal:

(i) if the population for which RMP *Implementation* is under consideration is considered atypical of those upon which the meta-analysis of growth rates in RMP WP8 is based (e.g. because the species concerned is either not or scarcely represented in the set contributing to the meta-analysis, or because the habitat which supports the population is considered marginal) the medium plausibility choice of MSYR = 1% will be reconsidered prior to commencing trials;

(ii) the situation will be kept under review in the light of further analyses, and the values proposed possibly amended accordingly if persuasive evidence comes to light (e.g. if the consequences of the stochastic environment model for upward bias in estimated values of MSYR where the true value is low are found, given information on variability in birth and mortality rates from baleen whale stocks to inform parameter value choices for stochastic environment models, to be appreciable when integrated into the meta-analysis approach of RMP WP8).

Appendix 5

TOWARDS A PLAUSIBLE RANGE OF MSYR VALUES: A SUGGESTED WAY FORWARD

Justin G. Cooke

The meta-analysis in Appendix 2 allows for variation in rates of increase across stocks and for the estimation error in individual estimates of rates of increase. Based on the findings of SC/61/Rep 6 and further discussions under item 2.1.2. of its report, the subcommittee has recognised the importance of taking account of the impacts of environmental variability on rates of increase when drawing inferences about MSYR values.

The main conclusion of the discussions on environmental variability is the following. Each species has a biologically maximum possible rate of increase, r_{max}, and a stock will increase at close to this rate when environmental conditions are good. The average rate will be less, because lower or negative increase rates will pertain in less good conditions. The realised distribution over time for increase rates for a population is liable to be markedly left-skewed, being bounded on the right by r_{max}, but with a long tail extending leftward into negative values that correspond to mortality events (as observed for example for eastern gray whales at the beginning of this century) .

Environmental variability results in an inter-temporal, intra-stock component of variance in increase rates that should be taken into account in drawing inferences on a plausible range for MSYR.

Appendix 3 suggests an approach to using different kinds of population data to estimate typical levels of environmental variability. The rest of this working paper outlines an approach to incorporating this information into the meta-analysis with the aim of identifying a plausible range of MSYR values for stocks without specific data.

Current version of the meta-analysis

The meta-analysis in Appendix 2 employs the Bayesian framework described in SC/F09/MSYR1. It was implemented in Annex D of SC/61/Rep6 using an earlier version of the Table 2. A conventional random-effects analysis of the same data (Annex C of SC/61/Rep6) yielded very similar results.

The meta-analysis is based on the following model. The distribution of true rates of increase (which are taken to represent values of r_0, the expected rate of increase at low population sizes) is assumed to be normal with mean μ and variance σ^2. Each estimate in the table has an observation variance, τ_i^2, which is treated as known and is part of the input data. The total variance of data point *i* is given by: $V_i = \sigma^2 + \tau_i^2$.

The meta-analysis proceeded as follows. A prior distribution for μ and σ² was assumed. Using the input table of estimates and their variances as data, the posterior distribution for μ and σ² was determined. From this, a "posterior" distribution of r_0 was determined for an "unknown stock" for which there are (as yet) no stock-specific data.

An anomalous feature of the assumption of normality for the inter-stock distribution of r_0 is that it permits negative values, as seen in the results of WP8. Although the realised rate of increase of a population can be temporarily negative, due to the influence of the environment, the true value of r_0 (the expected rate of increase at low population size) for persistent populations must be positive. A population with a negative r_0 cannot persist for long. Both the realism and the utility of a model that allows negative r_0 values are doubtful: one cannot construct sensible operating scenarios with negative r_0 values for testing management procedures.

Extension of the meta-analysis to include environmental variability

Environmental variability represents an additional component of variance to be included in the meta-analysis. This could be done as follows. The variance of the rate of increase of a given stock is the sum of three components: the inter-stock variance, the observation (estimation) variance, and the temporal (environmental) variance: $V_i = \sigma^2 + \tau_i^2 + \varepsilon_i^2$.

Each data point is an observation of the sum of three random variables:

$$\hat{r}_i = u_i + v_i + w_i$$

where u_i has mean μ and variance σ^2; v_i has mean zero and variance τ_i^2; and w_i has mean zero and variance ε_i^2.

There follow some comments on the choice of distributional form for these variables. These are only initial suggestions and should not be taken as prescriptive.

It is reasonable to treat v_i (observation error) as normally distributed, except where the nature of the observation suggests a different distribution.

The variable u_i represents the value of r_0 (the expectation of the rate of increase at low stock sizes) for stock *i*. As noted above, r_0 should be non-negative, and perhaps also explicitly bounded above by r_{max}. A beta distribution for r_0 / r_{max} might be appropriate, whose two parameters take the place of μ and σ² in the analyses of Appendix 2.

As discussed above, w_i should have a left-skewed distribution. Pending the results of the analyses proposed in Appendix 3, the choice of details of the distributional form for w_i is to some extent arbitrary, but the form used in Sc/61/RMP13 (whose biological motivation is given in SC/NO7/MSYR1) may be a reasonable candidate for the distribution of *r*:

$$r_0 = r_{\max}\left(1 - (1-q)^z\right)$$

$$r_0(t) = r_{\max}\left(1 - e^{-\left(\sigma v_t + \frac{1}{2}\sigma^2\right)}\left(1-q\right)^z\right)$$

This implies: $r_0(t) = \eta_t r_0 + (1-\eta_t) r_{\max}$ where $\eta_t = e^{-\left(\sigma v_t + \frac{1}{2}\sigma^2\right)}$ and v_t are a sequence of normally distributed annual deviates with mean zero, variance one and serial correlation ρ.

The corresponding distribution and variance of w_i can be computed given values for r_0, ρ, σ and the length of the data series over which the rate of increase is measured.

While the above approach may look complicated, it may be possible to simplify the expressions while retaining their essential properties.

Work plan

The steps to implement this approach are:

(1) Conduct analyses of data of the kind described in Appendix 3. These include the analyses recommended in item 8.2(4) of SC/61/Rep6.
(2) Tidy up (and preferably simply) the above approach to incorporating environmental variability into the meta-analysis (or develop and alternative approach if reasons emerge to do so).
(3) Implement and run the extended meta-analysis.
(4) Derive a plausible range for MSYR from the results. This should now be a genuinely plausible range; in particular it should not contain negative values.

Appendix 6

FURTHER COMMENTS ON TRIALS BASED ON HYPOTHESIS IV

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Hypothesis IV is not consistent with the lack of genetic structure for fin whales in the North Atlantic and the observed genetic exchange between areas. To make the hypothesis broadly fit the Discovery mark-recapture data which has shown interchange between the feeding/small areas, the isolated breeding stocks are assumed to slightly overlap in the feeding areas such that 90% of the middle breeding stock is assumed to be in the WI area while a random 5% are in the areas on each side each year. The proportion of visiting animals in nearby areas is, however, assumed to be immutable over time and independent of density or food availability. This hypothesis cannot explain why marks placed on the WI grounds are recovered soon after marking (2.7 years excluding same-season recoveries) while marks placed in the EG area have been recovered later (5 years after marking although including 1 same season recovery). This time trend is close to significant, and also supported by a few other observations that are not fitted in the *IST* model.

The Committee agreed at SC60 that historic CPUE could be used in a qualitative way in assigning weights to hypotheses in *IST*s. Fig. 1 of SC/61/RMP9 shows the catch composition in the early modern whaling period and Fig. 1 in the addendum to SC/61/RMP9 shows the early CPUE series. Although the CPUE series is crude, there is every reason to believe that the trend is real and in fact more severe. In the last years the whalers were taking an increasing proportion of the catch on the Greenland side of the midline, so in fact in the EG area. Stock trajectories based on stock structure hypothesis IV (JCRM 11(Suppl): 105), shows that this hypothesis has to fit the largest initial stock size to explain the catch data and shows relatively less decline during the early whaling period. This is followed by little recovery of the stock from 1915 to 1948 when the later whaling operation restarted and then operated with ease. According to the results for this hypothesis, densities were just as low when whaling resumed in 1948, as when whaling was abandoned in 1915 due to lack of whales on the grounds. According to this hypothesis the initial stock in the WI *Small Area* was over 15,000 fin whales in addition to the several thousand blue and humpback whales there initially.

Due to this and the poor fit of this hypothesis to the data and the unnaturalness of this hypothesis, which would not ever allow animals from the other breeding stocks to take advantage of the decreased density in this area, we believe that it should be given low plausibility.